TROPMET 2022

NATIONAL SYMPOSIUM

Organized by

Indian Meteorological Society

Advances in Weather and Climate Prediction and Climate Change Projection over South Asia:
Applications in Water and Agriculture Sectors

29 November - 02 December 2022

IISER Bhopal, Madhya Pradesh

Hosted by:
Indian Institute of Science Education and Research (IISER), Bhopal
and
Indian Meteorological Society - Bhopal Chapter

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Souvenir cum Abstract Volume

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Local Organizing Committee, TROPMET 2022

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TROPMET'22

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NATIONAL SYMPOSIUM

29 November - 02 December 2022

ON

Advances in Weather and Climate Prediction and Climate Change Projection over South Asia: *Applications in Water and Agriculture Sectors*

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About TROPMET

TROPMET is a series of national conferences organized each year by IMS. This year, TROPMET will be held in the city of Bhopal. TROPMET-2022 focuses on weather and climate prediction, including applications in the water and agricultural sectors. The climate varies naturally in space and time. Today's concern is the occurrence of climate changes due to human activities. These changes are manifested in an increase in temperature, and extreme weather events such as floods, droughts, heat waves, dust storms, heavy precipitation events, etc. These weather events need constant monitoring to reduce their potential impacts on society. Since observation stations are not available at every spatial point of interest, modeling efforts are required to help assess the situation. Also, process studies are essential to understand the phenomena in greater depth. Keeping these facts in mind, TROPMET 2022 will make efforts to bring together climate scientists, agricultural scientists, local government bodies, academics, policy-makers and disasters, and other related experts to discuss and share information for the benefit of the society.

The Indian Meteorological Society (IMS):

Established in 1957, is a non-profit organization that promotes the advancement and dissemination of knowledge, especially in the field of meteorology and related sciences. It has more than 3,500 Life Members from 100 or more research institutes, universities, user agencies, NGOs, and main industries. There are also several student members. The IMS's HQ is located in New Delhi.

The objectives of IMS are:

- Advancement of Meteorological & Allied sciences.
- Dissemination of knowledge of such sciences both among the scientific workers and among the public.
- Application of Meteorology and allied sciences to various constructive human activities, such as agriculture and land use, irrigation and power development, navigation of sea and air, engineering and technology, medicine and public health etc.

IMS Bhopal Chapter

The Bhopal chapter of the IMS was established in 1997. The members of this chapter are mainly from IMD and IISER Bhopal. The main objective of this chapter is to popularize meteorology and allied sciences along with their uses in various human activities mainly addressing the agriculture and water sectors. The Bhopal chapter had successfully organized the TROPMET-2007.

About IISER

Indian Institute of Science Education and Research (IISER) Bhopal, a premier academic institute, was established by the Ministry of Education, Govt. of India on February 20, 2008. It offers BS-MS dual and Ph.D. degrees in various academic disciplines. Over the years, IISER Bhopal has been attracting talented young minds. The Earth and Environmental Sciences department (EES) started as a minor course in the year 2014 and a major in 2016 to encourage multidisciplinary studies integrating chemistry, biology, physics, geology, and environmental science. It offers students a unique opportunity to build on their foundation in natural and engineering sciences to solve problems in the domain of EES.

About Bhopal

Bhopal, known as the 'City of Lakes', is the capital of Madhya Pradesh and one of the cleanest cities in India. The city offers a true combination of the scenic beauty of historical and modern urban planning. Bhopal and its surrounding regions are home to several cultural and chequered heritage sites, including Buddhist monuments at Sanchi and the rock shelter of Bhimbetka, both declared World Heritage Sites by UNESCO. One can also visit the Tropic of Cancer on their way to Sanchi. Other significant attractions in and around Bhopal include Fatehgarh Fort, Lakshminarayan Temple, the Museum of Man, and an open-air exhibit of replicas of different Indian tribal dwellings. The city is well connected by air, railways, and roads to major metro cities.

Climate: The climate of Bhopal during November and December is very pleasant and clear with an average maximum temperature being ~30°C and a minimum being 15°C with a mostly dry atmosphere.

Themes of symposium

- Weather and Climate Processes
- Climate Modelling, Prediction and Projections
- Applications of Weather and Climate in Hydrology
- Applications of Weather and Climate in Agriculture
- Monsoon Prediction and Projections
- Climate Services
- Remote Sensing Application in Weather and Climate Prediction
- Impact-based Weather and Climate Prediction
- Weather and Climate Extremes

Associated events

Inauguration	29 Nov 2022
Research Scholar's Competitive and Scientific Presentation and Poster Campaign	29 Nov 2022
Presentation and Exhibition	
Interaction Meet of Experts with Stakeholders, Media and NGO's	29 Nov - 2 Dec 2022
	29 Nov 2022

Registration fees

Category	Early bird (31 Oct)	On spot
IMS Members	Rs. 3000	Rs. 4000
Non-IMS members	Rs. 4000	Rs. 5000
Scholors/Students	Rs. 1000	Rs. 2000
Foreignnationals/private sectors	Rs. 10000	Rs. 12000

The Registration Fee can be paid through multiple payment options such as net banking or debit/credit cards or bank drafts. There is no registration fee for Honorary Fellows and Fellows of the Society.

Industry Presentation & Exhibition

Special sessions are planned to provide a platform for industry/entrepreneurs. A presentation slot of 15 to 20 minutes duration will be allowed for selected industries/entrepreneurs. Provision is also made for vendors to exhibit their products and services.

Best paper award

The best paper awards in the student category (lead author of the paper must be a student) and non-student category will be given to the selected papers presented. . It is advised to mention whether their paper should be considered for the best paper award during abstract submission.

Accommodation and Transport

TROPMET-2022 have minimal resources for offering accommodation and travel support, and all participants are expected to secure support from their sources. The support may be extended to a few case-by-case bases, with priority given to IMS members with no affiliations and students without financial support.

EVENT SCHEDULE

Time	29-11-2022 (Day-1)		
8:30-9:30	Registration		
9:30-10:30	Inauguration (VH Auditorium)		
10:30-11:00	High Tea		
11:00-11:45	Plenary Lecture (VH Auditorium) Dr. Akhilesh Gupta		
	Theme and Venue		
	VH Auditorium	Seminar Hall-1	Seminar Hall-2
	MPP1.1 (Dynamics and climate change)	WCP 1.5. (Ocean Variability and Extremes)	WCP1.6 (Cryosphere and Glaciology)
12:00-12:20	Keynote Lecture (1) Prof. Ravi Shankar Nanjundiah	Keynote Lecture (1) Dr. Anant Parekh	Keynote Lecture (1) Dr. Kalachand Sain
12:20-12:35 12:35-12:50	Invited Talk (2) Prof. Suneet Dwivedi Dr. Shailendra Rai	Invited Talk (1) Dr. Prasanth A Pillai	Invited Talk (1) Dr. Raaj Ramsankaran
12:50-13:30	Oral Presentation (4/4)	Oral Presentation (4/4)	Oral Presentation (3/4)
13:30-14:30	Lunch		
	Theme and Venue		
	Seminar Hall-1	Seminar Hall-2	VH Auditorium
	WCP 1.1 (Interacting Spheres and Land Use)	CS1.1 (Being Climate Smart)	Sustaining Green Life: Session on Energy
14:30-14:50	Keynote Lecture (1) Dr. Atul Kumar Sahai	Keynote Lecture (2) Dr. Rajeev Mahajan Dr. Satyaban B	Coordinators: Dr. P. Mukhopadhyay Dr. Raghavendra Ashrit Speakers Dr. Raghavendra Ashrit (NCMRWF) Mr. Suresh Pillai (ReNew Power) Dr. tripta Thakur (NPTI Faridabad) Mr.Sheshagiri Rao (Greenko Group) Mr. Anandh Thankaswamy (Adani Green Energy Ltd.)
14:50-15:30	Lightning Talks (9/10)	Lightning Talks (7/10)	
15:30-16:30	Tea & Poster Presentation (23+8+6+16(LTs) = 53)		
16:30-16:45 16:45-17:00	Invited Talk(2) Dr. S. Abhilash Dr. Samir Pokhrel	Invited Talk (1) Dr. Lokendra Thakkar	
17:00-18:20	Oral Presentation (8/8)	Oral Presentation (7/8)	
18:30-19:30	Cultural Event (LHC Auditorium)		
19:30-21:00	Dinner		

Time	30-11-2022 (Day-2)				
9:00-9:45	Plenary Lecture (VH Auditorium) Dr. R Krishnan				
9:45-10:30	Plenary Lecture (VH Auditorium) Dr. Nabansu Chattopadhyay				
10:30-10:50	Tea & Coffee				
	Theme and Venue				
	VH Auditorium	Seminar Hall-1	Seminar Hall-2	Board Room-3	
	WCE1.2 (Hydrological Extremes (A))	AWCA1.1 (Agroclimatic perspective)	WCP1.2A (Climate variability and predictability)	MPP1.2 (S2S prediction)	
11:00:11:20	Keynote Lecture (1) Dr. Jasti S. Choudhary	Keynote Lecture (1) Dr. Vinay Kumar Sehgal	Keynote Lecture (1') Dr. Yogesh K. Tiwari	Invited Talk (3) Dr. Swapna Panickal Dr. M.L. Sahu Dr. Susmitha Joseph	
11:20-11:35 11:35-11:50	Invited Talk (1) Dr. (Md) Saquib Saharwardi	Invited Talk (2) Dr. K.V. Ramana Rao Dr. N Shubash	Invited Talk (2) Dr. Susheela Negi Mr. Anup Duboliya		
11:50-13:00	Oral Presentation (7/7)	Oral Presentation (7/7)	Oral Presentation (5/7)	Oral Presentation (5/7)	
13:00-14:00	Lunch				
	Theme and Venue				
	Board Room-3	Seminar Hall-1	Seminar Hall-2	Board Room-1	VH Auditorium (16:00 to 18:00 Hour)
	CMPP 1.3 (Regional Climate Modelling and AI/ML)	RWACP 1.3. (Disaster Risk Reduction + Data Assimilation)	CMPP 1.1. (Weather and Climate Modelling)	WCE 1.4. (Cyclones and WDs)	Sustaining Green Life: Session on Energy
14:00-14:20	Keynote Lecture (2) Dr. J Sanjay	Keynote Lecture (1) Dr. S. D. Pawar	Keynote Lecture (1) Dr. A Suryachandra Rao	Keynote Lecture (1) Dr. S. Balachandran	Coordinators: Dr. P. Mukhopadhyay Dr. Raghavendra Ashrit Speakers Dr. Amresh Khosla (Manikaran Analytics Ltd.) Dr. Vikas Kumar Yadav (POSOCO) Dr. Rupa Kumar Kolli (IMS) Dr. Mukul Tewari (IBM) Dr. P. Mukhopadhyay (IITM Pune)
14:20-15:30	Lightning Talks (13/14)	Lightning Talks (10/14)	Lightning Talks (6/14)	Lightning Talks (8/14)	
15:30-16:30	Tea & Poster Presentation(20+7+10+14+38LTs =88)				
16:30-16:45	Dr. Rattan K. Datta	Invited Talk (2) Dr Rajendra Kumar Jenamani Dr. Arvind Sahay	Invited Talk (2) Prof. Rajeev Bhatla Dr. K. C. Gouda	Invited Talk (2) Dr. Gaurav Tiwari Mr. Aaquib Javed	
16:45-17:00	Invited Talk (1) Prof. P.P. Sarthi				
17:00-18:40	Oral Presentation (8/10)	Oral Presentation (10/10)	Oral Presentation (8/10)	Oral Presentation (7/10)	
18:30 - 19:30	IMS General Body Meeting				
19:30 - 21:00	Dinner				

Time	01-12-2022 (Day-3)			
9:00-9:45	Plenary Lecture (VH Auditorium) Dr. M Rajeevan			
9:45-10:30	Plenary Lecture (VH Auditorium) Dr. Nilesh Desai			
10:30-10:50	Tea & Coffee			
	Theme and Venue			
	VH Auditorium	Seminar Hall-1	Seminar Hall-2	Board Room-3
	WCE 1.2. (Hydrological extremes (B))	RAWCP1.1. (Eyes in the sky)	CMPP - 1.2. (Modelling strategies and physical processess)	RAWCP 1.2. (Aerosols and Atmospheric Chemistry)
11:00-11:20	Keynote Lecture (1) *Dr. Pankaj Kumar*	Keynote Lecture (1) Dr. Atul Varma	Keynote Lecture (1) Dr. V.S. Prasad	Invited Talk (1) Dr. Sumit Kumar Mishra*
11:20-11:35	Invited Talk (1) Dr. P. C. Joshi	Invited Talk (1) Dr. Prashant K Srivastava	Invited Talk (1) Dr. Rajib Chattopadhyay	Invited Talk (1) Dr. Saroj K. Sahu
11:50-13:00	Oral Presentation (7/7)	Oral Presentation (6/7)	Oral Presentation (7/7)	Oral Presentation (7/7)
13:00-14:00	Lunch			
	Theme and Venue			
	VH Auditorium	Seminar Hall-1	Seminar Hall-2	Board Room-1
	WCP 1.3. (Aerosol and Climate)	WCE 1.1. (Lightening and Thunderstorm)	AWCH1.1. (Hydrological Applications)	JAL: Resource for Life
14:00-14:20	Keynote Lecture (1) Dr. G. Pandithurai	Keynote Lecture (1) Dr. Abhijit Sarkar	Keynote Lecture (1) Prof. Manish K. Goyal	Invited Talk (2) Mr. Balasubramanian R Dr. Somil Swarnkar
14:20-15:30	Lightning Talks (14/14)	Lightning Talks (5/14)	Lightning Talks (9/14)	Lightning Talks (13/14)
15:30-16:30	Tea & Poster Presentation(23+8+11+7+1+41(LTs) = 92)			
16:30-16:45	Invited Talk (1) Dr. B. Lakshmi Madhavan	Invited Talk (1) Dr. Subhadeep Halder	Invited Talk (1) Dr. Sanjeev Jha	
17:00-18:20	Oral Presentation (8)	Oral Presentation (8/8)	Oral Presentation (6/8)	
18:30 - 19:30	Cultural Programme (VH Auditorium)			
19:30 - 21:00	Dinner			

Time	02-12-2022 (Day-4)		
9:00-9:45	Plenary Lecture (VH Auditorium) Prof. U C Mohanty		
9:45-10:30	Plenary Lecture (VH Auditorium) Shri Nilesh M. Desai		
10:30-10:45	Tea & Coffee		
	Themes and Venue		
	Board Room-3	TIME →	Board Room-1
	WCP 1.2B & 1.4 (Aerosol Impacts and Climate Variability)		WCE 1.3. (Climate change implications and Temperature Extremes)
10:45-11:05	Keynote Lecture (1) Dr. Atul Kumar Srivastava	10:45-11:05 → 11:05 - 11:25 →	Keynote Lecture (2) Dr. A. Chandrasekhar Dr. Mukul Tewari
11:05-11:20	Invited Talk (1) Dr. Akhilesh Kumar Mishra	11:25 - 11:40 →	Invited Talk (1) Dr. R. Vinnarasi
11:20-12:35	Oral Presentation	11:40 - 12:35 →	Oral Presentation
12:35-13:20	Valedictory Function (VH Auditorium)		
13:20-14:30	Lunch		
14:30-19:00	Local Tour & Departure		

सत्यमेव जयते

डॉ. एम. रविचंद्रन
Dr. M. Ravichandran

सचिव
भारत सरकार
पृथ्वी विज्ञान मंत्रालय
पृथ्वी भवन, लोदी रोड, नई दिल्ली–110003

SECRETARY
GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
PRITHVI BHAWAN, LODHI ROAD, NEW DELHI-110003

MESSAGE

I am glad to learn that the Indian Meteorological Society (IMS) is organizing the National Conference on Tropical Meteorology (TROPMET - 2022) on " **Advances in Weather and Climate Prediction and Climate Change Projection over South Asia: Applications in Water and Agriculture Sectors" from 29 November to 2 December 2022 at IISER Bhopal**.

It Is a universally accepted fact that the possible consequences of global warming and Climate Change are spreading to all spheres of life, Climate change will have adverse impacts over many parts of the globe, with a developing country like India impacted more compared to other regions. In the changing climate scenario, the demand for weather and climate services by society has increased many folds. This is because many production systems in different areas of technology want to explicitly account for weather/climate-based vulnerabilities in their planning strategy.

Considering this, the IMS, in collaboration with Indian Institute of Science Education and Research (IISER), Bhopal, India is organizing **National Conference on Tropical Meteorology (TROPMET - 2022)** on " Advances in weather and climate prediction and climate change projection over South Asia: Applications in water and agriculture sectors" from 29 November to 2 December 2022 at IISER Bhopal. This conference will make efforts to bring together atmospheric scientists, research professionals, policymakers, disaster managers, and other related experts to discuss and share information for the benefit of society.

I am confident that the National Conference 'TROPMET-2022 will provide a common platform to the academicians, scientists, numerical modelling communities, and industrialists from different organizations and help in drawing purposeful recommendations on the issues of the weather and climate services during the period of climate change.

I convey my best wishes for the success of this conference.

M. Ravichandran

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डॉ. एस. चंद्रशेखर
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Secretary
Government Of India
Ministry of Science and Technology
Department of Science and Technology

25th November, 2022

MESSAGE

I am pleased to note that the National Symposium TROPMET 2022 is being organized by Indian Meteorological Society (IMS) Chapter, Bhopal and IISER-Bhopal during 29th November- 02nd December, 2022 with the theme "Advances in weather and climate prediction and climate change projection over South Asia: Application in water and Agricultural sectors".

It is pertinent to note that the theme of the symposium is of great interest in today's climate scenario. The awareness of the changing weather and projection of future climatic conditions is integral to the various planning strategies adopted all over the world. India, being is close to the tropics and vulnerable to the associated climate challenges, urgently needs more such scientific platforms to discuss mitigation and adaptation to climate change. Moreover, the country faces the impending crisis of increased occurrences of droughts, floods, cyclones etc. Hence it is imperative for us to judiciously discuss this matter for our secure future.

I am sure that TROPMET 2022 will have participation of brightest young students, researchers, industrialists, and the representatives of the governing bodies to ponder over and initiate constructive ideas and consequent activities. This will certainly go a long way to contribute to the efforts of both, national as well as international community, regarding the tackling of the climate crisis.

I extend my best wishes to the organizers of the Symposium and convey my warm greetings to all the participants.

I wish the TROPMET 2022 a grand success.

(S. Chandrasekhar)

Technology Bhavan, New Mehrauli Road, New Delhi - 110016
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विज्ञान और इंजीनियरी अनुसंधान बोर्ड
(विज्ञान और प्रौद्योगिकी विभाग, भारत सरकार का एक सांविधिक निकाय)
SCIENCE & ENGINEERING RESEARCH BOARD
(A Statutory body of Department of Science and Technology, Govt. of India)

डॉ. अखिलेश गुप्ता
सचिव
Dr. AKHILESH GUPTA
SECRETARY

23rd November, 2022

MESSAGE

I am delighted to learn the Indian Meteorological Society, Bhopal Chapter is organising IMS's Annual symposium " TROPMET 2022" at IISER - Bhopal on the theme ***"Advances in weather and climate prediction and climate change projection over South Asia: Application in water and agricultural sectors"***. The beautiful city of Bhopal, with its rich cultural heritage, is getting ready to host the TROPMET-2022 during Nov 29 to Dec 02 2022 on such a relevant theme.

I am happy to see, TROPMET-2022 will be focusing on climate studies in the use of water and agriculture, climate projections and the associated uncertainties. This is an extremely relevant subject area especially in the context of the impact of climate change on water and food security. Of late India has been witnessing an increasing number of droughts and floods. This needs urgent attention of scientists and planners to evolve scientific solutions to impending climate crisis.

I am sure TROPMET 2022 will serve as a useful platform for meteorologists, hydrologists, agrometeorologists, policy makers, disaster managers and administrators to deliberate and evolve viable, practical and long term solutions to key challenges of weather and climate issues of present and future.

I congratulate the organisers for having thought of organising such an important event and wish the TROPMET-2022 a grand success.

(Akhilesh Gupta)

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डॉ. मृत्युंजय महापात्र
मौसम विज्ञान विभाग के महानिदेशक,
विश्व मौसम विज्ञान संगठन में भारत के स्थाई प्रतिनिधि
एवं कार्यकारी परिषद के सदस्य

Dr. Mrutyunjay Mohapatra
Director General of Meteorology,
Permanent Representative of India with WMO,
Member of Executive Council, WMO

भारत सरकार
पृथ्वी विज्ञान मंत्रालय
भारत मौसम विज्ञान विभाग
मौसम भवन, लोदी रोड़
नई दिल्ली–110003

Government of India
Ministry of Earth Sciences
India Meteorological Department
Mausam Bhawan, Lodi Road
New Delhi - 110003

Message

It gives me immense pleasure to know that Indian Meteorological Society (IMS) is organizing TROPMET-2022, a National Conference on Tropical Meteorology, on the topical theme "Advances in weather and climate prediction and climate change projection over South Asia: Applications in water and agriculture sectors" from 29 November to 2 December 2022 at Indian Institute of Science Education and Research (IISER) Bhopal.

Recently, India Meteorological Department (IMD), Ministry of Earth Sciences (MoES) has taken major steps in improving the weather, climate and hazards warning services in the country with the support of sister organizations of MoES like Indian Institute of Tropical Meteorology, National Centre for Medium Range Weather Forecasting, Indian National centre for Ocean Information Services etc. With the improvement in observational and forecasting tools including augmentation of NWP models, radar network and satellite products, forecasting/warning services in respect of tropical cyclones, severe thunderstorms, nowcasting, flash/urban floods, urban climate, heavy rainfall, heat waves/cold wave advisories to farmers, fishermen, pilgrims and many others has been further strengthened.

It is a very well-known fact that Global Warming and Climate Change is a reality and its possible consequences are spreading to all walks of life. In the changing climate scenario, the demand for weather and climate services by the society has increased many folds. Accordingly there is need of enhanced technology to explicitly account for weather/climate-based vulnerabilities. IMD in collaboration with other institutes of MoES and R&D institutes in the country and outside is continuously upgrading and enhancing the capabilities by augmenting modelling and observational network. The services to different sectors including the sectors with vulnerable population like farmers and fishermen are being enhanced to safeguard the lives & economy of the country.

I am very optimistic that the TROPMET-2022 Symposium will provide an excellent opportunity for interaction among weather scientists, academician, stakeholders and industrialists to discuss different aspects of weather and climate forecasts and bring out actionable recommendations for betterment of weather & climate services.

I wish the event a grand success.

10.11.2022

(Mrutyunjay Mohapatra)

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E-mail : directorgeneral.imd@imd.gov.in / dgmmet@gmail.com / m.mohapatra@imd.gov.in

राजीव गांधी प्रौद्योगिकी विश्वविद्यालय
(मध्यप्रदेश का तकनीकी विश्वविद्यालय)

Rajiv Gandhi Proudyogiki Vishwavidyalaya
(State Technological University of Madhya Pradesh)
(Accredited with 'A' grade by NAAC)

Prof. Sunil Kumar
Vice-Chancellor

DO Letter No. VC/DO/2022/Q
दिनांक / Date 25/11/2022

MESSAGE

I am extremely happy to learn that the Indian Meteorological Society (IMS) will hold its National Symposium on Tropical Meteorology (TROPMET) with the theme "Advances in Weather and Climate Predictions and Climate Change projection over South Asia: Applications in Water and Agriculture sectors" from November 29th to December 2nd, 2022, at the Indian Institute of Science Education and Research (IISER), Bhopal, Madhya Pradesh.

This year, IMS along with IISER-B is organizing TROPMET 2022 in the City of Lakes, Bhopal. The Indian Meteorological Society (IMS) is a nonprofit group that fosters the development, information transfer, and practical use of meteorology and associated disciplines. Due to climate change, extreme weather events including floods, droughts, heat waves, dust storms, and heavy precipitation are occurring more frequently nowadays. In order to lessen the possible negative effects on civilization, these weather occurrences need to be continuously monitored. Process studies are necessary to fully comprehend these phenomena. With these realities in mind, TROPMET-2022 will work to bring together experts on climate change, regional government agencies, academic institutions, and early warning services to exchange knowledge and engage in discussion for the sake of society.

Along with experts from various universities and institutes, I anticipate that a sizable number of delegates from around the nation will attend this conference and I hope all the participants will benefit from this symposium.

S Kumar

Prof. Sunil Kumar

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Airport Road, Gandhi Nagar, Bhopal–462 033. Ph. : +91 0755 2742001 Fax : +91 0755 2742002. Email : vcoffice@rgtu.net
Website : www.rgpv.ac.in

Dr Rupa Kumar Kolli
President, Indian Meteorological Society

Honorary Scientist & Former Executive Director
International Monsoons Project Office (IMPO)
Indian Institute of Tropical Meteorology (IITM)
Pune 411008, India

Email: rkolli.wmo@gmail.com; rkolli@tropmet.res.in

Former Chief, World Climate Applications & Services Division,
World Meteorological Organization (WMO)

MESSAGE

It gives me great pleasure to convey my warm greetings to the members of the Indian Meteorological Society (IMS) and its patrons and partners organizing TROPMET-2022, a National Conference on Tropical Meteorology, on the topical theme "**Advances in weather and climate prediction and climate change projection over South Asia: Applications in water and agriculture sectors**" from 29 November to 2 December 2022 at Indian Institute of Science Education and Research (IISER) Bhopal. I heartily compliment the Bhopal Chapter of IMS and the IISER Bhopal for hosting the event and making excellent organizational arrangements. I welcome all the participants to this widely acknowledged annual flagship event of the IMS that builds on the legacy of such events over the past three decades, and look forward to its grand success in terms of scientific quality and exposition.

It is a widely recognized fact that the impacts of global warming and climate change are being felt in all spheres of life. Climate change will have unprecedented and mostly adverse impacts over many parts of the globe, with serious consequences to all socio-economic sectors, particularly in developing countries including India. In the changing climate scenario and with growing societal awareness, the demand for weather and climate services has increased many folds to deal with the ongoing and future climate impacts. This is further accentuated by the fact that decision making in all weather- and climate-sensitive contexts needs to explicitly account for weather/climate-based vulnerabilities in the associated planning and operational strategies.

It is therefore very apt that the IMS, in collaboration with IISER Bhopal, is organizing TROPMET-2022 to highlight the research and operational advances in weather and climate prediction and projection, which have immense applications in water, agriculture and allied sectors. This conference brings together research scientists and students, operational experts, policy makers, disaster managers and other related experts to present, discuss and share information for the benefit of the scientific community as well as the society at large.

I have no doubt that the TROPMET series of annual conferences led by the IMS provide an excellent platform to the academic, operational, industrial and sectoral communities from different organizations and help in mutually sharing expertise and joining forces to jointly address the issues of the weather and climate services in these times of climate change taking centre stage at all levels.

I convey my best wishes for a grand success of TROPMET-2022.

Rupa Kumar Kolli
Rupa Kumar Kolli

प्रो. शिवा उमापति
निदेशक
Prof. Siva Umapathy
Director

भारतीय विज्ञान शिक्षा एवं अनुसंधान संस्थान भोपाल
Indian Institute of Science Education and Research Bhopal
An Institute of National Importance of the MoE, Govt. of India

आज़ादी का अमृत महोत्सव

MESSAGE

It is a matter of great pleasure to know that the Indian Institute of Science Education and Research, Bhopal (IISERB) has been chosen by the Indian Meteorological Society (IMS) to host the national conference (TROPMET-2022) on "Advances in Weather and Climate Prediction and Climate Change Projection over South Asia: Applications in Water and Agriculture Sectors" during 29th November - 2nd December 2022.

Climate services are crucial in reducing present-day and long-term climate risks in South Asia, where many communities are highly exposed to and sensitive to weather and climate disasters. Therefore, it is crucial to make efforts to address growing weather and climate concerns, including weather and climate services. In order to address concerns associated with climate change, climate services have a crucial role to play.

TROPMET-2022, co-organized by IISERB-IMS, will offer a great forum for dialogue amongst climate scientists, agricultural scientists, local government agencies, academics, and policymakers to go through various facets of weather and climate forecasts and their advantages for society.

Professor Siva Umapathy
Director
Indian Institute of Science Education and Research Bhopal

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भारतीय विज्ञान शिक्षा एवं अनुसंधान संस्थान भोपाल
Indian Institute of Science Education and Research Bhopal
Office of Earth and Environmental Sciences
Bhopal Bypass Road, Bhauri, Bhopal - 462066

Adjunct Professor
The Earth and Environmental Sciences Department
Indian Institute of Science Education and Research Bhopal

MESSAGE

It gives me great pleasure to learn that the Indian Meteorological Society (IMS) will host the National Symposium of Tropical Meteorology (TROPMET) with a special focus on "Advances in Weather and Climate Prediction and Climate Change Projection over South Asia: Applications in Water and Agriculture Sectors" from November 29 to December 2, 2022, at the Indian Institute of Science Education and Research (IISER) Bhopal.

The impact of climate change caused by human activities is one of the foremost concerns and challenges of the modern era. Extreme weather phenomena resulting in floods, droughts, heat waves, dust storms, and major precipitation occurrences are all pointers of these shifts. These climatic events must be understood and regularly analyzed in order to minimize their potential societal consequences.

A combination of observation and model-based efforts is required to assess the rapidly evolving situation. TROPMET 2022 will provide the ideal platform to bring together climate scientists, agricultural scientists, state/local government agencies, academic institutions, policymakers, disaster specialists, and other related experts to discuss and share knowledge for the benefit of society.

I am optimistic that this four-day symposium will advance knowledge of the numerous complex aspects of weather and climate, ultimately providing solutions to challenging problems and for planning the future well-being of our society.

I take this opportunity to extend my appreciation to IMS for planning this symposium at Bhopal and wish the symposium a grand success.

SKTandon

Prof. S K Tandon

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Office of Earth and Environmental Sciences
Bhopal Bypass Road, Bhauri, Bhopal - 462066

Head of the Department
The Earth and Environmental Sciences Department
Indian Institute of Science Education and Research Bhopal

MESSAGE

The National Symposium (TROPMET-2022) is being organized jointly by the Indian Institute of Science Education and Research, Bhopal (IISERB) and the Indian Meteorological Society (IMS). The theme of this conference is "Advances in Weather and Climate Prediction and Climate Change Projection over South Asia: Applications in Water and Agriculture Sectors."

The topic is extremely pertinent to the current situation, in which there is a lack of information among those living in rural regions who work in agriculture. People must be aware of the developments in the water and agricultural industries. The consequences of climate change is the increase in temperature, and extreme weather phenomena such as floods, droughts, heat waves, dust storms, heavy precipitation events, etc. To lessen their potential adverse effects on civilization, these weather occurrences need to be continuously monitored. Since there aren't observation stations at every location of interest, modeling attempts are necessary to assess the situation. Process studies are also necessary to fully comprehend the phenomenon.

On behalf of the EES department IISERB, I warmly greet all attendees and wish the organizers a very successful event.

Dr. Kumar Gaurav

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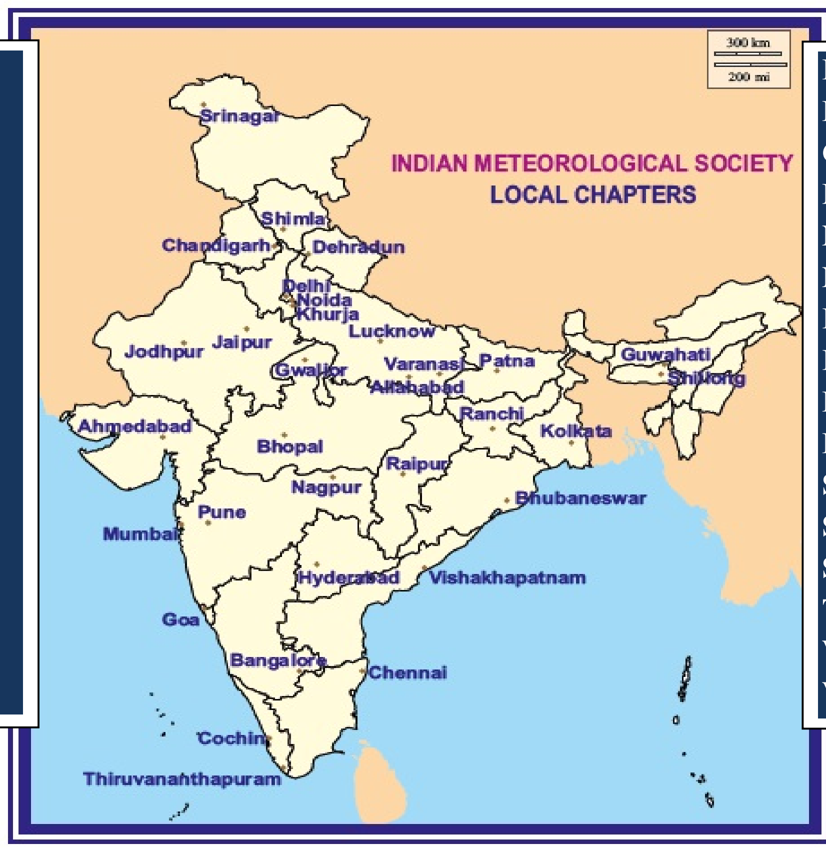
Overview of IMS Activities Since its Inception

D. R. Pattanaik[1] and R. K. Giri[2]
[2]Vice-President, Indian Meteorological Society, New Delhi
Email: drpattanaik@gmail.com
[2]Secretary, Indian Meteorological Society, New Delhi
Email: rk.giriccs@gmail.com

1. Establishment of IMS

The Indian Meteorological Society (IMS) established in 1956 during the Session of the Indian Science Congress, has made more than 3500 members at present. It was registered as a Society under the Societies Registration Act in 1972 in New Delhi. The society has its head Quarter in Delhi with 32 chapters spread across the country. The society is a non-profit organization and none of its income or assets shall accrue to the benefit of its members. A well discussed constitution is its major assets of IMS. The constitution is available at IMS website at the following URL: http://www.imd.gov.in/ims/

Ahmedabad
Allahabad
Bangalore
Bhopal
Bhubaneswar
Chandigarh
Chennai
Cochin
Dehradun
Delhi
Goa
Guwahati
Hyderabad
Jaipur
Jodhpur
Kolkata



Khurja
Lucknow
Gwalior
Mumbai
Nagpur
Noida
Patna
Pune
Raipur
Ranchi
Shillong
Shimla
Srinagar
Trivandrum
Varanasi
Visakhapatnam

IMS Local Chapters

2. The main objectives of the society are :

- Advancement of Meteorological and allied sciences in all their aspects.
- Dissemination of the knowledge of such sciences both among the scientific workers and among the public.
- Application of Meteorology and allied sciences to various constructive human activities, such as, agriculture and land uses, irrigation and power development, navigation of sea and air, engineering and technology, medicine and public health etc.

3. Membership of IMS

Any person who is interested in the aims and objectives of the Society is eligible to become a member. He shall apply for membership in the prescribed form available in the website and shall be notified on acceptance by the Council.

- ***Life Member (LM)***
  A Member who pays all his dues in a lump sum as prescribed by the General Body shall be a Life Member. The society has about 3000 life members.

- ***Annual Member (AM)***
  A Member who pays all his dues in a lump sum as prescribed by the General Body shall be a Life Member. The society has about 3000 life members.

- ***Student Members (SM)***
  In order to encourage students to becomes IMS member, IMS recently introduced student membership where a student can become IMS student member by paying Rs. 1000/- along with the forwarded application from head of the institution where he/she is working. The membership will be valid till the time he/she becomes 30 years of age or get some employment in any place whichever is early. He/she can become a regular life member of IMS by paying the balance amount.

- ***Institutional Members (Annual)***
  Any institution which is interested in the aims and objectives of the Society is eligible to become an Institutional Member on payment of an annual subscription. The institution shall apply for Membership and shall be notified on acceptance by the Council. The Institutional Member may nominate its representative to exercise the Membership privileges.

- ***Patron***
  A person or an institution who is interested in the aims and objectives of the Society and makes a donation of substantial sum to the Society will, at the discretion of the Council, be admitted as Patron.

SUBSCRIPTION

Annual Member	Indian : Rs.300
Life Member	Indian : Rs. 3000; Foreign : US$ 150
Entrance Fee	Indian : Rs. 00 ; Foreign : US$ 10
Student Member	Indian : Rs. 1000
Institutional Member	Indian : Rs. 10000 (annual); : US$ 250
Patron	Indian : Rs. 100000 ; Foreign : US$ 2500
Institutional Patron	Indian : Rs. 1000000 ; Foreign : US$ 25000

4. IMS Fellows

Honorary Fellow and Fellow

- Persons of acknowledged eminence in Meteorology and allied fields of Science and Technology or in their furtherance may be elected as honorary fellows by the General Body on proposal from the Council.

- Life members, who have made outstanding contribution of Meteorology and allied fields of Science and Technology, may be elected as Fellows by the General Body on proposal from the council. The following outstanding members of the society have been elected as Fellows/Honorary.

- IMS has also given Life Time Achievement Awards to three eminent scientists.

- **IMS LIFE TIME ACHIEVEMENT AWARDS**

S. No.	Name
1	Prof. P. V. Joseph
2	Shri Soundararajan Raghavan
3	Late Shri Dev Raj Sikka

- **List of IMS Honorary Fellows**

S. No.	Name
1	Late Dr. A. P. J. Abdul Kalam
2	Late Dr. J. S. Fein
3	Dr. P. S. Goel
4	Late Prof. V. R. Gowariker
5	Prof. Murli Manohar Joshi
6	Dr. Ramesh Kakar
7	Dr. K. Kasturirangan
8	Late Prof. T. N. Krishnamurti
9	Prof . G. O. P. Obasi
10	Dr. Kamal Puri
11	Prof. V. S. Ramamurthy
12	Prof. Veerabhadran Ramanathan
13	Dr. P. Krishna Rao
14	Dr. M. V. K. Siva Kumar
15	Dr. M. S. Swaminathan
16	Dr. Petteri Taalas
17	Er. Avinash Chand Tyagi
18	Dr. Upendra Narayan Singh

- **List of IMS Fellow**

S. No.	Name
1	Late Dr. R Ananthakrishanan
2	Late Dr. G.C. Asnani
3	Dr. Swati Basu
4	Prof. G. S. Bhat
5	Dr. V. K. Dadhwal
6	Late Prof. P. K. Das
7	Late S. K. Das
8	Prof. S. K. Dash
9	Dr. R.K. Datta
10	Dr. U. S. De
11	Dr. B. L. Deekshatulu
12	Late Dr. O.N. Dhar
13	Prof. S.K. Dube
14	Prof. (Mrs.) Sulochana Gadgil
15	Dr. B. N. Goswami
16	Dr. Akhilesh Gupta
17	Dr. George Joseph
18	Prof. P.V. Joseph
19	Dr. P.C. Joshi
20	Dr. A.K. Kamra
21	Dr. R.R. Kelkar
22	Prof. R. N. Keshavamurthy
23.	Late Dr. P. Koteswaram
24	Dr. R. Krishnan
25	Dr. S. M. Kulshrestha
26	Dr. Rupa Kumar Kolli
27	Sh. A. S. Kiran Kumar
28	Dr. Santosh Kr. Mishra
29	Prof. U.C. Mohanty
30	Late Dr. D.A. Mooley
31	Dr. Shailesh Nayak
32	Prof. P.C. Pandey
33	Late Dr. G.B. Pant
34	Late Prof. P.R. Pisharoty
35	Late Mr. S. Raghavan
36	Dr. M. Rajeevan
37	Late Dr. Y. Ramanathan
38	Dr. K. J. Ramesh
39	Dr. DV Bhaskar Rao
40	Dr. L. S. Rathore
41	Late Prof K. R. Saha
42	Late Dr. R. P. Sarkar
43	Dr. N. Sen Roy
44	Prof J. Shukla
45	Late Sh. D.R. Sikka
46	Prof. J. Srinivasan

47	Dr. S.K. Srivastav
48	Dr. H. N. Srivastava
49	AVM. Dr. Ajit Tyagi
50	Dr. G.Viswanathan
51	Prof. B. Padmanabha Murty
52	Prof. Ravi Sankar Nanjundiah
53	Dr. Mrutyunjay Mohapatra
54	Prof. S. K. Satheesh
55	Dr. (Mrs.) N. Jayanthi
56	Dr. G. Srinivasan
57	Dr. M. Ravichandran

- **List of IMS Presidents**

S. No.	Name	Period
1	Dr. P. Koteswaram	1971-74
2	Sh. Y. P. Rao	1974-78
3	Dr. P. K. Das	1978-83
4	Sh. S. K. Das	1983-86
5	Dr. R. P. Sarkar	1986-89
6	Dr. S. M. Kulshrestha	1989-91
7	Prof. P.R. Pisharoty	1991-93
8	Dr. N. Sen Roy	1993-95
9	Dr. R.K. Datta	1995-97
10	Dr. R. R. Kelkar	1997-99
11	Dr. S. K. Srivastav	1999-2001
12	Prof. S. K. Dube	2001-2003
13	Dr. S.K. Srivastav	2003-05
14	Dr. G. B. Pant	2005-07
15	Sh. R. C. Bhatia	2007-09
16	Dr. L. S. Rathore	2010-12
17	Dr. Shailesh Nayak	2012-14
18	Dr. Akhilesh Gupta	2014-16
19	AVM Dr. Ajit Tyagi	2016-18
20	Prof. S. K. Dash	2018-20
21	Dr. M. Mohapatra	2020-22
22	Dr. Rupa Kumar Kolli	2022-24

- **List of IMS Associate Fellow**

S. No.	Name
1	Prof. Sandeep Pattnaik
2	Dr. Ayantika Dey Choudhury

- **IMS National Council (2022-24):** The IMS new National Council took over the charge from the previous council 0n 26th April, 2022.

Indian Meteorological Society National Council 2022-24	
President	Dr. Rupa Kumar Kolli
Immediate Past President	Dr. Mrutyunjay Mohapatra
Vice President	Dr. D R Pattanaik Dr. N Subash
Secretary	Dr. R K Giri
Jt. Secretary	Dr. Ananda Kumar Das
Treasurer	Dr. Sankar Nath
Member	Prof. P V S Raju Dr. V K Soni Mr. Sikandar M Jamadar Mr. Sanjay Bist Ms. Samanti Sarkar Dr. Pankaj Kumar Dr. Rajiv Chattopadhyay Mr. Sunny Chug

5. General IMS Activities

To achieve the objectives the IMS involves in carrying out the following work.

- Encourages research activity.
- Organizes lectures, meetings, symposia, discussions etc.
- Arranges to publish suitable pamphlets, books, periodicals, brochures etc.
- Promotes Co-operation in scientific work.
- Encourages the members to foster common interests of the Meteorological professions
- Give awards and fellowship to distinguished scientists.

6. Sponsor Scientific Events and Organization of Symposia/Conferences

To Sponsor Scientific Events

- The Society sponsored for the first time a scientific event in April 1970. This was a symposium on Satellite Meteorology held at Pune.
- Later on it sponsored the International Symposium on Monsoons which held in March 1977 at New Delhi.
- It also sponsored the National Symposium on Early Results of Monsoon Experiments held at New Delhi in March 1981.

Organisation of Scientific Symposia

- With a beginning in 1976 the Society has organised the following National Symposia/Seminars so far:
- Seminar on Weather Modification New Delhi February **1976**
- Symposium of Local Severe Storms Calcutta February **1982**
- Symposium on Tropical Cyclones and Disaster Preparedness Bhubaneswar January **1984**

Annual National Symposia Series on Tropical Meteorology (TROPMET)

- Monsoon Variability, Satellite Application and Modelling, Ahmedabad, February **1992**
- Meteorology for National Development, New Delhi, February **1993**
- Climate Variability, Pune, February **1994**
- Advanced Techniques in Meteorology, Hyderabad, February **1995**
- Meteorology and Natural Disasters, Visakhapatnam, February **1996**
- Symposium on Monsoon, Climate and Agriculture, Bangalore, February **1997**
- Meteorology beyond 2000, Chennai, **1999**
- Ocean & Atmosphere, Cochin, February **2000**
- Meteorology for Sustainable Development, Mumbai, February **2001**
- Forecasting & Mitigation of Meteorological Disasters: Cyclones, Floods & Droughts, Bhubaneswar, February **2002**
- Role of Meteorology in National Development, Pune, **2006**
- Advances in Meteorology and their Applications, Bhopal, **2007**
- Meteorology, Atmospheric Science, Weather & Climate and allied services and disaster management, Kolkata **2010**
- Meteorology for Socio-economic Development, Hyderabad, **2011**
- National Symposium on Frontiers of Meteorology with special reference to the Himalayas. Dehradun **2012**
- National Symposium on Weather & Climate Extremes, Chandigarh – **2015**
- National Symposium on Tropical Meteorology: Climate Change and Coastal Vulnerability, Bhubaneswar **2016**
- National Symposium on Tropical Meteorology: Understanding Weather and Climate Variability: Research for Society, Varanasi **2018**
- National Symposium on Tropical Meteorology: Land, Ocean and Atmosphere Interactive Processes in the Context of Weather and Climate, Visakhapatnam **2019**

- National Symposium on Tropical Meteorology on “Weather and Climate Services over Mountainous Regions” at NESAC, Shillong during 14 - 17 December **2020**.
- National Symposium on Tropical Meteorology on “Advances in Weather and Climate Prediction and Climate Change Projection over South Asia: Applications in Water and Agriculture Sectors” at IISER, Bhopal during 29th November - 02 December **2022**

<u>International TROPMET (INTROPMET) Organised by IMS</u>

- International Symposium on Asian Monsoon & Pollution over Monsoon Environment, (INTROPMET-1997) New Delhi, December 2-5, **1997**
- International conference on monsoon (ICOM) and WMO Workshop on forecasting monsoons from days to years, New Delhi. March 21-26, **2001**
- International conference on Seismic Hazard with particular reference to Bhuj Earthquake of January 26, 2001. New Delhi, 3-5 October, **2001**
- International Symposium on Natural *hazards* (*INTROPMET 2004*) February 24-27 ,*2004,* Hyderabad.
- Monex-25, Celebrating *25*th Anniversary of Summer Monsoon Experiment-**1979** (Monex-25 and its Legacy), New Delhi, 3-7th February, 2005

On behalf of NSF, Jay Fein accepts a bouquet expressing thanks from the Indian research community for NSF's support of MONEX-1979. Also pictured are (left to right) Late D. R. Sikka, V. S. Ramamurthy (India Department of Science and Technology), S. K. Dube (Indian Institute of Technology), and Peter Webster (Georgia Institute of Technology). IMS function, Delhi 2005.

- International symposium on Challenges & Opportunities in Agro-meteorology (INTROPMET – 2009), New Delhi, 23-25 February **2009.**

- International Tropical Meteorology Symposium on Monsoons- Observation, Prediction and Simulation (MOPS) (INTROPMET -2013), Chennai**,** originally scheduled in 2013 but was organized during 21-24 February**, 2014.**
- International Tropical Meteorology Symposium on Advancements in Space-based Earth Observations and Services for Weather and Climate (INTROMET- 2017), 03-07 November, **2017,** Ahmedabad.
- Virtual International Symposium on Tropical Meteorology (INTROMET-2021) on "Changing Climate: Consequences and Challenges" at CUSAT, Cochin, India during 23 - 26 November **2021**.

A Brief Report of INTROMET-2021, 23-26 November, 2021, Cochin Chapter

The International Symposium on Tropical Meteorology (INTROMET-2021) was conducted at the Cochin University of Science and Technology (CUSAT), Kerala during 23-26 November 2021. The inaugural and the valedictory functions were conducted in hybrid mode. The Technical Sessions of the Symposium was organised in three parallel virtual Halls (Hall-1: Pampa, Hall-2: Periyar, Hall-3: Nila) hosted at the Advanced Centre for Atmospheric Radar Research (ACARR), CUSAT. The INTROMET-2021 received 537 abstracts from across the national and international delegates. There were 13 plenary talks, 38 lead talks, and 28 invited talks, in addition to 114 oral and 272 poster presentations. The symposium had 17 Technical Sessions, 3 Early Career Researcher's Sessions and an interactive session on the National Weather Service. Nationally and internationally reputed scientists became part of the Symposium as Session Chairs, Lead and Invited speakers. Young and leading scientists from all major States, National and International Institutions participated as oral and poster presenters.

Among the highlights of the Symposium were three elegant memorial lectures on behalf of the three eminent Atmospheric Scientists of Indian origin, viz., Prof. P.R. Pisharoty, Prof. R. Ananthakrishnan and Ms. Anna Mani, and the release of special Postal Covers on their behalf. A special session that widely attracted the interests of both the scientists and the common public was the interactive assembly of the National Weather Services which revealed largely the weather services rendered by various organisations under the Ministry of Earth Sciences, Govt. of India.

The Inaugural session of INTROMET-2021 was conducted in virtually connected two parallel physical venues (1) at ACARR, CUSAT and (2) Mahika Hall, Prithvi Bhavan

MoES, New Delhi from 10 AM on 23rd November 2021. Dr. Mrutyunjay Mohapatra, DGM, IMD & President, IMS presided over the Session. Dr. M. Ravichandran, Secretary, MoES and DST was the Chief Guest on this occasion. Dr. M. Rajeevan, former Secretary, MoES was the Guest of Honour. Dr. D. R. Pattanaik, Secretary, IMS New Delhi, Prof. K.N Madhusoodanan, Vice Chancellor, CUSAT, Prof. K. Mohankumar, Chairman of INTROMET-2021, CUSAT and Dr. Abhilash S, Director, ACARR, CUSAT & Secretary of IMS Cochin chapter were among the speakers in the opening ceremony. Dr. M. R. Rameshkumar, retired Chief Scientist, NIO, Goa, released the abstract volume. In this Session, Dr. M. Ravichandran was bestowed with the prestigious IMS Fellowship.

Presentation of IMS Fellow to Dr. M. Ravichandran

Release of INTROMET 2021 Souvenir

IMS, Cochin Chapter (INTROMET-2021, LOC)

Release of Abstract volume (INTROMET-2021)

7. IMS Publications

To popularize Meteorology and Atmospheric Sciences, the Indian Meteorological Society (IMS) brings out the Research journal "Vayu Mandal", which is the official Bulletin of IMS. This is brought out twice a year since 1971 to encourage research work and provide information on latest developments in the atmospheric sciences. At present the Chief Editor, Managing Editor and Executive Editor are given below.

Chief Editor: Prof. S.K. Dash, skdash@cas.iitd.ernet.in, IIT Delhi, New Delhi
Managing Editor: Dr.D.R.Pattanaik, drpattanaik@gmail.com, IMD, New Delhi
Executive Editor: Dr. Kamaljit Ray, kamal.ray@nic.in, MoES, New Delhi

The article can be submitted to :
Executive Editor
Vayu Mandal
Indian Meteorological Society
Room No. 605, VI Floor, Satellite Meteorological Building,
Mausam Bhavan Complex, Lodi Road, New Delhi-110 003.
Email: vayumandal.ims@gmail.com

8. IMS Awards and Fellows

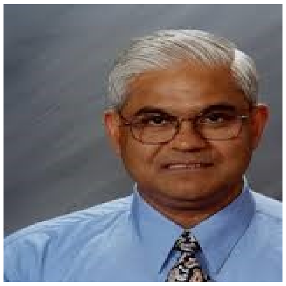
8.1 IMS International Award: "Sir Gilbert Walker Gold Medal"

IMS has instituted "Sir Gilbert Walker Gold Medal" in 2001 to be given biennially to an eminent Indian or foreign scientist of international recognition in the field of monsoon studies. There is no bar on the age and nationality. Now the Prize money for this award is Rs. 100000/- and a gold plated silver medals (100gm weight) and a Citation. The selection will be made by a judging committee with IMS President and minimum two Fellows of IMS as members. Sir Gilbert Walker, the legendary meteorologist who did pioneering and monumental work on long range forecasting of Indian monsoon, was the Director General of India Meteorological Department for 20 years (1904-1924).

"List of Sir Gilbert Walker Gold Medal Awardees" so far are:

(1) **Prof. J. Shukla,** COLA, USA
(2) **Late Prof. P. K. Das,** Former DGM, IMD
(3) **Prof. U. C. Mohanty,** IIT Delhi
(4) **Late Shri. D. R. Sikka,** Former Director, IITM, Pune
(5) **Late Prof. T. N. Krishnamurti,** Professor FSU, USA
(6) **Prof. (Mrs) Sulochana Gadgil,** IISC, Bangalore
(7) **Prof. R. N. Keshavmurty,** Former Director IITM, Pune.
(8) **Prof. P. V. Joseph,** UGC Visiting Prof./Emeritus Prof., CUSAT, Cochin

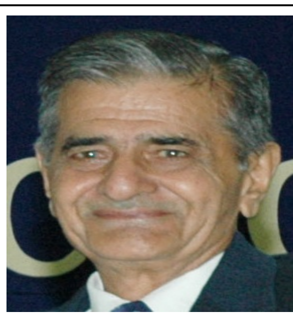
Sir Gilbert Walker Gold Medal Awardees of IMS



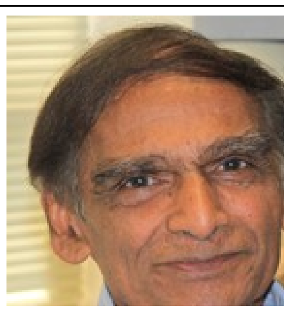
Prof. J Shukla is a Distinguished University Professor at George Mason University, USA, where he founded the Department of Atmospheric, Oceanic, and Earth Sciences and Climate Dynamics PhD Program. Prof. Shukla's scientific contributions include studies of: the dynamics of monsoon depressions; the climate variability; the influences of SST on seasonal variability; the intraseasonal and inter-annual variability of monsoons; the predictability and prediction of monsoons, tropical droughts, and ENSO.

Late Prof. P. K. Das, former Director General of Meteorology, India Meteorological Department (during 1979-1983) passed away on 14 January, 2011 at the age of 84. He had joined the IMD in 1949. Prof. Das made pioneering research and contributions to Meteorology, in particular to the development of Numerical Weather Prediction in India. He worked on cloud physics with Sir John Mason at Imperial College, London. He also worked with Prof. Jule Charney, Prof. Norman Philips and Ed Lorenz of the MIT and Reid Bryson at the University of Wisconsin.

Prof. U. C. Mohanty worked at IIT Delhi before shifting to IIT Bhubaneswar as Visiting Professor, in the School of Earth Ocean and Climate Sciences (SEOCS). He has made outstanding contribution in the field of tropical meteorology, in particular, Asian summer monsoon dynamics, tropical cyclone research, numerical weather prediction in tropics, mesoscale modeling of extreme weather events over Indian monsoonal regime, extended range prediction of Indian summer monsoon and regional climate modeling.



Late Prof. D. R. Sikka, Former Director of IITM (1986-1992) is an international expert on monsoon in particular and on Tropical Meteorology in general. His knowledge and experience of last six decades are considered brilliant. He never retired from the limits of his scientific capability. He was very active even at the age of more than eighty. He was spearheading many important projects/missions of Ministry of Earth Sciences, Department of Science & Technology related to Atmospheric Sciences.



Late Prof. T. N. Krishnamurti, at present is Professor Emeritus in the Department of Meteorology, Florida State University, where prior to his retirement he was the Lawton Distinguished Professor of Meteorology. He has specialized in studies of monsoon, hurricanes and numerical weather prediction and more recently on multi-model super-ensemble forecasts for global weather (including hurricanes) and climate. He has published over 250 papers and two textbooks.

Prof. Sulochana Gadgil: Worked at the Centre for Atmospheric and Oceanic Sciences (CAOS) in Bangalore, India for most of her career. She has studied the how and why of monsoon, including farming strategies to cope with rainfall variability and modeling ecological and evolutionary phenomena. Her research led to the discovery of a basic feature of the sub-seasonal variation in the monsoon cloud bands. She demonstrated monsoon is a manifestation of the seasonal migration of a planetary scale system.

Prof. R. N. Keshavamurty was born on 6th May 1936. He did M.Sc. in Physics and Ph.D. in Physics/Atmospheric Science. He joined IMD in the year 1959 and later he joined IITM, Pune as Senior Scientist in the year 1968. Other important positions held by him was Associate Professor and Professor at Physical Research Laboratory, Ahmedabad (1978-1992), Director of Indian Institute of Tropical Meteorology, Pune (1992-1996) and Member, WMO/ICSU Joint Scientific Committee of the World Climate Research Programme (WCRP) during 1987-1990.

Prof. P. V. Joseph was born on 29th December 1932 in Kerala, Prof. Porathur Vareed Joseph did his Master's degree in Physics in 1953 from the University of Madras. In 1957, he joined the India Meteorological Department (IMD) at Colaba and Alibag Observatories, Bombay. During 1980 to 1989 he was Director of the Meteorological Training School of IMD / WMO at Pune. In 1983 he obtained PhD degree in Physics from the University of Poona for research on monsoon variability. The IMS conferred upon Prof. (Dr.) P. V. Joseph – the Life Time Achievement Award of the IMS in 2016.

INDIAN METEOROLOGICAL SOCIETY
SIR GILBERT WALKER GOLD MEDAL
PROF (DR.) PROF. PORATHUR VAREED JOSEPH

Born on 29th December 1932 in Kerala, Prof. Porathur Vareed Joseph did his Master's degree 1953 from the University of Madras. Prof. Joseph taught Physics for four years at S. B. Colleg the University of Kerala. In 1957, he joined the India Meteorological Department (IMD) a Alibag Observatories, Bombay where he did data collection and research in geo-magnetism During 1962-1963 he was trained in Meteorology and Weather Prediction. For the following he was assigned to do operational weather forecasting at several centres of IMD, particular meteorology and cyclone warning. During 1980 to 1989 he was Director of the WM Meteorological Training Centre (RMTC) of IMD at Pune. In 1983 he obtained PhD degree in the University of Poona for research on monsoon variability.

Taking voluntary retirement from IMD in 1989, Dr. Joseph took up various assignments in Inc Visiting Scientist at the Universities of Colorado and Hawaii USA, Visiting Scientist at India Science, Bangalore, Visiting Faculty at Space Application Centre, Ahmedabad, and Scientis Norwegian research centre NERCI at Cochin. During about recent 22 years, Prof. Joseph w Visiting Professor / Emeritus Professor at the Department of Atmospheric Science of the Coch of Science and Technology where he did teaching of M. Sc and M. Tech courses and res atmosphere-ocean system in collaboration with the faculty and PhD students.

Prof. Joseph has done original research for more than five decades in Tropical Meteorolog Cyclones and Thunderstorms), Climate Change and Ocean-Atmosphere interaction. He ha publications (40 of them in peer reviewed scientific journals). In 1978, for original research in Physics and Hydrology, Joseph received the Hari Om Ashram Prerit Dr. Vikram Sarabhai Res In 2012 he was the recipient of the Swadeshi Science Puraskaram and also of felicitations on th Day of India Meteorological Department. In July 2016 the Ministry of Earth Sciences prese National Award for excellence in Atmospheric Science and Technology. In the same year 201 was conferred upon the Life Time Achievement Award of the Indian Meteorological Society. served as member of the International Advisory Panel of the Ministry of Earth Sciences, G India. Prof. Joseph is a Fellow of Indian Meteorological Society (was its General Secretary f and later Vice-president for four years), member and two term President of Ocean Society of I Emeritus Member of the American Meteorological Society.

Prof. Joseph discovered a low level Jet-stream in monsoon and found that its axis had differe positions over India in the active and break phases of the monsoon. During the recent years h climate change in global jet streams. His ongoing research work (published in June 2016) is or the ocean - atmosphere system (a negative feedback) that produces epochs like the recent 1961 to 1990 of frequent Indian monsoon droughts and north moving severe cyclones in the Ba

8.2 *IMS National Biennial and Annual Awards*

The IMS had instituted three biennial research awards from the endowment gifted by the sponsors viz., Dr. B.N. Desai Award, V. Bhavnanayana Award, J. Das Gupta Award, Dr. P. Krishna Rao and Prof. A.D. Vernekar awards. In 2011 IMS re-designed these awards by increasing the prize money by contributing from IMS along with the endowment gifted earlier by the sponsors. These awards are as per the details given below.

(i) ***IMS Award for Best Paper Published on Monsoon Research (Formerly B.N. Desai Award):*** A Citation and cash prize of Rs.15,000/-.

(ii) ***IMS Biennial award for best paper published on Atmospheric Observations & Technologies (Formerly J. Das Gupta Award):*** A Citation and cash prize of Rs.15,000/-.

(iii) ***IMS Biennial award for best paper published on Weather and Climate Services (Formerly Bhavanarayana Award):*** A Citation and cash prize of Rs. 15,000/-

(iv) ***IMS Biennial award for best paper published on Application of Satellite data and Remote Sensing in Meteorology (Formerly P. Krishna Rao Award) :*** A Citation and cash prize of Rs. 25,000/-

(v) ***IMS Biennial award for best paper published on Modelling study on Atmospheric and Oceanic Sciences (Formerly A. D. Vernekar Award) :*** A Citation and cash prize of Rs. 25,000/-

(vi) In addition to above five awards, IMS has also introduced another biennial award viz., "**VayuMandal Award**" from (2017-2018) for the best paper published in IMS journal – VayuMandal (Citation & Rs. 15,000/-).

(vii) IMS Young Scientist Award

During 2012 IMS has also instituted a young Scientist award (Below 45 years) to be given annually for the Best Paper Published in Tropical Meteorology with a Citation and award money of Rs. 50,000/-.

Constitution of IMS New Biennial Award

(viii) IMS has constituted another biennial award based on the contribution money donated by **Prof. DVB Bhaskar Rao** during the inaugural function of TROPMET 2019 held in Vishakhapatnam. The first award in this series will be given for the period 2020-2021 and it will be presented during the inaugural session of TROPMET-2022 to be held in IISER, Bhopal during 29 November to 02 December.

Winner of IMS Biennial Awards (2020-2021)

IMS has announced the winner of above mentioned three Biennial awards for the year 2020-2021. They will be awarded the same during the inaugural function of annual National symposium TROPMET, 2022 on 29th November, 2022.

S. No	Name of the Award	First Author	Full Paper
1	Best Paper Published on Monsoon Research	**Soumya Samanta**	Soumya Samanta, P. Murugavel, Dinesh Gurnule, Y. Jaya Rao, Jothiram Vivekanandan, and Thara V. Prabha **(2021)**: The Life Cycle of a Stationary Cloud Cluster during the Indian Summer Monsoon: A Microphysical Investigation Using Polarimetric C-Band Radar Monthly Weather Review, Vol. 149, Page No. 3761–3780.
2	Best Paper published on Weather and Climate Services	**Rishi Kumar Gangwar**	Rishi Kumar Gangwar and Pradeep Kumar Thapliyal **(2021)**: Optimal estimation of total precipitable water from INSAT-3D/3DR Imagers, Journal of the Royal Meteorological Society, DOI: 10.1002/qj.4215, Page No. 14.
3	Best Paper published on Climate Science and Climate Change (Prof. D. V. Bhaskar Rao Award)	**Kamaljit Ray**	Kamaljit Ray, R.K.Giri, S.S.Ray, A.P.Dimri and M.Rajeevan **(2021)**: An assessment of long-term changes in mortalities due to extreme weather events in India: A study of 50 years' data, 1970–2019, weather-and-climate-extremes, Vol. No 42, Page No. 1-10.

8.3 IMS National Annual Award [IMS Young Scientist Awards (Annual)]

IMS young scientist award for best paper published on Tropical Meteorology. **(Citation & Rs. 50,000/-; At least the 1st author should be below 45 years of age)**

Winner of IMS Young Scientist Award for 2021

IMS has also announced the winner of young scientist awards for the year 2021. She will be awarded the same during the inaugural function of annual National symposium TROPMET, 2022 on 29th November, 2022.

S. No	Name of the Award	First Author	Full Paper
1	Best Paper Published in Tropical Meteorology (2021)	**S. Indira Rani**	S. Indira Rani, Arulalan T., John P. George, E. N. Rajagopal, Richard Renshaw, Adam Maycock, Dale Barker and M. Rajeevan **(2021)**: IMDAA: High Resolution Satellite-era Reanalysis for the Indian Monsoon Region, Journal of Climate, Volume-34, Issue-12.

List of “IMS Young Scientist Awardees” so far since its inception in 2012 are:

S. No.	Name	Year
1	Dr. Hemant Chaudhary, IITM, Pune	2012
2	Dr. Randhir Singh, SAC, Ahemedabad	2013
3	Dr. D. R. Pattanaik, IMD, New Delhi	2014
4	Dr. Roxy Mathew, IITM, Pune	2015
5	Dr. (Ms.) P Rohini, IITM, Pune	2016
6	Dr. (Ms) Gayatri Kulkarni, IITM, Pune	2017
7	Dr. Siddarth S Das, VSSC, Trivandrum	2018
8	Shri Raju Mandal, IITM, Pune	2019
9	Dr. Vimal Mishra, IIT Gandhinagar	2020
10	Dr. S. Indira Rani, NCMRWF, Noida	2021

Dr. Hemantkumar Chaudhari

Dr. Randhir Singh Hooda

Dr. D. R. Pattanaik

Dr. Roxy Mathew Koll

Dr. (Ms) P. Rohini

Dr. (Ms) Gayatri Kulkarni

Dr. Siddarth S Das

Dr. Raju Mandal

Dr. Vimal Mishra

Dr. S. Indira Rani

INDIAN METEOROLOGICAL SOCIETY
YOUNG SCIENTIST AWARD FOR BEST PAPER
PUBLISHED ON TROPICAL METEOROLOGY

The Indian Meteorological Society (IMS) has a tradition of promoting excellence in the field of Meteorology and Allied disciplines through the institution of various awards. Accordingly, different annual and biennial awards are regularly conferred upon members of the society in recognition of their research accomplishments.

The IMS Young Scientist Award on Tropical Meteorology is given annually to the best research paper published by a Young Scientist of IMS. Keeping with the tradition of IMS, the research paper **entitled "IMDAA: High Resolution Satellite-era Reanalysis for the Indian Monsoon Region" by S. Indira Rani, Arulalan T., John P. George, E. N. Rajagopal, Richard Renshaw, Adam Maycock, Dale Barker and M. Rajeevan, published in Journal of Climate, Volume-34, Issue-12 during 2021** is adjudged as the Best Paper on Tropical Meteorology among other publications considered for 2021. *The paper indicates that Indian Monsoon Data Assimilation and Analysis (IMDAA) was a project under the National Monsoon Mission of MoES. Through collaborative R&D efforts of NCMRWF, the U.K Met Office, and IMD, IMDAA produced a state-of-the-art high-resolution (12 km) regional reanalysis over the India monsoon region for 40 years from 1979 using an advanced assimilation-forecast system and observation datasets from ECMWF, IMD and NCMRWF archives. The paper presented a comprehensive view of the IMDAA system and verification of IMDAA products over India during various seasons. It is shown that salient features of the Indian summer monsoon are well represented in this reanalysis. IMDAA captured fine-scale features associated with summer monsoon rainfall. The paper clearly shows that IMDAA is a good quality reanalysis dataset that can be used for research on weather and climate over the Indian monsoon region.*

In recognition of the above research accomplishment, the IMS Young Scientist Award on Tropical Meteorology for the year 2021 is conferred upon **S. Indira Rani** on this day of 29th November, 2022.

29th November, 2022

(Dr. Rupa Kumar Kolli)
President, IMS

INDIAN METEOROLOGICAL SOCIETY AWARD FOR BEST PAPER PUBLISHED ON MONSOON RESEARCH (FORMERLY B. N. DESAI AWARD)

The Indian Meteorological Society (IMS) has a tradition of promoting excellence in the field of Meteorology and Allied disciplines through the institution of various awards. Accordingly, different annual and biennial awards are regularly conferred upon members of the society in recognition of their research accomplishments.

The IMS award on Monsoon Research (Formerly B. N. Desai Award) is given biennially to the best research published by an IMS member. Keeping with the tradition of IMS, the research paper **entitled "The Life Cycle of a Stationary Cloud Cluster during the Indian Summer Monsoon: A Microphysical Investigation Using Polarimetric C-Band Radar" by Soumya Samanta, P. Murugavel, Dinesh Gurnule, Y. Jaya Rao, Jothiram Vivekanandan, and Thara V. Prabha published in Monthly Weather Review, Vol. 149, Page No. 3761–3780 during 2021** is adjudged as the Best Paper on Monsoon Research among other publications considered for 2020-2021. *This study illustrates the first-ever detailed microphysical pathways of precipitation during the lifecycle of a mesoscale cloud cluster over the Indian Summer Monsoon (ISM) region using dual-polarization radar. The unique features observed are: the size sorting of raindrops, dendritic growth zones, the occurrence of the saggy bright band, the presence of hail, vertical ice, etc. The observed benchmark case is used to evaluate the microphysical parameterizations over the ISM region, leading to several follow-up publications.*

In recognition of the above research accomplishment, the IMS Biennial Award on Monsoon Research for the year 2020-2021 is jointly conferred upon **Soumya Samanta, P. Murugavel, Dinesh Gurnule, Y. Jaya Rao, Jothiram Vivekanandan, and Thara V. Prabha** on this day of 29th November, 2022.

29th November, 2022 (Dr. Rupa Kumar Kolli)
President, IMS

INDIAN METEOROLOGICAL SOCIETY AWARD
FOR BEST PAPER PUBLISHED ON
WEATHER AND CLIMATE SERVICES
(FORMERLY BHAVANARAYANA AWARD)

The Indian Meteorological Society (IMS) has a tradition of promoting excellence in the field of Meteorology and Allied disciplines through the institution of various awards. Accordingly, different annual and biennial awards are regularly conferred upon members of the society in recognition of their research accomplishments.

The IMS award on Weather and Climate Services (Formerly Bhavanarayana Award) is given biennially to the best research paper published by an IMS member. Keeping with the tradition of IMS, the research paper **entitled "Optimal estimation of total precipitable water from INSAT-3D/3DR Imagers" by Rishi Kumar Gangwar and Pradeep Kumar Thapliyal published in Journal of the Royal Meteorological Society, DOI: 10.1002/qj.4215, Page No. 14 during 2021** is adjudged as the Best Paper on Weather and Climate Services among other publications considered for 2020-2021. *In this paper, the research describes the development of the optimal estimation-based retrieval algorithm of total precipitable water (TPW) from INSAT-3D/3DR Imagers. The assessment of the developed algorithm shows that not only it captures the seasonal variability of the TPW but also has the capability to produce state-of-the-art TPW products from INSAT-3D/3DR Imagers.*

In recognition of the above research accomplishment, the IMS Biennial Award on Weather and Climate Services for the year 2020-2021 is jointly conferred upon **Rishi Kumar Gangwar and Pradeep Kumar Thapliyal** on this day of 29th November 2022.

29th November 2022

(Dr. Rupa Kumar Kolli)
President, IMS

INDIAN METEOROLOGICAL SOCIETY AWARD
FOR BEST PAPER PUBLISHED ON
CLIMATE SCIENCE AND CLIMATE CHANGE
(PROF. D. V. BHASKAR RAO AWARD)

The Indian Meteorological Society (IMS) has a tradition of promoting excellence in the field of Meteorology and Allied disciplines through the institution of various awards. Accordingly, different annual and biennial awards are regularly conferred upon members of the society in recognition of their research accomplishments.

The IMS award on Climate Science and Climate Change (Prof. D. V. Bhaskar Rao Award) is given biennially to the best research paper published by an IMS member. Keeping with the tradition of IMS, the research paper **entitled "An assessment of long-term changes in mortalities due to extreme weather events in India: A study of 50 years' data, 1970–2019" by Kamaljit Ray, R.K.Giri, S.S.Ray, A.P.Dimri and M.Rajeevan published in weather-and-climate-extremes, Vol. No 42, Page No. 1-10 during 2021** is adjudged as the Best Paper on Weather and Climate Services among other publications considered for 2020-2021. *In this study, the authors examined the trends in mortality due to extreme weather events in India, using a 50-year (1970–2019) data set. The objective was to provide relevant information to the government for its disaster management policies. The study revealed that floods and tropical cyclones have been major disasters causing high mortality in India. Heat waves and lightning gained importance in recent years.*

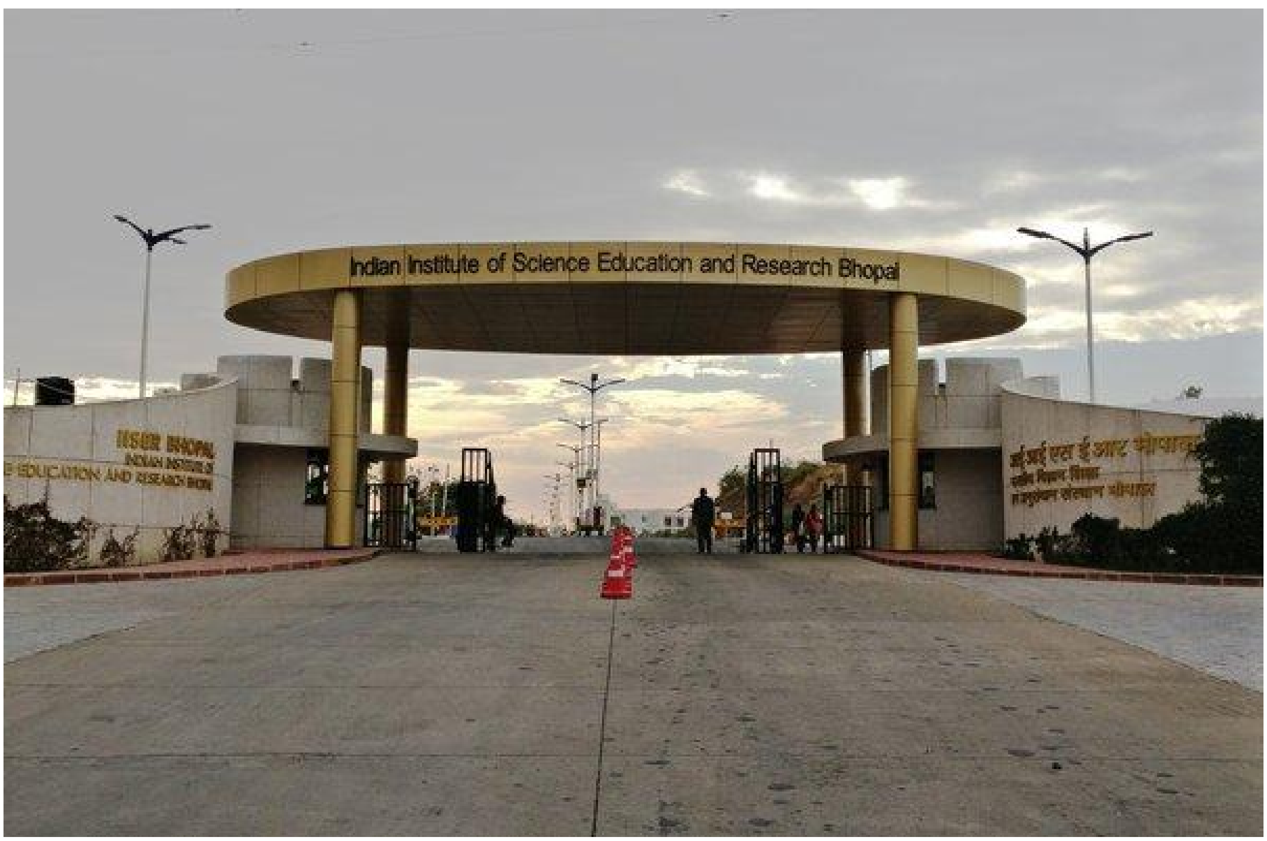
In recognition of the above research accomplishment, the IMS Biennial Award on Climate Science and Climate Change for the year 2020-2021 is jointly conferred upon **Kamaljit Ray, R.K.Giri, S.S.Ray, A.P.Dimri and M.Rajeevan** on this day of 29th November, 2022.

29th November, 2022

(Dr. Rupa Kumar Kolli)
President, IMS

Indian Institute of Science Education and Research (IISER Bhopal)

The Indian Institute of Science Education and Research (IISER) Bhopal, a premier academic institute, was established in 2008 by the Ministry of Education, Govt. of India. It offers BS-MS dual and Ph.D. degrees in various academic disciplines. Over the years, IISER Bhopal has been attracting talented young minds who want to delve into interdisciplinary science and research to shape the nation by inventing and implementing sustainable solutions for societal problems. The first academic session of IISER Bhopal began on August 16, 2008, from the Transit campus. The institute is currently governed by the NITSER (Amendment) Act, 2017, and the Statutes of IISERs.



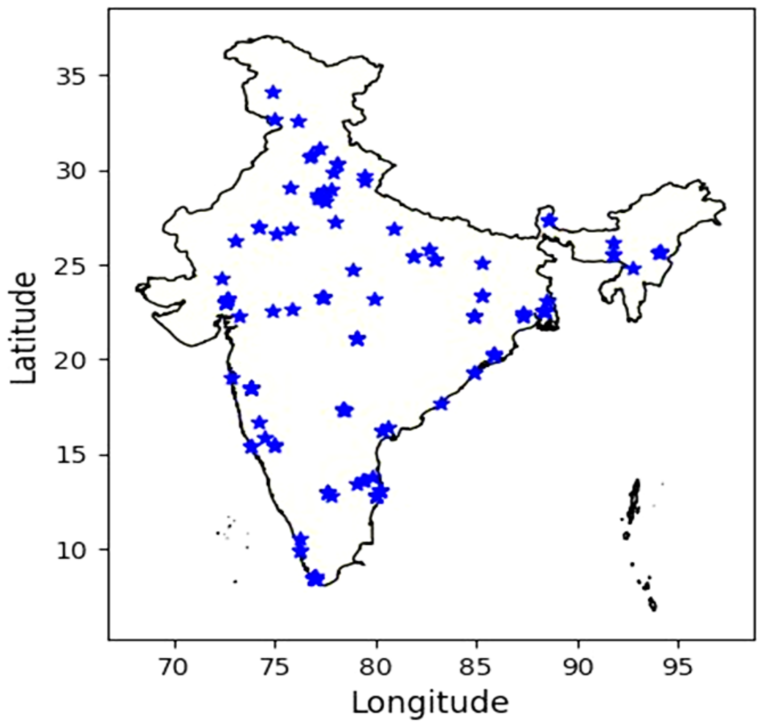
Earth and Environmental Science Department

The Earth and Environmental Sciences department (EES) started as a minor course in 2014 and a major in 2016 to encourage multidisciplinary studies integrating chemistry, biology, physics, geology, and environmental science. It offers students a unique opportunity to build on their foundation in natural and engineering sciences to solve problems in the domain of EES.

EES at IISER Bhopal endeavors to be truly interdisciplinary, integrating principles of natural and engineering sciences, to address geological and environmental issues related to the solid earth, the oceans, and the atmosphere.

The Department currently offers a doctoral degree (Ph.D.) and the Bachelor of Science-Master of Science (BS-MS Dual Degree) in EES/Geology/Environmental Sciences. In addition to a 'major' in EES, the Department also offers a 'minor' to BS-MS students. This offers students a unique opportunity to build on their foundation in natural and engineering sciences to solve problems in the domain of EES.

Participation in TROPMET-2022



Location of participants who took part in TROPMET 2022

Total abstract received	~470
Category	**Approx. Count**
Plenary Speakers	7
Keynote Speakers	26
Invited Speakers	36
Oral Talks	148
Lightening Talks	95
Poster Presentation	137
NOC members	49
LOC members	24
Volunteers	68
Total	590

ABSTRACTS

Temperature and Precipitation Characteristics over Tirupati-Tirumala

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ABSTRACT

Recent climate change-induced warming and associated changes in atmospheric patterns and air-sea interactions lead to extreme weather events on a temporal and spatial scale. Pertaining to the socio-economic losses posed by these extremes, understanding the occurrence of extreme events more locally is a high priority. In this work, we study the historical (1901- 2021) characteristics and future trends (2021-2060) in the temperature and precipitation patterns over Tirupati-Tirumala, the holy city and a rapidly developing centre for education, IT and healthcare in South India. We use the Indian metrological data (IMD) and 35 models from CMIP-6, respectively, with daily temporal and 0.25 spatial resolution. While this region receives peak precipitation in the winter monsoon during Oct-Nov (above 150 mm/month), average monthly rainfall of 100 mm/month has been noticed in the summer monsoon from Jun-Sep. Similarly, monthly average temperatures during summer (Apr-Jun) is about 35°C. Minimum mean monthly temperatures during Dec-Jan are at 10°C. Both annual and seasonal precipitation and temperature show a significant positive trend (increase) in the recent decades. This pattern is prevailing in the near future with an increase in heavy rainfall events and extremely hot days.

Potential Economic Value of probabilistic forecast from a global ensemble prediction system

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ABSTRACT

A weather forecast is only useful if it can help the users in decision making. A decision-maker strives to determine the best course of action based on the available meteorological data. One way for determining the difference in value between two forecasts is to compare Potential Economic Values (PEV). Due to the inevitable errors in prescribing initial condition and formulating the model the forecast from a numerical weather prediction model has uncertainty. The uncertainty information associated with the forecast provided by an ensemble prediction system (EPS) can be very useful in the decision-making processes. However, since PEV is dependent on the reliability and preciseness of the forecast an unreliable and inaccurate forecast from a poor EPS can never have higher PEV than a skillful single forecast.

NCMRWF Global Ensemble Prediction System (NEPS-G) has 23 ensemble members (1 control +22 perturbed) and about 12 km horizontal resolution. The perturbation in initial condition is generated by Ensemble Transform Kalman Filter (ETKF) method. Stochastic Kinetic Energy Back Scattering (SKEB) and Random Parameter (RP) schemes account for the uncertainty in the representation of model physics. The operational global deterministic model forecast is used as the control member of NEPS-G.

The medium range forecast from NEPS-G has been used in the present study to investigate the PEV of the probabilistic forecasting of maximum surface temperature (Tmax), temperature at 850hpa (T850) and precipitation with respect to that of the deterministic forecast during the period April-June 2019 over northern India. Ensemble and control forecasts of day 1 to day 7 have been considered for the present study.

Keywords: Ensemble Prdiction System, Potential Economic Vlaue, Cost-Loss Model, Reliability.
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Utilisation of GNSS IPW Measurements from CORS Network

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ABSTRACT

Continuously Operating Reference Stations (CORS) Network is managed by various agencies worldwide. They provide observation from the Global Navigation Satellite System (GNSS) networks. The information obtained from these GNSS measurements has multifarious utilization ranging from applications in meteorology, geo-positioning, geophysical and space weather. Integrated Precipitable Water (IPW), also known as Total Precipitable Water (TPWT) is one of the important parameters derived from the CORS network. It is the amount of atmospheric water vapour (in kilogram) overlying per unit area of the earth's surface. Its unit is kg/m^2. IPW data is currently used in Numerical Weather Prediction (NWP) by assimilating them on global and regional scales. IPW is directly linked to atmospheric water vapour content, and its assimilation has proven beneficial in short-range humidity and precipitation forecasts. This present study highlights the utilization of IPW data from the CORS network worldwide. The processing of IPW data is summarized. The quality assessment of IPW observation from existing and new CORS network are also discussed along with its current status and future scope in NWP.

Keywords: CORS, GNSS, IPW

EMERGENCE OF FLUORIDE POLLUTION IN CLIMATE IMPACTED PLEISTOCENE BARIND ALLUVIAL TERRACE: AN EXEMPLAR OF NANO-REMEDIATION FROM SOUTH DINAJPUR, WEST BENGAL

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ABSTRACT

The South Dinajpur district that flanks the peri-Himalayan Terai belt in northern fringe of West Bengal dominantly forms part of the Pleistocene Barind (Alluvial) terrace, with 5 out of 8 blocks reeling under acute fluoride pollution. Maximum value is reported from the Gangarampur block (7.49mg/L; 2015data). The provenance of fluoride is geogenic that owes its origin to the fore deep marginal trough of Eastern Himalayas. The area is covered by Older Alluvium (Barind) in the upland reaches and Older/Younger Alluvium (Diara) in the intervening plain lands. As this form of pollution is chiefly diffused and dispersed in the Barind-Diara geomorphic units, the spatial and temporal pattern of pollution needs to be appropriately delineated to assess the hydro geo-chemical analytics thereof. Ferricrete (ferruginous concrete) bearing clay and calcrete (calcareous concrete) bearing sand, silt and clay is the principal repository of fluoride in the Barind formation. A wide interplay of factors operating under diverse hydro-geological and physico-chemical conditions backed by concomitant weather extremes has triggered fluoride leaching from country rock. The treatment envisaged so far under private and/or govt. initiatives is expensive and failed to produce optimum results. In view of a suitable low-cost eco-friendly approach, a new sorbent comprising of nano-crystalline aggregates of Iron-Amended Activated Alumina (IAAA) was innovatively designed and developed in commercial scale for defluoridation of rural community tubewells. The efficiency of this bimetallic nano-oxide was analyzed under controlled laboratory condition by installing a prototype filter unit. The nano-media continued for 6 months, with excellent fluoride removal (2900-3000 mg/Kg) compared to conventional adsorbents. Both surface adsorption and intra-particle diffusion favoured quick removal with minimum interference of co-existing ions. There was no media loss and fluoride emission during de-clogging of filter bed. The findings strongly advocate the novelty of Fe-Al nano-crystallites as new emergent commercial media for fluoride removal from drinking water.

Key words: Bi-metallic, Filter, Fluoride, Groundwater, Nano-crystallites.

LONG-TERM CHANGES IN CLIMATIC VARIABLES – A CASE STUDY FOR CHAMBAL BASIN IN CENTRAL INDIA

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ABSTRACT

The relationships between climate change and extreme events including droughts and floods have begun to be unpacked through the analysis of a number of climate-related and biological feedback loops. Despite the uncertainties involved, the combined evidence of current trends of increased rainfall variability and intensity of extreme events including droughts, along with global climate model predictions of warming, add significantly to concerns that climate change is going to influence the mankind in a big way. As water resources development in Chambal basin is taking place at a rapid pace, the analysis for the changes in climate and its impact on water resources seems to be an interesting aspect. The historic climate analysis has been carried out using the daily gridded rainfall (0.25º×0.25º) and daily maximum and daily minimum temperature (1º×1º) datasets of India Meteorological Department (IMD) during the baseline period (1961-1990) and present period (1991-2015). The future climate analysis has been carried out using the daily scale bias corrected climate projections from 13 Coupled Model Inter comparison Project 6 (CMIP6) simulations under SSP2-45 and SSP5-85 scenarios during the near-term period (2021-2040); mid-term period (2041-2070) and end-term period (2071-2100). The average maximum temperature is projected to increase at the rate of 1.44ºC/100 yr under SSP2-45 scenario and 2.45ºC/100 yr under SSP5-85 scenario in Chambal basin. The average minimum temperature is projected to increase under all future time periods and is projected to increase at a much higher rate as compared to the maximum temperature. The extreme events depicted by the 1-day maximum temperature and the 1-day minimum temperature, are both projected to increase during all future time periods, but the increase is substantially higher during the end-period under SSP5-85 scenario. The very hot days (MaxT>40ºC) and hot days (MaxT>35ºC) are projected to increase substantially during the mid-term and end-term under both SSP2-45 scenario and SSP5-85 scenarios. Similarly, very hot nights (MinT>25ºC) and hot nights (MinT>25ºC) are also projected to increase substantially during the mid-term and end term under both SSP2-45 scenario and SSP5-85 scenarios. The frequency of the extreme precipitation events (Rainfall>200 mm/day) and very heavy precipitation days (Rainfall>100 mm/day) is projected to increase in future time periods, the highest increase being projected during the end-term under SSP5-85 scenario. The 1-day maximum rainfall is also projected to increase substantially and so there is a need to streamline the water management efforts to prevent floods in the region, which has off-late become a regular feature in the region. The ensemble climate models based analysis suggest that the Chambal region will face severe consequences of climate change related impacts in terms of increased precipitation and extreme weather events, which may be too intense during the end-term and calls for area-specific decision making for climate change adaptation and mitigation strategies.

Keywords: Climate change, Extreme events, Precipitation, CMIP6, Chambal basin

Seasonal Variations of the Characteristics of Electrified and Non-Electrified Rainfall Events over Northeastern Part of India

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ABSTRACT

A study is conducted to investigate the seasonal variation of the characteristics of electrified and non-electrified rainfall events over Kohima (Nagaland) in the north eastern region of India. Simultaneous observation of ambient electric field, step changes of electric field (ΔE) and rainfall are considered from the Electric Field Mill (EFM-100) and fast response tipping bucket rain gauge of one minute time integration. A rainfall event is defined for a continuous rain with a minimum duration of 20 minutes and intermittent time (MIT) of 30 minutes as recorded by the rain gauge. The selected rainfall events are designated as an electrified rainfall events if the absolute value of ΔE is greater than 600 V/m with at least one lightning discharge; otherwise it is designated as a non-electrified rainfall event.

A total number of 83 and 110 events were identified during premonsoon and monsoon season respectively.It was observed that 40% of the rainfall events were electrified rainfall events during premonsoon whereas, only 10% events are electrified rainfall events during the monsoon. The average duration of the electrified (non-electrified) events were found to be 55(30) and 75(40) minutes during premonsoon and monsoon respectively. This shows that electrified events are nearly 1.5 times longer in duration compared to the non-electrified events.The average lightning flash per event of the electrified events during pre-monsoon (30 events) were found to be higher than the monsoon (7 events) season. On the other hand, the average rainfall per electrified (non-electrified) event during premonsoon and monsoon were found to be 3.9 (1) mm and 6.2 (1.2) mm. A better correlation was found between the lightning and rainfall per event for electrified event during premonsoon (0.57) as compared to monsoon (0.51). Overall, the study shows distinct electrification processes of the rainfall events during the two seasons. Further investigations are in progress.

Keywords: Rainfall events, Electric Field, Lightning, Northeastern part of India.

FUTURE PROJECTIONS OF CROP WATER AND IRRIGATION WATER REQUIREMENT USING BIAS-CORRECTED REGIONAL CLIMATE MODEL COUPLED WITH CROPWAT

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ABSTRACT

Climate change poses a direct threat to our food and natural water resources. Considering this, a study is conducted to examine the how climate change would affect rice crop water requirement (CWR) and irrigation water requirement (IWR) over the Varanasi district using the NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) coupled with Food and Agricultural Organization CROPWAT 8.0 model. In this regard, for the baseline period (1981-2015) and the future period (2020-2040) under RCP 4.5, the maximum temperature (Tmax), minimum temperature (Tmin), and rainfall datasets were derived from NEX-GDDP. The projected climate variables obtained from Global Climate Models suffers many biases and should not be used directly in crop growth models. Therefore two bias correction methods i.e. linear scaling method (LSM) and modified difference approach (MDA) were employed. Results shows that LSA performed better than the MDA along with improved statistical measure i.e. Percent bias (Pbias). LSM reduces Pbias from 3.92 to 1.43 for Tmax, 1.88 to 0.33 for Tmin and 11 to 2.14 for rainfall. Whereas, in case of MDA, pbias increases from 3.92 to 6.47 for Tmax, 1.88 to 2.40 for Tmin and reduces from 11 to 7 for rainfall. The future projections shows an increasing trend on T_{max} and T_{min}, which are expected to increase by 4.1% and 19% respectively by the year 2040 with respect to historical period (1981-2015) over Varanasi district. This temperature rise will have a significant influence on CWR, causing an increase of 1.1% CWR in 2020, 1.2% in 2030, and 2% in 2040. Due to a wide variation in rainfall, IWR will increase by 18.7%, 4%, and 9% in 2020, 2030, and 2040 respectively. The above results will help in formulating the adaptation measures to alleviate the climate change impacts on agriculture production.

Keywords: Climate Change, NEX-GDDP, Bias Correction, Crop Water Requirement, Irrigation Water Requirement

ANALYTICAL STUDY OF RAINFALL ASSOCIATED WITH TROPICAL CYCLONE 'FANI' USING SATELLITE DATA

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ABSTRACT

Tropical cyclones (TCs) are a catastrophic event that poses a significant threat to coastal areas due to heavy rain. The rainfall associated with TC contributes a major amount to the annual rainfall in India. TC that makes landfall produces storm surges and floods, which can be disastrous to humans, infrastructure, and natural landscapes. Due to the limited research on the quantitative rainfall associated with TC, the prediction of the amount of precipitation remains a challenge. Therefore, a quantitative assessment of TC rainfall is required to forecast the information about the next TC's rainfall. This paper proposes an image processing approach to estimate the total accumulated precipitation and area affected by Extremely Severe Cyclonic Storm, 'FANI' over the Bay of Bengal that hit India in 2019. For this study, we have used the satellite images of IMERG-Late Run of Global Precipitation Measurement (GPM) that provide near real-time gridded global multi-satellite precipitation estimates with quasi-Lagrangian time interpolation for the region which is bounded by 0^o-48^oN and 68^o-98^oE. This will assist meteorologists in preparing the climatology of rainfall associated with TCs over the North Indian Ocean. It will also segregate the TC rainfall from the other concurrent events such as pre-monsoon and post-monsoon showers to a larger extent. It will aid in future research for estimating rainfall rate and predicting the quantitative rain during a cyclonic period.

Keywords: Tropical Cyclone, rainfall, Global Precipitation Measurement (GPM), IMERG

Development of a global mesoscale model (6km): Performance analysis during tropical cyclones: Asani and Tauktae.

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ABSTRACT

NCMRWF has developed a global mesoscale model at an effective spatial resolution of 6 km (5.8° (latitude) x 8.8° (longitude) spacing at Equator). The model, n2048e, is based on the UM grid-point model. The model was tested with Global Atmosphere (GA) v7.1 configuration for tropical cyclones (TC) Asani and Tauktae. The present study describes the development of relevant ancillaries and the suite that runs the simulations based on initialization data from the NCMRWF operational system. The paper presents the results on simulation of the above two mentioned TC. The preliminary results indicate a relative improvement in the prediction of cyclone track and amplitude. Also, the computational performance of the model for a 5-day forecast was found to be satisfactory using 175 nodes on *Mihir* HPCS. The study demonstrated the performance of model dynamics and identifies the need for upgradation of model physics as a scope for further improvement. The future development is targeted towards global convection-permitting modeling at weather time scales.

Establishment of Agro Automatic Weather Station network in India and its performance

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ABSTRACT

India Meteorological Department (IMD) has undertaken installation of Agro-Automatic Weather Stations (AWS) at 200 places to provide exact weather forecasts to people, especially farmers in first Phase. The 200 Agro-AWS installations were done at District Agromet Units (DAMUs) located in the Krishi Vigyan Kendras (KVKs). Recent developments in soil and water monitoring, the critical information is being received in real-time measurements from the field, helping farmers make faster, more accurate crop production decisions.

In the past, farmers collected soil and water conditions from the field by scouting and collecting soil and plant samples. These samples were sent off to a lab for testing, taking maybe precious weeks for results. Today, because of recent developments in soil and water monitoring, the critical information is being received in real-time measurements from the field, helping farmers make faster, more accurate crop production decisions.

IMD has installed Agro AWS with soil sensors at four depths- 10 cm, 30 cm, 70 cm, and 100 cm. Soil is never consistent across a field and this inconsistency is often amplified at the sensor level. Multiple sensors can statistically improve the accuracy and track the active changes, which are variable across a field. A wet area in the spring may become dry later as the crop grows and uses up the water. Sensor-based measurements are providing more specifics, such as moisture levels, fertilizer effectiveness, and plant reaction to variable conditions, including temperature and light. These sensor measurements permit farmers to take action when a field condition, such as low water levels, produces a stress reaction. The wind sensors installed in this Agro AWS at two heights – 3 m and 10 m and data useful for weather purpose and agriculture purpose. The winds are generally measured over level, open terrain at 3 metres about ground.

Key words: IMD, Agro AWS, Soil Sensors

Estimating Water Vapour Trends using GNSS signals for improved weather forecasting applications

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ABSTRACT

Realistic water vapour trends helps in estimating relative humidity which leads to an accurate weather forecasting for a region. GNSS signal gets delayed as it passes through the Earth's atmosphere especially the ionosphere and troposphere. Estimated ZTD directly helps us in understanding the water vapour variation in the atmosphere and can be very useful for meteorological applications with higher precision. In this study, PWV time-series are extracted using 10 and 1 ground-based GNSS receiver respectively. The two locations house the ground based GNSS stations provided by MNNIT Allahabad campus, Prayagraj, Uttar Pradesh, India and UNAVCO (California, USA). Precipitable Water Vapor (PWV) is calculated using the GAMIT/GLOBK (Ver. 10.7) and PRIDE PPP-AR (Ver. 2.1), and PWV has also been gathered for both sites from adjacent radiosonde stations utilizing the web service offered by Wyoming University. GNSS derived PWV are found to be having root mean square errors (RMSE) of 1.80 mm (GAMIT) and 7.69 mm (Pride PPP-AR) in Prayagraj, Uttar Pradesh, India with radiosonde data respectively. Further, a RMSE 4.19 mm (GAMIT) and 4.27 mm (Pride PPP-AR) in Southern California are used to validate the GNSS-derived PWV. Initial results proved that the when network of stations is included in the positioning solution, GAMIT has been found to produce more reliable and precise PWV readings, on the other hand PRIDE PPP-AR has been proven to provide a more accurate solution in cases of positioning on a single station. Further, sample GNSS data of four epochs of two IGS stations in India (IISC and HYDE) is processed to analyse the atmospheric error (especially ZTD). GNSS PPP derived ZTD is again compared with highly precise IGS product ZTD and is found to be good within 1 cm. Total Column water vapour obtained from ERA-INTERIM data is found to be highly correlated with GNSS PPP derived ZTD. Thus, multi-constellation GNSS PPP derived ZTD can be directly used to estimate the total column water vapour trends for improvement and realistic climate weather forecasting applications.

KEY WORDS: PPP, Zenith tropospheric delay, GNSS,

Impact of Intra-Decadal Variability of Meridional Heat Transport on the East African rainfall during Boreal Winter

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ABSTRACT

Rainfall is a key climatic factors which has serious consequences on the economies of east African countries, therefore it is highly vulnerable to the distribution of rainfall. The present study examines the impact of intra-decadal variability of heat transport associated with Indian Ocean Shallow Meridional Overturning Circulation (SMOC) on the east African rainfall variability during boreal winter, which is very less explored. Century long ocean reanalysis, atmospheric reanalysis and rainfall observations are used for the study. Spectrum analysis of Meridional Heat Transport (MHT) index reveals intra-decadal (5-7 years) varibility of MHT significant with 95% confidence level. The oceanic and atmospheric conditions during strong and weak phases of intra-decadal MHT variability are examined. Strong (weak) MHT years displayed reduction (increase) in upper 200m Ocean Heat Content (OHC) and Sea Surface Temperature (SST) in south Indian ocean. Further analysis reveals that the SST and OHC variations observed at intra-decadal timescale are out-of-phase with net heat flux but in phase with ocean circulation ruling out the role of surface heat fluxes in the SST/OHC evolution. Strong(weak) MHT co-occurred with intense(weak) subtropical anti-cyclonic circulation, dynamical inhibits(enhance) convection. Stronger (weaker) than normal southward heat transport leads to dry (wet) phase over east Africa, which explains 27% of boreal winter rainfall variability over east Africa. Study deduces that the SST evolution associated with the stronger intra-decdal MHT and OHC variability suppresses atmospheric moisture content, lowers atmosphere moist static energy, and support anticyclone circulation leading to deficit rainfall over east Africa and vice versa for the weaker intra-decadal variability. The association between intra-decadal variability of heat transport associated with SMOC and eastern African rainfall during boreal winter are reported for the first time. The study may pave the way for enhanced predictability of intra-decadal east African rainfall.

Keywords: East African rainfall, intra-decadal variability, Meridional Heat Transport, Climate prediction, Shallow Meridional Overturning Circulation

Tropical Cyclonic Disturbances in recent past over the Bay of Bengal in CORDEX-SA model environment

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ABSTRACT

Tropical Cyclonic Disturbances (TCDs) are one of the deadliest meteorological phenomena in nature harboring chaos everywhere they move around. These cause substantial losses in terms of life and livelihood, impact water resources, agriculture, health, and environment besides many sectors. The present study is aimed to evaluate the behavior of TCDs over the Bay of Bengal (BoB) in model environment of COrdinated Regional Climate Downscaling EXperiment - South Asia (CORDEX-SA) constituting regional climate model REMO2009 against the India Meteorological Department (IMD) observations and reanalysis product from European Center for Medium-Range Weather Forecasts (ECMWF) as ERA Interim. For the evaluation study we have considered TCDS in regional model REMO2009 (horizontal resolution 0.44˚X0.44˚) for the past historical experiment (1979-2005) and compared against the frequency, intensity and initial genesis geolocations of recorded TCDs in IMD observations and ERA-Interim reanalysis (horizontal resolution 0.25˚X0.25˚) during 1979-2005 for pre monsoon and post-monsoon months. Further we assessed the sea surface temperature (SST) in REMO2009 against the ERA-Interim as it plays a vital role in producing conducive conditions for tropical cyclogenesis. The results show that the model fairly well captures the TCDs against observations and reanalysis over the BoB in pre-monsoon and post-monsoon months. The intensity in terms of minimum central pressure (MCP) achieved during the lifetime of a TCD shows that REMO2009 overall underperforms in capturing the (MCP). Interestingly we find that REMO2009 underestimates (overestimates) TCDs of high (moderate) intensity. Similarly, we find REMO2009 well capturing the initial genesis geolocations over the BoB albeit with some spatial differences. The SST is found coherent with the genesis geolocations as regions with higher SSTs are noted with more genesis geolocations in comparison to low SSTs. The overall performance of REMO2009 in SSTs simulations against ERA-Interim shows cold bias.

Keywords: CORDEX; REMO2009; ERA-Interim; Sea Surface Temperature;

GNSS Meteorology for extreme precipitation forecasting based on improved Tm model: Initial results from newly established Uttarakhand CORS network, Survey of India (SOI)

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ABSTRACT

The highly dynamic spatio-temporal distribution of atmospheric water vapor, a key factor in regulating the earth's climate, is essential in understanding the evolution of extreme weather events and their prediction. The precipitable water vapor (PWV), a representation of atmospheric water vapor and an essential climate variable (ECV), can be measured using Global Navigation Satellite System (GNSS) with high precision and all weather operability. This study highlights the importance of local-level PWV analyses using a dense geodetic GNSS CORS network (mean interstation distance < 80 km) in predicting a severe storm event, as compared to analyses using a coarser network. Observations from (a) a recently installed network of 10 Continuously Operating Reference Stations (CORS) across Uttarakhand by SOI and (b) two pairs of permanent GPS stations in Himachal Pradesh situated around 100 km apart, are used to investigate the spatiotemporal features of GNSS-derived PWV under two severe rainfall events of 17 July 2015 in Himachal Pradesh and 19 October 2021 in Uttarakhand. The GNSS PWV estimates from GAMIT processing environment, show the correlated peaks and dips in the vicinity of extreme rainfall events which is also validated by the corresponding PWV estimates from ERA 5 and MERRA-2 reanalysis data (RMSE~0.35 and 0.28 respectively). The time series analysis shows that the PWV variation correlates well with the evolving storm, during the development and dissipation of the storm event. A spatiotemporal evolution of PWV is represented using PWV distribution maps during the three day span of the rain event. The study demonstrates that the results of spatio-temporal analyses are more consistent with rainfall patterns over Uttarakhand's dense network than in Himachal Pradesh having a coarser network. The hourly GNSS-derived local PWV measurements in our study can depict the fast-evolving rainfall events with lead time as low as three hours and thus are quite useful in the short-term forecasts of precipitation. Further, an improved Tm model for the region further enhanced the estimation of PWV from GNSS networks. In a first, a spatio-temporal distribution of PWV could be prepared which served as a precursor to an extreme rainfall event.

Keywords: Weather Forecasting, Precipitable Water Vapor, GNSS meteorology

CORRELATION BETWEEN HYDROGEOLOGICAL CHARACTERISTICS AND CLIMATE OF BIRBHUM AND MURSHIDABAD DISTRICTS, WEST BENGAL

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ABSTRACT

West Bengal has a diverse hydrogeological and groundwater conditions that vary from place to place. The Murshidabad and Birbhum districts, located in the Central-Western part of the Bengal Basin, are among the most geologically complex region within the state exhibiting topographical and hydrogeological conditions associated with the local climatic zones. This study area has also witnessed major changes in the groundwater. In this context, a study was conducted to observe the relationship between the spatial and temporal variability of the groundwater conditions and the local climatic factors (average temperate and precipitation). For this, we observe the hydrogeological, hydrogeochemical and satellite imagery based data to assess the impact of climatic factors along with anthropogenic activities in the study area. We analysed the general water table fluctuations as well as the quality variations using different hydrological parameters such as SAR, SSP, RSC, MAR, PI and CR. Further, we also looked into other factors such as soil moisture and vegetation covers using SMI (Soil Moisture Index) and NDVI (Normalized Difference Vegetation Index) respectively. Based on all the observations it was clearly seen that the impact of change in temperature and rainfall conditions seem to have some effects on the vegetation cover and soil moisture in the area. These changes are also correlateable with the variability in groundwater between the years 2012 and 2017. Further we were able to identify some parts of the study area where correlation between climate change and groundwater variability was clearly observed. However it also hints towards the fact that this direct correlation between the two is rather linked to local conditions prevailing in these parts of the study area than being general conditions for the entire region.

Keywords: Hydrogeology, Remote Sensing, Climate Change, SMI, NDVI.

Estimating of ground level particulate matter concentrations using different satellite-based AOD with meteorological parameters

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ABSTRACT

The ecological and public health are significantly affected by fine particles of less than 2.5 μm diameter (PM2.5). PM2.5 monitoring has recently started in most urban towns in India, due to negative health effects. Satellite-derived aerosol products such as aerosol optical depth (AOD) have been a useful source of data for ground level PM2.5 monitoring. In this study, ground based AOD from AERONET and Satellite-derived AOD from MODIS (Terra and Aqua) and VIIRS were used to predict ground based PM2.5 at Kanpur during the period from 2017 to 2021. Meteorological parameters were also included in the model to enhance the accuracy. The main objective of this study was to determine and identify the best performance between statistical models such as linear (LR), multilinear (MLR) and nonlinear regression models (ANN) models have been tested at Kanpur location using AOD with meteorological parameters to investigate the quantitative relationship between surface PM2.5 and satellite-derived columnar AOD. Model statistical performance were evaluated with standard descriptive performance measures, including the coefficient of correlation (r), mean absolute error (MAE), root mean squared error (RMSE), mean absolute percent error (MAPE) and index of agreement (IOA). Among the different methods, LR shows least significant model and ANN model was found to be the best suited model for PM2.5 prediction at Kanpur. Ground based AOD from the AERONET gives the based result based on predicted errors such as MAE (37.5), RMSE (54.28), MAPE (60), IOA (0.61) and Pearson coefficient r (0.77). Further potential source sectors and the transport pathways of pollutants have been widely characterized using the potential source contribution function (PSCF) and concentration weight trajectory (CWT) analyses with the backward air mass trajectories.

***Keywords*:** Particulate matter; aerosol; Prediction; Artificial neural networks

Characteristics and Causes of Thunderstorms and Lightning over India in a warming scenario

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ABSTRACT

The propensity for thunderstorms and lightning events causing extensive damage to human lives and properties have been increasing manifold globally as well as in India in the present warming scenario. Timely and accurate dynamical forecast of lightning, hail and heavy rainfall and simultaneous improvement of existing forecasting frameworks is therefore, the need of the hour. Thunderstorms accompanied by lightning, squally wind and hail are highly frequent in the pre-monsoon (March to May) months in India, mostly over the north-eastern and eastern, north western and peninsular regions of India. While thermodynamic parameters like moisture availability and atmospheric instability are highly important for the initiation of vigorous convective cells leading to thunderstorms, lower tropospheric dynamics also help in the intensification of these individual convective cells into organized structures like squall lines and mesoscale convective complexes. Moreover, changes in aerosol concentration can have an impact in the determining the microphysical structure of the convective systems. In this study, the impact of land-atmospheric feedbacks, thermodynamic, dynamic and aerosols on the evolving characteristics of thunderstorm, lightning and hailstorm frequency over different climatologically homogeneous regions of India is investigated for the last four decades using observations. It is intriguing to note that moisture availability, atmospheric instability, dynamical factors and aerosols have different levels on influence on such pre-monsoon severe convective events in different regions of India, which needs to be better incorporated in numerical models to improve the forecast skill and reduce casualties. This study shall enhance our understanding of the initiation and intensification mechanisms of pre-monsoon thunderstorms and lightning. The authors gratefully acknowledge the financial support given by the Earth System Science Organization, Ministry of Earth Sciences, Government of India to conduct this research.

Keywords: Thunderstorm, Lightning, Microphysics, Land-atmosphere feedback, Numerical modelling

Tropical Cyclone forecasting using multi-model ensemble forecasting system

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ABSTRACT

A timely accurate forecast of a devastating natural phenomenon like a Tropical Cyclone (TC) is essential for avoiding the loss of precious lives and property. A numerical weather prediction (NWP) model is an essential tool for operational weather forecasting. Obvious errors in initial condition and model formulation lead to the uncertainty in NWP forecast. An ensemble forecasting system (EFS) is used to quantify the uncertainty in the forecast and this uncertainty information helps the forecast users and disaster managers in better decision-making. Generally, an operational ensemble forecasting system based on a single global model suffers from the issue of under-dispersion and hence it underestimates the forecast uncertainty associated with the forecast, particularly at a longer forecast lead time. This is because all the sources of uncertainty during the processes involved in NWP are not taken into account while formulating the EFS. An ensemble forecast generated with the help of ensemble members from more than one ensemble forecasting system increases the ensemble size and hence might provide a pragmatic solution to the problem of under-dispersion.

The objective of the present study is to investigate the effect of combining the member forecasts of two global EFS on track, intensity and precipitation forecasting of TCs. These ensemble forecasting systems are: NEPS-G (NCMRWF Global Ensemble Prediction System) run by NCMRWF and GEFS (Global Ensemble Forecasting System) run by IMD. The forecast data of these ensemble systems available from the TIGGE website have been used for the present study. The experiments have been performed on two TCs over the Bay of Bengal. The direct position error (DPE) of the ensemble mean track has also been verified with IMD best track data.

