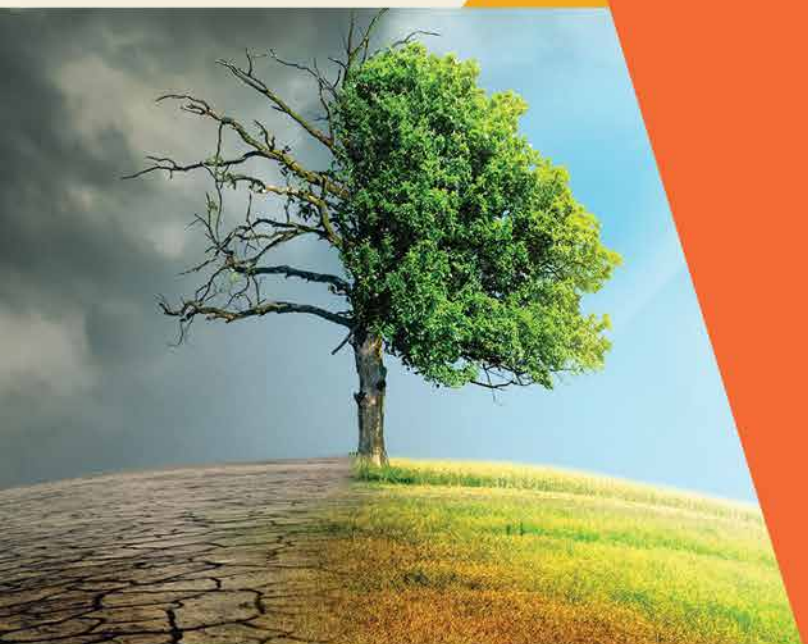
Abstract Volume



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Indian Meteorological Society
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Cochin Chapter

International Symposium on Tropical Meteorology (INTROMET-2021)
on
CHANGING CLIMATE: CONSEQUENCES AND CHALLENGES (C4-21)

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INTERNATIONAL SYMPOSIUM ON TROPICAL METEOROLOGY (INTROMET-2021)

On

CHANGING CLIMATE: CONSEQUENCES AND CHALLENGES (C4-21)

In virtual mode

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ABSTRACT VOLUME

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Cochin University of Science and Technology (CUSAT), Cochin, Kerala State, India

Contents

CHC

Changing Climate – Observations, Attribution and Model Projections

QUANTIFICATION OF ANNUAL AND SEMI-ANNUAL HARMONICS OF SST AND THE HEAT BUDGET TERMS IN THE TROPICAL INDIAN OCEAN DURING 1980-2019

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ABSTRACT

The sea surface temperature (SST) is a key indicator of the warming of oceans, and the global ocean has warmed at a rate of 0.12 ±0.03°C per decade since 1979. However, no studies in the Indian Ocean region have revealed how the annual and semi-annual harmonics of SST are changing. This study uses 40 years of SST data from NCEP-GODAS to quantify the annual and semi-annual harmonics in the tropical IO for the first time. It shows the importance of semi-annual harmonics as compared to annual harmonics. The harmonic analysis also indicates a dominant annual cycle on the Southern IO and a semi-annual cycle along the coast of Sumatra and Oman. Over the period, we could observe a decreasing trend in annual amplitude in the Indian Ocean (IO) except regions such as the east coast of India, west equatorial IO, and Seychelles-Chagos thermocline ridge region. Both harmonics are damped in the Bay of Bengal (BoB) and the southern IO. East equatorial IO is the only region where the semi-annual amplitude weakens while the annual amplitude strengthens. Further, we estimated the three important mixedlayer heat budget terms: net air-sea heat flux, horizontal advection, and vertical processes that drive the tendency of mixed-layer temperature. Net air-sea heat flux and vertical processes show a dominant semi-annual pattern over most of the north IO. Horizontal advection of mixed-layer temperature showed a predominance of annual harmonics in the major boundary currents (Somali current and West and East Indian Coastal currents). However, semi-annual harmonics dominated the horizontal advection in the equatorial-current region west of 90°E. Notable amplification of annual and semiannual harmonics of vertical processes and horizontal advection seen in the western equatorial IO, Arabian Sea, and the BoB.

Keywords: Sea surface temperature, annual, semi-annual, harmonics, Indian Ocean.

Atmospheric water budget as a constraint on precipitation response over agro-climatic zones in India under higher warming conditions: Regional Earth system model assessments

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ABSTRACT

A significant change in precipitation, especially on the local scale, is expected in the future, which has a tremendous impact on regional society and ecosystems. However, its reliable projection is key to effective adaptation strategies, remains a major scientific challenge. Therefore, improving the process associated with precipitation changes is highly demandable. This study employed the high-resolution regional earth system model (RESM), namely ROM driven by ESM MPI-ESMLR over the CORDEX-South Asia region under the RCP8.5 scenario. The ROM's performance is demonstrated with available observation, and its added value is investigated concerning their driving ESM. It is found that ROMs bear a reasonable resemblance with available observation and outperform over driving ECMs. After confirming the reliability of the ROM's simulated mean precipitation and its associated mechanism, an effort is made to investigate the projected changes in the atmospheric water budget and its contribution to the precipitation over agro-climatic zones during the near future (NF; 2041–2060) and far-future (FF; 2080–2099) with respect to the historical period (1995–2014) under RCP8.5 scenario. The changes in the precipitation and its driving constrain are found to vary with region and season.

Keywords: ISMR, RESM, CORDEX-SA, Agro-climatic zones, Atmospheric Water budget

Understanding the spatiotemporal evolution and dynamics of Marine heatwave over Tropical Indian Ocean in the warming climate

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ABSTRACT

Climate change poses severe threats to marine ecosystems due to the rise in the frequency and intensity of ocean temperature extreme events, also known as marine heatwaves (MHW). It has emerged as an active agent that imposes its devastating impact on the marine ecosystem and is an important factor responsible for the relocation of the marine species. Therefore, it is imperative for dynamic marine ecosystem management to understand the location based MHW severity, frequency, and pattern of growth and decline. The present study attempted to understand the spatiotemporal evolution and associated dynamics over the tropical Indian Ocean (TIO) (one main marine species region) in the warming scenario. TIO poses strange seasonality driven by the seasonal reversal of wind. Thus, a high-resolution regional earth system model (RESM) named ROM, having a global ocean model (MPIOM) with varying horizontal grid and fine resolution (10 km to 20 km) over the target region, is employed to understand the several variabilities of MHW in the present and future. MHW events show strong spatiotemporal variability in the historical period, with more pronounced during the JJAS season. The realistic spatiotemporal variability of MHW in ROM for historical periods indicates it's reliability for the projected MHW characteristics. The number of MHW events is found to decline significantly, however, duration is expected to be augmented with varying degrees of magnitude in different seasons.

Keywords: Marine-Heatwaves, RESM, CORDEX-SA, Tropical Indian Ocean.

THE EFFECTS OF CLIMATE CHANGE ON THE GLOBAL AND REGIONAL MONSOONS

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ABSTRACT

Monsoons supply the majority of annual rainfall to large regions of the tropics and affect the lives of billions of the global population through their reliance on monsoons to supply water for agriculture, industry and human health. This talk reviews the latest expert assessments of monsoon climate change, including from the recent IPCC 6th Assessment Report, and examines progress over generations of climate models. Observed 20th-century rainfall trends in the major monsoon regions as well as in the global monsoon are discussed, along with modelling studies that attempt to attribute these trends to anthropogenic factors. The latest future projections are presented, including from the most recent CMIP6 models which feature larger climate sensitivities, under the various shared socioeconomic pathways (SSPs), than their CMIP5 counterparts. The major uncertainties in near-term future projections of monsoon rainfall are also discussed, including the roles of coupled modes of internal variability and aerosol emissions patterns.

Keywords: climate change, monsoon, CMIP6, IPCC AR6

REGIONAL CLIMATE IMPACTS OF THE HADLEY CIRCULATION EXPANSION

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ABSTRACT

Recent studies shows global warming due to greenhouse effect and other anthropogenic activities causes the expansion of the Hadley Circulation (HC) towards poles and this expansion can have important climatic impacts and can influence the biota in the tropics and subtropics. Though there are large number of metrics to characterise the zonal mean HC, there are a very few metrics to identify the zonally resolved HC boundaries. In fact, there are no metrics available till date to identify the zonally resolved ascending and descending regions of the HC. The central objective of the present study is to propose a method to identify the zonally resolved ascending and descending regions of the HC and to investigate the impact of HC expansion on the precipitation pattern at regional scales. Measurements from Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC) satellite are used for the present study. A tropical tropopause based metric is used for identifying the HC edges whereas relative humidity is used to identify the Inter Tropical Convergence Zone (ITCZ) position and width, which coincides with the ascending region of the HC. Using this method, zonally resolved ascending and descending regions of the HC are delineated for the first time. This result provided an opportunity to study the regional HC dynamics in terms of co-variability of ITCZ and HC edges. The study shows that the HC boundaries (both ascending and descending) are not uniform across the longitudes and emphasizes the need for investigating the HC expansion and their consequences on regional scales. Further, Global Precipitation Climatology Project (GPCP) precipitation observations are used to study the consequences of HC expansion over tropics and subtropics. This is the first attempt in assessing the impact of rapidly changing HC dynamics on the precipitation pattern in the ascending and descending regions at regional scales.

Key words: Hadley Cell, Inter Tropical Convergence Zone, Climate Change, Precipitation

Variation of different meteorological state variables during Indian summer monsoon in changing climate

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ABSTRACT

Long term assessment of basic meteorological field variability is an important factor that influences Indian summer monsoon and consequently affects the socio-economic aspects of India. In this study, the spatial and temporal variation of meteorological parameters 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 regions. The significant spatial changes in the value of standard deviation and CV 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, 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 (LLJ) during ISM season. In recent years the variation in meteorological parameters and distribution are irregular during summer monsoon season in changing climate.

Key words: Meteorological parameters, Monsoon variability, NCEP/NCAR, Changing climate

APPLICATION OF DEEP LEARNING TECHNIQUE TO BIAS CORRECT CMIP6 SURFACE AIR TEMPERATURE DATA

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ABSTRACT

Results from the Global circulation models are used for the climate change assessments. However, these results from GCMs have bias which may result in uncertain prediction of various climate impact studies. It is necessary to provide bias corrected data as input to reduce uncertainity in the climate change studies. The aim of this study is to use and compare different statistical bias correction techniques and Convolutional Neural Network – (CNN-1D) to the biased climate model datasets and to suggest the better result yielding among them. Multimodel Mean is calculated for Seasonal Surface Air Temperature-MAM (march, April, may) of 17 Global Circulation Models of Coupled Model Intercomparison Project – phase 6 (CMIP6). This data has been regridded to 1°x1° resolution. Seasonal Surface Air Temperature (MAM) of Indian Monsoon Core region has been extracted from the regridded data for the historical period, 1985 to 2014. Bias-correction of the model data is then carried out with reference to the ERA5 reanalysis Seasonal Surface Air Temperature Dataset which has a resolution of 0.1°x 0.1° using statistical techniques such as Empirical Quantile Mapping (EQM), Scaling (Addition), Scaling (Multiplication), Mean Variance Adjustment (MVA), Parametric Quantile Mapping (PQM), Generalized Quantile Mapping (GPQM) and Artificial Neural Network-(CNN-1D). Among various bias correction techniques, CNN-1D method is observed to yield least root mean squared error (RMSE) of 1.346 °C and mean absolute error (MAE) of 1.08°C.

Keywords: Bias correction, CMIP6, CNN-1D, RMSE.

Rapid Drying of Northeast India in the Last Three Decades: Climate Change or Natural Variability?

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ABSTRACT

Northeast India (NEI), the wettest place on the Earth, has experienced a rapid decrease in summer monsoon rainfall (about 355 mm) in the last 36 years (1979–2014), which has serious implications on the ecosystem and the livelihood of the people of this region. However, it is not clear whether the observed drying is due to anthropogenic activities or it is linked with the global natural variability. A diagnostic model is employed to estimate the amount of recycled rainfall, which suggests that about 7% of the total rainfall is contributed by the local moisture recycling and decrease in recycled rainfall is about 30–50 mm. Using gridded observed rainfall and sea surface temperature data of the last 114 years (1901–2014), here we show that the recent decreasing trend of NEI summer monsoon rainfall is rather associated with the strong interdecadal variability of the subtropical Pacific Ocean. The strong interdecadal variability over NEI suggests a possibility of skillful decadal prediction of the monsoon rainfall, which may have important implications in terms of long-term planning and mitigation.

Local emission and long-range transport impacts on the CO, CO_2, and CH_4 concentrations at a tropical rural site

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ABSTRACT

Local emission and long-range transport impacts on the observed concentrations (dry air mole fractions) of CO, CO_2, and CH_4 have been investigated using three years (April 2016 to April 2019) of surface measurements at a tropical rural site, Gadanki (13.5° N, 79.2° E) in Southern peninsular India. Gadanki represents the poor coverage area of Greenhouse Gas (GHG) measurements in India and has both local emission and long-range transport influences on its air masses. All the three gases have shown strong seasonality and diurnal variations. Trend analysis showed a significant decreasing trend in CO (14.3 ± 0.2 ppbv/year) and increasing trends in CO_2 (2.5 ± 1.2 ppmv/year) and CH_4 (11.1 ± 0.03 ppbv/year). CO_2 and CH_4 trends are marginally higher than the global trends (2.2 ± 0.004 ppmv/year and 7.0 ± 0.001 ppbv/year, respectively) for the same period highlighting the sustained local emission impact on the observed concentrations. Among the three species, CO has been the most local emission impacted species with local emission contribution (to the total observed concentration) varying between 4 and 25% during different seasons with a median value always lying above 10% irrespective of the season. In the case of CO_2 and CH_4, the local emission contribution found to vary in the range of 0.8–7% and 0.15–3%, respectively. Longrange transport impact dominance over the local emission is observed in CO_2 and CH_4 during all the seasons. Analysis using MODIS fire count data, Concentration Weighted Trajectory (CWT) and FLEXPART have reconfirmed the combined effect of local and long-range transport impacts on the observed concentrations. Comparison of the IASI MetOp and AIRS satellite data products with surface measurements showed the significant bias and poor representation of the seasonality demonstrating the limitations on the sensitivity of satellite trace gas measurements within the boundary layer.

Keywords:

CMIP5 and satellite soil moisture climatological changes in 21st century over Indian region

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ABSTRACT

Climate data records of soil moisture (SM) are essential for improving our understanding of long-term dynamics in the coupled water, energy, and carbon cycles over land. The study examines spatial distribution of past, present, and future predictions of total SM using the 26 Coupled Model Intercomparison Project phase 5 (CMIP5) models simulations for the historical period (1850-2005) and future climate projections (2006-2099) based on Representative Concentration Pathways (RCP2.6, RCP4.5, RCP6.0, and RCP8.5).Initially, study focused on the comparison of model SM with the satellite AMSR-E (Advanced Microwave Scanning Radiometer-Earth observation system) rather than the causality. However, in a spatial perspective, a large deviation was observed in the interior peninsula during the Monsoon season from model to model in historical and RCP's. In addition, the spatial distribution of trends was highly diversified from model to model. Later, statistically by using the Taylor diagram, model's performance with observations was studied over the region. Furthermore, time series was estimated using the locally estimated scatter plot smoothing analysis technique on the annual data with twenty percent of smoothing to analyze the future trend of SM along with the past few decades, whereas the preindustrial (1861-1900) and industrial period (1901 onwards) changes were involved. Therefore, anomaly trends of 1861-2099 with the combined historical and future projections having the negative trends before 2021 and significant positive anomaly trends are noticed in the whole time series of SM during the future projection period of 2021-2099 using CMIP5 SM model datasets. In addition, the uncertainties of RCP model's year means were estimated through scatter plot. Hence, among all the discrepancies we observed that, CESM1-CM5, CSIRO-MK3-6-0, BCC-CSM1-1 and also BCC-CSM1-1-M, NorESM1-M models of CMIP5 performing with good agreement in historical as well as in future projections scenarios over the region. In addition, all of the MPI-ESM, BCC-CSM models are performing well in all future projection scenarios. Even though there exist uniqueness in projections, the RCP 4.5 and RCP 8.5 scenario exhibited similar and better performance for BNU-ESM, HadGEM2-AO, FGOALS-g2, MPI-ESM-LR models, and they were in good agreement with satellite observations over the Indian region.

Keywords: Soil moisture (SM), CMIP5, Representative Concentration Path ways (RCP's)

RAINFALL ANALYSIS IN THENI DISTRICT

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ABSTRACT

Theni district is one the 38 district in Tamil Nadu state in India. It lies in the foot of Western Ghats. The geographical location of Theni district is bounded by 9' 39' to 10' 30' N latitude and 77' 00' to 78' 30' E longitude and the area of the district is 2868 sq.km. The rainfall is the main source of water for agriculture in Theni district. The rainfall data from eight weather stations namely Periyakulam, Manjalar, Palayam, Cudalur, Vaigaidam, Veerapandi, Bodi and Thekkadi were collected from 2005 to 2014 and analyzed to understand the pattern. Theni has a wide range of vegetation and a range of hills. Important water reservoirs on which agriculture and livelihood depends are Mullai Periyar dam, Vaigai dam, Manjalaru dam, Sothuparai Dam and other rivers flowing through the district. Graphical representation helps for the better understand of the data. Thekkadi a tourist attraction place in Idukki receives the largest amount of rainfall with high being 2244.5 mm during the year 2007. Other regions nearly received the same amount of rainfall with sight deviation ranging from 1428 mm in 2010 at Manjalaru dam to 244.4 mm in 2006 at Vaigai dam. In the set of ten years 2006 is found to be the driest year with far less rain in all places but the previous year 2005 and the following year 2007 have received a pretty much good shower. The spatial interpolation techniques were applied on rainfall data to create surface data. The interpolation techniques (Spline, IDW, and Kriging) were compared and assessed against station rainfall data and satellite rainfall data. The accuracy was assessed using the mean absolute error (MAE), mean relative error (MRE), root mean squared error (RMSE), and the spatial and temporal distributions. Analyzing rainfall data helps to formulate policies related to crop cultivation, water availability for drinking and irrigation purpose, drainage system needed and others.

Keywords: Rainfall, Spatial Interpolation, Theni District

Evaluation of the ERA5 reanalysis over the Indian region

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ABSTRACT

ERA-5 is the latest meteorological reanalysis from the European Centre for Medium-Range Weather Forecasts (ECMWF), and is being used for a variety of climate analysis besides serving as input to global and regional chemistry-climate models. Here, we evaluate the ERA5 reanalysis over the Indian region by comparing it with other widely used datasets such as the NCEP/NCAR during contrasting seasons. The large-scale features in ERA5 meteorology are found to be generally consistent with the NCEP/NCAR. Bias of ERA5 with respect to NCEP/NCAR2 was lower as compared to that with NCEP/NCAR. Additionally, correlation of ERA5 with radiosonde observations over different parts of India (Delhi, Mumbai, Calcutta and Chennai) were analyzed. ERA5 captures the observed variations in temperature, relative humidity and wind speed well. Strong positive correlation($r^2 > 0.9$) is observed for temperature in lower and middle troposphere. ERA5 shows moderate correlation ($r^2 > 0.6$) in lower troposphere and strong correlation ($r^2 > 0.8$) in middle troposphere for relative humidity and wind speed. The findings would serve as reference for future applications of ERA5 for climatic inferences and as input in modeling studies focussing over Indian region.

Keywords:

Current Pace of Shifting Climate and its Interconnections with Land Use Land Cover Change in North-East India

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ABSTRACT

Numerous studies have reported that anthropogenic climate change has adversely affected the global biodiversity driving their range shift polewards, to higher elevations or deeper in the oceans. This already apparent threat to the ecosystem is exacerbated due to the synergistic effects of climate change and land use land cover (LULC) change. The movement of climate migrants tracking climate isolines is greatly hindered due to fragmented and disconnected habitats. Thus, it is essential to assess the consequences of interconnected impacts of the two anthropogenic drivers on the global and regional ecosystems. In the current study, the contemporary velocity of climate change (VoCC), for near-surface air temperature, for the period 1981-2020 was analyzed using observational (CRU) and latest reanalysis (ERA5) datasets for the North-East ecoregion of India. This region is a part of the Indo-Burma biodiversity hotspot. The resolution of climate data used to derive VoCC has a decisive impact on microclimate and local geography representation. The changes in the LULC of the region from 1989 to 2019 were also quantified. The VoCC was observed to be high (~3-5 km/yr) for the study region indicating that the climate migrants must travel longer distances to maintain their desired climate. The LULC of the region changed in the study period with decreasing forest cover and increased area under the bareland and agricultural classes. The study affirms that greater velocity of climate shift and decreased forest cover pose an immense threat to the conservation of keystone species in the study region by creating 'climate sinks', which may ultimately lead to local extinctions.

Keywords: Climate shift, Velocity of Climate Change, land use land cover, impacts

THE EFFECT OF AGRO-METEOROLOGICAL INDICES AND PLANTING DATE ON THE GROWTH, DEVELOPMENT AND PRODUCTIVITY OF WHEAT GROWN IN VERTISOLS.

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ABSTRACT

The present investigations entitled **"Forecasting of soybean and wheat production using DSSAT in Malwa Region"** was carried out in the experimental farm of AICRP on IFS, RVSKVV, College of Agriculture, Indore (M.P.) during Rabi season of 2013-14 and 2014-15. Phenological observations of soybean recorded at Anthesis days, first pod days, first seed days, physiological maturity day stage, showed that duration, growing degree days(GDD), and helio thermal units (HTU). The observed and simulated HTU required for Anthesis Phase day was 6887.7 and 6621.2, respectively for LOK-1 in case of D1: 22nd June, 6614 and 6931 for D2, 6596.4 and 6538.4 for D3 and 6322.6 and 6322.6 for D4. The observed and simulated HTU required for Anthesis Phase day was 3126.2 and 3174.2, respectively for HI1418 in case of D1: 22nd June, 6775.6 and 7018.2 for D2, 6765.7 and 6931.0 for D3 and 6538.4 and 6763.1 for D4. The cultivar HI8663 took 6887.7 (observed) and 7143.7 (predicted) HTU to attend Anthesis Phase day stage in case of D1: 22nd June, 7107.3 (observed) and 7073.1 (predicted) for D2, 6670.3 (observed) and 6763.1 (predicted) for D3, and 6429.5 (observed) and 6477.2 for D4 (predicted). The observed and simulated HTU required for dough phaseday was 7998.4 and 8652.6, respectively for LOK-1 in case of D1: 22nd June, 7896.8 and 8172 for D2, 7888.6 and 8062.6 for D3 and 8663.4 and 7704.7 for D4. The observed and simulated HTU required for dough phase day was 9071.5 and 9663.6, respectively for HI1418 in case of D1: 22nd June, 9103.2 and 9363 for D2, 9258.3 and 9672.2 for D3 and 8946.5 and 9701.3 for D4. The cultivar HI8663 took 9203.4 (observed) and 9532 (predicted) HTU to attend dough phase day stage in case of D1: 22nd June, 9272.3 (observed) and 9497.9 (predicted) for D2, 9129.4 (observed) and 9377 (predicted) for D3, and 9289.2 (observed) and 9486 for D4 (predicted). For the cultivar HI1418 it ranged from 2010-2255 and 2108 - 2364kgha^{-1} for simulated and observed data, respectively during 2012 to 2015. The simulated yields were 1.96 to 4.75 % higher than observed yields, but % RSME at 5% was 1.26% which was non-significant. Similarly, in case of HI8663 the yields ranged from 2010 to 2190 kg ha $^{-1}$ and 2107 to 2276 kgha^{-1} for simulated and observed yields, respectively. The simulated yield was 3.75 to 4.97 % higher than observed values. The % RMSE was 2.7 in case of HI8663.

Multifractal Approach to analyze the Urban Heat Islands (UHI's) using Satellite derived temperature for three decades (1990-2019)

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ABSTRACT

Anthropogenic forcing exacerbates the Urban Heat Islands (UHI's), which is the difference between urban and surrounding rural land surface temperature. Warmer temperature in urban areas compared to its environs, have potential health hazards due to heat waves apart from pollution. This may directly or indirectly influence the local or regional climate and is a critical issue for decision makers. In the context this study intends to investigate UHI's impact at macro and micro-level in the Doon valley of state Uttarakhand. Multifractal approach (MF-DFA) is applied to understand the multifractal behavior for different time frames (1990, 2013 and 2019) radiance temperature and to analyze the formation of urban Heat Island (UHI's). Statistical multifractal parameters are used to estimate the scaling properties of LST images for different land features such as urban, forest and mixed. Multifractal spectrum characteristics such as the 'Holder exponent' (Δh), the spectral-width ($\Delta\alpha$), the asymmetry, and the truncation type of the spectra and its spatial distribution are compared. The $h(q=2)$ values for urban land are larger than 0.5 and less than 1, which reveals that there is a strong positive long-range correlation in the LST pattern during the studied period. For urban areas the spectral width ($\Delta\alpha$) is observed 0.625 and 0.2948 for the year 1990 and 2019 respectively, which shows large multifractality in the UHI's fluctuation during the three decades. It is emphasized to understand the UHI and its impact at macro and micro-level in the context of the health hazard. The outcomes of the study will be useful in climate research for examining the reproducibility of the nonlinear dynamics of reanalysis datasets and model outputs.

Keywords: Climate change, LST, Urban Heat Island (UHI), MFDFA, Hurts exponent

EFFECT OF COVID 19 LOCKDOWN INDUCED CHANGES IN ATMOSPHERIC METEOROLOGICAL PROFILES FOR MAJOR CITIES AND INDUSTRIAL HUBS IN INDIA

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ABSTRACT

The COVID-19 pandemic forced a national wide lockdown in India as a whole from 24 March 2020 to 14 April 2020 as the first phase and further extended to May over most parts of the country with only some relaxations for the essential sector. The lockdown has led to an abrupt halt in majority of human activities. During this lockdown period a drastic reduction in the emission of major pollutants has been observed throughout all parts of India. Therefore the study aims to analyze the impact of lockdown on meteorological parameters such as temperature and humidity over four major cities in India namely Bangalore, Pune, Patna, Delhi and four industrial hubs include Chota Nagpur, Gurgaon, Gwalior and Kota. The vertical profiles of temperature and relative humidity at 16 isobaric levels from 1000 to 500 hPa were examined for 2020 and their respective climatologies for the Months March and April using ERA 5. The result revealed that the lockdown have reduced the temperature and increased the relative humidity over majority of the locations. A decrease in mean monthly temperature throughout the lower troposphere ranging from -0.592 to -2.683 K except for Bangalore and Pune with a maximum near 950 hPa as compared with climatology. The relative humidity increased at an amount of 0.66 to 19.875 % with an exception to Bangalore and the changes are significant at lower levels with respect to climatology. For analyzing the temporal changes in temperature and relative humidity during the lockdown period, AIRS Level 3 data 925 hPa for a period of March to April 2020 and previous year 2019 over the eight selected locations were studied. The results thus obtained shows a considerable decline in temperature and increase in relative humidity during the lockdown phase as compared to same time frame of the previous year.

Keywords: Covid 19 lockdown, Temperature, Relative humidity

CLIMATOLOGY STUDY OF TEMPERATURE OVER KERALA

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ABSTRACT

Kerala, once known for its moderate and comfortable climate is now bearing the brunt of climate change. Very high temperatures at certain places, very low temperatures at some other places, severe drought and extreme precipitation events are the conditions Kerala face in the present years. In the present study, using MERRA 2 reanalysis monthly mean temperature data (daily minimum, daily maximum, and daily mean) for 10 years (2009- 2018), temperature patterns and its variabilities through these years for all the 14 districts of Kerala are investigated. Daily maximum temperatures are observed at all the locations in the month of March, while this temperature is the lowest in the month of July. Average maximum temperature over a year is the highest over Palakkad and Thrissur (~31^0 C) and is the lowest at Idukki (below 28^0 C) and is moderate over the locations Alappuzha, Kannur, Kottayam, Pathanamthitta and Wayanad (between 29^0 C and 29.5^0 C). Minimum temperatures in a day are observed during the months January, February, and December at all stations. The minimum temperatures are the highest at Alappuzha and Kottayam. Idukki and Wayanad are the places which experience the lowest minimum temperatures compared to all the stations. Palakkad which experiences the highest maximum temperatures experiences the lowest minimum temperatures than all other places, except Idukki and Wayanad. On an average over Kerala, increasing trend is observed in the lowest minimum temperatures while the highest maximum temperature shows a decreasing trend over this period. It's quite interesting to notice that maximum temperatures in the months of October and August shows a decreasing trend over the years, while during all the other months the trend is opposite. Mean temperature also seems to decrease in the month of October during these years.

Keywords: Climatology, Temperature, Trend, Kerala

Impact of Urbanization on Land Surface Temperature in the City of Hyderabad, India

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ABSTRACT

In developing/developed cities, man-made modifications of the natural environment are massive, such as replacing vegetation, soil, and water with buildings, concrete, bricks, asphalt, and metal, reducing evapotranspiration, increasing heat storage, and decreases air movement. Many urban areas experience higher temperatures than their surrounding rural areas during nighttime. This temperature difference is known as Urban Heat Island (UHI). Hyderabad, India, has around 1.02 million population results a huge volume of urban density growth. UHI can present significant risks to human health. This study focuses on finding the urban growth over Hyderabad by using Landsat satellite data and the intensity of UHI during daytime and nighttime by using Moderate Resolution Imaging Spectroradiometer (MODIS) land surface temperature LST from 2001 to 2020. From the last two decades, due to rapid urbanization, the city has undergone significant changes in land use land cover (LULC), the urban area increases from 230.90 km^2 to 494.61 km^2, and the barren land decreases from 40.18% to 33.36%. The major changes in the built-up area were found along with the study area's North, South, Southeast, and East directions. The vegetation cover from 2000 to 2015 is decreased, but after 2015, the vegetation cover increases from 122.73 km^2 (2015) to 149.07 km^2 (2019). During the study period, the daytime LST decreases at 0.04°C/year, and night LST is increasing at 0.05°C/year hence during day time, the urban area behaves Urban Cool Island (UCI) and during night time the urban area behaves UHI. The analysis and findings of this study have important policy implications for sustainable LULC practices and mitigating the negative impacts in Hyderabad city.

Keywords: Urban heat island, Land use land cover, MODIS, Landsat

Enhancement of mean temperature by 0.4 ^{0}C over the Indian region during 1970-2009

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ABSTRACT

Many groups have evaluated global and regional annual mean temperature data to identify linear temperature trends over climatological time frames. The near-consistent results reveal a 0.07 °C increase per decade during the twentieth century. However, numerous fundamental issues such as spatial and temporal data gaps, non-uniform observation site distribution, superposition of internal/natural fluctuations at different scales with parametric feedbacks remain unanswered. The main aim of this work is to fill in some of the global data gaps by analyzing the global warming trend over the Indian region using a gridded data set from 1970 to 2009 and exploring the parametric impacts of more fundamental internal or natural causes to improve scientific understanding of the integrated phenomena of climatological variation.

Annual mean temperatures calculated using various spatial integrations reveal linear trends over this period, increasing around 0.4 °C. According to rigorous error analysis of the enormous data, the statistical errors at the 95 percent confidence range are lower than the increase in temperatures calculated from the linear trend. The yearly mean temperature time series also indicates periodic changes of 3-5 years with an average magnitude of ±0.4 °C that are consistent and virtually phase coherent. Possible causes of these temperature structures due to changes in solar activity, Galactic Cosmic Ray fluxes and El Nino and Southern are examined. With an insertion of one-year time delay in the time series of the mean annual temperatures, the findings reveal a positive correlation coefficient of 0.33 with the cosmic ray flux and an improved correlation with Southern oscillation index from 0 to +0.34.

Keywords: Climate change, Global warming, Surface-air temperatures, Sunspots, cosmic rays, El Nino/La Nina

Modelling stable water isotope fractionation to understand the effect of industrial deforestation on moisture recycling over the Indian subcontinent

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ABSTRACT

India is mostly dependent on the behaviour and changes in summer monsoon precipitation. To plan for suitable adaptation strategies for the future, it is important to study the moisture sources and associated mechanism. Stable water isotope is a good tool for identifying moisture sources. It is a well-known fact that the monsoon rainfall results directly from the transport of atmospheric moisture, but little attention was given to understand this transport phenomenon in earlier studies. The precipitation in an area is composed by water vapor advected and water vapor locally evaporated that reached the atmosphere; the percentage of contribution of the evaporated water to the total precipitation within a region is the recycling ratio. The feedback between recycled precipitation and evaporation referred to as moisture recycling. The significance of moisture recycling is an indicator of the climatic sensitivity to land-use and land cover (LULC) changes. Understanding and modelling of the feedback processes from the land surface to the atmosphere are of major importance for the study of any regional climate system. Here, the precipitation recycling in the Indian subcontinent during monsoon season has been modelled using to understand the feedback processes with the land surface and their strength and variability. It is shown that disentangling can qualitatively be achieved using climate model simulations with a land-derived precipitation tracer for the Indian subcontinent. The LULC is either fixed to preindustrial or varied as observed to determine the resulting signals. Our results indicate that effects of historically changing land cover on annual mean $\delta^{18}O_p$ isotope-ratio gradients are small and unlikely detectable, although there is a noticeable signal during the dry season. Furthermore, the effect of changes in water recycling on Indian $\delta^{18}O_p$ in paleo-records may have been overestimated and need reinterpretation.

Keywords:

Western disturbances and climate change: past, present, and future

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ABSTRACT

Western disturbances (WDs) are cyclonic perturbations, embedded in the subtropical westerly jet stream, that share many characteristics with extratropical cyclones. They are responsible for the majority of winter precipitation over the orography of Pakistan and north India, and are often associated with extreme precipitation events, such as the 2013 Uttarakhand floods. This talk summarises the results of six papers, using a tracking algorithm, applied to CMIP5 model output and reanalyses, to quantify and understand the changes in WD frequency, behaviour, and impacts in the mid-Holocene (6kya), the last century, and the coming century.

We start with an overview of WD behaviour and variability in recent reanalysis data, discussing their three-dimensional structure and showing how this relates to their precipitation, variability, and evolution through interaction with orography and baroclinic instability associated with the subtropical jet.

We then apply these techniques to six CMIP5 models used to simulate the mid-Holocene, a period with an increased seasonal insolation cycle, resulting in decreased insolation during the winter. We find that the resulting weakening of the upper-tropospheric temperature gradient produces a weaker jet, with less baroclinic instability available for WD growth. As a result, the mid-Holocene had 15% less winter precipitation than the present day.

Finally, we explore the fate of WDs in a changing climate. We use an ensemble of 24 CMIP5 models to show that in a high emissions scenario (RCP8.5) climate, WDs would be 15% less frequent and 12% less intense by 2100. This is attributed to weakening and poleward movement of the subtropical jet. We use high-resolution pseudo global warming experiments to show that despite this, precipitation associated with individual WDs is projected to increase, with extreme precipitation events increasing fiftyfold. In addition, there is a significant shift from solid to liquid precipitation over the Himalaya, which has important implications for water security.

Keywords: climate change, western disturbances, precipitation

Characteristic changes in climate projections from the bias corrected CMIP6 models for Indus Basin

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ABSTRACT

The Indus basin is one of the most vulnerable regions due to climate change. The presents work mainly focus on the mean precipitation and temperature changes along with their extremes over the Indus Basin (IB) using statistically downscaled, bias-corrected Coupled Model Intercomparison Project-6 (CMIP 6) data sets for different Shared Socioeconomic Pathways (SSP2-4.5 and SSP5-8.5) in response to global warming. The spatial variations of precipitation, maximum and minimum temperature obtained from the Multi-Model Mean (MMM) of CMIP6 models showed a good agreement with APHRODITE (precipitation) and CPC (temperature) for the base period (1995-2014) over the basin. Results suggest that the precipitation may increase as high as 40% from June to September (JJAS) and 25% from December to February (DJF) in the high emission scenario (SSP5-8.5) by the end of the century. Future temperature projections show that warming may continue over the basin. The warming is more in the SSP58.5 scenario compared to the SSP2-4.5 scenario, with a maximum increase with more than 4^0C by the end of the 21st century. Analysis of spatiotemporal variations of future extreme precipitation indices viz RD, SDII, RX1DAY, RX5DAY, R10MM, R20MM except CDD are high in number over Upper Indus Basin (UIB) compared to Lower Indus Basin (LIB). Extreme temperature indices such as Max. of maximum temperature, SU, CSU, Min. of minimum temperature, FD, CFD, TR except for Ice Days (ID) show an increase of 40% to more than 75% in the SSP5-8.5 scenario compared to the baseline period over the basin.

Key Words: CMIP6, Multi-Model Mean, Shared Socioeconomic Pathways, Extreme Indices

Projection of lightning flash rate using thermodynamic parameters in lower atmosphere over India

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ABSTRACT

Solar radiation plays an important role for the exchange processes between Earth surface and overlying atmosphere due to radiative heating, hence affecting the variation in atmospheric temperature and surface fluxes. The proposed relationship is justified on the basis of the conversion of the kinetic energy of charging hydrometeors to the energy of flash discharges. Climatological study of lighting flash rate using thermodynamic parameters has been carried out for the period of 1996-2013 using model and satellite data. The topography of the study region, surface heat fluxes and hydrometers showed a strong relation with lightning flash rate and which can be best suitable for the projection of lightning. The coastal region showed more lightning than inland and ocean due to land-ocean contrast. The evaporation is more in the ocean than land, therefore the land and ocean contrast has been observed very clearly. It is also observed that the parameters contribute significantly well for specific regions based on spatial analysis. The conversion efficiency is a maximum in the pre-monsoon season and minimum in the winter season. It is also observed different parameters contribute along the region of propagation of ITCZ which needs to be further investigated. The cape is 81% correlated with LFR whereas, (cape*preci) is 75% correlated with LFR during pre-monsoon season.The total heat flux best accounts for the seasonal variation of the LFR most prominently during the pre-monsoon season due to strong convective activity. Projection will be done for future periods using GCMs data.

Keywords: Lightning flash rate (LFR), Precipitation, ground heat fluxes, thermodynamics

REMOTE RESPONSE OF GREEN SAHARA ON INDIAN SUMMER MONSOON PRECIPITATION DURING PAST WARMER CLIMATE

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ABSTRACT

Analogous to future projections of the Anthropocene epoch, mid-Holocene (MH) was warmer and wetter than present in Earth's history due to natural, unlike anthropogenic forcing. Major human civilizations like the Indus Valley civilization flourished along the major river banks worldwide during this MH period. During the early to mid-Holocene, the present arid Sahara transformed into lush green vegetation with bigger waterbodies, widely known as the African Humid Period. This study attempts to understand the remote influence of enhanced vegetation and reduced dust conditions over north Africa on the Indian Summer Monsoon. We performed high-resolution paleoclimate simulation using a variable resolution global climate model (LMDZ: Laboratoire Meteorologie Dynamique and Z stand for zoom), configured in 35 km spatial resolution with a Green Sahara and reduced dust forcing conditions. The high-resolution simulation captures the precipitation enhancement over North-West India and the Indus Valley region, which was absent in the coarse resolution paleoclimate models part of PMIP simulations. We quantified the precipitation enhancement by comparing it with the simulation without the Green Sahara and reduced dust conditions during MH. The study further elaborates on the mechanisms behind the remote influence underlined in increased precipitation through strengthened circulation and other dynamical and thermodynamical factors. IPCC assessments from RCP/SSP based future CMIP simulations are invariably projecting an enhanced African monsoon in the near future, so the possible re-appearance of greening and reduced dust condition can have a more significant impact on Indian monsoon in future climate as well.

Keywords: Mid-Holocene, Green Sahara, Indus Valley Civilization, Indian Summer Monsoon.

Footprints of Southern Annular Mode on The Indian Ocean Waves

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ABSTRACT

The annular modes are hemispheric scale patterns of climate variability as part of internal atmospheric dynamics in the middle latitudes. On riveting our attention to Indian Ocean, the potential imprints of tropicalextra tropical teleconnection of Southern Annular Mode (SAM) through sequential changes of Hadley cell on the North Indian Ocean (NIO) wave parameters are investigated in the present study.The SAM index (SAMI) that captures the variability of mean sea level pressure (MSLP) over the midlatitudes of the southern hemisphere is constructed. Marshall SAMI values are taken for the present study which was carried out from December 1979 to February 2018 (Marshall et al,2018). In which the Marshall SAMI is computed using (Gong and Wang, 1999) method. The positive (negative) phase of the SAM occurs when the pressure anomaly is low (high) on the pole, and the mid-latitude westerly jet is shifted poleward (equatorward). ERA5(ECMWF ReAnalysis) model data were used for analysing the variables under study, covered from january 1979 to within 5 days of real time. It is the fifth generation atmospheric reanalysis from ECMWF, ERA5-hourly data at 31km horizontal resolution with 137 levels up to 0.01 hPa. The composite anomalies of Significant wave height(SWH), Swell wave height (SHTS), mean wave period (MWP), and wind sea height (SHWW)for SAM positive and negative years reveal that the JJA (June, July and August) season is most susceptible to other seasons. The anomalies of SWH, SHTS, MWP, and SHWW are stark opposites during the positive and negative phases of SAM and band-wise in the different IO regions. The southwest monsoon and the strengthening of SAM during the negative phase contribute to IO's highest mean wind fields during JJA. Wind speed is maximum (10m/s-14m/s) between 40°S-60°S. The dominance of wind seas during this period is visible from the lowest MWP fields of JJA. The swell fields are also indicative of this, with the highest swells during JJA. The signature of SAM is evident in the atmospheric signals linked to the change in wave parameters due to the altering wind as a result of modified Hadley cell over this region. A positive SAM event corresponds to a widespread downdraft and intense updraft of Hadley cell. For a negative SAM event, the cells are more constricted and less severe. These changes are a direct consequence of the poleward and equatorward shift of wind during SAM phases. The study establishes the relevance of SAM as a persuasive factor towards wave climate and the covarying atmospheric counterparts in the IO.

Keywords:

Sustenance of Global Climate Observation System Upper Air Network (GUAN) standard network of IMD

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ABSTRACT

National Meteorological and Hydrological Services work around the clock to monitor Earth System provide vital weather and climate information worldwide. Under the global observing system (GOS), for observations of climatic variables in the upper atmosphere, the Atmospheric Observation Panel for Climate (AOPC) was established to define the requirements for meteorological observations for Global Climate Observing System (GCOS). Under the GCOS, the GUAN consists of stations selected from the Global Observing System of the World Weather Watch (WWW) meeting specified standards for upper air climatological observations, set by WMO. India Meteorological Department (IMD) has established GUAN standard radiosounding systems at 6 stations at its regional head quarters namely New Delhi, Mumbai, Kolkata, Chennai, Nagpur and Guwahati using high quality radiosounding system during August 2015. Based on their performance of one year, IMD requested GCOS secretariat through Secretary General, WMO, for inclusion of these station into GUAN network. IMD's claim was examined and approved by Atmospheric Observation Panel on Climate (AOPC-22), Exeter, UK, 2731st March 2017. Since then, the performance has been closely monitored and found that these stations are fully compliant for the commitments to be made by the WMO Member for inclusion of a radiosounding station into the GUAN network. All the 6 stations have achieved minimum observational requirements like Nos. of sounding in a month, soundings observed beyond minimum requirement of 100 hPa level, and in most of the cases approach up to the target requirement of 5 hPa level. The RMS departures in case of geo-potential height, observed temperatures and wind vectors have been found well within the minimum requirements (MRQs) and very near to the target requirements (TRQs)-which establishes the accuracies of observed data. The biases observed in monthly climatological averages are observed within the MRQs and approaching to the TRQs. These stations actually fulfilled the essential minimum requirements of radiosounding observations for a GUAN standard radiosounding station, with respect to all the parameters of observation, and very closely approaching the target requirements of GUAN standard radiosounding observatories continuously. The network has sustained without a break since the establishment, performing well meeting all the standards, and committed for continuation.

Keywords:

Future Outlook on Heat Wave Occurrences over the Central East Coast of India by Application of Machine Learning on CORDEX-South Asia Simulations

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ABSTRACT

Owing to the recent global warming, the occurrences of weather and climate extremes such as Heatwaves, floods, droughts, etc. over the tropics have become even more intense and unpredictable. In the recent period, the heatwave-related deaths and casualties over Central-East-Coast-India (CECI; Odisha-Andhra Pradesh-Telangana) during pre-monsoon (March-April-May; MAM) have remarkably increased. Hence, there is a critical need for the Risk and Disaster Management Sectors to have a prior outlook on the long-term patterns and variations of the Heatwaves in the future in such a rapid global warming scenario for prior planning. This study aims to obtain optimal future projections of Heatwaves over CECI during MAM, based on three different greenhouse gas emission scenarios (i.e., RCP 2.6, RCP 4.5, and RCP 8.5) for the future period up to 2099. To achieve that, first a performance evaluation is done by comparing the outputs from 17 CORDEX-SA simulations against newly developed IMDAA. The results suggest that, although there are diverse spatial variations in capturing the frequency of heatwaves by most of the models, all the models were found to be under-estimating the Temperature over CECI. The experiments with RCA4 driven by CCCma, IPSL, and CSIRO had better pattern representation than the rest of the models. Further, Appropriate machine learning and Ensemble techniques were adapted in order to generate the best possible projection of Heatwaves for the 21st Century. On investigating the possible changes in the Heatwaves in the future period, a notable increase is observed in terms of frequency and a shift of spatial distribution is also observed. This study is very useful for impact and vulnerability analysis of various Natural resources and Human Health in the future for the planning of proper adaptation and mitigation strategies for a sustainable livelihood over this region.

Keywords: Heat Waves, Climate projections, Machine Learning, Model diagnostics, East-coast-India, Pre-monsoon

Correlating Urban Climatological Variations and Heat Stress in Indian Cities: Case Study of Delhi, Bhubaneswar and Rajkot cities

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ABSTRACT

Climate Change has affected every part of the globe with IPCC AR6 stating that it is virtually certain that hot extremes (including heatwaves) will become more frequent and more intense across most of the land regions. Impacts of heat stress are more severe in urban areas due to Urban Heat Island (UHI) effect. According to the Climate Impact Lab, heat stress-induced deaths in 2100 will be about 85 per 100,000. The months of June and July in 2020 were the warmest months on records, globally.

Integrated Research & Action for Development (IRADe) has studied the climatological variations of the three Indian cities – Delhi, Bhubaneswar and Rajkot. Due to their different geographical locations (coastal, inland), these cities experience varied climatology (sub-tropical, dry arid) and have been analysed to study the impact of changing climatological character and the increasing heat stress among the vulnerable section of the cities. The climatological variations of the summer months have been analysed for the parameters Temperature (Tmax, Tmin) and Relative Humidity (morning & evening) in the selected cities over the last two decades. The study has observed early onset of the summer and increase in number of hot days in all three cities.

Keywords: Heat Stress, Climatological variations, Adaptation, Mitigation, Thermal hotspots

QUANTIFICATION OF DOUBLE-ITCZ BIAS IN CMIP6 MODELS

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ABSTRACT

The Intertropical Convergence Zone, or ITCZ, is the region that circles the Earth, near the equator, where the trade winds of the Northern and Southern Hemispheres come together. One of the outstanding errors, double-ITCZ bias, in climate models is a major concern to study the future climate projections. Double-ITCZ means zonally elongated narrow belt of high precipitation in both northern and southern hemispheres, over the equatorial central and eastern Pacific and Atlantic. In this work, the quantification of double-ITCZ bias in 13 CMIP6 models is done with indices such as Tropical Precipitation Asymmetry Index (TPAI), the Equatorial Precipitation Index (EPI), Southern ITCZ index over the Pacific (SIIP) and Southern ITCZ index over the Atlantic (SIIA). The study is carried out based on long-term annual mean precipitations of CMIP6 models along with Global Precipitation Climatology Project (GPCP) data. Model and GPCP data are re-gridded to 2.5°x2.5° for better comparisons. The results were encouraging and have shown considerable reduction in double-ITCZ bias in few models of CMIP6 when compared with CMIP5 for historical period (1995-2014) as well as for future emission scenario.

Keywords: Double-ITCZ, bias, precipitation, CMIP6

The simulation of wintertime urban heat island over the city of Bhubaneswar and its relation to climate change and land use land cover

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ABSTRACT

Globally the temperature is rising as part of climate change due to increased anthropogenic emission of greenhouse gases. At the same time, on a local scale, urban heat islands are formed with elevated temperatures compared to the nearby rural or non-urban areas. The replacement of natural surfaces by artificial impervious surfaces with high thermal inertia contributes to these elevated temperatures. The increase in temperature that we observe could be a part of global climate change or part of the modification induced by changes in land use land cover (LULC). The model simulations at urban spatial scales are valuable tools to uncover these changes and to discern their respective contributions. In this study, using the weather research and forecasting (WRF) model, we simulate the winter time urban heat island over Bhubaneswar, one of the fastest-growing two-tier cities in India. The urban landscape has almost doubled over the region in the last 15 to 20 years, along with the growth accelerating with respect to time. The model replicates the urban heat island (UHI) effect (~ 1°C) and its changes (0.7°C) during the period 2004 to 2015 reasonably well. The contribution of LULC in the observed increase in temperature over the city is around 40%. In contrast, the changes up to 60% are due to regional climate change between the period 2004 to 2015.

Keywords: Urban Climate, Weather Research and Forecasting model, land use land cover

IMPACT OF CLIMATE CHANGE ON WATER SECTOR IN KERALA DAMS

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ABSTRACT

Water is one of the most valuable resources on the planet, and it can be properly preserved and utilized. Large reservoirs are created by erecting dams over flowing water in order to store and distribute water for various needs. As an impact of climate change, rainfall shows remarkable variations in intensity, distribution, duration, etc. and these changes can have considerable impacts on water levels in rivers, streams, and reservoirs. Therefore, the study aims to analyze the variations in water levels over major dams in Kerala, namely Idukki, Periyar, Malampuzha, Kakki, Kallada, and Idamalayar, as a result of changing trends in rainfall patterns. The weekly water level data from the Center Water Commission (CWC) and the corresponding weekly rainfall data from the India meteorological Department (IMD) were evaluated for the period of 2015-2020. The results obtained from the analysis showed a significant correlation between the change in water level and the calculated water level and the variations in water level were associated with changing rainfall patterns to an extent. The water level shows its minimum value when the discharge of water exceeds the inflow.

Keywords: Climate Change, Reservoir, Correlation

Projections of heat waves over seven temperature homogeneous zones of India from CMIP6 models

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ABSTRACT

Recent studies have shown that global mean temperatures are increasing and in future the heat waves will be more intense, frequent and long lasting. There are limited studies on the occurrence of future heat waves based on the projected daily maximum temperature from Coupled Model Intercomparison Project-6 (CMIP6) scenarios over temperature homogeneous zones of India. CMIP6 projection scenarios are based on a matrix of Shared Socioeconomic Pathways (SSPs) and Representative Concentration Pathways (RCP), and which is to improve the scientific gaps in CMIP5. Here we will classify Indian region into 7 temperature homogeneous zones as Interior Peninsula (IP), West Coast (WC), East Coast (EC), North Central (NC), North West (NW), North East (NE) and Western Himalaya (WH). The current study will use the bias corrected high resolution daily maximum temperature projections of 0.25° spatial resolution from 13 General Circulation Models (GCMs) under the four scenarios (SSP126, SSP245, SSP370, SSP585) of CMIP6. The historical bias corrected daily maximum temperature is validated with IMD gridded daily maximum temperature data and the future projections of heat waves occurrence will be studied during the pre-monsoon season (April-June). The results indicate that, in future there is a significant increase in the occurrence of heat waves over India and occurrence over each temperature homogenous zone varies.

Keywords: heat waves, CMIP6, India

IMPACT OF CLIMATE CHANGE ON AGRICULTURE IN DEVELOPING COUNTRIES

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ABSTRACT

The largest known economic impact of climate change is upon agriculture because of the size and sensitivity of the sector. Most tropical regions in the world are vulnerable to climate variability, given their dependence on rain-fed agricultural production and limited adaptive capacity owing to socio-economic conditions. This study evaluates the potential impact of climate variation on agricultural yield and production in ten developing countries. To analyses the data, various statistical techniques like correlation and various regression trends are used. From the study, we can conclude that crops are sensitive to changes in precipitation. In some countries, we can see that the production of crops decreases as rainfall increases and also that production increases as rainfall increases. From the study, we can understand that climate change affects agriculture by decreasing crop production.

Keywords: Climate Change, Agriculture, Correlation, Regression

Trends in extreme precipitation events over Western and Central Himalaya in changing climate scenario

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ABSTRACT

Changing climate has posed a great threat to the Indian Himalayas and its surrounding areas. Varying rain patterns, extreme events and other geo-hazards over these areas have started affecting food and water supply and overall economy of the country. Change in monsoon onset date and intensity along with increasing sea surface temperature is a direct evidence of climate change in Indian region. The present study deals with the effect of climate change on extreme precipitation events over the Western and Central Himalayan region. The global weather phenomena such as the occurrence of La-nina and EL-nino and its effect on cloud burst and very heavy (extreme) precipitation events in the context of present climate change and global warming has been studied. Data for the period from 1970 to 2020 have been used from the available source from internet. The whole period has been divided into excess, normal and deficit rain years. The extreme phenomena have been studied for these extreme years as well as for Lanina and EL-nino years. Preliminary results show that changing climate doesn't effect the Pattern and intensity of La-nina and El-nino years. More cloud burst events are observed in La-nina years in comparison to El-nino years. The possible cause has been investigated with respect to the trends in temperature and precipitation over these regions.

Keywords: Cloudburst, El Nino, La Nina, Extreme events

CMIP6 projections of meteorological drought over India

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ABSTRACT

Droughts are important natuaral 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 over India. But under all emission scenarios north India is going to face severe droughts in the twenty first century. There is 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.

Understanding the northeast monsoon over India in the warming climate: Present and future evidence from CMIP6

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ABSTRACT

An effort is made to investigate the northeast monsoon and its influencing drivers in a warming climate. This study utilized the outputs from models of Coupled Model Intercomparison Project version 6 (CMIP6). The model's performance is demonstrated for the present climate for historical simulations. The extensive evaluation analysis indicates that GFDL, NorESM2, BCCCSM2, CanESM, and HadGEM3 show good resemblance to observation in reproducing the mean precipitation and associated mechanism during the historical period with GFDL as the best performing model. The best five models are taken to investigate the projected changes during the near future (NF; 2010–2039), middle future (MF;2040-2069), and far future (FF; 2070–2099) with respect to the historical period (1976-2005) under RCP8.5 scenario. The projected precipitation and associated drivers are found experiencing continuous changes over most parts of the northeast monsoon regions under the RCP8.5 scenario.

Keywords: Northeast monsoon, CMIP6, ENSO.

Downscaling of Future Rainfall from CanESM2 Projections in Cherrapunji

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ABSTRACT

Climate projection has become quite comprehensive now a days by use of various climate models at global level. But challenges still loom at large, when it comes to regional level climate projections. Statistical and dynamical downscaling of General Circulation Model (GCM) are the only way to project at regional level. So, here we have used statistical downscaling model (SDSM 4.2) to predict future rainfall in Cherrapunji using the predictors of Second-Generation Canadian Earth System Model (CanESM2). Cherrapunji, located in the North-Eastern part of India, received about 11,478±2,384 mm (1979-2020) of annual average rainfall, thereby known to be a wettest place on earth. Daily rainfall data, starting from 1979 to 2020 has been obtained from weather station of Indian Meteorological Department (IMD) at Cherrapunji for the present study. For model calibration, data set of 1979-2005 is used, while the rest, 2006-2020 is used for model validation. Three future scenarios; near future (2021-2040), mid future (2041-2071) and far future (2071-2100) are generated for all the three RCP 2.6, 4.5 and 8.5 scenarios. We found that the rainfall at Cherrapunji is largely influenced by four major NCEP global predictors; mean sea level pressure (mslp), geopotential height at 500 hPa (p500), geopotential height at 850 hPa (p850) and specific humidity at 850 hPa height (s850). The R^2 value of the model for monthly average rainfall is 76% and 67%, while that for annual average rainfall is 99% and 97% during calibration and validation respectively. The projected future scenario reveals that, Cherrapunji will witness an increasing amount of annual average rainfall with respect to the three RCP scenarios. It is observed that during the three future periods, the annual average rainfall will increase upto 2-5 %, 1-10 % and 3-22 % with respect to RCP 2.6, 4.5 and 8.5 respectively. Moreover, a drastic increasing and decreasing change is also observed for monthly average and seasonal average rainfall. Thus, Cherrapunji will also have an impact of climate change in future.

Keywords: SDSM, Future Rainfall, CanESM2, Cherrapunji.

RESERVOIR INFLOW PREDICTION FOR CLIMATE CHANGE SCENARIO USING ARTIFICIAL INTELLIGENCE TECHNIQUE

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ABSTRACT

Climate change and uneven distribution of water resources have a significant influence on floods and droughts. Though surface water reservoirs are one of the tools to mitigate floods and droughts, however, their operation has become complex with ever-increasing demands and varying inflow due to climate change conditions. Because of this, the performance of the reservoir systems has come down and they are not able to achieve their objectives. This has necessitated the prediction of the future inflows for different climate change scenarios to operate the reservoirs appropriately. Therefore, the objective of this study is to predict the inflow into the Peruvannamuzhi reservoir using an artificial neural network (ANN) model. An ANN model was developed with monthly inflow data of seven years of observed data at the dam site. To evaluate the accuracy of the model, statistical measures such as mean squared error (MSE) and coefficient of determination (CC) were employed. On training, the model converged at MSE of 1832.67 and CC of 0.83. The trained model could forecast the testing data with MSE of 729.19 and CC of 0.80. The trained network was then used to predict the future inflow using the GCM climate change data for RCP 4.5 and RCP 8.5 emission scenarios. The results show that inflow forecasting using artificial neural network has better accuracy in forecasting the inflow under various climate change scenarios.

Keywords: Climate change, Inflow Prediction, Artificial Neural Network

GLOBAL AND REGIONAL MONSOONS; NEW INFERENCES FROM IPCC-AR6

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ABSTRACT

Human populations in the tropical land regions heavily depend on monsoon rainfall for freshwater, agriculture, and various socio-economic activities. The effects of GHG forcing combined with aerosols and water vapour feedbacks are fundamental to monsoon precipitation changes in a world that evolved through the industrial revolution and heading to a warmer future. This study explores the observed and projected precipitation changes associated with global and regional monsoons from an IPCC-AR6 perspective. We first re-defines the monsoon domains by incorporating the regional information that provides more acceptance and accuracy to this assessment. Through this, we quantify the observed and projected changes in South and Southeast Asian Monsoon, East Asian Monsoon, West African Monsoon, North American Monsoon and Australian-Maritime Continent monsoon based on historical and various SSP scenarios part of CMIP6. From the historical simulation, it is evident that the CMIP6 multi-model ensemble means are able to reproduce the observed long term declining trend over the central Indian region. In contrast, the recent recovery of African and South Asian monsoons was overestimated. The observed long term trend is bound with extensive decadal fluctuations, especially over North America, East Asia, South America and the Australian-Maritime Continental regions. However, these fluctuations are within the multi-model internal variability limit, which enhances the confidence in the simulation. Thus, we can depend on the projected future information even on regional monsoons, which we precisely further quantified in this study.

Keywords: Climate change, monsoons, IPCC-AR6 assessment of regional monsoons.

DECLINING AEROSOLS AND RECOVERING MONSOON

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ABSTRACT

South Asian summer monsoon went through a period of drastic decline since the 1950s for nearly 5 decades. It was attributed to the net cooling effect of increasing anthropogenic aerosol concentrations around the same time. The fate of monsoon precipitation in the near future and its attribution to various natural and anthropogenic factors is an important question of climate change. In this paper, we have made a detailed investigation of how the trend in South Asian summer monsoon precipitation evolves in the near future and what factors will influence it by analysing climate model projections of the SSP245 experiments from the CMIP6 model outputs. Analysis of ENSO statistics from model projections shows indications that the influence of warm ENSO events over precipitation may weaken once the anthropogenic influences become significant. Our investigations reveal that the precipitation will increase over South Asia at a slower rate till the 2040s, and a relatively steep recovery occurs thereafter. The cooling effects of aerosols and the heating effects of GHGs counter each other's effects and thus involve a tug of war over the control of monsoon precipitation. Till the 2040s, aerosols will be able to slow down precipitation recovery, but once aerosol concentrations start decreasing, GHGs take over with their ability to maintain a significant land-sea thermal contrast crucial to bring monsoon winds towards South Asia. The increasing moisture availability will also play its part in the precipitation recovery by means of latent heat mechanisms.

Keywords: Climate change, South Asian monsoon projection, Anthropogenic aerosols

High-resolution downscaled future Indian summer monsoon rainfall projections over the India

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ABSTRACT

Climate change is likely to affect precipitation patterns in the Indian summer monsoon. In the present work, we develop high-resolution downscaled scenarios of future projections of the summer monsoon precipitation over India using the state-of-art Weather Research and Forecasting (WRF) model. Atmospheric initial and boundary conditions are obtained from NCAR-CESM Global Bias-Corrected outputs. Sensitivity studies are carried out to identify the physics configuration and initialization protocol that performs best in simulating current conditions. The simulated rainfall is found to be remarkably sensitive to different parameterization schemes. The spatial distribution and spatial correlation of simulated rainfall is compared with IMD and ERA5. Results show that continuous simulation with WSM6 microphysics, KF cumulus and YSU PBL schemes are more accurate compared to other configurations. This configuration is used to downscale projected precipitations at one-degree resolution for RCP 8.5 for 2041-2050 and 2091-2100 periods to 10 km resolution. Results show significant regional effects of climate change on monsoon precipitation especially strong increases in the Western Ghats and the Northeast and some reduction in Central India. The downscaled data is made available in the public domain. Apart from improving our understanding of climate and climate change, this dataset can be valuable for water resource management applications.

Keywords: Climate change, Monsoon, WRF Model, Downscale

Quantification of Enhancement in atmospheric CO_2 background due to Indian biospheric fluxes and fossil fuel emissions

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ABSTRACT

Regional carbon emissions impact global atmospheric carbon dioxide (CO_2) background concentrations. This study quantified the enhancement in the atmospheric CO_2 mole fractions due to biospheric and fossil fuel fluxes from India. Sensitivity experiments using model simulations were conducted, allowing CO_2 enhancement due to biospheric and fossil fuel fluxes from India to diffuse into the global atmospheric background. The areal extent of columnaveraged enhancement of 0.2 ppm and above due to Indian fluxes are spread over a larger area covering the Indian subcontinent, neighboring Asian regions, and the north Indian Ocean in all four seasons. The boundary layer CO_2 enhancement due to biospheric fluxes (fossil fuel fluxes) have a maximum range of -2.6 to +1.4 ppm (1.8–2.0 ppm) most time of the year. At higher altitude, the amplitudes of enhancement are reduced from ±1.8 to ±0.6 ppm as we go up from 850 to 500 hPa due to diffusion by prevailing atmospheric dynamics and convection. With the information of the areal extent of > 0.2 ppm CO_2 enhancement due to Indian fluxes, we have evaluated the representativeness of satellite observations (GOSAT and OCO-2) in capturing those enhancements. Both the satellite coverage shows a similar number of observations (0.1 per day) during all seasons except for June to August, wherein the cloud screening eliminates almost all the satellite data over the region. Within this areal extent, the satellite XCO_2 shows average anomalies of nearly ±2.0 ppm; it is a valuable piece of information because it is well above the retrieval uncertainty, yet capturing the potential enhancement due to fluxes from India. The study implies that the regions of enhancement greater than 0.2 ppm can be considered locations for surface observations representing Indian fluxes. Similarly, the region with enhancement greater than one ppm could be covered by satellites/airborne observations to discern enhancement in the atmospheric CO_2 mole fractions due to Indian fluxes.

Performance Evaluation of Regional Climate Model Ensemble for Simulating Extreme temperature over India

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ABSTRACT

Extreme weather events associated with extreme temperature such as heat waves and cold waves have been observed to cause severe implications on health, agriculture, natural ecosystems and infrastructure. With the aid of regional climate models, the scientific community has been able to observe and project changes in the characteristics of climate variables for historical period and future scenarios. The reliability of future projections of extreme temperature events depends upon the ability of regional climate models to simulate observed events for historical period. The present study evaluates the performance of Conformal-Cubic Atmospheric Model(CCAM) and Regional Climate Model4 (RegCM4) RCM ensemble, from Coordinated Regional Climate Downscaling Experiments (CORDEX) for South Asia (SA) experiment, for simulating extreme temperature (March–June) for a long-term period (1971 to 2005) over India against observations from India Meteorological Department (IMD). Daily gridded maximum surface air temperature and regional climate simulations at a resolution of 0.5°x 0.5° were obtained from IMD and CCCR-IITM for the study period over India. Variance scaling technique was adopted to remove the bias associated with model simulations. Results show that after bias correction both the RCM ensemble simulations improved in capturing the daily and extreme maximum temperature variability. The results of statistical performance metrics used to study the comparative model performance (Taylor Diagram, correlation, MAE, ECDF) shows RegCM4 ensemble to be better performing in simulating inter-annual variability and extremes of daily maximum temperature over India. The results and distinct observations in model performance in the study will be useful for the scientific community to understand the uncertainties in RCM projections. Overall, the study concludes that RegCM4 ensemble can be used to study and project the changing characteristics of extreme temperature in future scenarios.

Keywords: Climate Change, Regional Climate Model, Bias Correction, Extreme weather events

Assessment of weather parameters on agriculture in Maharashtra under the impact of climate change

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ABSTRACT

In the present study, investigation of the trend study of agro-climatic zone is done in Maharashtra. Objectives have been fulfilled by analyzing temperature (maximum, minimum, mean) & rainfall data. Observed meteorological & projected data (CORDEX) based on Global Climate Models (GCM) are considered for assessment impact on taluka scale in order to know pattern, vulnerability and for policy-making decisions under changing climate. This data is an ensemble of high resolution regional climate change projections until 2099 at 50km spatial resolution generated at Centre for Climate Change Research (CCCR), Indian Institute of Tropical Meteorology (IITM), Pune by dynamical downscaling of Coupled Model Intercomparison Project (CMIP5) global climate model output.

Using Mann-Kendall test & Sen's slope estimator, the trend and pattern of temperature, rainfall are analysed. Assessment of minimum & mean temperature shows increasing trend whereas less variations in the maximum temperature. Historic data shows statistically significant months from July to September, winter season, pre-monsoon while Sen's estimate shows decreasing trend in winter and positive trend for rest of the months. December month shows negative Mann-Kendall & Sen's estimate but not significant. Cordex data for moderate & extreme climate scenarios shows statistical significant positive trend in January month for the station Padegaon, Sugarcane Research Station. To know the more precise/accurate data, bias correction using observed data in linear correlation method for downloaded cordex data is performed.

Keywords: Climate change, Cordex data, Man-Kendell Test, Sen's slope

Exposure to Climate Change: A Case Study of Beas River Basin

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ABSTRACT

The concept of exposure, sensitivity, and vulnerability has wide presence in academic research pertaining to the problems of society, environment, economy, health, demography, policy making, social work, etc. According to Intergovernmental panel on climate change, exposure could be defined as the presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected. Children, elderly people, disabled, women's, ethnic minorities, and socially deprived communities are often understood as being highly exposed to climatic changes. There is ongoing concern about current and potential climate change impacts on the Indian Himalayan Region from both a physical and societal perspective. This region is facing important challenges in view of coping with adverse effects of climate change. Thus understanding and anticipating the impacts of climate change on Himalayan mountain and the services it provides to people are critical. In this investigation, Beas river basin have been taken to measure the spatial patterns of exposure to climate change and associated hydrometeorological hazards that may become more intense due to ongoing climate crisis we have taken into account seven indicators. It is noted that upper Beas basin is relatively more exposed to climatic change as compare to lower Beas river basin.

Keywords: Climate Change, Exposure, Beas River Basin, Himalaya

Accessing the changing behaviour South West Monsoon Rainfall Using high resolution CORDEX data: a vulnerability analysis of Flood and Drought

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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 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 CORDEX ERA-Interim-driven simulations of South Asia-CORDEX i.e. RegCM4.7, COSMO and REMO2015 over the India for the period 1981-2015. The intercomparison of the dynamically 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 is serve as a standard measure of flood and seasonal drought. The capability of RegCM4.7 and REMO2015 in simulating Indian summer monsoon proves that the model simulation can realistically represented the monsoon drought than flood episode in term of duration, intensity and frequency.

Keywords: CORDEX, RCM, FLOOD, DROUGHT

Vertical atmospheric methane variation observed during an airborne campaign in India

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ABSTRACT

Cloud-Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX) (Prabha *et al.*, 2011) led by IITM, Pune was carried out in multiple phases during 2010, 2014, 2015, and 2018. Along with cloud properties measuring instruments, a Cavity Ring-Down Spectroscopy instrument, which provides continuous high-frequency monitoring of GHGs, was flown in an aircraft. It provided the airborne measurement of GHGs, which were post-processed and analyzed. This data, along with other observations of meteorological variables, is used to study the vertical variation in the profiles of the second most important greenhouse gas, methane (CH_4), in the atmosphere. In September, the caipeex-2014 experiment was carried out over the Ganga river basin base location Varanasi (VNS), U.P. India, which is one of the most densely populated regions in India. Few research flights were flown over the Mahabaleshwar (MBL) region during November. Caipeex-2015 was carried out over Maharashtra state in July 2015 near the Western Ghats around Kolhapur- Solapur (KHP) region, which is affected by the southwest monsoon. Flights went up to 8 km up in the troposphere. Analysis of observed CH_4 data and its validation with available chemistry model simulations were performed to understand the variation in the vertical transportation of methane in the troposphere. The models used are Atmospheric General Circulation Model (AGCM) based Chemistry Transport Model (ACTM), LMDZ is an atmospheric general circulation model developed in the 1970s at the Dynamic Meteorology Laboratory of the French National Centre for Scientific Research. The Community Atmosphere Model with Chemistry (CAM-Chem) is a component of the NCAR Community Earth System Model and is used to simulate global tropospheric and stratospheric atmospheric composition. All the three models are majorly in consensus with observed vertical methane profiles; however, within the boundary layer, there seem to be some differences with observations amongst the models. Overall, the profiles tend towards decreasing concentrations of CH_4 as we go higher in the troposphere except for the KHP site. Further correlation analysis on observed CH_4 and CO data, segregated according to the height in the troposphere, was done to understand the source characterization of methane. Such a study gives confidence in understanding the atmospheric transport process of the greenhouse gases in the atmosphere.

Keywords: atmospheric methane, greenhouse gases, aircraft observation

Hadley Cell Dynamics in IITM- Earth System Model: Evaluation using ERA5 reanalysis

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ABSTRACT

Hadley Circulation (HC) is the tropical circulation which is responsible for the typical wet climate of the tropics and the dry climate of the sub-tropics. According to the sixth Assessment Report (AR6) from Intergovernmental Panel for Climate Change (IPCC) the circulation is exhibiting a poleward expansion ~0.5-1 degree latitude per decade, with significant regional and seasonal variability. Studies are increasingly focusing on the tropical expansion phenomena and the associated dynamics as a result of its direct implications on the precipitation patterns of the tropics and the subtropics. It is important to evaluate these changes by means of observational studies, and project their evolution in a future warming scenario. In this regard, the present study uses the climate model simulation data from IITM Earth System Model (IITM-ESM) archived in the latest Coupled Model Inter-comparison Project 6 (CMIP6) to identify the long term changes in the width of the ascending and descending branches of the HC and validate it against the latest generation ERA5 reanalysis. IITM-ESM is the first model from India to participate in CMIP6. The current study delineates the HC ascent and descent regions within the IITM-ESM using the meridional mass stream function metric and compare it with that obtained from ERA5. Time series of evolution of width of the HC ascent and descent regions from since 1850 is made using historic simulation data from IITM-ESM. Future evolution of the width of these regions up to 2100 under two different high-forcing scenarios from IITM-ESM is investigated. Results show that the model successfully captures the observed changes in the total width of the HC and its ascending regions. It is for the first time that a model from India is evaluated for its efficiency in representing the HC dynamics.

Keywords: Climate change, Tropical Expansion, Climate Models, Reanalysis

Dynamics of Rainfall Extremes in the context of Indian Summer Monsoon

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ABSTRACT

The study demonstrates the distinct role of surface thermal forcing and moist processes over Indo-Pakistan Arid Region (IPAR) as another potential and significant precursor (16 to 10 days in advance), in causing monsoon rainfall daily extremes over the Monsoon Core Zone (MCZ). The IPAR warming is initially triggered by subtropical-midlatitude interactions characterized by the intrusion of Eurasian wave train into the Asian domain. Hydrodynamic longwave radiative teleconnections are the primary mechanism for the persistence of the surface thermal forcing over IPAR after the initial intrusion of the Eurasian wave train. Insights gained from this study suggest that enhanced surface warming and amplified water vapor feedbacks, as found over IPAR at daily time scales, may be another significant contributor to the recent increasing trend in rainfall extremes over MCZ in a global warming context. So, this study has larger implications on understanding changes in monsoon rainfall extremes over Indian subcontinent both for the present-day and future climate scenarios.

CHANGING SURFACE TEMPERATURE AND RAINFALL OVER A RAPIDLY GROWING TWIN CITY OVER EASTERN INDIA

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ABSTRACT

The rapid growth of Indian cities, both in size and number of urban inhabitants, makes a large section of people vulnerable to the ill impacts of local climate change. There is a need to understand the urbanization-led changes in local-scale climate. Here, we explore the signature of urbanization over the Cuttack-Bhubaneswar (CBTC) urban area, a rapidly growing twin city in the Eastern Indian state of Odisha using satellite based measurements. Our study explores both spatial and temporal patterns of night-time Land Surface Temperature (LST) and rainfall over the CBTC region for 16 years (2001-2016). A discernible surface urban heat island, having an intensity of ~1°C, is observed. During this period, the night-time LST has increased by ~0.46 °C and 0.67 °C over the urban areas of Cuttack and Bhubaneswar. The exact match between the spatial structures of LST with the urban population density categorically shows the significant role of anthropogenic activities and urbanization. The maximum climatological rainfall corresponds to areas over Bhubaneswar, including its southern periphery. Further, rainfall has decreased by up to 10 to 28%, with a maximum reduction in the perimeter of the Bhubaneswar city.

Keywords: Urban Climate, Urban heat island, Urban rainfall, Trends

FUTURE PROJECTION OF LOW LEVEL CIRCULATION FEATURES OF THE INDIAN SUMMER MONSOON WITH RESPECT TO ACTIVE-BREAK CYCLE

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ABSTRACT

Active-break cycle is an important sub seasonal variation that has an imperative role in regulating the performance of Indian summer monsoon. Coupled Model Intercomparison Project Phase 5 (CMIP5) provided a range of simulated climate futures, that has been utilized for exploring the climate change impacts towards end of the twenty first century with respect to active-break cycles. Performance of the monsoon has been investigated using the circulation features due to the greater fidelity of CMIP5 models in simulating the circulation features compared to rainfall. The active and break spells are identified using a criterion based on 850 hPa zonal wind speed. The projected changes in the intensity and duration of active-break spells are discussed. Twenty year climatology of models during historical period (1986-2005) is compared with NCEP/NCAR reanalysis data and the models which effectively capture the monsoon circulation pattern (CanESM2, CNRM-CM5, GFDL-ESM2M, MIROC5 and MPI-ESM-LR) have been considered for assessing the future climate in RCP 4.5 scenario. The ensemble means of the selected models projects strengthening of wind towards north (north of 15°N) and weakening towards south (especially south of 12°N) of India, which facilitates wetting of northern Indian regions and drying of southern peninsular regions. Active spells are found to be strengthening over northern India and weakening over the peninsular India. Break spells are strengthening over the peninsular India indicating intense breaks towards future. Increased propensity of short intense active days and decreased propensity of long active days are also projected by the models; however, there is no significant change in the number of break spells.

Keywords: Climate change, Summer monsoon, Active-break cycle, CMIP5

Future urban modification in spatiotemporal characteristics of rainfall extremes over Cauvery River Basin Karnataka using high resolution MultiForcings climate ensembles

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ABSTRACT

Urbanization can invariably changes the characteristics of the rainfall extremes and associated flood risks over Monsoon driven river basins (e.g. Krishna, Cauvery, Godavari, Mahanadi etc.) of India as a result of increased vulnerability to floods due to the high concentration of urban population and infrastructures. Alterations of the land-surface properties and moisture balances in the urban environments have concomitant impact on local and regional hydro-climatic regimes leading to elevated temperature and changes in precipitation patterns. Thus quantifying the spatiotemporal characteristics of the extreme rainfall events, at basin scale, under projected climate scenarios, in an urban setting become crucial to provide useful information to design proper infrastructure for effective water resources management. However, these projections are subjected to major uncertainties associated with the different climate scenarios from state-of theart Global Climate Models (GCM). Thus, using a multi-model ensemble from bias corrected downscaled high resolutions NASA Earth Exchange Global Daily Projections (NEX-GDDP) based on CMIP5 simulations as well as bias corrected downscaled CMIP6 simulations, spatiotemporal distribution of extreme rainfall indices like Maximum Monsoon Rainfall (MMR) and Events with >99th percentile thresholds (E99) will be quantified in urban and non-urban grids (based on maximum population density). The performance evaluation of the existing models will be based on the adequate evaluation strategy (multiple criterion evaluation metrics) against historical (1981-2005) observations (IMD) and reanalysis data (ERA5). Subsequently a multi-forcings ensemble from subset of models with relatively high fidelity will be used to generate future projections for the above rainfall indices during 2026-2050 and 2075-2090. Finally a geo-spatial risk based indices (low-risk urban, high-risk urban, moderate-risk urban) will be developed to design intervention strategies to mitigate the extreme rainfall-induced flood hazards over the Cauvery river basin Karnataka.

Keywords: Urbanization, Multi-forcings ensemble, NEX-GDDP, risk-indices (maximum 4 words)

ASSESSMENT OF CLIMATE CHANGE AND THEIR IMPACT ON RICE PRODUCTION THROUGH DSSAT MODEL IN THREE AGROCLIMATIC ZONES OF CHHATTISGARH

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ABSTRACT

Climate change due to anthropogenic pollution of the atmosphere in the 21st century became a higher profile issue than before. To evaluate the effects of climate change, different crop models have been developed and used across the world. The Decision Support System for Agro Technology Transfer (DSSAT) has been found to be most widely used decision support system which included models for cereals, legumes, oilseeds and vegetable crops. The present investigation was carried to assess the impact of climate change on rice production through DSSAT model in three Agro-climatic zones of Chhattisgarh. The studies were conducted in Dept of Agrometeorology in three varieties (Karma Mahsuri, Mahamaya and MTU-1010) with 3 dates of sowing (1st June, 15th June and 30th June). For these studies, used long term (1987-2017) daily weather data for 3 districts (Raipur, Bastar and Sarguja) and for future scenarios (2021-2050) used PRECIS (Providing Regional Climate data for Impact Studies) database of IITM, Pune. Simulation has been done for assessing the production potential of the three rice varieties for different agro-climatic zones of Chhattisgarh under the normal (2017) and projected climatic conditions (2030, 2040 and 2050) through DSSAT 4.6. The trend of baseline (1987-2017) and projected climatic condition (2021-2050) at three districts (Raipur, Bastar and Sarguja) were analyzed. Results revealed that maximum temperature were increased @ 0.025°C / year and 0.051°C /year at 5% and 1% of significance level at Raipur and Sarguja district, respectively under present climatic scenario (1987-2017). However, all districts (Raipur, Bastar and Sarguja) shows significantly increasing trend @ 0.091°C / year, 0.076°C / year and 0.088°C / year at 1 % level of significance, respectively in maximum temperature. Similarly, Raipur and Bastar districts show highly significant increasing trend in minimum temperature @ 0.070 °C / year and 0.059°C / year at 1% significance level, respectively. Annual rainfall shows non-significant trend under both the climatic conditions i.e. present and projected in all three agro climatic zones of Chhattisgarh.

Key words: Climate change, DSSAT

BIAS CORRECTION OF CMIP6 HISTORICAL PRECIPITATION DATASET OVER INDIAN MONSOON CORE REGION USING CONVOLUTIONAL NEURAL NETWORK.

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ABSTRACT

The presence of bias in the climate model outputs in relation to observed datasets affects future climate change assessment or projection. The aim of this study is to use and compare different statistical bias correction techniques and Convolutional Neural Network – one dimension (CNN1d) to the biased climate model datasets and to suggest the better result yielding technique among them. Multimodel Mean is calculated for Seasonal Precipitation JJAS (June, July, August, September) of 17 Global Circulation Models of Coupled Model Intercomparison Project – phase 6 (CMIP6). This data has been regridded to 1°x1° resolution. Seasonal Precipitation data of Indian Monsoon Core region has been extracted from the regridded data for the historical period, 1985 to 2014. Bias correction of the model data is then carried out with reference to the India Meteorological Department's (IMD) daily Rainfall Gridded Dataset (Seasonal Precipitation) which has a resolution of 0.25°x 0.25° using various statistical techniques such as Empirical Quantile Mapping (EQM), Scaling (Addition), Scaling (Multiplication), Power Transformation of Precipitation (PTR), Mean and Variance Adjustment (MVA), Parametric Quantile Mapping (PQM), Generalized Quantile Mapping (GPQM) and Artificial Neural Network(CNN1d). From the analysis, it is observed that CNN1d yields the least Root Mean Squared Error (RMSE) value of 101.77(mm/year) and Mean Absolute error (MAE) value of 80.63 (mm/year).

Keywords: Bias correction, CMIP6, RMSE, CNN1d.

PREDICTING MAIZE YIELD IN CHANGING CLIMATE OF SEMI-ARID AREA OF NAMAKKAL DISTRICT, TAMIL NADU, INDIA - A MICRO ASSESSMENT

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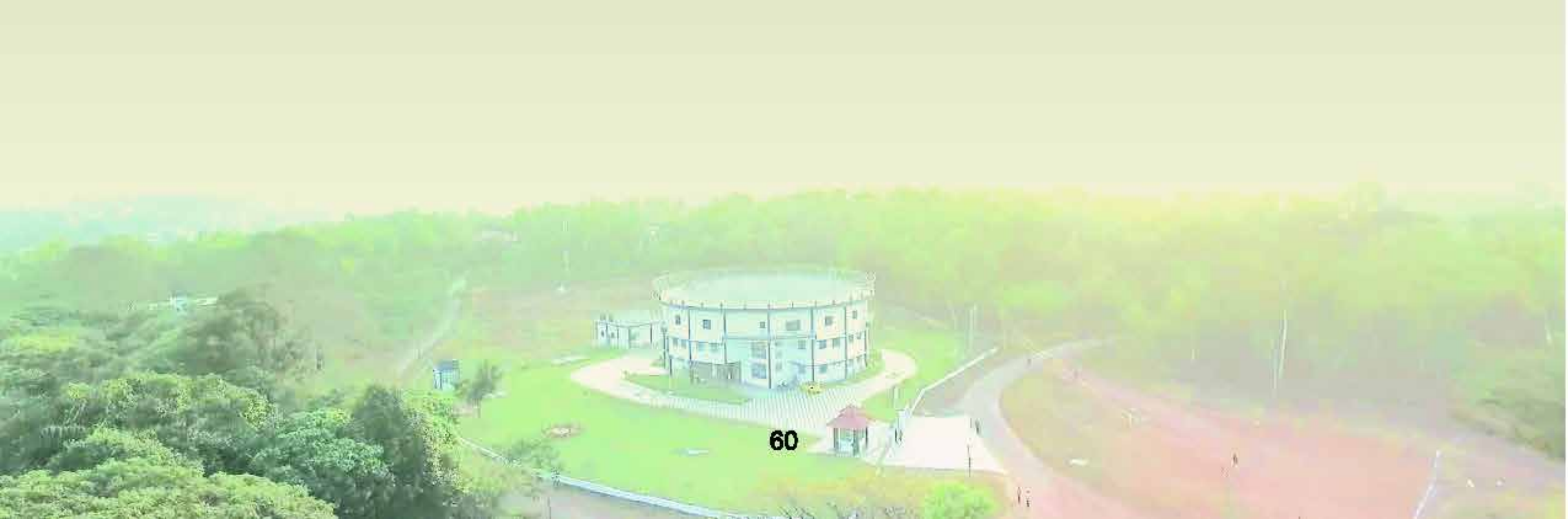
ABSTRACT

The main aim of this study is to understand the maize yield in changing climate at a microclimate in the semi-arid region of Namakkal district of Tamil Nadu. The gridded data of baseline rainfall at 0.25 X 0.25 and temperature at 1.0 X 1.0 degree resolution from IMD were used in this present study to identify the microclimate of the study area. Future climate and yield change were assessed based on the ensemble values for mid-century and end century using HadGEM2ES and GFDL-CM3 climate models. The projected annual mean maximum temperature shows a rise of 2.39 to 4.130C by HadGEM2-ES and 2.95 to 4.300C by GFDL-CM3. Projected rainfall shows an average increase of 23.83 to 47.77 percent by HadGEM2-ES and 11.60 to 38.23 percent GFDL-CM3. DSSAT crop model has been applied to predict the productivity of rainfed maize indicates a negative impact on the study area. A maximum decrease of yield is noted in the Kumarapalayam region of 3997 Kg ha-1 in baseline to 3358 Kg ha-1 in mid-century and 2682 Kg ha-1 by HadGEM2-ES and GFDL-CM3 models shows a maximum decrease over Rasipuram. The yield deviations from baseline to end century were varied from -3 to -18 percent for HadGEM2-ES and -9 to -22 percent for GFDL-CM3. This study focuses the attention on a change over micro rather than macro level to understand the need for crop improvement and better management practices carried out to improve the yield for the future generations.

Keywords: HadGEM2-ES, GFDL-CM3, maize yield, climate change

OLA

Ocean-Land-Atmosphere Interactions



Soil moisture - Temperature coupling over India

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ABSTRACT

Land atmosphere interactions plays a critical role in climatic variability over a region. Soil moisture is an important variable in land atmospheric processes due to its climatic memory. Soil moisture partitions incoming energy into latent and sensible heat flux thus controlling energy and mass fluxes to atmosphere. Various literature has pointed out that central and north India as hot spots of land-atmosphere interactions. However most studies have examined soil moisture - precipitation relationship and less attention has been given to soil moisture - temperature relationship. Hence our study tries to examine soil moisture - temperature relationship in detail using observations and reanalysis of land surface fields. A Better understanding of soil moisture - surface temperature coupling can untangle role of soil moisture in intensification and prolongation of extreme events like heat waves and droughts, hence improving predictability associated with these events.

We have employed two different statistical matrices to quantify land-atmosphere coupling during different seasons. One method uses energy balance approach, where effect of soil moisture is indirectly inferred from evaporation. This method relies on differential skill of latent heat flux obtained from evaporation and potential evaporation in explaining near surface temperature dynamics. Monthly values of evaporation and potential evaporation estimates are obtained from satellite derived GLEAM (Global Land-surface Evaporation: the Amsterdam Methodology) data. Other method is based on lagged covariance ratios of soil moisture and temperature. Monthly soil moisture from GLDAS (Global Land Data Assimilation System) land surface model and Era-5 reanalysis are used for calculation of feedback parameter. IMD observations and Era-5 reanalysis are utilized for surface temperature values. All metrics are calculated on 0.25°× 0.25° grids. Our analysis reveals strong soil moisture - temperature coupling over central and north India. Soil moisture coupling shows strong seasonal variations, with stronger coupling found during pre-monsoon months.

STUDY OF HEAT LOW OVER NORTH WEST INDIA AND ITS RELATION TO ALL INDIA SUMMER MONSOON PRECIPITATION RATE

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ABSTRACT

Ever since the technology of understanding the dynamics of meteorological parameters has evolved, precise monsoon prediction has been challenging. Moisture bound seasonal winds from South West Indian Ocean are influenced by various factors. Intense solar insolation in the pre monsoon months creates a region of low pressure over NW India. At the same time high pressure system monsoon progresses from South-West towards India. How the low pressured system might influence the progress of Monsoon system is an exquisite notion. An interesting thermo-dynamic phenomenon that sweeps across NW India exposes the land and air to intense solar insolation. But, solar radiation is only able to penetrate upto a few centimetres of the soil and due low heat capacity of air, the air above the land warms up much more rapidly creating temperature differences between land and air. As a consequence of this difference, warm air rises over land creating inversion in pressure distribution. Sensible heat flux gives the amount heat flow from one system to other system without change in phase. Pressure inversion is mainly influenced by differential heating of land and air resulting in flow of heat flux from land to atmosphere (surface sensible heat flux). Using the datasets available, the study mainly intents to show the structure of the low pressured (Heat Low) areas over NW India which involved plotting of 1 day averaged monthly vertical height profiles of different parameters viz; specific humidity, potential temperature and vertical Pressure velocity and plotting of 8 day 1 hourly average Surface sensible heat flux and corresponding mean sea level pressure using MCIDAS V data analysis tools. The physical quantity which is responsible for creating the Heat Low, the trends of Land Surface Temperature (LST) over NW India was extracted, analysed and mapped using a model of different geospatial tools. For better and higher spatial resolution, LANDSAT 8 OLI based LST over a part of NW India was retrieved using the model at 30m spatial resolution within the temporal scale of the study period. Vertical ascent of air mass is an important parameter for development of a low pressure area. Vertical pressure velocity over NW India showed a horizontal divergence during daytime and subsidence during night time. As a result of heat transfer from land to atmosphere the mean sea level pressure showed at least a month lag in reaching its minima prior to maximum surface sensible heat flux. It's observed that for the first three months of March, April and May, the CC between LST and Precipitation Rate is negatively correlated and for the months June and July, CC appears to be positively increasing towards higher order dependency.

EVALUATION OF ENERGY FLUXES IN THE NCEP CFSV2

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ABSTRACT

The energy fluxes at the surface and top of the atmosphere (TOA) from a long free run by the NCEP climate forecast system version 2.0 (CFSv2) are validated against several observation and reanalysis datasets. This study focuses on the annual mean energy fluxes and tries to link it with the systematic cold biases in the 2 m air temperature, particularly over the land regions. The imbalance in the long term mean global averaged energy fluxes are also evaluated. The global averaged imbalance at the surface and at the TOA is found to be 0.37 and 6.43 Wm−2, respectively. It is shown that CFSv2 overestimates the land surface albedo, particularly over the snow region, which in turn contributes to the cold biases in 2 m air temperature. On the other hand, surface albedo is highly underestimated over the coastal region around Antarctica and that may have contributed to the warm bias over that oceanic region. This study highlights the need for improvements in the parameterization of snow/sea-ice albedo scheme for a realistic simulation of surface temperature and that may have implications on the global energy imbalance in the model.

EFFECT OF LAND SURFACE PROCESSES ON THE SEA BREEZE CIRCULATION OVER THE KAIGA COMPLEX TERRAIN REGION NEAR WEST COAST OF INDIA

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ABSTRACT

Kaiga Nuclear Power Plant (NPP) site, located on the west coast of Karnataka, India has a complex topography. Kaiga NPP is located in the valley region surrounded by hills on three sides and open on the west towards the Arabian Sea. Kaiga being located on the west coast experiences thermally driven circulations such as sea breeze and land breeze especially during the hot summer months. Average height of hills surrounding the Kaiga valley region is 600 m and are mostly covered by dense evergreen broad leaf forest. In this paper, sensitivity of land surface physics in the WRF model on the sea breeze characteristics were studied using Noah and Noah-Multi-Physics (Noah-MP) Land Surface Models (LSM). Mini Boundary Layer Masts (MBLMs) and Doppler SODAR observations were used for evaluating the model performance. The study shows that WRF simulations showed large sensitivity of simulated sea breeze characteristics to the LSM. The Noah-MP LSM better represented the sea breeze characteristics such as the onset time, inland extent, intensity and duration of the sea breeze circulation over the Kaiga region. Simulations with Noah-MP produced lower MB, MAB and RMSE for surface meteorological parameters (wind speed, wind direction, temperature and relative humidity) in comparison to Noah. Noah-MP produced lower land sea temperature contrast during the daytime and higher temperature during the night to the early morning period compared to the Noah LSM. As a result, Noah-MP predicted higher land breeze intensity and lower sea breeze intensity compared to Naoh. The improvements with Noah-MP over Noah are due to the better representation of vegetation and soil hydrological processes over the dense forest region, realistic simulation of surface energy and momentum fluxes and reduction in the land-sea temperature contrast by including a separate canopy physics.

Keywords: Land Surface Model, Forest Canopy, Complex Terrain, Sea Breeze and Land Breeze

COMPARISON OF MSE BUDGET FOR MJO BETWEEN BAY OF BENGAL AND ARABIAN SEA

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ABSTRACT

Madden-Julian oscillation (MJO) is the dominant mode of tropical intraseasonal variability among the other convectively coupled equatorial waves. It originated in the Indian Ocean and moves eastwards with an average speed of 5 m/s. This study compares the behavior of the MJO convection over Arabian Sea (AS) and Bay of Bengal (BoB) in the north Indian Ocean during 1979 to 2020. Both AS and BoB are adjacent to Indian landmass system and play an important role on the weather phenomena in Indian region. It is observed that BoB received higher amount of rainfall due to MJO compared to the AS region. Moist static energy (MSE) budget analysis shows that the horizontal advection and build up of fluxes over BoB are responsible for the higher rainfall over this region. Also negative vertical advection over this region contributes in the rainfall event.
Keywords: Madden-Julian Oscillation, Moist Static Energy Budget

DOES THE FULL CONSIDERATION OF THE WATER TEMPERATURE - PHYTOPLANKTON FEEDBACK IN CLIMATE MODELS SIGNIFICANTLY AFFECT THE CHARACTERISTICS OF THE UPPER OCEAN LAYER AND PRECIPITATION IN THE NORTHERN INDIAN OCEAN?

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ABSTRACT

In twin experiments with a Regional Earth System Model we explore the impact of activating the full temperature-phytoplankton feedback on the simulated sea surface temperature (SST). We find that in a simulation where light attenuation is calculated allowing for the biogeochemical coupling the average SST is lower over most of the northern Indian ocean in comparison with the reference experiment in which a constant light attenuation coefficient equal to 0.06 m^{-1} is set. The strongest deviations (more than 1°C) in SST occur in the summer period and a cooling of subsurface layers and an upward movement of the thermocline are observed in the experiment with the water temperature-phytoplankton feedback. The activation of the feedback also leads to higher phytoplankton primary production, especially during periods of phytoplankton blooms. The associated SST cooling leads to a reduction of the precipitation but affects it in different ways. In the Arabian Sea, the reduction of the transport of humidity across the equator leads to a reduction of the large-scale precipitation in the eastern part of the basin, reinforcing the reduction of the convective precipitation. In the Bay of Bengal, it increases the large-scale precipitation, contouring convective precipitation decline. Thus, the key effects of including the full biogeochemical coupling with corresponding light attenuation, which depends on variable chlorophyll-a concentration, are the enhanced phytoplankton primary production, a shallower thermocline, decreased SST and water temperature in subsurface layers, with cascading effects upon the model ocean physics which further translates into altered atmosphere dynamics.

Keywords: Indian Ocean, Regional climate model, Phytoplankton

Surface layer Refractive index structure parameter (C_n^2) variability over a beach side location of north Kerala

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ABSTRACT

Atmospheric turbulence in the atmosphere affects the propagation of electromagnetic waves, which can be quantified by refractive index structure parameter (C_n^2). This study examines the variability of C_n^2 and the influence of the atmospheric parameters in a coastal region of north Kerala during winter (Jan-Feb), pre monsoon (Mar-May), monsoon (Jun-Sep) and post monsoon (Oct-Dec). A Boundary Layer Scintillometer (BLS900) and an automatic weather station are used for the direct measurement of C_n^2 and meteorological parameters (Temperature, Relative humidity, Wind speed and Solar flux) simultaneously along the 850m long path. The highest C_n^2 variability is observed in winter with a three-order variability from minimum to maximum (~10^3). The least variability is observed during monsoon measurements (~10^2). Correlation coefficients computed between meteorological parameters and C_n^2 vary from season to season and even from day to night. Temperature, which is the major driving factor of turbulence (Tatarskii, 1961), shows significant positive correlation with C_n^2 in the day time of winter (0.63) and monsoon (0.54). But at night time, temperature is negatively correlated with C_n^2 in all seasons except monsoon (0.07). Relative humidity shows exactly opposite trend of temperature in all seasons with negative daytime correlation in winter (-0.52) and monsoon (-0.56). Higher negative correlation of wind speed with C_n^2 is observed in pre-monsoon night time (-0.65), whereas in all other cases correlation (< 0.5) was comparatively small with positive values during day and negative values at night. In nutshell, the C_n^2 has a positive (negative) correlation with temperature (relative humidity) in day and negative (positive) correlation in night. The negative correlation coefficient value at night may be attributed to the decrease in the air temperature and increase in relative humidity. This in turn increases the heat flux due to latent heat release by the formation of dew causing an increase of C_n^2. Existing empirical models (Sadot and Kopeika, 1992; Bendersky et al.,2004) from the literatures were used to calculate C_n^2 from measured meteorological data but failed to predict the exact variability of C_n^2. Hence using regression analysis, a new model has been developed for the study region. More data needs to be collected and studies need to be done to validate the model.

Keywords: Refractive index structure parameter, Turbulence, Scintillometer

ESTIMATION AND VALIDATION STUDY OF SOIL MOISTURE USING GPS-IR TECHNIQUE OVER A TROPICAL REGION: VARIABILITY OF SM WITH RAINFALL AND ENERGY FLUXES

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ABSTRACT

In this study, Global Positioning System - Interferometric Reflectometry (GPS-IR) technique was used to estimate SM. This method analyses changes in the reflected multipath signals recorded in Signal-to-Noise Ratio (SNR) data called as interferograms. These multipath reflections are directly proportional to dielectric properties of the reflecting surface. Estimated SM data has been validated and compared with collocated in-situ probe, Soil Moisture and Ocean Salinity (SMOS) satellite measurements, ECMWF ERA-5 and NASA Global Land Data Assimilation System (GLDAS); the former shows a good correlation of 0.98 but the magnitudes of SMOS, ERA-5 and GLDAS data are overestimated. Vegetation effects are also included in the algorithm which significantly improves the accuracy between the GPS derived SM and in-situ probe measurements. The success of this technique indicates its high value and could be gainfully employed over a large geographical area like India with the existing receivers due to its advantage of uniformity over several sensors which is highly suitable for several applications like assimilation using models for the better understanding of crop yield, floods and drought monitoring and ground water management studies. Variability of SM with rainfall and energy fluxes like latent and sensible heat fluxes from ERA-5 and GLDAS data are investigated. Observed SM values are positively correlated with rainfall during the study period. Seasonal variations of rainfall and SM in different monsoons are clearly noticed. Latent heat fluxes are more during spring, summer months and positively correlated with rainfall whereas sensitive heat fluxes show negative correlation.

Keywords: GPS-IR Method, Multipath, Soil Moisture, Energy fluxes

Understanding the Continuum of Terrestrial and Aquatic Black Carbon in A High-Altitude Region in the Western Ghats, Southern India

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ABSTRACT

Black carbon (BC), a well-known potent climate influencer in the atmosphere, still hasn't been amply studied for its role in the soil and water continuum. BC resides in soil and water for long periods and plays a significant role in the carbon cycle, which is essential in the context of climate change. A high-altitude location in the eastward extension of the Western Ghats region in India has been selected for studying the spatial distribution, vertical profile and interrelation of black carbon and soil organic carbon. Moreover, this study also aims to estimate the flux of Dissolved Black Carbon (DBC) and Dissolved Organic Carbon (DOC) on a large watershed scale, i.e., from the headwater to downstream to understand the continuum of the terrestrial cycle. This study observed the quantity and quality of BC in soils, where the highest average BC concentration was found in the forest, followed by the agricultural and urban regions. This pattern indicates that the BC in the study region was caused primarily by wildfires and anthropogenic (slash burn activity for agricultural expansion) fires. It was observed that mean DBC concentration is found to decline consistently with the slope from headwaters to downstream. The DBC concentration was linearly related to the DOC concentration, irrespective of the differences in watershed characteristics and seasons. To understand biogeochemical processes and associated climatic impacts, there is an urgent need for consistent BC quantification and integration of the regional and global source-to-sink process.

Keywords: Black Carbon; Soil Organic Carbon, Dissolved organic carbon, Land Use land change, Terrestrial and aquatic environment

Projection of lightning flash rate using thermodynamic parameters in lower atmosphere over India

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ABSTRACT

The solar radiation plays an important role for the exchange processes between Earth surface and overlying atmosphere due to radiative heating, hence affects the variation in atmospheric temperature and surface fluxes. For that spatio-temporal variability of different thermodynamic parameters has been studied. The proposed relationship is justified on the basis of the conversion of the kinetic energy of charging hydrometeors to the energy of flash discharges. Climatological study of lighting as well as thermodynamic parameters has been done for the period of 1996-2013. Proxy will be determine using thermodynamic parameters of lower atmosphere. the topography of study region, surface heat fluxes and hydrometers plays strong relation with lightning flash rate and which can be best suitable for the projection of lightning. Based on the large exchange of heat fluxes on the Earth's surface in the tropics, we propose that the lightning flash rate (LFR) is proportional to a ground heat fluxes and hydrometeors over land as well as ocean in the study region. Evaporation rate and heat fluxes are the dominant proxies to relate with LFR over land as well as ocean. The conversion efficiency is a maximum in the pre-monsoon season and minimum in the winter season. The coastal region showed maximum lightning as compared to land and ocean. The total heat flux best accounts for the seasonal variation of the LFR most prominently during pre-monsoon season due to thunderstorm and strong convective activity. Projection will be done for future period using GCMs data.

Sensitivity of Sea Surface Temperature on the prediction of August 2018 flood event over Kerala

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ABSTRACT

The state of Kerala situated at the southern part of India receives major share of the annual rainfall from southwest monsoon. Any small change in the pattern and intensity of monsoon rain can affect farming, industries and daily lives of people. In August 2018, a heavy rainfall event resulted widespread flooding and landslides in Kerala. In this devastating event, more than 430 people lost their lives, a million people were moved to camps and thousands stranded. The maximum rainfall occurred during August 14 and August 15. Preliminary study is conducted to examine the role of cumulus parameterization in rainfall production, spatial distribution and intensification. Tropical physics suite with Kain Fritsch cumulus parameterization scheme is found to be suitable for capturing the evolution of rainfall over Kerala. In this study an attempt has been made to understand the impact of different sea surface temperature (SST) data sets on the prediction of this heavy rainfall event. The initial and lateral boundary condition for the high resolution configuration of Weather Research and Forecasting (WRF) model is obtained from FNL data. Two way nested domain is used for the simulation with 15 km outer domain and 5 km inner domain. Further, the model is forced with Optimum Interpolation Sea Surface Temperature (OISST), forecasted CFSSST and bias corrected SST to understand the sensitivity of different SST data sets in capturing the intensity and spatial distribution of the rainfall. Then the simulated rainfall is compared with India Meteorological Department gridded rainfall data with the resolution 0.25 degree. It is found that, significant improvements in rainfall simulation is achieved by updating SST.

Keywords: Mesoscale Modelling, Sea Surface Temperature, Flood, Rainfall

An objective technique to determine Mixing Height under multiple-layer conditions using ceilometer for the complete diurnal cycle

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In the atmospheric boundary layer (ABL) the mixing height (MH) is an important parameter which determines the vertical dispersion of air pollutants. Accurate retrieval of the MH is vital for estimation of near-surface air quality information and weather prediction. Aerosol lidar ceilometer is a powerful, low cost, low maintenance remote sensing instrument, which is frequently used for retrieval of MH with high vertical and temporal resolution. However, under multiple-layer conditions involving clouds, elevated aerosol layers, and RL, the standard methods for MH retrieval from lidars show inconsistencies. An objective, new technique based on determination of an altitude limiter from the gradient of aerosol backscatter signal is developed for accurate MH retrieval under such conditions. Results from the comparison with an evaluation database of MH derived from extensive collocated radiosonde ascents show an R_2 of 0.95 correlation and a root mean square error (RMSE) of 75 m for the new technique for conditions involving both cloudy and cloud-free cases, which is better than R_2 = 0.69, RMSE = 201 m for the MH derived from a widely used method of wavelet covariance transform (WCT). The low blind zone of the Vaisala CL31 ceilometer used in this study combined with the proposed technique based on altitude limiter makes this one of the few studies to report automatic identification of the evening transition of the ABL from convective to stable regime using an aerosol lidar. The accuracy of the MH retrieval depends upon ceilometer alone and no additional instruments are needed.

Keywords: Evening Transition • Mixing Height • Multiple-layer condition

Heat Content Variability in the Equatorial Indian Ocean

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ABSTRACT

The variability in oceanic heat content plays a major role in modulating the global climate. The present study focused on how the equatorial Indian Ocean heat content is varying in the Indian Ocean Dipole (IOD) years, with and without the forcing from Pacific (El-Nino). The Empirical Orthogonal Analysis (EOF) for oceanic heat content is done in order to find out the dominant feature in the Indian Ocean. The ECMWF ocean reanalysis and derived ocean heat content (ORAS4) potential temperature data (1° x 1°) for the period 1958 to 2013 is used for computing oceanic heat content. The preliminary results show that, the equatorial heat content is negative during the Independent IOD years, while a positive value is observed during the co-occurred years of El-Nino and IOD. The Indian Ocean Dipole is observed to be the dominant mode in the oceanic heat content of the Indian Ocean. During co-occurred events of IOD and El-Nino the warming will be towards south of the equatorial Indian Ocean.

Keywords: Indian Ocean, Oceanic Heat Content, Indian Ocean Dipole, El-Nino

Study of Monsoon onset in the coupled model framework with different land surface initialization

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ABSTRACT

Monsoon onset over Kerala (MOK) marks the beginning of the rainy season in India. The normal date of MOK is 1 June; however, it varies with a standard deviation of 8–9 days from year to year. Prediction and outlooks of monsoon onset are very important for agriculture planning. The timing of MOK can have a significant impact on agricultural productivity. So, the exact date of prediction of MOK is very important. The MOK is associated with changes in the large-scale dynamical parameters as well as local moisture parameters. The differential heating of land and sea is the primary cause that drives the ISM. However, several studies show the sensitivity of onset to different meteorological and climatic factors. It is not well known how the land surface initial states impact the forecast of the onset in the operational forecast models. In this study, we assess the spatiotemporal characteristics of different meteorological parameters during MOK from Met Office GLOSEA5-GC2 model hindcasts with different land surface initializations. In one, the soil moisture was initialised from a climatology and soil temperature and snow were initialised from ERA-Interim reanalyses. In the other, a land surface re-analysis is used which was created using the JULES land surface model forced by JRA-55 reanalyses from 1990 onwards. Following Joseph et al. (2015) we compare the skill of the coupled model with two different land initializations. For the observation, IMD and ERA5 reanalysis datasets have been used during the period of study (2003-2015). We compare biases from the observation and differences between the models themselves. We found that there is a huge bias in capturing the rainfall pattern and kinetic energy evolution during the monsoon onset days for the period (2003-2015). Our study indicates that the difference in the kinetic energy in the forecasts is responsible for bias in moisture convergence and rainfall patterns.

Variations of latent heat flux during tropical cyclones over Bay of Bengal

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ABSTRACT

Latent heat flux is an important component of air sea energy exchange. It plays an important role in the development and intensification of tropical cyclones (TCs). To examine the influence of latent heat flux on tropical cyclones over Bay of Bengal (BoB) this study has been undertaken. For this European Center for Medium Range Weather Forecasts (ECMWF) ERA5 data of surface latent heat flux (SLHF), mean sea level pressure (MSLP), temperature and wind at different levels for the period 1990-2020 have been used. It is found that latent heat flux increases while TCs are intensifying in the open areas of BoB. The decrease in latent flux during intensification of TCs is due to terrain friction. The genesis potential parameter (GPP) has also been modified by incorporating SLHF. It has been observed that modified GPP shows better coorelation with central pressure than GPP during lifetime of TCs.

Key Words: Surface Latent Heat Flux, ERA5, Bay of Bengal, Genesis Potential Parameter.

Variability of Indian summer monsoon rainfall and its association with west Pacific subtropical high and typhoon activity over the northwest Pacific

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ABSTRACT

In the present study we have examined the variability in zonal displacement of western edge of west Pacific subtropical high (WPSH) location and northwest Pacific (NWP) typhoon activity and their association with Indian summer monsoon rainfall (ISMR) during the peak summer monsoon season (July-August) from 1945 to 2019. The variability and inter-linkages of these parameters were analysed using geopotential height, circulation features and specific humidity data sets at different vertical levels from NCEP/NCAR reanalysis. Typhoon tracks, frequency and density over the NWP were collected from the Joint typhoon warning centre (JTWC) and rainfall data from APHRODITE. Eddy geopotential height is used to analyse the interannual variability in zonal displacement of western flank of WPSH (location index). Based on the relationship between location index and TCs count, the total study period is classified into four phases. Those are termed as 1st quadrant (eastward shift of western flank along with more number of TCs), 2nd quadrant (eastward shift of western flank along with less number of TCs), 3rd quadrant (westward shift of western flank along with less number of TCs) and 4th quadrant (westward shift of western flank along with more number of TCs). The WPSH attains more (less) intensity when there is less (more) number of typhoon activity during the peak monsoon season. The westward (eastward) shift in location index along with less (more) number of typhoons over the NWP is associated with surplus (deficit) rainfall over the Indian subcontinent. The composites of monthly sea surface temperature anomalies exhibit a strong El Nino pattern associated with eastward shift of WPSH and reduction of TC activity. Whereas strong La Nina patterns are associated with the westward shift of WPSH and enhanced TC activity over NWP. The westward shift associated with reduction in Tc activity (3rd quadrants) depicts the cooling patterns over the Indo-Pacific region. The composites of prtecipitable water column and vertical integrated moisture transport for four quadrants is consistent with rainfall patterns in the respective quadrants.

Influence of ENSO and IOD on the variability of atmospheric CO2 over the Indian Ocean

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ABSTRACT

Atmospheric carbon dioxide (CO2) has been on a steady increase since the industrial revolution broke out. As India and the neighbouring countries that share boundaries with the Indian Ocean are no exception to industry and related activities, the atmospheric CO2 over the Indian Ocean is also increasing at an alarming rate. We analyze the annual and seasonal distribution of atmospheric CO2 over the Indian Ocean using satellite measurements for the period 2003–2016. There exist seasonal and annual differences in the CO2 distribution over the north Indian Ocean and south Indian Ocean. In order to understand the influence of El-Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) on the distribution of atmospheric CO2 over the Indian Ocean, we analyse CO2 composites during El-Niño, La-Niña, Positive IOD, Negative IOD and normal years. The monthly CO2 data is segregated according to Niño indices for ENSO and Dipole Moment Index for IOD. The data was detrended and deseasonalized prior to the composite calculation. The eastern Indian Ocean is found to be more sensitive to ENSO and IOD events. During Positive IOD, over the eastern Indian Ocean, a smaller CO2 concentration is observed compared to normal years. However, a larger CO2 concentration is observed at the same location during negative IOD. ENSO events also have a similar influence on the distribution of atmospheric CO2, though not as strong as IOD. These analyses would give us insights into the responses of CO2 distribution over the Indian Ocean, which may impact CO2 flux exchanges between the atmosphere and ocean and vice versa.

Keywords: Atmospheric CO2, Global warming, ENSO/IOD, Indian Ocean

Indo-Pacific climate variability and its association with the Indian Monsoon in a changing climate

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ABSTRACT

The Indo-Pacific region is gaining global attention due to its significant influence on the global climate. In particular, Indo-Pacific warm pool comprising eastern Tropical Indian Ocean and western tropical Pacific Ocean has significant influence on the atmospheric circulation in various time scales. In the recent decades Indo-Pacific warm pool has undergone significant changes and started modulating the global climate. Recently a new climate mode named as warm pool dipole (WPD) over Indo-Pacific warm pool has been discussed in the context of climate variability, which is characterized by opposing sea surface temperature (SST) anomaly over western equatorial central pacific (WECP) and south eastern Indian Ocean (SEIO). WPD is observed to have large climate impacts. However, there are no studies explicitly addressing the decadal variability in the WPD and its association with the Indian Monsoon. By analyzing several reanalysis products our study reveals that WPD exhibits decadal and multidecadal variability. Further, WPD influences the rainfall over India with maximum impact over central and northern India in decadal time scale. However, since the mid 1990's, the association between WPD and rainfall has undergone large changes. The relationship between rainfall and WPD has been strengthened in the recent decades as compared to 1962-1993, highlighting the growing importance of WPD and associate climate impacts. The mechanisms responsible for decadal variability in the WPD and its association with the monsoon are explored in details in the present study. Further, the impact of SEIO and WECP on the Indian monsoon are also examined independently in this context.

Keywords: Indo-pacific warm pool, warm pool dipole, Indian monsoon

Variability of Atmospheric boundary layer height over Indian Subcontinent: A review analysis

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ABSTRACT

Planetary boundary layer (PBL) which has vital role in exchange of moisture, heat and momentum between earth's surface and free atmosphere through the process of turbulence has great role in various atmospheric processes. Many researchers reported that height of PBL depends upon various parameters such as convection availability at the surface, synoptic weather pattern, specific humidity, temperature, surface zonal wind, Richardson number, CAPE (Convective Available Potential Energy). Researches on PBL has reported that the role of land surface conditions has great influence on planetary boundary layer height (PBLH) due to spatial and temporal variations of albedo, roughness length, soil moisture and vegetation density. Scientists have observed that increased soil moisture conditions will decrease the surface albedo which ultimately increases the heat budget at the surface (latent and sensible heat fluxes) for transporting more heat and moisture deeper into PBL. Analysis of PBLH in extreme monsoon seasons has also been done by many researchers and observed that during pre-monsoon season height of PBL is greatest in all inland region (Indian subcontinent) but during monsoon greatest height of PBL is observed at N-W India. During Excess monsoon years PBLH is more as compared to deficient monsoon years mainly due to stronger convection and LLJ (Low level jets). Another research reported that PBLH is highest in island due to more convection, Low over coastal region due to moderation of soil conditions and lowest in Oceans due to low diurnal SST variations and Weak convectivity. Based on reviewed research papers, dynamics of PBLH and its interaction with land surface conditions, synoptic conditions were proven essential ingredients to shape the weather and climate of the region.

Keywords:Planetary boundary layer ,Turbulance ,land surface conditions ,monsoon

WARMING IN THE ARABIAN SEA DURING THE RECENT DECADES AND ITS IMPACT ON SURFACE Chl-*a* CONCENTRATION

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ABSTRACT

Tropical Indian ocean is experiencing rapid increase in the sea surface temperature (SST) over the last few decades. Arabian Sea is a highly productive region of the North Indian Ocean and is influenced by the summer monsoon phenomena that bring considerable changes in the upper ocean dynamics. The warming of the ocean waters adversely affect the biological productivity of the ocean. In this paper, we analysed the trend in SST in the Arabian Sea during the last five decades. The variations in SST are analysed at two locations, one in the southeastern Arabian Sea (SEAS) and the other in the northwestern Arabian Sea especially during the summer monsoon season. The increase in SST is higher in the northwestern Arabian Sea compared to the SEAS. Variability in surface chlorophyll-a (chl-*a*) in the Arabian Sea is also analysed during the last two decades using merged data from satellite observations and it is observed that chl-*a* show a decreasing trend in its concentration. If this trend continues, the decrease in biological productivity of the Arabian Sea will have a negative impact on the fishery of the region.

Smitha A acknowledges Cochin University of Science and Technology for the financial support and facilities to carry out this work.

Keywords: Sea surface temperature, Arabian Sea, chlorophyll-*a*, warming

A study on the interactions between the polar and subtropical weather systems in southern hemisphere in relation to the South West Monsoon over India

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ABSTRACT

The Indian summer monsoon from June to September determines the state of agriculture and in turn the economy of the country. One of the semi-permanent features of Indian summer monsoon is Mascarene High (MH) which is known as the genesis of the Indian Summer Monsoon. The Onset and Advance of SW Monsoon and the rainfall activity during the South West (SW) monsoon season is influenced by location and intensity of MH, which in turn, is dependent on the Meridional Oscillations of Circumpolar (60^0S to 70^0S) Low pressure belt. Thus, this becomes a classical example of the interactions between the polar, subtropical and tropical weather systems. In order to analyse and understand these interactions, a case study is undertaken. The position and the intensity of the Mascarene High (MH) along with the Sea Surface Temperature (SST) over Sub Tropical High region (20^0S to 40^0S) are studied to analyse the impact of SST on MH and in turn, on the Cross Equatorial Flow (CEF). The variations in the location and intensity of MH in relation to that of the Circumpolar lows circumventing the south pole, are also analysed, for contrasting cases of active and weak monsoon conditions over India during the months of June and July during the SW Monsoon season of 2021. It has been observed that, due to variations in the position and strength of the Sub Polar Low (in relation to SST over this region), the Sub Tropical High (STH) over the Mascarene High Region is stronger (weaker) than normal during the active (weak) monsoon conditions. This, in turn, leads to strengthening (weakening) of the CEF leading to enhanced (suppressed) rainfall activity over the Indian subcontinent. This contrasting signal is also clearly observed in the zonal and meridional wind patterns over the region. The further details are explicitly discussed in the paper.

Keywords: Planetary boundary layer, Turbulence, land surface conditions, monsoon

Influence of air-sea interaction in Surface layer turbulence Parameters over a Tropical station.

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ABSTRACT

The present study gives an estimate of turbulent parameters over Thumba Equatorial Rocket Launching Station,(TERLS)– a coastal station in the southern peninsular India. The Data used for analyses consist of u,v,w, component of wind, sonic temperature collected at 4Hz through Ultrasonic anemometers installed at two levels, 4m and 8m on a 50m Micro-meteorology tower for a period from April 2012 to March 2014. The paper examines the dependence of drag coefficient (Cd) and roughness length(Zo) on stability, structure of several turbulent parameter like momentum flux, heat flux,turbulent kinetic energy, frictional velocity etc are discussed elaborate in connection with meso-scale system like sea-land breeze and thunderstorm passage. The Zo values for unstable conditions shows a systematic dependence on (z/L), while for neutral conditions it satisfy the so-called Log-wind profile. The Cd values seems to show sensitivity to fluctuation in the wind direction, resulted as first time investigation.

Keywords: Roughness length,Wind-log Profile,Drag coefficient,Coastal Boundary Layer.

Salient features of the mudbank in Alappuzha during the SW monsoon season of 2021

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ABSTRACT

Mudbanks are regions of calm turbid water, most frequent along the southwest coast of India, during the Southwest Monsoon season. In the monsoon season of 2021, a well-formed mudbank is observed from the second week of July onwards along the coastal region of Alappuzha. In this study, an attempt is made to understand the salient features of the mudbank of Alappuzha. Along the coast, this mudbank stretches from Kakkazham (9.3953 N, 76.36 E) to Purakkad (9.35 N, 76.365 E), a distance of about 5 km alongshore and around 4 km offshore. Even though initially the northern end of the mudbank was observed at Valanjavazhi (9.3954 N, 76.35 E), after one week the northern end moved about one kilometer southward and was observed at Kakkazham. In the present study, we have collected water and sediment samples from the mudbank region and analyses are being carried out. We have determined the variation of settling velocity during different days within the mud bank region. The settling velocity is found to be increasing with an increase of temperature. Using Laser Scattering Particle Size Distribution Analyzer, the particle size distribution in the sediment samples from the coast (inter-tidal region) and at about 20m away from the coast and also in the water samples were analysed. In the sediment samples, sand is more predominant whereas in the water sample silt is predominant. Concentrations of SPM were determined in water samples collected from the mudbank region and outside the mudbank region using the filtration method. There is considerable variation in the concentration of SPM in the two regions. The chlorophyll concentrations in the samples are compared with the results using satellite observations.

Keywords : mudbank, southwest monsoon, sediment, settling velocity

Study of large-scale Atmospheric convection over the tropical Indian Ocean and its association with Oceanic variables.

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ABSTRACT

In India the summer monsoon rainfall occurs owing to large scale convection with reference to continental ITCZ. It was found that convection over tropical ocean increases with SST from 26 to 28 degree C and when SST is above 29 degree C it sharply decreases for warm pool areas of Indian and for monsoon areas of West Pacific ocean. The reduction in convection can be influenced by large scale subsidence forced by nearby or remotely generated deep convection, thus it was observed that under the influence of strong large scale rising motion convection does not decreases but increases monotonically with SST even if SST value is higher than 29.5 degree C. Since convection is related to SST gradient that helps to generate low level moisture convergence and upward vertical motion in the atmosphere. Strong wind fields like cross equatorial low level jet stream on equator ward side of the warm pool are produced due to convection initiated by SST gradient. Areas having maximum SST have low SST gradient and that result in feeble convection. Hence it is imperative to mention that the oceanic role (other than SST) could be prominent in influencing large Scale Atmospheric
convection. Since warm oceanic surface somewhere or the other contributes to penetrate the heat radiation to the subsurface of the ocean and as there is no studies seen related to oceanic subsurface role in large Scale Atmospheric convection, in the present study, we are concentrating on the oceanic subsurface contribution in large Scale Atmospheric convection by considering the SST gradient, mixed layer depth (MLD), thermocline, barrier layer. The present study examines the probable role of subsurface ocean parameters in influencing convection.

Role of Environmental Stable Isotopes as Hydro-Climatic Tracers in Subarnarekha River Basin, East Singhbhum, Jharkhand, India

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ABSTRACT

The Singhbhum region of Jharkhand, the storehouse of Indian minerals, is a geologically significant mineralized zone having long history of mining and beneficiation of economic minerals namely copper, and uranium. Back then these mining and mineral processing wastes have grossly polluted the regional water courses in the associated Subarnarekha river basin. The understanding of the recharge mechanism and hydrogeological dynamics of this mining-smelter affected watershed is important for protection and sustainable management of water resources. The subsurface water that primarily exists in unconfined and confined condition finds its way slowly through network of fissures and joints. The stable isotopes ($\delta^{18}O$ and $\delta^{2}H$) are considered as ideal conservative tracers that provide better insight into groundwater provenance, recharge processes and flow path delineation, as their composition remains same within the groundwater. Results of isotopic analyses show that δ18O and δ2H varies from -6.3% to -2.7% and -42.4% to -14.8% for groundwater, and from -5.2% to -1.9% and -35.3% to -15.3% for surface water. Samples enriched in δ18O show higher TDS which is indicative of high evaporation under the dominantly hot climatic conditions. Few samples show depletion in isotopic composition with higher EC and TDS, which is a result of intense rock-water interactions, influence of mine sump water and Acid Mine Drainage. Majority of groundwater fall on Global Meteoric Water line (GMWL) indicating recharge from rainwater. Most water samples belong to Ca-Mg-SO4-Cl hydrochemical facies, while others adhere to Na-K-SO4-Cl type, with high proportions of silica and strontium. The hydro-facies bear distinct evidence of mineral dissolution from hard crystalline Precambrian country rocks. Subarnarekha thus acts both as an effluent and influent river. The river is an important pollution sink from captive mines during hot lean dry weather flow and substantially adds to pollution of neighbourhood aquifers when it is at spate in monsoon season.

Keywords: Acid Mine Drainage, mining-smelter, stable isotopes, Singhbhum

IMPACTS OF VARIOUS RAINFALL FORCINGS ON SURFACE SOIL TEMPERATURE OVER INDIA USING LAND INFORMATION SYSTEM

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ABSTRACT

Considering the lack of in-situ data sets, estimates of land surface fluxes mostly rely on satellite retrievals and land surface models (LSMs). Hence, the quantification of errors due to forcings in the LSMs outputs are essential. Precipitation is the most critical forcing data used in LSMs, that determine land surface characteristics such as soil temperature, soil moisture, surface fluxes etc. Different types of precipitation data sets are available from rain gauges, satellites, analysis products, merged data sets etc. The present study evaluates the uncertainty in surface soil temperature estimates using three different precipitation data sets such as TRMM (Tropical Rainfall Measurement Mission), IMD (Indian Meteorological Department) gridded data, and GDAS (Global Data Assimilation System) data sets over the Indian domain using Noah LSM.
All the three simulations are performed using the three different precipitation data sets over the Indian domain for three years from 2012 to 2014. All the three simulations are performed with the same model configurations and physics except the rainfall, which is different for the three simulations. The results are validated with the IMD weekly soil temperature station data for the years 2012 to 2014. Results show that the surface soil temperature estimates of Noah LSM forced with IMD gridded rainfall data performs best as compared to the other two simulations. The above is attributed to the fact that as compared to GDAS and TRMM the IMD gridded rainfall is closest to the in- situ rainfall measurements (ground truth).

Keywords: Land Surface Models, Soil Temperature, Precipitation

Findlater Jet Induced Summer Monsoon Memory in the Arabian Sea

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ABSTRACT

The Arabian Sea (AS) has a unique feature where the wind circulation reverses direction annually due to the influence of the two contrasting monsoon winds. During the Indian Summer Monsoon (ISM), the cross-equatorial low-level winds also known as Findlater Jet (FJ) modulate the thermocline oscillation in the AS. Our study shows the impacts caused by the FJ-induced wind stress curl (WSC) over the AS. We find that the FJ signal gets 'trapped' in the Arabian Sea in the form of Tropical Cyclone Heat Potential (TCHP) till the following winter monsoon months. Wefind that the positive correlation of wind stress curl with TCHP in the south of the FJ core in the months of the winter monsoon. This memory is the consequence of the FJ-induced WSC and the annual downwelling Rossby waves in the AS. During the ISM months, the strong low -level westerlies winds cause a negative wind stress curl in the south of the FJ core over the central Arabian Sea resulting deeper thermocline which leads to a deep 26°C isotherm. In winter monsoon months, the winds are weaker and spread over the larger area causing a positive WSC over the entire AS, and still the signal remains in the subsurface due to presence of radiated downwelling Rossby waves which pushes the thermocline again resulting in the thicker mixed layer (ML). During the following spring, the Rossby waves collapse which leading to a shallower ML depth and erodes the cap which formed earlier. This leads to the mixing of underlying waters with surface waters and the resurfacing of the signal occurs. The resurfacing signal makes the Arabian Sea, a memory bank in which the monsoon signal is stored in the form heat till the next spring and available for next monsoon.

CCP

Clouds, Convection, and Precipitation Processes

ANALYSIS OF A MESOSCALE CONVECTIVE THUNDERSTORM EVENT IN ASSAM, INDIA

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ABSTRACT

Mesoscale convective thunderstorm events are among the major natural disasters and are often associated with lightning, precipitation, and strong winds, which could be fatal to human and animal lives. The north-Eastern part of India is one of the significant lightning-prone regions in the country. The frequency of lightning activities in this region is highest in Pre-Monsoon seasons. Nagaon district of Assam reported one such thunderstorm event on May 13th, 2021, where 18 elephants were reported dead due to a lightning flash associated with the thunderstorm event. In this study, we examine the thunderstorm event using Doppler Weather Radar (DWR) and Satellite data. We have also simulated thunderstorm-related parameters and indices like CAPE, CINE, KI, LI, RH, Precipitation, and Wind Speed using high-resolution numerical weather prediction model WRF. We performed these simulations for different (Planetary Boundary Layer) PBL schemes options available in the WRF model separately to determine which PBL schemes could efficiently capture the features of the observed event. We have further determined the sensitivity of WRF model simulations using different PBL schemes against ground-based observed and satellite data. A further detailed discussion of the event and simulated results are presented in this study.

Keywords: Thunderstorm, Convective, Pre-Monsoon DWR, WRF, PBL

WHAT REGULATES THE GROWTH OF MONSOON CONGESTUS CLOUDS INTO DEEP AND OVERSHOOTING MODES WITHIN A DAY?

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ABSTRACT

Significant tropical rainfall linked to convective activities during morning and afternoon hours of the day. Our day-to-day experience in solar heating, clouds, and convection visually suggest that shallow cumuli grow into congestus that will eventually grow into cumulonimbus. We examined the fundamental processes leading to such diurnal transition of convection in monsoon trough region using ground-based radar and multiple satellite observations along with reanalysis products. An objective identification for different cumulus modes is found by inspecting occurrence frequency of 35-dBZ top heights, near-ground rain rates and cell area using nine wet-season radar observations in Kolkata. Four cumulus modes were identified, namely a shallow cumulus mode with 35 dBZ tops in trade inversion layer (1–3 km), a congestus mode with tops in highly stable midtroposphere (3–7 km), a deep convective mode with tops in region of free convection (7–15 km), and an overshooting mode with tops in tropical tropopause layer (>15 km). Moreover, diurnal cycle of four modes show a lead-lag of few hours in their population, indicating transition from congestus to deep and overshooting modes. Using moisture budget derived from ERA5 reanalysis, it is shown that midtroposphere is moisten prior to deep and overshooting convection by thermodynamic (congestus moistening) and dynamic processes (vertical advection) in the radar domain. Furthermore, bulkanalysis performed to investigate thermodynamic versus dynamic control on observed diurnal transition of cumulus modes. The comparison of transition time-scales by congestus moistening (18-46 h) and large-scale dynamics (3 h) to the observed transition time-scale (2-4 h) revealed that congestus moistening is too slow to explain observed lead-lag in cumulus modes. Though, both thermodynamic and dynamic process found to bring moisture influx in the mid-level prior to deep and overshooting convection, large-scale dynamics acts as the dominant process in congestus to deep and overshooting transition within a day.

Keywords: Monsoon Trough, Radar, Convection, Characteristic time-scale.

Fidelity of CMIP6 models in future prediction of Indian winter monsoon rainfall (IWMR)

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Abstract

In the prediction of seasonal changes of the Indian monsoon system, the Indian winter monsoon (IWM) prediction is very important. The climate of the tropics is linked to the cold winds originating from the high latitude in the northern hemisphere. Western disturbances associated with winter monsoon season (WMS) play a decisive role in the Northern India climate. We have analyzed the CMIP6 data to anticipate temperature and precipitation over the Indian region for the WMS (December, January and February). In this analysis, we have analysed the mean and variation of precipitation and temperature of historical runs of CMIP6 models over the Indian region and validated them with the help of observation data from India Meteorological Department(IMD) and reanalysis datasets. We have found that some of the CMIP6 models are good at the simulation of the spatial distribution of the rainfall with a good degree of correlation with the observation and reanalysis datasets but most of the models have failed to capture the extreme rainfall events. The CMIP6 model simulations reveal biases in winter monsoon season mean temperature and precipitation over Indian regions in the present climate. The CMIP6 model is much improved but still there is scope for improvement in systematic errors and biases in the temperature and rainfall over the Indian region. We have also done the future prediction of rainfall and temperature and we got some different results as compared to the CMIP5 models.

Keywords: CMIP6, Indian Winter Monsoon,IMD.

LIFE CYCLE OF A TROPICAL MESOSCALE CONVECTIVE SYSTEM-INSIGHT OF COMPLEX PHYSICAL MECHANISMS USING SUITE OF OBSERVATIONS

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ABSTRACT

Understanding complex physical mechanisms of mesoscale process requires high resolution observations of temperature, moisture, wind, precipitation, lighting, clouds. Using collocated observations of microwave radiometer, wind profilers, electric field mill, weather radars over South-East India an observational analysis of tropical mesoscale convective system conducted. Analysis suggests that these systems developed in warm, moist environment associated with large-scale low-level convergence. Passage of system is accompanied by convective regions with intense upward motion and towers extending up to higher levels (developing phase), presence of upward/downward motion comprising of heavy precipitation (mature phase) followed by stratiform regions with prominent downdraft motion and less precipitation (decay phase). Large (small) values of reflectivity and cloud liquid water values represent presence of deep (shallow) convective (stratiform) regions. Cloud to Ground (CG) lightning activity showed the existence of both +CG and –CG flashes (convective), dominant –CG in stratiform regions. Combination of observations has provided the unique opportunity to examine interrelations of different physical mechanisms in storm environment. Inspection of reflectivity, CG lightning and cloud liquid water measurements have demonstrated the relationship of lightning mechanism with storm dynamics and cloud microphysics. Combined investigation of temperature, moisture and wind measurements have given considerable insight of thetae ridge formations resulting from thermal and moisture advections. Isentropic upgliding and downgliding facilitated the unique way to visualize the vertical transport of temperature and moisture through ascent, descent of air parcel.

Madhulatha, A., M. Rajeevan, T.S. Mohan and S.B. Thampi, Observational Aspects of Tropical Mesoscale convective systems over southeast India, 2020, J. Earth Syst. Sci., 129, 65

Keywords: MCS, Lighting, Isentropic lifting, Weather radar, radiometers, wind profilers.

Characteristics of rain events of different durations over a high altitude site in the Western Ghats of India

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ABSTRACT

Duration of rainfall is a key feature which is closely associated with the nature and structure of precipitating systems. Using ground-based disdrometer and X-band radar measurements, the present study explores the duration related properties of rain events during four pre-monsoon (March-May) and monsoon (June-September) seasons over a high-altitude cloud physics laboratory (HACPL) in the Western Ghats (WG). The pre-monsoon (monsoon) rain events follow a log-normal distribution spanning from 0.3 to 9 hr (0.1 to 160 hr). The study majorly focuses on monsoon season and shows that very short (<15 minutes) and very long rain events (>50 hr) are relatively more intense with smaller number of large drops. The diurnal variations of rain intensity and rain frequency peak in late afternoon around 15-18 hours (Local time) in all rain events. Based on the diurnal peaks, the rain events are categorized into short (<6 hr) and long (>6 hr) duration events. Our analysis reveals that the long-duration events are the major contributors of the total summer monsoon rainfall. Short (long) duration events occur morethan 70 % (less than 30 %) but contribute less than 20% (more than 80%) to the total rainfall amount. Further, the subseasonal variation of long-duration rainfall shows close linkage (correlation coefficient ~0.8) with the monsoon rainfall over the core monsoon zone (CMZ) whereas the short-duration rainfall is negatively correlated (correlation coefficient ~-0.3) with the CMZ rainfall. The vertical reflectivity structure for both short and long-duration events show ~20 dBZ reflectivity at 1.5 km level with higher vertical extent (> 10 km level) in case of short-duration events. The frequency distribution of 18 dBZ echo top heights exhibits unimodal (around 2 km) structure with a longer tail and bimodal (around 2 km and 4 km) for short and long-duration events respectively.

Keywords: Rain event, Indian monsoon, Western Ghats, Weather Radar

RECENT TRENDS AND CLIMATOLOGY OF ISCCP OBSERVED HIGH, MID AND LOW-LEVEL CLOUDS AND ITS RELATIONSHIP WITH INDIAN SUMMER MONSOON

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ABSTRACT

The International Satellite Cloud Climatology Project (ISCCP), a major program of World Climate Research Programme for global-scale observations on clouds, is the most versatile source of cloud information. Earlier studies have revealed that through deep convection, the cold rain processes contribute to the driving forces linked with planetary-scale circulations (e.g., Hadley circulation). The primary contributor of moisture and heat to the lower atmosphere is warm clouds. Furthermore, total rainfall is an outcome of contributions from convective and stratiform rain components. Hence, the focus of this study is to investigate the inter- annual variability, trends and teleconnections to Indian summer monsoon of different cloud types namely High, Mid and Low-level clouds over the tropical belt in the recent decades.

ISCCP D2 dataset of High, Mid and Low-level clouds for the available data period from July 1983 to December 2009 have been examined. The cloud amount (%) representing the fractional area covered has been used to understand the trends over the Indian domain [8°-38°N,68°-98°E]. Further, inter-annual variability and teleconnections of clouds at these three levels with global sea surface temperatures are evaluated. The spatial distribution of climatology of cloud amount during all the four seasons reveals that higher percentage of Low-level clouds are observed over the tropical ocean, whereas Mid and High-level clouds are largely spread over the tropical land. Northward propagation of High-level clouds from Equatorial Indian Ocean spreading over to South Asia (in particular, India) and East-Asia (in particular, China, Japan and Korea) is visible from winter through to the summer monsoon season (JJAS). The Low and Mid-level (High-level) clouds averaged over the Indian region show a significant increasing (decreasing) trend in the recent decades. Further, spatial correlation of detrended Low-level clouds with summer monsoon rainfall over India displays significant inverse correlation along the coast of north-west and south-east Indian regions. Furthermore, spatial correlation of detrended Mid and High-level clouds with summer monsoon rainfall shows significant positive correlation along the south-central and north-west Indian regions respectively.

Keywords: Clouds, Monsoon

CONFRONTING THE CHALLENGES OF PRECIPITATION MICROPHYSICS OVER WINDWARD SIDE OF THE SOUTHERN WESTERN GHATS

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ABSTRACT

This paper is overview of studies carried out pertaining to the microphysics of precipitation at different altitudinal location over southern western ghats using in-situ observations by National Center for Earth Science Studies and uncertainties in the microphysical process rates owing to fundamental gaps in knowledge of cloud physics. The Western Ghats (WG) mountain range running parallel to the west coast of India is an area where atmosphere interacts with orographic undulations play a major role in receiving heavy rainfall during Indian monsoon. The height of WG varies spatially to considerable extent presenting a complex topography, which makes the region a very distinctive location to understand the microphysics of precipitation. Rain microphysical observations at different terrain conditions are essential to make a holistic understanding of the processes and to formulate the parameterization of precipitation in weather and climate models. In-situ observational studies are more beneficial than satellite-based studies to understand the regional microphysical characteristics of precipitation in terms of raindrop size distributions (RSDs) and rain integral parameters. The primarily analysis given a comprehensive understanding of rain microphysics and distinct RSDs profiles for different rain types modifies significantly radar reflectivity and rain rate (Z-R) and rain integral parameters at monsoonal and non- monsoonal periods. These results have profound importance in quantitative precipitation estimation. However, observational studies on precipitation at regional in WG region are lacking. This is very important to enhance the small-scale spatial studies on precipitation using in-situ observation for better quantitative rainfall forecast.

Keywords: Raindrop size distributions, Radar reflectivity, Rain rate.

CHARACTERISATION OF RAIN EVENTSCOVER KERALA USING OBSERVATIONAL AND SATELLITE DATA

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ABSTRACT

The study analyses the rainfall amounts over north and south Kerala using the daily gridded rainfall data set (IMD4) at a high spatial resolution (0.25°×0.25°), (latitude × longitude) By using the IMD4 data for finding the intensity of rainfall in Kerala State. The study areas are fixed for North Kerala with latitude (10.50-12.50°N) and south Kerala with Latitude (8.15°N-10.15°N) and with longitude (74.50°E -77.30°E) same for both. Further analysis for rainfall intensity is performed using TRMM TMPA 3 hourly satellite data. These data is used for categorizing and observing their trends of rain events in North or South Kerala from 1998-2019. With the help of this data study also aims to find maximum and minimum rainfall rate from the years of 1998-2019.

Keywords: Rainfall amounts, Rainfall rate.

Morphology of the vertical structure of cloud and precipitation over a complex terrain of North East India

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ABSTRACT

The presence of clouds and their vertical structures can affect the incoming and outgoing radiation, thereby can have a serious influence on the radiative equilibrium, water cycle and climate. Knowledge on the vertical structure of precipitation can help us to understand the cloud dynamics, microphysical processes and hydrometeor distributions over any place. Therefore, Vertical distribution of Clouds and associated precipitation should be accurately portrayed to properly assess climate and its change. MODIS level 2 cloud products, Ceilometer data deployed over Umiam (25.67N, 91.91E) and precipitation flux of MERRA 2 have been used to get the cloud top (CTH), base (CBH) and precipitation information respectively. The study encompasses from March 2019 to February 2021 depending on data availability.

Cloud Occurrence frequency is found to be very high (~60%) over Umiam with a peak in July and dip in November and with about 27% cases of near ground occurrences. Presence of double layer clouds is there throughout the year (17%). Cloud geometrical thickness (CGT) obtained from the difference between CTH and CBH is having considerable seasonal variation although in pre-monsoon and monsoon, cloud depths are comparable. Seasonally averaged CGT is minimum in winter with a value of 2300±760m and maximum during Pre-monsoon with a value of 9250±650m. Morning time clouds are deeper than afternoon clouds which emphasizes the early morning convections which are predominant over orographic North East India. Detected cloud bases are usually found in lower troposphere except in pre-monsoon when for a considerable amount of time (~ 40%) first CBH is in the mid-troposphere indicating anvil of a nearby thundercloud to serve as the first cloud bases. Vertical distribution of precipitation flux in convective cases is similar in strength and pattern during Monsoon and Post-monsoon, whereas it is comparable between Post-monsoon and Pre-monsoon for non-convective precipitation.

Keywords: CBH, MODIS, Cloud morphology, Ceilometer, Precipitation morphology

Links between Asian summer monsoon convection and UTLS water vapor distribution

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ABSTRACT

Our work examines the links between Asian Summer Monsoon (ASM) convection and water vapor distribution in the upper troposphere and lower stratosphere (UTLS). While there has been a debate on the role of monsoon convective intensities on the UTLS water vapor accumulations, there are ambiguities with regard to the effects of organized monsoon convection on the spatial distribution of water vapor. Analysis from in situ high precision balloon measurements and Microwave Limb Sounder (MLS) observations indicate an increase in water vapor over the ASM UTLS during the monsoon season. We use precipitation estimates from the Tropical Rainfall Measuring Mission (TRMM), reanalysis circulation data, as well numerical model simulations to examine the role of ASM on water vapor distribution in the UTLS. An empirical analysis shows that global climate drivers such as El Niño-Southern Oscillation (ENSO), Brewer-Dobson circulation (BDC), and Quasi-Biennial Oscillation (QBO) can contribute to nearly one third of the UTLS water vapor variability over region, highlighting the dominant role of ASM. Results indicate that widespread spatial distribution and accumulation of water vapor in the LS (about 80% of total accumulation between May and August months) tend to co-occur with organized monsoon convection, intensified divergence of water vapor flux in the UTLS and intensified Tibetan anticyclone. The study highlights the effects of stronger localized convection, and large scale organized convection on the UTLS water vapor distribution. The ongoing work also explores the variability and recent trends in the water vapor.

Keywords: Asian Summer Monsoon, Organized convection, Water Vapor, upper troposphere and lower stratosphere

NUMERICAL SIMULATION OF WARM SEASON HORIZONTAL CONVECTIVE ROLLS USING HIGH RESOLUTION WRF - SENSITIVITY TO LAND SURFACE PHYSICS

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ABSTRACT

Horizontal Convective Rolls (HCR) are boundary layer sub-mesoscale motions forming under strong heating and high wind shear during warm seasons. HCRs are often observed over the southeast coastal region around Kalpakkam. These sub-mesoscale structures influence the pollution transport and boundary layer clouds. In this study numerical simulations are conducted using high resolution (0.666 km) Weather Research and Forecasting (WRF) model to study four summer season HCR cases which are identified based from streets of convective clouds from Landsat-8 satellite images and surface observations. Simulations are conducted using Noah (control) and Noah-MP land surface physics to study their role in the representation of simulated HCRs. The model simulated surface parameters are compared with a high temporal (10 min) surface meteorological tower data, sonic anemometer data and SODAR data available at the site location. Comparison with Landsat-8 imagery showed that Noah predicted a large number of HCRs over a wider area in the domain with significant differences in the simulated fluxes and surface variables. An improvement is found with Noah-MP which simulated the roll structures and distribution in better agreement with satellite imagery. The simulated surface parameters shows better agreement with the observation in the case of Noah MP over Noah. Orientation of stronger convergence along the coast, deeper PBL height and warm dry surface conditions simulated by Noah-MP relative to Noah reduce the inland progression of the convective rolls giving better agreement with observations. Results indicate that Noah-MP better represented local land surface processes leading to realistic simulation of HCRs.

Keywords: Horizontal convective rolls, WRF, Land surface model, Noah, Noah-MP.

CLOUD EVOLUTION ASSOCIATED WITH MONSOON INTRASEASONAL OSCILLATIONS

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ABSTRACT

The cloud features associated with Monsoon IntraSeasonal Oscillations(MISO) are investigated using the MODIS based cloud classifications. MISO modulates the distinct cloud types to different extent over the different subregions over the Indian Summer Monsoon(ISM) domain. The subregions where the total cloud evolution is most modulated by MISO shows an evolution with peak in shallow clouds leading to moisture preconditioning and causes the tropospheric column to be unstable which eventually leads to convective cloud enhancement with enhanced precipitation and later a peak in middle level clouds are observed. In the Boreal summer mean state clouds over the ISM domain show regional preferences based on the SST conditions

Keywords:Monsoon Intraseasonal Oscillations, Indian Summer Monsoon, MODIS cloud classification.

A study of charge structure of lower part of the overhead premonsoon thunderstorms and associated electrical discharge over the eastern and north-eastern part of India

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ABSTRACT

A study of the charge structure of the lower part of the overhead premonsoon thunderstorms and nature of electrical discharge is carried out over Rampurhat (Eastern India) and Kohima (North-eastern India). For this purpose, 5 years observations (2017-2021) of surface electric field (±E) and lightning induced step changes of electric field (±ΔE) have been used from EFM-100 measurements. Over Rampurhat (Kohima), a total number of 191 (242) thunderstorms are observed. A convention that, a positive (negative) field indicates positive (negative) charge overhead is utilized. For an overhead thunderstorm, ΔE of at least ± 600 Vm^{-1} occurring in a period of 2 sec is considered. The convention that +ΔE (-ΔE) indicates the removal of negative charge (positive charge) from the overhead thunderclouds is considered. Four cases of ambient electric field and electrical discharges from the overhead thunderstorms are identified namely, (i) -E; +ΔE, (ii) -E; -ΔE, (iii) +E; +ΔE, and (iv) -E; -ΔE. Overall, over the Kohima, the most dominant discharge is -E; +ΔE (52%) and followed by, -E; -ΔE (27%). Whereas over Rampurhat it is -E; -ΔE (45%) and followed by -E; +ΔE (32%). These results suggest that most of the time the positive dipole charge structure exists at the lower part of the thunderstorm both over Kohima (79%) as well as Rampurhat (77%) of course with different nature of discharge. On the contrary, relatively for the lesser time, inverted or negative dipole charge structure exists at the lower part of the thunderstorm both over Kohima (21%) as well as Rampurhat (23%). Over Kohima, the higher flash rate is found to be associated with the -E; +ΔE, whereas, over Rampurhat, it is found to be associated with –E; -ΔE. By virtue of higher flash rates, thunderstorm over Rampurhat are found to be more severe compared to Kohima.

Keywords: Thunderstorm, Charge structure, electric field

COMPARISON OF ISRO'S GROUND-BASED DOPPLER WEATHER RADAR REFLECTIVITY WITH GPM OBSERVATION

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ABSTRACT

This study compares the ISRO's ground-based Doppler weather radar reflectivity data with NASA's Global Precipitation Measurement Mission (GPM) satellite's Ka-band reflectivity dataset for the years 2018 and 2019 to study the spatio-temporal variability of weather events. For monitoring and modelling weather systems, hydrological cycle quantity and rainfall timing are very much important. The radar data which extends from 8° to 10°N and from 76° to 78° is re-projected into the GPM grid using the linear interpolation technique to compare both data. Standard statistical measures such as RMSE, MBE, MAE, and correlation coefficient are used to compare both datasets at coincident points. Using indices such as the probability of detection (POD), False Alarm Ratio (FAR), Frequency Bias Index (FBI), etc. the binary accordance of the radar and satellite data are evaluated in order to see if the events occur uniformly in both data sets in a particular duration of time. Furthermore, a pixel-by-pixel comparison is also performed to assess the ability of both the sensors to represent the spatial variability of the measured quantity. The above analysis is also carried out seasonally as the precipitation scheme varies according to seasons. The results thus obtained show a significant difference exist between both data sets.

Keywords: Doppler Weather Radar, GPM Satellite, Reflectivity

THE ROLE OF LAND SURFACE-ATMOSPHERE INTERACTIONS IN DEEP CONVECTION:WRF SIMULATIONS OVER NORTH-EASTERN PART OF INDIA

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ABSTRACT

Thunderstorms (a typical mesoscale convective system) often cause severe and devastating flash floods and related disasters. Prediction (in lead time) of the thunderstorm in the scale of time and space yet remain a challenge. Most of the mesoscale models of recent decades still have difficulties capturing the synoptic conditions that lead to thunderstorm formation. The north-eastern part of India remains highly prone to thunderstorm activities during March-April-May (pre-monsoon period), and we need a high predictability model. This study investigates the role of land surface- atmosphere processes in initiating deep moist convection during the pre-monsoon period over Kolkata and its nearby region. This is well known in advance that convection plays a vital role in the formation of severe thunderstorms. Hence, the Advanced Research version of the Weather Research and Forecasting (WRF-ARW) model was used in this study to perform the numerical simulation. The different sensitivity experiments were performed with different microphysical schemes. The model simulations outputs were validated with the observations. Thermodynamic and dynamic indices like the Convective Available Potential Energy, Convective Inhibition Energy, Lifted index, K-index, Total Total Index, Deep Convective index and SWEAT index was also studied to quantify the convective instability of the atmosphere. It was found that the model performs well in simulating the severe weather events, associated thermodynamical, dynamical processes and associated land surface-atmosphere processes. However, the model shows a sensitivity that varies with the experiments in different microphysical schemes.

Keywords: WRF-ARW, Thunderstorms, Microphysical Schemes, land surface-atmosphere processes, Convection.

ROLE OF MULTISCALE PROCESSES IN THE DEVELOPING AND NON-DEVELOPING TROPICAL CYCLONES OVER THE NORTH INDIAN OCEAN

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ABSTRACT

Tropical cyclogenesis are one of the most important and unsolved problem. Madden Julian oscillation and other equatorial waves play an important role in the genesis of TC through modulation of low-level vorticity and mid-level moisture. In spite of the favorable environment only few low-pressure areas develop as a depression (developing system) and further intensify as a tropical cyclone whereas other could not reach the strength of depression (non-developing system). In this study we have investigated the role of multiscale processes in the genesis of a cyclone considering a developing and non-developing case. Here the system which sustained to depression (day of genesis) is defined as developing else non-developing. It is observed in developing system there are multiple waves interaction. Presence of multiple waves modulated different dynamical and thermodynamical parameters prior to the formation of system. However, extend of modulation in case of non-developing case is negligible. For both the systems a Quasi Closed Circulation (QCC) formed in the initial stage but it strengthened and sustained in case of developing system. In case of non-developing cases QCC is weaker. The dynamical role of QCC in the aggregation of vorticity is investigated using high resolution satellite and reanalysis data.

Keywords:

A study of deep convective systems in relation with electrical discharge and bulk microphysical properties during the premonsoon and monsoon seasons over the north eastern and eastern part of India

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ABSTRACT

Deep Convective Systems (DCSs) are studied in relation with electrical discharge and bulk microphysical properties during the pre-monsoon and monsoon seasons of 2019-2020 over Kohima (North-Eastern India) and Rampurhat (Eastern India). The DCSs are identified with the help of minimum brightness temperature of 11 µm channel ($T_{b11(min)}$) of INSAT-3D with $T_{b11(min)}$ ≤ 235K. The property of electrical discharge (step change in electric field) of DCSs are studied with the help of peak value of flash rate (PFR), as obtained from EFM-100. The bulk microphysical properties are analyzed with the help of ERA-5 reanalysis datasets. On the basis of the median value of PFR, DCSs are classified in two categories, Type-1 (DCSs with PFR<18 flash-minute^{-1}) and Type-2 (DCSs with PFR≥18 flash-minute^{-1}). Over Rampurhat a total number of Type-1 DCSs, during the pre-monsoon and monsoon seasons are found to be 10 (16%) and 53 (29%) respectively. Whereas, over Kohima respective values are 19 (38%) and 110 (57%). Similarly, over Rampurhat the occurrence of Type-2 DCSs, during the pre-monsoon and monsoon seasons are found to be 53 (84%) and 130 (71%) respectively. Whereas, over Kohima respective values are 31 (62%) and 83 (43%). The diurnal variation of the occurrence of Type-1 DCSs during the pre-monsoon shows bimodal distribution with peaks during 12:00 hrs and 18:00 hrs over both the regions. However, during the monsoon there is no systematic diurnal variations. On the other hand, diurnal variations of the occurrence of Type-2 DCSs during the pre-monsoon (monsoon) is monomodal with a peak at 13:00 hrs (14:00 hrs) and 15:00 hrs (15:00 hrs) over Rampurhat and Kohima respectively. Overall Type-2 DCSs are associated with strong mixed phase regions as evident from higher values of ice water content in the mixed phase region. The further analysis is in progress.

Keywords: Convective systems, Electric field, Lightning.

A study of the association of rainfall and electric discharge during the pre monsoon and monsoon seasons over a tropical station in the Patkai Hill range of North East India

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ABSTRACT

In the present study, an association of rainfall characteristics with respect to electrical discharge is investigated during the pre- monsoon (March-May) and monsoon (June-September) season of 2018-19 over Kohima (Nagaland) in the Patkai hill range of North East India. Simultaneous observations of rainfall and electric field are considered from the Tipping Bucket Rain Gauge and Electric Field Mill (EFM-100) respectively. Electrical discharge is characterized in terms of flash rate by virtue of step change in electric field (ΔE) with a threshold value of 600 v- m^{-1}. A total number of 32 and 45 rainfall events were identified during the pre-monsoon and monsoon seasons respectively. During the pre-monsoon, nearly 90% (29 events) events are associated with the electric discharge, whereas it is only 68% (30 events) during monsoon. It is observed that the peak rainfall events normally coincide with the peak value of the total flash during pre-monsoon with nearly ±5 to ±15 minute diurnal phase difference. Whereas, during the monsoon, the diurnal phase difference ranges between ±10 to ±35 minute. The ambient atmospheric electric field (E) during the pre-monsoon rainfall events is observed to have both the positive as well as negative polarity, whereas during the monsoon season, it has predominantly negative polarity. The average rainfall to lightning fraction (amount of rainfall per lightning flash) during pre-monsoon and monsoon are found to be 0.8 mm/flash and 12 mm/flash. The correlation between the flash count and the hourly average rainfall intensity are found to be 58% and 41% during pre-monsoon and monsoon respectively. In addition, the rainfall and lightning activity are observed to occur more during the afternoon to evening hours (13:00 -17:00 hrs) during both the seasons. It is also observed that the pre-monsoon rainfall events are much shorter in duration than the monsoon events. Further analysis is in progress in order to provide a better insight about the association of rainfall characteristics with electrical discharge.

Keywords: rainfall, electric discharge, flash rate.

DISTRIBUTION OF TROPICAL CIRRUS AND ITS CHARACTERISTICS OVER INDIAN SUB CONTINENT AND NEIGHBORING OCEANS

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ABSTRACT

Cirrus is an important component of the atmosphere with a significant role in the tropopause thermodynamics and their by the regional climate. In this study an extensive survey of the tropical cirrus and its characteristics over the Indian subcontinent including the neighboring oceanic region (IS) is carried out. The regional distribution of cirrus, their optical and microphysical characteristics are obtained by analyzing the Cloud -Aerosol Lidar and Infrared Pathfinder satellite (CALIPSO) data during January to December 2015. The total cirrus observed over this region are grouped based on the mid cloud temperature (MCT) in to MCT-I (-60°C to 85°C), MCT- II (-30 °C to -59°C) and MCT-III (0°Cto -29°C). The vertical extent of the tropical cirrus is in the altitude range of 10 km to 17 km and the MCT of the tropical cirrus is observed to be in the range of -30°C to -85°C. The relationship between the depolarization ratio and the attenuated backscatter (δ-γ) of tropical cirrus is studied. Annual distribution of tropical cirrus over the IS region shows that the occurrence frequency is almost stable with an average of 87%. The occurrence of MCT-I &II groups is relatively high and shows a seasonal variation. The relationships of the tropopause height with the occurrence frequency of thin, thick and opaque cirrus are noted. It is observed that the single layered thin cirrus occurrence frequency is positively correlated with tropopause height where as the occurrence of multilayered thick and opaque cirrus are negatively correlated.

Keywords: Tropical cirrus, Optical depth, Depolarization ratio.

THE ROLE OF VERTICAL WIND SHEAR IN TORNADO GENESIS DURING KERALA FLOODS 2019

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ABSTRACT

The heavy to extreme rainfall episodes over the west coast of India during an active monsoon period usually associates with strengthening of cross equatorial flow of low-level jet (LLJ). Kerala, located over south-western part of India received extreme amount of rainfall during the month of August 2019. The unprecedented rainfall event occurred over the period was unusually convective in nature (P. Vijayakumar et al, 2021) and favoured by large anomalous warm waters along with veering atmospheric wind profile in lower to middle levels over Kerala and adjoining south-eastern Arabian sea. The vertical wind shear in the low-level jet is found to be capable of producing tornado genesis and organized severe thunderstorms, and the probability of occurrence of tornados associated with thunderstorms are found to be high when the wind profile in lower to middle levels (0-6 km) (Thompson et al, 2003) satisfies sufficient speed and directional shear along with an environment of high convective available potential energy (CAPE).

The analysis of the skew-T diagrams from different stations over Kerala and Lakshadweep reveals the anti-clockwise wind veering profile in lower to middle-levels (0-6 km). In addition, high resolution reanalysis data from ERA 5 supports wind patterns, favourable for tornado genesis in thunderstorms (Supercell Thunderstorms). Further study using photographs, satellite and doppler weather radar (DWR) products shows, the presence of supercell thunderstorm like structure on peak date of the extreme rainfall event. Such types of organized thunderstorms are capable of producing tornadoes along with torrential rainfall for a short period of time and poses threat to life and property. Since LLJ plays a significant role in shaping out convective storms to long living organized ones, this study will discuss the dynamics and environment for such a severe weather setup.

Keywords: Climate Change, Clouds and convection, Low Level Jet, Tornado.

ROLE OF LATENT HEATING IN MODIFYING BACKGROUND DYNAMICS: A STUDY USING DOPPLER WEATHER RADAR AND TRMM OBSERVATIONS

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ABSTRACT

The latent heating (LH) play a pivotal role in various atmospheric circulations and serves as a secondary energy source for driving the atmosphere, the Sun being the primary. Indian Summer Monsoon (ISM) region acts as a natural laboratory for studying the cloud systems embedded in monsoon and these systems release large amount of latent heat into the atmosphere, which further drives a circulation at meso-scales. The present study attempts to addresses how the cloud latent heating modifies the background dynamics as well as how the prevailing dynamics control the formation of cloud system over ISM. The analysis has been carried out using Doppler Weather Radar (DWR) observations at Chennai and Tropical Rainfall Measuring Mission (TRMM) measured latent heat (LH). We observed several isolated convective events during the month of May 2014 over Chennai. It is observed that the background wind directions are significantly modulated after the formation of convective cloud systems. The horizontal scale of change in winds is ~ 200 km and it depends on the strength of LH and spatial distribution of cloud systems. Further, on a large-scale, the co-variability of LH and Tropical Easterly Jet (TEJ) are investigated over the ISM region. The results show that TEJ has strong co-variability with LH. The LH can cause the changes in the vertical structure of temperature and thus the meridional gradient in the upper tropospheric temperature, which is responsible for the strength of TEJ. The results suggest that once the TEJ is established over the ISM region, its strength and structure can be modulated by the amount of latent heat released over the ISM region. The present study thus brings out the observational evidence for the changes in background winds by cloud latent heating on smaller as well as larger spatial scales.

Key words: Latent heating, Indian summer monsoon, DWR, TRMM, TEJ

GROUND BASED OBSERVATION OF CLOUD MICROPHYSICAL PROPERTIES AND THEIR RELATIONSHIP WITH AEROSOL PARAMETERS OVER A HIGH- ALTITUDE SITE IN WESTERN GHATS, INDIA, DURING SUMMER MONSOON

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ABSTRACT

Cloud plays a significant role in the dynamics and thermodynamics of the atmosphere, i.e. in radiation budget by reflection and absorption of the solar and terrestrial radiation, altering the precipitation intensity, etc. Along with understanding the cloud formation process, it is essential to know the cloud microphysics in detail due to the profound influence of clouds in the atmosphere. In depth understanding of these properties help in better representation of the same in modelling climate and climate change (Bony and Dufresne, 2005). Over Indian subcontinent, more studies on cloud microphysics have started after the experiment named the Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX) (Kulkarni et al., 2012). Review showed that that (a) most of the results are based on limited number of cases/observations and (b) results from Western Ghats (WG) are very few, being a region receiving high amount of monsoon rainfall and has different types of clouds systems (Rajeevan and Srinivasan., 2000). It is noted that monsoon clouds have bases even less than 2 km, hence in depth study of these are feasible only from a high- altitude ground observatory.

Thus, in the present study microphysics of the clouds over WG is analyzed during summer monsoon using ground based observation of High Altitude Cloud Physics Laboratory (HACPL). HACPL situated at Mahabaleshwar (17.92°N, 73.66°E, and 1348 m above mean sea level (AMSL)), wind ward side of WG, was established by Indian Institute of Tropical Meteorology (IITM), Pune. Cloud microphysical properties, such as cloud droplet number concentration (CDNC), liquid water content (LWC), and effective diameter (ED), have showed apparent day to day variation during monsoon. Cloud droplet size distribution (CDSD) analyzed showed two prominent peaks, suggesting presence of clouds with small and large cloud droplets over the study region. Aerosol and CCN (cloud condensation nuclei) number concentrations analyzed during summer monsoon showed apparent day to day and intra- seasonal variation. An attempt has been made to investigate the effect of aerosol on cloud microphysical properties and CDSD. Analysis showed clear variation in CCN concentration and cloud microphysical properties during high and low aerosol loading days categorized.

Keywords: Cloud microphysical properties, aerosol-CCN, ground observation, high-altitude.

INTRIGUING ASPECTS OF RAINFALL INITIATION OVER RAIN-SHADOW 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, Monsoon, Rossby waves, moisture budget.

ROLE OF DYNAMICAL VARIABLES ON THE RAIN MICROPHYSICS DURING WET AND DRY SPELLS OVER WESTERN GHATS

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ABSTRACT

The nature of raindrop size distribution (DSD) is analyzed for wet and dry spells of the Indian summer monsoon (ISM) in the Western Ghats (WG) region using Joss–Waldvogel disdrometer (JWD) measurements during the ISM period (June–September) in 2012–2015. The observed DSDs are fitted with a gamma distribution. Observations show a higher number of smaller drops in dry spells and more midsize and large drops in wet spells. The DSD spectra show distinct diurnal variation during wet and dry spells. The dry spells exhibit a strong diurnal cycle with two peaks, while the diurnal cycle is not very prominent in the wet spells. Results reveal the microphysical characteristics of warm rain during both wet and dry periods. However, the underlying dynamical parameters, such as moisture availability and vertical wind, cause the differences in DSD characteristics. The higher moisture and strong vertical winds can provide sufficient time for the raindrops to grow bigger in wet spells, whereas higher temperature may lead to evaporation and drop breakup processes in dry spells. In addition, the differences in DSD spectra with different rain rates are also observed. The DSD spectra are further analyzed by separating them into stratiform and convective rain types. Finally, an empirical relationship between the slope parameter Λ and the shape parameter μ is derived by fitting the quadratic polynomial during wet and dry spells as well as for stratiform and convective types of rain. The μ–Λ relations obtained in this work are slightly different compared to previous studies. These differences could be related to different rain microphysics such as collision–coalescence and breakup.

Keywords:

Cloud resolving model simulations for CAIPEEX CASE study With specific focus on Autoconversion parameterization

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ABSTRACT

The present study has four objectives a) to investigate the cloud droplet spectral characteristics in a deep convective cloud, b) investigate the model sensitivity to different microphysics schemes and document the literature on the autoconversion schemes c) investigate the autoconversion in different microphysics schemes and d) find the sensitivity on the accumulated rainfall and cloud parameters by using dispersion parameters from observations. All of these objectives are addressed with some of the preliminary analysis and model simulations in this study.

Autoconversion is the process to describe formation of raindrops through cloud droplets due to collision-coalescence. Autoconversion is an important and highly nonlinear parameter for aerosol cloud interaction. Weather Research and Forecasting (WRF) model is used to study sensitivity of models in different microphysical schemes. Five different double moment models used in this study. Millbrandt and WDM6 have the highest Cloud Water Content (CWC) The delayed surface precipitation is the reason for getting the highest Ice Water Path (IWP) in WDM6 and Millbrandt model. The Rain Water Path (RWP) in WDM6 and Millbrandt model is lowest while in NSSL and Morrison is highest.

Dispersion is a very sensitive parameter in the autoconversion, it is a function of the cloud droplets number concentration (CDNC). CAIPEEX (Cloud Aerosol Interaction and Precipitation Enhancement Experiments) observational data shows that it is inversely proportional to CDNC. This equation is linearly fitted in the WRF model under Nasl Schemes. Autoconversion rate will have an impact on precipitation. Increasing the dispersion will decrease the RWP and PW, hence reducing and delaying precipitation. In the P3 model by default it is using the kk2000 scheme, but you can change parameters in WRF model Fortran code and shift to SB2001 scheme. SB2001 scheme is showing higher autoconversion rate as compared to kk2000 schemes.

Keyword : Cloud Microphysics, Autoconversion, Parameterization, WRF-CRM.

Region-specific performances of Isotope enabled general circulation models for Indian summer monsoon and the factors controlling isotope biases

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ABSTRACT

Isotope-enabled General Circulation Models (GCMs) are often used to simulate precipitation stable isotope ratios $^{18}O/^{16}O$ and D/H. In this study, we aimed to evaluate the performance of eight such GCMs for simulation of monthly average precipitation stable isotope values ($\delta^{18}O$ and δD) over India during the summer monsoon. Three regions of India (west coast WCI, east coast ECI and northern India NI) are selected for this study. Analysis shows models underestimate the mean isotope values. Observed isotope data shows a minor amount effect in WCI and ECI zones but a strong effect in the NI zone. In contrast, most of the models show significant amount effect. It is estimated that 100 mm fall in rainfall is accompanied by a rise of -1‰ to -6‰ of $\delta^{18}O$ in the models. The study further shows that apart from local factors (topography, humidity, rainfall), isotope biases are considerably affected by large-scale atmospheric circulation. A decomposition of the isotope biases resulting from various processes is further explored in detail for both strong and weak models. This analysis clearly suggests that the efficacy of the models over the west coast of the Indian sub-continent depends on how proficiently the models (1) simulate mid tropospheric vapour isotope values, and (2) evaluate raindrop evaporation.

Keywords: Rain isotope ratios; SWING2 models; Indian Summer Monsoon; Amount effect

Water isotopes in Western Ghats during Indian summer monsoon.

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ABSTRACT

The Indian summer monsoon rainfall during June to September contributes most of the annual rainfall over India. The atmospheric water cycle is a central component of the climate system. A complementary perspective on the atmospheric water cycle is obtained from the analysis of stable water isotopes (SWI). The isotopic composition of water vapor and precipitation can provide information on, specific processes in the water cycle, such as the conditions during the evaporation of water from the ocean or land surface, the rain out history of air masses, and the microphysical interactions of hydrometeors and water vapor. In this study, we aimed to see the variation of rain and vapor oxygen and hydrogen isotopes ($\delta^{18}O$ and δD) at a station in Western India during summer monsoon of 2019. The rain and vapour isotopes show a large variation of isotope values (Mean = -2.54‰; Standard deviation = 3.73‰ for rain and Mean= -12.68‰; Standard deviation= 2.51‰ for vapour). The rain and vapour isotope values show a large and significant correlation (R=0.97). Analysis further shows that variability of isotope values are majorly controlled by the large scale atmospheric circulation rather than the local meteorological parameters.

Keywords: Water isotopes; Indian Summer Monsoon; Atmospheric circulation

INVESTIGATING WINTER EXTREME PRECIPITATION EVENTS AND ASSOCIATED DYNAMICS OVER NORTH INDIA

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ABSTRACT

Extreme precipitation events (EPEs) and associated flash flooding is one of the most pervasive weather-related natural hazards during the winter season over the north Indian region, owing to the interplay of western disturbances (WDs) and regional orography. The occurrence of such EPEs in this region can be catastrophic, particularly in terms of damages to life, infrastructure, environment and agricultural sustainability. In this study, an investigation of winter EPEs and associated dynamical processes has been conducted using gauge-based (IMD), satellite (TRMM) and the recently released high resolution reanalysis (IMDAA) datasets over the north Indian region from 1979-2019. EPEs have been identified using percentile approach from IMD and IMDAA and composite analysis for EPEs and non-EPEs in IMDAA and ERA5 has been carried out to understand the underlying physical mechanisms. An increasing trend of EPEs over the region has been observed. Furthermore, the composite analysis of various dynamical features and circulation patterns during EPEs and non-EPEs has been used to explain the conducive conditions developed during the occurrence of EPEs in comparison to non-EPE days. Our analysis suggests that the development of an intensified subtropical westerly jet (SWJ) during EPEs induces baroclinic instability over the region which favors the proclivity of such extreme events. Moreover, a southward shift of SWJ has been identified during EPEs which suggests an increased frequency for passage of WDs and therefore, enhanced contribution to winter precipitation over the region during EPEs. Detailed results will be discussed.

Keywords: Extreme precipitation events (EPEs), Winter precipitation, Western disturbances.

SIMULATION OF CLOUDBURST EVENT OVER KERALA DURING THE 2019 MONSOON SEASON

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ABSTRACT

The Cloudburst is an extreme weather event capable of producing torrential rainfall in a small area in a short time. A heavy rainfall event where the rainfall rate exceeds 100 mm/h is termed a classical Cloudburst. Cloudburst generally occurs during the monsoon season due to strong convection associated with orographic forcing over the western Ghats and Himalayan region which causes widespread damage to property and loss of lives. So it is crucial to predict such events to help authorities to take preventive measures. We use the numerical mesoscale model Weather Research Forecast model (WRF) to simulate the cloudburst of Kerala on 8 th August 2019, to capture and understand the underlying dynamical and thermodynamical characteristics of this event. The WRF model was initialized with NCEP GDAS and GFS data with two domains, the outer domain spans from 10°S to 30°N latitude, 55°E to 95°E longitude. The inner domain spans from 5°N to 15°N latitude, 70°E to 80°E longitude. We ran simulation with two sets of resolutions 15km, 5km and 9 km, 3km. Two cloud microphysics parameterizations namely Ferrier and WSM6 and two cumulus parameterizations namely Kain-Fritsch and New Tiedtke have been used for sensitivity study and examine the performance of the schemes. We conducted a sensitivity study on initializing data, resolution, and lead time. The results show that the best scheme to simulate the cloudburst was New Tiedtke and Ferrier with 9km and 3km two way nested configuration. The simulated hydrometeor structure of the cloud system from the best experiment is comapred with cloud hydrometeros derived from ERA-5 data sets. The result also showed that the 2-day lead simulation better captured the cloudburst characteristics and the simulation initialized with GDAS data performed marginally better than the simulation initialized with GFS data.

Keywords: Cloudburst, Extreme Weather Event, WRF.

STUDY OF LIGHTNING ACTIVITY OVER ODISHA IN DIFFERENT SEASONS AND RESPONSIBLE METEOROLOGICAL CONDITIONS

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ABSTRACT

Lightning is a giant spark of electricity in the atmosphere - between clouds or clouds to air or clouds to ground. Lightning can occur between opposite charges within the thunderstorm cloud (intra-cloud lightning) or between opposite charges of the cloud and the ground (cloud-to-ground lightning). It is the cloud-to-ground form of lightning that kills humans, as well as animals and livestock and can substantially damage assets and property. About 70% of lightning occurs on land in the Tropics where the majority of thunderstorms occur. In the recent years in India, it has been observed that the states like Odisha, Maharashtra, Chhattisgarh, West Bengal, Jharkhand have witnessed the maximum lightning strikes. The present study is undertaken to observe the lightning activity over Odisha during 2019-2020 and the intensity and variations in lightning activity in different synoptic systems like cyclones, low pressure etc.

The Lightning data is taken from the lightning location network (LLN) established by the Indian Institute of Tropical Meteorology Pune. The analysis reveals that the total average lightning flash counts in Odisha for the period 2019-2020 is the highest in monsoon. The average CG lightning flash counts is more in monsoon than pre-monsoon and the least in post monsoon. The analysis also indicates that the north and north-west parts (the districts like Balasore, Mayurbhanj, Sundergarh etc.) are more prone to lightning strikes as compared to other parts of Odisha. The favourable climatic conditions, such as availability of moisture content, unstable atmosphere and strong convection, cause severe cases of lightning over almost all the regions of Odisha.

Keywords: Lightning, Synoptic Systems, Lightning Flash Counts, Odisha.

Influence of Madden Julian Oscillation on the Diurnal Cycle of Convection and Wind over the West Coast of India

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ABSTRACT

Madden Julian Oscillation (MJO) is an eastward propagating convective system which passes through the Indian and Pacific Oceans with a frequency of 30-90 days, and influences most of the tropical weather systems. This study investigates the impact of MJO on the diurnal cycle of convection and wind over the west coast of India during different seasons. We have used TRMM precipitation data and ERA-5 wind for the period 2000-2019 in this analysis. A composite analysis of the precipitation shows that, convection over the west coast seems to be strong during phases 1, 2, 3 and 4 while it is suppressed during the 6, 7 and 8 phases. The harmonic analysis is used to derive the diurnal and semi diurnal amplitudes of precipitation and wind over the west coast. The active MJO phases enhance the diurnal amplitudes of convection over the west coast by more then 100 % with respect to climatological diurnal cycle whereas the suppressed phases reduce it (about 40 %). The mean diurnal cycle of wind at 850 hPa shows a positive anomaly in the diurnal cycle during the active phase with respect to climatology whereas the suppressed phase has negative anomaly. This confirms the modulation of diurnal cycle of wind and convection by MJO.

Keywords: Intra-seasonal Oscillation, MJO, Diurnal Convection

Sensitivity Analysis of Cloud Parameterizations to the Simulation of South Asian Summer Monsoon

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ABSTRACT

The sensitivity analysis of cloud parameterizations used in the NCAR CAM5 is performed. Morris method was used to identify parameters having large main and interactive effects on the simulation of south Asian summer monsoon (SASM). From the 180 inter-parameter perturbed simulations, the large variability in total precipitation is found to be arising from the large variability in convective precipitation caused by the large variance in liquid water path (LWP) and ice water path (IWP). The following parameters are found with the highest relative importance in total precipitation simulation: *rhminl, dcs, as, ai, dp*1, *wsub, and cdnl.* Cloud distribution and cloud forcings (CF) simulations are found to be very sensitive to *rhminl* and *dcs.* A monotonic decrease in precipitation with an increase in *rhminl* is found to be caused by reduced low-level stratiform and shallow cumulus clouds. Longwave CF and IWP increase with an increase in *dcs* because higher *dcs* leaves more ice clouds at high-level, reducing atmosphere stability and so precipitation. The response of precipitation simulation to *ai* and *as* is found to be opposite to *dcs.*

Further, the monsoon onset and withdrawal dates are found to be highly sensitive to some of the cloud parameters through their influence on the tropospheric temperature gradient (MTTG). MTTG is shown to be most sensitive to *dcs.* Somali Jet is also found to be most sensitive to *dcs.* Tropical Easterly Jet is shown to be most sensitive to *rhminl,* which is caused by the higher sensitivity of easterly wind to *rhminl* at 200 hPa than at 850hPa. Thus, by identifying the most sensitive parameters in the cloud parameterizations scheme, our study aids in the prioritization of tuning efforts for reducing parameter-sensitivity induced uncertainty in model simulations.

Keywords: Sensitivity Analysis, Cloud Parameterization, Monsson, NCAR CAM5

LIGHTNING CHARACTERISTICS OF THUNDERSTORMS OVER EASTERN INDIA (NOR'WESTERS)

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ABSTRACT

The Eastern and northeastern part of India experiences severe thunderstorms, locally known as Norwesters, during pre-monsoon seasons (April-May). The surface winds are predominantly South-easterly during these periods, which bring moisture from Bay-of- Bengal to this region. High moistures content at the surface layer and high temperatures during pre-monsoon months make the conditions favorable for severe thunderstorms. These thunderstorms are strongly electrified and exhibit high lightning activity. The electrical characteristics of these severe thunderstorms are studied very rarely. It has been observed that during the pre-monsoon season (April-May), this region (eastern part of India) receives large natural dust aerosols transported from the neighboring desert regions (Thar Desert) in the western part of India. This high aerosol concentration may play an important role in these severe thunderstorms' microphysical and electrical characteristics. Here, we study the lightning characteristics of these severe thunderstorms and their interactions with microphysical and dynamical properties using Doppler Weather Radar, Lightning Location Network, and aerosol data. The analysis shows when the radar reflectivity values close to 7.5 km altitude (or -10°C isotherm) level are in the range 35 to 40 dBZ, lightning initiation occurs. Contradictory to earlier studies, the IC to CG ratio decreases with the severity of thunderstorms. Negative CG was observed to be associated with convective precipitation region and positive CG with stratiform precipitation region.

Keywords: Thunderstorm, Lightning, Doppler Weather Radar, Precipitation.

ATTENUATION CHARACTERISTICS OF GSAT-14/KA-BAND SIGNALS OVER THE TROPICAL COASTAL REGION

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ABSTRACT

Collocated and concurrent measurements of the (1) attenuation in the GSAT-14 Ka-band transponder signals at 20.2 GHz and 30.5 GHz by using cross polarization Ka-band beacon receiver, (2) atmospheric and cloud parameters by using Microwave radiometer profiler, and (3) rain parameters using Micro rain radar and Laser precipitation monitor are carried out during the prolonged Indian monsoon and the tropical convective rain events over the tropical coastal station, Trivandrum (8.5 ∘ N, 76.98 ∘ E), located in the Indian peninsular region. The attenuations of 10-25 dB and 2-12 dB, respectively, observed during the convective and the stratiform rain events. The altitudinal variability of the water vapour (relative humidity) and cloud liquid water (CLW) content during rainy conditions indicated an enhanced band of CLW in the 4-5 km altitude level during the stratiform rain and an increase in CLW throughout the column for convective rain. The effect of rain rate and rain drop size for stratiform and convective rains to the attenuation of Ka-band signals has been examined and empirical relations between attenuation in Ka-band signal at 20.2 GHz and 30.5 GHz and the reflectivity have been formulated for this location which has application in the estimation of attenuation for reflectivity values measured by radars.

Keywords: Ka-band, attenuation, reflectivity, propagation.

INTENSIFICATION OF WARM SPELLS DURING HEAVY PRECIPITATION EVENTS OVER WESTERN GHATS: MICROPHYSICAL PERSPECTIVE

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ABSTRACT

A preliminary analysis has been carried out to examine the intense spells of a prolonged heavy rainfall event during the summer monsoon season of 2018 and 2019. Continuous measurements were made over high - altitude site on the windward side of the Western Ghats (WG). Heavy rainfall days identified using IMD criteria and the Bright Band (BB) & Non-Bright Band events are categorized using radar reflectivity profiles. In addition, intense spells are identified based on the rainfall intensity from PARSIVEL disdrometer rainfall data. About 66% of total heavy precipitation events in 2018 are dominated with bright band features. Number of Intense spells in each years contributes minimum 11% to 87% of rainfall in heavy rainfall conditions. Percentage of Bright Band and Non-Bright Band days are 56% and 41% respectively. The early morning and mid night hours shows minimum relative frequency of the occurrence of Intense spells and maximum in the daytime hours (05:00 to 15:00 LST). The microphysical changes in the rain drop size distribution becomes crucial in regulate the rain water content (RWC) variation at the site. Moisture laden or saturated low-level clouds (less than 2.5km base height) acts as a feeder to the droplets from aloft and the raindrop size distributions are characterized by dominance of small to mid-size droplets in near surface level leads to high RWC.

Keywords:Drop size distribution, Heavy precipitation, warm rain.

Simulation of cloud-to-ground lightning flash of premonsoon thunderstorms by using the WRF model in synergy with the lightning detector over the north eastern and eastern part of India

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ABSTRACT

A study is carried out to simulate cloud-to-ground (CG) lightning for the premonsoon thunderstorms by using the WRF model in synergy with a lightning detector (LD-350). The simulations are performed over the north-eastern (Kohima) and Eastern (Rampurhat) India for the full month of April, 2019. For this purpose, WRF single moment 6-class grauple microphysical and the multi scale Kain-Fritsch cumulus schemes are utilized. Over both the region, a spatio-temporal deviations of simulated flash density(FD) is noted compared to the observed values. The correlation coefficient between the simulated and observed FD over Kohima and Rampurhat are found to be 53.8% and 55.6%. The simulated average FD over Rampurhat and Kohima are found to be 4.3×10^{-3} and 2.1×10^{-3} flash $km^{-2}h^{-1}$ respectively. The simulated FD over Rampurhat (Kohima) shows underestimation (overestimation) compared to observed value. However, overall higher value of the FD over Rampurhat is consistent with the observed values. Diurnal phase difference of the simulated and the observed FD over Rampurhat and Kohima is found in the range 0-4.5 h and 0-8 h. The vertical distributions of the simulated mixing ratios (ice, grauple and cloud water) also show higher values in the mixed phase regions for the thunderstorms over Rampurhat compared to the Kohima region, broadly consistent with the ERA-5 reanalyzed cloud bulk properties. Further, with the help of WRF model simulation outputs, various stability indices are assessed in order to detect the thunderstorms. Overall, statistical analysis shows that, the stability indices over Rampurhat are associated with higher Probability of Detection(POD), Critical Success Index(CSI), Heidke Skill Score(HSS) and lower values of False Alarm Ratio (FAR) and Bias compared to Kohima. A CAPE value>1650 J kg^{-1} and Total Total Index(TTI) value>38 found to be the best skill scores over Rampurhat and Kohima respectively. With the best stability index over each region, hit, false alarm and missed thunderstorm days over Rampurhat (Kohima) are found to be 23(14), 1(3) and 0(5) respectively.

Keywords:, Thunderstorm, Cloud to Ground lightning, WRF model, Stability indices.

RELATIONSHIP BETWEEN THE ATMOSPHERIC BOUNDARY LAYER AND DIFFERENT PHASES OF THE SOUTH WEST MONSOON

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ABSTRACT

The All-India summer monsoon rainfall (ISMR) is defined as the rainfall received during June to September over India. The ISMR plays a vital role in both the agriculture as well as economy of the country. The ISMR shows different variabilities on the spatio-temporal domain and these variabilities arise from both internal and external feedback. During the summer monsoon season (June to September), a substantial component of variability arises from the fluctuation in the intra-seasonal scale between active spells with good rainfall and weak or breaks spells with little rainfall. Several studies have explored the roles of the active and break spells on the atmospheric boundary layer (ABL) height. They found that the ABL attains its maximum height during break monsoon conditions due to strong surface heating and convection while lower height during active monsoon conditions when cloudy conditions are prevalent. Our focus in this study is to explore the roles of the ISMR and active and break monsoon phases on the ABL using radiosonde data distributed across India.

The active and break spells are identified using the central India monsoon rainfall which represent the synoptic scale processes. However, ABL is mainly governed by the micro scale process. Thus, to understand the local versus synoptic scale processes on the ABL variability, the local rainfall along with ISMR over the individual station examined which will be presented during the conference.

Keywords: ABL Height, Active and break monsoon.

SENSITIVITY OF RAINFALL PREDICTION USING WRF DURING FUKUSHIMA ACCIDENT TO CLOUD MICROPHYSICAL PROCESSES

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ABSTRACT

In this work we analyse the cloud microphysics (MP) sensitivity in simulating the rainfall estimations during the Fukushima Dai-ichi Nuclear Power Plant (FDNPP) accident (11 th March 2011) using four cloud microphysics schemes namely WSM3, Lin, Thompson and Goddard scheme which vary by number of hydrometeor classes and distribution moments. The large quantities of radioactivity that were released to the environment during the accident period, had a significant wet deposition over the land due to occasional landward shifts in wind flow and moderate to heavy rainfall events caused by a synoptic scale low pressure system over the Pacific. Earlier studies reported large uncertainty in the simulated deposited activity of accident releases using WRF Single moment Class 3 (WSM3) MP scheme (Srinivas et al, 2014). Rainfall events during 11 March to 31 st March, 2011 are simulated using a series of 3-day model runs each with 12h spin-up period using NCEP FNL data for initial and boundary conditions. Comparisons of simulated meteorological parameters such as surface wind speed/direction, temperature etc., with observations at 5 weather stations near FDNPP indicated that all simulations produced nearly similar trends. Comparison of simulated rainfall data from Global Precipitation Measurement (GPM) IMERG Final Precipitation (L3 1 day 0.1°×0.1° V06) indicated that among the four MP schemes Goddard significantly overestimated (~ 4-5 factors) rainfall and Thompson produced the observed rainfall spatial pattern including high rainfall zones with least bias. Though the daily rainfall is overestimated by all microphysics schemes Thompson simulated closer to the observation. The better simulation of rainfall by Thompson is due to the assumption of non-spherical shape and combination of exponential and gamma distribution of single moment snow variable in the cloud.

Keywords: Rainfall, Fukushima Accident, WRF Microphysics, Sensitivity.

Contrasting Characteristics of Mixed Rossby-Gravity Wave Events Occurring with and without Extratropical Wave Intrusions

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ABSTRACT

Mixed Rossby-Gravity (MRG) waves are westward propagating synoptic scale equatorial disturbances and they are known to influence various modes of tropical variability. Intrusion of extratropical tropical waves are considered as one of the major factors that excite and amplify the MRG waves. In this study using an MRG event-based approach we group the MRG waves into two classes, MRG waves with and without extratropical wave intrusions. Meridional wind at 200 hPa and potential vorticity on 350K isentropic surface are used to identify the MRG waves and extratropical wave intrusions respectively. We find that about 20% of the MRG wave events that were observed during the 1979-2019 period were associated with extratropical wave intrusions. The MRG waves associated with extratropical wave intrusions exhibit a geographical preference and seasonality. Such events are mostly observed over the central and eastern Pacific and Atlantic domains during boreal winter and spring and majority of them take the Southern Hemisphere route. Closer examination reveals that the MRG wave events in the two categories exhibit differences in various dynamical properties. The MRG wave events associated with extratropical wave intrusions are observed to a have higher amplitude, slower phase speed and larger meridional extent. The observation of higher amplitude and zonal wavelength (wavenumber 6) similar to that of the extratropical waves support the hypothesis of resonant interactions between MRG and the extratropical waves. Since MRG wave events associated with extratropical wave intrusions account for a significant fraction of the total MRG wave events and such wave exhibits distinct dynamical properties, the interactions between MRG waves and extratropical waves need to be studied thoroughly.

Keywords: Mixed Rossby-Gravity Waves, Extratropical Waves, Potential Vorticity.

INTRASEASONAL VARIATION OF TROPICAL DEEP CONVECTIVE CLOUDS ASSOCIATED WITH SEA SURFACE TEMPERATURES

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ABSTRACT

Deep Convective Cloud (DCC)-Sea Surface Temperature (SST) relation on intraseasonal time scale over the tropical oceans is analysed using high quality satellite data for the first time. DCC pixels are derived using the brightness temperatures measured by Sondeur Atmosphérique du Profil d'Humidité Intertropicale par Radiométrie (SAPHIR) payload abroad Megha-Tropiques at channels ~183.31GHz and the SST is obtained from Tropical Rainfall Measuring Mission (TRMM). Both these payloads are on satellites with low orbital inclination, which provides higher temporal sampling of tropical regions at different local times, unlike polar-orbiting satellites.

The SST above 27°C is needed for significant occurrence of DCCs. The occurrence frequency increase up to an upper threshold of ~30°C and occurrence of DCCs decreases with further increase in SST. However, when the response time of DCCs to SST variation is considered, a positive correlation is observed between DCCs and SST even after 30°C. Such lead/lag relation between intraseasonal variations in SST-DCC is examined over the tropical ocean basins, such as the equatorial Indian ocean, the Atlantic ocean, and the western Pacific ocean. The present study shows that over the Atlantic ocean, DCCs lag SST by 0-5 days, the Indian Ocean and the western Pacific ocean have lags of 5-10 days and ~10 days, respectively. The strong surface wind convergence over the Atlantic ocean resulted in a faster response than other oceanic regions. Mid tropospheric humidity, surface latent heat and shortwave flux anomalies are consistent with intraseasonal variability of DCCs associated with SST. The study helps in quantifying SST-DCC relation over the tropical oceanic region and to validate ocean-atmospheric coupled models, thereby improving the predictability of weather forecast models.

Keywords: Clouds, Ocean-Atmosphere interaction, Sea Surface Temperature, Lead-Lag correlation

Trend and variability of high cloud over Indian Monsoon region

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ABSTRACT

The variability in the high cloud and aerosol in the atmosphere has a critical role in maintaining the atmospheric hydrological cycle and atmospheric heat budget. This study evaluated the high cloud variabilities and shortwave cloud radiative forcing over the Indian summer monsoon region (ISMR) during the last 20 years. The shortwave cloud radiative forcing shows a decadal trends of more than 10 w/m^2 over the equatorial Indian Ocean region. The changes in pattern of distribution of different aerosol species and their trends are evaluated. The variabilities in the profiles of latent heat over the Bay of Bengal, Arabian Sea and Indian ocean region are also analysed in the study.

Keywords: Aerosol, High, Cloud, monsoon (maximum 4 words)

CONVECTION OVER THE EASTERN EQUATORIAL INDIAN OCEAN AND IRANIAN BRANCH OF ASIAN SUMMER MONSOON ANTICYCLONE MODULATES THE WET AND DRY PHASES OF SUMMER MONSOON RAINFALL OVER KERALA

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ABSTRACT

Previous studies documented the rainfall characteristics over Kerala at various spatial and temporal scales during the monsoon season. Still, none aims to understand the reason behind the extreme cases of seasonal rainfall over the state. This study investigates the large-scale factors that favour the wet and dry phases of Kerala summer monsoon rainfall (KSMR) by analyzing the Merra-2 reanalysis dataset. The wet and dry phases are categorized during the 1980−2015 monsoon season based on (+/-) 20 % of rainfall departure (close to 1 standard deviation) from the long-term mean. Examining the circulation pattern, we noticed that KSMR is enhanced during the intensification of the Iranian branch of Asian summer monsoon anticyclone (ASMA) and suppressed by anomalous deep convection over the Eastern equatorial Indian Ocean (EEIO). The anomalous low-level easterly flow originating from the EEIO directs towards the Indian subcontinent results in oceanic upwelling in the wet phase of KSMR. As a result of this upwelling, sea-surface temperature (SST) over EEIO and Arabian sea get reduced, enhancing the temperature gradient between Indian land and Equatorial Indian Ocean (EIO) and strengthening the monsoon flow towards India. Additionally, anomalous lower level cyclonic circulation over the western north pacific (WNP) is pulling low-level jet (LLJ) through southern peninsular India, playing a vital role in establishing the KSMR wet phase. Contrarily, the dry phase of KSMR is associated with weak Tibetan and the Iranian branch of AMSA, and the former is shifted further east. The anomalous upper-level cyclonic circulation exhibited by the Iranian branch indicates the reduction in the deep convection, which is also visible in the divergence of wind at a lower level over the northwest and central Indian region. In response to the EIO warming, the land-sea thermal contrast reduced during the dry phase of KSMR, contributing to the deterioration of KSMR.

Keywords:

INVESTIGATION OF PRE-MONSOON TO MONSOON TRANSITION OF ATMOSPHERIC CONDITIONS AS OBSERVED WITH A 205 MHZ WIND PROFILING RADAR OVER COCHIN

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ABSTRACT

A wind profiler radar at the VHF range of 205 MHz is operational since January 2017, at Cochin University of Science and Technology (10.04°N; 76.33°E) in Cochin, a region lying on the west coast of Southern Peninsular India, which also is the entry point of the Indian summer monsoon. Using the wind Profiler radar, vertical structure of zonal and vertical wind pattern is studied in detail to investigate the pre-monsoon to monsoon transition of atmospheric conditions. The circulation pattern of the atmosphere is examined during the onset phase, which is shown to be a potential predictor for declaring the monsoon onset over Kerala in an objective manner. Monsoons are a dominant feature of the tropical and subtropical climate in many regions of the world, characterized by rainy summer and drier winter seasons, and companied by a seasonal reversal of the prevailing winds. Monsoon onset over Kerala is the crucial meteorological phenomenon over India and a major event related to India's agriculture and economy. Monsoon onset over Kerala (MOK) has been considered the beginning of India's rainy season. The monsoon low level jet (LLJ) and tropicaleasterly jet (TEJ) have a crucial role in the declaration of onset over Kerala; and these essential features are obtained from the radar. The purpose of the study is to understand the changes of atmospheric thermodynamic and dynamic characteristics in the troposphere and lower stratosphere associated with Indian Summer Monsoon Onset, with the help of data acquired from the Stratosphere-Troposphere Radar, the Automated Weather Station (AWS) located in the Advanced Center for Atmospheric Radar Research (ACARR), CUSAT. In order to understand the large-scale monsoon circulation, spatial pattern of wind and other crucial meteorological parameters are studied using secondary datasets.

Keywords:

CHANGES IN CLOUDS, CONVECTION AND LIGHTNING ACTIVITY OVER THE INDIAN REGION

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ABSTRACT

There has been an unprecedented increase in lightning activity over the Indian region in the recent decades. Lightning accounts for a substantial part of the total casualties in India happening due to natural causes. Furthermore, extreme precipitation events have also been reported to increase during the monsoon season. Deep convective activity, cloud formation, lightning and precipitation are very closely associated with each other. Therefore, this observations-based study attempts to analyze changes in convective and lightning activity over India in different seasons namely, pre-monsoon, monsoon and the post-monsoon during 1998- 2020. Furthermore, the probable mechanisms relating changes in convective activity and different cloud types, precipitation and lightning activity are also explored using various satellite and reanalysis data and statistical analysis. The relative role of land-atmosphere feedback in modulating the convective activity over the Indian region is investigated. It is noted that the impact of such feedback is strong mostly during the dry seasons or over areas that are relatively arid. Results of this study are expected to help better understand and represent such processes in numerical models to improve forecasts across weather, sub-seasonal to seasonal time scales.

Keywords: Convective cloud, thunderstorm, monsoon, land-atmosphere feedback.

PROPERTIES OF CONVECTIVE CLOUDS IN DRY AND WET ENVIRONMENT OF MONSOON USING LES AND OBSERVATIONS

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ABSTRACT

Daily radiosonde observations during the summer-monsoon season (August-October) over an observational site (near Hyderabad) are used to understand the changes in environmental parameters that dictate the cloud development. Variation of cloud condensation nuclei (CCN) during the season is also examined. Two contrasting environmental conditions (moist-monsoon and dry-monsoon) have been identified based on surface rainfall, vapour mixing ratio and moist static energy. Cloud simulations were carried out using Weather Research and Forecasting (WRF) Large Eddy Simulation (LES) model for the two distinct environmental conditions. Simulations showed that moist-monsoon clouds are deeper with higher fractional coverage compared to dry-monsoon clouds. Moist-monsoon condition produced higher amount of ice water in the mixed phase cloud region and produced rain water. However, clouds in dry-monsoon did not produce rain water due to smaller droplet size and reduced cloud-depth. Distinct differences are noted in dynamical cloud parameters for the moist and dry environmental conditions. Cloud-core buoyancy (positive) and updraft velocity are relatively higher for the dry-monsoon compared to the moist-monsoon condition. Nevertheless, the higher negative buoyancy at cloud-top does not allow the clouds to grow deeper in dry condition. Domain averaged vertical mass-flux is lower in dry-monsoon condition due to reduced cloud fraction. In-situ cloud observations (from CAIPEEX) on selected days during the two distinct environmental conditions are compared with the model simulations and found similarities in microphysical parameters.

Keywords: Convective clouds, Moist and dry monsoon environment, LES.

Microwave radiometer observations and WRF model simulations on the development and structure of Convective Systems over Cochin, India

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ABSTRACT

Understanding the evolution and structure of convective clouds is very significant in climate studies and weather forecasting. However, the short lifetime of convective systems and lack of high-resolution observations are major limitations. The key thermodynamic parameters which determine the characteristics of convective systems are moisture availability and convective instability. The frequently available information of thermodynamic parameters gives an overall understanding of convective systems. A ground-based microwave radiometer can solve the lack of high-resolution real-time observations, providing continuous temperature and humidity profiles with high temporal resolution. The higher temporal resolution of convective indices from microwave radiometer (MWR) can be used for thunderstorm nowcasting and fundamental studies on convection evolution.