Keywords: EFS, NEPS-G, GEFS, TIGGE, DPE

INFLUENCE OF LAND SURFACE PARAMETERIZATIONS IN CLIMATE SIMULATIONS OF NORTH INDIAN WINTER SEASON

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ABSTRACT

The winter climate during December, January, and February (DJF) over North India has endorsed with good amount of precipitation that occurs with the interaction between tropical and extra tropical flow. In this study, we examined two land surface parameterization schemes namely Biosphere Atmosphere Transfer Scheme (BAT) and Community Land Model (CLM) in the Regional Climate Model (RegCM) on resolving the winter climate over India. The model is integrated from 1st January 1982 to 31st December 2016 over Indian region with an initial and boundary condition of ERA interim analysis. The results reveal that the rainfall features are captured relatively well with CLM specifically over Western Himalaya with respect to Climatic Research Unit (CRU) rainfall observations. The temperature characteristics along with circulation at 700hPa of CLM provided an added value compared to BAT. The excess and deficient rainfall seasons revealed the relative resemblance of CLM with CRU by means of sensible heat flux and soil moisture analyses. BAT produced wet-bias of around 2 to 3mm over north-west India for the excess year. The Taylor diagram metrics show CLM better performed over BAT in both temperature and rainfall. Improvement parameter depicts CLM has high accuracy than BAT over the Western Himalaya and north-west India with values from 1 to 3 for rainfall and 10 to 12 for temperature. The Root Mean Square Deviation of BAT simulated extreme rainfall shows higher values around 3 to 4.5 which reveals its high erroneousness in performance with respect to CLM.

Keywords: Winter climate, Regional Climate Model (RegCM), Land surface parameterization.

Evaluation of various Characteristics of Precipitation Concentration Index in part of Western Ghats

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ABSTRACT

Western Ghats, which runs parallel to west coast of India has a significant role to play in controlling the rainfall distribution in the Deccan plateau during the monsoon period. The monsoon rainfall is the life line of the people of India in general and particularly peninsular India. There have several studies carried out understand the dynamics of monsoon rainfall, however, only few studies have been carried out evaluate the rainfall concentration in the Western Ghats. The Precipitation Concentration Index (PCI) one such index which define the temporal precipitation distribution. This is one of the powerful tool to assess the spatio-temporal changes in seasonal precipitation.

The present study was carried out by selecting 6 rainfall stations from Western Ghats part of Karnataka state. The data for 6 stations are for a period of 1960 to 2018 (58 years). The rainfall stations are selected based on their location and climatic regime. The selected stations represent the humid, sub-humid and transition zone of Western Ghats of Karnataka and defines the different rainfall regime as identified by Venkatesh and Jose (2007).

The results of the study reveals that variation trend of annual PCI values has decreased significantly over the 58 years. However, the PCI values of Monsoon recorded an increasing trend during the same period. These varying trend indicates that monsoon rainfall of these selected rainfall station may be more of regular in pattern and on annual scale it may be more of irregular. This is true in the sense that, study area is monsoon dominated and less to very less rain during the rest of year, hence may be irregularity of rainfall pattern and decrease in the PCI values. The results provide an important information to the water resource planners, policy makers to formulate an appropriate plan for effective management of water resources project and agricultural activities in the region.

Keywords: PCI, Western Ghats, Karnataka, (maximum 5 words)

Explicit lightning forecasting over North Eastern India and preliminary results over PAN India

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ABSTRACT

This work is an attempt to demonstrate the utility of an explicit electrification module coupled with the weather research and forecasting model (WRF) to forecast lightning activity initially over north eastern India followed by PAN India. In the lightning forecast model, both inductive and non-inductive charging scheme of hydrometeors are considered along with polarization of cloud water, and the exchange of charge during collisional mass transfer. This module calculates explicitly the three components of the ambient electric field through a computationally efficient multigrid elliptic solver. A bulk discharge scheme is also included, wherein charge within a volume is reduced whenever the magnitude of the electric field exceeds the local breakdown threshold. Several case studies have been evaluated over the study region. An extensive analysis has been carried out for thunderstorms events on 3 April and additional days over north-eastern India. The simulated flash origin densities (FOD) are evaluated against observed total lightning from the Earth Networks ground based sensors. Together with the electrification module, a lightning assimilation technique has also been employed in EWRF to better represent the observed lightning on the innermost convection allowing grid (3 km) during the analysis. This study further focuses the sensitivity analysis of EWRF and its validation for the complete pre-monsoon season of 2019. Different statistical score have been calculated for the whole season to assess the model performance over north astern part of India. The further work is going on to scale up the model for PAN India.

Explicit lightning forecasting Over North Eastern India and preliminary results over PAN India

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ABSTRACT

This work is an attempt to demonstrate the utility of an explicit electrification module coupled with the weather research and forecasting model (WRF) to forecast lightning activity initially over north eastern India followed by PAN India. In the lightning forecast model, both inductive and non-inductive charging scheme of hydrometeors are considered along with polarization of cloud water, and the exchange of charge during collisional mass transfer. This module calculates explicitly the three components of the ambient electric field through a computationally efficient multigrid elliptic solver. A bulk discharge scheme is also included, wherein charge within a volume is reduced whenever the magnitude of the electric field exceeds the local breakdown threshold. Several case studies have been evaluated over the study region. An extensive analysis has been carried out for thunderstorms events on 3 April and additional days over north-eastern India. The simulated flash origin densities (FOD) are evaluated against observed total lightning from the Earth Networks ground based sensors. Together with the electrification module, a lightning assimilation technique has also been employed in EWRF to better represent the observed lightning on the innermost convection-allowing grid (3 km) during the analysis. This study further focuses the sensitivity analysis of EWRF and its validation for the complete pre-monsoon season of 2019. Different statistical score have been calculated for the whole season to assess the model performance over north astern part of India. The further work is going on to scale up the model for PAN India.

Keywords: Lightning ,Weather Forecasting, flash origin densities, electric field

Nowcasting of Thunderstorm events using Indian GNSS IPWV and INSAT 3D/3DR data

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ABSTRACT

Satellite derived information plays an important role in weather forecasting and remote sensing. Both INSAT-3D/3DR and Global Navigation Satellite System (GNSS) derived products utilizing operationally at Satmet division, India Meteorological department (IMD) daily. These products are operationally available at 15 minutes intervals from INSAT-3D/3DR Imager and GNSS. GNSS derived Integrated Precipitable Water Vapour (IPWV) shows a gradual building up 3 to 4 hours prior to the event and has nowcasting potential. Therefore, with the support of INSAT products the weather events can be monitored prior to its occurrence and value added inputs were supplied to the decision support system of forecasting in IMD. Further data sets can be generated hourly, daily, monthly, seasonal and annual also as per the requirement of the forecasters and end users.

Few cases of rainfall events recently occurred have been analysed and presented in this work.

Keywords: INSAT-3D/#DR, GNSS, Rainfall and value addition in forecasting.

Impact of assimilation of INSAT-3DR radiance in the simulation of tropical cyclone Amphan

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ABSTRACT

The present study examines the assimilation of INSAT-3DR radiance data with the advanced Weather Research and Forecast (WRF-ARW) model for super cyclone Amphan over the Bay of Bengal. The Gridpoint Statistical Interpolation (GSI) system coupled with WRF has been used to assimilate sounder radiances with the 3D variational (3DVAR) method in the cyclic mode. Two sets of experiments with radiance assimilation (DA) and without assimilation (CNTL) are carried out with fifteen different initial conditions (ICs). The magnitude and position and the vortex structure at the initializations have been precisely captured by the DA compared to CNTL. The landfall position errors display an improvement of 25%-87% with the DA experiments. The low pressure at the peak stage is well predicted with DA (50%) over CNTL. A gradual decrease in the intensity errors is observed with the progress in the model initializations, which indicated the positive impact of cyclic assimilation of radiances. The minimal errors still persistent in the DA analysis can be the result of position error in the first guess which could be further corrected using vortex relocation.

Keywords: : Data assimilation, 3DVAR, tropical cyclones, INSAT-3DR, WRF-ARW

Analysis of diurnal nature of spatial variability of Land Surface Temperature in Delhi NCR using Sentinel 3 and INSAT-3D/R satellite data during summer,2018

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ABSTRACT

Urbanization in India is happening over a breakneck pace in last few years. The capital city, Delhi and NCR region is undergoing the aftermaths of increased urban density and resulting escalation in pollution. This study accounts the presence of nocturnal Urban Heat Island (UHI) effect of about 5-7°C during May, 2018.Also, the Urban Cool Island (UCI) effect is very prominent with presence of urban "cool-spots" with negative UHI of 5-10°C in central Delhi and surrounding urban clusters like Meerut, Greater Noida, Gurgaon, Bahadurgarh etc. during the daytime. We have also deduced that the UHI and UCI effects are not restricted to an overall city span or only urban settlements but can be prominent over micro regions such as major transport route intersections also. The dependence of the LST parameter over Normalized Difference Vegetation Index (NDVI) (from Sentinel 3 satellite) and Aerosol loading (from MODIS Terra satellite) has been assessed to justify the spatial changes of LST diurnally. A negative dependence of both parameters has been established and the formation of UCI due to increased loading of aerosols over urban dense areas and highway intersections during the day time ultimately affecting the short wave incoming radiation is observed. The areas of Central Delhi, Hapur and northern part of area of interest especially show the high aerosol loading and corresponding comparatively lesser temperature during daytime. The average range of aerosol optical depth over Delhi is between 0.4-0.8. Understanding the feasibility of using high temporal resolution (half hourly) Indian INSAT 3D LST data at 4000m spatial resolution for carrying out such studies has been also attempted. The algorithmic differences between the retrieval of LST from the two satellites has been studied and the difference in the LST values has been owed to the basic retrieval algorithms.

Decomposition based machine learning techniques for forecasting rainfall in India

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ABSTRACT

Indian agriculture is heavily dependent on total annual rainfall and its distribution. Therefore, accurate modelling and forecasting of rainfall has greater importance for all the stake holders related to agriculture. Time series data is mixed with actual signal and noise. It is difficult to extract actual signal form noisy data. In the recent years an extremely powerful nonparametric technique i.e. wavelet decomposition has been widely used in many fields of science and technology for de-noising the data. Time series analysis of climate data particularly rainfall can be an important tool to investigate its variability pattern and to predict the changes in future. In this study, pattern of annual rainfall in different sub-divisions of India along with all India annual rainfall for the period 1871 to 2016 has been investigated. Wavelet decomposition has been applied to de-noise the series followed by application of machine learning techniques such as artificial neural network (ANN), support vector regression (SVR) and random forest (RF). Maximal Overlap Discrete Wavelet Transform (MODWT) with tow wavelet filters viz. haar and Daubechies (D4) have been used in the present study. After suitable modelling of individual decomposed series, final prediction is obtained by means of inverse wavelet transformation (IWT). Moreover, for empirical comparison of forecast accuracy for the above algorithm, stochastic model i.e. autoregressive integrated moving average (ARIMA) has also been applied. Four criteria namely Mean error (ME), Mean absolute error (MAE), Root mean square error (RMSE) and Mean absolute percentage error (MAPE) revealed that the wavelet decomposition based application of machine learning and stochastic model has greater prediction power than that of usual application of machine learning and stochastic models.

Keywords: Forecast accuracy, Machine learning, Rainfall, Wavelets.

SUMMER MONSOON RAINFALL AND ITS SPATIOTEMPORAL VARIABILITY OVER INDIA IN THE TWENTY-FIRST CENTURY

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ABSTRACT

Indian summer monsoon (ISM) rainfall is undergoing a period of enhancement following a land warming trend since the beginning of the twenty-first century. A reported increase in rainfall magnitudes, however, does not guarantee homogeneous spatiotemporal increments. This study examines the changing characteristics of the ISM in the twenty-first century which demonstrates a significant increase in rainfall across India with tremendous variation in increments across its subregions and distinct months of the monsoon seasons. A sizable increase in the September rainfall contributes the most to an overall increasing trend in the ISM rainfall in recent decades. Similarly, the increases in the southern peninsula and northwestern areas of India are significant contributors across the country. Spatially, increments in the southern and northwestern regions of India act as the major contributors. Interestingly, the spatial variability of rainfall increases with an increase in rainfall magnitudes due to a rise in the heavy rainfall contribution to the seasonal sum. A land-warming induced enhancement in the moisture convection approximately between 10°N and 25°N. This results in increased rainfall over south India, the equatorial Indian Ocean, and adjacent continental regions. Since the ISM plays an intricate role in well being of the millions of population of the Indian sub-continent, it is very important to study their characteristics in the changing climatic conditions.

Keywords: ISM, climate change, land warming

BLACK CARBON EMISSIONS AND THEIR IMPACTS ON ATMOSPHERIC RADIATIVE FORCINGS : A CASE STUDY OF FOREST FIRE EVENT

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ABSTRACT

For Indian forests, uncontrolled fire is a major destructive factor which makes them highly vulnerable. Forest fires affect socio-economic conditions and play a vital role in atmospheric radiative balance. Forest fires were noted at various places in pine forests of Uttarakhand, the sub-Himalayan state of India, with maximum extent during the period of 22 - 30 April, 2016. Almost 3,500 hectares of forests had been burnt and 1,600 incidences of fires were detected that resulted in seven fatalities until 4th May, 2016. The present study investigates the impact of these forest fires on Black Carbon (BC) concentration, aerosol optical and radiative properties. Daily active forest fire locations over Uttarakhand region were derived using MODerate range Image Spectrometer (MODIS). MODIS derived Aerosol Optical Depth (AOD) had increased up to 0.802 during the study period which indicates the loading of aerosols into the atmosphere. The variation of BC concentration was in the range from 1200 to 7270 ng m^{-3}. A strong positive correlation of 0.86 was observed between BC and AOD. It has been noticed that the average contribution of biomass burning to the black carbon concentration was 88% during the study period. BC radiative forcing calculated using SBDART is found to be 140 W m^{-2} in the atmosphere with a heating rate of 3.93 Kelvin per day during the peak fire point day. During the forest fire event, black carbon concentration increased more than six times of the EBC concentration that was present before forest fire. Since the study area is a remote and high altitude region i.e. 2000 m from mean sea level, the biomass burning due to forest fire is the only source and cause for the increase in concentration of BC.

Keywords: Black Carbon, Biomass Burning, Aerosol Optical Depth, Forest Fires & Radiative forcing

CHARACTERISTICS OF MONSOON BOUNDARY LAYER OVER THE WEST COAST OF INDIA

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ABSTRACT

North and south parts of the West Coast of India is characterised by different cloud structure during the monsoon season. Vertically developed clouds often form over the north parts whereas they seldom form over the south parts where the clouds are mainly stratiform type. However, atmospheric boundary layer features over the region which has an important role in modulating the clouds are not properly understood. The present study investigates the boundary layer structure over the West Coast of India during May-October, 2018 using high vertical resolution (~5 m) radiosonde datasets of Mumbai (MUM), Mangalore (MNG) and Thruvananthapuram (TVM) from India Meteorological Department (IMD). Dynamic and thermodynamic features of the ABL during active and weak monsoon conditions are elucidated. Active and weak monsoon conditions were identified based on the OLR (outgoing longwave radiation) and rainfall values over the respective stations. TVM is characterised by an absolute stable or conditionally neutral layer (conditionally unstable) above a shallow conditionally unstable layer in the ABL during active (weak) condition, whereas a conditionally unstable layer over a shallow layer of absolute stability (due to the surface inversion) is observed in MNG and MUM during both active and weak monsoon conditions. Primary reason for the different stability structure over the stations is found to be the vertical shear of zonal wind. Zonal wind has a sharp increase from ground to above ABL (~1200 m) in TVM; however, it is in the lower levels of ABL over MNG and MUM. In MUM, strong wind is observed during active (>20 ms^{-1}) and weak (>12 ms^{-1}) situations that caused intense mixing and elevated ABL compared to other stations. Further, the ABL heights are high during weak monsoon conditions due to convective turbulence added to the mechanical turbulence associated with the strong prevailing wind during the season.

Keywords: Atmospheric boundary layer, southwest monsoon, west coast, thermodynamic structure, instability.

Anthropogenic influence on the changing risk of heat waves over India

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ABSTRACT

Surface Temperature (ST) over India has increased by ~0.055K/decade during 1860– 2005 and follows the global warming trend. Here, the natural and external forcings (e.g., natural and anthropogenic) responsible for ST variability are studied from Coupled Model Intercomparison phase 5 (CMIP5) models during the 20th century and projections during the 21st century along with seasonal variability. Greenhouse Gasses (GHG) and Land Use (LU) are the major factors that gave rise to warming during the 20th century. Anthropogenic Aerosols (AA) have slowed down the warming rate. The CMIP5 projection over India shows a sharp increase in ST under Representative Concentration Pathways (RCP) 8.5 where it reaches a maximum of 5K by the end of the 21st century. Under RCP2.6 emission scenarios, ST increases up to the year 2050 and decreases afterwards. Further, in this work we shed light on the human influence on the changing patterns of heat waves in India using the Heat Wave Magnitude Index daily (HWMId). The HWMId obtained from the observational data sets shows a large increase in the heat waves during the past decades. Investigating the effects of natural (e.g., solar variations and volcanic forcings) and anthropogenic (e.g., greenhouse gas emissions, anthropogenic, land use, and land cover) forcings revealed that the anthropogenic factors have cause a two-fold increase in the occurrence probability of severe heat waves in central and mid-southern India during twentieth century. The spatial distribution of maximum HWMId values under natural and all forcings (including anthropogenic) indicates that in most places human activities have increased the frequency, duration and intensity of extreme heat waves. Under the Representative Concentration Pathway (RCP) 4.5, the risk of heat waves is projected to increase tenfold during the twenty-first century. More than~ 70% of the land areas in India is projected to be influenced by heat waves with magnitudes greater than 9. Furthermore, we find a significant relationship between heat waves and deficits in precipitation. Results show that concurrent heat waves and droughts are projected to increase in most places in India during the twenty-first century.

Benthic N_2O and DIN fluxes in a coastal lagoon on the East coast of India

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ABSTRACT

Estimates of nitrous oxide (N_2O) production and consumption from tropical, coastal sediments remain scant, in spite of significant research on the subject in high latitude ecosystems. To bridge this gap, fluxes of N_2O at the sediment-water interface of Pulicat - a tropical lagoon situated on the South-East coast of India - are investigated through intact core incubations during the dry season (May-June) of 2022.

Positive N_2O fluxes at the sediment-water interface are observed in the northern and southern regions of the lagoon, indicating net efflux of N_2O. Limited exchange with the coastal waters of the Bay of Bengal occurs in these two regions. The Pulicat ecosystem characteristically has high ammonia concentrations. The impact of such physico-chemical parameters on the pathways of N_2O production and transformation at the sediment-water interface is investigated in this study. Additionally, the processes of nitrification and denitrification are investigated through the use of inhibitors. Coring experiments indicate that nitrification is an important process occurring in Pulicat waters. N_2O fluxes are closely linked to fluxes of dissolved inorganic nitrogen (DIN). DIN fluxes are also estimated through intact core incubations. The sediment microbial composition is studied using microbiological techniques.

In the context of changing climate, study of fluxes of N_2O - an important GHG – in hypersaline, coastal ecosystems like Pulicat is especially relevant. An understanding of the parameters that regulate N_2O fluxes is imperature for effective climate action.

Keywords: Nitrous oxide, Greenhouse Gas, Sediment-water interface, Benthic flux, Denitrification

Decadal Prediction of the Indian Ocean Dipole: Links from the Southern Ocean

ABSTRACT

The Indian Ocean Dipole is a leading phenomenon of climate variability in the tropics affecting not just the bordering regions of East Africa, Indonesia, but Australia, India, and farthest regions of the North and South Americas, Europe. However, the best lead prediction skills for Indian Ocean Dipole until recently are about a lead of six months. Decadal Prediction has made considerable advancement recently. With the emergence of serious decadal prediction efforts, state-of-art multiple decadal lead prediction datasets have been available since CMIP5. Our analysis of these datasets shows, for the first time, that two general circulation models, CanCM4 and MIROC5 have significant prediction skills for the Indian Ocean Dipole up to a decade. We find that the source of this decadal predictability lies in the Southern Ocean. These decadal prediction skills for a prominent climate driver like the Indian Ocean Dipole have wide-ranging benefits for climate science and society.

Characterizing the post-monsoon and winter Thunderstorms over Central India using C-band radar and reanalysis measurements

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ABSTRACT

The rise in frequency of heavy rainfall events causes significant socio-economic challenges in the Indian sub-continent. The forcing mechanisms driving these heavy rainfall events are still unclear. In this study, we explored the driving mechanism for two typical thunderstorm events that occurred in post-monsoon and winter over Bhopal, Central India using C-band Doppler weather radar alongwith other in-situ observations and ERA5 reanalysis measurements. The Atmospheric Research Testbed-Central India (ART-CI) set up dual-polarization C-band Doppler weather radar, which tracks the development of these thunderstorms. The radar observations show that the storm reaches above 12 km and 8 km, respectively during post-monsoon and winter. The in-situ measurements indicate that the rain events last for more than 30 minutes with maximum intensity reaching above 50 mm h^{-1}. Examining the environmental conditions revealed that the thermodynamical forcing is responsible for the development of thunderstorms over the central Indian landmass. The atmospheric water vapour transport from Bay of Bengal is a potential contributor for the moisture advection during post-monsoon event, whereas the Arabian Sea acts as a moisture source for the winter thunderstorm event. It is observed that both the mid-level (4-6 km) relative humidity and column moisture content characterize the environmental conditions preceding the occurrence of thunderstorm. It is also found that the prominent moisture flux convergence and potentially unstable atmosphere maintain the heavy rainfall event during the thunderstorm. The present findings have profound significance in improving the representation of these heavy rainfall events in the regional climate models.

A HIGH-RESOLUTION EMISSION INVENTORY OF CARBONACEOUS FINE PARTICULATE MATTER OVER THE INDIAN REGION

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ABSTRACT

Pollutant emissions from a variety of industries, including transportation, housing, thermal power plants (TPP), and others, have dramatically expanded throughout India and have been claimed to have a considerable impact on local air quality and climate change. Using Geographic Information Systems (GIS), we have created a high resolution emission inventory for carbonaceous fine particulate matter (CPFM) (Black Carbon) emissions at a resolution of 10 x 10 km2 for various sectors (transport, residential, TPPs, etc.) for the Indian geographical area. Based on micro-level specifics and current year activity data of fossil fuel and biofuels, the spatial distribution of emissions is downscaled to a finer resolution. For the base year 2018 over India, the total national black carbon (BC) emission has been calculated to be 1480 Gg yr-1. The two sectors generating the largest percentages to overall BC is transportation and residential, with 46% and 39%. In India, the transportation sector (36%) was slightly larger than residence sector in the BC emission. In order to assess the trend from all sources from 2011 to 2018, we also built an emission inventory for CFPM in 2011. According to all available data, the grid-wise total BC increment over the Indian region is predicted to be 35% (355 Gg). In order to better predict and control the hotspots of air pollution, policymakers will find this high-resolution inventory of CPFM to be useful for decision-making as well as input to regional chemical transport models in the atmosphere.

Keywords: Emission inventory, Black Carbon, Geographic Information System

Aerosol redistribution over the Indian subcontinent and the role of tropical cyclone Amphan

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ABSTRACT

Tropical cyclone is an important circulation system associated with low-pressure area and deep convection. Such as a vast system leads to three dimensional changes in the various meteorological variables including distributions of the atmospheric aerosols. Circulation causes the aerosol to redistribute horizontally, deep convection caused to its vertical transport and rainfall for scavenging of the aerosols. Thus, tropical cyclone though occurs for a short duration about less than a week significantly modifies the aerosol loading and hence local radiation budget of atmosphere. In this study, the redistribution of the atmospheric aerosols following Amphan cyclone is carried out. The Super Cyclone Amphan was the strongest tropical cyclone on record in the Bay Of Bengal. It originated as a low pressure area which occurred in the near Equatorial Easterly wave over south Andaman Sea and adjoining southeast Bay of Bengal (BOB) on 16th May 2020 and further intensified into Super Cyclonic Storm (SuCS). Cyclone Amphan weakened its intensity and made landfall at 17.30 hour local time on 20th May as a low pressure system. In the pre-cyclonic period high aerosol loading off the west coast is dominant. The cyclonic circulation washes out the tropospheric aerosols around it and during post-cyclonic period the aerosols are loaded over the western India and off the west coast. The tropical cyclone though occurs for a short duration about less than a week significantly modifies the aerosol loading and hence local radiation budget of atmosphere. Furthermore the interaction and exchange of aerosol between ABL and FT is studied using CALIPSO. In the study the re-distribution of aerosols is being investigated in pre, during and after the tropical cyclonic period.

Keywords**:** Tropical Cyclone, Amphan, ABL, FT, CALIPSO

Role of convection on the thermal structure and tracers in the TTL region and its variability over the northeast monsoon region, Chennai

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ABSTRACT

The variability of the tropical tropopause strongly influences the transport of the pollutants and trace gases into the lower stratosphere as well as the transport of the ozone into the upper troposphere. The exchange of these trace gases especially water vapour and ozone following deep convection in turn modifies the tropical tropopause height and temperature. In this study, we have utilized the radiosonde observations over Chennai, located in the north east monsoon region, to characterize the tropical tropopause during different seasons and different sky conditions. The cold point tropopause (CPT) height (CPT-H) and temperature (CPT-T), convective tropopause (COT) height (COT-H) and temperature (COT-T), lapse rate tropopause (LRT) height (LRT-H) and temperature (LRT-T) and the tropical tropopause layer (TTL) are obtained over the period 2014-2020. The TTL thickness is defined as the difference between CPT and COT heights. Using water vapor and ozone data from microwave limb sounder (MLS) simultaneous to the radiosonde observations, the relationship between them is analysed for different convective conditions which will be presented during the conference.

Keywords: Tropical Tropopause Layer (TTL), Cold Point Tropopause (CPT), Lapse Rate Tropopause (LRT), Convective Outflow Tropopause (COT), Radiosonde(RS)

Modulation of Atmospheric Aerosols by madden-Julian Oscillations and the Convectively Coupled Equatorial Waves over the Indian Region

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ABSTRACT

The modulation of atmospheric aerosols in response to the tropical intra-seasonal oscillations (ISOs) over the Indian region is an unexplored area of research. ISOs being one of the most important atmospheric phenomena that significantly modulate various weather parameters over the tropics. It is therefore expected to also modulate aerosol spatio-temporal distribution. In the present study, an attempt is made to investigate the distribution of atmospheric aerosols over the Indian subcontinent and the adjacent oceanic regions with respect to the ISOs like MJO, Equatorial Rossby (ER) wave, Kelvin wave (KE), and Mixed-Rossby-Gravity and Tropical depressions (MT). Using the long-term satellite datasets, it is found that the highest modulation in aerosol optical depth (AOD) happens due to MJO (10 - 15% with respect to the mean), followed by ER (10 - 15%), and the least due to KE (<5%). Further, an elongated area extending from the southeast of the Arabian Sea to the northeast of the Indian peninsula has been observed with a distinct dipole pattern between the Arabian Sea and the Bay of Bengal for MJO and ER. However, similar signatures were not observed for KE. Further analysis revealed that the observed AOD anomaly also induces a similar spatial distribution in the aerosol radiative forcing (ARF) with implications to the regional circulation. The underlying reasons and the dynamics will be discussed.

Keywords: Intraseasonal oscillations, aerosol over the Indian region, convectively coupled equatorial waves, Madden-Julian Oscillation.

Identification of storm eye from Satellite image data using fuzzy logic with machine learning

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ABSTRACT

The method discussed in this paper uses fuzzy logic and image processing to determine the eye of tropical cyclones from images of IR channels from geostationary satellites. This technique has been used to analyze images of four tropical cyclones: Amphan, Nivar, Tauktae, and Yaas. Fuzzy logic provides the ability to model the dynamic behavior of the storm and determines the location of the best eye in an area of interest. It provides an effective method for describing the uncertain behavior of complicated systems. After that, image processing is applied to enable accurate eye positioning based on the search results. A comparison has been made between this technique's experimental results and those of the Indian Meteorological Department and Cooperative Institute of Meteorological Satellite Studies. As a result, the storm's eye location can be found to improve performance significantly. Using the present technique, it is possible to determine the eye entirely automatically, thus replacing the manual method that has been employed in the past.

Keywords: Tropical Cyclone, Eye, IR image, Fuzzy logic, Image Processing

DIAGNOSTIC STUDY OF CLOUDBURST EVENTS OVER THE HIMALAYAN REGION FROM REANALYSIS-DATASETS

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ABSTRACT

A cloudburst is a sudden torrential downpour in a limited area that lasts only a few minutes. Cloudburst events are common over high elevations in the Himalayas. Cloudburst causes catastrophic loss of life, property, crops, and vegetation in high elevation regions. Consequently, it is crucial to anticipate these disastrous events to avoid the damage associated with them. The present study uses reanalysis datasets from the fifth generation ECMWF atmospheric reanalysis (ERA5) and the Indian Monsoon Data Assimilation and Analysis (IMDAA) for two cloudburst cases to understand the properties associated with cloudburst events and provide data direction for future research. The major similarities in these two cloudbursts included occurring during the Southwest Monsoon season and at night, impacting areas at elevations ranging from 1600 to 2100 metres. Both cases' accumulated rainfall is compared to the India Meteorological Department (IMD) observation. It is noted that the rainfall captured by both reanalysis products is less than observation; however, IMDAA captured more rain than ERA5. Furthermore, parameters including vertically integrated moisture transport, relative humidity, wind, potential vorticity, outgoing longwave radiation, sweat index, K- index, convective available potential energy, vertical velocity, and soil moisture are also compared to investigate the causes behind the performance of the ERA5 and IMDAA reanalysis datasets.

Keywords: Cloudburst, Reanalysis, ERA5, IMDAA, IMD

Does Stubble burning in nearby States really contribute to Delhi's Winter Air Pollution? - An empirical appraisal and data analysis evidence from Ground level observations, Geo-physical models and Satellite imagery data

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ABSTRACT

This study is an attempt to investigate and find out the facts and scientific evidences behind the proclamations and assumptions on the doubtful role and contribution of stubble burning (SB) in Delhi's Winter Air Pollution (DWAP). The study uses various scientific methods and data analysis protocols from ground level observations, geophysical models, and satellite- based measurements collected and recorded during 2019 to 2020. Analytical reports and evidences from ground-based measurements exhibited a drastic increase in the pollutant concentration during October-November of each year (when SB episode is proclaimed), which leads to the increase in air quality index (AQI), confirms in this study the significant contribution of SB in DWAP along with other internal sources. Geophysical models including Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) back trajectories and Navy Aerosol Analysis and Prediction System (NAAPS) also indicated contribution of regional SB in DWAP. Measurements from Moderate Resolution Imaging Spectroradiometer (MODIS), Visible Infrared Imagine Radiometer Suite (VIIRS), and Sentinel-P5 satellites further corroborates strengthen the findings of the study on the regional contribution of SB in DWAP, majorly from Punjab and Haryana States. Further, the meteorological conditions (derived both from ground and satellite data for these 2 States) worsen the air quality parameters and pollution index of Delhi during winter season.
Keywords: Stubble Burning, Air Pollution in Delhi, Air Quality Index, Remote Sensing, HYSPLIT, MODIS-FRP

Performance of HAR-V2 data in simulating winter precipitation forecast over different ranges of Western Himalaya

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ABSTRACT

Model forecast error restricts the model output parameters to use for operational as well as other research purposes. Thus, it is very important to find out the performance of the model outputs so as to correct the same for operational and other research activities. The present study deals with the performance of High Asia Refined analysis version 2 data at 10 km spatial resolution, which is the output from Weather Research and Forecasting model, in simulating winter precipitation forecast for selected stations of Western Himalaya. Precipitation data for the period from 2011 to 2020 (10 years) have been used for the study. Representative stations from different mountain ranges of Western Himalaya such as Pir Panjal, Shamshawari, Great Himalaya and Karakoram range have been selected. The WRF model simulated HAR-V2 precipitations and the respective observations were calculated. By considering the four winter seasons (December, January, February and March), Root Mean Square Error (RMSE) was calculated for these ranges. The observed Standard Deviation (SD) was also computed. The root mean square error of daily precipitation was compared with the observed standard deviation. Statistically, the performance of the model simulated data is good when the Root Mean Square Error is less than the Observed Standard Deviation. Results show that the RMSE is less than observed SD. results are good for all the stations except for the station in Karakoram Range.

Keywords: HAR-V2, Western Himalaya, Weather Research and Forecasting, RMSE and SD.

Impact of land cover change on land surface temperature and precipitation over Eastern Himalaya Region in last two decade

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ABSTRACT

The Eastern Himalaya Region (EHR) is one of the biodiversity-rich regions of the world having complex topography with extreme altitudinal gradients. We investigate the impact of changes in land use and land cover (LULC) on the land surface temperature (LST) and precipitation patterns over the EHR using satellite data products in the last two decades (2001-2019). We analyse NASA's Terra satellite Moderate Resolution Imaging Spectroradiometer (MODIS) MOD11C3 and MCD12C1 datasets for LST and LULC studies respectively. Further, we used Tropical Rainfall Measurement Mission (TRMM) 3B42 datasets for the precipitation pattern study. We also investigated the MODIS MOD16ET datasets for evapotranspiration study over the region. We investigate the spatial variations in the LST and precipitation over the regions in the different seasons in the light of LULC changes. We observed a 3% reduction in the forest area over the EHR in the last two decades. An increase in the LST is also detected in the summer and winter seasons over the study period in the EHR. Along with this, we find a decrease in the precipitation over the region particularly in the monsoon months in the last two decades

Keywords: Climate change, Eastern Himalaya, LST, Precipitation

DEVELOPMENT OF A HYBRID MODEL TO PREDICT AIR TEMPERATURE OVER AN URBAN AREA: A CASE STUDY OVER AHMEDABAD, INDIA

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ABSTRACT

The present study discusses the development of a hybrid model for predicting near surface air temperature (2m) over the city scale (~100 m). The model utilizes the forecast generated (5 km x 5km resolution) by regional weather prediction model viz. Weather and Research Forecast (WRF) model and downscale it to city scale using the spatial correlations estimated from the satellite based high resolution (1 km x 1km) Land surface temperature (LST) products. The LST products from Moderate resolution imaging spectroradiometer (MODIS) satellite during the Indian summer season (April-June) of the year 2017-2018 are used to estimate the spatial correlations. The daily routine forecasts of near surface air temperature generated by WRF model are used in the study to generate the city scale forecast. As a case study, the model is demonstrated for the Indian city Ahmedabad, but the same procedure can be extended for any other city. The results have been validated using the in-situ data based on the ground based observational network temporally installed at different locations of the city during 2019 and 2022. The developed model shows a potential to be used in the operational mode for generating location specific heat wave warning within a city.

Keywords**:** Heat wave, MODIS, Satellite, LST, Temperature, WRF

Exploring the Climatology, Trends, and Physical drivers of Extreme Winter Weather in India

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ABSTRACT

Under the present climate change scenario, there is a growing concern about the weather and climate extremes which can impose serious impacts on human and environment. Cold waves are one such type of extreme winter weather events prominent during the boreal winter season (November to February). It is well known that that north Indian region is constantly exposed to a number of cold wave events each year. These cold waves can be very intense at times leading to extreme weather situations that can have various impacts including the effect on human health. The present study identifies the extreme cold wave events over north India and then investigate the climatological conditions that are favourable for the extreme cold waves and trends in the region. Our analysis reveals that cold air intrusion from the higher latitudes is an important element for the genesis of extreme cold wave events over India. We show that the extreme cold wave events are strongly linked to different large scale circulation systems such as western disturbances and Siberian high-pressure system. Furthermore, a decrease in the number of extreme cold wave events have been observed during the period 1982-2020. This can probably be attributed to the rise in minimum temperatures due to global warming. Accordingly, these extremes can vary in the number, duration and intensity each year. Hence it is essential to study the factors to understand the dynamics behind extreme cold wave events.

Keywords: extreme cold waves, winter, climatology, India, responsible factors

Glacier Mass Budget and Associated influence of the Climate during 2000-2020 in Alaknanda Basin, Uttarakhand.

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ABSTRACT

The highest concentration of the glaciers in the High Mountain Asia are experiencing constant mass loss due to ongoing climate change, though significant spatio-temporal heterogeneities are also evident. However, due to insufficient ground observation, glacier-climate interactions in decadal scale are still poorly understood.

We examine the multi-temporal glacier change behavior and associated climate drivers in Alaknanda basin, Garhwal Himalaya, for last two decades (2000-2020) by exploiting satellite datasets and ERA5 land reanalysis grided climate data.

The glaciers (~427 glaciers) in the Alaknanda basin and its surroundings lost -10.2±1.14 m thickness during the entire observation periods (2000-2020). The glaciers are losing significant amount of mass (-0.68 ± 0.09 m w.e.a^{-1}) in recent time period (2015-2020) as compared (-0.22±0.09 m w.e.a^{-1}) to the earlier (2000-2006). We also investigated ERA5 Land reanalysis data and their implications to regional glacier mass balance and found a strong correlation between summer temperature and glacier mass balance (r^2 = 0.96 and p = 0.02). A strong increase of summer temperature (~0.7^0 C) and slight reduction in solid precipitation (0.5 mm) was observed during 2015-2020, which might affect the strong glacier mass loss. Additionally, two important glaciers (Bhagirath Kharak and Satopanth) in this basin are also experienced similar trend in mass budget; however, the overall mass loss of the Satopanth glacier was nearly doubled as compared to the Bhagirath Kharak glacier during the similar time period (2000-2021). The glacier surface conditions also influenced the mass loss in this region and found during 2000-2020 the glaciers with debris covered tongue (-0.44±0.06 m w.e.a^{-1}) lost considerably higher mass as compared to their counterparts (-0.38±0.06 m w.e.a^{-1}). Though, the temporal scale mass budget heteroginity are strongly influenced by local climate, but, different other factors such as glacier morphometry and surface velocity are also need to be investigated to understand the regional glacier responses.

Keywords: Climate change, Remote sensing, ERA5 land reanalysis data, Glacier mass budget.

Simulation of mesoscale convective systems using convection-permitting model and its comparison with remote sensing observations in the monsoon zone

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ABSTRACT

Mesoscale convective systems (MCSs) are one of the most significant forms of convection that effect the global water cycle and energy balance, and they produce high-impact weather events. During the Indian summer monsoon, synoptic-scale systems move across the monsoon zone and are responsible for frequently initiating MCSs. MCSs often produce widespread and heavy rain across the monsoon zone. Most current global circulation models do not represent MCSs because convection in these coarse resolution models is parameterized without explicit consideration of the mesoscale processes. Compared to models with parameterized convection, convection-permitting models (resolution ≤ 4 km) are able to simulate mesoscale and convective processes.

Here, Weather Research Forecast model at convection-permitting resolution with two microphysics parameterizations is used to simulate observed MCSs events in the monsoon zone which includes parts of Central India and North Bay of Bengal. Here, we do not expect the model to reproduce individual MCSs at the precise times and locations observed. Instead, we focus on assessing a composite MCS properties and microphysics sensitivities. To facilitate this comparison, we first apply a cloud-tracking algorithm to satellite infrared brightness temperature (IRTb) and GPM IMERG precipitation datasets to identify and track individual MCS events during monsoon. Ground-based radar observations are used to examine 3-D structures of storms embedded within the tracked MCSs and analyze evolution of convective, stratiform and anvil components of the MCSs. Then, similar cloud-tracking is applied to simulated data (radar reflectivity, IRTb and precipitation) to identify and track MCS in model. The uniformity of the cloud-tracking algorithm aided in comparing multiple aspects of MCSs (e.g. initiation, size, intensity, lifetime, propagation) and embedded storms (e.g. convective-stratiform araes, convective core length and depth) and associated precipitation among the two simulations and observations. Similarities and differences of this contrast would be discussed.

Keywords: Mesoscale convective system, Monsoon zone, Cloud tracking, Weather modelling

Signatures of convective aggregation in radar observations and its relation with the large-scale environment

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ABSTRACT

Deep convection and the degree of convective organization play an important role in the global circulation regarding moisture fluxes, energy, and momentum transport. During the Indian summer monsoon, deep moist convection is frequent, and it produces widespread and heavy precipitation over Central India. As part of the Atmospheric Research Testbed in Central India (ART-CI), a C-band polarimetric (C-Pol) radar was installed by IITM at Silkheda (60 km north of Bhopal). It collects time-continuous 3-D observations of precipitating clouds in the monsoon core zone.

To determine the degree of convective aggregation/clustering and their spatial distributon during the two-day rain episodes, we applied various organization indices of convective clustering to the C-Pol radar-identified convective objects. These metrics measure the degree of organization for each snapshot of radar volume with different parameters of clouds present within the radar domain, viz. number density, size, and distance between convective objects. As a depiction of the convective life cycle during the two-day rain event, the composite time series of aggregation metrics and related parameters averaged over the radar domain are made around the temporal maxima of radar-derived precipitation (at t=0). Composite evolution shows that small convective objects are blended into fewer and larger objects that are more grouped together, suggesting that convective aggregation is occurring. An increase in convective area fraction with time to its peak at t=0 is due to the spreading of towering clouds about the time of peak convective activity. We also use reanalysis data (thermodynamic and dynamic properties: vertical velocity, OLR, relative humidity) to relate the large-scale atmospheric state around radar to the degree of convective organization. Further, the diurnal evolution of rainfall is compared to the diurnal cycles of organization metrics and large-scale environment. This radar-based convective clustering would offer an observational basis to assess the depiction of convective clustering in the numerical model.

Keywords: Deep convection, Organization indices, Polarimetric radar, Large-scale environment.

Extreme weather events and associated hazards, deaths – need of the hour

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ABSTRACT

Vagaries of weather are quite common in various parts of country as well as in different seasons, in each of the years.These extreme weather events are affecting human beings, domestic animals and standing crops also. Every year there is huge death toll as well as economic loss due to these extreme weather events for which weather forecast/warnings as well as impact based forecast/advisories are getting importance in the current era. Various colour legends are in use to make the warnings/advisories prominent for taking suitable mitigative measures.

Among varous extreme weather events cold waves, fog, ground frost during winter season; thunderstorms, lightning, gusty wind, heat waves during summer season; heavy, very heavy, extremely heavy rains with associated floods in low lying areas are quite common during monsoon period and time to time severe wind (squally wind, gale) associated with cyclonic storms have devastating effects. The loss of life as well as revenue loss in each year prompted the authors for this study.

In the present paper various extreme weather events that affected mankind in recent years are analysed and discussed. The data were collected from the National data centre of IMD, Pune. Data on death toll, crop losses were collected from various RMCs, MCs, M.O.s, State Agriculture Departments and Agricultural Universities. The death toll due to different extreme weather events are analysed and presented here, which signifies the need for weather warnings/alerts/advisories. In this direction for providing different catagories of alerts for disaster managers and other users, IMD has developed different colour codes depending on severity of the incidence, is discussed suitabily. In recent times impact based forecast (IBF) for mega cities as well as for vulnerable areas has been found very effectively helping disaster manager vis-à-vis other users.

Key words : Extreme weather events, hazards, economic loss, warnings, alerts, IBF, colour codes.

ROLE OF SOUTHERN INDIAN OCEAN IN MODULATING INDIAN SUMMER MONSOON IN RECENT YEARS

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ABSTRACT

This study explores the impact of Southern Indian Ocean (SIO) sea surface temperature (SST) in modulating Indian summer monsoon. Subtropical dipole index (SDI) has been constructed based on the Empirical Orthogonal Function (EOF) analysis of SST anomaly over SIO region. It was observed that the positive (negative) SDI delays (early) the onset dates of Indian monsoon over Kerala during the time domain of our study.

Further, we identified eight SST predictors based on spatial patterns of correlation coefficients between Indian Summer Monsoon Rainfall (ISMR) and SST of the regions mentioned above during the time domain 1982–2013. The five multiple linear regression (MLR) models have been developed by these predictors in various combinations. The skill of forecast to predict observed ISMR from these MLR models is found to be substantially better based on various statistical verification measures. It is observed that the MLR models constructed using the combination of SST indices in tropical and extra tropical Indian and Pacific is able to predict ISMR accurately for almost all the years during the time domain of our study. We tried to propose the physical mechanism of the teleconnection through regression analysis with wind over Indian subcontinent and the eight predictors and the results are in the conformity with correlation coefficient analysis. The robustness of these models is seen by predicting the ISMR during recent independent years of 2014–2017 and found the model 5 is able to predict ISMR accurately in these years also.

Keywords: Southern Indian Ocean, Sea Surface Temperature, Predictors, Indian Monsoon

Weather based forewarning model for powdery mildew disease of mustard

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ABSTRACT

Powdery mildew disease is the most important disease of mustard (Brassica Juncea) which is highly sensitive to weather condition particularly temperature and humidity. To develop the weather based forewarning model for powdery mildew disease of mustard crop a Sardarkrushinagar, weekly powdery mildew data of 12 years (2010-11 to 2021-22) was collected from Centre for Oilseed Research, S.D. Agricultural University, Sardarkrushinagar. The data were pooled over the year and correlated with corresponding weather parameters recorded in Agromet Observatory, S.D. Agricultural University, Sardarkrushinagar. The forewarning regression equation was developed with the help of weather variables to predict the incidence of disease in an advance. The results revealed that the maximum and minimum temperature ranged 26.2 to 38.1oC and 8.7 to 18.5o C respectively found congenial for disease incidence. The weather variables like maximum temperature (Tmax) and minimum temperature (Tmin) significantly positive correlated with powdery mildew disease of mustard. While morning relative humidity (RH1) and evening relative humidity (RH2) correlated significantly negative with disease severity. The impact of rainfall (RF), sunshine hour (SSH) and wind speed (WS) found positive but non-significant on powdery mildew disease. The weather variables those have significant relationship with powdery mildew disease were used to develop step wise regression model. The regression equation Y = 62.837 + 8.072*Tmax – 3.919*RH1 R2 = 0.96 developed with maximum temperature and morning relative humidity caused variability up to 96 % in the powdery mildew disease. Hence the combine effect of Tmax and RH1, was more pronounced and most influencing weather parameters on powdery mildew disease. Therefore, model could be used for predicting the powdery mildew disease. The fungicides spraying could be done in advance which helps in reducing the losses caused by powdery mildew of mustard.

Key word: Weather, Powdery mildew and Forecasting.

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METEOROLOGICAL ASPECTS OF EXCEPTIONALLY HOT SUMMER SEASON-2022 OVER RAJASTHAN

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ABSTRACT

Rajasthan witnessed an early onset of hot spells, longer and frequent spells of heat wave during summer season in 2022. Heat wave days and extreme temperatures have been analysed by using daily maximum temperatures of sixteen stations of Rajasthan for the period of 1st March to 31st May, 2022. Wind anomaly at 850, 700, 500 and 250 hpa and temperature advection in lower level have been computed by using ECMWF reanalysis ERA5 data. The study reveals that, the maximum temperatures were above normal by 2 to 5 degree Celsius at many places in the month of March. First spell of heat wave to severe heat was observed during 16-22 March and second spell from 28th March onwards in the state.

Month wise extreme maximum temperatures 43.4 ℃ in Barmer on 18th March, 46.4 ℃ in Ganganagar on 30th April and 48.3 ℃ in Ganganagar on 15th May observed during the season. Highest 21 days of heat wave including severe heat wave days was observed in the month of April, followed by 15 days each in March & May in the state. Total dry weather conditions observed for about 44 consecutive days in the state from 09th March to 21st April. The study reveals that the absence of active western disturbances in pre monsoon season, presence of significant anticyclonic circulation in mid tropospheric levels and advection of heat by westerly winds in lower levels led to the longer, intense and frequent spells of heat wave over the state.

Keywords: Heat wave, Anticyclone, Western Disturbance, Extreme temperature.

Effect of meteorological factors on spread of COVID-19 in India and air quality during COVID-19 lockdown

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ABSTRACT

The novel Coronavirus (COVID-19) was identified in Wuhan, Hubei Province, China, in December 2019 and has created a medical emergency worldwide. The role of temperature, humidity, and absolute humidity in the transmission of COVID-19 has not yet been well established. In contrast, the previous many viral infections like influenza, it is well established. Therefore the study to investigate the meteorological condition for the incidence and spread of COVID-19 infection and to provide a scientific basis for prevention and control measures against the new disease is required for India. In this work, we analyze daily averaged meteorological data for the last three years (2017–2019) for March, April, and May months and the same for the year 2020 for March 1 to May 31. We found a positive association between daily COVID-19 cases and temperature and a mixed association with relative and absolute humidity over India. We have investigated the association of aerosols (AOD) and other pollutions (NO_2) with COVID-19 cases during the study period and also during the lockdown period (25 March-31 May) in India. During the lockdown period, aerosols (AOD) and NO_2 reduced sharply with a maximum percentage drop of about 60 and 45, respectively. We have also found a reduction in surface PM2.5 PM10 and NO2 for the six megacities of India during the lockdown period. Our results suggest that COVID-19 still may spread in warm, humid regions or during summer/monsoon, therefore an effective public health intervention should be implemented across India to slow down the transmission of COVID-19.

Keywords: COVID-19, AOD, Lockdown, Air-Quality, Pollutants

Ecosystem and Socio-Economic Disturbances of Melting the Himalayas

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ABSTRACT

Devastating impacts of climate change on the Himalaya are evident from shrinking ice mass, loss of soil carbon, downstream water budget, change in biodiversity pattern including predator- prey relationship and ecosystem boundary shifts. Impact of changing climate on the Himalaya has been noticed since mid-19th century. The Himalaya is also known as Third Pole because it is third largest source of solid water after the Arctic and the Antarctic and covers up to 100,000 km^2 of glaciers. Therefore, it has important role in global water reservoir and Asian Hydrology but due to increased temperature glaciers has started melting and its mass has changed. This results into release of unbound carbon and nutrient from ice pack into the river which effect biological carbon pump and increased the productivity of river water. The satellite captured image by US space agency, NASA has shown the toxic algal bloom in upper layer of Arabian Sea coast nearby Indo-Pakistan boarder is linked with the Himalayan snow cover loss. These changes are faster then prediction suggested by any climate models. Besides these, In past few decades the Himalayan belt has experienced increased natural hazards like vegetation fire, avalanches, land slides, cloud burst and flash flood which badly impacted the life and socio-economic status of people living there.

Keywords: Climate change, glacier melt, water budget, Ecosystem Disturbances, Natural Hazard

STABLE ISOTOPIC CHARACTERISTICS OF EXTREME EVENTS OVER KERALA

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ABSTRACT

Stable isotopes of precipitation (oxygen and hydrogen) are a useful tool to reconstruct the past climate variability from tree rings, glacial ice, lake sediments, speleothems, etc., beyond the instrumental observation period. Understanding the climatic factors controlling isotopic variability is thus crucial for such studies. A first step is to understand such factors at the seasonal to synoptic time scale for present-day. The amount effect, or anticorrelation between precipitation amount and the proportion of heavier isotopes in the precipitation, is a key characteristic of the isotopic composition of precipitation in the tropics. The physical processes behind this effect are complex and not fully understood yet. Our present study is an attempt to understand rain amount- heavy isotope concentration relation over Kochi (10.0431° N, 76.3243° E), Kerala by high resolution daily isotopic observations of rainfall and vapour as part of ISRO funded project(Respond). The collection of samples was done as per the guidelines of IAEA ;the vapor samples were taken by the push and trap method. LGR isotope analyzer and Thermo Scientific Mat 253 were used to determine the isotopic composition of the samples. The sampling period was from july 2018 to October 2018 and May 2019 to October 2019. Two monsoonal flood events and 4 cyclonic storms occurred during the sampling period. We observe significant isotopic depletion during the cyclonic events as reported elsewhere, while no significant isotopic depletion is observed during the flood events despite the higher rain amounts. The present study is an attempt to understand the isotopic variability associated with extreme precipitation events and cyclonic storm events.

Keywords: Stable isotopes, monsoon extreme events, amount effect

NOWCASTING OF FOG USING GROUND AND SATELLITE OBSERVATION OVER INDIA

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ABSTRACT

Fog is one of the main aviation weather hazard during winter season particularly over North-West India and Indo-Gangetic plains. This part of India witnesses prolonged period of fog from December to February months which results in delay/ diversion and accidents in aviation flights. As the spatial and temporal coverage of fog is very large over this region, the nowcasting of fog is very much essential for smooth and unhindered flying operations. In the present study, a technique was used to calculate Fog Stability Index (FOGSI) during December – January months of winter season for the last five years i.e. 2017 - 2022 using radiosonde data and INSAT-3DR sounder data at 1200 and 1700 UTC over Delhi. After calculating the FOGSI values for each day, the values were analysed with actual occurrence / non-occurrence of Fog the next day morning over Delhi with in-situ visibility data i.e. actual METAR. This is done so as to get some threshold values of FOGSI in the previous evening which will help in nowcasting of occurrence/ non-occurrence of Fog the next day morning. Using data of each month of December – January (2017 - 2022) of Fog Frequency and FOGSI as well as percentage (%) of occurrence, different thresholds were obtained which is used for fog nowcasting. In contrast to insitu sounder observation, as INSAT-3DR is capable of providing temperature and humidity profile every hour over the Indian landmass, the FOGSI generated from INSAT-3DR can be used as a tool for fog nowcasting.

Keywords: Fog, INSAT-3DR Sounder, Nowcasting

Mesoscale Simulation of Tropical Cyclone AMPHAN Over Bay of Bengal: Inter Comparison with NCEP and NCUM global models

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ABSTRACT

In this study, we analyzed the performance of the two global model data sets of the National Centre for Medium Range Weather Forecasting (NCMRWF) Unified Model (NCUM) and the National Center for Environmental Prediction (NCEP) global model for super cyclonic storm Amphan track, intensity and time of landfall. Further, Weather Research and Forecasting (WRF) model, has been utilized to simulate the super cyclonic storm with the National Center for Medium Range Weather Forecasting (NCMRWF) Unified Model (NCUM) and National Center for Environmental Prediction (NCEP) global model simulations as initial and boundary conditions for the WRF model simulations. The model is integrated, for every 12hour interval starting from 16 May 0000UTC to 18 May 0000UTC with a resolution of 9 km horizontal and 34 vertical levels.

The results reveal that the cyclone track, intensity, and time of landfall are reasonably well represented in NCEP and NCUM models. However, the NCEP model is closer to IMD's estimated track and intensity when compared with the NCUM. Further, the WRF simulations indicate that the initial conditions with NCEP are closer to the observation in terms of track and intensity. These errors in NCUM arise due to the differences in the cyclone vortex against the observation.

Keywords: Tropical Cyclone, NCEP and NCUM, Track and intensity, WRF model

STUDY OF INDIAN SUMMER MONSOON VARIABILITY OVER GUJARAT (WEST COAST INDIA) AND ASSOCIATED LARGE SCALE DYNAMICS

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ABSTRACT

The state of Gujarat, which is located along the west coast of India, is the seventh largest state and is having longest coastline of 1600 km. The state exhibit very large spatial and temporal variability of rainfall. The objective of the study is to understand the interannual variability of summer monsoon rainfall over Gujarat and associated large-scale dynamics. By using the Gujarat State-averaged rainfall data from India Meteorological Department, we studied the interannual variability of rainfall during the period 1961-2020. We identified 10 excess and 10 deficient monsoon years when the seasonal rainfall values are above and below one standard deviation respectively. It was found that most of the excess years over Gujarat are associated with La Niña in the Pacific Ocean whereas most of the deficient years are associated with El Niño. We then used winds, sea level pressure and omega vertical velocity from NCEP/NCAR analysis to understand the large-scale dynamics that contributed to the excess and deficient rainfall over Gujarat. We found that there was strong large-scale low level cyclonic circulation over Gujarat region during excess years that causes strong upward motion, enhanced convection, contributed to above normal rainfall anomaly over Gujarat. Whereas there was anticyclonic circulation over Gujarat region during deficient years which causes subsidence and supressed convection contributes to below rainfall anomaly over Gujarat. The study of variability of monsoon would help various organization such as Indian Coast Guard, Indian Navy, Indian Air force etc. in planning and execution of swift operations along the coast and adjoining areas, so it is important both strategic and safety wise for national security.

Keywords: Indian Summer Monsoon, Gujarat rainfall, convection, El Niño, La Niña, Large scale Dynamics

Forecasting of Western Disturbance using a WRF based Ensemble Forecasting System

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ABSTRACT

Error in initial condition and deficiency in model lead to the uncertainty in numerical weather prediction (NWP) model forecast. An ensemble forecasting system quantifies the uncertainty in the forecast which helps in decision making. In the present study, a Regional Ensemble Prediction System has been developed using different combinations of cloud microphysics and cumulous convection parameterization schemes of the Weather Research and Forecasting (WRF) model. Initial and boundary conditions of different ensemble members are provided by a Global Ensemble Prediction System. This Regional Ensemble Prediction System has been used for short-range (up to 3 days) probabilistic forecasting of two western disturbance cases. The root mean squared error of ensemble mean and ensemble spread relationship has been investigated for geopotential height at 500 hPa. The impact of perturbed initial conditions and perturbed model physics on ensemble spread has been studied by carrying out sensitivity experiments. The ensemble mean forecast of precipitation has been compared with the deterministic model forecast (control forecast) of precipitation. The skill of this Regional Ensemble Prediction System has been evaluated relative to that of the control forecast.

Keywords: Ensemble Prediction System, Western Disturbance, Ensemble Spread, Probabilistic Forecasting, Control Forecast

Enhanced precipitation over Karakoram due to eastward shift in Western Disturbance genesis

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ABSTRACT

Western Disturbances (WDs) is a popular term in South-Asia responsible for heavy and sometimes catastrophic precipitation events during winters. They are upper-tropospheric mid-latitude synoptic systems propagating eastward along the subtropical westerly jet stream providing extreme precipitation over the Karakoram-Himalayan ranges. WDs play a crucial role in the sustenance of the "Karakoram Anomaly," which refers to the anomalous stability/surge of a few Karakoram glaciers. Using the existing WD-catalog derived from ERA5 and MERRA2 reanalysis datasets, we observed that the core genesis zone for Karakoram WDs have shifted ~7.8^{o}E, migrating towards more favorable conditions for cyclogenesis. Plausible reasons for this shift are enhanced genesis potential, convergence, and advection along the WD path. Composite analysis suggests that upper-tropospheric moisture availability has risen significantly over the shifted zone, which explains the recent intensification of precipitation events over the Karakoram, thereby facilitating the establishment of the anomaly.

Keywords: Karakoram Anomaly, Western Disturbances, Climate Change

Track & Intensity Prediction skill of IMD GFS & NCEP GFS for Asani Cyclone

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Abstract

This study has attempted to predict and verify the track and intensity of Asani tropical cyclone formed over the Bay of Bengal using the IMD's Global forecast system (GFS) model and NCEP GFS. GFS is one of the operational models in the India Meteorological Department (IMD), which provides the medium-range weather forecast up to 10 days. The model predicted tracks are obtained using a vortex tracker developed by Geophysical Fluid Dynamics Laboratory (GFDL). The Severe Cyclonic storm ASANI track prediction has been started from 12 UTC of 7th May 2022 and continued till 00 UTC of 12th May 2022. The models predicted track and intensity had been verified up to 5 days with 6 hours interval. The track errors are verified in terms of Direct Position Error (DPE), Along-Track Error (ATE) and Cross-Track Error (CTE). The DPE for IMD-GFS varies from 66 to 187km up to 102hrs; and also the DPE is less than 100 km up to 42 hour; whereas for NCEP-GFS, DPE varies 62 to 736 km and also the DPE is less than 100 km up to 24 hours. The positive ATE for both cyclones indicates that the predicted track movement is faster than the observed track. The CTE shows positive errors for a few hours and negative errors for a few hours, indicating that the predicted track is the right/left side of the observed track. The cyclone Intensity forecast for the maximum sustained wind speed (MaxWS) and central mean sea level pressure (MinSLP) are verified in terms of mean error (ME), and root mean square error (RMSE) and the errors are lead time independent. However, most of the time both model underpredicted the cyclone intensity. Finally, the NCEP GFS based track errors are higher when compared with the operational IMD GFS model forecast track errors.

Keywords: Tropical cyclone, track prediction, GFS, NWP, global model, direct position error, intensity, GFDL

Seasonal uncertainty assessments of NCMRWF global ensemble prediction system

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ABSTRACT

An ensemble forecast provides an estimate of the forecast probability distribution of model variables, given an estimate of the probability distribution of analysis errors. The combined effect of uncertainties in model physics and the initial state provides a means to increase the dispersion of ensemble prediction systems. The ensemble prediction system based on Met Office Global and Regional Prediction Systems (MOGREPS) at NCMRWF is assessed in this study. The model physics is perturbed by the Stochastic Kinetic Energy Backscatter (SKEB) and Random Parameters (RP) schemes. The RP scheme incorporates uncertainties in the empirical parameters of the physical parameterization. The SKEB scheme is implemented in the Unified Model to inject the loss in kinetic energy back into the model. The global perturbation fields for wind, temperature, humidity and pressure are produced by the Ensemble Transform Kalman Filter method. The representativeness of an EPS is analyzed from the distribution of initial and forecast ensemble dispersion. The vertical profiles, latitudinal and longitudinal variations of dispersion of the ensemble are evaluated in this study for geopotential height at 500 hPa, temperature and relative humidity at 850 hPa to obtain physical insights into the uncertainty characteristics of the EPS over different seasons for further improvement.

Keywords: Uncertainty assessment, Ensemble prediction, Weather modeling, dispersion

Comparison study using reanalysis datasets to understand the evolution of a cloudburst event over Uttarkashi of Uttarakhand state.

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ABSTRACT

Two reanalysis dataset are used for understanding the role of atmospheric conditions controlling the cloudburst event evolution. For this a cloudburst event occurred on 3rd August 2012 at Uttarkashi in Uttarkhand district is analysed. The The Indian Monsoon Data Assimilation and Analysis (IMDAA) and ECMWF Reanalysis v5 (ERA5) data are evaluated to find out the better representation of wind, potential vorticity, OLR and Vertically Integrated Moisture Transport (VIMT). Also vertical structure of the humidity, vorticity, precipitation and severe index parameter like Convective Available Potential Energy (CAPE) and Severe Weather Threat Index (SWEAT) have been calculated in the two dataset with aim to determine in the best representation of severity of the cloudburst event. The higher value is found in IMDAA dataset compared to ERA5 data set. Also the rainfall from IMDAA and ERA5 dataset was compared with observed Global Precipitation Measurement (GPM) rainfall. The IMDAA dataset has more correlation than ERA5 with respect to GPM rainfall. The correlation of the rainfall from IMDAA data with GPM was 0.60 while ERA5 has 0.28. Also IMDAA rainfall has 3 hours time bias while ERA5 has 5 hours bias. The results also indicate that the moisture from BOB and Arabian sea interacted over Uttarkashi and orographic uplifting resulted in this cloudburst event was happened.

Keywords: Cloud Burst, IMDAA and ERA5 reanalysis data, SWEAT index, VIMT.

Impact of urban canopy models and integration of WUDAPT on the severe convection over Bhubaneswar city of Eastern India

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ABSTRACT

Amplified rates of urban convective systems pose a severe peril to the life and property of the inhabitants over urban regions, which needs a reliable urban weather forecasting system. However, accurate rainfall forecast at the city scale has constantly been a challenge as they are significantly pretentious by land use/ land cover changes (LULCC). Therefore, an attempt has been made to improve the forecast of the severe convective event by employing the comprehensive urban LULC map using Local Climate Zone (LCZ) classification from the World Urban Database and Access Portal Tools (WUDAPT) over the tropical city of Bhubaneswar in the eastern coast of India. These LCZs denote specific land cover class based on urban morphology characteristics and can be used in the Advanced Research version of Weather Research and Forecasting (ARW) model which also encapsulates Building Effect Parameterization (BEP) scheme. The BEP scheme considers the 3D structure of the buildings and allows complex land-atmosphere interaction for an urban area. The temple city Bhubaneswar, the capital of eastern state Odisha, which possesses significant rapid urbanization during the recent decade. The LCZs are generated at 500 m grids using supervised classification and are ingested into the ARW model. Two different LULC dataset i.e., Moderate Resolution Imaging Spectroradiometer (MODIS) and WUDAPT derived LCZs along with initial and boundary conditions from NCEP GFS at 6-hour interval are used for two pre-monsoon severe convective events of the year 2016. The results from WUDAPT based LCZ have shown an improvement in spatial variability and reduction in overall bias over MODIS LULC experiments. The WUDAPT based LCZ map enhances high-resolution forecast from WRF by incorporating the details of building height, terrain roughness and urban fraction..

Keywords: Severe convection, Urbanization, WUDAPT, ARW, LULCC

NCMRWF Seasonal Prediction: A tailored product for Wind Power Forecasting over India

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ABSTRACT

India has enormous wind power potential (302GW at 100 m) and currently the installed capacity is more than 40GW ranking it fourth in the world. Due to chaotic behavior of wind the generation of wind power and its integration into the grid throws multiple challenges on the power producers and the grid operators. The short- and medium- term forecasting (from few hours up to few days) are done using statistical, physical and hybrid models but on longer lead time a physical model is of better choice. Generation prediction at a month to few months ahead plays a crucial role in maintenance of wind farms and helps the concerned authority in power purchasing and power management.

The NCMRWF Seasonal Prediction System (NSPS) has been utilized for Monsoon forecast over India. In this study, we have evaluated the suitability of seasonal prediction of near surface winds from different models and evaluated the performance of NSPS against it. A case study for July 2020 in which Indian Wind Energy sector witnessed the lowest generation in last decade has also been addressed. The study based on data from 1993-2020 suggests that the inter-annual variability of near surface winds are well simulated in ECMWF and NCMRWF seasonal prediction system. The forecast based on model initialized in February and May are reasonably good (POD > 0.60 and POD > 0.85) for indicating the anomaly in wind power generation during high wind season (June-August). Based on NSPS a bias corrected tailored product has been developed which provides wind speed at 100 m having better accuracy and suitable for issuing wind power generation few months ahead.

Keywords: Wind Power, NWP model, Seasonal Forecasting, Unified Model

NUMERICAL ANALYSIS OF STRATIFORM EVENT USING WRF-SBM SCHEMES FOR HYDROMETEOR CLASSIFICATION: A CASE STUDY

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ABSTRACT

The numerical study investigates the hydrometeor characteristics using the cloud-resolving Weather Research Forcast (WRF) model. The evaluation is conducted for the stratiform event that occurred on 30th September, which took place at the High Altitude Cloud Physics Observatory (HACPO), Munnar, during the monsoon 2021. The distinctive structures of the hydrometeor are examined in a three-domain WRF model with spectral bin microphysics (SBM) full and fast simulation, with a horizontal resolution of 9, 3, and 1 km using ERA5-reanalysis hourly data. The analysis is focused to explore the capability to reproduce the observed stratiform precipitation features by these schemes and their differences. A detailed comparison among these two runs in terms of radar reflectivity, precipitation, thermodynamic fields, and microphysical processes is conducted. A high snow mixing ratio above 0-degree isotherm level with near zero vertical velocity simulated which is generally expected for stratiform precipitation. Further, it is highlighted that both SBM-Full and Fast numerical simulations successfully reproduced the spatial and temporal characteristics of the event rainfall as compared to the micro rain radar (MRR) observations, however, SBM fast shows a more consistent bright-band layer simulation than SBM-full. SBM-full simulation shows that 10-11 km altitude levels have a high concentration of dendrite and column particles. The snow mixing ratio has a maximum impact (with the highest concentration) on precipitation, which grows from 10 km and has the highest concentration at 6 km, further melts, and shows the bright-band structure as observed by MRR. Results show that both the simulations can reproduce but underestimate the rainfall characteristics. The bin schemes (consider 8 (4) different classes of hydrometeor for the full (fast) SBM scheme) can provide a better understanding of hydrometeor evolution throughout the vertical structure.

Keywords: WRF, Spectral Bin Microphysics, Stratiform precipitation, Remote Sensing.

SPATIAL DOWNSCALING OF IMD GRIDDED RAINFALL DATA USING GENERATIVE ADVERSARIAL NETWORK

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ABSTRACT

Downscaling of gridded climate data is an essential requirement for regional and local scale studies. Statistical and dynamical methods are the two conventional methods for downscaling. The suitability of Artificial Intelligence / Machine Learning / Deep Learning based image super-resolution techniques for the downscaling of gridded climate data is an ongoing research problem. In this study, the potential of Super-Resolution Generative Adversarial Network (SRGAN), a cutting-edge image super-resolution technique, is trained and evaluated for downscaling gridded rainfall data over India. For this analysis, the India Meteorological Department (IMD) gridded rainfall data at low-resolution (LR) and high-resolution (HR) for the years 1901–2021 are used. The SRGAN is trained to downscale the LR (1^{o}x1^{o}) rainfall data to its HR (0.25^{o}x0.25^{o}) counterpart by a factor of four. The generator network architecture is configured by combining four residual dense blocks with roughly 41,000 learning parameters. The SRGAN is trained via adversarial learning by minimising the perceptual loss using LR inputs and HR labels from the monsoon (June-July-August-September) months of 1901 to 1999 and is then tested for the remaining period, i.e., 2000-2021. To assess the effectiveness of trained networks, objective metrics like root mean squared error, percentage bias, Nash-Sutcliffe efficiency, Kling-Gupta efficiency, and an image-quality assessment metric known as structural similarity index measure are calculated. The SRGAN's generator network is also trained separately using the supervised training method. The high-frequency details are typically challenging to retrieve by neural networks trained in supervised training mode, which was also evident in our results. On the other hand, the generator network trained using adversarial learning operated more effectively. With outstanding perceptual accuracy, it could recreate the most extreme rainfall events throughout the testing period in the high-resolution space.

Keywords: Deep Learning, Super-resolution, Generative Adversarial Network, Downscaling, Gridded Rainfall

Ocean and Atmospheric Characteristics Associated with the Cyclogenesis and Rapid Intensification of NIO Super Cyclonic Storms

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ABSTRACT

An attempt is made to investigate the various atmospheric and oceanic conditions that contributed to the genesis and rapid intensification (RI) of the super cyclonic storms (SUCS) formed over the North Indian Ocean (NIO) basin during 1982-2020. Weak to moderate vertical wind shear values are found in all the cases supporting genesis. The genesis potential parameter was > 30 in four cases, whereas the other two cases, viz., Gonu and Odisha SUCS experienced values ≤ 30. Prior to genesis, Equatorial Rosssby (ER) waves followed by Madden Julian Oscillation (MJO) were dominant, whereas in case of Amphan, all the three convectively coupled equatorial waves viz., MJO, ER, and Kelvin wave were present. The Ocean conditions were more conducive for tropical cyclone (TC) genesis than the atmospheric conditions. Both sea surface temperature and tropical cyclone heat potential (TCHP) supported the cyclogenesis. In most cases, the setting up of the pre-genesis scenario was heavily influenced by the ocean characteristics, whereas the atmospheric conditions were supportive enough. The environmental conditions that prevailed before the starting of RI process, showed the presence of thick warm waters, a sufficient supply of moisture at the middle of the troposphere, and moderate wind shear in all cases. Mid-tropospheric relative humidity, sea surface temperature and low-level relative vorticity, all had a significant role in the RI process of all SUCS storms across the NIO basin. During the RI days, TCHP ≥ 60 $kJ.cm^{-2}$ was observed for Amphan and Gonu, with thick barrier layers for all cases. Gonu encountered a warm core eddy along its track, which provided extra fuel for the RI process. All six TCs are slow to moderate moving ones, which enabled them to spend significant time over the Ocean surface and interact with the warm waters to get positive feedback for the RI process.

Keywords: SUCS, Equatorial Rossby waves, MJO, TCHP, rapid intensification

FLOOD EXTENT MAPPING AND VULNERABILITY ANALYSIS USING GOOGLE EARTH ENGINE

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ABSTRACT

Assam and Meghalaya is experiences recurrent flooding, which affects large agricultural areas and poses a high risk to the population. This study is focused on the recent flood events in Assam & Meghalaya. In this study, the Google earth engine is used for flood extent mapping and vulnerability analysis. The C Band Sentinel 1A satellite images for the duration of June- July 2022 are used for the analysis. In the study we analyzed the flood extent, the number of exposed people, affected cropland, and affected urban areas during the flood events between 10.06.2022 to 08.07.2022. The composite area under flood inundation is estimated to be 249072 hectares. The Copernicus Global Land Cover dataset was used to extract the affected agricultural area and flood-affected settlements. Floods have caused adverse impacts on agricultural lands and settlements. The study provided a holistic spatial assessment of flood inundation in the region due to the combined impact of the Brahmaputra River. The identification of highly flood-prone areas with an estimated impact on cropland and population will provide necessary information to decision-makers for flood risk reduction, mitigation activities, and management.

Keywords: Flood extent mapping, Google earth engine, sentinel-1

ROLE OF SMOKE AEROSOLS IN GOVERNING WINTERTIME LOW-LEVEL CLOUD PROPERTIES OVER THE INDIAN REGION

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ABSTRACT

The influence of smoke aerosols on the low-level clouds over the Indian landmass during winter is examined using fifteen years (2005–2019) of long-term multi-satellite and reanalyses observations. Climatologically higher values of aerosol optical depth (AOD) (> 0.6), Angstrom exponent (> 1.5), UV-aerosol index (> 0.7), and black carbon and organic carbon (BC + OC) extinction aerosol optical thickness (EXTAOT) (> 0.18) are observed over the Indo-Gangetic Plain (IGP) compared to the rest of India. It indicates the dominance of carbonaceous aerosols over the IGP region. However, noticeable rises in AOD (~ 60%) and (BC + OC) EXTAOT (20–40%) are found over eastern parts of India (particularly Odisha and Chhattisgarh) and central-south India, compared to IGP (< 10% and < 5% respectively) in the recent years. Interestingly, fire activities are also increasing in these areas and their neighborhoods. This rise in aerosol loading over eastern and central-south India could be due to long-range transport from the northwestern parts and beyond and local anthropogenic emissions, including biomass burning. Besides, a significant enhancement in cloud fraction (CF) (50–60%) is noticed in and around the regions where smoke aerosols increased considerably, implying the possible influence of smoke aerosols on the cloud properties. The present study suggests that low-level clouds persisted over most parts of the considered area during wintertime. While CF and cloud effective radius showed a noticeable increase in the polluted condition, cloud optical thickness and liquid cloud water path decreased with an increase in aerosol loading. CALIPSO images suggest that a mixture of dust, polluted dust, and polluted continental/smoke aerosols dominated over the inland areas, mostly confined within 2 km altitude over the considered region. However, an elevated layer of absorbing aerosols (smoke and polluted dust) over the low-level cloud supports increased CF through the 'aerosol-cloud-boundary layer' feedback mechanism.

Keywords: Biomass burning, Smoke, Aerosol, Low-level cloud

ARTIFICIAL INTELLIGENCE BASED UPPER AIR RADIO SOUNDING BALLOON BURST ANALYSIS AND QUALITY ASSESSMENT

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ABSTRACT

Abstract: Weather balloons are deployed from yore for upper air sounding resulting in an upper air atmospheric profile. The upper air profile is a useful precursor in initializing the weather models and thus acts as a contributing factor in accurate weather prediction. The accuracy and quality of this exercise depend upon the endurance and absolute ceiling of carrier balloons. As weather balloons are expandable entities, so the size of the balloon keeps on increasing with decrease in pressure and increase in altitude. Balloons can stay airborne till busting determining the eventual sounding height. Realizing the importance of burst calculation in upper air sounding, this paper discusses the methodology for accurately estimating various operational weather ballon-burst parameters for better endurance and ceiling estimation.
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Keywords: Ballon-burst

Python package for the calculation of aerosol optical properties and mixing state

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ABSTRACT

Changes in the aerosol optical and physical properties due to aging and change in mixing state account for the large uncertainties in the estimation of aerosol-radiative effects and aerosol-cloud effects. Aerosols' aging and mixing states are strongly controlled by their chemical compositions. However, the in-situ measurements of the chemical composition of aerosols are sparse globally due to the technical complexity associated with the instrumentation and the high cost involved with the measurements. Alternatively, the Optical Properties of Aerosols and Clouds (OPAC) model has been used widely in the aerosol research community to calculate the optical properties of user defined external aerosol mixtures, which is a necessary input for radiative forcing models and for the chemical makeup of aerosols from available optical measurements, particularly in the region where the chemical composition is unavailable. The OPAC program written in FORTRAN is no longer maintained and is limited by its inability to treat complex aerosol internal mixing states. Here we present a Python successor of the OPAC model for calculating aerosol optical properties with different mixing states of aerosol. The package follows the same workflow as the OPAC, with additional options to define new aerosol components and core-shell mixed scenarios. The optical properties of aerosol mixtures at 61 wavelengths and 8 relative humidity values were calculated from the size distribution data and optical data of each aerosol component adopted from improved Global Aerosol Data Set. Calculated physical and optical parameters were validated for ten different aerosol mixtures. The current python package aims to provide a more portable and flexible open-source tool for calculating aerosol optical properties and mixing state studies, which can be easily integrated with other programs to perform computationally expensive tasks, including batch calculations and data analysis.

Keywords: Mixing state, Aerosol, OPAC, Aerosol Optical Depth

Performance Evaluation of Flow-Dependent error covariance in 3DVAR Data Assimilation system in the Simulation of Pre-monsoon Thunderstorm event over NER

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ABSTRACT

A hybrid ensemble adjustment Kalman filter-three dimensional variational data assimilation (EAKF-3DVAR) (hereafter HYBRID) system for the Weather Research and Forecasting (WRF) Model is used to improve the simulation of the pre-monsoon rainfall during thunderstorm event over north-eastern region (NER) of India. While 3DVAR is globally recognized among the DA community because of its cost effectiveness, but it uses static background error covariance (BEC) matrix to estimate the forecast error statistics that does not have any information about the error of the day. However, such information can be incorporated using more advanced but computationally demanding ensemble based DA method such as ensemble Kalman filter (EnKF) where the flow-dependent BEC is estimated from the ensemble of nonlinear model forecasts. The main strength of hybrid method is that it combines the strength of both variational and the ensemble based data assimilation (DA) system effectively. In this study, thunderstorm events occurred during 22-24 April 2017 over southern NER is simulated using both 3DVAR and HYBRID DA system. The assimilation experiments reveal superior performance of HYBRID DA system for simulation of rainfall compared to 3DVAR during this period. The spatial shift of the rainfall occurring areas observed in 3DVAR simulations are much reduced in the HYBRID simulations. Additional experiments are conducted by inclusion of model errors using combined Multiphysics scheme and Stochastic Kinetic Energy Back Scatter Scheme (SKEBS). In this experiment, 30 different combinations of WRF parameterization schemes are used for generation of ensemble members. The inclusion of model error further improves the rainfall distribution as well as intensity..

Key words: WRF, HYBRID, EAKF, thunderstorm, rainfall

Validation of Indian high resolution BUFR Radio Sonde profiles

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ABSTRACT

National Centre for Medium Range Weather Forecasting (NCMRWF) regularly receives global meteorological observations through Global Telecommunication System (GTS) in World Meteorological Organization’s (WMO) accepted codes. Most of the global conventional data (including surface and upper air) were transmitted in Traditional Alphanumeric Codes (TAC) till recently and are slowly changing to Table Driven Code Form (TDFC). One of the most common TDFC for meteorological and oceanic data transfer is the BUFR (Binary Universal Form for the Representation of Meteorological Data). Recently, India also has started disseminating some of its existing radio sonde stations’ data in high resolution BUFR. As per the communication from India Meteorological Department (IMD), six WMO Global Climate Observing System (GCOS) Upper-Air Network (GUAN) stations viz., New Delhi (42182), Guwahati (42410), Kolkata (42809), Nagpur (42867), Mumbai (43003), and Chennai (43279) are taking high resolution radiosonde observations twice daily at 0000 and 1200 UTC and disseminating through global GTS. As part of the NCMRWF regular observation monitoring, we are monitoring the frequency and quality of these Indian high resolution radiosonde observations. The study demonstrates the innovation profiles of different meteorological variables like temperature, humidity, and wind components of these radiosonde reports against NCMRWF NWP model background fields during monsoon 2022.

Keywords: GTS, BUFR, radio sonde, validation, innovation profiles

Variation in Surface Temperature over urban city of India during a Decade

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ABSTRACT

This study focuses on analysis of temperature over two metropolitan cities Delhi and Bengaluru in the recent years 2010-2022. The surface temperature observations are utilized from the India Meteorological Department (IMD) observational network and ERA 5 reanalysis data. The number of heat waves and cold wave days are obtained in each year over both the stations. For the heat wave days at Delhi the data is analyzed for the months of March, April, May and June whereas for cold wave days the months of December, January and February are selected over Delhi, whereas for Bengaluru the data is analyzed for the whole year. The number of heat and cold waves and the variability depends on the location and may be linked to the changing climate patterns.

IMPACT OF WEATHER AND POLLUTION OVER AGRO ZONE AND CROP YIELD FORECASTING USING STATISTICAL MODELING OVER NORTHWEST INDIA

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ABSTRACT

Due to rapid economic growth, industrialization (acid rain, Fossil fuel, biomass burning) urbanization (GHS, Transportation, stubble burning))is seems to play a major role in Air pollution (Ozone, sulfur dioxide, NOX, ROS (Reactive oxygen species) NO2, PAN, NH3, Fluoride) which maximum impact on reduction in yield quality and economic of the crops. This air pollutants risk depending on the emission pattern, atmospheric transport, leaf uptake, and biochemical defense capacity, weather factors (Temperature, Relative Humidity, Water availability) which can negatively impact on crop productivity. In this study focus was on the deals with present and future trends of major gaseous pollutants emissions and their impact on crop performance or development of crop yield forecast model through Regression technique. This model use pollutant emission, weather parameters during crop growing period and long-term yield data of soyabean, rice and wheat crops. Yield prediction was carried out for soyabean, rice and wheat crops for north west part of India is 1390 (kg/ha), 4154 (kg/ha), 2233(kg/ha) during 2020-2021 and accuracy of this model is tested with coefficient of determination (R2) 0.54, 0.62 and 0.71 respectively.

Ground based upward-looking Microwave Radiometer brightness temperature observations and retrieval of atmospheric profiles

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ABSTRACT

A ground based upward looking Microwave Radiometer (MWR) is installed in Space Applications Centre (SAC), Ahmedabad since May 2018. The MWR measures the brightness temperatures at 35 channels in the water vapour (22-30 GHz) and oxygen (51-60 GHz) aborption bands. These observations are inverted to retrieve the profiles of atmospheric temperature and humidity up to an altitude of ~8 km. In the current study, the MWR measured brightness temperature has been compared with the RT-model simulated brightness tempertures. Similarly, the MWR retrieved atmospheric profiles are compared with the atmospheric profiles obtained from a nearby radiosonde observations and reanalysis data. The brightness temperature measurement is found to have biases in the humidity as well as temperature sensitive channels. The retrieved profiles also have sigmificant large errors compared to the radiosonde measurements and reanalysis data. The in-built NN based retrieval coefficients needs fine-tuning/recalibration in order to obtain accurate profiles from MWR observations. Here, a new machine learning based inversion algorithm has been developed for retrieving the atmospheric profiles of temperature and humidity from ground based microwave radiometric observations. The newly developed algorithm shows a significant improvement in the retrieval accuracy. Currently, there are large number of MWRs operational in India (all are imported instruments) with vendor supplied reetrival coefficients, and presently, indigenous development of make-in-India MWRs is being attempted. In view of this, the current study is important in assessing the performance of existing as well as the new MWRs in addition to provide location specific retrieval coefficients.

Keywords: Microwave Radiometer, Temperatutre and humidity sounding, Remote Sensing, Retrieval, Machine Learning.

STUDY THE TRENDS OF REFERENCE EVAPOTRANSPIRATION IN RANCHI REGION OF EASTERN INDIA

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ABSTRACT

Evapotranspiration (ET), the process of water release to the atmosphere, plays a crucial role in irrigation management, water stress assessment, daily flux modelling, and climate change impact assessment. Various empirical formulae have been in use (e.g. Hargreaves, Penman-Montieth) to estimate ET for agricultural and hydrological purposes while actual measurements of ET by Lysimeter are a few. ET estimates are also available from MODIS that represent relatively large areas as compared to in-situ measurements/estimates. A good validation of Lysimeter measured ET against MODIS-derived ET would help study long-term trends of ET as satellite derived ET are available for different landscapes and for long.

ET becomes important for Jharkhand region as it is having high mountainous and hilly region, and also has high risk of drought. In order to do this climate data were collected from IMD Ranchi station along with actual Lysimeter measure ET. Values of ET also were calculated from different empirical equation available in the literature. It is found that Hargreaves method is the most suitable for ET estimate as compared to that by Pennman-Montieth over Ranchi. As the former method is based on temperature those are the relatively easy to measure, assessing ET for a station and hence deciding on the irrigation requirement will be relatively easy.

Lysimeter ET also was and validated from satellite data (MODIS based), on an 8 day cumulative scale, which also a decisive for watering the crop, they correlated well with a 0.73 (R^2). It is found that ET is varying between 0.3- 4 mm/day for the station. It was also seen that ET_{MODIS} is heavily dependent on soil moisture and then to NDVI. Since NDVI is the basis of land cover (plants/crop) and is available in high resolution, this relation can be tackled to find the ET changes/demands over different landscapes.

Keywords: Evapotranspiration, Agriculture, NDVI, Soil moisture, MODIS

Sequential Temporal Filling of Oceanographic and Atmospheric Variables

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ABSTRACT

Satellite observations of various earth science parameters have played a crucial role in our understanding of the ocean and atmosphere. These data not only help in building long-term datasets for various parameters, but these parameters can also be used as input data/proxies for understanding other important variables which cannot be directly observed. In order to do this, high temporal resolution data (daily) is helpful for better solutions and designing better algorithms. However, incomplete data can make the use of satellite products as proxies unreliable and lead to low skill predictions. It is observed that there are many missing data in the satellite data due to cloud cover, electronic noise, gaps between swaths etc.

In this work, we attempt to make complete high temporal resolution data that has no data gaps using sequential temporal filling of some oceanographic and atmospheric variables and test how this filled data performs when used as proxies. Variables such as chlorophyll-a, sea surface temperature, salinity etc. are utilised for this work. We focus on covering the missing data with low temporal resolution data in a sequential manner and identify various issues that this can present. The final data can then be used to train algorithms to model some oceanic parameters that are not directly measured by satellites. We assess the algorithm's performance using both the original satellite dataset and the newly created filled data.

Keywords: High temporal resolution, Missing data

Evaluation of atmospheric dust deposition fluxes and its relationship with Indian Summer Monsoon Rainfall by using Regional Climate Model

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ABSTRACT

Atmospheric dust has a direct impact on precipitation, cloud formation, visibility and climate change, plays a crucial role in the polluted atmosphere. Pre-monsoon dust aerosols are closely linked with Indian Summer Monsoon Rainfall. Using a regional climate chemistry model RegCM-4.9.2, we have simulated long term changes in dust and precipitation over Indian region. Analysis of dust deposition flux is investigated in this study by Regional Climate Model (RegCM), rainfall from Modern Era-Retrospective Analysis for Research and Applications (MERRA 2) reanalysis and India Meteorological Department (IMD) data in conjunction with the wind field from European Centre for Medium-Range Weather Forecasts (ECMWF). Wet deposition is the efficient removal process for fine dust aerosol. The wet deposition flux is found to be more dominant than dry deposition flux. As a response, significant changes in radiation fluxes at surface and top of the atmosphere are observed. The wet deposition of dust over Indian region is mainly in the large-scale wet removal process, which becomes strongest in pre-monsoon season. The comparison of wet deposition from RegCM simulation with the precipitation production rate from MERRA 2 and IMD shows a positive relationship. However, dust burden over IGP shows a negative correlation with precipitation over IGP.

Key words: Dust aerosols, Dust deposition, Indian Summer Monsoon Rainfall, Dust loading.

Regional-scale vegetation-climate interactions in India

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ABSTRACT

Climatic drivers predominantly shape the vegetation. As a feedback mechanism, it modifies the climate accordingly by changing the energy flux primarily through evapotranspiration, changes in the albedo, and roughness length. This feedback mechanism has been reported negative as well as positive, taking into consideration the variability within the vegetation. Various studies on understanding the vegetation-climate interactions have been conducted globally using different regional climate models. However, the influence of vegetation on climate in India is barely understood on a finer resolution scale. India has a diverse and natural forest ecosystem, and a complex monsoon climate needs a more comprehensive understanding of vegetation-climate interaction for better policy making toward a sustainable and resilient economy.

This study puts forward the study of different forest types (classified by Champion and Seth and FSI) and their influence on climate using satellite, observational, and model data of finer resolution. The study will help understand vegetation's compensatory role in mitigating climate change. This will also serve as the platform to explore a new dimension of meteorology and ecology.

Keywords: Climate change, Modelling, Vegetation, Forest ecosystem

Theme-Predictability and teleconnections: interannual to multi-decadal timescales

Is South West monsoon 2022 over Maharashtra State is unique during June and July as compared to last five years?

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ABSTRACT

Four meteorological sub-divisions, *viz*. Konkan and Goa, Madhya Maharashtra, Marathwada and Vidarbha in the State of Maharashtra rainfall varies widely due to orography and location. This year monsoon rainfall over Maharashtra is typical, a bit unique in nature which started with very less rainfall during June, while revival occurred in just around two weeks time during first fortnight of July 2022. This prompted the authors for this critical analysis and study.

For this study, daily rainfall data of June and July months from 2017 to 2022 is considered for analysis of rainfall patterns. From the daily rainfall data monthly rainfall series of each stations are computed and then monthly district wise rainfall series has been constructed by considering mean of all the stations' rainfall values within the district. During the year 2022, South West monsoon over Maharashtra State arrived on 10th June which is 5 days late from normal date and monsoon covered entire Maharashtra State on 17th June (around normal date). However, initial progress was slow as well as weak. In the month of June 2022 actual rainfall reported *viz.* Konkan and Goa, Madhya Maharashtra, Vidarbha were 24, 40 and 39% deficient rainfall respectively during this year 2022 except Marathawada, which was 7 percent more than LPA in normal category. However, in the month of July 2022, four sub divisions of Maharashtra reported excess rainfall viz. Konkan and Goa 26%, excess, Madhya Maharashtra 70% excess, Vidarbha 83 % excess and Marathwada 106% excess than normal cartogary. The paper discussed in detail regarding June and July rainfall for four meteorological sub-divisions for last six years commencing from 2017. The systems responsible for the revival of monsoon over the State during month of July 2022 is discussed in the paper. The result found is encouraging, which is highlighted,here.

Keywords: Rainfall, South West Monsoon, Maharashtra, Sub-divisions, Orography, Systems.

Deep learning based forecasting for Mixing Layer Depth: Understanding the dynamics of tropical cyclones

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ABSTRACT

Mixed layer is uppermost part of the ocean with a homogeneous distribution of the density, which establishes teleconnection with atmosphere by transferring heat and moisture, CO_2 exchange. Various atmospheric forcings (e.g. wind stress, heating and cooling, evaporation and precipitation) and ocean process trigger small scale eddies which further drive turbulent mixing and controls mixed layer depth (MLD). Changes in these atmospheric forcing over smaller to larger time scale thus leads to significant variation in MLD growth and further air-sea exchange. Particularly, during the extreme event like tropical cyclone, MLD modulation along with air-sea exchange is observed to be largest. Thus, it is important to predict MLD in order to understand ocean dynamics and its impact air-sea exchange. In particular, it can help to determine the intensity or severity of cyclones.However, predicting the mixing layer depth is one of the most difficult tasks in ocean science owing to large parameter space for diffident drivers and their complex relationship. The use of data-driven models is one method for predicting MLD. In this work, we use a deep learning model, ConvLSTM, to forecast MLD for a period of up to four weeks in Bay of Bengal area. Four decades of data (1979-2018) from the ERA5, ORAS5, and Tropflux repositories are used. In total, six oceanographic variables are included in model training in various combinations, allowing us to assess the contribution of each variable on MLD formation. For model evaluation, we used the correlation coefficient and RMSE. The model can forecast the MLD with a one-month advance time and a correlation of up to 0.67. This model can also be used to anticipate MLD in other oceanic regions.

Keywords: - Deep Learning, ConvLSTM, MLD forecasting, Bay of Bengal, Cyclone intensity

Comparing kriging and a deep learning approach for spatial interpolation

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ABSTRACT

Spatial interpolation techniques are essential to construct a gridded dataset from available station data. Out of possible spatial interpolation methods like, simple average, inverse distance weighted average (Shepard's method), etc. Kriging has proven to be the simplest and an accurate method in Geospatial Statistics. We employ the statistical Kriging method to construct a gridded dataset for daily precipitation using the values from IMD ground stations' data from 1980 to 2019. Considering this gridded data as the ground truth, we trained a Neural Network on grids to generate values back to IMD stations. The Neural Network takes in Surface Pressure, Relative Humidity, Temperature, u-v Wind Speed, coordinates, elevation, precipitation of 10 closest grid points, and finally, the coordinates and elevation of the grid point itself. The climate variables used have been retrieved from ERA5 reanalysis dataset. We test the trained Neural Network data, to assess its performance at the station locations as we have true precipitation values at the station locations. We again use Kriging to approximate gridded data at the station locations to input in the Neural Network. We compare the performance of the Neural Network against Kriging. RMSE loss for the Neural Network is lower than that of Kriging. This method can be used for other meteorological variables for approximating the data from grid to station location and filling the missing values in the datasets.

Keywords: Spatial Interpolation, Geospatial Statistics, Kriging, Deep Learning, Artificial Neural Networks

Machine Learning model for Air Pollution forecast in the NCR

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ABSTRACT

New Delhi is among the regions of the highest ambient particulate matter exposure in the country. Particulate matter ($PM_{2.5}$) remains one of the most dominant contributors to air pollution in Delhi, and its acute or chronic exposures have exerted severe health implications. Hence, it is necessary to predict the magnitude of $PM_{2.5}$ concentrations in advance so that timely information can be provided to vulnerable communities and individuals to help them minimize their exposure to acute air pollution. In this work, we use Machine Learning models, to predict $PM_{2.5}$ concentration with a lead time of 24 Hours. We employ five such models, namely Multi-Linear Regressor, Random Forest Regressor, Support Vector Regressor, XGBoost Regressor and ANN, and assessed their performance on test data. The XGBoost model stands out to be the best among all the five models. For our model we have used five and a half years of data from Jan 2017 to July 2022, taken from CPCB, and ERA5 reanalysis websites, which includes variables such as Wind Speed, Wind Direction, Temperature, Relative Humidity, PM_{10} concentration etc. and their correlation with $PM_{2.5}$ Pollutant is studied in detail. The XGBoost model provides pretty low RMSE of 0.28 on the Noida city data for which training set contains data comprising three hourly $PM_{2.5}$ concentrations from 01 Jan 2017 to 30 June 2022 and the testing set contains data comrprising three hourly $PM_{2.5}$ concentrations from 1 July to 31 July 2022. The developed model can be promising low-cost model for air pollution forecasting in different cities of NCR.

Keywords: Multi-Linear Regression, XGBoost, $PM_{2.5}$, Machine Learning.

CHARACTERISTICS OF VOCS AND THEIR CONTRIBUTION TO O_3 AND SOA FORMATION ACROSS SEASONS OVER A METROPOLITAN REGION IN INDIA

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ABSTRACT

Understanding and quantifying the influence of volatile organic compounds (VOCs) on ozone and secondary organic aerosol formation is essential for better prediction/estimation of these products. A total of 9 VOCs along with surface ozone were measured during the year 2019 at Pune (India) location. The ozone formation potential (OFP) and secondary organic aerosol formation potential (SOAFP) estimations are compared for 2 methods- using measured VOC concentrations and using their photochemical initial concentrations (PIC). The OFP and SOAFP estimated based on the measured VOC concentrations provide an incomplete understanding of these 2 formation processes. This is mainly because measured VOCs don't account for the photochemical losses that compounds undergo from the source to the receptor. The PIC values of VOCs have been estimated in this study to highlight the importance of considering the photochemical losses. For example, the PIC value of highly reactive compound, isoprene, was found to be 152% higher (1.48 ppbv) than its measured value (0.59 ppbv). The resultant total OFP estimate based on PIC values of all the VOCs was found to be 53.30±35.02 ppbv as compared to 45.99±29.35 ppbv obtained from measured VOCs. Based on k-means clustering analysis, it was found that the highest ozone formation was favored under transition regime chemistry when PIC values were considered. The average total SOAFP based on PIC values was found to be 1.32±1.40 ppbv, while it was 1.17±1.18 ppbv for measured VOCs. The aromatics contributed to over 90% of total SOAFP estimated for the region.

Keywords: VOCs, ozone, SOA, photochemical initial concentration, photochemical degradation

LONG TERM VARIATION IN THE MONSOON LOW LEVEL JET AND TROPICAL EASTERLY JET – OBSERVATIONAL AND MULTI-MODEL ANALYSIS

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ABSTRACT

Indian Summer Monsoon (ISM) consists of several elements that are inter-linked. Any change in one element will reflect on the other and finally on the rainfall characteristics. In the changing climate, several changes have been reported in these elements. Two important elements that directly affect the ISM are the Monsoon Low Level Jet (MLLJ) and Tropical Easterly Jet (TEJ). The long term changes in the characteristics of these important monsoon circulation features during ISM months (June, July, August and September) has been investigated and reported in the present study. Availability of more than four decades of high resolution reanalysis data sets over the Asian monsoon region are used to monitor the changes in spatial extent and strength of MLLJ and TEJ. The bias in estimating the LLJ and TEJ characteristics with reference to the high resolution radiosonde and radar wind profiler is quantified. The detailed characteristics of horizontal wind fields like LLJ peak height and strength, wind reversal height, TEJ peak strength, height and width over a given grid/location is estimated daily during monsoon months and then averaged for peak monsoon months July and August to represent the seasonal mean. The seasonal mean time series of LLJ and TEJ characteristics are subjected to multi-variate regression analysis to extract the dominance of natural variabilities like QBO, ENSO and solar cycle. The residual time series is then subjected to linear regression to estimate the long term trend in TEJ and LLJ strength and spatial extent. In addition, the forward moving regression is performed to find the point of origin that make the change in trend. The relation between LLJ and TEJ characteristics and monsoon rainfall and tropical cyclones is delineated. Finally the future projections in the LLJ and TEJ characteristics are examined with the help of CMIP model outputs.

Keywords: Indian Summer monsoon**,** Monsoon Low Leve Jet, Tropical Easterly Jet, Reanalysis data, Climate Projections.

Assimilation of Vertical Atmospheric Structures in a Regional Modeling Framework: Evaluation of Indian Summer Monsoon Features

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ABSTRACT

This work is the first attempt to produce a multi-year downscaled regional reanalysis of the Indian summer monsoon (ISM) using the National Centers for Environmental Prediction (NCEP) operational analyses and Atmospheric Infrared Sounder (AIRS) version 5 temperature and moisture retrievals in a regional model. Reanalysis of nine monsoon seasons (2003–2011) are produced in two parallel setups. The first set of experiments simply downscale the original NCEP operational analyses, whilst the second one assimilates the AIRS temperature and moisture profiles. The results show better representation of the key monsoon features such as low level jet, tropical easterly jet, subtropical westerly jet, monsoon trough and the spa- tial pattern of precipitation when AIRS profiles are assimilated (compared to those without AIRS data assimilation). The distribution of temperature, moisture and meridional gradients of dynamical and thermodynamical fields over the monsoon region are better represented in the reanaly- sis that assimilates AIRS profiles. The change induced by AIRS data on the moist and thermodynamic conditions results in more realistic rendering of the vertical shear associated with the monsoon, which in turn leads to a proper moisture transport and the moist convective feedback. This feedback benefits the representation of the regional monsoon characteristics, the monsoon dynamics and the moist convective processes on the seasonal time scale. This study emphasizes the use of AIRS soundings for downscaling of ISM representation in a regional reanalysis.

Keywords: Vertical Structures, Data Assimilation, Remote Sensing data, Climate modelling,

Assessement of impact of climate Change on hydrology of Son river basin under projected climate change scenarios

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ABSTRACT

The recent extreme temperature and rainfall events indicate that climate change is going to be the next big challenge for water resource management. The impact of climate change on surface runoff and other water balance components needs to be quantified to plan water resource strategies. The study was carried out to assess the impact of climate change on the hydrology of the Son river basin. The impact of climate change was assessed based on CMIP5 GCMs under two representative concentration pathways, RCP 4.5 and RCP 6.0, for the early century (2010-2039), mid century (2040-2069), and end century (2070-2099) periods. The Soil Water Assessment Tool (SWAT) was calibrated for the period 1994–2009 and validated for the period 2010–2018 using monthly streamflow. The sensitivity analysis, calibration, and validation were performed using the Sequential Uncertainty Fitting version-2 (SUFI-2) algorithm available in the SWAT-Calibration and Uncertainty Program (SWAT-CUP). The model performance indicators such as Nash-Sutcliffe efficiency, RMSE-observations standard deviation ratio (RSR) and coefficient of determination (R^2) revealed that the SWAT model simulated the streamflow with a good level of accuracy. The climate scenarios indicate the rise in rainfall, minimum and maximum temperatures for all three century periods. The results revealed that surface runoff and other water balance components such as water yield and potential evapotranspiration are increasing with rising rainfall and temperature. The findings may help planners and decision makers effectively plan water harvesting interventions in the Son river basin.

Keywords: Climate change, Surface runoff, Soil Water Assessment Tool, Son river basin

CHARACTERISTICS OF HIGH RESOLUTION LAND DATA ASSIMILATION SYSTEM (HRLDAS)

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ABSTRACT

A High-Resolution Land Data Assimilation System (HRLDAS) has been developed at the National Center for Atmospheric Research. It uses observed hourly precipitation and surface solar downward radiation to drive, in offline mode, a land surface model to simulate long-term evolution of soil state including soil moisture and temperature. The advantage of HRLDAS is its use of 1-km resolution land-use and soil texture maps and 4-km rainfall data. As a result, it is able to reflect spatial heterogeneity at the surface and in the soil. The HRLDAS characterizes soil moisture/temperature and vegetation variability at small scales (~4km) over large areas in order to provide improved initial land and vegetation conditions. Each individual LSM(Land surface model) has its own climatological description, especially for soil moisture, depending on its treatment of physical processes and chosen parameter values. Studies have shown that different LSMs exhibit substantially different climatological values of the annual mean of soil moisture and the amplitude of the seasonal change of soil moisture owing to differences in how the LSMs determine evaporation and runoff as functions of soil moisture. The length of time for an LSM to reach its preferred climatological state (or equilibrium state) from a set of initial conditions is referred to as spin up time. A number of studies have examined this which included a wide range of LSMs and analyzed simulations for single-vegetation-type and single-soil-type situations, as well as multiple grid points. Based on results of Noah LSM global simulations with 1° grid spacing, the equilibrium condition was established within 3 yr over most areas. In some regions with a deep total soil layer and sparse vegetation, the equilibrium process took longer, because the evaporation is limited by slow water diffusion time scales between the surface and deep soil layers. Keywords: HRLDAS, LSM, Soil moisture

Air-Sea Processes in the Bay of Bengal During Monsoon Using Moored Buoy Observations

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ABSTRACT

The air-sea interactions in the Bay of Bengal (BoB) are complex due to their geographical location. The basin is influenced by the reversing monsoonal winds, tropical cyclones, and depressions. The present study aims the identification of the transition phases of the monsoonal winds and their intraseasonal variations. The study also analyzed the associated air-sea interaction from 2016 to 2017 using met-ocean parameters measured by the deep ocean buoy (BD12) in the Andaman Sea, on the eastern BoB. The deep ocean buoy is deployed and maintained by ESSO-NIOT, Ministry of Earth Sciences (MoES). The observation data is taken from 2016 to 2017. A criterion of consistent wind at least for seven days will determine the arrival of north-easterly (NE) and south-westerly (SW) phases. The wind direction changed from NE to SW on May 15 in 2016, whereas transitions of the winds happen 2days early on May 13 in 2017. Within the SW and NE winds regime, 10 to 20 days of intraseasonal variability are identified from the wind observation. The study also showed the variability of sea surface temperature, air temperature, and air pressure within a season. Also, the study elucidates the changes in Barrier layer thickness during monsoon time and the ocean current pattern. The study presents the importance of time series observation in the air-sea interaction on different seasonal and intra-seasonal scales.

Decadal changes in Southern Indian Ocean Warming

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ABSTRACT

The present study explains sea surface temperatures over the south Indian Ocean (SIO) and observed decadal warming over two decades since the mid-1990s, and SSTs warmed steadily during 1996–2016 (Jingzhi Su, et, al 2021). In the recent decade (2011–2020), the SST increased by 0.4°C compared to the previous decade (1980–1995) during the summer monsoon season. The ocean heat content is also increasing (6.20 X 10^9 joules) further; the high surface trade winds lead to a change in wind stress over the south equatorial Indian Ocean. High wind stress (0.3 to 0.5 X 10^{-2} N/m^2) helps transport heat into the Arabian Sea, enhances the moisture content, and accumulates high humidity over the entire Indian Ocean. The zonal and meridional currents are the main contributors to the high northward heat transport, and the zonal currents increase in magnitude in the summer monsoon season. The findings contribute to our understanding of long-range rainfall antecedent forecasting for the summer monsoon from the southern Indian Ocean.

Key words: South-western Indian Ocean, Ocean heat content

PREDICTION OF OCEAN CURRENT IN SOUTH INDIA REGION USING NEURAL NETWORK MODEL

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ABSTRACT

In this paper we have used the Long Short Term Memory (LSTM) Neural Network model to predict Ocean Current in the South India Region. We have studied performance using correlation coefficient, Mean Square Error (MSE), Root Mean Square Error (RMSE) of models. In this paper we have taken South India Ocean Current datasets. Ocean Current data for the Central India Region starting from 1990 to 2016 has been taken at the resolution of 1.0º. The dataset is often divided into Training and Testing dataset. The Ocean Current dataset from 1990 to 2010 has been taken as training data for proposed models LSTM techniques and after that testing dataset has been evaluated from 2011 to 2016 of the year.The input variables used are twelve months lags values of rainfall data and the outcome variable is Ocean Current of the present months. The model LSTM takes the same input variable and its corresponding outcome variable of the dataset. MSE, RMSE and correlation coefficient is computed for the models which showed that the LSTM based RNN prediction model provided better results.

Keywords: Neural Network, Ocean Current Prediction, LSTM, RMSE

On the Dynamics of Atmospheric Rivers over the Indian Subcontinent

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ABSTRACT

Atmospheric rivers (AR) are narrow channels of atmospheric water vapor that usually extend from lower latitudes to higher latitudes and transports large volumes of water vapor along with them. Studies have found that AR may lead to extreme precipitation and heavy flooding episodes. The present study uses ERA-Interim reanalysis data to identify AR events over the Indian subcontinent using a set of criteria. The criteria include the integrated water vapor transport (IVT) Intensity, IVT direction, the geometry of the AR, and the landfall condition. High-resolution data for an AR event is generated using the Advanced Research Weather Research and Forecasting (ARW-WRF) model. The results thus obtained are further analyzed to understand the dynamics of the AR event. The findings may provide significant insights into the forecasts of extreme precipitation events over the Indian subcontinent.

Keywords: Atmospheric River, Integrated water vapor Transport, Extreme Precipitation Event

IMPORTANCE OF PRIMARY STANDARDS FOR CALIBRATION OF SOLAR RADIATION MEASURING INSTRUMENTS

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Abstract

Calibration determines measurement equipment performance. With routine equipment calibration and adjustment, you can measure safely, ensure compliance and avoid the costs of inaccurate measurements. Regular calibration of field equipment is important to help ensure operation within acceptable measurement tolerances. Calibration will assist in reducing instrument-related systematic observation errors, thus lowering the associated uncertainty of the data. Greater confidence in the interpretation and application of data from various sources can be achieved when instruments have been calibrated against a traceable reference. The fraction of the energy flux emitted by the sun and intercepted by the earth is characterized by the **solar constant**. The solar constant is defined as essentially the measures of the solar energy flux density perpendicular to the ray direction per unit are per unit time. It is most precisely measured by satellites outside the earth atmosphere. The solar constant is currently estimated at **1367 W/m^2**. This number actually varies by 3% because the orbit of the earth is elliptical, and the distance from the sun varies over the course of the year. Some small variation of the solar constant is also possible due to changes in Sun's luminosity. This measured value includes all types of radiation, a substantial fraction of which is lost as the light passes through the atmosphere. The amount of solar radiation on the earth surface can be instrumentally measured, and precise measurements are important for providing background solar data for solar energy conversion applications. There are two important types of instruments to measure solar radiation: **Pyrheliometer** is used to measure direct beam radiation at normal incidence and are calibrated against the primary standard methods. **Pyranometer** is used to measure total hemispherical radiation - beam plus diffuse - on a horizontal surface. These instruments are usually calibrated against standard Pyrheliometer. Certain standards are used frequently to calibrate radiometers deployed in continuous monitoring stations. The World Radiometric Reference (WRR) is the internationally recognized standard for solar (shortwave) irradiance measurement. A group of seven self-calibrating absolute cavity radiometers form its basis of World Standard group (WSG). Reference standard radiometers from around the world are compared every five years to the WRR at the World Radiation Center in Davos, Switzerland.

Keys words: WRR,WSG,Cavitiy Radiometers,Pyranometers,Pyrheliometer

Local and Regional Contribution of Black Carbon over Bhubaneswar

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ABSTRACT

Black Carbon (BC) is an important aerosol species for its potential to absorb incoming solar radiation and cause atmospheric warming, thereby modulating the vertical and horizontal thermal structure of the atmosphere, and hence weather and climate. Apart from locally emitted BC, though the BC has a very short life span, because of its small size, it can travel thousands of kilometres downwind and influence the atmospheric conditions at the destination. Therefore, at a particular place, characterization of the atmospheric BC concentration contributed from the local and regional sources is of great importance. In this context, Bhubaneswar is an emerging smart city with evidence of increasing atmospheric BC in recent times. This increased BC is mainly attributed to the outflow from Indo-Gangetic Plain (IGP) and local emissions like fossil-and bio-fuel combustions. Though the sources of BC for Bhubaneswar are well characterized, their quantification in terms of local and regional contributions is yet to be done. In the present study, applying the moving average subtraction technique to the observed high temporal resolution BC concentration at IIT Bhubaneswar (85.67 E, 20.14 N), we quantify the amount of local and regional BC both annually and seasonally from 2018 to 2021. The analysis shows that the average BC concentration over Bhubaneswar is annually 4.04 µg/m3. It is maximum during the winter season 7.70 µg/m3 and minimum during monsoon 1.53 µg/m3. The regional [local] concentration is the highest during the winter [monsoon] season 7.06 µg/m3 (91.77 %) [0.29 µg/m3 (19 %)], and lowest during the monsoon [winter] season 1.24 µg/m3 (81%) [0.64 µg/m3 (8.23 %)]. Similarly, month-wise, the regional [local] BC concentration was maximum during December [September] 7.53 µg/m3 (94.7 %) [0.37 µg/m3 (21.07 %)] and minimum during September [December] 1.40 µg/m3 (78.93 %) [0.42 µg/m3 (5.30 %)]. The majority of ambient BC over Bhubaneswar is regional, estimated to be 85.96% annually. Further analysis of wind and rainfall data shows that the high regional contribution during winter is due to the stable atmospheric condition, which keeps the long-range transported BCs at the surface level and helps increase their contribution. The opposite of that (low regional contribution) happens during the monsoon season because of the washing out due to rainfall. Overall, the study suggests that the temporal BC domination over Bhubaneswar in terms of local and regional is highly significant, which may give a new perspective to the government and policymakers for framing the rules and regulations accordingly.

Keywords: Local and Regional BC over Bhubaneswar, pollution over Bhubaneswar, Black Carbon, Moving average subtraction method.

A Numerical Study to Investigate the Precipitation Features of Monsoon Deep Depressions over Bay of Bengal

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The rainfall characteristics of Monsoon Deep Depressions (MDD) originating over the Bay of Bengal (BoB) basin have been investigated in the present study using a coupled ocean atmospheric model (COAWST) and a stand-alone atmospheric (WRF) model with a lead time of up to 72h. It is found that though the tracks of the four MDDs considered in the study have been reasonably simulated, the intensity was overestimated in both sets of simulations compared to India Meteorological Department (IMD) best estimates. Upon decomposition of the contributors to the rainrate for the composite of the storms in the deep depression (DD) phase, it was found that the moisture sources/sinks play a more important role than the cloud sources/sinks in modulating the rainfall processes. Further analysis of the moisture sources/sinks showed that the horizontal and vertical advection are the major drivers in modulating the contribution of the moisture sources/sinks. The validation of rainfall using CMORPH datasets suggested that the coupled simulations had a higher skill in rainfall prediction. Furthermore, the composite of different components of moisture sources/sinks (especially vertical advection) was found to be more realistically simulated in COAWST compared to CNTL upon validation with MERRA datasets. Analysis of the composite energetics showed that scarcity of bulk kinetic energy in the later hours of the DD phase in COAWST led to the dissipation of the storm core, which led to better prediction of rainfall. On the other hand, a re-intensification of the storm core by means of condensational heating led to an overestimation of rainfall in WRF, which finally resulted in lower skill in rainfall prediction.

Keywords : Monsoon deep depressions (MDD), Bay of Bengal (BoB), Coupled Ocean Atmosphere Wave and Sediment Transport (COAWST) model, vertical advection (VADV)

STUDY OF INDIAN SUMMER MONSOON VARIABILITY OVER GUJARAT (WEST COAST INDIA) AND ASSOCIATED LARGE SCALE DYNAMICS

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ABSTRACT

The state of Gujarat, which is located along the west coast of India, is the seventh largest state and is having longest coastline of 1600 km. The state exhibit very large spatial and temporal variability of rainfall. The objective of the study is to understand the interannual variability of summer monsoon rainfall over Gujarat and associated large-scale dynamics. By using the Gujarat State-averaged rainfall data from India Meteorological Department, we studied the interannual variability of rainfall during the period 1961-2020. We identified 10 excess and 10 deficient monsoon years when the seasonal rainfall values are above and below one standard deviation respectively. It was found that most of the excess years over Gujarat are associated with La Niña in the Pacific Ocean whereas most of the deficient years are associated with El Niño. We then used winds, sea level pressure and omega vertical velocity from NCEP/NCAR analysis to understand the large-scale dynamics that contributed to the excess and deficient rainfall over Gujarat. We found that there was strong large-scale low level cyclonic circulation over Gujarat region during excess years that causes strong upward motion, enhanced convection, contributed to above normal rainfall anomaly over Gujarat. Whereas there was anticyclonic circulation over Gujarat region during deficient years which causes subsidence and supressed convection contributes to below rainfall anomaly over Gujarat. The study of variability of monsoon would help various organization such as Indian Coast Guard, Indian Navy, Indian Air force etc. in planning and execution of swift operations along the coast and adjoining areas, so it is important both strategic and safety wise for national security.

Keywords: Indian Summer Monsoon, Gujarat rainfall, convection, El Niño, La Niña, Large scale Dynamics

Variation in Surface Temperature over urban city of India during a Decade

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Abstract

This study focuses on analysis of temperature over two metropolitan cities Delhi and Bengaluru in the recent years 2010-2022. The surface temperature observations are utilized from the India Meteorological Department (IMD) observational network and ERA 5 reanalysis data. The number of heat waves and cold wave days are obtained in each year over both the stations. For the heat wave days at Delhi the data is analyzed for the months of March, April, May and June whereas for cold wave days the months of December, January and February are selected over Delhi, whereas for Bengaluru the data is analyzed for the whole year. The number of heat and cold waves and the variability depends on the location and may be linked to the changing climate patterns.

Synoptic and dynamical Analysis of exceptionally heavy rainfall events over North- East India during June–July 2022

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ABSTRACT

A study of extreme weather events (for example, heavy rainfall events) is a hot subject because of the effects they have on various sectors, including the general public. Many authors believed that extreme weather events occurring in various parts of the world were caused by climate change. Climate change projections for the northeast states show an increase in exceptionally heavy rainfall events across almost the entire district of the North-East region during the southwest monsoon season.

The exceptionally heavy rainfall events over North-East India during June:- **case 1(50 cm < r 100 cm) ;**on 17th June, 2022: in Meghalaya Cherrapunji - 97 cm; Cherrapunji RKM 91 cm; Mawkyrwat 54cm; Mawphlan 51cm. **case 2 (21 cm < r 50 cm);** on 18th june, 2022: in Assam Beki Mathungari – 41 cm; Karimganj 21 cm). According to reports, this has resulted in significant socioeconomic and human loss (total fatalities were reported at 90 in Assam and Meghalaya) in India's North-East. Assam, a state prone to flooding and erosion, is flooded almost every year, and more than 4.8 million people have been affected in 34 of the state's 35 districts this year (2022).

As a result, such exceptionally heavy rainfall episodes are analysed in this paper using Synoptic, dynamical, and thermodynamic tools. The events are further validated using satellite rainfall products (INSAT-HEM) to understand synchronisation with observatory data.
The study's findings may be useful for future planning by disaster managers and other stakeholders, including forecasters, to better understand the mechanisms underlying extreme rainfall events in the country's north-east and to improve forecasts of exceptionally heavy rainfall events in the region.

Keywords: Southwest Monsoon, Exceptionally Heavy Rainfall, Synoptic Analysis.

India Meteorological Department

India Meteorological Department was established in 1875. It is the National Meteorological Service of the country and the principal government agency in all matters relating to meteorology and allied subjects.

- Take meteorological observations and to provide current and forecast meteorological information for optimum operation of weather-sensitive activities like agriculture, irrigation, shipping, aviation, offshore oil explorations, etc.
- Warn against severe weather phenomena like tropical cyclones, norwesters, duststorms, heavy rains and snow, cold and heat waves, etc., which cause destruction of life and property.
- Provide meteorological statistics required for agriculture, water resource management, industries, oil exploration and other nation-building activities.
- Conduct and promote research in meteorology and allied disciplines.

Artificial Neural Network Approach in Estimation of Particulate Matter Concentration over the Eastern India

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ABSTRACT

Air pollution is a global issue that worsens in developing countries like India. Thus various research approaches are adopted to quantify the air quality so that robust mitigation strategies can be implemented. Enormous heterogeneity is observed in air pollution; therefore, information at one place is not helpful at other locations. Indian cities observe a very high concentration of particulate matter (PM), the prime indicator for air quality. Short and long-term exposure to particulate matter is detrimental to health and causes various respiratory and lung diseases, cardiovascular diseases, and cancer. Smaller particulate matter (i.e., $PM_{2.5}$) is more hazardous to human health as it can go deeper into the lungs. Regularly monitoring $PM_{2.5}$ concentration is essential to investigate the associated effects, but establishing a dense network of monitoring stations for developing countries is not feasible. Thus numerical simulation methods came up as a better alternative. In the present work, we have implemented the Artificial Neural Network (ANN) technique to assess the concentration of PM2.5 over the Eastern part of India, which is less explored. We have developed the ANN incorporating satellite measurements and available ground-based measurements. The input parameters for the ANN are Aerosol Optical Depth (AOD), and meteorological parameters (ambient temperature, relative humidity, wind speed, and planetary boundary layer height). The satellite inputs are taken from MODIS and MERRA satellites. The concentration of $PM_{2.5}$ is estimated as the output of the ANN. The output of ANN is tested with different numbers of hidden layers to optimized the output. The results demonstrated the potential of ANN in air quality monitoring.
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Keywords: Artificial Neural Network, Particulate Matter, MODIS, Aerosol Optical Depth

How water isotopes are simulated over the Western Ghats in different spatiotemporal scales during Indian Summer Monsoon?

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ABSTRACT

Isotope-enabled General Circulation Models (GCMs) simulate stable water isotope ratios $^{18}O/^{16}O$ and $^{2}H/^{1}H$ (expressed as $\delta^{18}O$ and δD) considering various physical processes in the hydrologic cycle. Historical simulations of these models are often compared with proxy isotope data to constrain past atmospheric circulation. Western Ghats (WG) Mountain is rich in various natural proxies such as tree rings, speleothems etc from which past monsoon rainfall has been reconstructed in multidecadal to centennial time scales. The atmospheric circulations over the WG are strongly affected by the orography. The current study provides a thorough analysis for evaluating these GCMs over the mountain at different spatiotemporal scales and estimates the contribution of various physical processes controlling isotope biases. Model outputs are compared with available observation in both monthly and daily scales at various locations over the Westernghat. The models, in general, underestimate rain $\delta^{18}O$ values and rainfall in monthly time scale as well as in daily scale. The isotope bias is found to be controlled by the rainfall bias. The $\delta^{18}O$ values of both model and observation show a correlation of r=0.33 in daily scale. The decomposition of isotope biases suggests that the skill of the models depends on how proficiently the models simulate 1) mid-tropospheric vapor isotope values and 2) raindrop evaporation.

Keywords: Water isotopes, Orography, Rain evaporation, IsoGCMs

Development of merged cloud microphysical product for Indian region using INSAT-3D and VIIRS-SNPP

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ABSTRACT

Understanding the cloud microphysical processes and precise retrieval of parameters governing the same are crucial for weather and climate prediction. Advanced remote sensing sensors and techniques offer an opportunity for monitoring micro-level developments in cloud structure. Taking advantage of multiple sensors from different satellites could be a great way of making synergistic observations of these cloud properties, in more detail and with better accuracy. Hence, we present here one such approach for a small domain over the Indian region. We have used Indian National Satellite System -3D (INSAT-3D) cloud microphysical product (CMP), where Cloud Optical Thickness (COT) and Cloud Effective Radius (CER) have been generated over the Indian region (0-40 °N, 60-100 °E) for the analysis. CMPs have been derived using the INSAT-3D optical band radiances. Estimation of CER is carried out using Short Wave Infra Red (SWIR) (1.67 µm) band radiances, where the reflectance is a primarily a function of cloud droplet/particle size. This channel also offers the advantage of discriminating between liquid and ice phase clouds. Further, COT is derived using visible (0.65 µm) band radiances, where the reflectance field is a function of optical thickness. The retrieval is done with the help of look-up-table (LUT) approach which employs a radiative transfer (RT) model for generating the LUT. Along with this, we have used the globally accepted and acknowledged Visible Infrared Imaging Radiometer Suite (VIIRS) and MODerate Resolution Imaging Spectroradiometer (MODIS) CMP products, which have additional channels that provide more accurate CMP estimation. This study presents the merged CER product from INSAT-3D and VIIRS-SNPP over selected domain in Bay of Bengal, (14-26 °N, 80-100 °E). The end product is validated against the operational climate continuity (MODIS) CMP product as the standard reference. Validation results for one month data show a correlation of ~0.75, with RMSE of 8.43 µm and bias of 0.26 µm. Also, it is observed that the merged product can provide an additional 10-16% of valid pixels, which is quite helpful in various microphysical studies.

Keywords: Remote Sensing, Climate, Cloud Microphysical Parameters, INSAT, Merging

WINTER FOG VARIABILITY AND ITS OPTICAL & RADIATIVE CHARACTERISTICS USING GROUND-BASED REMOTE SENSING OVER A STATION IN IGB

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ABSTRACT

In the present scenario, it is essential to monitor the increased occurrence of severe and prolonged fog events over the Indo Gangetic Basin (IGB) by various remote sensing techniques to aid fog forecasting skills. In this study, a simple methodology is proposed to retrieve the fog events using the ground-based remote sensing techniques and study its variability, optical and radiative properties. The proposed methodology uses the surface shortwave irradiance (Rs) from the Multifilter Rotating Shadowband Radiometer (MFRSR), real-time sky images and Red-Blue Ratio (RBR) from the Total Sky Imager (TSI) during the period December 2014 to January 2015 at the station Varanasi in IGB. Also, Aerosol and fog optical depths (AOD, FOD) were retrieved from the MFRSR irradiance measurements using the radiative transfer models.

The ground retrieved fog events showed good association with that of INSAT-3D satellite retrieved fog over the same region. The fog events showed high temporal as well as diurnal variability with more occurrences and prolonged events in January as compared to December. The FOD variability also revealed intense fog events in January as compared to December.The parameter RBR is used to distinguish the sky condition from clear-haze-fog/cloud. Thus, using the regular surface measurements of Rs and RBR, the proposed method can be used as a proxy to identify fog events in the absence of satellite and also other regular surface visibility measurements.The surface shortwave radiative forcing (SWRF) due to fog revealed high temporal variability from -100Wm^{-2} to -300Wm^{-2} and the magnitude of negative forcing or cooling effect increased with increase in FOD, while forcing due to aerosols varied up to -50 Wm^{-2} for clear skies and up to -100 Wm^{-2} for high AODs/haze.

Thus, the network of high frequency surface measurements could play an important role in validating the satellite products as well as model results.

Keywords: Fog, Shortwave irradiance, Aerosol optical depth, Fog optical depth, Aerosol/haze/fog radiative forcing

WRF-MODEL FOR HIGH RESOLUTION WEATHER AND CLIMATE SIMULATIONS OVER THE KASHMIR VALLEY

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ABSTRACT

This study presents numerical experiments by WRF model to simulate high resolution weather and climate over Kashmir Himalayas from 1980 to 2020. The nesting and spin-up time choices were explored with different physics configurations. In this study, we investigated the long-term variation of meteorological parameters like temperature and precipitation (rain, snow), dew point, wind speed and wind direction. The WRF model simulations were analysed daily, monthly and seasonal during the period and compared with in situ observations from 6 IMD (Indian Meteorological Department) stations over Kashmir. The analysis showed that WRF can capture the daily precipitation with a correlation of ~80% for all the stations except for Gulmarg (59%). Whereas, relative bias of <10% was observed over all the stations except for the Pahalgam station (RB = 25%). In addition, the analysis showed an increase in total accumulated precipitation ranging from 1- 4 mm yr^{-1} over the different areas, and a decrease of 20-25 mm yr^{-1} in snow precipitation. A strong correlation (~80%) was observed between daily and monthly simulated and observed temperatures. The trend analysis of average monthly temperature from 1980-2020 indicated a positive trend Srinagar showing an increase of 1.10°C from the long-term annual average temperature during the last 40 years. The dew point temperature in Kashmir varies between -9 to 13 ℃., with the minimum mean over high altitude areas from -6 to 0℃. Wind speed over Kashmir valley varies from 0.7 to 5m/s. Hence, from the analysis of the near-surface temperature, precipitation, dew point, wind speed, snow thickness on annual and seasonal scales with respect to the 1980–2020 means, it is concluded that the WRF high-resolution simulations are equally good as the other state-of-the-art weather and climate prediction models that simulate weather and climate well over high altitude complex mountainous terrains.

Keywords: Climate change, Weather Prediction, Numerical Weather Forecasting, WRF modelling.

Usability gap of medium range weather forecast in agriculture risk management in Central India

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ABSTRACT

The forecasted and observed daily weather data from 2011 to 2021 were evaluated using different verification/usability criteria during sowing, reproductive and harvesting period during kharif and rabi seasons respectively at Tikamgarh. The different verification and usability of forecasted weather were presented on critical crop growth periods basis and compared. The forecasted weather data were compared with observed weather data to sudden deviation in rainfall, temperature and wind speed also. The ratio and threat score were varied from 0.31 to 0.77 and 0.31 to 0.68 respectively during kharif sowing period respectively. The root mean square (RMSE) error for maximum temperature was ranged from 0.24 to 3.6 and minimum temperature varied from 2.3 to 4.0 during kharif and rabi sowing periods. The usability percentage (correct + usable) of rainfall varied from 45 to 87 per cent during sowing period of kharif. The simple success of forecasted rainfall was varied from 0 to 13 per cent during sowing and from 0 to 64 per cent during harvesting period of rabi season. The usability of rainfall during harvesting period of kharif and rabi varied from 9 to 79 and 96 to 100. Similarly the usability of minimum temperature during the reproductive periods of rabi varied from 36 to 65. The RMSE of maximum and minimum temperature during reproductive, harvesting periods of rabi varied from 1.9 to 3.2 and 2.7 to 4.6. The minimum temperature usability was 17 to 66 and 35 to 65 percent during rabi sowing and reproductive period. It was found the usability percentage of rainfall during kharif sowing and temperature during rabi sowing growth periods were lower as compared to other crop growth period. It was observed that ratio score is not reflected the for rainfall forecast success as compare the true score. The low forecast accuracy was observed in predicting extreme deviation of weather parameters. The lower accuracy, inconsistency forecasting and low success percentage of extreme deviation limits their usability in decision making and thus their economic value.

Projection of heatwave characteristics and dynamics over India: A high-resolution regional earth system model perspective

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ABSTRACT

Temperature extremes, especially heat extremes, are a disastrous phenomenon known for silently affecting humans and other animals, sometimes lethal. Global warming due to anthropogenic activities has caused an accretion in the heatwave frequency, duration, and intensity. Getting an accurate representation of heatwaves is still challenging for most of the models (global or regional). Therefore, a high-resolution regional earth system model (RESM) has been used to investigate the present heatwave characteristics and dynamics and their respective future changes. The spatial patterns of averaged heatwave characteristics RESM are similar to observation though it has a negative bias in the frequency and duration and an overestimation in severity. For dynamical patterns, India's key regions are obtained by regressing the maximum daily temperature with the temporal coefficients of Rotated Empirical Orthogonal Analysis. The patterns are shown using composites of geopotential height thickness anomalies from surface to 500 hPa and 200 hPa, potential vorticity (PV) anomaly, and circulation patterns. RESM has efficiently captured these patterns with minor deviations in magnitude and location. During the heatwave days, geopotential height thickness increases over each region with anticyclonic circulation except the southeast coast (SEC). The negative PV anomaly is observed for each key region which shows the presence of anticyclonic blocks. The daily composites show the persistency of negative PV anomalies during heatwave days depicting its stagnation over the affected regions. The future projections based on Representative Concentration Pathway (RCP-8.5) emission scenarios show an increase in all characteristics during the near (2020-2049), middle (2050-2079), and far (2080-2099) future. Similarly, a gradual increase in geopotential height thickness and geopotential anomaly is observed from near to far future, but the strength of anticyclonic circulation has reduced.

Keywords: RESM, Projection, Heatwave, Dynamics, India

AEROSOL CLASSIFICATION USING FUZZY CLUSTERING OVER A TROPICAL RURAL SITE

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ABSTRACT

Aerosol classification is essential for understanding the impact of the different aerosol sources on Earth's radiation, climate, and air quality. Several techniques are available to classify the aerosols which have their own pros and cons. In the present study, a soft clustering technique, Fuzzy C-Means (FCM) is employed to classify aerosols using 26 aerosol parameters (derived from the Sky Radiometer measurements from April 2008 to October 2020) over a rural site Gadanki (13.48ºN, 79.18ºE), India. The cluster analysis resulted in three clusters, and were found to be distinct and compact based on high intra-cluster similarity and low inter-cluster similarity. The robustness of the FCM algorithm was tested and found that the correct classification percentage for each scenario was about 98.4%. Even by introducing a 10% random error in aerosol microphysical properties used in the cluster analysis, around 94.5% of the records were found to retain the original clusters. Based on the aerosol properties of the clusters, the three clusters were identified as mixed mode moderately absorbing, mixed mode slightly absorbing, and coarse mode slightly absorbing type of aerosols. While comparing with the global aerosol models, these three aerosol types showed similarities with the biomass burning, polluted marine, and polluted continental aerosol types. Significant seasonal variability of the identified aerosol types was observed with biomass burning dominating in the pre-monsoon season, polluted marine during monsoon season, and polluted continental in a relatively higher percentage compared to the other two in winter and post-monsoon seasons. An increasing trend in polluted marine aerosol type was noticed, whilst biomass burning and polluted continental showed decreasing trends. Furthermore, the existing knowledge on various aspects of aerosols over Gadanki ascertains that the identified aerosol types are reasonable, implying that the FCM clustering technique for aerosol classification is effective and it might be extend to other locations.

Keywords: Aerosol Classification, Cluster Analysis, FCM clustering, Sky Radiometer

Assessing the Performance of different Cumulus Parameterization Schemes for investigating Winter Precipitation Extremes over Western Himalayas in a High Resolution WRF Model

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ABSTRACT

Winter precipitation (December to March) over the western Himalayas (WH), contributed through extratropical systems (Western Disturbances) embedded in sub-tropical westerlies, is a crucial source for recharging Himalayan glacial mass balance and an important irrigational source for rabi crops. However, the occurrence of Extreme precipitation events (EPEs) over the WH have the potential to induce catastrophic damages to life, infrastructure, environment and agricultural sustainability. Sparse in-situ observational network over WH in conjunction with complex topography highlights the uncertainties in available coarse resolution precipitation products and emphasizes the necessity of finer grid scaled regional climate models for accurate simulation of precipitation variability, specifically EPEs with highly localized characteristics as well as underlying synoptic dynamics. In the present study, we investigate the performance of a high-resolution Weather Research and Forecasting (WRF) model through the evaluation of its sensitivity to three convective physical parameterization schemes (CPSs), namely, Betts-Miller-Janjic (BMJ), Kain-Fritsch (KF), Grell-Freitas (GF) and, their Ensemble for the simulation of winter precipitation extremes over the WH (2001-2016). The sensitivity of precipitation extremes (identified using percentile approach) to different CPSs (5km resolution), in the WRF model configured on two two-way nested domains (15km and 5km), has been validated using gauge-based (IMD) and satellite (IMERG) observations as well as with the recently released high-resolution reanalysis dataset, IMDAA. Furthermore, the elucidation of associated regional dynamical features and underlying processes simulated in the model has been carried out through a composite analysis for EPEs using the reanalyses, IMDAA and ERA5. Our findings underpin the sensitivity of model-simulated winter precipitation extremes over WH to different parameterizations. Detailed results will be discussed.

Keywords: Winter Precipitation; EPEs; WRF; Parameterizations; Western Himalayas; IMDAA

Analysis of Droughts in South-West Indian Ocean Countries using SPI and SPEI and their Relationship with Global SST

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ABSTRACT

Drought is a continuous period of dry weather and it is one of the most serious problem for human societies and ecosystems which caused by deficiency in rainfall in that region and the most affected are tropical monsoon dependent agriculture regions including Africa. Drought indices like Standardized Precipitation Index (SPI) and Standardised Precipitation Evapotranspiration Index (SPEI) are very useful and well accepted drought indices representing the magnitude and severity of drought at a particular location by identifying the water stresses. In present study, eight coastal and one landlocked country in South West Indian Ocean (SWIO) are selected as a study region. An approach has been made to see rainfall variability of these countries using monthly rainfall climatology which showed maximum rainfall amount received by these countries is during months of December-January-February-March (D-J-F-M) and using decadal rainfall percent departure (PD) which delineated the multi-decadal dry and wet phases precisely for these countries, with PD ranging lower than -18% to higher than 16% in some cases. To understand drought magnitude and severity in these countries we have calculated 4 months cumulative SPI and SPEI for the months of D-J-F-M.

In addition, correlation between both SPI and SPEI of all nine countries with global SST and various Nino and IOD SST regions is also analysed to understand various teleconnections responsible for drought.

Keywords: Drought index, Standardized precipitation index, Standardized precipitation evapotranspiration index, Global SST teleconnection, temporal correlation

INDIGENOUS DEVELOPMENT OF SODAR IN SAMEER

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ABSTRACT

Acoustic Radar or SODAR (sound detection and ranging) is a ground-based remote sensing instrument for the detection of vertical profiles of wind and turbulence data from near ground up to several hundreds of meters.

Phased Array Doppler SODAR is a versatile instrument used for Atmospheric Boundary Layer (ABL) studies and for environmental applications at the height range of 10 m to 1000m from the ground surface. This system transmits the acoustic pulses into the atmosphere and receives the back scattered acoustic echoes. The intensity of these echoes depends on the temperature in-homogeneity in the atmosphere. In a mono static SODAR system, the three-directional information can be obtained by transmitting consecutive pulses in the vertical and two orthogonal directions tilted slightly from the vertical.

Sodar or acoustic sounder is proved to be a very useful instrument for studying the lower atmosphere as it can continuously and reliably measure the vertical profiles of wind speed and direction, vertical motions, turbulence and the thermal structure in the lower part of the troposphere. The phased array antenna and the ease of installation are the factors that make the Doppler SODAR unique instrument for studying the lower atmosphere.

SODAR development was started with three axis antenna beam and subsequently Phased array SODAR was developed. Now the development of oblique beam SODAR is going on for near range measurements. The total system consists of Acoustic enclosure, phased array antenna using piezoelectric tweeters to generate acoustic power, Power Amplifiers, High Dynamic range receiver, Data acquisition and control system and Labview based signal processing and data processing software. In this paper complete configuration of the SODAR systems being developed and deployed all over the country and its results obtained at some of sites in India will be presented. Results obtained through new development 'Oblique Beam' Mini SODAR system also will be presented for higher range accuracy.

Keywords: Acoustic Radar, Remote Sensing, Phased array Antenna, Atmosphere, Doppler

INDIGENOUS DEVELOPMENT OF SODAR IN SAMEER

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Keywords: Acoustic Radar, Remote Sensing, Phased array Antenna, Atmosphere, Doppler

Assessment of Aerosol Optical and Radiative Properties over India: Results from Skynet-India Network of India Meteorological Department

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ABSTRACT

Tropospheric aerosols have a short lifetime; as a result their properties show high variability in space and time. In order to examine aerosol impact on the local and global climate in addition to understanding and modelling the impact of aerosol on radiation budget and precipitation efficiency, India Meteorological Department has established a network Skynet-India of Sun-skyradiometer stations located in different geographic regions.

The sky-radiometers (models POM-01 and POM-02; make Prede, Tokyo, Japan) installed in the Skynet-India network, measure solar direct and diffuse irradiances at ultraviolet, visible, and near-infrared wavelengths. These measurements are used for the remote sensing of aerosol, cloud, water vapor, and ozone.

The results from Skynet-India show that the aerosol loading over India have high spatial and temporal variability. Due to higher population, urbanization and industrialization combined with unfavourable meteorological conditions and geography, the AOD over the northern part of India is found to be higher than the southern counterpart. A significant variability in seasonally averaged Aerosol Optical Depth(AOD) and Angstrom Exponent(AE) was observed with maximum AOD values in the Indo-Gangetic plain. Higher AOD was observed over Delhi; while the lowest was observed over Ranichauri. AOD over the locations (Delhi, Varanasi, Guwahati and Kolkata) in the Indo-Gangetic basin were found to be higher than those measured in South India (Pune and Thiruvananthapuram). AODs during winter and pre-monsoon were found to be lower than that during monsoon season.
Angstrom exponent was found to exhibit large seasonal variations in the study regions. The alpha values during post monsoon and winter were higher than that in pre-monsoon and monsoon values at all the locations. In pre-monsoon season, coarse-mode aerosol particles were found to be dominant while in winter fine-mode particles were dominant.

Keywords: Aerosols, Aersol optical depth,remote sensing, radiative forcing.

Pre-monsoon, monsoon, and post-monsoon features of absorbing aerosols over North India

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ABSTRACT

Black Carbon (BC) aerosols are well recognized to be one of the major light absorbing components and second strongest contributor to the Global Warming and Climate Change, after carbon dioxide. Since evaporation from land surface, and long-range transport of moisture from Indian Ocean contributes to the monsoon precipitation, BC emissions increase the evaporation owing to less moisture feeding to monsoon winds and less rainfall. In this communication, we report the results of the analysis of a long series (2016-2021) of BC aerosol datasets, archived during pre-monsoon, monsoon, and post-monsoon seasons, by the IMD Black Carbon Monitoring Network in North India.

A seven-wavelength Aethalometer is used to measure BC concentration and biomass burning contribution. Being mostly in the sub-micron range, they possess long lifetime (up to weeks), and susceptible for long-range transport. Increase in BC aerosol concentration reduces evaporation, which in turn causes diminishing of meridional sea surface temperature, resulting in weaker monsoonal circulation. Thus, the study of BC aerosols and their impacts on monsoon rainfall play a pivotal role and hence in the Indian economy and growth.

In the present study, BC concentration during pre-monsoon and monsoon seasons show lower values and thereafter, concentrations increase from September onwards and peaks in winter months. The combined effects of washout, cloud-scavenging together with stronger winds lead to lower BC concentration in monsoon. BC mass concentrations over North Indian stations exhibit overall decreasing trend during 2016-2021. The Biomass burning in the study region during post-monsoon season contributes to higher BC mass concentration, due to domestic heating and stubble burning activity, often forms stable atmospheric conditions, and lowering of atmospheric boundary layer, which results in higher BC concentration during winter season. The average BC concentrations show a strong anti-correlation with ventilation coefficient and average mixing height.

Intraseasonal variability in rainfall over the Indian region in Multi-Physics Multi-Model Ensemble

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ABSTRACT

An assessment of a multi-physics multi-model ensemble (MPMME) strategy is provided to simulate the critical aspects of the Indian summer monsoon (ISM) and its intraseasonal variability. Using various physics combinations of Climate Forecast System (CFS) and its atmospheric component Global Forecast System (GFS), a 15-year hindcast for May—October is generated. Three different convective parameterizations, Simplified-Arakawa Shubert (*sas*), revised deep-convection SAS (*nsas*), and revised SAS with modified shallow-convection (*nsas_sc*) are coupled with two microphysics schemes Zhao and Carr (*zc*) and Ferrier (*fer*). Spatiotemporal characteristics of predicted ISM climatology and 20—70-day periodic intraseasonal oscillations (ISO) are evaluated using observations. MPMME members reproduce the overall characteristics of the seasonal mean, but they have significant biases over different regions. Pattern correlations reveal that *CFS_nsaszc* performs best among MPMME in simulating the observed characteristics of rainfall ISO and providing significant ISO forecast up to pentad-3 lead.

A diagnostic based on the vorticity budget equation during strong convective events (SCE) associated with ISO is used to understand better the mechanism of northward propagating ISO and the responsible factors that develop a vorticity tendency to the north of a convection maxima. The tilting term in the vorticity equation shows northward propagation and leads precipitation maxima by about a week over the Bay of Bengal. Vertical shear of mean zonal winds and meridional gradients of vertical winds are found to be essential in developing vorticity tendency. SCE are better represented in CFS compared to GFS. Notably, along with *CFS_nsaszc*, two *CFS_sas* members capture the occurrence of SCE reasonably well. However, errors in vertical shear of mean zonal winds are remarkably high after pentad-2 lead in *CFS_sas* and GFS, explaining their relative weakness in simulating ISO during June—September. This study demonstrates that the MPMME strategy could utilize individual physical schemes' strengths to provide better sub-seasonal forecasts.

Keywords: Indian Summer Monsoon; Intraseasonal Oscillation; Northward Propagation; Vorticity Budget; Climate Model; Physical parameterizations.

DEVELOPMENT OF REAL TIME IRRIGATION SYSTEM USING INTERNET OF THINGS FOR CUCUMBER IN A NATURALLY VENTILATED POLYHOUSE

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ABSTRACT

The primary purpose of polyhouse is to offer the best conditions for growth and to protect crops from adverse weather and harmful pests. This study was carried out in the Central Institute of Agricultural Engineering farm, Bhopal. The goal of this study was to compare evapotranspiration (ET) based irrigation for cucumber crop with real-time irrigation using internet of things (IoT) based on soil field capacity (FC) in a naturally ventilated polyhouse. The vegetative and yield characteristics were compared for two irrigation regimes. The system received the information of different parameters from the sensors and activates the solenoidal valve, if the actual value of soil moisture is more or less than the threshold values and also stores these values in the cloud database(Thingspeak). These results were displayed in the web page and user can monitor them directly from anywhere. The results of the study revealed that FC based irrigation using IoT gives 15.2% higher yield and water productivity by 13.1% when compared with ET based irrigation. The developed IoT network system could provide the global connectivity and management of sensors, devices, users with information and reduce the manual intervention.

Keywords: Internet of things, Irrigation, Field capacity, Evapotranspiration, Cucumber, Polyhouse

Climatology and characteristics of rapidly intensifying tropical cyclones over the North Indian Ocean

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ABSTRACT

Rapid Intensification (RI) of a tropical cyclone (TC) is defined as an increase in the wind speed by 30 knots within 24 hrs. RI of TCs is a less understood process, particularly over the North Indian Ocean. We considered data for 39 years (1982-2020) from JTWC and studied the climatology of RI TCs. Out of 197 cases, 44 TCs experienced RI. The occurrence of TCs is higher over the Bay of Bengal (BoB), whereas the percentage of RI is higher for the Arabian Sea (AS). We found a significant increasing trend in RI TCs frequency and duration over AS. Lifetime maximum intensity (LMI) is higher and genesis to LMI duration is longer for RI-TCs over AS. The longer duration to achieve the maximum intensity resulted in a longer total lifespan for RI TCs. All TCs reaching a super cyclonic storm underwent RI, and none of the cyclonic storm as LMI underwent RI. Generally, the RI onset happens in the depression stage.

To understand the characteristics of RI TCs in contrast to the NRI TCs, the composites are prepared. For RI composite, we considered the 24 hrs from the onset of RI and for NRI composite the 24 hrs from the initial intensification stage are considered for NRI TCs. The existence of warm waters with strong latent heat flux transport, positive low-level relative vorticity, high upper-level divergence, and high mid-level relative humidity with higher total column water vapour around the TC centre are observed during RI. The total surface rainfall for RI cases is symmetric around the center. RI-TCs have higher rainfall fractions with intense surface rain rates for stratiform and convective during the pre-monsoon. Cold top, deep convective clouds with IRBT < 208K predominate in NRI, while cold top high clouds with 208K < IRBT < 240K predominate in RI.

Keywords: tropical cyclones, North Indian Ocean, rapid intensification, climatology, characteristics

DRY-WET SPELL PROBABILITY ANALYSIS OVER INDIAN REGION USING CHIRPS RAINFALL ON GEE CLOUD PLATFORM

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ABSTRACT

Indian agriculture is linked to rainfall variability. The sequence of dry and wet spells along with onset and withdrawal of rainy season are essential for sustainable agricultural management. Google Earth Engine (GEE) as cloud computing platform plays significant role for analysis of large volume of global data at hourly to daily scale. The present study evaluates the performance of GEE platform to analysis daily rainfall data (2009-2020) from Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) at spatial scale of 0.05° for computation of dry and wet spell probabilities over Indian region using Markov Chain model. The time series of rainfall daily data was processed using GEE platform through JavaScript API and the daily rainfall for 12 years was extracted from the earth engine data catalogue (i.e., ee.ImageCollection). In the GEE platform, many functions are available (i.e. "Map.", "filterDate", "reduce", ".clip", ".print", ".expression", "Export.") were used to import, filter, process and map to compute dry and wet spells probabilities. The model calculates the initial probability of getting a dry-spell (P_d) /wet-spell (P_w) in a given standard meteorological week (SMW), whereas the conditional probabilities provides the information on the dry spell followed by dry spell (P_{dd}) or wet spell (P_{dw}) and *vice-versa*. From daily rainfall data, weekly sum of rainfall was computed from 1st-52nd SMWs. The highest mean weekly sum of rainfall (73.40 mm) was observed on 29th SMW (16th-23th July). The state-wise analysis of rainfall probability distributions at spatio-temporal scale indicated an effective monsoon window from 23rd SMW (4th-10th June) to 39th SMW (24th-30th September) over Indian region, at those weeks both P_d and P_w intersect each other at 50% probability level. The results showed good match with other source of rainfall e.g. (IMD) and NOAA CPC and can be effectively used for agricultural planning over Indian region.

Keywords: Rainfall probability modelling, Markov Chain model, Remote Sensing, Google Earth Engine (GEE), CHIRPS.

CONSTRUCTION OF NONLINEAR ASYMMETRIC MULTIVARIATE DROUGHT INDEX

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ABSTRACT

Drought is a multivariate natural hazard, which is categorized into meteorological (rainfall deficiency), agricultural (deficit of soil moisture) and hydrological (stream flow deficiency) droughts. Several drought indices have been developed to address the three kinds of droughts using one single drought index. Most of these are based on linearity assumptions such as Principal Component Analysis, linear combination and entropy weighted methods. These assumptions are often challenged for extreme events like droughts. Considering those limitations, the copula function was used to construct a nonlinear drought index. A 4-dimensional drought index was constructed by combining four univariate drought indices (Standardized Precipitation Index (SPI), Reconnaissance Drought Index (RDI), Standardized Soil Moisture Index (SSI) and Standardized Stream flow Drought Index (SDI)). So as to reflect many hydro-meteorological variables (Precipitation, Evapotranspiration, Soil moisture, and Stream flow) for three kinds of droughts simultaneously. Vine copula has been able to solve nonlinear and asymmetric relationships among drought indices due to their flexibility over the free selection of copula(s) in each step of hierarchical structure in high dimensional modelling. The region of the upper Tapti river basin was chosen for the study, which is more prone to frequent and highly intensive drought events. The performance of the constructed high-dimensional drought index was analyzed and evaluated with entropy theory based dependence measures and independent Terrestrial Water Storage Anomaly data obtained from the Gravity Recovery and Climate Experiment (GRACE) mission. Analysis has revealed that the vine copula based high-dimensional drought index comprehensively monitors all three kinds of drought events in the study area. Such a developed index could be helpful for addressing nonlinear and asymmetric relationships that exist between the variables associated with natural hazards like drought.

Keywords: Drought, Nonlinear, Kinds of Drought, Vine copula, TWSA, GRACE

RECENT CALAMITOUS CLIMATE CHANGE IN INDIA (1990-2019)

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ABSTRACT

In this study, we investigated the recent climate change in India. Our examination of changes for the recent past three decades (1990-2019) in the relevant meteorological parameters in a space and time frame revealed a rise in droughts in the recent years, which is mainly due to substantial decrease in rainfall and increase in surface temperature. Possible causes for these changes are also discussed. The reduction in rainfall as well as the rise in surface temperatures is due to the rise in static stability. This increment in static stability contributed to the weakening of rising limb of Hadley cell, provoking anomalous sinking motion, which in turn led to decrease of monsoon rainfall over parts of Central Northeast India (CNE) (which covers Indo-Ganges plains), Northeast India and adjoining regions. The observed anomaly sinking motion due to the increment in static stability, resulted in rise of surface temperatures over parts of CNE, Northeast India and adjoining regions. In the recent years, the decrease of rainfall associated with increase of surface temperature is calamitous, as this led to a significant evaporation and drying of soil, leading to severe meteorological droughts over these regions

Keywords: Indian summer monsoon · Static stability · Surface temperature · Weakening of Hadley cell

POLEWARD SHIFTING OF TROPICAL CYCLONE TRACKS AND THEIR ASSOCIATION WITH HADLEY CELL EXPANSION

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ABSTRACT

Tropical cyclones (TC) formed in the warm waters of tropical oceans bring torrential rains having potential to causing floods and damaging high speed winds leading to loss of life and properties. Relatively warm sea surface temperature, high mid tropospheric humidity and vorticity and low vertical shear of horizontal winds are the conducive conditions for the formation of TCs. Recently, it is reported that the latitudes of their formation and maximum intensity are shifting poleward under the climate changing scenario. In the present study, the analyses of TC tracks in the six oceanic basins are carried out to investigate this phenomenon using direct observations from the International Best Track Archive for Climate Stewardship (IBTrACS). The analyses carried out over the individual oceanic basins have shown unambiguous trends in poleward shifting of the formation as well as maximum intensity latitudes of TCs. However, the observed trends show varying degree of magnitudes in the various oceanic basins with poleward shifting at the rate of ~52 km/decade in the Western North Pacific Ocean. It is known that HC boundaries are expanding in recent times and its consequences such as shifting of precipitation patterns and sub-tropical dry zones and migration in certain forms of biodiversity are already reported. By employing ERA-5 reanalysis datasets, the HC boundaries are estimated at regional scales through the estimation of zonally resolved meridional mass stream function computed with Helmholtz decomposed meridional component of the non-divergent wind. It is noted that as a consequence of HC expansion the conducive conditions for the formation of TC are shifting poleward thus providing the evidence for association of both these phenomena. The significance of the present study lies in establishing the co-variance of TC formation latitudes and HC boundaries at regional scales and discussing the potential physical processes associated with these phenomena.

Keywords: Climate change, Tropical Cyclone, Hadley Cell expansion.

AEROSOL VARIABILITY AT TOPOGRAPHICALLY SIMILAR AND METEOROLOGICAL DIFFERENT VALLEYS IN HIMALAYA AND ALPS MOUNTAIN SYSTEMS

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ABSTRACT

Aerosol characteristics at a site is mostly governed by its emission sources, topography and mesoscale meteorology. The objective of this study is to understand the aerosols variability in topographically similar and meteorological different sites in complex mountain valleys. The topographically similar and meteorological different valleys selected in this study are Kashmir valley in Indian Himalaya, Kathmandu valley in Nepal Himalaya and Po valley in the Italian Alps. Po valley and Kashmir valley are topographically and meteorological similar, however, Kathmandu is topographically similar but meteorologically dissimilar to these valleys. The aerosol and meteorological data for Kathmandu was available for year 2017, however for Kashmir and Po valley the data was available from 2013-2017, therefore, we used these datasets for comparative analysis at diurnal and seasonal basis. High $PM_{2.5}$ concentration was observed from autumn to spring in Kathmandu (60-120 $\mu g/m^3$) due to the dry weather conditions and large-scale stable burning in the valley and nearby Indo-Gangetic Plains (IGP). The lowest $PM_{2.5}$ concentration at Kathmandu was observed in summer because of high monsoon precipitation. However, in Kashmir valley, the lowest $PM_{2.5}$ concentration was observed in spring (35 $\mu g/m^3$) owing to frequent and high precipitation amounts in this season. The highest $PM_{2.5}$ concentration in Kashmir valley was observed in Autumn (180 $\mu g/m^3$) due to dry and stable weather and increasing biomass and coal burning activity. The annual concentration of PM_{10} (35 $\mu g/m^3$) and $PM_{2.5}$ (29 $\mu g/m^3$) at Po valley is almost 4 times and 2.8 times lower than PM_{10} (138 $\mu g/m^3$) and $PM_{2.5}$ (81 $\mu g/m^3$) in Kashmir valley. However, due to similar topography and meteorological conditions, the Kashmir and Po valley exhibit similar diurnal, monthly and seasonal patterns of both PM_{10} and $PM_{2.5}$. This comparative analysis helped us to understand the effect of topography and meteorology on temporal characteristics of aerosols at different selected sites.

Keywords: Aerosol variability, Kashmir, Kathmandu, Po valley, meteorology

ESTIMATION OF PARTICULATE MATTER ($PM_{2.5}$) OVER KOLKATA

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ABSTRACT

Particulate matter has diverse range of effect on human health and climate due to which it has emerged as a key parameter in monitoring air quality. The current study explores and estimate concentration of particulate matter ($PM_{2.5}$) from MODIS AOD product over the city of Kolkata for a period of three years (2019 to 2021). $PM_{2.5}$ concentration dataset was acquired from seven CPCB ground stations spread throughout Kolkata. Further, 1-km MODIS AOD product and meteorological parameters from MERRA-2 were utilized in the study. Considering statistical analysis of data, three regression models were derived and considered for PM estimation. Daily estimated $PM_{2.5}$ concentrations was compared against respective observations and model performance was evaluated with the help of statistical methods. Model-2 based on the multi-linear regression equation was the best fit model having the strongest positive correlation between the estimated and observed $PM_{2.5}$ values ($R = 0.814$). The correlation coefficient between the ground-based $PM_{2.5}$ and estimated $PM_{2.5}$ values was found to be nearly 0.747. The root mean square error (RMSE) was estimated at 30.7. The estimated $PM_{2.5}$ values were able to capture trend of $PM_{2.5}$ concentrations on the ground level. The normalised mean bias result (NMB) value was -0.318 and mean absolute error was 0.38. The mean absolute percent error is estimated around 38.285. The results demonstrated that the model developed can be used to study the particulate matter concentration over areas where ground- based observation sites are sparse on a city-level.

Keywords: Particulate Matter, AOD, Regression Model, $PM_{2.5}$

Microphysical characteristics of seasonal precipitation of the Arabian Sea tropical cyclone observed by the GPM-DPR

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ABSTRACT

The drop size distribution (DSD) of the cyclonic cloud is necessary for the numerical modelling of the tropical cyclone (TC) and the physical interpretation of its microphysical processes. The dual-frequency precipitation radar installed on the Global Precipitation Measurement (GPM-DPR) satellite level 2 data of v06 from 2014 to 2021 of the TC occurring during the monsoon onset time and post-monsoon season over the Arabian Sea is investigated. The 2-D frequency distribution between the liquid water content, LWC (g/m^2), and non-liquid water content, IWC (g/m^2), in a precipitating cloud show significant variation with the cloud type and season. A large proportion of rain particles lies within the 0-800 (0-350) g/m^2 LWC (IWC) value for the stratiform precipitation of TC in both seasons. The amount of LWC is high, and IWC is low during the convective precipitation than the stratiform precipitation of TC in monsoon and post-monsoon season. The high density of rain particles of convective origin is mainly present between 0-1700 g/m^2 and 0-200 g/m^2 of the LWC and IWC, respectively. The mean value of mass-weighted mean diameter, Dm (mm) for the stratiform and convective precipitation in the monsoon (post-monsoon) season is 1.28 (1.27) mm and1.39 (1.30) mm, respectively. The convective precipitation in monsoon and post-monsoon has a significant concentration of bigger rain particles, while the stratiform precipitation contains a high density of smaller rain particles. The two-dimensional frequency distribution of the reflectivity, Ze (dBZ) and Dm with altitude is distinct for the stratiform and convective precipitation in monsoon and post-monsoon seasons. The fluctuation in DSD characteristics of TC is explained in terms of different microphysical processes like size sorting, breaking-up, and collision-coalescence process. The collision-coalescence process is the principal microphysical process occurring above the melting layer, while the breaking-up process is dominant below this layer.

Keywords: Arabian Sea, Tropical Cyclone, GPM-DPR, Cloud microphysics

Seasonal variability of tropical cyclone heat potential in the Bay of Bengal and its role in cyclone genesis and intensification

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ABSTRACT

Tropical cyclones are extreme weather events occurring in warm tropical oceans which can have a significant impact on the society. North Indian Ocean including the Bay of Bengal and Arabian Sea witness frequent occurrence of cyclones in the recent years, due to rapid warming over this region. Bay of Bengal is considered to be highly active basin for tropical cyclone occurrence in the North Indian Ocean. Tropical cyclone heat potential is one of the important parameters used in the prediction of the intensity of tropical cyclone. Very high tropical cyclone heat potential can enhance tropical cyclone genesis and intensification (Wada et al.,2007). In the present study, the tropical cyclone heat potential over the Bay of Bengal basin (divided as north and south bay) has been calculated for the post-monsoon season (October-November) and pre-monsoon season (March-May). The ocean temperature data for calculating the tropical cyclone heat potential was obtained from copernicus marine service (CMEMS), global ocean physics reanalysis during the period 2000-2020. It is observed that significant changes in the tropical cyclone heat potential has been observed in both the seasons over the Bay, indicating its role in the tropical cyclone intensification. Also the accumulated cyclone energy and the power dissipation index shows variability during both the seasons showing slight increase in the pre-monsoon accumulated cyclone energy when compared to the post monsoon season over the Bay of Bengal in the recent years. As the Indian Ocean continues to warm, (Deshpande et al., 2021) more frequent and intensified tropical cyclones are expected in the near future. So better study has to be conducted to understand the exact role of tropical cyclone heat potential on cyclone genesis and intensification.

Temperature Disturbances in the Stratosphere during Cyclonic Storms over the Bay of Bengal

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ABSTRACT

In this work we present the effects of cyclonic storms on the temperatures of different stratospheric layers (10 hPa&1 hPa level). We have analysed twenty five cyclonic storms over the Bay of Bengal from 2011 to 2021. While prominent and significant temperature perturbations on the 10 hPa level are found for most of the cyclones, significant temperature perturbation near the stratopause (1 hPa) are observed only for severe cyclonic storms (>CAT-4). The central pressure drop and maximum sustained wind speed during the maximum intensity phase of the cyclones show a good correlation with the temperature perturbation at the 10 hPa level, while the correlation is poor for 1 hPa level. The correlation coefficient between the absolute temperature perturbation at 10 hPa and maximum cyclone pressure drop is obtained around r~0.8 excluding 3/4 high intensity storms, while the same correlation is poor (r~0.34) for 1 hPa level. This indicates that atmospheric gravity waves originated from the cyclonic storms which transfer energy and momentum from the troposphere to upper atmosphere cannot propagate up to the stratopause for all cyclonic storms. Further, we have tried to find any relationship of the upward propagation of AGWs with the QBO phase during the storms as the QBO is an internal oscillation of the zonal mean flow resulting from wave mean flow interaction with the vertically propagating Kelvin and Rossby-gravity waves. We found, the stratospheric temperature during most of the cyclones at pressure level of 10 hPa generally decreased for westerly QBO phase and increased for the easterly QBO phase.

Keywords: Cyclone, Stratospheric temperature perturbation, Gravity wave, QBO

STUDY OF THE INDIAN SUMMER MONSOON FOR TWO CONTRASTING YEARS USING THE WRF MODEL

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ABSTRACT

The Indian monsoon system plays a vital role in the Atmospheric General Circulation. India being an agrarian country is highly dependent on the performance of the monsoon rainfall for her economy. A timely assessment of an ensuing monsoon is very crucial for the farming community in India. In the present study the time tested well established Weather Research and Forecasting (WRF) model is used at 25km resolution to simulate the Indian summer monsoon season for two contrasting years 2013 (Surplus) and 2014 (drought) in terms of Rainfall. The time varying boundary conditions are taken from the Community Climate System Model Version 4 (CCSM4) of Coupled Model Inter-comparison Project 5 (CMIP5) corresponding to Representative Concentration Pathways 6.0 (RCP6.0) for the period 2006 to 2022 over the South-Asia Coordinated Regional Downscaling Experiment (CORDEX) domain. This study has been carried out with the objective of assessing the future climate under RCP6.0 scenario. Hence the analysis of the basic variables like surface temperature, rainfall and the wind circulation at 850hPa and 100hPa are made for evaluation only for two contrasting years i.e 2013 and 2014. The outputs of the WRF model are compared to the ERA5 reanalysis products and the model simulated rainfall is compared to the IMD rainfall. The WRF model had produced the essential differences in the anomalies of surface temperature and, rainfall and wind regimes with the spatial distribution features agreeing with ERA.

Keywords: Summer monsoon, CCSM4, WRF, Surplus and Deficit.

Characteristics of the Atmospheric Boundary Layer Processes during Transient Monsoon Conditions

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ABSTRACT

Knowledge of atmospheric boundary layer height (ABL) during transient monsoon conditions is important to understand the role of the monsoon on the exchange between ABL and free troposphere (FT). As convection and advection processes becomes stronger during the monsoon seasons, greater exchange between the ABL and FT is expected. We have selected five Indian stations distributed across the central (New Delhi and Nagpur), western (Mumbai), eastern (Kolkata) and southern (Gadanki) monsoon regions. In this study, radiosonde datasets over 2004-2019 is utilized to obtain the ABL height during the active and breaks phases of the monsoon. IMD gridded rainfall dataset is used for identifying the active and break phases based on the central India rainfall. In total, 24 active and 20 break episodes are obtained over the period 2004-2019. However, we observed that these active and break phases need not necessarily represents the wet and dry over the individual stations. Thus, we have also obtained the wet and dry episodes based on the local rainfall data. In general, ABL is shallower during the active monsoon condition than the break monsoon conditions. The shallower and deeper ABL height is further quantified with respect to climatological mean ABL height at a given station. If the ABL height falls below (above) the mean minus (plus) one standard deviation of the climatological ABL is considered as shallower (deeper) ABL height. It is observed that, ~ 50% of the cases are shallower over New Delhi, Nagpur, Kolkata while 31% over Mumbai during the active phase. Rest of the days shows deeper ABL even during the active monsoon condition. During the break monsoon conditions, 60% of cases show deeper ABL while remaining 40% show shallower ABL. This disparity we have further examined using the local wet and dry conditions. The details of the ABL height variability during the active and break phases and the wet and dry conditions will be presented during the conference.

Keywords: ABL height, day-to-day variability, Active-break phases of monsoon

HARMONICS EMBEDDED IN INDIAN SUMMER MONSOON RAINFALL INTENSITY BINS AND ITS LINK WITH SST INDICES IN INTERDECDAL TO MULTIDECADAL TIME SCALES

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ABSTRACT

Indian summer monsoon rainfall (ISMR) plays a vital role on the economy of India. Hence it is better to understand dominant modes of ISMR variability. In this study, various harmonics embedded in Indian summer monsoon rainfall in different intensity bins from 1901 to 2021 over West Coast (WC) and Central India (CI) are examined. The analysis also aims to identify promising SST predictors of ISMR at various time scales, which assists in improving rainfall prediction skills. The study employs wavelet analysis of rainfall intensity bin and SST in Arabian Sea (AS), Bay of Bengal (BoB), Indian Ocean, over interdecadal, decadal and multidecadal time scales. Further, the co-variability and relationship between variables are investigated. Six rainfall intensity bins based on percentile value viz. dry, low, moderate, high, very high and extreme rainfall events were examined. From the spatial coherence of rainfall harmonics in two regions, it is observed that moderate intensity bin has significant positive (negative) correlation in interdecadal and decadal (multidecadal) time scale. It is also noticed that dry (extreme) intensity bin has significant positive (negative) correlation in multidecadal time scale. From the correlation analysis between different harmonics in each intensity bin and SST indices, it is observed that over WC, moderate and high (very high and extreme) intensity bin is positively (negatively) correlated with AS, BoB and Indian Ocean Dipole (IOD) indices in multidecadal time scale. However, in decadal time scale very high and extreme bins are positively correlated with IOD. While in CI, moderate and very high (high and extreme) intensity bins are negatively (positively) correlated with BoB and IOD indices in multidecadal time scale. Moreover, in CI all intensity bins show significant correlation with IOD in multidecadal time scale.

Keywords: Summer monsoon rainfall, Rainfall intensities, Rainfall harmonics, Rainfall-SST relationship.

EVALUATION OF VARIOUS CHARACTERISTICS OF PRECIPITATION CONCENTRATION INDEX IN PART OF WESTERN GHATS

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ABSTRACT

Western Ghats, which runs parallel to west coast of India has a significant role to play in controlling the rainfall distribution in the Deccan plateau during the monsoon period. The monsoon rainfall is the life line of the people of India in general and particularly peninsular India. There have several studies carried out understand the dynamics of monsoon rainfall, however, only few studies have been carried out evaluate the rainfall concentration in the Western Ghats. The Precipitation Concentration Index (PCI) one such index which define the temporal precipitation distribution. This is one of the powerful tool to assess the spatio-temporal changes in seasonal precipitation.

The present study was carried out by selecting 6 rainfall stations from Western Ghats part of Karnataka state. The data for 6 stations are for a period of 1960 to 2018 (58 years). The rainfall stations are selected based on their location and climatic regime. The selected stations represent the humid, sub-humid and transition zone of Western Ghats of Karnataka and defines the different rainfall regime as identified by Venkatesh and Jose (2007).

The results of the study reveals that variation trend of annual PCI values has decreased significantly over the 58 years. However, the PCI values of Monsoon recorded an increasing trend during the same period. These varying trend indicates that monsoon rainfall of these selected rainfall station may be more of regular in pattern and on annual scale it may be more of irregular. This is true in the sense that, study area is monsoon dominated and less to very less rain during the rest of year, hence may be irregularity of rainfall pattern and decrease in the PCI values. The results provide an important information to the water resource planners, policy makers to formulate an appropriate plan for effective management of water resources project and agricultural activities in the region.

Global changes in Aerosols Optical, Physical, and Morphological properties obtained using 20 years of Multi-sensor measurements

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ABSTRACT

It is well known that one of the main drivers of Earth's radiation budget and climate change is the drastic changes in the aerosol emissions. In this regard, numerous studies have been carried out to examine the trends in the rapidly changing aerosol loading through the total Aerosol Optical Depth (AOD). But very few investigations have acknowledged its long-term implications through the combined optical, physical, and morphological properties of the aerosols, as total AOD is a combination of the aerosols size, shape, and optical properties. To accomplish this on a global scale, multi-satellite and reanalysis measurements are used and a detailed comparison has been made prior with the ground-based observations as well. However, the long-term implications are estimated using the multivariate regression model in which contributions from the naturally occurring weather phenomenon such as Solar Cycle, Quasi-Biennial oscillations, and El-Niño southern oscillations, are isolated from the datasets. With the implementation of this approach on nearly two decades (2001-2020) of multisource datasets, we tried to relate the contribution of each of the varying aerosol properties to the changing total AOD trends across the globe. Region-wise analysis has shown that the decrease (increase) in the total AOD trends observed over North-Eastern America, South America, and Europe (Indian) regions are mainly in connection with the decline (incline) in the fine-mode and scattering aerosols. Interestingly, the Indo-Gangetic Plain region of India, where high total AOD trends are observed, has seen a plausible decrease (slight) in its absorbing, non-spherical, and coarse-mode aerosols in the recent years. This study also details the region-wise response accompanying the implementation of stringent mitigation strategies to ensure accurate quantification of the changing aerosol patterns in the atmosphere.

Keywords: Aerosol optical, physical properties, AOD, trends, multi-source datasets

Retrieving the changing behavior South West Monsoon Rainfall Using high resolution CORDEX data in context of variability in Flood and Drought event

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ABSTRACT

Indian summer monsoon is showing the phase alteration with frequent severe to moderate drought and flood episodes. In recent decades, India received an anomalously deficit and excess southwest monsoon rainfall. Accordingly, the consistent detection and monitoring of droughts and floods regarding its regional patterns, severity, duration, and areal extent are crucial for the reduction in climate change vulnerability and associated socio-economic impacts. This work evaluates the daily rainfall of three high resolution CORDEX ERA-Interim driven simulations of South Asia-CORDEX i.e., RegCM4.7, COSMO and REMO2015 over India for the period 1981-2015. The intercomparison of the dynamical downscaling of summer monsoon rainfall simulation have been performed with the help of IMD and RCMs simulations over India during 1981-2015. The analysis includes the calculation of consecutive dry days, consecutive wet days, heavy precipitation and very heavy precipitation days and standardized precipitation index which serves as a standard measure intensity, frequency and duration of flood and seasonal drought event. The capability of RegCM4.7 and REMO2015 in simulating the Indian summer monsoon proves that the model simulation can realistically represent the monsoon drought rather than flood episode in terms of duration, intensity and frequency.

Keywords: CORDEX, RCM, ISMR, FLOOD, DROUGHT

EVALUATION OF CMIP6 MODELS FOR SIMULATIONS OF SURPLUS/DEFICIT SUMMER MONSOON CONDITIONS OVER INDIA

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ABSTRACT

The study uses the 30 General Circulation Models (GCMs) from the Coupled Model Intercomparison Project (CMIP) phase-6 to examine the simulations of the surplus/deficit Indian summer monsoon rainfall (ISMR) and its associated air-sea interactions on intraseasonal timescales. The majority of the CMIP6 models simulate the seasonal mean state of ISMR over the Indian mainland with systematic biases. It is identified that, improvement of low-level winds and SST with high spatial resolutions would provide better precipitation simulations. B-MME (multi models ensemble mean of BPM) can capture the negative IOD-like (Indian Ocean Dipole) pattern during deficit monsoon years and fail to capture the positive IOD-like pattern during surplus monsoon years. Models overestimate the moisture transport from the West Indian Ocean to the sub-continent of India during deficit monsoons, which plays a crucial role in modulating the precipitation and its associated intraseasonal variability. The present analysis identified that during deficit monsoon years, the faster moving 20-100 day oscillations are evident; however, these oscillations are sluggish during surplus monsoon years, which affects the duration of convection activity and causes dry conditions over the regions. During surplus monsoon years, the Bay of Bengal (Arabian Sea) responds strongly (slowly) to the atmosphere than the deficit monsoon years. However, models are fail to represent the ocean's response to the atmosphere over the Bay of Bengal. The freshwater forcing improvement in the models simulates the ocean to atmosphere response over the Indian region. The present study further suggests that the improved simulation of the Indian summer monsoon (ISM) variability by the GCMs is possible by improving the ocean and atmosphere feedback mechanisms, sensitivities of the models among internal variables, and orographic features necessary for the accurate simulation of intraseasonal variability.

Keywords: Flood (Surplus)/Drought (Deficit), CMIP6 models, Intraseasonal oscillations, Air Sea interactions

IMPACTS OF CLIMATE CHANGE ON INDIAN RAINFALL TOWARDS THE END OF THE CENTURY

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ABSTRACT

The impact of climatic change on Summer Monsoon Rainfall is studied to understand the rainfall pattern towards the end of the century utilizing Coupled Model Inter-comparison Project, Phase 6 (CMIP6). The analysis was carried out using 64 years of the historic period (1951-2014) and future projections for the end of the century (2015-2100) from model simulations of CMIP6. The models are compared with the APHRODITE (Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation) daily rainfall data. Here, the Taylor analysis of model output is compared with APHRODITE as reference. The simulations that are in coherent with the observational data sets are selected for future projections in the four scenarios, viz: ssp1-2.6, ssp2-4.5, ssp3-7.0, and ssp5-8.5, which are available from the models EC-Earth3-Veg-LR, INM-CM4-8, INM-CM5-0, KIOST-ESM and MPI-ESM1-2-HR. Most of the models overestimate the inter-annual cycle of the rainfall in the historic period and a very few are underestimating. Most of them capture the onset signal of the summer monsoon in early June along with good seasonality in the daily rainfall climatology. The characteristics of summer monsoon rainfall captured by the selected models show far better agreement than the annual rainfall. We have given more emphasis on summer monsoon rainfall in the projection period since the recent trend of the rainfall is becoming more chaotic. The study aims to assess extreme rainfall events for understanding the plausible occurrence of catastrophic events.

Keywords: Climate change, Climate modelling, summer monsoon rainfall, Extreme Rainfall

SIMULATION OF THE NORTH INDIAN OCEAN TROPICAL CYCLONES: SENSITIVITY TO THE SKEBS-BASED ENSEMBLE-VARIATIONAL 3DVAR DATA ASSIMILATION

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ABSTRACT

The advanced research Weather Research and Forecasting (WRF-ARW) model is a next-generation mesoscale numerical weather prediction system that is used to anticipate short and medium-range weather events. With the effective deployment of cutting-edge atmospheric data assimilation techniques, the reliability of WRF-ARW prediction has been significantly improved. The stochastic kinetic energy backscatter scheme (SKEBS)-based 30-member three-dimensional ensemble-variational data assimilation approach was used in this work to improve the trajectory, intensity, and rainfall simulation of two tropical cyclones, Titli and Yaas, in the North Indian Ocean. The model results are compared to the ERA5 reanalysis dataset from the European Centre for Medium-Range Weather Forecasts (ECMWF) and tropical cyclone "best track" observations from the India Meteorological Department. Using an ensemble-variational data assimilation model configuration based on SKEBS offered considerable gains over the first guess analysis, simulating closer to the observations, albeit with minor differences.

Keywords: SKEBS, Weather Research and Forecasting, Data Assimilation, Tropical Cyclone

Decoding Precipitaion Pattern using Machine Learning

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ABSTRACT

Precipitation fields in a tropical setup are difficult to analyse and predict mainly due to their heterogeneity and convective scale sources. In this context, a network of observations helps us to resolve the high spatio-temporal variability in rainfall and is very important for Kerala, which is the onset point of South-West Monsoon in India. Automatic Weather Station (AWS) network forms an integral part of the system for meteorological variables, especially rainfall and its spatial aggregation of local observation can reduce noise and enhance the regional monsoonal signal. Inter-station rainfall association can be an important tool in decoding the hidden patterns in precipitation fields which can eventually help in clustering similar rain archetypes. In this study, an algorithm based on the Association Rules Mining (ARM) has been developed using different AWS station rain data over Kerala to explore the co-occurrence of the spatial rainfall pattern for the early monsoonal month of June (2008-2020). This is done under the framework of Apriori algorithm. The results demonstrate that the AWS stations SSF Vengad Kannur and SF Pullad Pathanamthitta of Kerala are closely associated with a high confidence and Zhang number. This analysis will help us to mine out the spatial association of precipitation, which is extremely useful for water resource management and understanding the disparity between local and large scale definition of timing of monsoon onset and retreat.

Keywords: Association Rules Mining, Apriori algorithm, Automatic Weather Station.

Is South West monsoon 2022 over Maharashtra State is unique during June and July as compared to last five years

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ABSTRACT

Four meteorological sub-divisions, *viz*. Konkan, Madhya Maharashtra, Marathwada and Vidarbha in the State of Maharashtra where due to orography and location rainfall varies widely. This year monsoon rainfall over Maharashtra is unique in nature which started with very less rainfall during June while revival occurred in just around two weeks time during first fortnight of July 2022. This prompted the authors for this critical analysis and study.
For this study, daily rainfall data of June and July months from 2017 to 2022 is considered for analysis of rainfall patterns. From the daily rainfall data monthly rainfall series of each stations are computed and then monthly district wise rainfall series has been constructed by considering arithmetic average of all the stations' rainfall values within the district. The data used in this study is with high resolution which makes district wise analysis over Maharashtra State encouraging.
During the year 2022, South West monsoon over Maharashtra State arrived on 10th June which is 5 days late from normal date and monsoon covered entire Maharashtra State on 17th June (around normal date). However, initial progress was slow as well as weak.
In the month of June 2022 actual rainfall reported *viz*. Konkan and Goa 24 percent deficient, Madhya Maharashtra 40 percent deficient and Vidarbha 39 percent deficient rainfall during this year 2022 except Marathawada, which was 7 percent more than LPA in normal category. However, first fortnight of July 2022, four sub-divisions of Maharashtra reported excess rainfall during 1st June to 15th July 2022 *viz*. Konkan and Goa 34% excess, Madhya Maharashtra 44% excess, Vidarbha have 46 % excess and Marathwada with 84% excess. The paper discussed in detail regarding June and first fifteen days of July rainfall for four meteorological sub-divisions for last six years commencing from 2017.The system responsible for the revival of monsoon over the State during first half of July 2022 is discussed in the paper. The result found is encouraging.

Keywords: Rainfall, South West Monsoon, Maharashtra, Sub-division, Systems.

MEASUREMENTS OF VOCs AT A RURAL SITE IN INDIA: VARIABILITY AND SOURCES DURING THE SEASONAL TRANSITION

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ABSTRACT

Volatile Organic Compounds (VOCs) play an important role in tropospheric chemistry as they are the potential precursors of ozone and secondary organic aerosols, and get involved in several chemical transformations. There are about 57 different ozone precursor VOCs listed by the United States Environmental Protection Agency (US-EPA). The concentration ranges of different VOCs are different in the urban and rural atmosphere due to the differences in their emission sources (biogenic or anthropogenic) and day-to-day activities (domestic and agricultural activities such as stubble burning, biomass burning in the rural atmosphere whereas traffic emissions in the urban atmosphere). Most of the reported VOC measurements are from urban atmospheres. However, in this study, VOCs are measured in a tropical rural atmosphere (global attempts are sparse and nil over India) using the Gas Chromatography technique coupled with a thermal desorber and Flame Ionization Detector (GC-FID). A total of 31 Ozone precursor VOCs are detected, and each of them offer significant contribution to the total VOC. They show strong seasonal and diurnal variations that will impact the ozone formation potential and oxidative capacity of the rural atmosphere. More details on measured VOCs seasonal and diurnal variability, their impact on ozone formation, and their potential sources will be presented in the symposium.

Keywords: VOCs, Rural atmosphere, GC-FID, Ozone

Simulation of an extreme rainfall event over Mumbai on 26th July 2005 using Regional Climate Model

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ABSTRACT

In present study the recent version of ICTP's regional climate model RegCM4.6 has been utilized to simulate one of the most catastrophic rainfall events recorded in the history of Mumbai, India on 26th July, 2005. The dynamical downscaling using RegCM4 has been performed at 25 km horizontal resolution over South-Asia Coordinated Regional Climate Downscaling Experiment (SA-CORDEX) domain with initial and lateral boundary conditions from ERA-Interim reanalysis (EIN15). Analysis suggests that the RegCM4.6 using mixed cumulus parameterization scheme (CPS; where the Emanuel scheme is considered over land and the Grell scheme is forced over ocean (EL_GO) is able to reproduce the heavy rainfall event with higher accuracy compared to the driving fields. This highly confined event over Mumbai might be a manifestation of the low-pressure area formed over Orissa and the adjoining regions associated with mid-tropospheric cyclonic (MTC) circulation over the western coastal region. There is a significant improvement in the model simulated output closer to the observations of rainfall and large-scale fields. Further, the RegCM satisfactorily simulates the features such as the convergence at the lower level accompanied with the divergence at the upper level, higher cyclonic vorticity near lower level, and presence of an enormous amount of moisture content at different pressure levels.

Keywords: RegCM4.6, CORDEX, Mixed CPS, Mid tropospheric cyclone (MTC).

Heat waves as signature of Climate Change impacts over Madhya Pradesh

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ABSTRACT

Research of weather extremes linked with temperature changes is gaining attention of world community now a days due to its high association with societal functional patterns. The prolong period of constantly high temperature and heat waves have become more frequent in past few years with increased large impacts and are likely to increase as global climate models are indicating warming in future. Heat wave (HW) and Severe Heat Wave (SHW) periods cause a spectrum of impacts on all the natural resources, ecosystems, health and economic activities. The Population of developing country like India are more susceptible towards the changing climate conditions due to limited adaptive measures like air conditioning and limited access to public health facilities for climate-related health burden in every changing season. The death related to heat waves are increasing not only in India but in the entire world. The probable impact of heat waves in terms of mortality and its future trends are of vital use for adaptation policy intervention. The Madhya Pradesh has semiarid climate and experiences heatwave conditions in premonsoon season mainly in month of May and some times heat waves show strength in june month also due to monsoon delay. As state is less affected by cyclonic storms in premonsoon season and mostly remain dry during hot summer season and peak temperature reaches up to 48 0C. Alirajpur, Badwani and Sheopur districts having very high heat vulnerability index (HVI index) values. The study aimed to analyze monthly, seasonal & decadal variations along with long-term trends of heat waves (HWs) / severe heat waves (SHWs) and diurnal temperature range (DRT) for pre-monsoon (March-May) and early summer monsoon (June) season during 1980-2022 period over land locked state MadhyaPradesh using IMD observatory data also explores future predictions of temperature and associated heatwaves using ARIMA model. Monthly temperature trends over Bundelkhand region are significantly increasing during past three decades.

Key Words: Heat wave, long term trends, decadal variation,

Seasonal variability in aerosol hygroscopicity and its contrast size dependence in Aitken and accumulation modes

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ABSTRACT

Hygroscopicity is the ability to water uptake by particles and modulates the size of aerosols especially in high humidity atmospheric conditions. Thus it influences the local visibility and aerosol-cloud interaction processes. More than 1 year of observations were collected at High Altitude Cloud Physics Laboratory (HACPL), Mahabaleshwar from May, 2019 to 10th May, 2020 covering all seasons are used in the study. Size segregated growth factor for particle diameters 32nm, 50nm, 75nm, 110nm, 150nm, 210nm, 260nm at 90% RH conditions were measured by Humidified tandem Differential Mobility Analyser (HTDMA). Hygroscopicity depends on the chemical composition of particles. The mass of different chemical species changes with the size of particles. So the size segregated observation was designed for particles ranging from Aitken to accumulation mode.

The mean hygroscopicity (k) for diameters 32nm, 50nm, 75nm, 110nm, 150nm, 210nm, and 260nm at 90% RH conditions are 0.189, 0.177, 0.163, 0.170, 0.183, 0.199, 0.207 respectively during the overall observation period. The minimum k (0.163) is observed for the particle size of 75nm and the maximum (0.207) for 260nm particle. Annual and in all the seasons, it is noted that hygroscopicity decreases with increasing diameter in Aitken mode size range whereas increases with increasing diameter in accumulation mode. This reverse trend is explained by different hygroscopic modes and the chemical composition analysis. Aerosols are categorized in three hygroscopic modes i.e. less-hygroscopic (LH) population $k < 0.1$, hygroscopic (H) population $0.1 \leq k < 0.2$, More-hygroscopic (MH) population $k \geq 0.2$. More hygroscopic population shows a reverse trend as it decreases in Aitken mode but in accumulation mode increases with increasing diameter. Size segregated chemical composition of particles was measured by High-Resolution Time of Flight Aerosol Mass Spectrometer (HR-ToF-AMS) in winter and pre-monsoon time. Chemical composition analysis also support inter- and intra- seasonal variation of hygroscopicity in each diameter. The detailed analysis and results will be presented.

Keywords: Hygroscopicity

Impact of ozone pollution on crop production in India

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ABSTRACT

Tropospheric ozone is a major secondary air pollutant and third most powerful greenhouse gas (GHG) formed by the photochemical reactions of its precursor gases. Studies have shown the adverse impact of ozone pollution on agriculture. It is a major threat to food security world-wide, particularly in the developing asian economies like India. However, our understanding of long-term trends in tropospheric ozone and its effects on agro-ecosystem and production is inadequate. Furthermore, it is a challenging task to feed the country's huge population and to the meet United Nations Sustainable Development Goal 2(UN SDG2) by 2030, when the population growth and declining production of foodgrains are considered. This study estimates the reduction in yield of the most important food crops in India; rabi wheat and kharif rice, due to surface ozone exposure for the period 2005—2018 using the Tropospheric Emission Spectrometer (TES) chemical reanalysis two hourly surface ozone mixing ratio and Special Data Dissemination Standard-Directorate of Economics and Statistics (SDDS-DES) district-wise crop production data. The 7-hour seasonal mean day time concentration (M7) and Accumulated daytime hourly ozone concentration above a threshold of 40 ppbv (AOT40) metrics are used to calculate the exposure-response function and crop production loss (CPL) for each year. Results show that the total all India annual loss of rabi wheat is increased two-fold (~8.4 – 16 million tonnes, Mt) from 2005 to 2018. Whereas, the kharif rice loss is increased from ~3.5 to 5 Mt during the same period. The corresponding total economic loss of rabi wheat is about ~1.9 – 4.4 billion USD and for kharif rice is ~0.46 – 1.19 billion USD for the study period. The analyses suggest that there is a serious decline in crop yield and heavy economic loss due to ozone pollution in India, and the situation calls for reduction in atmospheric pollution for suatainable crop production and food security in India.

Keywords: Tropospheric ozone, pollution, GHG, Agriculture, Crop production loss.

Changes of Snow Water Equivalent and Degree Day Factor over Sikkim Himalayas

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Abstract

India is a mega biodiverse agrarian nation whose fate is controlled by Monsoon and Himalayas. The glacial region of Hindukush Karakoram Himalaya (HKH) are called as *'water tower of Asia'* which stores large volumes of water in the form of ice and snow after the polar ice (*Adnan et al., 2017*). The trends of rising global temperature and accelerated receding of glacier. Sikkim is the second most vulnerable Indian state to climate change due to glaciers and stream power dependence. the present study focuses on understanding the impact of climate change to snow water equivalent (SWE) and snowmelt rate in Sikkim Himalayas for the time period of 1979 to 2017. Hence this study is conducted to discuss the temporal variation of melt rate and associated melt amount through degree day modeling. The average decadal rate of Snow water equivalent (SWE) and Degree day factor (DDF) for the months of March to August for Sikkim Himalayas over 1979-2017 is increasing except for 2009-2017 decade indicating the impact of Global Warming. The average decadal temperature trend is increasing with 0.91 coefficient of determination for Sikkim Himalayas for months of March to August from 1979-2017 indicating increase in humidity, increase in cloudiness and Climate change due to accelerated Greenhouse Effect in recent decades. Hence, the rate of snowmelt is critical for information about flood forecasting, extreme weather event, agriculture and optimal management of water resources.

Keywords: *Sikkim Himalaya, Snow Water Equivalent (SWE), Degree Day Modeling (DDM), climate change and impact,*

Long Term changes in basic meteorological parameters and surface fluxes over India during summer monsoon

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ABSTRACT

Long term estimation of basic meteorological field variability is an important factor that influences Indian summer monsoon (ISM) and consequently affects the socio-economic aspects of India. In this study, the spatio-temporal variation of basic meteorological parameters with surface fluxes during summer monsoon season using NCEP/NCAR reanalysis datasets for the period of 70 years (1948–2017) has been analysed. Statistical techniques have been employed to examine the linkage between meteorological fields and monsoon activity during climatology, early-late phase and multidecadal epochs over India and its subregions. The significant spatial changes in the value of standard deviation confirms the early-late phase and multidecadal modulation of the interannual variability of selected climatic parameter. The major hotspots of increasing early-late phase and multidecadal variability and of average precipitation have been found over BOB, AS and IO and PI (~1-3.5 mm/day). The decreasing changes in the mean rainfall pattern and associated variability is strongly linked with the increasing surface warming and significant reduction in the strength of surface zonal wind over BoB, IO, PI and CI region which cause the weakening of important atmospheric circulations such as the role of Somali jet and strong low-level jet during ISM season. In recent years the variation in meteorological parameters and surface fluxes are irregular during summer monsoon season in changing climate.

Keywords: Meteorological parameters, Monsoon Variability, Atmospheric Circulation, Changing Climate

VALIDATION OF IOT BASED LOW-COST WEATHER MONITORING DEVICE OVER A TROPICAL COASTAL STATION – KONDOTTY (13.13N, 79.95E), KERALA.

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ABSTRACT

Emergence of Internet of Things (IoT) and embedded system technologies opened an unprecedented opportunity to establish and monitor large number of weather observatories over a minimum spatial area. Its economical feasibility as compared to professional weather stations and ease of data access make such instruments popular to increase number density of weather monitoring points and, for the data assimilation in weather forecasting models. Initial assessment of Temperature, Relative Humidity ((RH) and Pressure obtained from a low-cost weather monitoring devices and its comparison and validation with a professional weather station over Calicut Airport, Kerala is investigated. While temperature and pressure observations show 0.82 correlation with the professional weather station, RH indicates 0.7. The bias correction is applied to the temperature and pressure measurements; however, RH value of the low-cost weather station is not disturbed. Interestingly, the RH measurements of the low-cost device is found to depict a better representation of background humidity condition than the professional weather station. In addition, two special events, between 20-06-2022 and 25-05-2022 (01-07-2022 and 04-07-2022), characterized by consecutive increase (decrease) in the surface air temperature, and associated variation in the background weather conditions are also investigated.

Keywords: Internet of Things (IoT), low-cost weather station, data assimilation, weather event

Predictability Assessment of South-West Monsoon Rainfall in India Using Intra Seasonal Oscillation Data Through Statistical and Machine Learning Techniques

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ABSTRACT

For an agrarian country like India, monsoon rainfall is highly desirable for its socio-economic growth. Thus, prediction of the southwest monsoon is beneficial for the development of the country. Intraseasonal oscillations are known to play an important role in modulating the monsoon intensity seasonally and interannually. In this study south-west monsoon rainfall is predicted over various regions of India and for various months within monsoon season (JJAS) using machine learning tools from intraseasonal oscillations. For the prediction of south-west monsoon, intra seasonal oscillation data over three ocean basins (AS, BoB and IO) are used as predictors by linear regression (LR), Artificial Neural Network (ANN), and Genetic programming (GP) methods. Outgoing long wave radiation (OLR) data from National Oceanic and Atmospheric Administration (NOAA) is used to quantify ISOs, rainfall data from India Meteorological Department (IMD) is used as output. For the machine learning technique 1979-2009 is used as the training dataset and 2010-2021 is used as the testing dataset. The performance of these models was analysed by different statistical methods and found that GP predicts better than ANN and LR techniques. According to the findings of this study, ISO data has the potential to be used as a predictor of South-West monsoon.

Keywords: Monsoon, Intra-Seasonal Oscillation, Machine Learning

BALLOON-BORNE AEROSOL-CLOUD INTERACTION STUDIES (BACIS): FIELD CAMPAIGNS TO UNDERSTAND AND QUANTIFY AEROSOL EFFECTS ON CLOUDS

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ABSTRACT

A better understanding of aerosol-cloud interaction processes is important to quantify the role of clouds and aerosols on the climate system. There have been significant efforts to explain the ways aerosols modulate cloud properties. However, from the observational point of view, it is indeed challenging to observe and/or verify some of these processes because no single instrument or platform is proven sufficient. With this motivation, a set of observational field campaigns named Balloon-borne Aerosol Cloud Interaction Studies (BACIS) is proposed and conducted using balloon-borne in-situ measurements in addition to the ground-based (Lidars, MST radar, LAWP, MWR, Ceilometer) and space-borne (CALIPSO) remote sensing instruments from Gadanki (13.45^{0}N, 79.2^{0}E), India. So far, 15 campaigns have been conducted as a part of BACIS campaigns from 2017 to 2020. Balloon-borne measurements are qualitatively assessed using data from simultaneous observations of ground-based, space-borne lidars. Aerosol/cloud vertical profiles obtained in multi-instrumental observations are found reasonably agreeing. A combination of the Compact Optical Backscatter AerosoL Detector (COBALD) and Cloud Particle Sensor (CPS) sonde is employed for the first time in this study. A threshold value of COBALD colour index (CI) for ice clouds is found to be between 18 and 20. Using the data from balloon measurements, statistically significant slope (aerosol-cloud interaction index) of 0.77 is found between aerosol backscatter and cloud particle count. The detailed results shall be presented in the conference.

Keyword: Aerosol-Cloud-Interaction, Aerosol, Balloon-borne in-situ measurements, Cloud.

STUDY OF HEAVY RAINFALL EVENTS OVER DELHI & NCR DURING MONSOON SEASON 2022

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ABSTRACT

Heavy rainfall in Delhi/NCR often leads to water logging in the city and this causes major disruptions in traffic and other day-to-day activities. In this study, heavy rainfall events over Delhi during the month of July 2022 have been studied and the possible reasons for the occurrence of heavy rainfall over Delhi are examined. The rainfall data of Delhi during July, synoptic conditions, convective available potential energy CAPE, satellite images, and wind patterns during the events have been examined.

The prominent features which led to the heavy rainfall event over Delhi on 30th June – 01st July 2022 were the presence of Monsoon trough from north-west Rajasthan to north-east Bay of Bengal, the presence of cyclonic circulation over east Rajasthan, and neighborhood between 3.1 km and 5.8 km above mean sea level, and a trough from above the cyclonic circulation over east Rajasthan to west-central Arabian sea between 3.1 km and 5.8 km above mean sea level.
The prominent features which caused the heavy rainfall event over Delhi on 20th – 21st July 2022 were the presence of the monsoon trough at mean sea level passing through Ganganagar, Rohtak, Hardoi, Dehri, Jamshedpur, Balasore, and thence east-southeastwards to Northeast Bay of Bengal, presence of a western disturbance as a cyclonic circulation over Himachal Pradesh and neighborhood between 3.1 & 5.8 km above mean sea level, and the presence of a cyclonic circulation over Haryana & neighborhood at 1.5 km above mean sea level.

Keywords: Heavy rainfall, Monsoon trough, Convective available potential energy (CAPE), western disturbance, cyclonic circulation

WRF simulations of thunderstorm events with different PBL parameterization schemes over Kerala:

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ABSTRACT

The Planetary Boundary Layer (PBL) has to be precisely represented within the WRF model for a reliable forecast of meteorological parameters within the PBL and regional air quality forecast.WRF simulations of thunderstorm events with different PBL parameterization schemes have been done over the Kerala region to know the sensitivity of PBL schemes in Weather Research Forecasting (WRF) simulation. The simulations are done with ERA5 reanalysis hourly data with 0.25° x 0.25° resolution. The forecasted profiles of parameters like temperature, winds and humidity are validated with radiosonde profiles.ARW v4.4 mesoscale model is used for the forecast. Different local and non-local schemes of first-order closure and one-and-a-half order closure are used for simulation and comparison.

Keywords: WRF , PBL schemes , Thunderstrom.

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NATIONAL EMISSION INVENTORY OF MAJOR GHGs AND ATMOSPHERIC POLLUTANTS FOR INDIA

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ABSTRACT

Air pollution has emerged as a major concern across the globe, where 7 out of 10 world's most polluting cities belong to India. The role of different countries towards the emission of GHGs/pollutants shifts with changing economic conditions, technology, development and lifestyle. In India, understanding emission sources and their quantification is a very complex process due to unorganized sectors. Emission inventory became the most essential national tool and needed to update every year. However, uncertainty in emission inventories is the key problem. The present attempt is first of its kind approach to compiling a GIS-based high-resolution gridded (~10 km or 0.1 deg) emission inventory of major pollutants including GHGs for 2020 which includes all possible major/minor anthropogenic and natural sources like power, transport, industry, paved/unpaved road, aviation, shipping, brick kiln, waste burning, residential, biomass, animal, agriculture etc. Apart from fuel activity data, inventory includes activity data like ~0.62 million village/district data, ~19000 industries, ~1.1 million km major/minor road network, 0.56 million sq km of forest, agriculture area, ~0.9 million points of interest (i.e. Commercial centre/market-malls/hotel/tourist-places/railway-station/hospital/etc.) to improve the spatial allocation of emission. As a case study: National inventory of PM_{10} (2020), the unattended paved and unpaved road dust (4.3 Tg/yr) has emerged as the largest source followed by transport (~1.63 Tg/yr), industry (~1.62 Tg/yr), thermal power plants (~1.4 Tg/yr), residential (~3.6 Tg/yr) and others (~2.9 Tg/yr). Present inventories could be alternative to existing Indian emission data in global inventories. This work is part of the Indo-Norway project of the Ministry of Earth Sciences to support the climate/chemistry model.

Keywords: Emission Inventory, Anthropogenic Sources, Climate change, Climate modelling

ASSESSMENT OF ANTHROPOGENIC EMISSION AND ITS HOTSPOTS IN INDIAN MEGACITY BENGALURU

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ABSTRACT

Air pollution in Indian megacities has been exceeding national and international standards. Indian megacity ‘Bengaluru’ is one amongst them where the identification of sources of air pollutants that contribute to the deterioration of air quality in cities and their spatio-temporal variability has become paramount importance. In this paper, we have made an attempt to develop a high resolution (~0.4 km × ~0.4 km) emission inventory of eight major pollutants for South-Asian megacity Bengaluru for 2020. The study quantifies the emission load from all possible sources in the city using megacity scenarios and bottom-up approach. The estimated annual emissionfor $PM_{2.5}$, PM_{10}, CO, NO_x, SO_2, VOC, BC and OC over Bengaluru are found to be 62.2 Gg/yr, 113.9 Gg/yr, 447.5Gg/yr, 294.5 Gg/yr, 194.9 Gg/yr, 393.8 Gg/yr, 22.9 Gg/yr, and 36.5 Gg/yr respectively. The transport sector remains the dominating source of all pollutants. The unattended anthropogenic sources like windblown roaddust, municipality solid waste burning are emerging sectors in the identified emission hotspots. Both traditionally dominating sectors like transport and industries play an acute role in the deteriorating air quality across the megacity. This developed new surface emission dataset will be a critical tool for air quality study and toframe pollution control strategies.

Keywords: Emission inventory, Anthropogenic sources, Biomass, Air quality, Megacity

IDENTIFICATION AND ASSESMENT OF ANTHROPOGENIC EMISSION HOTSPOTS IN SMART CITY BHUBANESWAR OF EASTERN INDIA

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ABSTRACT

Considering the need to identify the sources of air pollution of Bhubaneswar, which is one among the non-attainment cities of Odisha, a high resolution comprehensive gridded Emission Inventory (EI) of eight primary air pollutants has been developed for the base year 2018. The emission inventory involves detailed activity data with ~0.4 km× ~0.4 km resolution covering the city using Geographical Information System (GIS) based approach technique. In total, ~17 major and minor sectors are responsible for city's air pollution crisis. The major sectors considered here are transport, windblown road dust, industries, residential and others where windblown road dust and transport sector along with residential cooking activities have been found to play a major role in deteriorating the air quality of Bhubaneswar. The estimations for CO, NO_x, SO_2, VOC, $PM_{2.5}$, PM_{10}, BC and OC are found to be 111.58 Gg/yr, 44.41 Gg/yr, 10.58 Gg/yr, 72.84 Gg/yr, 8.89 Gg/yr, 16.51 Gg/yr, 4.61 Gg/yr and 5.09 Gg/yr respectively. The present gridded surface emission dataset is unique in many senses in terms of its application in smart city air quality management and its policy-making competencies for framing new mitigation strategies to combat air pollution crisis, environmental issues and public health measures.

Keywords: Emission Inventory, Air Pollution, Anthropogenic, Air Quality

Signature of irrigation effects on soil moisture simulations over India using Land Information System

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ABSTRACT

Triple collocation (TC) is a method which uses three independent datasets to characterize random errors in model outputs, satellite observations and in-situ measurements. This study employs the TC method to ascertain signatures of the irrigation effects over the Indian region. Two combination of triads were employed in this study, the three members of the first combination having the signature of irrigation effects, and the second combination did have one member without the signature of irrigation effects. The Noah LSM are forced with observed precipitation and surface meteorology. Hence, the soil moisture (SM) values provided by Noah LSMs do not have any signature of irrigation effects. The SM estimated from satellites have the signature of the irrigation effects. Hence, the SM obtained from Noah LSM, when the latter is assimilated with the Advanced Scatterometer (ASCAT) satellite derived SM, will definitely have the signature of the irrigation effects. In this study, the Noah LSM, as available in the Land Information System (LIS) is integrated over the Indian region for the year 2012, first as a Control (CTL) run without assimilation of ASCAT SM and then repeated the run, as an Experimental (EXP) run, the latter after assimilating ASCAT SM. The two other SM datasets, namely, Global Land Evaporation Amsterdam Model (GLEAM), the ESA Climate Change Initiative (ESA CCI) SM data set, that are employed in this study are common to both the first and the second combination of the triads and do reflect the signature of the irrigation effects as they have both assimilated satellite estimated SM. The differences in the correlation between the triads were determined and compared with the irrigation map of India for the year 2012. The results reveal lower magnitudes of correlations with the second combination that employed CTL, GLEAM and ESA CCI SM datasets as compared with the first combination of triads that utilized EXP, GLEAM and ESA CCI SM datasets. The ASCAT assimilated SM exhibits greater squared correlation coefficient values over heavily irrigated areas in the Indian region than the one without assimilation of ASCAT SM. The results provide decisive demonstration of the signature effects of irrigation in the NOAH LSM model output that had assimilated ASCAT SM.

Keywords: Triple Collocation, ASCAT, Soil moisture, GLEAM.

SPATIALLY RESOLVED INVENTORY OF ATMOSPHERIC POLLUTANTS FROM OPEN MSW BURNING IN INDIA

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ABSTRACT

Open burning of Municipal Solid Waste (MSW) is a significant source of GHGs emissions. In both developed and developing countries, MSW mismanagement adversely impacted public health. Most regulating authorities are poorly managing such a large amount of solid waste due to a lack of source segregation of waste, doorstep collection, options for recycling and reuse, technologies for treatment, and disposal methods. These factors play a crucial role in the MSW burning, resulting in elevated emissions. The emission inventories of such sectors critically serve as an input for air quality studies and atmospheric chemistry and climate models. The present work illustrates a national-level emission inventory of MSW burning across India at a finer resolution of 0.1° × 0.1°. The waste generation for 2022 was estimated to be at ~200 million tons in the Indian scenario out of which ~30% is burnt to open. Sixty-five major city emissions have been calculated separately to derive the contribution and emission pattern. The emission data of the Particulate and Gaseous pollutants viz. PM_{10}, $PM_{2.5}$, NO_x, and CO from open burning of MSW have been estimated and spatially allocated in this work. The developed gridded emissions inventory may serve as a critical input to atmospheric chemistry models to quantify its contribution to air quality assessment in various regions of India making a way for policymakers to create better mitigation strategies.

Keywords: Municipal solid waste, Open burning, Emission inventory, Anthropogenic sources, Air quality

CCN CHARACTERISTICS OVER A TROPICAL SEMI-RURAL STATION GADANKI: INFLUENCE OF PRIMARY SOURCES & METEOROLOGY

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ABSTRACT

It is known that the aerosol acts as a Cloud Condensation Nuclei (CCN) and plays a dual role in the formation of cloud as well as in the modification of cloud properties. However, it is important to note that a subset of aerosol only acts as a CCN which depends on their micro-physical properties such as size and chemical composition. Still there exists an ambiguity on the property of aerosol that plays a deterministic role in the activation of cloud droplet. In addition to this, CCN activity also depends on the sources specific to site, season and mixing state of aerosols. Over the Indian region, CCN measurements are reported mainly from coastal, high altitude sites. In the present study, we report CCN measurements from a semi-rural location in the Southern Peninsular India over Gadanki (13.45^{0}N, 79.17^{0}E and 375m AMSL). The sources of aerosol over Gadanki are among vehicular emissions from near by highway, mineral dust from land-use activities, agricultural waste burning, domestic wood burning and forest fires aprart from the long range transport. A DMT CCN Counter is operational from Gadanki since October, 2019. The instrument is operated at all the super saturations (SS in %) from 0.2-1% with an interval of 0.2%. Two years of CCN and collocated data of meteorological parameters, black carbon, CO and solar radition including boundary layer height has been analysed in the present study. Preliminary results shows, the highest values of CCN found in the Pre-monsoon season (March-May) followed by Winter (December-February), Post-monsoon (October-November) and minimum in Monsoon season (June-September) with the mean values of 2708.2 #/cc, 2364.0 #/cc, 2081.6 #/cc and 1163.0 #/cc, respectively. Observed seasonal variation in CCN over Gadanki is related to the bio-mass burning combined with the influence of the solar radiation. Detailed results shall be discussed during the conference.

Keywords : Aerosol, Cloud Condensation Nuclei (CCN), CCN activity, Cloud.

Soil-air interface solver for estimation of evaporation losses from different types of soil

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ABSTRACT

Soil moisture and its interaction with the atmosphere play a vital role in the formation of local thunderstorms. Our study focuses on physical processes at the soil-atmosphere interface and modelling the evaporation from different types of soil surfaces which may help to understand the formation of thunderstorms over different regions. The mass, momentum, and energy conservations are considered into the free flow and across the soil-air interface to understand different aspects of evaporation from different soils (Mosthaf K. et. al., 2014). Soil particles are determined in their textural fractions given by United State Department of Agriculture (USDA). We have considered the soil as a three phase system (solid, liquid, and gas), while only one phase (gas) is defined for the free flow. The movement of the water and vapor is defined by Darcy's law, whereas solid soil particles are considered to be steady during several stages of evaporation. Mass and energy conservation equations are computed inside the soil system. Using two domain approach to model the free flow and porous medium (soil), we have taken Navier-Stokes flow for free flow whereas Darcy's law is considered for the porous medium. Three kinds of equilibriums (mechanical, thermal, and chemical) are elaborated at the sharp and simple interface to couple the free flow and porous medium. The experiment is held at Gadanki (13.4593^0 N, 79.168^0 E), India, which has silty-loam soil type. Results show a gradient of temperature inside the soil during the evaporation stages, while there a drastic change in temperature is found above the soil during the first stage of evaporation which varied less after transformation into 2nd stage.

Keywords: Soil moisture, Evaporation loss, Land-atmosphere modeling.

SENSITIVITY OF ATMOSPHERIC RADIATIVE FORCING AND HEATING RATE TO THE ATMOSPHERIC STATE PARAMETERS OVER A TROPICAL RURAL LOCATION

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ABSTRACT

The interaction of solar radiation with atmospheric constituents exhibit significant impact on the Earth's radiation budget. There has been a substantial increase in the measurement sources (in-situ, satellites, and reanalysis) for defining the atmospheric state in recent years. Although the standard atmospheric conditions are considered most often in the absence of real-time atmospheric profile measurements, the differences in real-time measurements with standard conditions lead to differences in the estimates of atmospheric radiative forcing (RF) and heating rates (HRs) under different background conditions. In this context, this study examines the sensitivity of RF and HRs due to the differences in atmospheric state parameters, namely, pressure, temperature, water vapor density, and ozone density obtained from different sources, namely, standard tropical, in-situ, satellite, and reanalysis datasets over Gadanki (13.48^o N, 79.18^o E) under typical background conditions involving (i) no aerosol, and (ii) with aerosol (or cloud-less) scenarios. In the aerosol-laden scenario, the measured columnar aerosol optical properties were taken apart from the existing default aerosol models (rural and urban) to ascertain the differences in sensitivities of RF and HR. The satellite and reanalysis atmospheric state parameters are found to be less biased with the high resolution in-situ reference measurements whereas considerable biases were observed while considering the standard tropical atmospheric conditions. We found the estimated RF is sensitive to the differences in water vapour density and differences as high as 15 Wm^{-2} is observed under no-aerosol conditions. A deviation ranging from -0.06 to 0.1 $Kday^{-1}$ for HRs under aerosol-laden conditions is found where the estimation is found sensitive to the changes in standard pressure and ozone at higher altitudes (> 20 km). Similar inferences are obtained in this study with the emphasis on using real-time atmospheric states in the atmospheric radiative impact estimations.

Keywords: Aerosols, Sensitivity, Radiative Forcing, Heating Rate

A study on the trend in heavy rainfall events over India during southwest monsoon season.

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ABSTRACT

This study focuses on trend in heavy rainfall events (HRE) over India and its global teleconnections such as El Nino Southern Oscillation and Southern Annular Mode. The trend in frequency of the occurrences of HRE (>95thpercentile) during monsoon is studied using high resolution gridded daily rainfall datasets (IMD) for a period of 40 years (1981-2020). A Significant increasing trend in the frequency of HRE is observed over the west coast (WC) of India, Some parts of Northwest India, Some parts of central India (CI), and Assam region. Trend in HRE during different monsoon months shows varying trends over different parts of country. During June and July, no significant trend is observed in the frequency of HRE. During August, HRE shows a significant positive trend over WC of India. The contribution of rainfall from HRE to the mean rainfall is found to be increasing significantly over WC during August. The mean rainfall during August is significantly increasing over northern part of WC, while it is significantly decreasing over southern part of WC. It indicates the southern part of the WC is a favoured location for the occurrence ofHRE in August. During September, both the mean rainfall and the frequency of occurrences of HRE shows an increasing trend over WC of India. The correlation analysis between the monthly HRE (JJAS) and monthly Nino 3.4 SST index as well as monthly HRE and Southern Annular Mode (SAM) index from April to September is done as a part of this study. The results reveals that the SAM index during April is significantly correlated with the August month rainfall over Kerala region and along the broad region from Andhra Pradesh to Gujarat, which lies to the south of monsoon trough. The HRE over WC during September month is negatively correlated with the August month Nino3.4 SST.

Keywords:

CAUSES OF UNPRECEDENTED DEFICIT INDIAN MONSOON RAINFALL DURING JULY 2020: SUB-SEASONAL VARIATIONS IN IPOC MODE

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ABSTRACT

The Indian summer monsoon (ISM) seasonal mean rainfall is above-normal in 2020 with 109% of its long period average. However, the monthly mean rainfall anomalies of 2020 display unique sub-seasonal rainfall variations. In particular, the peak monsoon month of July 2020 experienced peculiarly deficit rainfall despite the presence of La Niña-like conditions that affected agricultural production and caused economic losses. The present study investigated the underlying aspects that are accountable for the unusually decreased rainfall in July 2020 over the Indian subcontinent. In observations, the primary reason responsible for reduced rainfall over the monsoon trough region in July 2020 is the intensified Western North Pacific (WNP) low-level anomalous anticyclone related to the Indo-western Pacific Ocean capacitor (IPOC) mode. It causes strong low-level moisture divergence corroborated with westward propagating atmospheric cold Rossby wave as a response to suppressed convection over the WNP. The tropical Indian Ocean (TIO) sea surface temperature (SST) warming-induced atmospheric Kelvin wave and strong low-level convergence over the Meiyu-Baiu rainband region due to mid-latitudinal circulation adjustments caused the southwestward shift of the WNP anticyclone. Unlike in July 2020, the strength of the WNP anticyclone and TIO warming are weaker in other summer months resulting in restricted IPOC impact on ISM rainfall. The predictability of 2020 ISM rainfall is examined using the National Centers for Environmental Prediction (NCEP) Climate Forecast System version-2 (CFSv2) hindcasts and real-time forecast from the North American Multi-Model Ensemble (NMME) project. Month-to-month variations in ISM 2020 rainfall are not well predicted by CFSv2 as it failed to represent the westward extension of the WNP anticyclone. NMME models also could not predict anomalous low rainfall over the monsoon trough region during July 2020. Furthermore, the CFSv2 sensitivity experiment affirms the role of WNP anticyclone in influencing the during July 2020 rainfall over the monsoon trough region.

Keywords: Indian Summer Monsoon Rainfall, Western North Pacific anticyclone, Tropical Indian Ocean, Precipitation, IPOC mode.

The Characteristics of Tropical Depressions Affecting India in Various Seasons

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ABSTRACT

Low-pressure systems in the tropics like a low pressure area, depressions and tropical cyclones are associated with intense rainfall and thus are a topic of interest. It is significant to understand the structure and the characteristic features of these low pressure systems. In the past, the structure of the depressions mostly over the land occurring during the monsoon season has been studied to a greater extent from which some peculiar features like a cold core at the low levels are observed. We wanted to know whether the same characteristics are present in the depressions occurring over the ocean during pre and post monsoon season which is the aim of this study. The structure of the depressions over the Bay of Bengal in the pre-monsoon, monsoon, post-monsoon and that over the land region during the monsoon is compared in this study from its genesis till dissipation. Here, several variables at multi-pressure levels are studied. ERA5 reanalysis data are used for each case and the horizontal and vertical structure of each system is studied. A warm core above the cold structure is observed in the case of the pre-monsoon and land depression, while a warm core structure extends up to a relative upper level in the case of monsoon and post-monsoon. During the intensification of the system, a significant increase in the intensity of the vorticity is observed in all the cases. The same study is carried out using recently launched reanalysis data IMDAA and NGFS by NCMRWF. We found that the obtained structure is sensitive to some extent to the reanalysis datasets utilized.

Keywords: Tropical depression, Vertical structure, Bay of Bengal, Rainfall

Turbulent flux transfer and coherent structures in ASL

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ABSTRACT

This study investigates the structure of momentum, turbulent kinetic energy (TKE), and scalar fluxes like heat, CO2, and H2O in the atmospheric surface layer (ASL) at the coastal station on the west coast of southern peninsular India. The transport efficiency and dissimilarity between fluxes are studied as a function of stability during the monsoonal season. The transport efficiency for heat and momentum fluxes shows a strong dependence on stability (ζ). However, the passive scalars (CO2 and H2O) do not show dependence on stability. The dissimilarity between momentum and heat flux and between CO2 and H2O is influenced by stability. Quadrant-Hole (QH) analysis is employed to study the contribution of different fluid motions to the aforementioned turbulent fluxes. Except for CO2 and H2O, where all the quadrants have an equal contribution, ejections (Q2) and sweeps (Q4) are found to be the dominating contributors in the case of momentum and heat fluxes as well TKE. The dominance of ejection and sweep cycle for turbulent fluxes and TKE provide direct evidence of the presence of organized structure in ASL. The contribution from these organized structures needs to be included in the present ABL models.

Keywords: Atmospheric surface layer · Physical Processes · Qudarant-hole ·Turbulent fluxes

Land Ocean Thermal Contrast over the Indian Sub-conditinent:Depiction through Observation

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ABSTRACT

Considering the present warming scenario and changing monsoon circulation, the present study aims to elucidate the pattern and change in Land Ocean Thermal Contrast (LOTC) over the Indian sub-continent. To define the land and ocean area, the present study has considered the region bounded by 26° N to 40° N and 70° E to 95° E (land region) and 15°S to 5° N and 52° E to 95° E (ocean region). The study has been done by analysing Sea surface temperature (SST), 2 metre air temperature and the Tropospheric temperature (TT). TT has been defined as temperature averaged over 600 hPa to 200 hPa. Study analysed LOTC data during pre-monsoon months to understand change and variability in thermal gradient between Land and Ocean over Indian subcontinent before Indian Summer Monsoon (ISM). Present study utilized data from ERA5 and IMDAA reanalysis. Study includes assessment of change in temperature field through trend and composite analysis. Analysis shows a significant decreasing trend of land-ocean thermal contrast in which contribution of land and ocean differs. The trend of 2m temperature provides details about the surface layer while TT can provide details about deep tropospheric heating sources. LOTC with Deep TT is observed to decline significantly around 1960 while LOTC with surface temperature declined around 1980. Hence it is evident that deep source of heating has reduced before than shallow heating. However, surface temperature shows significant long-term declination while TT manifests long as well as short term declination. Land Ocean coupling shows a significant decadal variation. Study also analysis the impact of ocean warming on both deep convection and shallow convection.

Keywords: *Land-Ocean Thermal Contrast. Sea Surface Temperature. 2 metre Temperature. TT, Variability, Trend*

IMPACT OF REGIONAL TRASNPORT ON TOTAL OX (NO_2+O_3) CONCENTRATIONS OBSERVED AT A TROPICAL RURAL LOCATION

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ABSTRACT

In general, local emissions and long-range transport will dictate the pollution levels over a given place. The former source will be based on the location whether it is urban/rural but there are no boundaries to the latter source. During most of the time in a year, long-range transport will decide the pollution levels. Here we present the experimental evidence for regional (long-range) transport impacts on the total OX (NO_2 + O_3) concentration at a tropical rural location. Two major independent events of the year 2020 in India, the COVID-19 lockdown and Deep depression in Bay of Bengal (BoB2) have been used to demonstrate the known fact of mixing of aged and freshly emitted ozone precursors on the total OX concentration and their influence on observed total OX. COVID-19 lockdown event happened in the summer season whereas the BoB2 event happened during the post-monsoon period. It has been found that they have contrasting impact on the observed OX at the observational site. Further, total OX observed has no local contribution and is controlled entirely by the regional contribution. These observations have been well supported by the CWT analysis and wind circulation patterns during the events. This study provides a clear demonstration of the regional pollution transport influence on the total OX at a rural environment (which control the oxidative capacity of the rural atmosphere). Thus, caution is advised in designating the location as rural/urban based on local emissions alone.

Key words: OX concentration, COVID-19, Depression, Long-range transport, PSS, Leighton Ratio, CWT.

Three-dimensional structure and variability of double-ITCZ over tropical oceans: Decadal observations using CloudSat and CALIPSO

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ABSTRACT

Intertropical convergence zone (ITCZ) is the most prominent feature of the tropical troposphere. The ITCZ over tropical oceans often have a double band structure straddling the equator (DITCZ). Horizontal structure and characteristics of DITCZ were investigated in the past using satellite observations of clouds, precipitation, outgoing longwave radiation and surface winds, which showed its most prominent occurrence over the western and central Pacific and the Atlantic oceans during April-May. However, studies on the vertical structure of DITCZ based on observations are extremely sparse. Such observations are essential for validation of general circulation models, which generally show a DITCZ bias, as well as for assessment of the feedback effect due to differential atmospheric heating by clouds. These aspects are addressed in the present study based on over a decade (2006-2018) of observations using the spaceborne radar and lidar, CloudSat and CALIPSO, which provide a unique opportunity to investigate the vertical structure of DITCZ on the basis of the global 3-dimensional distribution of cloud occurrence and cloud water content. During the peak occurrence of DITCZ in April-May, the northern and southern bands of the DITCZ appear as meridionally confined walls (3 to 7° on either side of the equator) of frequent cloud occurrence: over the western and central Pacific and the Atlantic, the northern band extends up to about 16 km and has significantly more frequent cloud occurrence compared to the southern band which generally extends only up to ~8 km and is capped by the outflow from the northern band. The net cloud heating in the DITCZ bands and the distinctly lower heating over the equator would induce equatorward flow and convergence in the middle troposphere over the equatorial band; the resulting downdraft would further inhibit convection in the equatorial middle troposphere and aids the sustenance of DITCZ.

Keywords: Double-ITCZ, Remote Sensing of clouds, Cloud heating rate, CloudSat

Water Budget and It's Relation with Extreme Precipitation Over Alaknanda River Basin

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ABSTRACT

The extreme precipitation is one of the major challenges for mountainous region. Very Less research has been reported on the relationship between extreme weather/climate and water budget. The most of the studies has been reported on water budget only, thereafter present study will fill the gap for better understating for weather/climate extreme and water budget relationship. The water budget can be controlled by various factors such as total evaporation (TE), soil-water (Sw), total precipitation (TP) and total runoff (TR) variation of a microclimatic region, specially having rough topography. This study is the assessment of the water budget of the Alaknanda River basin (using ERA5 reanalysis data for 1981-2020), which is the major tributary of the Ganga River feeding to the most populated region of the India. The temporal trends of total precipitation for the period 1981 to 2020 is found negative over north-western part of Alaknanda River basin, however southern part is positive (similar for total runoff) whereas, the opposite is found for the total evaporation and soil-water. The storage (ΔS) has been calculated as input minus output (TP – Sw – TE – TR = ΔS). In addition to this the storage is observed negative trend over entire basin (except northern-most region) with range value -20 to -60 mm/year. Moreover, the consecutive dry days (CDD) is found to be increasing over lower part of the basin with precipitation extremes. The strong correlation (temporal; negative and spatial; positive) between extreme precipitation and storage is observed. A strong negative correlation is seen for CDD and extreme precipitation. The EOF1, 2 and 3 suggests very high variability in all the hydrometeorological variables used for the hydrometeorological water budget. Empirical Orthogonal Function (EOF) analysis for the annual total evaporation (EOF1: 21.8%, EOF2: 8.7% and EOF3: 4.4%), total runoff (EOF1: 78.3%, EOF2: 9.7% and EOF3: 7.1%), total soil-water content (EOF1: 14.1%, EOF2: 7.1% and EOF3: 1.9%), and total precipitation (EOF1: 72.1%, EOF2: 7.2% and EOF3: 5.4%) has been observed.
Keywords: Weather/climate extremes, Water budget, Storage and Microclimate.