In the present study, the convective activity is examined using thermodynamic indices derived from the ground-based microwave radiometer observations located at Kochi (10 N, 76 E). MWR has the advantage of continuous monitoring of the atmosphere up to 10 km. A good comparison between the thermodynamic parameters derived from MWR and co-located GPS radiosonde observations indicates that MWR observations can be used to study severe convective activity. The Advanced Research WRF (WRF-ARW) model is also used to simulate the same convection event over Cochin. It captures the structure and evolution of convective clouds. There is a good comparison between the thermodynamic parameters derived from MWR. The analysis shows sharp changes in some thermodynamic indices, such as the K index, the humidity index, precipitable water content, and the stability index prior to deep convection in both MWR and WRF.

Keywords: MWR, WRF, convection, thermodynamics

OBSERVATIONAL EVIDENCE OF CLOUD TO RAIN TRANSITION ADVANCING GROUND-BASED CLOUD RADAR

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ABSTRACT

The role of turbulence in the transformation of cloud droplet into rain drop is still unknown from the observational point of view especially in the warm clouds. Due to narrow swath and more than a week revisit time of satellite observation over a station on tropical region has limitation to study onset of rain. In this regard, high-resolution ground-based 35-GHz cloud radar measurements are still instrumental for studying onset of rain process. Since cloud radar is much sensitive to cloud droplets, cloud radar observation is the one potential component to well capture the growth of cloud droplets to bigger droplets and then to drizzle/rain drop. Therefore, vertical looking observation available for every one second with a height resolution of 25 meter obtained from cloud radar deployed over Western Ghat, India has been utilized to understand the processes associated with the onset of rain. Since, equivalent reflectivity factor contain the information of drop diameter and its number concentration and vertical velocity isrelated to the drop size, combination of these two radar parameters has been used to understand the size evolution pertinent to the cloud droplets and rain drop. The measurement of the vertical spectral width has been used for this study to explore the condition responsible for the transition of cloud droplets. For the non-precipitating (precipitating) clouds, the spectrum width measurement describes the velocity variance (distribution of hydrometeor density) within the resolution volume. It can be considered as an indicator of turbulence within the cloud. Cloud radar observation shows that an abrupt enhancement (< 1 ms -1) in turbulence sustaining for more than 30 seconds near the cloud base has a positive impact to increase the size of the cloud droplets gradually. Thus, presence of brief but intense cloud turbulence acts as a triggering factor in the transition from cloud droplets into the rain. Once the transition occurs, about 6-8 minutes is required for the formed rain to gain fall velocity.

Keywords:

MESONET: MESO-SCALE RAIN GAUGE NETWORK OVER MEGA CITY MUMBAI FOR REAL TIME APPLICATIONS

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ABSTRACT

A MESO scale Rain gauge Network is established over Mumbai, Navi Mumbai, Kalyan and Thane region using ARG stations belong to various agencies. This MESO-scale Rain gauge NETwork (MESOET) comprises of rainfall information collected by139 rain gauges scattered over the Mumbai metropolitan region. Based on these rain gauge measurements, a real time web-based rainfall data portal for the metropolitan region of Mumbai was recently established by the Indian Institute of Tropical Meteorology (IITM), Pune, India. The online data portal is established as a public informative/awareness system that would help the common public to cope up with unanticipated situations caused by massive rainfall events. Users can monitor the real-time rainfall information of various temporal resolutions such as for the past 15 minutes, one hour, three hours, six hours, twelve hours, and daily accumulation. High-resolution rainfall data collected during South-West Monsoon season of 2019 is analysed to reveal the seasonal mean and associated small-scale spatiotemporal variability of rainfall over Mumbai. The preliminary results depict that heavy to extreme rainfall events contribute (~60%) to the maximum seasonal rainfall. The prevalent occurrence of very prolonged rainfall events of moderate to high intensity during mid-night and early morning hours is attributed to the diurnal variability of the duration of events. Temporal distribution of event durations for heavy rainfall events (65-125 mm) implies the possibility of occurrence of heavy rainfall events at sub-daily scale. Correlogram analysis of rainfall further reveals the good spatial coherence in the spatial variability of rainfall even at sub-daily scales. Current MESONET rainfall data can add a significant impact in several hydro-meteorological applications such as flash flood forecasting.

Keywords:

SENSITIVITY TO PBL PARAMETERIZATIONS ON MARINE LAYER CLOUDS IN THE SOUTHERN INDIAN OCEAN DURING THE INDIAN SUMMER MONSOON

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ABSTRACT

In this study, a suite of Weather Research and Forecasting (WRF) model simulations is conducted using various choices of planetary boundary layer (PBL) parameterizations to assess the boreal summertime marine layer cloud environment in the southern Indian Ocean (SIO). Local and non-local representation of PBL processes used in the simulations are generally able to produce the pertinent features of marine layer embedded with stratocumulus clouds in the SIO region 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 m [1700 m]. 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 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 is 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.

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 characteristic. The simulation of diurnal cycle of rainfall is a generic problem in most of the 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 researcher to take diurnal studies forward in global scale which was earlier limited to local scale due to scarcity of data. Very recently the constellation of satellites along with complete network of raingauge/radar is available under Global Precipitation Mission. It provides a very good quality data at 10 km resolution at half-hourly time interval thus providing a very good opportunity to revisit the climatological diurnal cycle. This new IMERG data is well placed to study complex mix of mechanisms of diurnal peak within the same land form, 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 entire central India, the Western and Eastern Ghats, the Himalayan region and the north-east region and similarly over Ocean, North Bay of Bengal has significant diurnal amplitude with varied time of peaking. These individual diurnal components, ultimately in a whole describes the whole monsoon process. However, when seen as a mean rain, it disguises these elementary components. This study brings out another way to look precipitation by dissociating it to the smallest temporal and spatial scale, thus giving one more avenue to improve monsoon simulation by climate models.

Keywords:

IMPACTS OF AEROSOL OVER DECREASING TREND OF RAINFALL OVER NORTHEAST INDIA

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ABSTRACT

Aerosols has potential role in modulating the rainfall pattern over the India. Most of the rainfall over India occurs from June to September and its variability is associated with aerosols concentration. Northeast India is one of the wettest places over Earth and experiencing decreasing trend in rainfall. In this study, the climatological analysis of the impacts of aerosols on rainfall over the Northeast India using observational data from 2000 to 2020 for June, July, August and September (JJAS) period is carried out. Aerosol optical depth (AOD) 550 nm at a resolution of 1° × 1° from Moderate Resolution Imaging Spectro-radiometer (MODIS) and India Meteorological Department (IMD) gridded rainfall dataset at resolution of 0.25° × 0.25° products are considered for the purpose. To clearly understand the impacts of aerosol on rainfall, cloud parameters such as Cloud Fraction (CF), Cloud Optical Depth (COD), Cloud Top Temperature (CTT) and Cloud Water Path (CWP) and meteorological variables are examined. An inverse relation between aerosol loading and rainfall is found.

Keywords: Aerosols Optical Depth, North East India, MODIS, IMD, Cloud Parameters.

SYNOPTIC SITUATIONS PRODUCING CONDITIONS FAVORABLE FOR SEVERE LOCAL STORM DURING THE PRE-MONSOON SEASON IN AND AROUND BANGLADESH

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ABSTRACT

It is well-known that severe local storm such as tornadoes and hail, lighting frequently occur in and around Bangladesh during the pre-monsoon season (March to May). In contrary, the number of severe local storms is drastically decreasing in the rainy season (June to September). Yamane and Hayashi (2006) show that CAPE (Convective Available Potential Energy) and vertical wind shear as defined the magnitude of wind vectors between the surface and 500 hPa level are larger during the pre-monsoon season in and around Bangladesh. This situation can lead to produce organized convection such as supercell with severe weather such as tornadoes. In contrary, both CAPE and vertical wind shear are significantly decreasing in the rainy season. The present study shows synoptic situations producing conditions with higher CAPE and vertical wind shear during the pre-monsoon season in and around Bangladesh. In the lower layer of 950 hPa level, southerly specific humidity flux from the Bay of Bengal is enhanced during the pre-monsoon season especially in April in and around Bangladesh, and this situation causes increasing of CAPE. In the middle layer of 500 hPa level, westerly wind component is strong in and around Bangladesh during the pre-monsoon season, and this situation can cause large magnitude of vertical wind shear between 950 hPa level and 500 hPa level.

Keywords: Severe Local Storm, Pre-monsoon, Bangladesh, Synoptic Situations.

IMPACT OF MICROPHYSICS ON CONVECTIVE EVENTS: A CASE STUDY OF HEAVY RAINFALL

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ABSTRACT

Heat, moisture and wind component defines the intensity and scale of the convective system over the Indian region throughout the year. Convective system have been analysed taking some cases occurred over Indian region and been simulated using microphysics schemes available in WRF-modelling system with nested domain of 9 and 3 Km. Micro-physical characteristics of clouds determines the convection moistening of the atmosphere resulting into convective water flux to the surface as precipitation and to humidify the atmosphere. WSM-6 and ETA-Ferrier Microphysics have been chosen to analyse the impact of microphysics on convective system. It has been observed that WSM-6 has improved the initiation of convective system occurrence closer to observation. Further, WSM-6 scheme has also better improved the intensity and time lag along with stronger updraft as compared to ETA scheme. With the availability of more moisture at lower levels in WSM-6 scheme, stronger updraft has transported it into the upper atmospheric level leading to stronger convective system. The results also observed the spatial and peak rainfall pattern closer to TRMM observation in WSM-6 scheme. The better spatial rainfall pattern in WSM-6 is due to better representation of ice cloud properties affecting the cloud–radiation feedback.

Keywords: Micro-physical, TRMM, ETA-Ferrier, WSM-6.

CVE

Climate Variability and Extreme Weather Events

Drivers of extreme rainfall over the south west coast of India

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ABSTRACT

This study investigates the life cycle of extreme rainfall events observed over the west coast and the large-scale conditions that modulate extreme rainfall initiation and decline. The evolution of meteorological variables such as wind, sea level pressure, vorticity, humidity, vertical velocity, longwave radiation and sea surface temperature associated with extreme rainfall events is studied and their link with extreme precipitation is explored. A mechanism of extreme precipitation over the south west coast is proposed and the role of monsoon intra-seasonal oscillation on heavy rainfall over the west coast is explored.

Keywords: ISO, extreme rainfall, South west coast

VARIABILITY OF INDIAN SUMMER MONSOON DROUGHTS: INFLUENCE OF TROPICAL INDO-PACIFIC CLIMATE DRIVERS

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ABSTRACT

Recent decades, since 1950s, witnessed frequent droughts and a declining trend in summer monsoon rainfall over India. In this study, an investigation of the variability of Indian summer monsoon rainfall (ISMR) and its association with the remote and regional climate drivers over the tropical Indo-Pacific sector are carried out for the past 150 year period (1871-2020). In India, droughts during monsoon season are more pronounced over regions of Western Ghats and central India. Weakened South Asian monsoon trough, southward intensification of the Mascarene high, and associated weakening of the low level cross equatorial flow could result in reduction of moisture transport over Indian subcontinent and hence reduction in ISMR. Consistent with this, weakening of the Tibetan high and the tropical easterly jet are observed in the upper troposphere. The relationship between ISMR and SST indices revealed dominant negative influence of canonical ENSO events during the entire period. ENSO Modoki events, also exhibit a negative relationship with ISMR, however with a weaker strength than the relationship between canonical ENSO and ISMR. Frequent occurrence of positive IOD events is also evident during the recent period. It is interesting to note that the positive relationship between IOD events and ISMR is stronger, specifically in the absence of ENSO forcings. The analysis suggests that co-occurrence of IOD events and canonical ENSO events can interfere and result in either reinforcement or cancellation of the effect, depending upon the phase of these events.

Keywords: ISMR, canonical ENSO, ENSO Modoki, IOD.

ASSESSMENT OF COUPLED CLIMATE MODELS (CMIP6) IN SIMULATING MONSOON CLIMATE OVER THE INDIAN REGION

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ABSTRACT

The influence of Southwest Monsoon rainfall on the economy and society is far beyond expectations and its impact on agricultural and irrigation sectors account for more than two thirds of the population around the world. Mean monsoonal rainfall exhibited significant changes in spatial patterns and epochal variations accompanied by the significant increase in extreme rainfall events in terms of its intensity and frequency over the regions. In this paper, we provide a glimpse of 32 coupled climate models simulation for 1901-2015 from the most recent Phase of Coupled Model Intercomparison Project (CMIP6) assessed with IMD, CRU and ERA5 datasets for the Indian region. Key outcomes of climatological features, physical and dynamical processes associated with the monsoon along with the challenges in simulating climate models are discussed. Spatially varying climate patterns determine the significant increase in intensity and frequency of extreme monsoon rainfalls, besides an increase in drought-like situations over certain regions. Interannual variability of Indian summer monsoon rainfall (ISMR) showed significant amplification of intensity and frequency of extreme rainfall events witnessed in observed trends however, models shows the tendentiousness which need to be investigated to mitigate hazards associated with it. In terms of frequency and intensity of monsoon rainfall, CMIP6 models simulating well on the other hand persistence of intermodal variability in spatial distribution of rainfall biasness observed. Monsoon rainfall exhibited the epochal variability over the study area however quantification and effect of natural and anthropogenic forcing in modulating the monsoon rainfall pattern is still a challenge to the scientific community.

Keywords: CMIP6, Indian monsoon, Climate models, Extreme rainfall

A complex network approach to evaluate multiple Quantitative Precipitation Forecasts based on spatial characteristics of extreme rainfall

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ABSTRACT

Quantitative Precipitation Forecast (QPFs) are the expected amount of precipitation that may occur at a specific location in a specified interval of time. Various QPFs are available from the numerical weather prediction models such as the European Centre for Medium-range Weather Forecasts (ECMWF), Japan Meteorological Agency (JMA), UK Met Office (UKMO) and the National Centre for Medium Range Weather Forecasting (NCMRWF). It is essential to evaluate the performance of the QPFs in forecasting various precipitation events. Such evaluation becomes more important when we consider the rising events of extreme precipitation during the monsoon season over the northern region of India. Previous studies have evaluated the statistical performance of QPFs without studying their ability to demonstrate the nonlinear spatial correlations among the extreme precipitation events. In this study, the performance of four different QPFs are evaluated by creating a gridded network of normal as well as extreme precipitation using the theory of complex networks. The application of complex network has the potential to identify regional spatial connections among precipitation events. The nonlinear correlation measure of event synchronization is used to identify spatially connected extreme events. The spatial connections of each QPF are compared to the network created using the available gridded observation data for evaluating their relative accuracy. Different measures of complex networks such as clustering coefficient and degree centrality are used to quantify the structural network of extreme precipitation. The study provides significant information regarding the precipitation network constructed using different temporal lengths of data which facilitates identification of suitable QPF to be used, for instance as input to hydrological models.

Keywords: Quantitative Precipitation Forecasts, Extreme Precipitation Events, Complex Network Theory, Indian Summer Monsoon

A trade-off between Discomfort Index and Rainfall, Surface-winds, and Clouds at Port Blair

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ABSTRACT

Discomforts feel by the human body due to surrounding temperature is a significant concern in today's world, where the rise in the discomfort of the human body leads to various diseases such as reduced blood pressure, increased heart rate, decreased respiratory rate, and multi-organ failure/damage(like kidneys, lungs, heart, brain). This paper studies the discomfort index (D.I.) at Port Blair city. This paper will show how parameters like rainfall, surface winds, and clouds affect D.I. with the help of statistical and graphical analysis. For the analysis of D.I., data had been taken of the past 30 years from India Meteorological Department, and a survey has also been conducted in the city of the different age groups for real-time data of discomforts of the people due to surrounding temperature.

Keywords: Discomfort Index, Port Blair

Simulation of short range prediction using Polar WRF model over Bharati and Maitri region in Antarctica

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ABSTRACT

Polar Regions are characterized by extreme weather and climate. The weather in Antarctica has a major effect on outdoor operations. High quality weather forecast is needed to support the safe operations in Antarctica. As a result of advances in modelling, observational data coverage, and communication systems, weather forecasts in support of the Indian Scientific Expeditions to Antarctic are now routinely made using the polar-optimized version of the Weather Research and Forecasting model (Polar-WRF). Currently, India has two operational stations Maitri and Bharati. Maitri (70°46 S, 11°44 E, 50 m amsl) is located at Schirmacher Oasis in Central Dronning Maud Land of East Antarctica. Bharati (69° 24.41 S, 76° 11.72 E, 35 m amsl) is approximately 3000 km east of Maitri and located between Thala Fjord and Quilty Bay, east of Stornes Peninsula in Antarctica.

Polar WRF model is configured for the forecast up to 72 hours with the initial and boundary conditions of the Global Forecast System (GFS T-1534) operational at the India Meteorological Department (IMD). A single static domain with 1100×900 grids with a 3 km horizontal grid spacing are used. Main objective of this paper is to examine the performance skill of the models (Polar WRF and GFS) in the short-range time scale (24 to 72 hours) over the Maitri and Bharati region. We investigated the performance of the Polar-WRF using meteorological data from Maitri and Bharati stations. An inter-comparison of daily mean sea level pressure, surface winds and surface temperature of Maitri and Bharai for the 24 hours, 48 hours and 72 hours forecast against the corresponding observed fields has been made for the period 2019 to 2021. Polar WRF simulation results show good agreement with most near-surface observations and reveal that the model is capable of capturing synoptic weather features of Antarctic region.

Keywords: Polar WRF, GFS, Bharati, Maitri

Investigations on the variability and trend in heat waves and cold waves in India

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ABSTRACT

Extreme weather events have become remarkably more evident in the recent decades. Heat waves and cold waves are such anomalous weather events resulting from the excessive heat and cold, respectively, in the near-surface atmosphere. They may last from a few days to a few weeks depending on the geography and climatology of the region. In this study, we have used the India Meteorological Department (IMD) daily maximum and minimum temperature data over the period from 1961 to 2016 to investigate the decadal variability and trends in the frequency, total duration and maximum duration of heat waves and cold waves in India. We found that the frequency of the occurrence of heat waves and cold waves increased by about 0.6 events per decade and 0.8 events per decade, respectively. The total duration of heat waves increased by about 2 days per decade and maximum duration by about 1 day per decade. Although, the major part of northwest India is extremely vulnerable to heat wave conditions, the central peninsular India is also experiencing frequent heat waves in the recent decade. The similar increase in the total duration of cold waves and the maximum duration of cold waves was observed in North India.

Keywords: surface temperature, heat wave, cold wave, India

SIMULATION OF A LIGHTNING EVENT OVER BIHAR USING AN ENSEMBLE OF DIFFERENT WRF MODEL CONFIGURATIONS

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ABSTRACT

Lightning claims several lives and loss of properties every year during pre-monsoon and monsoon months in India. A Specialized forecast system for lightning and thunderstorm is needed to minimize the loss. The updraft and ice particles concentration play important roles in the initialization of lightning inside the thundercloud. The charge generation and separation inside the clouds plays important role in the severity of lightning. Lightning Potential Index (LPI) measures the potential of charge generation and separation inside the clouds. It plays a significant role in determining the lightning-prone zones.

In this study LPI is calculated (Lynn and Yair 2008; Yair et al. 2010) using the Weather Research and Forecasting (WRF) model derived parameters. The study is based on simulation of Bihar lightning that occurred on June 25, 2020. As the monsoon intensified over the Indo Gangetic Plains, 83 people were killed by Lightning in Bihar and another 24 in Uttar Pradesh. Simulation of lightning is carried out using an ensemble of different WRF model configurations. The ensemble consists of 1 control + 9 members with different configuration of WRF model. One member is based on data assimilation using WRFDA. The results are analysed using ISS LIS data and NCUM model forecasts. The lightning flash count and ensemble probability are computed using the LPI derived from the WRF model simulations. The LPI predicted by the NCUM and ensemble based WRF model simulations are comparable.

Keywords: Weather Research and Forecasting Model, Lightning Potential Index, Lightning flash count, Ensemble probability

Towards Impact Based Forecasting in Kerala- Methodology and Implementation

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ABSTRACT

The National Meteorological services are changing from their usual way of providing simple weather warnings to "Impact-based Forecasting (IBF) and risk-based warnings", which integrates the likelihood and severity of impacts due to the severe weather (WMO, 2015; Silvestro et al., 2019). The IBF helps the public and the communities to prepare appropriately for the threats expected from the severe weather events (WMO, 2015). The IBF can lead to an improved understanding of forecasts (Potter et al., 2018) and may increase peoples' intention to take protective measures against severe weather (Casteel, 2016; Weyrich et al., 2018). The present study deals with a methodology for IBF over two districts of Kerala, namely, Thiruvananthapuram and Ernakulam, in connection with heavy rainfall events during the monsoon season. The past experiences of various impacts of heavy rainfall events and their severity were studied and documented for these two districts to implement IBF in operational mode. An impact matrix and a risk matrix are prepared and presented in the current study as a part of the risk assessment. The historical impact data (2004-2020) are collected from media reports corresponding to the days of the occurrence of heavy rainfall events. A heavy rainfall event may not create so much impact in a single day and may depend upon the previous days' rainfall too. To account for this factor, five-day cumulative rainfall up to the day of the event is calculated. The cumulative rainfall is categorized into different ranges, and disastrous rainfall events are segregated under the respective rainfall ranges. Within each cumulative rainfall category, the percentage of occurrence of rainfall at all stations within the district on the day of the events is again categorized as per the rainfall intensity category. All the collected impact events are tabulated in a contingency table as minimal, minor, significant, and severe categories against rainfall intensity categories on the day of the event. A lookup table for impact category is thus generated, which is utilized for issuing IBF over these districts. The study revealed that the same amount of rainfall might not have the same kind of impacts in these two districts as the extreme rainfall amounts calculated as 99th percentile is different for these two districts. The same historical data for the 17 years generated different risk matrices for these two districts. These two matrices with the probability of a heavy rainfall event are utilized by India Meteorological Department to issue IBF for these two districts since 2020 and implemented for all the 14 districts in 2021 by preparing the respective matrices based on the same methodology. It is planned to implement a machine learning technique to develop a model to predict the expected impacts from the existing scenario for which the historical data can be utilized for training those models.

Keywords: Impact based forecast, Risk matrix

LARGE-SCALE EXTREME RAIN EVENT ANALYSIS OF SEVEN HOMOGENEOUS ZONES OF INDIA IN RELATION TO GLOBAL THERMAL CHANGES

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ABSTRACT

In recent decades tropospheric warming is not uniform across the globe but it is significantly northward shifted. The troposphere of northern hemisphere is warming at faster rate (0.30°C/10-yr) than southern hemisphere (0.20°C/10-yr). This asymmetric global thermal changes are observed to modulate rainfall space-time distribution. We observe that, locations of warming and cooling across the globe are the determinant of the plausible locations for the origin of various type of weather systems and hence extremes. We hereby investigated the 3D changes in global atmospheric thermal structure and its role in occurrence of large-scale long-period extreme rain events (1- to 10-days) concerning rainfall intensity (ERE-RI) and cumulative rainfall amount (ERE-RM) over seven homogeneous zones across the country during 1951-2020. Climatological and fluctuation characteristics of EREs are studied in details. The mean RI of 1-day ERE-RI varies from 20.3mm over Northwest India (NWI) to 45.2mm over Northeast India (NEI) while that of 10-day ERE-RI varies form 9.8 mm over North mountainous India (NMI) to 24.5mm over NEI. The mean cumulative RM of 10-day ERE-RM varies form 97.8 mm over NMI to 245.1mm over NEI.

Visual examination revels that, the RI and RM of 1- to 10-day EREs does not show significant long-term trend over any of the 7 homogenous zones. However, few selected case studies of most extreme rain events revels that, abrupt warming and cooling in the atmosphere over different parts of the globe, drastically modulates the monsoon circulation and intensify the associated weather systems causing heavier rains over a region. Sudden intensification of the monsoon circulation is seen associated with anomalous warming of the upper troposphere between Tibet and Turkey sector and development of strengthened ridge in upper tropospheric westerlies over there. Persistence in temperature and circulation anomalies across the globe are strongly linked to the occurrences of severe rain events over a wide-ranging scale from small scale short-period heavy rain events to large-scale long-period extreme wet spells.

Keywords: Global temperature change, large-scale extreme rain events

Role of South Indian Ocean dynamics during 2018 and 2019 Kerala flood

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ABSTRACT

In August 2018 and 2019: two consecutive years, Kerala experienced extreme rainfall event, and the state witnessed large-scale flooding during the monsoon season. The study investigates the role of south Indian Ocean dynamics on both the Kerala floods. The southern Indian Ocean influences Indian Summer monsoon through the essential moisture transport and associated process. Southern Indian Ocean plays a dominant role in the formation of ocean- atmospheric coupling process like Indian Ocean dipole (IOD) which can have a major hand in the Indian Summer monsoon rainfall variability. Through this study we are trying to bring out the salient features of Southern Indian Ocean which had ultimately aided the flood havoc over Kerala.

IMPACT BASED HEAVY RAINFALL FORECAST IN UTTAR PRADESH: RECENT DEVELOPMENTS, STATUS, CHALLENGES & FUTURE PERSPECTIVES

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ABSTRACT

Phenomenal improvement has been observed in weather forecasting skills with great benefit from the introduction of Conceptual Multi-Hazard Impact Based Forecasting services by WMO in recent past. IBF has brought paradigm shift in the forecasting jargon by switching from Static system (Seamless-Forecasting) to Dynamic system (MHIBF), an initiative towards '*TRANSLATING HAZARD INFORMATION INTO IMPACT SCENARIOS*'.

Uttar Pradesh comprising of 75 districts broadly classified into two meteorological subdivisions having different climatic zones/features owing to its complex physiographic characteristics which make it home for various severe/disastrous weather hazards out of which Heavy/Intense rainfall episodes often result into high socio-economic impacts due to its peculiar geophysical settings in the vast Indo-Gangatic flood plains.

This study discusses about potential challenges and opportunities offered by this approach in decision-making workflow in operational context. First & foremost input comes from the collection of detailed Meteorological/Geophysical/Physical/Socio-Economic/Hazard/Exposure/Vulnerability/ Impact data in order to create Comprehensive District Profile Database. Second part comes in the form of computation of numerical thresholds for different impact scenarios & preparation of Impact/Risk matrix accordingly based on two subjective approaches viz. Threshold Method aided/supported by Qualitative Combinational Method. Final, but most vital part is creation of suitable Response Matrix for different Impact/Risk scenarios to include exposure & vulnerability factors qualitatively and to quantify the uncertainties for proper Risk Assessment and Decisive Action.

The present approach aims to offer a first insight about IBF with provision of qualitative cum quantitative IBF on zonal/regional basis consisting of cluster of districts classified on the basis of similar climatic/hazard/vulnerability profile with specified colour codes depending upon the scale of exposure/vulnerability pertaining to the specific type of hazard/multi-hazard, which may ultimately result in better contingency planning. This approach would also improve the objective evaluation of responsibilities of forecasters and decision makers with empirical justification.

Keywords: MHIBF, Hazards, Risk, Impact Matrix

Thermodynamical and microphysical dependencies of lightning events

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ABSTRACT

Extreme precipitation events along with thunderstorms and flooding have increased in recent era. The torrential rainfall in August 2018 in the state Kerala caused massive economic damage and casualties. Also during summer monsoon 2019, the coastal areas of Maharashtra especially Mumbai coast have witnessed an extremely heavy rainfall. One of the reasons for this heavy rainfall might be the presence of substantial oceanic Giant Cloud Condensation Nuclei (GCCN) in the coastal areas of Arabian Sea during summer monsoon (JJAS). Here in this study, the role of oceanic aerosol (GCCN) in these two extreme events has been examined. The sea salt aerosols which act as GCCN are formed mainly by bursting of air bubbles near the air-sea interface and the rate of production depends on the wind stress. Therefore, the strong south-westerly jet from Arabian Sea during monsoon may increase the chances of production of sea salt aerosol which acts as GCCN near the Arabian Sea coastal areas. The availability of cloud liquid water triggers convection which in turn influence the CAPE and vertical structure of heating. In this scenario, GCCN accelerates the rain process.

Large number of smaller cloud droplets suppresses the rain formation process due to lesser collision coalescence efficiency and reside in the atmosphere for longer span of time because of lower fall speed. The Large droplets having relatively less concentration in the marine environment will rather quickly reach the size needed for efficient growth by collision coalescence process as compared to cloud droplets nucleated on large number of smaller CCN. Also, some giant sea salt aerosols (Rain Embryo) directly activate the rain formation process. Hence the presence of giant cloud condensation nuclei coming from bursting of sea salt aerosol in the Arabian Sea enhance warm rain process and results into intense heavy rain events.

FIEDELITY OF CMIP6 MODELS IN SIMULATING THE RELATIONSHIP BETWEEN THE INDO-WESTERN PACIFIC OCEAN CAPACITOR MODE AND INDIAN SUMMER MONSOON RAINFALL

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ABSTRACT

Anomalous tropical Indian Ocean (TIO) sea surface temperature (SST) warming and western north Pacific (WNP) low-level anticyclonic circulation in the post-El Niño summer form an interbasin positive feedback through air-sea coupling known as the Indo-western Pacific Ocean capacitor (IPOC) mode. The IPOC mode have strong influence on East-Asian summer rainfall and WNP monsoon. Linkage between Indian Summer Monsoon rainfall (ISMR) and IPOC mode is previously studied in observations on different timescales. The present study examined the fidelity of the World Climate Research Programme's (WCRP's) forty Coupled Model Intercomparison Projects phase-6 (CMIP6) models in representing the IPOC-ISMR relationship in historical simulations. The IPOC mode is extracted by singular value decomposition (SVD) analysis between summer TIO SST and WNP 850-hPa vorticity anomalies over 1871-2014. Observation shows that the positive phase of IPOC mode linked with WNP anticyclone and TIO warming, induces a southwest-northeast (positive-negative) dipole rainfall pattern over India on interannual timescale. CMIP6 models exhibit good skill in capturing the IPOC mode. However, only eleven models could simulate IPOC induced ISMR pattern. Eastward shifted WNP anticyclone, persistent warming in the central equatorial Pacific, and excess cooling over the north Pacific are primarily affecting IPOC-ISMR connection in many models. The interdecadal modulations of IPOC-ISMR relationship is assessed in the selected eleven models using 21-year sliding correlation between IPOC index and dipole precipitation index, that leads to formation of high correlation epoch (HCE) and low correlation epoch (LCE). During HCE, IPOC mode and positive rainfall anomaly over southern peninsular and western India are well simulated with some discrepancies. In case of LCE, majority of models depict overestimated El Niño signals and distorted WNP anticyclone structure, which affect the IPOC development and hence IPOC-ISMR bond. This study would be useful for a predictive understanding of monsoon variability and associated contributing factors other than El Niño.

Keywords: Indian Summer Monsoon, El Niño Southern Oscillation, Tropical Indian Ocean warming, Western north Pacific anticyclone

Climate and crop yield variability in Bundelkhand Agroclimatic zone of Madhya Pradesh

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ABSTRACT

Climate change and variability affect the crop yield in general and particular in rainfed area.. The different scientific studies reported that the temperatures are increasing in the past decades and frequency of high temperature has increased more after 1990. To evaluation the climate and crop yield variability in Bundelkhand Agroclimatic zone of Madhya Pradesh, daily maximum and minimum temperature and soybean and wheat yield data from 1980 to 2019 was collected and analyzed. The frequency of critical threshold temperature during critical growth period of these crops at decadal scale was reported in the present study. The critical period for soybean is selected 24 th to 28 th and 33 rd to 37 th standard meteorological week (SMW) and for wheat 44 th to 46 th and 9 th to 13 th SMW. The decadal frequency of maximum and minimum temperature threshold are selected in accordance to the upper limit of coordinal temperature these crops and compared to the decade 1980-89 to 1990-99 with 2000-2009 to 2010-2019. It was found that the frequencies of the threshold limits of maximum temperature are lowered (12 to 66 %) during the 2000-2009 to 2010-19 as compared to 1980-89 to 1990-99 for both seasons. The frequency of minimum temperature threshold was observed to be increased (71 %) in the decade 2000-2009 for 9 th to 13 th SMW. However the variability (coefficient of variability) of soybean yield increased more (34.4 to 39.6 %) during 2000-2019 as compared to 1980-1999 (12.4 to 31.5%). But the increase in wheat yield variability during 2000-2019 (18.1-18.3 %) as compared to decades 1980-1999(8.7 to 16.3%). The decreased frequency in threshold limits of maximum temperature and increased frequency of minimum temperatures events are not the major factors for increased variability in soybean yield. The increased soybean yield variability would cause serious financial damages to the farmers; hence diversification of the cropping pattern during monsoon season may be advisable.

Thermodynamical relations of global atmospheric residence times with the intensified hydrological cycle in the changing climate scenario

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ABSTRACT

The time that the moisture stays in the atmosphere is known as Atmospheric Residence Time and is very much important in the context of increasing frequency of weather and climate extremes in the changing climate scenario. A multi model ensemble of 19 global climate models of Coupled Model Intercomparison Project (CMIP) 5 is obtained and used to study the spatiotemporal variations of atmospheric residence times over the globe. Space scale variations of atmospheric residence times are high during the RCP8.5 scenario compared to RCP4.5. Global atmospheric residence times deduced from the climate models of Coupled Model Intercomparison Project 5 under RCP 4.5 and 8.5 emission scenarios show a perceptible increase in January and July months with magnitudes 9.5±0.17 and 10.5±0.22 days by the end of 21 st century. Tropical and sub- tropical residence times are found to be more compared to that of mid and high latitudinal regions which are mainly due to the variations in water vapor. The increase in residence times is shown in relation to the decreased exchange of moisture flux within the boundary layer to the free atmosphere.

ANALYSIS OF TRENDS AND SPATIO-TEMPORAL PATTERNS OF PRECIPITATION EXTREMES INDICES OVER HIMACHAL PRADESH AND PUNJAB (1901-2015)

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ABSTRACT

Changes in extreme weather and climate events have profound impact on human societies and topography of a region. A long time series analysis of precipitation observations provides valuable information about hydrological changes, availability of water resources and potential hazards (floods and landslides). Understanding the processes involved with extreme events at regional scale provide useful information regarding changes in amount, intensity, frequency of extreme events which could impact on humans and mechanisms of the past change and future projections. Knowledge on the spatial variability and temporal trends of daily precipitation is essential for efficient management of water resource and agriculture. The spatial and temporal changes in the indices of precipitation extremes, on basis of daily gridded data (0.25° * 0.25°) over Punjab and Himachal Pradesh for the period 1901-2015 were analyzed. Five indices of extreme temperature i.e., R50, R75, R100, moderate rainfall index (MRI) and high rainfall index (HRI) were examined for the study. The analysis also includes a series of tests designed to determine whether monthly, seasonal and annual precipitation data is consistent, random and trend free. Himachal Pradesh and Punjab forms a physically contiguous natural region with strong physiographic, climatic and hydrological links. The temporal analysis reveals noticeable variations in different climatic zones with increasing precipitation throughout the region except in the temperate and cold semi-arid zone of Himachal Pradesh. The frequency of change magnitudes of R50, R75, R100 and moderate rainfall index (MRI) and high rainfall index (HRI) have indicated an increasing trend for the entire area with statistically significant at few locations.

Keywords: extreme events, gridded data, moderate rainfall index.

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 30°N and 50°N, 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 activity flux; Empirical Orthogonal Function; Principal Component.

Modelling Sub-Divisional Rainfall in India using Deep Learning Techniques

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Abstract

Indian agriculture is mostly rain dependent. Therefore, accurate modelling and forecasting of rainfall has greater importance for the sake of farmers and policy makers. In recent years an extremely powerful technique i.e. deep learning has been widely used in many fields of science and technology. As time series data of rainfall may consist of long memory, the usual short memory models like the autoregressive integrated moving average (ARIMA) model fails to model the underlying pattern satisfactorily. Time series analysis of climate data particularly rainfall can be an important tool to investigate its variability pattern and, maybe, even to predict short- and long-term changes in future. In this study, pattern of annual rainfall in 30 sub divisions of India for the period 1871 to 2016 has been investigated. In the present study, deep learning approach i.e. long short term memory (LSTM) introduced by Hochreiter and Schmidhuber (1997), a special form of recurrent neural network (RNN) has been used for modelling sub-divisional rainfall in India. Three variants of LSTM model i.e. Base LSTM, Stacked LSTM and Bi-directional LSTM (BD-LSTM) have been explored for empirical comparison of forecast performance. Empirical comparison of forecast accuracy for the above deep learning models along with machine learning techniques i.e. Artificial neural network (ANN) and Random forest regression (RFR) and stochastic model i.e. ARIMA in terms of four criteria namely Mean error (ME), Mean absolute error (MAE), Root mean square error (RMSE) and Mean absolute percentage error (MAPE) revealed that the deep learning techniques have better accuracy than others.

Keywords: Deep learning, Forecast accuracy, Long memory, Machine learning, Rainfall.

Climatic Variability of some Meteorological Parameters over Vidarbha –In New Trends

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ABSTRACT

The Earth's climate is never static—it varies at all timescales. It is therefore, needful to study the climatic variability of small areas from time to time. It will be useful to the policy makers and all concerned for the good planning in development and progress. In the present study, Vidarbha a meteorological sub-division has been considered to carry out research. It is a land area that lies on the northern part of the Deccan plateau in India. Orographically and geographically, it is divided into two parts of East and West Vidarbha. To analysis of data the departmental stations of Nagpur and Akola were considered representative for East & West Vidarbha respectively.

The meteorological data for sixty years (1961-2020) was divided into two parts part-I (1961-1990) & part-II(1991-2020) and analysed for interpretation. In rainfall, a decreasing trend (5.42mm /year) shows in part-I and an increasing trend (6.33mm/year) shows in part-II , and CV of 20% & 23% in part –I & II respectively in east Vidarbha and an increasing trends (4.56mm/year part-I &3.79mm / year part-II) was seen in both parts and CV of 24 % and 26% in west Vidarbha. It is seen that cyclonic circulation (CC) formed over land & both seas including cyclonic depressions, land depressions, cyclone and severe cyclones show decreasing trends in part-I and an increasing trend show in part-II with the rate of 0.15frequecy/ year. In the Bay of Bengal. CC , decreasing trend show in part- I & II with the rate of 0.34/year & 0.21/year respectively. In the Arabian sea, CC, a decreasing trend was seen in part-I with the rate of 0.12 frequency / year & an increasing trend shows with rate of 0.14frequency / year. It influenced to enhance rainfall activities with rate of 4.79mm /year over west Vidarbha. The temperatures for the decade (2011-2020), it is observed that an increasing trend shows with 0.048 ^{o}c /year in max temperature and a decreasing trends shows with rate of 0.012 ^{o}c / year in minimum temperature over east Vidarbha and an increasing trend shows for both maximum &minimum temperatures with rate of .039 ^{o}c / year & 0.097 ^{o}c / year respectively over west Vidarbha. t-test value indicates that significant differences were found at .05 level of confidence between rainfall of part-I & part-II of east Vidarbha and west Vidarbha.

Keywords: Trends,Variability,Significant,Standard Deviation(SD),Coefficient of Variation (CV)

NUMERICAL SIMULATION OF A CLEAR AIR TURBULENCE (CAT) EVENT of 2018 FOR ALLEVIATION OF AVIATION ACCIDENTS USING WEATHER RESEARCH AND FORECASTING (WRF) MODEL

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ABSTRACT

Atmospheric turbulence is a primary meteorological hazard to en-route air traffic. At a high altitude, aircraft may encounter turbulence unexpectedly without any significant cloudiness. Clear Air Turbulence (CAT) occurs when severe turbulence occurs in an environment with no clouds. It creates a ferocious buffeting effect in aircraft. The physical impact on crew and passengers varies from discomfort to loss of flight control, injuries, and fatalities in an uncommon intense turbulence event. The role of CAT for various processes in the atmosphere is still ambiguous. CAT incidents are reported all over the world.

The present study simulates a CAT event encountered by an Air India flight AI462 on 19th April 2018 as reported in India Today. This study is focused on understanding and investigating favorable conditions for the occurrence of the CAT. Weather Research and Forecasting (WRF) Model V 4.0.3 has been used to simulate the turbulence. The 6-hourly NCEP FNL Operational Global Analysis data at 0.25° X 0.25° resolution is taken as the input data to provide the model's initial and lateral boundary conditions. For simulating the atmospheric environments at the time of the event, Yonsei University Scheme, WSM 3-Class Simple Ice Scheme, Kain-Fritsch (New Eta) Scheme, Rapid Radiative Transfer Model (RRTM) Scheme, and Revised MM5 Monin Obukhov Scheme are used. This study shows that Vertical Velocity, Geopotential Thickness, Wind Shear and Bulk Richardson Number Shear are correlated with CAT as the model predicted both upward and downward velocity very close to each other between 400 hPa and 550 hPa levels along with strong geopotential thickness gradient and strong wind shear gradient near the accident location. This could lead to CAT.

Keywords: CAT, Clear Air Turbulence, Turbulence, CAT Index.

SENSITIVITY ANALYSIS OF MICROPHYSICS AND CUMULUS PARAMETERIZATION SCHEMES : NUMERICAL SIMULATION OF CLOUDBURSTS OVER UTTARAKHAND USING WRF MODELLING SYSTEM

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ABSTRACT

Cloudbursts are phenomena in which intense precipitation of order 100mm occurs in an hour over a small geographic area of about 20km^{2}triggering flash floods and landslides causing severe damage . This study examines three cloudburst events that occurred on 16th, 17th and 19th July, 2018 over Uttarakhand. The three cloudburst events were simulated on the Weather Research and Forecasting (WRF) model using three different configurations on a nested domain of 9 km and 3 km resolutions using initial and boundary conditions from 1° by 1° spatial resolution NCEP-FNL data at timestep of 18s and compared with IMDAA and NGFS data. Different configurations were carried out on WRF by using different microphysical parameterization schemes, namely, WSM6, Lin and Thompson scheme and cumulus parameterization schemes namely Kain-Fritsch and Grell 3D Ensemble schemes. All the simulations predict intense rainfall of order 100 mm, strong vertical velocity and vertical wind shear in the three events taken for study. The location of maximum rainfall and vertical velocity is displaced from its original location for two cases. Moreover, the child domain overestimates the rainfall and other variables and hence has greater bias when compared to the parent domain. The performance of each configuration has been evaluated based on GPM-IMERG rainfall measurements using deterministic and categorical measures. Equitable Threat Score and False Threat Score were calculated for rainfall threshold of 5 cm for each timestep. The performance of the third configuration was found to have the highest skill among the three configurations used in the study. The study also aims to identify the different synoptic features that prevailed during the cloudburst events that could have contributed to the development of the cloudburst. The southeasterlies and southwesterlies brought in moisture increasing the instability. The monsoon depression was identified near the coast of Odisha at 500 hPa geopotential height which over time took a northwestward track bringing along moisture into the mainland. The moisture convergence was further enhanced by the eastward moving cyclonic circulation at 300 hPa near Jammu and Kashmir region further adding to the instability making it more conducive for a cloudburst to occur.

Keywords : *Monsoon trough, Convection, Orographic lifting, Parameterization scheme.*

Performance of Flash Flood Guidance System Over South Asia Region

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ABSTRACT

Flash floods are floods of short duration with a relatively high peak discharge. They occur with torrential rainfall within a few minutes to a couple of hours depending upon the region's land surface, geomorphological and hydrological factors. They are recurring phenomena in south Asia, especially over the Indian area, causing significant loss of human lives and property. Most of the National Hydrological and Meteorological Services (NHMSs) lack flash flood warning capabilities. World Meteorological Organization (WMO) has taken up a project for developing the capabilities of NHMSs for enhancing the flash flood early warning system. These enhancements assist by empowering the mandated national authorities to adopt the Standard Operating Procedure (SOP) to protect the communities at risk from the adverse impacts of flash floods. As a regional center of the South Asia Flash flood guidance System (SAsiaFFGS), India Meteorological Department (IMD) has started monitoring and providing guidance of flash floods events associated with extreme rainfall. The SAsiaFFGS is a tool necessary to provide operational forecasters and disaster management agencies with real-time informational guidance products about the threat due to small-scale flash flooding with a lead time of 3 to 6 hours. The current study examines the performance of the SAsiaFFGS over the South Asian region with the help of flash floods events that occurred during 2019, 2020, and 2021. A detailed study is carried out, and results are presented in this paper.

Keywords: Flash flood, FFGS, Threat, Risk, South Asia

Changes in SST, wind and Sub-surface Ocean temperature associated with IOD during warming scenario

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ABSTRACT

IOD, is a prominent tropical mode which consist of inter-annual, decadal and multi-decadal variability and changes its skewness towards positive IOD events since 1980. It has been noted mean state of TIO has been changed and hence can have tendency to change local air-sea interaction. Present study has analyzed primary variables associated with ocean-atmosphere coupling using data from 1950. Initial analysis shows that change is prominent since 1980 hence to understand the ongoing physical process from 1950 to 2019, study divides timescale into four climatic epoch 1950-2019, 1960-2019, 1970-2019 and 1980-2019. Prominent change has been observed during the month of September-October-November which consider to be a peak time for IOD in recent decades. Climatological tendency for these four epochs for SST, wind at 10m and ocean sub-surface temperature has been analyzed which shows that instead of short-term, long term change is significant. Hence further analysis has been focused for two climatic epochs, 1950-

2019 and 1980-2019. During these two epochs change is positive IOD (pIOD) events with respect to climate and negative IOD (nIOD) events has been analyzed which shows that warming is significant in both epochs but area of warm region has shrunken in recent decade with respect to climatology. A significant variation in wind field has been observed. During 1950-2019, pIOD events are quit poses similar structure while during 1980-2019, dipole in wind field over equatorial region has been only observed with respect to climate. Also, during 1950-2019, an anomalous divergence over equatorial regional has been observed with respect to climate as well as nIOD event while during 1980-2019, an anomalous northerly flow has been observed with respect to climate. This wind dipole character is also observed to be a prominent mode of wind field over equatorial region which shows almost 29.3% variance. In the field of ocean subsurface, it is observed that during recent decade (1980-2019) sub-surface dipole gets prominent and develops a concise structure than previous one (1950-2019).

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Keywords: Climate change, Ocean Warming, SST, Wind, Sub-surface temperature

How interactions between tropical depressions and western disturbances affect heavy precipitation in South Asia

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ABSTRACT

Interactions over South Asia between tropical depressions (TDs) and extratropical storms known as western disturbances (WDs) are known to cause extreme precipitation events, including those responsible for the 2013 floods over northern India. In this study, existing databases of WD and TD tracks are used to identify potential WD–TD interactions from 1979 to 2015; these are filtered according to proximity and intensity, leaving 59 cases that form the basis of this work. Synoptic charts, vorticity budgets, and moisture trajectory analyses are employed to identify and elucidate common interaction types among these cases. Two broad families of interaction emerge. First, a dynamical coupling of the WD and TD, whereby either the upper- and lower-level vortices superpose (a vortex merger), or the TD is intensified as it passes into the entrance region of a jet streak associated with the WD (a jet-streak excitation). Second, a moisture exchange between the WD and TD, whereby either anomalous moisture is advected from the TD to the WD, resulting in anomalous precipitation near the WD (a TD-to-WD moisture exchange), or anomalous moisture is advected from the WD to the TD (a WD-to-TD moisture exchange). Interactions are most common in the post-monsoon period as the subtropical jet, which brings WDs to the subcontinent, returns south; there is a smaller peak in May and June, driven by monsoon onset vortices. Precipitation is heaviest in dynamically coupled interactions, particularly jet-streak excitations, although all four interaction types are associated with extreme precipitation events. Criteria for automated identification of interaction types are proposed, which may be useful in forecasting and climate science.

Keywords: western disturbances, monsoon depressions, precipitation, synoptic dynamics

Increasing trend of extreme rainfall events over Kerala in recent decades.

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ABSTRACT

In recent decades Kerala experienced unprecedented extreme rainfall events that resulted in floods. These devastating extreme rainfall events swept away life and property and marked as historic tragedy for Kerala. . This study has been conducted to bring further insight into extreme events over Kerala and its decadal variability. In this study, we analysed summer monsoon active day rainfall over Kerala for the four decades during 1980-2019. We found that, frequency and intensity of the extreme rainfall events over the region is increased during recent decades. We have analysed the kernel density estimation (KDE) of rain intensity during active days of summer monsoon during each decades (1980-89, 1990-99, 2000-09, 2010-19). Further an attemot has been made to link the relevant monsoon indices with the changes in the extreme active spells. In the last decade (2010-19), the increase in skin temperature and total column water vapour has resulted in a rise of extreme rainfall days in the active days.

Keywords: Active days, Extreme rainfall, Decadal variability. Website:

Dynamical Performance of Subseasonal to Seasonal Forecast Model during Extratropical-Tropical Interaction – A Case Study

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ABSTRACT

The key elements of general circulations are the transport of total momentum and heat fluxes. The total flux transport can be decomposed into three components: mean meridional circulation, stationary eddies, and transient eddies. 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 of weather and climate in both regions. The E2T interaction evolution based on eddy transport indices suggested in Kalshetti et al. 2020 could be useful in diagnosing extratropical-tropical interactions, especially extreme events over the Indian region. The present study glanced at the reinforcement of the monsoon phase on 16-17 June 2013 over the Uttarkhand region in subseasonal to seasonal (S2S) scale operational forecast. Observation depicts the deeper and narrow trough of 200hPa wind on 16-17 June. Interaction of the underlying low-level tropical system with deep through of extratropical system occurred on 16 June (geopotential height at 500hPA). The local impacts of transient eddy and its structure has been analyzed using E vector diagnostic tool (James, 1994; Trenbirth, 1986; Lau Haolopainen, JAS, Hoskins, et al., 1983). As forecast lead time increases, the model shows declination in jet stream magnitude and is prone to zonal orientation. Among all S2S models, UKMO captured the E2T interaction at 500hPa, but 200hPa through is broader, whereas ECMWF upper-level trough is well simulated, but the interaction of E2T at 500hPa is missing, and ERPAS responded feebly for E2T interactions as well as deepening of an upper-level trough.

Keywords: S2S prediction, extreme event, transient eddy, extratropical-tropical interaction

Desiphering Extremely Heavy Rainfall over Madhya Pradesh in Current Monsoon

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ABSTRACT

High impact causing severe weather events like extremely heavy rain are crucial component of climate systems. In recent time, these are catching attention of entire scientific community as blowing alarm of climate change. Extreme rainfall events covering large geographic area have potential to cause significant loss of human and animal lives, large scale damages to infrastructure, damages to electricity and telephone lines. Present study intend to insight meteorological conditions resulted in extremely heavy rainfall occurred over M.P and adjoining Rajasthan during July end and first week of August. Well Marked Low Pressure Area formed over coastal Bangladesh & adjoining West Bengal with the associated cyclonic circulation extended up to mid tropospheric levels on 28 th July, shifted over southwest Uttar Pradesh & adjoining northwest Madhya Pradesh with the associated cyclonic circulation extended upto 7.6 km above mean sea level on 02nd August. The position of monsoon trough, location of Tibetan anticyclone, movement of low pressure system analysed using IMD weather charts. Vorticity at 850 hpa, 700 hpa, 500 hpa and low level convergence and wind products of CIMSS, University of Wisconsin. The analysis of geopotential height (GPM) is done with NCEP reanalysis data. This low pressure system remained practically stationary for three-four days at same location due to almost no change in pressures field with respect to surrounding and supported by high positive vorticity and low level strong convergence and resulted three days continuously extremely heavy rainfall and heavy to very heavy rainfall for 5-6 days in North MP resulted in severe flooding due to over flow of Chambal and Sindh rivers. Sheopurkalan, Bhind, Shivpuri and Guna were the most severely affected by flood and massive damages to infrastructures like roads, connecting bridges, houses, loss of crops, animal and human lives also.

Keyword: Vorticity, Geopotential Height, Convergence, Low pressure area

Extreme rainfall event simulation over Mumbai using Regional Climate Model: A case study

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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).

Study of seasonal and sub-seasonal soil moisture variations using high frequency field scale observations and model simulations over the core monsoon zone of India.

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Abstract

Soil Moisture is a key contributor in surface and subsurface hydro-metrological processes. The precise quantification and continuous monitoring of high- resolution surface and subsurface soil moisture (SM) observations are very crucial. These long-term field-scale observations provide significant insight into the surface-subsurface soil water dynamics, under changing climate. In this study an attempt is made to analyse the surface and subsurface seasonal variation of soil water dynamics over the core monsoon zone of India. This analysis is performed using surface and sub-surface soil moisture data sets from IITM-COSMOS Pune site, ERA (reanalysis) and GLDAS (model simulation). Based on the wavelet analysis it is found that the surface and subsurface SM variations in 2019 are significantly less as compared to 2018 during monsoon season in contrast to pre-monsoon seasons. The long persisting dry conditions during 2019 pre-monsoon clearly brings out the role of enhancement of evaporation (ET) due to stronger exchange of sensible heat flux from land surface to atmosphere. On the other hand, the availability of excess latent heat flux during monsoon and post monsoon seasons of 2019 led to limit the ET. Thus the surface and sub-surface soil moisture variations exhibit the role of soil water dynamics in modulating dry and wet extremes.

Keywords: Soil water dynamics, sensible heat, latent heat flux, Soil moisture variations.

CHANGES IN CHARACTERISTICS OF HOT EXTREMES OVER INDIA AND THEIR DRIVING MECHANISMS

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ABSTRACT

In the present study, an attempt has been made to diagnose the change in the characteristics of hot extremes over India before and after the 1976 climate shift. Results provide compelling evidence that large parts of India, except the Indo-Gangetic plains, have experienced more occurrences of hot days having higher temperatures in the recent decades, compared to the past, suggesting a shift in climate. Strong positive mid-tropospheric geopotential height anomalies over the northern parts of India that dynamically produces subsidence and clear sky conditions along with reduced precipitable water and depleted soil moisture are identified to be the crucial factors responsible for an increase of hot extremes in recent decades. Moreover, the preceding December-February Niño-3.4 sea surface temperature (SST) anomalies are strongly connected with hot days frequency and the mechanism for the lag of several months is allied to 3-4 months delayed response of Indian Ocean SSTs to El Niño/Southern Oscillation. Thus, post-Niño hot extremes over India can be potentially anticipated in advance and this will help society to prepare for such extremes.

Study on Distribution and Variability of Seasonal Rainfall and its Extremes over Andhra Pradesh under Climate Change

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ABSTRACT

Andhra Pradesh (AP) is a southeastern coastal state in India, which is of high agro-economic importance as majority of its population is involved in agriculture and related activities. The rainfall over this region is an important component that contributes majorly to the state's agricultural production thereby its economy as well. Hence is very important to study the long term rainfall patterns on a climate scale over this region in order to have a better understanding of the regional rainfall and help in strategic planning for water resource and flood risk management in this global warming era. The present study investigates seasonal rainfall and its extreme events over AP and its 13 districts using the IMD rainfall analysis dataset (0.25° × 0.25°) for the period of 118 years (1901 to 2018). In order to achieve that normality, homogeneity, persistence and change point tests are performed and the recent spatial and temporal changes are also analyzed accordingly. The results suggest that long-term average annual rainfall over AP is 882 mm, most of which is contributed by the monsoon (55.7 %) and the post-monsoon rainfall (32.8%).The climatological features (mean, IAV & CV) of seasonal rainfall are highly heterogeneous with respect to region and time. The post monsoon rainfall over AP is more consistent than other seasons. However, the persistence is only during the monsoon season over all the districts. The monsoon and post monsoon rainfall and their extremes have increased (~ 10 %) over a few districts in the recent decades. The relationship of ENSO and Indian Ocean dipole is completely opposite for monsoon (negative) and post-monsoon seasons (positive), the relationship of Nino 3.4 SST and DMI is strikingly similar to post-monsoon season and has significantly weakened in the recent decades. This study is useful for proper planning and mitigation of agricultural and water resources sector in this global warming era.

Keywords : Seasonal rainfall; Climate change, Andhra Pradesh; District-level rainfall; ENSO;

Drought variability over homogenous regions of India during recent decades

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ABSTRACT

Drought is a long term, gradually occurring natural hazard, affects agriculture, water assets, economy, and livelihood. The complexity of hazard in terms of its frequency and spatiotemporal variability adversely impacts on regional water availability. Its intensity has risen across many parts of the globe, including tropical countries such as India, and is expected to be more severe in the future under changing environment. The problem over India is more complex due to the strong monsoon influence on regional water availability. Therefore understanding the dynamics and variability of drought is crucial for determining the imbalance of the hydrological cycle. This study investigates the spatiotemporal variability of historical drought over different homogenous regions of India in recent decades. Standardized Precipitation-Evapotranspiration index based on Hargreaves potential evapotranspiration methods has been used to determine the drought variability over the region. Drought homogenous regions based on Principle Component Analysis have been used for regional studies. Results are capable of capturing the reported variability of drought and long-term trend across homogeneous areas. The highest variability is observed over Central India, whereas the least variability is found over East India with an explicit drying pattern. Decadal variability of the drought characteristics is examined using duration, severity, and intensity, which strongly influence frequency over a distinctive timescale.

Keywords: Indian drought variability, teleconnections, homogenous regions, drought characteristics

UNUSUAL LESS WARM SUMMER MONTH OF MAY 2021 OVER VIDARBHA DURING THE PRESENT DECADE – A STUDY

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ABSTRACT

The meteorological subdivision Vidarbha in the state of Maharashtra, in central India is known for extremely hot summer season. In summer, the month of May is hottest and crosses 45°C for more than 15 days. Heat wave conditions are experienced in this region for many days during this month. Heat wave is exhibiting an increasing trend over the region (Pai.et.al. 2012). But in the year 2021 the summer in Vidarbha was unusually less warm so the present study has been undertaken. In the present study, temperatures (Maximum, Minimum and Mean) have been analysed for all the districts of Vidarbha and the subdivision as a whole for the month of May for 11 years (2011 to 2021) using the quality controlled IMDs archived data.

The mean maximum temperature in May 2021 was 40.0°C which is lowest in this decade. It has been observed that May-2021 exhibited the lowest maximum temperatures in Vidarbha during the entire period of study. Minimum temperatures during the month were also found to be the lowest in Vidarbha. No episode of heat wave was observed during May-2021 over the entire Vidarbha. Thus, in year 2021 May month was unusual less warm.

During May-2021, the Indian subcontinent experienced two tropical cyclones, one each originating in the Arabian Sea (Tauktae, 14-19 May 2021) and the Bay of Bengal (Yaas, 23-28 May 2021) is one of the main reasons. These cyclones contributed to the change in the normal wind flow pattern over the region which normally experiences the inflow of hot dry north westerly winds from Rajasthan and adjoining Pakistan. The occurrence of these two cyclonic storms (12 days in total) changed the wind flow pattern over the region, due to which increase in occurrences of thunderstorms due to moisture incursion were observed during the month. In addition to this other synoptic features which affected the weather in May2021 have also been studied and presented in this paper.

Key words: Tropical cyclone, Synoptic features, Highest maximum temperature, Heat wave.

Predictability of Extreme Rainfall Events over India during Summer Monsoon Season by using NCEP GEFSv12 Model in the Present Global Warming Era

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ABSTRACT

Climate change leads to increasing weather and climate extremes such as floods, droughts, cold waves, heat waves, etc. in most parts of the globe. Extreme rainfall events (ER) are responsible for floods, causing widespread destruction of infrastructure, loss of lives, economic losses of about $3 billion per year in India which is 10% of the global economic losses ($30 billion per year) due to floods. In recent years, the frequency of ER events and prolonged droughts has remarkably increased in various parts of India; it is particularly prevalent during the Indian summer monsoon (ISM) season (JJAS). ISM contributes 80% of annual rainfall, it controls the agricultural productivity and economy of the country. A forecast of the ISMR and associated ER events on an extended range is crucial for agriculture operations. In September 2020, NOAA NCEP has newly implemented Global Ensemble Forecast System version 12 (GEFSv12) to support stakeholders for sub-seasonal forecasts and hydrological applications. It has generated consistent reanalysis and reforecast data for the period 2000-2019. The reforecasts were initialized at 00 UTC everyday out to 16 days with 5 ensembles, except on Wednesdays when the integrations were extended to 35 days with 11 members. In the present study, the Raw-GEFSv12 reforecast rainfall products were calibrated by using the quantile-quantile (QQ) mapping technique against IMDAA for further improvement. The performance of Raw and QQ-GEFSv12 in depicting ISMR, associated ER events on an extended range time scale (Day-1 to 16 lead times) over India against IMDAA for the period 2000-2018 has been evaluated by using standard skill metrics. The results suggest that the ISMR patterns from Raw and QQ-GEFSv12 with (lead) Day 1 to 16 are like IMDAA, however, Raw-GEFSv12 having a dry bias in most parts of prominent rainfall regions. The frequency of the low and medium-intensity rainfall events from Raw-GEFSv12 is remarkably higher than the IMDAA, while the high and very-high intensity rainfall events are surprisingly less in Raw-GEFSv12 than the IMDAA. After calibration, GEFSv12's prediction skill notably increased for ISMR and associated ER events for all lead times.

Keywords: Indian Summer monsoon, GEFSv12, Extreme Rainfall events, Extended Range Forecast, Prediction skill

Role of equatorial central Pacific sea surface temperature in modulating rainfall over north India during Indian summer monsoon

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ABSTRACT

The summer monsoon season contributes about 80% of annual rainfall in the highly populated region of north India. The teleconnections moderating the variation of summer monsoon rainfall in this region are not satisfactorily understood. A pathway of the equatorial central Pacific sea surface temperature (PSST) influences the north India summer rainfall is revealed from the high resolution, more reliable and state-of-the-art 41-year (1979–2019) observational data analysis and numerical experiment. The rise in PSST intensifies convection over the equatorial central Pacific with compensatory subsidence over the western equatorial Pacific. Consequently, a much broader and intense anomalous convergence is developed at the upper-troposphere, which subsequently intensifies the Asian subtropical westerly jet-stream. The Asian jet intensification strengthens the tropospheric wind shear at north India, as the low-level monsoonal winds are easterlies over there. The strong wind shear restricts the convective activities in north India. These results are also confirmed using the CFSv2 model sensitivity experiment and a case study of the year 2010.

Keywords: north India, sea surface temperature, summer monsoon, tropospheric wind shear

Investigating the impact of soil moisture variability on temperature extremes over the Indian region

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ABSTRACT

Land-atmosphere coupling plays a key role in the occurrence of temperature extremes. To understand the influence of soil moisture on temperature extremes over India, we perform sensitivity experiments using the MRI-AGCM3.2 model for the historical (1951- 2010) and future (2051-2100) climate simulations. The simulations consist of a coupled model soil moisture framework (control simulation) as well as wet and dry one month integrated sensitivity experiments initialized by perturbing (increasing/decreasing) soil moisture from the control run. The outcome highlights the underlying impact of soil moisture on temperature extremes over the strong land-atmosphere coupling regions of north-central India (NCI). Dry (wet) sensitivity experiments indicate a significant increase (decrease) in frequency, duration and intensity of pre-monsoonal extreme temperature events over the NCI. The sensitivity experiments show that dry (wet) soil moisture can increase (decrease) the annual average extreme temperature frequency, duration and intensity nearly by 0.77 events, 4 days and 0.6 °C respectively over the NCI. Results from the analysis indicate that the enhanced (reduced) extreme temperature conditions in dry (wet) soil moisture simulation are caused by the intensification (abridgement) of conductive heat flux by limiting (intensifying) available total energy for evaporative cooling due to faster (slower) dissipation of positive soil moisture anomalies (also called as soil moisture memory).

Assessing the Climatic Drift of 40 years meteorological parameters over Vidarbha region using the RClimpact2 R-package

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ABSTRACT

This study aimed to analyse the temporal trends in extreme indices of climate variables for Vidarbha, Maharashtra. Vidarbha is the northernmost portion of the Deccan Plateau. Agriculture is the mainstay of the Vidarbha region. Various factors influence agricultural production, but climatic variables (precipitation and temperature) have the most significant impact. Due to the effects on agricultural productivity, many farmers in the Vidarbha area are committing suicide. The Vidarbha region's climate variables data were collected from 1980 to 2019 in the Indian meteorological department data portal. During the research period, data on aerosol optical depth (AOD) is collected from MEERA-2. This data is being used to examine the link between extreme indices and AOD. Climate extreme indices are calculated using RClimpact2 R-package software on 40 years of daily precipitation and daily maximum and minimum temperature data. The trends and slope changes in climatic indices were investigated using the Mann Kendall test and Sen's slope estimator. Temperature extremes indicators in this region, such as summer days (SU), tropical nights (TR20), warm evenings (TN90p), hot days (TX90p), and warm spell periods (WSDI), are rising, indicating a pattern toward warmer temperature extremes. For precipitation, extreme indices such as consecutive wet days (CWD) are found the decrease, consecutive dry days (CDD) increasing, extremely wet days (R99p) decreasing and simple daily intensity index (SDII) decreasing trend during the study periods. In this study, we also used the Climatic Research Unit (CRU) Google Earth interface for land temperature data and its long-term change (1875 to 2018). This analysis found that the temperature anomaly increases during the 21st century above 0.4°C in the Vidarbha region. As a result, the findings of this study, along with future climatic projections from the climate model, will be helpful for future planning and management for agricultural, water resource problems, and urban expansion.

Keywords: AOD, Climate change, Precipitation, Temperature, RClimpact2.

Impact Based Forecasting over Mumbai – Computation of Impact Matrix at City Level for Heavy Rainfall Events during SW Monsoon 2020; A Preliminary Study and Observations.

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ABSTRACT

The capital of the state of Maharashtra, Mumbai, a mega polis and the financial capital of India has been experiencing floods with increased periodicity. Mumbai is also one of the most vulnerable cities often affected during monsoon. Urban Flooding in Mumbai especially during extreme rainfall events, almost bring the city to halt, thereby severely affecting its economic and other aspects. In order to aid the mitigation activities of flood prone Mumbai and to provide early and effective warnings, Impact Based Forecasting System was initiated during Monsoon 2020 along with Integrated Flood Warning System (I - Flows Mumbai) .

In the present work an attempt has been made to develop an impact-based risk matrix for Mumbai for heavy rainfall events. Rainfall Data of Mumbai from past 30 years (1990 -2019) were analyzed to assess the high impact events. Disaster data available from NDMA, Mumbai Municipal Corporation and were also analyzed. Around 75 past flood events of different severity were analyzed to assess the various impacts in the city. Rainfall data was correlated with disaster data. Cumulative effect from past 5 days rainfall as well as individual heavy rainfall days were analyzed to find the potential impacts. Vulnerability zones and potential damages in the area were identified. Fixed thresholds of rainfall were set for different scenarios and different vulnerable areas. Impact matrix was finally prepared by correlating hazard and rainfall data. The present work also describes setting up of the observational network for Mumbai (Mumbai Mesonet) with field data of from more than 130 rain gauge stations setup by IITM, IMD and MCGM) for real time weather information, formulation of SOP and implementation of IBF in experimental mode, operational scenario, challenges and future scope of the system. The present case study describes lessons learnt in operation of the system during monsoon, verification of the system with field data and its applicability for providing effective advisories.

Keywords: Impact based weather Forecast,Flash flood and urban flood, Mumbai, IFLOWS .

CLIMATE CHANGE IMPACT AND VARIABILITY IN HEAVY RAINFALL

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ABSTRACT

With the change in climate, we are experiencing extreme weather events such as heat waves, droughts, heavy rainfall, floods, cyclones etc. The entire ecosystem has been affected and sectors like agriculture, health, infrastructure etc. are facing serious consequences.

In this paper, heavy rainfall events over Delhi during the month of July and August have been studied and the possible reasons for the occurrence of heavy rainfall over Delhi are examined. To do that, the cases of heavy rainfall events over Delhi for last 5 years have been considered. The rainfall data of Delhi during July and August, synoptic conditions, satellite images and wind patterns during the events have been examined.

Through the examination, it has been concluded that the shifting of Monsoon trough from south to north, presence of cyclonic circulation over north Rajasthan and neighborhood or trough in westerlies are the prominent features which causes the heavy rainfall events over Delhi.

The study is further extended to analyze the number of days of heavy rainfall with their intensity and it can be concluded that the number of light rainfall and moderate rainfall days are decreasing, while the number of extreme events (heavy and very heavy rainfall) are increasing. But total rainfall during the monsoon season has remained largely unchanged. It means rainfall is erratic. It has been also observed that the rainfall spread is not uniform throughout the days but rains heavily in shorter duration (of 3 hours) which may result in flash floods that further leads to water logging and traffic jams.

The study may prove to be beneficial in controlling the impact due to extreme impacts and reducing the vulnerabilities at large by issuing very realistic impact-based forecasts for extreme weather events.

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Analysis of extreme rainfall events 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 influenced the flash flood risk over the Teesta river basin (TRB). This study presents the impacts of extreme precipitation event on flood situation over the TRB in present and future scenario using different extreme indices like Extreme precipitation index (EPI), Standardized precipitation index (SPI) and Rainfall Anomaly Index (RAI). Also, evaluated the return period of extreme rainfall using Generalized extreme value (GEV) distribution theory. Evaluated extreme indices were calculated and compared using observed as well as historical and projected ensemble Coupled Model Intercomparison Project 5 (CMIP5) for RCP 8.5 scenarios. 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 of extreme precipitation event in both observed and projected 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 value (GEV)

Lightning and its relationship with aerosol and different climatic parameters

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ABSTRACT

The impact of aerosol, CAPE (Convective Available Potential Energy) and Relative Humidity (RH) on the lightning flash rate are investigated using data from lightning flash rates, aerosol optical depth (AOD), surface relative humidity, and Convective Available Potential Energy for the years 1998–2013 over India (8°4′ to 37°6′N and 68°7′ to 97°25′E). The given datasets are analysed to track seasonal variations and the correlation of the parameters with lightning over a specified time period. The lightning flash have been observed by the Lightning Imaging Sensor (LIS) on the board of the Tropical Rainfall Measuring Mission (TRMM) and CAPE from ERA Interim monthly/annual climatology. The spatial distribution of the parameters reveals that when CAPE increases there is the significant rise in the lightning activity over most of the regions. Maximum lightning activity is observed in Pre-monsoon season (March, April and May). The data demonstrate a positive correlation between lightning flash rate and CAPE (r = 0.993), AOD (r= 0.533), and RH (r = 0.802).

Keywords: Lightning, CAPE, RH, AOD.

IS THERE ANY CLIMATE CHANGE IMPACT OVER KOLKATA (INDIA)?

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ABSTRACT

To find out the climate change impact on Kolkata this study has been undertaken. Here the temperature, rainfall and thunderstorm data for the period 1969-2020 have been analysed. It is found that there is no significant impact of climate change on maximum temperature, rainfall and thunderstorm. Though this study reveals that there is an increase in the overall annual mean temperature in this city but that is due to the significant increase in the annual mean minimum temperature. The rise in annual mean minimum temperature can be attributed to the rapid urbanization and urban heat island effect and not to climate change. So in a nutshell climate change have less to nil impact on the climatic parameters in this city.

Key Words: Climate change, Urban heat island, M-K test, Kolkata.

Analysis of rainfall over homogeneous region of central India in the month of August.

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ABSTRACT

Percent departure of monthly rainfall of August from 2006 to 2020, over homogenous regions of central India comprising the meteorological sub-divisions and States of Odisha, Madhya Pradesh, Gujarat, Maharashtra and Chhattisgarh are considered for the study. Rainfall (percent departure) data and number of low-pressure systems (LPS) are collected from Mausam Publication. IMD's definition for meteorological homogenous regions with respect to percentage departure from the normal rainfall is considered, *viz.* large excess (LE) i.e.+ 60% or more, excess (E) i.e. + 20% to +59%, normal(N) i.e. + 19 % to – 19 %, deficient (D) i.e. 20% to – 59%. The Central India showed huge yearly variation (from -41% to +62%), in the 15 years of study period there were 1 LE (2020), 2 E (2006, 2019) and 3 D (2009, 2015 and 2017) years. The inter-monthly variation during the years was studied, rigorously, in this study. Monthly rainfall over central India in August 2020 was the highest in the last 120 years (1901-2020) followed by 2006 (IMD, 2020) and 2019 being the fourth highest rainfall year. The frequency of LPS and rainfall shows number of LPS are directly proportional to the distribution of rainfall.

Keywords: Southwest monsoon, Rainfall, Homogenous region, Central India, Low pressure systems.

AEROSOL-CLOUD CHARACTERISTICS OVER A TROPICAL COASTAL REGION- KERALA, DURING TWO EXTREME CLIMATIC EVENTS

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ABSTRACT

The aerosol that is increasing at an alarming rate is a major environmental hazard in the Asian monsoon regions affecting the monsoon water cycle. The effects of aerosol and the possible interactions with the monsoon dynamics remain largely unknown. Hence, a better understanding of the interaction of aerosols on the monsoon water cycle is supreme with huge science and societal benefits. The current work investigates the aerosol distribution over the Kerala landmass on two distinctly contrast periods of 2016 and 2018. The year 2016 was a year of minimum precipitation and 2018 was a period of extreme precipitation that leads to devastating floods in the region of study. Kerala land mass situated in the southernmost tip of the Indian peninsula is entirely covered with the Arabian Sea on the Western part and the Western Ghats on the Eastern part. The landmass now faces adverse effects of climate change in terms of flash floods and unprecedented droughts. The work analysis the aerosol and cloud characteristics during two extreme events-drought and flood. The current investigation will reveal the aerosol and cloud morphology, distribution and possible mechanism that would have prevailed for the surplus rain in 2018 and the extreme drought in 2016 by analysing the CALIPSO data.

Keywords: Aerosol, Cloud, Flood, Drought

MERRA-2 reanalysis maximum temperature datasets validation using 35 years of IMD observations

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ABSTRACT

Since industrialization, a noticeable increase in atmospheric GHGs emissions raising the surface air temperatures. Therefore, analysis and monitoring of surface temperature on regional and global level has gained importance. The Modern-Era Retrospective analysis for Research and Application Version 2 (MERRA-2) maximum temperature are validated against the Indian Meteorological Department (IMD) observed datasets. Analysis has been carried out for 35 years (1981-2015) over India and its different zones i.e.,Western Himalaya (WH), Northwest, North Central, Northeast (NE), West Peninsula India, East Peninsula India, and South Peninsula India. Robust statistics such as R2, RMSE, and MAE have been used for the validation of TMERRA-2 against TIMD monthly, annual and seasonal datasets. Statistical analysis of monthly TMERRA-2 and TIMD indicates good correlation for all the zones of India.Whereas seasonal analysis shows por correlation over hilly zones i.e.,WH and NE especially during monsoon season. Monthly percentage bias indicates overestimation of TMERRA-2 against TIMD for all the zones i.e., NW (4.1%), NC (2.4%), NE (1.6%), WPI (0.5%), EPI (0.2%) and SPI (0.8%) except WH where an underestimation by -82.5% is determined. This may be due to sparse network, cold climate and heterogeneity in their topography. The results demonstrate the importance ofMERRA-2 dataset, which can be thus utilized to study extreme temperature events over India.

Keywords: Validation, PBIAS, RMSE, Temperature

A case study of flash flood event in Jaipur city during SW monsoon 2020

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ABSTRACT

An extremely heavy rainfall event occurred in semi-arid parts of Northeastern Rajasthan in late 13^{th} August-14th August, 2020. The Jaipur and Bharatpur division of eastern Rajasthan were adversely affected, with highest accumulated station rainfall 250mm in 24hrs observed at Jamwaramgarh in Jaipur district. The heavy rainfall led to the flashflood in capital city Jaipur, which resulted about ten numbers of fatalities and huge loss of properties. This extremely heavy rainfall event in Jaipur city will be recognized as unique event, as it occurred without presence of monsoon low/depression system in Rajasthan. The synoptic features, IMD GFS model forecast, radar, satellite products have been analysed. Dynamical parameters Vorticity, convergence/divergence have also been analysed at three hour intervals by using ECMWF reanalysed data. Study reveals that the presence of low pressure area over North Coastal Odisha & adjoining Gangetic West Bengal area on 14th August strengthen the easterly wind component and resulted high moisture incursion from Bay of Bengal across East & central India. The normal position of trough line extending upto 0.9 km above mean sea level and an embedded cyclonic circulation over south Haryana & neighbourhood with vertical extention 1.5 km above mean sea level leads convergence over Northeastern Rajasthan on 14^{th} August morning enhanced unstability over the region. The vorticity enhances by $20\times10{-}6\ sec{-}1$ over small parts of NE Rajasthan and adjoining areas at 00Z of 14th August. The embaded cyclonic circulation slightly moved SE ward to its original position during the 21Z to 06Z period. The cycer weakened into North-South trough around 06Z of 14th August. The strong Southwesterly winds in the lower levels from Arabian sea also incurred moisture over the region and results extremely heavy rainfall over Jaipur.

Keyword: Extremely heavy rainfall, Flashflood, vorticity, divergence.

Development and Implementation impact based heavy rainfall forecast in Rajasthan

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ABSTRACT

The north-western state of Rajasthan is the largest Indian state which comprising of the 11% of the total geographical area of the country. The state is divided into east & west Rajasthan meteorological subdivisions, having 603mm & 265mm normal rainfall respectively during monsoon season. East Rajasthan is more prone to heavy rainfall events than west Rajasthan. Generally heavy rainfall events are associated with monsoon depression systems or Mid Tropospheric Cyclone during monsoon season in the state. However, occasionally it has also been observed that extremely heavy rainfall may occur without the presence of the low pressure area nearby the state. Impact based heavy rainfall forecast has been introduced by Meteorological centre Jaipur from monsoon season 2020 onwards. Geographical, physiographical, socio economical, vulnerability and climatological data have been collected and analysed for all 33 districts of the state. The study reveals that the impact of heavy rainfall is different in different parts of the state due to the diverse nature of the surface. The significant flood events and their actual impacts reported during past ten years have also been analysed and presented here. Based upon geography, physiography and climatology, all the districts have been divided into five homogeneous regions namely Hadoti, Eastern plain, Aravali, western desert plain and western desert. Region wise impacts of heavy rainfall have been listed and implemented for day to day weather forecast and warning.

Keyword: Monsoon, heavy rainfall, impact of heavy rainfall.

Operationalization of district level Impact Based Forecast for Heavy rainfall over Goa - Outcomes and scope of improvement

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ABSTRACT

Study shows in an effective disaster management system, knowledge of just the weather forecast has become insufficient for reducing the damages to lives and properties, because the threshold of heavy rainfall for hazards is changing every time and sometimes becoming lower than previous occasions. In these scenarios, IMD is trying to rise to the occasion and provide to disaster managers, impact based forecast for districts of a state by which adding more value to the process of disaster management. This work shows the methods adopted by Meteorological Centre, Goa for implementation of operational impact-based forecast for the districts of Goa.

The requirements for impact-based forecast are answers to three questions- what, where and when. understanding what are the possible impacts for a region, identifying which all are the vulnerable locations and finally deriving a correlation between the occurrence of hazard, quantum of rainfall along with other parameters so that the forecaster can predict when a hazard will take place. This involves collection of past data regarding hazards related to heavy rainfall and collecting information on possible reasons which led to the event including rainfall, high-tide timings, water level in neighbouring rivers, canals etc. For this purpose, logs maintained by Directorate of Fire & Emergency Services, Goa was collected for the past years. Different types of heavy rainfall related hazards were listed from this data and media reports. Hazards or impacts were divided in to different categories based on their severity. Then the probability of occurrences of these impacts in relation with district and state wise heavy rainfall was studied. A basic level correlation was identified between occurrence of hazards and heavy-very heavy extremely heavy rainfall events.

This works mentions the method followed for operationalizing impact-based forecast for the districts of Goa. It describes the evolution of impact-based forecast from Paradigm 2 to Paradigm 3 of WMO standards, by taking case studies of heavy rainfall episodes over Goa. Though there is a lot of room for improvement, it meets the operational requirements and suggests methods to improve the quality of impact-based forecast in an operational point of view. It also points out the challenges that an operational forecaster would face as he or she upgrades the regular forecast statements from paradigm 1 to paradigm 3 of the standards, which WMO has set for Multi-hazard Impact-based Forecast and Warning Services.

Keywords: Impact based weather Forecast, Goa, Flash flood and urban flood,

IDENTIFYING AGRICULTRAL DROUGHT USING PROBABILITY VEGETATION VULNERABILITY INDEX IN PAMBAR - KOTTAKARAIYAR RIVER BASIN

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ABSTRACT

This study examines the agriculture drought using Probability Vegetation Vulnerability Index (PVVI) with the help of Vegetation Health Index (VHI) in Pambar-Kottakaraiyar Basin. MODIS NDVI and LST data were used to identify Vegetation Condition Index (VCI) and Temperature Condition Index (TCI). Both VCI and TCI results were combined to develop the Vegetation Health Index (VHI). VHI is divided into extreme, severe, moderate, mild and no drought. The probability (%) of events in each class is calculated with the weight of each class and varies from 0 to 40 based on drought intensity. Finally, PVVI was calculated by summarizing the values obtained from each drought classes. The VHI result indicates that extreme and severe drought was noted in R.S Mangalam block occupies 37.94 sq.km and 131.12 sq.km respectively. Moderate and mild droughts were found in Thiruvadanai, Kalayarkovil block in the study basin. The PVVI results shows almost entire study area is in drought but extreme drought conditions are noted in 18 blocks out of 27 blocks. So, proper management practices for drought like consumption of water, cultivating the rainfed crops, rainwater harvesting methods should be thoroughly practiced to reduce the effect on agricultural drought.

Keywords: agricultural drought, NDVI, VHI, PVVI

How well Indian High-Resolution Regional Reanalysis represents Extreme Rainfall Events over Northwest India?

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ABSTRACT

Northwest India, known as breadbasket of the country, is extremely vulnerable to ramifications of extreme rainfall events (EREs) such as flash floods, landslides, agricultural and infrastructural damages, including significant loss of human and animal lives. Nevertheless, the characteristics of EREs are less explored over Northwest India compared to other parts of the country. Hence, this study investigates the spatio-temporal variability of monsoon EREs using the India's first highest resolution regional atmospheric reanalysis, Indian Monsoon Data Assimilation and Analysis (IMDAA) for the period 1979-2018 during Indian Summer Monsoon (ISM). Before studying the EREs, we critically evaluate the IMDAA's ability to represent ISM mean characteristics using global reanalysis and observations.

Our analysis reveals that IMDAA realistically represents the ISM salient features along with better spatial distribution of summer precipitation compared to IMD but with some overestimations over most regions of the country. The mean ISM precipitation over Northwest India is observed to be increasing (significant at 95% confidence level) in contrast to non-significant trends reported by previous studies. EREs from IMD, IMDAA and TRMM exhibit increasing trends over Northwest India with IMDAA showing significant increasing trend in widespread EREs (one event every two years) over the region. Furthermore, increasing (decreasing) trend in CAPE (CINE) indicates that the atmosphere over Northwest India during monsoon is becoming more unstable. This enables it to hold more moisture which is transported to the region from Bay of Bengal through cyclonic vorticity over Central India. Finally, the correlation analysis reveals that IMDAA reanalysis has succeeded in better representation of the physical linkages between moisture availability, instability, and convective precipitation formation over Northwest India compared to ERA5.

Keywords: Indian Summer Monsoon, IMDAA, Extreme Precipitation Events, Northwest India

Indian Monsoon extreme rainfall events and their spatial extent and recent changes

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ABSTRACT

Indian summer monsoon rainfall plays a crucial role in the development and economic strengthening of the Indian subcontinent. However, extreme rainfall events (ERE's)hinder this development and destroy available resources. In our study, ERE's were identified when the rainfall received per day exceeds 150 mm/day and 99% percentile value compared to the base period (1981 - 2010). The study identified ERE's throughout India from 1901 to 2020. The composite analysis of ERE's manifests the extensive presence of ERE's throughout India except for the leeward side of Western Ghats. Few clusters in Northeast India, Southeast India and Northwest India were identified as pockets of extremes. The intensity of ERE's in India during a later period (1981-2020) has increased compared to the early period (1901-1930) over the foothills of the Himalayas, west coast of Peninsular India, except few regions of Kerala. The ERE's in central India does not have a homogeneous trend. The variability of ERE's in Central India might be due to the variability in the development of convective clouds. The study identified a spatial extension of ERE's for a greater extent in the later period than in the early period. The ERE's extend to those areas such as Jammu and Kashmir and Southeast India, which sparingly experienced extremes in the early period but became usual in the later period. Thus understanding the spatial extension of ERE's is necessary for developing disaster management strategies for localities.

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ON DELAYED MONSOON BUT 121 YEARS RECORD BREAKING RAINS OVER DELHI-CAUSES, IMPACTS, ISSUES AND CHALLENGES OF PREDICTIONS

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Delhi's city proper population was over 11 million, 2nd highest city after Mumbai while the whole NCT's population was about 16.8 million. Like any major urban city, monsoon variability covering tis advance, heavy rainfall days and monthly and seasonal totals of rainfall play a very important role in day to life of common public, Govt pre-season preparation to manage recently emerging urban flash floods, better managing such situations, and drinking water and power distribution and storage plans and implementation time to time. In the present study, we have used data of daily rainfall of city of Delhi available for longer period at Safderjung and Palam airport for 1901-2021 and 1959-2021 respectively to compared unusual features of monsoon advance and Rainfall occurrences in monthly total rainfall amounts and in number of rainy days, heavy rainfall days etc, as observed in 2021 with those 1901-2021(1959-2021). Also, their trends have been analyzed to find impact of climate change and global warming as discussed in IPCC AR6. In monsoon 2021, preliminary analysis for 2021 monsoon shows Delhi has experienced following unusual monsoon conditions **a)** A delayed arrival on 13 July with 17 days delayed, the most delayed after 2002(19 July), and 3rd most delayed monsoon in last 61 years of monsoons in 1960-2021, with 1987 as the record most delayed with 27 July followed by 14 July both in 1987 and in 1991 **b)**As per Safderjung airport data, very low June month total rains of 3.48 cm, an excess July with 50.71cm, a normal Aug with 21.45, but an unusually record breaking rains in Sept 2021 with 41.3cm, 2nd highest after 1944, just 4mm shortage to break of last 121 year sept record, was observed and so also season had a total of 118cm, a highest in last 57-years among all monsoons since 1964(it was 119.09cm in 1964) **c) A** Highest heavy rainfall days of 7 and 8 in the season of 2021 monsoon over both airports respectively in last 121 years, which was after, 1964 when 6 days was reported. We have studied features those caused unusual delay of monsoon advance in 2021 to Delhi on 13 July We also have analyzed causes of 7 heavy rainfall events and their characteristics by using all 20 number of stations daily data for 2021 which IMD gets as DRMS.

Keywords: Impact based forecasting, heavy rainfall, southwest Monsoon

RECORD BREAKING HEAVY RAIN DAYS OVER DELHI IN 2021-DEVELOPMENT OF INTEGRATED URBAN MET SERVICES AND IMPACT BASED WARNING (CONCEPT, METHODOLOGY AND KEY MESSAGES)

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ABSTRACT

For a city like Delhi, a timely monsoon advance, though reduces chances of late June heat waves developmental impact, but an excess monsoon increases suffering of the people and impacted their lives severely, in terms of increasing travel time across sleeper and flooding roads and underpasses as short term impacts, which then compounds with longer term impacts followed by higher mosquito borne diseases like Malaria and Dengue.

In the recent 2021 monsoon, analysis of rainfall data shows Delhi experienced a total of 7 to 8 number of heavy rainfall days and highest in the last 121 years and also their impacts were unusually high(See twitter **#DelhiRains**). In this paper, we have analyzed meso- characteristics of all 8 heavy rainfall events of Delhi using data of 18 stations. We also have collected their area wise impacts and provided in-depth insight of areas of Delhi vulnerable to occurrences of heavy rainfall events in 2021. Rain data of Safderjung and Palam available daily since 1970 used to determine rainfall thresholds based IBF color code. Socio-economic exposure and LULC data with type of hazard occurrences(flash flood types Inundation, underpass flooding) and impact information at very high resolution are collected since 2010, to develop threshold based risk Matrix as well as impact types. Then, we propose overlaying of each of these data and information in GIS based high resolution map and their integration into the recently operational Web based "Urban met services of Delhi/NCR" of IMD at https://mausam.imd.gov.in/Delhi/, to develop and implement **a stage III and Stage IV of IBF.**

Keywords: Impact Based Forecasting, Integrated Urban Met Services, Heavy rain

IMPACT BASED WEATHER FORECAST AND WARNING SERVICES IN INDIA 2019- 2021: PROGRESS AND PERFORMANCES

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ABSTRACT

Study shows over the period, improvement of forecast and warning skill of any severe weather event alone, are not sufficient enough, to minimize damage to lives and property. Hence, it is becoming urgent for the countries to make the transition from focusing not only on the accuracy of severe weather event or a hazard-based forecasting to also outlining the potential impacts of a forecast in terms of risk based warning (RBW)(low, moderate and high risk) to various exposures– an evolution from "what the weather will be" to "what the weather will do." IMD was already providing impacted based forecast(IBF) and RBW upto coastal district level during tropical cyclone landfall periods and post land periods, using its longer period associated Hazard, exposure and vulnerability. From Aug 2019, IMD started implementing IBF and RBW at real time for various severe weather events and associated hazards for which country is vulnerable covering Heavy rainfall, Thunderstorms, heat wave, cold wave, etc. Presently, it is using threshold based severity of the various severe weather events determined from its past data and associated hazards and impacts at met sub-division wise. In monsoon 2020, such IBF and RBW services were made available operationally at 25 major capital cities. In the current monsoon season of 2021, scope of this IBF and RBW was further expanded for districts with collections and layering of exposure(LULC, socio-economic, etc), hazard, Vulnerability, and impact data and already, it had completed data collection for around 475 districts and 25 cities across India for which Risk matrix computations are in progress. Flood inundation, Exposure and impact from I-FLOWS and C-FLOWS and SA FFGS, Landslide impact from GSI are routinely in use to add impacts in IMD BF warnings. International collaboration under WCSSP INDO UKhttps://www.metoffice.gov.uk/research/approach/collaboration/newton/index in Hard forecasting and IBF also in progress since 2019. For cyclone related hazards WEB DCRA-DSS Tool was developed jointly with NDMA and operational at IMD since May 2021. For Heat Wave, Work to implement heat action plan for 100 cities as part of IBF are in progress. Present paper reviews various scientific approaches and stages of Development followed by IMD and other developed countries for various severe weather events. It also discusses performances of IBF, guide lines and SOP issued and implemented by IMD from time to time for 2019-2021.

Keywords: Impact based forecasting, Weather Warning Services

IBF FOR HEAVY RAINFALL DURING MONSOON 2020 AND 2021: PROGRESS, PERFORMANCES, GAP AREAS AND ROAD MAP

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IMD has been issuing Impact based forecast (IBF) and Risk based warning(RBW) for heavy rainfall events for monsoon 2020 and 2021. It has adopted threshold based severity of the event of IBF for heavy rainfall impact determined from past data based upon their associated hazards and impacts at met sub-division wise and city levels and likelihood of heavy rainfall event are determined from various NWP model based consensus(Stage-I method). In monsoon 2020, such IBF and RBW have been made available for around 25 major capital cities and for some district of Kerala and Gujarat. For this, SOP of IBF with four stages warning system adopted in Aug 2020. In the current monsoon season of 2021, scope of this IBF and RBW have been further expanded to implement experimentally at district level with utilization of larger data pool covering Hazard, exposure, Vulnerability, and impact data available with IMD, State Govt as well as with other central Gove offices. Till Sept 2021, IMD has got climate and extremes, hazards, vulnerability, exposure (socio-economic and geo-physical) and impact data for about 550 districts and 25 cities across India for which Risk matrix computations are in progress. In terms of hazard and impact models, IMD currently using inundation area and depth and likely impact severity with exposure already in-built from I-FLOWS and C-FLOWS operational for Mumbai and Chennai, which was jointly developed in collaboration IITM Pune, NCRWF and NCCR Chennai and city municipality admin. Similarly, for district based likely flash flood dynamical forecast,FFGS products are presently tested, while for its landslide impact, GSI land slide model products are currently in use at test mode basis for Uttarakhand and Kerala. In the present study, IBF and warning issued in monsoon 2020 and 2021 during various extreme heavy rainfall spells at various parts of India both by NWFC and MC/RWFC including their Impacts and performance have been discussed using observed rainfall data of IMD and impact data from SDMA and media.

Keywords: IBF, HEAVY RAINFALL, MONSOON

Synoptic features responsible for rainfall characteristics during Leh flash flood using High Resolution IMDAA Reanalysis Data

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ABSTRACT

Flash flood resulting from extremely heavy rainfall over Leh during 02–06 Aug 2010 was hazardous. The resulting flood killed more than 250 individuals, migrated thousands and destroyed the public property. Leh is a high-altitude valley located in the Ladakh region of Jammu and Kashmir. Majorly, rainfall over the region occurs by convection followed by orographically locked system. Such systems are responsible for producing heavy to very heavy rainfall over this region.

The present study is conducted to investigate atmospheric conditions during the Leh flood 2010 using the Indian Monsoon and the high-resolution reanalysis(IMDAA) data set. The wind climatology at the 500hPa shows/showed the westerly split flow pattern with weakening of northern branch. However, the 500-hPa geopotential height field showed a progressive northeasterly jet leading to the perturbed environmental conditions. By 5th August 2010, jet at 500hPa pointed directly at Leh region, causing the development of the Mesoscale Convective System over the region. These MCSs propagates over the high terrain of the Tibetan Plateau and then move over the steep Himalayan faces where they became strengthened by the moist flow. Detailed results attributed to the casual mechanisms altering the atmospheric conditions will be discussed.

Key words- Extreme Rainfall Event, Flash Flood, Mesoscale Convective System

Why extremes of rainfall over Konkan and ghats of Madhya Maharashtra ?

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ABSTRACT

In Maharashtra heavy rainfall zones lies over the districts of Konkan region, while extreme heavy rainfalls occur over a few districts of northern latitudes. The data used in this study are the district wise rainfall in millimeters (R/F) during monsoon season (June to September). The rainfall data for last 5 years from 2016 to 2020 were considered for analysis for monsoon rainfall pattern in the region. In this paper, author's have studied the causes for extremes of rainfall over Konkan and ghat areas of Madhya Maharashtra. For the month of July and August, entire Konkan sub-division showed rainfall above 600 mm in each of the months, might be due to the presence of strong off-shore trough, induced formation of precipitating systems. These system when upstream due to mountain barrier condenses into a deep cloud which later transforms into stratiform clouds giving widespread, isolated to scattered extremes of rainfall, over the coast. An off-shore trough running between Maharashtra and Kerala, often brings moisture laden westerly winds from the Arabian Sea over land resulting in huge moisture incursion. In addition, time to time formation of east-west shear zone cutting across Maharashtra, resulting in favourable vigorous monsoon conditions. Some more reasons for extreme of rainfall over Konkan and ghat areas of Madhya Maharashtra are orography of region over windward side of Sahyadri range creating convergence over Konkan and ghat areas; presence of trough from central India to south Gujarat, north Konkan, packed isobars, presence of MTC(Mid Tropospheric cyclonic circulation) and strong westerlies are also discussed in the paper as causes for extremes of rainfall over the region. The District Rainfall values in millimeters (R/F) shown in Table1 are the arithmatic averages of rainfall of stations under the district during monsoon season (June to September). For past five years 2016-2020, Raigarh district showed the highest value of rainfall (1818.1 mm) and Solapur district showed the lowest value of rainfall (24.9 mm) during monsoon season (June to September). The districts received the highest rainfall are in Konkan and Madhya Maharashtra mostly in July month and the lowest rainfall received districts in September month.

Key words – Extreme rainfall, Konkan & ghats of Madhya Maharashtra, Off -shore troughs, Shear zone, Packed isobars, MTC (Mid tropospheric cyclonic circulation), Orography.

SPATIAL VARIABILTY OF POST MONSOON AND WINTER TEMPERATURE OVER INDIA DURING RECENT DECADES

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ABSTRACT

Understanding the atmospheric variability and pattern has become quite complex considering the present climatic scenarios. The interactions between different drivers of climate, land-surface processes and other dynamical features make it a little difficult for researchers to make out any insightful comments about the prevailing atmospheric conditions. Critical temporal analysis including spectrums doesn't completely explain the spatial patterns of the climate. Thus, since the late 1940s, empirical orthogonal functions have become an important part of meteorology that is widely used to decompose the space-time fields into spatial patterns and the corresponding principal components that can be analysed to study the spatio-temporal trends, enhancing our knowledge about the atmosphere. Here, the EOF method has been utilised to study the winter (JF) decadal temperature patterns (for maximum and minimum temperature) of IMD dataset for the duration of 40 years spanning 1979-2018. The colder region is observed to be gradually engulfing the Indo-Gangetic plain area for OND, where the spread is relatively greater for minimum temperature as we move to recent decades. Higher variability in the Indo-Gangetic Plain area is observed for the maximum and minimum temperature of JF as we move towards the recent decade. The 3rd and 4th decades show greater variance accumulation compared to the 1st and 2nd decades for winter season. The spatial patterns explained in the research could thus, pave a way to understand the wintertime temperature variability over the country and also facilitate future scientific works to better understand the associated circulation features.

Keywords : EOF, Principal components, post monsoon, winter, Indo-Gangetic Plain

Changes in ENSO-Monsoon relationship and associated changes in circulation patterns on Multi-decadal time scale

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ABSTRACT

The All-India summer monsoon rainfall (ISMR) is defined as the rainfall received during June to September over India. The ISMR plays a vital role on both the agriculture as well as economy of Indian subcontinent. The ISMR is showing different variabilities on spatio-temporal domain and these variabilities arise from both internal and external feedbacks. The SST over the equatorial east and central Pacific Ocean related to ENSO phenomena has a general inverse relationship with ISMR. Recent studies found that a multidecadal variability between ISMR and ENSO due to concurrent variations in meridional temperature gradient over the tropics at upper troposphere. The objective of the present study is to explore how the ISMR - ENSO relationship vary on the multidecadal timescale and their possible connections with circulation features. Which of the Indian regions will get effect from the multidecadal variability of ENSO? The datasets used for exploring the decadal variabilities of ENSO-Monsoon relationship includes HadlSST1 (1^0 x 1^0), IMD rainfall data (1^0 x 1^0), CRU precipitation data (0.5^0 x 0.5^0) for the period 1901 to 2015. To explain the physical mechanism responsible for the variability we utilized NCEP–NCAR (2.5^0 x 2.5^0)reanalysis wind, vertical velocity and specific humidity datasetfor the period 1948 to 2015.