IMPACT OF LOCKDOWN ON THE ATMOSPHERIC PROCESSES: AN OVERVIEW

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ABSTRACT

The lockdown measures that were taken to combat the COVID-19 pandemic minimized anthropogenic activities and created natural laboratory conditions across the globe for investigating several atmospheric processes. Its impact is not only seen on the surface air pollution but extended to dynamic and thermodynamic processes. Inorder to see effect on these processes, quality observations from the surface, ground-based and space borne observations are utilised. Since these observations do not provide all the atmospheric parameters, WRF model simulations are also performed. Before using these simulations, they are validated/compared with ground based and satellite measurements. Both observations and WRF-Chem simulations show a 20–50% reduction (compared to pre-lockdown and same period of previous year) in the concentrations of most aerosols and trace gases over Northwest India, the Indo Gangetic Plain (IGP), and the Northeast Indian regions. It is observed that this was mainly due to a 70–80% increase in the height of the boundary layer and the low emissions during lockdown. However, a 60–70% increase in the pollutants was observed over Central and South India including Arabian sea and Bay of Bengal during this period, which is attributed to natural processes. Elevated (dust) aerosol layers are transported from the Middle East and Africa via long-range transport, and a decrease in the wind speed (20-40%) causes these aerosols to stagnate, enhancing the aerosol levels over Central and Southern India. A 40–60% increase in relative humidity further amplified aerosol concentrations. Effect of the lockdown is also seen on the convective processes. Our results suggest that besides emissions, natural processes such as background meteorology and dynamics play a crucial role in the pollution concentrations over the Indian sub-continent. COVID-19 provided an opportunity to test this hypothesis by ceasing all major anthropogenic activities, providing the background for a large-scale natural laboratory experiment.

Keywords : COVID-19 lockdown, air pollution, boundary layer proceses, impact on weather.

STUDY OF THE CORRELATION BETWEEN METEOROLOGICAL PARAMETERS AND AIR POLLUTANTS OVER DELHI & NCR

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ABSTRACT

Delhi & NCR is one of the most polluted regions in the world with aggravated levels of air pollution according to the World Health Organization (WHO). It is one of the most densely populated and industrial regions in the world and hence a major source of aerosols and other gaseous air pollutants. The geographical terrain of the area is also such that it facilitates the build-up of air pollutants particularly during dry winter season characterized by low temperatures, low surface wind speed & direction, shallow atmospheric boundary layer, and strong inversion all leading to build up of pollutants. Accurate statistical modelling of pollution levels for the region has been challenging due to uncertainties associated with emissions, confounding influence of meteorology on air pollution, and unique topography.

In this study, we have studied the relationship between aerosols, gaseous pollutants, and meteorological parameters like temperature, relative humidity, wind speed and visibility. The trend analysis between these meteorological parameters and various pollutants has been determined using the non-parametric Sen's slope and Mann Kendall (MK) test at a 5% significant level from 2019 to 2021(during post monsoon and winter season). Linear and non-linear Regression modelling has been done to predict AQI based on the correlation of two time series–dependent variables for air pollutants and meteorological parameters. We have collected the air pollutant data from Central Pollution Control Board and meteorological dataset from India Meteorological Department for these years.

It has been observed that there is a strong correlation of various air pollutants e.g, PM 2.5, PM 10 with these meteorological parameters. This dependency will further help to predict AQI which will be helpful for welfare of the nation and create awareness in public about the degradation of air quality and concerned health issues.

Keywords: Air Pollutants, Relative Humidity, Temperature, Mann Kendall, Time series

Characteristics of Hail Storms using Doppler Weather Radar and reanalysis over Kolkata

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ABSTRACT

Severe thunderstorms are important part of the tropical mesoscale convective systems (TMCS) that needs to be identified and forecasted because of the significant fatalities and damages (e.g., hail,strong surface winds or squall lines) they cause. During pre-monsoon, severe local convective storms occur over the Indo-Gangetic plain and Northeast India commonly known as 'Nor'westers or Kal-baisakhi in local Indian language. They are MCS which can develop under the large-scale envelope of the seasonal, low-level trough over the West Bengal – Bihar – Jharkhand belt, with a possible embedded low-pressure area. These thunderstorms can develop into squall lines and results in hail and heavy rain. The present study deals with the characteristics of convective storms that result in the formation of hail. Hail storms are identified using IMD weather reports and the corresponding data from the Doppler Weather Radar (DWR) data during the pre-monsoon period over Kolkata are analyzed. The analysis shows in most of the cases non-linear convective storms that have maximum reflectivity greater than 50 dBZ resulted in the formation of hail. The convective area of hail causing convective storms is found to be >1000 km^2. The probability of hail, Foote-Krauss criteria and the vertically integrated mass of hail also support the occurrence of hail. Strong convergence at the lower levels and divergence at the upper levels, inflow of moisture flux from the BoB, high values of Convective available potential energy are observed during each hail event. The details will be presented in the upcoming conference.

Keywords: 'Nor'westers, Reflectivity, Squall lines, Hail storms, Weather Radar

STRATOSPHERIC AEROSOL LAYER CHARACTERISTICS OF THE 2018 AMBAE VOLCANIC ERUPTIONS AS OBSERVED BY SAGE III/ISS

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ABSTRACT

Volcanic eruptions can impact global climate, reducing the amount of solar radiation reaching the Earth's surface, lowering temperature in the troposphere and changing atmospheric circulation patterns. In this study, two moderate volcanic eruptions at Ambae (15°S, 167°E), Vanuatu, in April and July 2018 are considered with observations from the Stratospheric Aerosol and Gas Experiment III on board International Space Station (SAGE III/ISS). An inversion method for the retrieval of number and volume size distributions along with other microphysical parameters from the spectral stratospheric aerosol optical depths (sAOD) values. The observational time period was classified into four different phases (pre-Ambae, Ambae1, Ambae2, and post-Ambae) in three regions (Global, Southern and Northern Hemispheres denoted as SH and NH, respectively) and two zonally averaged (along all longitudes) regions covering Gadanki (13.47°N, 79.18°E; 10°-20°N) and Ambae (10°-20°S). The role of the different wavelengths on the amplitude of the first mode and the shape of the second mode, volume size distributions are found to be interesting. The steepness in the spectral behavious of sAOD values increased during Ambae1 and Ambae2 periods due to increased concentrations of smaller size particles under the prevailing dynamical and transformation processes in different regions. The shapes (first and principal modes) of the number size distribution is very similar for retrievals using spectral sAOD values between pre-Ambae, Ambae and post-Ambae periods in respective regions. The geometric width and median radii do not really differ, only the total concentration varies. Further details related to the relationship between Angstrom exponent and effective radii, growth and decay phases of stratospheric aerosol loading on sAOD in different regions will be presented.

Keywords: Volcanic Eruptions, Stratospheric Aerosols, Size Distributions, Climate Change

Predictability of an Extreme Weather Event over the Indian Subcontinent using Sensitivity Analysis in EnKF Data Assimilation System

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ABSTRACT

In recent decades, extreme weather events have increased considerably in the context of changing climate. the changing climate. Therefore, it is essential to understand the key processes that lead to such events and quantify their predictability characteristics. Ensemble Sensitivity Analysis (ESA) is identified as a tool to understand the predictability associated with severe weather events. The optimal ensemble system required for the ESA is generated using an Ensemble Kalman Filter (EnKF) Data Assimilation system. The current study outlines general predictability characteristics of Tropical cyclones over the Bay of Bengal. Initial results indicate that intense, fast-moving, and north-landfalling exhibits low predictability than weak, slow-moving, south-landfalling tropical cyclones. Detailed results will be presented in the conference.

Keywords: Numerical Weather Prediction, Data Assimilation, Predictability of Weather

The outflow of Asian biomass burning carbonaceous aerosol into the UTLS in spring:

Radiative effects seen in a global model

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Abstract

Biomass burning (BB) over Asia is a strong source of carbonaceous aerosols during spring. From ECHAM6-HAMMOZ model simulations and satellite observations, we show that there is an outflow of Asian BB carbonaceous aerosols into the Upper Troposphere and Lower Stratosphere (UTLS) (black carbon: 0.1 to 6 ng $m^{-3}$and organic carbon: 0.2 to 10 ng m^{-3}) during the spring season. The model simulations show that the greatest transport of BB carbonaceous aerosols into the UTLS occurs from the Indochina and East Asia region by deep convection over the Malay peninsula and Indonesia. The increase in BB carbonaceous aerosols enhances atmospheric heating by 0.001 to 0.02 K d^{-1}in the UTLS. The aerosol induced heating and circulation changes increase the water vapour mixing ratios in the upper troposphere (by 20-80 ppmv) and in the lowermost stratosphere (by 0.02-0.3 ppmv) over the tropics. Once in the lower stratosphere, water vapour is further transported to the South Pole by the lowermost branch of the Brewer-Dobson circulation. These aerosols enhance the in atmosphere radiative forcing (0.68±0.25 W $m^{-2}$to 5.30±0.37 W m^{-2}), exacerbating atmospheric warming but produce a cooling effect on climate (TOA: -2.38±0.12 W $m^{-2}$to -7.08±0.72 W m^{-2}). The model simulations also show that Asian carbonaceous aerosols are transported to the Arctic in the troposphere. The maximum enhancement in aerosol extinction is seen at 400 hPa (by 0.0093 km^{-1}) and associated heating rates at 300 hPa (by 0.032 K d^{-1}) in the Arctic.

Estimation of crop water requirement and irrigation schedule of rice over Andhra Pradesh -Past, Present and future

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Abstract

Climate change is largely affecting rice production due to changes in rainfall and temperatures around the world. An irrigation schedule required a lot of time and effort but in recent times the computer applications are available to provide precise irrigation schedule based on the crop water requirement. The present study focuses on the estimation of crop water requirement and irrigation schedule for past, present and future time slices namely pre industrial period (1961- 1990), global warming period (1991-2017), near future (2021-2030), mid future (2031-2060) and far future (2061-2090) for all 13 districts of Andhra Pradesh. Krishna, Srikakulam, Visakhapatnam and Vizianagaram show total gross irrigation (TGI) around 200 mm for the far future. Except for the Nellore district (843.1 mm), all other districts show a reduction in TGI from the pre-industrial period compare to the far future. Except for Kurnool and Nellore, all other districts have surplus water available to meet irrigation requirements. Anantapur, Kadapa, Kurnool, Nellore and Prakasam show high total gross irrigation between 777 mm to 993 mm for the far future but except for Anantapur (19.3 mm). Potential water use by the crop (PWUC) was the same as that of actual water use by the crop (AWUC) as there was no limitation in the availability of water required by the crop. The present study will be useful for the efficient management and planning of irrigation water demands of rice in Andhra Pradesh.

Keywords: Climate change, Irrigation schedule, Rice production, Actual water use, Potential water use

METEOROLOGICAL ANALYSIS OF EXTREMELY HEAVY RAINFALL EPISODES OVER GUJARAT, MAHARASHTRA, TELANGANA AND COASTAL KARNATAKA DURING 7-13 JULY, 2022

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ABSTRACT

Rainfall distribution and the pattern of extreme high/low precipitation is very important for agriculture and the economy of our country. Understanding, the rainfall distribution is equally important for necessary planning purposes. It is well established that rainfall is the principal phenomenon driving for many hydrological extremes such as floods, droughts, landslides etc. During the southwest monsoon season, in India many heavy rainfall evets recorded each year. Therefore, meteorological analysis of such impact full heavy rainfall events is very important for further knowledge enhancement of operational forecaster. Second week of July, 2022 witnessed persistent heavy rainfall episode over Gujarat, Maharashtra, Telangana and coastal Karnataka. As per media reports, this led to localized flooding over these regions. As per rainfall data India Meteorological Department (IMD), heavy to very heavy rainfall with extremely heavy rainfall at isolated places had occurred over Gujarat Region on five days; over Saurashtra & Kutch, Konkan & Goa, Telangana and Coastal Karnataka on three days each; over Madhya Maharashtra, Vidarbha on 2 days each during the period of 7-13 July, 2022. This goal of this paper is to study the meteorological parameters, associated synoptic systems, dynamic and thermodynamic parameters responsible for such persistent heavy rainfall episode over these regions during the period of study.

Keywords: Heavy Rainfall, Southwest Monsoon

High elevated regions of Western Ghats are getting more and more wet

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ABSTRACT

The west coast of India consists of topography having elevation ranging from regions located few meters below mean sea level to more than two thousand m above mean sea level on the peak of the windward side of the Westen Ghats (WG). West coast is one of the heaviest rainfall receiving regions in India during Indian summer(southwest) monsoon (June - September). A comprehensive understanding of the spatio-temporal trends of rainfall events over the complex topography of the windward side of WG is rather crucial for reducing the risk associated with frequent occurrences of extreme precipitation events. The relationship between rainfall characteristics and elevation in this region still remains less explored. Using the IMD gridded rainfall data for the period of 1972-2021, this study examines the changes in the rainfall characteristics in 4 different elevation zones of WG. The seasonal mean rainfall during the southewest monsoon season shows an increasing trend on the windward side of WG particularly above 500 m elevation. The number of extreme rainfall events exhibits an rising trend in all 4 zones, in particular significant over the elevations between 500 and 800 m, while other elevations are influenced by light and moderate rainfall events. Further, the areal extent that receives extreme rainfall is also found to show an increase in all considered zones. This study highlights that there is a clear dependency of rainfall with different elevations and higher elevations in the WG region are getting more and more wet in a warming climate.

Keywords: Climate change, Extreme rainfall events, High elevated regions, Western Ghats, Rainfall trend

RECOGNITION OF SATELLITE CYCLONE IMAGES OVER BAY OF BENGAL AND ARABIAN SEA USING HYBRID COLOR FEATURES AND MACHINE LEARNING ALGORITHMS

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ABSTRACT: For the purposes of weather prediction modelling, satellite imagery is a crucial input.Employing Machine-learning algorithms for recognition of satellite cyclone cloud distribution is possible by retrieving colour features from various images of visible and infrared pictures of satellite.The development of more effective automatic image processing systems is achievable with a learning-based approach.That can be used in many different contexts.Annotated data with a range of different attributes must be available for training and testing.It will produce better weather prediction outcomes.Utilizing data augmentation techniques has enhanced character diversity and temporal resolution.Machine-learning algorithms for satellite image categorization and recognition has demonstrated more successful results.In this paper,we show how Hybrid features were used to categorise satellite images of cyclones in the Arabian Sea and Bay of Bengal seas (BoB).The dataset consists of infrared and visible spectrum images of Cyclone Nisarga,Cyclone TaukTae,Cyclone BoB,Cyclone Yaas,Cyclone Bureive,Cyclone-Gulab,Cyclone Jaawad etc.,Further,results were plotted using Confusion matrices for comparative purpose. Also,Validation Accuracies of 99% were achieved using multiple Classifiers during evaluation phase.

Keywords: Classification, Confusion Matrix, Precision,Accuracy,NVIDIA-Graphic card 1050.

VARIABILITY OF TROPICAL CYCLONES AND THE IMPACTS OF ITS DERIVATIVES IN SOCIAL LIFE

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ABSTRACT

Every year, cyclones affect dozens of countries around the world. Though a lot of deaths and destruction is caused by the winds, however the greatest damage to life and property is caused due to the massive piling of sea water in the form of what is known as storm surge that lead to sudden inundation and flooding of coastal region. Here an endeavor is made to show how storm surge is related to maximum wind speed of tropical cyclone over the Bay of Bengal and Arabian Sea. Also a special case of cyclone "AILA" has been discussed, which is an exception to the trend. The variability of cyclone with respect to CAPE and CINE have been analyzed and the impacts of their derivatives have been discussed which has immense application in social life and to the Natural Disaster Management Authority in India.

Keywords: Surge height, inundation, CAPE, CINE.

A role of Southern Oscillation in the formation of Cyclonic Systems over BoB, Arabian Sea and Land-In Recent trends

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ABSTRACT

Southern Oscillation is a naturally occurring phenomenon; it has a major influence on climatic conditions in various parts of the world. Bjerkenes (1969) pointed out Southern Oscillation is strongly coupled with sea level pressure between the equatorial eastern and western Pacific Ocean, Pant and Parthasarathy (1981) documented the relevance of the southern oscillation changes for the Indian summer monsoon. In forgoing studies, it is concluded that the climatic conditions of India have been associated with the atmospheric changes that occur over BoB, Arabian Sea, and Land.

In the present study, an investigator has emphasied finding the number of formations of cyclonic circulation (Cyclonic Depressions, Cyclone & Severe Cyclonic Strom) over BoB, Arabians Sea, and Land and its tendency. The concerned data for the year 1965-2021 was categorised and tabulated in the form of El-Nino, La-Nina and other years. The data has been graphically arranged in different cyclonic systems wise to analysis the objectives.

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Keywords: Southern Oscillation (SO), El-Nino & La-Nina, Cyclonic Systems(CD,C,SCS)

Heat wave during summer 2022 – How its severity differs as compared to other years

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ABSTRACT

Among the extreme events, heat wave and severe heat wave usually commences from March till May in each year. Sometimes, it is associated with health hazards in human as awell as in dometic animals. However, heat wave and severe heat wave conditions were acute in various parts of the country during 2022. This may be very likely due to very less rainfall during summer season especially over northwest, west and central India due to lack of rain bearing systems. As a result, the heat wave and severe heat wave were unique in nature during summer 2022 as compared to the last two years. This prompted the authors to undertake the study.

In the present paper, the data during the period for past few years were studied and analyzed. The study revealed that the areas and districts of central India, Madhya Maharashtra, Konkan – Goa, coastal areas of Saurashtra-Kutch and Gujarat region, Jammu division, Delhi, Haryana, Himachal Pradesh, Odisha, Bihar, Jharkhand, Gangetic West Bengal, Punjab were affected due to heat wave / severe heat wave conditions during summer 2022 in different months which are analyzed and discussed in the paper. The various categories of heat wave, severe heat wave, based on (i) actual temperature ≥ 40° C for plains, ≥ 37° C for coastal region and ≥ 30° C for hilly region and departure (4.5° C to 6.4° C or > 6.4° C), (ii) actual temperature only (≥ 45° C or ≥ 47° C).

The continuous period of heat wave and daily hours of (duration) temperature more than 45° C or above have been analyzed to identify the severity of the extreme events. The absence of rain bearing systems was prominent during the summer of 2022. The major reason for the severity in temperature was due to lack of summer rainfall over the region which resulted in dry soil especially over northwest, western and central parts of India. The paper highlighted the high values of positive temperature departure (i. e. actual-normal) over country during summer 2022 and the reason for less rainfall.

Key words – Heat wave, extreme temperature, summer, severity, affected areas.

Analysis of extreme weather events over the NE-Region of India using WRF, DWR and Satellite data.

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ABSTRACT

Extreme weather events like thunderstorms and heavy rainfall cause damage to properties and forests. Also, these events can be life-threatening and are responsible for the deaths of many humans and wild animals annually. In this context, analysis of these events is essential to understand their characteristics and accurately predict them. In this study, we represent the analysis of a few selected extreme weather events using a high-resolution model WRF and observations from Doppler Weather Radar (DWR), Satellite and ground-based lightning sensor data. The selected events occurred over parts of India's North-East (NE) region during the pre monsoon of 2022. Thunderstorms, lightning and heavy rainfall, were associated with all the events which caused property damage and loss of life. One such event occurred in the Nagaon district of Assam on 12th May 2021, where the deaths of 18 elephants were reported due to lightning strikes associated with the event. Other events were reported from the Tura district of Meghalaya on 5th May 2021 and from the Umiam district of Meghalaya on 24th May,2022. Genesis and propagation of these events were analysed using DWR, Satellite and ground-based lightning detectors. Most of these extreme weather events resulted from cumulonimbus clouds, which are brought to the event location through westerly winds, except in the Nagaon event where the system originated locally. Also, simulations of characteristic features of these events like wind velocities, precipitation, cloud liquid water content, and radar reflectivity were done using the WRF model. These simulated parameters were then compared with observations and ERA-5 reanalysis data. In most cases, WRF simulations were in agreement with the observed and reanalysis data. However, the temporal lags of one hour were seen in a few of the simulated results.

Keywords: INSAT-3D, DWR, Thunderstorms, Lightning, Cumulonimbus Cloud

Analysis of extreme weather events over the NE-Region of India using WRF, DWR and Satellite data.

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ABSTRACT

Extreme weather events like thunderstorms and heavy rainfall cause damage to properties and forests. Also, these events can be life-threatening and are responsible for the deaths of many humans and wild animals annually. In this context, analysis of these events is essential to understand their characteristics and accurately predict them. In this study, we represent the analysis of a few selected extreme weather events using a high-resolution model WRF and observations from Doppler Weather Radar (DWR), Satellite and ground-based lightning sensor data. The selected events occurred over parts of India's North-East (NE) region during the pre monsoon of 2022. Thunderstorms, lightning and heavy rainfall, were associated with all the events which caused property damage and loss of life. One such event occurred in the Nagaon district of Assam on 12th May 2021, where the deaths of 18 elephants were reported due to lightning strikes associated with the event. Other events were reported from the Tura district of Meghalaya on 5th May 2021 and from the Umiam district of Meghalaya on 24th May,2022. Genesis and propagation of these events were analysed using DWR, Satellite and ground-based lightning detectors. Most of these extreme weather events resulted from cumulonimbus clouds, which are brought to the event location through westerly winds, except in the Nagaon event where the system originated locally. Also, simulations of characteristic features of these events like wind velocities, precipitation, cloud liquid water content, and radar reflectivity were done using the WRF model. These simulated parameters were then compared with observations and ERA-5 reanalysis data. In most cases, WRF simulations were in agreement with the observed and reanalysis data. However, the temporal lags of one hour were seen in a few of the simulated results.

Keywords: INSAT-3D, DWR, Thunderstorms, Lightning, Cumulonimbus Cloud

Simulation of track and intensity of Tropical Cyclone Chapala over Arabian Sea, impact of Vortex Initialization

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ABSTRACT

Present study evaluates the impact of vortex initialization scheme within the NCMRWF for simulation of tropical cyclone (TC) formed over Arabian Sea (AS). For this purpose, two numerical experiments such as control simulation (CNTL) without using vortex initialization scheme and VOTX simulation using the vortex initialization scheme are performed by considering TC Chapala formed over AS basin from 28th October 2015 to 4th November 2015. The results suggest that even though TCs are large synoptic system, the introduction of vortex initialization scheme has a positive impact on the prediction of the location, movement, intensity and development of rain bands associated with the TC. Study results provide a positive proof of concept that the vortex initialization scheme can help to improve the simulation of track and intensity of TCs over Arabian Sea.

Keywords: Tropical cyclone, Vortex initialization, Chapala, Rain bands.

Predictability Assessment of South-West Monsoon Rainfall in India Using Intra Seasonal Oscillation Data Through Statistical and Machine Learning Techniques

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ABSTRACT

For an agrarian country like India, monsoon rainfall is highly desirable for its socio-economic growth. Thus, prediction of the southwest monsoon is beneficial for the development of the country. Intraseasonal oscillations are known to play an important role in modulating the monsoon intensity seasonally and interannually. In this study south-west monsoon rainfall is predicted over various regions of India and for various months within monsoon season (JJAS) using machine learning tools from intraseasonal oscillations. For the prediction of south-west monsoon, intra seasonal oscillation data over three ocean basins (AS, BoB and IO) are used as predictors by linear regression (LR), Artificial Neural Network (ANN), and Genetic programming (GP) methods. Outgoing long wave radiation (OLR) data from National Oceanic and Atmospheric Administration (NOAA) is used to quantify ISOs, rainfall data from India Meteorological Department (IMD) is used as output. For the machine learning technique 1979-2009 is used as the training dataset and 2010-2021 is used as the testing dataset. The performance of these models was analysed by different statistical methods and found that GP predicts better than ANN and LR techniques. According to the findings of this study, ISO data has the potential to be used as a predictor of South-West monsoon.

Keywords: Tropical cyclone, Vortex initialization, Chapala, Rain bands.

Changing spatio-temporal variability of Heat waves over India during the present and futureclimate

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ABSTRACT

Recent studies indicate an increase in heat wave occurrences, attributable to global warming. Heat waves leads to severe illness sometimes death. Also persisting heat wave conditions (i.e.) higher temperature may affect livestock. In this study, the frequencies of the days having different (above 40C, 42C, 45C) maximum temperature limits in Pre-monsoon season over India are evaluated using the grid-point maximum temperature data ofIndia Meteorological Department [IMD] for the period 1951–2022.The frequencies of Heat wave events will be computed for the individual months of March, April and May and the season as a whole (MAM). In the future climate change is considered to be one of the greatest environmental threats to the world, and the changes in climate extremes are estimated to have greater negative impacts on human society and the natural environment than the changes in mean climate. This study presents the projections of future changes in extreme temperature events under CMIP6 future models using the statistical downscaling model (SDSM) in the Indian region. This data compared with corresponding IMD daily gridded maximum temperature data and statistical metrics of BIAS, RMSE and MAE are computed for evaluating the model performance. This data have implications of low BIAS, High Correlation and IOA. The model downscale daily maximum temperature data from the future climate projections using the same model for the climate periods 2023-2052 and 2070-2099 are calculated. The data for the period from 1 March to 31 May, for each of the two climate periods, are used to characterise the heat waves in future climates. Specifically the characteristics of heat waves in terms of intensity, duration and area extent are calculated and compared to heat waves of the current climate. Analysis indicates heat waves duration, mean maximum temperature and frequencies of heat wave days are increasing in future climate.

Keywords: maximum temperature, heat waves, CMIP model, frequencies

Prominent features of Low-Level Jet in ERA5 and IMDAA during the satellite era for the Indian Summer Monsoon

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ABSTRACT

Around 850 hPa, the Low-Level Jet (LLJ) has substantial horizontal shear and carries moisture from the Oceanic regions to the landmass, making it crucial for convective rainfall distribution at the Indian mainland. The current study compares the performance of two reanalysis data sets: the ERA5 reanalysis product and the IMDAA from the National Center for Medium-Range Weather Forecasting. These data sets were used for 40 years, from 1981 to 2020, throughout the Indian summer monsoon season. It is crucial to understand how these two reanalysis data sets perform in terms of LLJ seasonal and sub-seasonal characteristics of rainfall variability. Both data sets well reflect the spatial climatological aspects of LLJ at seasonal and sub-seasonal scales. However, as compared to the ERA5 data sets, the amplitude of LLJ wind is lower in IMDAA. At 95 percent confidence levels, a one-way analysis of variance (ANOVA) is used to verify the significant difference between these data sets. Tukey’s test is also used for post-hoc analysis to determine which data sets are most similar to the observation data sets like IMD and CRU. The results show that there is a substantial discrepancy between these two data sets during the ISM season, with the IMDAA data set's temperature being closer to the observation and ERA5's rainfall being closer to the observation. In addition, we look at the relationship between LLJ and rainfall in four homogeneous regions across India. The IMDAA wind speed of LLJ at 850 hPa has escalated in recent decades. Northeast India region manifests the reducing trend of mean rainfall and Central India rising trend of mean rainfall with respect to multidecade. The outcome provides a valuable

understanding of the comparison of two data sets to build appropriate standards for the Indian region and in the ERA5 and IMDAA datasets for future use. frequencies of heat wave days are increasing in future climate.

Keywords: maximum temperature, heat waves, CMIP model, frequencies

Fluctuations in the short interval (6 hr) intensity changes induce an upward trend of Rapid Intensification/Weakening of Tropical Cyclone in the recent global warming period

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ABSTRACT

Tropical Cyclones (TCs) intensity alters at various rates throughout its life cycle. The rate at which TCs grow plays a crucial role in determining its Lifetime Maximum Intensity (LMI). This study presents, how the variations in short interval (6hr) intensity changes(ΔV_6) of TCs, have increased the frequency and magnitude of Rapid Intensification (RI) ($\Delta V_{24} \geq 30$kt)/Rapid Weakening (RW) ($\Delta V_{24} \leq -30$kt) events which are measured at 24 hr interval. Track data of TCs that formed during 1981-2020 in all global ocean basins from International Best Track Archive for Climate Stewardship (IBTrACS) have been used in this study. We have split the study period into two parts; 1981-2000 and 2001-2020. When compared to the previous two decades, ΔV_6 in the recent two decades shows an abnormal change. In the recent two decades (2001-2020), probabilities and frequencies of ΔV_6 specify an appreciable reduction in the events of intensification/weakening of the magnitude of less than or equal to 5kt; but, a perceptible increase in the events of intensification/weakening of the magnitude of more than or equal to 10kt. These changes are magnified with the increase of measuring interval of intensity changes (12hr, 18hr, 24hr), as they depend on ΔV_6. The upward trends in the RI/RW events are simply the consequences of amplification of upward trends of the 6hr interval intensification/weakening events with magnitude of more than 15kt. This was also confirmed in the changes of ΔV_6 compositions of RI/RW events. TCs of all categories have exhibited this type of changes. Intensification phase has been subjected to much variations compared to the weakening phase. The time span of Intensification phase has been reducing at the rate of 0.67 hr per year primarily by huge decrease of Neutral Intensity changes (ΔV_6 = 0kt) along with increasing mean intensification rate in the recent two decades of global warming.

Keywords: Tropical cyclones, Intensification rate, Rapid Intensification,

Identification and prediction of heat wave-2022 over Andhra Pradesh using ANN technique

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ABSTRACT

In recent decades, the lives of people and animals have been significantly impacted by the major meteorological disaster known as heat waves. Maximum temperature data from 2022 are analysed to determine the synoptic nature, intensity, frequency, and other important aspects of the heat wave over Andhra Pradesh. Because of the high number of casualties caused by heat waves, the state of AP declared disaster events to be state-specific disasters. As a result, forecasting disaster events in the coming years in light of changing climatic conditions is critical. During the period 1973-2022, an ensemble model was developed using CMIP-6 forecasted meteorological parameters (temperature, humidity, wind speed, and pressure) as predictors and observations as predictors. An Artificial Neural Network (ANN) approach is proposed to be used to develop the ensemble model. To create the ensemble model for temperature, all 5 ensembles of CMIPS-6 2 models with different initial conditions are used as predictors, and the IMD observation is used as a predictand. The data is then randomly divided into three categories: training, verification, and validation. 70% of the data is chosen for training, 30% for verification, and 30% for validation. The training dataset is used to develop the model, the verification data set is used to check for any inconsistencies between the developed model and the training dataset, and the validation data set is used to validate the model performance. The validation dataset is a separate collection that was not used in either training or verification. Similarly, the ensemble models are developed for the remaining parameters as well. This paper aims to predict the trends, frequencies and duration of heat waves to help the Disaster Management Authorities (DMA) to plan for mitigation activities. These findings will also aid in the creation of public awareness and community outreach by competent authorities through dissemination via social networks and local community centres.

Keywords: Temperature, Heatwave, Ensemble models, CMIP - 6, ANN, Andhra Pradesh

Unified response of Atlantic Multidecadal Oscillation and Quasi-Biennial Oscillation on Indian summer monsoon rainfall

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ABSTRACT

This study investigates the relationship between Indian Summer Monsoon rainfall (ISMR: June July-August-September) with Atlantic Multidecadal Oscillation (AMO) on monthly, bimonthly and seasonal basis overall India for the period 1953-2016 (64 years). The analysis is performed for the full time series as well as by dividing the monthly/seasonal rainfall of India and AMO index according to the westerly and easterly phase of the quasi-biennial oscillation (QBO) at 50 hPa. A direct positive association has been observed between ISM rainfall and AMO for full time-series during the pre-monsoon (March-April-May) and winter (January-February) seasons via the Rossby wave train from North Atlantic across South Asia, and thus increase the temperature gradient between the Indian Ocean and Eurasia which strengthen the ISM. The highest association was found during the pre-monsoon season and especially during April. The variability in ISMR is prominently modulated by pre- monsoon warm phase of AMO along with westerly phase of QBO than easterly phase. The elevated ISM rainfall during warm AMO phase and westerly phase of QBO ultimately triggered low Indian Ocean Sea surface temperature and salinity during September-October.

Keywords: Atlantic multidecadal oscillation, quasi-biennial oscillation, Indian summer monsoon rainfall, sea surface temperature, sea surface salinity

Overview of micropulse lidar observations of the boundary layer, aerosols and clouds over Kattankulathur: Insight to coupling processes

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ABSTRACT

This paper presents an overview of micropulse lidar (MPL) observations at coastal station Kattankulathur (12.82ºN, 80.04ºE) is carried out under network projects supported by Earth Science and Technology Cell (ESTC) under Ministry of earth sciences, India. Three years long continuous MPL observations almost every day between 15:00 IST on day one to 11:00 IST on day two on all clear sky days except on holidays is carried out during 2016-2018. MPL observations simultaneous to cloud aerosol lidar with orthogonal polarization (CALIOP) and regulation radiosonde observations from Indian Meteorological Department (IMD) Chennai located at Meenambakkam (13.0ºN, 80.06ºE) leads to compare the CALIOP level1 and level 2 products over the Indian monsoon region, explore the tropospheric aerosols variations and exchange of the aerosols between the atmospheric boundary layer (ABL) and free troposphere (FT) and characterize the elevated aerosols layer. The identification of the coastal ABL height and its monitoring to various temporal scales has several implications besides the exchange of pollutants, moment and energy. The coastal ABL is characterized with the thermal internal boundary layer (TIBL) due to sea breeze onset and its modification to the convective boundary layer (CBL). TIBL is found to grow with fetch with larger fetch and deeper TIBL during winter when compared to summer monsoon season. The continuous measurements of ABL parameters are further simulated using weather research forecasting (WRF) model to understand applicability of its various schemes in reproducing the ABL over Kattankulathur. The ABL over Kattankulathur is generally characterized with the double mixed layer providing an extra barrier to exchange between ABL and FT. The pollutants and aerosols escaping to the free troposphere either get advected and deposited to transboundary region or convectively transported to higher altitudes resulting in the nucleation of the clouds at various levels. Under the deep convection boundary layer, pollutants even reach to upper troposphere, providing a surface to high-level cirrus cloud formations. The knowledge of the Spatio-temporal cirrus clouds occurrence is vital in quantifying the radiation budget of the Earth-atmosphere system. The MPL observation over Kattankulathur shows a strong diurnal pattern with frequent occurrence of single-layer cirrus in the late evening and multi-layer cirrus clouds occurrence in the early morning. The maximum occurrence of cirrus clouds during the southwest (SW) monsoon and northeast (NE) monsoon and the minimum during the winter season. The vertical extent of the occurrence is ~ 8-17 km with frequent occurrence of cirrus clouds above the cold point tropopause (CPT) during May, July and August. The occurrence of the cirrus top above the CPT indicates the transport of water vapor into the lower stratosphere. Such water vapour transport by means of the formation of cirrus clouds can radiatively affect stratospheric ozone chemistry. Further, to understand the role of the cirrus clouds on the thermal structure of the tropical tropopause layer (TTL), the subvisible (SVC), optically thin and thick clouds occurring at the CPT and within the TTL are segregated. The temperature profiles in the presence of the SVC, optically thin and optically thick clouds with respect to clear sky temperature profiles show cooling between the cirrus top and CPT while warming below the cirrus top in the upper troposphere and above the CPT in the lower stratosphere.

Flood Prediction over Godavari Basin Using Deep Learning Techniques

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Abstract

The summer monsoon performance is considered to be a deciding factor for flood security in the Indian economy. However it Sometimes leads to natural calamities due to inundation of surface water caused by the heavy rainfall events (>64.5 mm/day and 12mm/hr in recurring period). The successive period of heavy rainfall (cloud burst) leads to flood. In the warming environment heavy rainfall events are more persistent particularly in main months of July and August. The study draws attention to the Godavari river basin flood (1950-2022) in Andhra Pradesh in the Southern part of India. From the selected historical data the highest flood events were identified and analysed using statometric equations to the catchment area/ reservoirs associated with the Godavari river basin. The rise/increase in the water level in relation to the rainfall activity were also analysed using deep learning techniques like ANN (artificial neural network), RNN (recurrent neural network), and KNN (K-Nearest Neighbor) where rainfall, water level, and reservoir level are given as the inputs. The occurrence of a flood will be predicted with accuracy and reliability of flood forecasting system. As it aims to prevent damage to human life, properties, and the environment with the known characteristics of a river basin it estimates and predicts the magnitude, timing, and duration of the flood which helps in accurate and timely flood forecasts and advance warning. This will help in flood mitigation, evacuation, relief, and rehabilitation measures for the Godavari and associated catchment areas.

Key words: Flood, Heavy rainfall, Deep Learning, ANN, RNN, Godavari Basin.

Wind energy prediction over Ananthapur district using AI techniques

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Abstract

Wind energy is one of the prominent renewable sources of energy that has a less environmental impact. Though wind farms have expanded over the years, there are a few problems that are faced in the operation of every wind farm. Since wind is inconsistent over time, there is difficulty in estimating the total wind power the farm produces along the day, and it is also difficult to identify the low wind speed hours to schedule a time for turbine maintenance. The wind data at the 10 m level at 12.5 km resolution for the period 1979–2020 are used. This paper presents wind power forecasting over a region using machine learning algorithms, which address the problems faced by the Industries. The deep learning algorithms are trained on the past geographical data of a selected location and successfully forecasted the wind power over the region. Furthermore, different case studies are conducted to measure the performance of various models and the model with accuracy is suggested. This study concerns forecasting the hourly wind speed over Ananthapur, which is the fundamental information used in the further estimation of wind power. Statistical analyses such as RMSE and MAE are used to measure the performance and accuracy of the model. Artificial intelligence and machine learning techniques will be used to predict wind power density over a region. The proposed deep learning model could be further used by the industries to forecast and analyze wind power over a farm and come to know the peak windy hours to generate wind power and times to shut down and perform maintenance.

Keywords: Wind energy, wind speed, Artificial Intelligence (AI), wind power density, wind turbine.

RAINFALL DISTRIBUTION PATTERN OVER INDIA: A QUANTITATIVE ANALYSIS

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ABSTRACT

Precipitation and its variability in different spatial and temporal scales have significant control on the climate of a place and its agriculture. In the present study, we used daily gridded rainfall data from IMD from 1901 to 2020 and assessed rainfall distribution patterns over India in different seasons as well as the temporal trends based on Oliver's Precipitation Concentration Index (PCI). A few studies examined the annual and seasonal rainfall concentration over India using PCI, but mostly used data up to 2011. This study uses the most updated data from 1901 to 2020 and evaluates the annual and seasonal(pre-monsoon, monsoon, post-monsoon, and winter) rainfall distribution over All of India and four homogeneous zones (NEI, NWI, CI, and SPI). The distribution of annual rainfall is strongly irregular over All India, CI, and NWI, while rainfall distribution is mostly irregular and occasionally strongly irregular over SPI and NEI. Rainfall distribution shows distinct seasonal as well as spatial variability. During premonsoon, distribution is moderate to irregular and strongly irregular over Gujrat and parts of Maharashtra. During monsoons, rainfall is uniformly distributed over parts of NEI and EI and moderately distributed over the rest of the country. Postmonsoon rainfall is moderately distributed over parts of SPI and irregular to strongly irregular over different homogeneous zones. Winter rainfall distribution is predominantly moderate, while it is irregular over parts of NWI and SPI. The study indicates significant Spatio-temporal variability in rainfall distribution over All of India and four homogeneous zones and points to the impacts on agriculture and flood/drought conditions.

Keywords: Rainfall, PCI, homogeneous zones, irregular distribution, agriculture

Impact of Urbanization on Heavy Rainfall Events Over Varanasi and Adjoining Areas: Present and Future

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ABSTRACT

Varanasi being one of the ancient city of the world having its own heritage and cultural importance has experienced urbanization in recent decades. In present study impact of urbanization is studied on heavy rainfall events (HRE's) including diurnal temperature range (DTR), wind speed and various other meteorological parameters over Varanasi and its adjoining areas for the period 1986 – 2015 (30 years) during monsoon season (JJAS). India meteorology department (IMD) data has been used as observational data. Historical data from different models of the Coupled Model Intercomparison Project Phase Six (CMIP6) has been compared with IMD data set. Best suitable models of (CMIP6) obtained after statistical analysis has been used to simulate HRE's in future for the period of 2030 – 2060. For urbanization land use and land cover ISRO data has been used. Results indicate inspite of growth of urbanization sharp decreasing trend in HRE's over the study region which is in contrast of the studies where increasing trend of HRE's has been found with increase in urbanization. The results suggest that urbanization plays an important role in change of monsoonal rainfall which impacts people's lives heavily.

Keywords : Climate Change, Land use Land cover, Urbanization, Heavy Rainfall Events.

Exploring retravel uncertainty of VIIRS Deep Blue aerosol retrieval algorithm over South Asia

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ABSTRACT

Visible Infrared Imaging Radiometer Suite (VIIRS) on-board Suomi National Polar‐orbiting Partnership (S‐NPP) satellite is a new generation radiometric sensor which inherit the capability of EOS-based MODIS in terms of spatial coverage and visible/infrared spectral channels. In this research, effect of prevailing aerosol sub-types and surface reflectance on the VIIRS level 2 version 1 Deep Blue (DB) aerosol optical depth (AOD) retrieval algorithm was explored over South Asia. The retrieval uncertainty in VIIRS AOD was compared against ground-truth AErosol RObotic NETwork (AERONET) AOD across South Asia which could be useful to build confidence in VIIRS based aerosol climatology, and to relate accuracy and limitations of the retrieval algorithm over a specific geographical region. AOD at 550 nm and 16-day average NDVI was retrieved from VIIRS across the South Asia along with AERONET version 3, level 2 based AOD at 500 nm and Angstrom Exponent (AE, α) at 440 to 675 nm. The AE was retrieved from AERONET to determine the dominance of fine or coarse mode aerosols, and was used to interpolate AERONET AOD. VIIRS and AERONET AOD based collocation was selected for ±30 minutes of satellite overpass time with a 27.5 km radius circle around each AERONET station namely, Dhaka, Gandhi College, Gual Pahari, Kanpur, Karachi, Kathmandu Bode, Lahore, Lumbini, Pokhara, Pune. Spatial heterogeneity in VIIRS AOD was noted across South Asia with comparatively high AOD across Indo-Gangetic Plain. Seasonal variations of AOD during pre-monsoon (AOD, MAM: 0.50-0.60), post-monsoon (ON: >0.75), winter (DJF: 0.80) across South Asia was noted. Overall, VIIRS AOD was found to be slightly over predicted against AERONET AOD having positive root mean bias (0.94) with 63.94% of retrieval falling within the expected error. Error statistics of the VIIRS AOD retrieval for different aerosol type dominating scenarios like fine, mixed and coarse-dominated aerosol was also explored.

Keywords: VIIRS, AOD, AERONET, aerosol type, aerosol loading.

VARIABILITY OF LIGHTNING ACTIVITY AND AEROSOL AND THEIR INTER-RELATION OVER EASTERN INDIA

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ABSTRACT

Lightning is an astonishing as well as dangerous atmospheric phenomenon that can cause serious risks to human life and property. Microphysical and radiative effects of atmospheric aerosols help to form convective cloud which poses lightning activities. The present study has been undertaken to analyse lightning and Aerosol Optical Depth (AOD) climatology and trends over Eastern India (one of the lightning-prone zones) and assess their correlation over the study region. For this purpose, gridded lightning flash data (0.5°×0.5°) from 2010-2020 developed by WGLC and gridded MODIS-Terra AOD data (1°×1°) from 2001-2020 based on two different algorithms Deep-Blue (DB) and Dark-Target (DT) have been used. Results from both algorithms have been found to be in good agreement with each other except in a few cases. Major lightning activities have been observed during the pre-monsoon and monsoon due to the convective weather formation and lower activities have been observed during post-monsoon and winter. Himalayan foothills, Western and coastal part of West Bengal, coastal areas of Odisha, and Chhota Nagpur plateau have been found to be lightning hotspots. Overall increasing trend of annual lightning has been noticed over the entire study area with stronger trends over Odisha and parts of West Bengal. Annual AOD over Indo Gangetic Plain (IGP) has been found to be much higher than in other regions. Higher aerosol concentration has been observed during the monsoon season which could be due to high RH and wind patterns from the ocean towards land. AOD trends have been found to increase significantly during post-monsoon and winter. Lightning activity has been found positively correlated with AOD annually over the majority areas of West Bengal, Bihar, Jharkhand, Odisha, and Chhattisgarh. Hence, the increasing AOD concentration over this region may be a precursor for enhanced lightning activities.

Keywords: Lightning, Aerosol Optical Depth (AOD), Indo Gangetic Plain (IGP), Eastern India

A comparative study of Air Quality and associated climate change issues in India

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ABSTRACT

Approximately seven million people die due to air pollution related diseases *viz* respiratory illness, heart diseases, cancer and cardiovascular problemsevery year. The air pollutants which cause health hazards are NO_2, SO_2, CO, $PM_{2.5}$, PM_{10}, Pb, NH_3, andO_3. Mainly, $PM_{2.5}$enters into body and causes lung cancer. The air quality of two metropolitan cities like New Delhi and Kolkata and industrial city like Haldia has been studied by using air quality index (AQI) with special reference to $PM_{2.5}$ to assess the situation. It is observed that the air quality of Kolkata is slightly better than Delhi and but high even in comparison with the industrial area like Haldia. In south east asia, India has the highest $PM_{2.5}$ concentration of 153 µg/m^3 and causing 6.7 lakhs deaths annually. Ozone and particulate matter (PM) may have both positive and negative impact on climate. Ozone and Carbon particle from fuel combustion are the major components responsible for rapid climate change. So air quality of our earth should be improved in time bound basis, will not only save life but also slow down the pace of climate change. Here, we have made an attempt to compute the level of air quality and associated climate change issues.

Keywords: Climate change, Air Quality, Particulate matter, Air pollutants, Health hazards.

Improving Precipitation Estimation with the Geostationary Satellite Observations: Algorithm and Evaluation

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ABSTRACT

Quantitative precipitation estimation (QPE) using geostationary (GEO) satellites is critical for detecting rapidly developing and evolving rainfall events, specifically over regions with sparse ground observation networks. Two key advantages of GEO observations over other satellites are their high temporal resolution and short data latency. While several QPE algorithms have been developed using GEO observations over the last five decades, their temporal information remains underexplored for QPE.

The objective of the study is to explore the use of the temporal dimension for QPE with the Advanced Baseline Imager observations on the GOES-16 satellite. Machine learning is used to derive temporal predictors for (1) precipitation detection, and (2) classification of stratiform and convective precipitation types, and (3) precipitation quantification. Promising results are obtained for both classification and quantification when the temporal information is introduced. In terms of classification, the maximum improvement is seen with convective precipitation, while reduced false alarms are noted with stratiform precipitation. Regarding quantification, the mitigation of low rain rates overestimation results in improved conditional bias and an overall increase in validation scores.

Keywords: Precipitation, Convective and stratiform precipitation types, Geostationary Satellites, Machine Learning.

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CMIP6 projections of meteorological drought over India

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ABSTRACT

Droughts are important natural hazards in many areas around the world. They cause significant social, economic and ecosystem impacts worldwide. In the scenario of future climate change there is a chance of increasing the frequency and severity of droughts over India. This study has been undertaken to find out the impact of climate change on droughts over India under different emission scenarios of Coupled Model Intercomparison Project, phase six (CMIP6). It is found that under different emission scenarios (SSP1-SSP3) drought conditions vary differently in different parts of India. But under all emission scenarios north India is going to face severe droughts in the twenty first century. There are also seasonal variations of precipitation over India under different emission scenarios. Under lowest emission scenario (SSP1) central India is going to receive more pre-monsoon precipitation whereas under higher emission scenario (SSP3) north western parts of India is going to receive more monsoon rainfall.

Key Words: CMIP6, meteorological drought, climate change, India.

Viewing the inter-relationship between some pollutants under the purview of binary and composite fuzzy relation

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ABSTRACT

Post-monsoon and winter months cater several conditions like temperature inversions, crop residue burning and firecracker bursting which enhance air pollution. This work utilizes this scenario to explore the inter-relationship between different pairs of pollutants using a fuzzy-set theory based approach. Conducted over Kolkata, the pollutants PM2.5, PM10, NO_x, SO_2, O_3 and the meteorological parameter temperature poses as the random variables(RV). Through computation of descriptive statistics, hypothesis testing through Chi-square test and uncertainty measurement by Shannon entropy, we found lack of symmetry and presence of uncertainty in the data.In this regard, we incorporated binary fuzzy relation(BFR), to study the inter-relationship between the pollutants, in its raw form and through max-min composition, where association between a pair of RV is obtained under the influence of a third RV.The membership matrices of BFR were developed by constructing bivariate frequency distributions and computing conditional probabilities to form membership grades. The results reveal important roles played by temperature to model PM2.5 and SO_2, NO_x in modelling PM2.5, SO_2 in modelling NO_x and PM2.5; under the influence of PM10. Considering the effect of PM2.5, significant role played by temperature in modelling PM10 and NO_x; NO_x in modelling PM10 was found.To model PM10, both PM2.5 and temperature were found to be necessary. The pairs were compared with their raw BFR's wherever possible for a more detailed analysis of the inter-relationships. The results were further consolidated by applying projection of BFR to conclude that low and very high values of the predictor influence the system the most when considering a multivariate predictive model.

Keywords: Binary fuzzy relation (BFR), Max-min composition, Pollutant, Uncertainty, Projection of BFR

EPCO

Vision

To strengthen and reposition EPCO in the environment sector, by building its capacity so that it is able to advise the state government on environmental matters and contemporary advances around the globe

The Environmental Planning & Coordination Organisation (EPCO) was established by the Housing and Environment Department of the Government of Madhya Pradesh in 1981 and presently under the Urban Development and Environment Department of the Government of Madhya Pradesh, its foundation stone was laid by Smt. Indira Gandhi, in the 50 acre "Paryavaran Parisar". Over the years, EPCO has steadily grown to become the State's premier organization in the field of environment related matters. It has worked closely with the State Government on various projects; yet it has established its own identity as an autonomous organization. It is a think-tank for environmental matters, but is also project oriented.

AEROSOL-CLOUD INTERACTION IN WATER CLOUDS OBSERVED USING GROUND-BASED, IN-SITU, AND SATELLITE-BASED OBSERVATIONS OVER AN INDIAN CONTINENTAL REGION

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ABSTRACT

The impact of aerosols on climate by acting as cloud condensation nuclei is very complex and unable to capture completely by climate models. In this study, an observational approach to estimate the aerosol-cloud interaction (ACI) in water clouds is presented using a combination of ground-based, in-situ balloon-borne, and satellite-based measurements of nearly 7 years over an Indian region. Aerosol and cloud optical depths (AOD and COD retrieved from lidar) are the aerosol and cloud proxies, respectively, used for estimating ACI by constraining liquid water path (LWP retrieved from radiosonde) and background meteorological conditions. Seasonal variation of the occurrence of water clouds detected from backscattered lidar signals using the wavelet covariance transform method are identical to those obtained from radiosonde observations. The ACI analysis shows that the correlation between AOD and COD is highest near the cloud base and it decreases as the height above the cloud base increases for all the LWP values ranging from 30 to 150 g/m^2. The calculated ACIτ parameter is within the theoretical limit. The highest correlation and ACIτ value near the cloud base are observed at the LWP bin of 60 to 90 g/m^2. ACI at the cloud base shows a decreasing pattern as the cloud base temperature decreases for LWP values of 30 to 60 g/m^2 whereas different patterns for all other LWPs. High (low) ACI is observed when the wind direction at the cloud base is northeasterly (southeasterly and southwesterly). This result supports the observation of the high occurrence of water clouds during winter followed by the post-monsoon season and low occurrence during monsoon and pre-monsoon seasons over the observational site. Thus, the estimated ACI is in accordance with the theoretical concept of aerosol indirect effect i.e. the polluted atmospheric condition leads to clouds with more cloud fraction and cloud optical depth.

Keywords: Aerosol-cloud interaction, water clouds, LWP, aerosol optical depth, cloud optical depth

GLOBAL DISTRIBUTION OF LIGHTNING TO RAINFALL RATIO

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ABSTRACT

The present study attempts to investigate the presence of various inconsistencies between lightning and rainfall in terms of their spatio-temporal distribution. The latitudinal variation revealed a symmetric distribution in lightning about the equator with a gradual decline towards the poles contrary to that in case of rainfall. Consequently, lightning to rainfall ratio (LRR), is prominent near the hot and moist equator followed by the horse latitudes experiencing cooler and arid conditions over the landmasses. However, longitudinally, lightning and LRR peaks only around the large landmasses in comparison to rainfall. But notably, the equatorial African regions experience arid climate with unprecedented lightning due to orographic convection and this leads to the highest values of LRR. A seasonal investigation further revealed a peak(dip) in both rainfall and lightning around $\pm 5^{o}$ latitude during their respective summer(winter) months. However, a symmetric distribution is observed along the equator during the equinoctial months.

Next, the thermodynamic properties are observed to explain the LRR ditributions. Lightning originates from ice-graupel collisions in higher portions of the cloud which requires sufficiently high potential energy (CAPE) to uplift the moisture to these levels. Accordingly, the CAPE, HCC percentage and ice water ratio reveal a single but gradual peak slightly north of the equator. Next, the longitudinal variation reveals that CAPE, HCC percentage and ice water ratio are higher over land due lower heat capacity. Further, the northern tropics has a larger percentage of landmass which explains the asymmetric peak in latitudinal distribution of lightning and LRR.

Finally, the seasonal variation of these parameters is observed keeping the equatorial and tropical regions as well as the land and sea regions seperately. The highest values are seen closest to the equator as expected. However, a higher seasonality is observed away from the equator with the local summers (winters) experiencing the maximum(minimum) values. When observed longitudinally, the highest average and variability are observed in the landmasses while the lower values are seen in the oceanic regions, particularly over the calm West Pacific, Atlantic Ocean.

Keywords: Lightning, Rainfall, Spatio-temporal distribution, Seasonality, Thermodynamics

Assessment of climate change impact on the various characteristics of the landfalling Tropical Cyclones formed over the North Indian Ocean

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ABSTRACT

The intensity of tropical cyclonic storms formed over the NIO has increased over the last four decades. The increasing severity of severe cyclonic storms has serious socioeconomic consequences. Many people are concerned about the impact of global warming caused by climate change on extreme weather events, such as the frequency and intensity of TCs that form over global ocean basins. High-intensity cyclones have become more common in the NIO, posing significant risks and vulnerability to coastal communities.

However, few studies have been conducted on the impact of climate change on various characteristics of TC land-falling between the years 2000 and 2021, as compared to prior to the year 2000. As a result, we carried out the research to assess the impact of climate change on various characteristics of the land-falling TCs. TCs formed over the NIO between the years 2000 and 2021 cross the coast with greater intensity, causing widespread torrential rainfall, storm surge, and strong winds. Furthermore, more eye-pattern TCs were observed from 2000 to 2021 than prior to the year 2000.

Keywords: Tropical Cyclone, Intensity, North Indian Ocean, Climate Change, mitigation.

Statistical Forecasting of the Post-monsoon Cyclonic Disturbance Frequency over the Bay of Bengal

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ABSTRACT

The deadly tropical cyclones (TC) during the post-monsoon season, which lasts from October to December (OND), are readily formed over the Bay of Bengal (BoB) and cause significant socio economic damages across India and its neighbouring countries. For better planning to reduce the risks associated with cyclonic activities, seasonal forecasting in advance would be beneficial. The current study has assessed the influences of large-scale dynamical and thermodynamical parameters of the preceding monsoon season (June to September) on the frequency of post monsoon cyclonic disturbances (CD) over BoB in order to develop statistical models for seasonal prediction. Six parameters in the prior months, including sea surface temperature (SST), sea level pressure (SLP), relative humidity at 500 hPa (RHUM500), zonal wind at 200 hPa and 850 hPa and meridional wind at 850 hPa levels, having significant correlations with the formation of CDs over BoB in subsequent OND season from 1982-2020 have been selected as potential predictors. By utilizing the selected predictors, four machine learning (ML) models namely Principal Component Regression (PCR), Support Vector Regression (SVR), RandomForest (RF) and Artificial Neural Network (ANN) have been built to forecast the frequency of CDs. The ANN model has outperformed the other three models in terms of accuracy with a highly significant correlation coefficient and smaller deviations between predicted and observed frequency of CD for both the training and testing period. Hence, this forecasting approach of seasonal CD frequency over BoB would be valuable for operational prediction purposes.

Keywords: Tropical cyclone; Cyclonic disturbance; Seasonal Forecast; Bay of Bengal; Machine learning model.

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Probabilistic Prediction of Active and Feeble Western Disturbances : Weeks to Month Lead Time

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ABSTRACT

Western disturbances (WDs) are formally defined by the India Meteorological Department as: "cyclonic circulation/trough in the mid and lower tropospheric levels or as a low pressure area on the surface, which occurs in middle latitude westerlies and originates over the Mediterranean Sea, Caspian Sea and Black Sea and moves eastwards across north India". WDs are, at the most fundamental level, synoptic-scale vertical perturbations embedded in the subtropical westerly jet stream (STWJ). They are often associated with extreme rainfall events in the Karakoram and Hindu Kush regions of Pakistan and north India, and have been the subject of a number of modelling case studies. The recent study Hunt et al., (2017) defined the algorithm to track WDs and found 3090 tracks using ERA-I reanalysis (1979-2016), elaborated the WD tracks by in terms of its ssociated precipitations (normal to heavy). In the current study, we implemented the same algorithm (Hunt et al., 2017) using NCMRWF operational global unified model (NCUM-G) analysis (near real time 4Dvar data assimilation) and global unified ensemble prediction system model (NEPS) with 21 members forecasts upto 10 days lead-time and global unified model - coupled with ocean for extended range prediction (NCUM-ERP) with 16 members ensemble forecasts upto 32 days lead-time, to predict the WDs tracks and its associated precipitation in a few days/weeks (medium-range) to month ahead (extended-range). We introduce a methodology to categorize the predicted Western Disturbance as active or feeble, and by using these NWP models we identify the probability of occurrences of active/feeble WDs in a week (10-days) to a month lead-time, which will become an important key in planning and managing extreme weather events (heavy rainfall, drought) by various stockholders during winter and transits from winter to summer seasons, also sometimes in monsoon season as well.

References: Kieran M. R. Hunt, et al., (2017): The evolution, seasonality and impacts of western disturbances. Q.J.R. Meteorol. Soc., 144: 278-290. doi:10.1002/qj.3200

Keywords: Western Disturbances, Active/Feeble, Probabilistic Predictions, Weeks, Month

DEFINING THE UPPER BOUNDARY OF THE ASIAN TROPOPAUSE AEROSOL LAYER (ATAL) USING THE STATIC STABILITY

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ABSTRACT

The Asian Tropopause Aerosol Layer (ATAL) is located in the Upper Troposphere and Lower Stratosphere (UTLS) during the Asian Summer Monsoon. However, what dynamical feature separates the ATAL from the well-known stratospheric 'Junge layer' is not yet clear. In this study, using the in-situ (Radiosonde, Ozonesonde, backscatter sonde and cryogenic frost-point hygrometer) observations from multiple locations in India (Gadanki (13.45◦ N, 79.18◦ E), Hyderabad (17.47◦ N, 78.58◦ E) and Varanasi (25.27◦ N, 82.99◦ E)) and multi-satellite observations ((Cloud-Aerosol Lidar and Infrared Pathfinder Observation, (CALIPSO), Atmospheric Chemistry Experiment (ACE) Fourier Transform Spectrometer (FTS) and Constellation Observation System for Meteorology, Ionosphere and Climate (COSMIC) Global Position System (GPS) Radio Occultation (RO) (COSMIC GPS-RO)) we show that the ATAL can exist up to the layer of maximum stability (LmaxS), located a few kilometers above the tropopause, determined using the square of Brunt V¨ais¨ala frequency. These in-situ observations over Indian stations collected during the ISRO-NASA Balloon Measurement Campaigns of the Asian Tropopause Aerosol Layer (BATAL) show that the ATAL top can reach up to ~442 K potential temperature level over the Indian region. The LmaxS delineated from COSMIC GPSRO observations over the Asian Summer Monsoon Anticyclone (ASMA) region indicates that the top of ATAL can reach up to 454 K potential temperature level, which is lower than the earlier Lagrangian transport model predicted 460 K. The temperature inversion at LmaxS acts as a lid and constrains the direct transport of aerosols to higher altitudes.

Keywords: Aerosol, ATAL, UTLS region, BATAL, Asian summer monsoon anticyclone

INTRASEASONAL MODES OF SUMMER TEMPERATURE VARIABILITY AND LONG TERM TRENDS OF HEATWAVES OVER INDIA

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ABSTRACT

Heatwaves are the periods of abnormally high temperatures more than the normal maximum temperature. Studies have discussed the role of quasi-stationary Rossby waves, SST anomalies over Indian Ocean, Western Pacific and North Atlantic etc. on the heatwave type of condition across the globe. Different modes of heatwaves are also been studied in many literatures. In this study the temperature variability during April-May season is analysed using the daily mean gridded temperature data from India Meteorological Department. The dominant modes of oscillation has been identified using principal component analysis. The extratropical Rossby wave incursions and large -scale tropical divergent circulation over Pacific have a dominant role in driving the strong upper-level anticyclones resulting in the intense surface warming.

From the observational records, it has become clear that the intensity, frequency and duration of heatwaves have been increasing both regionally and globally. Changes in the large-scale modes of variability in response to warming can affect the strength, frequency and persistence of temperature extremes. In both the regional and local scales, changes in temperature have a heterogeneous spatial distribution and this can impact the regional scale temperature extremes. A heterogeneity in the warming trend has been noted over the Indian region with both warming intensity and frequency of extremes increasing significantly in the nothwest Indian region. In the current global warming scenario, the observed spatial heterogeneity in warming and the trend in spatial distribution of extreme temperature events in India could be rationalized with the trend in these modes. Thus, attributing the observed extreme temperature events to an intrinsic mode of oscillation may raise the predictability and diagnostic studies of such events.

Keywords: Heatwaves, intraseasonal oscillation, global warming, climate change, extreme temperature events

CLOUD AND RAIN MICROPHYSICS MODELLED BY SUPER DROPLET METHOD (SDM) USING DISDROMETER DATA OVER A HILLY TERRAIN

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ABSTRACT

Cloud microphysics plays a very important role in governing the radiative properties of clouds, maintaining atmospheric circulation, thermodynamics, and hydrological cycle. Also, proper understanding of microphysical parameters helps in better simulations of cloud processes for climate models. However, the microphysics of cloud formation and conversion of clouds into rain in multitude of weather conditions and climatic zones is still an open and active field of research. In the paper, a particle-based, probabilistic approach for the simulation of cloud microphysics namely the super-droplet method (SDM), is used to study raindrop particle size distribution and its association with rain rate. The theoretical framework of SDM uses the primitive model, which is a detailed microphysics-dynamics coupled warm-cloud model with Monte Carlo scheme for the stochastic coalescence process. In conjunction with disdrometer data for a hilly Indian station (Shillong, 25.5788° N, 91.8933° E), we try to identify the critical values for super-droplet sizes which propagates from mild to moderate and eventually heavy rain rates. This study is very useful in understanding the micro-level precipitation features over the hilly terrain of North-Eastern India and may in due course lead to better parametrization in forecasting models.

DEVELOPMENT OF LOW COST GPS PILOT BALLOON SYSTEM

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ABSTRACT

Upper Air wind data collection is done by taking regular flights of Pilot Balloon, tracked with help of Optical Theodlites during ascent to obtain Balloon Position to estimate Wind Speed and Direction

The optically tracked pilot Balloons has it's own limitations and practically these systemare unusable under cloud & fog conditions in which the vertical visibility drops to 1-2 kms.

SAMEER has designed and developed Low cost GPS Pilot Balloon System for deployment at their Upper Air Laboratories across India. This low cost GPS Pibal System is capable of providing high resolution and accurate wind data up to 30 km in all weatherconditions

High resolution upper air wind data is an important input to Numerical Weather Forecasting and Aviation Meteorlogy.

The low cost and light weight Pibal System comprises of onboard ISM band transmitter along antenna operating at 403 MHz, microcontroller for acquisition and decimation of GPS data along with ground Receiver module with dual receive antennas with inbuilt LNA, & PC with Pibal data acquistionn and processing the data.

This GPS Pibal has undergone extensive trials and currently these systems are being deployed by IMD at their Uppler Air Network.

This paper describes GPS Pibal System's hardware and Software features along with the results.

Keywords: GPS, LNA , Receiver, ISM

MICROWAVE RADIOMETER FOR EXTRCATION OF CONTINUOUS TEMPERATURE & HUMIDITY PROFILE

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ABSTRACT

The lower atmospheric temperature and humidity profiles are important for a variety of studies including short term weather forecasting, air pollution monitoring, air sea interaction and support to a wide range of models of atmospheric processes, in particular single column and cloud resolving models. Ground based microwave radiometer is well suited for unattended continuous monitoring atmospheric temperature and humidity profiling which requires little maintenance.

SAMEER is designing &developing indegenpus Dual band Microwave Radiometer system, with indigenously developed millimeter wave components. This radiometer will provide continuous temperature and humidity profiles from surface to 10 km height with good accuracy. The temperature and humidity profiles are estimated by measuring the atmospheric emission from the pressure broadened molecular rotational lines of water vapor and oxygen in the microwave region. The 60 GHz oxygen absorption line is used for temperature profiling while 22.235 GHz water vapor line is used to obtain the humidity profile.

The system comprises of a K band (22-32 GHz) & V band (50-50GHz) single heterodyne ,double sideband down converter and a digitally tuned frequency synthesizer for frequency selection. After the mixer, VHF amplifier chain, VHF filter, VHF detector and integrator are used before the ADC and signal processing system. The data acquisition system for control, signal processing and external communication is achieved using STM32 controller. To measure cloud temperature separate IRT sensor is used. The temperature and humidity profiles will be retrieved based on Radiative Transfer Equation and Neural Networkmethods. The system also includes GPS and surface meteorological sensors for measuring air temperature, barometric pressure, rain and relative humidity. The radiometer output will be calibrated with a highly stable noise diode and an internal ambient target used as references.This paper describes system hardware and Software and its applications for nowcasting.

Keywords: Radiometer, Temperature, Humidity

LONG-TERM CHANGES IN PRECIPITABLE WATER VAPOUR OVER INDIA

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ABSTRACT

Precipitable water vapour (PWV) is one of the most important constituents of atmosphere that can affect weather and climate. India has tropical monsoon climate with significant regional variability in rainfall and temperature, where precipitation is closely connected to PWV. Here, the satellite and reanalysis data are used to study the long-term changes in PWV over India, and assess the influence on regional precipitation. Furthermore, we also analyse the impact of increasing regional temperature and evapotranspiration on the rise in PWV there. The analysis shows that the annual mean PWV is highest over the east coast (40–50 mm) and lowest in western Himalaya (< 10 mm). The expected seasonal cycle is also observed in the PWV over India, where the highest values are found in monsoon (June-July-August-September, with 40–65 mm) and the lowest in winter (January-February). Similarly, the monthly cycle of PWV shows the lowest amount in January, which gradually increases with time until it peaks in July, and then decreases thereafter. We find that the PWV shows a peak in 1997–1998, which can be related to the strong El-Nino during the period. Significant positive trend in annual mean PWV is observed over India, about 0.06–0.1 mm/yr. Furthermore, a notable rise in PWV is also observed in monsoon and post-monsoon seasons, with values of 0.1–0.15 mm/yr and 0.05–0.1 mm/yr, respectively. Evapotranspiration is one of the major sources of PWV over India, as we find correlation of about 0.3–0.9 during pre monsoon and monsoon seasons. Additionally, PWV influences the regional precipitation pattern, with a correlation of 0.3–0.8 during monsoon. Henceforth, the rise in PWV likely to affect the regional climate and weather processes.

Keywords: PWV; India; Precipitation; Temperature; Climate Change

ASSESSING THE IMPACT OF CLIMATE CHANGE ON THE SPATIOTEMPORAL VARIATION OF WATER QUALITY OF HOOGHLY RIVER USING MULTIVARIATE METHOD

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ABSTRACT

Rivers are vital for every living organism, but nowadays they are burdened by pollution. Various untreated or partially treated sewage and wastewater are discharged into the rivers. In addition to this climate change factors such as the increase in temperature, alteration in rainfall pattern, land-use changes, and increase in population also affects the pollution load of the rivers. The Hooghly river is a major tributary of the river Ganga in W.B, India. The river water quality is revealed to be extremely polluted due to various anthropogenic invasions. The present study is focused on the impact of climate change on the spatiotemporal variation of the water quality of river Hooghly in W.B, India

The water quality index, comprehensive pollution index, heavy metal index, hazard index, cluster analysis, and principle component analysis is calculated to understand the impact of climate change and anthropogenic invasions on the river water quality. The principle component analysis is used to identify the various pollution sources of the river water. The physiochemical parameters are mostly influenced by anthropogenic effects, while the dissolved oxygen and temperature are found to be influenced by seasonal variations. The water quality index and comprehensive pollution index reveal that the water is polluted. The heavy metal index (>100) indicates heavy metal contamination. The Hazard index confirmed the risk due to ingestion and dermal exposure of surface water (HI Ingestion and dermal > 1). The results visualizes the impacts of changing climate and land use pattern on the entire aquatic ecosystem.

Keywords: Climate change, Hooghly River, Water pollution, Water quality index, Hazard index

SMART OBSERVATORY SYSTEM

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ABSTRACT

SAMEER has successfully designed, developed and validated Smart Observatory System for accurate and reliable measurement of surface meteorological parameters(Temperature , Humidity , Rainfall ,wind speed & wind direction).

The Smart Observatory System comprises of Two numbers of 4 wire PT 100 RTDs to measure Dry and Wet bulb temperatures along with RTD Signal Conditioning Card, Tipping bucket Rain Gauge and Wind Speed and Direction Sensors and Single Board Computer for acqusition and processing of the data

The acquired dry bulb & wet bulb temperature data sent to single board computer (SBC). The SBC processes, archives, time stamps data in real time. The GPS receiver, 2x20 LCD display, RTC are also interfaced with SBC. The system can work with in remote places with solar power backup.

The standalone SBC based embedded firmware acquires and processes the senors data at specified intervals and coverts into physical parameters. The processed & corrected physical parameters are saved on SD card which is capable of storing 3 months data.

The PC is interfaced on Ethernet bus with SBC and PC based software displayscurrent and past acquired data in graphical & tabular format. The acquired surface met data is subjected to three step quality checks by the PC software. The Software is also capable of automatic generation of Synop message from the acquired data.

This paper will give full details of hardware and software of the SMART observatory system

Keywords: PT 100 RTD, SBC, ARG, SPI

TREE BASED MACHINE LEARNING MODELLING FOR REFERENCE EVAPOTRANSPIRATION PREDICTION: A CASE STUDY FOR SUB-HUMID TROPICS

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ABSTRACT

Reference evapotranspiration (ET_0) is an important component of hydrological water balance studies which is useful for crop water requirement estimation and proper irrigation scheduling. It needs a number of climatological data ranging from temperature, wind speed, relative humidity etc., which were not available for many places. This makes the prediction of ET_0 with simple methods cumbersome. Hence, there is a need for data-driven tools that could estimate ET_0 using limited data. The present study aims to estimate the ET_0 using two tree based machine learning algotithms: Extreme Gradient Boosting (XGB) and Light Gradient Boosting (LGB) for Jabalpur, which falls under sub-humid tropical region. Twenty year daily meterological from 2001 to 2020 were used for modelling at different cross-validation stages. A total of 18 combinations were developed ranging from two inputs to six inputs. These models were compared with empirical equations like temperature, radiation based methods of ET_0 calculation. The results indicated that the coefficient of determination (R^2) values ranged from 0.835 to 0.995 and 0.816 to 0.993 for LGB and XGB respectively. The root mean square error (RMSE) values for the least input (only temperature data) models in both the techniques were found to be 0.71 mm/day and 0.73 mm/day, which is quite promising. Accuracy of the model improved with the increase in number of inputs. LGB performed slightly better than XGB, while outperforming all other empirical models. This study implied that the models developed using machine learning gave satisfactory results with two input combination, that could be used in data scarce regions.

Keywords: Machine learning, Data-driven, Reference Evapotranspiration, Sub-humid, Tropics

LIGHTENING DETECTION NETWORK

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ABSTRACT

SAMEER has developed a Very Low Frequency (VLF) based indigenouslLightning Detection Network (LDN).

Each Lighnting node comprises of VLF Receiver along with Antenna, pre-amplifier, FPGA based data acquisition systems, embedded firmware acquiring the lightning signals and SBC. The system acquires the data continioulsy and the Lightning Detection Algorithm is used to distinguish between background LF noise signals and Lightning signals.

Using the SBC, the time stamped (Time of Arrival- TOA) Lightning data from all the nodes is sent to the Computer Server for estimation of lightning location , amplitude and type of lightning. The Lightning Location results are plotted on map in real time.

This paper will present he salient design features of the indigenous LDN along simulation results

Keywords: VLF, LDN

SIMULATION OF THE IMPACT OF INFRARED HEATING ON THE GROWTH OF THE CLOUD

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ABSTRACT

Thermodynamic and fluid-mechanical interactions between droplets and the surrounding air, which occur at micro-scales, significantly alter cloud microphysical properties (CMPs). The microscale characteristics of cloud and their interaction with infrared radiation at the cloud level determine the amount of precipitation from the cloud. The radiational interactions with clouds alter cloud growth/decay in various ways. For example, the local evaporation of cloud liquid and ice may be accelerated by infrared heating in the cloud's interior, releasing latent heat that changes the vertical velocity within the cloud and causes near-boundary turbulence. Additionally, significant optical processes like multiple scattering and infrared radiational absorption cause heat to be produced and redistributed throughout cloud layers. Radiative processes such as infrared heating/cooling, CMPs such as droplet size distribution, ice/liquid water content, and cloud internal dynamics all impact each other through turbulence, condensation, and collision coalescence. In the cloud, turbulence diffusivity caused rapid mixing and increased the transfer rate of momentum, heat, and mass, altering cloud growth. We have developed a parameterization to quantify the impact of infrared radiation heating on cloud growth. To validate the parameterization, we have selected a case of heavy rainfall over Chennai that occurred on 11 Jan 2021. The parameterization has been initialized by ECMWF Reanalysis-5 (ERA5) thermodynamical parameters like temperature, pressure, wind speed profiles, relative humidity, and specific humidity. These parameters have been interpolated on the finite volume nodes using the spline interpolation technique. In addition, we have used High-Resolution Transmission Molecular Absorption Database (HITRAN) spectroscopic parameters to calculate absorption heating. The temporal evolution of temperature distribution inside the cloud has been calculated by solving Advection diffusion equations (ADEs) and moist saturated entropy equations. We have quantified the changes in vertical-specific momentum due to infrared heating. It has been seen that the infrared heating from the bottom of the cloud causes the perturbation in vertical velocity of magnitude within the range of -0.4 ms^{-1} to 0.12ms^{-1}. The detailed formulation, along with the results, will be discussed in the symposium.

Keywords: cloud turbulence, Infrared heating, HITRAN, ERA5.

ANALYSIS OF TROPOSPHERIC NO_2 OVER THIRD POLE FOR THE PERIOD 2005-2020: IMPLICATIONS FOR ATMOSPHERIC POLLUTION

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ABSTRACT

The Hindu Kush Himalaya (HKH) and Tian Shan Mountain (TSM) together is known as the Third Pole (TP), characterized by mountainous environments with variety of regional climate conditions. The region is very sensitive to climate change. Many high altitude regions of TP store water in the form of snow and/or glaciers and continuously feed ten major rivers of Asia, which is often referred to as the water tower of Asia. Since the last few decades, the region is closely monitored because of its declining environmental condition. Therefore, to assess the changing environment of TP, we examine the spatio-temporal features of tropospheric NO_2 in the entire HKH and TSM regions from 2005 to 2020 by using satellite measurements. The highest NO_2 concentration is found in the boundaries of TP close to Indo-Gangetic Plain (IGP) and Yellow and Yangtze River basins (YYRB). Over the most of the regions of TP, trend in NO_2 (2005-2020) is positive, which suggests that the pollution is spreading even to the pristine regions of inner TP. The analysis of Emissions Database for Global Atmospheric Research (EDGARv6.1) shows that the major contribution to NO_2 in the region is from the road transport (81%) followed by power sector (7%). The analysis using HYSPLIT model shows that air mass transported pollutants to TP mostly originate from IGP, Southeast Asia, YYRB, Central Asia and Middle East. This study reveals that TP, one of the least polluted and pristine regions on the earth, is now gradually getting loaded with pollutants, which is a sign of the changes in climate and socio-economic framework of the region.

Keywords: Third Pole; Hindu Kush Himalaya ; Water Towers of Asia; NO_2.

Given the reciprocal changes in Ozone and NO_x during the COVID-19 lockdown, is a better pollution control approach necessary?

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ABSTRACT

Climate policies are a set of actions taken to address the effects of climate change, including policies to reduce or remove greenhouse gases from the atmosphere and adapt to climate change. Air quality is an emerging concern as evidence points out the adverse health effects and ecosystem damage from pollutants in the atmosphere. India witnessed a rapid expansion of its economy, infrastructure and industries in the past few decades, but at the same time, air pollution has also emerged as one of the important environmental issues. For instance, as per the World Bank (2013) report, around 1.4 million people lost their lives and additionally, $505 billion was spent on welfare loss due to air pollution in India. Therefore, a series of policy measures have been adopted to control air pollution by India. The COVID-19 lockdown provided an opportunityto study the baseline emissions and impact of atmospheric pollution due to anthropogenic activities. During the lockdown period, we observed a reciprocal change in tropospheric O_3 (upto10% increase) and NO_2 (upto15% decrease), as analysed using satellite (GOME-2B/OMI-MLS) and ground-based measurements (CPCB). This is particularly evident at the ground level due to the non-linear chemistry of the trace gases in the atmosphere, which include (i) an increase in O_3 due to the NO_x limited conditions in urban regions, (ii) when NO_x decreases, the O_3 consumption due toatmospheric titration slows down,and (iii) due to increase of solar insolation and temperatures insummer. We also studied the air quality changes during the unlock periods and for the year 2021, and found that the pollution again reached comparable levels tothat of the pre-pandemic periods. Our study further cautions that the regulations in controlling discrete sources of pollution may not be effective in controlling the total atmospheric pollution and therefore, careful planning is necessary for preparing any mitigation strategies and policy decisions.

Keywords: Climate change, Air pollution, Ozone, Nitrous Oxides, COVID-19.

PASSIVE MICROWAVE IMAGING SATELLITE BY INDIA FOR IMPROVING GPM PRODUCTS OVER INDIA

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ABSTRACT

High resolution data products (10 km x 10 km spatial and half hourly temporal) of Global Precipitation Mission (GPM) are being used extensively for various applications over the globe as also in India by many Institutions. The GPM constellation consists of GPM (Core) with a 13 - channel passive Microwave Imager (GMI), besides two frequency active radar. Nine other microwave imaging orbiting satellites in polar orbits are also part of this mission. Kalman filter morphing approach is used to fill the time gaps between the 10 satellite passes.

Studies by our and various other goups, of 24 years of GPM high resolution products suggest that over Indian land mass these are good at times even for studying flash floods and landslides in conjunction with ground observations – besides studies of ISO and IAV of Indian monsoon (Thakore 2020). Extensive validation with IMD daily gridded data show that the signal from IAV found from GPM get merged with the noise of the GPM errors (*vis a vis* IMD products), implying desirability of improvement in accuracy of the satellite products.

This is possible with the addition of a few more microwave imaging satellites in low orbit and / or in low inclination. India last launched in 1999 a Multichannel Scanning Microwave Radiometer (MSMR) onboard ISRO's Oceansat – 1 satellite in sun synchronous polar orbit. The radiometers had poor spatial resolution (~ 60 km) compared to that of the present day microwave radiometers (~ 10 km). The microwave imaging payload in Indo French venture, Megha Tropiques, launched in 2012 though with better resolution, also functioned for a short time.

In the light of the various Indian studies, it is felt highly desirable that a 11 - channel Microwave imager (with 18, 23, 36, 89 and 157 GHz with both vertical and Horizontal polarizations) in low inclination (for observing more frequently the tropical regions) and low altitude (for higher resolution) is launched by India, to be an active participant of the Global Precipitation Mission.

With these attempts, we may be able to even embark on a Microwave Imaging Satellite in Geostationary orbit in about 10 – 15 years.

Keywords: GPM, Microwave Imager, Remote Sensing, Microwave imager, ISO and IAV

RELATIONSHIP BETWEEN AZORES HIGH AND INDIAN SUMMER MONSOON

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ABSTRACT

The interannual variation of Indian summer monsoon (ISM) not only affects millions of people in India, but also the global weather and climate. The teleconnections of this variation are not stable. A dominant mode of the recent four decades ISM rainfall shows west-east dipole pattern with above normal rainfall towards west and central India and subdued rainfall towards the east and northeast India, and is related to the vigorous Azores High. The vigorous Azores High is accompanied by enhanced subsidence resulting in well-built widespread upper-troposphere convergence. This forms the meridional vorticity dipole consisting of anomalous cyclonic and anti-cyclonic circulation at 30ºN and 50ºN, respectively. The meridional vorticity dipole increases the Asian jet at its entrance. In addition, the widespread North Atlantic convergence boosts the Rossby wave source. The cascading down Rossby wave train imposes successive negative, positive and negative Geopotential height (GPH) anomalies over north Mediterranean, northwest of India and northeast of India, respectively. The negative GPH anomaly at the north Mediterranean further increases the Asian jet towards the Caspian Sea. The increased Asian jet strengthens the monsoon circulation through the 'silk-road' pattern. While, the dipole GPH anomalies north of India shift the core of the Tibetan High westward triggering monsoon activity towards the west and central India and subdued monsoon over east and northeast India, forming an anomalous west-east dipole rainfall pattern and vice-versa. Future work should examine the extent to which these teleconnections are represented in the climate forecast models to aid the seasonal prediction of ISM rainfall.

Keywords: Indian summer monsoon, India Landmass, Asian jet-stream, vorticity, Rossby wave

Application of recurrent neural network in rainfall forecasting – A case study of Rajasthan

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ABSTRACT

Rainfall is a most important part of hydrological dynamics in geosphere and change in its pattern directly affect the water resources available for sustainability of life form on earth surface. The change in dynamics of rainfall as direct impact of climate change is now a more pressing issue for availability of water, making it a necessity to predict rainfall accurately for better management of hydrological resources. Recurrent neural network (RNN) is a class of artificial neural network that can predict rainfall by identifying the hidden pattern in historical rainfall data. The present paper proposes a special class of RNN, LSTM for forecasting the rainfall for Rajasthan.For prediction,120 years of historical weather data (1901 to 2020) gridded data obtained from Indian Meteorological Department for the state of Rajasthan is considered. Pre-processingtasks such as cleaning and normalization were performed on the dataset before the classificationprocess.

Keywords: Rainfall, rainfall prediction, RNN, LSTM, IMD gridded data

Real-time probabilistic fog forecast based on ensemble prediction system: Skill verification and Challenges

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ABSTRACT

Widespread fog is frequent over the Indo Gangetic Plain (IGP) region during the winter (December and January). Over the past three decades, fog frequency has increased alarmingly in this region. To reduce its adverse impact on aviation, railroad transportation and human lives, the Winter Fog Experiment (WiFEX) aims to provide a real-time fog forecast since 2016. Despite the numerical model's reasonable skill in predicting fog days, accurate prediction of fog onset, intensity, sustainment, and dissipation remains challenging due to its high spatio temporal variability. Recent studies have demonstrated that fog variability can be effectively captured in an ensemble-based forecast system, which takes into account the uncertainty in the initial conditions (ICs), lateral boundary conditions (BCs), and model physics. Based on earlier research findings, Indian Institute of Tropical Meteorology (IITM), Pune developed an Ensemble Probabilistic Fog Forecast System (EPFS) as part of its Winter Fog Experiment (WiFEX) 2020-21 program. We explored the potential skill, benefits, and challenges of EPFS using high-quality observations from the different airports in the IGP region during the 2020- 21 and 2021-22 winter seasons. The EPFS is based on the Weather Research and Forecasting (WRF) model, which has a 4-km horizontal grid resolution covering the Northern parts of India. The system is composed of the twenty-one individual ensemble members, which are created using as many perturbations in the ICs and BCs supplied from the Global Ensemble Forecast System (GEFS). Compared to single-control forecasts, ensemble-based fog forecasts perform reasonably well for widespread as well as site-specific fog. In addition, EPFS facilitates probability forecasts of visibility in four categories (CAT2, CAT3A, CAT3B, and CAT3C) at six major airports in the IGP region. The main contribution of this paper is a novel decision support system for dense fog (visibility < 200 m) prediction at airfields to mitigate the economic losses. Overall, this study demonstrates that the ensemble approach could provide more socioeconomic benefits than a single forecast to end-users, especially for dense fog events.

Keywords: Ensemble Probabilistic Fog-forecast System; Skill verification; Horizontal visibility; WRF model; WiFEX

Glacier Mass Budget and Associated influence of the Climate during 2000-2020 in Alaknanda Basin, Uttarakhand.

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ABSTRACT

The highest concentration of the glaciers in the High Mountain Asia are experiencing constant mass loss due to ongoing climate change, however, significant spatio-temporal heterogeneities are also evident. However, due to insufficient ground observation, glacier-climate interactions in decadal scale are still poorly understood.

We examine the multi-temporal glacier change behavior and associated climate drivers in Alaknanda basin, Garhwal Himalaya, for last two decades (2000-2020) by exploiting satellite datasets and ERA5 land reanalysis grided climate data.

The glaciers (~427 glaciers) in the Alaknanda basin and its surroundings lost -10.2±1.14 m thickness during the entire observation periods (2000-2020). The glaciers are losing significant amount of mass (-0.68 ± 0.09 m w.e.a^{-1}) in recent time period (2015-2020) as compared (-0.22±0.09 m w.e.a^{-1}) to the earlier (2000-2006). We also investigated ERA5 Land reanalysis data and their implications to regional glacier mass balance and found a strong correlation between summer temperature and glacier mass balance ($r^2 = 0.96$ and $p = 0.02$). A strong increase of summer temperature (~0.7^0 C) and slight reduction in solid precipitation (0.5 mm) was observed during 2015-2020, which might affect the strong glacier mass loss. Additionally, two important glaciers (Bhagirath Kharak and Satopanth) in this basin are also experienced similar trend in mass budget; however, the overall mass loss of the Satopanth glacier was nearly doubled as compared to the Bhagirath Kharak glacier during the similar time period (2000-2021). The glacier surface conditions also influenced the mass loss in this region and found during 2000-2020 the glaciers with debris covered tongue (-0.44±0.06 m w.e.a^{-1}) lost considerably higher mass as compared to their counterparts (-0.38±0.06 m w.e.a^{-1}). These heterogeneous glacier mass budget behavior within a single basin indicated the influences of different other factors such as glacier morphometry and surface velocity need to be investigated to understand the regional glacier responses. 4

Reinvestigating the changing relationship between the Indian Summer Monsoon and ENSO in the recent decades

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ABSTRACT

The Indian summer monsoon rainfall (ISMR) from June to September plays a significant role in the most densely populated Indian region due to its direct impact on agriculture as well as the economy. El Niño-Southern Oscillation (ENSO) is a prominent ocean-atmosphere coupled interannual variability over Pacific Oceans that strongly modulates the variability of ISMR. However, the relationship between ENSO-ISMR has gone through many changes during the recent decades. Recently, the research and operational community started using new climatology considering the recent 30-year period 1991-2020 for various meteorological parameters. This study comprises a detailed analysis of the changing relationship between the ENSO and ISMR during two recent independent periods, (i) 1961-1990 and (ii) 1991-2020, using Sea Surface Temperature (SST), rainfall and various atmospheric variables.

It was found that the frequency of the occurrence of La Niña events has reduced to almost half during 1991-2020 as compared to the 1961-1990 period whereas the frequency of the El Niño events did not show huge variation. It was also observed that the ENSO-ISMR negative correlation has been significantly reduced in 1991-2020 compared to 1961-1990 especially, over north, northwest India and peninsular India. It was observed that La Niña associated above normal rainfall over central India during 1961-1990 was higher due to strong vertical wind shear and increased rising motion over central Indian region as compared to 1991-2020. In case of El Niño, there is a reduction of rainfall over central India during 1991-2020 owing to weakening of vertical wind shear as well as stronger subsidence compared to 1961-1990. This indicates that the weakening ENSO-ISMR relation in the recent period mostly contributed due to the weakened relationship between La Niña and ISMR during 1991-2020 period. This study highlights how the changes in the patterns and the intensity of the atmospheric as well as oceanic fields within the tropical Indo-Pacific Ocean contributed to the weakening of ENSO-ISMR relation in the recent decades.

Keywords: Indian Summer Monsoon Rainfall, El Niño, La Niña, Pacific Ocean, ENSO-ISMR relationship.

Unprecedented rainfall intensification over Western India during the 2019 summer monsoon

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ABSTRACT

Large areas of Western India (WI) recorded the highest seasonal (June–September) monsoon precipitation during 2019 since 1901, resulting in disastrous floods claiming hundreds of human lives. Our analysis illustrates that widespread heavy rainfall in this region markedly came from three intense rain episodes (IREs), viz. 1) 28 June to 12 July, 2) 24 July to 11 August and 3) 1–14 September, in the backdrop of strong positive Indian Ocean Dipole (pIOD) conditions evolving at the equatorial Indian Ocean. Based on the station count of heavy rainfall over WI, the IREs were defined in such a way that it captures the essence of both spatial and temporal coherences of heavy rainfall during those periods. The IREs favourably stemmed from northward propagating organized bands of convection embedded with stratiform precipitating systems. Analysis of satellite swaths brings out the prevalence of stratiform precipitation and elevated latent heating in the precipitating systems. Regression analyses of various atmospheric fields were performed to understand the dominant spatial structures during the IRE days. The continual top-heavy stratiform latent heating, in synergy with the pIOD-generated equatorial heating anomalies, forced a Rossby wave pattern of high mid-tropospheric potential vorticity with the maximum over WI and an associated massive cyclonic vortex stretching across South and Southeast Asia (SSEA). It is found that the pIOD-induced enhanced cross-equatorial moisture transport fostered large-scale moisture convergence and deep convective ascent over much of SSEA thereby leading to extensive heavy rainfall. This study highlights the ramifications of intense pIOD manifestations and their potential consequences for increasing the occurrence of hydrological extremes in WI as well as SSEA in the 21st century.

Keywords: Heavy precipitation, western India, stratiform latent heating, summer monsoon, Indian Ocean Dipole.

DEVELOPMENT AND PERFORMANCE EVALUATION OF REAL-TIME WIRELESS SMART DRIP IRRIGATION SYSTEM FOR SCHEDULING OF IRRIGATION USING INTERNET OF THINGS

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ABSTRACT

Smart irrigation is one form of precision irrigation that can help farmers maximize crop production while preserving water and energy. Many different types of smart irrigation system can be used, but there is no scientific consensus about which type is the finest. The purpose of this study was to compare various irrigation methods: an IoT-based soil moisture monitoring (IoT-SM) method using moisture sensors and an ET–based strategy. The best irrigation scheduling strategy should be determined by commercial production: keeping the soil water content near field capacity will result in a better fresh yield but not a more dry matter. Sweet corn was chosen as the crop under study. Growth characteristics (plant height, yield, and water productivity) were compared for each of the two approaches. For IoT based soil moisture monitoring method, two irrigation regimes were used: 43.5 per cent and 34.8 per cent (as field capacity (FC) of soil and 80% of FC, respectively) and crop evapotranspiration (ETc 100 percent) for the ET-based method. The results showed that the IoT-SM 43.5 per cent could produce higher yields of about 12.05% and water savings by 11% compared to the ETc 100 per cent based irrigation method. The developed IoT system was durable and water-resistant, allowing it to be deployed in outdoor agriculture. At the same time, a solar power supply eliminates the need for cabling and reduces sensor node maintenance.

Keywords: Zea mays, Smart irrigation; Evapotranspiration (ET), Soil moisture sensors, Water productivity

Characteristics of various extreme events over South Peninsular India during northeast monsoon using CMIP6

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ABSTRACT

The present study aims to examine the projected changes extremes related to temperature and precipitation over South Peninsular India (SPI) during the Northeast monsoon for Shared Socioeconomic Pathways (SSP245 and SSP585) scenarios of Coupled Model Inter comparison Project version 6 (CMIP6) model output. To gain confidence in the reliability of projected fields, the models are demonstrated for period (1950-2014) with available observations. The best three models namely CESM2, CESM2-WACCM, and CNRM-CM6-1 have been taken to investigate the future changes in the extremes related to precipitation and temperature during the period (2015-2079) with respect to the historical period. This study will be beneficial in assisting risk management under future scenario.

Keywords: Northeast monsoon, CMIP6, Precipitation and Temperature extremes

Space-time variation of large hail-producing mesoscale convective systems over a complex terrain of the Indian subcontinent as revealed by the integrated TRMM and GPM observations

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ABSTRACT

Space-time variation of large hail-producing mesoscale convective systems (MCSs) is investigated over the eastern and north eastern parts of the Indian subcontinent during the premonsoon (March-April-May) season by using long-term (1998-2020) integrated observations of Precipitation Radar and Microwave Imager onboard the TRMM and GPM satellites. A threshold from 37.0-GHz polarization corrected temperature (≤ 176 K), is utilized as a hail proxy and the statistics obtained qualitatively match with the ground based hail reports from the archive at the Indian Meteorological Department. The large hail-producing MCSs are most frequently observed over the plains, whereas, such MCSs are not found over mountains. The MCSs in April have the highest probability to contain hail though the hail-producing MCSs are more common in May. The average morphological and microphysical properties are distinctly different for the MCSs with and without hail. Compared to the active convective cores of MCSs without hail, the hail-producing convective cores of MCSs (i) extend higher vertically and wider horizontally, (ii) are associated with much larger area (~ 1000 km^2 vs 100 km^2) occupied by radar reflectivity larger than 40 dBZ in the mixed-phase region, and (iii) are associated with larger values of cloud ice water content (CIWC; 395 mg. m^{-3} vs 153 mg. m^{-3}) in the mixed-phase region. The results from the high-resolution ERA5 reanalysis data show that the hail-producing MCSs are more sensitive to synoptic forcing than the MCSs without hail. Very strong mean sea level pressure anomalies over the whole northern part of India along the Himalayan foothills to the Bay of Bengal occur for the MCSs with hail days. The findings of this study will help the forecasting of these hailstorms and mitigation of their damage within this less explored region.

Keywords: Mesoscale convective systems, Hail, Synoptic environment, TRMM, GPM

Lateral variations in Aerosol properties over Indian domain using multi-site, multi-year data

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ABSTRACT

Aerosols in the atmosphere, both natural and anthropogenic, are one of the main factors influencing the Earth-atmosphere system's energy balance. Due to their significant contribution to climate change, air quality, and health, the study of aerosols is becoming increasingly important. In the present work, we classified aerosols and their optical characteristics over seven locations across India using long-term AERONET (Aerosol Robotic Network) ground observation data. The study locations are Kanpur, Jaipur, Gandhi College, Pune, IIT Delhi, Amity University Gurgaon, and Gual Pahari. To characterize the aerosols species, we used Aerosol Optical Depth (AOD), Angstrom Exponent (AE), Single Scattering Albedo (SSA)) and volume Size Distribution (VSD). To identify different types of aerosols, i.e., marine, continental, biomass burning, desert dust, and mixed aerosols, AOD_{500} and $AE_{440\text{-}870}$ information are used. A wide heterogeneity is noticed in the aerosol type distribution over different sites. Dust aerosol varied from ~30% to 58%, mixed aerosol from ~21% to 47%, biomass burning aerosols from 3% to 15%, continental aerosols from 4% to 12 %, and marine aerosols from 2% 7% from one site to other. SSA spectral variation shows the dominance of coarse mode during pre-monsoon and monsoon season, while fine mode contributed significantly during winter and post-monsoon season. The VSD also confirms the same finding, though during winter and post-monsoon a shift in fine mode peak radius is noticed, indicating coagulation processes during these seasons. Along with these, we also studied the curvature effects on AOD and AE, which provides added information regarding the classification of aerosols types. To assess the information regarding the absorbing aerosols and their absorbing capability, we studied the differences between SSA at 440 nm and 1020 nm ($d_{SSA}=SSA_{440}$ nm–SSA_{1020} nm) and its correlation with AE.

Keywords: Aerosols; optical properties; SSA; VSD; Indian subcontinent

Precipitation variability in the Kashmir Himalaya and its relationship with EL-Nino phenomena

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ABSTRACT

Precipitation records from 1980 to 2020 over the Kashmir valley, India were analyzed to understand the relationship between the different El-Nino phases, El-Nino (EN) La-Nina (LN) and Normal (NN) events. Seasonal average, minimum and maximum precipitation data was analyzed during ten different – El-Nino (EN) La-Nina (LN) and Normal (NN) events. Results revealed that there is a good correlation of 0.56 between precipitation and El-Nino (EN). Comparatively, a weaker correlation of 0.45 and 0.34 was observed between the observed precipitation and La-Nina (LN) and Normal (NN) events respectively. During the winter months (DJF), analysis of the data revealed that, on an average, less precipitation (5643mm) is recorded in Li-Nina years and higher precipitation (2250mm) is observed during summer and autumn months (ASO). During the normal events, the Kashmir valley showed normal precipitation during winter (DJF) (4500mm) and summer months (ASO) (1947mm). However, during the El-Nino years, on an average, higher precipitation of 7154mm is recorded during the winter months (DJF) and less precipitation during the summer months (ASO) (1800mm). The study revealed a strong relationship between the EL-Nino phenomena and the precipitation pattern and variability over the study area.

Keywords: Kashmir Himalaya; El-Nino (EN); La-Nina (LN); Normal Event (NN)

Study the impact of atmospheric NPF events on CCN formation potential

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ABSTRACT

The measurement site a forest in Mahabaleshwar (17.92◦ N, 73.65◦ E) (India), High Altitude Cloud Physics Laboratory (HACPL), is situated at a height of 1378m above mean sea level. The Neutral Air Ion Spectrometer (NAIS) and Cloud Condensation Nuclei Counter (CCN) were used to measure new particle formation events and corresponding CCN. Computation of change in CCN during the NPF events were observed on 47 days and mainly associated with these north-easterly air masses and high SO_2 emissions and biomass burning activities, while weaker or non-NPF days were associated with westerly air masses and relatively higher influence of local air pollution. The growth of newly formed particles enhanced the mass concentration of secondary organic and inorganic species of aerosol particles. The mean growth rate, formation rate, condensation sink and coagulation loss for the 13 strongest events was computed. It was observed that low relative humidity and high solar radiation tend to favour the new particle formation and high CCN concentration.These 23 NPF events lead to a significant increase in CCN concentration (mean ~52 ± 36 %).

Keywords: Climate change, Remote Sensing, Aerosol Chemistry, Cloud Condensation Nuclei, New Particle formation

Assessment of Spatial Distribution of Seasonal Snow Cover during 2021-22 winter period in Himachal Pradesh Using AWIFS Satellite Data

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ABSTRACT

Climate Change issues are of global concern but poses major challenge to our mountain environment as mountain ecosystem is highly vulnerable and sensitive to the climatic variations. Mountains have special role in showing the effects of climate change. Retreating glaciers, depleting snow cover and Glacial Lake Outburst Floods (GLOFs) are of immediate concern in the mountain environment as GLOFs can have a devastating impact on hydro power, water sources, people, livestock, forests, farms and infrastructure. Decreases in snow accumulation and glacial retreat might lead to acute water shortages in the future. Himachal Pradesh receives winter precipitation in the form of snow at the higher altitudes and about 1/3rd of the total geographical area of the State remains under thick snow cover. Rivers like Chenab, Beas, Parvati, Baspa, Spiti, Ravi, Satluj, and their perennial tributaries originating from the Himalayas depend upon the seasonal snow cover for their discharge dependability. Besides this, snow cover also helps in controlling the accumulation and ablation patterns of the glaciated regions. Considering the importance of seasonal snow cover as a major input in controlling the hydrology of the river basins, seasonal snow cover assessment in terms of its spatial distribution was carried out in different river basins during 2021-22 from October to April using AWIFS satellite data and was compared with that of during the period 2020-21. Results obtained for the 2021-22 winter suggest that there was an overall increase in the monthly averaged area under snow cover during 2021-22 (October-April) by about 19% , which was negative during the last winter (2020-21). The abrupt rise in temperature during March (2022) has contributed in the early snow melt there by enhancing vacation of the snow cover area between March and April ranging between 19-25% in comparision to 4-10% vacation during 2021 affecting the discharge dependability.

Keywords: Remote Sensing, Snow Cover

Reduction in anthropogenic emissions inhibited the growth of sub-3nm particles during the COVID-19 lockdown

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ABSTRACT

The government of India enforced nationwide social and transportation restrictions (lockdown) in three phases from the evening of 24 March to 31 May 2020 to control the spread of the novel 2019 Coronavirus (COVID-19), which resulted in a significant reduction of primary emissions. In this study, we used particle number size distribution measurements in the particle size range of 1.2-3 nm and 10-514 nm carried out from 15 April to 31 May 2020 (lockdown, LCD) and compared with measurements from the previous year during the same time period (15 April to 31 May 2019, business-as-usual, BAU) at University of Hyderabad in Hyderabad, India. The number concentrations of sub-3nm particles were comparable between LCD and BAU, but the number concentrations of particles greater than 10 nm diameter were lower by about 85% during LCD than BAU. This implies that the primary anthropogenic emission reductions did not suppress the formation of sub-3nm particles. However, the frequency of occurrence of the new particle formation and growth (NPF&G) events was three-fold lower during LCD than BAU. The ratio of formaldehyde to nitrogen dioxide indicated that India falls in a NO_x-limited regime, which reduces ambient ozone concentrations (lower condensable vapors via ozone oxidation of volatile organic compounds). Besides, the lower temperature (lower hydroxyl radical concentration) and lower wind speed during LCD may have contributed to the suppression of NPF&G events. Therefore, we emphasize the need to account for processes and interactions related to NPF&G in formulating particulate pollution mitigation policies in urban environments.

Keywords: COVID-19 lockdown, sub-3nm particles, new particle formation and growth, urban pollution

TREND ANALYSIS AND CHANGE POINT DETECTION OF CLIMATIC PARAMETERS IN AMBEDKAR NAGAR DISTRICT OF UTTAR PRADESH

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ABSTRACT

Climate change is one of the most serious challenges confronting humanity today, and its effects can be seen all over the world. The assessment of changes in the long-term weather trend is critical for developing water resource management strategies under climate change scenarios. Long-term trends for annual, monsoon, non-monsoon rainfall, rainy days, maximum temperature, and minimum temperature of Akbarpur, Allapur, Bhiti, Jalalpur, and Tanda stations in Uttar Pradesh's Ambedkar Nagar district were examined in this study. The Mann Kendall test revealed a non-significant decreasing trend for annual and monsoon rainfall at Akbarpur, Bhiti, and Jalalpur stations with an average rate of 1.64 mm/year whereas, it shows a non-significant increasing trend for annual and monsoon rainfall at the Allapur and Tanda stations with an average rate of 3.168 mm/year. Non-monsoon rainfall showed an in-significant decreasing trend at Allapur and Jalalpur stations with an average rate of 0.415 mm/year, whereas a non-significant increasing trend was shown at Akbarpur, Bhiti, and Tanda stations with an average rate of 0.197 mm/year. Annual rainy days shows non-significant decreasing trend for all stations of Akbarpur district with an average rate of 0.117 day/year (one day decrease with in nine year). It indicates seasonal shift and increased possibility of high intensity rainfall. The impact of extreme events of rainfall on the trend was evaluated on the whole and partial series before and after the break point and it was observed that there was no significant climate change in Ambedkar Nagar district and non-significant changing year of precipitation data series was found in 1995. A significant increasing trend in maximum temperature was observed for all stations in the months of August and December, with an average rate of 0.02 ^{0}C per year, while Allapur station also shows a significant increasing trend in maximum temperature in September, with a rate of 0.012 ^{0}C per year. However, a significant decreasing trend was observed in minimum temperature in the month of May at Akbarpur, Allapur, Jalalpur, Tanda station with an average rate of 0.027 ^{0}C per year. Rainfall and temperature are a principal climatic parameter which regulates the environmental condition of a particular region by directly influencing the agricultural productivity and water resources.

Keywords: Climate change, Trend analysis, Mann–Kendall test, Sen's slope, Worsley Likelihood Ratio Test.

Assessment of Drought Conditions over the Kashmir Himalayan Region from 1981 to ending 21st Century using different Drought Indices and ERA-5 Reanalysis Data.

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ABSTRACT

Drought monitoring is essential for drought risk assessment and management and is normally performed using various drought indices that are effectively a function of rainfall and other hydrometeorological variables. The aim of this study was to analyse drought characteristics in Kashmir Himalaya, India from 1981 to 2020 using ERA5. Reanalysis data of the baseline period (1981-2020) was validated against the observed climate variables from 6 meteorological stations in the region using various statistical tests. The comparative analysis revealed a good agreement between the observed and the ERA5 temperature and precipitation simulations. Qazigund station showed high RB and RMSE of 168.2 and 328 respectively for precipitation while as Pahalgam station have high RB of -82.1 and lowest correlation coefficient of -0.2 for temperature. The Deciles index, Aridity Index, Standardized Precipitation index and Drought Area Index were used for drought assessment. Low discharge years of the River Jhelum and some of the tributaries were used to validate the meteorological drought years. In all the evaluated stations, an average of 19 out of 40 years were recognized as drought, with increasing frequency and severity, indicating a clear signal of climate change. The future temperature and precipitation projections, obtained from GFDL CM3 climate model under RCP4.5 and RCP8.5 emission scenario revealed that, compared to the baseline (1981-2020), the study area will experience more frequent and prolonged droughts. For RCP 4.5 and RCP 8.5, an average of 45 and 42 years respectively out of 78 years were predicted as drought years. The results showed that the region will experience more frequent and prolonged droughts from the Mid to end of the 21st century Severe droughts will become the new norm during 2051-2099 according to current climate change projections. The study will help to develop policies and strategies for mitigating and adapting to the changing climate in the Kashmir Himalayas.

Keywords: Drought, ERA5 Reanalysis, Drought Indices, GFDL CM3, Kashmir Himalaya

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Arctic Oscillation Induced Euro-Atlantic Blocking and Precipitation Extremes Over the Indian Region in January 2020

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ABSTRACT

The winter precipitation in the Northern Indian region is beneficial for the growth of the winter crops and the maintenance of the glaciers in a mountainous region. On the other hand, occurrences of hailstorms and thunderstorms over plains adversely affect the agriculture and allied sectors. Hence understanding the occurrence of these events and appropriate forecast and timely warning dissemination is indispensable. All India precipitation anomaly for January 2020 was 64% above long period average. Excess to large excess precipitation was received in most of the central and north Indian regions with various thunderstorms/hailstorm events. A strong positive phase of the Arctic Oscillation (AO) was perceived in January 2020. The AO-induced prolonged Euro-Atlantic blocking was identified and found in concurrence with precipitation departures over the Indian region. Large-scale analysis on different timescales (monthly, weekly and daily) reveals the detouring of the mid-latitudinal westerlies (southward intrusion) with induced cyclonic circulation over the North Indian region. The lowering of the 0oC isotherm, and development of the atmospheric instability with moisture supply from the Arabian Sea and Bay of Bengal resulted in occurrences of thunderstorm/hailstorms over the region. The excess to large excess precipitation during January 2020 over the Central and North Indian region is mainly attributed to the Euro-Atlantic Blocking-induced changes in regional dynamics and thermodynamics. The presence of the omega (Ω) block and its eastward movement was revealed from the weekly analysis. The fidelity of the extended range prediction system (ERPS) in envisaging the week-wise precipitation forecast was also examined. Prediction skills of the ERPS for week 1 were found to be fairly good, however region of occurrence and magnitude was underestimated with the progression of the lead time. The variations in the week-wise precipitation prediction are mainly attributed to the underestimation of the phase of the AO and intensity of the Euro-Atlantic blocking by ERPS.

Keywords: Arctic Oscillation, Atmospheric Blocking, Teleconnections, Thunderstorm, Hailstorm, Extended range prediction, ERPS

Predictive skill of extended-range forecast of 2020-21winter precipitation over north India

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ABSTRACT

Winter precipitation occurs over north India due to the passage of the synoptic system originating from the Mediterranean known as Western Disturbances (WDs). Heavy rainfall, cold waves and fog are associated with WDs. Snowfall during winter over high altitude regions of the Himalayas is vital to maintain glaciers and Himalayan rivers, thus acting as a lifeline for billions of people living on the plains. Any predictive information of rainfall well in advance helps farmers fight drought situations, and forecasts of extreme events help save life and property. In the present study, the multimodel ensemble (MME) based extended range forecast of winter rainfall over northIndia during the 2020-21 winter season is analyzed using the outputs of the National Centre for Environmental Prediction (NCEP) Climate Forecast System version 2 (CFSV2) coupled model.The real-time forecast during 2020-21 winter and hindcast during 2003-2019 is analyzed in this study. The present study evaluates the deterministic and probabilistic skill of the extended range prediction system (EPS) in forecasting winter rainfall over north India on a weekly lead time scale. It certifies the accuracy and usefulness of EPS from an operational point of view.EPS is skilful in predicting winter rainfall up to 3 weeks lead time in advance. Low bias, low RMSE are noted during the hindcast period. The positive anomaly correlation coefficient is observed in all lead time forecasts. Negative departure in rainfall during the January-February months is accurately captured in W1, W2 and W3 forecasts. Probabilistic forecast Prediction is determined using the ROC curve.

Keywords: Climate Forecast System version 2 (CFSV2) coupled model, extended range prediction system (EPS)

Analysis of Fog, inversion characteristics and prediction using NCUM model over Kempegowda International Airport, Bangalore.

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ABSTRACT

A detailed study of fog characteristics like frequency, intensity, duration, time of occurrence, associated upper air features/inversion parameters, and it's prediction skill using NCUM model over Kempegowda International Airport (KIAL), Bangalore are presented in this paper. The characteristics of nocturnal inversions are also studied on fog and non-fog days for a period of 11 years from January 2009 to December 2019. Fog/visibility data is collected from current weather registers and upper air data of Bangalore City (43295) from University of Wyoming is used. Results indicate that December, January, November, February, October and March recorded 129, 126, 96, 44, 33 and 11 events. December and January accounted for maximum fog hours. More than 80% of events were reported during 2200-0200 UTC with maximum (74) in 0100- 0129UTC slot and dispersal during 00-0400UTC indicating radiation type of fog. Intensity-wise, shallow fog is most frequent (51%) while moderate, dense and very-dense have frequencies of 29, 20 and 0.4%. Inversion analysis carried using RS/RW data is defined in terms of height of inversion, depth and strength of inversion. It is found that on foggy days, surface inversions (SI) are more frequent compared to elevated inversions. The height of is SI is 300m and temperature difference is around 1C indicating that fog is very shallow in nature over KIAL. We studied the skill of fog prediction using NCMRWF's NCUM model for events that occurred in Jan2019. Very dense fog (visibility <50m) was reported on 1st, 18, 19 and 22nd Jan and the model was able to predict fog over KIAL, but unable to predict the intensity correctly. Analysis of all events shows hit rate, false alarm rate and bias to be 42%, 5% & 0.76. Model produced mixed results, visibility and wind speed were under estimated while temperature and relative humidity were close to observed values. The impact of aerosol loading on fog prediction needs to be studied.

Keywords: Fog, Prediction, Radiation fog, Modelling

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PRECIPITATION DEPENDENCE ON VERTICALLY INTEGRATED MOISTURE VAPOR TRANSPORT AND ITS DIVERGENCE FOR DIFFERENT SYNOPTIC CONDITIONS

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ABSTRACT

Atmospheric moisture and its transport are significant factors controlling Earth's heat budget and several physical processes. In the lower troposphere, humidity changes affect weather, while in the upper troposphere, it can drive climate. A study of atmospheric moisture budget is essential while investigating the changes in the hydrologic cycle since an awareness of the mechanism causing precipitation variability is of great importance. Several studies have been made on the relation between precipitation variability and moisture budget over different regions, as well as their damaging impacts on agriculture and water resources. Intense moisture vapor transport plays a critical role in water resources of mid-latitude regions and is often associated with extreme hydro-meteorological events such as extreme precipitation and severe floods (Chen et al., 2019; Leung and Qian, 2009; Paltan et al., 2017; Ralph et al., 2006; Ralph and Dettinger, 2011). The recent period has witnessed significant changes in the convective processes associated with monsoon over the Bay of Bengal and the Arabian sea, potentially impacting the precipitation variability over the Indian region. This study analyses the influence of vertically integrated vapor transport and its divergence in modulating Indian summer monsoon rainfall during the period 1990-2020. This work uses profiles of wind and humidity from ERA5 reanalysis and daily IMD rainfall data for the period 1990-2020. The relationship between monsoon rainfall and vapor transport has been carried out for different synoptic conditions.

Keywords: Moisture transport, Moisture budget, Indian summer monsoon

'EARLY DUPLEX VERTICAL SEEDING (EDVS)' HAIL MITIGATION: SWARM-DRONE CONTROLLED TECHNOLOGY

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ABSTRACT

A concept on futuristic Quick Reaction Helicopter-Drone (QRHD) or a Rotary Unmanned Aerial Vehicle (RUAV) controlled technology by 'systems-approach', in hail-mitigation exercise, has been presented. After critically examining current standard practices for Hail Suppression operations a next generation concept of operations (CONOPs) by the name Early Duplex Vertical Seeding (EDVS) has been described. Ordered sequence of instructions are pre-programmed to chronologically input/activate various atmospheric parameters/actions. Drone neutralizes inevitable lag due to human reaction and fatigue in a piloted plane.

An empirical formula for quickly estimating the exact quantity of seeding agent (QSA) has been proposed for cold and warm regions. CONOPs would ensure efficient seeding (effective seeding + quick seeding) with appropriate quantity **[**≈ 0.75kg of the seeding agent per km^3 of cloud volume (NaCl in warm region of cloud - from cloud base to 0^0C level; AgI in cold region of cloud - from to 0^0C level cloud top)**]** in suitable temperature range within cloud and precisely during Available Reaction Time (ART), as far as possible, at initial cumulus growth phase 'prior to hail formation'. It is risk-free hail-mitigation operation which is well coordinated and ordered network of operations that includes nowcasting, satellite communication, Quick Reaction Helicopter Drone (QRHD), AgI & NaCl rockets, Navigation systems and Drone Machine Interface (DMI) system of firing controls. If EDVS operation extends more than ART duration then aviation weather hazards also increase. Self destroying rockets are recommended to avoid damage due to falling of empty rockets.

Technology is suitable to protect 'flat surface' rural farm land from hail damage. High speed and heavier payload drones and swarm-drones, would facilitate EDVS easier against multicell storm and over larger area.

Influence of the Eurasian winter snow on the regional Indian summer monsoon rainfall

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ABSTRACT

The inverse relation of winter-spring season snow over Eurasia with the following all-India summer monsoon rainfall index along with the associated physical mechanisms has been extensively studied in the past. Nonetheless, regional features of this snow-monsoon link and the governing physical processes are complex and thus have not been understood so far. The objective of the present study is to examine the spatial characteristics of snow-monsoon connection using grid-point high-resolution rainfall data over the India and satellite observations of Eurasian snow.

Trend, correlation and composite analysis is used to examine the snow-monsoon teleconnection. The respective trend for the period under consideration in the study from time series of both the variables is removed before conducting the correlation. Statistical significance at 95% confidence level is checked using student's T-test for correlations and trends are tested with standard F-test. The above-normal (below-normal) snow composite is developed from the five strongest above-normal (below-normal) snow years defined based on the detrended snow anomalies over Eurasia for respective season.

Correlation of Eurasian winter snow with spatial distribution of following summer monsoon rainfall over India displays a tri-polar pattern of significant negative-positive-negative correlations over the northern, east-central and peninsular India respectively. The physical mechanism explaining snow-monsoon relation is demonstrated through two approaches. One is through winter Eurasian snow directly affecting the monsoon by altering large scale meridional circulation, while the other is through modulation of large scale zonal circulation by Tropical Eastern Pacific (TEP) Sea Surface Temperatures (SSTs). Enhanced Eurasian wintertime snow is associated with warm TEP SSTs from preceding winter through to the following summer, leading to anomalous large scale zonal circulation during summer monsoon season, thereby affecting rainfall over India. The regional characteristics of snow-monsoon link are unchanged by North Atlantic Oscillation and Indian Ocean Dipole modes.

Climate Change Projections over the Upper Indus Basin ending 21st Century

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ABSTRACT

The study projects the downscaled temperature and precipitation over Upper Indus Basin (UIB), under different climate change scenarios ending 21st century. The multi-model climate projections for the baseline period (1980-2005) were validated against observartions from eight meteorological stations using various statistical tests, viz., Coefficient of Correlation (CC), Relative Bias (RB), Root Mean Square Error (RMSE) and Nash- Sutcliffe Coefficient (NSC). The temperature projections from GFDL CM3.1 were in good agreement with observed data showing a RB of -39%, RMSE of 1.5 and NSC of 0.5. The study also highlighted larger bias in precipitation projections compared to the temperature projections. Although GFDL CM3 outperformed all the participating models, however the bias was still significant and was hence reduced using the Aerts and Droogers statistical downscaling approach. The average RB of the modelled temperature and precipitation data over the region was significantly reduced to 2.9% and -13% respectively.

Based on the GFDL CM3 climate model simulations, the temperature projections indicate a rise of 3 and 5.2°C, 3.4 and 4.7 °C and 4.8 and 6.5 °C in Jhelum, Chenab and Indus basins under RCP4.5 and RCP8.5 respectively. The precipitation on the other hand is projected to witness a marginal increase of ~1% and 3.4% in Jhelum, an increase of 8 and 8.2%, and ~3% and ~9% ending 2100 for the Chenab and Indus basins under RCP4.5 and RCP8.5 respectively. The predicted climate change would have a profound impact on a range of ecosystem services, and dependent livelihoods and the high-resolution climate projections are therefore hoped to aid impact assessment studies to guide policymaking for climate change adaptation and mitigation in the UIB.

Key Words: Upper Indus Basin; Statistical Downscaling; Climate Model; Climate Projections

Investigation of aerosol size distributions over glacier basin of western Himalaya

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ABSTRACT

Himalayan Cryosphere region has unique environment and critically impacted under the changing climate. The Indian Himalayan region is mostly influenced by the aerosols transported from the Indo-Gangetic Basin and may significantly alter the radiation budget. The absorbing aerosol, deposited over the snow and ice covered surface, has a crucial impact on snow / ice albedo. The variations of aerosols and their influence on Himalayan climate are still not well understood due to the rare measurements of aerosol over the region. Therefore, physical and optical properties of aerosols are being measured over the Himansh Station (32.4° N, 77.6° E, 4080 m a.s.l.) located at Sutri Dhaka, Chandra Basin, in Lahaul and Spiti valley of western Himalaya during the ablation period (June-September) since 2019.

In the present study, the size distribution of aerosols is investigated over the western Himalaya using Aerodynamic Particle Sizer (APS) spectrometer (make TSI, USA). APS measures the aerosol number and mass distribution in the size range of 0.5 to 20 μm. Higher number concentrations of aerosols are observed in lower size range with diameter < 1.5 μm, while the larger size aerosols (>1.5 μm) are comparatively much lesser in number concentration during the ablation period. Higher concentration of lower size aerosols may be due to transport of fine mode particles from the Indo-Gangetic Basin. However, the major contribution of aerosol mass of ~40% and ~25% are observed in the size range of 5 to 10 μm and 2.5 to 5 μm respectively, which may be owing to larger size dust aerosols originated from local and long-range transport. The investigations of temporal variations of aerosol size distribution will improve our understanding of aerosol properties and their climatic impact over the western Himalayan glaciers. The detailed results will be presented and discussed.

Keywords: Aerosols, size distribution, Cryosphere, Himalayan glacier.

Study of thunderstorms events using the INSAT-3D/3DR Sounder

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ABSTRACT

Conventional observations are limited and have their own limitations. Therefore, the utilization of remote sensing observations in weather events predictions plays an important role, especially in deep convective mesoscale systems like thunderstorms. The recently established Multimedia Data Receiving and Processing System at the Indian National Satellite INSAT-3D/3DR satellite divisions has IMAGER and Sounder payloads having 6 and 19 channels respectively. Operationally a number of satellite-derived products have been generated and utilized for day-to-day weather forecasting. In this work, we have utilized both IMAGER (15 minutes) and Sounder-derived products (1 hour) of high spatial-temporal resolutions.

The changing climate is a global concern nowadays, and many organizations are working together to discuss, analyze, and interpret the information more meaningfully. In this study project, an effort has been made to analyze the evolution of the WINDEX, CTT, CAPE, CIN, and LFC for thunderstorm situations, all of which are derived from INSAT-3D/3DR. The findings of our investigation are supported by evidence that indicates rainfall has occurred in connection with these thunderstorm instances. The WINDEX data retrieved from clear sky pixels of INSAT-3D/3DR sounder data have been utilized in the recent Delhi NCR thunder squall case (20th July). and WINDEX values show>45 KT at least 3-4 hours prior. One of our studies shows that these INSAT-3D/3DR sounder-derived products allow us to record thunderstorm episodes up to a few hours before the system formation. The scientific community and forecasters can use this to predict how a system would develop convectively.

Keywords: Climate change, Weather Prediction, WINDEX, CAPE, CIN, CTT.

CHANGES IN PHOTOSYNTHETIC ACTIVITY FOR THE INDIAN REGION DURING LAST TWO DECADES

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ABSTRACT

In the recent decades, vegetation cover and photosynthetic activity exhibit substantial variability around the globe. Both climate drivers and human induced changes significantly impacts vegetation which is not adequately explored for the Indian region. Here we incorporated satellite and reanalysis data to unravel the vegetation dynamics and change in photosynthetic activity in India in the last two decades. Techniques such as linear scaling, hotspot analysis (Getis-Ord-Gi*), pixel wise change detection, correlation, influence estimation are used. The photosynthetic activity (FPAR mean = 0.57) is highest in the post-monsoon season (September, October, and November) due to high soil moisture (87.26 kg/m^2), good precipitation (5.2 mm/day), and optimal temperature (21.46 °C), while it is lowest in the summer season (March, April, and May) due to very high temperature (27.37 °C) and lower soil moisture (55.45 kg/m^2). Photosynthetic activity is enhanced for the Indian region during the period 2000–2019. Among the climate drivers, soil moisture (44.31%) has the major influence followed by temperature (32.54%) and precipitation (23.15%) respectively. Greening is predominantly observed in north west due to positive influence of both increasing soil moisture and reducing temperature termed as 'moisture induced greening'. Negative influence of reduced soil moisture and higher temperature termed as 'warming induced moisture stress' is leading to browning in peninsular region. The north east and eastern IGP shows browning due to large scale anthropogenic intrusions such as deforestation resulting in changes in land use and land cover (LULCC). Effective management of croplands and conservation of forest resources is the key to achieving sustainable development goals (SDGs). Furthermore, it serves as a tool to counter the challenges of food security, global warming, rising extreme events and mitigation strategy for climate change which are inevitable in the future.

Keywords: *Greening, Browning, Moisture induced greening, Warming induced moisture stress,Climate drivers*

THE EXTREME RAINFALL EVENT OF KERALA IN AUGUST 2018

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ABSTRACT

Extremely heavy rainfall has occurred over Kerala, southwest coast of India, during mid-August 2018. The meteorological conditions during this period are analysed by studying different parameters such as, rainfall, wind, vertical velocity, zonal gravity wave stress, precipitable water, potential evaporation, latent heat, lapse rate, divergence, vorticity, temperature and relative humidity. For this study different gridded climate data for a period of 30 years, 1990-2019, were downloaded from NCEP, ERA-Interim and IMD rainfall data sets. Spatial and temporal variations of different parameters were determined and their anomalies were computed using data for 30 years. It is found that a combination of many rain favouring conditions prevailed at that time. The positive phase of Madden Julian Oscillation (MJO) coupled with a monsoon depression in the Bay of Bengal and a weak trough in the south-eastern Arabian Sea strengthened the monsoon Low-Level Jet (LLJ) bringing moisture-laden winds over Kerala. The rising limb of Walker and Hadley circulations was also found over Kerala, which gave favourable updraft for cloud formation. In addition, the core of the Tropical Easterly Jet was found over the Kerala and Karnataka region. The cyclonic circulation in the mid-troposphere observed around the monsoon depression extended up to the west coast of India. Simultaneous occurrences of all these could have contributed to the extreme rainfall events and severe floods over Kerala. This work was done with the financial support of the Department of Science and Technology, Govt. of India, New Delhi to Dr. S. S. Suneela through No. SR/WOS-A/EA 18/2018 dated 09-12-2019.

Keywords:- extreme weather, flood, Low-Level Jet, global warming, Madden Julian Oscillation

RECENT CHANGES IN WATER VAPOUR OVER INDIA AND INDIAN OCEAN

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ABSTRACT

The increase in greenhouse gases (GHGs) caused by anthropogenic activities leads to rise in regional and global temperatures. Water vapour, the most abundant GHG, has a significant positive feedback effect on Earth's climate system and global warming. Unlike other greenhouse gases, which are controlled by emissions, atmospheric water vapour is influenced by the surface temperature. This study examines the impact of rising surface temperature, sea surface temperature, evaporation (ocean), and evapotranspiration (land) on water vapour rises and focuses on the recent changes in atmospheric water vapour over India and the Indian Ocean as assessed by reanalysis and satellite data. It is observed that the annual mean column water vapour is very high over the Bay of Bengal, Northern Indian Ocean and Peninsular India, varies from 30 to 60 kg/m^2. Furthermore, expected seasonal cycle is observed in water vapour over India, where highest value is found in summer (June-August) and least in winter (December February). Larger value during summer is attributed to the high evapotranspiration and water vapour transport by Indian Summer Monsoon winds from nearby ocean. Most Indian regions show notable increasing trends in the annual mean column water vapour, about 0.1–0.2 kg/m^2/yr, consistent with the rise in evapotranspiration and surface temperature there. Positive trends are also observed during summer in most of the regions. On the other hand, decreasing trends are obsereved in some areas in Bay of Bengal during spring (March-May), about -0.1 kg/m^2/yr. Henceforth, this study indicates that the water vapour is increasing over India and Indian ocean and it could affect the hydrological cycle, temperature and regional climate.

Keywords: Water Vapour, Evapotranspiration, Regional Climate, Indian Ocean

RETRIEVAL OF VERTICAL PROFILES OF MINOR ATMOSPHERIC CONSTITUENTS FOR CLOUD MICROPHYSICAL MODELLING DURING PRECIPITATION EVENTS

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ABSTRACT

Determining the number concentration of minor constituents in the atmosphere is very important as it drives the whole tropospheric chemistry. These constituents modulate the cloud development directly and indirectly, and consequently alter the precipitation amount. These constituents may act as cloud condensation nuclei (CCN) and ice nuclei (IN) and support cloud development through heterogeneous nucleation. Sulfur dioxide (SO_2) is hygroscopic in the vapor phase and hydrophilic in the aqueous phase. It interacts with water vapor and forms sulfuric acid in the gas phase. In the aqueous phase, it interacts with hydrogen peroxide and forms sulfate ions. Nitrous oxide (N_2O) is a long-lived greenhouse gas (GHG) with an atmospheric lifetime of ~116 years, which traps heat in the earth system and can act as CCN. Methane (CH_4) being an organic carbonaceous aerosol is also hydrophilic in nature and acts as CCN. Carbon Monoxide (CO) is a light-absorbing aerosol and the presence of these particles can cause the clouds to burn off. These interactions impact the development of the clouds by forming CCN and altering the rates of heterogeneous nucleations by growing from the fine particle size to coarse mode particle size. Therefore, to simulate these impacts, a single-column chemistry solver has been developed using Gear's Method, and SO_2, CH_4, N_2O and CO profiles have been retrieved. An idealized experiment is designed using the Monte Carlo method with perturbations in ERA5 temperature data during precipitation days as well as no precipitation days over four megacities, Delhi, Mumbai, Chennai, and Kolkata. ERA5 temperature datasets have been used to determine kinetic reaction rates of chemical transformations at different pressure levels. Maximum Likelihood Estimation (MLE) is used to generate a random sample of temperature data for the Monte Carlo Simulations. The model retrieved profiles have been bias-corrected using Gamma Mapping technique and compared with the Community Long-term Infrared Microwave Coupled Product System (CLIMCAPS) dataset. It is found that the difference between the model retrieved the CLIMCAPS satellite observations ranges up to 15.78 % for N_2O, 45% for CH_4, 49% for CO and 4.459% for SO_2. The model formulation and detailed analysis will be discussed in the symposium.

Keywords : 1-D Model, Gear's Method, Monte Carlo Simulations, Vertical Profiles

Seasonal uncertainty assessments of NCMRWF global ensemble prediction system

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ABSTRACT

An ensemble forecast provides an estimate of the forecast probability distribution of model variables, given an estimate of the probability distribution of analysis errors. The combined effect of uncertainties in model physics and the initial state provides a means to increase the dispersion of ensemble prediction systems. The ensemble prediction system based on Met Office Global and Regional Prediction Systems (MOGREPS) at NCMRWF is assessed in this study. The model physics is perturbed by the Stochastic Kinetic Energy Backscatter (SKEB) and Random Parameters (RP) schemes. The RP scheme incorporates uncertainties in the empirical parameters of the physical parameterization. The SKEB scheme is implemented in the Unified Model to inject the loss in kinetic energy back into the model. The global perturbation fields for wind, temperature, humidity and pressure are produced by the Ensemble Transform Kalman Filter method. The representativeness of an EPS is analyzed from the distribution of initial and forecast ensemble dispersion. The vertical profiles, latitudinal and longitudinal variations of dispersion of the ensemble are evaluated in this study for geopotential height at 500 hPa, temperature and relative humidity at 850 hPa to obtain physical insights into the uncertainty characteristics of the EPS over different seasons so that we can identify ways to improve the ensemble configuration.

Keywords: Uncertainty assessment, ensemble prediction, weather modeling, dispersion

The National Centre for Polar and Ocean Research (NCPOR) was established as an autonomous Research and Development Institution of the Ministry of Earth Sciences (formerly Department of Ocean Development), Government of India on the 25th May 1998 The Centre is designated as the nodal organization for the co-ordination and implementation of the Indian Antarctic Programme, including the maintenance of India's permanent station in Antarctica. Spread across 147,660 sq. mts sprawling area, set atop a picturesque plateau, NCPOR is located in India's most seafaring state of Goa.

Farm-scale Evaporation from ECOSTRESS Thermal Remote Sensing over Indian agroecosystems

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ABSTRACT

Farm-scale daily evaporation (ET) information is required for precise irrigation management, leading to 'more crop per drop' of water, which can be achieved by utilizing Thermal InfraRed (TIR) observations at ~ 50m spatial resolution from a suite of space-borne sensors. ECOSTRESS (ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station) is the mission that bridges the observational gap of TIR sensing between high spatial resolution with low receptivity from satellites like LANDSAT and medium spatial resolution with the high temporal cycle from satellites like MODIS. With a revisit period of 3-5 days, we obtain land surface temperature (LST or T_s) observations at 70 m spatial resolution, and the asynchronous orbit of ECOSTRESS facilitates to test the plant water use pattern at different instances in a day. This further helps examine the capability of models to capture the magnitude and variability of evaporation from a 'proxy' geostationary platform. This mission provides first of its kind T_s and surface emissivity (ϵ_s) at high spatial resolution from multiple TIR bands in 7 -12 μm spectral region.

We present a novel approach based on coupling a thermal inertia (TI)-based mechanistic ground heat flux (G) model with an analytical SEB model (Surface Temperature Initiated Closure) (STIC, version STIC1.2), and the coupled model is named as STIC-TI after Desai et al (2022). A recent study by them already demonstrated the potential of this coupled model over northern and southern hemispheres for agriculture, grassland and forest ecosystems using MODIS noon-night (1 pm/1 am) LST observations at 1 km spatial resolution. Present study uses T_s and ϵ_s products from ECOSTRESS acquired at 10:30 am. The night-time T_S from MODIS aqua (1 am) was used assuming no sub-grid variability. The other land surface inputs such as albedo (✔) and vegetation fraction (f_g) were derived from the surface reflectance of LANDSAT-8 (30 m spatial resolution) and were further resampled to ECOSTRESS spatial resolution. The meteorological forcings such as air temperature (T_a), relative humidity (R_H), and shortwave radiation (R_G) were obtained from Weather Research and Forecasting (WRF) and WMO models, respectively. SEB flux estimates from STIC-TI were evaluated with respect to in-situ fluxes from Eddy Covariance (EC) measurements during June 2019 to December 2020 in a broad spectrum of aridity in diverse agroecosystems in India at Nawagam Gujarat (22.80^{0}N, 72.57^{0}E) representing semi-arid climate having irrigated rice-wheat rotation, at Jaisalmer-Rajasthan (26.99^{0}N, 71.3^{0}E) representing arid climate having grassland, and at Samastipur-Bihar (25.57^{0}N, 85.64^{0}E) representing sub-humid climate with rice-wheat crop rotation, respectively. Evaporation estimates from STIC-TI and ECOSTRESS data showed RMSE of less than 0.25 mm d^{-1}(14% with respect to measured ET from eddy covariance towers) and R^2 = 0.87 which is better than the reported RMSE obtained from MODIS aqua at 1 km spatial resolution with the same model. The availability of noontime LST at enhanced spatial resolution (57 m) from the planned ISRO-CNES TRISHNA mission, instead of morning LST at 70 m resolution, is expected to further improve the accuracy of farm-scale ET estimates.

Orographic Precipitation Clouds over the Western Ghats during Indian Summer Monsoon: An overview

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ABSTRACT

It is now well established that the Earth's topographical features play a pivotal role in precipitation processes through orographic lifting of the moist air parcels and substantially modulate the spatial and temporal variability of precipitation pattern over a given region. The orographic precipitation contributes significantly to the global mean precipitation and thus is a topic of intense research across the globe for several decades. In the present communication, an over view of physical processes associated with precipitating clouds over the Western Ghats (WG) of Indian region during summer monsoon is discussed using seventeen years of precipitation radar measurements on-board Tropical Rainfall Measuring Mission (TRMM). During summer monsoon, the lower tropospheric winds are dominated by the presence of strong low level westerly jets, which interact with steep slopes of the WG and aids in the formation of precipitation clouds. The mean climatology of precipitation over the study region shows a peak of ~16 mm/day over the upslope of the WG during summer monsoon. The composite longitudinal distribution of vertical structure of precipitating clouds in terms of frequency of occurrence of radar reflectivities ≥ 23dBZ is constructed at four local time intervals. The results are discussed in terms of bands of high frequency of occurrence of precipitating clouds and their longitudinal position with respect to the WG. The potential formation mechanisms such as forced lifting over the upslope regions and the upstream blocking over the offshore during the summer monsoon are discussed. The present study thus provides an overview on the physical processes associated with precipitating clouds during summer monsoon over the WG using long-term observations.

Keywords: Orography, Precipitation, Remote Sensing, Low level Jet, Indian Summer Monsoon

On the contribution of the transient off-shore troughs and vortices to the summer monsoon rainfall

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ABSTRACT

During the southwest monsoon offshore troughs and vortices develop near the western coast of India owing to a mountain barrier called the Western Ghats. These Ghats about 1400 km in length extend from 8 N to 21 N and act as a wall facing the Arabian Sea. This geography is conducive to the formation and modulation of transient rain-bearing systems that influence the monsoon in short and medium timescales resulting in heavy to very heavy rainfall along the coast.
In this study, we explore two large-scale dynamical influences of the Western Ghats during the summer monsoon viz. a) synoptic-scale low-level westerly jet and b) mesoscale orographic variation of rainfall near the Western Ghats. The study reveals that the rainfall on the windward side is more than that on the leeward side. This is due to upstream blocking of low-level flow by the Western Ghats. The blocking causes deceleration of the low-level wind flow giving rise to the lifting of air parcels well ahead of the mountain range thereby building deep convection. The rain clouds on the windward side are large cumulus and that on the leeward side are altostratus. The variation in the cloud patterns is shown to be due to modulation of the vertical velocity by the mountain barrier.

Keywords: Off shore troughs, Western Ghats, Orographic Rain, Convection

Shifting Velocity of Precipitation Extremes Under Climate Change: An Outlook for Central India

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ABSTRACT

Climate change is leading to alterations in the dynamical climate systems worldwide. The Indian Summer Monsoon (ISM) is an essential climate system that supports more than a billion population in the sub-continent and drives the Indian economy. This system is governed by intra-annual to inter-decadal variabilities. However, the anthropogenic climate change is inducing unprecedented transformations in this natural system, such as the increased probability of precipitation extremes (dry and wet), changes in their frequency and duration, spatial variabilities etc. These changes, in turn, impact the human and ecological systems due to droughts, floods, and prolonged dry spells. In such scenarios, it is imperative to gain insights into the projected precipitation extremes (PEs) changes. The velocity of climate change (VoCC) or climate velocity can help us project the temporal and spatial shift of PEs. VoCC is a regional metric of climate change. It is defined as the ratio of the temporal gradient of a particular climate variable (temperature, precipitation, humidity etc.) with its spatial gradient, and the resultant units are in km/year. In the current study, the climate velocities of 2nd, 50th, 95th and 99.9th percentiles of precipitation for the JJAS season are projected over Central India for the two time periods: mid-future (2040-2069) and far future (2070-2099). Central India is a part of the monsoon core zone and thus experiences significant precipitation in the JJAS season. The regional climate models (RCMs) which participated in the CORDEX-CORE simulation and ROM (a regional earth system model over the CORDEX-South Asia domain) were used in the study. It was found that ROM showed a better resemblance with observation in simulating the PEs over other regional climate models (RCMs). The intense rainfall (95th percentile: R95) is expected to be enhanced over most of the study region in mid future and far future. Interestingly, very intense rainfall (99.9th percentile: R99) showed robust increases in both the mid and far future. The PEs also exhibited higher velocities as compared to the median values. The detailed results will be discussed further in the presentation.

Keywords: Climate change, Precipitation extremes, Climate velocity, Projection, Monsoon (maximum 5 words)

Meteorological analysis of Cloud Burst near Amarnath Holy Cave on 8th July 2022

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ABSTRACT

On 8th July 2022, in a very unfortunate incident, a cloud burst occurred over upper catchment areas of holy Amaranth shrine around 18:10-18:20 hrs IST which caused damages to lives and property over and around Amarnath Holy Cave. Deeper analysis of the available data from ASWs and officials posted at Holy Cave suggested that the highly localized convective cloud caused the cloud burst which led to flash flood leading to death of 15 live(as per official record).

The incident was caused by a highly localized cloud which layed over the Holy Cave & upper catchments of the Holy Cave during 16:30-19:30 hrs IST on 8th July, 2022. This cloud remained stationery there till 18:30 hrs. and caused intense rainfall spell. The IMD AWS function near Holy Cave had recorded 30 mm (3 cm) of rain from 16:30 -17:30hrs IST with occurrence of intense rainfall of 25 mm during 17:30-18:30 hrs IST at Holy Cave. However, it is most likely that the cloud burst incident occurred over upper catchments of the Holy Cave. The high volume of water within short period of time flowed from upper area of the Holy Cave through normal flash flood hannel which took live & damaged proiperty..

The accumulated water from the intense rainfall of short duration in the upper catchments of the Cave combined with those near the Holy Cave & adjoining area flowed downward brought with it lots of debris gaining more and more speed affecting all area coming under its path leading to loss of precious lives.

Keywords: cloud burst, flash flood, flash flood channel.

Premonsoon Thunderstorms with moderate and above rainfall over Sub – Himalayan West Bengal region during past 10 years: Thermodynamic Analysis.

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ABSTRACT

Pre monsoon thunderstorm activity of West Bengal, plays an important role in Indian Climatology. These thunderstorms are generally associated with squalls and torrential rain in the pre monsoon month March, April and May are known as "Norwesters', also locally known as 'Kalbaisakhi'. Majority of these thunderstorms originate in the afternoon over Chota Nagpur hills in Jharkhand where a heat low develops. They move southeast towards the Head Bay of Bengal and are sometimes associated with hail. There is a type which originates from the hills flanking northern and eastern border of northeast India in the night or early morning. From the hilly region of sub-Himalayan West Bengal they move south towards the mouth of Meghna River in Bangladesh. Very rarely these thunderstorms originate over khasi hills in the forenoon and travel from northeasterly or easterly direction. This study explores the role of of thermodynamic indices in highlighting the thunderstorm days with moderate or above rainfall. Surface data of Jalpaiguri station for period 2010 and 2012-2020 and upper air radiosonde profile of Guwahati station at a aerial distance of 338 Km from Jalpaiguri are considered for this study. It is observed from case studies that if any three threshold criteria (involving TTI, KI, LI, DCI, UVV, ΔL1(Probability of Deep Convection), ΔL2 (Deepness of Convection), CAPE, CIN, SWEAT, PW(Preciptible water)) is fulfilled then the possibility of the thunderstorm with heavy rainfall is likely over the region. Further, Analysis shows that no two events are similar and cause for occurrence of events may be one/more of the following Temperature and humidity based indices, Wind-related parameters, Advanced parameters, Thematic parameters. Also, few lightning indices are computed for above cases. Further gridpoint profile of Pressure, temperature, relative humidity, wind nearest to Jalpaiguri of model/reanalysis data is taken to verify the results.

Keywords: Thunderstorm days, moderate & above rainfall, CAPE, CIN, Preciptible water

Groundwater - Soil water interactions in a Land Surface Model

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ABSTRACT

Groundwater - soil water interactions are important in determining the evolution of soil moisture. The presence of vegetation cover, depending on the type of vegetation and seasonal variation, can modulate this interaction. For instance, deep-rooted trees can directly extract water from the deeper layers of soil, while plants with shallow soil roots have access only to the moisture in the upper layers of soil. This in turn, can lead to differences in evapotranspiration characteristics and boundary layer moisture content. In an environment that is amenable to precipitation, this land surface moisture source can play a crucial role in determining the intensity of the precipitation. In this study, we try to understand the spatial and temporal characteristics associated with groundwater effects in the Indian region. This is done by integrating a groundwater model with the Noah Land surface model. The distribution of soil types is found to have a prominent impact on soil moisture evolution in the model both with (Noah-GW) and without (Noah-Cntl) groundwater effects. This is further impacted by vegetation type distribution due to differing evapotranspiration rates. Groundwater effects are also found to be dependent on the timing and amount of rainfall. The largest difference in soil moisture between Noah-GW and Noah-Cntl is observed after the rainfall season in most places. It is also found that the groundwater effects are felt at sub-seasonal timescales. It is, therefore, necessary to incorporate groundwater effects in climate models to properly simulate the precipitation characteristics, especially in the regionswhere the land atmosphere coupling is high, and groundwater effects are important.

Impact of Initial and Boundary conditions in simulate the lightning event over Rajasthan

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ABSTRACT

Lightning is one of the most lethal natural phenomena. As per an annual lightning report by Indian Meteorological Department (IMD), India reported a 34% increase in lightning strikes in 2019-20. The widespread lightning event occurred over different parts of Rajasthan on 11 July 2021. This was recorded by the IMD and it was one of the deadliest lightning events. A study of lightning has been done using the WRF (Weather Research and Forecasting) model and ground-based lightning observation data.

As the monsoon gradual strengthening over Rajasthan after 10 July 2021, a simulation of lightning is carried out using the WRF model with different initial and boundary conditions. The model has been integrated from 10th July 00 UTC to 12th July 00UTC. National Centers for Environmental Prediction Final Analysis (NCEP-FNL) and the NCEP operational Global Forecast System (GFS) data have been used to derive the model and understand its impact. The lightning Potential Index (LPI) is calculated using the model-derived parameters. LPI provides the potential for charge generation and separation inside the clouds. It plays a significant role in determining lightning-prone zones. Furthermore, the model has simulated explicitly, lightning flash count using a lightning parameterization scheme. The results are evaluated and analyzed using IITM (Indian Institute of Tropical Meteorology) ground-based observation data, INSAT 3DR Brightness temperature, and ERA-5 reanalysis data.

The study is focused to understand the role of different initial and boundary conditions to simulate the lightning event. Numerical simulations are compared qualitatively and quantitatively with the observation. To determine the performance of the model different skill score has been calculated such as ETS, POD, and FAR. The model simulated output of lightning flash count and LPI give remarkable results towards the observation.

Keywords: Lightning, WRF Model, Initial condition and Boundary condition, Rajasthan

ENHANCED MID-HOLOCENE INDIAN SUMMER MONSOON RESPONSE OF GREEN SAHARA AND OCEANIC CONDITIONS

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ABSTRACT

The enhanced African monsoon is believed to be transformed the arid Sahara with lush green vegetation during the early to mid-Holocene (MH) period. These changes in land cover also reduced dust emissions over the African deserts and have local and remote influences in modulating monsoon precipitation. This study aims to understand the role of green Sahara with reduced dust conditions along with other major forcings viz, orbital and oceanic factors in northern hemisphere summer monsoons during MH. To understand the role of these aforementioned forcings, we designed a couple of high-resolution paleoclimate simulations using a variable resolution global climate model (LMDZ4: Laboratoire Meteorologie Dynamique and Z stand for zoom), configured with a 35 km zoomed domain over south Asia. These high-resolution simulations captured the precipitation extent of the Indian Summer Monsoon (ISM) even over northwest India (NWI), and the adjoining Indus Valley region, which most of the models participated in the Paleoclimate Modelling Intercomparison Project (PMIP) couldn't. The study could identify that the green Sahara with reduced dust conditions remotely intensifies the Indian Summer Monsoon precipitation by modifying the large-scale atmospheric circulation. The study further investigated the relative role of orbital and oceanic factors in enhancing the monsoon precipitation and quantified each forcing's relative roles over India, Africa, and East Asia during the MH.

Keywords: Mid-Holocene, Green Sahara, Indus Valley, Orbital forcing, Indian Summer Monsoon

Dissolution of marine cold spells from Tropical Indian Ocean in the warming climate: evidence from Regional Earth System Model

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ABSTRACT

There have been few studies on cold ocean temperature extremes known as marine cold spells (MCS) over the Tropical Indian Ocean (TIO), which could act as a potential buffer against the observed warming in this ocean. In this study, the first-ever future projection of MCS over TIO was made using a regional earth system model, namely ROM, under two Representative Concentration Pathways emission scenarios, RCP4.5 and RCP8.5. Future MCS properties were estimated using both RCPs in three slices: near future (2010-2039; NF), middle future (2040-2069; MF) and far future (2070-2099; FF). The MCS were frequent, intense and prolonged during the historical period, but in the future MCS will cease to occur in ~13(4), ~56(66) and ~69(93) percent area of TIO in the NF, MF and FF respectively with RCP4.5 (RCP8.5) scenario. This departure of MCS leads to the dissolution of events, which was first identified over the Arabian Sea in both RCPs, which is reportedly warming at an alarming rate. The decrease in net heat flux and increase in wind speed contribute to the genesis and severity of MCS events. Further during the El-Niño regime, MCS events dramatically decreases due to the basin-wide warming, but during the La-Niña phase, MCS intensity and spatial range increases.

Keywords: Regional Earth System Model, Marine cold spells, Tropical Indian Ocean.

Acknowledgment: This work is jointly supported by the Department of Science and Technology (DST), Govt. of India, grant number DST/INT/RUS/RSF/P-33/G, and the Russian Science Foundation (Project No.: 19-47-02015).

DISTRICT WISE CLIMATE VULNERABILITY ASSESSMENT OVER THE BUNDELKHAND REGION, INDIA

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ABSTRACT

Climate Change Vulnerability Index (CVI) has been used to define the extent of vulnerability of society due to climate exposure at the district level for the Bundelkhand region. Social, economic, demographic, and environmental indicators obtained from meteorological parameters (rainfall and temperature), population census, livestock census, forest survey report, and agriculture census, were analyzed, and the most relevant indicators were used to construct a composite vulnerability index to estimate differential spatio-temporal vulnerabilities in the region. Exposure, sensitivity, adaptive capacity, and vulnerability were calculated as an individual index for the decades of 1991s, 2001s, and 2011s separately. The study found that climate vulnerability has changed over the region with the change in climatic exposure, development strategies, policies, and planning changed over time. The study highlighted that the entire Bundelkhand region has become more vulnerable over time with Chitrakoot, Banda, and Chhatarpur districts being the most vulnerable districts in the region. Moreover, a strong relationship has been observed between adaptive capacity and vulnerability, the urban centers like Jhansi and Sagar have the highest coping capacities due to the concentration of resources and development. With this unequal development and accumulation of coping capacity, other regions have become more vulnerable than the urban regions. Therefore, to assist the region's marginalized groups in coping with the negative effects of climate change, equitable comprehensive adaptation plans must be developed and put into action at the policy and decision-making levels. Also, the most vulnerable areas should be prioritized for public policy initiatives to reduce their vulnerability.

Keywords: Vulnerability, Climate change, Extreme weather events, Drought, Bundelkhand

Comparision of the region of heavy rainfall for Cyclone AMPHAN, YAAS and JAWAD.

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ABSTRACT

In this article we have studied three recent cyclones namely AMPHAN, YAAS and JAWAD. The most affected coastal states were Odisha and West Bengal. The main period of influence for the coastal states were 18-20th May, 2020 for AMPHAN, for YASS 24-27th May, 2021 and 3-6th December, 2021 for JAWAD. Among these three AMPHAN was the strongest reaching the intensity of super cyclonic storm. YAAS attained the intensity of very severe cyclonic storm whereas JAWAD was a relatively weak cyclonic storm. Here, we have compared the region of heavy rainfall for these three cyclone. Also, each cyclone we compared how region of heavy rainfall changes with change in position and intensity of the system. This study may be useful in prediction of heavy rainfall areas for future cyclones.

Keywords: Cyclone, Heavy rainfall prediction.

Radar derived characteristics of convective storms in Southern India

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ABSTRACT

Convective storms (CSs) are defined as clusters of cumulus cells laterally placed on sub-mesoscale convective system (MCS) scales in the spatio-temporal scale hierarchy of tropical convection and thus are of ought most importance for rainfall. Southwest and northeast monsoon accounts for maximum rain over the Indian subcontinent. Southern peninsula (SP) receives highest fraction of annual rainfall during northeast while rest of the landmass experiences the same during southwest monsoon. Nevertheless, SP experiences both southwest and northeast monsoon.

While different aspects of CSs during summer monsoon have been investigated, characteristics of CSs during southwest and northeast monsoon in SP are limited. Therefore, we attempt a comparative study on CSs 3D structure, their relation with large-scale dynamics, and underlying physical mechanism in the SP during southwest and northeast monsoon using ground-based radar measurements. An object-oriented lagrangian framework cell-tracking method, Thunderstorm Identification, Tracking, Analysis, and Nowcasting (TITAN), is applied to the volumetric reflectivity data to identify and track CSs. A reflectivity threshold of 35 dBZ and volume threshold of at least 30 km^3 for a minimum of two consecutive radar scans have been adopted for CSs identification.

The identified CSs are further represented by a two-dimensional envelope after projecting their three-dimensional volume onto the surface. A fit ellipse defined by its center, orientation, and major/minor radius is used to derive the aggregate and instantaneous properties of the storm track. Then, the geometrical properties and intensity of storms are derived and explored for CSs characteristics. ERA5 hourly reanalysis products from ECMWF are utilized for the field variables representing the dynamics and other large-scale environment associated with CSs occurrences and underlying mechanism. The findings from the analysis will be presented at the conference.
Keywords: radar, convective storms, southwest monsoon, northeast monsoon, large-scale environment

Desert dust Aerosols from West Asian Deserts Reduce the Drought Conditions Over India

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ABSTRACT

Aerosols, the particulate matter suspended in the atmosphere apart from acting as cloud condensation nuclei, can also modulate the Indian summer monsoon through their direct effect on multiple timescales. On a weekly timescale, a positive correlation exists between aerosols over the Arabian Sea (AS) and the central Indian rainfall. The positive correlation is mainly attributed to the desert dust aerosols over the AS transported from the nearby desert regions, which dominate the aerosol loading over the AS during monsoon. During deficit monsoon years, there is an increased transport of desert dust aerosols from northwest India, Pakistan, and Afghanistan towards the AS. In addition, along with reduced rainfall over India, the rainfall anomalies are negative over the AS; leading to less wet deposition and increased desert dust loading. Whereas, during excess monsoon years, the enhanced rainfall over AS leads to more wet deposition and reduced aerosol loading. A significant correlation exists between the aerosol loading over the AS and the Central Indian rainfall during excess and deficit monsoon years, but the value is higher in deficit years, following the aerosol loading over the AS. The high aerosol loading conditions over the AS are leading to enhanced winds and moisture transport with the high winds shifting towards Indian mainland, leading to increased rainfall over India. In the future climate warming scenarios, the dust transport from the nearby dust source regions to AS is likely to increase, which has implications for the reduction of drought conditions over India.

Keywords: Aerosols, Desert dust, Arabian Sea, Monsoon, Drought

Intriguing aspects of rainfall initiation over rainshadow region during boreal summer monsoon.

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ABSTRACT

This novel study explains a plausible physical mechanism for rainfall initiation over the southeast peninsular India (SEPI, referred to be a 'rain shadow' region) during the southwest monsoon season. Further, the contrasting rainfall patterns between the rain shadow region and central India (CI) are also elucidated through the response of the maritime continent (MC) convection. MC is found to be a prominent source for the initiation of wet spells over the rain shadow region (during which CI is in dry phase), with the rainfall anomalies over MC leads SEPI by ~5–7 days. Evolution of convective anomalies resembles a classical Gill-type response, with a pair of Rossby waves on the poleward side of the convection center and Kelvin waves on the eastern side. Thus, the combined effect of large-scale circulation and moisture anomalies over MC contributes to the preconditioning and subsequent positive rainfall anomalies over the rain shadow region.

Keywords: Wet spells, Rainshadow region, Monsoon, Rossby waves, Maritime continent

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Impact of Different Nesting Methods on the Simulation of a Severe Convective Event Over South Korea Using the Weather Research and Forecasting Model

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ABSTRACT

In this study, the effects of different nesting methods on simulating a flash-flood-producing severe convective event over Cheongju, South Korea on July 16, 2017 was examined. This event developed as part of a mesoscale convective system (MCS) accompanied by frontal forcing. Numerical experiments were conducted using the Weather Research and Forecasting model (WRF) employing one-way concurrent (OWC), one-way sequential (OWS), and two-way (TW) nesting approaches with advanced physics options from Korean Integrated Model (KIM). Analysis of model simulations against Tropical Rainfall Measuring Mission (TRMM) and Automatic Weather Station (AWS) observations suggests that the TW nesting method performs better than both OW nesting methods in simulating rainfall. Large-scale features, moisture, instability in the boundary layer, and the vertical distribution of meteorological parameters favorable for convection are better represented by TW nesting. Probability distribution Function (PDF) analysis from AWS/WRF reveals that the local-scale distribution of surface meteorological parameters which affect storm intensity were well captured using TW. Further assessment of Equitable Threat score (ETS) also showed better precipitation forecast skill over different thresholds in TW. Vertical velocity in the innermost domain simulated using TW nesting is more consistent with ERA5 reanalysis. An additional MCS (11–13 July 2006) simulated using a similar numerical setup also benefited from TW nesting, increasing confidence in the initial findings. Along with frequent lateral boundary conditions, TW nesting allows multi-scale interactions between parent and nested domains and improves the representation of both synoptic and local-scale features, enhanced cloud hydrometeor, vertical velocity distributions, and subsequent rainfall.

Madhulatha, A., Choi, S.-J., Han, J.-Y., & Hong, S.-Y. (2021). Impact of different nesting methods on the simulation of a severe convective event over South Korea using the Weather Research and Forecasting model. *Journal of Geophysical Research: Atmospheres, 126*, e2020JD033084. https://doi.org/10.1029/2020JD033084

Keywords: Nesting Methods(one-way,two-way), MCS, WRF, Cloud Hydrometeors, Lateral Boundary Conditions

Evolution of a cloudburst event over Uttarkashi: Comparison of IMDAA and ERA5 ranalysis datasets.

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ABSTRACT

Two reanalysis datasets are used for understanding the role of atmospheric conditions controlling the evolution of a cloudburst event over Uttarkashi district of Uttaranchal during 3rd August 2012. The The Indian Monsoon Data Assimilation and Analysis (IMDAA) and ECMWF Reanalysis v5 (ERA5) datasets during this period are evaluated to find the atmospheric condition of wind, potential vorticity, OLR and Vertically Integrated Moisture Transport (VIMT) during the event. Also vertical structure of the humidity, vorticity, precipitation and severe index parameter like Convective Available Potential Energy (CAPE) and Severe Weather Threat Index (SWEAT) have been calculated using this datasets separately to determine to identify the dataset which has best representation of severity of the cloudburst event. The higher severiety values are produced by the IMDAA dataset, compared to ERA5. Rainfall from IMDAA and ERA5 dataset during this event were compared with observed Global Precipitation Measurement(GPM) rainfall estimates.The IMDAA dataset shoes more correlation with GPM rainfall than with the ERA5. The correlation of IMDAA rainfall with GPM is 0.60 while ERA5 with GPS is 0.28. The time bias of the occurrence of heavy rainfall is less in IMDAA (around 3 hrs) than ERA5 (5 hrs). The moisture from Bay of Bengal and Arabian Sea were interacted over Uttarkashi and the orographic uplifting were well brought out by IMDAA reanalyses compared to the ERA5.

Keywords: Cloud Burst, IMDAA and ERA5 reanalysis, Severe Weather Index, GPM rainfall.

Effect of Air Pollution on SST over the Bay of Bengal.

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ABSTRACT

Anthropogenic emissions have steadily grown since the industrial revolution of the globe. Although countries have introduced multiple measures to reduce emissions, particularly in developed nations, implementing these measures continues to pose a severe problem in developing countries. Against this backdrop, the world recently experienced the devastating effects of the COVID-19 pandemic, which subsequently led to strict lockdowns. This provided an excellent case to understand the impact of human activities on aerosol loading even over oceanic locations far from polluting sources. The Bay of Bengal (BoB) is one of the most polluted ocean basins globally, with human-made or anthropogenic aerosols making up to 65 to 70% of the aerosol load over the region. The aerosol load and composition over the region are severely affected by the outflow from the surrounding landmass, especially the Indo Gangetic Plains (IGP), one of the most polluted regions in the world. In this study, the effect of pandemic lockdown and the associated decrease in emissions on sea surface temperature (SST) is explored. We find that aerosol optical depth (AOD) over the BoB declined by as much as 0.1 or 30% during the peak lockdown of April 2020 compared to long-term climatology using almost two decades of satellite measurements. Simultaneously the net solar radiation at the surface is found to have increased by 6.62W/m^2 through analysis done using buoy data. Sea surface temperature (SST) is observed to have risen by 0.5 to 1.5 ºC over the central and northwestern parts of the BoB with an average increase of 0.83 ºC. We show up to 30% of this observed warming can be attributed to reduced atmospheric aerosols. The study highlights the importance of anthropogenic emissions and their short-term effects on SSTs over ocean basins with implications for regional weather.

Keywords: Air Pollution, Anthropogenic Aerosols, COVID-19, Sea Surface Temperature.

An Analysis of Fog/low Visibility in the Airports in Eastern India (Representative Station: Patna Airport).

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ABSTRACT

Strong variations in fog qualities have been found by analyzing hourly METAR observations for the period 2014-2022 for the Patna Airport which is situated in the Indo Gangetic Plains(IGP) of India. Fog is mainly a wintertime phenomenon for the entire IGP. Although fog is usually associated with the frequency, amplitude, and Intensity of Western Disturbance(WD) but in the present study it is found that both the initiation and onset process critically rely on local wind apart from other factors. A classification scheme based on the prevailing condition prior to onset of fog has been devised. As per this scheme fog can be classified in to five categories i.e. advection, precipitation, radiation, and cloud base lowering. The study's findings have identified a promising pre-fog diagnosis tool which has the potential of operational us provided it is validated with longer period data. The classification algorithm/methods correctly categorize the 100% fog events of Patna Airport into five categories. The dominant type of Fog is radiation
Fog(70.8%), Advection Fog(22.02%) Precipitation Fog(2%), and Cloud base lowering fog(0.62%) out of the 4300 hourly Fog events at the Patna Airports. None of the fog identified as evaporation type

Keywords:-Visibility, Fog formation, fog classification, etc.

Estimation of Disaster Losses in India – A Methodological Challenge

By

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ABSTRACT

There were 432 disastrous events related to natural hazards in 2021 alone, claiming the lives of 10,492 people, affecting 101.8 million people, and causing damages equivalent to 252.1 billion USD worldwide (*2021 Disasters in Numbers*, 2022)[1]. The planet has been facing a brutal onslaught of extreme weather events and natural disasters precipitated by the changing climate and a host of other factors. In the wake of such unprecedented devastation, millions of people have been left to rebuild their lives. Their impact goes beyond the immediate and visible fallout of the event and leaves an enduring mark on human welfare and economic development. Such disasters often derail socioeconomic progress for years to come and push thousands of people into poverty and homelessness. Although natural disasters may strike indiscriminately in rich and poor nations alike, the disaster losses are known to disproportionately affect the poor because of their increased vulnerability to the damaging effects of the hazard together with their lower capacity to cope (Hallegatte et al., 2017)[2].

This paper examines severe impacts of such extreme events, for example floods and cyclones on the mankind including loss of life and property in India and critically evaluates the existing internationally aclaimed mechanism Post Disaster Needs Assessment (PDNA) adopted to estimate the losses caused by such disasters. This paper also highlights some methodological improvement needed in the present procedure.

Key Words: Natural hazards, vulnerability, damages, disaster losses, PDNA

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An overview of the climate indices related to health sector over Kerala

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ABSTRACT

Climate change is affecting all the sectors of the human activities. Rise in global temperature increases the intensity and frequency of extreme weather events globally and locally. Many of the communicable diseases like malaria, dengue, chickenguniea etc. are influenced by the environemmtal and climate factors. Associated with the changes happened in climate, lot of variabilities observed in the distribution and population size of the disease vectors. This study attempt to understand the variblities and trends in the health sector specific climate indices over the major staions of Kerala. It also try to find out the relationship of communicable diseases with different climate indices and to characterize the climate sensitivity of health sector of Kerala state.

Keywords: Climate change, Communicalble Diseases, Climate Indices

Verification of Extreme Rain over India: Improved Skill in NCMRWF Model Rainfall forecasts in recent Years

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ABSTRACT

Forecasting of Extreme Rainfall events is a challenge is even for the most advanced, high regsolution state-of-art NWP system. The daily rainfall over India during the monsoon season (June-September) is governed by the interplay of the large-scale, synoptic and mesoscale disturbances, many of which are sporadic rainfall spells and extremely intense. These spells often bring extreme amounts of rain over only a few days, which can have sizable impacts on the estimated seasonal mean rainfall. The record rainfall of over 100 cm/day in Mumbai on 26th July, 2005 is an outlier/extreme at over 20 standard deviations for activity of typical June-September average rainfall of 18 mm/day with daily standard deviation of 28 mm/day. While such outliers are not uncommon in India during the monsoon season, they pose serious challenge to even the high resolution forecast models. The statistics of such similar outlier events are examined both for observed and model-forecast daily rainfall for recent five monsoon seasons (2018-2022). Some of the extreme one day rainfall events contribute up to 30% of the seasonal total rain.

This study presents rainfall verification over India using traditional verification scores such as Probability of Detection (POD), Equitable Threat Score (ETH), Critical Success Index (CSI) etc. for various categories. Stable Equitable Error in Probability Space (SEEPS) and the Symmetric Extremal Dependence Index (SEDI) are two advanced verification metrics which are complementary scores of forecast performance. While SEEPS quantifies general performance in the prediction of dry/wet spells, the SEDI focuses on higher threshold events. Both scores assess the locally important aspects of the forecast. They make use of the climatological distribution of precipitation at each location to define thresholds. Thus it is possible to aggregate the scores over climatologically diverse regions and an index can be computed.

High resolution rainfall forecasts over India based on NCUM-G, UKMO and GFS models is assessed during four recent monsoons (2018-2022) using SEEPS and SEDI metrics. The verification is carried out against (i) 0.25 x 0.25 grid IMD-NCMRWF merged rainfall analysis and (ii) 0.1 x0.1 deg grid IMERG rainfall data to assess the sensitivity of verification to grid resolution. The results indicate (i) the high grid resolution of the models is effective in producing the improved skill in prediction of rainfall exceeding 90th percentile rainfall threshold as indicated by SEDI.(ii) models predict excessive number of light and moderate rain and underestimate the heavy rains over India.

Keywords: Extreme Rain, Outlier, Verification, SEDI, SEEPS

IMPACT OF RAINFALL VARIABILITY & TRENDS ON RICE IN MADHYA PRADESH

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ABSTRACT

Climate variability and change exert pressure on various sectors, especially the agriculture sector. Due to the changes in temperature, we witness shift in rainfall pattern and intensity which is affecting crop production. Climate changes can be expected to pose serious impacts on crop productivity and eventually threats to food security through an increase in temperature and a decline in water availability. The impact of climate change is already felt on agriculture in many parts of the world. Climate change impact assessment at a regional scale is pivotal for framing suitable adaptation strategies and making appropriate policy decisions at a local scale. Agriculture in Madhya Pradesh faces enormous challenges related to climate variability and change. A study was carried out to assess the impact of climate change on rice over Madhya Pradesh through climate and crop simulation model integration. The historical long-term weather data (1991-2020) obtained from India Meteorological Department (IMD) was used for performing the current climate analysis. Future climate (2021-2050) was generated using a regional climate model with Representative Concentration Pathway scenarios (RCPs- 4.5/8.5). DSSAT, a dynamic crop simulation model, was employed to simulate the growth and yield of rice under current and future climatic conditions. Results of the current climate analysis manifested that air temperature showed an increasing trend with an increased number of hot days. Future climate projections indicated a rise in temperature during 2021-2050. The changes in rainfall are expected with more frequent extreme weather events. The projected warming and changes in rainfall pattern are expected to affect rice productivity and increase the climate related risks in rice production. The adverse impacts of climate change emphasis the need for devising adaptation strategies for sustainable rice production in a changing climate.

Keywords: Climate change, impact, rice, DSSAT, Madhya Pradesh

Model Evaluation Tools (MET) framework for Tropical cyclone (TC) verification in NCUM forecasts

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ABSTRACT

Operational forecast verification and evaluation is a crucial facet of model development. In recent times the rapid growth in the verification of model forecasts at different time scales has led to improvement of day-to-day forecasting. Specifically, verifying the position and intensity of Tropical cyclones (TCs) in operational numerical weather prediction (NWP) models is essential for both post-event evaluation and also in real time. At National Center for Medium Range Weather Forecasting (NCMRWF), one of the leading numerical modelling centers in India, verification of forecasts performed on regular basis. Recently, under the Met office's new generation verification system (NG-Ver) MET and METplus python wrappers are identified as replacement. Thus, with the aim of understand and improve the TC forecast performance, we have implemented Model Evaluation Tool (MET) framework for evaluation of TC forecasts over various basins of the world. MET is a blend of traditional and modern verification methods provides end-users a wide range of approaches to address the needs.

In the present work, we have prepared statistics for a large set of cases, collected over three years, during 2019-2021 TC events over different basins of the globe. For this purpose, we have used Joint Typhoon Warning Center (JTWC) track data as in ATCF format to examine the performance of NCMRWF Unified model (NCUM) track forecasts, which are obtained by applying a vortex tracker algorithm to gridded model output. The exercise is repeated by using the Met office (UKMO) forecast tracks obtained from MOGREPS and the stats and plots from TCPairs and TCStat are obtained. Preliminary results of TC forecasts evaluated by MET-TC module are very encouraging and we will also look into the rapid intensification/weakening (TC-RI/RW) and radius of maximum winds (TC-RMW) in both deterministic and ensembles for better understanding of the system.

An AI/ML-based study on North Indian Ocean Cyclonic Disturbances and City-specific rainfall: Climatological Analysis and Future Prediction

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ABSTRACT

Extreme weather events including the cyclonic disturbancs (CDs) can cause significant damage to livelihood. Hence, a precise prediction may have great positive impacts on the life and economy. This study is an attempt to use AI/ML-based frameworks for performing city-specific rainfall analysis, and studying North Indian Ocean (NIO) CD activity, and their landfalling over the Indian coasts (both eastern and western coasts) along with the rim countries. The NIO CD-related analysis involves both seasonal and annual variations along with categorization. Also, an effort is made for forecasting as well. NIO CD-related studies are carried out using the ARIMA model, whereas rainfall-related analysis is carried out using techniques like Long Short Term Memory (LSTM) networks, Gated Recurrent Unit (GRU) and Bidirectional LSTM (BiLSTM). The ARIMA model prediction shows a decreasing trend over the North Indian Ocean. An increasing trend is quite visible over the AS, whereas over the BOB, a decreasing trend is seen. On the east coast of India, an increase in landfal is predicted by the ARIMA model over Tamil Nadu, whereas on the west coast, Konkan and Goa is going to experience an increase. In case of the RIM countries, an increasing trend is seen in Bangladesh and IAA (Iran, Arabian Peninsula and Africa). The rainfall-related analysis is carried out over 45 smart cities using 121 years of IMD gridded data by computing monthly averages for the years 1901 to 2021. The model was trained using actual grid point value along with 8 neighbourhood grid points data based on region wise and city wise performance of the three deep learning (DL) models (i.e., LSTM, GRU, and BiLSTM) in terms of two performance indicators i.e. Root Means Squrae Error (RMSE) and Mean Absolute Error (MAE). BiLSTM model found to perform relatively better for all cities and GRU could predict better in places of large range of rainfall variation. Therefore, a combination of BiLSTM and GRU may be considered. In case of univariate rainfall prediction, the RMSE values range from 1.476 (Davangere) to 5.34 (Shillong), and MAE values range from 0.8232 (Jaipur) to 3.72 (Shillong). And, for multivariate forecasting, LSTM model performed better than others for all cities considered where RMSE values range from 1.376 (Tumukara) to 4.951 (Shillong) and MAE values range from 0.821 (Udaipur) to 3.057 (Shillong).

Keywords: NIO, rainfall, ARIMA, LSTM, BiLSTM,

Water Quality Analysis of River Sabarmati using in-situ and Remote Sensing Dataset

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ABSTRACT

Due to rapid urbanization and industrial growth in Ahmedabad and surrounding areas, the Sabarmati River has witnessed a degradation of water quality, which has put pressure on policymakers to ensure a sustainable drinking water supply. Remote sensing techniques of water quality parameters have emerged as an effective tool to monitor parameters like- Suspended particulate matter (SPM), Chlorophyll-a, Colored Dissolved Organic Matter (CDOM), Turbidity, etc. In this work, we accessed available water quality data from CWC (India-WRIS) and found that the DO ranges between 1.2-9 mg/L, BOD 0.45-50 mg/L, COD 10-1000 mg/l, Turbidity 0.60-200 NTU, and pH 6.4-9 respectively.

We also evaluated the performance and applicability of Landsat-8 and Sentinel-2A images for the estimation of optically active constituents like Chlorophyll and SPM (Nechad et al. 2010). For estimation of chlorophyll red-Nir and NDCI-based algorithms were used, that have higher applicability in productive turbid waters (Mishra et al. 2018). Time series analysis of water quality parameters near Ahmedabad was carried out from 2016 to 2022 using Google Earth Engine and the obtained revealed variability of water quality constituents as Chl-a 10-35 mg/m^3, SPM 13-25 g/m^3 and Turbidity 12-18 FTU. Nowadays due to less river discharge, rivers are converting into stagnant waters and an excess amount of Chl-a, particulate matter (living or non-living), and nutrients get accumulated especially adjacent to river banks and close to structures in water like pillars, pump houses etc. Further, we are aiming to develop a site-specific regional algorithm to estimate water quality constituents' concentration more accurately by collecting the water samples in-synchronous with the satellite overpass and analyzing them in the laboratory. These remote sensing-based observations will help to understand the dynamics of the rapid decline in the water quality of rivers and to identify the hot-spot pollution areas.

Keywords: Sabarmati River, water quality analysis, remote sensing, Chl-a etc.

Climate change impact on rainfall events with different consecutive days of Summer Monsoon Rainfall over NorthEast India

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ABSTRACT

World's highest rainfall occurs over north-east India (NEI) during boreal summer and is characterized by large spatial inhomogeneity. Quantification of global warming impact on the north-east India rainfall (NEIR) is, therefore, a crucial factor for the region's food security and delicate biodiversity. Daily rainfall data sets for the past century (from year to year) for a period of 1920-2009, derived from a network of 24 well distributed monitoring stations spread across low to high rainfall areas of NEI have been used in this study. This study investigated the nonlinear trends of various rainfall events with different consecutive days and their contribution to seasonal rainfall during summer monsoon. The rainfall events are classified based on the consecutive days of rainfall into 1-3, 4-7, 8-13 and above 14 days events. Frequency and contribution towards JJAS seasonal rainfall analysis shows that 1-3 days rainfall events over NEI has an increasing trend (p-value=0.9964) amongst all other rainfall events with different consecutive days whereas 8-13 rainy days event show significant decreasing trend (p value=0.9997) during the last century. The results of our study implies that climate warming exacerbates the isolated mesoscale rainfall events over the NEI and hence can cause catastrophic climate induced hydrological disasters.

Keywords: Climate change, types of rainfall events, nonlinear trend, frequency of rainfall events

Water Quality Analysis of River Sabarmati using in-situ and Remote Sensing Dataset

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ABSTRACT

Due to rapid urbanization and industrial growth in Ahmedabad and surrounding areas, the Sabarmati River has witnessed a degradation of water quality, which has put pressure on policymakers to ensure a sustainable drinking water supply. Remote sensing techniques of water quality parameters have emerged as an effective tool to monitor parameters like- Suspended particulate matter (SPM), Chlorophyll-a, Colored Dissolved Organic Matter (CDOM), Turbidity, etc. In this work, we accessed available water quality data from CWC (India-WRIS) and found that the DO ranges between 1.2-12 mg/L, BOD 0.45-65 mg/L, COD 10-1000 mg/l, Turbidity 0.60-200 NTU, and pH 6.4-9 respectively.

We also evaluated the performance and applicability of Landsat-8 and Sentinel-2A images for the estimation of optically active constituents like Chlorophyll and SPM (Nechad et al. 2010). For estimation of chlorophyll red-Nir and NDCI-based algorithms were used, that have higher applicability in productive turbid waters (Mishra et al. 2018). Time series analysis of water quality parameters near Ahmedabad was carried out from 2016 to 2022 using Google Earth Engine and the obtained revealed variability of water quality constituents as Chl-a 10-35 mg/m^3, SPM 13-25 g/m^3 and Turbidity 12-18 FTU. Nowadays due to less river discharge, rivers are converting into stagnant waters and an excess amount of Chl-a, particulate matter (living or non-living), and nutrients get accumulated especially adjacent to river banks and close to structures in water like pillars, pump houses etc. Further, we are aiming to develop a site-specific regional algorithm to estimate water quality constituents' concentration more accurately by collecting the water samples in-synchronous with the satellite overpass and analyzing them in the laboratory. These remote sensing-based observations will help to understand the dynamics of the rapid decline in the water quality of rivers and to identify the hot-spot pollution areas.

Keywords: Sabarmati River, water quality analysis, remote sensing, Chl-a etc.

Comparative study of Seasonal and Regional Variation of Rain DSDs for Different types of Precipitating Systems and Associated Microphysical Processes using OTT Parsivel^2 Disdrometer

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ABSTRACT

In this present work, seasonal and regional variation of rain DSDs for different types of precipitating systems and associated microphysical processes are studied by using the OTT Parsivel2 Disdrometer, The study is carried out during the premonsoon and monsoon season over Kohima (25.660N, 94.070E) and Rampurhat (24.170N, 87.780E). The utilized data is of five years (2017-2021). The precipitating systems are classified as (i) Stratiform (ii) Convective and (iii) Mixed precipitation system by using the standard deviation of rain rate. The Parsivel observations are validated with tipping bucket rain gauge and it shows a good correlation about 0.97 and 0.90 for 30 minutes rainfall accumulation over Kohima and Rampurhat respectively.

The frequency of occurrence shows maximum for mixed system for both the stations, whereas percentage of rain accumulation is maximum for mixed and Convective system over Kohima and Rampurhat respectively both during premonsoon and monsoon. The rain DSDs shows the occurrence of larger drops in the order of Convective>Mixed>Stratiform over Rampurhat for all types of rain as compared to Kohima. The mass weighted mean diameter (D_m) values are higher with larger standard deviation over Rampurhat and showing larger D_m values during pre monsoon as compared to the monsoon season in both the station. The derived Z-R relation for different rain types during pre-monsoon and monsoon shows significant seasonal and regional variation where coefficient 'a' shows larger values and exponent 'b' shows smaller values for all rain type except Stratiform over Rampurhat as compared to Kohima. The Microphysical process shows distinct regional variation where strong size controlled process is dominion over Kohima and mixed controlled process over Rampurhat .

INDIAN SUGARCANE UNDER WARMING CLIMATE: A SIMULATION STUDY

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ABSTRACT

The future response of sugarcane plant physiology and yields towards climate change remain uncertain due to differences in climate projections. The sensitivity of sugarcane ecophysiology to individual climate drivers (i.e. temperature, precipitation, solar radiation and CO2) and their interactions is largely uncertain. The accuracy in climate prediction offers potential to assess the future climate change impact on sugarcane plant. The quality of impact study approach using crop modelling basically relies on accuracy of climate input data from regional climate models (RCMs). It is important to quantify the errors incorporated during model development time as well as during downscaling processes and must be corrected to perform better yield estimates using crop simulation model. The present study is an attempt to assess the impact of climate change on sugarcane crop using various RCMs under Representative Concentration Pathway (RCP) scenarios (RCP 4.5 and RCP 8.5) for 2040-2069 (mid-future) and 2070-2099 (far-future) over the major sugarcane growing states of India. The primary analysis includes the selection of desired RCMs that performed well over the study region i.e. RegCM4, CCAM ensembled model. The biases in RCM incorporated due to imperfect model parametrization or incorrect model initialization was further quantified by comparing annually and seasonally with observed climate and was corrected with different bias correction approaches for climate variables. The bias-corrected data was further used in CANEGRO-Sugarcane crop model to predict the sugarcane yield under two RCP scenarios (RCP4.5, RCP8.5). This results from the multi-climate model assessment provides better information and reliable results to identify the future sugarcane yield under changing climate which will help in valuable decision support for crop adaptation and management strategies and policy planning.

Keywords: Sugarcane, CANEGRO-Sugarcane, RegCM4, Bias Correction

Changes in rainfall extreme over the Teesta River Basin, Sikkim, India

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ABSTRACT

Heavy precipitation over the northeast region of India mostly influenced by south-west monsoon of the South Asia which reveals the extreme rainfall events and flash flood risk over the Teesta River Basin (TRB). The study focused on the extreme precipitation event for flood situation over the TRB in present and future scenario by using different extreme indices like Extreme precipitation index (EPI), Standardized precipitation index (SPI) and Rainfall Anomaly Index (RAI) on the observed and projected climate model. Also, evaluated the return period of extreme rainfall events by using Generalized extreme value (GEV) distribution theory. Evaluated extreme indices were performed on observed IMD (1970-2018) rainfall and projected ensemble Coupled Model Intercomparison Project 5 (CMIP5) at Representative Concentration Pathway 8.5 (RCP 8.5) scenarios, respectively. The estimated EPI show 3605 number of heavy rainy days (Precip ≥ 10 mm) in last 35 years, while assembled CMIP5 (2019-40) showed increment in heavy rainy days indices (e.g. Pint) from 1677 to 1761 that indicates the higher frequency of future existences of floods in the study area. The results showed an increasing trend in the rate of extreme precipitation event in both observed and projected precipitation scenarios. Observed rainfall illustrated the heavy precipitation as extremely wet events represent the flood years in between 1981-1995 and 2003 were evaluated as defined threshold 300 mm/5days while projected flash flood years evaluated in monsoon months in between 2021-31 over the TRB, Sikkim.

Keywords: Extreme Rainfall events, Standardized precipitation index (SPI), Generalized extreme indices (GEV)

Performance Evaluation of WRF-ELEC in Simulating one lightning case over Rajasthan

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ABSTRACT

The modelling of lightning is still a challenging task for researchers and scientists. The WRF-ELEC model, which combines the electrification (ELEC) additional package with the Weather Research and Forecasting (WRF), has been used to study lightning activity. The numerical modelling and satellite datasets have been used to monitor the distribution of lightning flashes. The synoptic and spatial distribution of lightning flashes and the Lightning Potential Index (LPI), which is a measure of the potential for charge generation and separation within clouds, have been compared in this study using data from the NASA satellites Lightning Imaging Sensor (LIS), Tropical Rainfall Measurement Mission (TRMM), and INSAT-3DR Imager. This research based on a lightning strike in Jaipur, Rajasthan, on July 11, 2021, where 11 people died because of lightning strikes. The weather research forecasting (WRF) model has been used for modelling and simulation purposes, using the 0.25-degree resolution operational Global Forecast System (GFS) datasets from NCEP. The model has been integrated for the Jaipur region 24 hours from 00UTC between July 11 and 00 UTC on July 12, 2021, with double nested 9 and 3 km domain resolution. The new WRF-ELEC model with microphysical parameterization schemes NSSL-2 has been used for the calculations of lightning flashes, and LPI using (Yair et al., 2010) and (McCaul, 2009) method respectively. The model results simulated by NSSL-2 scheme have been compared to verify the findings, (i) accumulated precipitation, (ii) spatial distribution of lightning flashes, (iii) maximum reflectivity, (iv) CAPE, and (v) Lightning Potential Index, with the observational datasets. The model results performed remarkably well in predicting lightning over the region. The results show the strength of the WRF-ELEC model for the prediction of lightning. This research is a step toward building a reliable modelling and satellite remote sensing lightning warning system to reduce lightning-related hazards in India.

Keywords: Lightning, Satellite Datasets, Weather Forecasting Modelling, Microphysics Scheme, WRF-ELEC

RESPONSE OF WHEAT VARIETIES UNDER VARIED IRRIGATION SCHEDULING USING SPECTRAL INDICES

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ABSTRACT

A field experiment was initiated in rabi season 2021-22 with an aim to identify water sensitive stages in wheat varieties for optimizing yield with the help of canopy reflectance based spectral indices in vertisol at central India. Two varieties (Lok-1 and MP 3336) with four irrigation scheduled were laid in a factorial design. The water regimes were four levels of irrigated water (equaling to 1.0, 0.9, 0.8, and 0.7 times of open pan evaporation, CPE). A spectral reflectance indices were computed at different crop growth stages (booting, spikelet initiation, milk, soft dough and physiological maturity) using handheld spectro-radiometer (350-1100 nm with 0.5 nm band width). Among the varieties, there was no significant differences ($P<0.05$) in grain yield, while IW:CPE 1.0 exhibited higher grain yield than the other irrigation scheduled thereby suggesting full irrigation is a better practice for optimum grain yield. All the spectral indices were correlated significantly at soft dough stage with grain yield thereby considered it as more water sensitive stage in the growth period of wheat. However, some water indices also correlated significantly at milk and physiological maturity as water sensitive stages, particularly in MP 3336 variety. A linear multiple regression models were evaluated for predicting grain yield among both the varieties.

Estimation of crop water requirement and irrigation schedule of Cotton in Dharwad district of Karnataka using FAO-CROPWAT

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Abstract

The most popular natural fibre on earth is cotton. In India, its use began around 3500 BC. But cotton is a crop that is highly susceptible to climatic change. More water is needed in response to rising temperatures particularly during the development of flowers and bolls. 73% of cotton is currently thought to be cultivated with full or partial irrigation. As a result, it is anticipated that the production of cotton will vary in traditional cotton-growing areas around the globe due to climate change, drought, shortage of groundwater and unpredictable rain patterns.
Therefore, the present study focuses on the estimation of crop water requirement (CWR) and irrigation schedule of Cotton for Dharwad district of Karnataka, India from 2001 to 2020. In Dharwad, the average CWR for cotton was 582.39mm from the year 2001 to 2020 with highest CWR (596.8mm) recorded in the year 2001 while lowest in 2004 (561.6mm). Average effective rainfall for Dharwad district from 2001 to 2020 was 512.97mm with 2008 shown highest effective rainfall (646.7mm) and 2014 shown the lowest (372.6mm) for cotton. The average irrigation requirement for cotton was 221.5mm in Dharwad as the region received close to sufficient rainfall to meet the water demand from the year 2001 to 2020. 2018 was the year with highest irrigation requirement of 309.5mm and 2004 with lowest irrigation requirement with 109.4mm. The present study will be useful for the efficient management and planning of irrigation water demands of cotton in Dharwad district of Karnataka, India.

Keywords: Climate change, cotton, Crop water requirement, Effective rainfall, Irrigation requirement

Vulnerability of the Indian Himalayan region due to compound wet hazards

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ABSTRACT

Compound wet hazards can create severe widespread impacts than any single hazard alone. Generally, hazard assessment methods consider only one hazard at a time. Such assessments may lead to underestimation of actual impacts, especially when the drivers of the hazards interact in a common space and time. The Himalayan region, due to its complex geology, topography, uncertain weather patterns and increased anthropogenic activities is more prone to the devastating impacts of compound hazards. In this study, we conduct a vulnerability assessment of the Indian Himalayan Region (IHR) due to compound wet hazards (CWH) induced by a common precursor, i.e., extreme rainfall. We consider four types of hazards induced by extreme rainfall such as floods, cloudbursts, avalanches and landslides. The study area consists of 87 districts spanning across 11 states of the IHR. The vulnerability of each district is identified and classified on the basis of its susceptibility to the number of hazards and also on possible combinations of hazards. An integrated approach is adopted to inform the model with data of various indicators belonging to weather, topography, vegetation and local socio-economic conditions. Each indicator is allotted the dimensions of exposure, sensitivity and adaptive capacity based on its nature of function. The indicators are assigned appropriate weights and subsequently aggregated to form compound hazard vulnerability index (CHVI). Moreover, a scheme of compound hazard adaptation model (CHAM) is proposed for the districts prone to multiple hazards based on their vulnerability status. Such a vulnerability assessment which identifies the Himalayan districts prone to multiple natural hazards, classifies their hazard status based on impacts, evaluates the possible causes and suggest suitable adaptation models, can assist national and state disaster management agencies in reducing potential risks. Moreover, efficient mitigation measures can also be implemented based on suggested adaptation models.

Keywords: Himalayas, Vulnerability, Landslide, Flood, Avalanche

Assessing Heat waves Characteristics over Odisha

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ABSTRACT

The world has been witnessing sever heat waves indicating the climate change. Like other countries, India also experiencing the impact of the climate changes and the heatwave disasters during summer. In India the coastal state of Odisha was severely affected by the extreme heat waves in years like 1998, 2006, 2010 and so on covering almost all districts of Odisha. This work tries to assess the Heat Waves characteristics in the state of Odisha using the data from various sources like IMD, NCEP Reanalysis, APHRODITE, ERA-Interim and satellite products. The multisource data analysis is being used and the study are carried out at domains like Western Odisha, Eastern Odisha, Central Odisha and North Odisha etc. The maximum temperature, relative humidity, wind intensity etc. are considered to compute the Heat Index in order to find high zone of extreme heat waves of Odisha. The spatial as well temporal variability of Heave waves are also quantified and presented in the paper which will be useful in the disaster management.

Keywords: Heat Waves, Climate change, Weather Prediction, Remote Sensing, Climate modelling,

Tropical cyclone wind hazard estimation using a statistical-parametric model for Indian coast

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ABSTRACT

Tropical cyclones are one of the most destructive atmospheric systems that cause enormous loss to the life and properties. The growing number of intense cyclones is a huge concern for the administration as well as for the scientific community in India. The intense winds associated with the cyclones are among the prime causes accountable for most of these losses. Estimation of the probable maximum cyclone winds would help in the longtime preparation as well as in developing a better mitigation plan to minimize the damage caused by these systems. Using a statistical-parametric risk assessment model that creates synthetic events representing thousands of years of cyclonic activity, we estimate the wind hazard for the Indian coast. The return periods calculated using the model outputs and their comparison with the observation-based estimations suggest more insights into issue.

Keywords: Tropical Cyclone, Wind Hazard, Return Periods, Mitigation (maximum 5 words)

ON RAPID INCREASE IN THE MHW INTENSITY DURING LAST DECADE (2010-PRESENT) USING SATELLITE OBSERVATIONS: IMPLICATIONS ON CYCLONE ACTIVITY IN THE ARABIAN SEA

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ABSTRACT

In this study we have analysed Marine Heatwaves in the global oceans over the past 40 years i.e. 1982-2021, using satellite-based sea surface temperature observations. We have further characterised the Marine Heatwaves using global satellite SST data along with some impact analysis on Marine Heatwave properties. Along with it, an analysis on the possible correlation between Marine Heatwave events and cyclones is discussed for the northern Indian Ocean, specifically the Arabian Sea and Bay of Bengal.

From the analysis, it has been found that the number of Marine Heatwave events has increased drastically during the past 40 years, with a significant increase in the last decade (2010-present). The major Heatwave events in the last 40 years have been observed in the southern Pacific Ocean, the Northern Atlantic Ocean, and the Southern Indian Ocean. Intense heat wave events are observed in the polar regions. The northern Indian Ocean has witnessed comparatively lesser MHW events than the other regions during the 20th century. However, there is a rise of almost 15% in the last decade. We noticed that the number of cyclones has increased steadily in the Arabian Sea, and the intensity, as well as duration of those cyclones, increased dramatically during the observed time period. This goes without a doubt, that the rising MHW events may have some impact on the rising cyclone levels in the Arabian Sea. More details will be presented during the conference.

Evolving crisscross pattern in Indian summer monsoon rainfall and its relationship with the aerosols

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ABSTRACT

Decoding the continuously evolving climatic patterns is essential to understand and predict the climate. The Indian summer monsoon shows significant interannual variability due to various known and unknown factors and the agriculture sector which is considered as the backbone of the region's economy is highly vulnerable to these changes. In this work, we show a pattern observed in the mean monsoon rainfall trends for the recent period that resembles a crisscross like pattern with the significant yet opposite trends aligned along each one its flanks. It is also observed that the aerosol loading shows a significant high all over the region except over the Northwestern parts of the country where the rainfall has increased in the recent times. Therefore, the link between aerosols and the observed crisscross pattern is further investigated using various statistical methods. The study concludes that the relationship between the two is a multitude involving complex aerosol-climate interactions and some of these interactions associated with pattern will be presented.

Keywords: Climate Patterns, Indian summer monsoon, Aerosols, Trends (maximum 5 words)

SPATIAL DOWNSCALING OF IMD GRIDDED RAINFALL DATA USING SRCNN AND SRRESNET: A COMPARITIVE STUDY

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ABSTRACT

Given the importance of downscaling coarse resolution meteorological data, the use of AI/ML-based methods proves to be a promising and intriguing alternative to the traditional methods. Historically, several statistical and dynamical downscaling techniques have been employed to downscale coarse resolution data to a finer scale for studies on smaller regions. However, these traditional methods are either inefficient in capturing several finer resolution details or are computationally resource intensive with higher downscale factors/for relatively larger regions. Super Resolution Convolution Neural Network (SRCNN) is an image super-resolution technique designed for low-to-high resolution image downscaling. SRCNN was one of the first promising AI/ML alternatives for downscaling meteorological data. The main advantage of SRCNN was that it's a single trained model that can downscale spatially heterogeneous regions and is relatively less computationally demanding. Super Resolution Residual Neural Network (SRResNet) is an improvement over the SRCNN. It's a substantially deeper network consisting of residual blocks made of multiple convolutional layers and skip connections. In this study, we compared SRCNN and SRResNet downscaled products and assessed if SRResNet is an improvement over the SRCNN technique. For this study, the Indian Meteorological Department (IMD) gridded rainfall data at low-resolution (LR) and high-resolution (HR) for the years 1901–2021 was used. Both the SRCNN and SRResNet were trained to downscale the LR (1°x1°) rainfall data to its HR (0.25°x0.25°) counterpart by a factor of four. These networks were trained on gridded rainfall data of the monsoon (June-July-August-September or JJAS) months of 1901-1999 and then tested for the remaining period, i.e., 2000-2021. The resultant downscaled products were then compared using different objective metrics such as root mean squared error (RMSE), and structural similarity index (SSIM), among others. In conclusion, the SRResNet performed better in capturing the high resolution features and preserving structural similarity upon downscaling when compared to SRCNN.

Keywords: Deep Learning, Machine Learning, Super-Resolution, Residual Network, Downscaling

Artificial intelligence in forecasting Pressure drop and Maximum sustained wind speed of Tropical Cyclones over Arabian Sea

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ABSTRACT

An attempt is made in this study to develop a neuro-computing based adaptive intelligent model to forecast the central pressure drop (PD) and maximum sustained wind speed (MSWS) associated with cyclonic systems at the stage of the highest intensity over Arabian Sea of North Indian Ocean (NIO). Tropical cyclones are possibly the most detrimental of all meteorological hazards and become much more frequent in India with continued climate change. The cyclonic systems considered in this study include the phases from deep depression to extreme severe cyclones. The sea surface temperature, mid-tropospheric relative humidity, surface to middle tropospheric equivalent potential temperature gradient, inverse of wind shear, and vertical wind velocity at 200 hPa level are obtained as the most suitable predictors through principal component analysis. Various Artificial neural network models with different architectures have been trained with the data from 1990 to 2012 to select the best forecast model. The prediction skill of the intelligent models is verified by computing different accuracy measures. The results show that the multi-layer perceptron (MLP) model with five input layers, one hidden layer with four nodes and one output layer delivers the best result in forecasting the PD of tropical cyclone. The result further reveals that the MLP model is the most competent in forecasting the MSWS (48 hr lead time) at the highest intensity stage of cyclonic systems with minimum forecast error. The root mean-square error (RMSE) obtained in 48 hr MSWS forecast is 8.06 knots. The results are well validated using IMD cyclone track data from 2013 to 2020. The forecast skill of MLP model is compared with multiple linear regression model and existing operational models.

Keywords: Cyclonic systems, Artificial neural network model, forecast, pressure drop, wind speed

Tracking Mesoscale Convective Systems over Indian monsoon region: Method and Application

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ABSTRACT

Mesoscale convective systems (MCS) are organized clusters of cumulonimbus clouds with contiguous precipitation regions over 100 km in horizontal scale in at least one direction. They are responsible for about 60-70 % of rainfall over the tropical regions and cause extreme precipitation events which leads to flooding. Despite being the gateway of MCSs, these are not a thoroughly researched subject and an in-depth understanding of the system is still lacking, especially over the Indian Monsoon region. Here we use an Open Source framework named TOBAC which detects and tracks MCS over the Indian monsoon region. By doing so, various properties like spatial extent of convective cells over time and temporal evolution are obtained. The understanding of cloud lifetimes and statistics of cloud properties can be used to expand our current knowledge base in the context of monsoon. In the current study, the strengths and weaknesses of the framework are investigated and provide new insights to spatiotemporal patterns of MCSs over the monsoon region. In preliminary analysis, the algorithm could capture the relation between cloud area and frequency for different temperature classes over the study region along with the diurnal variation of maximum cell area detected. More details will be discussed.

Keywords: Mesoscale Convective Systems, Indian Monsoon Region, Clouds, TOBAC, Detection

Generating future skillful ensemble forecasts by relating forecast and satellite precipitation data over the northwest Himalayas

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ABSTRACT

Skillful quantitative precipitation forecast (QPF) is highly desirable for hydroclimatic studies in the Himalayas. The available deterministic raw forecasts often contain bias as obtained from the numerical weather prediction (NWP) models. In this work, we take into account the spatial inconsistency between a QPF and an observation data to set up a stochastic model based on the concepts of multiple-point geostatistics (MPS). The MPS model simulates the 'observation' data by using the corresponding forecast data obtained from the NWP model. The approach co-simulates the spatially connected precipitation patterns between two different sources of precipitation by constructing multivariate training images. Several covariates are also used to assist the identification and resampling of patterns. In the previous works which applies MPS, the spatial patterns of a model output and observation data is more or less similar. However, in the case of precipitation forecast, such an ideal condition may not exist since the NWP models are based on several assumptions. To account for that uncertainty, the inconsistency in the spatial scales of the two datasets is dealt by blending the approach of MPS with the 'spatial downscaling and bias correction (SDBC)'. Results show that the MPS approach (along with SDBC) generates skillful forecast ensembles by taking into consideration the slope, aspect and other topographical variables, along with the NWP model output and observation data. The model generates 25 ensemble forecast members at the selected avalanche and glaciers sites at the daily temporal scale. The study presents a novel method for stochastically generating a cost-effective and reliable precipitation forecast in complicated regions around the world such as the Himalayas. The results from the study will be presented at the conference.

Keywords: Quantitative precipitation forecast (QPF), Himalayas, multiple-point geostatistics (MPS), spatial downscaling and bias correction (SDBC), glaciers

Revisiting climatological Diurnal cycle of precipitation over Indian subcontinent using latest IMERG data

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ABSTRACT

Diurnal oscillation in precipitation is one of the most fundamental modes which are multidimensional and highly influenced by regional characteristics. The simulation of the diurnal cycle of rainfall is a generic problem in most climate models. The detailed understanding of the diurnal cycle of rainfall from observations is limited. Very high-resolution multiyear quality control satellite data with global coverage is best suited to study its intricacies. TRMM radiometer clubbed with ground-based observation provided three hourly 25 km horizontal resolution data, which stimulated a large number of researchers to take diurnal studies forward on a global scale which was earlier limited to a local scale due to scarcity of data. Very recently the constellation of satellites along with a complete network of rain-gauge/radar is available under the Global Precipitation Mission. It provides very good quality data at 10 km resolution at half-hourly time intervals thus providing a very good opportunity to revisit the climatological diurnal cycle. This new IMERG data is well placed to study a complex mix of mechanisms of diurnal peaks within the same landform, separated by coastal area, low-laid hills, vast plain area and very high snow-fed mountains. It will also pinpoint the locations within the broad area where peaking times differ. Harmonics corresponding to diurnal and semi-diurnal is calculated in terms of amplitude and phase using 20 years of IMERG data. It has clearly brought out the region dominated by significant diurnal oscillation. Over the land, almost the entire central India, the Western and Eastern Ghats, the Himalayan region and the north-east region and similarly over the Ocean, the North Bay of Bengal has significant diurnal amplitude with the varied time of peaking. These individual diurnal components, ultimately as a whole describe the whole monsoon process. However, when seen as a mean rain, it disguises these elementary components. This study brings out another way to look at precipitation by dissociating it to the smallest temporal and spatial scale, thus giving one more avenue to improve monsoon simulation by climate models.

Keywords: Diurnal, IMERG, Harmonics, Amplitude, Phase

VARIATIONS IN THE TROPICAL COASTAL ATMOSPHERIC BOUNDARY LAYER: FROM DIURNAL TO INTER-ANNUAL TIME SCALES

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ABSTRACT

Atmospheric boundary layer (ABL) plays a pivotal role in the vertical transport of energy, moisture and pollutants from the surface to the free troposphere and hence considerably affects air quality, convection, and cloud development. The entire exchange of heat energy between the surface and the atmosphere through the ABL is enabled through a chain of processes that modify the thermo

dynamical state of the ABL itself and play an important role in water cycle, pollutant dispersal and weather prediction. In response to the diurnal variation of surface temperature caused by the incoming solar radiation, height of the ABL undergoes substantial diurnal changes over tropical coastal and continental regions with rapid development during the forenoon period. In addition to the systematic diurnal variations, the ABL height over coastal and continental regions also undergoes significant intraseasonal, annual and interannual variations. Continuous observations from the ground based passive multi-frequency radiometer (MRP) provide a unique opportunity to profile the troposphere from surface up to about 10 km altitude at a given location with temporal and vertical resolutions of ≈ 3 min and 50–250 m respectively to address a wide spectrum of variations in the ABL height. Based on multi-year (2010–2017) MRP observations carried out at the tropical coastal station, Thumba, this study presents the temporal variations of ABL height from diurnal to interannual scale and quantifies the role of downwelling shortwave flux, soil skin and near-surface atmospheric temperatures and atmospheric stability in regulating the daytime peak ABL height. Mechanisms responsible for the rapid forenoon growth of ABL and the effects of clouds as well as background flow in modulating the ABL growth are investigated. Intraseasonal variations of the daytime peak ABL height and the effect of synoptic circulation in driving such variations are investigated using MRP observations and reanalysis data.

Keywords: Atmospheric Boundary Layer, Microwave Radiometer Profiler, Diurnal, Background Flow, Coastal

Assessment of Difference in Emission vs Deposition Budgets of Organic Carbon in Northern India

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ABSTRACT

This study focuses upon the ongoing arguments about organic carbon emission vs deposition budgets. In this study, water soluble organic carbon (WSOC) in dustfall and wet deposition was compared with the CAMS modelled values of dustfall and hydrophilic organic carbon. The dustfall and rainwater samples were collected during monsoon months (July, August and September) in 2018. The samples were collected using a polypropylene unit of funnel and bottle, for dustfall samples the funnel and bottle were washed using milliQ water and aqueous extract of dustfall was collected as sample, rainfall samples were collected on event basis. The samples were analysed for WSOC using Schimadzu TOC analyser. The total emission of organic carbon of study period was calculated from the monthly rate of emission data from ECMWF-CAMS emission inventory product.

Calculations resulted in the WSOC deposition in dusfall as 1.00 kg/ha at Mathura, 0.71 kg/ha at Delhi and 0.92 kg/ha at Jaipur whereas in wet deposition as 5.44 kg/ha, 3.57 kg/ha and 2.01 kg/ha respectively at Delhi, Mathura and Jaipur. The CAMS global emission inventory based organic carbon emissions were estimated as 34.49 kg/ha, 11.28 kg/ha and 6.80 kg/ha respectively at Delhi, Jaipur and Mathura. The values clearly depicted very large margin of difference between emission and deposition of organic carbon. The results indicated that emissions exceed deposition heavily at Delhi compared to other sampling locations suggesting to investigate atmospheric deposition of organic carbon in comprehensive manner in order to reduce the gap between its emissions and deposition estimates in northern India.

Keywords: Water soluble organic carbon, Deposition, Emissions, ECMWF, CAMS, TOC analyser.

Understanding the genesis of a dense fog event over Delhi using observations and high-resolution model experiments

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ABSTRACT

The present study aims to understand the three-dimensional structure of a dense fog event during the Winter Fog Experiment (WiFEX) 2016–2017 carried out at the Indira Gandhi International Airport (IGIA). The event is analysed with the help of ground-based measurements and the Weather Research and Forecasting (WRF) model. Sensitivity experiments were conducted using diferent initial conditions and compared to various observations. We fnd that higher resolution dynamical downscaling and the initial conditions from the Indian Institute of Tropical Meteorology's Global Forecasting System (IITM-GFS) database yield satisfactory agreements with the observations carried out during the fog event. We note that a strong surface inversion layer exists in the model and observations before the fog onset. Once the fog forms, the simulations suggest that the fog layer grows vertically, destabilizing the temperature stratifcation. The intensity of the longwave radiative cooling near the fog top increases as the fog grows vertically and shows maximum liquid water content (LWC) near the fog top. The vertical evolution of fog in the model is well identifed by the intensity of turbulent kinetic energy (TKE), which is low before the development of dense fog and endures more TKE as the fog becomes dense and vertically thick. The results demonstrate that the WRF model captures the complexity of the physical process and their interaction during the fog evolution in a manner that can be explored further to improve the accuracy of the operational fog forecast.

Keywords: Fog life cycle,WRF model, High-resolution simulation,Vertical evolution,Cooling rate

Impact of rainfall on the sap flux densities of Pinus roxburghii stands of central Himalaya

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ABSTRACT

The central Himalayan Pine, particularly, Pinus roxburghii, one of the dominant tree species that covers a large portion (approx. 16%) of the total forest cover of Uttarakhand, significantly modulates the water cycle of the region from micro to catchment scale. In general, Pine forests are associated to low ecosystem respiration and high carbon sequestration values. However, transpiration dynamics of Pine stands as responses to varying rainfall amount and event are not studied yet in detail. In order to address this knowledge gap, the present study aims to quantify the seasonal changes of the Pinus roxburghii sap flux densities due to varying rainfall spells and amounts. Along with the daily rainfall, daily sap flux data used in this study were collected from 03 Pinus roxburghii trees using SF-L type sap flow analysers, from Kosi-Katarmal, Almora, Uttarakhand (29°3'N, 79°3'E), during 2021. A rainfall spell was defined when no daily rainfall was noted 2-days before and after a day having rainfall greater than 0 mm. The general sap flux densities of Pinus roxburghii indicated that the annual mean value was 8.5 $ml.cm^{-2}.min^{-1}$ during 2021; the post-monsoon season notably had high sap flux density (11.18 $ml.cm^{-2}.min^{-1}$) than pre-monsoon (5.52 $ml.cm^{-2}.min^{-1}$) and monsoon season (10.4 $ml.cm^{-2}.min^{-1}$) due to greater availability of water. Moreover, we find that heavy to extreme rainfall events, when total rainfall of the event was greater than 64.4 mm of pre-monsoon season, increased sap flux density by 78% after the event; however, in post-monsoon, a counter effect was observed. The initial observations of this study leads to the inference that Pinus roxburghii stands were more sensitive to rainfall pulse during pre-monsoon due to generic prevalence of dryness, subsequently, increasing rainfall significantly increased sap flux densities after two days of a rainfall event.

Keywords: Sap flux densities, Himalayan Pine, rainfall pulse

A roadmap of Impact based Weather Forecast for a city Lucknow

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ABSTRACT

In recent years, continuous improvements have been made in weather forecasting with great benefit from Early Warning Systems (EWSs). Despite the continuous quest for innovation from the scientific and user communities, EWSs remain based mostly on hazard forecast, and the information on possible consequences and potential impacts is generally missing.

In this work, a methodology for real-time impact assessment for weather is presented. The methodology uses a geo-referencing (The internal coordinate system of a map can be related to a geographic coordinate system) approach. Moreover, a damage estimation model to quantitatively assess impacts in terms of economic losses and the people involved for a city Lucknow on pilot basis. The impact consist of locality or specific region informaton of impact that giving much feeling of real time weather situaton to the administraton to take necessary action.

Keywords: Impact Based Forecast, Early Warning Systems, Weather Prediction, Geo Referencing.

The National Institute of Ocean Technology (NIOT) was established in November 1993 as an autonomous society under the Ministry of Earth Sciences, Government of India. NIOT is managed by a Governing Council and the Director is the head of the Institute. Major aim of starting NIOT under the Ministry of Earth Sciences, is to develop reliable indigenous technologies to solve the various engineering problems associated with harvesting of non-living and living resources in the Indian Exclusive Economic Zone (EEZ), which is about two-thirds of the land area of India.

Winter- season lightning Climatology over Maharashtra, India.

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ABSTRACT

Most lightning climatologies have focused on warm-season patterns and associated convective phenomena during which lightning is most prevalent. In India, diurnal heating and moisture availability are ordinarily weak during the winter season (November to February), resulting in fewer thunderstorms and lightning activity. However, many hailstorms and snowfall activities are reported over the northern parts of India, extending up to Maharashtra state, due to western disturbances impacting losses and livelihoods (Kulkarni et al., 2015). Several investigations about winter lightning and its diurnal characteristics have been done across the USA, Europe, and Japan (Brook M et al.,1982; Holle et al.,1996,1997; Bentley et al., 2018); However, rarely lighting investigation has been done for the winter season of the Indian Subcontinent. We have examined the spatial and temporal distribution of winter lightning and studied its characteristics over the Maharashtra region for ten years, from 2013 to 2022, with the help of the IITM lightning detection network (LLN) data. We have observed predominant lightning activity during the winter transition months (November and February). The spatial distribution of winter lightning is heavily concentrated in the northern part of Maharashtra, and a noticeable reduction in flash densities over the central region. Also, the substantial diurnal variation with a pronounced peak in the afternoon at about 11 UTC (16.00 to 17.00 IST) has been noted. This diurnal lightning variation is similar to the monsoon diurnal variation observed by Pawar et al. 2011 over central India. We have also noticed a decreasing trend in lightning activity over the years from 2013 to 2022 in Maharashtra. Our observation shows a good correlation between the falling trend in lightning activity with an associated decline trend in rainfall over the years in the Indian region because the majority of winter precipitation is influenced by western disturbance and accounts for 90% of extreme precipitation events in northern India (Dimri et al. 2013; Hunt et al.,2018).

Keywords: Lightning, Thunderstorm, Maharashtra , Winter season, western disturbance.

Prediction of Indian Summer Monsoon Rainfall under Changing Climate during the recent Decade

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ABSTRACT

Seasonal prediction of Indian summer monsoon rainfall (ISMR) is attempted worldwide by different groups of weather research community every year. The major challenge in the prediction of ISMR is to capture the spatial and temporal variability of rainfall during June through September. Though the large scale features of the event are replicated by most of the models, the inter-annual and intra-seasonal variations in rainfall are yet to have significant skills. Further, the regional variability of ISMR due to the recent climate changes has not been captured by most of the models. Satellite observations play an important role there in. To demonstrate various applications of satellite observations (atmosphere and land surface) on ISMR in research and operational mode, a seasonal prediction system has been set up at Space Applications Centre (SAC) Ahmedabad. End of season (EOS) validation has been conducted every year to measure the model prediction skill and to identify the shortcomings and lacuna of the prediction system. It is a continuous evolving process of the prediction system to improve its skill of prediction year after year.

Here we have documented the present status of the prediction system, its recent developments and validation results for the recent years. The Extensive validation of the experimental seasonal forecasts of ISM rainfall carried out at SAC using CAM-CLM model during the year 2015 to present year has been presented here.The prediction of ISMR has been generated through a 50-member ensemble CAM model simulation. Each ensemble member was started with different initial conditions and sea-surface boundary conditions. An improved rain-bias correction technique has been applied to the model to eliminate the rainfall bias in the prediction system. The rainfall forecast done by model in daily, monthly and seasonal scale has been evaluated against IMD observations.

There are a number of short-comings which have also been identified during the validation activity. The bias correction process induces small over-estimation over oceanic region viz. shadow region of Western Ghats and Arabian Sea, head Bay of Bengal. The ensemble process using a large number of ensemble reduces the uncertainty in the prediction but at the same time it reduces the skill in predicting the extreme events and heavy rainfall events. Further, the fully coupled model will remove the dependency on predicted SST for future months, that has been used as boundary conditions for the atmospheric component of the model.

Keywords: Summer Monsoon, Seasonal Prediction, Climate model, Ensemble Prediction.

Vicennial linear trend of wind speed over Indian subcontinent

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ABSTRACT

Climate change is expected to have an impact on various aspects of renewable energy production, particularly wind and solar power generation. Thus, consistent change in the same is critical for the energy sector. We examined the surface wind speed patterns over the entire Indian subcontinent in this study. The wind speed data sets used in this study for recent years are from the ECMWF atmospheric reanalysis of global climate (ERA5) and the Indian Monsoon Data Assimilation and Analysis (IMDAA) for the years 2001-2021. The primary goal of this study is to determine the annual and seasonal variability of wind speeds over the Indian region, as well as the long-term changes in wind speed. Wind speed decreased significantly over the north-western and peninsular regions during the pre-monsoon and monsoon seasons. Potential explanations for this were also investigated. NOAA Extended Reconstructed SST V5 was utilised to investigate changes in the sea surface temperature over the last decade (ERSST). The Indian Ocean has indeed been observed to be significantly warming, which can impact the land sea gradient, resulting in changes in wind speed over time.

Keywords: Climate change, Renewable energy, Wind energy potential

Relationship of aerosol-cloud in case of low and high rainfall over Gangetic plain of India

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ABSTRACT

The Indian summer monsoon (ISM) rainfall plays an important role in rainfed agriculture, economy and water resource availability over the India. Aerosols may enhance or suppress the rainfall through aerosol-cloud interaction over a region. The relationship of aerosol-cloud in two rainfall classes (high rainfall and low rainfall) is studied over the Gangetic plain of India. The daily datasets are used for the monsoon months June, July, August and September for the time period of 2003-21. The median value of daily rainfall data is computed to sort the aerosol optical depth (AOD), cloud optical thickness (COT), cloud top pressure (CTP) and cloud fraction (CF) into subset of dataset associated to high (rainfall > 5.81 mm) and low ($0 <$ rainfall ≤ 5.81) daily rainfall. As AOD increased, the linear trend of high rainfall amount is appeared to be increasing and the linear trend of low rainfall amount showed decreasing. Higher CF, lower CTP and higher COT are associated with high rainfall and lower CF, higher CTP and lower COT are associated with low rainfall. In case of high rainfall amount, as AOD increased, the trend of CF is increasing and decreasing trend of CTP and COT are observed. Moreover in case of low rainfall amount, as AOD increased, the trend of CF is increasing and decreasing trend of CTP and COT are appeared. Higher CF and lower CTP with increase in AOD may cause due to invigoration effect. However, other cloud parameters and influence of meteorological variables should be considered to get insight about the aerosol-cloud relationship.

Keywords: Aerosols, clouds, rainfall, Gangetic plain

Cyclonic Disturbances and its association with monsoon rainfall over South Asia region

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ABSTRACT

Cyclonic Disturbances (CDs) during the monsoon period is the most common phenomenon over the South Asia region (SAR), often associated with abundant rainfall most of the region. The current study examined the spatial variability of genesis of CDs over the study region during 1998-2019 for the monsoon season and their rainfall contribution to the seasonal rainfall. The track data of CDs for this study is utilized from Indian Meteorological Department (IMD) Besttrak archive. In this study, CDs are categorized into the low pressure area classes (LPACs), depression classes (DCs) and the cyclonic storms classes (CSCs). But IMD track data do not provide the information of the LPACs. Therefore, an automated tracking algorithm is used here for identifying the LPACs using the ERA Interim reanalysis datasets during the study period. We have found total 384 CDs (LPACs:80%, DCs:16%, CSCs:4%) over the study region. Around 9.5 per year genesis are observed over the Bay of Bengal, followed by 6.5 per year in Land and lowest in Arabian Sea, 1.5 per year. The peak rainfall attributed to CDs are found to the east of the monsoon trough in central India and the northern of Bay of Bengal (BOB), while the non-CD origin rainfall are spaced in the wettest part of SAR, west coast of India and Myanmar, slope of Himalayas and Shillong plateau. The annual monsoon rainfall of CD origin has large spatial variation of around 2-60%. And the month wise (June-September) rainfall distribution attributed to CD varies around 2-22% of the total rainfall of CD origin, in each month. LPACs contributed more rainfall than DCs and CSCs combined during monsoon. Due to topological barrier a large amount of rainfall attributed to CD is confined to coastal parts.

Keywords: Cyclonic Disturbances, Low pressure area classes, Depression, Rainfall

Role of MJO oscillation in the intraseasonal variability of cirrus clouds over tropical Indian region

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ABSTRACT

Cirrus clouds, which mainly determine the dehydration in the upper troposphere and lower stratosphere (UTLS), influence the radiative heating and vertical motion in the Tropical Tropopause layer (TTL) and lower stratosphere (eg., Fujiwara et al., 2009) and significantly contribute to the diabatic heating in the upper troposphere. Indian region is thought as the source region for the lower stratospheric water vapour in summer monsoon season and this makes this region unique for TTL dehydration studies. The intraseasonal variation of dehydration and cirrus clouds in the UTLS is examined using satellite and reanalysis datasets. Occurrence of cirrus clouds show a clear variation with the phases of Madden-Julian oscillation (MJO). The occurrence frequency of cirrus clouds is maximum with a peak occurrence of 60% in the phases 2 and 3 of MJO over the southern Peninsular India and adjoint oceanic region, the phases in which the occurrence of deep convection also peaks in winter, pre-monsoon and post-monsoon seasons. There is significant percentage of occurrence of multilayer cirrus. However, direct connection between MJO phases and occurrence of cirrus clouds is not observed in summer monsoon season, the season in which the cirrus clouds occurrence is determined by monsoon dynamics too. The MLS observations of water vapour and reanalysis obtained temperature and wind also shows significant variability with MJO phases and clearly influence the occurrence of cirrus clouds especially in the TTL.

Keywords: cirrus clouds, intraseasonal variation, Madden-Julian oscillation, UTLS

Improved PQPF during Monsoon 2020 and 2021 using EnsembleBMA and EnsembleMOS Methods

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ABSTRACT

Ensemble prediction system (EPS) with multiple forecasts using perturbed initial conditions has proven successful over the deterministic forecasts to provide probabilistic forecasts and to support risk-based forecasts and warnings.

Ensemble forecast often tends to be underdispersive, i. e., the spread becomes insufficient to represent the actual uncertainty and exhibits systematic biases due to initial condition errors, model uncertainties and approximations and data assimilation assumptions, hence any ensemble prediction system that aims to produce reliable and accurate forecast must now include statistical post-processing to proper calibration of ensemble spread and removal of systematic biases. The Postprocessing systems that improve EPS forecast quality are much more cost-effective to develop and implement and can lead to improvements in EPS forecast skill comparable to many years of EPS system upgrades. These calibration methods include parametric distributional regression models as well as nonparametric approaches and semi-parametric methods based on modern machine learning techniques.

In the present study a comparison of the skill of a parametric, ensemble model output statistics (EMOS) approach in which the forecast distribution is given by a parametric probability distribution and a non-parametric, Bayesian model averaging method of postprocessing ensembles, which is a standard method for combining predictive distributions from different sources in giving quantile-based precipitation forecast is attempted. In the ensembleMOS methods two distribution Censored and shifted gamma distribution (CSG) and generalized extreme value distribution which are suitable for precipitation are used. BMA and MOS methods are used to postprocess rainfall of 1–8-days lead time, 24-h accumulated NCMRWF high resolution ensemble rainfall forecasts from NEPS-G (12km resolution global model) for two monsoon seasons. The results are verified using metrices viz. CRPS, Brier Score ROC and Reliability diagrams. Both the EMOS and BMA methods have exhibited an overall improvement in CRPS, ROC and reliability over raw forecasts while marginal improvement was observed in brier score. The CRPS value have shown more than 50% improvement in both the methods compared to raw forecasts.

Keywords: : ensemble, post processing, model output statistics, Bayesian model averaging, CRPS

Characteristics of Thunderstorm and its correlation with the prevailing weather condition over Bihar, India

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ABSTRACT

The state of Bihar lies between the transition zone of humid West Bengal and dry Uttar Pradesh and because of which it experiences varied type of weathers including intense Thunderstorm. Every year state around 200 lives are lost due to lightning and other adverse impact of thunderstorm. In the present paper an effort has been made to study the spatial and temporal distribution of Thunderstorms in the multi-hazard-prone state of Bihar along with its correlations with daily prevailing Maximum Temperatures.
The study has been classified as per the three agro climatic zones in which the state has been divided. The study is based on daily, monthly, and seasonal average maximum temperatures recorded over the state during the pre-monsoon and monsoon season between 1969-2021. In the study it is found that while there is a decreasing trends in monthly and seasonal mean maximum temperatures for most of the stations in the state, the monthly and seasonal average temperature shows an increasing trend. The corresponding frequency of seasonal thunderstorms in the pre-monsoon season averaged over the state, has an increasing trend in pre-Monsoon as well as Monsoon seasons. Correlation coefficient of seasonal mean averaged over the entire state for the maximum temperature and seasonal frequency of thunderstorms during the pre-monsoon season were found to be -0.83, which is statistically significant at the 100% level. In all of Bihar's agro climatic zones, the frequency of thunderstorms typically decreases as maximum temperature rises during the pre-monsoon season.

Keywords: - Thunderstorms, Maximum Temperature, Pre-Monsoon Seasons, etc.

Interannual variability of Cold Pool in the southern Bay of Bengal in response to the Indian Ocean Dipole events

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ABSTRACT

A lesser-known oceanic process is the formation of a cold pool (CP) at the southern Bay of Bengal, near the southern edges of India and Sri Lanka. The CP is characterized by relatively cooler temperatures than the surrounding equatorial Indian Ocean and the northern part of the Bay. The major factor behind this cooling event is the reduction in incoming solar radiation and an upsurge in latent heat loss. The cooling event starts around mid-May, continues till September, and is influenced by the intraseasonal variability of the summer monsoon. In this study, the inter-annual variability of the CP over a span of 19 years is studied using satellite-derived products. The impact of the negative phase of the Indian Ocean Dipole (IOD) events on the CP is also investigated. From the satellite data, significant variability of sea surface temperature over the CP region is observed in response to the IOD events. Unusual warming of the CP at the development stage is observed for the negative IOD years. It was also observed that apart from the upwelling around the southwest coast of India, the pumping of cooler waters around the Sri Lankan Dome and the formation of a warm core eddy adjacent to it, help sustain the cold pool. Considering the significant interaction of the CP in association with the IOD event and eventually, the prevailing monsoon system over the Asian countries, a better understanding of its variability is of utmost importance.