We divided the entire period into three 1931-1960, 1961-1990 and 1991-2015 based Nino3.4 index and ISMR relationship. We understood that the ENSO-ISMR relationship is subjected to variations in these three epochs. The early period was wet but the middle and recent decades are relatively dry. The occurring of El-Nino is increased during the recent decades. The ENSO phenomena are mostly effecting to the Monsoon Core Zone. The correlation among the Nino 3.4 SST and Indian summer monsoon rainfall is more during the middle period. Even though, the number of La-Nina is more, the El-Nino has more strength during this period. During recent periods, the La-Nina condition is prevailing and it contributes more rainfall to the southwest coastal regions. The effect of La-Nina was more on that period accounts for the surplus rainfall over the most regions of Indian landmass. The drying of Northeast region

cannot be linked with Nino 3.4 SST. The physical mechanism of the variability is explained on the basis of changes in circulation features. The weakening of Low Level Jet during the recent decade can be a reason to deficit monsoon rainfall during recent periods. It is evident that the reduced moisture transport also accounts for the reduced precipitation. The changes in Walker and Hadley circulation during the three periods were also studied.

Keywords: Enso-monsoon, Circulation, Multidecadal time scale

WHY SUMMERS OF 2020 AND 2021 OF INDIA HAD RARE RELIEF FROM HEATWAVES?

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ABSTRACT

During summer, heatwave (HW) episodes in India have severe impact on human lives, livestock and agriculture. Therefore, in coordination with NDMA and other state agencies, IMD implemented a heatwave monitoring and early warning system at city and district levels since 2019. Surprisingly, during summer of both 2020 and 2021 substantially a smaller number of heatwave days were reported by various states and their impacts. In the present study, we collected met sub-division wise heatwave days for last 5 years (2017-202) using data from FDP-report of 2017-2020 of IMD and heatwave bulletins of 2021. We compared heatwave to severe heatwave days (HWTSHW) for the months of April to June and we analyzed causes of such unusual a smaller number of heatwave occurrences during 2020 and 2021 summer seasons and impacts if any using met data from IMD and impact data as available in NDMA, SDMA reports and also from media. Results show a total number of HWTSHW events in 2017, 2018, 2019, 2020 and 2021 as 195, 147, 352, 82 and 40 respectively with the lowest in the summer of 2021 followed by 2020. Similarly, month-wise data shows, April 2020, June 2020, May 2021 and June 2021 are months of summer when "unusually very low or nil number of days" of HWTSHW were reported as their total monthly values were 7, 1, 2 and 7 respectively against five-year average for April to June as 48.8, 68.2 and 46.2 respectively. Synoptic discussion is also carried out to understand the possible causes for such events.

Keywords: Impact Based Forecasting, Heat Wave

Investigation of thunderstorm frequency and amplitude over northwest India on a climate scale

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ABSTRACT

The tropical region serves as the key player in the convective churning of the atmosphere. Thunderstorms and associated weather features prevail as the significant extreme weather event over northwest India. The hot and dry pre-monsoon period over northwest India also leads to dust storms, drastically reducing the visibility for human outdoor movement. Squalls and hail damage the crops, buildings and destroy life and property. The squall-associated turbulence leads to severe gusty winds over the airports leading to aircraft safety hazards. Knowledge of thunderstorms on a time scale varying from few minutes to 2-3 hours in prior helps in averting irreparable damage to livestock and property. In this study, the thunderstorm occurrence over major stations of northwest India is investigated for 50 years. The analysis was carried to delineate the temporal and spatial thunderstorm shift over northwest India by performing decadal and designated time slicing to understand station and region-specific thunderstorm occurrence. The statistical techniques are also utilized for an improved understanding of the monthly variation of thunderstorm occurrence over the plains of northwest India.

Keywords: Thunderstorm, Squall, Weather, Dust storms.

Impact based Forecast for Heavy Rainfall for Delhi-NCR in Monsoon 2021

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ABSTRACT

India is prone to heavy rainfall nearly all through the year in various parts of the country and over major parts & more frequently during the monsoon season. Occurrence of high monsoonal precipitation event over a much localized area in very short time span has been major cause of damage to lives and properties in India. India Meteorological Department has implemented Impact based Forecast and warning services based on WMO guidelines on Multi-hazard Impact based Forecast and Warning Services. In present study Impact based forecast system for heavy rainfall for national capital Delhi-NCR during the Southwest Monsoon 2021 season has been analyzed.

Keywords: IBF, RWB, DELHI, HEAVY RAINFALL

Observations on IPCC-AR6-WG-I: Scenarios of Indian temperature and rainfall

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ABSTRACT

It is the summary of comments/observations on 9th August 2021 Report "IPCC-AR6-WG-I" submitted to IPCC/UNFCCC/WMO. Don't panic, Fundamentally Climate Change is "Real" however Global Warming is a misnomer. The outcome of 1300 pages IPCC's AR6 is global warming of 1.5°C and 2.0°C will be exceeded during the 21st century but observed "adjusted" global annual average temperature anomaly data series presented a global warming component of the trend of 0.45°C for 1951 to 2100 as per the definition of IPCC; without such adjustments it is 0.0°C only – which is seen in Hyderabad, Sydney and USA temperatures. Indian temperature at state level showed increasing, decreasing and zero trends. 2021 heat-waves recorded around the world are part of local general circulation patterns, like Western Disturbances in India and Circumpolar Vortices-Jet Steams in New Zealand and USA-Canada. Rainfall showed natural rhythmic variations all over the world. However recent droughts and floods were attributed to global warming by UN Agencies, which are not based on facts. All-India annual/southwest monsoon rainfall presented 60-year cycle, which is evident in tree rings study in Brahmaputra River zone for 1309-2004. Water flows in Godavari River and frequency of severe floods in NW Indian Rivers also followed this pattern. However, the two Telugu states rainfall presented different patterns, namely: (i) annual rainfall showed 132 year cycle – water flows in river Krishna followed this pattern; and (ii) seasonal rainfall showed 56 year cycle. Southwest and Northeast monsoons rainfall followed in the reverse order – similar trend was noticed in Australian rainfall. Yearly number of cyclones in Bay of Bengal followed Coastal Andhra Southwest Monsoon Rainfall pattern. Ethiopia rainfall showed two prominent cycles, namely 36 & 28 year, respectively in high-lands and low-lands zones. The recent dry and wet conditions observed in Beira in Mozambique, Durban [Cape Town] in South Africa and Brazil were attributed by WMO and other UN Agencies to global warming a false propaganda as I predicted them in 1984-86 publications itself.

Keywords: Climate Change, Ethiopia, India, Mozambique, IPCC, UN, UNFCCC, WMO.

VARIABILITY OF RAINFALL EXTREMES AND FLOODS OVER INDIA

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ABSTRACT

Indian subcontinent experiences an increase in frequency of extreme rainfall events and floods, during recent decades (post 1950 period) in a warming environment. In this context, a detailed investigation of rainfall extremes and floods have carried out using available datasets. Extremes in rainfall over India have been examined by computing the indices of total rainfall, number of rainy days, daily intensity (SDII), one-day (RX1day) and five-day (RX5day) maximum rainfall, for all the months, seasons and annually, using daily rainfall data. Variations in floods are examined using the data provided by India flood Inventory. Over the Indian subcontinent, annual rainfall and number of rainy days have a spatial pattern similar to each other, whereas the intensity indices of SDII, RX1day, and RX5day have similar patterns. Rainfall extremes occur mainly during the summer monsoon season (contribution of about 70% towards the annual) and has a similar spatial and temporal variation as that of the annual values. The total rainfall and rainy days over all-India and Kerala exhibit a decreasing trend over the years. Whereas an increasing trend in the intensity indices are seen for all-India. For both the regions, all India as well as Kerala, a large variability of the intensity indices are seen during the recent decades particularly after 2000. Flood events also exhibit a spatial pattern similar to that of rainfall extremes, and occur mainly during the summer monsoon season. The heavy rainfall regions of the west coast, east coast, northeast India, and the Himalayan foothills appear to experience a high number of flood events each year. Flood frequency as well as intensity have also shown an increase during the recent decades. In particular, the frequency of floods under severity class 1 has decreased since 2000, whereas the frequency of floods under severity class 1.5 has increased across the Indian subcontinent, including Kerala. Extreme flood events under the category of class 2 have also become common during recent years.

Keywords: Rainfall extreme indices, Floods, Inter-annual variability, Climatology

An investigations on the decreasing trend in surface temperature over Indian subcontinent during pre-monsoon.

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ABSTRACT

Long term global surface temperature anomaly data from various platforms (satellite, reanalysis and global climate models) unequivocally reveals that the Earth is going through an era of global warming. Interestingly regional analysis over Indian landmass reveals a surface cooling trend (~0.5 K decade^{-1}) during pre-monsoon months while a warming signature is observed at higher pressure levels (upto to 300 hPa). Present study is an attempt to investigate various plausible reasons for this anomalous observation. The trend in total cloud coverage area observed from satellite data showed a decreasing trend, while an increasing trend in liquid clouds is observed especially over central and peninsular India. Specific humidity also showed a significantly increasing trend at lower pressure levels. Long term trend in columnar aerosol optical depth (AOD) from various satellite observations revealed a statistically significant positive trend, while trend analysis carried out for various aerosol types retrieved by CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation) revealed a positive trend for absorbing aerosol types (polluted dust and elevated smoke). Aerosol cloud interaction analysis carried out on physically interacting aerosol and cloud layers suggest that dust aerosol can play a significant role in reversing the Twomey effect in case of clouds having low liquid water path. Our observations suggest that although surface temperature shows a decreasing trend over Indian subcontinent, enhanced presence of watervaour and absorbing aerosol types, can trap the energy and warms the atmosphere. This can have serious climate implications which is implicitly reflected in the decreasing trend in Short Wave flux at TOA (SW_{TOA}, Wm^{-2}) and an increasing trend in precipitation observed during June over Indian subcontinent.

Keywords: Climate change, surface temperature, absorbing aerosol types

VERTICAL RAINDROP SIZE DISTRIBUTION OF HEAVY TO VERY HEAVY PRECIPITATION OVER WESTERN GHAT: A CASE STUDY

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ABSTRACT

A comprehensive analysis on the bright band (BB) features of the heavy precipitation occurred during 5th to 10th August 2019at mid (Braemore;8°46′3.24″N, 77°5′39.2″E, 400m above MSL)and high-altitude (Rajamallay; 10°9′19.94″N, 77°1′6.6″E, 1820m above MSL) cloud physics observatories namely MACPO and HACPO respectively, is presented. The simultaneous measurements from the Micro-Rain Radar (MRR), rain gauge and Optical Disdrometer (OD) are used to investigate the raindrop size distribution (DSD) properties of the heavy precipitation during the summer monsoon of 2019. The instruments deployed at both cloud physics observatories, located in the complex mountain terrain of the Western Ghats (WGs), India. During the monsoon period of 2019, at HACPO (MACPO) a total of 4059.8mm (1720mm) precipitation was received, out of which 1151mm (355mm) was observed between 5th to 10th August. Two categories are identified as Bright-Band (BB) and non-BB(NBB) using the vertical profile of reflectivity, rain rate, and fall-velocity. In terms of rain occurrence frequency (5th to 10th August 2019), it is found that the rain over MACPO is primarily contributed by the BB system whereas at HACPO mixture of BB and NBB system contributes. Precipitation characteristics like mass-weighted mean diameter, normalized intercept parameter, shape and slope parameters are calculated using the second, third and fourth moment (moment method) from the observed DSDs. The reflectivity-rain rate (Z–R) relation ($Z = aR^b$) is estimated for both precipitation categories, clearly depicts the microphysical changes in the heavy to very heavy precipitation events and results are summarized.

Keywords: Heavy Precipitation, DSD, Z-R relationship, Western Ghats

Extreme Rainfall Events Over Andhra Pradesh State during Deep depression and Very severe Cyclonic storm Nivar 2020.

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ABSTRACT

Climate change has been the global phenomenon affecting the mankind. The ill effect of climate Change necessitated the research and development in various aspects of global climate change. Extreme rainfall events are a significant cause of loss of life and livelihoods in Andhra Pradesh. Objectives of the present study are to determine the trend of the extreme rainfall events during Deep Depression and VSCS Nivar in 2020. Block level daily rainfall data were used in identifying the extreme rainfall events, while district level aggregation was used in analyzing the trend in three categories, Heavy (64.5-124.5 mm per day rainfall), Very Heavy (124.5- 200.5 mm per day rainfall) and Extremely Heavy rainfall (≥ 200.5 mm per day rainfall) as per the criteria given by IMD. The state on an average received one extremely heavy rainfall, twenty six very heavy rainfall and fifty eight heavy rainfall events for Deep depression from 11th October to 14th October and Six extremely heavy rainfall, Forty two very heavy rainfall and sixty eight heavy rainfall events for VSCS Nivar from 26th to 27th November in Andhra Pradesh in the year 2020. A record of one day rainfall event clearly indicated Four places experiencing extremely heavy rain fall and Kavali block of Nellore district experienced Highest extremely heavy rainfall (270mm) on 27th July 2020.

Key words: Extreme rainfall events, Heavy rainfall, Dynamic features, climate change.

Recent Changes in the spatio-temporal characteristics of Monsoon Intraseasonal Oscillations

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ABSTRACT

Monsoon Intraseasonal Oscillations (MISOs) define a significant proportion of intraseasonal variability of the Indian summer monsoon. In the backdrop of increasing temperatures related to global warming, it is expected that MISOs, which are manifested as active and break spells, would exhibit more spatio-temporal variability, prompting an increased frequency of extreme events. Hence, the present study investigates the observed changes in the characteristics of long (>=7 days) and short (<7 days) active and break spells in the early twenty-first century (2001-2019) in comparison with the late twentieth century (1982-2000).

In the recent period, a decreased (increased) frequency of the short (long) active/break spells along with a strengthening of short spells have been noticed. An east-west asymmetry in the spatial distribution of rainfall is further noted with western India experiencing intensified (weakened) active (break) spells. Contrariwise, the central and eastern parts of the country witness weakening (intensification) of active (break) spell in the early twenty-first century. A comprehensive composite investigation of various dynamical and thermodynamical parameters reveals an increase in the strength of low-level winds in the Arabian Sea, thereby increasing the moisture convergence and instability over the western Indian region and the nearby oceanic regions, resulting in the observed east-west asymmetry in the rainfall spatial distribution. Increased intensity of the equatorial Madden Julian Oscillation and its coupling with the northward propagating MISO spells seems to play a pivotal role in lengthening the active/break spells. It is speculated that such changes are triggered by the amplified temperatures over the global oceans in the recent period.

Keywords: Indian summer monsoon, Monsoon Intraseasonal Oscillations, Madden-Julian Oscillation

STUDY OF MOISTURE RIVER PATTERN ASSOCIATED WITH EXTREME RAINFALL INDICES OVER INDIA

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ABSTRACT

Here, we have analysed extreme rainfall events during the southwest monsoon season for 1979 to 2020 and the prominent moisture river patterns are identified. Over the Indian subcontinent the patterns of narrow currents of lower atmospheric moisture are observed to be influencing daily rainfall indices and the extreme events are closely associated with prominent moisture river. Among the atmospheric moisture transport mechanisms that push water vapour from the far southern parts of the Indian Ocean, moisture rivers are considered significant. For this study we have used daily rainfall data from IMD, wind and humidity data from NCEP and ERA5. The identification of extreme rainfall events done by a criterion based on the standard deviation and amount of rainfall. We have considered only the moisture river patterns from the calculated vertically integrated moisture flux (IVT), which have minimum length of 2000 km and maximum width of 1500 km. Only significant patterns are selected for the study by fixing a threshold percentile value. The spatial distribution of extreme events was observed to be wide spread with some clustering in the west coastal regions and north eastern parts. The highest recorded events of each year with a significant areal spread considered for the Moisture River (MR) analysis. The number of moisture river patterns are increased during the past decade and the paths of the MR apparently coincide with the core of the LLJ (Low Level Jet). In some of the recent extreme rainfall events the presence of the MR is justifying the cross-equatorial flow of moisture from far southern Indian Ocean. The MR is mostly intensified when passing through the Arabian Sea region where the increase in the SST anomaly is stronger.

Keywords: Moisture River, Extreme Rainfall, Moisture Transport

A study using three years of Lightning Data over the PAN India during 2017, 2018 and 2019

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ABSTRACT

Lightning strikes were worst killer among all the natural disasters in India as per the data of National crime records bureau of India (ncrb.gov.in). Lightning strikes major impacts is human deaths and many people who survived after lightning strikes showed symptoms of "memory loss, dizziness, weakness, numbness, and other life altering elements". Lightning strikes impact trees by vaporize water present in the tree into steam and may blow the tree apart (nationalgeographic.com).The present study aims to analyse lightning strokes across the India for the three consecutive years i.e., 2017, 2018 and 2019 respectively. Observance of lightning events determined using installation of lightning sensors and data preparation and analysis done using earth network. Lightning sensors installation increased from 2017 to 2019 and thus accuracy in reporting of forecast for lightning events also got improved effectively. 10 and 8 Lightning sensors installed in states like Karnataka, West Bengal in 2018 respectively, while 6 and 2 more lightning sensors installed in Odisha, Assam and 1 each in Nagaland and Mizoram respectively in 2019. Increase in installation of lightning sensors in West Bengal region improved in reporting of lightning events in West Bengal, Odisha, Jharkhand states mainly in 2018 and as a result we observed increase in number of lightning strokes in Eastern region of India in 2018. Similarly, lightning events were more accurately reported in North Eastern states and Odisha in 2019. Considering such increase of lightning sensors yearly we have incorporated detection efficiency calculation for the cloud to ground (CG) lightning strokes. Major parameters like lightning strokes density, CG and Inter as well as Intra cloud (IC) lightning densities, positive CG and negative CG lightning density, CG by IC lightning events ratios, Average IC lightning heights and total lightning events recorded in each states and union territories of India from 2017 to 2019 were reported in this study respectively.

Keywords: lightning, Cloud to ground, Earth Networks

INFLUENCE OF CONVECTIVELY COUPLED EQUATORIAL WAVES AND BOREAL SUMMER INTRASEASONAL OSCILLATIONS ON HEATWAVES OVER INDIA

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ABSTRACT

The heatwave is a major concern due to its disastrous effect on various sectors such as health, agriculture, infrastructure, environment, etc. Hence, predicting these events is vital for reducing losses and managing resources, and this mainly depends on an understanding of the factors that modulate these events on different time scales. In particular, understanding and prediction on sub-seasonal time scales are beneficial for decision-makers. In this study, the effect of tropical intraseasonal oscillations like convectively coupled equatorial waves (CCEWs) and Boreal Summer Intraseasonal Oscillation (BSISO) in modulating heat waves occurrence over India is explored. The effect of CCEWs like equatorial Rossby wave (ER), Kelvin wave, mixed Rossby gravity waves along with tropical depressions (MT), and Boreal Summer Intraseasonal Oscillation (BSISO) on extreme heat events during pre-monsoon months of April, May, and June are explored. It is shown that these oscillations have a significant effect on modulating extreme events, and the extent of modulation is highly dependent on the type and phase of the waves and varies spatially. The maximum effect is observed in the case of ER with dry (wet) phase increasing (decreasing) the frequency of heatwaves throughout the country. The frequencies of heatwaves are found to almost double when the positive phase of ER and BSISO prevails. However, during the negative phase of ER and BSISO, the whole region shows a decline in heatwaves with frequency reduced to almost zero over many parts of the country. The effect of Kelvin and MT waves is smaller and mainly reduces heatwave occurrence. Overall, the study shows that the BSISO and ER wave has the most significant impact on the frequency, duration, and Intensity of heatwaves over the Indian region.

Keywords: Heatwaves, Intraseasonal oscillations, convectively coupled equatorial waves

OPTIMUM WIND FEATURES FOR THE PRE-CONDITIONING OF EXTREME RAINFALL EVENTS OVER KERALA USING RADAR AND RADIOSONDE DATA

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ABSTRACT

Extreme rainfall events (EREs) associated with the Indian summer monsoon mostly occur without warning. While the synoptic conditions primarily drive the large-scale wind pattern, perturbations in the three dimensional wind field may lead to extreme rainfall locally. We attempt to tag potentially predictive 'indicators' of EREs over the southwest coastal India by making use of the observations from a state of the art 205 MHz wind profiler radar and radiosonde profiles from adjacent locations. We postulate two factors as most decisive in the EREs in this region during monsoon season- one, the altitude of the core of LLJ and two, the direction at which it strikes the western Ghats. We have identified EREs occurring in August of three consecutive years, 2018-2020. EREs were identified as two or more consecutive rainy days with rainfall amounts > the .99 quantile of the climatology (1990-2017). We observe the strengthening of wind speed, the vertical shear of horizontal winds and direction of low level winds generate favourable conditions for each of such EREs. While other factors like the availability of humidity, stability of the atmosphere and low level convergence are decisive in the realization of EREs, the observed wind is a stand-alone direct potential indicator. This paper put forth the optimum wind features and radiosonde model tracks as a predictive tool for EREs over the south west tip of India.

Keywords: Extreme Rainfall events, Low level Jet stream, Optimum wind features

Impact of climate change on summer monsoon rainfall over Northeast India

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ABSTRACT

World's largest rain falls over north-east India during boreal and is characterized by large spatial inhomogeneity. Quantification of global warming impact on the northeast India rainfall (NEIR) is, therefore, a crucial factor for the region's food security and delicate bio- diversity. Here, using a long (~200 years) record of seasonal mean NEIR we separate oscillatory modes of variability from the secular trend using the Improved Ensemble Empirical Mode Decomposition (ICEEMD). The long term change in NEIR estimated from this nonlinear trend is unbiased by the oscillatory modes and leads to a climate sensitivity of NEIR of $(-3.2 \pm 1.65)\%/^0K$. For the study of extreme events, 90 years long daily rainfall data based on 24 well-distributed fixed stations over north-east India (NEI) is constructed through a data mining effort. Our estimate indicates that the frequency of occurrence of daily extremes (exceeding 99.5 percentile) over the NEI is increasing at $(+51 \pm 4.99)\% /^0K$ while the intensity is increasing at $(+12.5 \pm 3.32)\% /^0K$ over the past century, a rate much faster than envisaged by Clausius-Clapeyron scaling. Also, a significant multi-decadal variability (MDV) of summer rainfall over rest of India is found in contrast to a much weaker MDV of NEIR and both are out of phase. Our findings suggest that vulnerability to meso-scale hydrological disasters over the NEI in the coming years will be much higher than that over the rest of India.

Keywords: Extreme events, Climate sensitivity, Improved Ensemble Empirical Mode Decomposition

MPP

Monsoons: Seasonal Variability, Prediction, and Predictability

Downscaling precipitation using random forest model to predict rainfall in the north-eastern zone of Bangladesh

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ABSTRACT

Although rainfall is one of the principal climatic phenomena, many areas with high rainfall patterns often do not have enough stations because of geographical or political issues. The northeastern side of Bangladesh is one such area. Currently, Bangladesh meteorological Board (BMD) has one functioning station at Rangamati in that area. The variables from the IMDAA dataset have been downscaled using the rainfall data of Rangamati to find the relationship between the observed data and the grid data. Different models were used for season type one and season type two. Season type one consists of the monsoon season and season type two has pre-monsoon and post-monsoon seasons. To predict the rainfall during season type two, two different models have been used. Firstly, a random forest classifier model was built to classify whether it rained on a particular day. Then the amount of rainfall was generated using a random forest regressor model. The predictions of the new models improved the Pearson's correlation with the observed data by 1.41% for the dry seasons and by 3.17% for the monsoon season. As there are no other stations from BMD in the northeastern zone of Bangladesh, rainfall data from the IMERG dataset have been used to validate the models for other locations in that area. Twenty points have randomly been selected in the northeastern part near Rangamati. For the dry seasons, the predicted values consistently showed a higher Pearson's correlation with the IMERG dataset comparing to the Pearson's correlation between the IMERG dataset and precipitation from the IMDAA dataset. The models performed better for locations near the same or lower latitude than Rangamti. For the monsoon seasons, the predicted values are not always better than the precipitation value from the IMDAA dataset. The models performed better for the locations whose longitude was close to Rangamti's.

Keywords: seasonal variability, IMDAA dataset

Understanding the prediction and structure of Indian monsoon low-pressure systems in Subseasonal-to-Seasonal prediction models

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ABSTRACT

More than half of the summer monsoon precipitation and extreme precipitation events in eastern and central India are attributable to Indian monsoon low-pressure systems (LPSs). It is therefore important to understand the prediction skill and the structure of LPSs at the forecast lead times associated with numerical weather prediction and extended-range models. In this study, we use a feature-tracking algorithm to track LPSs in eleven models of the Subseasonal-to-Seasonal (S2S) prediction project. We consider only those LPSs that occurred at common forecast lead times of up to 32 days during June–September 1999–2010. We then verify forecasts and composite structures of LPSs against ERA-Interim and MERRA-2 reanalyses. At lead times of less than 15 days, the BoM, CMA, ECCC and HMCR models have large biases in the propagation of LPSs over India. The CMA model exhibits the largest track error and the intensity of LPSs is overestimated (underestimated) by most models when verified against ERA-I (MERRA-2). The location and amplitude of the lower-tropospheric cold core and the location of maximum precipitation is not well simulated by many S2S models. At lead times of up-to five weeks, deterministic predictions of LPS genesis by all S2S models are less accurate than their respective climatological predictions. In contrast, probabilistic predictions by many S2S models are more accurate than their respective climatological predictions. The results of this study may encourage stakeholders to use S2S models for forecasting LPSs.

Keywords: Indian monsoon low-pressure systems, monsoon depressions, S2S, forecast skill, Indian monsoon

VARIATIONS IN ATMOSPHERIC WATER VAPUOR OVER INDIAN MONSOON REGION USING AIRS DATA

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ABSTRACT

This study presents the the water vapour variations over the summer monsoon in Indian region is explored by means of water vapour products of AIRS on board the Aqua satellite.Analyse climatology and anomaly of water vapour variations over the standard pressure levels 1000,925,850,700,600hPa and also the spatial and temporal variations over mid pressure levels 961,886,771,648,547hPa.It was found that large amount of water vapour is visible at the lowest pressure levels.The intensity of wvmmr is more observed at 886hpa over July and August due to the presence of seasonal low level jet during the monsoon season.The amount of water vapour is found to be more over Arabian sea and south peninsular India.

Keywords: water vapour,variations

INTERACTION OF CONVECTIVE ORGANIZATION WITH MONSOON PRECIPITATION, ATMOSPHERE, SURFACE AND SEA: THE 2016 INCOMPASS FIELD CAMPAIGN IN INDIA

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ABSTRACT

The INCOMPASS field campaign combined airborne and ground measurements of the 2016 Indian monsoon. The monsoon supplies the majority of water in South Asia but forecasting from days to the season ahead is limited by large, rapidly developing errors in model parametrizations. The lack of detailed observations prevents thorough understanding of the interaction between monsoon circulation and the land surface: a process governed by boundary-layer and convective-cloud dynamics.

INCOMPASS used the UK Facility for Airborne Atmospheric Measurements (FAAM) BAe-146 aircraft for the first project of this scale in India, to accrue almost 100 hours of flight observations in June and July 2016. Flights from Lucknow in the northern plains sampled the contrast in surface and boundary layer structures between dry desert air in the west and the humid environment over the northern Bay of Bengal, during pre-monsoon and monsoon conditions. Flights from Bengaluru in southern India measured contrasts from the Arabian Sea, over the Western Ghats mountains, the rain shadow of southeast India and the southern Bay of Bengal. Flight planning was aided by forecasts from bespoke 4 km convection-permitting models at the Met Office and India's NCMRWF.

On the ground, INCOMPASS installed eddy-covariance flux towers to provide detailed measurements of surface fluxes and their modulation by diurnal and seasonal cycles. These data will be used to better quantify the coupling between the atmosphere and land surface.

Here we describe some of the major results from the INCOMPASS field campaign and its associated modelling work and discuss implications for monsoon prediction.

Keywords: Indian monsoon, field campaign, model systematic error, parameterisation

STATISTICAL CHARACTERIZATION OF HYDRO METEOROLOGICAL DATASETS OF CALICUT, KERALA

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ABSTRACT

Understanding, quantifying and assessing the hydrological impacts of climate change is pivotal for the proper management of scarce water resources. Proper statistical characterization of hydro-meteorological variables is an essential prerequisite in the climate change impact studies. This study analyse the temporal variability of different variables like rainfall, maximum temperature, minimum temperature, evaporation and wind speed of Calicut, Kerala at seasonal, monthly and annual scale resolutions. Four methods of trend analysis and two methods of change point analysis are invoked for the statistical characterization of the datasets of 1970-2019 period. The trend analysis using linear regression, Mann-Kendall (MK) test, Sen's slope estimator and Sen's innovative trend analysis (ITA) showed that both the maximum and minimum temperature series display significantly increasing trend for the data of all the temporal resolutions. The analysis further showed a significant reduction in wind speed series of all temporal resolutions. No significant trend was noticed in the rainfall and evaporation series of Calicut. The change point analysis using Sequential Mann-Kendall (SQMK) and Pettit tests showed that seasonal and annual data of all the parameters a change point is observed between 1990-2000. The present study provide a better understanding to assess the impacts of climate change on the hydrologic cycle, which greatly influences agriculture, eco-environment and human society.

Keywords: Climate change, trend analysis, rainfall, change point

ANALYSIS OF DRY SPELLS USING Z-SCORE OVER VIDARBHA REGION OF MAHARASHTRA, INDIA

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ABSTRACT

Drought is a long-period gradually creeping natural disaster, caused due to continued dry spells of rainfall with considerable lack of rainfall. Thus, it is characterized by sustained low precipitation, significant fall of groundwater and surface water levels, scarcity/non-availability of drinking water and adverse impacts on crop production. Drought periods bring lot of human sufferings, unfortunate deaths of human & livestock, distress to the society, crop failures, adverse impacts on economy & many other socio-economic problems. Vidarbha region of Maharashtra state is one of the most drought prone regions of India, as it frequently experiences continued dry spells. A statistical analysis has been attempted to study these dry spells over eleven districts in the Vidarbha region. The present study aims to monitor the drought occurrence on the basis of rainfall using Statistical Z Score in the Vidarbha region of Maharashtra. For this analysis, monthly precipitation data over 11 districts of Vidarbha have been collected from IWP during 1951-2020. The autocorrelation function (correlogram) for these monthly precipitation data over each district of Vidarbha region, has been plotted for determining the randomness of the data set. The autocorrelation values lies outside the Upper confidence level and lower confidence level, strongly infers that the data are purely dependent. Since the data are not random so, the concept of probability distribution function fitting is not likely to be suitable for forecasting the monthly precipitation values. Different types of models for e. g., MARKOV CHAIN Models, moving average method, BOX JENIKENS model are more likely to be preferred for forecasting monthly precipitation. Statistical Z-score Index on different timescales (3, 6, 9, 12 & 24 months) has been utilized for monitoring drought years and severity of drought conditions over the study region during 1951-2020. It has been found that higher time scales of Z score can better indicate severe drought events over individual districts of Vidarbha region.

[**Key words:** Statistical analysis, Z score index, dry spells of rainfall, autocorrelation function.]

UNDERSTANDING THE ROLE OF DEEP CONVECTION ON SEASONAL MONSOON RAINFALL OVER INDIA

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ABSTRACT

Skilful prediction of the seasonal Indian summer monsoon (ISM) rainfall (ISMR) at least one season in advance has great socio-economic value. The ISMR prediction remained a challenging problem with the sub-critical skills of the dynamical models attributable to limited understanding of the interaction among clouds, convection, and circulation. The GCM-Oriented CALIPSO Cloud Product (GOCCP), CloudSat and MODIS, MERRA and TRMM data are used in this study. During Indian summer monsoon, high cloud fraction (HCF) is found to be dominant (more than 50%) in total cloud fraction. Moreover, HCF maxima is also well associated with rainfall distribution over Western Ghats, northeast India, Myanmar coast, BoB, south China sea and other regions. The high values of deep convection counts (DCC) are seen over BoB and adjacent regions, central India. These deep convective clouds contain more ice mixing ration (MFCI) (Rysman et al. 2016) in the upper tropospheric levels, which is also evident from this study. Field and Heymsfield (2015) from satellite observations also showed about 40-50% of rainfall events originates from snow melting. Also higher cloud optical thickness-ice (COTI) values over Indian land region and BoB is observed. All these findings connote that, clouds play a seminal role in determining the seasonal mean ISMR (Hazra et al., 2017, 2020; Dutta et al., 2021). The misrepresentation of clouds, precipitation, and circulation has been continued for many new-generation models. The variability of cloud ice and microphysical process rates (auto-conversion, accretion etc.) in different time scales during ISM are also analyzed. The results from the sensitivity simulations using coupled global climate model (CGCM) are provided to demonstrate the importance of the cloud ice on ISM rainfall predictability. Therefore, this study provides a scientific basis for improving the simulation of the seasonal ISMR by improving the physical processes of the cloud on a sub-seasonal time scale and motivating further research in this direction.

Keywords: Cloud; Variability; Indian summer monsoon; CGCM

DYNAMICS AND EVOLUTION OF A CASE STUDY MONSOON DEPRESSION IN A HIGH-RESOLUTION MODEL SIMULATION

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ABSTRACT

Monsoon depressions (MD) are synoptic-scale cyclonic vortices that form over the Bay of Bengal and propagate northwestward through the monsoon trough onto the Indian subcontinent, bringing substantial amounts of rainfall to central and northern India. Despite their importance, key questions on the mechanisms driving their generation and development are still open. In this study we inspect the structure and dynamics of a MD case study (1-10 July 2016) using a high-resolution (1.5 km) simulation performed using the Met Office Unified Model. We take advantage of this high resolution, which is effective at resolving intense rainfall caused by deep convection, convergence lines and orographic enhancement, to understand the dynamic processes influencing the evolution of the MD. The evolution of the case-study MD can be divided into two stages: initially the MD is completely embedded in a near-saturated environment up to the mid-troposphere, whilst in the following stage a western intrusion of low-potential-temperature dry air at low and mid-levels starts interacting with the MD. Using Lagrangian trajectory analysis, we find that during the initial stage of the MD, the high-θe air from mesoscale convective systems in the vicinity of the MD reaches its centre at low and mid-levels, enabling its growth. During the second stage, the intrusions of stable and subsiding dry air bring low-θe, low-PV air at low and mid-levels towards the centre of the depression, hindering its development. The 1.5 km simulation enables us to highlight the presence of individual vorticity towers embedded within the MD that were not otherwise resolved at coarser (17 km) resolution. A detailed understanding of the structure, dynamics and the processes driving MD evolution is necessary to assess its representation in numerical weather prediction and high- resolution climate models.

Keywords: Monsoon depression, Dry-air intrusion, Unified Model, High-resolution

Circum-global teleconnection associated with early summer North Atlantic Oscillation and its implication for Indian summer monsoon

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ABSTRACT

Influence of the north Atlantic variability on Indian summer monsoon (ISM) is well-known in literature. The Atlantic influence on the ISM is observed from intraseasonal to multi-decadal timescales. Modulation of the dominant interannual variability over the Atlantic - the North Atlantic Oscillation (NAO), is known to produce surface pressure changes over Eurasia and hence impact the monsoon. Modulations of the El Nino Southern Oscillation (ENSO) conditions over the Pacific via the Atlantic-Pacific atmospheric bridge is also well known. In this study we explore how the circum-global teleconnection (CGT) pattern is modulated by the NAO and how it impacts the ISM. The CGT is a recurrent feature of the boreal summer midlatitude circulation which is known to impact the ISM. We find the existence of a CGT-like pattern associated with June North Atlantic Oscillation (NAO) anomalies. This downstream pattern is primarily confined within the westerly jet stream. Our analysis indicates that the CGT pattern is possibly driven by vorticity anomalies and maintained by barotropic conversion of kinetic energy from the basic state. Since upstream CGT is known to interact with Indian summer monsoon (ISM) through the upper tropospheric west central Asian (WCA) high, development of CGT from early summer NAO may be important for understanding the relationship between Atlantic variability and ISM. Also since this teleconnection pattern is sensitive to the basic state of the midlatitudes, it is likely that north Atlantic-ISM linkages may change in a warmer climate.

Keywords: NAO, CGT, ISM

Performance of GFS, NCUM-G, WRF and NCUM-R for Estimating Sub-basin-wise Quantitative Rainfall Forecast for SW Monsoon 2021 over Indian Region

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ABSTRACT

Numerical Weather Prediction(NWP) models, viz., Global Forecast System (GFS)(12km×12km), NCUM-G(12kmx12km), Weather Research & Forecast (WRF)(3km×3km) & NCUM-R(4kmx4km) operationally have been utilized as tools to estimate sub-basin-wise quantitative rainfall forecast for issuing operational Quantitative Precipitation Forecast (QPF).The performance of GFS, NCUM-G, WRF & NCUM-R models rainfall forecast at the sub-basin level have been studied over 153 river sub-basins in detail. The various prediction skill scores are examined and discussed in the paper during southwest monsoon 2021. The skill scores are computed considering following sub-basin-wise Average Areal Rainfall(AAP) categories for both observed and model rainfall; 0, 0.1-10mm, 11-25mm, 26-50mm, 51-100mm and > 100mm. These rainfall categories are used in issuing operational QPF bulletin in the sub-basins. The skill scores viz., Percentage Correct(PC), Critical Success Index(CSI), Probability of Detection(POD), False Alarm Rate(FAR) are computed from the 6x6 and then 2x2 Occurrence/Non-occurrence(Yes/NO) contingency table. The accuracy of the models in predicting sub-basin-wise quantitative rainfall decrease for high rainfall categories like 51-100 and >100 mm. Also, performance of models are decreased with the increase in forecast lead time. CSI & POD decrease and FAR increases as we proceed to higher rainfall category for all models under study which reveals the success rate of heavy rainfall forecast is less and false alarm rate is more. This may be due to the spatial difference of synoptic system captured by the model from its actual position which may change the spatial distribution of rainfall and consequently decreases the performance of the models in forecasting of rainfall over smaller river sub-basin areas.

Key words – Quantitative Precipitation Forecast (QPF), Observed Rainfall, AAP, Skill Score, NWP model, River Basin/sub-basin.

An assessment of the Desilets function on field-scale soil moisture and downscaled data products

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ABSTRACT

Soil moisture (SM) is an important parameter in most hydro-meteorological processes. The cutting edge technology, Cosmic-Ray Neutron Probe (CRNP) presents a promising passive method, based on Neutron theory, to estimate field-scale soil moisture. Hydrogen, with mass equivalent to that of the neutron, serves as the major moderator for the neutron intensity emitted by Cosmic-Ray in the vicinity of Earth's surface. Since soil water content is the largest source of Hydrogen, SM can be estimated using neutron intensity. The thermal and epithermal neutrons are collected by the CRNP, placed a few meters above the ground. Desilets function plays a key role in extracting SM (Volumetric Water Content in %) from the CRNP neutron count. The functional relation corrects the neutron count, for the sources of Hydrogen other than SM, through calibration parameters. In the present work, we review and address the challenges in calibration and accuracy of the estimates of field scale SM. Data is obtained from COsmic-ray Soil Moisture Observing System (COSMOS) at IITM Pune site as well as from the GLDAS and ERA5. The evaluation of SM calibration using CRNP neutron counts and various SM data products is carried out using Desilets function. This analysis would be useful in validating downscaled SM data products, providing means of quantifying sources of errors.

Keywords: Neutron count, Soil moisture, Calibration, Validation.

Real-time performance of the Extended Range Prediction System of IITM during Indian Summer Monsoon Season, 2021

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ABSTRACT

In the recent decade, prediction in the sub-seasonal/extended range time scale has got much attention since it bridges the gap between medium-range and seasonal forecast. Skillful Prediction of above normal rainfall (active periods) and below normal rainfall (break periods) during the Monsoon season (JJAS) at least few weeks in advance could have huge socio-economic value. Limit of Predictability in the extended range time scale mainly controlled by the Northward propagating Monsoon Intra-seasonal Oscillation (MISO) and eastward propagating Madden Julian Oscillation (MJO). Hence, real time monitoring and skillful prediction of MISO and MJO is very crucial.

The performance of real-time Multi Model Extended Range Prediction (ERP) System will be evaluated in the present study. This study would focus on observed features of monsoon season, such as onset, progression and withdrawal phases of the monsoon, role of intra-seasonal oscillation (ISO) in Extended Range Prediction (ERP), highlights of the monsoon prediction in extended range, performance and skill evaluation of the prediction system during 2021 monsoon season. Few important spells during this season will also be highlighted. The skill of Extended Range Prediction System over different homogeneous regions of India will be computed at different week lead. The subdivision wise skill and its verification would also be shown. The predicted and its verification of the dominant ISOs (MISO & MJO) would also be discussed.

PREDICTION OF RAINFALL OVER KERALA USING DEEP NEURAL NETWORK

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ABSTRACT

Precipitation is one of the key elements which support all life on Earth. From ancient times the prediction of precipitation has always been a tough grind for the weather forecasters. As precipitation is influenced by a plethora of variables giving precipitation a non linear characteristic, this unique nature makes the variable difficult to analytically model. To bridge the gap we are presenting the framework of a deep neural network which can improve the accuracy of precipitation forecasts a few days ahead over the Kerala region. The prime focus of our study is to reduce the forecast errors and false alarms in precipitation forecasts. For this, we have developed a deep neural network model which feeds on relevant meteorological parameters and learns the features from it. The efficiency of the trained model is determined by validating the model against data which are not used for training the network. The results revealed that the neural network model can be used for predicting the daily accumulated rainfall over the Kerala region with minimal amount of error and false predictions.

Keywords: Weather Prediction, Deep Neural Network

ON THE INTERANNUAL VARIABILITY OF THE ONSET AND WITHDRAWAL OF THE MONSOON SEASON IN BANGLADESH

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ABSTRACT

This research investigates the interannual variability of monsoon onset and withdrawal in Bangladesh, both of which are major climate features shaping multiple societal activities. There is considerable research on the monsoon timing in South Asia, but with much less focus on Bangladesh. We applied a local monsoon onset and withdrawal definition to observations and the latest-generation high-resolution gridded precipitation data from the Climate Hazards Center for the period 1981 through 2018. We analyzed the interannual variability in monsoon timing in Bangladesh and its teleconnection with the sea surface temperature anomalies (SSTA) over the Pacific Ocean (El Niño Southern Oscillation, ENSO) and the Indian Ocean (IO). The monsoon starts with early significant rains in northeast Bangladesh and propagates westward, and a similar pattern is observed for withdrawal, which tends to be more homogeneous in time and space. A high spatial and temporal variability in monsoon onset and withdrawal is observed in Bangladesh, with a within-country average range of around one month despite its being a country of relatively small size. The association between monsoon onset and withdrawal and ENSO and IO is addressed at the country and regional level by analyzing composites for different ENSO and IO phases and associated atmospheric circulation and moisture transport. A similar association between monsoon onset anomalies and ENSO and IO phases was found, with generally earlier (later) onset dates during the negative (positive) phase of ENSO and IO. Monsoon withdrawal anomalies show a clearer association with ENSO, with earlier (later) anomalies during the positive (negative) phase. Monsoon withdrawal presents strong negative anomalies during the negative IO phase. SSTA-induced anomalies in circulation and moisture transport contribute to anomalies in monsoon timing. Results suggest both ENSO and IOD can be potentially used as sources of predictability of monsoon onset and withdrawal over specific regions of Bangladesh.

Keywords: South Asia; gridded precipitation; rainy season; ENSO; IOD

TRACKING OF RAINING CLOUD SYSTEM USING SATELLITE DATA

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ABSTRACT

Optical flow techniques are crucial in determination of the advection field of dynamical weather systems especially useful for nowcasting. In the present paper, we use pysteps, an open source library, which allows us to easily analyze the impact of the optical flow method and scale filtering. We have experimented on different optical flow techniques like the Lucas-Kanade (local tracking approach), VET approach (global optimization routine that seeks at minimizing a cost function between the displaced and the reference image) and DARTS (spectral approach to optical flow that is based on the discrete Fourier transform (DFT) coefficients). The extrapolation nowcast is based on the estimation of the motion field. In the present study, each optical flow method was used with two deterministic nowcasting methods, a simple extrapolation-based method and S-PROG method. These models provide very short term forecasts of rainfall fields using INSAT-3D Hydroestimator (HE). The Rain forecast is evaluated using the Fractions Skill Score. This metric provides an intuitive assessment of the dependency of forecast skill on spatial scale and intensity. As a result of the analysis verification, it was concluded that the FSS increases with increasing lead time and gradually it decreases. This is expected, as the forecasting quality slowly decreases from 0.5 to 0 when we forecast further ahead. The study shows an increasing trend of skill-score upto is 1.5 to 2 hours lead time. This base time analysis may be useful for developing real time nowcasting system over Indian region.

Modelling surface fluxes and crop biomass over diverse agro-ecosystems of India using satellite remote sensing

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ABSTRACT

Agricultural production monitoring plays a key role in a variety of economic and environmental practices including crop yield forecasting, identifying risk of disease and water budgeting. Remote sensing and accurate ground-based observations has the potential to provide accurate crop condition information across large areas and has the ability to deliver information products in a timely within-season manner. Biomass and surface fluxes has a direct relationship with agricultural production and may help to predict crop biomass and yield. In this view state-of-art three eddy covariance systems have been installed on ISRO micro-meteorological towers over diverse terrestrial ecosystems such as rice-wheat semi-arid agro-ecosystem in Nawagam, Gujarat, sub-humid rice-wheat system in Samastipur, Bihar and arid grassland system in Jaisalmer, Rajasthan falling in the south-west monsoon trough under (INCOMPASS) INteraction of Convective Organisation and Monsoon Precipitation, Atmosphere, Surface and Sea programme. High-frequency flux data of H_2O and CO_2 over these three sites have been measured and analyzed for the period 2016-2020. Energy balance closure has been quantified at half-an-hourly and day-time scale. The intra and inter-seasonal variability of surface fluxes across the ecosystems have been studied. The conservative trend in the diurnality of evaporative fraction (ratio of latent heat flux and sum of sensible and latent heat fluxes) was noticed for both clear and cloudy-sky conditions. Flux simulations was carried out using an analytical model derived from Penman-Monteith formulation that requires net radiation, soil heat flux, air temperature, humidity and land surface temperature and were validated with measured fluxes. The error in instantaneous latent heat flux estimates were found to be in order of 10-25% across diverse agroecosystems. The biomass model developed shown an error of 20%. These flux data will be useful for validating and fine-tuning land surface model simulated fluxes embedded in climate or numerical weather prediction (NWP) model.

Keywords: Climate change, surface flues, biomass, INCOMPASS

Variability of the Summer Monsoon Rainfall Events over the Eastern Gangatic Plain of India

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ABSTRACT

The Indian Summer Monsoon Season (ISMS) comprises four months namely June, July, August, and September (JJAS). These four month are very important for the cultivation of rice product over the Gangetic plain of India. The rainfall during JJAS over the Gangetic plain depends on the behavior of Indian Summer Monsoon (ISM) circulation and its Intraseasonal Variability (ISV). Such variability of rainfall leads to impact the rice production and affects the economies and livelihoods of the people. For this purpose, the Indian meteorological department (IMD) gridded data of rainfall of resolution 0.25*0.25 for the period 1901-2019 is considered. Based on the IMD criteria for the rainfall episodes, no. of rainy days decreases as time progresses. The heavy rainfall events are mostly concentrated over the meteorological subdivisions of the West Bengal. The changes in the frequency of rainfall episodes are also noticed over the meteorological subdivisions of West Bengal, Bihar, East and West Uttar Pradesh.

Keywords: Intra-seasonal Variability (ISV), The Gangatic Plain, Meteorological subdivisions, Gridded rainfall data, Rainfall events

A study on the changes in the vertical distribution of water vapor for different modes of climatic conditions and monsoon intraseasonal oscillations

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ABSTRACT

This study presents a detailed analysis of the vertical distribution of humidity from lower to upper troposphere for different modes of climatic conditions (El Niño, La Niña, and Indian Ocean Dipole (IOD), etc.), and monsoon intraseasonal oscillations (ISO) over the Indian monsoon region. The water vapor profiles retrieved from the SAPHIR sensor on-board Megha-Tropiques satellite during the year 2013-2020 have been used in this study. The work specifically looks into the modulations of various climatic conditions and ISO on the vertical profiles of water vapor and their culmination as monsoon rainfall. The high-resolution ERA-5 reanalysis data is also used to understand the circulation characteristics which leads to the changes in the vertical distribution of water vapor over the monsoon region.

Keywords: Water vapor, ENSO, IOD, ISO

Onset of monsoon and monsoon rainfall in Kerala

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ABSTRACT

The onset of monsoon over the West Coast of Kerala is very stable and tends to be towards 1st June rather than after 1st June as it revolved mostly between 30th May and 1st June during the study period of 152 years from 1870 to 2021. The monsoon directory of Kerala indicated that the earliest onset of monsoon was on 11th May in 1918 while the belated monsoon on 18th June in 1972. The normal onset of monsoon is 1st June with a standard deviation of 7 days, revolving mostly between 25th May and 8th June. Early onset of monsoon over Kerala in recent years was seen in 1990 (19th May), 1999 (25th May), 2001(23rd May), 2004 (18th May), 2006 (26th May) and 2009 (23rd May) while belated onset of monsoon in 1967(9th June), 1972(18th June, 1979(13th June) and 1997(9th June). The onset of monsoon was early (on or before 25th May) in 18 years out of 152 years. The percentage occurrence of early onset of monsoon was 11.8% while late (on or after 8thJune) in 28 years (18.4%) out of 152 years. The monsoon rainfall is likely to be below or normal if the onset of monsoon is early or late (that is on or before 25th May/on or after 8thJune). The monsoon rainfall was declining though inter-annual variability existed. A significant decline was noticed in monthly rainfall during June and July while increase in August and September. Rainfall increase in of August and September may not compensate to the total monsoon rainfall since June and July are the rainiest months. This phenomenon may result in water resources decline. This information on monsoon variability can be utilized in crop contingency plans during Virippu season to choose long/medium/short duration varieties in case of paddy and irrigation schedule in mid and upland paddy areas

Spatio-temporal analysis of rainfall changes in Wayanad region of Kerala using block-bootstrapping approach

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ABSTRACT

During changing climate scenarios, the identification of rainfall patterns precisely is essential for planning and implementation of various activities, including agricultural practices, and mitigation of landslide especially in high range areas. Wayanad district is one of the high altitude and high rainfall regions of northern Kerala, where the majority of livelihood depends on agriculture. Recent changes in global climate, has a greater impact on the distribution of rainfall pattern. So, it's important to identify the potential rainfall trends accurately in order to adopt mitigation practices. In general, the Mann-Kendal test will be misleading the monotonic trend if series possess significant autocorrelation. Adoption of block bootstrapping in Mann-Kendal test (bbmk) will effectively correct this error by making resample in the original series with prefixed block length. Therefore, we attempted to study the trend pattern of rainfall for four gauging stations in Wayanad region viz., Mananthavady, Vythiri, Ambalavayal, and Kuppady for a period of 33 years using block bootstrap technique. Test of randomness result indicates January, February, March, and April in the Mananthavady region; January, February, and November rainfall in Vythiri and January, and April rainfall in Kuppadi shows the significant dependency of the lag period. The bbmk results confirm that Wayanad is under a downward rainfall trend in almost all the months, seasons, and annual rainfall. Further the results indicated that invariably all the four stations in the Wayanad region showed a significant downward trend for Post monsoon rainfall. However, Kuppadi region possesses a significant downward pattern for southwest monsoon also. On an average every year 14 mm post-monsoon rainfall is reducing in Wayanad [Mananthavady (8.56 mm), Vythiri (10.94 mm), Ambalavayal (8.50 mm), and Kuppady (26.88 mm)]. Even the number of rainy days in post-monsoon also taken the negative trend and about 63 per cent reduction was noticed during the last 10 years. It is essential to revisit the water management practices in Wayanad for effective utilisation of water resources in the changing climatic scenario.

Keywords: Rainfall trend, Block bootstrapping in Mann–Kendall trend test, Post-monsoon

Rainfall in Kerala based on *Njattuvela* and Position of *Rahu*

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ABSTRACT

Weather pattern in Kerala has a cycle due to the rotation of earth in its imaginary axis and its revolution around the sun. These patterns will be identified in a circular model rather than a linear model. Hence analysis based on directional data was done here to identify certain patterns in weather across Kerala. An attempt has been made to estimate the possible amount of rainfall in Kerala during each *Njattuvela* (approximately with 14 day period classified by movement of earth around the sun about an angle of $13^{o}20$" calculated from the starting of *Aswini* Star) based on the daily data collected from Thrissur District of Kerala. *Makeeram njattuvela* (8th June to 21st June) is identified as having the highest average rainfall in the district. *Thiruvathira njattuvela* (22nd June to 5th July) is having the highest variability of rainfall. The lowest amount of rainfall was in *Pooradam njattuvela* (29th December-11thJanuary) and succeeded by *Uthradam njattuvela* (12th January-24th January). The calculation of amount of rainfall and flood based on solar eclipse observed from Kerala is analysed using one and half centuries of monthly rainfall data of Kerala state. An analysis of rainfall data based on certain astronomical facts was done along with the *njattuvela*. Astronomically, Rahu and Ketu are the north and the south lunar nodes. They are the points of intersection of the paths of the Sun and the Moon on the celestial sphere. The position of rahu and the pattern of rainfall in Kerala were analysed and found that the flood years due to intensive rains occurred in years when there was a solar eclipse in between 12th July and 12th August. Since such years are easily forecasted very early, the flood in Kerala also can also be forecasted earlier.

MULTISCALE COHERENCE ANALYSIS BETWEEN RAINFALL AND METEOROLOGICAL VARIABLES OF CALICUT, KERALA USING WAVELET TRANSFORM

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ABSTRACT

Understanding the multiscale teleconnection between local scale meteorological variables with rainfall is of immense importance in the climate change studies. This study uses Continuous Wavelet Transform (CWT), Bivariate Wavelet Coherence (BWC), Partial Wavelet Coherence (PWC) and Multiple Wavelet Coherence (MWC) formulations for investigating the multiscale coherence of monthly rainfall of Calicut, Kerala India of 1970-2019 period with a diverse set of local meteorological variables. The CWT analysis of rainfall, max temperature (Tmax), minimum temperature (Tmin), wind speed (U) and evaporation (E) series displayed a strong annual periodicity in all the time series. An additional band with strong power was also noted in Tmin series at intra-annual scale of 6 months, while such a band for Tmax series was found to be weak. The BWC analysis of rainfall with different meteorological variables deciphered a strong coherence from seasonal scale to inter annual scale upto 18 months with in-phase coherence in rainfall-Tmin and rainfall-E teleconnections. The coherence strength was quantified in terms of Average Wavelet Coherence (AWC) and Percentage of Significant Coherence (PoSC) criteria and the analysis revealed that evaporation display the highest coherence (AWC of 0.66 and PoSC of 54 %) with the monthly precipitation of Calicut. Ten cases of PWC analysis by excluding the effect of remaining variables one at a time from the BWC analysis performed in this study showed that the removal of Tmax has maximum influence on the coherence relationships of monthly rainfall over Calicut. Moreover, seven cases of MWC analysis considering both two and three variable combinations are performed in this study. The MWC analysis showed that Tmin-E and U-Tmin-E combinations with rainfall induce maximum coherence strength in the rainfall pattern of Calicut.

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Keywords: Climate change, coherence, rainfall, wavelet, meteorological variables

Critical analysis of performance of southwest monsoon in last one decade

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ABSTRACT

Southwest monsoon is a phenomenon which occurs during June to September in the country and it contributes around 80 to 85% of annual rainfall (except southern peninsula). As per IMD criteria, all India is divided into four homogeneous regions *viz.* North-west, Central, North-East and Southern peninsula. The paper studied performance of southwest monsoon, critically in the four homogeneous regions as well as for country for latest one decade, i. e. from 2011 to 2020. The rainfall data during 2011 to 2020 during monsoon period for each of the homogeneous regions were collected and analysed. The overall performance of southwest monsoon in different homogeneous regions are presented in table – 1, which indicated most of the years during 2011 to 2020 were normal (i. e. within + or - 10% of LPA), while consecutive 2 years i. e. 2014 and 2015 received less than normal rainfall. The paper studied rigorously performance of southwest monsoon in each of the four months commencing from June to September for all the four regions. The objective of the study is to identify year wise as well as region wise variability of monsoon in past 10 years. The paper studied number of (normal + excess + large excess) meteorological sub-divisions as against (deficient + large deficient + scanty) in each of the month for different homogeneous regions during 2011 to 2020. The year wise number of (normal + excess + large excess) and (deficient + large deficient + scanty) meteorological sub-divisions throughout the country in different years are presented in table – 2. The critical study indicated year to year and region to region variability in performance of southwest monsoon in the last decade, which is presented and discussed in the paper.

Keywords – Performance, Southwest monsoon, Decadal study, Homogeneous regions, Monsoon variability, meteorological sub-divisions, LPA (Long period average)

Table 1. Performance of southwest monsoon (%) in different homogeneous regions during 2011-2020

Year	NW India	Central India	South peninsular India	NE India	Country as a whole
2020	84	115	130	106	109
2019	98	129	116	88	110
2018	98	93	98	76	91
2017	90	94	100	96	95
2016	95	106	92	89	97
2015	85	90	90	92	86
2014	85	94	93	99	88
2013	94	98	103	98	98
2012	93	96	95	99	93
2011	97	95	94	95	95

Table 2. Year wise number of (N + E + LE) meteorological sub – divisions as against (D + LD + S) rainfall areas during 2011 – 2020

Year	Normal(N) + Excess(E) + Large excess (LE)	Deficient(D) + Large deficient (LD) + Scanty(S)
2020	31	5
2019	31	5
2018	25	11
2017	30	6
2016	29	7
2015	19	17
2014	24	12
2013	30	6
2012	23	13
2011	33	3

Characteristics of Low Level Jet and its Relationship with the Indian Summer Monsoon Rainfall

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ABSTRACT

The Low Level Jet (LLJ) is a strong cross-equatorial flow of winds in the lower troposphere occurring in the Indian summer monsoon season (June – September) over the Indian Ocean and the Indian region [Joseph and Raman, 1996]. It is also called monsoon jet or low level westerly jet. LLJ is considered s one of the pivotal components of the Indian summer monsoon and its variability [Webster and Hoyos, 2004]. The strong cross equatorial flow from the Southern Indian Ocean to the Central Arabian Sea is a climatological feature driven by the thermal gradient between landmass and surrounding ocean region during summer monsoon season [Krishnamurti et al., 1976]. Objectives of the present study are to study about the intraseasonal variability of Low Level Jet Stream during the summer monsoon season of 2011-2015, multiyear regional variation or changes in horizontal and vertical extent of LLJ and to relate the regional differences in rainfall with the strength of LLJ. For that, Wind data at different standard pressure levels for the time period 2011 to 2015 summer monsoon season is obtained from the European Centre for Medium- Range Weather Forecasts (ECMWF) interim reanalysis. The GPCP data is used to analyse rainfall. A large study area (30ºS-40ºN, 30ºE-180ºE) is selected to understand the migration of LLJ locations as well as to relate or compare the rainfall contributed with the presence or absence of LLJ. The seasonal mean wind analysis show the wind core aligned southwesterly in the zone of maximum winds and it turns to becomes westerlies and northwesterlies on reaching the southern Indian Peninsula. Multi-year monthly mean LLJ shows that the maximum wind zone establishes over a large area in the Arabian Sea. Vertical structure of LLJ shows that the wind direction is almost steady in southwesterly once the LLJ has set in irrespective of year. Day composites of precipitation corresponding to strong LLJ days and weak LLJ days shows the regions receiving more and less precipitation respectively. Some of major conclusions arrived from the study include that the strength of LLJ influence the regional distribution of monsoon precipitation and its quantity. Also, when the LLJ is stronger, the pool of inhibited cloudiness has a larger spatial extent resulting in lesser rainfall over the region.

Keywords: LLJ, Monsoon variability, Precipitation

Simulation of monsoon Intraseasonal oscillations by CMIP6 models over the North Indian Ocean

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ABSTRACT

Historical runs of 30 Coupled Model Intercomparison Project (CMIP) Phase-6 models General circulation models (GCMs) are evaluated for the representation of Boreal Summer Intraseasonal Oscillations (BSISO). Several statistical metrics were developed to evaluate the characteristic features of BSISO, such as propagation, phase speed, and exchange of air-sea fluxes at the air-sea interface over the major regions of the Indian Summer Monsoon (ISM). The majorities of CMIP6 models underestimate the precipitation over central India and overestimate the precipitation over the eastern equatorial region. Ensemble mean of the models shows good agreement of precipitation pattern with the observations. In the observations, the precipitation anomalies propagate northward from the equatorial latitudes to the northern latitudes over the ISM region (60°E to 100°E longitudes). However, the initiation of northward propagating convection shows a significant variation with time in the CMIP6 models. Surface turbulent fluxes and zonal winds lag the deep convection over the North Indian Ocean on intraseasonal timescales. However, misrepresentation of air-sea fluxes in the CMIP6 models leads to the significant biases of intraseasonal variances The present study further suggests that improving atmospheric-oceanic feedback mechanisms, specific humidity, and low-level winds in the CMIP6 models is necessary to predict the ISM intraseasonal variability accurately.

Keywords: CMIP6 models, Intraseasonal Oscillations, BSISO, Air-Sea interactions.

Synoptic and dynamical analysis of Extremely Heavy Rainfall during 2016-2020 Southwest Monsoon Season

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ABSTRACT

Extremely Heavy Rainfall (EHRF) during the Monsoon season over the Western Himalayan Region causes landslides, riverine flooding and severe loss to public life and property. Synoptic and dynamical aspects of EHRF events during the period 2016-2020 southwest Monsoon (SWM) season is the study area of this article. EHRF data has been collected from real time observation of India Meteorological Department (IMD). Synoptic and dynamical aspects of have been analysed from NCEP Reanalysis and CIMMS products. It has been found that EHRF events are caused due to four major reasons: i) When Monsoon trough runs close to foothills of Himalayas ii) When there is a Low Pressure Area over the Bay of Bengal iii) when western end of the monsoon trough is to the north of its normal position and there is high moisture feeding from north Arabian Sea at lower tropospheric levels into the western end of the trough and iv) when there is interaction of lower level easterlies from the Bay of Bengal and Mid latitude westerlies over the Western Himalayan Region.

Keywords: Southwest Monsoon, Western Himalayan Region, Extremely Heavy Rainfall, Monsoon Trough

Relation between rainfall and soil moisture variability during dry and wet extremes over core monsoon zone of India

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ABSTRACT

Monsoon variability plays a major role in soil moisture dynamics, distribution and variability. Though monsoon and soil moisture are tightly coupled, the patterns are different each year. With the availability of high resolution observational and reanalysis estimates of rainfall, soil moisture, and meteorological parameters one can examine the interconnection between them. In particular, The recent deficit monsoon rainfall during 2015 and excess rainfall during 2019 presents a unique opportunity to explore the response of soil moisture to the monsoon. We consider daily anomalies of rainfall and soil moisture over the core monsoon zone (CMZ) of India for the two contrasting years in the present analysis. Wavelet transform analysis shows the persistent and short lived signals in rainfall and soil moisture. While 2015 monsoon deficit was dominated by a longer persistence of zonally propagating ISOs, the 2019 monsoon season was dominated by meridionally propagating ISOs. Interestingly, the dry soil moisture memory time-scale during 2015 indicates a period of 40–50 days, while it exceeded 60 days during 2019 by virtue of long-lived spells of rainfall. The study establishes strong relationship in variability patterns of soil moisture and rainfall extremes over CMZ. This will enhance the understanding of hydrologic process and can be used effectively to improve water resource management strategies in extreme conditions.

Keywords: rainfall extremes, soil moisture, Core Monsoon zone, wavelet transform

Synoptic to Large-scale features of Monsoon 2021 in a Multi-physics Framework for Extended Range

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ABSTRACT

Agro-based Indian economy thrives on monsoon, and the impactful intraseasonal variations in rainfall during monsoon make its prediction crucial and challenging. Like every other year, the 2021 monsoon also brought unique features to be unravelled by meteorologists. The study presents a few of these features as predicted by a multi-physics framework. An ensemble of physics combinations in the climate forecast system (CFS) is synthesized to generate predictions at the extended range. These predictions are evaluated against observation as well as an initial-condition ensemble based on CFS. The initial results show that the multi-physics CFS has the advantage in capturing significant sub-seasonal features of the 2021 monsoon.

Keywords: Monsoon, Extended Range Prediction, Multi-physics, Ensemble Prediction

Hydration of the upper troposphere and lower stratosphere over the Indian region during summer monsoon season inferred from insitu and satellite observations

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ABSTRACT

Cryogenic frost-point hygrometer (CFH) observations of water vapour in the upper troposphere and lower stratosphere (UTLS) over Trivandrum, Hyderabad and Kolkata during the period 2014-2017 along with water vapour derived from Microwave Limb Sounder (MLS) observations are used to examine the hydration in the UTLS over Indian region during summer monsoon season. The amount of water vapour in the upper troposphere (UT) is the maximum during the summer-monsoon over all the stations. CFH observations shows a water vapour enhancement of ~40-250% in the UT and 0.5-1ppmv (10-40%) in the lower stratosphere (LS) in summer monsoon compared to pre-monsoon. MLS observations showed water vapor maxima at 100 hPa over the eastern side of the monsoon anticyclonic circulation, northeast of the deep convection over Bay of Bengal (BoB). Water vapour maximum shows a south westward shift with increase in altitude in the LS region. The effect of dehydration is found to be significant on the western side of the peak in deep convection. The competing effects of temperature dependent freeze drying and rehydration due to recurrent deep convections determine the day-to-day variability of water vapour in the UT. The relative humidity with respect to ice (RHi) shows multiple super saturated layers in the UT indicating the occurrence of multi-layer cirrus clouds. Thin supersaturated layers/cirrus are observed just above the cold point tropopause also and can have implications on radiation and water vapour budgets of the UTLS region.

Keywords: water vapour, summer monsoon, UTLS

PREDICTION OF RAINFALL IN CENTRAL INDIA REGION USING MACHINE LEARNING APPROACH

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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 are dependent on the climate. There are various models that have been developed to predict the rainfall forecast. In this paper we have used the Random Forest (RF) Regressor and Long Short Term Memory (LSTM) Neural Network model to predict rainfall in central India Regions. We have also studied performance using correlation coefficient, Mean Square Error (MSE), Root Mean Square Error (RMSE) of models. In this paper we have taken five different cities of Rainfall datasets in the central India Region which is Allahabad, Kanpur, Varanasi, Lucknow and Gorakhpur. Precipitation data for the Central India Region starting from 1901 to 2016 has been taken from Indian Meteorological Department (IMD) at the resolution of 0.5°. In each city, the dataset is often divided into Training and Testing dataset. The rainfall dataset from 1901 to 2005 has been taken as training data for proposed models of RF and LSTM techniques and after that testing dataset has been evaluated from 2006 to 2016 of the year. The rainfall data which we use in central India has been taken fromIn the model I have taken Quarterly data from 1901 to 2016 years for training and testing dataset. The input variables used are twelve months lags values of rainfall data and the outcome variable is Rainfall of the present months. The model RF and LSTM take the same input variable and its corresponding outcome variable of rainfall dataset. MSE, RMSE and correlation coefficient is computed for the models which showed that the LSTM based RNN prediction model provided better results in comparison to RF.

Keywords: Machine Learning, Rainfall Prediction, LSTM, RF.

Seasonal atmospheric features over a core Monsoon zone in Central India

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ABSTRACT

The Indian Summer Monsoon (ISM) core zone is characterized by the fluctuation of monsoon trough/ Continental Tropical Convergence Zone during the monsoon season and helps in identifying active and break spells by average rainfall over the region. Observations of environment vertical structures of turbulence, atmospheric parameters, stability parameters, and cloud vertical structure over Bhopal in Central India, a vital core monsoon zone, can bring new insights on better ISM understanding and predictability. Monsoon at the study site is characterized by the seasonal wind reversal, higher humidity content, elevated levels of freezing layer, and active presence of all levels of clouds. The study uses GPS-Radiosonde data for 2011-2020 (10 years) to study the seasonal features of turbulence in the atmosphere parameterized by turbulence structure parameter of refractive index; C_n^2 , which is a function of temperature and humidity gradients in the atmosphere. The values of log range from -11 m-2/3 to -18 m-2/3 in the height range of 0.5 km to 25 km. Monsoon shows its significant signature in the structure with higher values at elevated heights due to thermodynamic and dynamic factors. Contour frequency altitude diagram (CFAD) analysis is invoked to understand the contrasting seasonal features of C_n^2 vertical structure. Active and break phase of the monsoon displays the notable difference in the turbulence structure in the atmosphere. The seasonal features of retrieved stability parameters like convective available potential energy (CAPE), convective inhibition (CIN), and precipitable water are utilized for the interpretation of atmospheric state. The fractional cloud cover from reanalysis data features the cloud cover in the vertical atmosphere which features the low, mid, and high-level clouds, especially during monsoon. During the study period, an attempt has been made to understand the characteristics of turbulence during different events such as depression mainly in the monsoon season, cold wave, and heat wave. The physics of sub-grid scale convective, cloud, and turbulent processes help for a better understanding of ISM and improve its modelling.

Keywords: Monsoon core zone, turbulence parameter, seasonal features, atmospheric vertical structure.

Monitoring of field-scale soil moisture variations in monsoonal environment

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ABSTRACT

The realistic estimate of high-frequency soil moisture (SM) variability at field-scale is crucial in understanding land surface hydro-meteorological processes, particularly across the core monsoon zone of India. This study unravels the monsoonal and non-monsoonal influences on field-scale SM variations in the time-frequency domain at COSMOS-IITM, Pune site during 2017-2020, located across strong soil moisture-surface temperature coupling zone. The impacts of distinct seasonal, sub-seasonal, and extreme hydro-meteorological conditions on field-scale soil moisture variability are intriguing, particularly for the year 2019. The field-scale SM variability in the time-frequency domain, memory time-scale, and power transfer to the low-frequency are two times higher during 2019 at COSMOS-IITM site. The validation of available coarser-resolution SM data sets from remote sensing, reanalysis, and model simulations revealed that relatively higher range of observed variabilities of field-scale SM in time-frequency domain is reasonably represented by coarser-resolution GLDAS and ERA products over this COSMOS observational site.

Keywords: Soil Moisture, Seasonal and sub-seasonal variability, memory time-scale

Regional climate simulation of Indian Summer Monsoon for extreme rainfall seasons and its performance evaluation with different land surface schemes

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ABSTRACT

The contribution of Indian Summer Monsoon(ISM) with above 70% of the total annual rainfall is irreplaceable in the regional economy. It has profound significance in power generation, agriculture, fresh-water renewal, etc. Hence the truthful projection of the same is substantial. Therefore, here we experiment the performance of customized regional climate model (RegCM4) with its non – hydrostatic runs for the simulation of ISM. The schemes Emanuel and Grell are used as the cumulus convection schemes over land and ocean respectively. The projection of different land surface parameterizations namely Biosphere – Atmosphere Transfer (BAT) and Community Land Model (CLM4.5) schemes are also investigated, and it is tested for Indian domain for a recent climate period (1982-2016) with initial-boundary condition ERA-Interim reanalysis. Further, the precipitation characteristics of extreme years are estimated by giving relevance to extreme and deficit rainfall seasons. The India Meteorological Department (IMD) and ERA-Interim observations of respective parameters are utilized for the validation of the model simulations. The climatology of rainfall fetches the closer characteristics of CLM towards observational IMD features especially over north-east, south, west and north-west India. The Taylor metrics, added value indices of mean square errors and correlation, and modified Brier skill score(MBSS) are also evaluated with the findings. The CLM simulations demonstrate more prediction skills with respect to the corresponding BAT Taylor metrics, and also reasonably better CLM features are observed for extreme rainfall seasons in the other skill scores. Thus the results suggest that CLM adds more value in the regional climate simulation of ISM with respect to BAT particularly during its extreme rainfall seasons.

Keywords: Indian Summer Monsoon, Regional Climate Modelling, land surface processes, Extreme rainfall.

A MACHINE LEARNING APPROACH TO PREDICT INDIAN MONSOON ONSET

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ABSTRACT

Monsoon Advance of the southwest monsoon over the Indian mainland is marked by monsoon onset over Kerala (MOK) as it is the beginning of the rainy season for the country. MOK is associated with many changes in the large-scale and local atmospheric variables. Although the climatological date of MOK is 1st June; it varies by a few days from year to year with a standard deviation. As the arrival of the monsoon is crucial for farmers to plan their crop strategy during the season, a reliable prediction of MOK is very crucial. Since 2005, India Meteorological Department (IMD) has been issuing operational forecasts for MOK. This forecasting system is based on a Principal Component Regression (PCR) between large-scale circulation features in the Asia-Pacific region, local pre-monsoon rainfall peak in, and the MOK date. We aim to improve upon the accuracy of MOK predictions to explore sophisticated machine learning (ML) based prediction models. Two families of ML models: decision trees that involve bagging (Random Forest) and boosting (XGBoost), and neural networks based on extreme learning machine (ELM), have been explored in this study and have been compared to the benchmark PCR model. All the prediction models were implemented in a leave-one-out manner from 1975 to 2020 and their skill is assessed using a set of statistical skill metrics. Results suggest that the ELM methods are outperformed compared to all other models whereas Random Forest or XGBoost doesn't bring much skill compared to PCR.

Keywords: Monsoon Onset over Kerala, Principal Component Regression, Machine Learning methods, Random Forest, Extreme Learning Machine.

SPATIAL & TEMPORAL VARIATION OF RAINFALL, SOIL MOISTURE, AND SOIL TEMPERATURE OVER JHARKHAND BY USING HIGN-RESOLUTION DATASET

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ABSTRACT

Climate and seasonal pattern unevenness are causing climate variables to change due to an increase in agricultural and settlement areas in the last few decades ultimately leading to the destruction of natural resources like forests, rivers, lakes, etc. India receives 70-80% of the rainfall in the southeast monsoon season throughout June to September (JJAS) which further increases soil moisture, groundwater helps in the restoration of ponds, lakes, rivers, etc.

The present research work was undertaken to analyze the Spatiotemporal variations of rainfall, surface runoff, soil temperature, and moisture in 5 administrative divisions of Jharkhand using era5 land hourly data from 1981-2020 of 0.1*0.1degree resolution. Spatial distributions are analyzed in Arc-GIS software version 10.4. Temporal distributions are analyzed using Arc-GIS and windows excel both.

All five divisions of Jharkhand showed an increasing trend for rainfall, soil moisture & soil temperature but South Chotanagpur showed a decreasing trend for runoff. Four divisions showed a decrease in light rainfall and an increase in moderate & heavy rainfall whereas Kolhan showed an increase in light rainfall and a decrease in moderate rainfall. Only Palamu division showed p-Value<0.05 for rainfall data used for trend analysis. Hence, out of five divisions, only rainfall of Palamu division is significant and all other increasing/decreasing trend is insignificant.

Keywords: Spatiotemporal variation, Southeast monsoon, Rainfall, Surface runoff, Soil temperature, Soil moisture

Understanding the dynamics of northward propagation of convection during boreal summer over Arabian Sea and Bay of Bengal

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ABSTRACT

Indian summer monsoon exhibits a dominant mode of variability in intraseasonal timescale (20-70 days), which is associated with northward propagation of convection from the equatorial region to the foothills of the Himalayas. We aim to understand the governing dynamics behind this northward propagation of convection over the Arabian Sea (AS) and Bay of Bengal (BoB) using the vorticity budget equation. Phase speed of northward propagation is comparatively higher over AS (~1.25°/day) than over BoB (~0.75°/day), resulting into a northwest-southeast tilted structure in large-scale convection over the Indian region. Many previous theories have suggested that generation of vorticity to the north of an existing convection center in the presence of mean easterly shear is essential for the convection to move northward. Using observational analysis, here we found that the tilting term in the vorticity equation leads the rainfall maxima by about 6-8 days over BoB and 2-3 days over AS. Moreover, tilting term exhibits stronger nature over BoB as compared to AS. Further investigation shows that the component of tilting term associated with the meridional gradients in vertical velocity in intraseasonal timescale acts to the vertical gradient of the zonal mean flow to generate positive anomalies in tilting. It is also found that convective updrafts are generally stronger and more vertically stretched over BoB, which could be responsible for the enhanced tilting. Beta effect is found to be important for northward propagation over BoB. However, a component of tilting term associated with vertical shear of mean meridional winds modulate ISO propagation over AS and helps explain the higher phase speed over AS compared to BoB. This study underlines the role of convection in northward propagation and provides a pathway to improve model performance for simulating intraseasonal variability and summer monsoon.

Keywords: Indian Summer Monsoon, Intraseasonal Oscillation, Northward Propagation, Vorticity Budget

Distinct Response of Different Phases of Madden Julian Oscillation on the Monsoon Onset over Kerala

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ABSTRACT

This study has attempted to understand the characteristics of monsoon onset over Kerala (MOK) during different phases of Madden Julian Oscillation (MJO). The MJO, the dominant intra-seasonal oscillation over the tropics, plays a major role in setting the monsoon onset over Kerala (MOK). The study is carried out for the period 1980 to 2020 to understand the basic variation of MJO and its impact on MOK. It is found that phases I, II and III of MJO are modulating the conducive environment suitable for the MOK. 80% of the MOK occurred in phases I, II and III of MJO. The remaining 20% occurred in other phases of MJO except in phase VIII, where there is no incidence of MOK. The onset period is divided into early (before 30th May), Normal (30th May to 02nd June) and Delayed (after 2nd June) onset for analysing the fluctuation of onset date with respect to different MJO phases. Further, various environmental parameters during different phases of MJO were analysed to understand the cyclogenesis close to the MOK period. It is found that phases I and III favour a conducive atmosphere for cyclogenesis, and phase II is not supporting cyclogenesis. The negative anomaly area of zonal wind shear endorses the formation of cyclones in these phases. The TPW shows a negative anomaly during onset in phases I and II of MJO. However, phase III shows a positive anomaly of TPW and the convective activity is also more in phase III, where the amplitude of MJO is maximum.

Rainfall Variability and its Trends over India

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ABSTRACT

This study attempted to demonstrate the rainfall changing patterns which have significant effect on global/regional scale and agricultural productivity especially over India where the economy depends on rain-fed agriculture. June-September (JJAS) season is very crucial for India's economy. The impact of rainfall over India is investigated to understand the rainfall variability over the period of 1951-2020 (69 years) using daily Indian Meteorological Department (IMD) datasets. Analysis of variability has done on annual and seasonal scale. The trend analysis has been carried out to find the long-term trends in rainfall over India. Also, seasonal contribution of each season of the monsoon months to annual rainfall in each year has been computed to find out the trends and observed the contribution of June, July, August and September rainfall to annual rainfall.

South Asian monsoon simulations in CMIP6 Models and future projections.

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ABSTRACT

Recent developments in coupled ocean–atmosphere dynamical model prediction systems has provided important advances in the seasonal prediction and current generation coupled models. In spite of these advances, Indian Summer Monsoon Rainfall (ISMR) has remained a grand challenge and there are still significant shortcomings in the representation of the mean monsoon climate and its variation on different time scales. Current models have incorporated better theoretical understanding of climate and improved physical basis of modelling. In this perspective, CMIP6 models provides the best opportunity to evaluate the performance of the coupled models and provides chance to estimate future projections. Most of the CMIP6 models are able to capture the mean and variability of the monsoon. For the study, we have classified models into different groups and selected good models based on mean, annual cycle and rainfall statistics of the model. Multi-model ensemble (MME) mean is prepared and MME pattern is able to the capture the mean monsoon reasonably well. Future projections of the radiative forcing of 1 % yr_{-1} CO2 increase (1pctCO2) is examined in the study. Most of the model indicates robust increase in rainfall over Indian region under future warming in CMIP6.

Impact of drop in ENSO prediction skill on ISMR prediction in recent decades

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ABSTRACT

Ability of coupled models to represent Indian summer monsoon rainfall (ISMR) depends on the accurate representation of El Nino Southern Oscillation (ENSO) influence on ISMR. In nature, this ENSO-ISMR relationship has strengthened recently after 2000 even though ENSO variability has reduced. At the same time, Monsoon Mission Climate Forecast system (MMCFS), which is the operational seasonal prediction model for India Meteorological Department, shows a drastic decrease in ISMR skill for long lead hindcasts (i.e., model forecasts initialized 3 months before June) and increased skill for short lead hindcasts, initialized in the month of April. Further analysis indicates that ENSO skill and ENSO-ISMR relationship is weak for Feb IC hindcast of MMCFS, while both have not much decrease/change for April IC before abd after 2000. Significant fall in the ENSO persistence skill after 2000 is noticed for January-March initial months compared to other months. The drop in ENSO prediction skill and its association with ISMR resulted in decrease of ISMR skill in February hindcasts. But April IC hindccast have not much change for ENSO and ENSO-ISMR relationship indicating the presence of another predictor for ISMR, which is strengthened after 2000. The analysis concludes that tropical SST anomalies during the boreal summer are the extra prediction componenet for short lead hindcasts in the recent period for MMCFS. The presence of a predictor other than ENSO contributes to the skillful hindcast of ISMR at short lead, which is absent for long-lead hindcast.

Derivation of angular momentum budget equation for a region bounded by $\lambda 1$to $\lambda 2$, $\phi 1$ to $\phi 2$ and $P1$ to $P2$ in spherical(λ,ϕ,P,t) co-ordinate system with reviews and a case study .

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ABSTRACT

In this study an effort is done to explain the importance of general circulation(GC) Studies and a review of some of the earlier studies . Different constraints on GC study viz. Heat ,Water vapour ,Atmospheric mass and Angular momentum(AM) balance is explained. The importance of energy transport from tropics to extra tropics is explained with the help of Classical AM budget . An original derivation of AM budget equation is given for a region bounded by $\lambda 1 to\ \lambda 2$, $\phi 1$ to $\phi 2$ and $P1$ to $P2$ in spherical (λ,ϕ,P,t) co-ordinate system. The different terms are explained with relative importance. This technique is used to the diagnosis of different small, medium and large weather systems by several authors. A sample case study is given with a reanalysed dataset in a fine mesh width. The trapezoidal rule is used to quantify the integrals. The values of different terms in the AM budget equation are calculated for various pressure levels and periods. The sink and source terms are compared and the results are correlated with the help of charts and diagrams. This study could help to understand the system diagnosis of various systems such as monsoon depression, monsoon onset vertex, tropical cyclones , thunderstorms, jet streams , dust storm etc.

Keywords: - Angular Momentum Budget, Equation, Source/Sink terms,
Weather system case study, Diagnosis

Subseasonal Characteristics of Rainfall during Indian Monsoon Floods

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ABSTRACT

The seasonal extremes of Indian Summer Monsoon Rainfall (ISMR) - floods and droughts – are often thought to be triggered by external forcing such as the El Niño Southern Oscillation. Specifically, La Niña (El Niño) conditions are believed to modulate monsoon circulation leading to seasonally anomalous excess (deficit) rain over India. However, historical records suggest that ~ 40-50 % of these seasonal extremes (floods or droughts) over India have occurred when the equatorial Pacific sea surface temperatures were near neutral. Here, we focus specifically on monsoon floods and highlight the differences in rainfall evolution during (i) flood and normal rainfall years, and (ii) floods associated with La Niña and No La Niña conditions. Our analysis suggests that floods appear to be mainly because of increased rainfall either at the beginning and/or end of the season. Furthermore, the No La Niña floods are subseasonal, with a substantial increase in rainfall late in the season. We will also discuss, based on reanalysis data, a potential dynamical pathway in the latter category of floods that leads to a near doubling of rainfall over a 20 day period in late August.

Keywords: Floods, La Niña, Subseasonal Variability

ANALYSIS OF SOUTH WEST MONSOON WIND SPEEDS OVER INDIAN OCEAN USING WINDSAT DATA

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ABSTRACT

This study presents the analysis southwest wind speed over Indian ocean using windsat data. The observations of spatial monthly wind speed distribution in 40^0 to 120 ^{0}E longitude and -20 ^{0} S to 40 ^{0} N latitude is performed in this work. To examine Monthly wind speed (m/s) variations over Indian Ocean in summer monsoon season 16 years of monthly climatology over 2003 to 2019 was computed. The spatial distribution of wind speed in JJAS during each year is using windsat data from remote sensing system is also examined . As a result,the weaker wind speed than normal south-westerly winds over AS and maximum wind speed at 16m/s was observed in July month. The study help to determine the distribution of wind over JJAS during south west monsoon .

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 30°N and 50°N, 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 jetstrengthens 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.

Key words Indian summer monsoon; India Landmass; Asian jet-stream; vorticity; Rossby wave activity flux; Empirical Orthogonal Function; Principal Component

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Trends and Variability of Summer Monsoon Rainfall in Six Intensity Bins over Northeast India and Northcentral India

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ABSTRACT

The Summer Monsoon Rainfall (SMR) accounts for 75-80% of annual rainfall of India and its variability causes far-reaching consequences. So, research on SMR variability has significant socio-economic implications. In this study, features of SMR are investigated, to understand the variabilities of rainfall utilising gridded rainfall data of IMD and sea surface temperature (SST) data of Met Office Hadley Centre for 1901-2020. We classified rain events into different intensity bins viz. dry, low, moderate, high, very high, extreme rainfall events, for the two homogeneous regions, viz. Northeast India (NEI) and Northcentral India (NCI). From long-term trend (1901-2020) of seasonal rainfall intensity, it is observed that dry bin exhibits a significant increasing trend over NEI and NCI. A significant increasing trend is registered for very high bin in NEI; however, it is decreasing significantly in NCI. Extreme bin, showed significant increasing trends in NEI. Another important feature is that rainfall patterns in both regions have changed since 1960s, indicating impact of climate shift on the rainfall pattern. In NEI from 1960s the contribution by moderate (very high and extreme) bins was decreased (increased). In NCI, during 1961-1990, changes in contribution are observed from all the intensity classes, extreme bin shows a twofold increase in its contribution. And for the period 1991-2020, there is a dominant decrease in contribution by very high and extreme bins. Analysis on relationship of rainfall with SST in Indo-Pacific water domains brings out that NEI rainfall has significant positive correlation with SST in Indo-Pacific water while NCI has negative correlation. In NEI the extreme bin correlation has increased (decreased) significantly with SST in Arabian Sea, Bay of Bengal and South China Sea (North Central Pacific Ocean); likewise variations in relationship are found by high and extreme bins in NCI with South China Sea SST.

Keywords: Summer monsoon rainfall, Rainfall intensities, Regional rainfall variabilities, Rainfall-SST relationship

Seasonal variability of aerosols and its impact on cloud properties over Central and Western India

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ABSTRACT

Due to the constant rise of anthropogenic activities, the net global aerosol content has been increasing, having an impact on Indian Summer Monsoon Rainfall (ISMR). Among the other factors affecting ISMR and its variability, aerosol plays a vital role. Since aerosol serves as the seed upon which cloud droplets form, they get activated into cloud droplets/ ice crystals in subsaturated/ supersaturated air. The present study endeavors to assess the cloud-aerosol interaction and its impact on Central and Western India and its surroundings over the period of 2005 to 2020. The cloud and aerosol properties are thus, collected from MODIS (Moderate Resolution Imaging Spectro-radiometer). The Aerosol Index (AI) has been collected from OMI (2005-2020). Cloud fraction has been considered from ARIS. Tropical rainfall measuring mission (TRMM) data and IMD gridded rainfall daily data also have been used to calculate the mean rainfall and the percentage contribution of heavy, moderate, and low rainfall. The annual and seasonal variation shows that Aerosol Optical Depth (AOD) has a considerable increasing trend over Central and Western India and its surroundings during the study period of 16 years. The aerosol (i.e., concentration of pollutants) has been classified based on Angstrom Exponent (AE) and AOD through frequency distribution as low, moderate, high, and very high and the types of pollutants are made through AOD. The classification of the size and types of aerosol particles are made through AE. The result depicts that in the presence of coarse particles moderate and high pollution conditions are found to be more favorable for altering the behaviors of cloud properties. The absorbing aerosols show a direct effect in the presence of coarse particles while it shows an indirect effect in presence of fine particles. Further, the result shows the impact on the frequency and the magnitude of extreme rain events and moderate events during monsoon seasons over the study area.

Keywords: Aerosol, Cloud, Monsoon Rainfall (maximum 4 words)

EARLY WARNING SIGNALS OF HEAVY RAINFALL EVENTS FROM GPS DERIVED PRECIPITABLE WATER VAPOUR AND ZENITH DELAY ESTIMATES

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ABSTRACT

The heavy rain events pose a major threat to many inhabited and urbanized places around the world. A precise estimate of the frequency and distribution of these events can significantly aid in policy planning and observation system design. Measurements based on the Global Positioning System (GPS) open up new and exciting possibilities in this context. One of them is the ability to provide data of comparable quality in all weather conditions. Here we explore the relationship between Global Positioning System derived Zenith Total Delay (GPS-ZTD) as well as GPS derived Precipitable Water Vapour (GPS-PWV) content and its feasibility in forecasting heavy precipitation events. As water vapour is one of the most important characteristics to analyse rainfall activities, and precipitation is dependent on its condensation, we used GPS-PWV and GPS-ZTD to try to pinpoint heavy rainfall events related with water vapour fluxes. The continuously observed GPS data from Trivandrum, Kerala, was used for the estimation and analysis of ZTD over a nine-month period (April 1 to December 31 of 2018). The results show a precursory increase in ZTD followed by a decreasing phase prior to each major precipitation event associated with the Indian summer monsoon from 5:45 h to 6:45 h. These jumps are caused by the convergence of water vapour and the continued formation of cloud condensate and precipitation particles. Furthermore, a 45-year analysis of GPS and radiosonde-derived ZTD shows that the onset of the southwest monsoon over Kerala is clearly marked by an increased ZTD of 2.55 m to 2.7 m. As a result, the GPS-derived ZTD and PWV could be used to provide early warning of severe precipitation events and the onset time of the Indian summer monsoon, respectively.

Key Words: precipitable water vapor, zenith total delay, global positioning system, condensation

Role of LETKF based coupled data assimilation on seasonal prediction of Monsoon

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ABSTRACT

Early prediction of monsoon has multifaceted benefits. The improved ocean-atmospheric analysis (initial state) quality could enhance the predictions, as monsoon prediction is partly an initial value problem. In this study, the monsoon seasonal predictions are been analyzed by examining the role of two distinct coupled initial states, viz. the Climate Forecast System (CFS) Reanalysis (CFSR) and Indian Institute of Tropical Meteorology, University of Maryland - Weakly Coupled Analysis (IWCA). The IWCA implements the local ensemble transform Kalman filter, hence incorporates theoretically advanced features of flow-dependency and ensemble-based analysis compared to CFSR. The predictions initialized by IWCA has better represented the tropical modes of variability (Nino3.4 and IOD) in seasonal predictions compared to CFSR. In-addition, the CFSv2 predictions using IWCA simulate the large-scale monsoon features, convection centers, well and improved prediction skill (~22%) compared to CFSR predictions with a gain of one month lead time. The present study further insights the probable role of advances in coupled –data assimilation (IWCA) in enhancing the monsoon seasonal predictions.

Keywords: Data Assimilation, Seasonal Monsoon Prediction, Initialization shocks, Perturbed ensembles

GFS model fidelity in capturing the transition of low pressure area to monsoon depression

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ABSTRACT

Low pressure areas and monsoon depressions are the synoptic-scale systems that contribute largely to the Indian summer monsoon rainfall. India Meteorological Department currently uses a high resolution (~12 km) Global Forecasting System (GFS) model for short and medium-range operational forecasts over Indian region. In this study, we have evaluated the performance of the GFS model in capturing the transition of low-pressure areas to monsoon depressions (L2D). GFS has a good fidelity in capturing synoptic variance over the Indian region. GFS can simulate the composite precipitation structure for L2D cases. The upper-level warm core temperature structure is prominent for L2D cases, while it is at the lower level for the cases where LPS doesn't intensify and remains as low (RL). GFS can simulate the upper-level warm core temperature structure up to 24 hour. Model has good fidelity in capturing the upper-level potential vorticity maxima for L2D cases but amplitude is underestimated as the lead time increases. GFS fails to reproduce the potential vorticity structure and amplitude for RL cases. Positive lower to middle-level heating to the west-southwest sector of the system is seen for L2D cases but the heating is at the lower level for RL cases. Model greatly underestimates the verticalvelocity for L2D cases and RL cases with increasing lead time. GFS has good fidelity in simulating the dynamical parameters associated with L2D cases but shows lesser fidelity for RL cases. SYN eddy kinetic energy (EKE) is higher for L2D cases as compared to RL cases. Low-frequency background state (LFBS) and Intra-seasonal (ISO) scale to the SYN conversion and the eddy available potential energy (EAPE) to EKE conversion contribute positively and help to increase the SYN-EKE for L2D cases. However, the conversions are significantly small for RL cases and hence the SYN-EKE. Model has fidelity in capturing LFBS and ISO scale to SYN-EKE conversion but less fidelity in capturing EAPE to EKE conversion.

KEYWORDS
monsoon depression, monsoon low pressure area, monsoon, high-resolution model, GFS T1534, low to depression, remains low pressure system, synoptic system

PERFORMANCE OF HIGH RESOLUTION WRF MODEL OVER THE KERALA COAST DURING 2020 SUMMER MONSOON SEASON

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ABSTRACT

The state of Kerala receives 60-70% of the annual rainfall during the southwest monsoon season. The extreme rainfall and associated landslide events have shaken the backbone of Kerala during the last three years. They have had a crippling effect on our economy, our people, and our ecosystem. This study made an attempt to simulate the features of the Indian summer monsoon, over the coast of Kerala using the Weather Research and Forecasting model (WRF) and to verify the forecast using various matrices. Observational data from IMD, NOAA, ECMWF, etc., have been used in this investigation to seek qualitative and quantitative comparison between the simulated and actual magnitudes of relevant meteorological processes especially the coastal wind and rainfall. The model was initialized at 0000UTC for 72 hours on each day of the monsoon season of the year 2020 (30/05/2020 to 30/09/2020) producing a total of 124 simulations. Initial and lateral boundary conditions were forced by NCEP-GFS historical archive analysis data which has a spatial resolution of about 25 km and temporal resolution of 6 hrs. It is found from the analysis that, this particular model configuration is most suited for the prediction of light rainfall spells and heavy rainfall events are underestimated. The high-resolution model is able to capture the evolution of the average wind and is successful in predicting the different categories of peak winds based on the Beaufort scale. The three-day simulations also underlines the gradual decay in the quality of forecasts with lead time, especially in the tropical climate.

Keywords: Monsoon, Weather Research and Forecasting model, Meteorological processes, Coastal wind.

Study of Different Interpolation Techniques on Meteorological Parameters

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ABSTRACT

Filling missing values in big datasets is always an important concern. Most of the results of any research highly depends on data accuracy and one of the important parameters for data accuracy is efficiency of filling missing values in any dataset. In this paper we have tried to highlight this issue and studied different techniques of filling missing values. We have used different interpolation techniques along with simple mean, median and mode. For Statistical analysis we have calculated root mean square error (RMSE) of original and interpolated missing values to find out best suitable scheme. We have focused our study to different meteorological parameters such as temperature, relative humidity, dew point temperature and mixing ratio. This study suggests that median and Spline with order 1 will give us best results as compared to other difficult interpolation techniques such as Akima, polynomial etc.

Keywords - Missing values, Interpolation, Temperature

DISTRICT-WISE LONG-TERM TREND ANALYSIS OF RAINFALL PATTERN OVER GANGETIC REGION IN WEST BENGAL

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ABSTRACT

The changing pattern of rainfall, in the area of climate change, draws urgent and systematic attention, since it has significant effect on both the availability of freshwater and food production. The Aim of the present study was to estimate long-term trend in the amount of rainfall for Gangetic West Bengal (GWB) meteorological sub-division of India and each of the 13 districts under GWB separately. Monthly rainfall time series data of 113 years (1901-2013) were analyzed to measure monotonous trend of rainfall employing Sen's slope estimator. Statistical significance of the trend was determined using non-parametric Mann-Kendall test. An important result derived from the analysis was that the GWB sub-division and 5 districts showed significant increasing trend (mm/year) of annual rainfall. An inclining trend of monsoon precipitation, which was significant, found in four districts viz. Bankura, East Midnapore, South 24 Parganas (S24P) and West Midnapore along with GWB itself. A major finding of the study revealed that nine districts and GWB had significant increasing trend in September rainfall with a maximum value of 1.077 mm/year in S24P district. Contribution of rainfall in post-monsoon season increased considerably in Kolkata and Birbhum districts. On the contrary, Burdwan and Nadia districts, in the pre-monsoon season, had considerable declining trend of rainfall. Significant decreasing trend of precipitation, a concern for Nadia district, with magnitude of 0.094 and 0.224 mm/year, was observed in the months of March and April respectively. It can be concluded from the present study that the GWB sub-division and the districts under it showed substantial changes in rainfall pattern over the time period.