Keywords: Cold pool, Indian Ocean Dipole, Interannual variability.

ANALYSIS OF SEASONAL AND ANNUAL RAINFALL TRENDS FOR VIDISHA DISTRICT, MADHYA PRADESH, INDIA

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ABSTRACT

The main objective of this study was to examine temporal variation in seasonal and annual rainfall trend over Vidisha district of Madhya Pradesh, India for the period (1901–2021: 121 years). High resolution gridded (0.25°×0.25°) rainfall data obtained from the India Meteorological Department, Pune were used to determine the significance and magnitude of the trend using non-parametric Mann–Kendall and Sen's slope estimator. The analysis showed a decreased in rainfall during winter, pre-monsoon and post-monsoon rainfall while increased in annual and monsoon rainfall over the Vidisha district. A positive trend is detected in monsoon and annual rainfall data series while winter, pre-monsoon and post-monsoon rainfall showed a negative trend. The maximum decrease in rainfall was found for winter (− 0.089 mm year−1) and minimum (− 0.014 mm year−1) during post-monsoon rainfall. The trend of pre-monsoon rainfall was found downward (-0.04 mm year−1). The positive trends of annual and monsoon rainfall were found (0.050 mm year−1) and (0.028 mm year−1). The positive and negative trends of annual and seasonal rainfall were found statistically non-significant at 5% level of significance. Rainfall variability pattern was calculated using coefficient of variation CV, %. Winter rainfall showed the maximum value of CV (68.29%), where as annual rainfall exhibited the minimum value of CV (23.66%), respectively. In general, high variation of CV was found which showed that the entire region is very vulnerable to droughts and floods.

Key words: - Trend analysis, Mann-Kendall test, Sen's slope, Vidisha

Physical characteristics of extreme rainfall events during Indian summer monsoon as projected by CMIP6 models

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ABSTRACT

Projection of extreme rainfall events has its importance for planning adaptation and mitigation strategies as well as in impact assessment studies. Many studies have shown changes in the frequency, intensity, type and duration of extreme events during the summer monsoon season over India, especially under a higher climate change scenario. In our study, we identified a set of good CMIP6 models capable of simulating observed mean monsoon and extreme events. We then estimated the future trends in monsoons and extreme events as simulated by the good models. The spatial variability of mean and extreme events were identified. The dependence of atmospheric water holding capacity to increase in temperature, given by the Clausius Clapeyron (CC) relation, describes much of the changes in extreme rainfall intensities at warmer atmospheric states. Thus we also quantified the physical characteristics of extreme events to delineate any changes in the relationship between extreme rainfall events and air temperature. Such regional scale information will help in identifying regions of heavy rainfall in future.

Keywords: Climate change, Extreme events, CC scaling, CMIP6 models

Assessment of black carbon aerosols, its source apportionment and aerosol radiative forcing during lockdown and unlock restrictions during coronavirus disease 2019 (COVID-19) Over India

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ABSTRACT

Anthropogenic emissions were significantly reduced during a nationwide lockdown imposed in India due to the Coronavirus Disease 2019 (COVID-19) pandemic. In this study, extensive measurements of equivalent black carbon (EBC) aerosol mass concentration using a multiwavelength aethalometer were examined at eight stations (Bhuj, Delhi, Guwahati, Jodhpur, Nagpur, Pune, Ranichauri and Thiruvananthapuram) of India Meteorological Department (IMD) BC observation network during the period 2016–2020. We estimated the changes in EBC, its quantitative contribution of biomass burning (EBC_{BB}) and fossil fuel (EBC_{FF}) fuels during lockdown (LD) and unlock (UL) periods in 2020 with respect to 2016 to 2019 (normal period). The EBC mass concentration decreased by 47% and 24% during lockdown (LD) and unlocks (UL) periods respectively in comparison to normal period. The EBC_{FF} and EBC_{BB} concentrations were decreased by 53% and 17% during lockdown period than normal period due to significant decrease in the fossil fuel and biomass burning emissions during the lockdown period. The average contributions of EBC_{FF} and EBC_{BB} to total EBC mass concentrations were 70% and 30% respectively during lockdown period, whereas these values were 82% and 18% respectively during the normal period. The reductions in BC concentrations were in line with the reductions in emissions from transportation as well as industrial activities. In addition, the radiative forcing was also reduced due to the restrictions associated with COVID-19 pandemic lockdown and leading to a cooling of the atmosphere. The findings in the present study can provide a comprehensive understanding of the EBC sources and its emission control strategies during the unprecedented COVID-19 induced lockdown restrictions, and thus can help for future emission control strategies aimed to improve air quality and climate.

Keywords: Equivalent black carbon (EBC), Biomass burning, Fossil fuel, COVID-19

Precipitation efficiency and its impact on rainfall characteristics during tropical cyclones over Bay of Bengal

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ABSTRACT

Tropical cyclones and their associated rainfall are among the major forms of extreme weather events which impact the coastal regions of India severely. In recent studies, it has been noted that there is an increase in the frequency and severity of pre-monsoon tropical cyclones making landfall over the coasts of India. An accurate prediction of rainfall is among the significant challenges in TC forecasting. The present study emphasizes to investigate the precipitation efficiency (PE) and associated processes responsible for copious rainfall associated with tropical cyclones (TCs). Two pre-monsoon TCs, i.e., Fani and Yaas, making landfall over the east coast of India and caused devastation, are considered for this study. Weather Research and Forecasting (WRF) model with 3km resolution has been used for carrying out this study up to 96 forecast hours. The model has been integrated to quantify the impact of precipitation efficiency on rainfall associated with TCs. Preliminary results suggest Yass (VSCS), being relatively weaker, TC produced a much higher amount of rainfall compared to Fani (ESCS). An intercomparison of results which have been carried out in terms of cyclone track, intensity, precipitation efficiency, and diagnostic variables will be presented. Further, efforts are made to elucidate the possible mechanisms responsible for storm precipitation efficiency modulation in terms of air-sea interaction process and flux exchanges. Results in terms of modulation of storm structure, dynamics, and thermodynamics due to surface forcings and the complex rapid intensification process of the storms will be examined. Findings of the present study encapsulating the interactions between large-scale environmental conditions and local scale precipitation efficiency deserve as much attention to accurately determine the rainfall during intensification of the TC.

Key Words: Tropical Cyclone, Precipitation efficiency, Micro-physics, WRF model

VARIATION IN THE RAIN DSD AND ITS RESPONSE TO CLOUD REGIMES OVER TWO COASTAL STATIONS IN INDIA

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ABSTRACT

Rain drop size distribution (DSD) is a fundamental characteristic of cloud microphysical properties and precipitation processes and varies drastically at different regions. In this study, the seasonal variation in DSD, rain integral and gamma parameters and its response to cloud regimes over two coastal sites of India (i.e. Kolkata and Trivandrum) are presented. Rain DSD data were collected from the ground-based laser precipitation monitor disdrometers (LPM's) over Kolkata during July 2020- June 2022 and over Trivandrum during Aug 2018 – Mar 2021. The annual cycle of rainfall shows a mountain slope during the monsoon and associated thunderstorm seasons (pre- and post- monsoons) and minimal rainfall during the winter season over the both locations. A unimodal distribution of DSD has been observed over Kolkata and Trivandrum. In general, the presence of bigger drops dominate during the pre-monsoon while smaller drops are dominant during monsoon and post-monsoon seasons. Precipitating cloud regimes are classified into three rain types (Convective, Transition and Stratiform) based on the ratio of mass-weighted mean rain drop diameter (Dm) and rain rate (R). The DSD spectra in the convective regime have relatively higher number concentration as compared to other precipitation regimes, resulting in larger Dm values than the other two rain regimes. The mean values of rain integral parameters i.e., RR, Dm, liquid water content (LWC) and Radar reflectivity (Z) are observed to be ~5.04 mm/h, 1.38mm, 0.24 g/m3 and 26.57 dBz over Kolkata and ~2.86 mm/h, 1.12mm, 0.15 g/m3 and 19.86 dBz over Trivandrum, respectively and also have distinct seasonal variability. The gamma parameters (No, Λ, μ) and Z-R relationship coefficients (A and b) are having a clear-cut seasonal variation in both the locations. The present results show that the regional microphysical processes and the origin of cloud systems play a vital role in characterizing the rain drop size distributions.

Keywords : DSD, Gamma parameter, Rain types, Z-R relations.

Monsoonal rainfall variability over the State of Bihar

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ABSTRACT

The state of Bihar is situated in the Gangatic plain in east of the Uttar Pradesh, North of the Jharkhand and west of the West Bengal while its north boundary touches the Nepal (foothills of Himalayan). For the current study the Bihar has been divided into four agroclimatic zone, viz: agroclimatic zone 1, 2, 3A and 3B.The rainfall variability on intraseasonal scale was studied by using IMD (Indian Meteorological Department) gridded data of observed rainfall with spatial resolution 0.25*0.25 for the period of 1961-2020 in Summer Monsoon Season (JJAS). It is found that the excess of rainfall occur in agroclimatic zone 1 and 2 while in agroclimatic zine 3A and 3B deficit rainfall commonly found. The active phase more pronounced in agroclimatic zone 1 and 2 while break phase is more in agroclimatic zine 3A and 3B. That result that sharp difference between these four agroclimati regions in rainfall variability occur and need to make policies according to this so that the agricultural activity can be improved.

Keywords: Intraseasonal Variability, Observed rainfall, Summer Monsoon Season, Active and Break phase.

Martian cold spot regions and associated properties during a global dust storm year using MRO satellite observations

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ABSTRACT

The weather and climate on Mars depend heavily on the characteristics of Martian aerosols. Dust, CO_2 ice, water ice, etc., suspended in the air, play a critical role in the thermal equilibrium, circulation, and transfer of momentum in Mars' atmosphere. Cold spot regions are those radiometrically cold areas where the temperature is less than CO_2 frost point temperature. These are the regions with the most probable chance of CO_2 ice formation. On Mars, global dust storms (GDS) drastically change the microphysical characteristics of CO_2 ice aerosols besides their geographical and vertical distributions. With the help of the Derived Data Record (DDR) version 5 obtained from the Mars Climate Sounder (MCS) instrument on board the NASA Mars Reconnaissance Orbiter (MRO) mission, we attempted to investigate the origin of cold spots, their spatial and temporal variation, etc.The work focuses on the cold spot regions' vertical, temporal, and spatial variation during the global dust storm (GDS) of Martian Year 34. It was found in the study that GDS affected the latitudinal variation in the formation of ice caps and lowered solar insolation, which in return impacted the cold spot formation. In the south pole, cold spot regions were more dominant than in the north pole, especially in non-polar ring regions. It was found that most North Pole cold spots formed on the polar nights, and during the global dust storm season, the cold spot regions in the northern hemisphere started to develop outside of polar ring regions. Also, during dust storms, there is a high concentration of dust at higher altitudes, which in return provides a nucleation site for CO_2 ice, leading to the formation of polar clouds.

Keywords: Mars, Cold spot, CO_2 ice, GDS, MCS

FOG CHARACTERISTICS STUDY OVER THE IGI AIRPORT, NEW DELHI DURING THE WINTER SEASONS 2010-2022

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ABSTRACT

IGI Airport experiences severe fog events in every winter seasons which leads to flight cancellations and diversions. In the present study, fog characteristics study has been performed over the IGI airport using the METAR observations during the winter seasons 2010-2022. The fog categorization and duration of the events have been analyzed in detail. Moreover, the role of various meteorological parameters such as wind speed and direction, relative humidity, temperature and dew point temperature etc. which play crucial role in fog formation has been studied in detail. The study observed that these weather parameters can vary from year to year and can influence the fog variability over the IGI Airport. The monthly fog frequency has been observed to be maximum in January followed by December in all the winter sesons at the IGI airport. In order to study the uncertain pattern of fog in the past winter seasons, a time series analysis has been carried out. Inter annual variability of fog has been discussed on a monthly basis which can provide a better estimation about the increase/decrease in fog percentage during the winter seasons from 2010 to 2022. The results of the present study such as fog categorization and duration, inter annual variability and mean monthly frequency of fog, inter winter seasonal comparisons etc. can be used to better understand the nature of fog over the IGI Airport. Further, this information can be used to better predict fog occurrence in future now casting/forecasting applications.

Keywords: Fog, Visibility, Meteorology, IGI Airport, METAR

Lightning Activity in Tropical Cyclones

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ABSTRACT

North Indian Ocean (NIO) accounts for almost 8 per cent of all tropical cyclones (TCs) that originate across the globe and almost 75% (5 to 6) of the genesis of NIO TCs are in the Bay of Bengal (BoB) basin. For tropical cyclogenesis, the pre-existing low-level disturbances and the associated convective cloud clusters over tropical ocean play a crucial role during the initiation of TCs. The pre-existing convection provides the latent heating to create warm core which results in increased upper level height fields and increased divergence aloft, which lowers the suface pressure. Lightning is an indicator of intense convection and investigations on lightning activity in tropical cyclones could help to understand the impacts of TCs to lightning activity and convective characterstics within the TCs.

The analysis domain for the present study is geographically restricted to 15°-24°N and 82°-89°E (covers the entire coast of Odisha, parts of West Bengal coast and few regions of Andhra Pradesh coast) which is the main activity area of TCs over Bay of Bengal basin. For this study three pre monsoon TCs have been considered viz., Fani in 2019, Amphan in 2020 and Yaas in 2021. The Lightning data is taken from the lightning location network (LLN) established by the Indian Institute of Tropical Meteorology Pune.

The analysis reveals that at the time of peak intensity of TCs, the lightning counts are high just before the landfall and most of the lightning activity are over the sea. After landfall of the TCs, the lightning counts are less compared to the time of peak intensity of the TCs and again the lightning counts increases after the TCs got weakened.

Keywords: Tropical Cyclone, North Indian Ocean, Lightning

Madden Julian Oscillation and the diurnal cycle of precipitation over the West Coast of India

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ABSTRACT

Madden Julian Oscillation (MJO) is an eastward propagating convective system that passes over the Indian and Pacific Oceans with a periodicity of 30–90 days and influences most of the tropical weather systems. This study explores the impact of MJO on the diurnal cycle of precipitation over the west coast of India. Satellite measurements of precipitation, deep convection and profiles of wind and humidity from ERA5 for the period 2000-2019 are used. An enhancement (decrease) in diurnal cycle of precipitation is observed during active (suppressed) MJO phases with respect to climatology. Active phases are instrumental in the generation of mesoscale convective cloud systems with much more spatial extension and temporal duration than that in the suppressed phase. We show that the modification of tropospheric dynamics, thermodynamics and deep convection by MJO can cause abnormal rainfall activity over the west coast.

Keywords: Diurnal cycle, MJO, Deep Convection

ANALYZING URBAN GROWTH DYNAMICS OVER SIXTEEN MAJOR INDIAN CITIES USING IRS AND SENTINEL SATELLITE OBSERVATIONS

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ABSTRACT

Urbanization in Indian megacities is pacing at an unparalleled and irreversible rate (31.1%). The current study focused on analyzing the growth dynamics of sixteen major Indian cities having population above one million. Rise in population corresponds to the increasing demand for land resulting in abrupt growth of the city known as sprawling. Land Use Land Cover (LULC) thematic datasets were acquired from ISRO (IRS data) and ESRI (Sentinel data) for 2005, 2010, 2015 and 2021 for the study. The variability of the five LULC classes viz., urban built-up, vegetation, water body, agriculture and barren land indicated that urban expansion mostly took place at the expense of barren lands. The urban landscape of Indian cities mostly depicts dispersive outward growth since the beginning of the 21st century with significant amount of compaction near the Central Business District (CBD) in the recent years. The results derived through Shannon's Entropy (SE) approach, various Spatial Metrics and urban density gradient analysis have also indicated the same. SE values nearing ln(n) indicates dispersion away from the CBD (maximum observed in Bhubaneshwar-Cuttack urban agglomeration i.e., ~1.702 in 2021). Spatial metrics like Patch Density, Contagion Index, Diversity Index, etc., and urban density gradient analysis have further confirmed the compaction of cities near the CBD (~95% within 5 km), and gradual decrease thereafter. Additionally, the morphology associated with the cities, influences the direction of city growth just like the course of river Hooghly dictates Kolkata's urban expansion. Population density compared with urban expansion indicates that both are proportional to each other (e.g., Pune exhibited ~83% increase in urban area corresponding to ~47% increase in population density). Thus, the derived results offer vital information regarding the existing patterns of urbanization and hence could be of use to city planners for better management of resources while building a sustainable city.

Keywords: Land Use Land Cover, Central Business District, Shannon's Entropy, Spatial Metrics, Urban density gradient

Thunderstorm prediction from satellite data using deep learning methods

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ABSTRACT

Thunderstorms activities are frequent over certain parts of the Indian subcontinent during pre-monsoon season. Accurate forecasting of thunderstorms is important to prevent serious damage to human life and property. Numerical Weather Prediction (NWP) models are found to be inefficient in predicting short-lived weather phenomena such as Thunderstorms. Deep learning techniques have proven to be more accurate for short-range weather forecasts as compared to NWP models. The present study utilizes advanced deep learning approach, *viz.* U-net architecture, to forecast convective storms over Trivandrum, Kerala. Brightness-Temperature observations from INSAT-3D satellite is used as a predictor for the deep learning algorithm. The model has been trained for the entire year of 2018 while validation and testing is performed over 2019 and 2020 observations, respectively. The initial results of the study are encouraging.

Keywords: Thunderstorm Prediction, Deep Learning, U-net architecture, Convective storms.

MONSOONAL RAINFALL EXTREMES ON THE RISE OVER THE POCKETS OF WESTERN GHATS, NORTH-EAST AND CENTRAL INDIA

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ABSTRACT

The present investigation provides a comprehensive analysis for identifying and quantifying the patterns of heavy, very heavy and extremely heavy rainfall with their temporal changes during last 70 years (1951 to 2020) of monsoon (June to September) under the changing warming scenario. This study also intends to project the monsoonal extreme rainfall counts in the near- (2036–2060) and late-21st century (2075–2099) w.r.t. historical period (1990–2014) using the bias-corrected rainfall dataset from Coupled Model Intercomparison Project-6 (CMIP6) multi-model ensembles. This bias-corrected dataset was developed using Empirical Quantile Mapping (EQM) for both historic and projected climate during the three scenarios (namely SSP1-2.6, SSP2-4.5 and SSP5-8.5) utilizing the outputs from 20 General Circulation Models (GCMs) from CMIP6. The observational rainfall patterns during 1951-2020 indicated that Central India, North-East India, Western Ghats and Eastern Ghats were prone to monsoonal extreme rainfall occurrences over the Indian landmass. During this period, an increase of 6-9 heavy rainfall events per decade has been identified over Orissa, Chattisgarh and parts of Madhya Pradesh with a declination in rainfall intensities over Uttar Pradesh, Kerala and hilly regions of North-East India as obtained from the trend during 1951-2020. Moreover, this study also suggests the causal theory for the rise of monsoon rainfall extremes in terms of both dynamics and local-scale thermodynamics over the sub-continent. The bias-corrected multi-model projections propose that Mumbai, Pune, Panaji in the Western coasts of India (Western Ghats), Itanagar and Shillong in the North-East India, Raipur and Bhopal in the Central India are going to realize increased monsoonal heavy rainfall extremes in the near- and late-21st century under all scenarios in a warming climate. Thus, this bias-corrected projections from CMIP6-GCMs can be used for hydroclimate impact assessment in Indian region under the changing atmospheric circulation dynamics and warming induced by greenhouse gases.

Keywords: Monsoon-extremes, Bias-correction, Observations, Climate-projections, CMIP6.

Sub seasonal Drought Assessment in NCMRWF Multi-Week Extended Range Prediction System

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ABSTRACT

Drought is a complicated phenomenon, and the least understood of all "weather and climate extremes". Drought can be classified into different categories such as meteorological, agricultural, hydrological, and socio-economic droughts. In this study, we particularly focused on meteorological droughts which occur in long gaps in normal rainfall. The water shortages caused by meteorological droughts impact life even beyond health and hygiene. The countries like India where the livelihood of 60% of the population depends on agriculture, drought is one of the most feared natural calamities as it impacts food production, economy, and morale of millions of farmers in the country. More importantly, recent studies stressed on flash droughts are characterized by rapid onset and intensification, unfolding on sub-seasonal to seasonal(S2S) time scales posing a new challenge for the S2S model prediction capability. Hence, we explored the performance of a multi-week extended range prediction system (NERP) based on the Unified global coupled modelling system that has been implemented at the National Centre for Medium Range Weather Forecasting (NCMRWF) in characterizing the droughts on sub-seasonal time scales. For identifying the droughts, we use two types of indices based on the Standardized Precipitation Index (SPI) and standardized evaporation precipitation index (SPEI), where the former index considers only precipitation while the latter one includes temperature data in addition to precipitation in its calculation, allowing for a more complete approach to explore the effects of climate change on drought conditions. Furthermore, our focus is primarily on the Southwest monsoon season (June–September) which is the primary rainy season in India and contributes 70–90% of the annual mean rainfall. Hence, this study has important implications for drought assessment, monitoring, and mitigation.

Keywords: Drought, Extended Range Prediction, Standardized Precipitation Index, Monsoon

Comparative study of model performance for a series of cloudburst events over North – West Himalaya region

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ABSTRACT

Cloudburst or extreme rainfall events (ERE) are catastrophic events in which a tremendous amount of precipitation occurs over a small area on a short period of time. The present study investigates the fine scale processes of a series of specific cloudburst events (14th to 18th August 2019) occurring over the North West Himalaya (NWH) region. High resolution data of INSAT 3D HE-Rain, OLR are used to look into events during that period over NWH. Also, a WRF ARW simulation have been done over the study region. INSAT 3D data shows multiple events occurring at NWH with rainfall rate exceeding 100 mm/hr. The performance of the model simulation is compared with the INSAT product. Though WRF-ARW shows more areas with heavy precipitation but, the overall rainfall rate is underestimated. The fine scale processes of cloudburst events are visible through the model simulation. The high value of moisture flux convergence (MFC) (0.04 kg m^{-1}s$^{-1)}$ over isolated areas shows the role of topography on cloudburst events. Vertical profile of water mixing ratio shows strong vertical uplifting over isolated areas. ERA 5 temperature shows no role of moist air convection during that period. Analysis of DEM with vertical cloud profile shows strong orographic convection over windward slope of the Himalayas.

Keywords: Extreme Rainfall Events (ERE), NWH, INSAT, WRF-ARW, MFC.

HOW SENSITIVE ARE INDIAN TEAKS FOR TELECONNECTION STUDIES?

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ABSTRACT

Ring width and isotope studies of tropical teak samples have long been useful for rainfall reconstruction and understanding climate change and variability. Apart from local rainfall, humidity, and soil moisture, the ring widths of tropical teaks are sometimes sensitive to regional scale atmospheric circulation. Reasonably strong correlations between ring width and several climate indices further confirm teleconnections. The study of Indian teak samples reveals a strong correlation between local rainfall and ring width index based on which decadal to centennial-scale rainfall reconstructions were carried out earlier. However, the connection between Indian teak ring width and regional scale atmospheric circulation and their efficacy in teleconnection studies have not been extensively studied. It has been demonstrated earlier from a 523-year-long teak ring chronology in Kerala that ring width variations were strongly associated with the corresponding variation in Nino indices. The prominent drought periods marked in that chronology also match the El-Nino years. A recent study with a shorter chronology from NE India also exhibited a strong correlation between ENSO and ring width indices. Although altitude-specific climate responses on the Himalayan conifers have been studied in detail, no such region-specific climate responses and sensitivity of teleconnections on Indian teaks were ever attempted earlier. Towards this, the current work attempts a robust compilation of teak ring with-climate (rainfall, temperature, vapour pressure deficit, soil moisture content, PDO, ENSO, etc.) relationships from several Indian sites. The objective is to envisage how sensitive ring widths are to regional scale atmospheric circulation and teleconnection studies.

Keywords: Climate change, Teak ring width, Teleconnections

Aerosol -Warm Cloud Interactions Over Different Zones of India

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ABSTRACT

Assessing the impact of aerosols on cloud microphysics is critically important to provide insight into the interaction between aerosol-cloud under distinct geographical and meteorological conditions. This thesis is designed to assess aerosol-cloud interaction (ACI) over the five zones by using a synergy of Aqua MODIS satellite and ground-based Radiometer/Sunphotometer data over the seven regions of India, namely: Gual Pahari, Jaipur, Kanpur, Gandhi College, Pune, Hyderabad, and Tirupati. For the period from January to December from 2005 to 2021. As part of the thesis, initially, aerosol optical thickness (AOT550) and Angstrom exponent derived with Aqua MODIS were compared with ground truth Radiometer/Sunphotometer observations. MODIS-derived AOT and Angstrom exponent were used to classify various types of aerosols over the seven regions. Classification of different types of aerosols was also carried out using various parameters such as Fine mode Fraction, Ansgrtrom exponent, Aerosol Optical Depth, and Absorption Aerosol Optical Depth, derived with AERONET to ensure the robust aerosol classification.

The impact of various types of aerosols on the ACI over the five study zones was studied. We then examine the cloud properties; namely, cloud droplet effective radius and liquid water path, in association with aerosol properties such as aerosol optical thickness (AOT550), and Ångström Exponent over the observation domain. Preliminary results indicate that (i) Dust-type aerosol is dominant over Jaipur and Pune. Biomass burning is dominant in all other regions in India. (ii)Average ACI values of different zones in India are Central India : -0.1092, East India : -0.0213, IGP : -0.0617, South India : -0.1001, West India :0.0279. Overall, our analyses suggest that the present findings largely corroborate with the Anti-Twomey effect over all the five study regions irrespective of aerosol types present over that region.

Keywords: Aqua MODIS, AERONET, Aerosol-Cloud Interaction (ACI), Anti-Twomey Effect (maximum 5 words)

A STUDY TO IMPROVE FOG/VISIBILITY FORECAST AT IGI AIRPORT, NEW DELHI DURING THE WINTER SEASONS OF 2020-21 & 2021-22

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ABSTRACT

The reduction in visibility due to fog leads to cancellation of flights, delay and diversion at IGI Airport, New Delhi during the winter season. Accurate prediction of Fog/ Visibility is required in advance to make the flight operations safer, economical and more convenient. This study attempts to improve the Fog/Visibility forecast at IGI airport for the months of December and January during the winter season of 2020-21 and 2021-22. Various meteorological parameters required to predict the Fog/Visibility are obtained from IMD GFS forecasted meteorological information which are valid for next 24 and 48 hours. Forecast verification was performed using the METAR and synoptic observations. The results for 2020-21 fog/visibility forecast for 24 hours are promising with a POD of 0.92, critical success index as 0.68, and a low False alarm ratio at 0.28. Moreover, the 2021-22 results for 24 hours fog /visibility forecast also observed to be promising with a POD of 0.73, critical success index of 0.54 and false alarm ratio at 0.32. This method gives fairly accurate predictions in point locations and can also be used for a larger spatial area. However, The 48 hour forecast performance needs further improvement. The method also predicted the wind speed and relative humidity which were found to be in agreement with the observed data to a great extent. In the upcoming years, the Fog/Visibility forecast method will be more robust with better prediction accuracy of meteorological parameters from model outputs.

Keywords: Fog, Visibility, Forecast, IMD GFS, IGI Airport

Performance of Cumulus Parameterization in Nested WRF model on Simulation of Western Disturbances over North India

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ABSTRACT

Northwestern parts of India receive significant precipitation in the form of snow in winter months (December-February) due to the movement of synoptic systems known as western disturbances (WD). The heavy precipitation during WD affects the agriculture, horticulture, transport, logistics over north Indian states.

In this paper, a non-hydrostatic Weather Research and Forecasting (WRF) model has been used to simulate the severe WD event on 06-08 January 2020. The model is integrated in three nested (27, 9 and 3 km) domains with the initial and boundary forcing derived from the NCEP analysis and forecast fields. The model is integrated up to 120 hours with the initial condition of 05 January 0000 UTC. Four Sensitivity experiments of cumulus parameterization schemes namely Kain-Fritish, Belts-Miller-Janjic, Grell-3, New Tiedtke are carried out with Eta (Ferrier) microphysics scheme, YSU planetary boundary layer scheme to identify the suitable cumulus schemes.

The results reveal that nested model simulations are in close agreement with IMD rainfall observations. Error analysis and RMSE values reveal that the Precipitation patterns are well captured by Grell-3 cumulus scheme accurately with respect to ERA-5 data. Grell-3 cumulus scheme captures the rainfall patterns accurately in terms of the spatial distribution and intensity as compared with other cumulus schemes. Further the spatial pattern of surface temperature is also reasonably simulated with Grell-3 cumulus schemes against other three schemes considered. The wind circulations and wind speed are better captured by the New-Tiedtke scheme. Further few stations observed precipitation is compared and discussed with the nested model simulations, which reveal that the RMSE values are least obtained in case of Domain-3 which indicates that the model simulations with high resolution are mandatory in detecting natural hazards.

Keywords: Climate change, Weather Prediction, Climate modelling, WRF Model, Western Disturbances

Implementation of Common alert protocol in India Meteorological Department

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ABSTRACT

The India Meteological Department (IMD) of the Ministry of Earth Sciences issues various range of forecast associated with weather conditions such as lightining, strong gusty winds, heavy rainfall, Cyclone warning, hail, thunderstorm etc. To disseminate forecasts to common public and stakeholdes, IMD used various types of dissemntaiton tools like SMS service, Website, Fax, Press &Media briefing, Social media, Mobile Apps etc. To further enhance our dissemination system IMD has taken various initiatives and one of them is implementation of Common Alert Protocol. The Common Alerting Protocol (CAP) provides an open, non-proprietary digital message format for all types of alerts and notifications. The CAP data model is specified in terms of the eXtensible Markup Language (XML) for communication compatibility with current technologies. In this article we will discuss about CAP protocol and Implementation of protocol in India Meterorological Depeatment. IMD's CAP feeds are now operational and it is disseminated simultaneously to many applications like Google public alerts and Cell broadcast . During April 2020 to September 2020, four cyclones formed in Bay of Bengal (BOB) and Arabian Sea which affect four different states. During Cyclone Tauktae and Cyclone Nisarga 1.82 Milliion and 19.8 Million SMS disseminated respectively to affected states Gujarat and Maharashtra. Similarly, during Cyclone Yaas state authorities disseminated 71 Million SMS which have major impact on West Bengal and Odisha. During Cyclone Gulab state authorities disseminated around 3.2 million SMSs to the public of Andhra Pradesh.

Keywords: Dissemination , CAP, Common Alert Protocol, Cyclone, XML

Characterization of Mixing Condensation Particle Counter (MCPC) on-board Balloon-borne Observation in the Troposphere

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ABSTRACT

In this study, we have analyzed the Mixing Condensation Particle Counter (MCPC) Data on board during The Balloon Measurement Campaigns of the Asian Tropopause Aerosol Layer (BATAL) Campaign. The instrument is flown over Tata Institute of Fundamental Research (TIFR), Hyderabad during Monsoon Period of July-2019 to study the vertical distribution of Aerosols in the Troposphere. We have analyzed the MCPC data over 3 flights (July 18, July 23 and July 31, 2019) and compared this data with other on board Aerosol Optical Particle Counters (OPCs) such as Portable Optical Particle Spectrometer (POPS), Portable Optical Particle Counter (POPC), Light Optical Aerosol Counter (LOAC), Light Optical Particle Counter (LiOPC). MCPC data showed an increased number concentration between 5km – 8km in Troposphere which corresponds to an Elevated Aerosol Layer (EALs) in the Mid Troposphere. The POPS, POPC, LiOPC and LOAC showed similar results for 0.14 um - 0.65 um , 0.3 um – 1um, 0.05 um -0.25 um and 0.3 um – 1um respectively. This results have been consistent for all data from 3 flights over the duration of 2 weeks. All these findings indicate the presence of a persistent elevated layer of aerosol in Mid-Troposphere during Monsoon.

Keywords: Mixing Condensation Particle Counter (MCPC), Portable Optical Particle Spectrometer (POPS), Portable Optical Particle Counter (POPC), Light Optical Aerosol Counter (LOAC) , Light Optical Particle Counter (LiOPC), Elevated Aerosol Layers (EALs)

Vertical Structure of an Extreme Rainfall Event of 17-19 October, 2021, over Central Himalaya

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ABSTRACT

The Central Indian Himalayan Region is prone to extreme rainfall and cloudburst events limited to less than 10 km^2 areas and often resulting loss of life and property. However, due to insufficient monitoring stations across the central Himalaya, the vertical structures of cloud microphysical properties and integral rainfall parameters are inadequately studied. This study is amongst the very first reports of vertical structures of cloud microphysical properties of an extreme rainfall event occurred during October 17 - 19, 2021, over Uttarakhand, India, observed using a vertically pointing Ka-band micro rain radar (MRR, at 24.2 GHz) at a Central Himalayan location, Almora, Uttarakhand, India. The surface meteorological parameters and rainfall were observed using a 32 m instrumented flux tower and a Raingauge. We found that the rainfall event was triggered by an intense western disturbance, resulting around 313.18 mm of rainfall within a span of approx. 72 hours. Analysis of the radar reflectivity profiles of the event indicated that the event was due to persistent extreme stratiform rain where bright band signatures comprised 46.8±14.3 % of all the ground rainfall observations, with the presence of maximum bright bands (63.38 %) on 19th October. We found that the average melting layer height of the event was significantly closer to the ground 1915.1 (±1038.9) m in comparison to the monsoon (2353.7 ±1301.7 m) and winter (2536.5 ±422.1 m) season stratiform rain over Central Himalaya. Since the MRR observed maximum rain rate 200 m above ground during 17-19 October was 41.51 mm h^{-1}, the event was not a cloud burst as per the rainfall classification of India meteorological Department. Moreover, the severity of the event could be attributed to significantly high droplet fall velocities (> 4.5 m/s) near ground comparison to monsoon and winter season (< 3.75 m/s) during the presence of bright bands. Hence, we could summarized that the severity of the event was triggered by relatively near-ground formation of melting, snow, and rain layers due to the cold air advection in the upper atmosphere as a result of synoptic changes associated with the withdrawal of the monsoon system.

Keywords: Rainfall vertical structures, Extreme event, Central Himalaya, Ka-band radar

Monsoonal rainfall variability over the State of Bihar

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ABSTRACT

The state of Bihar is situated in the Gangatic plain in east of the Uttar Pradesh, North of the Jharkhand and west of the West Bengal while its north boundary touches the Nepal (foothills of Himalayan). For the current study the Bihar has been divided into four agroclimatic zone, viz: agroclimatic zone 1, 2, 3A and 3B.The rainfall variability on intraseasonal scale was studied by using IMD (Indian Meteorological Department) gridded data of observed rainfall with spatial resolution 0.25*0.25 for the period of 1961-2020 in Summer Monsoon Season (JJAS). It is found that the excess of rainfall occur in agroclimatic zone 1 and 2 while in agroclimatic zine 3A and 3B deficit rainfall commonly found. The active phase more pronounced in agroclimatic zone 1 and 2 while break phase is more in agroclimatic zine 3A and 3B. That result that sharp difference between these four agroclimati regions in rainfall variability occur and need to make policies according to this so that the agricultural activity can be improved.

Keywords: Intraseasonal Variability, Observed rainfall, Summer Monsoon Season, Active and Break phase.

Assessment of Land-Atmosphere coupled model in simulating Indian Summer Monsoon and its extremes

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ABSTRACT

This study examines the ability of a Land-Atmosphere coupled model in simulating the Indian Summer Monsoon and its extremes. In this regard, a recent version of the regional climate model (RegCM4.9) coupled with the community land model (CLM4.5) is integrated over the CORDEX-South Asia domain for 35 years (1982-2017) at 25 km horizontal resolution, which is forced by Era-Interim reanalysis. The model bears a good resemblance to observations in the spatial distribution of mean summer monsoon precipitation, its extremes, and associated dynamical and thermodynamical processes. However, some systematic dry bias (long persisting) is present over central India and western Ghats. These biases are mostly associated with model's limited skill in simulating the heavy extreme events caused due to the misrepresentation of mesoscale activity. The overestimation of the rainy days and underestimation of the dry days is one of the possible regions of higher mean rainfall in MLGO. The weaker south-westerly wind from the Arabian Sea, results in suppression of moisture availability and hence precipitation leading to dry bias. Additionally, the stronger convergent flow from the equatorial Indian Ocean to southern peninsular India facilitates the moisture pulling mechanisms enhancing moisture availability and hence precipitation.

Keywords: Indian Summer Monsoon, regional climate model, CORDEX-South Asia

Meteorological analysis of Cloud Burst near Amarnath Holy Cave on 8th July 2022

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ABSTRACT

On 8th July 2022, in a very unfortunate incident, a cloud burst occurred over upper catchment areas of holy Amaranth shrine around 18:10-18:20 hrs IST which caused damages to lives and property over and around Amarnath Holy Cave. Deeper analysis of the available data from ASWs and officials posted at Holy Cave suggested that the highly localized convective cloud caused the cloud burst which led to flash flood leading to death of 15 live(as per official record).
The incident was caused by a highly localized cloud which layed over the Holy Cave & upper catchments of the Holy Cave during 16:30-19:30 hrs IST on 8th July, 2022. This cloud remained stationery there till 18:30 hrs. and caused intense rainfall spell. The IMD AWS function near Holy Cave had recorded 30 mm (3 cm) of rain from 16:30 -17:30hrs IST with occurrence of intense rainfall of 25 mm during 17:30-18:30 hrs IST at Holy Cave. However, it is most likely that the cloud burst incident occurred over upper catchments of the Holy Cave. The high volume of water within short period of time flowed from upper area of the Holy Cave through normal flash flood hannel which took live & damaged proiperty..
The accumulated water from the intense rainfall of short duration in the upper catchments of the Cave combined with those near the Holy Cave & adjoining area flowed downward brought with it lots of debris gaining more and more speed affecting all area coming under its path leading to loss of precious lives.

Keywords: cloud burst, flash flood, flash flood channel.

“Meteorological analysis of Cloud Burst near Amarnath Holy Cave on 8th July 2022”.

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Abstract

On 8th July 2022, in a very unfortunate incident, a cloud burst occurred over upper catchment areas of holy Amaranth shrine around 18:10-18:20 hrs IST which caused damages to lives and property over and around Amarnath Holy Cave. Deeper analysis of the available data from ASWs and officials posted at Holy Cave suggested that the highly localized convective cloud casued the cloud burst which led to flash flood leading to death of 15 live(as per official record).

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Key words: cloud burst, flash flood, flash flood channel.

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ABSTRACT

The state of Bihar is situated in the Gangatic plain in east of the Uttar Pradesh, North of the Jharkhand and west of the West Bengal while its north boundary touches the Nepal (foothills of Himalayan). For the current study the Bihar has been divided into four agroclimatic zone, viz: agroclimatic zone 1, 2, 3A and 3B.The rainfall variability on intraseasonal scale was studied by using IMD (Indian Meteorological Department) gridded data of observed rainfall with spatial resolution 0.25*0.25 for the period of 1961 -2020 in Summer Monsoon Season (JJAS). It is found that the excess of rainfall occur in agroclimatic zone 1 and 2 while in agroclimatic zine 3A and 3B deficit rainfall commonly found. The active phase more pronounced in agroclimatic zone 1 and 2 while break phase is more in agroclimatic zine 3A and 3B. That result that sharp difference between these four agroclimati regions in rainfall variability occur and need to make policies according to this so that the agricultural activity can be improved.

Keywords: Intraseasonal Variability, Observed rainfall, Summer Monsoon Season, Active and Break phase.

"Meteorological analysis of Cloud Burst near Amarnath Holy Cave on 8th July 2022".

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Key words: cloud burst, flash flood, flash flood channel.

Modeling SST Rectification and its Impact on Intra-Seasonal Scale

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ABSTRACT

In most general circulation models, including Climate Forecast System version 2 (CFSv2), the simulation of diurnal variability in oceanic, atmospheric, and interfacial properties is reported to be problematic. The present study shows how the coupled model re-forecasts with a revised flux and diurnal skin temperature scheme can improve the simulation of parameters and processes at diurnal, intra-seasonal, and seasonal time scales. The study reports reduced biases in sea surface temperature (SST), precipitation, surface fluxes, and mixed layer depth over the tropical Oceans and landmasses. Better simulation of El Niño–Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) related non-linearity, ENSO-Indian Summer Monsoon Rainfall (ISMR), and IOD-ISMR relation is among the most critical improvements achieved by revising the turbulent flux parameterization. In the present study, the SST rectification process and its impact on intra-seasonal variability is assessed w.r.t. monsoon simulation. The mechanism by which amplitude of intra-seasonal SST variability is modulated by the diurnal cycle is known as SST rectification. With the implementation of revised diurnal skin temperature parameterization, the persistence and amplitude of SST rectification have significantly improved in the model simulations. The model characteristics during strong diurnal warming events are better represented with revised flux and SST schemes. From a monsoon simulation perspective, the revised flux and SST scheme helps simulate stronger and organized rainfall anomalies coupled with stronger SST, mixed layer depth, and turbulent flux anomalies during the active and break phases. Also, better simulation of the northward propagation of intra-seasonal oscillations is explicitly shown for strong diurnal warming and weak wind conditions.

Keywords: SST Rectification, Intra-Seasonal Variability, Active-Break Monsoon, Climate Forecast System.

Understanding drought dynamics and variability over the Arabian Peninsula

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ABSTRACT

Drought is a ubiquitous problem in arid to semi-arid regions and has significant impacts on water resources and agriculture. It has been noticed that drought frequency has increased in the recent past over the different parts of the AP. Hence, this study examines the spatiotemporal variability of the drought and associated physical processes over the Arabian Peninsula (AP). We computed the Standardized Precipitation Evapotranspiration Index (SPEI) for the 1951 to 2020 period using Climate Research Unit and the fifth-generation ECMWF Reanalysis datasets. By applying a rotated empirical orthogonal function analysis on the SPEI datasets, we identified four homogenous and coherent drought regions over the AP. Our findings show a significant drying trend ($p<0.01$) for the entire period, with an abrupt acceleration in drought frequency and severity in recent decades (since 1998) over all four sub-regions of AP. Interestingly, all the hydroclimatic variables exhibit contrasting patterns between the wet and dry extreme composites across the region. The drought occurrence is associated with positive potential evapotranspiration (PET) and negative precipitation anomalies, which exhibit the highest contrasting features in winter. In particular, the northern and southern regions exhibit significant variations due to the seasonal response to precipitation changes. The dynamic processes for driving drought will be discussed briefly during the conference.

Keywords: Climate change, drought, Arabian Peninsula, hydro-climatology

Performance evaluation of WRF model with various parameterization schemes in simulating thunderstorm over the west coast of India

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ABSTRACT

The development of the giant cumulus clouds into a towering dark cumulonimbus accompanied by lightning flashes and thunder is a serious concern as it can wreak havoc. Being a mesoscale weather phenomenon, thunderstorm events are associated with high-speed winds, lightning, thunder, rainfall, and even hail. The prediction of thunderstorms with accurate and reliable space-time-intensity is a challenging task for various climatic regions. This work is the case study of a pre-monsoon thunderstorm event that occurred over Cochin, Kerala on 10th May 2018. Weather Forecasting and Research (WRF-ARW) model simulation has been done with different sets of microphysics and cumulus parametrization schemes. The performance of each combination of various parameterization schemes employed in the simulation in terms of correlation, standard deviation and root mean square errors are provided in the Taylor diagram. Out of the 24 various combinations, it is found that the combination of Thompson microphysics scheme and Grell Freitas Ensemble cumulus scheme is able to produce the best result as compared with ground observations involving the automatic weather station (AWS) and an advanced VHF Radar installed at the Advanced Centre for Atmospheric Radar Research, Cochin University of Science and Technology (CUSAT). The study offers a future prospect of real-time prediction of thunderstorms with the best combination of parameterization schemes available with the WRF model.

Keywords: Thunderstorm, modeling, microphysics, parametrization

EVALUATION AND INTERCOMPARISON OF THE SUBSEASONAL PREDICTION SKILL OF INDIAN SUMMER MONSOON

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ABSTRACT

Documentation of the skill of a prediction system and its comparison with those of leading modelling centres are crucial in model development. This facilitates understanding the limitations of the existing prediction system and aids in its improvement. The current study compares the extended range prediction skill of the Indian Institute of Tropical Meteorology (IITM) generated real-time forecast with that of the UK Met Office (UKMO) forecast during the boreal summer monsoon season. It is found that both models suffer from biases in the climatological mean state of the monsoon. IITM forecast possesses a skill comparable to UKMO coupled seasonal forecast as compared to the observation in the first two weeks lead over most of the meteorological subdivisions during the monsoon months of June to September. However, at longer leads, the UKMO model outperforms the IITM model, which could be credited to its enhanced skill in predicting the monsoon intraseasonal oscillations and the better representation of monsoon variability.

Keywords: Boreal Summer Monsoon; Extended Range Prediction; Monsoon Intraseasonal Oscillations; Model Intercomparison; Prediction skill.

A Numerical Study to Investigate the Precipitation Features of Monsoon Deep Depressions over Bay of Bengal

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ABSTRACT

The rainfall characteristics of Monsoon Deep Depressions (MDD) originating over the Bay of Bengal (BoB) basin have been investigated in the present study using a coupled ocean-atmospheric model (COAWST) and a stand-alone atmospheric (WRF) model with a lead time of up to 72h. It is found that though the tracks of the four MDDs considered in the study have been reasonably simulated, the intensity was overestimated in both sets of simulations compared to India Meteorological Department (IMD) best estimates. Upon decomposition of the contributors to the rainrate for the composite of the storms in the deep depression (DD) phase, it was found that the moisture sources/sinks play a more important role than the cloud sources/sinks in modulating the rainfall processes. Further analysis of the moisture sources/sinks showed that the horizontal and vertical advection are the major drivers in modulating the contribution of the moisture sources/sinks. The validation of rainfall using CMORPH datasets suggested that the coupled simulations had a higher skill in rainfall prediction. Furthermore, the composite of different components of moisture sources/sinks (especially vertical advection) was found to be more realistically simulated in COAWST compared to CNTL upon validation with MERRA datasets. Analysis of the composite energetics showed that scarcity of bulk kinetic energy in the later hours of the DD phase in COAWST led to the dissipation of the storm core, which led to better prediction of rainfall. On the other hand, a re-intensification of the storm core by means of condensational heating led to an overestimation of rainfall in WRF, which finally resulted in lower skill in rainfall prediction.

Keywords: Monsoon deep depressions (MDD), Bay of Bengal (BoB), Coupled Ocean Atmosphere Wave and Sediment Transport (COAWST) model, vertical advection (VADV)

Western Ghats rainfall decadal variability and associated physical processes

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ABSTRACT

The Western Ghats (WG) is a vast montane forest ecosystem known for its biodiversity and endemism. The present study examined the variability of summer monsoon rainfall over the WG using century (1900-2010) long observed rainfall data. Spectrum and wavelet analysis of rainfall observation reveal significant decadal variability (at 90% confidence level) in WG rainfall. The decadal variability of WG summer monsoon rainfall is higher than in most of the other regions of India. Wavelet analysis also revealed that in the recent period, the amplitude of decadal variability is amplified by 1.5 to 2 times compared to the prior half-century. Correlation analysis with dominant sea surface temperature (SST) indices of the global ocean confirms that WG rainfall decadal variability undergoes temporal modulations. Indian Ocean SST variability displayed a significant correlation during 1901–1942 whereas, during 1943–1977 and 1978–2010, Pacific Ocean SST variability displayed a significant correlation with WG rainfall variability. The analysis associated with decadal rainfall variability reveals the dominance of dynamical processes during 1901–1942 and moist thermodynamical processes during 1943–1977 and 1978–2010. The study concludes that the decadal variability of WG rainfall is robust, and the forcing mechanisms are essentially maintained by the Indian and Pacific Oceans variability, adding value to developing decadal prediction systems and contributing to understanding the evolution of the WG ecosystem.

Keywords: Western Ghats, Rainfall, Decadal variability, SST, Dynamical, Thermodynamical. resonant interaction.

Identification and prediction of heat wave-2022 over Andhra Pradesh using ANN technique

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ABSTRACT

In recent decades, the lives of people and animals have been significantly impacted by the major meteorological disaster known as heat waves. Maximum temperature data from 2022 are analysed to determine the synoptic nature, intensity, frequency, and other important aspects of the heat wave over Andhra Pradesh. Because of the high number of casualties caused by heat waves, the state of AP declared disaster events to be state-specific disasters. As a result, forecasting disaster events in the coming years in light of changing climatic conditions is critical. During the period 1973-2022, an ensemble model was developed using CMIP-6 forecasted meteorological parameters (temperature, humidity, wind speed, and pressure) as predictors and observations as predictors. An Artificial Neural Network (ANN) approach is proposed to be used to develop the ensemble model. To create the ensemble model for temperature, all 5 ensembles of CMIPS-6 2 models with different initial conditions are used as predictors, and the IMD observation is used as predictand. The data is then randomly divided into three categories: training, verification, and validation. 70% of the data is chosen for training, 30% for verification, and 30% for validation. The training dataset is used to develop the model, the verification data set is used to check for any inconsistencies between the developed model and the training dataset, and the validation data set is used to validate the model performance. The validation dataset is a separate collection that was not used in either training or verification. Similarly, the ensemble models are developed for the remaining parameters as well. This paper aims to predict the trends, frequencies and duration of heat waves help the Disaster Management Authorities (DMA) to plan for the mitigation activities. These findings will also aid in the creation of public awareness and community outreach by the competent authorities through dissemination via social networks and local community centres.

Keywords: Temperature, Heat wave, Ensemble models, CMIP - 6,ANN, Andhra Pradesh.

Mapping of Normal and Abnormal Routes of Cyclone Tracks and Prediction Using Artificial Neural Network

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ABSTRACT

Track evaluation and prediction are crucial for cyclone disaster management. The current work was carried out in the BoB area of NIO. Point location data of past 40 years downloaded from e-atlas portal of India Meteorological Department's RSMC were used to depict the cyclone track in GIS environment. Artificial Neural Network (ANN) was used to predict cyclone track. The accuracy of the cyclone track prediction was assessed using RMSE (Root Mean Square Error) and MAE (Mean Absolute error) to evaluate the positional accuracy of predicted track. It is found that the predicted track locations were within RSME of plus /minus of 45 Km. The prediction model based on ANN found to perform pretty well. The method developed as part of this project work can be extended to other parts of the Indian Ocean with appropriate modifications.

Keywords: Tropical Cyclones, Artificial Neural Network, RMSE, MAE, Prediction.

Wind energy prediction over Ananthapur district using AI techniques

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ABSTRACT

Wind energy is one of the prominent renewable sources of energy that has a less environmental impact. Though wind farms have expanded over the years, there are a few problems that are faced in the operation of every wind farm. Since wind is inconsistent over time, there is difficulty in estimating the total wind power the farm produces along the day, and it is also difficult to identify the low wind speed hours to schedule a time for turbine maintenance. The wind data at the 10 m level at 12.5 km resolution for the period 1979–2020 are used. This paper presents wind power forecasting over a region using machine learning algorithms, which address the problems faced by the Industries. The deep learning algorithms are trained on the past geographical data of a selected location and successfully forecasted the wind power over the region. Furthermore, different case studies are conducted to measure the performance of various models and the model with accuracy is suggested. This study concerns forecasting the hourly wind speed over Ananthapur, which is the fundamental information used in the further estimation of wind power. Statistical analyses such as RMSE and MAE are used to measure the performance and accuracy of the model. Artificial intelligence and machine learning techniques will be used to predict wind power density over a region. The proposed deep learning model could be further used by the industries to forecast and analyze wind power over a farm and come to know the peak windy hours to generate wind power and times to shut down and perform maintenance.

Keywords: Wind energy, wind speed, Artificial Intelligence (AI), wind power density, wind turbine.

DROUGHTS IN INDIAN SUMMER MONSOON AND ITS ASSOCIATION WITH INDO-PACIFIC CLIMATE DRIVERS

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ABSTRACT

Indian subcontinent has witnessed a declining trend in summer monsoon rainfall since 1960, along with an increase in frequency and areal extend of droughts. Out of the 6 severe droughts in the past 150-year period (1871-2020), 3 occurred during 1961-2020. Moreover, the recent decades of 1980s, 2000s, and 2010s experienced three droughts per decade, including the two severe droughts of 2002 and 2009. Interestingly, all these changes have occurred in the backdrop of a rise in global mean temperature. In view of this, a revisit to the variability of droughts in Indian summer monsoon rainfall have been carried out using the 150-year long (1871-2020) available dataset. Further, an examination of the variation in the relationship between the Indian summer monsoon rainfall and the Indo-Pacific climate drivers namely El Nino Southern Oscillation (ENSO), ENSO Modoki and Indian Ocean Dipole events have been performed for the period of 1871-2020, with particular emphasis on the recent decades.

Keywords: Indian summer monsoon, droughts, Indo-Pacific climate drivers

Multi-hazard Early Warning System(MHEWS): Current status and future scope

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With post COIVD period, when we are meeting, in this national seminar, to discuss about delivering a truly people-centric customized weather and climate and environmental services and early warning systems(EWS) for all related hazards, we like to discuss various progress in the field and their real time performances. Further, it needs to find, how far have been our progress in the in the four well known pillars of EWS **(1.Exposure andHazard specific Risk knowledge 2. Detection, Monitoring and Observations, Forecasting of hazards with risk based early warnings or IBF, 3.Warning dissemination and 4. Preparedness and response or coping capability of communities or stake holders)** and how IMD, CWC, SDMA, NDMA etc, have been working together as a team in order to address timely to all our users needs. To start with, it is to note that WMO work agenda and objective reviewed for recent period of 2019-2022, all have also been focused on one major issue i.e. "On integration of Weather climate water environmental related services and their applications into one and only one" **"as part of the real time services to various users communities to keep them and their assets safe".** The main reason has been "to move fast to serve the gap-what various users are demanding and what we can serve", so that "with the pace which climate change induced disasters and vulnerability have been in increasing mode" to be balanced by "increasing our capacity across all value chains and thus have to be linked in order to achieve various targets and goals of **COP 25-27(2020-2022) of IPCC and UNEP,** Sendai Framework for Disaster Risk Reduction 2015-2030 and future **Sustainable Development Goals** (**SDGs**) or **Global Goals** for 2015-2030 as fixed by UN-GA 2015. **In the present talk, global and national status has been reviewed. It covers recent trends in the service components in setting up, the best practice and policy for sharing of various Data covering hazards-exposures- vulnerability and Impact (HIVE), partnership with stake holders. The talk also covers various operational new services strategy adopted by IMD and new customized service added in recent years of 2019-2002 in order to improve MHEWS to various sectors, as par with other developed countries, including development and implementation of IBF and risk based warnings for various weather hazards at real time during 2020-2022. Various issues and challenges have also been discussed.**

Keywords: Weather, climate, multi-hazard early warning system, Impact based weather forecast and risk based early warnings, exposure and vulnerability

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REGIONAL CLIMATE MODELING IN THE FRAMEWORK OF CORDEX SOUTH ASIA

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ABSTRACT

The talk will summarise the regional climate activity of the World Climate Research Program (WCRP) Coordinated Regional climate Downscaling Experiment (CORDEX) coordination by the Centre for Climate Change Research (CCCR) at the Indian Institute of Tropical Meteorology (IITM) Pune, and the high resolution (50km and 25km) downscaled CMIP5 climate change projections available for Southern Asia domain (WAS). The recent recommendations by the CORDEX Science Advisory Team (SAT) will be highlighted, including the CORDEX experiment design for dynamical downscaling of CMIP6 global climate model projections, a white paper on the future scientific challenges for CORDEX, and on the CORDEX Flagship Pilot Studies (FPSs). The opportunities for regional capacity building, and challenges for better assessment of regional climate change provided by the availability of the CORDEX South Asia (WAS domain) high resolution datasets will be briefly discussed. A summary of the useful contributions from the CORDEX South Asia ensemble of high resolution downscaled projections to the regional climate change assessments for the Indian region; over the Hindu Kush Himalaya mountains; and to the latest IPCC AR6 Working Group I report will be presented. Finally, an ongoing CORDEX FPS activity using convection-permitting high resolution (~4km) climate simulations aimed to better understand the regional characteristics of water cycle over the Third Pole and adjoining regions will be showcased.

Keywords: Regional Climate modeling, CORDEX, South Asia.

Surface PM2.5 estimation using machine learning and remote sensing

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ABSTRACT

Fine particulate matter (PM2.5) has received a widespread attention all over the world because of its direct association with the degradation of air quality and the related human health effects. The regular monitoring of PM2.5 concentrations is critically necessary to analyze their aftermath effects but the limited number of ground based air quality monitoring stations acts as a barrier in the evaluation of space-time dynamics of air pollution. This study is conducted to estimate the ground-level concentrations of fine particulate matter from statistical models developed using algorithms of machine learning (ML) incorporating satellite measurements. A total of four ML (Random Forest, Extra Tree, Light Gradient Booster and Gradient Booster) models were developed for Kanpur city using MERRA-2 (Modern-Era Retrospective Analysis for Research and Applications) aerosol products (AOD, AE and PM2.5 mass concentrations) to estimate the ground-level PM2.5 concentrations from Jan - Dec 2021. The ML models were pre-trained using the MERRA-2 reanalysis dataset of the previous five years (2016-2020) along with surface measurements of PM2.5 provided by CPCB. Good positive correlation (r) values were obtained during the training (R ~ 0.81) as well as the testing of models (R ~ 0.78). The hyper-tuned models provided good correlation coefficients obtained from the regression analysis of estimated and observed values accompanied with moderate Root Mean Square Error (RMSE) and Mean Absolute Error (MAE values). The Gradient Booster model showed highest correlation coefficient (r) = 0.785 and lowest RMSE (52.01 μg m-3) but with overall underestimated values. However, in further studies, the more in-depth validations will be required.

Keywords: Western Ghats, Rainfall, Decadal variability, SST, Dynamical, Thermodynamical.

Reinvestigating the changing relationship between the Indian Summer Monsoon and ENSO in the recent decades

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ABSTRACT

The Indian summer monsoon rainfall (ISMR) from June to September plays a significant role in the most densely populated Indian region due to its direct impact on agriculture as well as the economy. El Niño-Southern Oscillation (ENSO) is a prominent ocean-atmosphere coupled interannual variability over Pacific Oceans that strongly modulates the variability of ISMR. However, the relationship between ENSO-ISMR has gone through many changes during the recent decades. Recently, the research and operational community started using new climatology considering the recent 30-year period 1991-2020 for various meteorological parameters. This study comprises a detailed analysis of the changing relationship between the ENSO and ISMR during two recent independent periods, (i) 1961-1990 and (ii) 1991-2020, using Sea Surface Temperature (SST), rainfall and various atmospheric variables.It was found that the frequency of the occurrence of La Niña events has reduced to almost half during 1991-2020 as compared to the 1961-1990 period whereas the frequency of the El Niño events did not show huge variation. It was also observed that the ENSO-ISMR negative correlation has been significantly reduced in 1991-2020 compared to 1961-1990 especially, over north, northwest India and peninsular India. It was observed that La Niña associated above normal rainfall over central India during 1961-1990 was higher due to strong vertical wind shear and increased rising motion over central Indian region as compared to 1991-2020. In case of El Niño, there is a reduction of rainfall over central India during 1991-2020 owing to weakening of vertical wind shear as well as stronger subsidence compared to 1961-1990. This indicates that the weakening ENSO-ISMR relation in the recent period mostly contributed due to the weakened relationship between La Niña and ISMR during 1991-2020 period. This study highlights how the changes in the patterns and the intensity of the atmospheric as well as oceanic fields within the tropical Indo-Pacific Ocean contributed to the weakening of ENSO-ISMR relation in the recent decades.

Keywords: Indian Summer Monsoon Rainfall, El Niño, La Niña, Pacific Ocean, ENSO-ISMR relationship.

QUANTIFICATION OF UPPER-TROPOSPHERIC MRG ACTIVITY AN THEIR ASSOCIATION WITH EXTRATROPICAL WAVE INTRUSIONS

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ABSTRACT

Westward propagating Mixed Rossby-gravity(MRG) waves are synoptic-scale equatorial disturbances that play a pivotal role in modulating tropical weather. Scale analysis of large-scale tropical motions suggests that in the absence of organized convection, intrusion of extra-tropical waves is an important forcing mechanism that excites MRG wave events. In the current study,we adopt an MRG event-based approach to classify MRG events into two categories:-MRG events associated with and without extra-tropical wave intrusions. MRG events and extra-tropical wave intrusions are identified using equatorial meridional wind at 200hPa and potential vorticity on 350K isentropic surfaces, respectively. We find that about 35-40% of MRG events exhibit association with extra-tropical wave intrusions. Half of the MRG activity occurring over central, eastern Pacific, and Atlantic basins during the boreal winter and spring are associated with extra-tropical intrusions. Majority of the events prefer Northern Hemispheric pathway. Events associated with Southern Hemispheric intrusions also select Pacific and Atlantic but showpeak activity during boreal summer. The geographical preference and seasonality of maximum MRGevents associated with intrusions are co-located with the westerly duct. MRG event associated with extra-tropical waves exhibit slightly higher amplitude and larger meridional extent. The observation of higher amplitude and zonal wavelength(wavenumber 6) similar to extra-tropical waves supports the hypothesis of resonant interactions between MRG and extra-tropical waves during boreal winter. Since the background wind configuration during the two classes of MRG events is significantly different, it is difficult to attribute the differences in dynamical properties to Doppler and non-Doppler effects of the mean or lateral forcing by mid-latitude waves. Since MRG events associated with extra-tropical wave intrusions account for a major fraction of total MRG wave activity, we speculate it to have a cascading effect on other tropical modes of variability. Hence tropical-extratropical interactions should be considered an important factor in modulating tropical weather.

Keywords: Mixed Rossby-gravity Waves, extra-tropical wave intrusions, Potential Vorticity, resonant interaction.

Machine Learning based Crop Water Management

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ABSTRACT

Increasing water and food demand from the growing population of India needs organised water management with increased crop yield. In the recent decade, there have been enormous improvements in the weather prediction systems with dynamical models in spatial and temporal scales. However, their direct applications in crop water management have not been fully explored. This is to study a novel algorithm for crop water management proposed by our institute. One of the major mandates of our Institute is to promote research in the state of art technologies, providing solutions to human problems especially in the area of Water, Energy, and Food etc. Here we made an attempt to apply the Machine Learning (ML) algorithms in the theme of application of weather in agriculture. The main objective of this study is to predict solar radiation and Evapotranspiration (ET) using ML algorithms. Also, to predict events like heavy rainfall/ wind speed to provide accurate warnings sufficiently well in advance to reduce loss in crop yield. The predicted ET data is used to determine the water demand of field crops in agro-meteorological applications to help farmers better predict future climatic patterns, thereby highlighting better planting or crops, effective water management and hence creating a useful climate service. Evapotranspiration is the most tough water balance component to directly measure. An accurate estimate of ET is the preliminary step involved in determining the water demand of field crops. Also, the solar radiation data is the essential input for estimating the reference crop ET. Due to high cost and difficulties in measurement techniques, solar radiation and evapotranspiration is predicted using empirical equations and tree-based ML algorithms. The ground-truth/observation data from India Meteorological Department (IMD) would be considered for the ML model inputs. The findings of this study can be used as a platform for irrigation planning, design and management.

Keywords
Climate services, Evapotranspiration, Solar Radiation, Machine Learning.

Role of the air-sea interaction process in the tropical Indian Ocean on the onset, active, and break phases of the monsoon and its radical changes in recent decades.

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ABSTRACT

Interaction between the Ocean and atmosphere drives and modulates the weather and climate through dynamical and thermodynamical feedback. The exchange of energy and mass in the form of fluxes takes place at the air-sea interface mainly in the form of heat, water and momentum fluxes which influence the weather and climate. The interaction of radiation, sea surface temperature (SST), wind, evaporation, SST gradient, wind stress, total precipitable water (TPW), and convection processes is postulated as a new mechanism for the evolution of MOK. The ocean warming by short wave radiation during pre-monsoon creates the background, and then the ocean surface transfers the required energy to the atmosphere in the form of latent heat flux in response to wind caused by the forming SST gradient. Over the North Indian Ocean during this time, there are notable inter-annual relationships between wind stress, TPW, and precipitation, which confirm the above-described hypothesis. In the pre-20 and post-20 epochs, the characteristics of the onset phase noticeably differ. With a midway downward shift of 3 days compared to the prior 2000s epoch, the late 2000s epoch is apparent. During the most recent period, the onset process's strength also waned. Convection is suppressed by a strengthening of the dynamic tele-connections in the south Indian ocean and a weakening of the upper-level divergence over the Indian subcontinent, which eventually leads to a less intense ISM onset for the later epoch. Similar to the onset phase, the active phase has undergone notable alterations during the entire study period. Recently, both Western IO and the Indian subcontinent region have been able to discern the twin convection band within ISO propagation domain. South IO tele-connection is strengthened as equatorial IO convection extends more to South IO.

Keywords: Air-Sea Interaction, Monsoon Onset, Monsoon Intra-Seasonal Oscillation

Potential linkage between Antarctic sea ice, Pacific SST and Indian summer monsoon

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ABSTRACT

In this study, results of diagnostic analysis for the period 1983-2015, demonstrate a robust relationship between Indian Summer Monsoon Rainfall (ISMR) and sea ice area (SIA) over the two sectors of Antarctica namely, Western Pacific Ocean (WPO) and Bellingshausen and Amundsen Seas (BAS). A significant direct (inverse) relationship is observed between ISMR and SIA over the WPO (BAS) sector. Further**,** plausible physical mechanism governing this relationship is proposed. El Niño Modoki exhibit direct (inverse) relation with SIA over BAS (WPO) sector during summer monsoon season, which has prompted investigation of SIA-El Niño Modoki-ISMR connection. The linkage between southern polar sea ice and the Indian summer monsoon has been demonstrated through the Pacific Ocean, wherein above normal SIA over the BAS (WPO) sector is associated with concurrent warm equatorial central (western) Pacific Sea Surface Temperature (SST) anomalies. Associated meridional circulations supplemented by BAS (WPO) SIA extremes is accompanied by an ascending motion over the equatorial central (western Pacific). In turn, through large-scale zonal circulation, ascending branch of circulation over the central (western) Pacific Ocean contemporaneously impacts ISMR adversely (favourably). Large-scale atmospheric circulation modulated by equatorial Pacific SST signature is suggested as a possible link between Antarctic sea ice and ISMR.

High Impact Weather Analysis using observation and Modelling

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ABSTRACT

India witnesses the High Impact Weather Events (HIWE) frequently in the recent times resulting loss in lives and property. It is also expected that there will be increase in the frequency and intensity of such events in the wake of climate change in the coming years. There is need of understanding the mechanisms which is mainly possible by analysing the multi-source observation data. Progress have been made in the monitoring and observation and prediction of such events but there is still gaps of utilizing this knowledge in the proper disaster management. In this paper an attempt is being made to classify the disasters and assess the spatio-temporal variability in terms of the intensity-duration-frequency analysis using the observation and modelling works. The frame work of the early warning system and the valu chain process for the impact based forecasting system are also explored from the Indian context. This discussion will provide a better guideline for the policy makers in the real time disaster management and planning.

Keywords: High Impact weather Events, Climate change, Weather Prediction, Multi-source data, Impact based prediction

Statistical downscaling and bias correction of surface meteorological variables using machine learning algorithms.

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ABSTRACT

Biases in hindcasting and forecasting surface meteorological variables, such as temperature at 2m, relative humidity, wind speed (above 10m), and many more, arise due to initial and boundary conditions generated using global and regional reanalysis datasets in numerical mesoscale models. Meteorological biases vary depending on the topography and synoptic condition of the region present in the reanalysis (NGFS) dataset with a spatial resolution of 25 kilometers at six hourly available from the year 1999 to 2021, by National Centre for Medium-Range Weather Forcasting, India. Datasets are further statistically downscaled to 12 kilometers at six hours and validated, and biases correction with a six hourly averaged Indian Monsoon Data Assimilation and Analysis reanalysis dataset (IMDAA). The study uses seven different machine learning regression models such as Ridge Regression(RR), Random Forst(RF), K-Nearest Neighbors (KNN), Support Vector Machine, AdaBoost Regression (ABR), Extra Tree Regression (ETR), and Gradient Boosting Machine (GBM) for statistical downscaling of the meteorological variables implemented over 55 observation stations of India. The study focuses on the winter months in India, from Octuber to Februrary of each year from 2005 to 2019, as calibration dataset and validation datasets are from 2019 to 2020. We found that Gradient Boosting Machine(GBM) was the best performing statical downscaling model among other models and for all meteorological variables,especially surface temperature at 2m, with the highest R2 score of 0.85 and lowest RMSE of 4.02 degree C. We used quantile mapping as a bias correction technique to improve the forecasting of the GBM model. We Overall GBM model with quantile mapping can be used to improve surface meteorological variables over the Indian region.

Keyword: Downscaling, bias correction, reanalysis dataset and machine learning.

INVESTIGATING EL NIÑO - SOUTHERN OSCILLATION AND INDIAN SUMMER MONSOON RAINFALL TELECONNECTION ON A DECADAL TIMESCALE USING DECADAL CLIMATE PREDICTION DATASET

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ABSTRACT

The El Nino and Southern Oscillation (ENSO) is considered as the strongest predictable driver of the Indian summer monsoon rainfall (ISMR) on the intraseasonal and interannual time scales. While the ENSO is also a strong predictable signal of the ISMR at the decadal and longer time scales, however, the teleconnection between the two undergoes signigicantly high variability on these time scales. An effort is made to investigate the ENSO-ISMR teleconnection on a decadal time scale using the recently developed Decadal Climate Prediction Project (DCPP) dataset for a lead time of 1-10 years. The analysis is carried out using the 52 years of dataset with decadal predictions of climate models initialized each year during 1961-2012. It is found that most of the analysed climate models show good skill in capturing the NINO3.4 anomaly (e.g. ENSO) at a lead time of 12 months (1 year), after which the decadal predictions of NINO3.4 may not be very useful (except 1-2 models where predictions remain significant upto 24 months). However, the models show no skill in simulating the ISMR at any lead time (i.e. from 12-120 months). In other words, the ISMR prediction may not be skilful on decadal time scales. Interestingly, most of the models show good skill in capturing the ENSO-ISMR relationship even up to a lead time of 5-10 years. It is strange to note from the DCPP output that the ISMR predictions are failing on decadal time scales, but the ENSO-ISMR relationship remains intact on these time scales.

Keywords: Indian summer monsoon rainfall; ENSO; DCPP; Teleconnection; Decadal Predictions

Climate Change Projections over the Upper Indus Basin ending 21st Century

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ABSTRACT

The study projects the downscaled temperature and precipitation over Upper Indus Basin (UIB), under different climate change scenarios ending 21st century. The multi-model climate projections for the baseline period (1980-2005) were validated against observartions from eight meteorological stations using various statistical tests, viz., Coefficient of Correlation (CC), Relative Bias (RB), Root Mean Square Error (RMSE) and Nash- Sutcliffe Coefficient (NSC). The temperature projections from GFDL CM3.1 were in good agreement with observed data showing a RB of -39%, RMSE of 1.5 and NSC of 0.5. The study also highlighted larger bias in precipitation projections compared to the temperature projections. Although GFDL CM3 outperformed all the participating models, however the bias was still significant and was hence reduced using the Aerts and Droogers statistical downscaling approach. The average RB of the modelled temperature and precipitation data over the region was significantly reduced to 2.9% and -13% respectively.Based on the GFDL CM3 climate model simulations, the temperature projections indicate a rise of 3 and 5.2°C, 3.4 and 4.7 °C and 4.8 and 6.5 °C in Jhelum, Chenab and Indus basins under RCP4.5 and RCP8.5 respectively. The precipitation on the other hand is projected to witness a marginal increase of ~1% and 3.4% in Jhelum, an increase of 8 and 8.2%, and ~3% and ~9% ending 2100 for the Chenab and Indus basins under RCP4.5 and RCP8.5 respectively. The predicted climate change would have a profound impact on a range of ecosystem services, and dependent livelihoods and the high-resolution climate projections are therefore hoped to aid impact assessment studies to guide policymaking for climate change adaptation and mitigation in the UIB.

Keywords: Upper Indus Basin; Statistical Downscaling; Climate Model; Climate Projections

Fog intensity and temporal estimation using different machine learning algorithms: a case study over highly dense urban cities of the Indo Gangetic region

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ABSTRACT

Indo-Gangetic cities such as Delhi, Varanasi, Patna, Lucknow, and many more have witnessed high fog intensities days (visibility less than 1 km) in winters due to poor air quality caused by crop burning, traffic, and urbanization which further affects transportation, causing health hazards and economic loss. It becomes an important environmental issue that happens for a short time (spatially and temporally) and is difficult to predict in a short time series dataset. In the current study, the reanalysis dataset of Monsoon Data Assimilation and Analysis reanalysis (IMDAA) dataset of 12 km at 1 hour from 1999 to 2020 provided by the National Centre for Medium-Range Weather Forecasting India has been used as an input dataset for nine different machine learning (ML) algorithms as Logistics Regression (LR), Random Forest (RF), Decision Tree (DT), Gaussian Naive Bayes (GNB), Distributed Random Forest (DRF), Extreme Randomized Tree (ERT), Gradient Boosting Machine (GBM), Generalized Linear Model (GLM), and Stacked Ensemble (SE) ML algorithms to classify fog days for winter months (October to February) over 15 years starting from 2005 to 2019 for calibration and validation for 2019 to 2020. Statistical indexes such as F1 score (harmonic mean between precision and recall), Logloss, and AUC (Area under ROC curve) have been used to validate the model performance. We noted that after parameterized tunning with GridSearchCV, F1 score found to be best in SE: 0.97, followed by DRF: 0.97, RF: 0.93, GLM: 0.92, ERT: 0.92, DT: 0.92, GNB: 0.87, GBM: 0.80 and LR: 0.72. The performance of advanced ML algorithms (DRF, GBM, GLM, XRT, and SE) was best for New Delhi as it experienced the worst fog events in the Indo-Gangetic region. DRF could predict all 19 days followed by SE (18 days) out of 19 high fog days in the winter month of 2019 to 2020.
Keywords: Downscaling, bias correction, reanalysis dataset and machine learning

Futuristic Risk Index of Extreme Rainfall Events under Climate Change for Indian Smart Cities

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ABSTRACT

India, the world's second-largest populated country is observing an increase in urbanization, urban population, and the associated impacts of climate change and weather variability. Urban infrastructure, high population density, and urban heat islands effect increase the potential risk of warming conditions and extreme weather events through changing frequency and severity of extreme weather events. Therefore, the Ministry of Housing and Urban Affairs (MHUA) of India launched the "Climate Smart Cities Assessment Framework" in February 2019 for 100 Indian smart cities to make them climate resilient due to climate change and extreme weather events. This study analyzed the impact of extreme rainfall events based on six homogeneous rainfall zones and populations by computing the risk index ranking for cities all indices under different return levels for all smart cities. This study provides the future trends of extreme rainfall events by non-stationary analysis of extreme precipitation indicators (i.e., maximum 1-day precipitation, Rx1; simple precipitation intensity index, SDII; annual count of days when precipitation > 10 mm, R10; and the maximum number of consecutive days with precipitation >1 mm, CWD) for smart cities in India. Results showed the increasing trends in future extreme precipitation events for Rx1, SDII, R10, and CWD in 68, 69, 89, and 64 smart cities for different return levels (RL), respectively; the impact of SDII and R10 is significantly greater than Rx1 and CWD for Indian cities. The CWD events showed a maximum increase greater than 100% among different indices, while R10 indicated more occurrence among smart cities in different homogeneous rainfall zones of India. The minimum and maximum intensification of extreme rainfall events through all precipitation indices in the future is predicted for Panaji and Belagavi cities, respectively.

Keywords: Climate change, Extreme Rainfall Events, Nonstationary Analysis, Smart Cities

Numerical Simulation of the Indian monsoon Regional Climate using the WRF Model

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ABSTRACT

In the present paper we studied the mean features of the Indian summer monsoon (June through September) climate simulated by the Weather Research and Forecasting (WRF) model in a regional climate mode. For this purpose the WRF model at 25km horizontal resolution was forced with Community Climate System Model version4 (CCSM4) which is a part of the Coupled Model Inter comparison Project (CMIP5) using Representative Concentration Pathway 6.0 (RCP6.0) as initial boundary conditions for the hind cast period (2006-2022) and for future climate projections (2023-2100) for all the months in a calendar year. But for the analysis, the authors chose the summer monsoon months only for the period 2008 to 2022 and discarded the years, 2006 and 2007 as spin-up time. The model physics has been configured with WSM6 for MicroPhysics, BMJ for Cumulus Physics, YSU for PBL and RRTMG for radiation. The performance of the model was assessed through the study of the spatial distribution of Temperature, Winds, Pressure, Moisture flux convergence and Rainfall. The simulated parameters were compared to ERA5 reanalysis; India Meteorological Department (IMD) gridded rainfall dataset and the results were tested with statistical techniques. The analysis revealed that the WRF model is able to reproduce most of the observed characteristics of large scale mean features along with the spatial variations of rainfall and winds at 850hPa and 200hPa levels.

Keywords: SA-Cordex, WRF Model, CMIP5 Model.

Keywords: Climate change, Weather Prediction, Remote Sensing, Climate modelling, (maximum 5 words)

Nowcast using an S-Band Doppler Weather Radar Observations and Its Verification

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ABSTRACT

An S-Band Doppler Weather Radar (DWR) is operational at 2875 MHz with a PRF of 300 Hz at Nagpur (21.09N 79.06E, 301 AMSL). Observations from this DWR are used to issue nowcast under the surveillance of 250 km radii in different seasons as part of the operational activities of IMD. In Nowcast different DWR image products like Reflectivity (PPZ), Velocity (PPV), Surface Rainfall Intensity (SRI), 24 hours Precipitation Accumulation (PAC), and Maximum Reflectivity (Max-Z) are made use of to issue forecast. Images generated every 10 minutes are analyzed continuously, and three hourly nowcasts are issued from RWFC, Nagpur. An investigation is being carried out to check the accuracy of the nowcast with realised weather events for the Pre-Monsoon season of 2021. Synop observations from different stations within the radar coverage area would be used to verify the nowcast. Nowcast verification skill scores such as Ratio Score, Probability of Detection, False Alarm Ratio, Critical Success Index, and Equitable Threat Score, etc have been

Varying Seasonal length of India and its teleconnections

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ABSTRACT

When the seasons of tropical climates vary in length, the seasonal anomalies in surface temperature and rainfall over India are predominantly tied to the corresponding SST anomalies of the tropical oceans, especially over the north Indian. The teleconnections between seasonal anomalies of surface temperature and rainfall over India and corresponding SST anomalies of the tropical Oceans (especially over the northern Indian and equatorial Pacific Oceans) are stronger than when the length of the seasons is fixed. It is worth noting that these teleconnections across the Indian subcontinent are highly spatially heterogeneous.

Role of tropical Oceans in the recent change of Indian summer monsoon rainfall (ISMR) skill of seasonal prediction models

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ABSTRACT

Seasonal prediction of Indian summer monsoon rainfall (ISMR) in the recent coupled models depend heavily on the simulation of ISMR relationship with El Nino Southern Oscillation (ENSO). At the same time ENSO has undergone strong modification during the recent period (after 2000) with reduced interannual variability and amplitude causing reduced skill of long-lead ENSO prediction. Thus, it will be interesting to investigate how these change in ENSO predictability will be reflected in the ISMR skill of the general circulation models. Our analysis with Monsoon Mission Climate Forecast system (MMCFS) indicates a sharp decrease (increase) in ISMR skill and ENSO-ISMR teleconnection since 2000 at long lead, Feb IC, (short lead, Apr IC) hindcasts. The persistence skill of ENSO decreased sharply for Jan-Mar initial months after 2000 causing a natural decrease of ENSO skill for models initialized during these months compared to other months. Thus, the model hindcasts that depend heavily on ENSO teleconnection for ISMR simulation have reduced skill in recent years. It is shown that after 2000, tropical Atlantic SST anomalies mainly in the northern Atlantic contributed significantly to both ENSO and ISMR interannual variability in observations. Atlantic SST influence on ISMR is captured by April IC hindcasts during period 2, while Feb IC has the opposite relationship. During the recent period, the warm SST in the north equatorial Atlantic confines more to the east, and the upper-level convergence associated with AMM extends to the Indian Ocean and Indian monsoon region with divergence over the east Pacific north of the equator. The divergent wind from the cool northeast Pacific also induces anomalies easterlies to the Indian monsoon region. Model ability to capture the Atlantic SST and its influence on ISMR is also important for ISMR skill in the recent period. The result is confirmed with other recent general circulation models also

Keywords: Indian summer monsoon rainfall, seasonal Prediction, ENSO, teleconnections, North Atlantic SST

Three-dimensional structure and variability of double-ITCZ over tropical oceans:

Decadal observations using CloudSat and CALIPSO

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ABSTRACT

Intertropical convergence zone (ITCZ) is the most prominent feature of the tropical troposphere. The ITCZ over tropical oceans often have a double band structure straddling the equator (DITCZ).Horizontal structure and characteristics of DITCZ were investigated in the past using satelliteobservations of clouds, precipitation, outgoing longwave radiation and surface winds, whichshowed its most prominent occurrence over the western and central Pacific and the Atlantic oceans during April-May. However, studies on the vertical structure of DITCZ based on observations are extremely sparse. Such observations are essential for validation of general circulation models, which generally show a DITCZ bias, as well as for assessment of the feedback effect due to differential atmospheric heating by clouds. These aspects are addressed in the present study based on over a decade (2006-2018) of observations using the spaceborne radar and lidar, CloudSat and CALIPSO, which provide a unique opportunity to investigate the vertical structure of DITCZ on the basis of the global 3-dimensional distribution of cloud occurrence and cloud water content. During the peak occurrence of DITCZ in April-May, the northern and southern bands of the DITCZ appear as meridionally confined walls (3 to 7° on either side of the equator) of frequent cloud occurrence: over the western and central Pacific and the Atlantic, the northern band extends up to about 16 km and has significantly more frequent cloud occurrence compared to the southern band which generally extends only up to ~8 km and is capped by the outflow from the northern band. The net cloud heating in the DITCZ bands and the distinctly lower heating over the equator would induce equatorward flow and convergence in the middle troposphere over the equatorial band; the resulting downdraft would further inhibit convection in the equatorial middle troposphere and aids the sustenance of DITCZ.

Keywords: Double-ITCZ, Remote Sensing of clouds, Cloud heating rate, CloudSat

Assessing the effect of weather parameters on crop productivity of the major crops cultivated in Krishna District of Andhra Pradesh State of India

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ABSTRACT

Impacts of climate variability are already experienced across the global. The Indian agriculture mostly affects by changes in climate, it represent in the form of flood situation in some part of the country on the other hand some parts experiences severe drought conditions and that results in the regional inequality in crop production. The present study is about the effect of various weather parameters on crop productivity of major crops (Arhar/Tur, Cotton, Groundnut and Rice) cultivated in Krishna District of Andhra Pradesh State of India. The various statistical methods has been used for statistical analysis like detrending, correlation, test of significance for measuring relationship between various weather parameters (Rainfall, Temperature and wind speed) and crop productivity (Tones/Hectare). The statistical significance (at 95% and 99% level) of the various parameters was ascertained by testing significance for the recent 23 years (1997-98 to 2019-20). Crop weather calendars were used to understand crop stage-wise water requirements; favourable and unfavourable weather parameters *etc*.

It is observed that in Arhar crop rainfall during sowing, vegetative growth, and flowering stages is favourable whereas rainfall during germination, grain formation and harvesting is not favourable for crop productivity. For the Cotton crop rainfall during initial boll maturity stages is not favourable where as rainfall during sowing, germination, vegetative growth, and flowering stage is favourable. For the groundnut crop rainfall during flowering and grain formation stage is favourable for crop productivity. For the rice crop rainfall during vegetative growth and flowering stages is favourable where as it is unfavourable during grain formation and harvesting stage. High maximum temperature during sowing and germination is not favourable whereas during grain formation and harvesting it is favourable for better crop productivity. Similar analysis is also carried out for minimum temperature and wind speed and promising results were obtained. This study can help in better crop planning, to understand crop weather relationship, for yield estimation and ultimately increasing crop productivity.

Keywords: Crop productivity, weather parameters, growth stage, Crop weather calendar.

SUSTAINABLE CROP MANAGEMENT PRACTICES UNDER EXTREME CLIMATIC CONDITIONS

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ABSTRACT

The estimates of Food and Agriculture Organization indicates that the food production must increase by 70 per cent by 2050 to meet out the demand for food. On the other hand,agriculture production is greatly influenced by the extreme climatic events. Estimates indicate that due to global warming the ambient temperatures would increase by 1.0ºC by 2025. Variability in rainfall quantity and intensities are already been experienced across the globe. The extreme events of temperature and/or rainfall leads to soil erosion, shorter window for field operations, increase in biotic and abiotic stresses on crops, increased frequency of floods or droughts, decreased fertilizer use efficiency, change in land use pattern, increased greenhouse gas emissions etc. It is therefore, planning of sustainable crop management practices even under changing climatic conditions is essential for feeding the ever increasing population.

Adtopting minimum soil disturbance, zero tillage, crop diversification and rotation would not only help in minimizing soil erosion but also in timely sowing of crops. The problems associated with excess water and deficit water can be addressed with the adotion of raised bed farming practices. The most ignored aspect of crop cultivation is 'agricultural drainage', adoption of suitable drainage systems will help in providing proper environment to the rootzone leading to higher crop production even under untimely and excess rainfall. The modern irrigation methods not only helps in minimizing greenhouse gas emissions but also in getting more crop per drop of water. Laser guided land levelling especially in rice fields would enhance the water use efficiency. The economic benefit of adopting atleast any one of these technologies would fetch minimum additional revenue of Rs.4000/month/acre (IFPRI&ICRISAT study report, 2020). Though the initial investment is high but protected cultivation structures would address the biotic and abotic stresses resulted from externalities of climatic events with enhanced crop yields.

Key words: Climate change, Crop yield, Conservation agriculture, Irrigation, Drainage

Flood Prediction over Godavari Basin Using Deep Learning Techniques

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ABSTRACT

The summer monsoon performance is considered to be a deciding factor for flood security in Indian economy. However it Sometimes leads to natural calamities due to inundation of surface water caused by the heavy rainfall events (>64.5 mm/day and 12mm/hr in recurring period). The successive period of heavy rainfall (cloud burst) leads to flood. In the warming environment heavy rainfall events are more persistent particularly in main months of July and August. The study draws attention to the Godavari river basin flood (1950-2022) in Andhra Pradesh in the Southern part of India. From the selected historical data the highest flood events were identified and analysed using statometric equations to the catchment area/ reservoirs associated with the Godavari river basin. The raise/increase in the water level in relation to the rainfall activity were also analysed using deep learning techniques like ANN (artificial neural network), RNN (recurrent neural network), and KNN (K-Nearest Neighbor) where rainfall, water level, and reservoir level are given as the inputs. The occurrence of a flood will be predicted with accuracy and reliability of flood forecasting system. As it aims to prevent damage to human life, properties, and the environment with the known characteristics of a river basin it estimates and predicts the magnitude, timing, and duration of the flood which helps in accurate and timely flood forecasts and advance warning. This will help in flood mitigation, evacuation, relief, and rehabilitation measures for the Godavari and associated catchment areas.

Keywords: Flood, Heavy rainfall, Deep Learning, ANN, RNN, Godavari Basin.

Processes controlling the interannual variability of sea surface salinity in the South Eastern Arabian Sea warm pool

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ABSTRACT

The southeastern Arabian Sea (SEAS) hosts some of the warmest oceanic area globally, with sea surface temperatures (SST) exceeding 30℃ in May, prior to the monsoon onset. This " Arabian Sea warm pool" is thought to play key role in the summer monsoon onset vortex formation. This warm pool is also characterized by fresh waters, which are thought to influence the SEAS seasonal SST evolution through their impact on oceanic stability and vertical mixing of heat. While SEAS sea surface salinity (SSS) seasonal variations and their impact of SST have been previously studied, much less is known on salinity variations at other timescales. Here, we assess the SEAS SSS interannual variability, as well as its driving mechanisms and impact on SST, using a regional eddy-permitting ocean general circulation model and 8-years long record of merged ESA-CCI satellite SSS. The main near-surface oceanic features (SSS, SST, mixed layer depth, surface currents etc.) in the model compare favourably with in situ and satellite data over the SEAS, at both seasonal and interannual timescales. The largest SEAS interannual SSS variations occur during winter, in association with the Indian Ocean Dipole (IOD). The IOD remote impact on the strength of the East Indian Coastal Current modulates the amount of freshwater advected from the Bay of Bengal into the SEAS. This yields a strong interannual variability of the SEAS mixed layer depth. These SSS and mixed layer depth interannualvariations however do not significantly alter the surface layer heat budget, which is rather primarily controlled by net surface heat flux, especially during boreal winter and spring.

Keywords: Keywords: Southeastern Arabian Sea, Sea surface salinity, Sea surface temperature, Mixed layer Depth, Indian Ocean Dipole

MULTI-DECADAL VARIABILITY IN THE TELECONNECTION BETWEEN EURASIAN SNOW COVER FRACTION AND INDIAN SUMMER MONSOON RAINFALL

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ABSTRACT

The predictability of the Indian summer monsoon rainfall (ISMR) at any given time period depends on the strength of its relationship with predictable drivers like the El Nino and Southern Oscillation (ENSO) that are known to undergo significant epochal variations. While a similar relationship between the Eurasian snow cover fraction (SCF) and ISMR has also shown epochal variation in recent decades, its stationarity on centennial or longer time-scales remains unknown. Here, on the basis of the observed relationship between the dominant modes of ISMR and SCF over a period of 115 years (1901-2015), two indices of SCF that encapsulate its space-time variability are unraveled. It is found that the SCF indices and ISMR relationship shows a statistically significant increasing trend with a weak multi-decadal variability superimposed on it, making significant positive correlations between the two highly probable in the coming decades. With SCF driving the North Atlantic Oscillation (NAO) that in turn driving the ISMR, it is found that the NAO plays a pivotal role in modulating the SCF-ISMR teleconnection on a multidecadal time scale. Further, the SCF also regulates the ISMR low-frequency variability through modulation of the tropospheric temperature gradient of the Indian region. The Causality theory is used to propose new teleconnection pathways between SCF and ISMR.

Keywords: Indian summer monsoon rainfall; Eurasian snow cover fraction; North Atlantic Oscillation; Teleconnection; Causal Associations

MODELAND VALUE ADDED FORECAST VERIFICATION ANALYSIS FOR RAINFALLAND TEMPERATURE OF VIDARBHA

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ABSTRACT

The farming community incur huge losses if they are not made aware of the unfavourable weather conditions during various stages of crop production, right from sowing to harvesting. Medium range weather forecasts and weather based agro advisories help the farming community to minimize such losses. In this regard, the study of reliability and suitability of the medium range weather forecasts holds great importance. District-wise Medium range weather forecast for the subsequent 5 days is disseminated to the DAMU (District Agro Meteorology unit) and KVK (Krishi Vigyaan Kendra) every Tuesday and Friday for all the districts of Vidarbha by Regional Meteorological Centre, Nagpur. This information is further disseminated to the farmers by DAMU and KVK of the district on the various agronomic practices to be followed to increase crop production and minimize the production losses due to unfavourable weather conditions. In this study, the verification of medium range weather forecasts (both GFS T1534 model and value added) for Vidarbha subdivision as a whole for the four seasons during the period 2021-2022 (SW Monsoon season 2021 to pre-monsoon season 2022) are analysed and discussed for temperature and rainfall based on the latest normal-based rainfall and temperature verification templates received from AAS, IMD New Delhi. Rainfall forecast revealed higher accuracy during post-monsoon to pre-monsoon seasons around 95% and little less accuracy during the SW Monsoon season around 85%. However, the accuracy of value-added forecasts was higher than those of the model forecasts in all the seasons, the model is giving overestimated forecast in most of the cases. The maximum and minimum temperature forecasts revealed higher accuracy during all the seasons for value added forecasts around 95% as compared to the model forecasts around 90%. However, there is further scope of improvement in accuracy of value added rainfall forecast mainly for monsoon season to further minimize the losses incurred by the farming community.
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Role of climate forcing agents in changing the regional trends of the global hydrological cycle

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ABSTRACT

In recent decades, the global hydrological cycle is severely affected by Green-House Gases (GHG), Anthropogenic Aerosols (AA), LULC, etc. in addition to climate variability. The northern hemispheric monsoon precipitation trends are reported to have a strong connection to the GHGs and AAs. In this work, we attempted to carefully investigate the trends of regional precipitation globally, by examining the connection of downward solar radiation with evapotranspiration using the CMIP6 General circulation models historical simulations along with the individual experiments of GHGs, AA, and Natural forcings for the study period 1850 to 2014. The regional trends of downward solar radiation showed that India and East China have undergone a substantial decline from the 1960s onwards. We focus on these regions to report the changes in the hydrological cycle. The trend analysis of evapotranspiration and precipitation over south and east Asia from the 1950s to 2010s showed a drying trend in Eastern China, while India had an increase in annual total evapotranspiration and rainfall in the same period. These opposing responses in these two regions are due to, more so than the greenhouse gas effect, AA emissions have considerable control over Eastern China's precipitation. In contrast, the greenhouse effect has strong controls on the Indian land region's hydrological cycle exceeding the forcing brought on by the AA emissions.

Keywords: Climate change, Climate modelling, Anthropogenic aerosols, GHG, Hydrological cycle.

Evolution of Predictability aspect of Indian Summer Monsoon Rainfall using Coupled Model

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ABSTRACT

The predictability of the Indian summer monsoon rainfall (ISMR) using coupled model has garnered umpteen interest due to its large socioeconomic impact since the advent of modeling era. This is further bolstered by the recent progress in understanding the contributing factors of ISMR skill of forecast and finding new sources of prediction drivers. Here we surmise the finding of latest work in this direction. The potential predictability is sensitive to initial conditions in classical as well as in entropy based techniques and in general there is increase in potential predictability with a decrease in lead time. ISMR prediction skill is highest at lead-3 forecast and it is due to combined effects of initial tropical SST and Eurasian snow. Overall predictability is large over the Pacific Ocean basin as compared to that of the Indian Ocean basin. It is found that the model error (forecast error) outruns the error acquired by the inadequacies in the initial conditions (predictability error).It has been shown that the internal variability contributed by the ISM subseasonal (synoptic + intraseasonal) fluctuations is partly predictable as it is found to be tied to slowly varying forcing (e.g., El Niño and Southern Oscillation). By improving two major physics in coupled model we establish a much higher actual limit of PP (r ~ 0.82) through an extensive reforecast experiment. This finding provides a huge optimism and scope for a very reliable dynamical seasonal ISM forecasting in the near future.

Keywords: Seasonal Prediction, Potential predictability, ISMR skill

Characteristics of the Atmospheric Boundary Layer Processes during Transient Monsoon Conditions

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ABSTRACT

Knowledge of atmospheric boundary layer height (ABL) during transient monsoon conditions is important to understand the role of the monsoon on the exchange between ABL and free troposphere (FT). As convection and advection processes becomes stronger during the monsoon seasons, greater exchange between the ABL and FT is expected. We have selected five Indian stations distributed across the central (New Delhi and Nagpur), western (Mumbai), eastern (Kolkata) and southern (Gadanki) monsoon regions. In this study, radiosonde datasets over 2004-2019 is utilized to obtain the ABL height during the active and breaks phases of the monsoon. IMD gridded rainfall dataset is used for identifying the active and break phases based on the central India rainfall. In total, 24 active and 20 break episodes are obtained over the period 2004-2019. However, we observed that these active and break phases need not necessarily represents the wet and dry over the individual stations. Thus, we have also obtained the wet and dry episodes based on the local rainfall data. In general, ABL is shallower during the active monsoon condition than the break monsoon conditions. The shallower and deeper ABL height is further quantified with respect to climatological mean ABL height at a given station. If the ABL height falls below (above) the mean minus (plus) one standard deviation of the climatological ABL is considered as shallower (deeper) ABL height. It is observed that, ~ 50% of the cases are shallower over New Delhi, Nagpur, Kolkata while 31% over Mumbai during the active phase. Rest of the days shows deeper ABL even during the active monsoon condition. During the break monsoon conditions, 60% of cases show deeper ABL while remaining 40% show shallower ABL. This disparity we have further examined using the local wet and dry conditions. The details of the ABL height variability during the active and break phases and the wet and dry conditions will be presented during the conference.

Keywords: ABL height, day-to-day variability, Active-break phases of monsoon

Prominent features of Low-Level Jet in ERA5 and IMDAA during the satellite era for the Indian Summer Monsoon

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ABSTRACT

Around 850 hPa, the Low-Level Jet (LLJ) has substantial horizontal shear and carries moisture from the Oceanic regions to the landmass, making it crucial for convective rainfall distribution at the Indian mainland. The current study compares the performance of two reanalysis data sets: the ERA5 reanalysis product and the IMDAA from the National Center for MediumRange Weather Forecasting. These data sets were used for 40 years, from 1981 to 2020, throughout the Indian summer monsoon season. It is crucial to understand how these two reanalysis data sets perform in terms of LLJ seasonal and sub-seasonal characteristics of rainfall variability.
Both data sets well reflect the spatial climatological aspects of LLJ at seasonal and sub-seasonal scales. However, as compared to the ERA5 data sets, the amplitude of LLJ wind is lower in IMDAA. At 95 percent confidence levels, a one-way analysis of variance (ANOVA) is used to verify the significant difference between these data sets. Tukey's test is also used for post-hoc analysis to determine which data sets are most similar to the observation data sets like IMD and CRU. The results show that there is a substantial discrepancy between these two data sets during the ISM season, with the IMDAA data set's temperature being closer to the observation and ERA5's rainfall being closer to the observation.
In addition, we look at the relationship between LLJ and rainfall in four homogeneous regions across India. The IMDAA wind speed of LLJ at 850 hPa has escalated in recent decades. Northeast India region manifests the reducing trend of mean rainfall and Central India rising trend of mean rainfall with respect to multidecade. The outcome provides a valuable understanding of the comparison of two data sets to build appropriate standards for the Indian region and in the ERA5 and IMDAA datasets for future use.

Keywords: LLJ, Indian summer monsoon, ERA5, IMDAA, ANOVA.

Cloud Microphysics and Its Relationship with Black and Brown Carbon Over Gangtok Sikkim

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ABSTRACT

The study of the cloud microphysics related to black and brown carbon is particularly dependent on the planetary boundary layer and climate change. The global average temperature has been rising at a faster rate since preindustrial times, which is well established by various scientists (IPCC, AR5). Fossil fuel emissions are a major contributor to black and brown carbon emissions and is a well-established science and has been reported for half a century. The warming of mountainous region is much more rapid than that of the plain (Tian and Miao 2019; Rangwala and Miller 2012), which is affecting the indigenous life sustenance. The present study is a discussion of black carbon (BC) and brown carbon (BrC) and their effects on the Sikkim weather pattern using in-situ and ERA5 reanalysis data sets. The black and brown carbons have a very distinct nature. The regional weather and climate processes, such as orographic cloud formation and precipitation over Himalayan regions like Sikkim are therefore very susceptible to investigation. The concentration of black and brown carbon over the study region (Gangtok) is observed to be very high, however in this region the major sources for these pollutants are very few except for vehicular emissions (mostly due to tourist activity). In addition, this study also discusses the surface warming, LCL (lifting condensation level) and radiative nature of the BC and BrC, as well as longwave radiation anomalous rise, resulting in cloud formation and foggy days. The fog days have been increasing over Gangtok and supressing the precipitation and inducing extreme weather events over Sikkim.

Keywords: Black Carbon, Brown Carbon, Cloud Microphysics, and Extreme Precipitation.

PREDICTION OF RAINFALL IN CENTRAL INDIA REGION USING LSTM BASED MODEL

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ABSTRACT

Climate forecasting is the important attribute to predict because most of the atmospheric as well as agriculture fields are dependent on the climate conditions. Rainfall is one of the most important parameters which is dependent on the climate condition. In this paper we have used the Random Forest Regressor and Long Short Term Memory (LSTM) Neural Network model and done a comparison between them. LSTM have very similar model in comparison with the Recurrent neural networks model. In LSTM have the power of non linear mapping capabilities of the multi layer perceptron and it is a form of a memory. There are various models that have been developed to predict the rainfall forecast. In other hand Random Forest Regressor is techniques have been widely applied to various atmospheric and ocean fields because of providing good accuracy in prediction. We have also studied performance using correlation coefficient, Mean Square error (MSE) of both models. We use classification techniques in LSTM and Random Forest Regressor model for predicting rainfall in the five City of Central India Region .The rainfall data have been provided by during the period from 1901 to 2020. A predictive neural network model is developed for the rainfall prediction program and the results compared with actual rainfall data for the predicted periods.**Keywords**: Neural Network, LSTM, RMSE,Rainfall.

Primary observations of Black Carbon at North Sikkim and its impact on temperature and glacier albedo

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ABSTRACT

The cryosphere predicted to vanish in coming few decades due to increase in temperature worldwide. Different region with glaciers has reported to have different pollutant responsible for it. The Himalaya region is receding much faster than any other part of world and has shown variation in glacier receding procedure along their long stretch. The North Sikkim has developed many glacial lakes at higher altitude. BC is primary suspect for expansion of glacial lake area. In connection to this issue, BC mass concentration monitored with an Aethalometer at higher altitude of North Sikkim Headquarter (Mangan) during winter month of January 2020. The average value of black carbon found is 4.14 µg/m^3; the maximum and minimum value was accounted, 9.26 µg/m^3 and 1.08 µg/m^3 respectively. The variation in day and night time concentration observed with average reduction of 37% in concentration of BC at night. The black carbon data compared with the temperature variation during day and night. The significant co-relation (r=0.66) detected at 5% significance level between black carbon and temperature. The albedo and BC co-relation has found to be r=0.51 at 5% significance level particularly of glaciated region of the Sikkim state. The average BC concentration reported in Kolkata city is 4.8 to 5.2 µg/m^3, which is quite close to Sikkim's concentration. This result indicates that this exquisite state needs to protect in terms of environmental destruction.

Keywords: Black Carbon; Aerosol; Glacier; Temperature; Albedo

Monsoon Mission Coupled Forecast System Model Version 2.0

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ABSTRACT

Monsoon Mission Coupled Forecasting System version 2 (MMCFSv2) model, which has been recently deployed at IITM is to replace the currently operational MMCFSv1 (version 1). MMCFSv2 is built around the coupler based on the NEMS framework and brings in a number of upgrades to the individual model components of MMCFSv1. These include upgrading the MOM4 ocean model with MOM6, using the CICE5 sea-ice model from LANL instead of the sea-ice model of MMCFSv1, and the Semi-Lagrangian dynamical core replacing the Eulerian one for integrating the Global Forecast System atmospheric model. Among many other changes, MOM6 allows for increased ocean model resolution from 0.25^0 to 0.10^0. Semi-Lagrangian dynamical core in the atmospheric component allows the use of longer time steps while keeping the model resolutions the same, or having a much higher resolution for a given time step. The major improvements of CICE5 over the Sea-ice model of MMCFSv1 include ice velocity in atm-ice coupling updates and a variable coefficient for the ice-ocean heat flux. NEMS framework has resulted in seamless model development capability in the model which, can now be interfaced with numerous external model components. Retrospective coupled hindcast simulations have been carried out for 25 years with initial conditions from CFSR to document the skill improvements over MMCFSv1 in simulating the mean tropical circulation, precipitation, and SST. The model integration is performed for the duration of the Indian Summer Monsoon season and a focused study is performed to document the model skills in simulating the mean and inter-annual variability of ISMR and its teleconnection with ENSO and IOD. This dataset will serve as the baseline for future sensitivity studies of MMCFSv2.

Keywords: Monsoon Mission, Coupled Forecasting System, MMCFSv2, ISMR, ENSO and IOD.

Monsoon Prediction and Projection (MPP)

Analysis for withdrawal dates of southwest monsoon rainfall during the past three decades.

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ABSTRACT

The operational dates for withdrawal of southwest monsoon, framed and finalized by India Meteorological Department, when it begins to retreat from Northwest India and the withdrawal is complete from the entire country, are collected from Weather Forecasting Division (WFD), Pune documents, for the past 30 years (1992-2021). The decadal and 30 years mean dates have been computed along with time taken to withdraw from the entire country for each year, decade and the entire study period. The critical statistical analysis of these dates show that there is considerable delay of around 8 days in monsoon withdrawal from northwest India in decade 2 (i.e. 2002-2011) than decade 1 (i.e.1992-2001) and about 2 days in decade 3 (i.e.2012- 2021) than decade 2. It further revealed that the retreat of the monsoon from the entire country delayed with each succeeding decade by 1 day and 2 days with respect to the previous decade. It further showed that the entire withdrawal process (from northwest India to the whole country) was the slowest in the first decade (34 days) while it remained nearly the same in the last 2 decades (28 days each). For the last 5 years i.e. 2017 onwards withdrawal began from northwest India only towards end of September while in 2019 and 2021 it was as late as 9 October and 6 October, respectively, though in 2019, the withdrawal process was the fastest, which took only 7 days to retreat from the entire country. For the past 13 years i.e. from the year 2009 onwards the retreat of monsoon from the entire country is after 15 October, which is IMD`s old and new normal withdrawal date for monsoon to withdraw from the entire country. The mean withdrawal dates for the 30 years of the study period is 19 September from northwest India against new normal date of 17 September while for withdrawal from the entire country is 19 October i.e. delayed by 4 days with respect to the new normal date of 15 October.

Key words: Southwest monsoon, Withdrawal, Retreat, Decadal, Northwest India and Entire Country.

Recent advances in tropical cyclone track and intensity forecasting and future scopes over the North Indian Ocean

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ABSTRACT

Among various hydrometeorological hazards, the tropical cyclones (TCs) over the North Indian Ocean(NIO) pose the greatest threat to coastal population as well as the marine community of the region. However, there has been significant improvement in TC track and intensity monitoring and prediction over this region during recent years. A study has been undertaken to review the TC track and intensity forecasting process of India Meteorological Department during recent years (2018-22) so as to identify the gap areas and future plans. There has been significant improvement in TC observational and analysis system with launch of web-GIS based Rapid tool for quick visualization and analysis of satellite products, availability of multiple satellite platforms, increase in Indian coastal Doppler Weather Radars from 11 in 2018 to 13 in 2021 and increase in high wind speed recorders from 20 in 2018 to 34 in 2022 apart from increase in automated weather stations. There has been improvement in numerical models with commissioning of Global Forecast System, Unified model, Global Ensemble Forecasting System and Unified model ensemble prediction system all with same resolution of 12 km by MoES in 2018, improved assimilation including radar data into numerical models, and introduction of high resolution(2 km) ocean atmosphere coupled hurricane WRF model in 2018. All these along with introduction of new methodology like (i)extended range outlook for genesis, track and intensity issued every Thursday valid for next two weeks since 2018, (ii) extension of validity period of tropical weather outlook upto five days issued daily since 2018, (iii)quantitative track & intensity forecast from depression stage in 2018 unlike from deep depression stage previously, (iv)pre-genesis forecast from the stage of low pressure area in 2022 for the first time, (v)surface wind forecast over entire NIO in 2018 unlike for coastal water only previously, (vi)probabilistic forecast of wind exceeding 45 kmph in 2022, (vii)TC track & intensity forecast on web-GIS in 2019 and web based dynamic composite risk atlas in 2020 for generating location specific dynamic impact based warnings and (viii)improved web-GIS based decision support system to compare, comprehend, analyse and develop a multi-model consensus on TC track and intensity forecast bringing significant improvement in forecast accuracy and lead period. The average track(intensity) forecast errors were 73(7.8), 106(11.5) & 144(14.2) km(knots) in 2017-21 against 97(10.7), 149(15.5) & 203(16.3) km(knots) during 2012-16 for 24, 48 and 72 hrs lead period respectively. Thus, there has been an improvement of 25-30%, in track and 13-27% in intensity forecasts upto 72 hours lead period. However, there is still scope to improve TC track forecast further, especially for recurving TCs, stationary/slow moving TCs and intensity forecast for rapidly intensifying/weakening TCs, TC intensity change during/prior to landfall.

Key words: Tropical cyclones, errors, track, intensity

Precipitation biases in the East Asian monsoon regions and their association with circulation biases in the CMIP6 models

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Abstract

The East Asian summer monsoon (EASM) variability affects about one-third of the world's population. Thus, its accurate predictions are of great economic importance. However, most of the CMIP6 models have large precipitation biases in East Asia (EA) and nearby oceanic monsoon regions in their historical simulations. In this work, we aim to examine the EASM biases in the CMIP6 models, its relationship with adjacent oceanic region precipitation bias, and the role of low-level circulation biases across the models in modulating the precipitation distribution in these regions. Our study domains comprise of Northern East Asia (NEA) and North-Western Pacific (NWP). Observation based analysis revealed that EA total precipitation has a high percentage of recycled moisture component but it's contribution to the total rainfall is consistent from June through September. Major moisture flux into EA is brought in by south-westerlies from the Indian Ocean and south-easterlies associated with the Western North Pacific Subtropical High (WNPSH) ridge. The southern Indian and Pacific oceans moisture components show higher inter-annual variations from June through September, indicating that the precipitation variability in EA is potentially controlled by moisture advection components. Analysis of 27 models from the CMIP6 historical simulations shows large precipitation biases in EA and NWP. Evaporation biases are found to be much smaller than precipitation biases across the models. Precipitation-evaporation (depicting moisture convergence) biases closely resemble the precipitation biases across the models in pattern and magnitude. Analysis of JJAS mean 1500 m geopotential height contours in CMIP6 models revealed varied longitudinal position/extent of the WNPSH ridge in the northern Pacific Ocean with concomitant low-level wind and precipitation anomalies. NEA (NWP) precipitation and western edge of WNPSH show a negative (positive) correlation across the CMIP6 historical simulations, that is westward (eastward) shifted WNPSH increase the precipitation in NEA (NWP).