Keywords: Gangetic West Bengal, Mann-Kendall test, Sen's slope estimator, Trend estimation

On the simulation of northeast monsoon rainfall over southern peninsular India in CMIP5 models

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ABSTRACT

The skill of 34 CMIP5 models to simulate the mean state and interannual variability of Northeast Monsoon Rainfall (NEMR) is studied here. The mean (1979-2005) NEMR over southern Peninsular India (SPIRF), Indian Ocean and Maritime continents (10°S-30°N,40°E- 120°E) is simulated reasonably well by CMIP5 models with pattern correlation ranges from 0.6 to 0.93. Diverse behaviour in the simulation of Indian and Pacific Ocean SST is observed in the CMIP5 models. A set of models (high skill models: HSM), which shows an NIOD like mean (1979-2005) SST bias in Indian Ocean and strong La Nina like mean SST bias in the Pacific Ocean, are able to simulate the mean NEMR more realistically. Another set of models (low skill models: LSM) which shows a Positive IOD (PIOD) like mean SST bias in the Indian Ocean and weak La Nina like mean SST bias in the Pacific Ocean are not able to simulate the observed equatorial Indian Ocean westerlies, which leads to an abnormal ascending motion and unrealistic wet bias over the western Indian Ocean and dry bias over the southern Peninsular India, southeast Asia and southeast Indian Ocean. The observation analysis reveals that the establishment of South China Sea anticyclone and Bay of Bengal anticyclone during El Nino and PIOD are strongly related with the ascending motion over south peninsular India and enhances the south Peninsular Indian rainfall during NEM season. Around 70% of the CMIP5 models were not able to capture the observed positive correlation that exist between SPIRF and Nino3.4 SST as well as SPIRF and DMI. Unrealistic westward extension of South China Sea anticyclone and Bay of Bengal anticyclone (up to 70°E) is also observed in the LSM-IAV model ensemble. This is manifested as the abnormal descending anomalies and unrealistic dry bias over the southern Peninsular India and negative CC between SPIRF and Nino 3.4 SST as well as SPIRF and Dipole Mode Index. The descending anomalies over South China Sea and ascending anomalies over the western Indian Ocean and southern Peninsular India (50°E-80°E) is wellcaptured but with lower intensity in HSM-IAV model ensemble and hence it captures the observed positive CC between SPIRF and Nino3.4 SST as well as SPIRF and DMI.

SEASONAL RAINFALL VARIABILITY OVER KERALA IN A WARMING CLIMATE

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ABSTRACT

Indian summer monsoon contributes 65-75% of the annual rainfall over Kerala, which influences the economic activities, way of living, food preferences and even the behavioral responses of the community. Despite lot of scientific and technological advancement, our dependence on monsoon has not been averted. For the period 1948-2019, an attempt was made to understand the annual rainfall variability over Kerala during excess and deficit years. The Kerala summer monsoon rainfall (KSMR) shows decreasing trend with time over the last seven decades. The influence of dominant phases of ENSO largely affects ISMR variability but has little influence on KSMR, however IOD phases has strong influence on KSMR. Excess (deficit) years are characterized by high (low) Tropospheric Temperature (TT) over the Indo-Tibetan plains due to high (low) diabatic heating contributed from sensible and latent heat. Corresponding reduction (enhancement) of TT over Equatorial Indian Ocean contributes strong (weak) TT gradient during excess (deficit) years which trigger strong (weak) easterly wind shear and positive (negative) moisture flux convergence over Kerala region. In the lower levels, this is associated with strong (weak) cross equatorial low level jet during excess (deficit) years. Hence it may be concluded that, TT gradient and easterly shear are the dominant factors modulates the excess and deficit KSMR.

Keywords: Excess and Deficit KSMR, Tropospheric Temperature, Easterly Shear, IOD

Artificial Intelligence and Machine Learning for prediction of Summer Monsoon Rainfall for Homogeneous Rainfall Regions of India

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ABSTRACT

Indian summer monsoon plays a key role in agriculture and in turn effect the country's economy. The India receives nearly 80% its annual rainfall during June to September (JJAS) season. Agricultural production is mainly depends on Summer monsoon rainfall. About 65% of India land has been in influence of rainfed agriculture. The seasonal and sub-seasonal forecasts are required for advance planning of agriculture activity and water management. The timely and accurate predictions are necessary for robust planning and mitigation policies. The forecast of ISMR started more than a century ago. Many researchers are adopted various statistical and dynamical models to predict the ISMR. Even now with advanced computational facility the accuracy of seasonal forecast limited 60-70%. Every monsoon is unique and its association with various climate drivers vary, which will add the complexity in ISMR prediction. In addition to inter-annual & intra-seasonal variability, the ISMR varies spatially over different regions of India. Prediction of ISMR at a regional scale is very important for agriculture planning and water management. The seasonal forecast of ISMR has been attempted in many research studies using Neural Network techniques and less focused on regional scale. To fill this gap, In this research work we have introduced Neural Networks (NNs) techniques at regional scale and developed two types of models; NNs model and Hybrid model. In NNs model category we have used ANN, LSTM and CNN. For Hybrid models we combined the NNs model with the SVR algorithm and developed ANN_SVR, LSTM_SVR, CNN_SVR hybrid models. We have adopted these models to predict the JJAS rainfall over homogeneous rainfall regions of India; North West India, West Central India, Central North East India, North East India and Peninsula India. And various statistical parameters have been calculated to assess the performance of these models such as Willmott's Index of Agreement and Kendall's Tau. The forecast error of 1). North West India for NNs models is 11.74%, 11.94%, 10.98% and for the Hybrid models 11.93%, 12.80%, 12.62% respectively. 2). West Central India for NNs models 11.05%, 11.45%, 10.25% and for the Hybrid models 11.26%, 9.95%, 8.82%. 3). Central North East India for NNs models is 19.14%, 18.41%, 13.35% and for the Hybrid models 17.75%, 16.29%, 12.54%. 4). North East India for NNs models 9.45%, 10.57%, 8.60% and for the Hybrid models 9.02%, 8.60%, 8.12%. 6). Peninsula India for NNs models 9.60%, 10.68%, 10.85% and for the Hybrid models 9.72%, 10.59%, 11.39%. Overall, the hybrid model has shown superior skill when compared to the NNs model.

Keywords: ISMR, Neural Networks, Support Vector Regression.

Weekly rainfall probability analysis by Gamma distribution model and advisory to farmers for crop operations in Anand Station of Gujarat

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ABSTRACT

Distribution of rainfall in India is frequently considered as one of the most important parameters in cropping patterns. Many agricultural activities, such as crop planting, crop harvesting, and pest management, need daily or weekly probabilities rather than annual or average rainfalls. Therefore, an attempt has been made here to predict weekly rainfall probabilities of Anand station of Gujarat by the Gamma Distribution Model. Used weekly rainfall data series is of 40 years i.e. from 19802020 of Anand station. The rainfall data of Meteorological standard weeks from 22 nd (28 th may -3 rd June) to 42 nd (15 th -21 st October) were analyzed to compute rainfall probabilities. Here, shape & Scale parameter estimated by method of Maximum Likely Hood. The relation of Scale and Shape parameter with Weekly Mean Rainfall is decreasing & increasing respectively. Probabilities of getting Weekly Rainfall (WRF) for the amount of 0.1, 0.5, 1.27 and 15 inches were computed by Gamma distribution compared with actual probabilities and found significant. The highest difference was found 12% in the standard week (SW) of 33. Rests of the differences were less than 7%. Differences between computed and actual probabilities for Weekly Rainfall of 1.27 and 15 inches were less than 1 %. Found Percentage of Average error less than 10% for all computations. Computed probabilities are tested with student t-test for two tails and found significant with actual probabilities. Vice-a versa weekly rainfall predicted for standard week of 22 to 42 nd at different probabilities level. These levels were 10% to 100 % with the increment of 10. As the probabilities were increases Weekly Rainfall decreasing. In the month of August in each case were weekly rainfalls increasing. For the 100% probability, weekly rainfall is nearly zero very small amounts. The probabilities obtained to receive weekly rainfall of 0.5 or 1 inch in the standard weeks from 24 to 26 is between 50 to 66%. Therefore, here, farmers shall be advised to go for sowing in these weeks for kharif crops. As the monsoon advances getting good amount of rainfall like 0.1,0.5- & 1.27- inches probabilities become high so farmers can be advise to go for more farm operations like fertilizing, spraying insecticides, etc for a particular crop. Lastly, as probabilities of getting weekly rainfall for fixed amount decreases in the standard week of 29 to 42 nd it is advisable for crop harvesting. Also, farmers will be advising for getting certain amount of rainfall vice –a versa.

Keywords: Gamma distribution, weekly rainfall, Probability.

GEWEX ASIAPEX: TOWARD UNDERSTANDING OF VARIABILITY OF THE ASIAN HYDROCLIMATOLOGICAL SYSTEM

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ABSTRACT

We have launched the Asian Precipitation Experiment (AsiaPEX) in 2019 to understand Asian land precipitation over diverse hydroclimatological conditions and multiple time scales for better prediction, disaster reduction, and sustainable development. AsiaPEX is a prospective Regional Hydroclimatorogical Project (RHP) under the Global Hydroclimate Panel (GHP). It is a successor of the GEXEX Asia Monsoon Experiment (GAME) and the Monsoon Asian Hydro-Atmosphere Scientific Research and Prediction Initiative (MAHASRI). One of our key questions of our project is to elucidate the future projection of the Asian monsoon system, which emerges as a crucial mission under the climate change.We defined our project strategy in our six approaches: 1) observation and estimation of variation and extremes in Asian land precipitation and important variables, 2) process studies of Asian land precipitation focusing on diverse land-atmosphere coupling, 3) understanding and prediction of the variability of Asian monsoon from subseasonal to interdecadal time scales, 4) high-resolution land surface hydrological modeling and monitoring incorporatingimpacts of human water withdrawal, agriculture, vegetation and cryosphere, 5) coordinated observation and modeling initiatives, 6) detection and projection of the climate change impact on regional precipitation in Asia. We had a Kick-off Conference in 2019 and develop research activities from above approaches. One of our main activities will be conducting an observational and modeling initiatives. We will propose to conduct Asia Monsoon Year-II as a coordinated observational and modeling initiative toward the understanding of the systematic view of Asian hydroclimatological system under the influence of summer and winter Asian monsoon system. Coupling of the land surface and the atmospheric processes including the convection would be a focus of the project. An improvement of the predictability in sub-seasonal to seasonal (S2S) time scales will be a benchmark of our understanding of the system. The intensive observation period will be around 2025/26-2026/27 monsoon seasons.

Keywords: Asian monsoon, Precipitation, Observation and Modeling Initiatives, Predictability

Predictability of Indian Summer Monsoon clouds: An Improved Journey from CMIP5 to CMIP6

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ABSTRACT

Skillful seasonal prediction of monsoon has great socio-economic value. Indian summer monsoon rainfall (ISMR) prediction remained a great challenging problem with the sub-critical skills of the dynamical models. This is attributed to the limited understanding of the interaction among clouds and convection. Here, we have analyzed the teleconnection of total cloud fraction (TCF) with global sea surface temperature (SST) in multi-model ensembles (MME) of the fifth and sixth Coupled Model Intercomparison Projects (CMIP5 and CMIP6). CMIP6-MME has stronger teleconnection (TCF and global SST) pattern over extra-tropics (R ~0.43) and north Atlantic (R ~0.39) region, which in turn resulted in improvement of rainfall bias over Asian monsoon region (ASM). CMIP6-MME has improved seasonal mean rainfall, TCF and outgoing long-wave radiation (OLR) than CMIP5-MME along with better representation of spatial correlation. There are improvement in mean TCF, OLR and rainfall by ~45%, ~31% and ~29% respectively in CMIP6-MME than CMIP5-MME. CMIP6-MME displays a higher capability in reproducing the TCF along with improved dry (wet) bias of rainfall on land (ocean). The development in the physical representation of clouds in models has led to better mean and teleconnection relative to the previous generation of models. Therefore, it is crucial to have new generation models, which most likely represent the improved relationship of clouds and SST than their predecessors for providing a more realistic simulation of monsoon. Our results establish the credibility of the sixth generation coupled models and provide a scientific basis for the betterment of seasonal prediction.

Keywords: CMIP5, CMIP6, ISMR, Seasonal Prediction

Time series rainfall forecasting for Kumaon region of Uttarakhand using SARIMA model

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ABSTRACT

Rainfall is an important parameter for water resources application particularly in rainfed agricultural system. Rainfall in Himalaya varies from palace to place due to complex topography and it is hard to predict based on empirical formula. The objective of the present study is to develop SARIMA model for Almora, Hawlbagh and Mukteshwar station located in Kumaon division of Uttarakhand and to determine the accuracy of the developed model in the same region. The present research utilized univariate time series rainfall model to forecast rainfall in Kumon region. We have selected the best SARIMA model fitted to our data which exhibited the least AIC and BIC values. Finally, we identified the best model separately for each location after following three Box-Jenkings methodologies (model identification, elimination of parameters and diagnostic checking). The selected model is evaluated for residual normality test and the forecasting performance statistics was found (Almora= 57.42mm, Hawalbagh= 54.71mm and Mukteshwar= 44.11mm). The model forecast results showed that the forecast data mimics well with the observed in the data except in extreme events.

Keywords: SARIMA, Prediction, AIC, Himalaya, Precipitation

Changes in Asian jet meridional displacement and its influence on Indian summer monsoon rainfall in observations and CFSv2 hindcast

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ABSTRACT

Studies have analyzed the meridional displacement of Asian jet (MDAJ) and its influence on East Asian rainfall; however, the relation with Indian summer monsoon rainfall (ISMR) is not fully explored, limiting the prediction skill of ISMR. In this study the impact of MDAJ on the ISMR in observations and Climate Forecast System version 2 hindcast is examined, for the period of 1985 to 2019 boreal summer (JJAS). Empirical Orthogonal Function, correlation and regression analysis etc has been used for the study. The leading mode of variability in the upper-tropospheric zonal wind anomalies along the Asian jet exhibits a north–south seesaw pattern in both observation and model. The strength of the meridional displacement/loading of the summer Asian jet is robust over the East Asian region in the observations, whereas in the case of CFSv2 the signals are strong both over the West and East Asian regions. The southward displacement of the Asian jet (SWDAJ) provokes reduced precipitation over the central and northern India regions in observation which is well captured by the model but with slight overestimation of its strength. Physical mechanisms that link the SWDAJ and monsoon rainfall are unravelled in this study. Observed precipitation enhancement in the Meiyu–Baiu rain band is the characteristics of SWDAJ over East Asia (EA), linked with divergence over India, which is completely absent in the model. During June and July, the dominant meridional displacement of the Asian jet is located over both West and EA regions. These dominant anomalies migrated eastward to the EA region by September in the observations, whereas persisted over both regions in the model. This study suggests that the teleconnections of the Asian jet variability and ISM rainfall are over dependent on ENSO in the model, specifically in late monsoon season, limiting ISMR prediction skill.

Keywords: Asian Jet variability, Indian Summer Monsoon, Meridional Displacement

ASSESSING THE ROLE OF CLOUD MICROPHYSICAL PARAMETERIZATIONS IN SIMULATING THE DIFFERENT PHASES OF MONSOON LOW PRESSURE SYSTEMS OVER THE INDIAN REGION

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ABSTRACT

Numerical Weather Prediction (NWP) is one of the vital components of meteorology and has direct implications for society. However, the most significant contributions to the forecast errors have sources in the parameterization schemes of the NWP model. This study assesses the impact of five cloud microphysical parameterization schemes (MP) in simulating the different phases of monsoon low-pressure systems (LPS) using the Weather Research and Forecasting (WRF) model. These LPSs are significant rain-bearing synoptic disturbances that account for ample monsoonal rainfall over the Indian subcontinent. Total twenty-six cases comprising of 12 depressions (MD) and 14 deep depressions (MDD) that formed over the Bay of Bengal are considered. A total of 130 simulations are carried out with a lead time of up to 96 hours at 27, 9, and 3km horizontal resolution, and composite results are presented. The five MP schemes are WRF single moment 6 class (WSM6), WRF double moment 6 class (WDM6), Milbrandt (MIL), Thompson (THOM), and Aerosol Aware Thompson (AAT). ECMWF reanalysis 5 th generation (ERA5) datasets are used to initialise the model as well as validate the basic atmospheric variables (e.g., wind, temperature, humidity, vertical velocity, etc.) and hydrometeor species (cloud water, rainwater, snow, and ice). It is found that the choice of MP significantly impacts the characteristics of the LPSs, such as rainfall, wind, temperature, and associated convective processes. However, in general, all the MPs have underestimated the precipitation, and WDM6 has the least errors for both MD and MDD; WDM6 produced the lowest amount of wind underestimation in the south-western sector of the storm up to 96 hours of simulation. The lowest biases in moisture convergence and absolute vorticity are found in WDM6, which leads to accurate surface moisture flux and rainfall. Further, results related to the inter-comparisons of MD and MDD will be discussed.

Keywords: WRF, Cloud Microphysics, Monsoon Depressions, Composite Analysis

Predictability and Prediction of the Seasonal Indian Summer Monsoon

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ABSTRACT

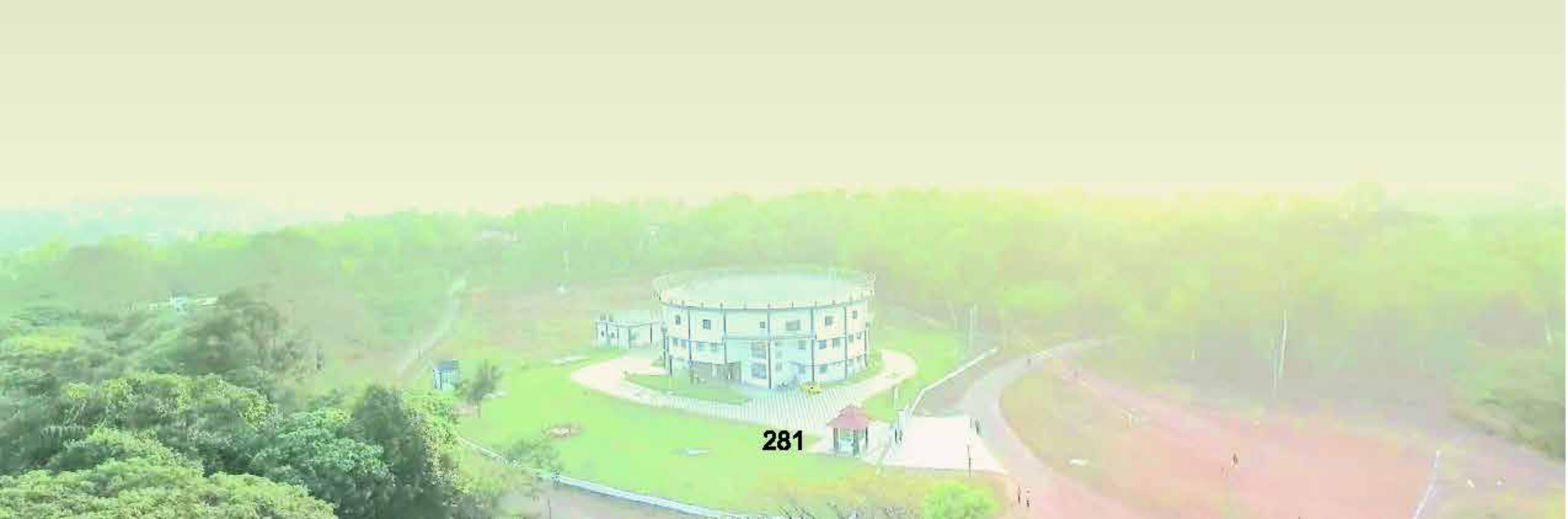
The Indian summer monsoon rainfall (ISMR) being the lifeline for millions in the South Asian region, predicting monsoon rainfall at least a season ahead has remained an insurmountable problem for over a century (Walker, G.T. (1924)). Moreover, the limit of ISMR predictability based on the 'signal-to-noise'/'perfect model' framework is estimated to be low (r~0.65), which suggests an inherent limitation in the estimation of the predictability limit of ISMR. However, in recent studies, the paradoxical behaviour of the "signal-to-noise" framework is increasingly apparent, and skill in climate prediction is often higher than the estimated limit of predictability (e.g. Smith *et al.* 2020). The Indian summer monsoon is also not an exception to the Signal-to-noise paradox, and there are some indications that ISMR might have higher predictability than estimated earlier (e.g. Saha et al., 2019).

Using re-forecast experiments of state-of-the-art climate model (IITM CFS; 52 ensembles, 30-years), we show a much higher potential predictability limit of ISMR (r~0.80) in one season advance. As the sub-seasonal components are the building blocks of the monsoon, it is shown that a realistic contribution of individual sub-seasonal modes to the seasonal rainfall is essential for increasing the ISMR prediction skill and predictability limit. Most climate models have difficulty in simulating subseasonal modes, and therefore, their projection on ISMR anomaly is affected. For a similar reason, teleconnection between sub-seasonal mode and predictor also suffers. We used an innovative technique to identify ensemble members with a reasonable sub-seasonal contribution to the seasonal anomaly, and that shows a possibility of further improvements in ISMR skill using AI/ML.

Keywords: Seasonal Prediction, Potential Predictability

TCC

Tropical Cyclones in Changing Climate



Rapid Intensification of Tropical Cyclones - A Perspective from the North Indian Ocean

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ABSTRACT

On average, 5 to 6 tropical cyclones form every year over the North Indian Ocean (NIO). Even though the annual frequency of tropical cyclones in the North Indian Ocean is low compared to other basins, they have caused severe destruction and loss of life to the neighbouring region. The tropical cyclone forecasts have improved substantially in the recent decades in terms of minimising the intensity and track prediction errors. However, forecasting the rapid intensification process of tropical cyclones under rapid warming of the Indian Ocean remains a challenging task to the forecasters. Rapid intensification significantly increases the risk posed by tropical cyclones, especially when they occur close to the coast. Rapid intensification (RI) is defined as an increase in the maximum sustained wind speed of 30 knots or more within a period of 24 hours. Rapid intensification events occurred in the North Indian Ocean are investigated to better understand the dynamical and thermodynamic processes controlling the RI. The position and intensity changes obtained from the available best track data is used to identify the cyclones undergoing the rapid intensification process in their entire life cycle. Then individual influence of cyclogenesis parameters forming the commonly used genesis potential index variations are investigated to understand the RI process during the pre-monsoon and post-monsoon seasons.

Keywords: Tropical cyclones, climate change, rapid intensification, North Indian Ocean

Understanding the Variations in Translational Speed of Tropical Cyclones Over North Indian Ocean in Last Three Decades

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ABSTRACT

Tropical cyclones have great destruction potential which causes serious harm to economy, ecosystem, and society. The movement of tropical cyclone affects sea surface temperature; leaving behind cooler sea surface temperature because of cyclone induced upwelling [Greatbatch R. J. 1985]. Larger cooling is generated by slower moving tropical cyclones as they give more momentum to the ocean which leads to increased vertical mixing of warm water of surface with underlying cold water [Lin et al., 2009]. So, it is necessary to understand the variation of translational speed in the past. This study aims to understand the variation of translational speed of tropical cyclones generated in north Indian ocean region in last three decades (1990-2019). For this purpose, the variation of translational speed with intensity is studied along with its annual variation. Also, the relation of translational speed with TCHP and the spatial distribution of translational speed is studied. It is found that the average translational speed has been decreased in last three decades. This translational speed is negatively correlated to TCHP. The decrease in translational speed with the increasing intensity of tropical cyclones is also observed. Moreover, it is also observed that rapidly intensifying cyclones formed over Bay of Bengal arefast moving than their counterparts over Arabian Sea.

Keywords: Translational speed, North Indian Ocean cyclones, Decadal variability, Tropical Cyclone Heat Potential

Assessment of Dependency of Waves on Tropical Cyclone

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ABSTRACT

This study aims to analyze dependency of waves on tropical cyclone in North Indian Ocean (NIO), which is restricted to coordinates of 0-20N and 40E-100E. The cyclone parameters were obtained from the International Best Track Archive for Climate Stewardship (IBTrACS) dataset and the hourly Significant wave height (SWH) from the ERA-5 global atmospheric reanalysis data from the period 1979 to 2020. The cyclone parameters like wind speed, location, and time were extracted for all individual cyclones over the location during the study period. The significant wave heights (SWH) were extracted from the cyclone tracks for all 366 cyclones. In addition, SWH were spatially averaged over cyclone track for 200 km resolution from the track position. Both the SWH from the track and spatially averaged SWH were used in further calculations. In order to understand the waves distribution along the cyclone tracks the occurrence frequency of the waves along the cyclones was plotted. Based on this information, the important wave bins were sorted out for understanding the wave dependence on cyclones on this individual bins. The wind and wave dependency have been seen without time lag and with a time lag of one day. The purpose of this method is to delineate the wave dependence on winds from wind dependence on wave. The correlation coefficient is more in the case of the wave relationship with winds on the eye-wall of the cyclone. Though the wave-wind relationship with one day lag wave from cyclone winds is less, it is found to be statistically significant considering the high degree of freedom. Since the objective of this study is to find the wave dependence on cyclone winds, the wind and waves are grouped into different bins based on the occurrence frequencies. If there is any relationship of waves on cyclone winds, it could be seen in the scatter plots obtained for the different wind-wave groups. From the scatter plots of different group it could be seen that there is no statistically significant relationship between waves and cyclone winds for any of the classified bins. This is true in the case of waves with one day lag from cyclone winds. Understanding the dependence of waves on cyclone winds is important for the prediction of tropical cyclones occurring in the Bay of Bengal and the Arabian Sea. Though the present study could not establish any relationship

Keywords: Climate change, Weather Prediction, Atmospheric Radar

Impact of tropical cyclones over Bay Of Bengal on the surface boundary layer parameters during different monsoon seasons

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ABSTRACT

In this paper we are analyzing the impact of tropical cyclones (TCs) over the Bay Of Bengal (BoB) on surface boundary layer parameters during the pre monsoon, monsoon and postmonsoon seasons. We utilized track of tropical cyclones over BoB from Joint Typhoon Warning Centre Best Track data and boundary layer parameters are obtained from tropflux data products. The climatology of momentum flux (MF), sensible heat flux (SHF), latent heat flux (LHF), wind speed (WS), atmospheric boundary layer height (ABLH), outgoing longwave radiation (OLR) and rainfall have been studied during all the three seasons by considering base period as 1979-2018. By tracking locations of TCs occured in BoB from 1979-2018 in different monsoon seasons, we find that more tropical cyclones have occurred in the post monsoon season compared to the pre monsoon season, and the least is in the southwest monsoon season. Forgetting the impact of TCs in surface boundary layer parameters we are taking anomalies of each parameter by analyzing 5 days before, during and 5 days after the cyclone in order to explore the boundary layer conditions before, during and after the TCs. From anomalies of MF one thing is clear that during the 5 days before the cyclone in all 3 seasons we are getting a decrease in MF compared to during the cyclone and after 5 days of the cyclone. Then during the cyclone in all 3 seasons TCs trigger more increase in MF, but it again increases to higher value in the after 5 days of cyclone only during pre monsoon, while in south west monsoon and post monsoon seasons MF is showing a decreasing trend. We have also found that other surface boundary layer parameters too have profound differences during the TC periods while comparing with before and after the TC phases.

Keywords: Boundary layer parameters, Tropical cyclones, Bay of Bengal

Role of warm Ocean conditions in the genesis of cyclone 'Tauktae' along the west coast of India

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ABSTRACT

Recent studies show that there is a rapid rise in the frequency of occurrence of tropical cyclones over the Arabian Sea (AS). Tropical cyclones occurring over this region can have catastrophic impact over life and property. Earlier AS was less prone to tropical cyclones when compared to Bay of Bengal (BOB), however recent years shows that there is an increase in the number of tropical cyclones over AS than in the BOB (Deshpande et al.,2021). This is evident from the cyclone 'Tauktae' which recently developed over Lakshadweep in mid-May 2021, which further intensified in to a very severe cyclonic storm (VSCS). While analysing the OI-SST data in our study during the pre-monsoon period (MAM) of 2021, it was found that the western coast of India shows more warming compared to that of the eastern coast. Also the three month ocean heat content data anomaly observed from NOAA-NCEI from the period 1955 to present showed an increasing trend with an observed heat content of 10^{18}-11^{18} Joules during the year 2020-2021, indicating favourable conditions for cyclogenesis. Increase in the number of cyclone formation is associated with the rise in sea surface temperature (SST). Warmer atmosphere could hold more moisture and can lead to more cyclone activity. Cyclones are intensifying rapidly due to consistent warming occurring over the Indian Ocean. The study was intended to identify the frequent occurrence of cyclones over the west coast of India and their association with the change in SST, which can open the way to predict and mitigate the catastrophic impact of changing weather phenomena over the Indian region.

Keywords: Weather Extremes, Climate Change, Tropical Cyclone

Tropical Cyclone Track & Intensity Prediction skill of GFS Model during 2021

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ABSTRACT

This study has attempted to predict and verify the tropical cyclone tracks over the North Indian Ocean using the Global forecast system (GFS) model. 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). A total of two tropical cyclones formed over the North Indian Ocean during 2021, i.e., Tauktae over the Arabian Sea and the Yaas cyclone over the Bay of Bengal, are considered for this study. The model predicted tracks 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 Tauktae varies from 40 to 320km for 6 to 108hrs and is less than 100 km up to 72hrs; whereas for Yaas cyclone, DPE varies from 33 to 203km for 6 to 96hrs and is less than 125km up to 48hrs. 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 model underpredicted the cyclone intensity. Finally, there is a large variance in track & intensity errors from the cyclone to cyclone and Bay of Bengal basin to the Arabian Sea basin.

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

"FACTS" AND "MYTHS" ABOUT THE VERTICAL STRUCTURE OF MARINE ATMOSPHERIC BOUNDARY LAYER (MABL) UNDER THE INFLUENCE OF A TROPICAL CYCLONE

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ABSTRACT

Although considerable progress has been made in improving the early predictability of the tropical cyclones, our knowledge of the vertical structure of the marine atmospheric boundary layer (MABL) over a cyclone-affected ocean remains limited. Due to limited in situ observational data of MABL during the passage of a tropical cyclone, most of our understanding about the vertical structure of MABL during a cyclonic storm comes from numerical simulations. Here, we investigate the impact of a very severe cyclonic storm 'OCKHI' on the MABL parameters over the Arabian Sea by using a regional numerical weather prediction model, namely Consortium for Small-scale Modelling (COSMO). Time-series Meteograms of the surface-layer and upper-air meteorological parameters are examined for six distinct locations on the trajectory of OCKHI. Equivalent day analysis on the surface-layer turbulent fluxes over these locations reveals a substantial rise in the magnitude of sensible and latent heat fluxes during the passage of the storm. Surface-layer parameters within the MABL exhibit large diurnal variability during the passage of the storm compared to the normal days. Profiles of thermodynamic parameters indicate a significant dip in the mixed layer heights near the eye of the storm due to the formation of deep convective precipitating clouds. A decline in the mixed layer height during the propagation of the storm was a persistent feature. The present study also provides a conserved variable analysis of the equivalent potential temperature and specific humidity for a diagnostic investigation on the MABL processes and the movement of an air parcel.

Keywords: Tropical Cyclone, Marine Atmospheric Boundary Layer, Conserved Variable Analysis, Convection

THE SCENARIO OF SEA SURFACE SALINTY AND CYCLONE IN THE COSTAL PART OF BAY OF BENGAL DURING LAST DECADES

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ABSTRACT

Sundarban is situated in coast of the world largest delta of Ganges and Brahmaputra. Nearly 10 thousand square kilometre is exposed as a coastal region of India(40%) and Bangladesh (60%).From last few decades due to human population expansion the clearance of mangroves(for agriculture and aquaculture production) become a very alarming condition.

Here it has been studied the degradation of world largest mangrove and the variation of sea surface salinity(SSS) in last few years, also my another concern is about the effect of the tropical cyclones occurred in the Bay of Bengal and land fall in the sundarban coast. NASA Landsat and SMAP data has been used for mangrove cover and SSS measurement respectively. The best tract data and e-atlas of Tropical cyclones provided by IMD, New Delhi has been used for cyclone study . The evaporation caused by the mangrove degradation directly effects SSS which can modulate the TCs occurrences. On the other hand the mangrove always played like a barrier of TCs to protect the costal habitat. Whereas on the day of TC passes the SSS significantly decrease at that part of region. This symbiotic relationship of mangroves, SSS and cyclones is the main concern of this study. I have found some significant result and correlation statistically and analytically between all of them.

Cirrus characteristics over Indian Peninsular Plateau during Tropical Cyclones

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ABSTRACT

Any perturbations in the atmosphere can change the physical as well as the optical properties of tropical cirrus clouds. Tropical cyclones modulate the troposphere- stratosphere exchange processes resulting deep convective system beneath the tropopause. In this study, the vital role of tropical cyclones on atmospheric processes in shifting the tropopause level and their interaction on cirrus formations, dissipation and other related microphysical properties over the Indian Peninsular region was examined. Results of this study reveal that a substantial variability exists in the cirrus cloud characteristics during the tropical cyclones and in between stages of cyclones like pre-cyclone, post-cyclone and the severely affected day. The results also describe the effects of deep convective system associated with the tropical cyclones on the physical and optical characteristics of cirrus formations. The characteristics of cirrus cloud observed during the passage of tropical cyclones Hudhud (2014), Phailin (2013) and Nilam (2012) are analysed. From the unique conditions observed in tropical cirrus properties, we can analyse how the tropical cyclone modulates the cirrus characteristics. And thus, by analysing the cirrus cloud characteristics, we can predict the intensity variations of the ongoing cyclone.

Keywords: Tropical cirrus clouds, Tropical cyclones, Indian Region, Lidar

Recent changes in Tropical Cyclone activity over Bay of Bengal associated with ENSO

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ABSTRACT

El Niño-Southern Oscillation (ENSO) is the important phenomenon causing global climate variability on inter-annual time scales. The impact of ENSO on tropical cyclone (TC) in different ocean basins like North Pacific and Atlantic has been widely investigated. ENSO also influences TC activity in the Bay of Bengal (BoB) during post-monsoon season. Accumulated cyclone energy (ACE) in the BoB is negatively correlated with Niño3.4 SST anomaly during Oct-Dec for the period of 1993–2010 (Grishkumar, Ravichandran,2012) and during 1972-2015 (Pankaj Bhardwaj etal.,2019).

However, in the recent 5 years 2016-2020, the correlation has changed it's sign (CC value= +0.47). 2018 and 2019 were El Niño years and 2020 a LaNiña year. 2018 and 2019 ended with high TC activity in BoB during post monsoon season, while 2020 was very less active .

In the present study ocean thermal structure for two contrast years 2019 and 2020 are examined, which plays a critical role in the genesis, intensity change of tropical cyclones, along with environmental parameters which impact tropical cyclone (TC) formation and intensity change. Using NCEP GODAS data, different parameters such as SST, MLD, D20, TCHP, SSH which have effect on TC intensity and movement, are analysed. Monthly SSTs for 2019 post monsoon season are found to be greater by 0.5° C than that for 2020 in the BoB. MLD (SSHA) is higher by 10-15m (0.1m) and D20 is deeper by 20 m during 2019. Also TCHP is more in 2019 by 40 kJ/cm^2 supporting increased TC activity. Atmospheric parameters like wind shear and middle tropospheric relative humidity from NCEP products, are also found to be favorable for higher TC activity during 2019. Further, analysis is performed for the year 2018 which also has high TC activity in the basin during this period. In addition large scale circulation pattern will be discussed.

Keywords: ENSO, Bay of Bengal, Tropical cyclone, Ocean thermal structure

INITIAL RESULTS OF WIND OBSERVATION OF PHASED ARRAY DOPPLER SODAR INSTALLED AT ATIGRE, KOLHAPUR STATION

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ABSTRACT

The mean wind profile in the tropical cyclone boundary layer is one of the important parameters in the field of meteorology. A phased-array Doppler sodar system has installed at the Center for Space and Atmospheric Science (CSAS), Sanjay Ghodawat University, Kolhapur (16.74° N, 74.37° E; near the western coast of India), in collaboration with Indian Institute of Tropical Meteorology (IITM), Pune for continuous measurements of the wind profile upto 1.2 km altitude. The present paper reports initial results of sodar and introduction of CSAS.The vertical profile of wind speed and wind direction have measured by the sodar during the pre monsoon, monsoon and post monsoon seasons. These findings may help in the understanding and improvement of forecasting in this region.

Keywords: Phased Array Doppler sodar, Atmospheric Boundary Layer, Vertical Turbulence Intensity, Vertical Wind Profile

MONSOON ONSET AND TROPICAL CYCLONES OVER THE ARABIAN SEA IN CHANGING CLIMATE

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ABSTRACT

Recent years experienced many intense tropical cyclones (TCs) over Arabian Sea during the onset phase of monsoon. Gonu (2007), Phet (2010), Sagar (2018), Vayu (2019), Nisarga (2020) and the most recent Tauktae (2021); all formed during the monsoon onset. These cases raised the question; whether the Arabian Sea is experiencing more number of intense TCs during the monsoon onset? If yes, what are the reasons for this? Is the monsoon onset current changing over time? Our study aims to answer these questions. We considered the period of 4 weeks (15th May-15th June) as monsoon onset period and considered TCs (maximum wind speed > 33 knots) during 1982-2021 over the Arabian Sea. Total 24 TCs occurred during the study period. Out of these 12 formed in past (1982-2001) and 12 formed in recent epoch (2002-2021). There were 3 VSCS intensity (>64 knots) TCs in the past whereas 6 were observed in the recent epoch. Last 4 years had VSCS intensity TCs successively. To understand the conditions supporting the higher number of intense TCs in recent years, we analysed the trend in the large scale parameters and found that SST over Arabian Sea is increasing at the rate of 0.4° per year. Vertical temperature gradient, moist static energy is also increasing significantly. Further, lower tropospheric temperature is increasing and lower stratospheric temperature is decreasing. No significant trend is seen for dynamical parameters like vertical wind shear and low-level relative vorticity. Later part of the study deals with the analysis of monsoon onset circulation and its characteristics. Monsoon onset current includes Tropical easterly jet, Somalia jet, cross equatorial flow, and monsoon Hadley circulation. These currents have an influence on atmospheric variables like moisture and tropospheric temperature. The study claims more heating of the troposphere enhances increased moisture content in the atmosphere over Arabian Sea which increases the potential for cyclone genesis and intensification during the monsoon onset.

Variation of Total Column Ozone (TCO) during the land falling Very Severe Cyclonic Storms "VARDAH" and "GAJA" over Bay of Bengal

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ABSTRACT

The present work investigates the variation of Total Column Ozone (TCO) during the land falling Very Severe Cyclonic Storms (VSCS) "VARDAH (6-13 December 2016)" and "GAJA (10-19 November 2018)" over Bay of Bengal. In this work, we have utilized Cyclone Track and data from Indian Meteorological Center (IMD), New Delhi and TCO data from Ozone Mapping and Profiler Suite (OMPS), joint NASA/NOAA Suomi National Polar Orbiting Partnership Satellite. In both the Cyclonic storm events VARDAH and GAJA, it is found that TCO concentration decreases along the cyclone path. At the time of VSCS stage of Cyclone VARDAH on 10 December 2016, the TCO concentration lowered to ~222 DU (Dobson Unit) from its 8-day mean value (240DU). Further the TCO concentration decreases to 219 DU on 12 December 2016 followed by the landfall crossed over North Tamil Nadu, 13.13°N, 80.30°E around 09.30-11.30 UTC. On 13 December 2016, TCO regains its mean value after the passage of cyclone. During the initial stages of cyclone GAJA (10-19 November 2018), TCO profile shows similar variation as like Cyclone VARDAH. At the time of VSCS stage of Cyclone GAJA on 15 November 2018, TCO decreases to 226DU from its 10-day mean value (245DU) followed by the landfall crossed over Tamil Nadu and Puducherry coastal near 10,45°N and 79.80°E around 19.00-21.00 UTC. At the time of weakened phase of cyclone GAJA on 19 November 2018, TCO further decreases (~225DU) and fills the spatial grid 65-90°E and 11-13.5°N, contracting with cyclone VARDAH. The present work infers that the TCO drops drastically (~11 to 20DU) during the passage of cyclonic storms.

Keywords: Total Column Ozone, Very Severe Cyclonic Storms, Bay of Bengal

Climatology of rapidly intensifying tropical cyclones over the North Indian Ocean

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ABSTRACT

Tropical cyclones (TCs) are one of the world's most dangerous weather events. Even though the TC track and landfall positions have improved significantly, forecasters are still having difficulty in predicting rapid intensification (RI) and intensity changes. The intensity forecast has a lower accuracy than the track and landfall forecast. Because, due to the complex process of TCs, which includes small and large-scale environmental changes, and interactions between the ocean and atmosphere at multiple scales. Based on the distribution of 24 hr intensity change in terms of maximum sustained surface wind speed (MSW), the 95th percentile value is coming to be 25 knot. So the increase in MSW by 25 knot in 24 hr is considered as the threshold for RI of a TC. Here the best track data for the period of 38 years (1982-2019) is obtained from Joint Typhoon Warning Center (JTWC). We examined the climatological characteristics of rapidly intensifying TCs. A total of 133 TCs formed over Bay of Bengal and out of these 35 (26%) TCs exhibited RI. Over Arabian Sea total 61 TCs formed and 20 (33%) underwent RI. Over Arabian Sea, there has been a significant increase in the frequency and duration of RI-TCs, over Bay of Bengal there is no trend. All the TCs over Arabian Sea which reached SuCS and ESCS strength have undergone RI whereas for Bay of Bengal TCs, all SuCS underwent RI. In both basins, the occurrence of RI-TCs is highest in May and November. Further the role of large scale conditions during RI is investigated using reanalysis data.

Keywords: rapid intensification, tropical cyclones, Arabian Sea, Bay of Bengal, Climate change

Exceptional Rainfall Activity over plains of Northwest India during May, 2021

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ABSTRACT

A Low Pressure Area formed over Southeast Arabian Sea and adjoining Lakshadweep area on 12th May which intensified into an Extremely Severe Cyclonic Storm 'Tauktae' on 17th May. Tauktae crossed Saurashtra coast as an ESCS during 1430-1730 UTC of 17th May. The remnant of the TC Tauktae took more than normal time in its dissipation. Its remnant persisted for more than 48 hours after landfall. This caused abysmally high rainfall over the plains of Northwest India on 19th May. All time highest rainfall record for the month of May over Delhi (Safdarjung) was set during this rain spell when 119.3 mm rainfall was recorded on 20th May. This caused All India Rainfall departure for the month of May to be +75% where departures of Rajasthan, Haryana, Chandigarh & Delhi, West Madhya Pradesh, West Uttar Pradesh and Uttarakhand ranged from +150% to 1000%. Generally, no such persistent rainfall after landfall of a TC takes place. Synoptic and dynamical aspects of this abnormal rainfall event has been diagnosed. It has been found that such an episode occurred due to high amplitude Westerly trough in lower and mid levels. Mid level trough dipped southwards into the Arabian Sea upto Latitude 7°N. Upper and lower level moisture feeding due to this trough had been the reason that the remnant of the TC Tauktae did not weaken at a usual pace. Subsequently, upper level divergence, lower level convergence and lower & mid level vorticity were also found to be conducive for such an abnormal rainfall episode over the plains of Northwest and adjoining Central India.

Keywords: Tropical Cyclone, Middle Tropospheric Levels, Low Level Vorticity

Changing status of tropical cyclones over the north Indian Ocean

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ABSTRACT

Climatologically, the frequency of tropical cyclones (TCs) in the Bay of Bengal (BoB) is higher relative to that over the Arabian Sea (ARB). However, recent years exhibit a greater number of TCs forming in the ARB than in the BoB. During the study period (1982–2019), a significant increasing trend in the intensity, frequency, and duration of cyclonic storms (CS) and very severe CS (VSCS) is observed over the ARB. There is a 52% increase in the frequency of CS during the recent epoch (2001–2019) in the ARB, while there is a decrease of 8% in the BoB. Over the ARB, increment in CS duration is 80% and VSCS is almost threefold in the recent epoch as compared to the past epoch (1982–2000). Also, lifetime maximum intensity and accumulated cyclone energy have increased over the ARB implying an increase in the strength of TCs. The increase in TC duration over the ARB is prominent during May, June, and October and a decrease over the BoB is noted during November. The increase in the duration of TCs in the ARB is associated with an increase in mid-level relative humidity and column averaged (950-150 hPa) moist static energy, which is significantly correlated to an increase in sea surface temperatures and tropical cyclone heat potential in the basin. In the recent epoch, TC genesis is observed at lower latitudes (< 8° N), which is another factor contributing to longer durations of TCs. This increases the probability of TC intensification with the support from other favourable environmental parameters. Significant changes in TC tracks are also noted in May, June, and October due to changes in steering currents.

Keywords: Tropical cyclones, Climate change, North Indian Ocean, Bay of Bengal, Arabian Sea

Optimization of physical schemes in WRF model on cyclone simulations over Bay of Bengal using One-way ANOVA and Tukey's test

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ABSTRACT

Evaluation of appropriate physics parameterization schemes for the Weather Research and Forecasting (WRF) model is vital for accurately forecasting tropical cyclones. Three cyclones Nargis, Titli and Fani have been chosen to investigate combination of five cloud microphysics (MP), three cumulus convection (CC), and two planetary boundary layer (PBL) schemes of WRF model (ver. 4.0) with ARW core with respect to track and intensity to determine an optimal combination of these physical schemes. The initial and boundary conditions for sensitivity experiments are drawn from the National Centers for Environmental Prediction (NCEP) global forecasting system (GFS) data. All the model simulated track and intensity are compared with the India Meteorological Department (IMD) observations. One-way analysis of variance (ANOVA) is applied to check the significance of the data obtained from thirty combination of physics schemes (hereby treatments) and IMD observations. Further, Tukey's test is applied for post-hoc analysis in order to identify the cluster of treatments close to IMD observations for all three cyclones. Results are obtained through the statistical analysis; average root means square error (RMSE) of intensity throughout the cyclone period and time error at landfall with the step-by-step elimination method. Through the elimination method, the optimal scheme combination is obtained. The YSU planetary boundary layer with Kain-Fritsch cumulus convection and Ferrier microphysics scheme combination are identified as an optimal combination in this study for the forecasting of tropical cyclones over the Bay of Bengal.

Performance of extended range cyclogenesis forecast of RSMC New Delhi

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ABSTRACT

India Meteorological Department IMD) acts as Regional Specialised Meteorological Centre (RSMC), New Delhi and provides tropical cyclone advisories over the North Indian Ocean (NIO) to 13 WMO/ESCAP Panel member countries. IMD issues extended range probabilistic cyclogenesis (formation of depression) forecast valid for next two weeks every Thursday since 22nd April, 2018. It is issued in four categories viz. nil(0%), low(1-33%), moderate(34-67%) and high(68-100%) based on diagnosis of various large scale features and guidance from global deterministic & ensemble numerical weather prediction(NWP) models & extended range forecasting(ERF) models. The verification of the operational ERF of cyclogenesis by IMD has been carried out based on the data during 2018 to 2020. As such 282 forecasts issued for week 1 and week 2 each during April 2018 to 2020 have been verified and Brier Score (BS) is calculated over the NIO. To evaluate the skill, the climatological probability of cyclogenesis for each week based on the data during 1891-2010 has been used to determine reference BS. Comparing operational BS with reference BS, the Brier Skill Score (BSS) has been calculated and analysed.

The reliability diagram for week 1 indicates that the forecast is biased towards over warning for low and moderate categories and no bias in prediction of nil and high categories of probability in week 1. However, in case of week 2, the forecast is biased towards under warning for high category and towards over warning in case of low & moderate category forecast. The BS (BSS) for week 1 and week 2 are 0.06(46%) and 0.125(10.7%) respectively. Thus, the skill for week 1 is highly reasonable and the skill for week 2 needs further improvement. This study helps in finding out the gaps in forecast methodology and will help in further improvement of cyclogenesis forecast over the NIO.

Decadal variability of environmental dynamics for intensification of tropical cyclones over the Bay of Bengal during post-monsoon season

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ABSTRACT

The North Indian Ocean (NIO) has intensifying the temperature in recent three decades due to global warming. Based on the rising of ocean temperatures consistent theory by *Elsner (2020)* suggested that tropical cyclones (TCs) during 1981–2006 and 2007-2019 have shown the strongest tropical cyclones getting stronger. Warming in the tropical Indian Ocean has increased at a faster rate 0.16 oC/decade during 1990-2019 as compared to global ocean 0.11 oC/decade. This warming was non-uniform and ~90% of warming is attributed to anthropogenic activities. The warm SST anomaly and moisture content for three decades (1990-1999, 2000-2009 and 2010-2019) during post-monsoon season that contributes positively to TC formation and its intensifications over the Bay of Bengal (BoB). The warming over the western and central Indian Ocean, is one of few and prominent features of local warming. The availability of moisture content in the atmosphere during the recent decade is very important aspect of the rapid intensification and strengthening of TCs before their landfall. Essentially over the BoB basins individually have shown upward intensity trends of extreme severe cyclonic storm (ESCS) in recent decades (2009-2019). The rapid intensification of the tropical storms before their landfall, the decadal variability of environmental conditions which are mostly responsible for genesis and intensification (such as SST, vorticity, wind shear and moisture) of the TCs have analysed from the ERA5 and NOAA datasets during post-monsoon season (OND) over the BoB. The results are shown there may be a decadal or large-scale shift in the basic component of ocean-atmospheric conditions that facilitate the TC formation. It is found that an increase in cyclonic activity over the BoB, because of the warm SST induced-moisture supply in recent decades 2010-2019.

Keywords: Bay of Bengal, Tropical cyclone, Post-monsoon season, Climate change

AEROSOL-CLOUD PROPERTIES DURING TROPICAL CYCLONE EVENT

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ABSTRACT

The role of aerosol on the microphysical and dynamical properties of the cloud and their effect in producing precipitation during tropical cyclones has to be well understood to examine the cloud process responses to a wide range of aerosol concentrations in a cyclone environment. The objective of the study is to understand the microphysical changes occurring within the cyclone environment due to aerosol perturbation. The study addresses the aerosol microphysics and the cloud characteristics during the pre-cyclone, cyclone and post-cyclone events, over a period of 8 years (2014-2021) in the Indian subcontinent region. The Level-3 Moderate Resolution Imaging Spectroradiometer (MODIS) Monthly Atmosphere Gridded Products from the Terra platform is used for investigations in the region of study.

Keywords: Tropical cyclone, Indian subcontinent, Aerosols, Clouds

Influence of Urbanization on Precipitation and Intensity of Tropical Cyclone Fani: A Case Study over Bhubaneswar

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ABSTRACT

Extremely Severe Cyclonic Storm (ESCS) 'Fani' made landfall on May 03, 2019 causing more than 150 mm rainfall near Puri coast, Odisha. With a maximum sustained wind speed of 170 – 180 km h-1 during its landfall, Fani persisted as a severe cyclonic storm (SCS) over land for more than 24 hours. Although it is well-known that urban development alters the magnitude and location of precipitation caused by localized convective systems, its impact on synoptic-scale systems is still uncertain. This study aims to assess the potential effect of urbanization of Bhubaneswar city on storm's track and intensity over land. Advanced Research Version of Weather Research and Forecasting Model (ARW) with a single fixed domain of 3-km grid spacing (initialized with NCEP-GFS reanalysis dataset) have been used to simulate the landfall characteristics of Fani. Total nine experiments have been carried out with the combination of three land-use datasets (default WRF, supervised United States Geological Survey (USGS) datasets for the years 1980 and 2019) and three surface urban physics options: (1) without Urban Canopy Model (Control), (2) Urban Canopy Model (UCM), and (3) Building Environment Parameterization (BEP). Incorporation of updated land use land cover (LULC) in the model improves total rainfall prediction compared to default runs. Track error and landfall error are minimum with 2019-LULC UCM simulations. The vertical profile of convergence of winds, 2-m surface temperature, sensible heat flux and storage flux, planetary boundary layer height, and friction velocity are analyzed to understand the urban-atmospheric feedbacks responsible for heavy rainfall over coastal cities Odisha. Surface - precipitation feedback analysis suggests that surface effect is more prominent in the 2019_UCM experiment than others. This study highlights the importance of incorporating updated LULC when assessing the projected risks of such extreme events in urbanized coastal cities.

Keywords: Urbanization, Tropical Cyclone, Bhubaneswar, LULC, UCM

A STUDY OF THE TROPICAL CYCLONES THAT AFFECTED ANDHRA PRADESH DURING THE PERIOD FROM 2010-2019.

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ABSTRACT

In the present study the data of various cyclonic storms that affected the Andhra Pradesh state during the period from 1991-2019 has been studied. For this purpose, the details of the cyclones during the period from 2010-2019 were collected from 'Reports on cyclonic storms over North Indian Ocean' published by RSMC, New Delhi. For the purpose of comparison of intensity and frequency of cyclones, the data for the period from 1991-2010 obtained from Cyclone Warning Centre Visakhapatnam is also considered for study. It is observed that there is a considerable decrease in the frequency and intensity of cyclones which affected the Andhra Pradesh during the period 2010-2019. Most of the cyclones, during study period, originated during the period from 10th October to 15th November of the year. Highest rainfall associated with the system was more for the slow-moving low intense cyclones than with high intense cyclones. The cyclones which affected Andhra Pradesh during the period from 2010-2019 moved mainly under the influence of the upper air anticyclonic flow over Bay of Bengal and neighbourhood. The frequency of Cyclonic Storms crossing around Nellore district of South Coastal Andhra Pradesh gradually decreasing. There are no cases of cyclonic storms crossing Vizianagaram and West Godavari districts. The Cyclonic Storms originated in southeast Bay of Bengal have more chances of affecting Andhra Pradesh coast than the Cyclonic Storms originated in other parts of Bay of Bengal.

Key words: Cyclonic storms, intensity, Rainfall, frequency

Short to medium range cyclogenesis forecast performance of RSMC New Delhi

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ABSTRACT

India Meteorological Department (IMD) maintains a continuous watch over the north Indian Ocean (NIO) including the Bay of Bengal (BoB) and the Arabian Sea (AS). It issues short to medium range probabilistic cyclogenesis (formation of depression) forecast over the region daily valid for next 5 days in the tropical weather outlook. Probability of cyclogenesis in short to medium range is predicted in five categories, viz., nil (0%), low (1-25%), fair (26-50%), moderate(51-75%) and high(76-100%) based on the consensus developed from various numerical weather prediction(NWP) models, dynamical statistical models and guidance from atmospheric & oceanic observational analyses. A review of the operational cyclogenesis forecast performance of IMD in the short to medium range (upto 5 days) has been carried out based on the data during 2019 to 2020 with a view to determine the skill in forecasting and hence identify the future scope for further improvement. As such a total of 731 (365 days in 2019 and 366 days in 2020) forecasts have been verified for each of day-1(0-24 hrs), day-2(24-48 hrs), day-3(48-72 hrs), day-4(72-96 hrs) and day-5(96-120 hrs) lead period against the actual occurrence of cyclogenesis as determined by IMD. The Brier Score (BS) and Brier Skill Score (BSS) have been calculated & analysed. To calculate BSS, the climatological probability of cyclogenesis for each day based on the data during 1891-2010 has been used to determine reference BS. Comparing operational BS with reference BS, the BSS has been calculated. The results indicate that over the NIO, the BS for day1, day 2, day 3, day 4 and day 5 forecasts is 0.014, 0.018, 0.032, 0.030 and 0.027 respectively. The BSS varies from 25% to 65% during day1 to day5. This study will help in finding out the gaps in forecast methodology and will help in further improvement of daily cyclogenesis forecast by IMD over the NIO.

Key words: cyclogenesis, short to medium range, north Indian Ocean

A Numerical Study on the Influence of Oceanic Sub-Surface Processes on the Moist Static Energy Scenario in Tropical Cyclone Phailin (2013) Using a Coupled Modeling Framework

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ABSTRACT

As the ocean is the primary source of energy in a tropical cyclone (TC), it modulates the atmospheric thermodynamics by means of heat fluxes from the air-sea interface and thus plays an important role in its intensification. However, there is still a lack of understanding of these ocean-atmosphere interaction processes, and it appears that there is a severe scarcity of studies on this topic, especially in the context of the Bay of Bengal (BoB). The present study is aimed to investigate the sub-surface ocean processes and their influence on the moist static energy (MSE) during the intensification of TC Phailin (2013), using the Coupled Ocean Atmosphere Wave Sediment Transport (COAWST) model. Three sub-surface ocean conditions, viz., a) European Centre for Medium-Range Weather Forecast (ECMWF) Ocean Reanalysis, b) Climate Forecast System Version 2 (CFSV2) Operational Analysis, and c) HYbrid Coordinate Ocean Model (HYCOM) Reanalysis are used as the initial and boundary conditions. All the simulations showed a delay in intensification, and ECMWF simulated the most intensified TC among the three experiments. The deeper mixed layer simulated by CFSV2 hindered the intensification of the TC in that experiment. Furthermore, cold water reaching the surface and consequently decreasing the sea surface temperature (SST) in CFSV2 and HYCOM acted as negative feedback in the intensification. To better understand the influence of MSE in relation to the ocean heat fluxes, an extensive analysis of the MSE budget has been carried out. Results suggest that the ocean processes take part massively in changing the atmospheric heating profiles in the intensification of TCs. This is further corroborated by the diabatic heating and tangential wind scenarios. The findings of this study strengthen the fact that incorporation of coupled ocean-atmosphere models is essential for a proper understanding of the air-sea interactive processes responsible for the intensification of TCs.

Keywords: Tropical Cyclone (TC), Coupled Ocean Atmosphere Wave Sediment Transport (COAWST) Model, Moist Static Energy (MSE), Ocean-Atmosphere Interaction

The processes associated with intensity changes of tropical cyclone AMPHAN over the Bay of Bengal

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ABSTRACT

With the world facing weather extremes now and then and with the climate change haunting people around the globe, it has been highly important to study global warming and its potential impact on weather and climate. In recent decade, the North Indian Ocean experienced very intense and frequent tropical cyclones (TCs). Among all cyclones in each year, at least 3 underwent rapid intensification (RI) considering the increase in wind speed by 30 knots or more within the 24-hr period. The focus of present study is to understand processes during TC intensification using WRF-ARW (version4.0) model. We considered the recent super cyclonic storm AMPHAN over Bay of Bengal occurred during 16-21 May,2020. Five sensitivity experiments with two nested domains are performed to examine the impact of cloud microphysics parameterization schemes on the storm's track and intensity simulation. Furthermore, one experiment was conducted using three domains (64km, 16km, and 4km) to check the performance of high horizontal resolution on cyclone simulation. It was found that the simulated cyclone with Ferrier scheme has least forecast track error and Morrison has highest storm intensity nearly comparable with IMD. Ferrier experiment also produced the pattern of RI. When compared with GPM data, the Kessler method closely followed precipitation distribution. The results demonstrate that selected moisture schemes have a significant impact on storm intensity and forecast whereas experiment with high horizontal resolution gives the positive impact on the storm track simulation. In this study, we note a good correlation between the evolution of frozen and liquid hydrometeors and storm intensification rate. WSM6 scheme has shown a substantial reduction in the rainwater formation in the simulated storm. In general, it is concluded that the microphysical processes influence the intensification rate and maximum intensity of a storm. Further we plan to explore the remote sensing observations of hydrometeors during the intensity changes.

Keywords: Tropical cyclone, Mesoscale Model, Super cyclone AMPHAN (May 2020), Microphysics Parameterization.

Role of Microphysical Processes Impacting the Rainfall of Cyclone Yaas

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ABSTRACT

T-6: Tropical Cyclones in Changing Climate(TCC) Tropical cyclones and their associated rainfall and wind are among the primary forms of extreme weather events that severely impact India's coastal region. 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 east and west coast of India. The Very Severe Cyclonic Storm Yaas is among the cyclones that have experienced rapid intensification, making landfall over the east coast and caused heavy rainfall and storm surge. In this study, high-resolution simulations are carried out to understand microphysical processes impacting the rainfall and intensity over the finer core and large scale of YAAS up to day-4. The Weather Research and Forecasting (WRF) model with 3km resolution is used for carrying out these simulations. The model has been integrated using five cloud microphysical parameterizations to quantify its impact on cyclone precipitation and its efficiency. Intercomparison of results in terms of cyclone track, intensity, rainfall, and associated diagnostic variables will be presented. Further, efforts are made to elucidate the possible mechanisms responsible for storm precipitation modulation in terms of the 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 also be examined.

Key Words: Tropical cyclone, Precipitation, Microphysics, WRF model.

Changes in the cyclone activity and the ocean-atmosphere-cyclone coupled interaction in the north Indian Ocean

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ABSTRACT

The north Indian Ocean is seeing significant changes in cyclone frequency and intensity in recent years with the most significant changes observed in the Arabian Sea. It is observed that there is a 48% increase in the frequency of cyclones during the period 2001–2019 as compared to the period 1982–2000. Also, in the above-mentioned period, the lifetime maximum intensity of the Arabian Sea cyclones has increased by 38% in the pre-monsoon season and 22% in the post-monsoon season. This increase in the frequency and the intensity of the cyclones in the Arabian Sea is attributed to the increase in the mid-level humidity and increase in the ocean surface and sub-surface temperatures. It is observed that in the last four decades the Arabian Sea is warming at a rapid pace as compared to the Bay of Bengal with an increase in SSTs by 1.4°C and 1.2°C in the pre-monsoon and the post-monsoon season respectively. The increase in the ocean surface and sub-surface temperatures in the entire north Indian Ocean is aiding the cyclones to intensify rapidly in a short time. The rate of rapid intensification of the cyclones in the north Indian Ocean in the pre-monsoon season has increased from ~28% to 40% in the recent period. The cyclones are also causing a large mid to upper-level atmosphere warming of magnitude 3°C especially in the pre-monsoon season which is linked to the coupled ocean-atmosphere interaction. With the increase in the SSTs, it is observed that the upper-level atmospheric warming induced by the cyclone is also increasing. These changes in the cyclone activity and the coupled ocean-atmosphere interaction during the cyclone in the north Indian Ocean pose a significant risk to the densely populated coastline of the north Indian Ocean rim countries.

Computational Correlational Studies of Tropical Cyclone Energetic with Dynamical Fluid Motions and Physical features of Meso-Scale Convective Systems to Develop Tropical Cyclone Numerical Forecasting Models (TC-NFM)".

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ABSTRACT

The efforts are to test, evaluate, and improve predictions of Tropical Cyclone's track, intensity, speed, and inner core Structure, beyond 5 days , through the study of Tropical Cyclone Energetic in correlation with dynamical fluid motions and physical features (e.g. radiative transfer, chemistry, cloud processes), of meso-scale NH-SH Convective systems in order to develop a unique Tropical Cyclone Forecast Models (TCFM), acting as an Operational real-time forecast guidance for all Tropical Cyclones/Hurricanes across the Atlantic, Asia Pacific, North Indian Ocean and SH-Ocean basins. The key to this new prediction system (TC-NFM) would be the development of a very fine (1deg–1deg) grid nests moving with individual storms within the global model, having a coupling capability for these nests in space & time mode. (TC-NFM) would be coupled to Atlantic, and North Indian Ocean basins Storms, so that its grid filter gets updated whenever, there are active cyclonic storms in these basins. High-resolution Satellite imageries of the two Super Cyclonic Storms (SCS) over the Atlantic& North Indian Oceanic basins occurred during May- October 2020 would be examined with emphasis on the large scale kinematic and thermodynamic behavior of these two SCS, viz. Laura'(Atlantic,26Aug'20,240Kmph,937hPaAmphan'(BOB,17May'20,240Kmph,920hPa) and other selected mesoscale Convective Systems, e.g. intense Cloud Clusters Thunderstorms, by making use of Aircraft, Doppler Weather Radar and conventional data over the selected domain in order to study mathematical and computational aspects of weather and climate through spatial structure of Cloud field incorporating the Hurricane Weather Research Forecast Models.
Based on Suchman, Martin, Sikdar (1977), Cloud Cluster studies, and of Goswami. V.K et.al. (1990); wherein, the two plausible Models of Monsoon Depression have been postulated in terms of Cluster Coalescence Theory and Giant Cluster Theory, would be employed to study the said two SCS over Atlantic & North Indian Oceanic basins during the Storm-Cycle (May-Oct)'20 to develop (TC-NFM).
KEY WORDS: Energetic, Meso-Scale Convective Systems, Cluster Coalescence Theory, Giant Cluster Theory, Tropical Cyclone Numerical Forecasting Models-TCNFM.

AAP

Aerosols, Air Pollution and Climate Sensitivity

Role of Air Pollutants Formation of Fog in an urban Environment of India

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Abstract

Fog plays a significant role in many environmental and ecological processes. The aerosol particles present in the atmosphere becomes fog droplets due to condensation of water vapor on them in high humidity conditions. The formation and intensity of fog over an urban area depends on various factors that may promote or mitigate the process. The combustion processes are responsible for the presence of air pollutants and moisture in the atmosphere. The urban heat island effect may raise the temperature, lower the humidity and can even change the wind pattern of any region.

The urban areas have often reported increase in frequency of fog due to emissions of air pollutants. The objective of the present study is to find a relationship between fog and air pollutants in an urban area of India. The response of real concentrations of air pollutants measured by an automatic weather station is studied in the present work. The increased pollution levels may result into the reactions forming secondary pollutants that may lead to increased air pollution levels. The study focuses on connecting fog with air pollution.

Particulate Matter estimation using multi-Satellite datasets: A Deep Learning Approach

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ABSTRACT

The present work proposes Particulate Matter (PM) estimation using multi-satellite AOD and deep learning algorithm. Four different satellites, Moderate Resolution Imaging Spectroradiometer (MODIS), Ozone Monitoring Instrument (OMI), Multi-angle Imaging Spectro Radiometer (MISR) and INSAT-3D is used to retrieve AOD over period of 6 years (2014 to 2020) over India. Ground datasets of AOD is taken from Aerosol Robotic Network (AERONET) for the validation of satellite retrieved AOD. The observation of PM data is acquired from Central Pollution Control Board (CPCB) station across the India. Analysis has been performed on monthly basis for given time period. In this study, we have performed an inter-comparison between all four satellite AOD with AERONET AOD for the accuracy assessment of the satellite datasets. The result shows that AOD product of MODIS, MISR and OMI exhibit good correlation with AERONET AOD whereas INSAT-3D AOD is not well correlated with AERONET AOD. Remote sensing AOD data together with ground PM concentration data is used to train the deep learning model for the estimation of the monthly PM distribution across India. Finally, the deep learning model used for PM estimation is found to be optimal for calibrated satellite AOD product.

Keywords: Particulate Matter, Aerosol Optical Depth (AOD), Deep Learning.

PHYSIOCHEMICAL PROPERTIES OF SUB-MICRON AEROSOLS AND ITS ASSOCIATION WITH CLOUD CONDENSATION NUCLEI OVER A TROPICAL COASTAL LOCATION

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ABSTRACT

Understanding aerosol-cloud interactions and associated feedback process is essential to address the indirect climate forcing of aerosols. The primary parameter required for this is the cloud condensation nuclei (CCN), which is the sub-set of atmospheric aerosols that can activate into cloud droplets at a given supersaturation. The ability of an aerosol to act as potential CCN depends on its size and composition. However, relative importance of these two variables on CCN activation is widely debated because of the contrasting picture presented by different studies. The limited information about the concurrent aerosol chemical composition, especially organic aerosols and lack of understanding about their CCN activation ability, makes accurate estimation of the CCN complicated. Knowledge about simultaneous aerosol size and chemistry are essential to address this issue. In this regard, multi-year (2017-2020) high-resolution measurements of aerosol physical and chemical properties were made from a tropical coastal station-Thumba during winter. During this season, synoptically, the site is in the downwind of South Asian outflow to the south-eastern Arabian Sea, whereas it experiences contrasting air masses owing to mesoscale land-sea breeze circulation within a day which provides a natural laboratory to study aerosol properties in contrasting conditions. The results revealed a larger variability in aerosol number concentrations, chemical composition and CCN activation (0.3-0.6) within a day; but, the particle number size distributions are nearly similar (with mode ~ 97-106 nm). Overall, organics are the dominant species (> 70%) over inorganics, the presence of higher sulfate due to photochemical/aqueous production and hygroscopic organic aerosols (> 80% of organics) resulted in the higher CCN activation during daytime. In contrast, enhanced concentrations of hydrophobic organics severely reduced the activation during night time. Further, CCN closure studies were performed and the relative importance of particle size, composition and mixing state are evaluated.

Keywords: Aerosol chemical composition, cloud condensation nuclei, mixing state, diurnal variation

AEROSOL RADIATIVE FORCING DURING THE PRE-MONSOON TO MONSOON TRANSITION OVER THE INDIAN MONSOON REGION

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ABSTRACT

The study estimates (i) the spatial distribution of aerosols across the study area, and the relative contributions of different aerosol species (ii) aerosol radiative forcing and the consequent atmospheric heating rates, and (iii) the aerosol-rainfall association by focusing at the regional influence of aerosol loading on precipitation. During the transition, northward progression (advance), and peak phases of the monsoon, the seasonally averaged aerosol radiative forcing at the surface was found to be negative, whereas at the top of the atmosphere it was shown to be positive. Aerosol radiative effects differ significantly globally because regions are characterized by different types of aerosol sources and meteorological conditions; thus, for a comprehensive examination of aerosol and radiative properties on a regional scale, we chose two regions: the Indo Gangetic Plain (IGP), which has a high aerosol burden, and the Equatorial Indian Ocean (EIO), which has a low aerosol burden. The climatologically averaged atmospheric Heating Rate associated with atmospheric radiative forcing during pre-monsoon, monsoon, and post-monsoon seasons were computed using the data inferred from the SBDART model. During the transition phase of the monsoon season from 2001 to 2017, the estimated mean aerosol radiative forcing values over IGP at the surface, TOA, and atmosphere were -31.96 Wm -2 , 9.45 Wm -2 , and 41.4 W/m2, respectively, whereas over EIO it was -6.85 W/m2, -3.30 W/m2, and -10.25 W/m2. Desert regions such as the Thar-Pakistan deserts, Arabian deserts, and Taklimakan deserts have much higher aerosol indexes than 2, and hence have been identified as large absorbing aerosol repositories that play a major role in keeping higher aerosol forcing over the study area during the transition phase. It is found that the north-south temperature gradient is positively amplified by the presence of absorbing aerosols which helps in the transition from pre-monsoon to monsoon over the peninsular region.

Keywords: Particulate Matter, Aerosol Optical Depth (AOD), Deep Learning.

Impact of severe forest fires on Air Quality in Uttarakhand

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ABSTRACT

In the recent decade the area of wildfires in India has increased dramatically and the resulting smoke has exposed millions of people to unhealthy air quality. Fires emit particulate matter and gaseous compounds affecting human health and, potentially, the global climate. Satellite-inferred burn severity data have become increasingly popular over the last decade for management and research purposes. In this study, the effects of forest fire have been presented using Sentinel-2 and Sentinel-5p satellite images acquired during January 2021 and April 2021 over Almora district of Uttarakhand. The burnt area of the forest has been analysed and classified on the basis of burn severity using delta Normalized Burn Ratio (dNBR) with bands in the NIR and SWIR regions for pre-fire and post-fire events respectively. The dNBR is an absolute difference which can present problems in areas with low pre-fire vegetation cover, where the absolute change between pre-fire and post-fire NBR will be small. In such cases the relativized version of burn severity is advantageous. We have used Relativized Burn Ratio (RBR) as well as dNBR in order to increase the accuracy of our results. The results have shown Moderate to High severity RBR over most of the places within the district. The objective of the study is to examine the effects of forest fires, including the natural role of forest fire, emissions, transport, chemistry, and human health impacts. We highlight the estimated emissions and resulting effects on regional air quality across the region. The motive is to clarify which areas are well understood and how the results can be utilized for Air Quality modelling over Indian subcontinent. We conclude with a set of recommendations for future research.

Keywords: Wildfires, Smoke, Aerosol–cloud interactions, Climate change

Vertical Distribution of Light Absorbing Aerosols and Water-soluble Ions in Snowpits of the Himalayas and its Implications

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ABSTRACT

The Himalayas and the Tibetan plateau (HTP), known as the "third polar" of the Earth is highly sensitive to anthropogenic activities of South and East Asia. Among various factors, light absorbing aerosols (LAA) have been identified as major climatic concern to the retreat of Himalayan glaciers through their impact on snow physical properties and the reduction of snow albedo. The present study investiges the vertical distribution of Black carbon (BC) and major water-soluble ions in the Khardungla (KG) and Phuche (PG) glaciers (> 5 km a.s.l.) of western Himalayas. The observation showed significant vertical heterogeneity of BC in both PG (~ 59 to 299 ng g -1) and KG (~ 42 to 428 ng g -1) glaciers. This is attributed to the seasonal modulations in deposition as well as the post-depositional processes of BC within the snowpack. The analysis of water-soluble ions revealed strong crustal influence (as indicated by $nssCa^{2+}$) in the aged snow layers of the study region. Further, the neutralization ratios for both KG and PG snowpits were found to be > 2, suggesting that NH 4+ present in the snow fully neutralized the acidic ions SO 42- and NO 3- confirming the alkaline nature of snow. In addition to this, the vertical distribution of ions in the snowpack shows the effect of elution and refreezing in PG, whereas it is not much evident in the KG samples where the accumulated snow is relatively shallow. Further to understand the effects of BC on snow, multi-layer simulations of snow-albedo changess were estimated using SNICAR model with various physical properties of snow. It showed a change in snow albedo by 2.5–9.0% for the amount of BC observed in this study, resulting in snow albedo forcing of 49.2 Wm -2 for PG, 30.2 Wm -2 for KG respectively. The present study serves as a backbone in the data sparse region of western Himalayas for the development of Aerosol – Cryosphere – Radiation model to predict the albedo change due to aerosol induced snow darkening and the associated melting of snow/glacier over the Himalayas.

Keywords: Black carbon, Water-soluble ions, Snow albedo forcing, Himalayas.

SEASONAL VARIATION OF BLACK CARBON AND ITS POTENTIAL SOURCE IDENTIFICATION OVER COCHIN

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ABSTRACT

Continuous monitoring of black carbon (BC) aerosols was carried over the station Cochin (10°02'33.3"N 76°19'55.2"E) at the southwest coast of the Indian peninsula from October 2018 to March 2019. In this study, we have manifested the outcomes of our analysis carried on the data collected during post-monsoon, winter and the pre-monsoon seasons. This study investigates the diurnal variations, seasonal variations, potential sources and the long-range transport of BC aerosols along with the meteorological impacts.

Black carbon aerosol mass concentration was measured using an aethalometer at the cochin station. During the daytime black carbon build-up gradually after sunrise and reaches a maximum during 0700 to 0900LT. BC concentration reduced in the afternoon. After midnight due to reduced anthropogenic activities, the concentration of black carbon further reduces.

The data collected from the cochin station during the study period shows that the seasonal average BC mass concentration at Cochin is 6.54μg/m³. The BC mass concentration is minimum at the beginning of the post-monsoon season and gradually increases during winter. After reaching the peak in December, BC mass concentration decreases and reaches a minimum during March. Source identification using HYSPLIT was also done as a part of this work. It shows that long-range transport is less during this period. Local anthropogenic activities and wind speed variations play a crucial role in BC concentration over the cochin station.

Keywords: Black Carbon, Atmospheric Aerosols, Aethalometer

MONITORING TRACE GASES AND PARTICULATE MATTER AT AN INDUSTRIAL LOCATION - KOCHI , IN SOUTHERN INDIA.

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ABSTRACT

- Air pollution is a significant environmental health issue in India, with a major population living in areas with poor ambient air quality. In this study, we present the ground based measurements on air pollution, at an industrial location, Kochi (10.07°N, 76.30°E), in Kerala, South India from March 2018 to May 2021. The diurnal variations and effects of lockdown on trace gases (Nitrogen Oxides (NO_X) and Sulphur Dioxide (SO_2)) and particulate matter ($PM_{2.5}$ and PM_{10}) were studied. The concentrations of both the trace gases and particulate matter were highest during the winter season. This could be attributed mainly to the near-surface anthropogenic sources (fertilizer plant and automobile emissions) and low mixing height in winter. The concentration of all the products were observed to decrease during monsoon season due to efficient wet scavenging by precipitation followed by lowest concentration during post-monsoon season; the averaged diurnal patterns also showed similar seasonal variations. NO_X showed peaks during the morning and evening traffic hours and also a valley in the afternoon irrespective of all the seasons, which is clearly linked with the boundary layer height evolution. Due to the COVID-19 pandemic, nationwide lockdowns were implemented to contain the spread of coronavirus, also many reported studies have shown that the air quality had improved appreciably due to the imposed lockdowns. We inspected the variations of all the above-mentioned products during the lockdown period, the ground based measurements have shown a significant drop in the first phase of lockdown period compared with the pre-lockdown period.

Keywords: Air Quality, Trace Gases, Particulate Matter, Seasonal Variations.

Studies on Black Carbon aerosols in relation to Boundary Layer Height and Rainfall over sub urban Chennai

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ABSTRACT

Seasonal variations of Surface Black Carbon Mass Concentration (SBCMC) obtained from the Aethalometer (AE-31) has been studied for the period of January-2016 to February-2019 February over semi urban location (12.81°N, 80.03°E) in Chennai. Boundary Layer Height (BLH) data deduced from the Mini Micro Pulse LiDAR (MPL 532-C) is used to study the short term variations of SBCMC during the fumigation period for different seasons. Further the paper focuses on wet scavenging of black carbon aerosols during different rainy days. Raindrop distribution from the laser precipitation monitor is used to study the wet scavenging coefficient over the study area. The results show that BLH during sunrise is lesser than BLH when BC attains the peak due to fumigation effect. This feature is conspicuous in southwest and northeast monsoons compared to other seasons. The scavenging avenging ratio obtained from the SBCMC is substantially correlated (r = + 0.84) with the scavenging coefficient that has been obtained for different raindrop sizes.

Role of tropical cyclone in the redistribution of aerosols over Indian subcontinent

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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 (BOB) developed on 16th May 2020 and weakened its intensity after the landfall at 17.30 IST on 20th May. Before the cyclone, high aerosol loading off the west coast was dominant and scavenging was observed after the cyclone passed out. The detailed results will be presented during the conference

Keywords: Tropical cyclone, Aerosols

INTER-MODEL VARIATIONS AND FIDELITY OF CMIP6 GLOBAL CLIMATE MODELS' SIMULATIONS OF AEROSOL OPTICAL DEPTH

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ABSTRACT

The ability of global climate models (GCM) in accurately simulating the atmosphere in the historical period is a matter of great concern to rely upon the future projections in the changing climate. The present study considers the Aerosol Optical Depth (AOD) obtained from the 26 GCMs of Coupled Model Intercomparison Project – Phase 6 (CMIP6) to understand the model-to-model variations in showing the performance metrics such as mean, standard deviation, trends, etc. A multi-model ensemble (MME) has been obtained by clustering the models depicting significant correlations with the MME (brought to the uniform footing of 1° x 1° using the bilinear interpolation technique) and the same is used to study the AOD at 550 nm. The AOD of MME has been compared with that of MODIS TERRA data for the period 2001 to 2014 to report the fidelity of CMIP6 MME. We found that the trends of AOD of 550nm over different hemispheres, varied distinctly from increasing to decreasing trends during 1971 to 2014. Eight (8) GCMs namely., AWI-ESM-1-1-LR, BCC-ESM-1, MPI-ESM-1-2-HAM, MPI-ESM-1-2-LR, CESM2-WACCM, MPI-ESM-1-2-HR, MRI-ESM2-0, and CESM2-WACCM-FV2 showed substantial correlations (above +0.90) with the MME. Tropical regions have shown the highest AOD followed by the mid-latitudes of the Northern Hemisphere. The percentage bias with the MODIS is high over land compared to the ocean. Angstrom exponent obtained from the two GCMs (MRI-ESM2-0, MPI-ESM-1-2-HAM) along with the second derivative of AOD (470, 550, and 870 nm) i.e., the curvature effect of particles shows the abundance of fine mode and coarse mode particles over land during January and July months respectively.

Keywords: Aerosol Optical Depth, CMIP6, Angstrom Exponent, MODIS

Surface measurements of atmospheric electrical conductivity at a typical urban location in India

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ABSTRACT

Scientists from all across the world have recently attempted to show a link between accelerated climate change and atmospheric electricity. Atmospheric electrical conductivity is one of the most important parameters in atmospheric electricity, and it is used as a measure of air pollution in the atmosphere. Simultaneous measurements of atmospheric electrical conductivity and meteorological parameters were conducted during January 2014 - December 2015 at Department of Physics, Bangalore University (12°56′44″N, 77°30′25″E, 840m AMSL), as to create baseline data for Bengaluru environment. An attempt was made to see how conductivity fluctuates under different weather conditions.The Gerdien Condenser setup was conceived, constructed, and calibrated at the Indian Institute of Tropical Meteorology in Pune, India, and then deployed for continuous measurements at Bangalore University.The findings reveal that on clear days, there is a clear diurnal trend in air conductivity levels, with early morning maxima and afternoon minima. Most of the studied meteorological factors had a substantial association with air electrical conductivity.Radon, a natural tracer gas, was measured alongside air conductivity, and it was discovered that fluctuations in air conductivity mirrored Radon activity.The findings suggest that the lower atmosphere's stability is crucial in determining diurnal fluctuations in air conductivity.In the Bengaluru environment, the mean positive conductivity was $1.44\times10^{-14}\ \Omega^{-1}m^{-1}$, the mean negative conductivity was $2.28\times10^{-14}\ \Omega^{-1}m^{-1}$, and the overall mean atmospheric electricity conductivity was $3.72\times10^{-14}\ \Omega^{-1}m^{-1}$.

Keywords: Atmospheric electrical conductivity, pollution, stability, meteorological parameters

Air Quality Early Warning System and Evaluations of $PM_{2.5}$ during Winter 2020 over India

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ABSTRACT

Air pollution has become a serious hazard for human health and public welfare in recent decades. A large population in India lives in areas that exceed National Ambient Air Quality Standards. The role of air quality forecasts and assessment systems is growing as an Air Quality Management tool to help air pollution control authorities and other decision makers to improve air quality, mitigate the occurrence of extreme air pollution episodes, particularly in urban areas. Ministry of Earth Sciences (MoES) has been entrusted to develop and deploy an operational air quality forecasting system for India. India Meteorological Department (IMD) has developed air quality forecasting system in mutual collaboration with Finnish Meteorological Institute (FMI) Finland. In this work, offline-coupled chemistry-transport model System for Integrated Modeling of Atmospheric Composition (SILAM) to produce hourly air quality forecast for next 72 hours of all criteria pollutants (particulate matter and gaseous species) is generated in a dynamical framework for the domain 60° – 100°E, 0 - 40°N. The meteorological forcing is provided from the operational 3km IMD-WRF model. The chemical initial condition is derived from the previous day of forecast and boundary condition is supplied from global SILAM model. We used the emission inventories CAMS-GLOB v2.1, 0.1-deg supplemented with EDGAR v4.3.2 for coarse and mineral-fine anthropogenic particulate matter, GEIA v1 lightning climatology and MEGAN-MACC biogenic climatology for isoprene and mono-terpene. The forecast focus on major cities of India including Delhi, Mumbai, Kolkata, Chennai, Bengaluru, Ahmedabad, Pune, Noida, Ghaziabad, Chandigarh, Faridabad, Hyderabad, Jaipur, Kanpur, Lucknow, Meerut, Patna, Prayagraj, Varanasi and Thiruvananthapuram etc. The paper presents an overview of IMD air quality forecasting system and comprehensive evaluation of SILAM model performance for the first day, second day and third day of forecast against the surface data. The forecast is found to be very skillful for Very Poor / Severe air quality index (AQI) categories of $PM_{2.5}$, and has been helping the decision-makers in India make informed decisions.

Keywords: WRF, SILAM, $PM_{2.5}$, AQI

Variability of O 3 , NO, NO 2 , NO X in the southern tropical megacity, Bengaluru

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ABSTRACT

Bengaluru, India's tropical megacity, has undergone rapid urbanisation in recent decades. The urbanization has resulted in rising population which has consequently led to increased emissions and altered land usage patterns. These factors have influenced O_3 production and the chemistry of tropospheric trace gases in this region. Surface ozone (O_3) and its precursors (NO, NO_2 , NO_x) were measured at an urban site in Bengaluru, India, between January 2015 and December 2018. Seasonal fluctuations of O_3 , NO, NO_2 , and NO X were studied. The amplitude of O_3 varied greatly by season, with the maximum concentration (13.07 ppbv) in the winter and the lowest amplitude in the monsoon (9.52 ppbv). The highest concentrations of NO were found in the post-monsoon season (17.38 ppbv), while the highest concentrations of NO 2 and NO X were found in the winter season (41.75, 50.42 ppbv). Summer had the lowest values of NO (5.70 ppbv), NO 2 (30.43 ppbv), and NO_x (36.28 ppbv). The TNMHC/ NO_X ratio was used as a photochemical measure to evaluate the site's VOC- NO_X sensitivity. This ratio implies that the study area is VOC sensitive during the summer, post-monsoon, and winter seasons. The correlation of pollutants with meteorological conditions was explored for different seasons. O_3 was found to be favourably connected with temperature and wind speed, but inversely correlated with relative humidity. The association between nitrogen oxides and temperature, relative humidity, wind speed showed discrete results. The effects PBL heights on O_3 , NO, NO_2 , and NO_X were investigated. O_3 had a negative connection with BC in all seasons, which was attributable to the heterogeneous reactions in the environment.

Key words: ozone, oxides of nitrogen, BC, meteorological parameters

NUMERICAL SIMULATION AND OBSERVATIONAL COMPARISON OF INVERSION CONDITIONS FOR STUDYING DISPERSION AT COASTAL SITE KALPAKKAM

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ABSTRACT

Inversion layer is a stable atmospheric layer (Diallo, M., Pal, S., 2015) which develops under strongly radiative cooling condition which traps the air pollutants and lead to high concentrations. The inversion layer characteristics depend on the location and seasons. In this study the surface inversions at the coastal site of Kalpakkam are analyzed using observations and numerical simulations to study their significance in pollution dispersion. Observations using GPS-SONDE, meteorological tower and Doppler SODAR at Kalpakkam are used for model comparison and stability assessment. From the observation it has been found that the surface inversions are predominant mainly in December-January during winter at Kalpakkam. Numerical simulations are conducted using triple-nested high resolution (2km) WRF model using the NCEP FNL analysis for initial and boundary conditions for 6-days (17 Sep, 20 Sep, 12 Dec and 16 Dec 2019; 17 Sep and 14 Dec 2010) to study the characteristics of the inversions. The SODAR backscatters and GPS Sonde indicate strong inversion layers extending to 200-300m in the late night and morning conditions on these days. Simulations are conducted with two boundary layer schemes namely the K-theory based nonlocal YSU (Hong, S., Noh, Y., Dudhia, J., 2006) scheme and TKE based MYNN 2.5 level scheme (Nakanishi, M., Niino, H., 2006 & 2009). It has been found that WRF simulations using the YSU scheme better compare with observed inversions in terms of vertical extent and duration of the inversion compared to the simulations using MYNN level 2.5 scheme. It is found that YSU simulates better PBL properties compared to TKE scheme in both stable and convective conditions. The preliminary results of hypothetical tracer dispersion simulations using HotSpot software indicated that the concentration during inversion is nearly 1.2 to 1.3 times higher compared to release in convective atmospheric scenario for the same wind speed condition.

Keywords: Inversion, Air Pollution, SODAR, WRF PBL

STUDIES ON WEATHER CHANGES DUE TO ANTHROPOGENIC ACTIVITIES USING AEROSOL VERTICAL PROFILES

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ABSTRACT

There is ample evidence that anthropogenic activities during road construction work are an important source of aerosols into the atmosphere and can have a substantial temporary impact on air quality. Aerosol measurement were carried out at Kolhapur (16°42'N, 74°14'E) by using semiautomatic twilight photometer to study the vertical distribution of tropospheric Aerosol Number Density per cm^3 (AND) for three consecutive years 2009-11.

Aerosol vertical profiles obtained pre, during and post anthropogenic activities were studied. The observations reveal that different types of aerosols introduced in the atmosphere during the road construction work remained suspended in the atmosphere for some hours to days. Hence, one new tropospheric aerosol layer (in between ~6 and ~9 km) was observed on the vertical profiles of aerosols. The calculations showed that the minimum increase in AND was ~55% and the maximum was ~210% due to the road construction activities. This layer was the result of enhanced aerosol generation due to the primary production (bulk-to-particle conversion) and photochemical processes (secondary production) at the time of road construction activities. No such tropospheric aerosol layer was observed before or after this period.

The AND of the newly observed tropospheric aerosol layer at road construction time and its altitudes for clear sky days showed day to day, monthly and seasonal variations with highest height in the month of October and lowest in the middle of March. The considerable difference was observed in morning and evening altitudes of this layer. At evening, this aerosol layer was observed at higher altitudes than morning for all the months.

During the period of road construction, considerable increase in the atmospheric temperature and pressure was observed. Relative humidity in the atmosphere was decreased. Hence, it is clear that anthropogenic activities affect the tropospheric aerosol loading and there by affects the local climate.

Keywords: tropospheric aerosol loading, anthropogenic activities, weather changes, twilight technique

Uttarakhand fire event and its radiative impact

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ABSTRACT

Fires induce aerosols in the atmosphere and have a significant impact on the health and climate of the region. In the present study, we simulate the Uttarakhand fire event, which occurred during April 2016 using Weather Research and Forecasting with Chemistry (WRF- Chem) model to understand the radiative impact of the emitted aerosols and their extent of transport into the atmosphere. We have used multiple datasets from ground based, and from satellite (MODIS, CALIPSO), Central Pollution Control Board (CPCB), and ERA5 reanalysis data) to access the model performance. Our analysis showed overestimation of aerosol optical depths (AODs) during fire event simulated by WRF-Chem compared very well with MODIS AODs over the Uttarakhand region. The vertical profile of elevated smoke aerosols derived from CALIPSO shows enhancement of smoke aerosols extending up to a height of 5 km altitude during the fire event. The fire has caused an increase in the near surface air temperatures by 1-3 o C and decrease in relative humidity by ~10% over the affected areas. The NET (shortwave + longwave) atmospheric radiative forcing due to fire is found to vary in the range of 10 to 40 Wm -2 in the entire affected areas with the highest value over the source region. It is also found that the fire induced atmospheric heating rates are found to be higher in longwave region (0.4 to 1 K/day) than in the shortwave (0.1 to 1 K/day) region.

STUDY THE VARIATIONS IN TCO AND AOT DURING PRE- AND POST-MONSOON SEASONS AT ATIGRE, KOLHAPUR

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ABSTRACT

The total column ozone (TCO) and aerosol optical depth (AOD) have measured by using the highly advanced, compact and portable photometer called as Mixrotops-II ozonometer during April 2019 to 15 th March, 2020 at Aigre village (16.74° N, 74.37° E, 604 meters above sea level, masl), located on the southeastern slope of Indian western Ghats. The measurements have been carried out hourly basis on a day from morning 9:00 to 17:00 LT. The diurnal variation of AOT shows the distinctive diurnal variation in in post monsoon, winter and summer season. In the post monsoon it remains constant due to rain washout. However, it shows high concentration in winter and summer season. The daily mean variations in TCO was higher in the morning at ~9:00 to 10:00 am and it decrease in the noon time at around 12:00 to 13:00 pm then it increases upto 17:00 pm. The daily patern of variations in TCO was same in seasonal variations while it is found that concentration of TCO was high in post monsson as campare to winter and summer season. The AOT is vary with weather changes as well as local activities such as biomass burning. While TCO is highly depending on the intensity of the incoming solar UV irradiance. Therefore, the daily mean TCO shows particular pattern while the daily mean AOT didn't shows any significant trend. However, our results shows that the TCO and AOT have some significant relationship in winter and summer season. Herein, we have only presented observational data but it needs to know what kind of mechanism behand it.

Keywords: ozone, aerosol, ozonometer, monsoon

Temporal variation and chemical characterization of atmospheric particulatematter in the Jaipur region of Rajasthan, India

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ABSTRACT

PM 10 and PM 2.5 samples were collected in the area of Jaipur region (Rajasthan) during a one year long period (October 2018–September 2019). Twenty–four hour PM 10 and PM 2.5 filter samples were collected, and about 50 aerosol samples of each type were obtained. The samples were analysed for chemical concentrations (Cations and Anions) using Ion chromatography. Average of a year-long measurements shows that PM 10 results as 32.45±9.34 µg/m 3 for background sampling station, 71.84±35.73 µg/m 3 for traffic and combustion sourced areas and 87.29±26.32 µg/m 3 relatively industrial part of the city. PM 2.5 results for the same sampling points measured as 15.48±8.44 µg/m 3 , 46.23±23.37 µg/m 3 and 44.10±22.57 µg/m 3 , respectively. The results show that the concentration range water soluble ions of the Coarse Particles (PM 10) and Fine Particles (PM 2.5) fractions varied from 1.17 to 28.45 µg/m 3 and from 3.82 to 35.58 respectively in the study sites. The concentrations of all the ions, except that of Na + and Cl - were significantly higher in the warm period compared to the cold period of the year, whereas the PM 10 and PM 2.5 results presented the opposite trend. Source identification was attempted by Enrichment Factor (EF) calculations and by Principal Component analysis (PCA) in relation to wind directions. The results show that soil/road dust re-suspension from opencast mines and unpaved roads, emissions from vehicle exhausts and mining activities are the main sources of PM 10 in the air over Jaipur region. The sources were soil dust, vehicle exhaust, secondary aerosol, road dust and biomass burning. Our study aims to: (1) characterize the particulate concentrations and associated chemical species in urban atmosphere (2) identify the potential sources and estimate their apportionment.

On the Influencing Factors Responsible for Aerosol Optical Depth trends over Indo-Gangetic Plain

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ABSTRACT

Long-term trends in aerosol optical depth (AOD) are paramount for understanding the factors that influence the western and eastern Indo-Gangetic Plain (IGP) regions. MERRA-2 different aerosols illustrate that dust aerosols dominate over the western IGP, while sulphate and carboneous (black carbon (BC) and organic carbon (OC)) aerosols majorly contributes in the total AOD over eastern IGP, during the pre-monsoon season from 2003 to 2019. The OC/BC ratio shows that the carbonaceous aerosols are generally emitted from fossil fuel (ratio < 2) and biomass burning (ratio >2) over western and eastern IGP. Here, using satellite (Terra and Aqua) and reanalysis (MERRA-2) AOD data, we demonstrate a significant declining and rising trend over western and eastern IGP, respectively. The declining trend in AOD over western IGP is mainly due to increased pre-monsoon rainfall that increases soil moisture and thus reducing soil erodibility; along with slowing circulation patterns. The rising trend in AOD over the eastern IGP appears to be influenced by an increase in regional anthropogenically-generated aerosols (i.e., BC, OC, and sulphate) from industrial activity. The correlation between AOD and different atmospheric conditions suggests that AOD trends over western IGP are highly influenced by meteorology, whereas the eastern IGP has a weak association, implying that rising trends in the region may be due to increased regional anthropogenic aerosols.

Keywords: Indo-Gangetic Plain, Aerosol optical depth, Dust, Black carbon

Changing patterns in aerosol vertical distribution over South and East Asia

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ABSTRACT

Changing patterns in aerosol concentrations over the Asian region is well documented with a concurrent increase over India and a marked reduction over China. However, aerosol vertical distribution in the changing climate is not fully understood. By combining long-term satellite observations from MODerate resolution Imaging Spectroradiometer (MODIS) on-board the Terra and Aqua satellites and Cloud-Aerosol LIdar with Orthogonal Polarization (CALIOP) sensor on-board Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO), here we show rapid changes in the aerosol vertical distribution over the south and East Asia covering India and China. A statistically significant decreasing (increasing) trend in the boundary layer (free troposphere) aerosol concentrations is noticed over India. ERA-Interim reanalysis model suggests that this increase in free tropospheric aerosol concentrations is due to the lifting of boundary layer pollutants through an increase in convection (and vertical velocity) in a changing climate. In contrast, a consistent decreasing trend is observed over China irrespective of the altitude. Interestingly, a decreasing trend in Aerosol Optical Depth (AOD) is observed over northwest India and we relate this to an observed increase in precipitation leading to increase in the vegetation. It is also found that long-term oscillations like QBO, ENSO and solar cycle significantly affect the aerosol concentrations. Thus, it is prudent to conclude that background meteorology and dynamics play an important role in changing patterns of aerosol vertical distribution.

Keywords: Aerosol vertical distribution, changing patterns, satellite measurements.

SECONDARY AEROSOL FORMATION IN THE SOUTH ASIAN OUTFLOW TO THE NORTHERN INDIAN OCEAN: RESULTS FROM ICARB-2018

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ABSTRACT

Particle number size distribution (PNSD) is one of the critical microphysical properties of aerosols to understand their role in affecting the earth's radiation balance. New particle formation (NPF) from gaseous precursors and their subsequent growth to larger climatically relevant sizes is a widely investigated topic globally due to its impact on PNSDs, aerosol direct and indirect effects. Notwithstanding this, large gaps still exist in the understanding of NPF due to the complexities associated with the nature and abundance of precursor vapours, pre-existing particles, and prevailing meteorological conditions that control the gas-phase and particle dynamics. Moreover, NPF over oceans, especially adjoining India, is explored limitedly due to observational constraints, despite the impact of the marine aerosol burden on cloud properties, regional and global climate. During winter, prevailing north-easterly winds favour the transport of the pollutants from South Asia to the northern Indian Ocean, and such extensive outflow results in a variety of chemical transformations and secondary aerosol formation over the ocean. In this study, first-ever observations of submicron PNSDs and NPF events in South Asian outflow are examined using high-resolution measurements from sophisticated aerosol instrumentation on-board ship as part of the Integrated Campaign for Aerosols, gases, and Radiation Budget (ICARB) during winter-2018. We found that the particle concentrations are highest near the coast but dropped fivefold in the remote equatorial Indian Ocean (EIO). However, such spatial variability pattern is perturbed by frequent NPF events with an enormous influx (nearly 5-10 times) of ultrafine particles. The events were intense close to the outflow but frequent over EIO. A mechanism is proposed involving the entrainment and mixing of the free tropospheric airmasses to the marine atmospheric boundary layer triggering NPF. Concurrent aerosol composition measurements confirmed the participation of secondary organics from distinct sources, including polluted outflow and marine biogenic emissions, in NPF.

Keywords: New particle formation, particle number size distributions, South Asian outflow

NON-UNIFORM EFFECT OF COVID-19 LOCKDOWN ON THE AMBIENT AIR QUALITY IN DIFFERENT LOCAL CLIMATE ZONES OF URBAN REGION OF KOCHI, INDIA

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ABSTRACT

Deterioration of ambient air quality associated with urbanisation is a serious concern in many parts of the world. In India, air pollution, primarily due to particulate matter, has increased exponentially in the last few decades due to rapid urbanisation, industrialisation and population growth. Air pollution is not only a serious economic and environmental concern but also has severe health impacts, resulting in millions of premature deaths. However, the lockdown period (in 2020) due to the COVID-19 pandemic witnessed improved air quality in the urbanised areas and less-urbanised/industrialised regions, such as Kerala (India). This study investigates the influence of COVID-19 lockdown (in 2021) on the ambient air quality of three distinct local climate zones (LCZs) in the urban region of Kochi, India. Air pollutants data were collected from the ambient air quality monitoring stations of the Kerala State Pollution Control Board in Ernakulam district. The monitoring stations are located at compact midrise zone (City Centre), compact lowrise zone (Mobility Hub) and heavy industry zone (Industrial Area) of the urban region. Temporal variations in the National Air Quality Index (NAQI) were examined during pre-lockdown, lockdown and post-lockdown periods of 2021 (i.e., 1st March to 31st July 2021). The analysis shows that the NAQI exhibits characteristic variability during the lockdown period in different LCZs of the urban region. Compared to the pre-lockdown period, the mean NAQI showed drastic improvement during and after lockdown at City Centre (45% and 19%) and Mobility Hub (45 % and 38%). However, there was no discernible improvement in the NAQI in the Industrial Area, which is contrasting to the air quality pattern during the lockdown period of 2020. Although differing in intensity, the COVID-19 shutdown had a significant impact in reducing air pollution in different LCZs of the urban region of Kochi. However, effective strategies are required to improve ambient air quality in the compact and populated urban regions, even after the pandemic-related restrictions, to ensure a better quality of life.

Keywords: Air Quality, COVID-19, Local Climate Zones, Urban Areas

Vertical and Spatial distribution of Elevated Aerosol Layers obtained using long-term ground-based and space-borne LIDAR observations

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ABSTRACT

At present, the study of aerosols optical, microphysical, and chemical properties is relatively mature, but knowledge on their vertical distribution is still considered to be limited. To examine this, long-term ground-based (Micro Pulse Lidar and Mie lidar) and space-borne (CALIOP) vertical distribution of aerosol extinction covering from near surface to 30 km is examined by combining the observations co-located over a tropical station Gadanki, India. The presence of two elevated aerosol layers, one between 2 and 5 km (lower troposphere) and the other between 15 and 18 km (UTLS), are simultaneously observed during the Indian summer monsoon season. Furthermore, aerosol sub-types obtained for these elevated aerosol layers using CALIOP measurements reveals the dominance of polluted dust (44.6%) whereas the occurrence frequency of polluted continental, dust, and elevated smoke is ~19.6%, 20.7%, and 13.1%, respectively, for the lower layer. However, the occurrence frequency of volcanic ash and sulfate aerosols is ~50.3% and 49.7%, respectively, for the UTLS region. Depolarization ratio (color ratio) values vary between 0.21 and 0.34 (> 0.6) in the lower layer while the values > 0.15 (<0.6) are present in the UTLS layer during monsoon season revealing the influence of non-spherical and coarse mode particles in the lower layer while spherical and fine mode particles in the UTLS region over the site. Global extent of these elevated aerosol layers observed using CALIOP measurements reveals the presence of the troposphere elevated layer extending from Africa to the South Asia region during both pre-monsoon and monsoon seasons. Increasing aerosol trend (0.1 AOD/ decade) is observed over the developing countries like South Asia and Africa region in this layer but no significant trend is being observed in the UTLS aerosols. These findings play a decisive role in the estimation of reliable radiative forcing owing to the aerosol-radiation interaction on the regional climate.

Keywords: Elevated aerosol layer, Lidar, CALIOP.

RELATIONSHIPS BETWEEN $PM_{2.5}$ AND METEOROLOGICAL FACTORS (TEMPERATURE, WIND SPEED AND RELATIVE HUMIDITY) SEASONAL VARIATIONS IN AGRA

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ABSTRACT

The pollution of particulate matter less than 2.5µm ($PM_{2.5}$) is a serious environmental problem. The interactions between $PM_{2.5}$ and meteorological factors play a crucial role in air pollution analysis. In this study, the relationships between $PM_{2.5}$ concentration with meteorological factors investigated for a period of one year from March 2019 to February 2020 in Agra (Uttar Pradesh). The data was collected from Central Pollution Control Board (CPCB) https://app.cpcbccr.com/ccr/#/caaqm-dashboard-all/caaqm-landing/data. Effects of meteorological conditions (Temperature, Wind Speed and Relative Humidity) on the $PM_{2.5}$ concentration seasonally. The seasons were categorized as Winter (December-February), Summer (March-June) and Monsoon (July-September). Average $PM_{2.5}$ concentration during Winter 89.912 µg/m^3, Summer 68.02464 µg/m^{3}and 46.396 µg/m^3 in Monsoon. Average temperature during winter 13.73 °C, Summer 40.63°C and in Monsoon 31.70 °C. The observed data indicates that concentrations of pm 2.5 decreased during monsoon due to washout effect of $PM_{2.5}$, wet scavenging of pollutants and due to higher precipitation during that season. Highest concentration of $PM_{2.5}$ in the winter season, may be due to calm atmospheric conditions and higher anthropogenic sources (bio-mass burning, wood burning etc.). TEM has a negative relationship with $PM_{2.5}$ in Monsoon but opposite in Winter. Average Wind speed during Winter 1.733 m/s, Summer 2.635m/s and in Monsoon 26.155m/s which has negative relation with $PM_{2.5}$ concentration. Average Relative Humidity during Winter 72.762%, Summer 43.095% and 2.387% in Monsoon. The positive relation between $PM_{2.5}$ concentration and RH is stronger in winter because humidity affects the natural deposition of particulate matter in the air. $PM_{2.5}$ concentration has a weak co-relation with wind speed and was least in Monsoon.$PM_{2.5}$ and meteorological factors in terms of seasonal variations, and the conclusions about the relationships between $PM_{2.5}$ and meteorological factors are more comprehensive.

Keywords: Particulate matter, Fireworks, Air Quality, Health risk

Understanding the impact of dust aerosols on Indian Summer Monsoon Rainfall using Regional Climate Model

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ABSTRACT

The interactions between aerosols and Indian Monsoon have received increasing attention. Southwest monsoon brings warm and humid air from tropical oceans to continents and thus causes heavy rainfall over Indian region. In mid-June, the Indian subcontinent warms up more than the Indian Ocean does, forming a strong land-ocean thermal contrast, which drives strong low-level southwesterly winds. Aerosols are the liquid droplets or solid particles suspended in the air. Absorbing aerosol such as dust works as a heating source to influence the ISM system. It is observed that dust-cloud interactions can modulate the circulation and precipitation of the ISM through absorption of shortwave and long-wave radiation when suspended in the atmosphere. Several studies demonstrated that remote dust aerosols over the Middle East and the Arabian Sea can exert significant impact on the ISM due to strong transport by low level south westerlies winds. Air quality depends on the distribution of multiple chemical species across a number of particles within an aerosol. Recent data from CPCB shows that the level of pollutants in Delhi is between moderate to unhealthy during heavy rainfall days. In this study, data from Regional Climate Model (RegCM) showed that ISM rainfall is positively correlated with satellite retrieved AOD and is attributed to the significance of the prevailing monsoon circulation on dust emissions.

Keywords: Dust aerosol, RegCM, ISMR.

Variation in photosynthetically active radiation over Delhi during COVID lockdown

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ABSTRACT

Due to COVID-19 pandemic, unprecedented nationwide lockdown was imposed to curb its repercussions on economy and environment. The lockdown was imposed in four phases from 25th March to 31st May, 2020 (LD1.0: 25th March to 14th April, LD2.0: 15th April to 3rd May 2020, LD3.0: 4th May to 17th May 2020, LD4.0: 18th May to 31st May 2020). The enforced lockdown reduced the anthropogenic activities which provided an opportunity to study its impact on air quality. The present study focuses on quantification of effect of aerosols on incoming photosynthetically active radiation (PAR) and enhanced vegetation index (EVI) during pre- and during different lockdown phases over Delhi. For this purpose, CERES synoptic 1 degree Edition 4.1A product was used to retrieve Aerosol optical depth (AOD), direct and diffuse component of PAR with hourly temporal resolution in all sky conditions. Additionally, enhanced vegetation index (EVI) was calculated using sentinel-2 data for visual interpretation of crop growth health and to observe the improvement in greenness of the city. Total incoming PAR was calculated by adding direct and diffuse component of PAR. The lockdown implicated a decline of 16% in AOD values as compared to the same time period average observations of previous decade (2010-2019) and 20% decrease when comparison done between pre- and during lockdown period. The observed PAR values during lockdown show an increase of 1.4% as compared to the average (previous decade) observations of same time and 30% increase when compared to pre-lockdown period of 2020. The direct and diffuse components of PAR were significantly increased by 11% and decreased by 7%, respectively during lockdown period. The EVI showed minimum 0.20 and maximum 0.76 which represents effect of lockdown on terrestrial ecosystem.

Keywords: COVID-19, PAR, AOD, EVI

Real Time Measurement of Fine Particle Associated Oxidative Potential Using Dithiothreitol (DTT) in Agra During COVID 19 Lockdown Period

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ABSTRACT

The COVID-19 outbreak has shown some positive impacts on the natural environment. The lockdown events have reduced air pollution levels by approximately 20% across 27 countries due to the reduction in major anthropogenic activities. Oxidative potential (OP) of PM 2.5 was a selected indicator to link the aerosol exposure to its adverse health effects . Samples collected before (Feb - Mar) and during (Apr - May) lockdown period of 2020 were measured by using dithiothreitol (DTT) assay, at a residential, urban background site in Agra, India. The result showed that the average drop in PM 2.5 mass concentration was 42% and air quality was quite moderate. Solar radiation was increased because of reduction in anthropogenic pollution due to COVID-19 measures. Mean value of nine heavy metals during lockdown period followed the order: Al > Zn > Pb > Mn > Cu > Cr > Ni > Cd > Ba. The volume- and mass-based dithiothreitol (DTTv and DTTm) activities of PM 2.5 were significantly lower in lockdown period by 36.6% and 33.3% respectively. The long ranged air mass is transported from European, Gulf and African region to Afghanistan to study site, whereas short trajectories were influenced by the regional/local emission.

Particulate Pollution Estimation during COVID 19 using Urban Aerosol Pollution Island Index over Delhi India

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ABSTRACT

The urban atmosphere usually suffers from higher air pollutant concentrations than the surrounding rural atmosphere, due to the continuous pollutant emitting sources in the urban agglomeration. According to numerous researchers, global-lockdown to curb the outbreak of coronavirus disease 2019 (COVID-19) has caused an unprecedented reduction in air pollution levels in many regions of the world. The current study focuses on determining the spatial variability in particulate pollution over Delhi, pre- and during the lockdown. The hourly PM 2.5 and PM 10 concentration dataset was obtained from eleven air quality measurements sites of Delhi Pollution Control Committee (DPCC) for the duration of January 2019 to December 2020. The diurnal, monthly and annual variability in the trend of Urban-Aerosol Pollution Island (UAPI) Index have been analysed. It was observed that the UAPI Index decreased for traffic affected regions of Delhi for the year 2020 while the opposite trend was observed in the Urban Background areas. The lowest UAPI Index for PM 10 in the Traffic affected region was -97.12 during April, 2020 while the highest was 117.39 during December, 2019. Similarly, the lowest UAPI Index for PM 2.5 in in the Traffic affected region was -51.48 during February, 2020 while the highest value was 167.60 during February, 2019. Lastly, we have constructed the bar-graphs between UAPI (Traffic) and UAPI (Background) for 2019 and 2020 respectively. The analysis depicted that traffic-affected urban site experienced lower levels of particulate pollution during 2020 while the urban- background station suffered increase in pollution levels during 2020 as compared with 2019. The results indicated that the lockdown implemented to control COVID-19 outbreak resulted in unexpected decrease in the traffic-related pollutants while other sources of pollution increased drastically over Delhi.

Keywords: Air Pollution, UAPI, PM 10 , Traffic Emissions

MONITORING THE SPATIAL VARIATION OF AEROSOLS AND THEIR CORRELATION WITH LAND USE/LAND COVER IN DELHI: A COMPREHENSIVE APPROACH TOWARDS URBAN PLANNING

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ABSTRACT

For better understanding of the impact of aerosols over climate, it is essential to know their spatial and temporal variability. The present study is focused on the Indian urban city, Delhi which is considered one of the most polluted regions in the world. In this study, spatial analysis of atmospheric aerosols has been carried out by using geo-statistical methods. Satellite remote sensing of aerosols is advantageous due to its extensive and continuous spatial coverage and lower cost for acquisition. Spatial statistics and correlation analysis of the relationship between Land Use/Land Cover (LULC) and AOD were performed to examine the impact of LULC on AOD in Delhi. It was observed that the major part of central and east Delhi showing maximum built-up area depicted highest AOD and particulate matter. Whereas, the surrounding areas around Delhi with mostly agricultural farmlands showed lower values. The correlation of particulate matter and each land-use category has also been computed in this study. Further, the application of stochastic modeling technique in analyzing the future trends of aerosol optical properties was performed using the Box–Jenkins ARIMA (AutoRegressive Integrated Moving Average) modeling technique. After rigorous evaluation, the ARIMA (1,0,0)x(0,1,2) 12 model was identified as the best predictive model for the time series under study, suggesting a simplistic modeling technique for determining the future values of AOD. It was observed in the study that geo-statistical tools integrated with time series modeling techniques prove to be essential for air quality management. These findings can provide a comprehensive approach for urban planning, land use management and air quality improvement.

Keywords: Air quality, Geo-statistical, ARIMA, Delhi

INDOOR AIR CHEMISTRY AND ITS RELATION WITH OUTDOOR ENVIRONMENT

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ABSTRACT

People spend most of their time indoors, in buildings such as schools and offices, as well as their homes. Recent interest in Indoor Air Quality (IAQ) suggests that the contribution of outdoor pollutants, indoor airborne particulate and gaseous pollutants may be responsible for a number of respiratory illnesses, because of these possible health implications it is important to understand the characteristics of each air pollutant inside/outside. However, understanding the chemistry that occurs on indoor surfaces and its impact on air quality is still in its nascent stages due to the complexity of indoor surfaces. Indoor air quality is affected by many factors including the type and running conditions of indoor pollution sources, ventilation conditions, as well as indoor activities. Studies have revealed that the outdoor environment is also an important factor that cannot be neglected for indoor air quality studies. Despite this fact, there are not many studies reported on the simultaneous measurement of indoor and outdoor air pollutants. In the present work, an assessment of particulate matter and their chemical composition was studied both indoor and outdoor for highlighting the major challenges and opportunities in indoor/outdoor air pollution studies. It was found that the average concentration of PM indoors was higher than of outdoor aerosols suggesting that the air indoors is more polluted as compared to outdoors. Since the indoor PM of outdoor origin accounts for only a proportion of the overall exposure, the average net adjustment required for indoor exposure is very modest. The results suggested that the higher PM concentrations and the chemical composition indoors were influenced by the infiltration of outdoor air and by the indoor activities carried out by its inhabitants. By combining laboratory studies, field measurements, and modelling we can gain insights into the molecular processes necessary for our further understanding of the indoor environment.

Keywords: Indoor Air Quality, Particulate Matter.

Machine Learning Regression Technique Applied to Improve Visibility Prediction at Airports in China

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ABSTRACT

Fog, heavy precipitation, and other obstructions to surface visibility pose a significant and important hazard to all forms of transport, especially in the aviation industry. Correct visibility forecasts can reduce flight delays due to the weather by 20-35%. However, accurate forecasting of low visibility is still a challenging task for meteorologists. In this paper, we employ a machine- learning regression technique (Multilayer Perceptron (MLP) Neural Networks) to improve current visibility forecasts provided by the European Centre for Medium-Range Weather Forecasts (ECMWF) at airports in China during winter. We developed two models: the first using only high resolution meteorological data (Model I), and the second with the addition of air quality data (PM2.5 & PM10) (Model II). The models were trained and tested using data from the ECMWF and METeorological Aerodrome Reports (METARs). Our analysis shows that Model II is consistent with the observational METARs and can accurately predict changes in visibility with thresholds of 1000 m and 3000 m. Model I displays good results at the 3000 m threshold, but fails to predict well visibility of 1000 m or lower. This study indicates that atmospheric visibility forecasts can be improved by utilising the machine learning regression technique with high resolution meteorological data and air quality data.

A systematic method for mapping carbonaceous aerosol concentrations in a tourist high altitude location in the Western Ghats

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ABSTRACT

Pollution monitoring and mapping investigations in rural/peri-urban India are sparse because most studies focus on metropolitan cities and urban areas. Understanding the geographic variability of climate-sensitive black carbon aerosols in a tourist hotspotand a pristine peri-urban region will be beneficial, especially after accounting for larger spatial fluctuations of black carbon. Hence, this study uses aethalometers to offer source attribution and characterization of B.C. from February to April 2021 at numerous locations (AE-31). Diurnal Black Carbon (B.C.) examinations indicated discernible peaks, one in the morning hours, during peak hours, and the other in the late evening hours. To determine the relative contribution of fossil fuel and wood burning sources. The percentage of wood burning in the background location ranges from 21.12 to 88.98 %. Wood burning leads residential sites with 57.3 %, whereas fossil fuel contribution dominates traffic sites with 69.84%. A Scanning Electron Microscope (S.E.M.) paired with an Energy Dispersive X-ray system was also used to analyse the morphology and chemical composition of air particles (E.D.X.). The E.D.X. data show that there is a higher concentration of silica and carbon in the atmosphere at the background site than at the residential site, indicating that particles generated from geogenic sources and resuspension dust in the neighbourhood predominate. The presence of high levels of carbon in traffic areas indicates that automotive activity is causing significant pollution. Wind profiles and factor contributions were used to calculate Conditional Bivariate Probability Functions (CBPF). CBPF analysis results were used to identify local point sources. The results pointed to a competition between anthropogenic and natural source processes over the monitoring stations.

Keywords: Black carbon, Source Apportionment, Conditional Bivariate Probability Function, Aerosol absorption coefficient, Morphology and Elemental composition.

CHARACTERISTICS OF ATMOSPHERIC BOUNDARY LAYER OVER UMIAM, MEGHALAYA

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ABSTRACT

Atmospheric Boundary Layer Height (ABLH) is a key determinant of vertical and horizontal distribution and dispersion of atmospheric pollutants in the atmosphere. The Mixed Layer Height (MLH) is a fundamental parameter of ABL up to which maximum vertical mixing of the pollutants take place in the atmosphere. Accurate information on elevated layer (EL) of aerosols and atmospheric parameters are of dire importance and for that in situ measurements is essential for proper understanding of regional ABL. In this study, we characterize ABL over high altitude station Umiam from 106 balloon launches since 2009 to 2020. Although these launches are limited owing to the extreme weather conditions and other logistic difficulties, it gives us an overall picture of the ABL over Umiam and also for the diurnal and seasonal evolution of ABL we have used the data obtained from Vaisala Ceilometer from November 2019 to August 2021. Seasonal variation of MLH from the radiosonde showed highest during pre-monsoon followed by winter, post monsoon and minimum during monsoon. The backscattering signal of the ceilometer is strong in the ABL where particle concentration is higher and thus distinct diurnal and seasonal variation have been observed with BLH evolution. Maximum BLH is observed during pre - monsoon where the backscattering signal clearly indicates well mixing of particles up to an average height of about 1400 m in the afternoon and minimum during monsoon where BLH is around 700 m and particles seem to be concentrated near to the surface within the BL.

Keywords: Atmospheric Boundary Layer, Mixed Layer Height, Elevated Layer

INVESTIGATING AEROSOL HYGROSCOPICITY DURING MONSOON TRANSISTION OVER THE RAIN SHADOW REGION

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ABSTRACT

As the monsoon transitions from southwest to northeast, the large scale winds weakens and lead to aerosol loading especially over the Indian landmass. This also marks the season of crop burning in the Indo Gangetic Plains (IGP) specifically over the west IGP. The cloud base aerosol characteristics specifically from the rain shadow (RS) region of India are least studied during this period. This case study involves the analysis of in situ aerosol measurements (CAIPPEX Phase IV) over the RS region during the 2018 monsoon transition period. Measurements were made during the morning and afternoon to investigate possible changes happening in the aerosol loading before and after full boundary layer development, respectively. The hygroscopicity (κ) of the aerosols is estimated to understand its CCN activity. κ varied between 0.25 and 0.3 with higher values obtained during the afternoon, suggesting towards probable aging of aerosols.

Keywords: hygroscopicity, monsoon transition, CAIPEEX, boundary layer

INFLUENCE OF AMBIENT AIR QUALITY ON NET EFFECTIVE TEMPERATURE, WEATHER STRESS INDEX AND DISCOMFORT INDEX OF KOLKATA IN SUMMER SEASON.

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ABSTRACT

Industrial revolution started 200 years ago and its consequences to human beings were in the middle of 20 th century. Different weather parameters such as temperature, wind speed, wind direction humidity , rainfall etc. are influenced by Ambient Air Quality (AAQ) in different part of India mainly industrial places.

Meteorological parameters such as air temperature, humidity and rainfall are influenced by AAQ such as Sulfur dioxide (SO2), Nitrogen dioxide(NO),Carbon monoxide (CO), Carbon dioxide(CO2),Suspended Particulates Matter(SPM), Respirable Particulates Matter (RPM),Inhalable Particles with diameter 10 micrometer (PM10), Inhalable Particulates with diameter 2.5 micro meter(PM2.5), Lead contains (Pb) etc.

This study analyses the influence of Ambient Air Quality (AAQ) such as SO2, NO2, SPM, RPM, PM10,CO2 on Net effective Temperature (NET), Weather Stress Index (WSI) and Discomfort Index(DI) of Kolkata in Summer Season of last 10 years. The result of the study shows that NET, WSI and DI are positively correlated with SO2,NO2,CO2, SPM,PM10 due to industrial and vehicular pollutions.

Findings are : (1) The influence of gaseous pollutants on NET, WSI,DI are much more positively correlated in Summer. (2) The influence of SPM,PM10 are weak to moderately correlated with NET,WSI,DI.

Key words: Ambient Air Quality(AAQ), Pollutants, Weather stress index, Discomfort index.

SATELLITE-BASED AEROSOL OPTICAL PROPERTIES OVER KASHMIR VALLEY, NORTHWEST HIMALAYA

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ABSTRACT

Atmospheric aerosols are known to influence the radiation budget of the Earth. The primary aerosol optical properties which determine the cooling or warming of the earth are aerosol optical depth (AOD), aerosol Ångström exponent (AE), asymmetry parameter (AP), single scattering albedo (SSA) and aerosol refractive index. In this study, three main aerosol optical parameters; AOD, SSA and AE were retried from MODIS satellite data over the Kashmir valley from 2013-2017 to investigate the seasonal variation in aerosol loading, aerosol types (anthropogenic and natural), size (fine and coarse mode) and their absorbing or scattering properties. The lowest and highest AOD was observed during spring (0.16) and autumn (0.52), and moderate and comparable AOD values were observed during summer (0.34) and winter (0.31) respectively. High AOD value during autumn season indicates high aerosol loading which are in line with the ground observations of particulate pollution over the Kashmir valley. During autumn, winter and spring, the average AE value was greater than unity varying in the range of 1.5 – 1.8, which depicts the dominance of fine mode aerosols like organic carbon (OC) and black carbon (BC). During summer, the average AE was 0.98 varying in the range of 0.5 – 1.3, indicating the dominance of larger aerosol particles like sulfate and dust. Similarly, light absorbing aerosols, which are emitted as combustion by-products are the dominant aerosol types during autumn, winter and spring as indicated by the lower SSA values (< 0.85). Contrarily, the SSA values during summer were >0.85, indicating the dominances of scattering aerosols like sulfate and dust. The peculiar meteorological and geomorphic settings of the Kashmir valley together with the intensive biomass and coal burning practices prevalent over the study area during cold periods, leads to the higher levels of absorbing aerosols (BC) which have adverse implication on the surrounding Himalayan Cryosphere and public health.

Keywords: Aerosols, AOD, SSA, AE, Himalaya

CHARACTERISTICS OF FOG OVER AGARTALA AIRPORT

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ABSTRACT

Fog is considered as an important aviation hazard. The characteristics of fog at Agartala Airport during 2011-2020 have been analysed. The fog season generally starts from November and lasts till February, with its highest intensity during December and January. The frequency of dense fog is also relatively higher in these two months. The onset of fog mostly takes place between 0001-0100 UTC. The duration of fog is found to be short in November, however frequency of late dispersion of fog is higher in December and January. The frequency of different ranges of lowest visibility associated with fog has also been studied and found that in most of the cases, the lowest visibility occurs between 0001-0100 UTC. The study also shows that the frequency of fog over Agartala in November-February has increased as compared to the climatological mean of 1981-2010.

Keywords: Fog, Aviation, Climatology, Visibility

COVID LOCKDOWN INDUCED AIR POLLUTION ASSESMENT ACROSS MEGA CITIES IN INDIA

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ABSTRACT

Air pollution has become a major environmental and health problem in India. According to the risk assessment of Global Burden of Disease comparative for 2015, exposure to the air pollution adds around 1.8 million premature deaths and 49 million disability-adjusted life-years (DALYs) lost, and ranked among one of the top risk factors for health problems in India (PHFI and CEH, 2017). Due to COVID 19 Indian government has imposed lockdown from 25 March 2020 to slow down the coronavirus pandemic and because of this lockdown situation Air Quality in India has improved significantly. According to World Air Quality Index countries like the United States, Spain, Italy, China, France, Mexico, and the UK have reported a drop in the concentration of air pollutants. In India states which fall under the most polluted city in the world, the category has shown improved AQI (IQAir, 2019). Here we discuss that how meteorological conditions, reduction in mobility and decrease in anthropogenic activities have affected the concentration of air pollutants. Despite the prodigious economic loss and social distancing, this lockdown situation has proved that weather corona situation is a curse to human but it is a boon to the environment.

Role of Climatic conditions in formation of tropospheric ozone, dynamic interactions (VOCs, NO x and CO) and health impact of VOCs on human health at a suburban site, Agra

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ABSTRACT

The atmospheric chemistry and health implications of pollutants are important scientific concerns. The present study deals with the concentration and diurnal variations of (VOCs) mainly BTEX, ($NOx=NO+NO_2$), (CO) and (O_3) at Dayalbagh Agra (27°10'N, 78°05'E), during Jan-dec 2019. Surface O 3 , CO and NO x concentration were recorded by continuously operating online trace gas analyzer (Thermo Fischer Model 49i, Model T300 and Thermo Fischer Model 42i, respectively. Benzene, Toluene, Ethylbenzene and Xylenes were analyzed by using Gas Chromatograph coupled with MS/FID. O_3 showed positive correlation with temperature (R = 0.6), solar radiation (R = 0.2) and wind speed (R = 0.2) and negative correlation with planetary boundary layer height (R = -0.1) and relative humidity (R = -0.6). The highest O 3 concentration (45.8 ppb) in May is attributed to high temperature (37.1 °C) and intense solar radiations (489.9 W/m 2) whereas the lowest O_3 concentration (18.6 ppb) in August was due to high relative humidity (75%) and low solar radiation (310.0 W/m 2). The average concentration of NO_x , O_3 and CO were recorded (5.14± 3.2), (41.1±20.1) and (513±205.1) ppb, respectively. The average concentration of BTEX were (65.3 ± 25.2) $\mu g/m^3$. Diurnal pattern of VOCs, NO_x and CO are highly influenced by vehicular traffic and photochemical oxidation which showed maximum value in the morning and late evening. O_3 showed maximum value in afternoon due to the photochemical generation from its precursors. Among BTEX toluene has the highest ozone formation potential. The cancer risks for benzene was higher than 1 x 10 -6 (more than the acceptable value). Hazard index for BTEX were within acceptable limit.

Variation of Major Air Pollutants in Megacity Mumbai

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ABSTRACT

Mega cities' poor air quality is a serious problem and is governed mainly by anthropogenic activity and meteorological conditions. This study aims to determine the diurnal, daily, and monthly variation in five major pollutants particulate Matter (PM_{10} and $PM_{2.5}$), surface ozone (O_3), carbon monoxide (CO), and Nitrogen dioxide (NO_2) with meteorological parameters over coastal city Mumbai (19.070N,72.870E) for a period January 2016 to December 2018. The concentrations of major pollutants were monitored by SAFAR -Mumbai, a ground-based continuous air quality monitoring station network within Mumbai. The particulate matter's daily concentration was maximum in winter and minimum in monsoon, mainly attributable to those seasons' meteorology, also the gaseous pollutants show the highest concentration in winter. During the monsoon season, the concentration of these major pollutants was lowest due to the washout effect of monsoonal rain, also the amplitude of diurnal variation was weak in the monsoon months (June to September). On the diurnal scale, PM_{10} and $PM_{2.5}$ higher during the morning hours after that reduces while the concentration of O_3 shows a peak at 12 to 15 and the diurnal patterns CO and NO_2 are different than O_3. The annual concentration PM_{10},$PM_{2.5}$,O_3 ,CO and NO_2 during 2016-2018 are observed in the range of 99-103 $\mu g/m^3$, 59 -69 $\mu g/m^3$,34 – 35 ppb ,0.67-0.77 ppm ,21 -23 ppb respectively. This distribution of major pollutants can be used for the implementation of emission control policies in megacities.

Keywords: Particulate matter , Ozone , Emissions, Meteorology.

Ozone Connections with VOCs, Precursors and Meteorological Conditions during Severe Smog Condition over Delhi

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ABSTRACT

Climate, health, air quality, aquatic and terrestrial ecosystems are significantly affected by the air pollutants. In the last few decades, a tremendous increase in air pollutants has remarkably affected the breathing space in our ecosystem and severely degraded the air quality. Production of air pollutants integrated with boundary layer meteorology controls the concentration and dilution of contaminants over any location. Air pollution condition worsens during the wintertime due to formation of smog in the urban areas. In India, Delhi is severely gets affected due to smog in the winter season, where surface ozone (O_3) and fine particulate matter ($PM_{2.5}$, PM_{10}) are major air pollutants. In the present work, we have explored the contribution of VOCs, trace gases, other air pollutants, and meteorological conditions in enhancing ozone, which is the main contributor to smog. A period (Nov 2017- Jan 2018) when severe smog conditions persisted over the region is taken for this study.

In this paper, we have performed a detailed analysis of the connection between O_3, its precursors(oxides of nitrogen (NO_x)), trace gases (carbon monoxide (CO), benzene (C_6H_6), and toluene (C_6H_5-CH_3)) along with particulate matter (PM_{10} and $PM_{2.5}$); and also the influence of meteorological conditions. Most of the pollutants are well above the prescribed Indian standards. Investigations showed a negative correlation between ozone and its precursors and particulate matter. VOCs (Volatile Organic Carbon) play an important role in ozone formation by various photochemical reactions. VOC trace gases contribute significantly towards the ozone and ultimately smog formation. The meteorological conditions and parameters also moderated the ozone concentration over the location significantly. The present study's results emphasize understanding air quality and climate effects to reduce the severity of future smog hazards in Delhi and formulate policies to mitigate these complex pollution episodes in an anthropogenic future.

Keywords: Smog, Ozone, VOCs, Meteorology,

Study of three different dust storms characteristics and their radiative properties over Indo-Gangetic Basin

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ABSTRACT

The Indo – Gangetic basin (IGB) frequently suffers intense dust storms arise from the mid arid and Thar Desert regions during the pre-monsoon season (March- June). By tracking three dust storms throughout the different years (21 Apr 2015, 08 Apr 2017, and 16 Mar 2021), we have analysed different aerosol characteristics and their radiative impacts by evaluating aerosol radiative forcing (ARF) over Kanpur regions (26.51° N, 80.23° E, 123 amsl). The true colour images of Moderate Resolution Imaging Spectroradiometer (MODIS), pathway trajectory with HYSPLIT model along with ground based observation from AErosol Robotic NETwork (AERONET) reveal that all these three dust storms generated from the Thar desert and transported towards the IGB regions, give rise to high aerosol loading and changes the different aerosol optical, physical and radiative properties (i.e. aerosol optical depth, angstrom exponent, refractive index, size distribution, single scattering albedo, asymmetric parameter etc.). The space-borne Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) measurement shows the appearance of vertically distributed dust aerosol up to 2–5 km confirmed with the observation by Atmospheric Infrared Sounder (AIRS), Ozone Monitoring Instrument (OMI), and MODIS. Higher concentration of dust particles over Kanpur during the dust storm days is observed by the Dust Regional Atmospheric Model (DREAM8b) which shows a good agreement with satellite extracted data. Large ARF is observed during all these dust storm days along with higher heating rate which may affect the regional climate system as well as atmospheric dynamics.

Keywords: Dust storms, MODIS, AERONET, CALIPSO.

INTRICATE INTERACTIONS BETWEEN STRATOSPHERIC AEROSOL LAYER AND DIFFERENT TYPES OF CLOUDS

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ABSTRACT

Stratospheric aerosol layer plays a crucial role in the weather aspects of a region since it effects on cloud formation. The stratospheric aerosol layer, often known as the Junge layer exists at an altitude of around 15-25 km. Aerosol vertical profiles obtained by semiautomatic twilight photometer utilized to measure aerosol number density (AND), altitudes and the FWHM of stratospheric aerosol layer peaks. The trend observed amongst these quantities and different types of clouds was examined from data sets ranging over three consecutive years 2009-11. All these three parameters showed day-to-day, monthly, seasonal and annual variations in association with some weather parameters such as temperature, pressure, humidity, different types of clouds etc. The annual variations of the altitudes and the AND of these peaks showed opposite phase relation.

It was observed that the altitude of stratospheric aerosol layer peak for clear sky day, preceding the high level cloudy sky day lowered down to ~11 Km and increased up to ~19 Km on the clear sky day following the high level cloudy sky day.

Middle and low level clouds were frequently observed following with high-level clouds. In very rare cases, middle level cloudy days were noticed separately after any clear sky day. It was detected that the altitude of Junge layer peak decreased one day before the low-level cloudy days, value of, AND increased near about three times the normal values.

In winter, fog or dewdrops were observed. Fog is also one type of cloud in contact with ground. The AND of Junge layer peak increased nearly three times for clear sky days prior to the days on which fog or dew drops were observed.

Hence, long-term remote sensing of stratospheric aerosol loading in a wide range of spatial and vertical resolution is essential for prediction of different weather parameters.

Keywords: stratospheric aerosols layer, weather prediction, remote sensing, twilight technique

INVESTIGATION OF BLACK CARBON DIRECT RADIATIVE FORCING OVER INDIA

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ABSTRACT

In India, there is large uncertainty as to estimate of loading of black carbon (BC), direct radiative forcing (DRF) and climate response because, lack of countrywide monitoring and coarse emission inventory of BC in early years. Here we used emission inventory (EDGAR-HTAPs) of BC to investigate its loading and optical depth (AOD) at 550 nm and DRF using weather research forecasting model coupled with chemistry (WRF-Chem). The model framework consists of 2 interactive domains. The outer most domain covers the Asian region with 45 km resolution whereas inner domain cover mainly the Indian geographical region with a finer resolution of 15 km x 15 km. The levels of BC simulated by the model have been validated by the pan-India observational network of MAPAN (Modelling Atmosphere Pollution and Network) project. Model simulated pattern of AODs is found to be smaller than from satellite and AERONET. Preliminary model results suggest a significant bias in simulated results of BC and DRF against observation. The model is being fine-tuned. Initial results and model capability will be discussed in this paper.

Distribution of Aerosols over South Asia and its Distinct Regional Influence on the Dry and Wet Phases of the Indian Summer Monsoon

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ABSTRACT

The inter-annual variability of aerosol over south Asia and its possible implications on Indian summer monsoon is investigated using Moderate Resolution Imaging Spectrometer (MODIS) Aerosol Optical Depth (AOD) data during the period 2001 to 2016. An attempt has been made to link the seasonal aerosol distribution during pre-monsoon and monsoon season to Indian Summer Monsoon Rainfall (ISMR) distribution. AOD derived from MODIS Terra observations shows large spatial inhomogeneity and characteristic variability with distinct temporal distributions. Pre-monsoon season (March-April-May; MAM) is characterized by high aerosol concentration over China peninsula extending up to Vietnam peninsula. During south west monsoon season (June-July-August-September; JJAS), large aerosol concentration is confined to China peninsula, wide area of high aerosol loading along Indo Gangetic plains extending from North Arabian sea through northwest India and up to Himalayan foothills. The regional rainfall distribution and its relationship with spatial and temporal aerosol distribution is then evaluated. Further, distinct variability in the aerosol distribution with respect to excess, deficit and normal monsoon years are analysed to understand the role of aerosols on the inter-annual variability of ISMR. Monthly aerosol distribution over Central India and Gangetic plains shows increased aerosol loading during deficit rainfall years and corresponding delay in the monthly rainfall peak. This study emphasises the active role of regional aerosol loading on regulating the inter-annual variability of Indian summer monsoon.

Keywords: Aerosol optical depth, Mid Tropospheric Temperature, Indian Summer Monsoon Rainfall.

Aerosol Feedbacks associated with the Monsoon Onset over Kerala

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ABSTRACT

The date and variability of monsoon onset over Kerala (MOK) has significant impact on the agriculture sector as well as the economy of South Asia. Ground and satellite observations confirm high aerosol loading over the region during the pre-monsoon period which could be playing an important role in the monsoon processes especially the MOK. Using observations and model simulations, we investigate the interactions among aerosols, radiation and precipitation and their impact on different synoptic aspects related to MOK. Our analysis shows scenarios defined mostly based on the hotspots of pre-monsoon aerosol loading over South Asia. The work also analyses the aerosol impact on various meteorological components of MOK and discusses the differences among the defined scenarios. The possible pathways which help in improving our understanding of the aerosol-monsoon feedbacks associated with each of the scenarios will be presented.

Keywords: Aerosol, Monsoon onset, feedbacks, climate sensitivity

Formulation and incorporation of a dense gas diffusion scheme in FLEXPART for chemical gas dispersion

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ABSTRACT

In this study, a diffusion scheme for buoyant gas releases is incorporated in the well known particle dispersion model FLEXPART for the purpose of addressing impact of chemical effluents during industrial accidents. The Lagrangian framework mentioned in Gopalakrishnan and Sharan (1997) has been followed for buoyant gas dispersion. This scheme takes into account of the buoyancy for relevant species with the entrainment correction because of air ingress in to the plume. The scheme is tested by numerical simulations of hypothetical releases of anhydrous ammonia for different seasons, under varying atmospheric (stability, wind flow) conditions. In all the simulations, ground level release of anhydrous ammonia is considered. It has been found that buoyancy effect is predominant under unstable atmospheric conditions during deep boundary layer formation. Under stable atmospheric conditions, when the boundary layer height is shallow, the effect of buoyancy is not realizable as the inversion acts to limit the vertical motion of the buoyant gas. A chemical reaction kinetics is also introduced for the conversion of ammonia to ammonium hydroxide as the gas is highly reactive assuming constant conversion rate as mentioned in Erisman et al. (1988), which is 7.5× 〖10〗 ^(-5) s^(-1). As the effect of buoyancy is significant in daytimes with deeper PBLs but not in the nighttime with shallow PBLs and stable condition, the effect of chemical reaction is the opposite. Although significant higher concentration in ammonia level is simulated during the shallow PBLs and stable condition than during the unstable conditions with deeper PBLs, a large fraction of this higher NH3 levels gets converted to increased NH4OH levels under stable conditions. With both the effects, the simulation shows more significant reduction in ammonia concentration in downwind sectors.

Keywords: Dense gas diffusion, buoyancy, Chemical kinetics, FLEXPART

AN EMPIRICAL METHOD FOR SOURCE APPORTIONMENT OF BLACK CARBON AEROSOL: RESULTS FROM AETHALOMETER OBSERVATIONS AT FIVE DIFFERENT LOCATIONS IN INDIA

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ABSTRACT

Black carbon (BC) aerosol emitted in incomplete combustion processes is known for causing warming in the climate system also poses serious health issues. Identification of the sources of BC is essential for the development of mitigation strategies to regulate their effects in changing climate. Among different observational and analytical techniques currently available, source apportionment methods based on optical measurements are relatively simple. For example, 'Aethalometer model' was developed based on Aethalometer observations. However, there are a few limitations with this model arising from assumption of wavelength and angstrom exponent pairs. We have developed an empirical method which also relies on Aethalometer observations named as 'Two alpha method' which assumes angstrom exponent from fossil fuel as 1 and estimates bio-mass fraction and angstrom exponent for bio-mass burning. This method has been applied to Aethalometer observations from five different locations (rural, semi-urban and urban) over Indian sub-continent to quantify sources of BC. Fossil fuel is found to be the major source of BC (~70%) irrespective of the location. Collocated measurements of Carbon Monoxide (CO) over rural site correlated well with derived bio-mass fraction. Results from this study demonstrated the capabilities of empirical method and shall provide spatio-temporal variability in sources of BC if applied to more locations.

Keywords: Black carbon, Source apportionment, Bio mass burning, Fossil fuel combustion

TRENDS AND VARIABILITY OF BACK TRAJECTORIES OF AEROSOLS OVER SOUTHERN PENINSULAR INDIA

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ABSTRACT

Atmospheric aerosols play a key role in earth atmospheric radiation budget. Aerosols undergo scattering and absorption, thus modify the incoming and outgoing solar radiation. The lifetime of tropospheric aerosols is up to 10 days and they will be lost via wet and dry removal processes. Also aerosols travel large distances and add to the local sources. So keeping the importance of aerosol transport pathways, present study focuses on the trends and variability of back trajectories over different locations of southern peninsular India. Seven day back trajectories from HYSPLIT single particle lagrangian interpolation method at 500m and 1500m above ground level have been obtained for seven (7) locations covering coastal and land lock areas for the period 2005 to 2020. The cluster percentage of the days originating from different directions have been carried out and the same is studied in detail for different seasons. Based on the direction of the sources and taking into consideration of the study period, dominance of coarse/fine mode particles have been identified. Aerosol optical thickness from MODerate Resolution Imaging Spetroradiometer (MODIS) Terra at 550nm is also used to understand the back trajectories of different locations. A semi urban location of Chennai (12.81 o N, 80.03 o E) has shown a steady increase of percentage of days pertaining to continental region from 2005 to 2020 which is an indication of increase of fine mode particles coming from the remote continental areas. The results of the entire study will be presented at the conference.

Estimation of Aerosol Complex Refractive Index over a tropical atmosphere using a synergy of in-situ measurements

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ABSTRACT

Aerosol Complex Refractive Index (ACRI)is a key microphysical parameter used for modeling their radiative effects.The uncertainty in the estimation of aerosol optical properties, which indirectly depends on their microphysical properties, is one of the main reasons for the large uncertainty in estimating the effects of aerosols on climate. The traditional approach of determining ACRI is from bulk chemical compositions and known values of refractive indices of pure components based on volume mixing rules. But in view of its importance, many studies were focused on developing different approaches for estimating the ACRI. An approach,based on Mie theory for spherical particles, is developed to estimate the ACRI using a combination of surface-based measurements (2008-2015) from the Aerodynamic Particle Sizer (APS), the integrating nephelometer, and theaethalometer over a tropical rural location in the southern peninsular India. The estimatedimaginary parts are found to be high during pre-monsoon season suggesting the dominance of the increased absorption type aerosols. This is in line with the high concentration of black carbon aerosol observed during the pre-monsoon.In addition, the retrieved ACRI values are within the range of refractive index of aerosol particles obtained from possible combination of cations and anions obtained using rainwater analysis over Gadanki during north-east and south-west monsoons. The significance of refractive index of surface aerosols in columnar properties is also analysed by using the columnar single scattering albedo (SSA) and aerosol optical depth (AOD) observations from sky radiometer. During winter season, the contribution to the total columnar scattering and absorption are mainly from surface or below the atmospheric boundary layer aerosols, whereas in monsoon season 80-90% contribution is from aerosols above. Refractive index ofelevated aerosols also needed to be studied in order to completely understandthe total scattering and absorption in the atmosphere by theaerosols.

Keywords: Absorption, Scattering, Complex Refractive Index, Aerosol.

Ground based observation on the variation of trace air pollutants at Kannur, Kerala

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ABSTRACT

This work describes diurnal and seasonal variations of air pollutants include surface ozone (O_3), oxides of nitrogen (NOx), carbon monoxide (CO), volatile organic compounds (Benzene, Toluene, Ethyl Benzene, Xylenes which are classified as BTEX)), ammonia (NH_3), sulphur dioxide (SO_2), particulate matters (PM_{10} and $PM_{2.5}$), and meteorological parameters observed at Kannur town (11.87° N, 75.37° E, 2m msl) for a period of one year from September 2019. Seasonal variations of trace air pollutants exhibit a day time maximum during winter and minimum during the monsoon period. Surprisingly, air pollutants except O_3 show a reduction in concentration in the months of April and May in 2020 due to countrywide lockdown in the wake of restricting the spread of COVID 19. Weekday/weekend variations of air pollutants reveal that high concentrations of O_3 are found on weekends compared to weekdays, unlike the concentrations of all other pollutants are found low during weekends. Intercorrelations between trace pollutants showed a strong negative correlation between PM_{10} and O_3, a strong positive correlation between O_3 and CO, a negative correlation between O_3 and NO_x. Further, CO showed a strong positive correlation with NOx, PM_{10} and $PM_{2.5}$. Moreover, air quality index analysis carried out as per the criteria of Centre Pollution Board of India (CPCB), revealed that the air quality of the observational site becomes better during June July, August and poor during January, February, March.

INVESTIGATING THE IMPACT OF VOC SOURCES DURING DIFFERENT SEASONS ON THE AIR QUALITY OF A METROPOLITAN REGION IN INDIA

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ABSTRACT

Volatile organic compounds (VOCs) play a crucial role in influencing the air quality of the urban atmospheres, especially in nitrogen oxide (NO_x) dominated regions like India. Additionally, the associated direct health risks necessitate the identification of VOC sources and their contribution to the VOC budget of a region. This study presents the seasonal variability of VOCs measured using a Proton Transfer Reaction Quadrupole Mass Spectrometer (PTR-QMS) during the year 2019 over the metropolitan Pune region. Also, the VOC sources have been identified using the US EPA PMF 5.0 model for different seasons. Toluene (summer: 2 $\mu g/m^3$, monsoon: 1.11 $\mu g/m^3$, winter: 7 $\mu g/m^3$), o-Xylene (summer: 1.41 $\mu g/m^3$, monsoon: 1.24 $\mu g/m^3$, winter: 5.67 $\mu g/m^3$), Acetaldehyde (summer: 2.80 $\mu g/m^3$, monsoon: 1.84 $\mu g/m^3$, winter: 5.10 $\mu g/m^3$) and Acetone (summer: 5.95 $\mu g/m^3$, monsoon: 2.58 $\mu g/m^3$, winter: 6.21 $\mu g/m^3$) were found to be the prominent anthropogenic source-based emissions apart from Methanol (summer: 8.68 $\mu g/m^3$, monsoon: 5.24 $\mu g/m^3$, winter: 7.72 $\mu g/m^3$) which mostly has a biogenic source. While most of the identified sources (vehicular emissions, biomass burning, biogenic emissions, photochemical secondary products) are common throughout the year, their contribution to the total measured VOCs across seasons has varied considerably (9-17%, 8-12%, 5-14%, 19-27% respectively). Of the resolved factors, ozone formation potential (OFP) was found to be highest for photochemical secondary products (26%) during all the seasons, followed by vehicular emissions (23%) and background emissions (17%). The sources identified in this work are in agreement with a recent bottom to top emission inventory developed for the region which shows vehicular emissions as a dominant VOC source. This work highlights the role of meteorology in varying the VOCs concentration over Pune region and eventually the local air quality.

Keywords: VOCs, Seasonal variability, Sources, Meteorology

Atmospheric boundary layer height measured by micro pulse lidar over a tropical coastal station Kattankulathur (12.83^0 N, 80.04^0 E) using fuzzy logic methods

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ABSTRACT

The atmospheric boundary layer (ABL) height and its diurnal characteristics measured by micro pulse lidar (MPL) over Kattankulathur ($12.82°\,N, 80.04°E$) is detected using fuzzy logic methods. The algorithm classifies the signals according to the membership functions based on the score occupied by the individual extracted features (Lewis et al, 2013). In general, fuzzy algorithm estimated lower ABL depth and is less subjective to residuals and therefore it avoids random fluctuations. A 2018 comparison shows that conventional WCT algorithm is more influenced with other strong gradients. The diurnal characteristics of ABL from IMDAA observation is also used to compare the characteristics of ABL in our location. The comparison ends up with result that IMDAA CBL are overestimated with MPL observations whereas the SBL is underestimate with lidar outputs. The mean of maximum day time CBL from the IMDAA during pre-monsoon, summer monsoon, post monsoon, winter are 1.65 (mpl-1.58) km, 1.8 (mpl-1.632) km, 1.37 (mpl-1.24) km, and 1.5 (mpl-1.40) km respectively. The comparison of MPL with IMDAA observations ends up with a result of moderate correlation (~0.44) of CBL heights.

Keywords: ABL, Fuzzy logic

CHANGING AEROSOL LOADING OVER CENTRAL INDIA AND ITS RELATIONSHIP TO FIRE EMISSION AND PREVAILING METEOROLOGY

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ABSTRACT

Aerosols play an essential role in the global, regional, and local climatic systems, impacting the Earth's radiation budget. The loading and impact of aerosols are closely related to the local meteorology and anthropogenic activities. The Central Indian region encompassing Madhya Pradesh is considered meteorologically representative of the Indian subcontinent (especiallyrainfall). Recent studies show that the aerosol load within the region is increasing, with potential modulation to several other meteorological parameters and vice versa. Therefore, it is crucial to understand the long-term changes and interrelation between these parameters. Using long-term satellite datasets, we explored the climatology, trends, and inter-relationship between aerosol, fire, and other meteorological parameters. The study revealed a rapid increase in aerosol loading (47%) along with fire counts (~756%), NDVI (~33%), and precipitation (~19%) over Central India with a concurrent decline in surface and air temperature (~2 ° C). The pre-monsoon period (Mar-May) displayed a maximum rise in the fire counts and surface temperature, while NDVI, AOD, and rainfall were moderate or minimal. The differing nature (period of occurrence) of the trends in fire incidences and aerosol load suggests that the rise in fire incidences is not the primary reason for the increased aerosol loading. The increase in precipitation and various technological advancements in cropping could have lead to an increase in greenness. Additionally, the increase in aerosol loading and the rise in greenness within the region could be the causative factor for the cooling phenomenon observed in the area.

Keywords: Aerosol Optical Depth (AOD), Normalized Difference Vegetation Index (NDVI), Fire Count, Surface Temperature

Large scale modulation of aerosol loading by Madden Julian Oscillations over Northern Arabian Sea

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ABSTRACT

The IntraSeasonal Oscillation (ISO)s are known to have a significant impact on weather and hence climate regionally. These ISO's can alter the thermal and radiative forcing of the atmosphere due to atmospheric aerosols as their longrange transport and properties depend on prevailing environmental conditions. In this context, Madden Julian Oscillation (MJO) is one such atmospheric intraseasonal oscillation that significantly modulates aerosol loading on large spatial scales. The Northern Arabian Sea (NAS) is one of the locations with the most extensive aerosol loading over the south Asian region; the aerosols over NAS are known to have significant impact on the various weather phenomena including the Indian summer monsoon. However, their variability has not been systematically explored with ISO's such as MJO. This study is an attempt to characterize the aerosol loading over the Northern Arabian Sea due to MJO during its active and break phases. It is found that MJO leads to the most extensive variability in aerosol loading during the Monsoon season followed by the Postmonsoon, and the least during the Premonsoon and Winter Season. The maximum modulation is quantified to be around 3.5 4% of the climatological loading with certain pockets close to significant dust sources going even higher. The details regarding their seasonality, potential causes for these will further be discussed.

Keywords: Arabian Sea, Dust, Aerosols, MJO, IntraSeasonal Oscillation

Impact of Aerosol Outflow from IGP on SST over the Bay of Bengal.

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ABSTRACT

Anthropogenic emissions have steadily grown since the start of the industrial revolution in most parts of the globe. Although countries have introduced multiple measures to reduce emissions, particularly in developed nations, the implementation of these measures continues to pose a serious 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). In this study, the effect of pandemic lockdown and the associated decrease in emissions and the subsequent effect 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 sea surface temperature (SST) rose by 0.5 to 1.5 ° C over the central and northwestern parts of the BoB with an average increase of 0.83 ° C. We show that 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 SST's over ocean basins with implications to regional weather.

Keywords: Air Pollution, Anthropogenic Aerosols, COVID-19, Sea Surface Temperature.

Variability of ozone in the troposphere and lower stratosphere over a tropical station Thumba: Effect of meteorology and transport

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ABSTRACT

Seasonal variability in the vertical distribution of ozone over a tropical station, Thumba (8.5°N, 76.9°E) is investigated using nine-years (2011-2019) of ECC ozonesonde data obtained as part of Tropical Tropopause Dynamics (TTD) campaign. Ozone exhibits a clear annual variation in the lower troposphere (0-2 km) with winter maximum (49.2±3.6 ppbv) and summer monsoon minimum (21.9±0.7 ppbv). In the middle (2-10 km) and upper (11-17 km) troposphere, ozone is maximum in pre-monsoon and minimum in summer monsoon. Ozone in the lower stratosphere exhibits a clear annual variation with summer monsoon maximum and winter minimum in tandem with the temperature cycle. The relative standard deviation (RSD) of ozone computed at different altitudes exhibits large intra-seasonal variability in the troposphere (↔20- 30 %) compared to the stratosphere (↔5%) and is significantly high close to the surface and in the tropical tropopause layer (TTL) (30%). Maximum RSD is observed during summer monsoon (June-September) in the upper troposphere (↔50%) close to cold point tropopause (CPT). RSD in ozone and temperature profiles show a sharp peak immediately above the CPT in all the seasons, coinciding with the altitude of maximum wind shear. Tropospheric ozone shows an in phase relationship with temperature and is opposite in phase with water vapour. A significant negative correlation is observed between ozone and water vapour in the 2-5 km altitude region. Long-range transport and local convection contribute substantially to the observed variability in tropospheric ozone. The tropospheric column ozone shows a semi-annual variation with maximum contribution to the total columnar ozone during pre-monsoon (↔16%) and minimum during summer monsoon (↔8%). Mid-tropospheric ozone contributes more to the tropospheric column ozone (40-60%) compared to lower and upper tropospheric ozone. Tropospheric column ozone exhibits a similar seasonality as that of its precursors like NO_2, CO and CH_4.

Keywords: Ozone, ECC Ozonesonde, Seasonal cycle, Transport

Spatiotemporal variability in aerosol optical depth during COVID-19 imposed lockdown: Global vs regional vagaries

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ABSTRACT

Long term space-based aerosol observations indicate the upward trend in aerosols; however, the air quality had improved worldwide post declaration of the Coronavirus disease-2019 (COVID-19) as a global pandemic mid-March-2020. Moderate Resolution Imaging Spectroradiometer (MODIS) satellite-derived aerosol optical depth (AOD) and MERRA reanalysis demonstrates the regional variation in aerosol loading during the peak of the lockdown period. The aerosol loading reduction over most of the aerosol hotspots is observed from mid-March/April 2020, with the highest percentage reduction in May. Reduction in aerosol loading over global hotspots resulted in positive surface aerosol radiative forcing (ARF, up to 6 Wm-2). Albeit reduction in aerosol loading observed worldwide, the considerable above-average aerosol burden was identified during April–May 2020 over the Amazon river basin, northern parts of South America, Mexico region, South-West parts of Africa and South-East Asian region. Analysis revealed that the wildfire emission contributed significantly to anomalous aerosol burden over these regions during the lockdown period. An appropriate mitigation measure to reduce wildfire emissions is essential in addition to controlled anthropogenic emissions as far as air quality, deforestation, and ecosystem are concerned.

Keywords: COVID-19, Aerosols, Global and Regional AOD, Aerosol Radiative Forcing.

EFFECT OF COVID 19 LOCKDOWN INDUCED CHANGES IN AEROSOL OPTICAL DEPTH AND GREENHOUSE GASES FOR MAJOR CITIES AND INDUSTRIAL HUBS OF INDIA

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ABSTRACT

On March 25th 2020, the Indian Government placed its 1.3 billion citizens under a strict lockdown to reduce the spread of disease. However, the improvement in the air quality across the globe has emerged as a key benefit of this lockdown due to the abrupt reduction in the industrial, commercial and vehicular pollution. Therefore this study aims to assess the lockdown induced changes in the Aerosol Optical Depth (AOD) and the Greenhouse gases concentration in 4 major cities; Delhi, Bangalore, Patna and Pune and 4 industrial hubs; Gurgaon, Gwalior, Kota and Chota Nagpur of India. The result reveals a widespread reduction in AOD over most of the selected regions during the lockdown phase using the data from MODIS at 550 nm. The study evaluated the spatio-temporal variations in AOD over two time periods; 1st March-30th April 2020 and the corresponding period of the previous 20 years, 2000-2019. The results highlighted a significant decline in AOD (~28%) in all the major cities and industrial hubs of India, except for the city Pune which showed an unexpected increase of 12% during the lockdown phase, as compared to the previous 20 years. The industrial hub Gwalior accounts for the highest reduction in AOD (42%) and the lowest reduction in AOD was observed over Kota (24%). The AIRS_L3, Multi Instrument Fused XCO2 and CPCB station data were used to assess the concentrations of greenhouse gases; CO2, CH4, O3, CO and NO2. The analysis was carried out for March & April 2020 and the same period of the previous 5 years, 2015-2019. From the analysis, A decrease in the NO2 concentration (12%) was observed for most of the regions, except for Patna, Gurgaon and Chota Nagpur. Similarly, a decreasing trend in the concentration of CO (2%) was observed. Whereas, the concentration of CO2, CH4 and O3 exhibited an increase of about 1.9%, 0.9% and 3.2% respectively, as compared to the previous 5 years.

Keywords: Covid 19 Lockdown, Aerosol optical depth, Greenhouse gases

MICROPHYSICAL PROPERTIES OF BLACK CARBON AEROSOL IN THE SOUTH ASIAN OUTFLOW: RESULTS FROM ICARB-2018

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ABSTRACT

Black carbon (BC) is one of the dominant absorbing aerosols over South Asia, with potential implications to regional climate, cloud dynamics, monsoon circulation, and the hydrological cycle. Significant uncertainties remain in its quantification due to the variety of sources, their spatio-temporal variability, and lack of detailed information on the BC microphysical properties (its concentration, size, and mixing state with other aerosol components). The mixing state of BC varies during *atmospheric aging*, which involves the coating of other condensable species on it. Such a coated BC has enhanced absorption potential and altered hygroscopicity, therefore, potential climate impact. However, the information on the mixing state of BC over South Asia is extremely sparse. In this study, the size distribution and mixing state of BC particles in the South Asian outflow to the adjoining oceanic regions, favoured by prevailing synoptic winds, are presented. The observations are conducted as part of the Integrated Campaign for Aerosols, gases, and Radiation Budget (ICARB-2018) during winter-2018 using laser-induced incandescence technique. The BC size distributions revealed mixed sources (core sizes ~0.18-0.20 μm) in the outflow to the northern Indian Ocean. Significant spatial heterogeneity of BC characteristics is seen with the highest mass concentrations and coating thickness (~109±20 nm) in the proximity of the continental outflow due to extensive chemical aging and abundance of condensable material. Though mass-loading dropped by fivefold, BC remained thickly coated (coating thickness ~72±17 nm) even over the remote equatorial Indian Ocean. These results highlighted the contrasting nature of BC lifecycle processes in the extensive continental outflow to the ocean. This is the first-ever study to quantify the size-resolved mixing state of BC in the South Asian outflow, highlighting the role of sources of BC, nature of condensable coating material, and secondary processing of their complex mixtures under highly polluted conditions, with potential climate implications.

Keywords: Aerosol microphysical properties, black carbon size distribution, mixing state, South Asian outflow

SEASONAL VARIATION OF VOCS AND OVOCS OVER DELHI: ANALYSIS OF FIRE-IMPACTED PERIODS

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ABSTRACT

Volatile Organic Compounds (VOCs/OVOCs) are contributors to short lived climate forcing agents like Ozone and Secondary Organic Aerosols. Assessment of VOCs over an urban area like Delhi is be very important because of its unique landlocked geographical location and high pollution level. So, purpose of our study was to understand seasonal variability of VOCs, and impact of fire on VOCs on seasonal scale. We analysed VOCs measured using Proton transfer reaction mass spectrometer (PTR-QMS) at Delhi during in 2018-19, with emphasizing two periods which are impacted by fire (pre-monsoon, and post-monsoon). Our results indicate, OVOCs (e.g. Methanol, Acetaldehyde), and Isoprene show seasonal high in pre-monsoon season due to secondary production, and biogenic emission. All VOCs show seasonal low in monsoon season. Benzene and Toluene show seasonal highest concentration in winter season (when BLH is lowest), and Acetonitrile, which is a tracer of biomass burning, and traffic in urban areas shows seasonal high in post-monsoon through winter. Fires during Post-monsoon (October–November) are much higher compared to pre-monsoon (April–May) season over Indi-Gangetic Plain region. Back-trajectory analysis indicates high contribution of local/mesoscale fires during post-monsoon. OVOCs and Ozone show higher concentrations in pre-monsoon, and PM2.5 and BC show higher concentration during post-monsoon. This indicates secondary production at high temperature occurring in pre-monsoon contributes to ozone, while heterogenous reaction over pre-existing and biomass-generated aerosol dominate in post-monsoon season. This study concludes that fire emission plays a significant role in seasonal variability of VOCs in pre- and post-monsoon period. In addition, secondary production, and biogenic emissions are important contributor to VOC during pre-monsoon season.

Aerosols Association to Glaciers and Climate Change over the Sikkim Himalaya Region

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ABSTRACT

Aerosols in our environment plays critical role in cloud microphysics and affect the climate of the region. They have different interacting properties especially with incoming solar radiation, closely influencing the earth-radiation budget. As the glaciers are very much sensitive towards any changes in the atmosphere, aerosols significantly affect their formation and retreat. Many cold places with glaciers has reported the deposition of aerosol particles in glacier and their enhanced melting. In this study, we have taken 40 years (1980-2020) satellite data of black carbon, sulphate aerosols, radiation, sensible latent heat flux, temperature, aerosol optical depth (AOD), glaciated area fraction for Sikkim Himalaya region to see the aerosol impact on glaciers. The Pearson co-relation is analysed for the mentioned data and random forest regression has run for evaluating the most important variable. The data are analysed for summer and winter season trends separately. The data clearly shows that the black carbon concentration has increased resulting increase in the temperature over the period. The results reveal that the black carbon, sulphate, temperature and AOD are positively co-related, whereas the co-relation with glaciated area is negative for black carbon, temperature, AOD, sensible latent heat flux and radiation. The glaciated area has found positively co-related to sulphate aerosol. The random forest decision tree represents the importance of these factors as latent heat flux (1.0), sensible latent heat flux (0.62), temperature (0.63), black carbon (0.98), sulphate (0.73), radiation (0.37), and AOD (0.43) for winter season. The summer season trend is nearly similar, latent heat flux (0.95), Sensible latent heat flux (0.65) temperature (0.60), black carbon (1.0), sulphate (0.78), radiation (0.42), and AOD (0.49). This study suggests that the aerosols complex interaction over the sensitive climatic zone needs to explore in more detail for better understanding of regional climate change

RECENT CHANGES IN THE TRACE GASES CONCENTRATION AND HOTSPOTS OVER THE INDIAN REGION

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ABSTRACT

Despite their minute presence in the atmosphere, trace gases can significantly alter the climatic system and human health. It can impact the global radiation budget by acting as potent greenhouse gases. The swift economic growth over the Indian region significantly increases anthropogenic activity, changing the trace gases concentrations. Therefore, it is crucial to identify the changes and hotspots of these gases over the Indian subcontinent. Several point based studies have reported remarkable changes in trace gases in recent years. However, knowledge regarding these changes on a large spatial scale is yet to achieve. Therefore, the present study explored the recent changes in the concentration and hotspots of four major trace gases (Methane (CH_4), Nitrogen Dioxide (NO_2), Tropospheric Ozone (O_3), and Carbon Monoxide (CO)) over the Indian region using large-scale satellite data (2005-2019). Our study shows a significant increase in CH_4, NO_2, and O_3 and a decline in the CO concentration. Northwestern India experiences a more than 70 ppbv increase in methane possibly due to rising agricultural activities. However, it also shows a significant decline in CO (~30 ppbv). On the other hand, the rapid growth of NO_2 and tropospheric O_3 is observed over eastern and central-eastern India. Several isolated locations over the east part of the Indo-Gangetic Plain act as NO_2 hotspots. The percentage increase per decade for NO_2 reaches up to 50% in selected places. Ozone shows a significant rise in eastern and southern India (more than 15% per decade). The rapid urbanization, increase in vehicular emission, and establishment of several thermal power plants may be attributed to the rise of NO_2 and thus tropospheric ozone. These rapid rises in trace gases concentration can impact the local climate and affect the health of the inhabitants.

Keywords: Trace gases, Ozone, NO 2 , Trend analysis

THE IMPACT OF METEOROLOGICAL FACTORS ON THE VARIATION OF PARTICULATE MATTER: A CASE STUDY OF AHMEDABAD CITY IN GUJARAT

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ABSTRACT

This study aims to explore the impact of meteorological factors on Particulate Matter (PM_{10}, $PM_{2.5}$ and PM_1) concentrations in Ahmedabad city, Gujarat. The PM_{10}, $PM_{2.5}$ and PM_1 and meteorology data including temperature (T), atmospheric pressure (AP), rainfall(RF), relative humidity (RH), wind speed(WS) and wind direction(WD) were collected from December 2016 to November 2017. The initial linear analysis between PM and meteorological factors were conducted for each month and season of the year. The meteorology data were classified into several intervals and the mean PM concentrations for each interval were calculated to see the tendency. According to the preliminary linear correlation analysis results, the PM concentrations have a positive relationship with AP and RH while have negative relationships with T, RF and WS. In addition, the WD influence PM concentrations through affecting the spreading direction of PM. The east wind in winter increased the PM concentration in Ahmedabad while the west wind in summer decrease the PM concentration. It has been observed that in the months of monsoon due to rainfall the relation between meteorological parameters and PM changes from positive to negative and vice versa. The meteorological factors and PM relation have thresholds i.e. when the meteorological variables were higher or lower than threshold, the correlation is different. Therefore, the meteorological factors affect the aggregation, diffusion, and spread of PM. They have a leading impact on PM concentrations when the domestic emission stays stable. Present study provides the relationships between PM and met parameters, which enable improving the understanding of PM formation and the PM forecast.

Keywords: Particulate Matter, Linear Analysis, Meteorological Factors

Stratification of aerosols over South Asian megacities

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ABSTRACT

Abundance of aerosols over South Asia vary with respect to emission sources and their strengths. Columnar aerosol loading in terms of Aerosol Optical Depth (AOD) is reported to remain highest during monsoon and summer months over South Asia. These aerosols, especially the absorbing aerosols can strongly modulate the formation, circulation and precipitation of Indian monsoon which link it directly with the hydrological cycle. Aerosol optical and microphysical properties were therefore, retrieved over entire South Asia with specific emphasis on urban pollution hotspots to understand spatial and altitudinal variations of aerosol layer. Multiple satellite retrieved aerosol data namely, Earth-observing system (EOS) Afternoon Constellation (A-Train) satellites Aqua and Aura MODIS AOD, C-Train satellite CALIPSO aerosol extinction coefficient and MERRA-2 reanalysis datasets were used. Spatial signature of aerosol loading, in terms of its optical and microphysical properties were initially explored. We note a very high AOD especially over the Indo-Gangetic Plain (IGP), and over eastern coast of India. Both these regions were previously reported to be dominated by aerosols but vertical distribution of such aerosols still remains unexplored. We noted that these aerosols were highly absorbing and coarse during summer months. A definite indication of the presence of atmospheric dust aerosols was also identified, especially over the Northwestern part of India. We have also explored the prevailing aerosol types over selected urban hotspots across South Asia and tried to establish an altitudinal distribution of such aerosol types. Overall, we noted that approximately 50-60% of total aerosol loading remained close to the surface (<2 km) thereby, having a greater potential to enhance the level of population exposure. Besides, we noted the distinction of prevailing aerosol types across South Asian cities which should be taken into consideration for exposure based epidemiological modelling.

Identification of the Nitrogen Dioxide (NO_2) hotspots over Gujarat

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ABSTRACT

It is necessary to identify the cause and hotspot for air pollutants such as Nitrogen Dioxide (NO_2) in order to improve public health in the region and understand its effects on regional seasonal patterns. In this study we identified the hotspots of NO_2 over Gujarat for the years 2019 and 2020, by using satellite data derived from Sentinel-5P satellite. The mean of daily data are carried out for monthly mean value of NO_2 concentration to understand the seasonal variation. The results shows that total number of 8 main hotspots are in Gujarat that are Ahmedabad, Ankleshwar, Mandvi, Morbi, Moti Khavdi, Sikka, Sonagadh, Balacinor. All of these locations have GIDC (Gujarat Industrial Development Corporation) in common. Morbi is the centre of Gujarat's numerous ceramic industries. Mandvi is home to a number of mining operations. Sikka and Moti Khavdi are well-known for its reliance crude oil refinery and other industries. The rest are along Gujarat's chemical flow, which is known for its numerous chemical plants. The findings underlined the COVID-19 outbreak's lockdown effect. Despite the presence of industries in all areas, the lockdown had such an impact that overall hotspots dropped by -26.74% and as assumed the concentrations were hiked by 24.81% after the lockdown ended. On an average decrease of -4.70% was detected on seasonal trend by the seasonal trend analysis across all hotspot locations. Overall, all of these locations are having significant contribution on the state's NO_2 concentration and seasonal trend.

Keywords: Nitrogen Dioxide (NO_2), Seasonal trend, Sentinel-5P, COVID-19 lockdown

Evaluation of credibility of multi-reanalysis aerosol products through intercomparison with AERONET

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ABSTRACT

The Earth system is variable in nature, and sampling of geophysical datasets is inadequate or needs to be verified. The comparative estimate of datasets derived from ground instrumentations and computational models may focus on precise weather monitoring. Therefore, validation of satellite retrieved AOD data and multi-reanalysis aerosol optical depth (AOD) data with AERONET AOD data has been presented in this study to examine the better performance. Specifically, the evaluation of the reliability of two long-term atmospheric composition reanalysis datasets- the Copernicus Atmosphere Monitoring Service Reanalysis (CAMSRA) and Modern-Era Retrospective Analysis for Research and Applications, version 2 (MERRA-2) has been done using MODIS Multi-angle Implementation of Atmospheric Correction (MAIAC) products over Indo-Gangetic Basin (IGB) during the period of 15 years (2005-2019). The statistical analysis suggests a robust agreement of the high Spatio-temporal resolution products (MAIAC) AOD with six AERONET station's AOD data. However, in comparison to MAIAC, the CAMSRA and MERRA-2 suggest an overestimation and underestimation, respectively with AERONET AOD dataset over the different time scales, by the mean of coefficient of determination (R2), mean absolute error (MAE), root mean bias (RMB) and root means square error (RMSE). The intercomparisons of these three datasets demonstrate some appealing similarities and differences over the seasonal and annual scale with each another. CAMSRA shows good agreement in Spatio-temporal variations with MAIAC AOD in comparison to the MERRA2 over the study regions during the 15-years study period. Overall, comparisons among all the products indicate that CAMSRA seems to be more satisfying and promising. The disagreement of the total AOD affects the AOD retrieval for each size classification and causes errors in estimations of size-fractioned AOD. Moreover, due to different pollution levels, distribution patterns, and meteorological conditions, there are distinct seasonal characteristics in the performance of AOD products for different regions.

Keywords: AOD, CAMSRA, IGB, MAE

Investigation of Aerosol Optical Depth over Guruvayur using Microtop- II sunphotometer

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ABSTRACT

Aerosols are classified as solid or liquid particles suspended in the atmosphere. Aerosols are produced either by the mechanical disintegration processes occurring over land and ocean or by chemical reaction taking place in atmosphere. Here we describe the diurnal seasonal and monthly variations of Aerosol Optical Depth over Guruvayur using a handheld MICROTOP II Sun photometer. Data were collected with extreme care from 9:00-17:00hr of IST at 30 minutes intervals from November 2019 to October 2020. AODs are found to exhibit distinct diurnal, day to day and seasonal variations. Angstrom parameters derived from the Angstroms empirical relation is used to classify the size distribution of the suspended particles. Columnar AOD values are found to be high in summer and low in winter at this coastal site. There is an increase of about 45% observed from winter to summer in the AOD value at 340nm wavelength. Relative higher values of angstrom exponent retrieved during summer season indicate the abundance of fine mode particles present over this region which is getting transported from nearby local industries.

Inter-annual variability in PM_{10} and $PM_{2.5}$ particles in different environments of a western Indian City

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ABSTRACT

Megacities have emerged as the hubs of air pollution due to the expansive developmental and urbanization that has been taking place. The key to controlling air pollutants at megacities depends on the monitoring and assessment of the pollutant trends and variability. The variability of PM_{10} and $PM_{2.5}$ concentrations obtained from the air quality monitoring stations (AQMS) established at six different environments of Pune Metropolitan Region (PMR) which is situated in the western part of India is analyzed for the period 2014 to 2018. The PM_{10} concentration was seen to decrease at all the locations under consideration except for an urban location. The $PM_{2.5}$ concentrations showed an increasing trend at almost all locations within the city. Significant features observed were that the green/background location, showed a declining trend in $PM_{2.5}$ concentrations which is due to the green cover in its vicinity. However, the industrial location of the city indicated an increase in the $PM_{2.5}$ concentrations over the years, due to increased industrial productivity in this region. The bivariate polar plots of $PM_{2.5}$ indicate that mainly local sources play a role in the $PM_{2.5}$ mass concentration. the continuous wavelet transform is used to assess the periodic and local modulations present in the $PM_{2.5}$ concentration. The local emission sources influence the variability of the pollutants and thus are a key for the mitigation strategies to be adopted in future.

Keywords: Megacity, Wavelet Transform, inter-annual variability, Polar plots

Decadal reversal of dust aerosols: Implication over the summer monsoon precipitation chemistry over the Western Ghats

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ABSTRACT

The Western Ghats (WG) covers a vast area of 160,000 km^2 that runs parallel to the west coast of the Peninsular India. It experiences on an average of ~1000 mm of summer monsoon rainfall each year and is best known for its rich ecological biodiversity and flora and fauna. Apart from the amount of rainfall; the yield of agriculture farming, quality of drinking water and the surface erosion over the WG highly varies depending on the pH of rainfall. Over the past few years (1984-2000), summer monsoon rainfall at Pune and Kodaikanal stations located in the WG region, shows a declining trend (increased acidity) of rainwater pH, inheriting to an increase in anthropogenic $SO^{2-}{}_4$ and NO_3^- aerosols, concurrent with a decrease in transported Ca^{2+} mineral dust. However, in spite of an increase in anthropogenic emissions over the recent period (2000-2015) a viable stabilization of monsoon rainwater pH (stable alkalinity) over the WG has been noticed. The mineral dust, which acts as a major neutralizer for the summer monsoon rainwater shows that mid-tropospheric transport of dust from the middle-east countries across the Arabian Sea has increased in this recent period, stabilizing the rainwater pH. The rainwater samples collected in the open ocean cruise during ARMEX (Arabian Sea Monsoon Experiment) expedition were found with higher rainwater Ca^{2+} than the continental inland, which supported the high dust loading over the Arabian Sea. The Empirical Orthogonal Function (EOF) analysis of total AOD (550 nm) revealed a unique reversal of EOF1 (60% variability explained) after the year 2000 over the Arabian Sea, indicating changes in mineral dust transport during Indian summer monsoon. This shift in AOD phase over the Arabian Sea and an increase in pH (alkalinity due to increase in Ca^{2+}) over the WG associated with each other, showcase a wider implication of dust over the monsoon precipitation chemistry.

Keywords: Indian Summer Monsoon, Western Ghats, Rainwater pH, Mineral Dust

SPC

Stratospheric Processes and their Role in Weather and Climate

Variability in the UTLS chemical composition during different modes of the Asian Summer Monsoon Anti-cyclone

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ABSTRACT

The Asian Summer Monsoon Anticyclone (ASMA) is an important circulation in the upper troposphere and lower stratosphere (UTLS) region during the boreal summer. The center of the ASMA is not a stationary feature but oscillates between longitudes 50°-92.5°E showing different modes. The ASMA center oscillating over 50°-67.5°E, 80°-92.5°E and 67.5°-80°E are termed as IP (Iranian Plateau), TP (Tibetan Plateau) and Elongated mode, respectively. This work explores the spatial variability and the influence of the background dynamical conditions on the vertical chemical distribution of carbon-monoxide (CO), water vapor (WV) and ozone (O3) in the UTLS region during the different ASMA modes using MLS satellite and NCEP/NCAR reanalysis observations. MLS observations for the period 2010–2018 showed maximum CO, WV and minimum O3 concentrations at 100 hPa in the ASMA center over the respective IP, TP and elongated modes. Enhancement in the tropospheric tracers (CO and WV) throughout the upper troposphere during TP and Elongated mode is observed indicating the transport of boundary layer air to the UTLS region from across these regions. In contrast, the enhancement in the tropopause region during the IP mode is mainly due to the convective lifting over the Tibtean plateau longitudes and strong horizontal advection towards the IP longitudes. Our study also revealed that the vertical transport of the tropospheric tracers to the stratosphere is effective over Tibetan Plateau irrespective of the ASMA mode. The warmer tropopause temperature due to an increase in O3 concentrations over the TP supported the vertical transport of WV to lower stratosphere over this region irrespective of the ASMA mode.

Keywords: UTLS, Iranian Plateau, Tibetan Plateau and Elongated mode

THE SEASONAL AND DIURNAL VARIABILITY IN UV IRRADIANCE USING THE MICROMETRE II OZONOMETER AT VILLAGE ATIGRE, KOLHAPUR, INDIA.

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ABSTRACT

UV radiation from the sun has harmful impacts on living life. As a result, research into Ultraviolet radiation, ozone distribution, and their impact on the environment, weather, and climate is important. Ozone over Atigre village near to Kolhapur is measured by using highly advanced Microtops II Ozonometer. Microtops II Ozonometer contains the five optical filters (five channels) for solar irradiance measurements of five different wavelengths (305.5 nm, 312.5nm, 320.5nm, 936 nm and 1020 nm). The first three filters, out of a total of five, are used to measure the sun's ultra-violet (UV) radiation. The photodiodes in the instrument measure UV irradiation as voltage. 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. We have investigated the seasonal, daily, and diurnal variability in UV irradiation for the time periods under consideration in this study. It is commonly known that ozone and UV irradiation have an inverse relationship. The reduction in the stratospheric ozone concentration is indicated by an increase in UV irradiation. We observed that the UV irradiation decreases from monsoon through winter, then increases as summer approaches. These variations are also caused due to the apparent position of the sun. We also observed 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 behaviour 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: Ozone, Microtops II Ozonometer, UV irradiance, diurnal and seasonal variation.

Influence of southern hemispheric upper troposphere potential vorticity intrusion events on the southwest monsoon rainfall.

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ABSTRACT

The possible influence of potential vorticity (PV) intrusion events into the southern low-latitude upper troposphere over the longitude region 0-90 o E during June-September on the southwest monsoon rainfall is investigated using ERA interim potential vorticity data and high resolution gridded IMD (India Meteorological Department) rainfall data. It is found that unlike in the northern hemisphere, the PV intrusion events are more frequent in the southern low-latitudes 0-90 o E during June-September and they present irrespective of the phase of the El Nino Southern Oscillation (ENSO). More PV intrusion events in to the southern hemispheric low-latitude upper troposphere are observed during the negative rainfall anomaly years. The cross-equatorial flow is observed to be weak during the intrusion events. It is suggested that the weakening of the cross equatorial flow induced by the PV intrusion event may have prevented moisture transport to India resulting in more break spells and hence the reduced rainfall. (Acknowledgment SR/WOS-A/EA-34/2018).

Keywords: Potential Vorticity anomaly, South West Monsoon, PV anomaly and South West Monsoon.

Influence of Indian Summer Monsoon on Tropopause, Trace gases and Aerosols in AsianSummer Monsoon Anticyclone observed by COSMIC, MLS and CALIPSO

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ABSTRACT

The existence of the Asian Summer Monsoon Anticyclone (ASMA) during the summer in the northern hemisphere, upper troposphere and lower stratosphere (UTLS) region plays a significant role in confining the trace gases and aerosols for a long duration thus affecting regional and global climate. Though several studies have been carried out, our understanding of the trace gases and aerosols variability in the ASMA is limited during different phases of the Indian monsoon. This work quantifies the role of Indian Summer Monsoon (ISM) activity on the tropopause, trace gases (Water Vapour (WV), Ozone (O 3), Carbon Monoxide (CO)), and aerosols (Attenuated Scattering Ratio (ASR)) obtained from Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC), Microwave Limb Sounder (MLS), Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite observations, respectively, during the period 2006-2016. Enhancement in the tropopause altitude, WV, CO, ASR, and low tropopause temperatures, O 3 in the ASMA region is clearly noticed during peak monsoon months (July and August) with large inter-annual variability. Further, a significant increase in the WV, CO, and decrease in O 3 during the active phase of the ISM, strong monsoon years, and strong La Niña years in the ASMA is noticed. Enhancement in the ASR values during the strong monsoon years and strong La Niña years is also observed. In addition, our results showed that the presence of deep convection spreading from India land regions to the Bay of Bengal with strong updrafts can transport the trace gases and aerosols to the upper troposphere during active spells, strong monsoon years and La Niña years when compared to their counterparts. Observations show that ASMA is very sensitive to active spells, strong monsoon years and La Niña years compared to break spells, weak monsoon years and El Niño years. It is concluded that the dynamics play a significant role in constraining several trace gases and aerosols in ASMA and suggested considering the activity of the summer monsoon while dealing with them at sub- seasonal scales.

Keywords: Anticyclone; Monsoon; Temperature; water vapour; ozone; COSMIC; MLS; and CALIPSO

UNUSUAL EFFECT OF EXTRA-TROPICAL PLANETARY WAVE FORCING ON THE TROPICAL WEATHER

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ABSTRACT

Sudden stratospheric warming is a robust dynamical event which occurs in the polar stratosphere. It is well known that the mechanism for the occurrence of stratospheric warming is due to the interaction between planetary waves generated from lower atmosphere and mean flow. The present work describes the unusual effect of extra-tropical planetary wave forcing on the tropical atmosphere during 2015/16 in northern hemisphere and 2019/20 in southern hemisphere. The dynamical variables temperature, wind components and geopotential height are utilized from ECMWF ERA Reanalysis datasets. The realistic visualization of stratospheric processes can be achieved by using the diagnostic tool, Eliassen Palm flux (E-P) flux. Horizontal and vertical component of E-P flux is used to characterize the intensity of upward propagating planetary waves from troposphere. We found a prominent horizontal transfer of planetary wave energy from high to tropical latitudes both in the case of 2015/16 and 2019/20. The reach of this upward and equatorward propagating planetary waves to tropical band significantly disturbs the stratospheric QBO circulation. The role of planetary wave forcing on the two unusual QBO disruptions are examined and will be presented in detail.

Keywords: Sudden Stratospheric Warming, Quasi-biennial Oscillation, Planetary Waves, E-P flux

Amplitude modulation of the Quasi-Biennial Oscillation (QBO) by the Convectively Coupled Kelvin and Mixed Rossby-Gravity Waves

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ABSTRACT

Quasi-Biannual Oscillation is a dominant mode of stratospheric circulation and it is characterized by downward propagation of easterly and westerly phases of zonal wind with a periodicity of 26-32 months. Vertically propagating Kelvin waves, Mixed Rossby-Gravity (MRG) waves and meso-scale gravity waves excited mainly by convective processes in the troposphere are considered as the major factors that cause the QBO. However, recent studies could not establish any statistical relationship between convectively coupled Kelvin and MRG waves and QBO and we assume it is mainly due to improper identification and isolation of these waves. Combination of wavenumber-frequency filtering and empirical orthogonal functional analysis (EOF) of outgoing longwave radiation (OLR) show that convectively coupled Kelvin and MRG waves exhibit strong geographical preference and also exhibit seasonal amplitude variability. This information has not been considered by previous studies when evaluating the relationship between these waves and QBO. In contrast to previous studies, lead-lag correlation and composite analyses reveal that there is a strong correlation between the amplitude of the waves and the QBO when the QBO lags the waves by three months. Coherence squared spectral analysis between OLR and stratospheric zonal winds and the vertical zonal momentum transport estimated through Eliassen-Palm flux method show consistent results.

Detangling the Stratospheric Processes Influencing the Tropospheric Weather and Climate

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The physical and chemical processes taking place in one layer of the atmosphere affects the mean state of the other layers and there are several investigations illustrating this vertical coupling process in the Earth's atmosphere. However, the studies pertaining to the vertical coupling processes in the atmosphere predominantly focused on upward coupling, i.e. influence of the tropospheric processes on the middle and upper atmosphere. However, the downward coupling processes, i.e., middle and upper atmosphere influence on tropospheric weather and climate is yet to be explored in details. Especially, changes in the chemical composition as well as dynamics of stratosphere are expected to have profound impact on the troposphere as well as surface climate. Thanks to the efforts of many researchers across the globe, now there is increasing evidence that a better representation of the stratosphere in numerical models result in improved predictability of the state of the tropospheric climate. Though there are ample evidences on the influence of stratospheric process on climate, investigations are very limited to arrive at any general conclusion. In the present study, efforts are made to delineate the role of stratospheric dynamics in determining the state of the troposphere using 40 years of MERRA-2 reanalysis dataset. The results show that the lower atmospheric climate of tropics as well as the Sothern Hemispheric high latitude exhibits the signature of stratospheric dynamics. Further, the ozone recovery in the Antarctic stratosphere seems to be an important factor in the Southern Hemispheric high latitude tropospheric climate whereas quasi-biennial oscillations, stratospheric water vapour in the tropical stratosphere as well as potential vorticity intrusion events seem to play pivotal roles in the downward coupling of tropical stratosphere to the troposphere. The significance of the present study lies in bringing out the potential stratospheric processes that influence the tropospheric weather and climate.

Key words: Stratosphere, Ozone Recovery, Quasi-biennial oscillation, Climate

Asian summer monsoon anticyclone and its relationship with tropical easterly and subtropical westerly jets

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ABSTRACT

Asian Summer monsoon anticyclone (ASMA) is a prominent upper tropospheric circulation pattern which plays an important role in the redistribution of the atmospheric pollutant and tracer to the global scale. Various pollutants and tracers such as CO, SO_2 and H_2O mainly transported from the surface in the ASMA are prone to enter to the lower stratosphere and finally towards the poles due to Brewer-Dobson circulation. ASMA shows a large spatial extent both horizontally and vertically which varies on short time scale. Thus, ASMA region is very challenging to define accurately on the day-to-day basis due to its highly dynamic nature. The extent of the AMSA is defined by using the modified potential vorticity (MPV) and zonal wind circulation which closely coincides with 14.32 km geopotential height at 150hPa. ASMA also defined as the region surrounding the 16.77 km geopotential height at 100hPa. These two different geopotential heights are generally used to study the ASMA region. ASMA is characterized as dynamically varying system having an east-west quasi-biweekly oscillation along with north-south variability. It is bounded by subtropical westerly jet (SWJ) stream in north and the tropical easterly jet (TEJ) in the south. In this study, we have investigated the geopotential height contours within the bounding of TEJ and SWJ and its relationship with ASMA which will be presented during the conference.

Keywords: ASMA, TEJ, SWJ

THE SEASONAL AND DIURNAL VARIABILITY IN UV IRRADIANCE USING THE MICROMETRE II OZONOMETER AT VILLAGE ATIGRE, KOLHAPUR, INDIA.

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ABSTRACT

UV radiation from the sun has harmful impacts on living life. As a result, research into Ultraviolet radiation, ozone distribution, and their impact on the environment, weather, and climate is important. Ozone over Atigre village near to Kolhapur is measured by using highly advanced Microtops II Ozonometer. Microtops II Ozonometer contains the five optical filters (five channels) for solar irradiance measurements of five different wavelengths (305.5 nm, 312.5nm, 320.5nm, 936 nm and 1020 nm). The first three filters, out of a total of five, are used to measure the sun's ultra-violet (UV) radiation. The photodiodes in the instrument measure UV irradiation as voltage. 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. We have investigated the seasonal, daily, and diurnal variability in UV irradiation for the time periods under consideration in this study. It is commonly known that ozone and UV irradiation have an inverse relationship. The reduction in the stratospheric ozone concentration is indicated by an increase in UV irradiation. We observed that the UV irradiation decreases from monsoon through winter, then increases as summer approaches. These variations are also caused due to the apparent position of the sun. We also observed 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 behaviour 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: Ozone, Microtops II Ozonometer, UV irradiance, diurnal and seasonal variation.

Stratospheric control of surface ozone variability in Antarctica and its tropical teleconnection

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ABSTRACT

Tropospheric ozone is a prominent air pollutant and greenhouse gas despite being only 10% of the total column amount. The inter-annual variability of ozone concentration is governed by changes in emission of photochemical precursors, various favorable/unfavorable weather conditions, or a combined effect of all these. In this study, we investigate enhanced surface ozone events in Antarctica and identify the causes of surface ozone variability using a neural network based causal discovery algorithm. The analyses reveal the overarching influence of the stratosphere on the surface ozone variability in Antarctica, buttressed by the southern annular mode and tropospheric wave forcing in mid-latitudes. We find no significant and robust evidence for the influence of tropical teleconnection on the ground-level ozone in Antarctica.

Keywords: Tropospheric ozone, Causal Discovery, Tropical Teleconnection

Characteristics of the tropical tropopause and tracers over the north east monsoon region

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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, Cold Point Tropopause, Radiosonde, Microwave Limb Sounder.

The Sudden Stratospheric Warmings in the Arctic winters 2010/2011–2020/2021

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Sudden Stratospheric Warming (SSW) is an episode of rapid warming in the polar winter stratosphere in a short period of time. Based on the intensity of the event, it can alter the dynamics of the zonal winds and the stratosphere. These unique events are induced by the interactions of tropospheric planetary wave forcings with the polar vortex. The frequency of these warming events is higher in the boreal winter compared to the austral winter. This difference is attributed to the greater land-sea temperature contrast in the Northern Hemisphere (NH) compared to that in the Southern Hemisphere (SH). Here, we perform an analysis of SSWs in the past eleven Arctic winters (2010/11 - 2020/21). Among the 11 winters studied, Major Warming (MW) was observed in 4 winters (2012/13, 2017/18, 2018/19, and 2020/21) and Minor Warming (mW) was present in all the other winters. The MW occurred in early January in the 2012/13, 2018/19, and 2020/21 winters, and mid-February in the 2017/18 winter. The winters are analysed for their vortex dynamics, meteorological characteristics, tropospheric wave forcings, and ozone loss during the period. Previous studies have shown that the frequency of SSWs in the Arctic has been increasing at a rate of ~0.7 MWs/winter for 1957/58 to 2009/10 and ~1.1MWs/winter in recent years 1998/99 to 2009/10. However, we hereby find that the frequency has reduced to ~0.36 MWs/winter for the years 2010/11 to 2020/21 and ~0.74 MWs/winter for the years 1998/99 to 2020/21. We observe a concurrent increase in the amount of ozone during the periods of SSWs suggestive of a proportional relationship between the timings of SSWs and the reduction in the ozone loss consistent with the results of previous studies.

Influence of High Latitude Sudden Stratospheric Warming on Tropical Weather: Observed from a 205 MHz Stratosphere Troposphere Radar and Surface Meteorological Parameters

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ABSTRACT

The study illustrates the evidence of dynamical coupling between the high-latitude sudden stratospheric warming (SSW) events that occurred in three consecutive winter seasons and the concomitant changes in the wind pattern in the lower stratosphere and troposphere observed with a state-of-the-art 205 MHz stratosphere troposphere wind profiling Radar, located at Cochin (10.03°N, 77.33°E), a tropical station in southwest peninsular India. Associated with the occurrence of SSW, the tropical region experiences a change in zonal wind speed and direction at upper tropospheric altitudes after the central day of warming. The zonal wind in the troposphere also reversed its prevailing direction. Downward propagation of zonal wind during the SSW period is noticed, which is also supported by the re-analysis data set. In the lower troposphere, vertical wind experienced sudden fluctuations with varying amplitudes soon after the peak day of the SSW event. The surface meteorological parameters in an area (8° -12° N, 74° -78° E), centred at Cochin from ERA-Interim, are also examined. An abrupt fall in OLR, followed by convection and unusual rainfall in the tropical region 5-6 days before the peak of SSW events, is a unique and exciting feature noted in the study. Detailed analysis of the past 20 years of SSW events confirmed the observational evidence. It indicates that a priori knowledge of the peak day of warming in the polar stratosphere offers a prognostic value in predicting the rainfall over the tropical study region.

Keywords: Sudden stratospheric warming, ST wind profiler radar, Horizontal wind vector profiles, Downward propagation, Outgoing longwave radiation

Diurnal variability of lower and middle atmospheric water vapour over the Indian Monsoon Region : Results inferred from COSMIC and TIMED/SABER measurements

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ABSTRACT

Water vapour (H_2O) (WV) is one of the most important greenhouse gases which play a vital role throughout the Earth's atmosphere in both chemistry and global radiative balance, especially in the upper troposphere and lower stratosphere (UTLS). It is estimated the climate feedback of about +0.3 Wm^{-2} K^{-1} due to an increase in the stratospheric water vapour (SWV), which is about 5-10 % responsible for the global warming from all the greenhouse gases. The primary source of hydroxyl ion (OH) in the Earth's atmosphere is WV, and these OH-radicals control the lifetime of a shorter-lived greenhouse gas like ozone (O_3) and long-lived like methane (CH_4). Any variations from hourly to annual scale in the WV distribution have a significant impact on the global climate-weather system. It is observed that any increase in SWV acts to cool the stratosphere but warm the troposphere. Thus, the SWV plays an important role in stratospheric ozone chemistry and therefore, the global radiation budget. Diurnal variation, in general, is associated with the large and well-defined cycle in solar heating during the day and is accounted as the most fundamental component for the variability of the climate-system. The strong coupling between WV and temperature, even a diurnal scale can provide the basis for a strong positive WV feedback that amplifies the initial temperature changes induced by other greenhouse gases. The main intent of this study is to present and discuss the diurnal variability of WV in the lower and middle atmosphere (from the troposphere to stratosphere) in the ASM region, which is the first of its kind and its linkage to the diurnal variability of CPT temperature and methane oxidation. We used WV and temperature profiles measured by the Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) mission based on Global positioning System-Radio Occultation measurement and Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) onboard Thermosphere Ionosphere Mesosphere Energetics Dynamics (TIMED) satellite using satellite measurements. The detail results will be presented and discussed in the upcoming symposium.

Keywords: Diurnal tides, water vapour, tropical region, COSMIC, SABER-TIMED

Tropospheric warming and stratospheric cooling in response to global warming using Coupled Model Intercomparison Project (CMIP) - 6 models

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ABSTRACT

Warming in the troposphere and cooling in the stratosphere is one of the important atmospheric processes since mid of the 20th Century. Present work focuses on analyzing the Newtonian cooling Coefficients (NCCs) over different hemispheric regions using the Multi-Model Mean (MMM) of fifteen (15) global climate models' simulations from the Coupled Model Intercomparison Project (CMIP) phase 6. Spatiotemporal trends of temperature showed the highest warming and cooling of 1.28°K and 1.68°K over tropical regions of the northern hemisphere at 250 and 30hPa levels. The wave kinetic energies of the lower stratosphere showed a decreasing trend which is an indication of continuous cooling over different latitudinal regions. The NCC is found high (varied up to 3.456°K) with reference to the standard atmospheric profile of 1976 over the NH tropical region and is pronounced in the period 2071 to 2099 under the shared socioeconomic pathway (SSP) of RCP5.8.5 scenario.

Key words: Lower stratosphere, cooling coefficients, CMIP6, Future scenarios

Role of Sudden Stratospheric Warming induced Brewer-Dobson Circulation changes in the thermal structure and compositions in the upper troposphere and lower stratosphere region

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ABSTRACT

The sudden stratospheric warming (SSW) is one of the most important phenomena observed in the polar region during wintertime. Major SSW is characterized by a significant increase of stratospheric temperature below 10 hPa, which occurs rapidly within a few days along with wind reversal at these levels. These large-scale disturbances are the consequences of upward propagating transient planetary waves and their interaction with the zonal mean flow. The reversal (or deceleration) of the eastward winter winds leads to (a) downward circulation in the stratosphere resulting in adiabatic heating, and (b) upward circulation in the mesosphere resulting in adiabatic cooling. Recent studies have also shown the influence of SSWs in tropical convective activity, rainfall, and the tropical tropopause layer. The present study deals with the changes in the tropical atmosphere due to the intensity variation in Brewer-Dobson Circulation (BDC) associated with major SSW event occurring in the northern hemisphere. The effect of SSW through BDC intensity on the temperature structure and ozone mixing ratio over the tropical upper troposphere and lower stratosphere (UTLS) region are studied in detail using space-borne observations. Warming and cooling effects were observed in the UTLS region which is attributed to the change in the ozone distribution. Further analysis was also carried out using Goddard Earth Observing System-Chemistry (GEOS-Chem) model. These changes in the UTLS region, modulate the radiation balance and hence the surface climate. The detailed results will be presented and discussed in the upcoming symposium.