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Changes of Snow Water Equivalent and Degree Day Factor over Sikkim Himalayas

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ABSTRACT

India is a mega biodiverse agrarian nation whose fate is controlled by Monsoon and Himalayas. The glacial region of Hindukush Karakoram Himalaya (HKH) are called as *'water tower of Asia'* which stores large volumes of water in the form of ice and snow after the polar ice (*Adnan et al., 2017*). The trends of rising global temperature and accelerated receding of glacier. Sikkim is the second most vulnerable Indian state to climate change due to glaciers and stream power dependence. the present study focuses on understanding the impact of climate change to snow water equivalent (SWE) and snowmelt rate in Sikkim Himalayas for the time period of 1979 to 2017. Hence this study is conducted to discuss the temporal variation of melt rate and associated melt amount through degree day modeling. The average decadal rate of Snow water equivalent (SWE) and Degree day factor (DDF) for the months of March to August for Sikkim Himalayas over 1979-2017 is increasing except for 2009-2017 decade indicating the impact of Global Warming. The average decadal temperature trend is increasing with 0.91 coefficient of determination for Sikkim Himalayas for months of March to August from 1979-2017 indicating increase in humidity, increase in cloudiness and Climate change due to accelerated Greenhouse Effect in recent decades. Hence, the rate of snowmelt is critical for information about flood forecasting, extreme weather event, agriculture and optimal management of water resources.

***Keywords**: Sikkim Himalaya, Snow Water Equivalent (SWE), Degree Day Modeling (DDM), climate change and impact*

Improving seasonal forecasts of Indian Monsoon: Closing the land-surface hydrology in coupled models

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ABSTRACT

Huge quantity of freshwater received by the Bay of Bengal (BoB) due to rains and rivers causes very low upper-ocean salinity. This gives rise to a unique upper-ocean stratification. BoB also plays a pivotal role in modulating the summer monsoon rainfall over India by affecting the sub-seasonal to seasonal modes of rainfall variability. This study quantifies the impact of the riverine freshwater forcing on the sub-seasonal modes of Indian Summer Monsoon (ISM) variability and the effect on seasonal monsoon forecasts by employing a river-routing model coupled to an ocean-atmosphere-land general circulation model (GCM). It is found that closing the land-surface hydrology in coupled models enhances the mixed layer temperature gradients in the Bay. The resultant monsoon low-pressure systems formed have a longer lifetime and travel much more inland. Significant upper-ocean variability is noted at intra-seasonal time scales, leading to enhanced air-sea interactions and stronger northward propagating rainfall pulses associated with monsoon active-break phases. The inclusion of rivers causes a significant improvement in the rainfall-runoff coupled feedback, the inter-annual variability of the mixed layer heat budget terms, and modulates the remote teleconnections. Improved seasonal mean temperature and salinity profiles in the BoB lead to thicker barrier layers, which are closely tied to the freshwater from rivers. The improvements in oceanic processes result in an overall improvement in the seasonal rainfall prediction skill. These results are important for seasonal forecasting of ISM rainfall.

Keywords: Indian Summer Monsoon, Seasonal Prediction, Coupled models, Sub-seasonal to seasonal variability, land-surface hydrology (maximum 5 words)

Assessment of vulnerability of agricultural farms under climate change- an integrated modeling approach

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ABSTRACT

Climate change could push up to 132 million people into extreme poverty by 2030. India has a population of about 1.3 billion, growing at 1.9% per annum, expected to double in 2070s. Around 85% of the Indian farming community belongs to marginal and small farmer categories that are resource poor. Climate is the most important determinant of crop productivity, particularly in a country like India, where about 2/3rd of the cultivated area is rainfed. Indian farmers are heterogeneous and unorganized in nature. Climate change and variability are likely to aggravate future food security by putting pressure on agriculture affecting its sustainability. The total food grain production has increased from 50.8 million tonnes in 1950–51 to 316.06 million tonnes in 2021–22. The country is categorized into 15 different agro-climatic zones (ACZs) with diversity in climatic conditions and followed more than 80 pre-dominant cropping systems. Continuous cultivation of the existing dominant cropping system resulted in stagnation or decline in productivity, particularly in rice-wheat cropping system in the Indo-Gangetic Plains. Excess use of inorganic fertilizer along with frequent use of pesticides adversely affected the soil health. Under these conditions, climate change threatens productivity, livelihoods and nutritional security of small and marginal farmers. Another factor is each farm household is a farming system because each one have their own resource availability. Under this situation, there is a need to study the vulnerability of these small and marginal farms under projected climate change. Under ICAR-AgMIP Collaborative Project, we have studied the impact as well as vulnerability of agricultural farms in two districts (Meerut in Uttar Pradesh and Karnal in Haryana) using Climate-Crop-Economic modelling approach. Current farms exposed to climate changes could experience a decline in net farm returns of 4% to 14% and a decline in per capita income by 3.0% to 8.6%. As a result, population poverty rates may increase by 1.0% to 2.6%. Though the magnitude of decline in net farm returns and per capita income may seem small, these will adversely affect a large proportion of farms – nearly 49% to 74% of the population. Future rice-wheat production systems in 2050s are also vulnerable to climate change. Up to 55% of rice-wheat farm households could be vulnerable to climate change impacts if unsustainable growth pathways are followed, while up to 51% are vulnerable under a sustainable pathway. In the future production system the adaptation strategy would result in 9% to 12% increase in net farm returns, about 6% to 9% increase in per capita income and 3% to 4% decline in poverty. Under sustainable pathways, about 53% to 60% of the farm population would adopt the adaptation. The adoption rate is higher (57% to 74%) under the unsustainable pathway. There is a need to make this study more meaningful by adopting an agro ecological approach rather than a district-based approach. Similarly, in India, there is a lot of diversity in soil characteristics; hence, at least three to four major soil types and their characteristics should be included for simulation, so that more accurate and realistic assessment results can be drawn.

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UNRAVELING THE CHARACTERISTICS OF ATMOSPHERIC AEROSOLS OVER THE INDIAN SUMMER MONSOON REGION

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ABSTRACT

Atmospheric aerosol, the tiny suspended particulate matter coming from various natural and anthropogenic sources is one of the most visible aspects of air pollution, and has vast effect span in the areas of air quality, health, radiation, cloud microphysics and climate change. The Indian summer monsoon (ISM) region, comprises the Indo-Gangetic Basin (IGB) in the northern part of India, is dominated by the enhanced loading of anthropogenic aerosol pollution and thus considered as one of the global hotspots. It is one such region, where heterogeneity in aerosol optical and microphysical properties over a wide range of spatial and temporal scales continues to hinder in improving the estimates of aerosol-induced climate forcing. Rapid increase in population and urbanization has resulted in excessive fossil fuel combustion and biomass burning leading to high anthropogenic aerosol loading over this region. The large increase in anthropogenic aerosols over the IGB is hypothesized to cause considerable changes in regional monsoonal circulation and also the global climate system apart from the aerosol-induced negative health impacts.

The recent worldwide lockdown, imposed due to current pandemic of coronavirus was found to lower the emissions from various anthropogenic sources across the world, including India by restricting various community mobility activities, like traffic, construction and industrial. This resulted an improved air quality at the highly polluted regions, like IGB. Though, the reductions were found to be temporary, such lockdown may be used as one of the possible emergency measures to combat severe air pollution episodes in India, especially over the urban polluted regions in northern India, which is severely polluted during the winter/post-monsoon period.

Keywords: Aerosols, IGB, anthropogenic emission, lockdown.

Pre-monsoon, monsoon, and post-monsoon features of absorbing aerosols over North India

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ABSTRACT

Black Carbon (BC) aerosols are well recognized to be one of the major light absorbing components and second strongest contributor to the Global Warming and Climate Change, after carbon dioxide. Since evaporation from land surface, and long-range transport of moisture from Indian Ocean contributes to the monsoon precipitation, BC emissions increase the evaporation owing to less moisture feeding to monsoon winds and less rainfall. In this communication, we report the results of the analysis of a long series (2016-2021) of BC aerosol datasets, archived during pre-monsoon, monsoon, and post-monsoon seasons, by the IMD Black Carbon Monitoring Network in North India.

A seven-wavelength Aethalometer is used to measure BC concentration and biomass burning contribution. Being mostly in the sub-micron range, they possess long lifetime (up to weeks), and susceptible for long-range transport. Increase in BC aerosol concentration reduces evaporation, which in turn causes diminishing of meridional sea surface temperature, resulting in weaker monsoonal circulation. Thus, the study of BC aerosols and their impacts on monsoon rainfall play a pivotal role and hence in the Indian economy and growth.

In the present study, BC concentration during pre-monsoon and monsoon seasons show lower values and thereafter, concentrations increase from September onwards and peaks in winter months. The combined effects of washout, cloud-scavenging together with stronger winds lead to lower BC concentration in monsoon. BC mass concentrations over North Indian stations exhibit overall decreasing trend during 2016-2021. The Biomass burning in the study region during postmonsoon season contributes to higher BC mass concentration, due to domestic heating and stubble burning activity, often forms stable atmospheric conditions, and lowering of atmospheric boundary layer, which results in higher BC concentration during winter season. The average BC concentrations show a strong anti-correlation with ventilation coefficient and average mixing height.

Characteristics of Exceptionally Heavy Rainfall Event over Assam and Meghalaya during the Southwest Monsoon Season 2022

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ABSTRACT

Scientific studies are indicating an increase in the frequency of extreme weather events in recent years across the globe and our country also witnessed several extreme weather events during the last few years. This study is dealing with the exceptionally heavy rainfall event that occurred over Assam and Meghalaya in June 2022. Monsoon rainfall received over Assam & Meghalaya during 10-20 June 2022 was exceptionally high with record-breaking rainfall spells over Meghalaya during 15-17 June 2022. The departure from the normal rainfall during 15-17 June 2022 for Assam was 387%, and that for Meghalaya was 483% which was enormous. Cherrapunjee (Sohra) recorded the 3rd highest (972.0 mm) and 7th highest (811.6 mm) 24-hour rainfall for June on 17th and 15th June 2022 respectively. Cherrapunjee (RKM) station recorded the highest (908.4 mm) and 2nd highest (906.8 mm) 24-hour rainfall for June on 17th and 15th June 2022 respectively. Mawsynram station recorded the highest (1003.6 mm) and 6th highest (710.6 mm) 24-hour rainfall for June on 17th and 15th June 2022 respectively. The major synoptic system during 10-13 June 2022 was an east-west trough from UP to Assam across Bihar and Sub Himalayan West Bengal and extends up to 0.9 km above mean sea level. During 14-19 June, a trough at the mean sea level was observed from UP to Manipur. Moisture incursion due to strong lower-level Southerly/ South-westerly winds from the Bay of Bengal to Northeast India was also observed during 12-19 June 2022. The analysis of various dynamical parameters associated with this event is under evaluation.

Keywords: Extreme Weather, South West Monsoon

The outflow of Asian biomass burning carbonaceous aerosol into the UTLS in spring: Radiative effects seen in a global model

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ABSTRACT

Biomass burning (BB) over Asia is a strong source of carbonaceous aerosols during spring. From ECHAM6-HAMMOZ model simulations and satellite observations, we show that there is an outflow of Asian BB carbonaceous aerosols into the Upper Troposphere and Lower Stratosphere (UTLS) (black carbon: 0.1 to 6 ng m^{-3} and organic carbon: 0.2 to 10 ng m^{-3}) during the spring season. The model simulations show that the greatest transport of BB carbonaceous aerosols into the UTLS occurs from the Indochina and East Asia region by deep convection over the Malay peninsula and Indonesia. The increase in BB carbonaceous aerosols enhances atmospheric heating by 0.001 to 0.02 K d^{-1} in the UTLS. The aerosolinduced heating and circulation changes increase the water vapour mixing ratios in the upper troposphere (by 20-80 ppmv) and in the lowermost stratosphere (by 0.02-0.3 ppmv) over the tropics. Once in the lower stratosphere, water vapour is further transported to the South Pole by the lowermost branch of the Brewer-Dobson circulation. These aerosols enhance the inatmosphere radiative forcing (0.68±0.25 W m^{-2} to 5.30±0.37 W m^{-2}), exacerbating atmospheric warming but produce a cooling effect on climate (TOA: -2.38±0.12 W m^{-2} to 7.08±0.72 W m^{-2}). The model simulations also show that Asian carbonaceous aerosols are transported to the Arctic in the troposphere. The maximum enhancement in aerosol extinction is seen at 400 hPa (by 0.0093 km^{-1}) and associated heating rates at 300 hPa (by 0.032 K d^{-1}) in the Arctic.

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Intraseasonal variability of west Pacific subtropical high and its linkage with Indian summer monsoon in the recent decade

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Abstract

In the present study we analyzed the intraseasonal variability in zonal displacement of western edge of west Pacific subtropical high (WPSH) along with variation in intensity of WPSH center over the recent decade (2010 to 2021). The coherent analysis of Indian summer monsoon rainfall (ISMR) provides an opportunity to explore its linkage with the variability of WPSH. The variability in zonal displacement and intensity of WPSH is examined using geopotential height data from NCEP/NCAR. Further, rainfall from the climate prediction center (CPC) over the Indian region is also analyzed. The location and intensity indices of WPSH are prepared by using eddy geopotential height at 1000 hPa. The positive (negative) values of the location index represents the eastward (westward) shift as compared to the climatological position of the western flank. In the study period (2010-2021), the variability in zonal shift of WPSH is high during July and August months as compared to June and September. In addition, the center of WPSH strengthens in July and August months only. On an average the 38 eastward shifting days per season are observed while 32 westward shifting days per season are observed during the study period. The standard deviations of variabilities of WPSH is highly varying from year to year. The higher number of westward (eastward) shifting days observed during the 2010 (2018) JJAS season is about 74 days (59 days). In addition, the westward shift of WPSH in 2010 continued more than 5 days while the eastward shift of WPSH in 2018 was a short period of about less than 5days. Further, the patterns of rainfall are analyzed for westward/eastward shifting days of 2010 and 2018. The extreme westward shift of WPSH in 2010 leads to surplus rainfall over the ISM region except east central parts of India while deficit rainfall occurred over central India during eastward shifting days in 2010 JJAS. The eastward shifting days in 2018 lead to deficit rainfall in the southern peninsula and regional rainfall changes.

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ANALYSIS OF THUNDERSTORM ACTIVITY DURING MARCH TO MAY-2022

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ABSTRACT

In India, summer season, also termed as hot weather season or pre-monsoon season is characterized by intense convective activity over land areas. Significant convective activity starts in March and peaks in May and continues upto June, however, with a reduced severity. On preliminary analysis of the thunderstorm activity it was noticed that this year the frequency, intensity as well as the spatial distribution of this activity was significantly different as compared to previous pre-monsoon seasons. The effect was visible in terms of frequency and intensity during March over most of the Indian region, and during April & May over northern and western parts of the country.

The thunderstorm activity over the Indian region is modulated by the seasonal low level/surface anticyclones over Arabian Sea & Bay of Bengal and the wind discontinuities over the interior Indian subcontinent. The position and intensity of these systems largely define the frequency and severity of convection over Indian land mass. Thunderstorm activity is triggered in association with the movement of Westerly troughs (Western Disturbances) over north India and easterly troughs over south India. The monthly average and monthly anomaly wind field at all levels clearly indicate the anomalous pattern of wind field during this pre-monsoon season, which affected the spatial pattern and intensity of thunderstorm activity over the Indian region. These aspects will be discussed in detail during the presentation.

Local and Regional Contribution of Black Carbon over Bhubaneswar

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ABSTRACT

Black Carbon (BC) is an important aerosol species for its potential to absorb incoming solar radiation and cause atmospheric warming, thereby modulating the vertical and horizontal thermal structure of the atmosphere, and hence weather and climate. Apart from locally emitted BC, though the BC has a very short life span, because of its small size, it can travel thousands of kilometres downwind and influence the atmospheric conditions at the destination. Therefore, at a particular place, characterization of the atmospheric BC concentration contributed from the local and regional sources is of great importance. In this context, Bhubaneswar is an emerging smart city with evidence of increasing atmospheric BC in recent times. This increased BC is mainly attributed to the outflow from Indo-Gangetic Plain (IGP) and local emissions like fossil-and bio-fuel combustions. Though the sources of BC for Bhubaneswar are well characterized, their quantification in terms of local and regional contributions is yet to be done. In the present study, applying the moving average subtraction technique to the observed high temporal resolution BC concentration at IIT Bhubaneswar (85.67 E, 20.14 N), we quantify the amount of local and regional BC both annually and seasonally from 2018 to 2021. The analysis shows that the average BC concentration over Bhubaneswar is annually 4.04 µg/m3. It is maximum during the winter season 7.70 µg/m3 and minimum during monsoon 1.53 µg/m3. The regional [local] concentration is the highest during the winter [monsoon] season 7.06 µg/m3 (91.77 %) [0.29 µg/m3 (19 %)], and lowest during the monsoon [winter] season 1.24 µg/m3 (81%) [0.64 µg/m3 (8.23 %)]. Similarly, month-wise, the regional [local] BC concentration was maximum during December [September] 7.53 µg/m3 (94.7 %) [0.37 µg/m3 (21.07 %)] and minimum during September [December] 1.40 µg/m3 (78.93 %) [0.42 µg/m3 (5.30 %)]. The majority of ambient BC over Bhubaneswar is regional, estimated to be 85.96% annually. Further analysis of wind and rainfall data shows that the high regional contribution during winter is due to the stable atmospheric condition, which keeps the long-range transported BCs at the surface level and helps increase their contribution. The opposite of that (low regional contribution) happens during the monsoon season because of the washing out due to rainfall. Overall, the study suggests that the temporal BC domination over Bhubaneswar in terms of local and regional is highly significant, which may give a new perspective to the government and policymakers for framing the rules and regulations accordingly.

Keywords: Local and Regional BC over Bhubaneswar, pollution over Bhubaneswar, Black Carbon, Moving average subtraction method.

IMPORTANCE OF PRIMARY STANDARDS FOR CALIBRATION OF SOLAR RADIATION MEASURING INSTRUMENTS

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ABSTRACT

Calibration determines measurement equipment performance. With routine equipment calibration and adjustment, you can measure safely, ensure compliance and avoid the costs of inaccurate measurements. Regular calibration of field equipment is important to help ensure operation within acceptable measurement tolerances. Calibration will assist in reducing instrument-related systematic observation errors, thus lowering the associated uncertainty of the data. Greater confidence in the interpretation and application of data from various sources can be achieved when instruments have been calibrated against a traceable reference. The fraction of the energy flux emitted by the sun and intercepted by the earth is characterized by the solar constant. The solar constant is defined as essentially the measures of the solar energy flux density perpendicular to the ray direction per unit are per unit time. It is most precisely measured by satellites outside the earth atmosphere. The solar constant is currently estimated at 1367 W/m2. This number actually varies by 3% because the orbit of the earth is elliptical, and the distance from the sun varies over the course of the year. Some small variation of the solar constant is also possible due to changes in Sun's luminosity. This measured value includes all types of radiation, a substantial fraction of which is lost as the light passes through the atmosphere. The amount of solar radiation on the earth surface can be instrumentally measured, and precise measurements are important for providing background solar data for solar energy conversion applications. There are two important types of instruments to measure solar radiation: Pyrheliometer is used to measure direct beam radiation at normal incidence and are calibrated against the primary standard methods. Pyranometer is used to measure total hemispherical radiation - beam plus diffuse on a horizontal surface. These instruments are usually calibrated against standard Pyrheliometer. Certain standards are used frequently to calibrate radiometers deployed in continuous monitoring stations. The World Radiometric Reference (WRR) is the internationally recognized standard for solar (shortwave) irradiance measurement. A group of seven self-calibrating absolute cavity radiometers form its basis of World Standard group (WSG). Reference standard radiometers from around the world are compared every five years to the WRR at the World Radiation Center in Davos, Switzerland.

Keywords: WRR, WSG, Cavitiy Radiometers, Pyranometers, Pyrheliometer

Real-time performance of Multi-Physics-Multi-Ensemble (MPME) IITM Extended Range Prediction System during ISMR 2022.

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ABSTRACT

Prediction at sub-seasonal/extended range time scale has got huge attention since it bridges the gap between medium-range and seasonal forecasts. Skillful Prediction of above normal rainfall (active spell) and below normal rainfall (break spell) of Indian Summer Monsoon (JJAS) rainfall at least a few weeks in advance could have immense socio-economic value.

The present study will emphasise the performance of the experimental real-time Multi-Physics-multi-Ensemble (MPME) Extended Range Prediction (ERP) System (which is being run at IITM) in predicting monsoon 2022. This study will focus on the extended range prediction and its verification of monsoon features, such as onset, progression and withdrawal phases of the monsoon, and the role of intra-seasonal oscillation (ISO) signal in Extended Range Prediction (ERP) etc. A few important spells during this season will also be highlighted. The skill of the MPME ERP System over different homogeneous regions of India will be computed at different week-wise forecast leads. Since the active-break spells of ISMR are the manifestation of Monsoon Intra-seasonal Oscillation (MISO), the predicted and observed large-scale low-frequency component, i.e., MISO, will be discussed. The bivariate correlations and RMSE between the observed and predicted MISO would be computed to make a comparison between hindcast skill and the skill for 2022.

Keywords: Extended range prediction, Monsoon, MISO

Comparative Analysis of Benzene, Toluene, Xylene (BTX) Concentration and Seasonal Variation in two most Polluted Cities of IGP Region: Agra and Ghaziabad

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ABSTRACT

Air pollution is one of the primary sources of risk to human health in the world. Vehicular exhaust is one of the most important anthropogenic sources of air pollution, a major constituent of which include Volatile Organic Compounds (VOCs) such as benzene, toluene, and xylene (BTX). In this study, seasonal and annual variations of BTX were evaluated at Agra and Ghaziabad for the pre (2019), during (2020) and post-Lockdown period (LP) (2021), for which the data on BTX were obtained from the Central Pollution Control Board (CPCB).

The data suggested that the level of BTX increased during lockdown period in Ghaziabad by 17, 41 and 23% and decreased by 10, 20, 2% after lockdown, respectively. However, the level of BTX decreased by 28, 27, 33% in Agra during lockdown and further decreased by 40, 64 and 48% after LP. The decline in BTX during LP could be attributed to complete restrictions imposed. In contrast, a slight increase in BTX during the LP in Ghaziabad could be attributed to poor photochemistry between the precursors of O_3 and conditional relaxation to certain businesses, including agricultural businesses, transportation to operate which were significant sources for BTX. Toluene was found to be the most abundant VOCs in the atmosphere of Agra and Ghaziabad. The seasonal mean concentration of VOCs was observed highest in Winter > post-Monsoon > Monsoon > Summer. Further, the T/B ratio were found lower in the LP as compared to the pre-LP which is attributed to the complete closure of non-traffic sources such as industries and factories during the LP. Among different seasons the maximum (6.91, 28.28) and minimum (0.01, 0.08) T/B ratio was observed in winter and summer for Agra and Ghaziabad which suggested traffic emissions as major source of BTX. Based on the findings of the present study, some special measures like promotion of cleaner technologies to reduce vehicular pollution, increasing greenery by massive plantation can be taken for reducing the levels of these pollutants.

Keywords: BTX, VOCs, Seasonal Variation, Lockdown, Air Pollution

Identification of Sources and Sinks of Atmospheric Aerosols and their Impact on East African Rainfall

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ABSTRACT

Aerosols' role is crucial in climate change by providing a radiation balance between the Earth and atmosphere. In the present study, aerosol sources and sinks have been identified over African region using MERRA-2 reanalysis data from 1985 to 2015. The study mainly focused on climatological and seasonal changes in aerosol distribution and concentrations over African continent and its impact on East African rainfall. Western Africa shows high concentrations of AOD (> 0.3) due to localized pressure changes and diverging winds from the Sahara desert. A strong inverse relationship was observed between the West African aerosol concentrations and the East African (latitude 300 S to 300 N and longitude 250 E to 500 E) rainfall. The increase in rainfall is associated with an increase in relative humidity. During the monsoon months, the presence of huge amounts of aerosols causes the production of convective clouds with a more significant number of ice particles and, consequently, more rainfall.

Keywords: Aerosols, Precipitation, Continuity Equation, Wind

Findlater Jet Induced Summer Monsoon Memory in the Arabian Sea

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ABSTRACT

A cross-equatorial low-level wind, known as Findlater Jet (FJ), modulates the thermocline in the Arabian Sea (AS) during summer monsoon (June to September). By analysing ocean and atmospheric data, we show that the FJ signal gets 'trapped' in the AS in the form of tropical cyclone heat potential till the following winter monsoon months (December to February). This memory is the consequence of the combined effect of FJ-induced wind stress curl and the annual downwelling Rossby waves in the AS. During the summer monsoon months, the strong low-level westerly winds cause a negative wind stress curl in the south of the FJ axis over the central AS, resulting in a deep thermocline and high magnitude of heat being trapped. In winter monsoon months, though the wind stress curl is positive over large parts of the AS and could potentially shoal the thermocline and reduce the upper ocean heat content in the central AS, this does not happen due to two reasons. Firstly, winds are weaker, and spread over a larger area over the AS making the magnitude of the wind stress curl low. Secondly, westward propagating downwelling Rossby wave radiated from the eastern AS deepens the thermocline and prevents ventilation of the trapped heat. During the following spring, the collapse of the Rossby waves leads to the shoaling and mixing of underlying waters with surface waters thereby resurfacing of the trapped heat. The resurfacing of the trapped heat makes the AS a memory bank of the FJ induced signal.

Keywords: Arabian Sea, Indian summer monsoon, Findlater Jet, Upper Ocean Heat Content, Rossby wave

DIURNAL VARIATION OF MONSOON RAINFALL DURING EARLY AND RECENT EPOCHS OVER WEST COAST OF INDIA

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ABSTRACT

During the recent past, Indian summer monsoon rainfall demonstrated wide spatial and temporal variability. Increase in occurrence of extreme rainfall events causes natural disasters such as mudslides or landslides. Here, an attempt is made to study diurnal variation of summer monsoon rainfall for a period from 1998 to 2019 over west coast of India. IMD gridded daily rainfall data and TRMM satellite derived 3 hourly rainfall data were utilised for the analysis. West coast of India is divided into 6 regions in the south-north and each region is subdivided into coastal, midland, and highland regions on the basis of the elevation. Changes in rainfall pattern on a diurnal basis between early epoch (1998-2002) and recent epoch (2015-2019) are analysed. The subsections exhibit a similar pattern in rainfall even though the intensity of rainfall varies from region to region. In general, maximum intensity of rainfall was observed at 12 UTC during early epoch over coastal, midland and highland regions. However, this peak shifted from 12 UTC to 09 UTC over coastal and midland regions during recent epoch. And highland regions exhibit the peak at 12 UTC as in the early epoch. The intensity of rainfall at peak hour is decreased during recent epoch in comparison with early epoch. However, intensity of rainfall at 00 UTC, 03 UTC and 06 UTC is increased. Southern part of west coast region exhibited lowest rainfall with an increase towards north. In recent epoch, southern regions (coastal, midland and high land) exhibited an increase in rainfall. In early epoch, central region of west coast exhibited maximum rainfall intensity. But in recent epoch, northern regions exhibited more rainfall intensity than central region. Diurnal pattern of summer monsoon rainfall over west coast of India during past 20 years shows a remarkable variation especially during early and recent epochs.

Keywords: Indian summer monsoon, Diurnal variation, west coast of India

WINTER FOG VARIABILITY AND ITS OPTICAL & RADIATIVE CHARACTERISTICS USING GROUND-BASED REMOTE SENSING OVER A STATION IN IGB

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ABSTRACT

In the present scenario, it is essential to monitor the increased occurrence of severe and prolonged fog events over the Indo Gangetic Basin (IGB) by various remote sensing techniques to aid fog forecasting skills. In this study, a simple methodology is proposed to retrieve the fog events using the ground-based remote sensing techniques and study its variability, optical and radiative properties. The proposed methodology uses the surface shortwave irradiance (Rs) from the Multifilter Rotating Shadowband Radiometer (MFRSR), real-time sky images and Red-Blue Ratio (RBR) from the Total Sky Imager (TSI) during the period December 2014 to January 2015 at the station Varanasi in IGB. Also, Aerosol and fog optical depths (AOD, FOD) were retrieved from the MFRSR irradiance measurements using the radiative transfer models.
The ground retrieved fog events showed good association with that of INSAT-3D satellite retrieved fog over the same region. The fog events showed high temporal as well as diurnal variability with more occurrences and prolonged events in January as compared to December. The FOD variability also revealed intense fog events in January as compared to December.The parameter RBR is used to distinguish the sky condition from clear-hazefog/cloud. Thus, using the regular surface measurements of Rs and RBR, the proposed method can be used as a proxy to identify fog events in the absence of satellite and also other regular surface visibility measurements.The surface shortwave radiative forcing (SWRF) due to fog revealed high temporal variability from -100Wm^{-2} to -300Wm^{-2} and the magnitude of negative forcing or cooling effect increased with increase in FOD, while forcing due to aerosols varied up to -50 Wm^{-2} for clear skies and up to -100 Wm^{-2} for high AODs/haze.
Thus, the network of high frequency surface measurements could play an important role in validating the satellite products as well as model results.

Keywords: Fog, Shortwave irradiance, Aerosol optical depth, Fog optical depth, Aerosol/haze/fog radiative forcing

Decadal Variability of Tropical Indian Ocean Sea Surface Temperature

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ABSTRACT

Decadal variations in the regional and global Sea Surface Temperature (SST) are mainly associated with ocean heat uptake and heat distribution. The most prominent climate variability patterns associated with ocean are the Pacific Decadal Oscillation or its nearly interchangeable companion inter-decadal Pacific oscillation and Atlantic Multi-decadal Oscillation (AMO), are relatively well studied. However decadal variability of tropical Indian Ocean (TIO) SST is relatively new and meagrely explored and models' ability in representing it remained unexplored. The present study examines the ability of Coupled Model Inter-comparison Project phase 6 (CMIP6) models in representing the dominant modes of TIO SST variability on the decadal time scale. Historical simulations from 27 CMIP6 models are assessed against Extended Reconstructed SST over the period of 1854 to 2014. Spectrum analysis reveals that many models reproduce decadal variability of TIO SST but underestimate the amplitude of variability with some disparity in the periodicity. Skill score analysis reveals FGOALS-f3-L, CanESM5- CanOE, KACE-1-0-G and CanESM5, respectively, showed highest skills for decadal variability. Taylor diagram analysis reveals that all the models exhibit better skill for the radiative flux; however, skill for the latent heat and momentum flux varies from model to model. It is important to note that the models in which the latent heat flux and zonal wind are better represented have produced better TIO SST variability compared to other models. A higher discrepancy in latent heat and zonal momentum flux leads to improper wind-evaporation-SST and wind-circulation-SST feedback, which in turn restricts the model skill. Besides, model that has realistic central and eastern Pacific SST variability show better skill for TIO SST decadal variability. The present study advocates that better representation of latent heat flux and zonal wind in coupled models is important for the accurate simulation of decadal variability in TIO SST.

Keywords: CMIP6 models, decadal variability, tropical Indian Ocean, sea surface temperature, latent heat flux

AUTOMATIC VERIFICATION OF DISTRICT LEVEL NOWCASTS

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ABSTRACT

IMD operationally issues district level nowcasts for severe weather for all districts of India round the clock at three hourly intervals since 2018. The phenomena for which nowcasts are issued include: (a) Thunderstorms and associated weather and (b) rainfall. All these nowcasts are updated every three hours on the IMD website (https://mausam.imd.gov.in/imd_latest/contents/districtwisewarnings.php) . The current study details a method for automatic verification of these district level nowcasts. The data from the ground based lightning array network of the Indian Institute of Tropical Meteorology and Indian Air Force has been used for verification of the District level Nowcasts. This network currently has 83 sensors and provides spatial accuracy of about 500 m. The point data for lightning with lat-long coordinates is provided from the network in near realtime mode to IMD at 15 minute intervals for operational use. The point data is geolocated up to the district level using open source "Nominatim Server" software. For verification purposes, a yes-no criterion (2x2 configuration table) is applied for occurrence-non-occurrence of thunderstorms in each district. All the eleven categories of nowcasts for thunderstorms and associated weather are considered for verification. A minimum of 2 (two) incidences of lightning occurrence in a district within the validity period of a nowcast is considered occurrence of thunderstorm over that district. The two flashes may occur concurrently or subsequently in time in any part of the district within a period of three hours, i.e. during the validity time of the nowcast for the district. Based on both observation and nowcast for thunderstorms (any one of the eleven categories), the forecast skill scores have been calculated. Some significant results across the months are as follows:

(a) Probability of Detection score is highest for central India (Madhya Pradesh) and is generally good for the adjoining plain regions of northcentral (Uttar Pradesh, , west central (east Rajasthan), east central (Vidarbha, Chhattisgarh) and southeast peninsular India (Andhra Pradesh, Tamilnadu).

(b) False Alarm Ratio is 1 for many of the districts in Jammu and Kashmir and Northeast India. After detailed analysis, it is noted that the density of lightning detection sensors is not sufficient over these regions to adequately capture all lightning flashes in a mountainous terrain.

(c) False Alarms are generally high for arid regions. This may be attributed to forecaster's cautiousness while issuing nowcasts.

The methodology of verification being uniform, the results clearly bring out the spatial biases in nowcasting across Meteorological Centres issuing the nowcasts.

Unraveling the characteristics of atmospheric aerosol over the Indian Summer Monsoon region

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ABSTRACT

Atmospheric aerosol, the tiny suspended particulate matter coming from various natural and anthropogenic sources is one of the most visible aspects of air pollution, and has vast effect span in the areas of air quality, health, radiation, cloud microphysics and climate change. The Indian summer monsoon (ISM) region, comprises the Indo-Gangetic Basin (IGB) in the northern part of India, is dominated by the enhanced loading of anthropogenic aerosol pollution and thus considered as one of the global hotspots. It is one such region, where heterogeneity in aerosol optical and microphysical properties over a wide range of spatial and temporal scales continues to hinder in improving the estimates of aerosol-induced climate forcing. Rapid increase in population and urbanization has resulted in excessive fossil fuel combustion and biomass burning leading to high anthropogenic aerosol loading over this region. The large increase in anthropogenic aerosols over the IGB is hypothesized to cause considerable changes in regional monsoonal circulation and also the global climate system apart from the aerosol-induced negative health impacts.

The recent worldwide lockdown, imposed due to current pandemic of coronavirus was found to lower the emissions from various anthropogenic sources across the world, including India by restricting various community mobility activities, like traffic, construction and industrial. This resulted an improved air quality at the highly polluted regions, like IGB. Though, the reductions were found to be temporary, such lockdown may be used as one of the possible emergency measures to combat severe air pollution episodes in India, especially over the urban polluted regions in northern India, which is severely polluted during the winter/post-monsoon period.

Keywords: Aerosols, IGB, anthropogenic emission, lockdown.

Rainfall efficiency in cleansing the atmospheric aerosols over a tropical coastal environment (12.81°N, 80.03°E)

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ABSTRACT

Rainfall is an efficient mechanism that cleanses the atmospheric aerosols from the atmosphere by way of wet scavenging processes. The rainfall intensity, duration and drop size play key role in removing the atmospheric aerosols. In the present study, we use a set of observations of rainfall from rain gauge, drop size from laser precipitation monitor, black carbon aerosol concentration from the aethalometer to study the rainfall efficiency in black carbon aerosol scavenging over a tropical environment of Chennai (12.81°N, 80.03°E) located on the east coast of India, for the period of January-2016 to February-2019. Aerosol scavenging coefficients have been calculated using the rain drop diameter, aerosol diameter and terminal velocity for different rain events by considering the Brownian diffusion between the aerosols and raindrops. The aerosol scavenging was found to be maximum at a rain drop size of 1mm and as the size increases further, the scavenging efficiency decreased. Using the rainfall data and black carbon mass concentration data, we estimated the BC scavenging ratio for different rain events. The estimations of scavenging coefficients from the two methods were correlated substantially with +0.84 correlation. The role of the duration of rainfall and intensity of rainfall also contribute to the changes in scavenging. The detailed results will be presented during the conference.

Keywords: Rainfall intensity, Wet scavenging, BC scavenging ratio.

Seasonal variability in aerosol hygroscopicity and its contrast size dependence in Aitken and accumulation modes

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ABSTRACT

Hygroscopicity is the ability to water uptake by particles and modulates the size of aerosols especially in high humidity atmospheric conditions. Thus it influences the local visibility and aerosol-cloud interaction processes. More than 1 year of observations were collected at High Altitude Cloud Physics Laboratory (HACPL), Mahabaleshwar from May, 2019 to 10th May, 2020 covering all seasons are used in the study. Size segregated growth factor for particle diameters 32nm, 50nm, 75nm, 110nm, 150nm, 210nm, 260nm at 90% RH conditions were measured by Humidified tandem Differential Mobility Analyser (HTDMA). Hygroscopicity depends on the chemical composition of particles. The mass of different chemical species changes with the size of particle. So the size segregated observation was designed for particles ranges from Aitken to accumulation mode.

The mean hygroscopicity (k) for diameters 32nm, 50nm, 75nm, 110nm, 150nm, 210nm, and 260nm at 90% RH conditions are 0.189, 0.177, 0.163, 0.170, 0.183, 0.199, 0.207 respectively during the overall observation period. The minimum k (0.163) is observed for the particle size of 75nm and the maximum (0.207) for 260nm particle. Annual and in all the seasons, it is noted that hygroscopicity decreases with increasing diameter in Aitken mode size range whereas increases with increasing diameter in accumulation mode. This reverse trend is explained by different hygroscopic modes and the chemical composition analysis. Aerosols are categorized in three hygroscopic modes i.e. less-hygroscopic (LH) population $k < 0.1$, hygroscopic (H) population $0.1 \leq k < 0.2$, More-hygroscopic (MH) population $k \geq 0.2$. More hygroscopic population shows a reverse trend as it decreases in Aitken mode but in accumulation mode increases with increasing diameter. Size segregated chemical composition of particles was measured by High-Resolution Time of Flight Aerosol Mass Spectrometer (HR-ToF-AMS) in winter and pre-monsoon time. Chemical composition analysis also support inter- and intra-seasonal variation of hygroscopicity in each diameter. The detailed analysis and results will be presented.

Keywords: Hygroscopicity

Spatio-temporal correspondence of aerosol optical depth between CMIP6 simulations and MODIS retrievals over India

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ABSTRACT

Aerosols play an important role in the earth's radiation budget by their direct and indirect effects. Due to the lack of adequate measurements of aerosol characteristics, the data of satellite and regional/global climate model simulations surrogate the purpose of the large-scale and long-term studies. In the present work, we used the Aerosol Optical Depth (AOD) of the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard Terra satellite at 550 nm to understand the space and time scale variations of AOD over Indian Land Mass for the period 2001 to 2014. The main aim of the study is to compare the MODIS retrieved AOD with the newly emerged global climate models (GCM) of Coupled Model Intercomparison Project (CMIP) phase 6 and to unravel the Spatio-temporal correspondence. Further, we have studied the evolution of aerosols in the future up to 2050 under various Shared Socio-economic Pathways (SSP) of CMIP6. A Multi-Model Ensemble (MME) of five GCMs (AWI-ESM-1-1- LR, BCC-ESM1, MPI-ESM-1-2-HAM, MPI-ESM-1-2-HR, MRI-ESM2-0) was obtained and has been compared against MODIS. The results show that the percent bias of MME with MODIS was the lowest during winter (January-February) and post-monsoon (October to December) seasons varying between (-20 to 20 %). In all the seasons, a positive bias in AOD was observed over the monsoon core region while a negative bias has been observed over a few portions of the Indo-Gangetic plain. The spatial pattern of temporal correlation between MODIS and MME showed the highest positive correlation (> +0.8) over Peninsular India and negative correlation (< -0.4) over northwest India. Among the six GCMs, MPI-ESM-1-2-HR and MPI-ESM-1-2-LR models have shown substantial and statically significant correlations (+0.9) with MODIS for the period 2001-2014. In the future, under SSP370 the aerosols continued their increasing trend and reach the maximum mean annual AOD (~0.64) and under SSP126 the aerosol followed a decreasing trend after the 2020s and reaches the minimum AOD of 0.34 in 2050.

Keywords: Aerosol optical depth, CMIP6, Remote Sensing, and Climate modelling

SPATIO-TEMPORAL ANALYSIS REVEALS THE IMPACT OF CLIMATE CHANGE ON SOUTH ASIAN RAMSAR WETLANDS

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ABSTRACT

Wetlands are significant habitats for vital flora and fauna, have aesthetic and cultural value, and contain biodiversity stocks with potentially great pharmaceutical value. Wetland ecosystems are altering and vanishing because of agricultural and industrial expansion, water deviation, increased temperatures, and change in rainfall patterns. Wetlands are projected to have lost and shrunk over the last several decades, threatening important ecosystem functions such as control flooding, protection of biodiversity, supply of food, etc. In this study, 89 Ramsar sites from South Asian countries were studied based on the inundation patterns they have seen over the past 30 years. The study makes use of pre-processed Landsat imageries (1991-2020) to create annual composites from June to September. These composites were subjected to the Short-Wave Infrared (SWIR) Thresholding technique to produce inundation maps using Google Earth Engine (GEE). These inundation maps were used to analyze the changes in wetlands and then further analysis was carried out on each Ramsar site individually to account for its typical behavior owing to regional climatic and geographical conditions. The Mann-Kendall (MK) test was used on each wetland site individually to understand the trends in the variation of inundation extent. The trend analysis revealed that 46 sites follow an increasing trend, and the remaining 43 sites were found to be decreasing. Among these, 12 sites were found to be significantly decreasing, with the Upper Ganga River showing a maximum decrease of about 59% in the inundation extent. The automated method of generating inundation maps was validated using image-based accuracy assessment. The overall accuracy of wetlands was found to be 88.96 ± 6.93%, with average dry and wet Producer's accuracies of 90.67 ± 9.52% and 86.65 ± 11.89% respectively. The study also focused to understand wetlands (the significantly decreasing) which were observed to be at the maximum risk of extinction.

Keywords: Ramsar Wetlands, Google Earth Engine, Remote Sensing, Inundation mapping, Climate change

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HEAT WAVES IN INDIA: HISTORICAL AND FUTURE PERSPECTIVE

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ABSTRACT

Heat waves (HWs) are unusual events characterized by exceptionally high surface air temperatures that last several days and have severe repercussions on human and natural systems. Heat waves have grown in frequency, duration and intensity in last some decades globally and even latest climate projections (CMIP6) reveal these to get worsen under enhanced global warming. Heat
waves have adverse impact over biophysical and human systems. Therefore, to predict HWs accurately, it is required to understand the regional trend and variability associated with HWs. Bivariate copula based joint exceedance probability analysis of HW frequency and intensity have been carried out to better assess the vulnerability of Indian regions. Rajasthan, Madhya Pradesh, Uttar Pradesh, Punjab, Bihar, Chhattisgarh, Gujrat, Karnataka, Maharashtra, Telangana, Andhra Pradesh, and Odisha have been found vulnerable for HW disaster. To unveil the spatio-temporal variability in HW characteristics, we investigated the relative influence of crucial large-scale climate oscillations (ENSO, IOD, and AMO) on HW by introducing these atmospheric variables as covariates in non-stationary EVT-based models. ENSO and IOD together have been recognized with relatively stronger connection associated with HW variability. In past some decades Odisha, Andhra Pradesh, Bihar, Gujrat, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Uttar Pradesh and West Bengal are extremely hit by HWs. The regions experiencing more HWs (vulnerable zones) are projected to get even worse in warming future climate (as per the SSP 245 and SSP 585 projections).
Keywords: Heat waves, Copula, Nonstationary, Large-scale climate oscillations, Extremes.

Association of CAPE on rain occurence systems over Ongole

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ABSTRACT

The most common greenhouse gas in the atmosphere is water vapour, which is also essential to the hydrological cycle and energy balance of the planet. This study will measure the relative humidity (RH), convective accessible potential energy (CAPE), and convective inhibition during the course of 2021 using surface and radiosonde data (CIN). The findings demonstrate that extremely high RH values are represented during the pre-monsoon season while low values are shown throughout this time. In contrast to other Andhra Pradesh stations, Ongole station has high RH values. Coastal places of Prakasam district have greater RH values during monsoon season, regardless of the season. Coastal regions have higher RH values during the monsoon season, regardless of season. While other areas have high RH levels during the monsoon season, the coastal region has high RH levels throughout the pre-monsoon season. An increase in water vapour causes a rise in temperature, which alters the circumstances for instability. According to our research, CAPE has a seasonal pattern that is comparable to that of RH.

Keywords: Extreme, Coastal, Season, humidity, CAPE.

Machine Learning based Crop Water Management

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ABSTRACT

Increasing water and food demand from the growing population of India needs organised water management with increased crop yield. In the recent decade, there have been enormous improvements in the weather prediction systems with dynamical models in spatial and temporal scales. however, their direct applications in crop water management have not been fully explored. This is to study a novel algorithm for crop water management proposed by our institute. One of the major mandates of our Institute is to promote research in the state of art technologies, providing solutions to human problems especially in the area of Water, Energy, and Food etc. Here we made an attempt to apply the Machine Learning (ML) algorithms in the theme of application of weather in agriculture. The main objective of this study is to predict solar radiation and Evapotranspiration (ET) using ML algorithms. Also, to predict events like heavy rainfall/ wind speed to provide accurate warnings sufficiently well in advance to reduce loss in crop yield. The predicted ET data is used to determine the water demand of field crops in agro-meteorological applications to help farmers better predict future climatic patterns, thereby highlighting better planting or crops, effective water management and hence creating a useful climate service. Evapotranspiration is the most tough water balance component to directly measure. An accurate estimate of ET is the preliminary step involved in determining the water demand of field crops. Also, the solar radiation data is the essential input for estimating the reference crop ET. Due to high cost and difficulties in measurement techniques, solar radiation and evapotranspiration is predicted using empirical equations and tree-based ML algorithms. The ground-truth/observation data from India Meteorological Department (IMD) would be considered for the ML model inputs. The findings of this study can be used as a platform for irrigation planning, design and management.

Keywords :-*Climate services, Evapotranspiration, Solar Radiation, Machine Learning.*

A Satellite Study of Cloud Clusters Over South-East Asia During SMONEX-79

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ABSTRACT

This paper presents the distribution, size, intensity, lifetime and trajectories of the SMONEX clusters of South and South-east Asia 0-30N and 70-120E and relates their distribution to the synoptic-scale weather disturbances. Defense Meteorological Satellite Program DMSP infrared (day and night) and visible day pictures for June, July, August 1979 were used. The first GARP Global Experiment FGGE-Level III-b data were used to examine the association of cluster activity to synoptic scale systems. Satellite nephanalysis was employed to diagnose the Cloud Cluster characteristics from the DMSP imagery by using the techniques described by Martin, Sikdar and Schreiner in the past. Due to different meteorological situations and terrain, the study domain has been defined into four Zones, A-D (Arabian Sea, Indian Peninsula, Bay of Bengal and the South China Sea) – and three latitudinal belts I=0-10^{0}N, II=0-20^{0}N and III = 20-30^{0}N.

It was found that lifetime of cloud clusters more than a day 31 h and it increased size and intensity. The intense and very large clusters were found to be related with monsoon depressions. The maximum cluster frequency according to size and intensity occurred between 5^0 – 20^{0}N and to the East of 85^{0}E longitude. This favorable area for cloud cluster activity may be due to the prevailing high sea surface temperatures SSTS and cyclogenetic nature of the region. The oceanic clusters were more active than those over the land. The cluster activity was significantly greater at 12GMT than at 00 GMT during the SMONEX. The intense clusters generally moved in the west north-west direction, with average speed of 2.11 deg per day. Comparative studies showed that SMONEX clusters were slower in movement but of longer lifetime than GATE clusters.

Key Words: SMONEX, GATE clusters, SST'S, (FGGE) Level III-b Data, McIDAS, DMSP Imageries

Variation in potential evapotranspiration over western Himalaya based on tree ring-width records in India

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ABSTRACT

Tree-ring chronologies from different sites of western Himalaya have been used in this study to examine the climate variability / change over the region. The 1st principal component (PC1) which has been computed by multi species tree ring chronologies of western Himalaya is negatively correlated with heat index (HT), temperature (TM) and potential evapotranspiration (PET) but positively with the rainfall of the region during spring season. However, HT and PET showed the stronger influence on tree growth than temperature which has been used to reconstruct the spring season PET back to A.D. 1779. The extended periods of low PET have been found at ending phase of Little Ice Age (LIA) during 1827-1845. The reconstructed PET showed that the advance of the glaciers over the western Himalaya might have influence on reduction of downward shortwave radiation on the earth's surface; which may in turn cause low temperature and low PET over the region. The result indicates that longer tree ring chronologies from the western Himalaya are very useful to get valuable information on PET and glacier fluctuation during the last few centuries.

IMPACT OF WEATHER AND CLIMATE CHANGES ON THE STATE OF ODISHA, INDIA.

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ABSTRACT

Climate change pretends to be a serious challenge for different states of India. Odisha which is present on the eastern side of India is susceptible to several natural calamities viz. cyclones, changes in sea level, rises in temperature, and variability in rainfall which invite vulnerability to coastal communities. The frequent climate changes lead to adverse impacts on the habitats of ecosystems in the form of loss of crop damage, health and property. The agricultural sector in Odisha is one of the dominant sectors, which turns the most vulnerable due to climate change. Our study approaches by adopting the IPCC's integrated indicator approach to create a vulnerability index of districts of Odisha. Several social, economic, environmental and physical indicators were identified under three components of vulnerability: (i) sensitivity, (ii) exposure, and (iii) adaptive capacity. For unequal weight assignment, indicators are assigned weight through SPSS (PCA), which helps in the identification of overall ranking of the district. The analysis with respect to the annual rainfall pattern observed deviations in districts like Bolangir, Ganjam, Kalahandi, Nuapada, and Rayagada. Moreover, lightening a key drivers for districts like Ganjam, Cuttack, Keonjhar, Mayurbhanj and Sundargarh, attracts a no. of 1837 deaths overall in the state during 2016-17 to 2020-21. More frequent heat waves, floods and cyclones were observed in different districts of Odisha. The heat wave that took 164 lives in the state during 2016-17 to 2020-21, is a key driver for the district of Angul, Bolangir and Jajpur. From the overall integrated vulnerability index study, it is clear that Kalahandi is most vulnerable and Boudh is least vulnerable district in the State, Odisha. All generated data suggested that climate extremes are intensifying the water cycle (rainfall, drought and floods). The principal indicators contributing to vulnerability is due to low adaptive capacity and high sensitivity. The observations need to develop specific policy interventions to address climate change at district level on a long-term basis.

Keywords: Climate change, lightening, key drivers, vulnerability, heat wave

Identification of Sources and Sinks of Atmospheric Aerosols and their Impact on East African Rainfall

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Abstract

Aerosols' role is crucial in climate change by providing a radiation balance between the Earth and atmosphere. In the present study, aerosol sources and sinks have been identified over African region using MERRA-2 reanalysis data from 1985 to 2015. The study mainly focused on climatological and seasonal changes in aerosol distribution and concentrations over African continent and its impact on East African rainfall. Western Africa shows high concentrations of AOD (> 0.3) due to localized pressure changes and diverging winds from the Sahara desert. A strong inverse relationship was observed between the West African aerosol concentrations and the East African (latitude 30^0 S to 30^0 N and longitude 25^0 E to 50^0 E) rainfall. The increase in rainfall is associated with an increase in relative humidity. During the monsoon months, the presence of huge amounts of aerosols causes the production of convective clouds with a more significant number of ice particles and, consequently, more rainfall.

Keywords: Aerosols, Precipitation, Continuity Equation, Wind

Analysis of long-term Spatio-temporal changes in rainfall characteristics over major river basins of Western India

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ABSTRACT

There is a strong scientific consensus that climate change has adversely affected precipitation, altering the overall hydrological cycle globally. It has wider implications, particularly at a river basin scale that will eventually affect the overall water availability of the basin. The present study evaluates long-term (1950-2020) Spatio-temporal changes in monsoon season (JJAS) rainfall characteristics over two major river basins of western India: Narmada (NRB) and Sabarmati (SRB) river basins using IMD 0.25x0.25º daily gridded rainfall dataset.

It was observed that SRB witnessed a positive linear rate of change (1.02 mm/year) while no overall change in rainfall was observed over NRB (0.2mm/year). Monthly rainfall distribution indicated that while July has the highest contribution to the overall rainfall for both basins, maximum variability in rainfall occurred in August. It was further observed that the basins have shown an increase in the number of dry day events and a decline in the number of wet day events. Low rainfall events decreased over SRB and an increasing trend was obtained in heavy rainfall events over SRB and NRB. However, there was a decrease in moderate rainfall events which indicates that rainfall has intensified in Western India. Spatially, NRB witnessed a decline in rainfall and an increase in the number of dry days and low rainfall events along the west-central region while a slight increase in overall rainfall along eastern parts was observed. Moderate rainfall events increased along eastern NRB. An increase in rainfall and the number of wet days were observed along central SRB. Interestingly, an overall increase in moderate and heavy rainfall events along central parts of SRB was obtained. The study has implications for understanding the dynamics of rainfall variability in Western India.

Keywords: Western India, NRB, Rainfall characteristics, Wet days, Heavy rainfall events

ANALYSIS OF THE CHARACTERISTICS ASSOCIATED WITH SUPER CYCLONIC STORM 'AMPHAN' OVER THE BAY OF BENGAL USING RE-ANALYSIS DATASETS

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ABSTRACT

Reanalysis datasets are used for analysing the characteristics of the super cyclonic storm (SuCS) 'Amphan' evolution. On May 13th, 2020, the SuCS developed over the southern Andaman sea and established contact with the southeast BoB. The SuCS 'Amphan' quickly became a very severe cyclonic storm (VSCS) on May 17th, 2020, an extremely severe cyclonic storm (ESCS) on May 18th, 2020, and finally a super cyclonic storm (SuCS) around 1200 UTC on May 18th, 2020 for the following 24 hours before weakening into an ESCS and eventually made landfall as a low-pressure coastal region over north Bangladesh and its environs around midnight on May 21st, 2020. Two reanalysis data sets, namely, the Fifth Generation of European Centre for Medium-Range Weather Forecasts (ECMWF) reanalysis (ERA5) and the Indian Monsoon Data Assimilation and Analysis (IMDAA), are used to study different characteristics of SuCS 'Amphan'. Eight parameters, namely, wind vector, minimum sea level pressure, potential vorticity, vertically integrated moisture transport, potential temperature, geopotential height, track, and track error, are analysed in this study. The obtained results of PV are also mapped with its mathematical formulation. The error analysis for the track, intensity and minimum sea level pressure of Amphan are estimated with the observed data sets from the India Meteorological Department.

Keywords: Tropical Cyclone, Super Cyclonic Storm, IMDAA, ERA5

Understanding the mechanism of Mesoscale Convective System and associated Cloud Structure from model simulations and Satellites over Indian region

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ABSTRACT

Mesoscale Convective Systems(MCS) are a region of collective multi-centered thunderstorms resulting into convective instability and heavy rainfall events over the region. On a temporal scale of several hours and characterized with cloud horizontal extent greater than 100km. Heavy rainfall events over India in recents years e.g.,Maharashtra-2021, 2019, Kerla-2018, Chennai 2018 needs an accurate forecast with lead time for minimizing the loss of lives and properties. In our study we discussed about the identification and key factor of these mesoscale convective systems using WRF-ARW model and INSAT-3D imageries. High equivalent potential temperature, pronounced warm advection, low-level convergence, and local maximum in relative vorticity is associated with large-scale environments are the key indicators in identifying MCS. Five heavy rainfall events are simulated using WRF with a lead time of 96 hours. Four cloud microphysics, two cumulus parametrization schemes and their combinations investigated for the MCS system cause heavy rainfall over India. The heavy rainfall events are best identified using Betts–Miller–Janjic–Thompson scheme combination. Hydrometeors are also better represented by this combination. Finally, a more robust (weaker) intensity MCS is better (poorly) predicted by the model. These findings can enhance the better prediction of MCS events over Indian region in future.

Keywords: Mesoscale Convective Systems, Heavy Rainfall Events, WRF

IDENTIFYING DROUGHT CONDITIONS OVER ODISHA DURING MONSOON

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ABSTRACT

Changes in rainfall pattern and their impact on water resources, agriculture, health, and disaster management is a big concern in the era of climate change. The drought resulting from deficient rainfall, particularly during monsoon, influences agriculture and other associated sectors. Hence, monitoring drought condition is extremely important. The present study uses block level daily rainfall data of monsoon seasons (JJAS) from 1993 to 2021 collected from the Special Relief Commissioner (SRC) of Odisha and identifies drought conditions by computing different indices like Standardized Precipitation Index (SPI), Effective Drought Index (EDI), Decile Index (DI) and Percentage Departure (PD). Precipitation Concentration Index (PCI) is computed to understand the rainfall distribution pattern. Based on physiographic provinces we categorized the Odisha state into four zones (a) Central River Basin, (b) Coastal Plain, (c) Northern Upland, and (d) Southwest Hilly Region, and studied the interannual variability of different indices in Odisha as a whole and also over the four zones. The analysis reveals that DI is not appropriate for drought characterization in Odisha while SPI and EDI represent the drought condition most realistically. Considering Odisha as a whole, no extreme droughts are observed. Based on EDI, extreme drought in 1996 and severe drought in 2000 are observed in the Coastal plain while severe droughts are observed in the central river basin(two), northern upland, and southwest hilly region (one each) in 1996. Based on SPI, the Central River basin has no extreme and severe drought conditions while severe drought is observed (one each) in the other three zones. PCI indicates highly uniform distributed rainfall and moderately distributed rainfall in Odisha and four zones. Trend analysis indicates the decreasing trend of precipitation during monsoon over the southwest hilly region while increasing trends are observed in Odisha as a whole and other three zones. The results bring out the spatio-temporal variability in drought conditions over Odisha.

Keywords: Extreme drought, EDI, SPI, PCI, Interannual Variability

CLIMATIC TENDENCY OF CONVECTIVE TRIGGERS AND THEIR LONG -TERM EFFECT ON REGIONAL PRECIPITATION

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ABSTRACT

The Convective Available Potential Energy (CAPE) and Level of Free Convection (LFC) with Dew Point Temperature are the essential parameters used to predict atmospheric stability for saturated adiabatic conditions. The proposed study compares CAPE and Precipitable water at 00Z & 12Z with regards to prevailing conditions for convective precipitation. In this study, the upper air observations were collected from radiosonde data available for 42867 VANP Nagpur-Sonegaon Station in Nagpur region of Maharashtra, India for series of 20 years for pre-monsoon estimates. Using timely average CAPE, LFCs, LCL (K), LCL (hPa), Precipitable water for 00Z & 12Z over this region, the relationship between average convective activity and average rainfall as well as the series of changes in these parameters and its influence of precipitation pattern are examined during the pre-monsoon period. This study based on findings clearly demonstrates that the CAPE predominantly for 12Z have been systematically decreased from 773.71 J/Kg with average precipitable water 27.35 mm in the year 2007 to lowest 1.06 J/kg with average 3.51mm precipitable water in the year 2021 for the Nagpur region and rapidly increased by 588.5J/Kg with 33.19 mm in the year 2022 for pre-monsoon periods. In the past two decades, high in CAPE was found to be 1446.36 J/kg with average precipitable water 230.51mm in the month of April for year 2003. Based on above observations, this can be attributed that warmer air can hold large amount of water vapors and shows strong dependency of extreme rainfall on CAPE.The change in CAPE values represents the interlinked dynamics and atmospheric energy budget, therefore the variability in CAPE could be used as a prime indicator of climate change.

Keywords: Convective Available Potential Energy, Precipitable water, Upper Air Observation, Pre-monsoon.

ARIES ST Radar to observe precipitation from the Himalayan perspective

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ABSTRACT

The extensive mountain ranges and complex topography of the Himalayas play a significant role in the development of clouds and precipitation systems depending on background atmospheric conditions such as moisture content, stability, and the lifting of air by mechanical or thermal forcing over mountain slopes. These regions experience two distinguishable precipitation systems- stratiform or convective during the south-westerly monsoon and in winter the western disturbances resulting in the form of rain and snow. Moreover, in a precipitating atmosphere, a thick horizontal layer just below the 0^{o}C level where the large snowflakes melt is marked as a bright band of intense reflectivity has been a major interest in vertically pointing wind profiler radars. The ST radar at 206.5 Mhz can be better utilized for precipitation studies, preferably in the presence of a stronger cloud system with a fine spatial and temporal resolution. This study deals with the case studies of different types of precipitation systems from the observed backscattered signal at 206.5 MHz frequency of ARIES ST Radar installed in the central Himalayan region. The vertical variation of equivalent reflectivity dBZe and spectral width will be analyzed over the site and compared with other auxiliary observations and other operational radar frequencies. In the case of convective precipitation, all such parameters will be computed for the evolution, mature, and dissipation stage. The quantitative assessment of the bright band comprising the locations of freezing height and melting layer will also be discussed in this study.

Keywords: stratiform or convective precipitation, Central Himalaya, Bright band.

Role of climate forcing agents in changing the regional trends of the global hydrological cycle

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ABSTRACT

In recent decades, the global hydrological cycle is severely affected by Green-House Gases (GHG), Anthropogenic Aerosols (AA), LULC, etc. in addition to climate variability. The northern hemispheric monsoon precipitation trends are reported to have a strong connection to the GHGs and AAs. In this work, we attempted to carefully investigate the trends of regional precipitation globally, by examining the connection of downward solar radiation with evapotranspiration using the CMIP6 General circulation models historical simulations along with the individual experiments of GHGs, AA, and Natural forcings for the study period 1850 to 2014. The regional trends of downward solar radiation showed that India and East China have undergone a substantial decline from the 1960s onwards. We focus on these regions to report the changes in the hydrological cycle. The trend analysis of evapotranspiration and precipitation over south and east Asia from the 1950s to 2010s showed a drying trend in Eastern China, while India had an increase in annual total evapotranspiration and rainfall in the same period. These opposing responses in these two regions are due to, more so than the greenhouse gas effect, AA emissions have considerable control over Eastern China's precipitation. In contrast, the greenhouse effect has strong controls on the Indian land region's hydrological cycle exceeding the forcing brought on by the AA emissions.

Keywords: Climate change, Climate modelling, Anthropogenic aerosols, GHG, Hydrological cycle.

TEMPORAL VARIABILITY OF RAINFALL AND TEMPERATURE OVER JAIPUR CITY IN CONTEXT OF CLIMATE CHANGE

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ABSTRACT

Variability in rainfall & temperatures over a region are the principle parameters for assessment of climate change. Mean monthly rainfall, extreme rainfall in a day, rainy days have been analysed for the monsoon season by using daily rainfall data 1993-2021. Mean maximum temperature, extreme temperature events and number of heat wave days have also been analysed for the summer season by using daily maximum temperature data for the period of 1993-2022 for Jaipur city. The study reveals that the mean monthly rainfall, extreme rainfall in a day and rainy days are decreasing significantly for the months of June. The number of rainy days is increasing in the months of August and September. Highest ever 170.1 mm rainfall observed in a day in year 2012 for the study period.

The mean monthly maximum and extreme temperatures shows significantly increasing trend for the months of March, slightly increasing for the months of May and June, while no significant change observed for the months of May during the study period. The study also reveals that the highest average number of heat wave days observed in the months of June (1.8 days) followed by May (1.7days). The changes in the rainfall and temperatures may associated with the changing pattern of onset and withdrawal pattern of monsoon and climate change. The increasing maximum temperature in the months of March indicates the early onset of summer season over the Jaipur city.

Keywords: Climate change, Extreme rainfall, Monsoon, Heat wave, Extreme temperature

STUDY THE TRENDS OF EVAPOTRANSPIRATION IN RANCHI REGION OF EASTERN INDIA

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ABSTRACT

Evapotranspiration (ET), the process of water release to the atmosphere, plays a crucial role in irrigation management, water stress assessment, daily flux modelling, and climate change impact assessment. So it become important to do accurate and affective meseaurement of ET and its response to climate change. The useful way to check response of ET to climate variability is using ground based ET but due to less availability of station based observation we can use the satellite data derived land surface factors like soil moisture, temperature, radiation data related to ET. The ET become important for Jharkhand region as it is having high mountanious and hilly region, and is also having the high risk of drought, hence, a proper irrigation model is required for the irrigation of agriculture so as to minimize the dependency in rainfed agriculture. The aim of the study was to calculate ET from different empirical equations and validate with satellite data. The study also analyse the sensitivity of ET to global warming in terms of possible changes in meteorological parameters in the region and Mann-Kendall (MK) nonparametric methods have been employed for identifying trends in data change in humidity, radiations temperature, and wind velocity (which mainly affect ET). The calculated ET were also validated with satellite based soil moisture, normalized difference vegetative index (NDVI) of the studied area. The climatic data for the were collected from IMD Ranchi station and values of ET calculated from different empirical equation and validated from satellite data. It is found that ET is varying between 0.3- 4 mm/day for the station. And correlation between measured ET and satellite is good corelating. It shows that the increase of ET demand increase with temperature and less sensitive to increase in net solar radiation followed by wind speed.

Keywords: Evapotranspiration, Agriculture, Global warming, NDVI

Study of an extreme rainfall event occurred over Kerala during monsoon

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ABSTRACT

Frequency of occurrence of extreme rainfall events in summer monsoon increases during the course of time and it leads to natural disasters such as landslides, flooding, devastation of residential area, etc. Study on extreme rainfall events provides causative mechanism responsible for the extreme rainfall events. Here, an attempt is made to study dynamic and thermodynamic structure of the atmosphere causing occurrence of extreme rainfall event and subsequent flooding and landslides over Kerala during August 2019. The analysis is carried out using wind, temperature, humidity and rainfall data. Dynamical structure of the atmosphere based on vorticity, divergence, vertical velocity and thermodynamic parameters CAPE, CIN, LCL, LFC, moist static energy, precipitable water, etc were studied for the extreme rainfall event. The area of high rainfall was identified using IMD and TRMM rainfall data. The dynamic and thermodynamic parameters using high resolution reanalysis data sets were evaluated from 03 to 07 August. It is found that low level convergence and upper level divergence increased from 05 August and cyclonic vorticity increased from 06 August. The ascending motion of humid air played vital role for the torrential rainfall over the area. In addition, abrupt increase of CAPE, decreasing of CIN, lowering of LCL and LFC and increase of precipitable water and Moist Static Energy over the area are responsible for the extreme rainfall event. Analysis of 3 hourly TRMM rain rate indicated that the peak rainfall occurred over the area is just above 1 cm per hour over a relatively large area continuously for more than 6 hours leading to flooding and land slides. Strong moisture transport from Arabian Sea, favourable dynamic and thermodynamic structure and orographic lifting in the Western Ghats played vital role in generating strong ascending motion of humid air leading to rapid cloud growth and subsequent extreme rainfall event.

Keywords: Extreme rainfall event, monsoon, dynamic forcing, thermodynamic structure, climate change

Thermodynamic structure of the atmospheric boundary layer over coastal stations Chennai for contrasting sky conditions during different seasons

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ABSTRACT

Since, the global climate depends on the transport of energy and momentum to the free troposphere, ABL acts as a gateway for such transport and hence the parametarization of CBL for different forecast model is necessary. The thermodynamic structure of the ABL for contrasting sky conditions during different seasons is investigated using CVA by utilizing radiosonde and surface meteorological observations at Meenambakkam (13.0^{o} N, 80.18^{o} E) and the micropulse lidar (MPL) observations at Kattankulathur (12.82^{o} N, 80.04^{o} E) in the year 2018 over Chennai. The double mixing line structures occur throughout the year over Chennai both during the clear and cloudy sky conditions. Sometimes triple mixing lines are also observed mainly during the pre-monsoon and southwest (SW) monsoon seasons. The formation of different mixing lines are due to the dominance of advection and convection during different season. The frequent occurrence of the double mixing lines over Chennai is mainly from restratification of the convective boundary layer (CBL) due to sea-breeze onset as well as cloud layer above the CBL. Whereas, the triple mixing lines mainly account the fair-weather boundary layer (FWBL). In total, 355 observations are collected during 2018, out of which the first, second and third mixing lines occurs 100%, 70% and 14%, respectively. The thermal internal boundary layer (TIBL), CBL and FWBL occur ~ 50%, ~97% and ~30%, respectively. The first mixing line is represented both as the TIBL and CBL, the second mixing lines are represented as by CBL and FWBL and the third mixing line represent only by FWBL. Thus, the longterm changes in the first mixing line can be investigated for understanding the role played for climate changes especially over the coastal region.

Keywords: Transport, CVA, Mixing line

Modulation of climate zones of subdivisions of India in the historical records

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ABSTRACT

The present study assesses the changes of climate zones of India subdivisions in the historical period from 1951-2020 of moving climatological mean 30-years updated every decade in order to reflect the signatures of changing climate as recommended by the World Meteorological Organization. In the context, this study focuses on the timely evolving climatological reference period modulation on the climate zones of India which are estimated based on the Köppen-Geiger climate classification from the observational records of gridded rainfall, minimum and maximum temperatures from India Meteorological Department. India spans six major climate zones as the Köppen-Geiger climate classification i.e., Arid, Semi-Arid, Tropical Monsoon, Tropical Savannah, Subtropical Temperate and Cold Mountain. It is noticed that there are major changes on the Arid and Semi-Arid climate zones in the historical periods 1961-1990 and 1991-2020. The western Saurashtra and Kutch sub-division is changed from Arid region to Semi-Arid region in the recent climate period. Apart from it during current climate period (1991-2020) the eastward extension of Semi-Arid zone extended till East Uttar Pradesh which was till West Uttar Pradesh in past period (1961-1990). In 1991-2020 west Vidarbha and Marathawada sub-division are in Semi-Arid climate zone however during 1961-1990 it was mostly in Tropical Savannah zone. There is a progression in the Tropical Monsoon zones over the sub-divisions Konkan & Goa, Coastal Karnataka and Kerala & Mahe from previous to recent period. The change in Arid and Semi-Arid zone is mainly due to the variation in maximum temperature and minimum temperature. This climate zone shift may affect in future the agriculture side in the West and East Uttar Pradesh sub-division where cultivation of paddy is important of Indian agriculture. Overall, this study enhances our knowledge about changes of climate zones and therefore the IMD forecasting system where their main focus on the Indian agriculture.

Keywords: Climate change, Climate zone, Decade, Sub-division.

Dynamic Cone of Uncertainty using ensemble forecasting of tropical cyclone

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ABSTRACT

The Cone of Uncertainty (COU) depicts the expected track of a Tropical Cyclone (TC), as well as the likely inaccuracy (or uncertainty) in the forecast track. Most of the operational forecast centres issue the COU (associated with the forecast track) based on the predictive skill of the latest few years. Forecasters' input is not considered in prescribing the COU. Since it is based on climatological forecast error the probability of TC track forecast using such a COU is nearly static in nature and does not vary from one case to another. So the flow-dependent predictability of TC track forecast is ignored.
The uncertainty information from the ensemble prediction system can help in producing a flow-dependent dynamic COU. The objective of present work is to build a dynamic COU using multiple member forecasts from National Centre for Medium Range Weather Forecasting (NCMRWF) Global Ensemble Prediction System (NEPS-G) and compare the performance of the ensemble-based dynamic COU with climatological static COU. NEPS-G has 23 ensemble members. The control and 11 perturbed ensemble members have the initial conditions of 00 UTC. The start time of the other 11 perturbed members is 12 UTC of the previous day. Dynamic COU is constructed by, first determining the distances of the cyclone centres of individual member forecasts from the location of centre in ensemble mean forecast. Then these distances are arranged in increasing order to construct the probability circle which is centered at ensemble mean centre and encloses 70 % of the ensemble members. This algorithm of constructing probability circles is followed at each forecast lead time. A smooth surface that touches all the circles of each lead time generate the COU.
Forecast track data from NEPS-G for all cyclonic disturbances with different intensities (deep depression and above) for the period 2019-2021 over the North Indian Ocean (NIO) have been used to determine the ability of dynamic COU generated from NEPS-G forecast in including the observed track with refernce to static COU. The study has been carried out for pre and post monsoon TCs over Bay of Bengal and Arabian sea with both straight and curved tracks.

Keywords: Ensemble Prdiction System, Tropical Cyclone, Cone of Uncertainity, North Indian Ocean, Track.

The seasonal, daily and diurnal variability in UV irradiance using the Micrometer II ozonometer at village Atigre

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ABSTRACT

The highly advanced Microtop II ozonometer has been used for the measurement of ozone over Atigre village near to Kolhapur. Micrometer II ozonometer contains the five optical filters (five channels) for solar irradiance measurements at five different wavelengths (305.5 nm, 312.5nm, 320.5nm, 936 nm and 1020 nm). Out of five, sequentially first three filters are used to measure the ultra-violet (UV) irradiance which are coming from the sun. The UV irradiance a measured in the form of voltage by the photodiodes incorporated in the instrument. Atigre village (16.74°N latitude, 74.37°E longitude, 604 meters altitude above sea level) is placed at low latitude stations and it is a unique station for the atmospheric study since it is covered by many small as well as large scale industries and urban activity. In this work, we have studied the variabilities in the UV irradiance and it's seasonal, daily and diurnally variability for the considered time periods. The inverse relationship between the ozone and UV irradiance is very well known. The increase in UV irradiance indicates the loss of stratospheric ozone concentration. We observed that the UV irradiance is decreased from monsoon to winter and then after it increased towards the summer season. The apparent position of the sun is also responsible for such variation. We also found that the UV irradiance varies daily representing synoptic variation in the ozone and the effects of the weather conditions on the ozone. We have considered some days in a particular month to represent the diurnal behavior of the UV irradiance. The characteristic bell shaped UV irradiance diurnal structure is obtained which shows the seasonal variation in its amplitude. We have discussed the possible mechanism for variation of UV radiations in the Kolhapur region.

Keywords: Microtop-II ozonometer, UV Irradiance.

Machine learning based downscaling for precipitation data

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ABSTRACT

Meteorological data from observations or weather/climate forecasting models usually doesn't have enough detail to get projections at the local level that can help stack holders make predictions and act as soon as possible. One way to solve these problems is the data downscaling. In recent years, the deep learning (DL) algorithm has become a popular tool in the field of earth science. Several DL approaches are used to downscale meteorological data from a coarser to a higher resolution and make more accurate and reliable estimates at local (5 km or even smaller) scales. It has been a challenging task to measure the accuracy of these methods one of them is to compare the downscaled data to point-scale observations. In this work, we employ the DL-based downscaling techniques to estimate the local precipitation data obtained from the India Meteorological Department (IMD). Four different DL methods employed for downscaling to evaluate their performance. In this work, we use precipitation data to train a proprietary VGG network for use in the SR-GAN. The results indicate that SR-GAN is the best method out of four methods used for precipitation data downscaling. Precipitation values at the IMD station are used to verify the accuracy of the downscaled data. This DL approach is a potential substitute for traditional statistical downscaling which can be applied to forecast model output to get local projections.

Keywords: ML-downscaling, VGG model, SR-GAN method, Station data, Kriging method.

Fire prediction with a data-driven deep learning model

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ABSTRACT

Fire incidences have recently increased as a result of climate change and other human-caused factors. Incidents such as stubble burning in Punjab-Haryana, forest fires in north-eastern and central India, and so on, leads to dangerously high levels of particulate matter of aerodynamic diameter smaller than 2.5 µm ($PM_{2.5}$). Timely forecasts of $PM_{2.5}$ can help prevent various air quality-related public health issues, as well as plan ahead of time and implement temporary control measures. However, most of the operational air quality forecasting systems around the world have to employ a persistence assumption for representing fire emissions due to lack of information about future evolution of fires. Under the persistence assumption, near-real-time fire emissions are assumed to be constant for the entire duration of a forecast cycle that can lead to large errors in air quality forecasts if the fire emissions change significantly from day to day. This study aims to fill this gap by forecasting fire emissions for the next 2-3 days using spatiotemporal deep learning models such as the Convolutional long short-term memory (ConvLSTM) model. Using this approach, we are able to get a reliable correlation coefficient which we are attempting to further improve by adding normalised difference vegetation index (NDVI) as input variable during model training.

Keywords: Fire emission, Deep leaning, ConvLSTM, Air quality forecasting

Observed the relationship between rainfall and land surface variables during active/break days

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ABSTRACT

The monsoon rainfall inherently exhibits quasiperiodic intraseasonal oscillations (ISO) that are evident in the sub-seasonal active and break spells of monsoon rainfall over the Indian region Rajeevan et al. (2010). It is generally accepted that such low-frequency variabilities in the land ocean-atmosphere system can be generated through interaction between its components. The land surface influences the climate system at various time and spatial scales. Firstly, the atmosphere is in direct contact with the surface, and the surface conditions act as regulators for important feedback cycles in the climate system. Secondly, the partitioning of net radiation at the surface into sensible and latent heat fluxes determines the soil wetness evolution, which acts as a forcing. In fact, after the sea surface temperature, soil moisture and snow mass are the most essential "memory" mechanisms for time scales ranging from weeks to season. To analyze the observed relationship between rainfall and land surface parameters, ERA5 datasets have been used from the period (1989-2019). Results manifest that, like the rainfall, the soil parameter (soil -moisture and soil temperature) also shows the maximum variance in the low-frequency band (30-60 days). And as we go deeper into the soil layer, maximum variance is observed in the lower frequency band. Also, it is moderately correlated with the rainfall during JJAS, and maximum correlation occurs in the first two layers of the soil moisture (i.e.layer 1 and layer 2). Spatial inhomogeneity in correlation. North of IGP shows a strong correlation at lag 0. The same is observed in soil temperature. We also found that during the active phase of monsoon, soil moisture act as preconditioning to the rainfall. Spatially separated maxima of soil--Moisture and rainfall at the top layer same is true for the next layer also. The bottom two layers are responding inadequately as compared to the top layers. It is clear that the propagation of intraseasonal oscillations provides a spatially inhomogeneous response in terms of rainfall and surface moisture, and it could be related to the soil type.

Keywords: Soil-moisture ,Active/break phase , intraseasonal oscillations (ISO)

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Characterization of Aerosol Optical Properties and Its Classification Over Indian Region

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ABSTRACT

This study analyzed the spatiotemporal variation of aerosol optical characteristics over polluted Indian cities. The remote sensed daily Aerosol optical depth (AOD), Angstrom exponent (AE), Aerosol index (AI), and Single scattering albedo (SSA) values of MODIS and OMI are obtained for the Indian area. India classify under the Northwest, West, North, Central, East, Northeast, South zones are extracted into seven regions. During Study period from October 2004 to September 2019 Maximum daily AOD is 3.5 in Kolkata's East Region and minimum 0.01 in Dehradun's North Region. Maximum value of AE is 1.8 at multiple study locations, and minimum value is 0.0005 in Silvassa, West Region. Similarly, the maximum value of AI in Gangtok city's Northeast regions is 6.6 and all regional zones have an AI value of 0.5, while the maximum SSA value is 0.999 for the multi-zone city of Dehradun, Dispur, Shimla, Daman diu, and Silvassa. The minimum SSA value is 0.884 for the South Region in Port Blair. Aerosol classification based on AOD, AE classify aerosols (marinetime, Dusty, Urban, Biomass Burning). Maximum values in marinetime in (94%) Shimla city Northeast zone and minimum value in (8%) New Delhi city North zone. Maximum values in Dusty in (30%) Lucknow North zone and (0.1%) across multiple study locations. maximums value in urban (45%) and minimum (4%) in Mumbai West zone Northwest Shimla Biomass Burning maximums (50%) in Patna East zone and minimum (0%) Southport Blair. Here classify seasonal classification based on AOD, AE, where (Winter, Pre monsoon, Monsoon, post monsoon) the maximum percentage is marinetime in Winter, (63 %) Northwest zone, and minimum are (30%) East zone. Pre monsoon Central zone has the most marinetime (59%) and North zone the least (25%). Monsoon marinetime is (55%) in the Northwest and (16%) in the East. Post-monsoon has the maximum marinetime (78%) in Northwest and minimum (27%) in North. Maximum and minimum dust in winter (5%, 0.4%) west and central, pre monsoon (46%,4%) north and Central,monsoon(40%,10%) Central and Northeast. South and Central post-monsoon (14%, 0.63%). Zones like Urban and Biomass Burning

Keywords: Aerosol Optical Depth, Aerosol Type, Spatiotemporal Variation

SRGAN: A Deep learning method for Meteorological data downscaling

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ABSTRACT

Generally, the meteorological data obtained from observations or weather forecasting models is available at a coarse resolution, limiting its utility for local-level studies and planning. To solve these problems, data downscaling techniques are used for resolution enhancement. The recent success of deep learning in the earth science domain motivates the use of DL-based downscaling methods. In this study, we use and compare four DL methods for downscaling of precipitation data over the Indian region. We first trained the DL models (DeepSD, Augmented ConvLSTM, DCN UNet, and SRGAN) for 4x downscaling from 1° to 0.25°. The downscaling results indicate that SRGAN performs relatively better than other methods. SRGAN is a deep generative model composed of a generator and a discriminator network. These networks are trained in an adversarial setting to achieve data downscaling. SRGAN recovers finer details for large scaling factors accredited to its loss function called perceptual loss. We developed a custom VGG-based feature extractor trained on precipitation data to aid the training of SRGAN. Such a feature extractor can be utilised in other works that use DL for meteorological data. It also addresses the problem of smooth generation faced by other MSE and RMSE based models. We use SRGAN to downscale data from 0.25° to 0.125° and 0.0625°. We evaluate the generated local precipitation projections using the station observations from the India Meteorological Department (IMD). Notably, the downscaling results using SRGAN have a high degree of congruence with the observation data from IMD. Our research shows that SRGAN is a reliable and robust model for data downscaling. It has the potential to replace existing statistical downscaling models for meteorological data downscaling.

Keywords: ML-downscaling, VGG model, SR-GAN method, Station data, Kriging method.

IMPACT OF BLACK CARBON AEROSOLS IN THE RAINFALL DISTRIBUTION OVER CHENNAI (12.81°N,80.03°E)

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ABSTRACT

Black carbon (BC) aerosols are one of the anthropogenic aerosols that can influence the atmospheric stability. Also, the BC can make an impact in the rainfall by modifying the atmospheric processes. In the present work, we study the relationship between aerosols and atmospheric process causing rainfall. Aerosol optical depth (AOD) from MODISTerra and Aqua satellite, surface Black Carbon mass concentration (BC) from Aethalometer (AE-31) along with the rainfall (IMD) and Lower Tropospheric Stability (LTS) from radiosonde observations, Outgoing Longwave Radiation (OLR) from ERA5 were used in this study. We used time series analysis, Wavelet Coherence (WTC) technique and Principal Component Analysis (PCA) to study the objectives. The study has been carried out for the north-east monsoon (Oct-Dec) of 2011to 2019 over SRM IST location (12.81°N,80.03°E). Our results show that i) a connection of aerosol with the atmospheric stability and thus cause the rainfall, ii) more dependence of LTS on rainfall compared to OLR, which is a proxy of convection and iii) BC aerosols show 14% of variability in rainfall over the study location.

From the results it is clear that BC is affecting the rainfall distribution. That is during rainfall BC is washed out from the atmosphere. Similarly, if the black carbon concentration is high, there shows a decrement in the amount of rainfall distribution. The results of the study are useful in rainfall prediction and projections.

Analyzing Effect of Lockdown during COVID-19 on Aerosol Concentration over Major Cities of Gujarat

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ABSTRACT

Aerosols contribute significantly to the atmospheric conditions directly and indirectly. Covid-19 lockdown was a unique opportunity to assess its anthropogenic contribution. Present study is done over Gujarat as it is a far away region from the coastal effects while representing gateway to the the South-west monsoon. Also only major cities are considered as the aim was to study anthropogenic contribution. So to understand aerosol variability within the region, four different cities from four separate zones categorized by Central Pollution Control Board have been selected (Surat from zone 1, Ahmedabad from zone 2, Rajkot from zone 3 and Bhuj from zone 4). Present study has utilized satellite retrieved Aerosol Optical Depth (AOD) from Moderate Resolution Imaging Spectroradiometer (MODIS) onboard Terra during pre-covid (2010-2019), covid (2020) and post-covid (2021). Variation in AOD shows a significant decrease over all the cities i.e. over Ahmedabad (-28% to -54%), Rajkot (-19% to -31%), Surat (-17% to -26%) and Bhuj (-20% to -18%) during April-May of 2020 with respect to past ten years average. Also, to know an immediate impact of lockdown, comparison is done with only one year of pre-covid (2019). Results show a notable reduction in AOD with a drop of -53% over Ahmedabad, -22% over Rajkot and -16% over Surat, except Bhuj during the month of May 2020. In April, 2020 observations doesn't show noticeable fall in AOD for all cities except Surat as lockdown was just implemented in the end of March, 2020. Detailed zone wise results will be presented to understand variability of various aerosol properties along with meterological conditions. Such studies may be useful to determine regional heterogeneity during lockdown period which may be helpful to support the clean atmosphere in the coming future if necessary.

Keywords: Aerosol optical depth, COVID-19, MODIS, Regional variability.

Comparative Study of Thunderstorm Events using Ground Observations and WRF-ARW Model

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ABSTRACT

Anthropogenic forcings in the environment are one of the primary causes of the altered land surface dynamics, processes and microclimate. Tropical countries experience wide range of climatic extremes such as thunderstorms due to their unique topographical position, solar insolation, oceanic circulation among many other determining factors. Southeast Asian countries, and India to be specific, have essentially agrarian based economies which is completely dependent on weather and water availability. For Eastern India, the Chotanagpur plateau region comprising of Ranchi experiences frequent thunderstorms in the Pre-monsoon months accompanied by lightning, thunder and rain with occasional hailstorms. These storms are a menace to life and property but are also useful to farmers as the summer rains soften the soil and help in tillage before the monsoon arrives. This study was aimed at combining ground-based observations of fluxes and wind components, and comparing them to the model-based observations of WRF- ARW 3.9 model. The micrometeorological tower at BIT Mesra was used to collect observations of temperature, sensible heat flux, turbulent kinetic energy and wind circulation patterns. These data belonged to 2 cases - one of hailstorm in May 2009 and another of thunderstorm in the same month. Wind circulation pattern and temperature were depicted accurately by the model and was corroborated by the ground-based observations in both cases. Similarly turbulent kinetic energy, heat fluxes were also well represented for the area. Cloud water mixing ratio simulated by the model did not yield satisfactory results. WRF-ARW model was found to be well suited for simulation of short term climatic extreme events such as thunderstorm and hailstorm as the results were in consonance with ground observations. Finally, in cases where there is a lack of ground-based observations, models such as WRF-ARW can be an effective tool for researchers to study climatic processes.

Keywords: Thunderstorms, Flux, Turbulence, WRF-ARW, extreme events

Estimation of Precipitation Concertation Index (PCI) over India for the past 120 years

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ABSTRACT

The Precipitation Concentration Index (PCI) (Oliver et. al; 1980) is a powerful indicator for the temporal and spatial distribution of precipitation and also very useful for the assessment of annual and seasonal changes in precipitation. In this study we have analyzed the precipitation distribution across India for the past 120 (1901-2020) years by using IMD's daily gridded rainfall data. The results show that, there is a large variation in PCI across India during the study period. The highest PCI is observed in the state of Diu and Daman (27.09%) and lowest is observed in Ladakh (9.81%) which shows that in Diu and Daman there is extremely irregular distribution of precipitation and there is a uniform distribution of precipitation for Ladakh. The annual and seasonal PCI values over India, indicates that, Goa contributes high PCI in pre-monsoon season contributes with the value of 27.87% and the low value (8.63%) was observed in Ladakh. Whereas in the southwest monsoon Mizoram (10.55%) gets extremely irregular precipitation distribution and Maharashtra (8.4%) with less values of PCI and more uniform distribution in precipitation. And in northeast monsoon season, it is observed a regular distribution pattern in precipitation in Meghalaya with high PCI (18.49%) values and Tamil Nadu is having uniform distribution of precipitation with less PCI (8.92%). Hence, most of the meteorological sub-divisions (34) of India, comes under moderate and irregular distribution for both annual and seasonal PCI.

Keywords: Precipitation, PCI, Uniform distribution, Regular and Irregular distributions.

How vulnerable are the people working in Indian coastal cities under climate change scenarios?

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ABSTRACT

Climate change affects the living and working environments and poses the threats to human health. An increase in heat stress due to climate change results in the loss of global productivity equivalent to 80 million jobs in future (International Labor Organization (ILO, 2019). Our earlier results found that the Indian coastal regions are the most vulnerable to the increased heat stress levels and its associated decline in work performance (doi.org/10.1038/s41598-020-73245-3). In the present study, we use the data sets of the Indian Monsoon Data Assimilation and Analysis (IMDAA) for the estimation of heat stress over different Indian coastal locations for the period 1981 to 2020. Further, the decline in work performance due to heat stress was calculated for the respective locations using the data sets of IMDAA as well as the down scaled simulations of IITM-ESM (NEX-GDDP with 0.25° resolution) for the period 1981 to 2050 under SSP2-4.5 and SSP5-8.5 future climate change scenarios. Further, heat stress values for the corresponding wet bulb globe temperatures' thresholds for work performance relative to metabolic rates have been estimated for the study locations. Our results report that relative humidity plays key role in heat stress over the west coastal locations while the temperature contributes more in the east coastal locations. The decline in work performance is high in the east coast compared to west coast. Work performance based on the body metabolic rates suggests that the work breaks are essential to the people working in open environments.

Keywords: Climate change, heat stress, work performance, CMIP 6, IITM -ESM

Quantitative assessment of real time lightning forecast made with lightning parameterization schemes coupled with WRF Model

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ABSTRACT

Accurate prediction of lightning remains a challenge due to the spatio-temporal scale involved. With a view to develop an in-house lightning prediction system for the Indian subcontinent, research has been carried out by the authors by implementing the dynamical lightning parameterization (DLP), in a high-resolution model, namely Weather Research and Forecasting (WRF). With the availability of observed lightning measurements over India based on Lightning Detection Network by IITM, the validation of the lightning forecast over entire Indian region is carried out. Lightning parameterization based on cloud top height defined by a reflectivity threshold factor of 20 dBZ is chosen. Initial analysis is carried out on the real time lightning forecast for the pre monsoon years 2019-2020. The skills are evaluated for 10- and 50-km2 boxes from the 1-km domain. All the months showed a decent spatial agreement with minimum of 0.63 (63%) for the month of May 2020 and maximum agreement of 0.81 (81%) in March 2020. Overall, the number of grid boxes (at 3-km resolution) that match spatially is approximately 72% for the duration of five pre-monsoon months. The model skill score shows an average POD of 0.90, FAR of 0.64, hit rate of 0.57, and POFD of 0.50 over the whole region for all months. A decent spatial agreement ranging from 0.63 (63%) to 0.81 (81%) is obtained from the real-time lightning forecast.

Keywords: Lightning Parameterization, Skill Score, Lightning Flash, WRF

Role of surface and subsurface oceanic conditions in generation of cyclones over Arabian Sea using Artificial Neural Network

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ABSTRACT

Genesis and intensification of tropical cyclone over Arabian Sea is induced by coupling process between atmosphere and ocean at surface and subsurface level. In the present study, daily latent heat flux data (1^0 x 1^0),Extended Reconstructed SSTv5, Hadley Centre Global Sea Ice and Sea Surface Temperature (HadISST) monthly data (1^0x1^0), Argo data from INCOIS (2004-2020), best track data from IMD were used from 1981-2020. Later, energy indices like ACE and PDI were used to identify the tropical cyclone intensity and devastation impact over Arabian sea from 1983-2020. In methodology the ANN back propagation Levenberg–Marquardt learning algorithm for network training was applied to different tropical cyclone parameters namely SST, LHF, SHF, MLD, TCHP.The ANN algorithm applied namely training,validation, testing and forecast. First, the regression equation was developed based on frequency of tropical cyclones(FTC) and ACE and very well coincide at epoch 21,with 0.65 in training state while validation and test case, the regression is 0.96,and 0.94 respectively for forecast is 0.61. The same criterion applied to PDI and best performed at epoch 15 (0.62) in training state,0.72 in validation, 0.57 for forecast while PDI is not well coincide in testing period(0.12). The R values between FTC and SST is 0.68 in training, 0.85 in validation and 0.58 in all with best performance at 9 epoch. The regression value of LHF and FTC is 0.62 in training state,0.44 in validation ,in testing it was -0.25 but for forecast, it is 0.63 with best performance at epoch 6.The performance of ANN is further validated by comparing with the observations. The number of cyclone formation over Arabian Sea is much associated with LHF (~0.63) and then SST (~0.58) and these results are much helpful for tropical cyclone forecasting.

Key words: Artificial neural network (ANN), Accumulative cyclone energy (ACE), Potential dissipative index (PDI), Levenberg–Marquardt algorithm

Electrical characteristics of thunderstorms under different weather conditions in the Kashmir valley, India

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ABSTRACT

The surface measurements of atmospheric electric field at the University of Kashmir, Srinagar (34° 13' N, 74° 83' E, 1585 m amsl) and Gulmarg (34° 05' N, 74° 39' E, 2617 m amsl) in Kashmir valley from March 2018 to August 2020 are analysed to understand the behaviour of electric field during precipitation, snowfall, and fog. The maximum thunderstorm activity observed in May, June, and July is attributed to the higher amount of moisture transport from the Bay of Bengal during the monsoon and its transition period. Several severe convective thunderclouds associated with the positive end-of-storm-oscillations and an inverted dipole structured clouds are also reported and explained using INSAT- 3D satellite cloud properties. In addition, the observation of mirror images and 90-minute periodic oscillation in the potential gradient (PG) are explained in terms of the charge impact carried by raindrops during the precipitation and suspended snowflakes in snowfall episodes. It is also observed that the particulate matters significantly (~70 %) modulate the PG even within the diurnal scale and orographic lifting and mountain-valley wind circulation affect the PG measurement in all-weather conditions.

Keywords: Thunderstorms, Potential gradient, Fair-weather, Atmospheric electric field, Rainfall, Snowfall, Fog

On the hybrid deep learning model for NEE seasonal forecasting: Implications to understand the biosphere-atmosphere interactions

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ABSTRACT

Terrestrial ecosystems play a crucial role in the global carbon cycle and climate change mitigation as a major sink of carbon. The atmospheric carbon exchange of any ecosystem is defined as the net ecosystem exchange (NEE) which is important to be accurately estimated for ecosystem health monitoring, climate change mitigation and impact assessment. Future projections of NEE using the traditional vegetation models heavily depend on our understanding of the underlying coupled plant physiological, biogeophysical and biogeochemical processes such as photosynthesis, radiation limitation etc. which in turn require measurements of multiple variables which are mostly unfeasible or unavailable over the Indian subcontinent due to insufficient observations. Moreover, running such process-based models can be computationally expensive. This region, however, remains highly vulnerable to climate change, which underlines the need for a NEE modelling framework. To address this problem, we propose harnessing the benefit of AI/ML using the available reanalysis and remote sensing datasets. In this study, we develop a deep learning model for the seasonal forecasting of NEE over the Indian subcontinent. Using the UNet and ConvLSTM algorithms, we construct a hybrid model capable of capturing the spatial and temporal dependencies. In addition, we incorporate a temporal attention mechanism that allows the model to learn about long-term time dependencies. Along with NEE, taken from the global Fluxcom database, the inputs for this model are meteorological and soil variables derived from ERA5 and GLEAM datasets. This improves the model's understanding of the underlying physics and enables a more accurate forecast. We train the model using 25 years of data (1980–2005), test during 2006–2013, and use the refined Willmott's Index as its performance evaluation metric. Our model is able to simulate the NEE 6 months in advance with high confidence, whereas the model forecast has spatial correlation of 0.75 with ground truth.

Keywords: Hybrid DL model, NEE forecasting, Climate mitigation, Carbon cycle

Estimation of Atmospheric Boundary Layer Height using 205 MHz VHF radar at a tropical station Cochin

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ABSTRACT

The atmospheric boundary layer height (ABLH) is viewed as the height where atmospheric turbulence diminishes upward from the surface. Knowledge of the ABLH and its temporal fluctuations is essential for understanding the exchange of heat, moisture, momentum and transport of atmospheric constituents between the Earth's surface and the free atmosphere. The present study investigates the ABLH over a tropical site, Cochin using the VHF radar at the Advanced Centre for Atmospheric Radar Research (ACARR), Cochin University of Science and Technology along with concurrent radiosonde observations. Clear sky days of the year 2021 have been used for this study, provided for which both the radar and radiosonde datasets are available. The reference ABL Height is obtained from the mixing ratio profile and its gradient from the radiosonde data. A novel method has been devised to estimate the ABLH from the radar by combining the profiles of three parameters, viz. signal to noise ratio (SNR), wind speed (WS) and wind direction (WD). The ABLH is identified as that height at which the sum of the normalized standard deviations (NSD) of the three profiles peaks and subsequently drops immediately above it. This method has been verified against the ABLHs estimated from four other variables from the radiosonde, and a strong correlation (r=0.901 at 99.9% confidence level, N=35) between the ABLH derived from Radar and Radiosonde has been observed. This study extends ample opportunity in exploring the high temporal variability such as the diurnal cycle of ABLH from the Radar unlike radiosonde measurement which are sparsely available.

Keywords: Atmospheric Boundary Layer, 205 MHz VHF radar, Radiosonde

TREND ANALYSIS OF ATMOSPHERIC TEMPERATURE AND POSSIBLE SHIFTING IN CROPPING PATTERNS

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ABSTRACT

The inter annual variations the mean atmospheric temperature is studied with respect to the changes in the Growing Degree Days (GDD) of various major food grain crops namely rice, wheat, sorghum in the projected climate scenarios. The results show that, an increasing trend in the GDD is observed for these crops over the Northern India than Southern India. Hence, the crops growing in Southern parts of India may have a shift to Northern parts of India due to the change in the average atmospheric temperatures in the projected climatic conditions. The crop planning could be done with respect to the spatial and temporal variations in the temperature, which would help in increasing the productivity of the crops in the projected climate.

Key words: GDD, Rice, Wheat, Sorghum, Crop planning.

Simulation of extreme seasonal rainfall over India in current seasonal coupled models

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ABSTRACT

In the present study, we have assessed the fidelity of seasonal prediction coupled models to simulate the seasonal extremes (June through September; JJAS) over the Indian region from 1981-2018. For this, we have obtained retrospective state/re-forecast/hindcast simulations (10 ensembles mean) with February and May initial conditions from Northern American Multimodel Ensemble (NMME) and Climate Forecast System version 2 (CFSv2) models. It is noticed that all models show significant seasonal dry bias over the Northern and west coast of Indian regions (associated with northerly wind bias at lower troposphere), whereas strong wet bias over the southeastern Indian region which is associated with cyclonic circulation (at 850 hPa) over the central Bay of Bengal in both lead times. From February hindcasts, CFSv2 has more dry bias over India compared to the other NMME models due to strong northerly wind bias over the Northern Indian region and strong cyclonic circulation over the North West Pacific region, whereas, that dry bias is reduced significantly over the Northern Indian region in all models except GEM_NEMO in May simulations. All NMME models are not able to reproduce orographic (i.e., west coast and northeastern parts of India) rainfall over the Indian sub-continent compared to the CFSv2 in both initial conditions. It is noticed that many models are not able to estimate the deficient and excess years of rainfall over the Indian region mainly due to the misrepresentation of ascending and descending branches of Walker circulation over the tropical region during the extreme years. Majority of the models are not able to capture the extreme years that are associated with El Nino southern osciallation, Indian Ocean dipole mode and Atlantic Nino boundary forcings, while the observed normal years which co-occure with these boundary forcings are reperesnted as excess years in the models. Different categorical skill scores suggest that, all models can capture the normal years only as similar to observations whereas deficient and excess years have more false alarms. Overall, this study reveals that the CFSv2 model reasonably captured the observed deficient and excess rainfall (seasonal extremes) over the Indian region compared to the NMME models with February simulation during the summer season. In contrast, NMME models better simulate mean features and seasonal extremes of ISMR with May simulation than February.

EVAPOTRANSPIRATION BASED INDEX AS A POTENTIAL PREDICTOR OF INDIAN SUMMER MONSOON RAINFALL

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ABSTRACT

Indian Summer Monsoon, the most prominent of the world's monsoon systems, which primarily affects India and its adjacent countries. In this study we have developed an Evapotranspiration based index namely the E_Index, as a potential predictor of Indian Summer Monsoon, by taking product of the Evapotanspiration, Surface temperature, and the Mean Sea Level Pressure. Using this index the spatial and temporal correlations have been obtained with the precipitation in order to understand the inter annual variabilities of the Indian Summer Monsoon rainfall in both historical (1991-2020) and projected (2021-2050) climatic scenarios. The results show that, there is a significant positive correlation between precipitation and E_Index for all the historical periods except, in central India and Himalayan regions during 1991-2005. And in the projected climate, there is a significant positive correlation between precipitation and E_Index for all over India except, the Himalayan and the Eastern India during the period 2021-2050.

Key words: E_Index, Evapotranspiration, South West monsoon, Precipitation.

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Marine layer cloud simulations in the Southern Indian Ocean

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ABSTRACT

In this study, a suite of nine Weather Research and Forecasting (WRF) model simulations is conducted using various choices of local and non-local representations of vertical mixing adopted in the planetary boundary layer (PBL) parameterizations to assess the boreal summertime marine layer cloud environment in the southern Indian Ocean (SIO). The local, non-local and hybrid type PBL schemes used in the simulations are generally able to produce the pertinent features of marine layer embedded with stratocumulus clouds in the SIO region, viz, nocturnal coverage of low clouds with warm cloud tops, well-mixed marine layer etc as conceptually envisaged in earlier investigations. However, there is a large spatial variability noticed in the simulated low-clouds over the SIO region. The simulated cloud liquid water paths show a large mesoscale variability exhibiting a range of values between 0.04 and 2.8 mm corresponding to cloud depths as small [high] as 200 [1700] m. It is further noticed that LWPs reproduced from hybrid PBL schemes employed with Eddy Diffusivity Mass Flux (EDMF) formulation are closer to observed estimates.The model representation of PBL processes appears to have more bearing for this spatial variability than from the choice of microphysical representation of cloud processes used in the simulations. While the non-local PBL mixing schemes tend to produce more organized sheeted low-cloud layers, the prognostic turbulence kinetic energy formulations included PBL schemes tend to produce more discreteness in the low-cloud decks and also exhibit substantial cloud depth variability. Also, the coupling of in-cloud turbulence in association with cloud-top radiative cooling and sub-cloud layer turbulence are not uniquely reproduced by these schemes. This study suggests non-local type of PBL parameterizations in global/regional climate simulations can promote better realism of low cloud production in the SIO region, and also can provide superior marine layer cloud-climate feedback estimates.

Keywords: Climate change, Low Clouds, Southern Indian Ocean.

INFLUENCE OF THE CONVECTIVE SYSTEMS FORMED OVER NORTH INDIAN OCEAN ON THE CONVECTIVE PRECIPITATION OVER INDIA

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ABSTRACT

The Convective Precipitation anomalies for the periods of the convective systems formed over North Indian Ocean (Arabian Sea and Bay of Bengal) has been obtained for the recent decades from 1979-2021. The results show that, the Convective Systems such as Depressions, Cyclones and Severe Cyclones are highly influencing the local Convective Processes and Precipitation over various regions in India. The composite of the Convective Precipitation is made for various climatic episodes namely the El Niño, La Niña, Positive IODs, Negative IODs, etc. It further results that, the Convective Precipitation is significantly influenced by the intensity variations of the Convective Systems over the North Indian Ocean with respect to these climatic episodes.

Keywords: Convective systems, Convective Precipitation, Tropical cyclones, ENSO and IOD.

Comparative Analysis of Soil Parameters during Landfall of Deep Depression System, using WRF and NU-WRF

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ABSTRACT

The accuracy of modeling various land-air-sea interactions can be improved by considering the insitu land surface states. Since the spread of soil moisture observatory stations is scarce, NASA's Land Information System (LIS) is used to generate the initial state of the soil. The modeling of Deep Depressions during landfall at the Head Bay of Bengal (BoB) basin is done using a stand alone ARW-WRF modeling software and NASA Unified WRF (NU-WRF) modeling system, where the input of initial state of the soil for the latter model is provided by LIS. The result of NU-WRF and WRF simulations for the same Deep Depression are compared at the time of landfall of the system.

The Deep Depressions under study propagate towards the Central Indian region post landfall over the Head BoB. Two different cases of study are used in this study, the first case which is during the onset of Indian Summer monsoon and the latter during the monsoon season. The landfall of the systems under study are between 09:00 UTC and 12:00 UTC on 16th June, 2011 for the first case, and between 09:00 UTC and 12:00 UTC on 17th August, 2016 for the second case respectively.

The comparison between the forecast models is through the simulation of near surface soil moisture and soil temperature fields. The soil moisture results at time of landfall show higher values for the WRF model as compared to NU-WRF model, where as the soil temperature shows higher values for the NU-WRF model as compared to WRF model. The above differences in the behavior of the results of NU-WRF model as compared to the WRF model is consistent with expected behavior.

The results of the modeling study indicate strong correlation with Heat fluxes, surface air temperature and PBL height for both the individual model results.

Keywords: LIS, NU-WRF, Deep depression, Soil Moisture, Soil Temperature.

INFLUENCE OF THE CONVECTIVE SYSTEMS FORMED OVER NORTH-WEST PACIFIC OCEAN ON THE CONVECTIVE PRECIPITATION OVER INDIA

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ABSTRACT

The Convective Precipitation anomalies for the periods of the Tropical Storms and Typhoons formed over North West Pacific Ocean has been obtained for the recent decades. The results show that, the Convective Systems such as Tropical Depressions, Tropical Storms and Typhoons are highly influencing the local Convective Processes and Precipitation over various regions in India. The composite of the Convective Precipitation is made for various climatic episodes namely the El Niño, La Niña, Positive IODs, Negative IODs, etc. It further results that, the Convective Precipitation is significantly influenced by the intensity variations of the convective systems over the North-West Pacific Ocean with respect to these climatic episodes.

Keywords: Tropical Storms, Convective Precipitation, Tropical Depressions and Typhoons, ENSO and IOD.

INFLUENCE OF THE CONVECTIVE SYSTEMS OVER NORTH-EAST PACIFIC OCEAN ON THE CONVECTIVE PRECIPITATION OVER INDIA

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ABSTRACT

The Convective Precipitation anomalies for the periods of the Tropical Storms and Typhoons formed over North East Pacific Ocean has been obtained for the recent decades. The results show that, the Convective Systems such as Tropical Depressions, Tropical Storms and Typhoons are highly influencing the local Convective Processes and Precipitation over various regions in India. The composite of the Convective Precipitation is made for various climatic episodes namely the El Niño, La Niña, Positive IODs, Negative IODs, etc. It further results that, the Convective Precipitation is significantly influenced by the intensity variations of the Convective Systems over the North-East Ocean with respect to these climatic episodes.

Key words: Tropical Storms, Convective Precipitation, Tropical Depressions and Typhoons, ENSO and IOD.

TEMPERATURE BASED INDEX AS A POTENTIAL PREDICTOR OF INDIAN SUMMER MONSOON

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ABSTRACT

Indian Summer Monsoon Rainfall is a component of the South Asian monsoon system, one of the most worldwide occurrences of the general circulation, which affects the weather and climate around the world. In this study the spatial and temporal correlations have been analysed with a Precipitation and Temperature based Index namely T_Index. This index is developed by taking the product of the Near Surface Air Temperature, Latent Heat Flux and Mean Sea Level Pressure, in order to understand the inter annual variability of the Indian Summer Monsoon Rainfall for both the historical (1991-2020) and projected (2021-2050) climatic scenarios. The Results show that, in historical periods there is a highly positive correlation between T_Index and Precipitation throughout India except, during 1991 to 2000 in central and some eastern parts of India. And there is a positive correlation between the T_Index and Precipitation throughout India except some regions of north-eastern parts of India in the projected climatic scenario.

Key words: T_Index, Temperature, Historical and Projected climatic scenarios, South West Monsoon, Precipitation,

HUMIDITY BASED INDEX AS A POTENTIAL PREDICTOR OF INDIAN SUMMER MONSOON RAINFALL

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ABSTRACT

Indian Summer Monsoon Rainfall (ISMR) which is a part of the south Asian monsoon system, undergoes significant temporal and spatial variations. It is one of the largest global phenomena of the general circulation that has its impacts on the global weather and climate, and the life of millions of Indians. In this study we have developed a Humidity based index namely the H_Index, by taking product of the Near surface specific humidity, Outgoing longwave radiation, and the Mean Sea Level Pressure, in order to forecast the Indian summer monsoon rainfall. Using this H_ index the spatial and temporal correlations have been obtained with the precipitation in order to understand the inter annual variabilities of the Indian Summer Monsoon rainfall in both historical (1991-2020) and projected (2021-2050) climatic scenarios. The results show that, there is a significant positive correlation between precipitation and H_Index on the central and northern regions of India. And it shows high positive correlations all over India during the period of 2006-2010. In projected climate, there is a significant positive correlation between precipitation and H_Index in the central parts of India. And it shows a positive correlation in both central and north western parts of India during period of 2041-2050.

Key words: H_Index, Humidity, South West Monsoon, Precipitation.

Investigating the Atlantic-Indian summer monsoon multidecadal teleconnections in the PMIP3 Last Millennial simulations

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ABSTRACT

Understanding the natural variability of Indian summer monsoon (ISM) is a crucial aspect relevant for decadal climate predictions and climate change studies. The multidecadal variability of ISM is known to have a close association with the Atlantic multidecadal oscillations (AMO). Several teleconnection pathways have been suggested to explain the co-variability of the AMO and ISM in multidecadal timescales. One hypothesis is that the AMO modulates the interannual North Atlantic Oscillation (NAO) mode and there by influences the monsoon via Eurasian temperature modulations. Another possibility is the AMO modulating the monsoon via the Pacific pathway through the atmospheric bridge mechanism and associated modulations of the Hadley-Walker circulations. The Last millennial (850-1850) climate simulations part of the PMIP3 gives an opportunity to better understand the fidelity of climate models in capturing the AMO-ISM teleconnection mechanisms. In this study we explore how well the proposed mechanisms are represented in eight global climate models (GCM) LM simulations. Such a study, assessing the validity of different AMO-monsoon teleconnection mechanisms in different model climates provides crucial information about how reliable the respective GCMs may be in making decadal climate predictions.