Keywords: Sudden stratospheric warming, Brewer-Dobson circulation, Upper troposphere lower stratosphere region

DAP

Data Assimilation Techniques and Numerical Weather Prediction

High-resolution Regional Coupled Model at NCMRWF

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ABSTRACT

Medium-range forecasts are vital sources of information, especially for severe weather events such as tropical cyclone, monsoon depressions, and cloudbursts. High-resolution regional models are extensively used for short to medium-range weather forecasts by research and operational groups. Direct and catered products from high-resolution regional models can benefit end-users (e.g., farming communities and several decision-making bodies). Many research groups and operational weather forecast agencies worldwide use regional models (also known as limited area models) to generate area/site-specific forecasts. However, providing short to medium-range high-resolution forecasts with very high skills over the Indian monsoon region remains a big challenge. An Ocean-Atmosphere-Wave coupled regional model at a very high resolution can be a handy tool to simulate and forecast coupled processes over India. Such a regional coupled system is required to understand air-sea interactions and oceanic mixing over the region correctly. An attempt is underway for the development of a regional coupled prediction prototype by U. K. Met office. This model uses NEMO as the regional ocean, Met Office's Unified Model (UM) model as the regional atmosphere, and Wave-watch III as the wave model. Case study of 2019 Tropical Cyclone Fani is carried out using UM regional coupled model over Indian domain. Some of the very early results are going to be shared. This work is in the early stages, and many more sensitivity tests and fine-tuning of the model are still ongoing.

Keywords: Regional Coupled Model, Unified Model, NEMO Ocean Model, Tropical Cyclone

PREDICTION OF DYNAMICAL CONE OF UNCERTAINTY AND TRACK OF TROPICAL CYCLONES OVER NORTH INDIAN OCEAN: UTILITY OF ENSEMBLE PREDICTION SYSTEMS

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ABSTRACT

The accurate forecast of the tropical cyclone (TC) track and the Cone of Uncertainty (CoU) are essential for disaster managers and relief agencies to minimize the loss of life and properties. The variations in the track forecast from different deterministic numerical weather prediction (NWP) models make it very challenging for the forecasters to predict the TC track. It has been seen in various studies that the mean track forecast from the ensemble prediction system has shown comparatively better (lesser) track errors as compared to their control (deterministic) model-based track forecast. In this study, the mean track forecast from two ensemble prediction systems (EPSs), Global Ensemble Forecasting System (GEFS) and NCMRWF Global Ensemble Prediction System (NEPS), are evaluated for 13 cyclones formed over the North Indian Ocean (NIO) during 2019 and 2020. Further, the blending of track forecasts from GEFS and NEPS is performed. It is evaluated against the Best Track information provided by the Regional Specialized Meteorological Centre (RSMC), New Delhi. It is found that the ensemble means of each EPS produced lesser track errors as compared to the corresponding deterministic control forecast. In a simple approach, even blending both EPSs with equal weights could improve the final track forecasts. In current operational practice, the Cone of Uncertainty (CoU) is based on climatological values. However, an attempt has been made to generate a Dynamical Cone of Uncertainty utilizing the probabilistic track information from GEFS and NEPS. The comparative evaluation of climatological CoU, dynamical CoU, and their weighted combination has been carried out for 13 cyclones formed over NIO during 2019-2020. The results show an obvious forecasting advantage with the dynamical CoU over climatology.

Keywords: Ensemble Prediction System, Tropical cyclone and Cone of Uncertainty

An atmospheric inverse modeling approach for assessing CO_2 and CH_4 fluxes over the peninsular India using measurements from Thumba

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ABSTRACT

Increasing concentration of the two important greenhouse gases, Carbon Dioxide (CO_2) and Methane (CH_4), has the ability to perturb the radiative properties of the atmosphere and hence the Earth's radiation budget and climate system. There is a substantial increase in their concentration since the pre-industrial era and has increased by 46% and 157%, respectively. This unprecedented increase, which is mainly attributed to anthropogenic activities, has a lead role in the recently observed global mean surface temperature increase and subsequent changes in the climate. In this scenario, it is of primary importance to get an adequate quantification of CO_2 and CH_4 fluxes and their geographical distribution for identifying source and sink regions. Atmospheric inverse modeling is one of the state-of-the-art methodologies to identify the source and sink of greenhouse gas fluxes. To understand regional distribution of carbon fluxes over southern India, atmospheric inverse estimation of CO_2 and CH_4 fluxes are carried out using observations from Thumba (8.55° N,77° E), Thiruvananthapuram during the years 2017 and 2018. The particle dispersion model FLEXPART is used to get the transport component for inversion. Biospheric and fossil fuel fluxes are taken as prior fluxes for CO_2 inversion and for CH_4, fluxes due to anthropogenic emission, geological emission, emission from wetland, termites and wildfire are considered as prior fluxes. After inversion, maximum changes in fluxes are observed over the region near to the station. However, notable changes are observed almost all over the peninsular India. In general, the annual scale posterior flux dominates the prior flux. This may be due to the fact that observed concentrations are higher than the modeled values during most of the year.

Keywords: Greenhouse Gas Fluxes, Bayesian Inverse Modeling, Transport Model

Assessing the skill of ensemble prediction system for rainfall forecast over Odisha

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ABSTRACT

In climate change scenarios, accurate prediction of localized rainfall with an adequate lead time is a major challenge in existing weather forecasting models. A localized prediction of rainfall is associated with characteristics such as time of occurrence, intensity, and amount of rainfall. An ensemble prediction system is conceived using 5 Cloud Microphysics (CMP) and 5 Planetary Boundary layer (PBL) schemes. A total of 525 multi physics simulations for 21 monsoon synoptic-scale systems using 25 different combinations are carried out using Weather Research and Forecasting (WRF V4.0) model up to a lead time of 72 hours. The simulations are carried out using ERA5 initial and boundary conditions at six hourly intervals with two-way interative nested domains (9 and 3 km). Extensive analyses are carried out using benchmark skills indices(i.e., Equitable Threat Score, False Alarm Ratio, Fraction skill score) to identify five top-performing schemes in terms of rainfall and to create members for the ensemble system. Initial results suggest that YSU and MRF are the best two PBL schemes along with Thompson and Morrison (CMP), respectively. Results indicate that ensemble forecast has higher skills than best deterministic models. The localised prediction is also attributed by taylor's diagram, which indicates an increase in correlation coefficient and decrease in root mean square deviation for ensemble forecast up to day-4. Overall, it is also noted that results from optimized ensemble performed consistently better in simulating intensity, location and amount of rainfall compared to deterministic models.

Random Forest-based Prediction Model for Rainfall

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ABSTRACT

Rainfall is one of the most important parameters, which governs the climatic characteristic of a region. However, it is very challenging to predict precipitation, especially at a nowcast scale for a precise location. One of the most interesting questions to address here is the prediction of the occurrence of rain during the next few hours. The proposed article develops a random forest-based data mining approach using hourly rainfall data from an Automatic Weather Station (AWS). Here, we have experimented with different parameters and finalized 24-time varying predictors. These predictors are used in the framework of random forest, which is built in a sequence of multiple decision trees. The developed algorithm is tested on the data collected by AWS, Thiruvananthapuram and is found to predict rainfall with a detection rate of 65 percent and a lead time of 3 hours.

Keywords: Data mining, Random Forest, Rainfall Prediction

Prediction of Western Disturbances Tracks using NWP models

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ABSTRACT

Western disturbances (WDs) are synoptic-scale cyclonic weather systems (extratropical storm) originating in the Mediterranean region, the Caspian Sea and the Black Sea, advected over Afghanistan, Pakistan and northern India by the subtropical westerly jet stream, that brings sudden winter rain to the northern parts of the Indian subcontinent, which extends as east as up to northern parts of Bangladesh and South eastern Nepal [1]. It is a non-monsoonal, westerly-driven precipitation trend, also brings snow and fog in northwest India. Extratropical storms are a global phenomenon with moisture usually carried in the upper atmosphere, unlike their tropical counterparts where the moisture is carried in the lower atmosphere. In the case of the Indian subcontinent, moisture is sometimes shed as rain when the storm system encounters the Himalayas. There, they are responsible for most of the winter precipitation, which is crucial for agriculture of the rabi crop (includes the locally important staple wheat) as well for as more extreme precipitation events, which can lead to local flooding and avalanches. Using ERA5 reanalysis (1979-2018) found more than 3000 WDs tracks, 5% out of which caused heavy precipitations (40mm/day), which have a frequency of about per 4 year [2]. The Numerical Weather Predictions (NWP) play a major role in forecasts at 3 different lead time such as Nowcast (hours to 3 days), Medium range (4-10 days), Extended range (up to 32 days). In this study, we bring a modernized method [2] to predict and verify the WDs tracks by using the NWP's multi models and its different lead time forecasts. Prediction of WDs is a most essential to take necessary precautions in advance by local government during winter extreme precipitation events.

Keywords: Numerical Weather Prediction, Western Disturbances, Tracks, Forecast Verification

Impact of high resolution land surface data assimilation on Fog: A case study from the WiFEX campaign

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ABSTRACT

The present study is a novelty attempt from Winter Fog EXperiment (WiFEX) to investigate the land data assimilation impact on the fog life cycle. As a case study, we have chosen a very dense fog (Visibility < 200m) event that occurred over the Indo Gangetic Plain (IGP) region during 24-25 January 2018. The Noah-MP Land Surface Model (LSM) based High- resolution land data assimilation system (HRLDAS) is used to develop high-resolution (2 km grid resolution) land surface products over the same region. The outcome of SM/ST from HRLDAS is utilized to initialize the land surface fields in the Weather Research and Forecasting (WRF) model. Prior to the case study, the quality of developed high-resolution gridded SM/ST product for 2017–2018 boreal winter month (December-January) is examined with reanalysis and observational dataset. It is found that the actual soil state over the observational site was drier in condition which was reasonably represented in HRLDAS output compared to reanalysis soil products. Therefore, two sensitive experiments have been carried out in the WRF model: CNTL (with default SM/ST) and EHRLDAS (replaced only SM/ST initial field by HRLDAS product) during fog event. The results reveal that the bias in micrometeorological parameters (T2, RH2, WS10) are significantly improved in EHRLDAS simulation, where it shows small root mean square error (RMSE) and better Index of Agreement (IoA) than CNTL simulation. As a result, error in fog onset timing is notably reduced and the vertical representation of fog is skillfully demonstrated.

Keywords: Land data assimilation, Fog life cycle, Soil moisture, Soil temperature, WiFEX

Comparison of Multivariate and Univariate Ensemble Sensitivities for an Extreme Rainfall over Chennai

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ABSTRACT

Ensemble sensitivity analysis (ESA) is a linear regression method that uses sample statistics from ensemble forecasts to evaluate the impact of changes in initial conditions on subsequent forecasts. ESA becomes univariate ensemble sensitivity as it calculates the response to a forecast metric resulted from each state variable on a grid independently, and neglects the covariances across state variables. Therefore, univariate ensemble sensitivity analysis is obtained by approximating the analysis covariance matrix with the corresponding diagonal matrix. However, the possibility of UV method to overestimate the forecast responses due to sampling error cannot be neglected. To mitigate the sampling error problem, multivariate ensemble sensitivity is introduced that accounts for the collective contributions from all state variables across all nearby grid points simultaneously and thereby retains the full covariance matrix. The performance of multivariate ensemble sensitivity over univariate is examined by applying it to a heavy rainfall event that happened over Chennai on 1 December 2015. The Advanced Research version of the Weather Research and Forecasting (WRF) model DART based Ensemble Kalman Filter is used to generate the ensemble forecasts and analyses of the extreme rainfall event. Generally, sensitivity patterns are localized in multivariate ensemble sensitivity compared to univariate, and the sensitivity magnitude also differ among the two methods, especially at higher levels. Using multivariate sensitivity, it is found that the precipitation forecast is sensitive to an initial low pressure system over south Bay of Bengal. Further, the two methods are verified by perturbing the initial conditions and it is found that multivariate gives a more accurate forecast response compared to univariate ensemble sensitivity.

Keywords: Weather Prediction, Forecast Sensitivity, Ensembles, Chennai Rainfall

NUMERICAL MODELING OF DUST STORM HAZARD MAPPING OVER KUWAIT USING WRF-CHEM MODEL

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ABSTRACT

Dust storms are common meteorological hazards in arid and semi-arid regions. Kuwait is one of the countries that has been adversely impacted by dust storms. The diurnal analysis of weather and dust parameters revealed that dust storms were more severe between noon and late evening hours and gradually weakened during the night. However, strong dust storms have occasionally lasted up to 2-3 days in a row. To analyze the genesis, intensification, and dissipation of the dust storm events, the WRF-Chemistry (WRF-Chem) model has been used. It was determined from the WRF-Chem model simulations that the diurnal variations in weather parameters such as relative humidity, temperature, and wind speed associated with the dust storms are realistically simulated over the State of Kuwait and are significantly comparable with the station observations. Additionally, it was noted that there are significant variations in the amount of dust deposition, dust concentration, and dust emission at the district level over the State of Kuwait on an hourly to three-hour timescale. The sensitivity analysis of the dust parameterization was also conducted within the WRF-Chem model and validated the model simulated weather parameters with the station observations. It was observed that the daily-accumulated dust deposition could reach maximum up to 140-160 g/m^2 over the State of Kuwait. However, on a dust storm day, maximum dust concentrations can reach up to 0.015 g/m^3, and dust particles can rise up to 3 kilometers in the air from the ground surface. Due to the fact that, dust storms do not have a fixed season of occurrence in Kuwait, hence an early warning system for dust storms should be implemented and public awareness should be increased to mitigate the hazard's effects.

Keywords: WRF-Chem, Dust storm, Hazard mapping

Use of Aeolus Horizontal Line of Sight Wind Observations in a Global NWP system

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Abstract

Horizontal line of sight (HLOS) wind profiles from ESA's Aeolus satellite is a new type of observation, which became available to the global scientific community recently. National Centre for Medium Range Weather Forecasting (NCMRWF) is one of a few Numerical Weather Prediction (NWP) centres that started using this novel class of observation in its operational NWP systems. Impact of this observation on the forecast has been studied in detail before its use in the operational NWP system. Observing System Experiment (OSE) and adjoint based Forecast Sensitivity to Observation Impact (FSOI) methods has been used to assess the impact of the Aeolus HLOS wind observations on the forecast. The quality of Aeolus HLOS wind observation from both Mie and Rayleigh channels were validated against other wind observations before its use in the assimilation. Both FSOI and OSE studies clearly show that HLOS wind observations from both Mie and Rayleigh Channels have beneficial impact on the global model forecast, especially over the Tropics and Southern Hemisphere extra-tropics. The impact of HLOS winds in the upper troposphere and above are more marked. Details will be presented in the workshop.

Assessment of Predictability of Tropical Cyclones over Bay of Bengal using Ensemble-based Methods

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ABSTRACT

The predictability of Tropical Cyclones over Bay of Bengal is a topic of importance owing to its disastrous impacts over the coasts of India, Bangladesh, Myanmar and Sri Lanka. In this study, ECMWF's ensemble forecast data from TIGGE dataset is used to examine the predictability of cyclones over Bay of Bengal during the period 2010 - 2019. The study comprises of three parts; predictability analysis during deepening phase, landfall phase and genesis phase of a cyclone. Predictability is defined as the ensemble spread of the response function, cyclone central pressure, at final forecast time where high spread indicates low predictability. The ensemble sensitivity of forecast metric to different initial state variables like sea level pressure, mid-tropospheric humidity etc. is examined for all the cyclones that occurred during our study period. Storms that end north of 17° N and which rapidly intensify during their deepening phase are found to have the lowest predictability among all the storms. An increasing trend in the frequency of rapid deepening and north landfalling cyclones is also observed in the recent years. In case of season-wise predictability analysis, no significant difference in predictability is observed for pre-monsoon and postmonsoon cyclones, despite atmospheric flow conditions being different during pre-monsoon and post-monsoon seasons.

Keywords: Tropical cyclones, Ensemble Sensitivity, TIGGE

Monitoring and forecasting of flash floods by interpretation of NWP products

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ABSTRACT

Realizing that flash floods are among the world's deadliest disasters, their monitoring and forecasting have become more critical, especially with climate change and global warming has caused an increase in heavy rainfall events, including cloudbursts. South Asia Flash Flood Guidance System (SAsiaFFGS) is implemented in the India Meteorological Department (IMD) to minimize the loss of life and property caused due to flash floods. As it is a small-scale and high-impact flooding, timely and accurate guidance is significant for the disaster management authorities and other stakeholders. To address these issues, three Numerical Weather Prediction (NWP) models, i.e., IMD WRF, NCUM, and GFS forecast products, are integrated into the SAsiaFFGS System. Interpretation of these three models and their use as an effective tool for the flash flood forecast is discussed in this paper with the help of various case studies.

Keywords: FFGS, NWP, small-scale, Flash Floods, IMD.

Evaluation of global NEMO based ocean analysis in the Tropical Indian Ocean

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ABSTRACT

In National Centre for Medium Range Weather Forecasting (NCMRWF), the ocean analysis is used as initial condition for coupled atmosphere-ocean model to predict the weather and climate. It is based on the global Nucleus European Modelling of the Ocean (NEMO) variational assimilation scheme. In this study, the two years of ocean analysis data (2016-2018) is assessed against in-situ observations from the Research Moored Array for African–Asian–Australian Monsoon Analysis and Prediction (RAMA) buoys and Array for Real-Time Geostrophic Oceanography (ARGO) dataset in the Tropical Indian Ocean (TIO). Comparison of NEMO based analysis with seven in-situ observations on daily and 5-day average timescale showed the very good mutual agreement with systematically underestimates the variability for temperature and salinity. Further, it has large mean and variability difference with maximum RMSE over the Equatorial Indian Ocean (EIO) for surface zonal and meridional current. NEMO analysis with ARGO dataset average over the northern Arabian Sea (NAS; 12–22° N; 55–75° E), the Bay of Bengal (BOB; 10–20° N; 80–95° E), the eastern equatorial Indian Ocean (EEIO; 10° S–5° N; 70–100° E), and the western equatorial Indian Ocean (WEIO; 5° S–10° N; 45–70° E) regions show the systematically marginal underestimation of mean temperature and salinity from the surface to 300 m depth. Further, the temperature RMSE gradually increases from surface to thermocline depth for all regions. The detail evaluation of global NEMO analysis will be presented in conference.

Keywords: Ocean Assimilation, NEMO, ARGO, in-situ, tropical Indian Ocean

Diurnal variation of Surface temperature and humidity variables from IMDAA regional reanalysis

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ABSTRACT

This study illustrates the diurnal variation of surface temperature and humidity variables from the Indian Monsoon Data Assimilation and Analysis (IMDAA) regional reanalysis produced by the National Centre for Medium Range Weather Forecasting (NCMRWF), Ministry of Earth Sciences (MoES) in collaboration with the U. K. Met Office. Representative stations from different parts over the Indian landmass are selected and extracted the surface mass fields from the IMDAA datasets over these locations during the past 2000-2018 years. Similar variables are also extracted from the ECMWF latest global reanalysis dataset (ERA5) over the same locations. A location specific comparison of the estimated hourly surface temperature and humidity from the IMDAA and ERA5 datasets is carried out. Also, verified the diurnal variation of surface parameters from the reanalyses datasets with the available 3 hourly surface observations from the India Meteorological Department (IMD) during the study period. Both the reanalyses datasets exhibit the expected behaviour of diurnal variations in the surface temperature and humidity variables, but with some differences when compared with the observations. The study also investigates the underlying reasons for the differences in the diurnal variation of surface temperature and humidity estimated from the two reanalyses datasets.

Keywords: Surface temperature, IMDAA, Diurnal variation, Humidity variables

Analyses and Assimilation of satellite's AMV with GSI-4DEnVar in tropical cyclone predictions over Bay of Bengal

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ABSTRACT

Atmospheric motion vectors (AMVs), an important source of tropospheric wind information are satellite derived winds obtained by tracking clouds and water vapor features in consecutive satellite images. Polar satellites provide coverage over polar regions, whereas geostationary satellites provide coverage across the tropics and oceans where conventional data sources are in scarcity. AMV observations from Infrared (IR), Visible (VIS), and Water Vapor (WV) imagery from INSAT-3DR and Meteosat-8 satellites are available over Bay of Bengal (BoB). The advanced regional data assimilation like *4DEnVar* combines static background error with an ensemble of current forecasts to examine the structure of dynamic error, bringing the "errors of the day" into focus by making greater use of observations spread throughout time. The advanced *4DEnVar* has the capability to improve the prediction of Tropical Cyclones (TCs) over the region. TCs in the Bob frequently occur during the pre-monsoon (April-May) and post-monsoon seasons (October-November). The study and forecasting of tropical cyclone simulations is critical because the surrounding land is densely populated, and severe weather and inland flooding can lead to significant loss of life and property. The present study encompasses the analysis and assimilation of satellite's AMVs to improve the prediction of TCs over BoB. The AMV observations are statistically analyses over the region before its assimilation. During the study period, root mean square error (RMSE) and speed bias were estimated for AMV observations available at NCMRWF. The impact of AMV observation on track and intensity prediction is investigated. The preliminary results will be presented during the conference.

Keywords: Satellite AMV, *4DEnVar*, regional GSI, Tropical Cyclone

ANALYSIS TOOLS AND METHODS TO DETECT TREND OF TEMPRATURE: BRIEF REVIEW

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ABSTRACT

The detection, estimation and prediction of trends and associated statistical and physical significance are important aspects of climate research. The trend is the rate at which temperature changes over a time period. The trend may be linear or non-linear. It is synonymous with the linear slope of the line fit to the time series. To estimate the linear trend (slope) and statistical significance Linear Regression Models are used. The magnitude of trend in a time series was determined using a nonparametric method known as Sen's estimator and statistical significance of the trend in the time series was analyzed using Mann–Kendall (MK) test. There are several things that should be kept in mind while analysing the trend. Variables with large spatial autocorrelation (eg, temperature, sea level pressure) may have smaller sampling errors. The climate system within which the observations are made is not stationary.

FOSTERING THE NEED OF L-BAND RADIOMETER FOR EXTREME OCEANIC WIND RESEARCH

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ABSTRACT

Ocean surface winds from space borne radiometers and scatterometers are crucial inputs for numerical models for the operational weather and oceanic sea state forecasts. The rainfall, associated mainly with deep convective clouds, influences the wind retrievals from these sensors during extreme winds conditions (higher than 30 ms^{-1}), as the signal strongly gets affected by the intervening atmosphere, mainly the precipitation. This study emphasizes on the importance of the winds from L-Band radiometric measurements from SMAP satellite compared to the operational ASCAT (C-Band) and SCATSAT-1 (Ku-Band) scatterometers, NCEP final analysis, and ERA5 reanalysis wind products. Investigation at global scale suggests that except SMAP, no other selected data are able to capture wind speed more than 56 ms^{-1}, and large under-estimations are found in presently available scatterometers and reanalysis. These high wind speed errors are more prominent when verified with JTWC best track data for global storms. Moreover, the high winds near storms from scatterometers are generally flagged as rainy pixels and not used for operational applications. These limitations of capturing high winds in scatterometers has been addressed here using histogram corrections approach using SMAP retrieved winds. Moreover, the regional model simulations for a case study suggest that the modified scatterometer winds have larger impact on tropical storm prediction mainly on track and intensity.

Keywords: SMAP, ASCAT, SCATSAT-1, ERA5, NCEP, Storm.

Data Driven Approach for Airport Visibility Forecasting using Deep-Learning algorithms

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ABSTRACT

The demand for the accurate airport visibility forecasting has been increasing day by day in aviation sector by the rapid development of the national economy thereby increasing the popularity of civil aviation transport and airport operations. Improving the level of visibility is an important measure to ensure the safe and stable operation of the airport. At present, the low visibility forecast for the smoke, fog and other weather, is still based on statistical models. Although the NWP models are producing visibility forecasts, the direct use of such forecasts still remain a challenging task considering its reliability and accuracy. Another method recently used for such forecast is the Deep Learning using the time series data. Deep Learning can be used in sorting, regression and information retrieval and other specific issues. Considering the complexity and non-linearity of weather features at airport, the combination of deep learning algorithms such as 1D-CNN, LSTM and Bi LSTM were implemented. 1D-CNN to extract features from sequence data which is used as input of LSTM and Bi-LSTM to predict the airport visibility. All experiments are carried out in the python compiling environment using google co-lab through the browser, and is especially well suited to machine learning, data analysis along with TPU and GPU facility. All deep learning based models were developed using the TensorFlow packages. Here the current weather information from the METAR during the period of 2010-2020 has been used. The model performance was evaluated quantitatively and qualitatively using several statistical approaches. By adjusting the loss function and network structure, we optimize the hybrid CNN, LSTM and BI-LSTM model to make it more suitable for practical applications, which is found to be superior to previous models in short-term low visibility prediction.

The application of deep learning models for visibility forecasting as a regression problem is a scarce topic in the literature and has not been fully addressed, hence, this study represents a baseline for further research on this problem.

Keywords: Deep learning, Machine Learning, Visibility, Aviation.

IMPACT OF HYPER- AND NON-HYPER-SPECTRAL SATELLITE RADIANCE OBSERVATIONS ON PREDICTION OF SUPER CYCLONIC STORM AMPHAN USING GSI-4DENVAR ASSIMILATION SYSTEM

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ABSTRACT

Tropical cyclone (TC) is one of the most severe weather systems, with catastrophic hazards to human lives, properties, and society that potentially impact the country's socio-economic condition. TC Amphan, the super cyclone of this century to have genesised over the Bay of Bengal on 13 May 2020, intensified into a cyclonic storm on 16 May 2020 and into a Super Cyclonic Storm (SuCS) on 06 UTC 18 May 2020. Though the TC's developed over a warm Tropical Ocean that lacks in-situ observations and is usually far away from land, remote sensing observation and especially satellite remote sensing is the only way to detect the TC genesis. With the advancement of hyper- and non-hyper-spectral satellite observations, the TC genesis and its movement are well tracked. In the present study, the assimilation of satellite radiance observation and the impact of each satellite type are investigated. The assimilation experiments use the 4-Dimensional Ensemble Variational (4DEnVar) assimilation technique of the Grid-point Statistical Interpolation (GSI) in the framework of the Weather Research and Forecasting (WRF) system. Three types of experiments named CNTL (no assimilation), GTS (assimilation of Global Telecommunication System observations), and SAT (satellite radiance along with GTS observations) are conducted. Furthermore, the SAT experiment is demonstrated using data from each satellite platform. The National Centre for Medium Range Weather Forecasting (NCMRWF) receives a wide range of satellite observations daily through NOAA, EUMETSAT, KMA, CMA, SATMET, JMA, etc. The satellite radiance observations from AMSU, ATMS, MHS, HIRS, AVHRR, GOES, SEVIRI, IRIS, CRIS, AIRS AQUA, SSMIS etc., are used in this study. The analysis's averaged root mean square errors (RMSE) are relatively lower in the SAT experiments than in the GTS experiments. The assimilation of radiance data positively impacts predicting the track, intensity, and thermodynamic structures of the TC Amphan.

Keywords: Satellite radiance, Tropical Cyclone, 4DEnVar, regional GSI

Explicit lightning forecasting Over North Eastern India: Preliminary results

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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 over north eastern 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.

Keywords: WRF, FOD, WWLLN, Assimilation

RSO

Radars and Satellites in Observations and Prediction

Thunderstorm tracking and lightning jump characteristics over north eastern region of India

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ABSTRACT

Lightning and severe weather are the key issues in various part of India. Recently, a thunderstorm tracking system is tested over the north eastern region of India that is validated with Radar and satellite data. Further, Abrupt increase of lightning flashes called lightning jump and is key indicator of severe weather. The present study shows characteristics of intra-cloud, cloud to ground and total lightning flash rate in accompanying severe weather thunderstorm cluster. Additionally, using these total lightning flashes the lightning jump with a suitable lead time have been tested for severe weather warning when thunderstorm reached over the effective vicinity.

Keywords: Lightning Jump, Weather Prediction, thunderstorm

A methodical analysis of the dynamical evolution of active western disturbances over central Himalayas using Stratosphere Troposphere Radar

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ABSTRACT

Western disturbance (WD) is an eastward propagating extratropical frontal weather system steered by the subtropical westerly jet. It is trapped and intensified by the large scale topographic notch formed by the Himalayan mountain ranges. It contributes about one third of the annual rainfall over north Indian region thus having significant climatological influence on glaciers and hydrology over Himalayan region. It also adversely impact the region through hailstorms and extreme precipitation events. The limited observational network over Himalayan region have kept the studies of these events mostly confined with the reanalysis and satellite datasets. Hence it is imperative to enhance surface based and upper air observations for the correct assessment of the impact of these systems and dynamics throughout the lower atmosphere.

In this context, a 206.5 MHz Stratosphere Troposphere radar located among Himalayan foothills at a subtropical site of Nainital (29.4N, 79.5E; 1790m amsl) was operated in alert mode during WD induced extreme weather episodes. Intense western disturbance events spanning from winter season (February 4-6), pre-monsoon (March 10, May 5 – 6, May 11- 13) and monsoon (June 17 - 18) have been observed up to lower stratosphere (22 km amsl). Barring the WD episodes in winter, most of the events were of deep convective nature peaking around afternoon (12 -14 hr) with observation of strong updrafts (~20-25 m/s) in the 12 – 20 km height region. The diurnal evolution of these events and their influence on upper troposphere and lower stratosphere dynamics have been studied using radar products. Reanalysis dataset have been used for the synoptic analysis. The study is expected to determine the impact assessments of these systems at different vertical scales of the atmosphere at high vertical resolution and will be a useful input for mesoscale models for coarse corrections in their estimates.

Keywords: Western Disturbance, Stratosphere Troposphere Radar

ESTIMATION OF BOUNDARY LAYER HEIGHT FROM 205 MHz S-T RADAR AND RADIOSONDE AT COCHIN

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ABSTRACT

The planetary boundary layer is the lowest layer of the troposphere which poses great importance in weather, climate and air quality models. It is characterized by large-scale turbulent flows, the exchange of heat momentum and mass between the atmosphere and earth surface. Several studies to estimate the BLH using wind profile radar and radiosonde have been made in the past years. Signal to noise ratio and variance of vertical velocity were used for the estimation with radar while in radiosonde, several methods the BLH was identified from the gradients of potential temperature, RH, mixing ratio and from the bulk Richardson number. In this work we estimate the boundary layer height (BLH) from the 205 MHz Stratosphere-Troposphere (S-T) radar located at Cochin (10.94°N, 76.33°E). The Height is estimated from an improved method using the vertical profiles of the signal to noise ratio. The result from the radar is then validated using simultaneous radiosonde profiles. The diurnal variation of the BLH identified using this method from the radar is also presented.

Key words : Boundary layer, Signal-to- noise ratio, S-T radar

Use of CHIRPS rainfall dataset for monsoonal rainfall variability and trend analysis over the district of Patiala, Punjab, India

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ABSTRACT

India is in the tropical monsoon zone receives most of the rainfall during the southwest monsoon (SWM) season, which lasts from June to September (JJAS). The SWM rainfall exhibits high spatial and temporal variability over the Indian subcontinent. There have been significant changes in SWM mean rainfall pattern and variability as a result of climate change. Moreover, the climate change has impacted the intensity and frequency of extreme rainfall events. In this study we used the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) is a 30+ year quasi-global rainfall dataset from 1981 to 2020 for carrying out annual and SWM rainfall spatial and temporal variability over the district of Patiala of Punjab state with a spatial resolution of 0.05°. This study analysed rainfall using statistical non-parametric tests – the modified Mann-Kendall (MMK) test and Sen's slope which revealed an increasing trend in southwest monsoon rainfall in Patiala district. The statistically significant increasing trend is observed over monsoon rainfall over Patiala district from the World Meteorological Organisation (WMO) standard period of 1981-2010 to 1991-2020.

Keywords: Rainfall variability, Trend Analysis, CHIRPS, Patiala

Classification of Doppler Power Spectra of 205 MHz Wind Profiler Radar using Machine Learning Approaches

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ABSTRACT

The Advanced Centre for Atmospheric Radar Research (ACARR), located at Cochin University of Science and Technology (CUSAT), operates the World's first 205 MHz stratosphere troposphere (ST) wind profiler radar (WPR). During non-rainy conditions, the wind profiler provides observations of the Doppler power spectrum for ambient air motion. In contrast, both ambient air motion and the fall velocity of the rain droplets can be obtained during rainy conditions. The Doppler power spectra should be classified for rainy and non-rainy conditions to improve the accuracy of wind profiles which usually require human intervention. This work intends to automate Doppler power spectra classification by using machine learning (ML) techniques, which have been widely applied in classification problems during the past decades. In order to perform the classification, the raw radar data is first converted into Doppler images. The features of the Doppler images are then derived using feature extraction methods like Gray-Level Co-occurrence Matrix (GLCM), Local Binary Pattern (LBP), Histogram of Oriented Gradients (HOG), and Hu moments. The extracted features fused with principal component analysis (PCA) and K-fold cross-validation are used to train the ML classifiers. In this study, classification algorithms such as K-Nearest Neighbors (K-NN), Support Vector Machine (SVM), Naive Bayes (NB), and Decision trees are used to build different ML models. The performance of these models with different features is studied to identify the best feature-model pair that gives the highest classification accuracy.

Keywords: Wind Profiler Radar, Radar Target Classification, Machine Learning

Weather Radar Observations vis-à-vis High Wind Speed Recorder data revealing fine-scale features of NIVAR & TAUKTAE Tropical Cyclones

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ABSTRACT

Improved observations, analysis, prediction, early warning and impact of Tropical Cyclones(TC) has considerably reduced life and property losses. The present study utilizing DWR Chennai and DWR Goa data streams reviews TC fine features and its impact at the coast through wind and pressure field variation as observed by recently commissioned IMD HWSR at Cuddalore and Panjim.
Instead of radar centric analysis, present study adopts cyclone-centric radar reflectivity field data, similar to Morphed Integrated Microwave Imagery at the Cooperative Institute for Meteorological Satellite Studies (MIMIC), enabling to review finer details of the Eye Variations, Eye-wall organization, strewing out vortices, shredding and reorganization spiral bands. For verifying these variations, nearby coastal HWSR data has been utilized. The 1minute, 3minute wind and pressure values of HWSR observations enabled identifying gusts, indicative of sudden variation in wind field with the micro feature passing by.

NIVAR Cyclone declared in SCS & VSCS category didn't cause much impact during landfall as like TAUKTAE; DWR observation also shown large vortex strewing resulting in multiple eye structures, not a common feature observed. Earlier reported multiple eye features was during 1976 near Mumbai coast, but not to the intensity of a TC. DWR Observations of TAUKTAE showed no strewing vortices, a probable indicator of an organized system; the nearby HWSR wind and pressure fields were also not showing rapid fluctuations, except during spiral bands crossing in conformity to it.

These additional findings correlating Weather radar and supportive surface data would enhance impact-based forecasts during landfall and better understanding the land-air-sea dynamic interaction during various stages of the Cyclonic storm.

Keywords: Tropical Cyclone, Doppler Weather Radar, High Wind Speed recorder, MIMIC

DWR Patiala & Aviation Safety in the states of Punjab, Haryana & Chandigarh

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ABSTRACT

The states of Punjab, Haryana & UT of Chandigarh are located in strategic location of India. Civil airports in Ludhiana, Amritsar, Hisar and Chandigarh and airbases of Indian Air Force in Adampur (Jalandhar), Halwara (Ludhiana), Pathankot, Bathinda, Sirsa, Ambala and Chandigarh, make it a region where aviation safety should be given prime concern.

Wind Direction (WD) & Wind Speed (WS) are prime meteorological factors on which aviation services are dependent. While landing and taking off, the proper knowledge of WD/WS is must for the safety of the aircraft. Instruments / Observers are available for measurement of surface WD/WS on real time basis.

GPS / PB ascent is the usual procedure to determine the vertical wind structure of the atmosphere. But, because of practical limitations (limited number of flights / observations), it cannot provide the vertical structure of the wind on real time basis, whereas for aviation safety, the upper air wind structure is needed in real time basis particularly in adverse weather conditions. With the induction of state of art, smart intelligent Doppler Weather Radar (DWR) system in the network of IMD, it has become possible to monitor the upper air wind structure on real time basis. For monitoring the weather, S-Band DWR has been installed at Patiala. In the present study, an attempt has been made to establish the fact that how the DWR is capable of giving vertical wind structure of the weather on real time basis in adverse weather condition.

The states of Punjab, Haryana & UT of Chandigarh were facing adverse weather conditions on 19th July 2021. The Wind pattern obtained from DWR at Patiala, at different heights from 0500 UTC to 1100 UTC has been studied to establish the importance of DWR for the aviation safety.

Evaluation, structure and dynamics of tropical cyclone Phethai: Results inferred from DWR, MST radar, GPM-DPR and radiosonde observations

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ABSTRACT

A severe cyclonic storm namely "Phethai" occurred over the north Indian Ocean during 13-17 December 2018. During the initial stage, a depression formed over the Bay of Bengal which developed into a deep depression, which further intensified and matured into a cyclonic storm. The depression then strengthened to a deep depression later that day before becoming a cyclonic storm on 15 December. Phethai further intensified and peaked to a severe cyclonic storm, the following day. The system then steadily weakened due to land interaction and increasing wind shear, before making landfall as a disorganized system over East Godavari Dist. of Andhra Pradesh on 17 December. During this cyclonic event, S-band Doppler weather radar (DWR) at a wavelength of 10.43 cm (frequency = 2875 MHz) was continuously operated at Sriharikota. A campaign mode of operation was also carried out by operating Indian MST radar along with radiosonde launches from Gadanki. In addition to the ground-based radars, space born radars operating at Ka (35.6 GHz) and Ku (13.5 GHz) bands onboard Global Precipitation Measurement (GPM) DPR was also analysed along with Indian National Satellite (INSAT)-3D/3DR. DWR reflectivity shows the organization of cloud clusters into a deep convective system with typical rain-bands over the southern peninsular India. The rain-bands also showed high reflectivity (> 35 dBZ) is observed. The reflectivity also shows the eye of cyclones which are surrounded thick wall of clouds. The reflectivity from MST radar shows that the overshooting convection reached up to the height of tropopause. Intense turbulence activity is also observed from the spectral width. The vertical velocity show strong updrafts in the lower troposphere and both updrafts and downdrafts are observed in the upper troposphere. The detail results will be presented and discussed in the upcoming symposium.

[Keywords: Tropical cyclone, Doppler weather radar, Phethai, MST radar]

Structure of convective systems from C-band Doppler Weather Radar measurements over southern peninsula of India

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ABSTRACT

Thunderstorm (TS) is a severe weather phenomenon develops mainly due to intense convection and accompanied by the heavy rainfall, thunder, lightning and hail. Usually, these thunderstorms have spatial extent of a few kilometres and life span less than an hour. However multi-cell thunderstorms developed due to organized intense convection may have a life span of several hours and may travel over a few hundreds of kilometres. Understanding the 3-dimensional structure of these convective systems is crucial to unravel the processes associated with deep convection. In this study we have used data from a C-band Doppler weather radar (DWR) installed at Space Physics Laboratory (8.52N, 76.89E), Trivandrum (southern tip of India). We have identified 12 prominent convective events having reflectivity greater than 40 dBZ persistent for at least an hour over a 60X60km region during pre-monsoon (Mar-May) of 2018. Then, an algorithm was applied to identify the convective and stratiform regions. This study shows that- mean vertical profile of radar reflectivity for convective pixels peak near 2 km altitude and then gradually decreases towards higher altitudes. On the other hand, the profile in case of stratiform pixels peak near 5 km altitude due to the presence of bright band near that level over stratiform pixels, Further, frequency distribution of reflectivity at 3 km altitude shows peak near 33 dBZ ($\equiv$ 5.86 mm h^{-1}) for convective pixels and for stratiform pixels the peak is around 20 dBZ ($\equiv$ 0.69 mm h^{-1}). Certain overlap between the two distributions is seen. ZR relation ($Z=168R^{1.4}$) has been used to retrieve rainfall rate from radar reflectivity. The ZR relation used here, has been obtained from a previous study over the region using Micro Rain Radar measurements.

A fuzzy-logic based hydrometeor identification (HID) has been implemented. The HID scheme reveals the presence of graupel particles in the convective core. Also, the presence of ice crystals and aggregates are seen above freezing level. The presence of graupels and ice crystals could cause cloud-charging via non-inductive collision charging and subsequent lightning.

Analysis of Melting Layer Characteristics over Kochi by making use of a Micro Rain Radar (MRR) and a 205 MHz Stratosphere Troposphere (ST) wind profiler Radar

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ABSTRACT

The present study analyses the rainfall and melting layer characteristics based on the height of the radar bright band over Kochi, which is a tropical station located on the south west coast of India, during the 10-month period from September 2020 to June 2021. The study is carried out by making use of data from a Micro Rain Radar (MRR) operating at 24.1 GHz and a Stratosphere Troposphere (ST) wind profiler radar operating at 205 MHz in the VHF band, located at the campus of Advanced Centre for Atmospheric Radar Research (ACARR), CUSAT, Kochi, Kerala. The MRR is a vertically pointed radar used to analyze rainfall characteristics such as rain rate, fall velocity and raindrop size distribution (DSD) at the study area. We have delineated the rainfall into convective and stratiform rain types based on parameters such as rain rate and melting layer characteristics. The monthly and seasonal variability in the height and thickness of the melting layer is identified by making use of data from the two co-located instruments. The high vertical resolution (45 m) of the ST radar helps to accurately identify the melting layer height and thickness by supplementing the coarser resolution (200 m) MRR data. The frequency of occurrence of radar bright bands is found to be highest during the summer monsoon months. It is also observed that significant increase in fall velocity occurs near the melting layer and also the highest increase in fall velocity is seen during the monsoon season.

Keywords: Micro Rain Radar, Stratosphere Troposphere Radar, Melting Layer, Convective Rain, Stratiform rain.

Investigation of Changes in Precipitation Patterns in Warming Climate using High Resolution Precipitation Estimates from space

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ABSTRACT

Studies on changes in precipitation patterns over India and globe using gauge data, gridded products and climate models have reported increase in heavy precipitation and decrease in light and moderate precipitation in changing climate causing floods (due to heavy precipitation) and droughts (due to decrease in light and moderate precipitation). Observational data and climate models have their limitations in exploring short lived intense precipitation events due to coarser spatial and temporal resolutions. Furthermore, precipitation spectrum can be very different when precipitation events lasting for several hours are averaged over a day. Recent studies over India report increase in the magnitude and frequency of flash floods due to increase in short-duration intense rain storms. Thus, it is crucial to examine the changes in precipitation patterns (especially short lived intense events) for mitigation and adaptation strategies against flash floods. Present study explores the changing characteristics of precipitation patterns over India in changing climate using accurate precipitation estimates at fine resolution (hourly observations at 10 km resolution) from multi-spectral satellite observations using 24 years (1998-2021) of high resolution data of precipitation over India. Though only a 24 years short period is perceived to be inadequate to explore the long-term changes in precipitation spectrum, this study still represents best possible way to explore the changes in short lived intense precipitation events in changing climate in the high-resolution satellite era. Significant increase in heavy precipitation events was observed over the India. The highest increase of about 118% in heavy precipitation events for a unit degree increase in warming was found over northeastern part of India. Low and moderate precipitation events show decrease over all homogeneous regions of the country. Results reported in this study highlight the importance of disaster preparedness against floods events due to increased heavy rain events.

Keywords: Precipitation extremes, Satellite observations, Mitigation and adaptation

A new approach to atmospheric turbulence measurements using higher order spectral analysis on radar back scattered echoes

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ABSTRACT

Turbulence eddy dissipation rate (ε) (which indicates the strength of turbulence) is one of the key parameter, in order to understand the energy flow in the atmosphere. Various methods have been established to measure the turbulence eddy dissipation rate from the VHF radar, though, these methods requires additional insitu measurements. Some methods uses Spectrum width which is most frequently used technique in the wind profiler radars for the measurement of turbulence dissipation energy. The spectrum width method either uses antenna characteristics or Brunt vaisala frequency for the turbulence measurements. However, these methods require spectral broadening corrections, which yield negative values of spectral width in the presence of high wind shear. A new approach has been proposed for the estimation of turbulence dissipation energy using higher order statistics. Nonlinear interactions among eddies can be identified and characterized by using bicoherence obtained through higher order spectral estimation technique (Bispectrum). In order to understand this process, Higher order spectral analysis has been carried out on various datasets of the back scattered signals received from the MST radar, located at Gadanki. In this method a new index has been developed to test the nonlinearities present in the back scattered received signals from the MST radar. We observed that the Index of nonlinearity which gives the information about nonlinearities present in the received signals indirectly measures the turbulence energy. The results of the turbulence energy dissipation rate (ε) measured from both nonlinear index and from the spectrum width have been compared. It is found that turbulence measured from the index of nonlinearity fairly matches with the turbulence energy dissipation rate measured from the spectrum width. In order to quantify these two variables (Nonlinear index and turbulence energy dissipation rate) regression analysis has been carried out to establish the relationship between these two variables.

Keywords: Higher order spectral analysis, bispectrum, Nonlinear index, Turbulence energy dissipation rate, Atmospheric Radar

Assessment of soil moisture distribution over homogeneous regions of India using remote sensing data products

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ABSTRACT

Soil moisture (SM) acts as an important component in earths energy and water exchanges. The soil moisture data products obtained from Advanced Scatterometer (ASCAT), Soil Moisture and Ocean Salinity (SMOS), Soil Moisture Active Passive (SMAP), ERA, GLDAS are widely used to assess the SM variability on various scales. Therefore, the accurate assessment of soil moisture variability using near-real time remote sensing observational products such as Advanced Scatterometer (ASCAT), Soil Moisture and Ocean Salinity (SMOS), Soil Moisture Active Passive (SMAP) has various applications in climate sciences. However, these SM data products have coarse spatial resolutions and are unable to capture realistic regional SM variability. The downscaling techniques are useful to enhance the resolution of SM data products and assess the improvement in capturing the regional soil moisture variability. The present study follows a downscaling approach based on nearest neighbor method and statistical models. The downscaled data has higher correlations and lower bias. High-resolution SM products can be generated by fusing various machine-learning algorithms. Statistical and dynamical methods are also available for downscaling. In comparison to dynamical methods, statistical downscaling techniques require less computer resources and are easier to implement. The downscaling algorithm is most effective for grasslands, large area, complex terrains and different topographical features and the downscaling is very impactful for region of strong soil moisture temperature coupling zone like core monsoon zone of tropical south-Asia. The downscaled results are found to be more consistent with the available SM data products. Validation of the data between available data and product is commonly carried out using metrics like RMSE (Root Mean Squared Error), Pearson's correlation coefficient (R), bias and unbiased RMSE (ubRMSE). The spatial distribution of SM captured by downscaled products is better represented across homogeneous regions of India.

Keywords: Soil moisture, downscaling, validation

Rainfall nowcasting using DWR over Delhi

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ABSTRACT

Precipitation nowcasting using Doppler Weather Radar (DWR) is helpful owing to their high temporal and spatial resolution in anticipating extreme weather events such as flash floods, lightning, and convective downpour. Inconvenience and financial loss are both caused by such severe weather. In the present study, the latest ensemble-based probabilistic precipitation nowcasting, convolution neural network, and the traditional statistical methodology of nowcasting, i.e. optical flow method, are used for predicting severe rainfall events. A comparative study is performed between rainfall forecasts derived using these algorithms over the Delhi region. The comparison demonstrates the utility of these algorithms in nowcasting severe weather up to a few hours in advance. The capability of these algorithms to nowcast events such as stratiform and convection is the main focus of this paper. Also, a new method is proposed for dealing with missing data, which is very common in radar rainfall and has an impact on the quantitative precipitation estimate. The results of the comparison reveal which method is more appropriate for forecasting extreme rainfall events and deriving quantitative precipitation estimates.

Keywords: Radar, Nowcasting, extreme events

CHARACTERIZATION OF CONVECTIVE CLOUDS USING MULTI-FREQUENCY SPACEBORNE RADAR OBSERVATIONS

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ABSTRACT

Clouds play a vital role in the energy budget of Earth's atmosphere and in the hydrological cycle by redistributing moisture and precipitation. Spaceborne radars offer a unique view of three-dimensional distribution of clouds and precipitation at different frequencies. It is difficult to obtain the full spectrum of clouds by probing with single wavelength. Capabilities of existing spaceborne radars such as CloudSat and Global Precipitation Measurement (GPM) mission indicate that there are considerable gap areas in detecting the key cloud and precipitation processes. In the present study, by combining three spaceborne radar measurements, multi-frequency radar observations of clouds and precipitation are achieved. The unique combination of CloudSat (W-band) and GPM (Ku-, & Ka-band) are used simultaneously to investigate the deep convective clouds and their characteristics. The GPM measurements are being mapped onto the CloudSat satellite track. These simultaneous observations enhanced the cloud detection capability and provided the comprehensive reflectivity structure of the clouds. Dual frequency ratio (DFR) for Ku- & W-band (Ku-W) and Ku-& Ka-band (Ku-Ka) for convective and stratiform cases is also estimated to investigate the microphysical processes in details. It is observed that the convective mean DFR values of Ku-W increases with decreasing altitude below the melting layer than that of DFR of Ku-Ka. Further, the temperature dependence of triple frequency signature is also studied and widening of Ku-W DFR between -20^{o}C to -5^{o}C temperature zones is noted. This suggests that an increasing number of larger aggregates of hydrometeors due to stronger growth of precipitation particles. Also, it is noted that the vertical profile of DFRs can potentially be used to identify the multiple-scattering signatures, which further enable to locate the areas of densely populated ice particles. The present study thus provided a synergetic view of vertical structure of clouds by combining CloudSat and GPM observations, simultaneously.

Key words*:* Clouds, CloudSat, GPM, dual frequency ratio (DFR), multi-frequency

Assessment of vertical air motion among reanalyses and qualitative comparison with VHF radar measurements over the two tropical stations

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ABSTRACT

Vertical air motion (*w*) in any region of the Earth's atmosphere reflects the structure and dynamical features of that region. Importantly, in the lower part of the atmosphere, sudden widespread changes in the weather are usually associated with variations in vertical air motion. The magnitude of *w* is a factor of ten or more smaller than the horizontal wind; nevertheless, it is crucial in the evolution of severe weather. Adiabatic cooling associated with upward motion leads to the formation of clouds and precipitation and adiabatic warming associated with downward motion leads to the dissipation of clouds. In addition, subsidence leads to adiabatic warming, which results in the formation of stable inversion layers. Extensive studies have been done on the relationships between *w* and precipitation/convection over the tropics. Thus, *w* plays a vital role in day-to-day changes in the weather. A very few direct measurements of *w* are available so that most of the time one must depend on reanalysis products. In the present study, assessment of *w* among selected reanalyses, (ERAi, ERA5, MERRA-2, NCEP/DOE-2 and JRA-55) and qualitative comparison of those datasets with VHF radar measurements over the convectively active regions Gadanki (13.5°N and 79.2°E), India and Kototabang (0°S and 100.2°E), Indonesia are presented for the first time in the troposphere and lower stratosphere. The magnitude of *w* derived from reanalyses is 10-50 % less than that from the radar observations. Radar measurements of *w* show downdrafts below 8 to 10 km and updrafts above 8-10 km over both locations. Inter-comparison between the ensembles of reanalyses with respect to individual reanalysis shows that ERAi, MERRA-2 and JRA-55 compares well with the ensemble compared to ERA5 and NCEP/DOE-2. There is no significant improvement in the *w* due to the effect of different spatial sampling for reanalysis data around the Gadanki station. Directional tendency shows that the percentage of updrafts captured is reasonably good, but downdrafts are not well captured by all reanalyses. Thus, caution is advised when using vertical velocities from reanalyses. The detail results will be presented and discussed in the upcoming symposium.

Keywords: Vertical velocity, VHF radar, tropical region

Storm Properties of Tropical Cyclones over two distinct testbeds as observed by GPMDPR

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ABSTRACT

The Indian subcontinent extends southwards into the Indian Ocean with the Arabian Sea (AS) to the southwest and the Bay of Bengal (BoB) to the southeast. Most of the Coastal regions are highly vulnerable to the consequences of tropical cyclones form over two basins. We have investigated the storm macro/microphysical properties of Tropical Cyclones (TC's) in the light of different regions in TC's over the BoB and the AS for the period of 2014-2019 using GPM-DPR swath data. During the study period, 20 cyclone cases are examined. Reflectivity factor (Ze), storm top height (STH), near-surface rain rate, bright band height and width, and mass-weighted mean diameter (Dm) from the GPM-DPR products are used for the analysis. Stroms from over BoB show active bright band features and larger Dm, dominantly in the eyewall region of TC's. Surface rain rate and STH are higher in the case of BoB irrespective of different areas within TC's. Nevertheless, different rainfall regimes such as stratiform and convective within eyewall, inner rain band, and an outer rainband region depict apparent differences in terms of surface rain rate and storm height over BoB and AS. Stratiform rain puts a significant contribution to total rainfall in BoB prominently in eyewall region. Two-dimensional histogram analysis using Dm and Z at different heights reveals that the coalescence process seems to be much prominent for convective nature precipitation than stratiform in EW and IB regions. Break up process has broader distribution in the EW region over BoB. However, this feature is not present over AS. Overall, the microphysical drop growth/breakup processes are dominant in convective rainfall regimes dominantly over the eyewall region. Though the breakup process is hardly observed in stratiform rainfall regimes, it is significantly observed in eyewall regions of cyclones over AO. The relative availability of moisture over BoB influences the drop growth over BoB, dominantly in eyewall region.

HIGH LATITUDE MESOSPHERIC RESPONSE TO THE SOUTHERN HEMISPHERIC STRATOSPHERIC WARMING IN 2019 OVER ROTHERA (68°S, 68°W)

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ABSTRACT

The present work describes the high latitude mesospheric response to the minor stratospheric warming (SSW) that occurred in the southern hemispheric winter of 2019. The minor SSW observed at September 2019 is similar in intensity to the stratospheric warming of 2002. The present work utilizes Skiymet Meteor radar wind observations over Rothera (68°S, 68°W) and ECMWF ERA Reanalysis data. The high latitude mesospheric horizontal winds show dominance of the quasi-6-day and 10-day planetary wave oscillations. The quasi-6-day wave was strongly observed in the month of July 2019, whereas, the intensified quasi-10-day planetary wave occurred prior to the minor warming. The amplitude and phase profiles reveal that the wave amplitude increases with increase in altitude. In addition to this, a weak 16-day planetary wave was found in August 2019. This paper provides a detailed analysis on the polar mesospheric response to the southern hemispheric SSW of 2019.

Keywords: Mesosphere, Skiymet Meteor Radar, Sudden Stratospheric Warming, Planetary waves

CLOUD RADAR TECHNIQUE INFERRED CLOUD VERTICAL STRUCTURE PROSPECTIVE ON EARLY IDENTIFICATION OF ISM VIGOR

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ABSTRACT

IITM's Cloud radar (KaSPR) technique is capable in probing the small non-precipitating cloud droplets due to its superior sensitivity of -45 dBZ at 5 km range. KaSPR is deployed over a site in the Indian Western Ghats to make cloud measurements around the Indian Summer Monsoon (ISM) period (MJJASO). The contrasting ISM dry and wet spells over any ISM region is expected to closely link to the local cloud macro- and micro-physical characteristics. On the investigation of characteristic difference of wet and dry ISM spells, cloud radar spectral moments profiles are utilized to cross check against the regional active and break ISM spells. Our research analysis using cloud radar vertical looking spectral profiling measurements unravels the importance of continuous (gap) Cloud Vertical Structure (VSC) during active (break) ISM spell. Contour frequency altitude diagram (CFAD) analysis further aided in accessing the pivotal role of middle level mixed phase cloud regions through either vigorous convection process from hot ground or cool ice process from descending avails, or blending of both high and low cloud interaction through cloud merging. Therefore, local wet and dry ISM spells are consequence of large scale active and break phase of the monsoon which cause the notable difference in the local vertical structure of cloud in the atmosphere. During the study period, an attempt has been made to understand the characteristics of VSC during different phases of the monsoon season. The physics of sub-grid scale convective, cloud, and turbulent processes help for a better understanding of vertical structure of ISM and improve its modeling.

Keywords: Cloud Radar, Cloud vertical structure, CFAD, Indian Summer Monsoon (ISM), Wet and Dry ISM spells.

An Advanced Deep Learning Algorithm for Classification and Prediction of Tropical Cyclone Images Based on Infrared Satellite Imagery

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ABSTRACT

A significant input to weather prediction modelling is Satellite imagery. Using a Deep learning-based algorithm, it is possible to produce better automatic image processing systems that can apply across various applications. For training and testing, it is necessary to have sets of annotated data with varied properties. Better weather prediction results will be obtained when data is gathered and processed with temporal resolution having a greater density. Temporal resolution and character diversification have been improved by employing data augmentation approaches. More effective outcomes were shown with Deep learning for picture recognition and classification. We demonstrate how Residual networks(**ResNet**) was employed in the classification of Satellite pictures for Cyclones across the Bay of Bengal (BoB) and the Arabian Sea (AoS).This paper also researched the Cyclone's distribution in infrared Satellite pictures. While describing the process of implementation of neural net for classification, we will further discuss the relative findings of training and testing phases of neural network design for image classification with regards to the Confusion Matrix (CM).Results found at the end of the experiment shows that the neural network is competent in identifying Cyclonic Storms. Performance metrics and graphs are provided for Cyclonic and Non-Cyclonic picture recognition and classification. Cyclone images of Satellite are localised further by means of Activation Mappings (AM).Accuracy for Residual networks approaches 99.1 percent, and these are reported in order to allow for comparisons. The extensive experiments were conducted
on the Tropical Cyclones which includes Cyclone Yaas,Cyclone Tauktae,Cyclone Amphan,Cyclone Bureive,Cyclone Nivar ,Cyclone Nisarga ,Depression-BoB using INSAT 3-D Satellite pictures shows that our method performs comparably or exceeds other algorithms with available data. **Keywords** : Residual Neural Networks, Classification, Activation mapping, NVIDIA RTX 3080 Graphic card .

Improved estimation of planetary boundary layer height over low and mid-latitudes using COSMIC-2 radio occultation

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ABSTRACT

There is a general overestimation of the global planetary boundary layer heights (PBLH) derived from prevalent techniques based on refractivity profiles from radio occultation (RO), especially over regions which have clouds in the mid-troposphere and upper troposphere. In this study, about 1500 radiosonde ascents conducted over the tropical Indian Ocean are used to quantify PBLH overestimation from prevalent techniques (using refractivity) with respect to standard PBLH derived from radiosonde. Results indicate an overestimation by 1000 m to 2500 m making the refractivity based measurements questionable under specific circumstances. The PBLH for such cases is shown to correspond to significant gradients of refractivity below the minimum refractivity gradient (MRG) which was chosen as the PBLH in the prevalent methods. The MRG corresponds to cloud tops or subsidence top instead of the PBLH for such cases.

The effect of significant refractivity gradients below the MRG on the global seasonal mean PBLH was then investigated in detail using RO based refractivity profiles from COSMIC-2 satellites for the period of October-2019 to May 2021. Results show PBLH decreases non-uniformly on a global scale as compared to prevalent PBLH detection methods but compares better with ERA5 reanalyses-based PBLH. Maximum improvement is observed over the ITCZ, deserts and the Indian Ocean region while the improvement is small over the marine stratocumulus capped subtropical oceanic regions to the west of continents, for all seasons. Sensitivity analyses for refractivity gradient peaks of different significance showed that a mean decrease in peak strength of 5% or lesser (of the corresponding MRG) produced PBLH decrease and improvement of 400-600 m in general. In the context of COSMIC-2 giving unprecedented number of RO profiles reaching below 500 m height over the tropical and the sub-tropical regions, this study becomes important for better estimation of PBLH.

Keywords: Planetary Boundary Layer Height (PBLH), Global seasonal mean distribution

DETECTION OF CLEAR AIR TURBULENCE USING MICROWAVE RADIOMETRY

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ABSTRACT

Clear Air Turbulence (CAT) is an atmospheric phenomenon which occurs due to variations in the atmospheric parameters causing vertical wind shear, convection and mountain waves. CAT is a major hazard faced by the aviation industry as it causes discomfort and injuries to the passengers and crew. It also leads to considerable economic loss in the form of compensation as well as maintenance cost of aircrafts. It is predicted that the accelerating climate change will increase the frequency and geographical distribution of CAT in near future. Aviation industry is seeking low-cost solutions to detect CAT for prompt early warnings since the current LiDAR-based solutions are too expensive to be deployed in all aircrafts.

In this article, we propose a cost-effective solution that uses Signals of OPportunity (SoOP) to estimate atmospheric parameters at high resolution. The technique exhibits an improved performance by minimizing estimation error and eliminates the need for a time stamp through the use of differential path delay measurements and reconstruction based on compressed sensing. The path of the signal corresponding to each observation leads to a sparse measurement system, which is improved through differential path delay observations. Through the appropriate choice of dictionary atoms for sparsity-based reconstruction, the solution has the inherent capability to detect abrupt changes in the refractivity profile of the atmosphere with reduced number of observations, which removes the need for additional data from other sources. The estimated refractive profile is assimilated into Numerical Weather Prediction (NWP) models to forecast atmospheric parameters such as Temperature, Pressure, and Water vapour content. In summary, the proposed solution has the potential to improve CAT detection, hyper-local weather forecasting and other applications which depend on accurate forecast of atmospheric parameters derived from refractivity at high spatio-temporal resolution.

Keywords: Clear Air Turbulence Detection, Refractivity Profile, Compressed Sensing, Aviation Industry

Vertical structure of cloud properties of tropical cyclone inner core and rainbands from 14 years of CloudSat cloud radar measurements

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ABSTRACT

Using a 14-years (2006-2019) of CloudSat cloud-profiling-radar observations over the global tropical oceans, this study examines the vertical structure of cloud properties in the inner-core, inner-rainband, and outer-rainband regions of tropical cyclones (TCs) for the different intensity categories including tropical-depression, tropical-storm, category 1-2 (CAT12) and category 3-5 (CAT35). Result shows that cloud systems of TCs are dominated by the deep-convective clouds and they occur most frequently in the inner-core and their occurrence frequency increases as the TC intensity increases. After the deep-convective clouds, the Cirrus and Altostratus clouds dominate in the cloud systems. The highest occurrence of the Cirrus clouds exists in the inner-rainband region at 10-15 km altitude range and their occurrence frequency increases as TCs intensity increases. Similar to the deep-convective clouds in the inner-core, the Cirrus clouds in the inner-rainband is suggested to be a good indicator of TC intensity evolution. CloudSat CPR detects more clouds with reflectivity 10 dBZ in the inner-core region and clouds with reflectivity -10 dBZ in the inner-rainband regions. Moreover, the strong TCs have more clouds with precipitating particles in the inner-core and stronger radial outflow of clouds with non-precipitating particles at the upper levels. The stronger TCs maintain larger amount of cloud-ice-water-content in the inner-core.

Further insight into the regional variation of vertical structure of cloud properties of TCs in the different ocean basins, six TC-prone basins are considered in this study: northern Indian ocean, northwestern pacific, eastern + central pacific, Atlantic, southern Indian ocean, and south pacific. Result shows significant regional variability of cloud properties of TCs over different basins. The stronger TCs over the northwestern pacific basin have larger occurrence of deep-convective clouds in the inner-core as well as cloud with more precipitating particles and large cloud-ice-water-content.

Keywords: Tropical Cyclone, CloudSat, Cloud, Cloud Ice Water Content

IMD CYCLONE BEST TRACK AND DOPPLER RADAR OBSERVED TRACK FOR THE SYSTEMS BETWEEN 2005-2020

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ABSTRACT

India Meteorological Department (IMD), a WMO designated Regional Specialized Meteorological Center (RSMC) for Tropical Cyclones(TC), is mandated with responsibility on Bay of Bengal and Arabian Sea area in predicting, tracking and issuing bulletins to WMO-ESCAP Member countries. Taking into various observations viz. Satellite, Radar, Ship, Buoy, Upper-air, surface, Special-Obs, etc and its analysis by experts, the operational and the Best track data for all the tropical cyclones is finalized by IMD. Doppler Weather Radar (DWR) a remote observational tool for meso-scale weather is also used for Cyclone tracking, especially the S-Band systems along the coast.

Every Tropical cyclone is unique in its feature with respect to formation, intensification, shape, rainfall and movement, thus gathers interest in detailed analysis towards improved prediction. The present study attempts to compare the best cyclone smoothen track given by IMD and actual tracked observations of DWR Chennai for the period 2005 to 2020. Best track data of Eighteen TC was under DWR coverage, Ten systems exhibiting predictable features and closer were alone tracked by DWR. For these 10 cyclones, difference in position between Best track and DWR has being computed for different time spans and intensity scales of the system adopting python libraries.

The result depicts the variations due to single observational instrument anomalies, that how the radar track and smoothen best track data differs, especially for the cyclones during the dissipative stages over land. And also the better agreement of results between both the tracks for most of the TC while in sea, except for the systems [Laila-42km, Thane-92km, Nivar-83km] that exerted high trochoidal movements and rapid variations in regenerating eye due to converging spiral bands. This additional detail of radar track would enable in studying the micro-scale variations of the system, uniquely captured by the radar having higher temporal and spatial resolution.

Keywords: Doppler Weather Radar, Tropical Cyclone, Best Track

Merging Ground-based Measurements and Remote Sensing Rainfall Estimates for Improved Hydrological Modeling

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ABSTRACT

Hydrological responses in urban regions are complex and require rainfall data at high spatial-temporal resolution for accurate flood estimates. Remote Sensing Precipitation (RRPs) estimates developed using microwave and infrared data measured by satellite sensors are available at high resolution and serve as a valuable resource to study the spatial variability of precipitation and its impact on hydrological response of a basin especially in data-sparse regions. The present study evaluates the performance of RRPs and their hydrologic application for the Adyar River basin. Latest versions of Global Precipitation Measurement (GPM) and Global Satellite Mapping of Precipitation (GSMaP) rainfall estimates are evaluated using ground-based station data. Hydrological modeling is performed using HEC-HMS model for two heavy precipitation events occurred over the region of Chennai city and the calibrated model is driven with satellite precipitation estimates. Due to the bias present in the RRPs, hydrological simulations underestimated the peak flow but closely captured the shape of the measured hydrograph. Gridded observed rainfall data is obtained by conducting Inverse Distance Weighting (IDW) interpolation to gauge data and bias correction of gridded satellite estimate is performed using multiplicative ratio method. We also utilised a Random Forest (RF) regression technique to merge gauge and RRPs which has combined information from both ground-based and satellite estimates. Topographic and atmospheric variables from Indian Monsoon Data Assimilation and Analysis reanalysis (IMDAA) are used as covariates during the development of RF regression relationship. The bias adjusted rainfall and RF merged product improved the hydrological simulation results with NSE value between 0.8-0.9 and with lower PBias. The study shows the importance of spatial representation of rainfall data in improving the hydrologic model simulations especially in the data-sparse regions.

Keywords: Satellite precipitation estimates, Bias correction, Random Forest, Hydrologic modeling

A STATISTICAL STUDY OF NOCTURNAL F-REGION IRREGULARITIES DURING GEOMAGNETICALLY QUIESCENT CONDITIONS USING 205 MHz VHF RADAR AT COCHIN

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ABSTRACT

The Stratosphere Troposphere wind profiling radar operating at 205 MHz installed at the Cochin University of Science and Technology (CUSAT), India, is a remote sensing instrument capable of measuring 3-dimensional winds from 315 m to 20 km heights in the atmosphere. During various experiments, it is found that it has got immense application in probing the ionosphere. The radar is explicitly configured to probe the nighttime (06:00 pm-06:00 am local time-LT) ionospheric irregularities. The characteristics of nighttime field-aligned irregularities (FAIs) over the near-equatorial site at Cochin (Geomagnetic coordinates: 1.88^0 N, 149.51^0 E, and Geographic coordinates: 10.04^0 N, 76.33^0 E) have been derived during the solar minimum periods. Even though the study period includes the minimum of the 24th and 25th solar cycle, a total of forty nighttime irregularity events were observed at the F-region heights (150-500 km). Both bottom-type or bottom-side irregularities were present during the observations, and large-scale topside irregularities have not been observed in F-region heights. It is estimated that the nighttime irregularities are most commonly observed at average heights of 200-250 km which accounts for 50% of the total events, and 27.5 % of the nighttime irregularities have occurred preferentially during the post-sunset hours 19:00-19:59 LT. It is observed that long-duration irregularity events were not prominent over Cochin during this period. In contrast, irregularities that last for less than an hour were predominant during the period of study. This communication portrays the scope of 205 MHz VHF radar in monitoring near-equatorial ionospheric irregularities over the Indian equatorial ionization anomaly (EIA) trough sector.

Keywords: 205 MHz VHF radar, F-region ionosphere, Spread-F

Meteor Trail Induced Backscattered Echoes observed with 205 MHz Stratosphere Troposphere (ST) Radar at CUSAT, Kochi

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ABSTRACT

We present meteor trail induced backscattered echoes observed with the high power large aperture 205 MHz Stratosphere Troposphere (ST) Radar at CUSAT, Kochi (10.04° N, 76.33° E). The narrow beam width (Beam width ~ 3°) and high-pulse repetition rate of ST Radar can be used to study meteors which satisfies geometrical condition of specular reflection by pointing the radar beam perpendicular to the geomagnetic filed lines. This paper contains analysis on the Orionid meteor showers that were recorded with ST Radar on October 2019 & 2020, its head echo statistics along with mean altitude and radial velocity are presented. The observations we report are highly resolved "head-echo" which are apparently due to low-mass meteors and its "trail" signature. Additionally, because of the narrow radar beam width our system is most sensitive to meteors with trajectories along the beam and least sensitive to those with trajectories across the beam. The meteor echo sometimes was found to occur in 2 or 3 range bins and persist for a few seconds. Meteor induced backscatter was recorded mainly in the 80 – 100 km altitude region. Activity of the meteor showers recorded was characterized by the Zenithal Hourly Rate (ZHR). Meteor Trail induced Ionospheric Irregularity studies for 205 MHz ST Radar is also briefly discussed in this paper.

Keywords: Wind Profiler Radar Observations, Meteor Induced Backscatter, Meteor Shower.

Estimating Tropical Cyclone (TC) intensity by satellite imagery utilizing SATCON algorithm during the post-monsoon season over the Indian region.

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ABSTRACT

The accuracy of TC intensity is one of the key steps in TC forecasting, model initiation, issuance of a warning, and disaster management. For over almost 50 years, the Subjective Dvorak Technique (SDT) has been applied for estimating the TC intensity worldwide. However, the SDT used by the various agencies has several deficiencies and limitations, such as inherent subjectivity. This study is carried to find out the effectiveness of the objective-based SATCON algorithm, which utilized both Geostationary and microwave satellite images to estimate the TC intensity.

For this purpose, TCs formed during 2016-2020 (5 years) have been analyzed using the SATCON algorithm estimates and best track estimates of Regional Specialized Meteorological Centre (RSMC), New Delhi. The intensity estimates are compared for the different stages of TCs formed over the Bay of Bengal and the Arabian Sea during the post-monsoon season. During the post-monsoon season, the SATCON algorithm performs quite well in the Arabian Sea compared to the Bay of Bengal, with root mean square intensity errors of 10.7 and 13.2 knots, respectively.

Keywords: Tropical Cyclone, Intensity, Bay of Bengal. Arabian Sea

DERIVING Z – R RELATIONSHIP USING IMERG DATA: CASE STUDY USING DWR, GPM AND GROUND DATA DURING CHENNAI 2015 DELUGE

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ABSTRACT

The unprecedented heavy rainfall for two cases (14 - 16 November and 30 November – 03 December) during November – December 2015 over Chennai had been analyzed using DWR products (both SRI – Surface Rainfall Intensity and PAC – Precipitation Accumulation), along with IMERG (Integrated Multi-satellitE Retrievals for GPM (Global Precipitation Mission) Version – 5, INSAT QPE and IMD daily gridded rainfall. In our earlier study, we had used IMERG version 5 rainfall products and shown many mismatches between the various products. However, the DWR–IMERG had shown some promise with a correlation of 0.81. In this study, we have used the same 10 minute – 300 m spatial resolution Chennai DWR SRI data and compared (after up - scaling to 30 minutes and 0.1 deg × 0.1 deg) it with GPM – IMERG Version - 6 data.

Using nearly 80% of this data at full spatio-temporal resolution, we demonstrate a new method to derive the Z – R relation for the radar. The remaining 20% of the data have been used to verify the efficacy of the method. The promise of this method is that the Z – R relation can be continually upgraded and improved as more and more radar (and simultaneous IMERG) data become available in future. On a weekly/monthly or seasonal scale, these relations can be verified with IMD's daily 0.25 deg × 0.25 deg products. This method, thus, can also be adopted to derive / improve Z – R relation for any / all other DWRs in the country. We have also used the limited GMI (GPM Microwave Imager) observations around the DWR site, which are expected to be more accurate at the satellite pass time.

Keywords: INSAT, GPM - IMERG, Heavy Rainfall, DWR

Microphysical retrieval of rain bands of Tropical Cyclone "Ockhi"

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ABSTRACT

Polarimetric radars are capable of retrieving microphysical signatures of land falling cyclones. Vertical distribution of all polarimetric varibles gives an insight to the processes involved in cloud formation and dissipation. These observations can be used for better representation of tropical cyclones in numerical model.

The purpose of this study is to analyse the different precipitation processes in the rain bands of tropical cyclone 'Ockhi'. The primary data for investigation is collected from the C Band operational weather radar at Thiruvananthapuram. In addition to the conventional radar variables like reflectivity (Z) and radial velocity (V), a polarimetric radar provides additional variables namely differential reflectivity (ZDR), specific differential phase (KDP), and the copolar correlation coefficient between horizontal and vertical and polarizations (Rho), which gives more useful information to characterize bulk microphysical characteristics. Here vertical profile of Z, ZDR and KDP is used to study and differentiate the physical mechanisms involved in the precipitation formation and dissipation. Atmospheric parameters including temperature, relative humidity and specific humidity has been analysed using ERA5 hourly data on pressure levels from by ECMWF. The study characterises and quantifies the convective and stratiform parts of precipitation occurred at different stages of the cyclone. This study also examines the vertical displacement of melting layer within the storm and its dependence to cyclone intensity.

Keywords: Weather Prediction, Atmospheric Radar

Analysis of extreme weather events over northwest India- A multivariate data analysis perspective

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ABSTRACT

Significant rise in extreme weather events of recent years have been well documented resulting in maximum impact on densely populated countries by disturbing the social and economic strata of the society. In this study, a multivariate data analysis is attempted for investigating the severe convective events over the country. Severe thunderstorm cases across the country are identified and the associated synoptic conditions is analyzed. Data analysis from satellites, in-situ, Radiosonde, NWP model are utilized. The spatial and temporal shift of the severe weather episodes from different observing platforms are compared with the observational data. Thunderstorm indices like CAPE, CIN, etc are also utilized for understanding the energy content in the atmosphere. The stability indices are also derived for improved understanding of the vertical state of the atmosphere.

Keywords: Thunderstorm, Multivariate Data Analysis, Radiosonde, CAPE.

A CASE STUDY ON THE RESPONSE OF THE OBSERVED IONOSPHERIC IRREGULARITIES DUE TO A GEOMAGNETIC STORM EVENT USING 205 MHz VHF RADAR AT COCHIN

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ABSTRACT

The characteristics of nighttime field-aligned irregularities (FAIs) over Cochin (Geographical coordinates: 10.04^0 N, Lon. 76.33^0 E and Geomagnetic coordinates: 1.88^0 N, Lon. 149.51^0 E) have been explored using a 205 MHz VHF radar during the solar minimum periods. The ST Radar is a wind profiling radar operating at 205-MHz frequency, installed at the Cochin University of Science and Technology (CUSAT), India, which is capable of measuring both the horizontal and vertical components of wind. It is designed to operate in a height ranging from 315 meters to 20 kilometers and is specially configured to probe the ionosphere. Most often, nighttime (06:00 pm-06:00 am IST) ionospheric irregularities are observed with this Radar. In this case study, the response of the ionospheric nighttime irregularities due to a geomagnetic storm event during 28 February-09 March 2021 is analyzed. For this intense storm event, the SYM-H had reached a minimum of -80 nT (storm-I) at 11:33 IST on 01 March 2021 and -55 nT (storm-II) at 10:09 IST on 03 March 2021.Continuous and quasi-periodic E-region echoes were observed over Cochin in connection with counter electro jet (CEJ)-like conditions during intense storms. The plume-like equatorial spread-F (ESF) irregularity with topside extension was also perceived in association with the enhanced eastward electric field due to delayed disturbance dynamo electric field (DDEF) in the recovery phase of the intense storm. In this paper, the potential of 205 MHz VHF radar in monitoring near-equatorial ionospheric irregularities over the Indian equatorial ionization anomaly (EIA) trough sector amid intense geomagnetic storm is substantiated.

Keywords: 205 MHz VHF radar, Ionospheric irregularities, Geomagnetic storm

RAIN SCREENING ALGORITHM FROM COMBINED RADAR RADIOMETER OBSERVATIONS USING MACHINE LEARNING

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ABSTRACT

Rain screening is a crucial step in the rainfall estimation process. Radars and radiometers are two primary instruments that are used to estimate rain. While radar can detect and measure rainfall over both land and oceans pretty accurately, radiometers do not perform well overland due to non homogenous and warm background radiation. The present study considers the Tropical Rainfall Measuring Mission (TRMM) Microwave imager measured brightness temperatures and the rain flag from the Precipitation Radar (PR). Rain screening methods have predominantly been based on scattering thresholds of brightness temperature (TB) at higher frequency channels. The Goddard Rain Profiling Algorithm (GPROF) used in TMI classification screens rain based on the scattering of 85(V) GHz channel. This study presents an ML-based rain no-rain classification method over land using Artificial Neural Networks (ANN) and Random Forests (RF). The ML models are trained on the 2012 monsoon (JJAS) data over the Indian landmass. Using feature engineering, new features are generated from the TBs, and a total of 11 of them are finally selected for training. These serve as the input features that get mapped to the binary rain flag labels obtained from PR, considered the truth value. In addition, the results of ML models trained on an oversampled dataset is also presented. Oversampling was done to reduce the data imbalance by generating new rain data points and removing ambiguous no-rain data. A comparison is made between the different ML-based methods against GPROF for the complete 2013 unseen data for all months over the Indian Land region. F1 score of 0.66 and 0.61 was obtained for ANN and RFC respectively as against 0.58 for GPROF. With oversampling, the scores are 0.65 and 0.66, respectively. This method doesn't require the use of desert and snow masks. The results show that ML methods are promising for rain screening tasks.

Keywords: Rain/No Rain classification, artificial neural network, random forest, TRMM

PLANETARY BOUNDARY LAYER HEIGHT OVER KOCHI USING 449MHZ WIND PROFILING RADAR

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ABSTRACT

The Planetary boundary layer (PBL) is the lowest layer of the troposphere in contact with the ground surface, which is subject to strong influences from the changes in geophysical variables of the Earth's surface. The PBL plays an important role in many fields including Air pollution, Agricultural meteorology, hydrology, Aviation meteorology, Mesoscale meteorology, weather forecasting and climate. But the determination of PBL is still a major challenge due to the dynamic variation of turbulent mixing and dispersion of air pollutants. In this paper, an adaptive method is used to estimate PBL height from measurements of 449 MHz wind profiling radar installed at Wellington Island, Kochi. One complete year's (Jan 2018- Dec 2018) data from a height of 200m to 8000m at every 50m height interval have been utilized in the study. The principle behind the PBL height retrieval from wind profiling radar is largely based on the well-defined vertical structure of the Boundary Layer, which consists of the near-surface layer, mixed layer, and entrainment layer. Because of the small scale buoyancy fluctuations associated with the entrainment process, the Cn^2 reaches a maximum at the top of the inversion. Meanwhile, the value of Cn^2 is directly proportional to the SNR of the backscattered power of radar, which allows for the possibility of continuous monitoring of the PBL. In the adapted threshold method to characterize the evolution of the PBL using continuous radar wind profiler measurements, a criterion of SNR was set to determine the PBL height. However, this threshold method strongly depends on the choice of the SNR threshold, which varies with regional atmospheric conditions and instrument's performance. The estimated PBL height is validated using calculated that using Radiosonde data. Diurnal variations of PBL are also examined. The PBL height is found to be increased from sunrise, reached a maximum in the afternoon, and then dropped sharply after sunset.

Keywords: Planetary Boundary Layer, Wind profiling Radar, SNR threshold, Radiosonde

Differential wind regimes over Kerala during contrasting northeast monsoons of 2019 and 2020

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ABSTRACT

Kerala state, located on the south west coast of India, experienced contrasting rainfall during the north east monsoon (NEM) seasons of 2019 (excess) and 2020 (deficit). These two years were characterized by the delayed withdrawal of the south west monsoon (SWM) season, which extended well into the month of October, thereby significantly altering the rainfall characteristics during the NEM that lasts from October to December. We have used wind data from a Stratosphere Troposphere (ST) wind profiler radar located in Kerala, in combination with rainfall observations and reanalysis data to analyze the differential wind regime over the study area during the contrasting NEM seasons of 2019 and 2020. During both these years rainfall was deficient and winds were weak during the final stages of the SWM. Once the SWM withdrew entirely from the country in 2019, unusually warm sea surface temperatures (SSTs) over the Arabian Sea and associated extreme positive Indian Ocean Dipole (IOD) coupled with favourable phases of Madden Julian Oscillation (MJO) and reduced wind shear resulted in the development of anomalous number of cyclones in the Arabian Sea including a super cyclone in the latter half of October. Thus anomalous convective activity over the Arabian Sea helped to recover from the deficient rainfall experienced during the initial stages of the NEM season. Most of this rainfall positive anomaly was concentrated along the northern and central parts of Kerala north of 10°N, owing to the increased elevation of the Western Ghats that resulted in large scale orography induced rainfall. In 2020, reduced convective activity over the Arabian Sea, unfavourable phase of MJO and neutral IOD resulted in reduced orography induced rainfall over the central and northern parts of Kerala.

Keywords: North east monsoon, Delayed withdrawal of south west monsoon, Kerala, Indian Ocean Dipole (IOD).

Hourly Radar-based Quantitative Precipitation Estimation

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ABSTRACT

Progress in rainfall estimation is important for advancing science and applications in weather and water budget studies, as well as forecasting natural hazards due to extreme rainfall events at all scales, from regional to global. Doppler Weather Radar (DWR) technology enables us to measure areal precipitation close to the ground and estimation of quantitative precipitation estimation (QPE) is one of the important radar applications. Hydrological forecasting and early warning systems require accurate, timely, and reliable precipitation observations. Weather radar-based quantitative precipitation amount (QPA) that has brought in this report as traditional well-known surface rainfall accumulation (SRA). SRA has traditionally been computed using radar reflectivity measurements associated with surface rainfall intensity well known as the Z-R relation. An improved algorithm for the categorization of radar retrieved rainfall into convective and stratiform rain has been the key for interpolating SRA for inferring it as QPA. This estimated SRA / QPA from the IITM's X-Band Radar situated over a Western Ghats site used for its hourly evolutions and that has been compared with ground truth. The radar volume scan data at various elevation angles PPI has been the basis for generating gridded form of radar data using in-house developed CAPPI at various heights i.e., the 3D format of radar data display. The radar-retrieved QPA/SRA map produced better results than the traditionally fixed Marshal-Palmer relationship, which were confirmed using the GPM level 3b precipitation product.

Keywords: Doppler Weather Radar, Quantitative Precipitation Estimation

"What level of Minimal Optimization of Signal Featuring AIP is Significant in Pre-seismic Signature Against Solar X-ray flux variant in the F layer of Ionosphere: a Research Report!"

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ABSTRACT

Electron flux data available among numerous parameters causing AIP in different layers of D,E and F layer displays diurnal variation . It rises night time and declines during day .X ray flux is indicative of solar storm and wind as SME release is observed at different layers of ionosphere. In absence of any solar activity anomalous variation in the electron flux graph signifies terrestrial stress upsurge or any tectonic disruption. data observant monitored through the Radar or INSAR or GOES11-15 of NOAA/Madrigal or ESA have depicted exponential declines in variation. Specifically during seismic event of 2013 April Iran 7.1M, Pakistan 6.7,6.4 M on 2 4th,25 September 2013, and Nepal 25April records similar features classics of Maxwell and Faraday EM theory explains the phenomenon as consequent to stress transformation into induced EM waves propagation .optimization technique through Matlab tool assists enshapement of minimal for electron flux and maximum for x-ray flux values about 2-2.5 Mev and 1.1e-5j/m2 are observed. correlation between X ray and electron flux data obtained for Nepal event stands as positive r= .85 for Pearson method and z= 1.56 forα -.05 .Gauss Newton correction method allows error 15% for optimization technique adopted.. Similar run were recorded for other events of Iran and Pakistan with r=.657,z=1.57α=-.05 were determined. Error calibration were 12% by Gauss Netwon RMS method.

Keywords: Optimization ,correlation Electron fux solar Xray flux, remote sensing

A STUDY ON LIGHTNING ACTIVITY IN SOUTH INDIA USING SATELLITE AND GROUND OBSERVATIONS

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ABSTRACT

A study on lightning characteristics using satellite-based Lightning Imaging Sensor (LIS) and ground-based Indian Lightning Detection Network (ILDN) shows that the synoptic weather systems are the primary cause of large-scale lightning activity in Southern India (SI). The lower tropospheric troughs (850 hPa) and easterlies play a significant role in the lightning activity in SIs. A standardized regional lightning index was developed to identify the lightning hotspots. A well-marked spatial variation in lightning activity was observed in SI. The midland region and foothills of Western Ghats in southern Kerala had relatively high lightning activity. Intra-Cloud lightning is higher over the Western Ghats compared to the neighboring locations. Interestingly, though pre-monsoon periods had significantly higher incidences of lightning, the hazardous Cloud to Ground (CG) lightning activity was more seen during the post-monsoon. Study shows that the lightning activity is higher before monsoon onset and after that, the activity decreases. Also, lighting activity shows a peak before the active monsoon period. Monsoon low-level jet shows an inverse relation with lightning activity in SI. Harmonic analysis of lightning data indicates that the regional lightning activity has a strong diurnal dependence. Oceanic and leeward sides experienced peak lightning activity in the late night and early morning. The 30–60 day oscillations are mainly influencing the lightning activity. The lower tropospheric north-easterly and easterly winds have a significant role in lightning activity in SI. Overall, 55% of lightning was observed during low-level easterlies and north-easterlies, and 45% occurred in conjunction with low-level northerlies and north-westerlies. Our study indicates that wind direction is one of the prime factors for the large-scale lightning activity. Long-term data showed an increase in annual lightning activity in SI. Oceanic teleconnections have significantly influenced lightning activity in SI. El Niño and negative Indian Ocean Dipole periods experience above-average lightning activity.

Keywords: Lightning, South India, Lightning Imaging Sensor, Lightning Detection Network

Orography-Diurnal cycle of convective storms: Inference from Radar and Reanalysis measurements

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ABSTRACT

Diurnal variation of convective storms (CSs) during monsoon season and associated physical mechanisms are significantly important for accurate forecast of short-time and extreme precipitation. The present study examined the diurnal cycle of CSs with the underlying topography. For this, high spatial and temporal resolution measurements from the ground-based X-band radar along with Tropical Rainfall Measuring Mission satellite and reanalysis data are utilized during the summer monsoon (June-September of 2014) over complex mountain terrain of Western Ghats, India. Diurnally, CSs show a bimodal distribution in the coastal areas, but this bimodality became weak along the upslope regions and on the mountain top. The first occurrence mode of CSs is in the afternoon-evening hours, while the second peak is in the early-morning hours. The diurnal cycle's intensity varies with location, such that it reaches a maximum in the afternoon-evening hours and early morning on the mountain top and coastal areas, respectively. Two possible mechanisms are proposed for the diurnal variation in CSs (a) the radiative cooling effect and (b) the surface wind convergence induced by the interaction between land-sea breeze, local topography and largescale monsoon winds. It is also observed that the CSs developed on the mountain top during afternoon-evening hours are deeper than those along the coast. The higher moisture in the lower- and mid-troposphere, higher instability and strong upward motion facilitate deeper CSs during afternoon-evening hours. The detailed mechanisms for the observed diurnal variability in convective storms will be presented during the conference.

The present study provides the large-scale mechanisms responsible for the convective storm variability over complex mountain terrain, which will be helpful for the modelling community to improve the simulation of diurnal cycle in the parameterization schemes.

Keywords: Convective storm, Orography, Diurnal Cycle, Doppler Weather Radar

GTE

Geo-spatial Techniques and Earth Observations

A SPATIALLY EXPLICIT DEEP-LEARNING MODEL FOR LANDSLIDE SUSCEPTIBILITY MAPPING IN WESTERN GHATS OF SOUTHERN INDIA

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ABSTRACT

The unique physiographic conditions, high intensity rainfall and anthropogenic disturbances in the mountainous Western Ghat region often cause landslides, which leads to loss of life and properties. Development of early warning systems for landslide forecasting always needs efficient and accurate landslide susceptibility maps. In the present study a spatially explicit deep-learning neural network is developed for landslide susceptibility mapping of Idukki district of Kerala. A total of 1239 landslide locations are compiled from fieldwork and other sources. Thereafter, fourteen landslide influencing factors such as lithology, landuse/ landcover, slope angle, distance from roads, distance from lineaments, soil texture, distance from streams, profile curvature, plan curvature, cross sectional curvature slope aspect, topographical wetness index and annual average rainfall is collected and a multi-collinearity analysis is carried out to eliminate highly correlated variables. Subsequently cross-sectional curvature and longitudinal curvature is omitted from further analysis. To model the landslide susceptibility a deep learning neural networks (DNN) using three hidden layers with ReLU activation function and output layer with Softmax activation is developed. The proposed model is compared with machine-learning random forest (RF) model. The results are validated using receiver operating characteristics curve with area under curve values (ROC-AUC) and other measures. Overall DNN outperform RF with 0.973 AUC value in training phase and 0.968 in testing phase. Further, DNN shows better ability in discriminating spatial pattern of landslide susceptibility over RF model.

Keywords: Deep-learning, Landslides, Western Ghats, India

Characteristics of Cyclonic & Anticyclonic Circulations at 850 hPa over India and Adjoining Areas

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ABSTRACT

Integrating wind data from Satellites, Radiosondes, Pilot Balloons and DWR; wind streamlines are drawn for 850 hPa. Tapping the potential of hand drawn highly packed streamline charts, cyclonic and anticyclonic circulations centre points are identified and the characteristics of circulations are explored spatially in seasonal and long term over the Indian and surrounding regions. Several interesting weather features are visualised and their role in dynamics are discussed in the present study. Probability distribution shows large numbers of cyclonic circulations are present over the north and northwest India, the Indo-Gangetic plain, and in the east equatorial Indian Ocean region. Seasonal analysis reveal the association with the southwest monsoon trough, the head Bay of Bengal lows, heat lows over land and in the southern peninsula. Anticyclonic circulation centre point distribution is concentrated further south of the trough region and concentrated mainly over the land. Winter season has noticeably high anticyclonic circulations which could be attributed to the descending limb of the Hadley Cell. Station-wise analysis on seasonal circulation characteristics highlights the quadrants of higher probability of occurrence of cyclonic/ anticyclonic circulations aloft. The analysis has several applications including operational weather forecasting, aviation and ballistic meteorology and research.

Keywords: Cyclonic Circulations, Anticyclonic Circulations, Streamline Analysis, Operational Meteorology

Mapping the pre and post-seismic b-values to assess crustal stress heterogeneity associated with 2016, Mw7.8, Kaikoura earthquake, New Zealand

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ABSTRACT

The Mw 7.8 Kaikoura, New Zealand earthquake on November 14, 2016 provides an unprecedented opportunity to investigate crustal heterogeneity in the pre- and post-seismic stress field over a very complicated fault system where a subduction zone converges with a strike slip fault system. The size distribution of earthquakes as quantified by the Gutenberg-Richter b-value is potentially a proxy for differentiating stress conditions and is useful for seismic hazard assessment. We analyze the pre and post seismic stress field asperity in terms of spatial and temporal variations of b-values for the first time using earthquake data from the GeoNet catalogue consisting of 17231 events with Mw 3 from January 2000 to July 2020. The b-values are computed using the maximum -likelihood method on a spatial grid of 0.050x 0.050, taking into account overlapping circular volumes with a minimum of 150 nearby events on each node. The temporal variation of b-values is calculated using a moving window of 250 events with a minimum of 50 events and a 10% event overlap. The pre-seismic spatial distribution of b-value indicates the presence of two distinct low-b-value clusters, one to the southwest, closer to the epicenter, and the other to the north of the rupture zone. Because of the stress release near the epicentral area during the co-seismic period, the pattern of prominent low b-value pattern has become negligible in the post-seismic period. However, the pattern of low b-values to the north of the rupture zone has not changed in the post-seismic period. This could be an indication of unreleased strain energy in the province. The temporal distribution of b over the period also shows an analogous pattern in which the b-values were significantly decreased prior to the large earthquakes in the study region.

Keywords: Gutenberg-Richter relation, b-value, 2016 Kaikoura earthquake, spatial and temporal variation

SEASONAL VARIATIONS AND INFLUENCE OF LAND COVER ON SURFACE URBAN HEAT ISLAND INTENSITY OVER THE GANGETIC PLAINS

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ABSTRACT

Urbanization and subsequent modification of local climate is well documented phenomenon across the world. The ill impacts of urbanization cause severe changes in local environment by increase in local pollution concentration, changes in land cover and formation of urban heat islands. Spatially the remote sensing data provides an opportunity to visualize the Urban Heat Island (UHI) across different spatio-temporal scales and provide capabilities to know the seasonal trends in the urban climatic variables with the reference to the local Land Cover (LC). The Surface Urban Heat Island (SUHI) is a microscale phenomenon, which is well governed by local factors like LC and exhibit a seasonal pattern too. For the present study, the night-time Land Surface Temperature (LST) from Terra-MODIS is used to envisage the UHI over different cities of the Gangetic plains. The Terra-MODIS satellite due to its greater available temporal span and early overpass time can very accurately visualize the trapped heat within the urban structures. Therefore, the possible influence of land cover on SUHI and the seasonal trends of SUHI are analyzed. It is found that the LC has a vital role in determining the intensity of SUHI. The regional influence on the formation and the magnitude of SUHI has also been envisaged in the study.

Keywords: SUHI, Gangetic Plains, Terra-MODIS

Progressive changes in Land Use and Land Cover Dynamics and their Impacts on Ecosystem Service in Himalaya

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ABSTRACT

Land use and land cover (LULC) changes are regarded as one of the key drivers of ecosystem services degradation, especially in mountain regions where they may provide various ecosystem services to the local sources of revenue and surrounding areas. Western Himalaya is an important region in terms of its enriched biodiversity and immense ecosystem services (ESS). However, its biodiversity and ESS are under tremendous pressure from rapid population growth, developmental activities, unplanned urbanization, agricultural expansion, climate change, and the associated changes LULC. Here, the study quantifies the changes in LULC and its associated impact on ESS between 2000 to 2020 using Landsat-5 Thematic Mapper (TM), Landsat-7 Enhanced Thematic Mapper Plus (ETM+), and Landsat-8 Operational Land Imager (OLI) top-of-atmosphere (TOA). The results suggest that a general decrease in forest cover and an increase in forest fragmentation along with generally increasing trends in built-up areas, croplands, and barren lands. These results imply ecosystem degradation and a reduction in the potential for the sustainable flow of ESS from this region.

Keywords: land use and land cover, ecosystem service value, forest fragmentation, Climate Change

NOWCASTING OF STORMS FROM GNSS SATELLITE BASED PRECIPITABLE WATER VAPOR DATA USING MACHINE LEARNING APPROACH

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ABSTRACT

Accurate estimation of PWV is mandatory for quantitative precipitation forecasting. With the advancement in GPS remote sensing, it is now possible to precisely estimate the precipitable water vapor (PWV) in the atmosphere. The objective of this work is the exploitation of GNSS signals for forecast of PWV and nowcasting storms using machine learning model for shorter time horizons. For continuous monitoring of PWV, GNSS receiver network is established in Gadanki(13.4593°N, 79.1684°E) and nearby regions, India. Automatic weather station located at Gadanki is used for parameters like temperature, humidity, soil temperature and soil moisture while ERA-5 Model re-analysis data based wind speed is taken for 8 discrete pressure levels to calculate vertically integrated moisture flux. A gradient booting machine based approach is developed for nowcasting of storms based on the forecast of PWV using data from multiple GNSS receivers established during 2019. Further feature engineering has been done on the dataset to improve the performance of model by performing null hypothesis testing with 95% confidence level. Results suggest indicate the potential capability of machine learning models in predicting PWV for 30, 60, 90 and 120 minutes in advance with good accuracy. Strong enhancement in PWV is observed 2-6 hours prior for different scale storms with sudden fall of Temperature and increase of wind speed during rainfall. Results obtained through this approach can be utilized for better weather forecasting and anticipating storm events.

Flood Hazard Risk Area Mapping: Physical Susceptibility Zonation of Adayar Watershed, Tamil Nadu, India

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ABSTRACT

Chennai city in India experienced some historic rainfall events in the past and associated flooding, particularly in 1976, 1985, 1996, 2005, 2008 and 2015. This resulted in extensive flooding of the low-lying areas along the Adayar river course, particularly at Anakaputhur, Nesapakkam, Jafferkhanpet, Saidapet, and Kotturpuram neighbourhoods in Chennai. River flooding in Chennai is caused mostly by the formation of cyclones during northeast monsoon (October-November-December) and is often associated with intense rainfall in a couple of days. People interviewed for this research study also indicated that flooding occurred on occasions when Chembarambakkam Lake had excess of inflow, which was released to avoid the breaches of the bunds. In order to understand the flood potential and the physical vulnerability of the Adayar watershed, rainfall, size of the watersheds, land use, hydrological soils, and infrastructures (road network) in the watersheds were mapped in GIS environment and weightage analysis was performed to categorize the physical vulnerability of the Adayar basin. Using raster overlay analysis in ArcGIS, physical vulnerability to flooding in ranges from very low (weightage 2), low (weightage 3), high (weightage 4) to very high (weightage 5) was mapped. This analysis helps the authority to identify the flood prone areas to take appropriate measures to minimize the damage potential incurred by floods. From this study, it is also clear that the areas falling within the Chennai Corporation are exposed to high flood frequency due to factors such as high population density, flat terrain, and large number of populations living along the river banks and are being flood-prone and vulnerable for floods.