Keywords: Atlantic Multi-decadal Oscillation, Monsoon multi-decadal variability, AMO-ISM teleconnection, PMIP3, Last Millennial simulations

The cloud evolution characteristics of Monsoon Intraseasonal Oscillation

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ABSTRACT

Monsoon Intraseasonal oscillation(MISO), with the 20-90 day periodicity, is characterised by the northward propagation of clouds and rainfall from the equatorial Indian Ocean towards the Indian Land region. The general cloud evolution associated with the MISO over Indian Summer Monsoon(ISM) domain is characterised by the shallow clouds leading to mid-level clouds followed by the deep convective clouds. This study uses passive and active sensor-based cloud products to examine the cloud evolution characteristics linked to MISO over the various ISM subregions. The findings imply that there are differences in the MISO cloud evolution over ISM subregions. In particular, the cloud evolution over the central Indian region is different from that over the oceanic regions surrounding the Indian land region. The rainfall evolution over the different ISM subregions considered also reflects these differences. These results suggest that along with a proper representation of MISO cloud evolution, its regional differences also should be incorporated into the models for a better simulation of MISO.

Keywords: Monsoon Intraseasonal Oscillations, Indian Summer Monsoon, Clouds

Surface $PM_{2.5}$ estimation using machine learning and remote sensing

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ABSTRACT

Fine particulate matter ($PM_{2.5}$) has received a widespread attention all over the world because of its direct association with the degradation of air quality and the related human health effects. The regular monitoring of $PM_{2.5}$ concentrations is critically necessary to analyze their aftermath effects but the limited number of ground based air quality monitoring stations acts as a barrier in the evaluation of space-time dynamics of air pollution. This study is conducted to estimate the ground-level concentrations of fine particulate matter from statistical models developed using algorithms of machine learning (ML) incorporating satellite measurements. A total of four ML (Random Forest, Extra Tree, Light Gradient Booster and Gradient Booster) models were developed for Kanpur city using MERRA-2 (Modern-Era Retrospective Analysis for Research and Applications) aerosol products (AOD, AE and $PM_{2.5}$ mass concentrations) to estimate the ground-level $PM_{2.5}$ concentrations from Jan - Dec 2021. The ML models were pre-trained using the MERRA-2 reanalysis dataset of the previous five years (2016-2020) along with surface measurements of $PM_{2.5}$ provided by CPCB. Good positive correlation (r) values were obtained during the training (R ~ 0.81) as well as the testing of models (R ~ 0.78). The hyper-tuned models provided good correlation coefficients obtained from the regression analysis of estimated and observed values accompanied with moderate Root Mean Square Error (RMSE) and Mean Absolute Error (MAE values). The Gradient Booster model showed highest correlation coefficient (r) = 0.785 and lowest RMSE (52.01 $\mu g\ m^{-3}$) but with overall underestimated values. However, in further studies, the more in-depth validations will be required.

Keywords: MERRA-2, Fine particulate matter ($PM_{2.5}$), machine learning methods, AOD

Tmax and Tmin Future Projected Changes in CMIP6 Model Simulations of Different Emission Scenarios over Central India

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ABSTRACT

Changes in the maximum temperature (Tmax) and the minimum temperature (Tmin) are seen all over the world during the summer and winter seasons, respectively. Under a changing climate, further warming is anticipated in the near and far future. In the simulation of CMIP6 models under various emission scenarios, the current study aims to discuss the projected future changes in Tmax and Tmin for December, January and February (Winter Season) and March, April and May (Summer Season) over Central India. The CMIP6 framework includes numerous model runs. However, we tried to choose the models that had a spatial resolution that was comparatively higher (1° x 1° or less) and includes CNRM-CM3, EC-EARTH3, EC-EARTH3-Veg and MPI-ESM 1-2-HR. The Central Indian regions were included for the current study and the model evaluations were performed for the historical period 1970–2014 (45 years). The central India region includes East Madhya Pradesh, West Madhya Pradesh, Chhattisgarh, and Vidarbha have been considered for the CMIP6 model's evaluation. Further, the socio-economic scenario assumptions from Shared Socio-economic Pathways (SSPs) of SSP1-2.6 and SSP5-8.5 are carried for the climatological period of 2020–2064 and the projected future changes in Tmax and Tmin over the region of interest was carried out. For the months of March through May, it was found that the Tmax in the regions under the SSP126 and SSP585 scenarios could increase by 0.5 to 1 °C. Further, in comparison to historical period, a warming of 1.5 °C to 2.0 °C may be observed over the regions in March month. Similarly, central India may experience a warming of 2 to 2.5 °C in the winter months of December, January, and February. Hence this may be concluded that the part of central India may face more warmer summers and less cold winters in the upcoming future and this could impact the agricultural practices, water resources, and human health.

Keywords: CMIP6; Temperature; SSP; Future Projections

Western Ghats rainfall decadal variability and associated physical processes

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The Western Ghats (WG) is a vast montane forest ecosystem known for its biodiversity and endemism. The present study examined the variability of summer monsoon rainfall over the WG using century (1900-2010) long observed rainfall data. Spectrum and wavelet analysis of rainfall observation reveal significant decadal variability (at 90% confidence level) in WG rainfall. The decadal variability of WG summer monsoon rainfall is higher than in most of the other regions of India. Wavelet analysis also revealed that in the recent period, the amplitude of decadal variability is amplified by 1.5 to 2 times compared to the prior half-century. Correlation analysis with dominant sea surface temperature (SST) indices of the global ocean confirms that WG rainfall decadal variability undergoes temporal modulations. Indian Ocean SST variability displayed a significant correlation during 1901–1942 whereas, during 1943–1977 and 1978–2010, Pacific Ocean SST variability displayed a significant correlation with WG rainfall variability. The analysis associated with decadal rainfall variability reveals the dominance of dynamical processes during 1901–1942 and moist thermodynamical processes during 1943–1977 and 1978–2010. The study concludes that the decadal variability of WG rainfall is robust, and the forcing mechanisms are essentially maintained by the Indian and Pacific Oceans variability, adding value to developing decadal prediction systems and contributing to understanding the evolution of the WG ecosystem.

Keywords: Western Ghats, Rainfall, Decadal variability, SST, Dynamical, Thermodynamical

Extratropical-Tropical interaction in the perspective of Eddy Transport, Wave-mean Interaction, and Eddy Forcing during Extreme Events

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ABSTRACT

Numerous studies have pointed out that the mean flow modulation due to eddy forcing is a significant part of the general circulation over the extratropics and the tropics. The atmospheric transient eddies redistribute heat and momentum. A bidirectional teleconnection process exists between the tropical to extratropical (T2E) and extratropical to tropical (E2T), in which transient eddies cause a significant variation in weather and climate in both regions. The eddy transport indices described in Kalshetti et al. 2020 suggests helpful in diagnosing the evolution of the extratropical-tropical interactions. In this study, to explore the wave-mean interaction during the monsoon season, we investigate (a) the potential role of transient eddy forcing and the wave-mean interaction on the monsoon weather during the June 2013 Uttarakhand (India) heavy rainfall event over the Himalayan regions and, (b) how they are captured in a set of operational models. Some studies have pointed out how prolonged breaks can occur due to extratropical trough incursions. However, there is a lack of clarity on how transient eddy forcing associated with such interactions can lead to modulation of monsoonal circulation or whether such interaction can lead to heavy rainfall events. E-vector fields are analyzed to quantify the eddy forcing from the extratropical transient eddies and the feedback mechanism between the transient eddies and the mean flow during June 2013. Analysis reveals that along with local factors (orography, moisture convergence), the large-scale heavy rainfall event over the Uttarakhand region during 16-17 June 2013 was influenced by eddy forcing due to the intrusion of extratropical Rossby waves over the Indian region.

Diurnal cycle of winds as observed with a 205 MHz VHF Radar during the onset and northward progression phases of summer monsoon 2021

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ABSTRACT

The monsoon low level jet (LLJ) and tropical easterly jet (TEJ) are among the prominent factors dictating the fate of the Indian summer monsoon (ISM). This study investigates the diurnal cycle of LLJ and TEJ with reference to the core speed and core height variations during its onset phase over Kerala and subsequent northward progression in the year 2021. It is mainly facilitated by the 205 MHz wind profiling Radar installed at the Cochin University of Science and Technology, Kerala, India. It is observed that the core speed and heights of both the LLJ and TEJ undergo significant diurnal variation, and the TEJ core height is found to be decreasing with the monsoon northward progression as observed at Cochin station. The amplitude of diurnal range of LLJ is 15.8 m s^{-1}, and the ratio of the diurnal cycle amplitude to the time-mean wind is estimated to be 2.21 during the onset over Kerala. The diurnal variability of the moisture flux is found to be positively correlated with the monsoon wind shear (r=0.74 at 5% significance level) which can have profound influence on the quantum of rainfall (r=0.72). It is noticed that wind speed is mostly responsible for the morning and evening peak of convection and strong rainfall. Causative factors of the diurnal oscillations are discussed.

Keywords: LLJ, TEJ, Radar, Diurnal cycle.

Evaluation of sustainable climate adaptive nutrient management technologies for semi-arid tropical drylands in India

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ABSTRACT

Climate and agriculture experts emphasize the need to develop a carbon sink in the soil to help mitigate the effects of climate change. A two-year field experiment tested sustainable nutrient management approaches to sequester carbon in the soils of semi-arid tropical drylands of India, which endure a very harsh climate. This study aimed to test compost and biochar as a part of integrated nutrient management (INM) strategies in the Maize-chickpea cropping sequence. We analysed nine different treatments, including chemical fertilizers (as blanket and soil test-based recommendations: STB), sole organic (biochar and compost) and their combinations (with 75% and 50% STB) as integrated applications (INM) under field experiment for their ability to store carbon in topsoil and system productivity. Nevertheless, after two years of the field experiment, the biochar treatments show higher (24–30%) organic carbon stock in the top layer of soil than the respective compost treatments. Furthermore, the biochar-based INM approach showed the maximum residual effect in chickpea crops under both cropping sequences, which might be due to improved humic fractions. The system equivalent yield in field crops showed the best results (8 Mg ha^{-1}) for 50% need-based fertilizer and 50% biochar as INM. Although, we observed that sole biochar sequestered the highest soil organic carbon (0.69%) in the topsoil compared to the other treatments, but were not scalable due to lower yield for maize crops. The system performance expressed as net-returns and benefits-cost ratio also showed better results for high dose biochar based INM. The findings show that drylands face widespread land degradation in terms of nutrient imbalances and low C levels will benefit from an integrated approach of need-based fertilizer with biochar application. Therefore, this might be a long-term sustainable strategy or solution for semi arid tropical drylands.

Keywords: Climate change; Drylands; Crop yield; Biochar; India

Role of equatorial Rossby wave in 2010 Indian heatwave.

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ABSTRACT

The heatwave is one of the sever weather extreme that has received less attention compare to other weather extreme such as cyclone and rainfall as far as India is concern. However, reports indicates that in recent years, heatwave have caused more damage than any other weather extremes. According to heatwave trends, heatwaves are becoming more frequent, more intense, and longer in length. Therefore, it's crucial to comprehend the numerous processes that contribute to heatwave. So that a precise and long-range prediction of such catastrophic event can be produced for societal vigilance and preparation. It is well established in the literature that intraseasonal oscillations and convectively coupled equatorial waves have a significant impact on tropical weather. Therefore, it is essential to understand how this oscillation affects heatwaves in order to make extended range prediction of heatwaves. In this study, we investigated the role of equatorial Rossby wave on the 2010 Indian heatwave. Our findings from observational and numerical analysis demonstrate that the equatorial Rossby wave was crucial to the development of the 2010 heat wave over the northwestern parts of India. Surfaces fluxes indicate that the clear sky conditions associated with ER dry phase increases the shortwave and longwave radiations at the surface which results in the increase in surface air temperature ultimately resulting in heatwave Condition. Also, the rapid increase in sensible heat flux and rapid decrease in latent heat flux is observed due to the presence of ER wave. Additionally from the numerical analysis it is observed that the presence of ER wave leads to an increase in the intensity of heatwave by 1.5 to 2.5 degrees.

Keywords: Heatwave, Equatorial Rossby Wave, Weather Extreme, Convectively Coupled Equatorial Waves.

Changing characteristics of extreme rainfall events in the Indian subcontinent during summer monsoon period

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ABSTRACT

Extreme rainfall events are one of the extreme weather events in India which is also a prime contributor to the average mortality rate in India among the weather extreme events and therefore the changing features of these events should be given proper attention by the scientific community. Therefore, the present study explores the extreme rainfall events during the southwest monsoon and their relationship with moisture parameters and their changing back trajectories. For this analysis, we have used daily rainfall data from IMD, wind and humidity data from NCEP for the period 1950 to 2020. The extreme rainfall events are identified when the daily rainfall value exceeds the three times the standard deviation and also this rainfall amount should exceed the threshold value of more than 100 mm day^{-1} in a grid point on the spatial domain. The entire study period was divided into the first (1951-1985) and the second (1986-2020) epochs to understand their spatial distribution characteristics. The significant epochal differences in some of the key aspects of extreme rainfall events related to moisture transport mechanisms were also examined. For the selected epochs, distinct variabilities in monsoon rainfall were observed, especially in the northern parts of India. Furthermore, we have observed spatial variability in the frequency of occurrence of extreme rainfall events, the Central Indian region indicates an increasing trend in the frequency and its relative contribution. Whereas, a significant negative trend is found in the northeast sector of the Indian subcontinent. Moreover, prominent moisture sources and their pathways that account for the extreme events were also identified using a 5-day back trajectory using HYSPLIT model. Comparing the two epochs, a notable westward shift was obtained in the seasonal moisture flux and trajectories of selected rainfall events in the recent epoch.

Keywords: Extreme rainfall event; Moisture transport; back trajectory; climate change

Air pollution derived Variabilities in Energy Fluxes estimated using WRF-Chem : A case study of Urban Ahmedabad

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ABSTRACT

Radiative Forcing is the change in energy balance as a consequence of variation in atmospheric composition. This study emphasizes on the spatial seasonal variation of near-surface forcings, temperature simulated with WRF-Chem model with a 2 km resolution over Ahmedabad city, Gujarat, India for the period of May 16 to 29 and December 2018. The forcings were simulated using the EDGAR Global anthropogenic emission inventory and derived by ECMWF ERA-Interim and NCEP meteorology. Latent Heat (LH) and Sensible Heat Flux (HFX) illustrated similar temporal diurnal variation in the summer and winter seasons. Higher LH and HFX were observed at the middle of the city, which represents densely populated as well as highly polluted areas of the city. 44% HFX values observed between 375 – 425 W/m^2 and 52% HFX values observed between 425 – 475 W/m^2. LH majorly varies between 5 – 12 hr and 57% LH values were observed for 43 – 63 W/m^2. Major urban areas generally experience higher HFX than the surrounding areas following the temperature variation, exactly the opposite spatial pattern of LH. In May, average LH was observed for 30 W/m^2 whereas 36 W/m^2 was observed in December. 117 W/m^2 HFX was observed in May whereas 41 W/m^2 was observed in December using Global EDGAR emissions. The average temperature varies between 36 °C in May whereas 20°C was observed for December. NCEP simulates better temperature (R^2 0.78) than ERA-Interim (R^2 0.65). The maximum temperature was observed 39 °C and 34 °C minimum temperature observed in May with both meteorological inputs. Whereas the maximum and minimum temperature were observed for 25 °C and 16 °C respectively for December. Temperature followed the same spatial pattern when the central city observed higher temperature where perriferial wards experienced comparatively lower temperature. The study concluded that high values were observed for all three parameters in the central city with both meteorological as well as emission input variations.

Keywords: Air Pollution, WRF-Chem model, Surface Forcing, Temperature, Ahmedabad

The role of equatorial waves and the Madden-Julian Oscillation in the trends of extreme rainfall events over India

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ABSTRACT

Convectively coupled equatorial waves (CCEWs) and the Madden-Julian Oscillation (MJO) are known to impact tropical rainfall to a great extent. Understanding their influence on tropical dynamics will bring down many uncertainties in understanding and predicting tropical weather on these time scales. In general, CCEWs refer collectively to Kelvin waves (KW), Equatorial Rossby waves (ER), Mixed Rossby gravity waves (MRG), and Tropical depressions (TD). As MRG and TD have identical wave characteristics, they are together referred to as MT. This study analyses how these oscillations influence the trends in extreme precipitation (P90: precipitation with intensities exceeding the 90th percentile) over the Indian subcontinent. During the summer monsoon season, CCEWs individually contribute around 20% of rainfall, and 30% of extreme precipitation during the wet phase, and make weak contributions during the dry phase. However, MT's contributions to rainfall and extremes are also significant during the dry phase. Extreme rainfall over India shows increasing trends, with some locations reaching about 130 (150) % increase (decrease) over a period of 40 years. While most of the positive trends are observed over the parts of northern, eastern, and northwestern India, the trend in central-eastern India shows a negative pattern. In the northeastern parts, where the overall rainfall is decreasing, the trend in extreme frequency is mixed. Surprisingly, trends are insignificant when the CCEWs are absent in a region, except for central-eastern India. The study shows that the long-term trends in the intensity of rainfall and extremes are related significantly to the trends in the intensity of CCEWs.

Keywords: Extreme rainfall events, convectively coupled equatorial waves, MJO.

TEMPERATURE BASED INDEX AS A POTENTIAL PREDICTOR OF INDIAN SUMMER MONSOON

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ABSTRACT

Indian Summer Monsoon Rainfall is a component of the South Asian monsoon system, one of the most worldwide occurrences of the general circulation, which affects the weather and climate around the world. In this study the spatial and temporal correlations have been analysed with a Precipitation and Temperature based Index namely T_Index. This index is developed by taking the product of the Near Surface Air Temperature, Latent Heat Flux and Mean Sea Level Pressure, in order to understand the inter annual variability of the Indian Summer Monsoon Rainfall for both the historical (1991-2020) and projected (2021-2050) climatic scenarios. The Results show that, in historical periods there is a highly positive correlation between T_Index and Precipitation throughout India except, during 1991 to 2000 in central and some eastern parts of India. And there is a positive correlation between the T_Index and Precipitation throughout India except some regions of north-eastern parts of India in the projected climatic scenario.

Key words: T_Index, Temperature, Historical and Projected climatic scenarios, South West Monsoon, Precipitation,

MONSOON 2022 SEEN FROM INSAT – 3DR : 4 MONTHS' MOVIE LOOP AND IMPORTANT SYNOPTIC EVENTS

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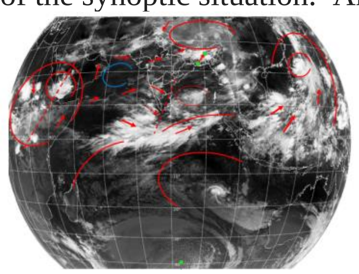
ABSTRACT

As per India Met Dept.(IMD) forecast in early June, the Southwest monsoon seasonal (June to September) rainfall over the country as a whole for 2022 is likely to be 103 % of the Long Period Average (LPA) with a model error of ± 4%.
Daily infrared full disc INSAT images of India and surrounding ocean, taken from MOSDAC site have been analysed in conjunction with synoptic IMD analysis and NWP results. Position of monsoon trough and streamlines have been drawn in the daily images. The full disc images were then converted to Mercator projection for a convenient viewing.
The onset over Kerala itself was highly debated during the last week of May / early June, finally declared as on June 4. Till July 6, the all-India rainfall was much below average, only the eastern parts of India showing above normal rainfall. The picture changed drastically with very good rainfall from July 7 over western and northern India. As of July 25, the ISMR was nearly 10% more than the corresponding time of the of the same time of LPA. Long lasting western disturbances had influenced resulting in heavy rainfall over Rajasthan, Gujarat, central India etc. The eastern part did not get much rain during July. Western India did not get heavy rainfall normally associated with July. Southern India was near normal.
The movie loop from May 1 to Oct 31 will be shown (with streamlines) with an oral description of the synoptic situation. An image of July 31, 2022 is shown as an example of the movie loop.



July 31, 22: 0600 IST

Tibetan Low is significant and could because for heavy rains today over NE-India bordering Himalayas.

Keywords: INSAT - 3DR, Southwest monsoon, IMD

SEASONAL VARIATION OF AEROSOL OXIDATIVE POTENTIAL AT AN URBAN SITE IN INDO-GANGETIC PLAIN (IGP)

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ABSTRACT

Epidemiological studies have consistently linked exposure to particulate matter (PM) with adverse health effects. The oxidative potential (OP) of aerosol particles has been widely suggested as a measure of their potential toxicity. The potential of PM to produce reactive oxygen species (ROS) with subsequent anti-oxidant depletion upon inhalation is defined as OP. Several acellular chemical assays are now readily employed to measure OP, including the Dithiothreitol (DTT) assay, Ascorbic acid (AA) assay and 2',7'-dichlorofluoroscein/hydrogen peroxidase (DCFH/HRP) assay. In this work, 24-hr $PM_{2.5}$ samples were analysed for the OP of aerosol in each season, collected during winter (December 2020–February 2021) and summer (March 2021–June 2021) periods at an urban site in Agra, India. The DCFH assay was used to measure OP and to extensively characterise the seasonal variation of aerosol-OP in the city. The data of meteorological parameters, trace gases (NOx, SO_2, CO and ozone) and volatile organic carbons (VOCs; namely benzene, toluene and xylene) was also explored during the abovementioned periods. The results showed that the mean concentrations of $PM_{2.5}$ were 130 ± 76 μgm^{-3} 191 ± 111 μgm^{-3} in the summer and winter periods, respectively, and exceeded the air quality standards proposed by WHO, 2021 and NAAQS, 2019. The oxidative potential (OP^{DCFH}) of $PM_{2.5}$ in the winter period (0.97±0.76 nmol H_2O_2 m^{-3}) was higher than in the summer period (0.51 ± 0.14 nmol H_2O_2 m^{-3}), indicating OP^{DCFH} values were variable with time. All OP measurements show a significantly stronger correlation with $PM_{2.5}$ mass (r = 0.75) in the winter in comparison to summer (r = 0.15). The results also show that OP^{DCFH} also positively correlated with the meteorological parameters (relative humidity; RH), trace gases like CO, ozone and VOCs. Thus, our investigation revealed the possible significant contributions of meteorology, trace gases, and VOCs to $PM_{2.5}$ toxicity.

Keywords: Reactive oxygen species (ROS), Oxidative Potential (OP), DCFH assay, $PM_{2.5}$, Meteorology.

Spatio-temporal analysis of rainfall pattern for Krishna basin

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ABSTRACT

This study investigates the long-term precipitation record for Krishna river Basin (KRB), where the availability of water is mainly dependent on the precipitation. In this study, rainfall data of 62 years (1951-2012) of the KRB, were analyzed for annual and seasonal trends. The trend and magnitude of change were identified using the Mann-Kendall (MK) test and Sen's slope estimator, respectively. Spatial interpolation technique such as Inverse distance weighting (IDW) was used for interpolating the spatial pattern over the KRB in GIS environment. The results showed that there is a significant trend in daily, annual and seasonal rainfall. In particular annual, monsoon and post-monsoon precipitation exhibited a significant negative deviation in the magnitude from the normal. The analysis revealed the significantly increase in the precipitation trend in both seasonal and annual rainfall in the span of 62 years. The overall analysis based on Sen's estimator for annual and monsoon rainfall showed a negative and falling trend in the sub-basins of Krishna, Tungabhadra and the lower part of the Bhima. The overall analysis using MK sign test demonstrates that there is significant and positive trend in rainfall at 95% confidence level, but a change in the magnitude of the rainfall throughout the basin. It is also observed that magnitude of rainfall is reducing in the upstream sub-basin compared to downstream sub-basins.

STATISTICAL AND EMPERICAL MODELING OF CROP-WEATHER RELATIONSHIP IN INDIA

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ABSTRACT

The systematic recording of data by meteorological departments on different climatic factors on the observatory plot with controlled experiment holds less relevance for the agricultural economy. This is because the weather is really uncontrollable as it affects crop production at various stages. Weather variables are direct inputs in agricultural production, just like other elements like labour, seeds, irrigation, fertiliser, and pesticides. Weather considerations matter more than other inputs in a condition of agriculture when the adoption and diffusion of contemporary technology is very low or nearly nonexistent due to their direct and indirect effects. Thus, the relationship between weather and crop output will affect crop forecasts and management strategies, as well as the availability of food. Understanding this relationship is crucial for policymakers, agricultural economists, agricultural scientists, and meteorologists. The approach to analyse this relationship has evolved significantly over time. This study attempts to review the studies in this area done in India and a few from abroad that brought an evolution in the methodology of crop-weather modelling including numerous statistical and emperical modelling.

Keywords: *Weather, Crop Model, Calibration, Validation, Emperical Model*

Statistical and Emperical Modeling of Crop-Weather Relationship in India

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Keywords : *Weather, Crop Model, Calibration, Validation, Emperical Model*

QUANTIFICATION OF UPPER-TROPOSPHERIC MRG ACTIVITY AND THEIR ASSOCIATION WITH EXTRATROPICAL WAVE INTRUSIONS

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ABSTRACT

Westward propagating Mixed Rossby-gravity(MRG) waves are synoptic-scale equatorial disturbances that play a pivotal role in modulating tropical weather. Scale analysis of large-scale tropical motions suggests that in the absence of organized convection, intrusion of extra-tropical waves is an important forcing mechanism that excites MRG wave events. In the current study, we adopt an MRG event-based approach to classify MRG events into two categories:-MRG events associated with and without extra-tropical wave intrusions. MRG events and extra tropical wave intrusions are identified using equatorial meridional wind at 200hPa and potential vorticity on 350K isentropic surfaces, respectively. We find that about 35-40% of MRG events exhibit association with extra-tropical wave intrusions. Half of the MRG activity occurring over central, eastern Pacific, and Atlantic basins during the boreal winter and spring are associated with extra-tropical intrusions. Majority of the events prefer Northern Hemispheric pathway. Events associated with Southern Hemispheric intrusions also select Pacific and Atlantic but show peak activity during boreal summer. The geographical preference and seasonality of maximum MRG events associated with intrusions are co-located with the westerly duct. MRG events associated with extra-tropical waves exhibit slightly higher amplitude and larger meridional extent. The observation of higher amplitude and zonal wavelength(wavenumber 6) similar to extra-tropical waves supports the hypothesis of resonant interactions between MRG and extra tropical waves during boreal winter. Since the background wind configuration during the two classes of MRG events is significantly different, it is difficult to attribute the differences in dynamical properties to Doppler and non-Doppler effects of the mean or lateral forcing by mid latitude waves. Since MRG events associated with extra-tropical wave intrusions account for a major fraction of total MRG wave activity, we speculate it to have a cascading effect on other tropical modes of variability. Hence tropical-extratropical interactions should be considered an important factor in modulating tropical weather.

Keywords: Mixed Rossby-gravity Waves, extra-tropical wave intrusions, Potential Vorticity, resonant interaction.

Temporal dependence of river discharge and precipitation over the Godavari basin using Event Coincidence Analysis method

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ABSTRACT

Event Coincidence Analysis (ECA) is a newly developed statistical method to quantify the interdependency between the events in a two series of observations. The present study employs the ECA method to investigate the temporal dependence of hourly precipitation and river discharge of few gauge sites of the Godavari basin for a 3 year period (2017-2019). For the present study NASA's Global precipitation mission (GPM) product extracted using the Integrated Multi-satelliteE Retrievals algorithm (IMERG) precipitation data set, which is available with a temporal resolution of 30 minutes, is used for precipitation and the river discharge data is taken from the Central Water Commission, Govt of India, the latter is available every hour. Eight stations over the Godavari basin are considered for the present study, which are named as Bamani, Mancherial, Tekra, Chindnar, Konta, Perur, Koida, and Ashti.

To ensure the results are not random, the present study uses a statistical significance test with 95% confidence level. Since, out of 8 stations 3 stations cannot reject the null hypothesis with 95% of confidence level, only the remaining stations are considered for the study. The results of ECA analysis indicate quantitatively that the trigger coincidence rate, with a lag of 1 hour between the precipitation events and the river discharge events over Bamani, Chindnar, Konta, Perur, and Koida, are 0.29, 0.30, 0.29, 0.38, and 0.40 respectively. The study concludes that the spatial spread of precipitation can impact the river discharge with maximum trigger coincidence rate within one hour.

Keywords: ECA, Precipitation, River discharge, Godavari basin.

IMPACT OF URBANIZATION ON PRECIPITATION OVER THE GANGETIC PLAIN.

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ABSTRACT

The Gangetic plain is one of India's most economically dynamic regions, and it has seen rapid urbanization in recent decades. Urbanization significantly influences the local climate through the modification in land use land cover. Causative factors for the alteration of urban precipitation can be urban heat island, surface roughness and anthropogenic aerosol. High-resolution CHIRPS gridded rainfall data from 1981 to 2021 has been used for a detailed study in the cities of Varanasi and Prayagraj. Each month of the Indian summer monsoon (JJAS) is analyzed to visualize the trend of low to moderate rainfall events (0-35.6mm/day) and rather heavy to extremely heavy rainfall (>=35.6mm) events during the last four decades. The statistical tests Mann-Kendall test and Pettitt's test are used to detect the trend in time series along with the change in central tendency. This study showed a significantly increasing trend in the frequency of light rainy days for July and August in Varanasi and the same two-month significant change is observed in the 17th and 13th years respectively. This implies that Varanasi's rainfall regime is changing in the recent past, especially for the months when the monsoon peak is approaching and departing as seen from long-term climatology. Prayagraj during the monsoon season experienced a non-significant increasing trend (P-value>0.05) in the frequency of light rainy days (For June, July August and September) and decreasing trend of heavy rainy days (for August and September). In the future cities are more likely to be influenced by regional weather conditions, so it is important to predict urban precipitation anomalies.

Keywords: Climate change; CHIRPS; Precipitation; Urbanization

Characterization of Intertropical Convergence Zone Using SAPHIR/Megha-Tropiques Satellite Brightness Temperature Data

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ABSTRACT

The intertropical convergence zone (ITCZ) is a region encircling the globe near the equator where the surface trade winds of both hemispheres meet and accounts for more than 30% of global precipitation. Conventionally, parameters such as low outgoing longwave radiation (OLR), high precipitation and surface wind convergence (SWC) are used to identify and characterise the ITCZ. These parameters suffer from some inherent issues while identifying ITCZ. A new method based on the identification of deep convective cloud cores (DCCCs), derived from brightness temperature (T_B) data of the water vapour absorption channels of Sondeur Atmosphérique du Profil d'Humidité Intertropicale par Radiométrie (SAPHIR), aboard Megha-Tropiques satellite will be presented . The present method satisfies to identify the DCCCs and performs better over (a) anvils and cirrus-dominated areas where OLR-based methods face difficulties (b) coastal and continental areas where satellite scatterometer data are unavailable to estimate surface convergence and (c) windward side of orographic rainfall where rainfall based methods fail. The ITCZ has a broad structure over the West Pacific Ocean (WPO) and Indian Ocean (IO) and is a narrow-band structure over the Central Pacific Ocean (CPO), East Pacific Ocean (EPO), and Atlantic Ocean (AO). Over AO and WPO, the ITCZ has reduced strength in the occurrence frequency of DCCC (OFD) during the El-Niño period compared to normal years. The trend in DCCC for different land and oceanic regions cancels out in such a way that the trend is insignificant when averaged over the entire tropics during the study period of 2011-2018
Keywords: Megha-Tropiques, ITCZ, deep convective cloud core

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Keywords: Megha-Tropiques, ITCZ, deep convective cloud core

Upper-tropospheric MRG wave events: Trends and Variability

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ABSTRACT

Mixed Rossby-Gravity (MRG) waves are westward propagating synoptic scale equatorial disturbances. MRG waves play a crucial role in the genesis of tropical cyclones and tropical depressions and they constitute integral part of the major tropical modes of variability, for e.g. Madden-Julian Oscillation (MJO) and Quasi-Biennial Oscillations (QBO). In this study, we investigate the trends and variability in MRG wave events at 200 hPa using ERA-I reanalysis data for the period 1979-2019. MRG wave events are identified by projecting the meridional wind onto the theoretical spatial structure of the MRG waves. We find that there is a steady increasing trend in the number of occurrences of MRG wave events on the interannual timescale in the upper troposphere. Further analysis revealed that MRG events occurred over the Pacific and Atlantic basins account for more than 75% of the interannual variability in MRG events. El Nino Southern Oscillation (ENSO) explains about 20% of the interannual variability in MRG events. ENSO modulation of the MRG wave events occur by quasi-stationary ENSO heating altering the upper-tropospheric winds. La Nina phase of the ENSO widen the upper-tropospheric westerly wind duct over the east Pacific and Atlantic basins which in turn favor intrusion of extratropical disturbances results in the occurrence of a greater number of MRG wave events. Strong and active convection on intraseasonal timescale over the west Pacific is another factor that set up favorable environment for the occurrence of the MRG wave events over the central and east Pacific domain.

Keywords: Equatorial waves, Interannual variability, ENSO.

HEAT WAVES AND HEAT STRESS ASSESSMENT OVER EASTERN INDIA UNDER CHANGING CLIMATE

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ABSTRACT

The extreme events like heat waves are often responsible for thermal discomfort or heat injury caused to the human body through heat stress. The impact of climate change has led to an increase in heat waves, and thus, elevated heat stress levels in India over the recent years. This study has been undertaken to analyse heat stress patterns over Eastern India during the period 1981-2020. First, to identify a heat wave episode, the 90th percentile of daily maximum temperature over a 5-day window has been considered as the threshold. Three heat stress indices (HSIs) namely, Humidex, Simplified Wet-Bulb Globe Temperature, and Apparent Temperature have been used to estimate and categorize heat stress levels. In general, heat stress has peaked in June, after the majority of heatwaves, occurring during April and May, have receded from over the study region. Considerable changes have been found in heat stress levels during the recent decade, i.e., the strength of heat stress has increased from slight to moderate and from moderate to strong (in case of Apparent Temperature), or an increase in area coverage by a specific heat stress level has been noticed from April to May and May to June respectively, as compared to the preceding years. The specific regions over which a particular class of heat stress is found, varies according to each indicator. These findings give the impression that climate change has played a major part in the enhancement of heat stress over the study region.

Keywords: Extreme events, Heat waves Frequency, Heat waves duration, Heat Stress Indices, Climate Change, Eastern India

SURFACE OZONE INFERENCE FROM OMI AND IASI-A SENSORS OVER THE INDIAN SUBCONTINENT

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ABSTRACT

Satellite-based ozone (O_3) is helpful for studying ozone pollution, but it is challenging to estimate it due to the presence of tropospheric and high stratospheric abundance. Ground-based point observations and chemical transport models provide information on the chemical formation and its transport. Here we have used the vertical profiles of O_3 from different sensors and reanalysis-surface O_3 to detect the surface ozone over the Indian subcontinent.
The daily day time vertical profiles of O_3 from the Ozone Monitoring Instrument (OMI) sensor onboard Aura satellite from 2005 to 2019 and the Infrared Atmospheric Sounder Interferometer (IASI) on board the Meteorological Operational Satellite-A (MetOp-A) platform O_3 from 2008 to 2019 were used. The ratio of reanalysis surface ozone and reanalysis vertical column ozone concentration (up to 3 km) was applied to the satellite vertical column-averaged profile at each pixel. The vertical profile of the satellite's data was validated with ozone profile available from two ozone sonde profiles located in Pune and Thiruvananthapuram. The resultant surface ozone was validated against the observed surface ozone at Shadnagar station as Central Pollution Control Board stations. Surface ozone from both sensors captured seasonality.

Keywords: Surface Ozone, Ozonesondes, Satellite Remote Sensing.

Primary observations of Black Carbon at North Sikkim and its impact on temperature and glacier albedo

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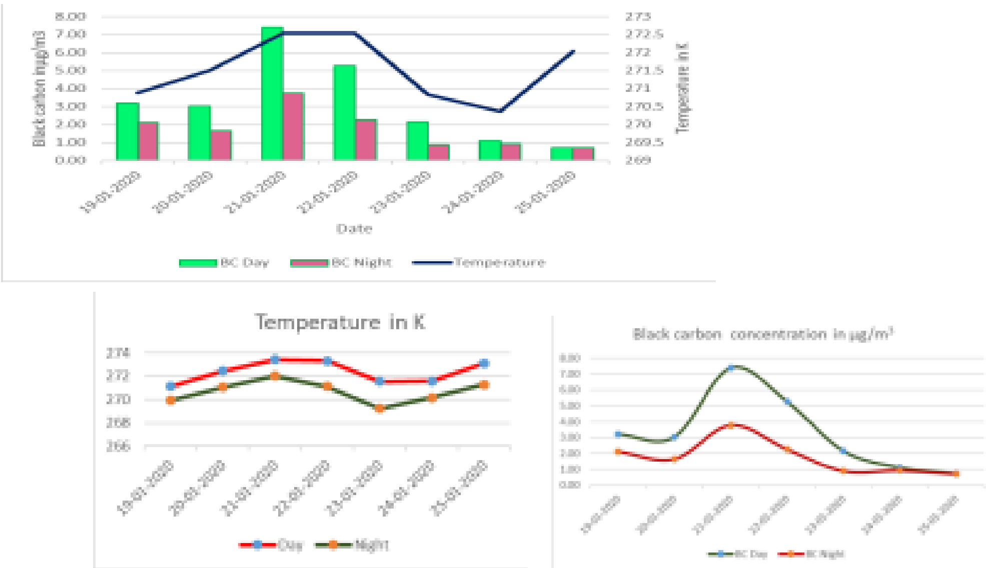
Graphical Abstract



Abstract

The cryosphere predicted to vanish in coming few decades due to increase in temperature worldwide. Different region with glaciers has reported to have different pollutant responsible for it. The Himalaya region is receding much faster than any other part of world and has shown variation in glacier receding procedure along their long stretch. The North Sikkim has developed many glacial lakes at higher altitude. BC is primary suspect for expansion of glacial lake area. In connection to this issue, BC mass concentration monitored with an Aethalometer at higher altitude of North Sikkim Headquarter (Mangan) during winter month of January 2020. The average value of black carbon found is 4.14 µg/m^3; the maximum and minimum value was accounted, 9.26 µg/m^{3}and 1.08 µg/m^{3}respectively. The variation in day and night time concentration observed with average reduction of 37% in concentration of BC at night. The black carbon data compared with the temperature variation during day and night. The significant co-relation (r=0.66) detected at 5% significance level between black carbon and temperature. The albedo and BC co-relation has found to be r=0.51 at 5% significance level particularly of glaciated region of the Sikkim state. The average BC concentration reported in Kolkata city is 4.8 to 5.2 µg/m^3, which is quite close to Sikkim's concentration. This result indicates that this exquisite state needs to protect in terms of environmental destruction.

Keywords: Black Carbon; Aerosol; Glacier; Temperature; Albedo

TRENDS OF RAINFALL IN THE URBAN AND RURAL AREAS OF BANGLADESH: A COMPARATIVE STUDY

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ABSTRACT

The variability of rainfall patterns in urban and rural areas is very important for hydrological study in Bangladesh. Spatial patterns of seasonal rainfall trends of urban and rural Bangladesh over the time period 2006-2021 has been assessed using rainfall data recorded at 10 local stations distributed over the country. Mann–Kendall trend test is used to detect the significance and the magnitude of rainfall change. The trends of the observation data has been compared with the reanalysis gridded data from ERA-5. The spatial distribution of the precipitation rain rate has been plotted for the given stations indicating the urban and rural areas. The result represents a significant increase in the average pre-monsoon and monsoon rainfall of Bangladesh. In pre-monsoon and monsoon, the highest rainfall observation has been found in Sylhet among the urban areas and in Madaripur among the rural areas.

Keywords: Rainfall, Trends, Gridded Data, Seasonal Variability, Precipitation rain rate.

Pre and Post Flood Inundation mapping of Silchar town using Sentinel data in Google Earth Engine along with rainfall and flood level data

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ABSTRACT

Silchar, the second largest city of Assam after Guwahati is situated on the banks of river Barak. Since the Barak flows past this area, Silchar and other adjoining towns and villages are commonly called the Barak Valley. It is located at a latitude of $24^{O}82`$N and longitude of $92^{O}8`$E with an elevation close to 70-75 feet(ASL). In the recent flood in Assam during June 2022, it was witnessed that among the various districts, Silchar town was the most affected. It was deluged for almost 10 days impacting more than 5 lakh human lives, reported the state disaster agency. Urban flooding is a serious concern as it affects not just the life of the people, it damages the infrastructure and agriculture, and impacts the economy of the state as a whole. The objective of our work is to study the flood inundated areas of Silchar town with a comprehensive pre and post-flood analysis. Sentinel 1 & 2 data has been considered for carrying out the above-mentioned tasks. The Image analysis is done using GEE. In addition to the above, building footprint, rainfall and flood level data has also been integrated to draw a correlation of the flood affected area.

Keywords: Urban flood, GEE (Google Earth Engine), Building Footprint, Rainfall

Comparative Analysis of $PM_{2.5}$ along with the Impact of Meteorological Parameters from Normal (2019) to New Normal (2021) Era

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In this study, we assessed change in air quality from pre-lockdown period (2019) to post-lockdown period (2021) by determining the relationships between air quality and meteorological conditions. From January 2019 to December 2021, the particulate matter mass concentration and meteorological data from CPCB along with the backward air mass trajectory from HYSPLIT were analyzed. This study has been done over seven cities, namely Agra, Noida, Faridabad, Kanpur, Lucknow, Ghaziabad, and Delhi, of Indo Gangetic Plain (IGP) to compare the air quality in the era of COVID-19 from Normal (2019) to New Normal (2021). Thus, the results show that the maximum annual decrease of $PM_{2.5}$ was observed at Noida (17%) followed by Ghaziabad (14%), Delhi (11%), Faridabad (8%), Kanpur (8%) and Lucknow (4%), whereas slight increase was observed at Agra (9%) in the year 2020. Changes in $PM_{2.5}$ concentration was also compared from 2020 to 2021, and a noticeable increase in $PM_{2.5}$ level was found throughout 2021. The maximum improvement in air-quality index (AQI) was noticed at Noida (24%) and minimum at Faridabad and Lucknow (3% each) in 2020, while it rose by 12% at Delhi in 2021, indicating that air quality returned back to its prior levels when the epidemic control measures were discontinued. Also the results showed that among the local meteorological elements, relative humidity (RH) had the highest influence on the annual average concentration of $PM_{2.5}$ in the studied cities, followed by temperature (T) and wind speed (WS). The results showed negative correlation between WS and $PM_{2.5}$ in most of the studied cities which suggest that the local emissions were more dominant. Similarly, some cities showed negative correlation with RH suggesting dominance of long range transported aerosols. Thus, by analyzing the results of this study it can be concluded that the pollutant concentration at any particular site has great influence on its meteorological conditions.

Keywords: COVID-19, Particulate Matter, Meteorological Parameters

Assessment of convective parameters during post-monsoon season over Nellore district, India

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ABSTRACT

In the current study, a number of meteorological variables that affect the frequency of convective systems over the Chittoor district were examined. The convection-related indicators used in this analysis are the K Index (KI), Total Totals Index (TTI), Enhanced Total Totals Index (ETTI), Total Precipitable Water (TPW), Humidity Index (HI), Lifted Index (LI), and Convective Potential Energy Available (CAPE). The development of rainfall-connected convective storms during the 2021 post-monsoon season (POMS) was studied using daily ERA5 reanalysis datasets. Convection in the POMS was certainly possible, as evidenced by the elevated KI and TTI indices. The HI parameter values indicated that the Nellore region was more prone to have severe convective systems than other regions. Compared to Ananthapur, the TPW measurements in the Nellore region are significantly greater. Across the region, CAPE values were average throughout the season. We found that, while the Kandukur region had a moderate risk of witnessing a severe convective system, the LI parameter had indicated a substantial possibility of a severe convective system. At pressure levels of 400–500 hPa, considerable negative values are found in vertical velocity profiles, which suggests a significant probability for intense rainfall activity with rising air motion. An increase in relative humidity readings and a drop in dew point depression values signify the presence of enough moisture for convective rainfall. Convective rainfall is more likely to occur at 500 hPa pressure level due to the reduction in particular humidity levels.

Keywords: Velocity, Pressure, level, Negative, Index

Simulation of heavy rainfall event over Indian southern city of chennai using the weather research and forecasting model (WRF).

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ABSTRACT

From November 07 to November 11, 2021, India's southern city of Chennai witnessed very heavy rainfall. The heavy rainfall was caused due to depression in Bay of Bengal that moved west-northwestwards cross north Tamil Nadu and adjoining south Andhra Pradesh coasts around Chennai by November 11 evening. On 6 November, IMD stations recorded rainfall upto 139 mm over Chennai. By 7 November,IMD recorded the highest rainfall of 213.5mm. Present research simulates this meteorological event using the WRF Model. The model output result was compared with multiple data sets (TRMM, CMORPH, ECMWF and IMD AWS). The result showed that the WRF Model was able to capture the event well, though in terms of spatial distribution of rainfall, the model had slightly overpredicted the event. **Keywords:** Rainfall, chennai, WRF.

SIMULATION OF FLUXES AND STRESSES AT ATMOSPHERE-OCEAN INTERFACE

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ABSTRACT

Oceans influence the occurrence and evolution of major weather phenomena. However, there are fewer atmospheric and oceanic observations over most maritime areas. Therefore, the model-generated reanalysis is being used for understanding air-sea interaction. The air-sea interaction parameterization inside the coupled model plays a vital role in understanding weather events. The wind is essential in transferring the momentum flux from the atmosphere to the ocean. For understanding the momentum flux transfer, the parameterization of the drag coefficient is crucial. The total stress at the interface can be divided into turbulent and surface stress. The surface stresses are again divided into viscous, wave, and separation. Wave stress induces wave-related perturbation in the atmosphere. The wave stress depends on the directional wave spectrum, the wave growth rate, and the density of the water. However, the density of the ocean is a variable and varies from place to place depending on the evaporation or the precipitation flux. In this work, we have simulated the fluxes and stresses at the atmosphere-ocean interface to understand their influence on the marine boundary layer. The ocean density has been determined from the equation of state for seawater TEOS-10 (Thermodynamic Equation of State for Seawater, 2010). TOES-10 model density in terms of salinity, temperature, and pressure. This evaporation or precipitation-induced salinity change causes density changes in the seawater density and has been modeled using observation (IMERG precipitation). The influence of density changes on radiative and advective heat fluxes and the role of density changes and their effect on the transfer of momentum flux has been studied. The results from the simulations will be presented at the symposium.

Keywords: Drag coefficient, momentum flux, parameterization

OPTIMAL OPERATION POLICY OF TUMARIA RESERVOIR UNDER CLIMATE CHANGE SCENARIO USING NON LINEAR PROGRAMMING

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ABSTRACT

Water is a renewable source but extreme handling causes severe environmental and economical unevenness. The present study has been conducted on Tumaria reservoir system situated in Jaspur block of district Udham Singh Nagar of Uttarakhand state in India. The AOGCM models tried with monthly temperature and precipitation data were CGCM2, HadCM3, CSIRO MK 2 and ECHAM 4. HadCM3 simulated the precipitation and temperature values accurately than the other models and it was selected for the estimation of future precipitation and temperature change. Rainfall-runoff modelling of catchment area of Tumaria reservoir using IHACRES for base period and monthly inflow volume into the reservoir in future period was found decrease by 2.6%. Regression relationship between reference evapotranspiration and temperature was developed in the base period and it was used for the estimation of reference evapotranspiration for future period. The non-linear programming model was used to find out optimal operation policy for baseline and future period considering reservoir storage, spill volume and release volume of reservoir as constraints. Results showed that Tumaria reservoir has the ability to satisfy only 53% of the crop water demand in all months of base period. This ability of reservoir was decreased in future period by satisfying only 48% of demand due to an increase in the crop water demand (19.54%) and decrease in the inflow water.

Key words: Climate change, Operational policy, Nonlinear programming.

Evaluation of Active/Break Spells Over India During Summer Monsoon Using Regional Climate Model

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ABSTRACT

The Indian summer monsoon (ISM) rainfall is associated with four different phases viz. onset, active, break, and withdrawal of monsoon. In present study ICTP's Regional Climate Model (RegCM4.3) has been employed over South Asia CORDEX domain to simulate the active and break phases of ISM over the Indo-Gangetic Plain (IGP) in India during 2001 to 2010. A new criterion has been developed to represent the active and break spells of ISM using accumulated daily rainfall over the IGP. The analysis shows that RegCM4.3 has shown better skills in capturing the break spells or dry state than the active spells. The new criterion has shown a degree of improvement in computing the break spells using IMD daily rainfall and model schemes. Further, it is found that the RegCM4.3 with Mix98 parameterization scheme is able to capture the maximum probability of hit of active and break spells compared with observed/actual which was 50% and 76% respectively. The occurrences of break spells are consistently longer in length and more frequent per season. The interannual variability of the active and break spells and frequency during the years 2001-2010 is quite depictive and showing increasing trend.

Keywords: ISM, CORDEX, IGP, active and break spells, RegCM4.3.

Impact Analysis of WRF PBL Schemes on Simulation of Convective events Over Indian Region

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ABSTRACT

ABL is the most important layer as it connects the atmosphere (free atmosphere) with the surface (land or ocean).All the energy and the moisture transport occurs through this layer which ultimately responsible for the various weather events. By understanding the the dynamics of ABL, atmospheric behaviour at different spatial temporal scales can be predicted/calculated. Biggest improvements in the model forecasts will come from improving parameterisations. In this study, heavy precipitation events (Convective events) over Different regions of the Indian Subcontinent were simulated using WRF model. Series of experiments were conducted using varying the planetary boundary layer (PBL) parameterization schemes over different regions of Indian subcontinent to find the best combination of schemes .The different PBL Schemes includes Yonsei University(YSU), Mellor-Yamada-Janji Scheme(MYJ), NCEP Global Forecast System(GFS), Quasi-normal Scale Elimination(QNSE), Mellor-Yamada Nakanishi Niino(MYNN) Level 2.5, Mellor-Yamada Nakanishi Niino (MYNN) Level 3, Asymmetric Convection Model2 Scheme (ACM2), Bougeault-Lacarrere Scheme (BouLac), University of Washington (TKE)Boundary Layer, Shin-Hong Scale-aware, Grenier-Bretherton-McCaa.The results were compared with IMD and TRMM data to find out which combination of schemes has performed better when compared with observations.

Keywords: Weather Prediction, WRF , Convection , PBL

A COMPARATIVE ASSESSMENT OF ESTIMATION OF PRECIPITABLE WATER VAPOR (PWV) USING SCIENTIFIC GPS PROCESSING ENVIRONMENT SOFTWARE GAMIT AND PRIDE PPP-AR

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ABSTRACT

PWV is an important variable to track when trying to keep an eye on both the climate and the hydrological cycle. PWV is estimated for two sites in this study effort utilizing 10 and 1 ground-based GNSS sensors, respectively. The two locations house the ground-based GNSS stations provided by MNNIT and UNAVCO (California, USA) (Prayagraj, Uttar Pradesh, India). Precipitable Water Vapor (PWV) is calculated using the GAMIT/GLOBK (Ver. 10.7) and PRIDE PPP-AR (Ver. 2.1), and PWV has also been gathered for both sites from adjacent radiosonde stations utilizing the web service offered by Wyoming University. The radiosonde data with root mean square errors (RMSE) of 1.80 mm (GAMIT) and 7.69 mm (Pride PPP-AR) in Prayagraj, Uttar Pradesh, India and 4.19 mm (GAMIT) and 4.27 mm (Pride PPP-AR) in Southern California are used to validate the GNSS-derived PWV. When a network of stations is included in the positioning solution, GAMIT has been found to produce more reliable and precise PWV readings, but PRIDE PPP-AR has been proven to provide a more accurate solution in cases of positioning on a single station.

Keywords: Climate change, PWV, GNSS, GPS, GAMIT, Network Adjustment

Mesoscale dynamics of western disturbance causing heavy precipitation over Western Himalaya

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ABSTRACT

WDs are extratropical synoptic-scale low-pressure systems associated with weather events over northern India, especially over the Western Himalayas. WD development usually takes several days and is connected to weather fronts, resulting in cloudiness, precipitation, and even severe weather, including strong winds. These disturbances are embedded in the subtropical westerly jet stream, which acts as a waveguide for such systems. These wave-like disturbances in ridges and troughs interact with the Himalayan terrain's orography to generate instability conditions over the Western Himalayan region and produce changes in atmospheric dynamical and thermodynamical characteristics throughout the troposphere resulting in anomalous moisture, precipitation, temperature, and circulation. The present study analyzes WD dynamics using mesoscale modeling to unveil the heavy precipitation dynamic. We have generated a high resolution (12 km) analysis using a three-dimensional variational data assimilation technique and Weather Research and Forecasting model. The generated high-resolution reanalysis was used to understand the middle and upper tropospheric circulations, the behavior of kinetic energy, and the role of potential vorticity and baroclinicity in heavy precipitation. Major results are as follows: The developed analysis is found useful in simulating the position and life cycle of all five WDs cases. It is found that the topography of the Western Himalayas influences the life cycle of WDs, which are embedded into the southern branch of the Subtropical Westerly Jet. Significant changes were observed in the jet stream structure and middle and upper air circulations due to the passage of WDs over the WH region. The increase in Kinetic energy on the southwest edge of the trough facilitates two processes. First, it allows the intrusion of dry and cold air from northern latitudes, and second, it helps to fetch moist and warm air from the Arabian Sea when a trough passes over it. This mixing of air masses leads to the development of a large-scale unstable atmosphere on WHs. This interaction complicates when the trough interacts with complex topography. The orographic lifting of moisture causes further enhancement in the instability leading to the development of a large scale convective system over WHs. This large scale system causes heavy precipitation over the WH region.
Keywords: Western Disturbances, Extratropical cyclone, Western Himalayas, Baroclinicity

ROLE OF INTERNAL VARIABILITY IN AEROSOL OPTICAL THICKNESS PROJECTIONS OVER INDIA

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ABSTRACT

Future climate change is uncertain due to three key factors: forcing (scenario), model response (epistemic), and internal variability (aleatoric). Observations and climate models give different estimates of the number of particles in the atmosphere, despite the fact that many studies have looked at such aerosol consequences. Since aerosols continue to be the primary source of uncertainty in climate change, it is necessary to study their variations over the globe. Even in the absence of external forcing, the chaotic structure of the climate system causes natural fluctuations that might lead to differences in the outcome. The accuracy of regional climate forecasts is constrained by internal climatic variability, which coexists with anthropogenic climate change and is inherently unpredictable. This study uses the Coupled Model Intercomparison Project - phase 6(CMIP6) datasets, which comprises of different Global climate Models with reference to MERRA2 reanalysis data to understand the spatial-temporal patterns and seasonal-variations of Ambient Aerosol Optical Thickness at 550nm over the homogeneous rainfall zones in India for the period 1995-2014. To explore the role of internal variability in Future Projections, we quantify the aleatoric uncertainty using Shared Socioeconomic Pathway (SSP) 585 scenario over four 20-year periods: 2015–2034, 2035–2054, 2055–2074, and 2075–2094 and four seasons, June–July–August (JJA), September–October–November (SON), December–January–February (DJF) and March–April–May (MAM). The Central Northeast region shows the highest aleatoric uncertainty for SON season for the period 2015-2034. Northwest India exhibits higher uncertainty over all the time whereas the lowest, is observed over Peninsular India. Our results suggest that AOT projections from CMIP6 outcomes are likely uncertain. Even if aleatoric uncertainty often cannot be reduced it need to be quantified for better understanding its responses under different climate change conditions.

Keywords: CMIP6, Aleatoric Uncertainty, India, Aerosol optical thickness at 550nm, MERRA2

CMIP6 Simulations of Surface Air Temperature and Aerosol Optical Thickness over Homogeneous Regions of India

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ABSTRACT

The impacts of anthropogenic aerosols on surface air temperature on the regional scale remain complicated to unravel. Several studies are focusing on the role of aerosols in altering physical processes on the earth's surface. The focus of this study is to analyze the impacts of atmospheric aerosols on surface air temperature over the Homogeneous regions of India during the period 1985-2014. The Surface air temperature (SAT) and Ambient Aerosol optical thickness at 550nm (AOT) are obtained from the General Circulation Models (GCMs) of Coupled Model Intercomparison Project-6 (CMIP6). The SAT model data is compared with ERA5 (European Centre for Medium-Range Weather Forecast (ECMWF) Reanalysis 5th generation's) SAT and AOT with MERRA2 (The Modern-Era Retrospective analysis for Research and Applications, Version-2). The results show that there exists a high bias between CMIP6 SAT and ERA5 SAT over northwest and a low bias over southern peninsular regions of India. With respect to AOT, there exists a high bias between CMIP6 AOT and MERRA2 AOT over northwest and a low bias over southern peninsular regions of India. Monthly mean correlation analysis between ERA5 SAT and MERRA-2 AOT reveals that there exists a high correlation over west-central and low correlation over northeast and hilly regions of India. The correlation analysis is also performed with model data and we found that there exists a high correlation over central northeast and low correlation over northeast regions of India. Hence, this study gives a better understanding of the impacts of aerosols on SAT over India for different seasons with respect to CMIP6 simulations.

Keywords: aerosols, surface air temperature, CMIP6, Homogeneous regions.

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IITM-ESM SIMULATIONS OF PRECIPITATION AND CLOUD AREA FRACTION OVER HOMOGENEOUS RAINFALL ZONES OF INDIA

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ABSTRACT

Clouds play a major significant role in influencing global hydrological cycle. The better representation of cloud and its associated physical processes in the global climate models will aid in understanding the dynamics behind the temporal variations of precipitation. The scope of this work is to examine the simulations and the relations of precipitation and cloud area fraction by IITM-ESM model of Coupled Model Intercomparison Project - Phase 6 (CMIP6) over the homogeneous rainfall zones of India for the historical time period from 2001 to 2014. Two rain bearing monsoon seasons namely Southwest - SW (June, July, August and September) and Northeast - NE (October, November and December) are chosen during which India receives major portion of country's total rainfall that directly impact the agricultural economy as well. Rainfall gridded dataset from India Meteorological Department and Cloud area fraction data obtained from MODIS-Terra satellite are used as reference dataset for the study. From the performance metric analysis of the two variables of the model and observed data, precipitation in Hilly Region seems to have lower Percent Bias, Northwest zone has higher percent bias, while Southern Peninsular zone has lower and Hilly region has higher percent bias for Cloud area fraction variable during SW monsoon. Central Northeast zone has lower percent bias for both variables, while Hilly region and Northwest zones have higher percent bias for precipitation and cloud area fraction respectively during NE monsoon. Higher correlations between the seasonal sum of precipitation and mean of cloud area fraction are found in Northwest and Northeast zones, while Hilly region and Southern Peninsular zone have lower correlation of the observed data and model data respectively, during SW monsoon. For NE monsoon, higher correlation zones are Central Northeast and Hilly Region, lower correlation zones are Hilly region and Northwest for observed data and model data respectively.

Keywords: Precipitation, Cloud Area Fraction, Rainfall zones, Monsoon.


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METEOROLOGICAL ASPECTS OF BLIZZARDS OVER BHARATI RESEARCH STATION, LARSEMANN HILLS, EAST ANTARCTICA

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ABSTRACT

First winter team of India Meteorological Department started observations at Bharati research staion ($69^0$24'28"S, $76^0$11'14"E, 74m) since 01^{st} December, 2014. The period of March to November months are considered as winter season and December to February as summer season over Antarctica. Lowest minimum temperatures -40.3 ^oC recorded on 08^{th} September, 2016 while highest Maximum temperature 09.9 ^oC recorded on 05^{th} January, 2019. Blizzards are the main adverse weather system over Antarctica continent. A combination of strong surface winds winds speed 23Kts or more accompanied with blowing snow, visibility less then one km lasting atleast one hour is defined as blizzard. Frequency of blizzards, duration, gustiness, snowfall and other meteorlogical parameters have been analysed by using every minutes Digital Current Weather Instrument System (DCWIS) data of Bharati Research station for the period of 1^{st} January 2015 to 31^{st} December, 2020.

The study reveals that the annual frequency of blizzards varies from 07 to 21. Highest 21 number of blizzards observed in the year 2015 followed by 18 in 2017. Least 07 number of blizzards observed during the year 2018 and 2019 each. Cumulatively highest monthwise frequency observed in the month of August (15) followed by May (14) and September (13) during the study period. Highest Gust reported during a Blizzard is 086 kts at 2100 UTC on 20th Sept-2020. Maximum duration of a Blizzard in a month is 28 hrs. 45 Min. during 19^{th} to 21^{st} September, 2020. The study also reveals that, generally blizzards approaches the station from East direction. Variation of temperature, pressure, wind speed, precipitation and other meteorological parameters during the blizzards have also been analysed and presented here.

Keywords: Blizzard, Gusty winds, Precipitation, blowing snow, frequency.

INVESTIGATION OF PERFORMANCE OF A NEW GENERATION EARTH SYSTEM MODEL AT A REGIONAL SCALE OVER INDIA

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ABSTRACT

The present study is an attempt to evaluate India's first indigenously developed earth system model to contribute to the CMIP6 project, the IITM-ESM v2 in its capability to simulate one of the most complicated phenomena of the global climate system, the Indian summer monsoon and also to assess how different statistical downscaling techniques perform in improving the model simulation of the monsoon system in India. The earth system model simulation for the historic period 1975-2010 has been evaluated based on several statistical parameters like mean, standard deviation, correlation and bias. The model is also assessed on its capability to capture the extreme rainfall events or the right tail of the probability distribution of rainfall intensity. India Meteorological Department's (IMD) daily gridded rainfall data at 0.250 x 0.250 spatial resolution was used as the reference dataset. Four statistical downscaling techniques such as Viz; linear scaling, power transformation, parametric quantile mapping and empirical quantile mapping were applied to the model and evaluated with reference to the IMD dataset. It was found that empirical quantile mapping and power transformation techniques performed best in the case of various statistical parameters. However, power transformation being a relatively simpler technique and requiring lesser computational resource, could be used for downscaling IITM-ESM model over India for regional studies on the impact of climate change especially for academic research where resource availability is limited. Suitability of the bias correction techniques for each of the five homogeneous regions in India i.e, North-West India, North Central India, West Peninsular India, East Peninsular India and Southern Peninsular India is intended to be pursued as an extension of the present study. The evaluation and bias correction of the temperature variable will also be carried out in the future study to provide a better understanding of the model's overall performance on a regional scale across India.

Keywords: General Circulation models, Climate Change, Bias Correction, Downscaling, Indian Summer Monsoon

NOTE: Milan Mathew under the supervision of Mr. Saurabh Bhardwaj, Senior Fellow (Until May 13, 2022) and Mr. Santosh Kumar Muriki, Associate Fellow at Center for Climate Modelling, TERI has carried out this work at The Energy and Resources Institute (TERI), New Delhi as part of his Master's degree project and submitted to TERI School of Advanced Studies (TERI SAS) on June, 2022

A FULLY-DISTRIBUTED HYDROLOGICAL MODEL TO ASSESS THE WATER BALANCE COMPONENTS IN THE ALAKNANDA RIVER BASIN

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ABSTRACT

A fully distributed hydrological model can simulate water balance with the help of runoff data in the Himalayan region (Alaknanda River basin). The Alaknanda River is a snow fedregion with a rough and complicated landscape. Commonly used semi-distributed hydrological models, such as Soil and Water Assessment Tool, are insufficient in simulating the water balance in such conditions. In this study, we set up a Waterloo Flood Forecasting tool, WATFLOOD, to consider the contribution of snowmelt in terms of snow water equivalent (SWE) in the runoff due to the presence of glaciers and snow cover in the Alaknanda River Basin. We assess six more water balance components, surface runoff, discharge, snow water equivalent, evapotranspiration, groundwater discharge, storage in upper and lower zone. Further, the variation in the different water balance components in a decade (2001 to 2010) is analyzed.The outcome of this study demonstrates that the WATFLOOD hydrological model is capable of simulating the water balance in the mountainous and snow-fed region with a NSE value of 0.75 and $R^2$is 0.85. Results also reveal that there is a depletion in the snow cover and reduction in the snow water equivalent in this decade. Additionally, our results show that some elements of the water balance, storage in lower zone and storage in the upper zone of the surface are not directly impacted by the amount of rainfall in the area, while surface runoff, snow water equivalent and discharge are affected directly.

Keywords: WATFLOOD hydrological model, Alaknanda River basin, Snow water equivalent, Water balance.

Performance of MPAS-A in simulation and prediction of pre genesis of Tropical cyclone over the North Indian Ocean

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ABSTRACT

Using atmospheric model prediction across scales(MPAS-A), the performance of models in simulating and predicting tropical cyclones (TCs) over the North Indian Ocean is assessed. A global, completely compressible, non-hydrostatic atmospheric model named MPAS-A was developed using the WRF model as a base; it was however spatially discretized using a C-grid staggered unstructured Voronoi mesh. Such unstructured spherical centroidal Voronoi tessellations (SCVTs) enable local refinement via variable resolution mesh, resulting in a smooth change in the horizontal resolution from coarse to finer regions. In this study, experiment is performed in predicting and simulation of TCs over North Indian Ocean (NIO). The experiment is done for three TCs namely, SCS Mora, ESCS, Fani and SUCS Amphan. Genesis of all three cyclones as per IMD commenced on 28th May 2017, 26th April 2019 and 16th May 2020 respectively. In all three cases, experiments are performed using different initial condition (IC) date prior to 8-10 days in lead. The experiments were checked for two suites that include a different combination of microphysics and convection parameterization scheme. Namely Mesoscale reference suite (MRS) and Convective permitting scheme (CPS). Uniform mesh of 3km resolution is used in this experiment. The forcing is obtained from reanalysis data ERA-5(ECMWF). It is observed that using 8-10 days in lead IC the model could simulate genesis of TCs Mora, Amphan and Fani. It is observed that in case of Mora the model could simulate the low formation area (LPA) on 25th May as compared with IMD and the day of depression on 28th May 2017 along with close similarity of track of Mora. Further analysis of the model output shows the vortex evolution on 24th May onward prior to 1 day leading to the day of LPA formation as per IMD. It is also observed that, model could well simulate the quasi close circulation (QCC), track and intensity, including wind field parameters humidity and rainfall, when compared with observation from reanalysis and Indian satellite data (INSAT-3D). Similarly, the experiment is done for Amphan and Fani with a lead day of 8-10 days and the results are addressed.

Comparison between WRF prediction and Machine learning based prediction of convective systems over Surathkal using satellite datasets

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ABSTRACT

Convective systems have a significant impact on population because of how their frequency, severity, and scale affect agricultural production and watershed hydrology. Convection is a phenomenon that allows for the redistribution of energy, heat, water, and trace gases from both natural and human-made sources in the atmosphere. Convection thus has a significant impact on both the quality of the air we breathe and the weather and climate. One of the most terrible disasters to strike our nation in recent memory is this one. They develop over distances of a few kilometres to a few hundred kilometres and at time intervals of a few minutes to a few hours. Violent thunderstorms frequently occur in coastal Karnataka during the hot pre-monsoon season. We have located a couple convective systems over coastal Karnataka for our investigation (India). We made an effort to look at convective systems every 30 minutes for the years 2021 and 2021 using satellite datasets, Doppler Radar Images, and IMD daily gridded rainfall data. In the past two years, seven severe convective systems have been recorded. In this study, we employ two prediction algorithms. Statistically based Atmospheric Stability Indicators and short-range weather forecasts from advanced research weather and forecasting models make up the first and second, respectively. With a lead time of 24 hours, the 3-km resolution accuracy of the WRF model has been verified. A high index of agreement, low mean absolute error, and low root-mean square error show that convection progression is predictable. The statistically based atmospheric stability gave us a good indication of how the convective system would develop in the next three to four hours. Two to three hours in advance, these two algorithms provide precise estimates of convection strength and movement.

Keywords: Precipitable water, Humidity, Winds, temperature amd Rainfall.

Impacts of varying marine biogeochemical variability on the simulated marine heatwaves and marine cold spells of South Asia

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ABSTRACT

In twin experiments with a Regional Earth System Model namely ROM, the varying marine biogeochemical light attenuation coefficient is taken into account in the one experiment (1950-2005 and 2006-2099 with RCP8.5) compared to the reference experiment (1920-2005 and 2006-2099 with RCP8.5) with a constant light attenuation coefficient equal to 0.06 m-1 over the Tropical Indian ocean. Both the simulations adequately reproduced the oceanic parameters in the historical period. However, in the biogeochemical active experiment phytoplankton primary production enhances which decreases SST and water temperature in subsurface layers. Cascading changes in SST-based extremes, marine heatwaves (MHW) and marine cold spells (MCS) have been observed due to the effect of the varying biogeochemical light absorption coefficients. A considerable change in the frequency, intensity, duration and spatial extent of extreme events have been observed in the historical as well as future periods. In the context of climate change the Spatio-temporal appearance of permanent MHW and dissolution of MCS has been investigated in both experiment with reference to the historical period. The region of appearance of permanent MHW and dissolution of MCS remains relatively the same in both experiments. However, significant differences in the year of the appearance of permanent MHW and dissolution of MCS have been witnessed. The presented study demonstrates the locally substantial impact of the biogeochemical process on ocean extremes.

Keywords: Regional Earth System Model, Marine Heatwaves, Marine cold spells, Tropical Indian Ocean

AI enabled next-generation cyclone intensity estimation

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ABSTRACT

Accurately estimating tropical cyclone (TC) intensity is one of the most critical steps in TC forecasting and disaster warning/management. For over 40 years, the Dvorak technique (and several improved versions) has been applied for estimating TC intensity by forecasters worldwide. However, the operational Dvorak techniques primarily used in various agencies have several deficiencies, such as inherent subjectivity leading to inconsistent intensity estimates within various basins. This collaborative study between meteorologists and data scientists has developed a deep-learning model using satellite imagery to estimate TC intensity.

Deep Learning algorithm design has recently seen improvements due to vast development in technologies and advancement in hardware resources for implementation. Image recognition has been able to solve the problem of classifying ambiguous data, and hence it is important to remember that the application of Deep Learning algorithm may solve typical tasks like storm image classification and prediction Also Deep Learning may be used for extraction complex features of images which the traditional approaches fail to do so in feature engineering. Thus Deep learning may be useful at user's choice leading to specific task achievement. The preliminary objectives of this chapter are to reveal the facts about Classification of Cyclone images and non -Cyclone images along with Cyclonic storm intensity using Auto-encoder on satellite imagery can be a game changer for TC intensity estimation. We have also discussed the different models performances which are trained on a dataset with images of recent cyclones across Bay of Bengal and Arabian Sea.

Keywords: Tropical Cyclone, Deep Learning, Feature Engineering, Auto –Encoder, model performance.

Carbon dioxide concentration over India from an agricultural perspective

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ABSTRACT

The ongoing climate change could be evaluated by analysing the concentration of atmospheric CO_2 originating from industries and intensive agricultural activities. We analyse the long-term changes in CO_2 concentrations between 2009 and 2020 in India using GOSAT satellite measurements. We use NDVI and NPP as proxies to show the variations in CO_2 concentration across India over the agricultural seasons with regard to vegetation. We find that the CO_2 concentration is lowest during the kharif (JJAS) season. In addition, a vast stretch of vegetation in India during kharif season might be acting as a potent sink for CO_2. However, since there are fallow croplands in India during the zaid (MAM) season, due to the lack of own farm irrigation infrastructure, atmospheric CO_2 reaches its peak. We also present the agro-management (semi-annual) analyses of CO_2 over India to determine the role of agricultural activities in setting up the seasonal concentration of CO_2 in the atmosphere. Based on agricultural management approaches, we consider the whole year into two sections: the management intensive period (July–December) and the management non-intensive period (January–June). The management non-intensive period shows a higher concentration of CO_2 than the management intensive period, which might be attributed to the higher land surface temperature and low soil moisture promoting the oxidation of soil organic carbon. India's atmospheric CO_2 concentration indicates a substantial upward trend from 2009 to 2020 of 2.42 ppm/year. Anthropogenic activities such as increased use of coal, fossil fuels and biomass burning events are the factors that significantly drive these temporal trends of CO_2 in India. The increasing CO_2 implies serious anthropogenic global warming and thus, calls for mitigation measures and continuous monitoring for timely policy interventions.

Keywords: Climate Change, Carbon Dioxide, Agriculture, Greenhouse Gas Emissions

Application of Integrated Hydrological Model for Simulation of Snowmelt Runoff over Parbati Sub-basin Using Degree-day Approach

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ABSTRACT

Snow is an important environmental parameter that influences not only the Earth's radiation balance but also river discharge, water cycle, sea level, primary productivity, etc. Snowmelt from the Earth's mountainous regions contributes significantly to runoff and ground water recharge in the middle and upper latitudes. Himalaya has one of the most extensive glacier systems, from which snow and glacier melt runoff sustains the perennial flow of the Indus, Ganga, and Brahmaputra river systems. In this study, temperature degree-day approach based Snowmelt Runoff Model (SRM) has been developed for accurate estimation of discharge during the snowmelt period. Satellite based 10-daily snow cover products from AWiFS data, ASTER Digital Elevation Model (DEM), ERA5 climatic dataset of 2m Air Temperature and Total Precipitation, in-situ observed discharge data and coefficients were used as input parameters for discharge simulation. Extrapolation of AWS 2m air temperature data including lapse rate over the Himalayan region leads to inaccuracies in the simulation of discharge, therefore ERA5 grided data was used. The model was implemented for the period of year 2013-2016 over Parbati sub-basin, Himachal Pradesh. Simulated discharge has been validated with in-situ observed discharge data from Bhuntar Station, Himachal Pradesh. However, the model underestimates the streamflow in all seasons but adequate results were observed during autumn, winter and summer season, which demonstrates the usefulness of the snowmelt runoff model to assess and predict snow and glacier melt runoff across the Himalaya. Also, sensitivity analysis has been done by varying input parameters ±05 percent and ±10 percent. Analysis shows that the model is more sensitive to recession coefficient and moderately to temperature and precipitation. This study aims at providing development and implementation of integrated hydrological model at sub-basin scale in Himalayan region for simulation of snow and glacier hydrological processes to understand the climate change impact on glacier hydrology.

Keywords: Snowmelt Runoff, Degree-day Approach, Himalayan Region, Integrated Hydrological Model

ASSESSMENT OF CMIP6 MODELS IN SIMULATING MJO

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ABSTRACT

The major constituent of sub-seasonal variability and sub-seasonal predictability is Madden Julian Oscillation (MJO). However, the majority of modern Global climate models (GCMs) perform poorly, when modeling variability associated with MJO. The performance of ten CMIP6 models are evaluated in simulating the eastward propagation of Madden Julian Oscillation. The study investigates the possible roles played by the various dynamic and thermodynamic parameters in controlling the simulation efficiency of MJO. The seasonal and climatological variation of MJO in these simulations is compared with the observations and the parameters which control the seasonal variations of these oscillations are explored. The results indicated that the better MJO simulations in some of the models were due to their capability to simulate the background features similar to the observation case . We also explore the relative importance of spatial structures of empirical orthogonal functions on the model performance of generated MJO. From these characteristic evaluations we concluded that the capability of models to reproduce the propagation of MJO is dependent upon their ability to capture the regional structure of subseasonal variability.

Keywords: Madden Julian Oscillations (MJO), CMIP6, Subseasonal variability, Climate modeling, Global Climate Models (GCMs)

Sensitivity of WRF-ARW model microphysics schemes in simulating the extreme heavy precipitation events over the central Himalaya

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ABSTRACT

The Himalayan region is witnessed extreme precipitation events in recent years. An attempt has been made to assess the sensitivity of the different microphysics parameterization in the Advanced Research Weather Research and Forecasting (ARW-WRF) model. The study evaluates the sensitivity of seven microphysical (Lin, Eta, WSM6, WSM5, WDM, Thompson, and Morrison) schemes to explore the potential to simulate heavy precipitation events over this sparse observational region. The model simulations were reasonably successful at reproducing key structural and dynamical characteristics associated with this extreme event, including water vapor transport and meteorological fields. Most of the microphysics schemes are able to simulate the temperature and specific humidity except the Eta schemes. The wind and precipitation pattern is found to be highly sensitive to the microphysics schemes. Further, this study highlights the comparative model performance between grid resolution and microphysics schemes. Our study highlights the selectivity of an appropriate microphysics scheme for reliable prediction of such HPE over the observationally scarce Himalayan region.

Understanding the Holika festival related biomass burning on air quality and aerosol optical properties on the basis of long-term study for a central Indo-Gangetic location, Varanasi

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ABSTRACT

Air pollution is one of the major causes of mortality and morbidity cases worldwide. Several studies have reported that episodic events, such as forest fire, large-scale agricultural residue burning, dust storms, and fireworks, are huge sources of air pollution that directly and indirectly impact the air quality, visibility, human health, and climate. Among these short-term events, festivals that are celebrated with fireworks and wood-log fires modifies the air quality. In India, Diwali and Holi are two major festivals that fall in this category and are celebrated across the nation. As per the religious belief, Holi, a spring season festival, is celebrated by burning numerous lots of wood-log and natural biomass (called Holika). The impacts of such widespread Holika burning on air quality, particulate matter concentration, and optical properties of aerosol is studied for a central Indo-Gangetic Location, Varanasi (25.5^0N, 83.0^0E). The effects of Holika burning are obtained by comparing the pre-burning and post-burning values of $PM_{2.5}$, PM_{10}, aerosol optical depth (AOD) and other parameters. Preliminary results show significant increase in $PM_{2.5}$ and PM_{10} concentrations and AOD values for post-burning duration from 2017 till 2022 as compared to pre-burning duration. Maximum impact was observed in 2019, with 140% increase in $PM_{2.5}$ concentration, 64% increase in PM_{10} concentration, and 390% increase in AOD values, and minimum impact was observed in 2017, with 21% increase in $PM_{2.5}$, 14% increase in PM_{10} and 42% increase in AOD values. This increase in primary data is expected to change the localized aerosol radiative forcing efficiency and atmospheric heating rate. An analysis is being done at present in this regard, and aerosol radiative forcing and heating rate is being computed. Considering the large-scale celebration of Holi over the Indian subcontinent, the regional impact of radiative properties of biomass burning on weather and climate is anticipated.

Keywords: Air pollution, Biomass burning, Aerosol optical properties, Radiative forcing, Holika

Regional Study of Extreme Weather Impact of Climate Change Over Lower Mahanadi Basin

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ABSTRACT

Temperature rise and changes in rainfall patterns are two of the most visible and immediate effects of climate change. Changes are not uniform around the world, making regional impact assessments necessary. This study is focused on the extreme events and spatio-temporal variations of seasonal maximum and minimum temperature and precipitation over the lower Mahanadi basin. The study area is divided into two sub-regions which are near coast and far coast. The main objective of this study is to ascertain the possible changes in seasonal precipitation, temperature, and frequency of extreme events. Several climate Extreme Indices for the future period (2015- 2100) were analyzed based on the station data from two CMIP6 general circulation models (GCMs), which are ACCESS-CM2, BCC-CSM2-MR under two shared socioeconomic pathways (SSP370, SSP 585) scenarios. Three-time horizons were taken: (2015-2044), (2045-2075), and (2076-2100) for the analysis of spatial and temporal variation of seasonal precipitation and temperature with the base period (1981 -2014).

Results suggest that R10mm (annual no. of days when precipitation >= 10mm), PRCPTOT (annual sum of daily precipitation>=1.0mm), WSDI (warm spell duration index), TXX (maximum value of daily maximum temperature), Tropical nights, Heat waves, have the increasing slope. Whereas decreasing slope has been found for Consecutive Dry Day and Simple Precipitation Intensity Index. The slopes for SU (number of summer days), consecutive wet days, and R20mm are constant. In the end period (2075-2100) seasonal rainfall decreases over coastal regions. The analysis also suggests that the seasonal rainfall in the middle region increases drastically from (2015-2045). Apart from the seasonal rainfall, variation of the minimum and maximum temperature near the coastal areas and southwest areas has been found to be increasing in the end period (2075-2100) with respect to the base period.

Keywords: Extreme indices, Climate change, SSP , GCMs.

JG

ANALYSIS OF LONG-PERIOD SEASONAL VARIATION OF TEMPERATURE AND RAIN FALL FOR 6(SIX) SUB CATCHMENTS OF DAMODAR VALLEY AREA IN A TIME OF CLIMATE CHANGE

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ABSTRACT

The hydrological cycle is influenced by the temperature. The long period variation of seasonal temperature and rainfall of the six catchments namely Damodar West, Damodar East,Barakar West, Barakar East, Lower Valley North and Lower Valley South located on Damodar Valley area in Jharkhand and South West Bengal. The present study is carried out to find out the variability in magnitude of temperature and rain fall over the period 1951-2020(70 years). The temperature and rainfall data of the stations located at six sub catchments have been collected from India Meteorological Department(IMD). Trends are analyzed using Mann-Kendell test for the data period 1950-2020. From the trend analysis we observed that seasonal temperature variation of Summer of Damodar West, Barakar West, Damodar East, Lower Valley North are increasing trend and temperature variation of Summar of Barakar East and Lower Valley North are decreasing trend. The fluctuation of Monsoonal and post monsoonal temperature of all six sub catchments are decreasing trend , but variation of Winter temperature of all six sub catchments are increasing trend . For all cases the value of Mann- Kendell Z value are greater than 1.65 at 0.05(95 %) level. So, all results are statistically significant. From the trend analysis of rainfall we observed that seasonal rainfall variation of Summer of all six Sub catchments are in decreasing trend. Seasonal rainfall trends of all six Sub catchments are increasing trend in monsoon (except Damodar West) and post monsoon seasons. Seasonal rainfall variation of Winter season are in decreasing trend of all six Sub catchments except Lower Valley North and Lower Valley South. For all cases the value of Mann Kendell Z value are greater than 1.71 at 0.05(95%) level. So, all results are statistically Significant except in monsoon season it is non significant.

Key words: seasonal trend, Sub catchmemt, Mann Kendell test, Statistically significant

Comparative Analysis of Benzene, Toluene, Xylene (BTX) Concentration and Seasonal Variation in two most Polluted Cities of IGP Region: Agra and Ghaziabad

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ABSTRACT

Air pollution is one of the primary sources of risk to human health in the world. Vehicular exhaust is one of the most important anthropogenic sources of air pollution, a major constituent of which include Volatile Organic Compounds (VOCs) such as benzene, toluene, and xylene (BTX). In this study, seasonal and annual variations of BTX were evaluated at Agra and Ghaziabad for the pre (2019), during (2020) and post-Lockdown period (LP) (2021), for which the data on BTX were obtained from the Central Pollution Control Board (CPCB).

The data suggested that the level of BTX increased during lockdown period in Ghaziabad by 17, 41 and 23% and decreased by 10, 20, 2% after lockdown, respectively. However, the level of BTX decreased by 28, 27, 33% in Agra during lockdown and further decreased by 40, 64 and 48% after LP. The decline in BTX during LP could be attributed to complete restrictions
imposed. In contrast, a slight increase in BTX during the LP in Ghaziabad could be attributed to poor photochemistry between the precursors of O3 and conditional relaxation to certain businesses, including agricultural businesses, transportation to operate which were significant sources for BTX. Toluene was found to be the most abundant VOCs in the atmosphere of Agra and Ghaziabad. The seasonal mean concentration of VOCs was observed highest in Winter > post-Monsoon > Monsoon > Summer. Further, the T/B ratio were found lower in the LP as compared to the pre-LP which is attributed to the complete closure of non-traffic sources such as industries and factories during the LP. Among different seasons the maximum (6.91, 28.28) and minimum (0.01, 0.08) T/B ratio was observed in winter and summer for Agra and Ghaziabad which suggested traffic emissions as major source of BTX. Based on the findings of the present study, some special measures like promotion of cleaner technologies to reduce vehicular pollution, increasing greenery by massive plantation can be taken for reducing the levels of these pollutants.

Keywords: BTX, VOCs, Seasonal Variation, Lockdown, Air Pollution

Changing Hydro-Climatic Responses of Subarnarekha Watershed: A Multi Dimensional Multi-Centric Isotope-based Hydro-Chemical Approach

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ABSTRACT

Assessment of risks associated with climatic extremes plays a vital role in management of water resources in tropical India. In the present paper, hydro-meteorological characterization of Subarnarekha basin of East Jharkhand, India is done to evaluate chemical fluctuations, precipitation milieus, trend analyses, periodicity, and sensitivity of water-balance parameters to climate change effects. Subarnarekha overflows its banks during the monsoon months (June
September) and remains dry in middle and upper reaches during summer (April-May). The altered hydrological system brings in uncertainties to agrarian economy of Subarnarekha watershed. In the backdrop of such contingent issues, understanding and assessing of hydrological responses of Subarnarekha is vital for scientific planning and management of its water resources. The spatial and temporal hydro-chemical behaviour of the basin reveals consistent increase in average temperature that might shorten crop growing period resulting in yield penalty and biomass cover. Epistemic uncertainties in hydro-chemical discharges due to imposition of climate variables were quantified and discussed. Further, impacts of climate change scenarios on various components of basin hydrology, coterminous to agricultural land segment, were estimated. Changes in monsoon precipitation may cause steady deterioration in future scenarios. The degree of uncertainty may increase manifold, resulting in frequent extreme precipitation events and occurrences of floods. The analyses in this study are intended to forge on a plan based on the permissible degree of uncertainty in stream flow forecasting that indirectly affects the other hydrological fluxes beneficial to agricultural water management. Besides, congruent decentralized water management strategy can be developed in vulnerable ridges of the basin to attenuate the effects of extremities in seasonal runoff discharges and augmenting green water components. Findings of this study will possibly help in devising new policies to reduce agricultural production risk through focussed water management plan imperative to an improved economy of the region. Keywords: agrarian, green water, hydro-chemistry, isotopes, Subarnarekha

Temperature and Precipitation Characteristics over Tirupati-Tirumala

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ABSTRACT

Recent climate change-induced warming and associated changes in atmospheric patterns and air-sea interactions lead to extreme weather events on a temporal and spatial scale. Pertaining to the socio-economic losses posed by these extremes, understanding the occurrence of extreme events more locally is a high priority. In this work, we study the historical (1901- 2021) characteristics and future trends (2021-2060) in the temperature and precipitation patterns over Tirupati-Tirumala, the holy city and a rapidly developing centre for education, IT and healthcare in South India. We use the Indian metrological data (IMD) and 35 models from CMIP-6, respectively, with daily temporal and 0.25 spatial resolution. While this region receives peak precipitation in the winter monsoon during Oct-Nov (above 150 mm/month), average monthly rainfall of 100 mm/month has been noticed in the summer monsoon from Jun-Sep. Similarly, monthly average temperatures during summer (Apr-Jun) is about 35°C. Minimum mean monthly temperatures during Dec-Jan are at 10°C. Both annual and seasonal precipitation and temperature show a significant positive trend (increase) in the recent decades. This pattern is prevailing in the near future with an increase in heavy rainfall events and extremely hot days.

Cloud Microphysics and Its Relationship with Black and Brown Carbon Over Gangtok Sikkim

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ABSTRACT

The study of the cloud microphysics related to black and brown carbon is particularly dependent on the planetary boundary layer and climate change. The global average temperature has been rising at a faster rate since preindustrial times, which is well established by various scientists (IPCC, AR5). Fossil fuel emissions are a major contributor to black and brown carbon emissions and is a well-established science and has been reported for half a century. The warming of mountainous region is much more rapid than that of the plain (Tian and Miao 2019; Rangwala and Miller 2012), which is affecting the indigenous life sustenance. The present study is a discussion of black carbon (BC) and brown carbon (BrC) and their effects on the Sikkim weather pattern using in-situ and ERA5 reanalysis data sets. The black and brown carbons have a very distinct nature. The regional weather and climate processes, such as orographic cloud formation and precipitation over Himalayan regions like Sikkim are therefore very susceptible to investigation. The concentration of black and brown carbon over the study region (Gangtok) is observed to be very high, however in this region the major sources for these pollutants are very few except for vehicular emissions (mostly due to tourist activity). In addition, this study also discusses the surface warming, LCL (lifting condensation level) and radiative nature of the BC and BrC, as well as longwave radiation anomalous rise, resulting in cloud formation and foggy days. The fog days have been increasing over Gangtok and supressing the precipitation and inducing extreme weather events over Sikkim.

Key words: Black Carbon, Brown Carbon, Cloud Microphysics, and Extreme Precipitation.

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ANALYSIS OF LONG-PERIOD SEASONAL VARIATION OF TEMPERATURE AND RAIN FALL FOR 6(SIX) SUB CATCHMENTS OF DAMODAR VALLEY AREA IN A TIME OF CLIMATE CHANGE

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ABSTRACT

The hydrological cycle is influenced by the temperature. The long period variation of seasonal temperature and rainfall of the six catchments namely Damodar West, Damodar East,Barakar West, Barakar East, Lower Valley North and Lower Valley South located on Damodar Valley area in Jharkhand and South West Bengal. The present study is carried out to find out the variability in magnitude of temperature and rain fall over the period 1951-2020(70 years). The temperature and rainfall data of the stations located at six sub catchments have been collected from India Meteorological Department(IMD). Trends are analyzed using Mann-Kendell test for the data period 1950-2020. From the trend analysis we observed that seasonal temperature variation of Summer of Damodar West, Barakar West, Damodar East, Lower Valley North are increasing trend and temperature variation of Summar of Barakar East and Lower Valley North are decreasing trend. The fluctuation of Monsoonal and post monsoonal temperature of all six sub catchments are decreasing trend , but variation of Winter temperature of all six sub catchments are increasing trend . For all cases the value of Mann- Kendell Z value are greater than 1.65 at 0.05(95 %) level. So, all results are statistically significant. From the trend analysis of rainfall we observed that seasonal rainfall variation of Summer of all six Sub catchments are in decreasing trend. Seasonal rainfall trends of all six Sub catchments are increasing trend in monsoon (except Damodar West) and post monsoon seasons. Seasonal rainfall variation of Winter season are in decreasing trend of all six Sub catchments except Lower Valley North and Lower Valley South. For all cases the value of Mann Kendell Z value are greater than 1.71 at 0.05(95%) level. So, all results are statistically Significant except in monsoon season it is non significant.

Key words: seasonal trend, Sub catchmemt, Mann Kendell test, Statistically significant

Changing Hydro-Climatic Responses of Subarnarekha Watershed: A Multi Dimensional Multi-Centric Isotope-based Hydro-Chemical Approach

Susnata Ray[1], Swagupta Biswas[2], Archana Deodhar[3], Md. Arzoo Ansari[4]and Sharadindra Chakrabarti[5]

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ABSTRACT

Assessment of risks associated with climatic extremes plays a vital role in management of water resources in tropical India. In the present paper, hydro-meteorological characterization of Subarnarekha basin of East Jharkhand, India is done to evaluate chemical fluctuations, precipitation milieus, trend analyses, periodicity, and sensitivity of water-balance parameters to climate change effects. Subarnarekha overflows its banks during the monsoon months (June

September) and remains dry in middle and upper reaches during summer (April-May). The altered hydrological system brings in uncertainties to agrarian economy of Subarnarekha watershed. In the backdrop of such contingent issues, understanding and assessing of hydrological responses of Subarnarekha is vital for scientific planning and management of its water resources. The spatial and temporal hydro-chemical behaviour of the basin reveals consistent increase in average temperature that might shorten crop growing period resulting in yield penalty and biomass cover. Epistemic uncertainties in hydro-chemical discharges due to imposition of climate variables were quantified and discussed. Further, impacts of climate change scenarios on various components of basin hydrology, coterminous to agricultural land segment, were estimated. Changes in monsoon precipitation may cause steady deterioration in future scenarios. The degree of uncertainty may increase manifold, resulting in frequent extreme precipitation events and occurrences of floods. The analyses in this study are intended to forge on a plan based on the permissible degree of uncertainty in stream flow forecasting that indirectly affects the other hydrological fluxes beneficial to agricultural water management. Besides, congruent decentralized water management strategy can be developed in vulnerable ridges of the basin to attenuate the effects of extremities in seasonal runoff discharges and augmenting green water components. Findings of this study will possibly help in devising new policies to reduce agricultural production risk through focussed water management plan imperative to an improved economy of the region. Keywords: agrarian, green water, hydro-chemistry, isotopes, Subarnarekha

Cloud Microphysics and Its Relationship with Black and Brown Carbon Over Gangtok Sikkim

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ABSTRACT

The study of the cloud microphysics related to black and brown carbon is particularly dependent on the planetary boundary layer and climate change. The global average temperature has been rising at a faster rate since preindustrial times, which is well established by various scientists (IPCC, AR5). Fossil fuel emissions are a major contributor to black and brown carbon emissions and is a well-established science and has been reported for half a century. The warming of mountainous region is much more rapid than that of the plain (Tian and Miao 2019; Rangwala and Miller 2012), which is affecting the indigenous life sustenance. The present study is a discussion of black carbon (BC) and brown carbon (BrC) and their effects on the Sikkim weather pattern using in-situ and ERA5 reanalysis data sets. The black and brown carbons have a very distinct nature. The regional weather and climate processes, such as orographic cloud formation and precipitation over Himalayan regions like Sikkim are therefore very susceptible to investigation. The concentration of black and brown carbon over the study region (Gangtok) is observed to be very high, however in this region the major sources for these pollutants are very few except for vehicular emissions (mostly due to tourist activity). In addition, this study also discusses the surface warming, LCL (lifting condensation level) and radiative nature of the BC and BrC, as well as longwave radiation anomalous rise, resulting in cloud formation and foggy days. The fog days have been increasing over Gangtok and supressing the precipitation and inducing extreme weather events over Sikkim.

Key words: Black Carbon, Brown Carbon, Cloud Microphysics, and Extreme Precipitation.

Cloud Microphysics and Its Relationship with Black and Brown Carbon Over Gangtok Sikkim

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ABSTRACT

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Key words: Black Carbon, Brown Carbon, Cloud Microphysics, and Extreme Precipitation.

IMPORTANCE OF PRIMARY STANDARDS FOR CALIBRATION OF SOLAR RADIATION MEASURING INSTRUMENTS

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ABSTRACT

Calibration determines measurement equipment performance. With routine equipment calibration and adjustment, you can measure safely, ensure compliance and avoid the costs of inaccurate measurements. Regular calibration of field equipment is important to help ensure operation within acceptable measurement tolerances. Calibration will assist in reducing instrument-related systematic observation errors, thus lowering the associated uncertainty of the data. Greater confidence in the interpretation and application of data from various sources can be achieved when instruments have been calibrated against a traceable reference. The fraction of the energy flux emitted by the sun and intercepted by the earth is characterized by the ***solar constant****. The solar constant is defined as essentially the measures of the solar energy flux density perpendicular to the ray direction per unit are per unit time. It is most precisely measured by satellites outside the earth atmosphere. The solar constant is currently estimated at* ***1367 W/m²****. This number actually varies by 3% because the orbit of the earth is elliptical, and the distance from the sun varies over the course of the year. Some small variation of the solar constant is also possible due to changes in Sun's luminosity. This measured value includes all types of radiation, a substantial fraction of which is lost as the light passes through the atmosphere. The amount of solar radiation on the earth surface can be instrumentally measured, and precise measurements are important for providing background solar data for solar energy conversion applications. There are two important types of instruments to measure solar radiation:* ***Pyrheliometer*** *is used to measure direct beam radiation at normal incidence and are calibrated against the primary standard methods.* ***Pyranometer*** *is used to measure total hemispherical radiation - beam plus diffuse - on a horizontal surface. These instruments are usually calibrated against standard Pyrheliometer. Certain standards are used frequently to calibrate radiometers deployed in continuous monitoring stations. The World Radiometric Reference (WRR) is the internationally recognized standard for solar (shortwave) irradiance measurement. A group of seven self-calibrating absolute cavity radiometers form its basis of World Standard group (WSG). Reference standard radiometers from around the world are compared every five years to the WRR at the World Radiation Center in Davos, Switzerland.*

Keys words: *WRR,WSG,Cavitiy Radiometers,Pyranometers,Pyrheliometer*

Local and Regional Contribution of Black Carbon over Bhubaneswar

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ABSTRACT

Black Carbon (BC) is an important aerosol species for its potential to absorb incoming solar radiation and cause atmospheric warming, thereby modulating the vertical and horizontal thermal structure of the atmosphere, and hence weather and climate. Apart from locally emitted BC, though the BC has a very short life span, because of its small size, it can travel thousands of kilometres downwind and influence the atmospheric conditions at the destination. Therefore, at a particular place, characterization of the atmospheric BC concentration contributed from the local and regional sources is of great importance. In this context, Bhubaneswar is an emerging smart city with evidence of increasing atmospheric BC in recent times. This increased BC is mainly attributed to the outflow from Indo-Gangetic Plain (IGP) and local emissions like fossil-and bio-fuel combustions. Though the sources of BC for Bhubaneswar are well characterized, their quantification in terms of local and regional contributions is yet to be done. In the present study, applying the moving average subtraction technique to the observed high temporal resolution BC concentration at IIT Bhubaneswar (85.67 E, 20.14 N), we quantify the amount of local and regional BC both annually and seasonally from 2018 to 2021. The analysis shows that the average BC concentration over Bhubaneswar is annually 4.04 μg/m3. It is maximum during the winter season 7.70 μg/m3 and minimum during monsoon 1.53 μg/m3. The regional [local] concentration is the highest during the winter [monsoon] season 7.06 μg/m3 (91.77 %) [0.29 μg/m3 (19 %)], and lowest during the monsoon [winter] season 1.24 μg/m3 (81%) [0.64 μg/m3 (8.23 %)]. Similarly, month-wise, the regional [local] BC concentration was maximum during December [September] 7.53 μg/m3 (94.7 %) [0.37 μg/m3 (21.07 %)] and minimum during September [December] 1.40 μg/m3 (78.93 %) [0.42 μg/m3 (5.30 %)]. The majority of ambient BC over Bhubaneswar is regional, estimated to be 85.96% annually. Further analysis of wind and rainfall data shows that the high regional contribution during winter is due to the stable atmospheric condition, which keeps the long-range transported BCs at the surface level and helps increase their contribution. The opposite of that (low regional contribution) happens during the monsoon season because of the washing out due to rainfall. Overall, the study suggests that the temporal BC domination over Bhubaneswar in terms of local and regional is highly significant, which may give a new perspective to the government and policymakers for framing the rules and regulations accordingly.

Keywords: Local and Regional BC over Bhubaneswar, pollution over Bhubaneswar, Black Carbon, Moving average subtraction method.

A Numerical Study to Investigate the Precipitation Features of Monsoon Deep Depressions over Bay of Bengal

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ABSTRACT

The rainfall characteristics of Monsoon Deep Depressions (MDD) originating over the Bay of Bengal (BoB) basin have been investigated in the present study using a coupled ocean atmospheric model (COAWST) and a stand-alone atmospheric (WRF) model with a lead time of up to 72h. It is found that though the tracks of the four MDDs considered in the study have been reasonably simulated, the intensity was overestimated in both sets of simulations compared to India Meteorological Department (IMD) best estimates. Upon decomposition of the contributors to the rainrate for the composite of the storms in the deep depression (DD) phase, it was found that the moisture sources/sinks play a more important role than the cloud sources/sinks in modulating the rainfall processes. Further analysis of the moisture sources/sinks showed that the horizontal and vertical advection are the major drivers in modulating the contribution of the moisture sources/sinks. The validation of rainfall using CMORPH datasets suggested that the coupled simulations had a higher skill in rainfall prediction. Furthermore, the composite of different components of moisture sources/sinks (especially vertical advection) was found to be more realistically simulated in COAWST compared to CNTL upon validation with MERRA datasets. Analysis of the composite energetics showed that scarcity of bulk kinetic energy in the later hours of the DD phase in COAWST led to the dissipation of the storm core, which led to better prediction of rainfall. On the other hand, a re-intensification of the storm core by means of condensational heating led to an overestimation of rainfall in WRF, which finally resulted in lower skill in rainfall prediction.

Keywords

Monsoon deep depressions (MDD), Bay of Bengal (BoB), Coupled Ocean Atmosphere Wave and Sediment Transport (COAWST) model, vertical advection (VADV)

A HIGH-RESOLUTION EMISSION INVENTORY OF CARBONACEOUS FINE PARTICULATE MATTER OVER THE INDIAN REGION

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ABSTRACT:

Pollutant emissions from a variety of industries, including transportation, housing, thermal power plants (TPP), and others, have dramatically expanded throughout India and have been claimed to have a considerable impact on local air quality and climate change. Using Geographic Information Systems (GIS), we have created a high-resolution emission inventory for carbonaceous, fine particulate matter (CPFM) (Black Carbon) emissions at a resolution of 10 x 10 km2 for various sectors (transport, residential, TPPs, etc.) for the Indian geographical area. Based on micro-level specifics and current year activity data of fossil fuel and biofuels, the spatial distribution of emissions is downscaled to a finer resolution. For the base year 2018 over India, the total national black carbon (BC) emission has been calculated to be 1480 Gg yr^{-1}. The two sectors generating the largest percentages to overall BC is a transportation and residential, with 46% and 39%. In India, the transportation sector (36%) was slightly larger than the residence sector in the BC emission. In order to assess the trend from all sources from 2011 to 2018, we also built an emission inventory for CFPM in 2011. According to all available data, the grid-wise total BC increment over the Indian region is predicted to be 35% (355 Gg). In order to better predict and control the hotspots of air pollution, policymakers will find this high-resolution inventory of CPFM to be useful for decision-making as well as input to regional chemical transport models in the atmosphere.

Keywords: Emission inventory, Black Carbon, Geographic Information System

Validation of Indian high resolution BUFR Radio Sonde profiles

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ABSTRACT

National Centre for Medium Range Weather Forecasting (NCMRWF) regularly receives global meteorological observations through Global Telecommunication System (GTS) in World Meteorological Organization's (WMO) accepted codes. Most of the global conventional data (including surface and upper air) were transmitted in Traditional Alphanumeric Codes (TAC) till recently and are slowly changing to Table Driven Code Form (TDFC). One of the most common TDFC for meteorological and oceanic data transfer is the BUFR (Binary Universal Form for the Representation of Meteorological Data). Recently, India also has started disseminating some of its existing radio sonde stations' data in high resolution BUFR. As per the communication from India Meteorological Department (IMD), six WMO Global Climate Observing System (GCOS) Upper-Air Network (GUAN) stations viz., New Delhi (42182), Guwahati (42410), Kolkata (42809), Nagpur (42867), Mumbai (43003), and Chennai (43279) are taking high resolution radiosonde observations twice daily at 0000 and 1200 UTC and disseminating through global GTS. As part of the NCMRWF regular observation monitoring, we are monitoring the frequency and quality of these Indian high resolution radiosonde observations. The study demonstrates the innovation profiles of different meteorological variables like temperature, humidity, and wind components of these radiosonde reports against NCMRWF NWP model background fields during monsoon 2022.

Characteristics of rainfall spells triggering landslides in parts of East Sikkim, Eastern Himalaya, India

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ABSTRACT

The state of Sikkim in Eastern Indian Himalaya faces grave danger of landslides where rainfall is happened to be the most influencing factor for triggering of landslides every year during the months of June to September. To characterize rainfall initiating landslides in parts of East Sikkim, rainfall spell duration (D), intensity (I) and antecedent amount of rain (E) have been evaluated using NASA POWER precipitation dataset. Geological Survey of India (GSI) landslide inventory recorded 332 total numbers of landslide scars in the area of interest (AOI) of present work. A detailed landslide inventory has been prepared for the period of 2010 to 2021 and 19 landslides has been taken for study. Most of the landslides in the area are distributed over Chlorite Sericite Schist and Quartzite of Proterozoic age. In the area highest rainfall is recorded during July, August and September (JAS) followed by April, May and June (AMJ). Total number of rainfall days has been increased for the studied time period following almost a linear trend but the total number of rainfall spells has not followed a preferred trend over the same period. This signifies increasing possibility of extreme precipitation events in the AOI. An extreme intensity precipitation event i.e., high rainfall amount within a less duration can hamper weak slopes and triggers instability. Days of antecedent rainfall and amount of rainfall needed to trigger landslide are higher in the southern part of the AOI then other areas. Traditional Emap method (i.e., if in a single rainfall spell more than 10% of long term average annual rainfall accumulates then landslide will always occur in Eastern Himalaya) has been applied for the study area and shows 63% accuracy in predicting landslides. Antecedent cumulative rainfall impact on landslide triggering has been evaluated using 3, 5, 7, 10, 15, 30 and 60 days antecedent rainfall period. Power law equation for determination of amount-duration (ED) and intensity-duration (ID) threshold has been applied. ED threshold relation gives best result for duration of 7 days and 10 days with threshold amount of 67.32 mm and 95.80 mm of rainfall respectively with 85% accuracy. ID threshold relation give best result for period of 10 days with an intensity of 9.6 mm/day. Recurring problem and risk of instability along roads in the AOI during monsoon period can be addressed through early warning to avoid any kind of hazard scenario. This study and its findings are intended to help achieve the goal of minimizing risk and avoiding hazard related to rainfall triggered landslides in the AOI.

Processes controlling the interannual variability of sea surface salinity in the South Eastern Arabian Sea warm pool

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ABSTRACT

The southeastern Arabian Sea (SEAS) hosts some of the warmest oceanic area globally, with sea surface temperatures (SST) exceeding 30℃ in May, prior to the monsoon onset. This " Arabian Sea warm pool" is thought to play key role in the summer monsoon onset vortex formation. This warm pool is also characterized by fresh waters, which are thought to influence the SEAS seasonal SST evolution through their impact on oceanic stability and vertical mixing of heat. While SEAS sea surface salinity (SSS) seasonal variations and their impact of SST have been previously studied, much less is known on salinity variations at other timescales. Here, we assess the SEAS SSS interannual variability, as well as its driving mechanisms and impact on SST, using a regional eddy-permitting ocean general circulation model and 8-years long record of merged ESA-CCI satellite SSS. The main near-surface oceanic features (SSS, SST, mixed layer depth, surface currents etc.) in the model compare favourably with in situ and satellite data over the SEAS, at both seasonal and interannual timescales. The largest SEAS interannual SS variations occur during winter, in association with the Indian Ocean Dipole (IOD). The IOD remote impact on the strength of the East Indian Coastal Current modulates the amount of freshwater advected from the Bay of Bengal into the SEAS. This yields a strong interannual variability of the SEAS mixed layer depth. These SSS and mixed layer depth interannual variations however do not significantly alter the surface layer heat budget, which is rather rimarily controlled by net surface heat flux, especially during boreal winter and spring.

Keywords: Southeastern Arabian Sea, Sea surface salinity, Sea surface temperature, Mixed layer Depth, Indian Ocean Dipole

An object-based approach for Heat Wave Verification during MAM-2022

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ABSTRACT

The method for object-based evaluation (MODE) in the METplus approach was originally developed for application to spatial precipitation forecasts, but it can also be applied to other fields with coherent spatial structures (e.g., clouds, convection). It is the only one of a number of different approaches developed in recent years to meet these needs. It is widely applied only for the verification of Rainfall forecasts. Using MODE for Tmax verification for heat waves is a new idea. For the object-based verification of maximum temperatures (Tmax) forecast, first time in India the mode module is used to track the record heat wave episodes during March, April and May (MAM) 2022. The module mode verifies grid-to-grid forecast along with the gridded India Meteorological Department (IMD) observations with a horizontal resolution of 50 km. The NCUM-G Tmax forecast data was re-gridded to observe resolution using bilinear interpolation and several scores were produced, like the centroid distance, angle difference, symmetric difference, area ratio and total interest. For forecast and observations, can track the centroid's daily movement over the heat wave region. In this study, we have used the NCUM-G forecast to verify Tmax to identify the heat-wave regions during MAM 2022 and to track the movement of the record Heatwave episodes over Indian sub-divisions.

Keywords: METplus, heat waves, centroid distance, area ratio, total interest, deterministic

forecast

An Analysis of Fog/low Visibility in the Airports in Eastern India (Representative Station: Patna Airport).

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ABSTRACT

Strong variations in fog qualities have been found by analyzing hourly METAR observations for the period 2014-2022 for the Patna Airport which is situated in the Indo Gangetic Plains(IGP) of India. Fog is mainly a wintertime phenomenon for the entire IGP. Although fog is usually associated with the frequency, amplitude, and Intensity of Western Disturbance(WD) but in the present study it is found that both the initiation and onset process critically rely on local wind apart from other factors. A classification scheme based on the prevailing condition prior to onset of fog has been devised. As per this scheme fog can be classified in to five categories i.e. advection, precipitation, radiation, and cloud base lowering. The study's findings have identified a promising pre-fog diagnosis tool which has the potential of operational us provided it is validated with longer period data. The classification algorithm/methods correctly categorize the 100% fog events of Patna Airport into five categories. The dominant type of Fog is radiation Fog(70.8%), Advection Fog(22.02%) Precipitation Fog(2%), and Cloud base lowering fog(0.62%) out of the 4300 hourly Fog events at the Patna Airports. None of the fog identified as evaporation type

Keywords: Visibility, Fog formation, fog classification, etc.

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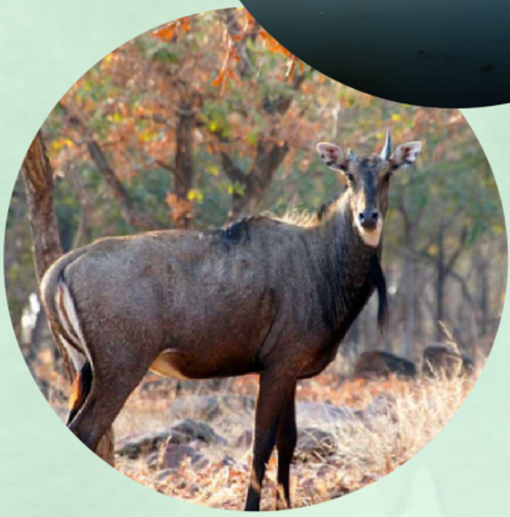

BHOPAL - 'CITY OF LAKES'

Bhopal, the capital of Madhya Pradesh, is a wonderful confluence of scenic beauty, old-world charm and urban planning.

The two main lakes, the Upper Lake and the Lower Lake are the nuclei of all the hustle and bustle. Bhopal today presents a beautifully mixed profile – the old city's architectural grandeur is seen in its marketplaces, fine old mosques and palaces which still breathe aristocratic imprint of former rulers – among them a succession of powerful Begums who ruled the city from 1819 to 1926. Equally impressive is the new city with its lush, exquisitely laid out parks and gardens, broad avenues and streamlined modern edifices.

It is considered among the greenest and cleanest cities in the country. One can stumble upon the vibrant impact of different faiths and cultures here; the footprints of the Mughals and the Afghans, and reflections of Islam, Buddhism and Hinduism – all of which have been blended to perfection, to provide Bhopal a distinct identity.

Source: *Incredible India*

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