KEYWORDS: Flood hazard, Multi-criteria analysis, Physical vulnerability, Weightage

Wayback Imagery: Review and its Advantages

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ABSTRACT

Historical maps have been created in the past to depict the snapshots of the physical and cultural features of the timeline of a country. In India, topographical features of the Earth's surface were mapped in the past and presented in the form of Toposheets. Availability of Toposheets on different scales in multiple grids being used as a standard reference by the urban planners, surveyors, academicians, and policymakers, etc., Remote sensing and GIS technologies have changed the way towards topographical survey in the present world scenario. Satellite data with spatial resolution ranging from low, medium, high and very high are available in India which helps us in understanding the never-ending dynamic topography. The most important limitations behind the satellite data are, very high resolution satellite images of less than 10 m are not available as open-source. These images are not affordable and involving complicated analysis in the preparation of change detection maps. Google Earth historical images are available through the Google Earth software, but these images can't be used as base maps since it is very difficult to extract and perform the process of georeferencing. Environmental Systems Research Institute (ESRI) started giving "Wayback" imagery from 2014 onwards at frequent intervals, having very high spatial resolution as ArcGIS portal items. It can be effectively utilized for multiple purposes and mainly to do quick study on the change in topography of our Earth. The images available are georeferenced and in the WGS1984 datum. In this present study an attempt has been made to review the advantages and applications of Wayback imagery which will be helpful in various studies like urban topographical changes; Grazing lands/waste lands, Agricultural lands, Water Bodies, Vegetation / Forest, etc. and Land Surface Temperature studies etc.

Keywords: Historical maps; Toposheets; Topographical Maps; Google Earth Historical Images; ESRI Wayback Imagery; Land Surface Temperature.

Grid point INSAT cloud climatology over India and neighborhood using a simple multi layer Convolution Neural Network (CNN) model

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ABSTRACT

INSAT program has more than 30 years of multi-channel image data with high temporal and spatial resolution thus providing an opportunity of research into the automation of climatology of clouds associated with different weather systems over India and neighborhood at 1 degree latitude and 1 degree longitude rectangular grid points. In this paper it is reported about an image processing Deep Neural Network (DNN) model called Convolution Neural Network (CNN) to train on 6-channel INSAT cloud imagery data sets ['WV', 'MIR', 'IR2',' IR1', 'SWIR', 'VIS'] to recognize cloud patterns as reported from manned IMD surface observatories and to perform automatic grid point cloud classification. Real Time Analysis of Products and Information Dissemination (RAPID) version 2 website of IMD/ISRO provided images with 4-Dimensional analysis capabilities. 5 stages of processing was followed with every picture: a) Image downloading , b) Image georeferencing, c) Creating a model, d) Learning the model parameters and e) Evaluating (a.k.a. testing/prediction) the model. INSAT cloud imagery corresponding to 06 UTC was used both for training and testing of the model to ensure availability of both visible and SWIR channels and also for validating with surface observations reporting observed cloud types from the departmental surface observatories of IMD. Input data is formatted in the form of text files. Each line of these text files takes the form: |labels 0 0 0 0 0 0 0 0|features 0 0 0 0 ... (6 x 9 x 9 integers each representing a pixel). Image pixels corresponding to the integer stream named "features" are used for training as well as testing of the model. Thus the number of features is equal to 486 (6 x 9 x 9 pixels), 1 per pixel. This simple model is configured to detect 8 cloud types (low, low+medium, low+high, medium, medium+high, high, low+medium+high and no cloud) in the INSAT picture representing 8 labels in the input data. Microsoft Cognitive Toolkit (CNTK) frame work in Python is used for data reading and to experiment with Convolution Neural Network model. Three convolution layers comprising 8, 32 and 128 filters respectively each having a weight and bias followed by a dropout layer (0.2) are used to prevent over-fitting. It trained with 6 x 9 x 9 size pixels located over latitude and longitude of a surface observatory reporting synoptic cloud types and tested and evaluated unknown INSAT images at grid points with an average accuracy of more than 75 percent.

Keywords: INSAT, CNN, Classification, Climatology

APPLICATION AND CHALLENGES IN FLOOD AND DROUGHT MITIGATION USING GEOLOGICAL DATA

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ABSTRACT

India receives around 4000 billion cubic meters (BCM) of water every year in different forms of precipitation. The amount of water is more than enough to satisfy all the needs of the country. But we are continuously suffering from water scarcity as all the excess amount of water is lost as sea water due to intense rainfalls in short durations and lack of water management. Hence dependency on groundwater is increasing rigorously resulting into over exploitation of ancient non-renewable sources. Building surface water storage adversely affects society, economy and climate, so there is more need of exploring potential ground water storage sites than discovering sources for sustainable management of the resource. In order to achieve this, there is requirement of high-resolution earth observation data in the respective fields. The most important data required for the management are geological and Digital Elevation Model (DEM). NASA earth explorer provides free DEM of 90-meter resolution, but there is no such source of geological data. To communicate potentials of geological data, in this paper, a small test area is considered and resistivity data is collected using transient electromagnetic (TEM) method. Thematic maps of the surveyed area based on various surface parameters viz. temperature, DEM, soil type, vegetation indices, water indices and subsurface parameters viz. Soil depth, infiltration capacity, depth wise aquifer map are prepared. Soil depth, infiltration capacity and aquifer map are based on resistivity data. The prepared maps locate the highest potential storage site irrespective of DEM elevation and infiltration capacity. In order to recharge the aquifer located at high DEM elevation and greater depth there is need of artificial recharge technique. In conclusion, availability of high-resolution geological data will help in mitigating effects of climate change like droughts and floods.

Keywords: Digital Elevation Model, Geological Data, Aquifer, Artificial Recharge

Overview of Big data tools & techniques and their application in weather forecasting over the Indian region

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ABSTRACT

Weather forecasting has consistently been tricky because of several variables associated and the complicated connections among those variables. It utilizes technology to anticipate the weather for a given area, dependent on past or current data as accessible. Recently it has been getting a lot of importance owing to the increase in extreme weather events. A considerable amount of weather data is being recorded regularly at different sites and hours. This drastic rise in the capacity to gather and process the data has strengthened the weather forecasters' potential to accurately predict the severity of phenomena like floods, thunderstorms, dust storms, and other weather events. Utilizing conventional methods to study the information has become very traditional. This vast information makes weather forecasting an optimal possibility for Big Data innovation. This study explores various tools and techniques of Big data in weather data analysis to enhance the forecast skills over the Indian region.

Keywords: Big Data, Weather, data analysis, forecast

GENERATION OF GRAPHICAL PRODUCTS FOR WEATHER BULLETINS AND REPORTS USING QGIS – A NEW INITIATIVE

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ABSTRACT

The significance of weather information is growing because of the need to serve more elaborate societal needs, minimize loss of life and property. Weather impacts the society through its influence on several economic activities like agriculture, water, power, industry, infrastructure development, fishery, transport, health, tourism, etc. India Meteorological Department (IMD) issues various types of daily weather bulletins and weekly weather reports, to warn against severe weather phenomena. The weather bulletins and reports contain text, table and figures which represent the observations, forecasts and warnings. The graphical part is included in these bulletins from various sources which are based on proprietary software. Efforts have been made to automate the generation of the graphics which are used in bulletins and reports at a single place by using QGIS, a cross-platform free and open-source desktop geographic information system (GIS) application and latest shape files procured from Survey of India (SoI). The observation products are maximum & minimum temperature, departure of maximum & minimum temperature from normal, subdivision wise realized maximum temperature, minimum temperature and rainfall, distribution of 24 hours cumulative rainfall and monsoon activity with respect to Long Period Average (LPA) etc. The forecast and warning graphical products include subdivision wise daily rainfall forecast, daily rainfall warning, weekly rainfall forecast and warnings etc. Some new graphical products generated are being used in daily special monsoon report in year 2021 and also put on IMD social media platforms. It has resulted in better visualization of the weather bulletins and reports. The method will reduce the dependency on more than 10 years old systems procured by IMD under modernization phase-I and now they have become old and need replacement. It has been planned that the whole process for generation of bulletins will be automated which will reduce the time and efforts of the forecasters in preparation of weather bulletins and reports.

Keywords: Weather bulletin, Weather report, QGIS, GIS

ANALYSIS OF URBAN GROWTH OF AHMEDABAD CITY USING REMOTELY SENSED IMAGERY.

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ABSTRACT

Urbanization is necessary to achieve better standard of living. Urbanization is mainly indicated by change in land surface feature. Remotely sensed imagery is ideally used to discover and detect land cover changes that occur routinely in urban and suburban areas as a consequence of perpetual urbanization. This article targets on the quick urbanization of Ahmedabad city using multi-temporal Landsat TM data from 2000 to 2020. Spectral indices such as Normalized Difference Vegetation Index (NDVI) and Normalized Difference Built-up Index were generated from Landsat TM bands. Built-up areas are effectively mapped through arithmetic action of re-coded NDBI images obtained from TM imagery. The devised NDBI method was applied to map urban land in the city of Ahmedabad, Gujarat. The mapped results indicate that 101.92% urbanization has increased in 2 decades of time period whereas, vegetation area has decreased 25.54%. Growth in urbanization also indicates surge in population over the years adding to it, which also stipulates how much emission of Green House gas such as CO has ascended.

Keywords: — Landsat TM, Normalized Difference Vegetation Index, Normalized Difference Built-up Index, TM imagery

A comparative study of reference evapotranspiration estimation between WRF downscaled and NASA-power data over agriculture area of Varanasi

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ABSTRACT

Estimation of Reference evapotranspiration (ETo) is an important component for the hydrological, agro-meteorological and water resources management related studies. One of the most successful method which recommended by FAO, The Penman-Monteith method was used in the presented study for the estimation of Reference Evapotranspiration. In The presented study NASA/POWER and National Centre for Environmental Prediction (NCEP) downscaled global reanalysis data were used for the estimation of Reference Evapotranspiration (ETo)and compared with the observed data (2009-2016). Dynamical downscaling was done using Weather Research and Forecasting (WRF) model. Various types of performance indices were estimated such as correlation (r), bias and root mean square error (RMSE), which showed the values 0.780, 0.208, and 1.215 for NCEP downscaled data and 0.571, 0.269, and 1.270 for the NASA-POWER data respectively. The results indicated that WRF downscaled data was showing satisfactory performance with observed data. So, NCEP- WRF downscaled data Further can be used for ETo estimation, especially in the ungauged areas.

Keywords: Evapotranspiration, NCEP, WRF, Performance indices

Scientific aspects of recent developments in South Asia Flash Flood Guidance System

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ABSTRACT

Flash floods are one of the world's most destructive natural disasters, with more than 5,000 lives lost yearly, resulting in critical economic, social, and environmental impacts. To mitigate the adverse effects of flash floods, the South Asia Flash Flood Guidance System (SAsiaFFGS) has been operational from October 2020 in India and the member countries, i.e., Bangladesh, Bhutan, Nepal, and Sri Lanka. The system has been running in the pre-operational mode in India Meteorological Department (IMD) since 2018. Since its inception, the system has been updated and improved based on the feedback received from the member countries and other stakeholders for better and accurate flash flood guidance. For every hydrological system, it has been found that observations play a very crucial role in improving the skill of the forecast. Also, the higher the resolution of the Numerical Weather Prediction (NWP) model, the better the flash flood guidance at the watershed and block level. In this paper, scientific aspects regarding rainfall observations, NWP models, higher watersheds delineations, radar integration, etc. are discussed for improvement in the SAsiaFFGS.

Keywords: FFGS, Flash Floods, Rainfall observations, NWP, Radar.

Quantifying the land use land cover changes over Western India using Landsat over the last three decades

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ABSTRACT

The Western coast of India has Western Ghats running parallel to the coastline and spanning the states of Tamil Nadu, Karnataka, Kerala, Goa and Maharashtra. It is a region of significance from ecological as well as climate perspective. It plays a key role in concentrating rainfall over the west coast region and is a hotspot of biodiversity. However, Western Ghats has undergone significant changes in its land use and landcover (LULC) due to human interventions. These changes can be quantified ideally using satellite imagery. In this work, we quantify the land use land cover changes over some Landsat scenes in the West-Coast region for the years 1995, 2000 and 2017.

Keywords: LULC, Landsat, West-Coast

Image Gallery: A tool for synoptic meteorology

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ABSTRACT

Quick visualization of satellite images helps synoptic meteorologist for analysis and prediction of large-scale weather systems. Meteorologist use this information for study of current weather and for the forecast prediction. Animation of satellite images helps in tagging events with time and for study of their growth or progression. With the advancement of mobile internet, there is a requirement for light-weight visualization system.

This paper describes the design and optimizations carried out for development of light-weight visualization of satellite images. Image Gallery provides animated view of satellite images for the selected duration. Currently it provides visualization from INSAT-3D, INSAT-3DR, Scatsat-1, Weather forecast, Sea state forecast and Doppler Weather Radar. This tool is built upon the *Single page architecture,* which gives the flexibility to the webpage to load only the image component and not the whole page. It is fast, responsive and has caching capabilities and hence all html/css/javascript are loaded only once. A web service run on the server, which provides the latest imagery animation to the client. For the fast visualization of images, data is encoded in compressed JPEG format, this provides fast data visualization. This gallery can be visualized on any device viz mobile/tablet/laptop/desktop/TV screen etc.

This single page architecture, with caching enabled on the contents provides a reduction of size upto 80% and provides a fast visualization across all the devices.

Keywords: Image gallery, Visualization, Satellite Images, Weather Forecast, synoptic meteorology

SEASONAL VARIABILITY OF REFRACTIVITY OVER COCHIN

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ABSTRACT

This study investigates the anomalous propagation of radio waves over Cochin (10.04 °N, 76.33 °E, and 33m above mean sea level). During warm weather, radio signals will have problems with signal drops and interference due to long-lasting propagation, particularly on hot days. A high vertical gradient in temperature, humidity, and atmospheric pressure may be contributing to this feature. Vertical profile of atmospheric refractivity can be used to analyze this effect qualitatively. The Earth's curvature will affect refractivity, allowing us to better understand it using modified refractivity. In this paper, more than 300 radiosonde profiles since 2018 are statistically analyzed. Then the modified refractivity is analyzed by season to understand the differences with respect to season. Special consideration is given to seasonal variations in refractivity at the surface, planetary boundary, and tropopause levels. Throughout the year, surface ducts are very prominent over the region, with an average thickness of 50m. Observations indicate that elevated ducts occur up to a height of three kilometers. Observations of ducting during solar eclipse days have been examined. For comparison, refractivity is also calculated from the humidity and temperature profiles derived from microwave radiometer.
Keywords: Anomalous propagation, Ducting, Refractivity, Radiosonde.

ASSESSMENT OF SPATIAL AND TEMPORAL CHANGES OF SURFACE URBAN HEAT ISLAND IN THE CITIES OF KERALA

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ABSTRACT

The urban heat island (UHI), the phenomena by which the urbanized areas experience relatively warmer temperatures compared to suburban areas, is major evidence of anthropogenic impact on urban climate. It has potential health effects such as mortality due to high temperatures and heat waves. Additionally, UHI demands more energy, required for running cooling systems such as air-conditioners that would generate greenhouse gas emissions. This study presents a comprehensive analysis of surface urban heat island, during both day and night and across all seasons, of cities in the state of Kerala, India, using high spatial (LANDSAT) and temporal resolution (MODIS) satellite observations. The land surface temperature (LST), retrieved using thermal infrared (10.78–12.2 microns) by means of split-window algorithm, is used as the indicator of UHI. The difference in LST of urban and surrounding rural areas is defined as the surface urban heat island intensity (SUHII). A significant UHI exists in these cities with an annual mean SUHII of 1 – 2 °C during day and 0 – 1 °C during night. The cities of Trivandrum and Thrissur show a significant positive trend in SUHII for summer and winter during both days and nights. The analysis of LANDSAT data confirms rapid urbanization that happened in the state during past two decades. Construction of new impermeable urban infrastructure happens at the expense of clearing vegetated areas enhances UHI. The analysis of UHI hotspots supports that increased human activities are amplifying the effects of UHI. Therefore, the results of this study are expected to be key for devising effective urban planning strategies in the future in a perspective of UHI mitigation.

Keywords: Anthropogenic forcing; Climate change; Land surface temperature; MODIS;

Co-seismic Ground Deformation and Ionospheric Perturbations Associated with the Recent Mw 8.2 Alaska Earthquake

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ABSTRACT

Earth, Ocean, and Atmosphere are all part of a coupled system. Energy transfer occurs when any of these systems are subjected to a natural triggering. Similarly, a small part of the released energy is transferred from earth/ocean to the atmosphere when an earthquake occurs. In general, pressure waves produced by large earthquakes generates mechanical waves in the nearby atmosphere, which propagate to ionospheric altitudes and cause Co-seismic Ionospheric Perturbations (CIP). The recent Mw 8.2 Alaska Earthquake, which occurred on July 29, 2021, was instigated by a thrust faulting on or near the subduction zone interface between the Pacific and North American plates. This earthquake's rupture propagated to the east-southeast of the epicenter. Further, the GPS static displacements are used to study and constrain the associated co-seismic deformation. In the present study, we looked into the characteristics of the ionospheric electron density perturbations caused by this event. Previous research has shown that earthquakes with magnitudes greater than 6.5 (Mw>6.5) can cause detectable ionospheric perturbations. Using Total Electron Content (TEC) derived from dual frequency Global Positioning System (GPS) data, we investigated the characteristics of CIP associated with the Mw 8.2 Alaska earthquake. A bandpass filter of 1 – 10 mHz is applied to the TEC time series to highlight the desired signals. Signals having significant amplitudes are recorded in multiple satellites from different GPS stations. Studies report that, usually the rupture propagation and CIP correlates fairly well. However in the present study reveals that the distribution of ionospheric signal amplitudes does not match the ground deformation pattern. We modelled the effects of the geomagnetic field and background ionization density, which have a significant impact on the evolution of CIP at ionospheric heights, to figure out why this particular behavior exists. The combined effect of these two parameters is identified as the driving force behind the particular CIP distribution.

Keywords: Alaska Earthquake, Co-seismic ground deformation, Co-seismic ionospheric perturbations, GPS-TEC.

Estimation of Granite Quarrying in Selected Area of Kanakkari Village,Kottayam District using Geospatial Technology

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ABSTRACT

Kottayam district is one among the leading granite quarrying area in Kerala and 13.86 Ha of area is excavated during 2016-17 period(District survey report of minor minerals,2016). The study was carried out for Department of Mining & Geology to identify the rock quarrying and assess the geographical area outside the lease area of resurvey no. 349/6, 349/7, 350/3, 350/4, 350/6,350/7,350/8, 350/9 and 350/10 in Kanakkari Village during 1960-2020 periods. The study area falling in Block no.11 of Kanakkari Village, Meenachil Taluk, Kottayam district at an elevation of 123m from MSL. The quarry is located in eastern side of the Village, latitude and longitude 9 0 41' 30.01"N and 76 0 34' 22.99"E. Charnockite type of rock is present in the hill. The land use classes of the village are Mixed plantations, Agriculture plantation (Rubber), Double crop (Paddy), Fallow land and River/water bodies. Data sources are Survey of India Toposheet (1967), IRS P6 LISS-IV Data(2006) , IRS P5 Cartosat-1 PAN Data (2010), Google Earth Imagery (2011, 2013, 2016, 2019 & 2020) Methodology involves Scanning of FMB , plotting of quarry boundary, georeferencing of resurvey boundary with cadastral data, digitization of resurvey boundary, downloading imagery from Google Earth, spatial adjustment of survey boundary with Google earth imagery, mapping of rock quarrying from Survey of India Toposheet (1967) and high resolution Satellite imageries through visual interpretation technique. Through overlay analysis, geographical area of rock quarrying during different periods were estimated. The study using Toposheet shows no quarrying during 1967. The geographical area of rock quarrying seems to be increasing during 2006-2020 period. The total area of quarry during 2006, 2010, 04-02-2011, 26-04-2013, 01-03-2016, 04-01-2019 and 21-12-2020 are 5,284.4 m 2 , 8,234.47 m 2 , 9303.42 m 2 , 12,524.06 m 2 , 19,497.59 m 2 , 21,468.74 m 2 and 21,874.20 m 2 .

Keywords : Quarry, cadastral boundary, overlay analysis, high resolution satellite data

Changing Geo-spatial Scenarios of Fluoride Pollution in Groundwater of Bankura District, West Bengal, India: Scope for Environmental Analytics and Sustainable Water Management

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ABSTRACT

The sub-surface rock-water interaction of Bankura district in West Bengal is interlaced with occurrence of deadly fluoride, and represents a grim exemplar of geogenic pollution in eastern India. Latest reports (2019-20) indicate that 14 out of 22 blocks of Bankura are fluoride-affected (> 1.0 mg/l) covering 202 villages and 218 habitations. Hydrochemical analyses were undertaken to correlate fluoride with key water parameters like pH, iron and Total Hardness that are known to influence fluoride mobility. Health surveys conducted amongst groundwater end users have revealed prevalence of dental and skeletal fluorosis which corroborates the earlier hydrochemical findings of the study area. As fluoride endemicity spreads day by day, proper understanding of nature and pattern of pollution fabric has become necessary for evolving of sustainable water management plan of the region. Geospatial maps of fluoride and related hydrochemical parameters were developed to portray the emergence, spread and changing pattern of fluoride pollution over the last decade across inventoried network of 6396 tubewells in the entire district. Principal Component Analyses and Hierarchical Cluster Analyses were applied to comprehend multivariate data matrix and derivation of biplots corresponding to 22 blocks of Bankura for clear visualization of hydrochemical data. Two Principal Components (PC1 and PC2) were found to dominantly influence the distribution of fluoride in groundwater. Surveys revealed that high fluoride is the result of desorption and leaching of fluoride-rich country rocks, alkaline hydrochemistry of participating groundwater, physico-chemical effects of weathering, strong evaporation under arid controls of climate change, and anthropogenic interferences. Formation of ultra- high fluoride groundwater was noted in close proximity of hydrologically significant fracturezones. Further research is recommended based on big data, deep learning, neural network, artificial intelligence and IOT-enabled sensors for holistic understanding of the source, fate, pathways and transport of fluoride pollution in the project area.

Key Words: fluoride, geo-spatial, hierarchical cluster analyses, principal component analyses

VALIDATION OF SATELLITE-BASED PRECIPITATION PRODUCTS OVER TAMIL NADU

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ABSTRACT

In this study, Integrated Multi-satellite Retrievals for Global Precipitation Measurement (IMERG), Tropical Rainfall Measuring Mission (TMPA) daily product (or 3B42), Climate Hazards Group InfraRed Precipitation with Stations (CHIRPS), and Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN) were used to evaluate the accuracy of rainfall amount and spatial distribution over Tamil Nadu. The monthly and seasonal precipitation data were compared during North-East Monsoon (NEM) season (Oct-Dec) between 2015 and 2017. The ground data was collected from Tamil Nadu Agricultural Weather Network (TAWN) established by Tamil Nadu Agricultural University (TNAU) in Tamil Nadu. Statistical indices such as Pearson's Correlation Coefficient (CC), Root Mean Square Error (RMSE), Mean error (ME), Mean Absolute Error (MAE), and Percent of Bias (PB) were used. Point to point evaluation result showed that IMERG and TRMM 3B42 rainfall products have showed better correlation (CC > 0.6). In the monthly time scale, IMERG has shown better correlation (CC > 0.96), while in the seasonal time scale, CHIRPS showed a good correlation (CC > 0.77). Mean Error (ME = −5.00 mm) and Root Mean Square Error (RMSE = 60.72 mm) at seasonal scales indicated that GPM IMERG performance was highly significant. Four precipitation products based on satellites showed significant seasonal resemblances compared to a monthly scale. This comparison study showed that GPM IMERG and TRMM 3B42 performed better and would be a valuable replacement for precipitation data from the rain gauge.

Keywords: North-East Monsoon, Satellite precipitation, Validation, Statistical indices

ANALYSIS OF INTERCONNECTION AMONG VEGETATION COVER, PRECIPITATION AND LAND SURFACE TEMPERATURE OVER INDIA USING GEO-SPATIAL TECHNIQUES AND EARTH OBSERVATION DATA SETS

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ABSTRACT

Now a day's use of geospatial techniques to study the responses of vegetation dynamics with respect to the seasonal variations in meteorological factors has been gaining more attention among researchers. This study probes the interconnection among vegetation cover, precipitation and land surface temperature during pre-monsoon, monsoon and post-monsoon seasons over India. Satellite based datasets of normalized difference vegetation index (NDVI) & land-surface temperature (LST) has been obtained from MODIS and precipitation data has been taken from IMD & TRMM for the period of sixteen years i.e. 2000 to 2016. The observed precipitation data of IMD has been compared with the satellite based precipitation data of TRMM by the means of statistical analysis viz. RMSE, biasness and correlation coefficient. The correlation analysis of IMD and TRMM precipitation data shows higher value for the monsoon season especially over North-East regions and Western Ghats. Further the correlation coefficient analysis between NDVI, LST and precipitation have also been performed for finding the degree of impact of LST and precipitation on NDVI. The result shows that the correlation coefficient between vegetation index and land surface temperature is least during the pre-monsoon season whereas correlation coefficient between vegetation index and rainfall is at peak during the monsoon season. Thus the study reveals that the vegetation cover gets influenced more by the precipitation especially during monsoon and post-monsoon than the land surface temperature over India.

Keywords: Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI), TRMM -Precipitation, Remote Sensing and GIS

AN ASSESSMENT OF THE IMPACT OF LAND USE LAND COVER DYNAMICS ON SOIL EROSION RATE IN THE BETWA RIVER BASIN, CENTRAL INDIA

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ABSTRACT

Ever growing human population and associated land use activities have accelerated the rate of soil erosion to a greater or lesser extent in almost all parts of the earth. Assessing the impact of LULC dynamics on rate of soil erosion in a river basin is therefore imperative for soil conservation and sustainable river basin management. Hence, this study aims to measure the impact of LULC dynamics on rate of soil erosion in Betwa River Basin of Central India using GIS-based Revised Universal Soil Loss Equation (RUSLE) model. The LULC dynamics of the basin for the study period (1995-2015) has been processed using multi-temporal Landsat data. The RUSLE parameters namely rainfall erosivity (R factor), soil erodibility (K factor), slope length and steepness (LS-factor), cover-management (C factor), and support practice (P factor) has been derived from both remote sensing and ancillary data. The soil erosion rate has been calculated using pixel overlay method within GIS environment. Further, the RUSLE outputs have been validated with the ground based gauge observation data of Central Water Commission (CWC), India. LULC dynamics shows that over the study period water bodies and dense forest area decreases significantly by 0.062% and 4.71 % respectively whereas agriculture, open forest and builtup area increases by 1.52%, 2.59% and 0.97% respectively. Low soil erosion rate (16.55 $t\ ha^{-1}\ yr^{-1}$) has been recorded from the dense forest area while high rate of soil erosion (40.48 $t\ ha^{-1}\ yr^{-1}$) has been found in hilly open forest area along the upper west portion of the basin. This study provides relevant information about the impact of LULC dynamics on rate of soil erosion and would be an aid and source for the sustainable development of Betwa River Basin.

Keywords: Land Use Land Cover, Soil erosion, Revised Universal Soil Loss Equation, Remote Sensing and GIS

WAC

Water Resources, Agriculture and Climate Change

Spatio-temporal variability of atmospheric carbon dioxide in relation with agricultural activities in India

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ABSTRACT

The ongoing climate change could be evaluated by analyzing the concentration of atmospheric CO_2 originating from industries and intensive agricultural activities. We analyzed and present the long-term changes in CO_2 concentrations between 2009 and 2020 in India using GOSAT satellite measurements. Our analyses provide a better understanding of the spatio–temporal variations of CO_2 over India during agricultural seasons in relation to biomass burning, NDVI and anthropogenic activities. Atmospheric CO_2 concentration in India shows a significant increasing trend of 2.42 ppm/year from 2009 to 2020. Anthropogenic activities such as increased use of coal, fossil fuels and biomass burning events are the factors that significantly drives these temporal trends of CO_2 in India. We found out that the CO_2 concentration is lowest during the kharif (JJAS) season. We observed that vast stretch of vegetation in India during kharif season might be acting as a strong sink for atmospheric CO_2. However, it reaches its peak during the zaid (MAM) season in India because of fallow croplands due to the unavailability of own farm irrigation facilities. Our pilot-scale agricultural nutrient management experiment suggests that stable carbon alternatives like biochar can reduce the soil CO_2 emissions without losing grain yield in paddy. Therefore, our study also proposes measures to mitigate soil emissions through agricultural management, which help in reducing CO_2 emissions from agricultural lands in India.

Keywords: Climate Change, Carbon Dioxide, Agriculture, Greenhouse gas emissions

CLASS A PAN COEFFICIENT (Kp) TO ESTIMATE REFERENCE EVAPOTRANSPIRATION (ETo)

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ABSTRACT

When using the evaporation pan to estimate the reference evapotranspiration (ETo), in fact a comparison is made between the evaporation from the water surface in the pan (Epan) and the evapotranspiration of the standard grass. Epan is multiplied by a Pan coefficient (Kp) to get the ETo values. Kp depends on (i) the type of pan used, (ii) the pan environment, if the pan is placed in a fallow or cropped area, and (iii) the climate : the humidity and wind speed.

The direct measurement methods used for calculating crop water consumptions are expensive and time consuming and for the coming years due to global climate change, estimation using climate data will become more important. Pan evaporation method is useful for getting results in a short time in irrigation scheduling in terms of technical facilities and easy adaptation to climate change. Here we have arrived at the Kp values of two stations in the humid region, Kottamparamba in Kozhikode and Mannuthy in Thrissur district of Kerala State, using the historical data for a period of 25 years. Kp value for both the station is found to be maximum during rainy season and minimum during summer month. For Kottamparamba station Kp varies from 0.91 (in March) to 1.21 (in October) and at Mannuthy from 0.65 (in January) to 1.03 (in October). The Mann-Kendall trend analysis shows significant increasing trend for Kp values for both the stations. Although calculating ETo using Epan data is considered less reliable than using the FAO56-Penman Monteith equation, Epan data are widely available and is useful for calculating average values of ETo over several days especially for water resources planning and irrigation scheduling. Hence this study will be useful for getting the crop water requirements for areas in humid regions were climate data is not readily available.

Keywords: Crop water, Evaporation, Pan coefficient, Climate change

Linking nitrous oxide emission and functional soil microbes from rice soil exposed to elevated carbon dioxide: a modelling approach

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ABSTRACT

Understanding the effect of elevated atmospheric CO_2 (eCO_2) on nitrous oxide emission (N_2O) and plant-microbe interactions in rice soils is of great significance for predicting the long-term response of rice ecosystems to eCO_2 concentration. Elevated atmospheric CO_2 concentration has the potential to augment rice production and alter the soil nitrogen (N) dynamics. Because N_2O emission is controlled by microbial activity, we reasoned that changes in soil N chemistry and activity of soil microbes may affect N_2O flux from rice soil. In this study, path analyses using partial least square path modelling (PLS-PM) approach was used to distinguish the direct and indirect factors influencing N_2O emission under ambient and elevated CO_2 conditions. We designed a field experiment to examine the influence of eCO_2 on N_2O emission from rice soil under different water regimes and N doses. Percent increase was found for labile N fractions such as microbial biomass-N (32%; $p \leq 0.03$) whereas percent decrease was found for NH_4^+-N (40%; $p \leq 0.0005$) and NO_3^--N (32%; $p \leq 0.001$) concentration under eCO_2 over ambient CO_2 (aCO_2). Rhizospheric denitrifier population was increased (39%; $p \leq 0.001$) whereas, nitrifier population decreased (41%; $p \leq 0.001$) under eCO_2 as compared to aCO_2. Exposure of eCO_2 decreased (20%; $p \leq 0.001$) N mineralization whereas it increased N_2O emission (43%; $p \leq 0.001$). Elevated CO_2 level increased activities of β- glucosidase, urease, dehydrogenase and Fluorescein diacetate showing significant effects on soil N dynamics. Path modelling indicated that under aCO_2 condition nitrogen mineralization, NH_4^--N and NO^-_3-N concentration were significantly ($p < 0.001$) and positively correlated with N_2O emission, whereas under eCO_2 condition nitrogen mineralization, nitrification potential and microbial population were significantly ($p < 0.001$) and positively correlated. Regression analysis revealed complex interactions among the important variables influencing N_2O emission under ambient and elevated CO_2 conditions.

Keywords*:* Elevated CO_2, Nitrous Oxide Emission, Water Deficit Stress.

Estimation of Soil Erosion and Sediment Yield in Manikpur coalfield area, Chhattisgarh, India

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ABSTRACT

Manikpur coal field area is located in Korba district of Chhattisgarh state of India and is spread over 300 km^2 area. Soil erosion is one of the major problems in India. Most Opencast mines releases huge amount of mining wastes as OBD materials that are prone to soil erosion and creating problems of sedimentation and water quality, affecting agriculture around the Manikpur coalfield area. Soil erosion and sediment yield is modeled in two ways in this study. 1. Direct Method 2. Empirical equation of Revised Universal Soil Loss Equation (RUSLE) and Sediment Delivery Distributed Model (SEDD). Direct field measurements were employed to observe Hasdeo river tributary discharge, and sediment load samples were obtained at thirteen surface water locations around the MANIKPUR coalfield area from Hasdeo river tributaries using suitable suspended sediment sampler. On gathered surface water samples, laboratory analyses using standard procedures were performed. Assessment of soil erosion & sediment yield by an empirical equation of Revised Universal Soil Loss Equation (RUSLE) and Sediment Delivery Distributed Model (SEDD) was compared with the direct field measurements taken around the opencast area using suitable suspended sediment sampler. The result of this study showed the maximum soil erosion value obtained is 79.2 tons/ha/ yr & the maximum sediment yield which is 57.92 tons/ha/yr. Sediment load values obtained from these two models are showing the same trend. These models were tested for performance and found to be effective, with values of simulated & observed sediment yields and R2=0.81, RRMSE=0.66.The Observations showed that most of area is of very slight erosion potential zone with having low slope gradient and the opencast mine & overburden dump area is showed slight erosion potential caused by higher slope inclination. According to the study, GIS is an effective tool for modelling soil erosion potential and sediment output.

Keywords: GIS, OBD, RUSLE, SEDD

Assessing the impact of thermal stress on the physiological responses of dairy cattle in Kerala

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ABSTRACT

Climate change is a petrifying challenge to the progress and sustenance of the dairy sector in Kerala. During summer months various climatic parameters such as above normal ambient temperature, relative humidity and intense solar radiation alter the micro environment inside the cattle shelters. Animal integrate these environmental conditions and responds to it adaptively by evoking certain physiological, behavioral, and immunological responses. A field study was conducted to elucidate the impact of thermal stress on the immediate physiological responses of dairy cattle during the summer months in different THI (Temperature Humidity Index) zones of Kerala. It was observed that dairy cattle in more than 90 per cent of the farms were experiencing thermal stress with varying physiological responses. Body temperature and respiration rate showed a significant increase and positive correlation with THI. Present study signifies the need for adopting thermal stress alleviating measures which will rather reduce the production potential and profitability of dairy sector in Kerala.

Keywords: Climate change, Livestock, Thermal stress, THI

Extreme Weather Events and Paddy Production in the Humid Tropics,Kerala

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ABSTRACT

The surface air temperature across the State of Kerala on an average had increased by 0.65oC from 1956 to 2014 and the warmest years were recorded during the decade 2011-2020. Increase in day temperature was high (0.99°C) during this period when compared to that of night temperature (0.31°C). Warming Kerala is real since the surface air temperature was in increasing trend. Recent floods in August 2018 and 2019 and failure of post monsoon in 2016 (63 per cent less when compared to that of normal rainfall), indicating that occurrence of floods and summer droughts are not uncommon in the State of Kerala. These extreme weather events may be one of the reasons for decline in paddy production. Rice production was only 4.36 lakh tonnes during 2016-17 as against the production of 5.5 lakh tonnes during 2015-16. The unprecedented summer showers received across the State during March 2008 led to a decline in paddy production. Similar was the situation when unusual and unprecedented rainfall received during the first and second week of January 2021. Increase in air temperature may not be a constraint for paddy production in Kerala during Kharif (Virippu) since the mean air temperature revolves around 27oC and the maximum is always less than 30^{0}C during the crop season which is optimum for rice production. Even under rainfed condition, water is also not a constraint in paddy fields during the monsoon period from June to September. Availability of water and optimum atmospheric temperature during Virippu season (Kharif) across the State of Kerala may increase paddy productivity to a considerable extent.

Climate change and Rice crop sensitivity study in Maharashtra State, India.

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ABSTRACT

Climate Change has become a reality today. A country like India with its vast agrarian economy and a huge population, any change in climatic variables, would have a profound impact on agriculture and on public health. The scope of the present study is to examine the possible adaptability of agriculture to such a change in climate in the Indian context.

The study would comprise the entire nine agro climatic zones of Maharashtra covering representative seventeen districts in the state. The data collected at district level in Maharashtra state would for around 30 years, (minimum number of years of timeline required to analyze the climate data for climate change as per world meteorological organization).The IMD data includes maximum temperature and minimum temperature, rainfall, and relative humidity morning and evening would be analyzed using different statistical techniques. The major food rice productivity would be analyzed for the sensitivity analysis with the help of 'Detrending Method' and the Crop Simulation Model 'DSSAT'. For the crop simulation model the soil data collected from NBSS & LUP would be analyzed in conjunction with the crop data to find out the 'soil moisture stress'. Further, 'crop water stress' would be analyzed to check the crop sensitivity stage. The 'crop diversification' analysis plays an important role for giving advisories in districts subject to vagaries of climatic effect. The Remote Sensing & GIS Techniques would be used to carry image interpretation, data capture, spatial overlay analysis, neighborhood and proximity analysis. Geographical distribution of vulnerable districts prone to crop stress and their physical environment will be studied. The spatial distribution of rainfall, rainy days and temperature by considering various geographical factors like orographic, seasonality, land cover, land use and technology practices etc would also be analyzed. To identify long term variations in Area, Production and Yield of Rice in major growing districts of Maharashtra. Expected Findings and Results: The 'intra' and 'inter' changes brought out by the analyzed data would be spatially represented by using GIS mapping tools, at the District level and to give a Macro visualization at State level. The data also would be represented in choropleth maps, probability maps, trend maps and flow maps, along with set of tables and graphs to support the text. The study examined the temporal variability and change in some of key parameter and its effect on rice productivity.

Key word – Climate Change, Detrending method, DSSAT Crop simulation model, Adaptation strategy.

Effect of different establishment methods and P fertilization practices on yield, water use efficiency and water productivity of maize (*Zea mays* L.) in maize–wheat cropping system in Indo-Gangetic plains region

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ABSTRACT

A field experiment was conducted in maize (*Zea mays*) during *Kharif* 2018 and 2019 under maize–wheat cropping system (MWCS) to study the effect of 4 crop establishment and tillage management (CETM) practices [FBCT–FBCT; Flat bed–conventional tillage (FBCT) both in maize & wheat; RBCT–RBZT: Raised bed–CT (RBCT) in maize & RB–zero tillage (RBZT) in wheat; FBZT–FBZT: FBZT both in maize & wheat; PRBZT–PRBZT: Permanent raised bed–ZT (PRBZT) both in maize & wheat], and 5 P-fertilization practices [P_{100}: 100% P as basal; P_{50} + 2FSP: 50% P as basal (P_{50}) + 2 foliar sprays of phosphorus (2FSP) as DAP (2%) at knee-high stage (KHS) and pre-tasseling stage (PTS); P_{50} + PSB + AMF: P_{50} + PSB + AM-fungi (AMF); P_{50} + PSB + AMF + 2 FSP: P_{50} + PSB + AMF + 2FSP at KHS & PTS; P_0: 100% N & K with no P (P_0) as control] on yield, water use efficiency and water productivity of maize in a split-plot design replicated thrice. The results revealed that CETM practices exhibited a significant influence on yield, water use efficiency and water productivity throughout the crop seasons. PRBZT–PRBZT resulted in significantly higher grain yield (6.08; 6.19 t ha^{-1}), water-use efficiency (7.78; 11.28 kg ha^{-1} mm^{-1}), economic water productivity (132.2; 198.47 INR ha^{-1} mm^{-1}) and irrigation water productivity (3.04; 4.12 kg m^{-3}) in maize during both years, however, it remained statistically at par with RBCT–RBZT. During both the years following trend was observed PRBZT–PRBZT>RBCT–RBZT>FBZT–FBZT>FBCT–FBCT. Among P–fertilization practices, P_{50}+PSB+AMF+2FSP resulted in significantly highest grain yield (6.24; 6.37 t ha^{-1}), water-use efficiency (7.97; 11.61 kg ha^{-1} mm^{-1}), economic water productivity (135.54; 204.277 INR ha^{-1} mm^{-1}) and irrigation water productivity (3.12; 4.24 kg m^{-3}), following the trend ofP_{50}+PSB+AMF+2FSP>P_{50}+PSB+AMF>P_{50}+2FSP>P_{100}>P_0, respectively during both years. A significant interaction effect was found between CETM and P–fertilization practices for total water-use, water-use efficiency and water productivity during both the years of experimentation. Overall, PRBZT–PRBZT practice coupled with P_{50} + PSB + AMF and 2 foliar sprays of 2% DAP at KHS and PTS in maize may prove highly effective for harnessing higher growth and water productivity in maize under MWCS in a semi-arid climate of Indo-Gangetic plains region of India.

Key words: Crop establishment methods, Crop growth, Conventional tillage, Maize productivity, Phosphorus, Zero-tillage

TEMPORAL AND SPATIAL VARIABILITY OF RAINFALL PATTERN IN ARID REGION OF RAJASTHAN, INDIA

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ABSTRACT

Rainfall is an important natural resource in arid regions and knowledge of its variability is important for regional-scale planning and management of water resources in agriculture. This study explored spatio-temporal variations and trends in monthly (June-September), seasonal (pre-monsoon, monsoon, post-monsoon and winter), and annual rainfall patterns using long term data (1957-2011) of 62 stations located in the arid region of Rajasthan, India. The rainfall variability was analyzed by plotting box-whisker plots, applying multiple statistical tests and by performing geostatistical modeling. Two statistical tests, i.e., Sen's innovative test and modified Mann-Kendall test were used for trend identification. Furthermore, trends were quantified by Sen's slope method. Basic statistics such as mean, standard deviation, and coefficient of variation (CV), of the rainfall were computed to understand the rainfall patterns. Finally, four geostatistical models, i.e., spherical, circular, exponential and Gaussian were fitted and the best-fit model was selected. Spatial distribution of the mean and CV of daily rainfall was mapped using the best-fit model. The mean and CV of rainfall revealed a high inter-annual variability (CV > 200%) in the western portion where the mean annual rainfall was very low. A general gradient of the mean monthly, seasonal and annual rainfall was visible from northwest to southeast direction, which is orthogonal to the gradient of the CV. Box-whisker plots indicated presence of outliers and extremes in annual rainfall, which made the distribution of annual rainfall right-skewed. Sen's innovative trend test was found over-sensitive in evaluating statistical significance of the rainfall trends, while the Mann-Kendall test identified the significant increasing trends in June and September. Rainfall in July showed prominently decreasing trends although none of them were found statistically significant. Monsoon and annual rainfall showed significantly increasing trends at only four stations. The magnitude of trends indicated that the rainfall was increasing at a mean rate of 1.11, 2.85, and 2.89 mm year-1 in August, monsoon season, and annual series. Findings of this study indicated that there were few increasing trends in rainfall of this Indian arid region.

Keywords: Arid region, Geostatistical modeling, Spatio-Temporal Variability, Rainfall Trend

Biochar presents a natural climate solution through agricultural management practices

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ABSTRACT

Management of agro-residues are an immense challenge for the environment. Field burning or direct incorporation of stubbles to soil increases the greenhouse gas emissions aggravating global warming. We need to recycle the agro-residues in the valorized form (e.g., Biochar and compost) to improve soil quality, maintain crop yield, and provide natural solutions to climate change. Continuous use of chemical fertilizers to increase the productivity of staple cereal crops such as rice deteriorates the quality of soils and the environment. The emission of nitrous oxide directly from soil increases with nitrogen inputs. We present the results from a controlled environment study to assess legume biochar fertilizer in comparison to compost to sustainably replace mineral fertilizers in integrated nutrient management of paddy crops. Our results suggest that a relatively small dose of balanced mineral fertilization (75% of required nutrients) supplemented with biochar (25% of N equivalence) is the best combination compared to other fertilization methods. We observed that the biochar fertilizer shows similar total–N content to compost, although surface area and C: N ratio is significantly higher for biochar (i.e., 4.47 m^2g^{-1}; 37.68) than that of compost (i.e., 0.87m^2g^{-1}; 10.5). However, both biochar and compost applications with reduced doses of mineral fertilizers improve soil organic carbon at the harvest of paddy by 44 – 54% and 10 – 15%, respectively, over just mineral fertilizer application. We also observe the highest yield response with lower potential yield scaled N_2O-N emissions for the integrated biochar fertilization. The apparent nutrient recovery for macronutrients in straw and grain components of paddy were observed higher in case of biochar than compost. Henceforth, this study suggests biochar as more climate adaptive alternative to compost that can have policy implications for developing a carbon-negative fertilization technique in paddy farming.

Keywords: Agro-residues, Climate change, Biochar, Paddy farming

ASSESSING GLACIER RECESSION AND DYNAMICS UNDER CHANGING CLIMATE IN KISHTWAR BASIN, WESTERN HIMALAYA

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ABSTRACT

Mountain glaciers are critical component of the Earth's system, and serve as a key freshwater resource in many regions of the world. The observed changes in glacier systems serve as a direct indicator of climate change. This study reports glacier recession and dynamics in the Kishtwar basin, Western Himalaya India, using the remotely sensed data from 2000 to 2020. The information generated about the glacier recession is critical for sustaining the perenniality of the Chenab river, one of the important tributaries of the Indus. The role of topography, morphology and changing climate on the observed glacier recession and surface ice velocity (SIV) was also investigated in this study. A total of 155 glaciers were identified and mapped using the visual image interpretation of the Landsat satellite imageries at 1: 25000 scale. From analysis of the data, it is evident that the glacier area has shrunk from 1070 km^2 in 2000 to 994 km^2 in 2020, showing a deglaciation of 76 km^2 during the last two decades. Further, there is a significant influence of the debris-cover observed on the glacier recession. The debris-free glaciers showed a higher recession of ~22% compared to ~5% recession shown by the debris-covered glaciers. Surface ice velocities of few representative glaciers was estimated using the Co-registration of Optically Sensed Images and Correlation (COSI-Corr) technique employing 1999/2000 and 2019/2020 satellite data. Results revealed that there is a significant slowdown in the SIV due to the continuous glacier recession observed in the study area. The varied glacier recession and decreasing SIV indicates a strong influence of the local morphological and topographical parameters. In addition to the topographic parameters, changing climate is also one of the possible factors influencing glacier recession and dynamics in this Himalayan basin. The observed glacier recession if continued, in the region can severely impact the streamflow and thus adversely affecting hydropower generation, and other water-dependent sectors in the region.

Keywords: Satellite data, COSI-Corr, Kishtwar, Climate Change, Himalaya

Estimating the response of hydrological flows under climate change in a humid subtropical River basin

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ABSTRACT

It is commonly recognized that the green house gases are drastically boosting the weather events in the Himalayan region. The rivers of Himalayas are boon for Indo-Gangetic region and when coupled with extreme weather events, it aggravates the hydrological risks in the region. These risks are witness of climate extremities and therefore needs to depict their role in flood. We employed earth observation data and a hydrological modeling approach with the four CMIP-5 climate models. We have gone through the downscaling of climate models using the CMhyd (Climate Model data for hydrologic modeling) tool. The gauge observations were used to calibrate and to evaluate the performance of SWAT model in the basin. The results showed good agreement between model and observation at Turtipar gauge station for calibration (1991-1997) and validation (1998-2011) period. The SWAT model was used to estimate future hydrological extremes in the basin using future climate projections. At the end of the century, the flow duration curve (FDC) revealed consistent and significant shifts in flows. For different return years, the model CSIRO-Mk3-6-0 was shown near to observed data in RCP4.5 and larger magnitude in RCP8.5. For both RCPs, the average monthly flow for climate projections was found to be high for CSIRO-Mk3-6-0. The hydrologic fluxes from the CMIP5 models have been found to be more vulnerable to climate change and large flood of short duration will be more frequent in the future.

Keywords: CMIP-5,SWAT,CMhyd

Impact of solar radiation potential on wheat crop

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ABSTRACT

The amount and duration of observed solar radiation (OSR) play a crucial role in plant growth. The capability of plants to use solar radiation is the function of their leaf area index. Weeds, insects, and leaf diseases are some of the agronomical factors that may negatively affect the leaf area which eventually leads to less energy capture by plants. Solar radiation impacts cereal's number and its maturation during the period of inflorescence. Its analysis through different methods is necessary to develop long-term data sets for agricultural and environmental applications. This study aimed to analyze the influence of generated daily solar radiation (GSR) on simulated crop growth and yield production. Daily weather data acquired from the Indian Meteorological Department (IMD) including solar radiation, maximum and minimum temperature, and precipitation. We proffer a conceptual model for change in the number and production of cereals. The Decision Support System for Agrotechnology Transfer (DSSAT) v4.7 has been used to simulate crop growth and yield production by using OSR and GSR, for rainfed and irrigated conditions. We consider the prospective use of daily minimum and maximum temperature, canopy temperature, and solar radiation load to decide the crop retort in the model. The study also shows the demand for a prominent perception on how the period of solar radiation affects yield productivity. The measurable investigation included summary statistics, Pearson's coefficient of correlation; mean squared deviation (MSD).

Keywords: Solar Radiation, Leaf area index, dssat-ceres

TITLE: Implementation of IITM-IMD extended range forecasts in the Kharif rice yield prediction on experimental basis

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ABSTRACT

In this study, the Kharif rice yield prediction over Gangetic West Bengal using the IITM-IMD extended range forecast (ERF) data is carried out on experimental basis. The choice of the study area is made considering the large amount of rice productivity of the region. The state of West Bengal contributes significantly towards the total rice production of India and the economy and livelihood of this state mainly depend on rice cultivation among the other crops. For the prediction of Kharif rice over this region, the forecast products from a CFS-based multi-model ensemble (MME) prediction system developed at IITM, is used. This MME system has a significant skill over a relatively larger domain as compared to the study area in predicting the rainfall, maximum and minimum temperatures, and incoming solar radiation which are to be incorporated for the running of crop model. Since, the rice crop yields mainly driven by the monsoon rainfall, the skill of ERF to capture the large-scale monsoon rainfall is evaluated. It is found that the MME system has a satisfactory skill in terms of high CC values and low nRMSE up to 3 weeks lead time for most of the ICs.

The bias corrected weekly ERF variables (above mentioned) have been incorporated into a process-based crop model (CERES-rice) available in the Decision Support System for Agro-technology Transfer (DSSAT). It is found that the ERF-driven crop model has performed better to reproduce the inter-annual variability of observed rice yield compared to the yield simulated using the climatology alone. Also, the ERF-driven model is able to capture the below and above normal yield categories better than the climatology-driven model. Therefore, the incorporation of ERF in crop models has the potential to provide value-added predictions, which may be useful for the stakeholders and decision-makers.

Keywords: Kharif rice yield, CERES-Rice module, DSSAT and extended range prediction

Heavy Metal- Isotope Associations as Pollution Signatures In Mining and Climate Impacted Subarnarekha Watershed : An Exemplar from Ghatshila Region, Jharkhand, India

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ABSTRACT

The presence and release of toxic metal-isotope nanoparticles from heavy metal-mining complexes, and their associated processing plants (active/abandoned), through discharge of acid/alkaline/metal effluents has important implications for the environment. Primary movers of these ubiquitous particles are the river channels - their riverine signatures stand unique for local and regional environmental fabric. Mining operations involving sulphide minerals generally result in excavation of rocks and minerals from subsurface anoxic onto surface oxic environment. This transformation triggers leaching of strong acids and metals that find way into neighbouring soil, surface- and ground- water regimes. In the process, isotopic and metal-rich nanoparticulates get access to streams and rivers, with latent deleterious reactions occurring even decades to centuries later. The present research highlights the characterization of heavy metals and isotopic nanoparticles/nanites in mining impacted water pollution milieus of Subarnarekha river basin, East Jharkhand and find out their spatial distribution and imprints on hydrogeochemical systems. The project area is located in Singhbhum mineral belt in and around the Mosabani/Rakha/Surda copper mine-smelter units and the Jaduguda Uranium mine. The project comprises three main thrust areas: (i) Physical, chemical and isotopic (stable and/or radioactive) characterization of nanoparticles, (ii) their environmental impacts on hydro-geo-environmental system/s, and (iii) developing methodology to use the latter for environmental monitoring. Multi-isotopic approaches (δ18O and δ2H) and geochemical correlations have been applied for tracing the origin, fate, transport and pathways of pollution released by mining, ore processing and metallurgical activities at the catchment basin of Subarnarekha in the Ghatshila stretch. Results of isotope systematics conclusively prove impacts of mining processes and derived minerals on surface and sub surface domains.

Key Words: environmental monitoring, heavy metals, isotope, Subarnarekha

EFFECT OF RAINFALL VARIABILITY ON CROP PRODUCTIVITY OF *KHARIF* COTTON CROP FOR VARIOUS DISTRICTS OF MAHARASHTRA STATE

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ABSTRACT

India accounts around 25 percent of world's total Cotton area and 16 percent production. Cotton is one of the major crops in Maharashtra state, which is grown during June to December (*Kharif* season) over more than 40 lakh hectares and about 97% crop cultivated under rainfed condition. It is well known fact that monsoon plays a critical role in planning of agriculture operations and crop yield. An attempt has been made to evaluate effect of rainfall on cotton (lint) yield. Statistical tools are used in the study to find out the relationship between Crop productivity (as production and area is variable) and rainfall departure from normal (as amount of rainfall is variable). Out of total 35 district of Maharashtra state 27 districts of where Cotton is cultivated as major crop are considered for this study. 21 years (1998-99 to 2018-19) Crop productivity (Tonnes / Hectare) of selected district and Percent of departure for monthly and seasonal Rainfall data (Area Weighted Average) of same district is considered for this study.

For July month out of 27 districts, 5 districts showed (positive) significant correlation at 95% level of significance and 7 districts at 99% level. 4 districts showed (positive) significant correlation at 95% level and 2 districts at 99% level. During South West Monsoon Season (June-September), 5 districts showed (positive) significant correlation at 95 % and 7 districts at 99% level during September month. Whereas, for November month, 2 districts showed (negative) significant correlation at 95% level and only 1 district at 99% level. Similarly, for December month 3 districts showed significant (negative) correlation at 95% level and only 1 district showed at 99% level. From the above results is can be stated that rainfall during July, September and South West Monsoon Season (June-September) positively effects while rainfall during November and December negatively effects the yield of cotton crop. This study can help in deciding the suitability of crop, early planning of crops and estimation of yield.

Keywords: Cotton, crop productivity, yield, rainfall and rainfall departure

Long term Analysis of Agricultural Drought over Bangladesh using Drought Severity Index (DSI)

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ABSTRACT

Devastating and recurrent droughts caused by varying rainfall patterns occur frequently in many parts of Bangladesh, causing substantial damage and loss to agriculture and allied sectors. This study uses long term MODIS evapotranspiration (ET), potential evapotranspiration (PET) and Normalized Difference Vegetation Index (NDVI) data to compute the Drought Severity Index (DSI). DSI is then used to analyze the severity and the frequency of drought over cropland at both national and divisional levels for December-May from 2000 to 2019. February was recorded as the drought prone month with approximately 50 % of the cropland area showing extreme, severe and moderate drought conditions except for the years 2007, 2014, 2015, 2016, 2017, 2018 and 2019. The least affected month was April with less than 30% of the cropland being affected during all years except for 2001. Among the administrative divisions of Bangladesh, Dhaka was found to be least affected from extreme condition with only 10% of the study period having less than -0.9 DSI value. On the other hand, Chittagong experienced 9 years of extreme drought condition among the studied period. Minimal to no occurrences of extreme drought was found in Khulna, Rajshahi and Rangpur divisions. However, frequency of severe drought was highest in Barishal with 6 and 12 years of occurrences during the month of January and February respectively. This shows that drought coping strategies and more irrigation facilities needs to be adopted in cropland of Bangladesh especially for winter months.

Keywords: Bangladesh, Cropland, Drought, Drought Severity Index

Simulating Rice Yield In The Near Future Under Seasonal Climatic Variability: A Predictive Approach Using DSSAT Crop Simulation Model

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ABSTRACT

Climate change has added a new dimension to the uncertainty in rice yield worldwide. The present study estimated the potential impacts of climate change on the yield of Swarna rice variety in Odisha using the DSSAT crop simulation model. Available data on soil and typical crop management practice for Swarna rice were used in the simulations. The daily weather inputs required for this model were generated using the HadGEM3-RA regional climate model for RCP 4.5 and 8.5. Although the amount of rainfall during rainfed rice season is expected to be higher under both scenarios, the average future monthly rainfall is expected to increase in July and August, but decrease in September and October under both scenarios. Decreasing future rainfall during the reproductive phase of rice growth (September to October) can have a significant influence on the rice yield. Furthermore, the rice yield is projected to continually decline in the future (2050) with respect to the baseline (2010-2015) as much as 18.5% and 22% under RCP 4.5 and 8.5 scenarios, respectively. Changes of monthly average temperatures and variability in rainfall pattern over the growing period of Swarna rice were found to be primarily responsible for the reduction in rice yield. Furthermore, model outcomes envisaged that climate change may make rice yield more susceptible to its transplanting date, forecasting a significant change in yield as the transplanting date is shifted from beginning to the end of July. These outcomes may provide valuable insight into the potential impacts of climate change on rice yield and adequate adaptive measures to mitigate the adverse effect of future climate change in Odisha, as rice cultivation is synonymous with food in this state.

Keywords: Swarna rice, DSSAT model, yield simulation, transplanting date

Empowering Community Based Organisations as a Strategy for Adaptation and Mitigation of Climate Change in Kerala, India

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ABSTRACT

In the past when scientists talked about climate change, many believed that it was only their estimation/Imagination. But now we see that Climate Change is the greatest ecological, economic and social challenge of our time. Though, Earth's climate is undergoing noteworthy natural changes over centuries, the consequences are more tangible in recent years. There is an urgent need not only to equip the society to face the consequences by suitable adaptation techniques but also take adequate measures to mitigate for better future. These efforts cannot be successful without participation of Community Based Organisations (CBOs).

Kerala with rich and hot spots of biodiversity is acclaimed for its unique development trajectory and high vulnerability due to high physical exposure to climate related disasters and dependence on climate-sensitive sectors such as agriculture, forests, tourism and fisheries. The field experiences, outputs and outcome of various climate change adaptation and mitigation strategies taken up in two watershed areas namely Mugu and Kunjar watersheds covering 3 villages in Kasaragod district are discussed in detail in this paper.

The paper focus on the importance of stakeholder participatory climate change analysis with scientific inputs, knowledge management/capacity building trainings and exposures on climate change, its adaptation and mitigation, climate resilient farming practices as well as field oriented trainings on sustainable agricultural practices for making CBOs prepared to face the challenges and consequences of climate change. The focus is given on climate resilient agriculture practices, efficient water use, soil & water conservation, alternate livelihood opportunities and formation & effective contribution by CBOs owning the interventions.

It was found that convergence of scientific community, government interventions, programmes of developmental organisations and community at large owning the project is a must for addressing the challenges of climate change. The paper,based on field experience, suggest the action points for various stakeholders namely Government, Developmental agencies, Local Self Government agencies, NGOs, Banks and public at large.

Key words: Community Based Organisations, capacity Building, Climate change, watershed

Climate change impacts on the hydrological response of a Himalayan region dominated by glacier melt runoff

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ABSTRACT

The impact of climate change on glacier melt runoff examined for the Himalayan region. Snow and glacier melt water contribute significantly to the river's overall streamflow. The increased rate of melting caused by a warmer climate has resulted in glacier retreat. On a longer time, scale, greater melting of glaciers in the coming years could deplete available water resources and influence river flow. Such changes are also very likely to have occurred in Himalayan glaciers, but they may have gone unnoticed or not. Because more than half of India's water resources are located in the various tributaries of the Ganges, Indus, and Brahmaputra river systems, which are highly dependent on snow and glacier runoff, the water resources of the Himalayan region may also be highly vulnerable to such climate changes. In this study of long-term time series spatiotemporal (1980-2021) in the coverage of fractional glacier area, snow surface temperature and others land surface parameters for the Himalayan region by using satellite data (MEERA-2) at (0.5*0.625) spatial resolution. The findings show that runoff increased linearly with increasing snow surface temperature in the study. A significant increasing trend was observed in the annual mean runoff and snow surface temperature with Sen's slope rate= +0.0311 mm/year ($p<0.05$), +0.0367 °C/year ($p<0.05$), respectively. According to the seasonal analysis of total streamflow, an increase in snow temperature causes an increase in the pre-monsoon season, which is followed by an increase in the monsoon season. The consequences of such seasonal changes are also briefly discussed. Such research is needed to properly estimate available water supplies in the Himalayan region in the light of climate change.

Keywords: Climate change, Mann-Kendall test, Himalayas, Glacier melt runoff.

Water augmentation using Low cost polytank in hilly region of Uttarakhand Jal Shakti Abhiyan

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ABSTRACT

Agriculture in hill and mountain ecosystem is predominantly rainfed with common occurrence of moisture stress. This increase risk to success of hill farming in general and cultivation of high value crops like vegetables in particular. Development of water harvesting structure is the key to higher production by mitigating water stress and meeting crop requirement particularly during critical growth stages. This leads not only to the conservation of water but also its efficient distribution in the field. The cost of creating water resources in hills is very high, thus storage and application losses should be reduced to utilize scarce water efficiently. Pond line plastic sheet can make significant contribution towards fulfilling this goal. The purpose of this study was to estimate the increase in water availability through the additional polytanks made under Jal Shakti Abhiyan Programme of ICAR-VPKAS, Almora, specific to the Darima village of Nainital district of Uttarakhand state which falls in higher hills of Himalayas. The ponds were dugout and lined with plastic sheet which is multi-layered cross laminated, U.V stabilized 250 μ thickness. Total number of tanks made in the study area are 65 which was geo tagged for regular monitoring. The average length, breadth and depth of all polytank is 7.1 m, 4.4 m and 1.6 m respectively. The impact of above work will create additional water storage capacity of approximately 3312 cubic meter, which will enhance the farmer`s income and water availability throughout the year.

Keywords: Jal Shakti Abhiyan, Polytank, Conservation, Irrigation, Hilly area

Uncertain Rains, River flows and Inter basin transfers for meeting water scarcity in climate change

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ABSTRACT

Inter basin transfer from the projects in peninsular India is common now a days. Most of the rivers like Godavari, Krishna, Kaveri and Tunga Bhadra derive their inflows from the rains falling in western Ghats which runs parallel to Arabian sea. Windward side of western Ghats gets more rains than leeward side. After some distance from leeward side arid and semi-arid areas are situated where rainfall is less and uncertain. These areas are classified as rain shadow regions. Inter basin transfer of water resources are taking place to meet deficits in water availability.

Reservoirs are situated in different states. Water is released only when floods occur. Even if reservoirs are holding sufficient water and long monsoon season is ahead, states do not release water to other states in downstream areas. The downstream areas which are in rain shadow regions looks upon releases from upstream reservoirs to meet rainfall deficit during monsoon season. When actual releases take place, the crops are withered and irretrievable damage happens which affects farmers income and GDP of a nation.

Water resources particularly those serve inter basin has to look upon this issue of availability and scarcity in a holistic manner. Good forecast systems must be in place to monitor flows of present and future crop period. Parochial approach for water resource management is leading to holding water tight behind dams and sudden releases during floods. Integrated approach is necessary to take care of the needs in time and space rather than allocations alone as a sole guiding factor in water regulation.

A case study of competing demands between upstream Almatti reservoir and Srisailam dam is studied for the year 2018. There are dry spells in Rayalaseema when sufficient water is available in upstream reservoirs. In the absence of timely releases crops withered in Rayalaseema where as water releases later could not revive the crops. It happens frequently in climate change scenario when high intensity rains followed by dry spells in western Ghats play havoc with farmers.

Symptoms of climate change is already being felt now if rainfall and inflows are analyzed. IMD is forecasting daily rain fall and observed rainfall in different basins. Real time monitoring set up exists to record daily rainfall. Since there is a time lag from western ghats to Bay of Bengal for a river like Krishna offering sufficient time to effectively regulate water in reservoirs to take care of deficit rainfall regions. In climate change scenario the response has to be swift to manage water resources for which collection of real time data goes a long way in climate change scenario as discussed in full paper presented.

CME

Coastal and Marine Ecosystems in Changing Climate

LEAF THERMOTOLERANCE IN MANGROVE PLANTS: VARIATION ACROSS SPECIES AND RELATIONSHIP WITH LEAF TRAITS

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ABSTRACT

Global warming is predicted to increase mean daily temperature at an alarming rate in the coming decades and committed in-depth efforts are the needs of the hour to limit the rise within the preindustrial limit of 2°C. Heat extremes have increased in the previous decade, and the marine heatwaves are predicted to continue to increase with high confidence. Heatwaves and humid heat stress will increase intensity and frequency in the South Asian region (IPCC 2021). Knowing the upper limits of thermotolerance of plant performance is pivotal in understanding and predicting the impact of changing climate on plant communities.

Here we studied the leaf thermotolerance of mangrove plants from five sedimentary islands of Ashtamudy lake. We studied thirteen true mangrove species. Here, we treated excised leaf discs for different temperatures ranging from room temperature to 60°C and measured the Photosynthetic Quantum Efficiency (PSII Fv/Fm) and calculated the T50: the temperature at which the PQE drops to 50 % of its maximum value. We have estimated the Leaf Temperature (T_L) with the help of the leaf energy budget model using plant traits and weather parameters. We also calculated the ⊔T (Difference in T_L and T_{Air}), which helps predict the vulnerability to future temperatures (Michaletz *et al.* 2016). Our results showed that T50 values for most of the studied mangrove species are around 50°C, with the lowest (48.5°C) *Avicennia marina*; the most dominant species in Kerala and *Bruguiera sexangula* with the highest (56°C); a rare species in the region (Sujanapal and Sasidharan 2013). Our study did not find any significant relationship for leaf thermotolerance with other leaf traits. A.m maybe the most vulnerable mangrove species to the future temperature extremes. All other mangrove species studied have a uniform vulnerability to the temperature extremes and it was expected as they are specialist species.

Keywords: Photosynthetic quantum efficiency, Leaf thermotolerance, Global warming, Climate change

Mechanisms and Contributions of wave-surge-tide interactions in the Bay of Bengal

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ABSTRACT

The semi-enclosed tropical basin Bay of Bengal (BoB) is often impacted by destructive tropical cyclones (TCs) and accounts for hazardous storm surges at the coasts surrounding the bay. Shallow-water numerical models developed for simulating the order of magnitude of maximum observed storm surges have progressed tremendously in recent years for the basin. Nevertheless these storm surge models have not yet demonstrated their ability to adequately reproduce patterns of coastal flooding both in space and time. In the current paper, we use a state of the art numerical modeling system of coupled circulation-wave model for the entire BoB region to simulate the extreme water levels induced by some of the fatal TCs in BoB. Model is able to reproduce the measured astronomical tides and storm surge well. Numerical experiments are conducted to separate the water level variations due to waves, surge, tides and their non-linear interactions. The wave-induced setup due to radiation stress gradients to storm tides are often significant, contributing upto 35% during an extreme storm event. The overall effect of the tide-surge interaction is of fewer magnitude including during the peak storm tide.

UPWELLING IN THE EASTERN ARABIAN SEA USING NEMO-PISCES MODEL- IMPACT OF RIVER RUNOFF

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ABSTRACT

The southwest monsoon (SWM) upwelling in the Eastern Arabian Sea (EAS) occurs annually during May to October. Most upwelling systems brings nutrient-rich sub-surface waters to the surface making the surface layers more productive. However, in the EAS, upwelling brings the hypoxic sub-surface waters as well to the surface depleting them of oxygen. This is therefore important for fisheries and marine life. Recent studies have indicated that precipitation and runoff have considerable impact the upwelling and the current of the Indian Ocean, while climate models indicate enhanced precipitation over the region. Modelling experiments are conducted using coupled physico- bio- geo- chemical model NEMO-PISCES to study the impact of the river runoff on the dynamics of the upwelling in the EAS. The model horizontal resolution is 1/12° and with 31 vertical levels. The control-run is evaluated first and it is found that the coupled model simulates the dynamics of the Indian ocean well. The model reproduces the climatological features of the upwelling system in physical variables like temperature and salinity as well as biogeochemical parameters like oxygen and chlorophyll. Experiments with and without river runoff in the model show that the presence of river runoff in the model reduces the strength of the upwelling during SWM. Reduction chlorophyll in the upper layers is observed in the presence of river runoff. The energy required to overcome the stratification is computed in either case and it is found that that fresh water enhances the stratification thus restricting upwelling in the presence of river run-off.

Keywords: Upwelling, coupled bio-physical model, NEMO-PISCES

An Enquiry into Coastal erosion and its Sustainable management: A Case Study of Chellanam Coastal Village.

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ABSTRACT

Coastal erosion is wearing away of land mainly due to strong winds, high waves, high tides, and storm surge conditions which results in the landward recession of the shoreline and land area. It is a dreadful phenomenon faced by the people living in the coastal areas and is greatly intensifying worldwide in the present era. The coastal areas have become more prone and vulnerable due to natural occurrences and human interferences. Sea wall has been damaged mainly due to climatic variations and heavy monsoons in Kerala, and it has increased the intensity of vulnerability of the coastal people of Chellanam. This paper explores the causes and consequences of coastal erosion in Chellanam and the resilient and sustainable measures taken to prevent coastal erosion. The social and economic effects of coastal erosion on the coastal community and the sustainable measures taken to protect Chellanam are assessed. Secondary and primary data tools were used for the data collection and multivariate analysis has used for evaluating the causes and effects of coastal erosion. The increasing intensity and frequency of environmental hazards made it clear that unless the government takes appropriate action, the degradation of the coastal environment becomes severe and creates far-reaching consequences. Immediate attention needs to be given to combat coastal erosion effectively on a scientific basis for evolving suitable sustainable design of the coastal protective structure.

Keywords: Coastal erosion, Climate change, Sustainable measures, Environmental hazards.

IS CLIMATE CHANGE ATTRIBUTED TO ENIGMATIC GELATINOUS ZOOPLANKTON BLOOMS IN THE ARABIAN SEA

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ABSTRACT

Gelatinous zooplankton blooms are frequently recorded over the past two centuries from historical monographs to recent scientific articles. Only a few scattered information available on their distribution, ecology and taxonomy from the Indian waters. During the present study information from different research cruises and field visits to estuaries, coastal waters and of shore regions of Arabian Sea from September 2018 to July 2021 period. Though various species of gelatinous organisms were recorded, only a few species have been attained the population size to form large blooms. They were *Netrostoma coerulescens, Lychnorhiza malayensis, Aequorea pensilis, Pelagia nocticula, Acromitus flagellates, Crambionella orsini, Chrysaora caliparea, Cyanea nozakii, Beroe ovata, Porpita porpita, Physalia physalis and Pleurobrachia pileus.* Samples were collected by using a bongo net having 200 µm mesh with a diameter of 60 cm from motorized boat or from FORV "Sagar Sampada". Collected specimens were preserved in 4% neutralized formalin solution. In the laboratory, they were identified up to species or higher taxon level using standard reference material. The present study provides formal record of invasive ctenophore species *Beroe ovata* from Arabian Sea for the first time; they are native to the Atlantic coasts of North and South America. Except for *Crambionella orsini*, *Acromitus flagellates* and *Pleurobrachia pileus*, which blooms from monsoon to non-monsoon, most of the species involved in blooms were dominant during monsoon. The analysis suggested strong correlations between jellyfish abundance and dissolved inorganic nutrients and chlorophyll-a content. World oceans are reported to be losing many species of meso and micro planktonic groups and their ecological niche replaced by the pervading gelatinous species possibly altering food web structure. So that the correct identification, documentation of physical and ecological information related to their ecology is important to understand their respond to climate-related issues from the Indian Ocean region.

Keywords. Indian Ocean, Arabian Sea, Gelatinous zooplankton, Climate change

Monitoring of Gulf of Kachchh Coastal Zone with Reference to Land Use Land Cover Change using Geo-Spatial Technology

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ABSTRACT

Human population and activities in the world are generally concentrated near the coast, which has modified the environment for thousands of years. Coastal development leads to modification of foreshore and loss of key habitats such as mangroves, coral, sea grasses etc. Because of this impacts and uses, managing coastal zone can be a high priority for all the coastal nations. Urban growth has increased the use of natural resources and has changed land use land cover patterns. Coastal zones are incredibly vulnerable for land use changes in the period of rapid urbanization and industrialization. To sustain the current natural resources and to know about the causes and consequences of more utilization of water and soil resources a land use land cover (LULC) monitoring and mapping was prepared in the Gulf of Kachchh, one of the most hastily growing industrial hub in India. Remote Sensing (RS) and Geographical Information System (GIS) were utilized as a tool to evaluate the LULC change in the study area. The main objective of this research is to monitor and evaluate LULC changes during the year 1997, 2002, 2007, 2012, 2016 and 2021. LISS-III satellite images were used for the digital change detection method. Supervised classification and expert visual interpretation techniques were used to classify the images. Nine LULC classes were defined for the classification technique. Error matrix and KAPPA analysis have been prepared for accuracy assessment of the classification. Change detection between the different satellite images for all the LULC classes was calculated. The overall classification accuracy of the image is 91.46% with Kappa statistics of 0.89. This study shows that the major LULC change identified in agricultural land followed by mudflats and water bodies, which are significantly decreased, while mangrove, saltpan, built up, industries and mining are increased from 1997 to 2021.

Keywords: LISS III image, Supervised classification, KAPPA analysis, Change detection

Future Projection of Surface Temperature and Total Precipitation Over Southeast Asia Under Climate Change Scenarios

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ABSTRACT

Climate change effects analysis on the surface temperature and precipitation are essential for the assessment of impact vulnerability, and mitigation and adaptation strategies. Climate models can provide projections of climatic changes in the future, based on greenhouse gas emissions scenarios. In this study, the Weather Research and Forecasting (WRF) climate model was used to project and evaluate the future changes (2050 and 2100) of surface temperature and total precipitation over the Southeast Asia (SEA) region under the RCP4.5 and RCP8.5 emission scenarios. In the mid- and end of this century, under the RCP4.5 scenario, the average surface temperatures were projected to increase between 0.60 °C and 0.82 °C in January (winter monsoon) and 0.77 °C and 0.93 °C in July (summer monsoon). There were even more notable atmospheric warmings under the RCP8.5 scenario, which were ranging from 0.22 °C to 2.11 °C during winter monsoon and 0.99 °C to 2.50 °C during summer monsoon respectively. Comparatively, Cambodia and Thailand would be experiencing the highest temperature increment during both monsoons and time slices under RCP4.5 than other countries in SEA. Across the region, there were increments in total precipitation with larger variability for both monsoons under the RCP4.5 scenario (between 43 inches/day and 1395 inches/day) at the mid-and end of the century. Similarly, under the RCP8.5 scenario, the region would also be experiencing an increase in total precipitation with high variability though comparatively lower magnitude than RCP4.5 for both monsoons and time slices. These results suggest that significant changes in the surface temperature and total precipitation in the region could potentially increase the climate-related risks and vulnerability in this region

Keywords: Climate change, surface temperature, total precipitation, Southeast Asia

Crustal Structure and tectonics of the southwestern continental margin of India based on geophysical datasets: Implications to the breakup and its probable genesis

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ABSTRACT

The episodic distensional events-breakup of India from Madagascar during mid-Cretaceous, the massive Deccan Volcanism during 65 Ma followed by rifting between India and Seychelles during the early Tertiary have majorly imprinted the entire western continental margin of India and its adjoining basins. Based on well-delineated offshore sedimentary structures and ridges, the entire western continental margin is divided from north to south into several sedimentary basins: Kutch offshore, Saurashtra offshore, Mumbai offshore, Konkan offshore and Kerala offshore. Some of these basins, to a large extent appear to have influenced the formation of hydrocarbon resources. The Southwest Continental Margin of India (SWCMI) comprises of narrow shelf, wide slope, Laccadive Basin, Laccadive Ridge and eastern part of the Arabian Basin. The margins are mostly resulted from extensional tectonics, thinning and shear rifting since the Cretaceous and their geologic section consists of Paleocene to Recent sediment deposits, Deccan Flood basalts and Mesozoic sediments.

The genesis of each major tectonic elements, nature of the crust and margin classification are not well understood for understanding a detailed evolutionary history of SWCMI. Analysis of multi-channel seismic reflection profiles across this margin reveals numerous structural and tectonic features. In this present study geophysical datasets are analysed in detail to understand the structural pattern along the Southwest Continental Margin of India. We have also carried out 2-D gravity modeling along few selected profiles that implies thin transitional crust of continental affinity. This indicates that the SWCMI has been evolved by distensional tectonics/ stretching and has thrown light on the tectonomagmatic frame work and the voyage of the Indian plate through different time span.

Keywords: South western continental margin of India, Laccadive Ridge, Laccadive Basin, gravity anomaly

CHANGES IN COASTAL ECO SYSTEM DUE TO CLIMATE CHANGE AND ITS EFFECT ON COASTAL COMMUNITIES

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ABSTRACT

Climate change is having paramount importance in today's world. The impact of climate change is evident in all spheres of life, which needs serious attention. Coastal ecosystem is one of the badly affected areas due to the change in climate, which is primarily caused by human activities. Coastal eco system consist of coastal wetlands, mangroves, estuaries, lagoons, and coral reefs, which are among the most biologically productive ecosystems in the world. An increase in the temperature, rising sea level, alteration in the wave pattern and water circulation, and changes in the nutrients and oxygen available to the marine species are important effects of climate change on the coastal ecosystem. India is having coastline of 7,517 km and it is home to about 171 million of the country's entire population. According to Coastal Protection and Development Advisory committee Report (2016), 45.5 percent of India's total coastline is under erosion. The present paper aims to discuss on changes in the coastal ecosystem due to climate change and how it is affecting the coastal communities Secondary data from various sources is used for analyzing the impact of climate change on the coastal communities.

Keywords: Climate change, Coastal communities, Coastal ecosystem

Spatial Variability and Trends of Marine Heat Waves in North Indian Ocean

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ABSTRACT

Anthropogenic climate change has brought out negative feedbacks to ecological goods and services provided by marine ecosystem. One such implication is brought out in marine ecosystem in form of Marine Heatwaves (MHW). MHW is classified as anomalously warm event, which last for 5 or more days, with temperature warmer than 90th percentile based on a 30-year historical baseline period. The frequency of MHW is expected to rise as the ocean continues to warm. The present study investigates the variability and trends of MHW and its properties over North Indian Ocean (NIO) from 1993 to 2020 based on the historical baseline period from 1982-2020 (39 years) using Sea Surface Temperature (SST) data obtained from the National Oceanic and Atmospheric Administration Optimum Interpolation ([NOAA] OI SST V2.1).

The analysis shows that Arabian Sea is warming rapidly compared to Bay of Bengal and highly intensified MHW (>1.9°C) is occurring in northern Arabian Sea and western Tropical Indian Ocean along the Somalia and Oman Coast. While, high intensity MHW (1.6°C) is observed over north Bay of Bengal and along the northeast Bay of Bengal adjacent to the western coast of Myanmar. It is also observed that the frequency of MHW over NIO shows increasing trend significant at 95% level with a rate of 1.2 events per decade, while over the southwest Arabian Sea near the Somalia coast the MHW frequency shows higher rate of increasing trend (2.4 events per decade). Global teleconnection indicators such as El Nino, Indian Ocean Dipole (IOD) is observed to modulate the MHW in NIO by increasing the duration of MHW events.

Keywords: Marine Heatwaves, Sea Surface Temperature, North Indian Ocean

Atmospheric methane contribution from urbanised estuary can potentially hasten climate change, a case study

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ABSTRACT

Understanding the methane (CH_4) dynamics from urbanised estuaries has received increasing attention in the recent years due to its role in global CH_4 budget. As Indian estuaries are undergoing degradation at a speedy rate due to rising urbanisation, it is imperative to understand the atmospheric CH_4 contribution from Indian estuaries. Here we report that the Cochin estuary, a large tropical estuary along the southwestern coast of India, that runs parallel to a large urban centre act as net atmospheric source of CH_4 (113.4 ± 53.3 µmol m^{-2} day^{-1}), which was equated to high CH_4 supersaturations (4950.8 ± 1596.6 %). The dissolved CH_4 concentrations spanned from 35.4 to 220.1 nmol. Intense pollution and other anthropogenic disturbances have led to high organic carbon in the estuary. The dissolved CH_4 concentrations and its flux rates were high in stations with high organic carbon loading, against the salinity and dissolved oxygen gradients. The study suggests that the urbanised Indian estuaries are subject to high organic matter inputs from various sources, may be a significant component of the global CH_4 budget. This study provides the impetus for ongoing conservation efforts to protect estuaries against the impact of rising urbanisation on lowering the CH_4 emission potential for this system, which can have implications for other tropical estuarine systems as well.

Keywords: methane, total organic carbon, urban, atmospheric warming

Impact of climate change on Marine Ecosystem-A case study of Bhitarkanika Mangrove Forest, Odisha.

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ABSTRACT

The Earth's climate is not static. Climate change is mainly attributed directly or indirectly to human activity that alters the composition of global atmosphere. Climate change has the potential to cause immense damage to biodiversity affecting both individual species and their ecosystem. In this paper we have given importance to marine ecosystem. Mangroves are amongst the world most fragile ecosystem, it shows morphological and physiological adaptation skills to counter environmental stress. Changes in sea level impact the structure, growth and extent of mangroves while rise in temperature affects its density. We have lost 35% mangroves in last 30 years. Bhitarkanika Wildlife Sanctuary is located with an area of 672sq.Kilometer in the deltaic region of river Brahmani and Baitarani in Kedrapada district of Odisha out of which about 192 Sq Kilometer is covered by the mangroves which is the concerned of this study, it holds the 2nd largest mangroves in India designated as "Ramsar" site wetland of national importance. This mangrove forest act as buffers in protecting the coastlines from cyclonic storms, intrusion, soil erosion and sea water seepage. We have analyzed that the intensity of extreme weather events has increased over the last few years with the application of statistical and GIS methods . In 2007 cyclone Sidr caused 20-30% damage to the ecologically fragile areas where as the recent cyclones Amphan and Yaas in the year 2020 and 2021 respectively took a trail over Bhitarkanika resulting in uprooting of trees suffered massive damage. The flooding due to cyclones and rise in sea level has resulted in Stalinization of deltaic region making it completely unprofitable for farming. So there is a need to conserve and preserve these marine ecosystems so that the ecological balance is maintained.

Keywords: Climate change, ecosystem, mangroves, Odisha.

INVESTIGATING THE ROLES OF MARINE FISHERY ADVISORIES IN THE REDUCTION OF CARBON DIOXIDE UNDER VARYING CLIMATE CHANGE SCENARIOS FOR THE BAY OF BENGAL

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ABSTRACT

The effects of global warming on the sea adversely impacts the ecosystem services offered to the marine and coastal communities in terms of fishing efforts. The impacts are further directly related to the accelerated increase in the emission of carbon dioxide (CO_2) largely, attributed to human-induced burning of fossil fuels. The land-based transport sector has been contributing to almost one-fourth of the total global CO_2 emission since the industrial revolution of the 1850s. However, less attention is being paid to the marine fishing crafts using diesel as fuel, which also emit a significant amount of CO_2 to the marine environment. Reduction in the contributions of CO_2 in the marine environment can be controlled by the number of diesel-based boats operated in the sea for fishing. The roles of marine fishery advisories such as Potential Fishing Zone (PFZ) to reach reliable fish aggregation zones with optimal fuel consumption can be considered pivotal to the reduction of CO_2 emission in the Indian seas. PFZ advisory is being disseminated daily except during the fishing ban period, to help the marine fishers access the potential location for fishing by minimizing the search time, and thereby, reducing diesel consumption. The successes of the short-term and reliable PFZ forecasts on reducing the impacts of climate change through the reduction in relative contributions of CO_2 will be explored in the current study. In the present study, we investigated the impacts of the use of the PFZ advisories under two warming scenarios, i.e., RCP4.5 and RCP8.5, corresponding to the extent of CO_2 contributed from the marine fishing activities at Odisha, India. The present investigation can provide useful insights into the formulation of policies with respect to scenario-based usages of PFZ leading to differential emissions of CO_2 for the Bay of Bengal.

Keywords: Carbon dioxide, PFZ advisory, Bay of Bengal, RCPs

INTER-ANNUAL VARIABILITY IN SURFACE PARTICULATE ORGANIC CARBON CONCENTRATION ALONG THE EAST COAST OF INDIA

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ABSTRACT

Coastal waters play a key role in regulating the global climate through important processes such as primary production, respiration of organic carbon to carbon dioxide (CO_2), and burial of organic carbon. Organic carbon (OC) concentration – comprising of dissolved organic carbon (DOC) and particulate organic carbon (POC) – is driven by in-situ primary production and riverine discharge of OC to coastal waters. Primary production, in turn, is driven by concentrations of nutrients such as nitrogen (N) and phosphorus (P).

Inter-annual changes in POC along the East coast of India have been investigated using annual, monthly, and daily POC data products from Moderate-resolution Imaging Spectroradiometer (MODIS) aqua. Preliminary analysis reveals that POC concentrations are higher as compared to the climatological average in certain years, coinciding with severe cyclonic events. OC concentration in coastal waters off the Godavari estuary in May 2020 coincided with Cyclone Amphan. Hydrologic events such as heavy rainfall associated with cyclonic storms increase the riverine discharge of POC to coastal waters. In addition, cyclonic upwelling also enhances primary productivity by bringing up nutrient-rich sub-surface waters.

Further, recent studies indicate that frequency and severity of cyclonic storms in the Bay of Bengal have increased as a result of global warming. Therefore, impacts of global warming on the concentration of POC in coastal waters may be expected. An increase in POC has implications for the coastal carbon cycle, because of the change in pCO_2 as a result of transport, sink, and remineralization of POC. This has further implications for global CO_2 emissions and sequestration.

Keywords: Particulate Organic Carbon, Climate change, Bay of Bengal, MODIS

Is rising *Trichodesmium* blooms an indication of the warming of Arabian Sea?

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ABSTRACT

Well-known for their sporadic and abrupt blooms in the surface waters of warm oceans, *Trichodesmium* blooms occur during the pre-monsoon period (March to May), when the sea surface temperature is high with brilliant sunlight and stable high salinity. The present study deals with the unusual occurrence of *Trichodesmium* blooms along the Southeastern Arabian Sea during the winter monsoon (January 2020). During the study, extensive blooms of cyanobacteria *Trichodesmium erythraeum* were observed towards the southern transects which decreased further north. High SST and surface water salinity with low wind speed might have favoured the aggregation of extensive *Trichodesmium erythraeum* bloom patches in these regions. *In-situ*, as well as satellite based optical observations of SEAS, showed a warming trend during the month of January (winter monsoon). High sea surface temperatures (29°C – 32°C) were clearly visible along the Indian coast from Kanyakumari to Gujarat with the largest warming being observed at the Kerala Coast (1.0°C higher than the climatological mean). This warming which was more prominent towards the southern extend of SEAS might have supported the bloom of *Trichodesmium erythraeum* along the SEAS particularly off the Kerala coast. Thus, the increasing sea surface temperature might be the triggering factor for the advancement of the onset of *Trichodesmium* bloom along SEAS which otherwise occurs during spring inter monsoon season. The study suggests the possibility of considering *Trichodesmium erythraeum* as an indicator of global warming and climate change.

Keywords: *Trichodesmium erythraeum*, winter monsoon, Climate change, Southeastern Arabian Sea

CHH

Climate and Human Health Issues

ASSOCIATION BETWEEN AIR POLLUTION & MORTALITY IN NORTHERN INDIA

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ABSTRACT

Climate change and air pollution are inter connected with each other and both effect the environmental health. Under changing climate scenario, it is also important to keep a track of the effects of air pollution on many outcomes including human health. This study reports, for the period 2012–2018, on acute exposure to air pollution and mortality (cause-specific) from northern India within the Indo-Gangetic Plain (IGP) covering east UP and west Bihar region. To best of our knowledge, this study is the first systematic study from Indian region on cause-specific mortality & air pollution. Records of hospital admittance, air pollution (AP), and meteorological parameters were assessed from Varanasi for the period 2012–2018. We have built Poisson time-series models, specifically five series, for over dispersed data incorporating multiple air pollutants. Our model accounted for pollutant's lag effect and maximum and minimum temperature, relative humidity, and time-trends were controlled. Using the next generation model i.e. "Next-Gen" model with lag effect, we show the statistically significant association between air pollution and cause-specific mortality. The dose-response analysis has revealed that cause-specific mortalities are reaching up to 200%. The two prominent mortality risks linked to $PM_{2.5}$ were of cardiovascular and nephrological deaths. For every 10 units increase in short-term $PM_{2.5}$ exposure there was ~12% increase in both the cardiovascular and nephrological deaths. However, ~37% rise in respiratory deaths was associated with every 10 units increase in O_3. Cause-specific mortality and AP analysis revealed for vulnerable population in a stratified manner by sex, age, season, and region (east UP, west Bihar). The National Clean Air Programme (NCAP) is targeting to achieve 20–30% reduction in $PM_{2.5}$ across 122 non-attainment cities in India by 2024 as compared to 2017 levels. So, we have considered the NCAP's projected reduction and tried to assess the scenario about mortality. Our analysis shows that even if we consider the upper-bound of 30% reduction in $PM_{2.5}$, we would see a maximum percent change in mortality from 200% to 175% only in the cause-specific mortalities. We urge that 30% reduction in $PM_{2.5}$ would not be sufficient to significantly reduce the air pollution led mortality in north India. This demands for a new national air quality standard.

Keywords: Air Pollution; Public Health; Mortality; India.

ANALYSIS OF OUTDOOR THERMAL DISCOMFORT OVER INDIA

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ABSTRACT

To find out the variability and trends of the outdoor thermal discomfort index (DI) in India this study has been carried out. The hourly DI has been calculated based on air temperature and relative humidity (RH) data obtained from the European Centre for Medium Range Weather Forecasts' next generation global reanalysis datasts (ERA5) for the period 1990-2020. The result shows that DI exceeds 28°C, which is the thresold for human discomfort, in all summer months (March-June), over most parts of the India, except hilly regions and the Himalayas. The main reason for this high discomfort is the consistent high temperatures and relative humidity. The DI>28°C for more than 8 hours is observed over a great parts of India, especially Eastern India and Northern India during these months. The trends in the number of days with DI>28°C indicate a drcrease and increase in different parts of India in this period. Eastern parts of India particularly shows the increasing trend in number of thermal discomfort days (DI>28°C).

Keywords: Discomfort index, ERA5, M-K test.

CHARACTERISTICS OF SUMMER HEAT STRESS IN INDIA DURING 1990-2020: CLIMATOLOGY AND LONG TERM TRENDS

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ABSTRACT

Heat stress poses severe impacts on public health and socio-economic activities. However, its characteristics have not been fully investigated. In this study a comprehensive examination of the climatological pattern and long-term trends of summer heat stress events across India during 1990-2020 have been carried out using European Centre for Medium Range Weather Forecasts' next generation global reanalysis (ERA5) datasets. It has been observed that India experienced severe heat stress conditions, particularly in densely populated and urbanized areas during this period. Heat stress events in all these areas are accompanied by high temperature and high relative humidity (RH). It has also been found that heat stress in most parts of India has increased significantly during recent decades due to increase in apparent temperature (AT), temperature (T) and RH.

Keywords: Heat stress, ERA5, M-K test, Apparent temperature.

PROJECTED CHANGES IN TMAX AND TMIN IN THE SIMULATION OF HIGH-RESOLUTION CMIP6 MODELS UNDER A WARMING CLIMATE

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ABSTRACT

The anthropogenic activities causes the rise in atmospheric CO 2 concentration and greenhouse gases (GHGs), resulting in global warming. The changing climate pattern severely impacts the weather in terms of extreme events and causes melting of glaciers, sea level rise or ocean temperature. There is a subsequent impact of global warming to sectors agriculture, hydrology and biometeorology, etc. The climate models from the CMIP6 experiment were able to predict the projected changes in maximum and minimum temperature (T max and T min , respectively) in near and far futures under different warming conditions, based on their performance of historical simulations. The high-resolution (order of 1° x 1°) models of CMIP6 was evaluated for the historical simulation of T max and T min over the landmass of India. For this purpose, observed T max and T min data was obtained from the India Meteorological Department (IMD) at a spatial resolution of 1° x 1°. The model MPI-ESM1-2-HR and CNRM-CM6-1-HR were selected for the study. The historical simulations were validated for the daily climatology of T max and T min using the bias and eyeball verifications. The predictability of the model for T max and T min was skilful. Further, under Shared Socioeconomic Pathway 370 (SSP370), the projection was carried. Significant warming was observed in the near future over the Indian landmass.

Keywords:

THERMAL STRESS OVER NORTHWESTERN INDIA: CLIMATOLOGY, TRENDS AND EXTREMES

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ABSTRACT

Heat waves are becoming more common in the Indian subcontinent during the summer season as a consequence of increasing anthropogenic activity and global temperature. These extreme events cause an increase in heat extremes over India, resulting in increased of discomfort, adverse health impacts, and even mortality depending on the intensity of thermal stress. In the present study, the bioclimatology of thermal stress is studied by using a Universal Thermal Comfort Index (UTCI) to investigate the thermal discomfort due to heat stress over northwest (NW) India during summer season (April-July) over a period of 1981-2019. The monthly and seasonal UTCI climatology demonstrates that the NW India has higher climatological mean UTCI values than the rest of the country. The climatology of soil moisture revealed that there was less soil moisture over northwest India, indicating a semi-arid climate in the region. These pre-existing dry conditions over NW India play a major role in increasing surface temperature and related surface radiative fluxes during the summer season. The UTCI, surface temperature and relative humidity shows the significant increasing trends during summer season over NW India. The area-averaged temporal trend in UTCI shows significant increasing trends over NW India (+0.024 K year -1) and for entire India (+0.017 K year -1). The number of heat stress days are showing increasing trend over NW India during summer season. The composite analysis of UTCI shows the highest UTCI values during UTCI days compared to normal days. Similarly, the composite analysis of soil temperature showed the maximum during heat stress days than normal days, resulting in a higher surface sensible heat flux and subsequently warming the surroundings. The composite anomaly of soil moisture and latent heat flux shows the low magnitude due to dry condition over NW Indian region. The strong westerly winds bring the significant amount of moisture from Arabian Sea during extreme thermal stress days, which could be causing the high thermal stress in combination with high air temperatures. The current research will provide an insight of thermal stress and benchmark for the policymakers to mitigate the impact of thermal heat stress.

Keywords: Northwest India, Thermal stress, UTCI, ERA5.

ANALYSIS OF RELATIONSHIP BETWEEN METEOROLOGICAL VARIABLES AND MALARIA OCCURRENCES OVER ODISHA

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ABSTRACT

Malaria is a vector-born disease spread by mosquitoes. Africa and South-East Asia are worst affected by malaria. Almost 90% of malaria cases in Southeast Asia are contributed by India. This study analyses the relationship between malaria and meteorological variables over 10 districts in Odisha for the period 2012-2016. The temperature range of 20-30o c with 60 % Relative humidity is the optimum condition for the growth of mosquitoes. Above/below this range negatively affects the mosquito's growth. The complete life cycle of plasmodium is dependent primarily on meteorological variables like rainfall, temperature, humidity. Rainfall increases the survival chances of mosquitoes by providing a habitat for the different development stages of mosquito larvae. Temperature and humidity affect the survival of plasmodium and mosquitoes. Malaria cases peak in the monsoon season and decrease thereafter. The malaria cases have almost doubled over Odisha in 2014-2016 in compare to 2012-2013. Tmin, Rainfall, and RH at 12:00 hours show a significant maximum positive correlation with the malaria cases while the DRH (diurnal variation of temp) and relative humidity is negatively correlated with the malaria cases. Almost all the peak incidences of malaria are associated with the Tmin >20 o c range. DTR of 6-8 o C is associated with almost all of the peak malaria cases. The combination of all these meteorological variables decides the transmission of malaria at any place, condition on the presence of plasmodium in the vector mosquitoes. The climatic, seasonal, ecological, environmental, social, and economic factors also regulate the transmission of malaria at a location. The simple multiple linear regression and Artificial Neural Network (ANN) model are applied for this forecast purpose. The ANN and multiple linear regression models perform quite well for almost all of the cases. Since the malaria data is on a monthly scale and the plasmodium life cycle is on sub monthly scale so it is very beneficial to have malaria data on a weekly scale for the future forecast of malaria.

Keywords: Malaria, Meteorological Variables, Multiple Linear Regression,Artificial Neural Network.

THE IMPACT OF CLIMATIC CONDITIONS ON MALARIA TRANSMISSION IN CHHATTISGARH STATE OF INDIA

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ABSTRACT

Malaria is a major cause of health concern in India especially in the remote forested areas of the country. India with diverse climatic conditions provide sustainable and ideal environment to malaria parasites and their vectors to cause transmission. According to the report of WHO World Malaria Report 2020, India continues to make impressive gains in reduction of Malaria Burden. India being the only high endemic country which has reported a decline of 17.6% in 2019 over 2018 and has sustained Annual Parasitic Incidence (API) of less than one since 2012.

The study includes the use of VECTRI model of International Centre of Theoretical Physics (ICTP, Italy), is a mathematic dynamical model for malaria transmission that accounts for the impact of climate variability and population for analyzing the impact of climatic factors on malaria transmission in Chhattisgarh which is one of the major endemic region of malaria transmission historically.

The model is calibrated over the region of Chhattisgarh for the time period of 20 years from 2000- 2020. The results shows the transmission is seen more in the months from October to December and less during June to August. There has been decline in the number of malaria cases in the state from 2014 onwards but being among majorly remote forested and mountain range areas of the country, the states shows presence of more mosquito population, infected bite rates and increase in entomological inoculation rate (EIR) and parasite ratio (PR) values. Rainfall is found to be the main driver of malaria transmission in the state as compared to the temperature.

Keywords: VECTRI, Annual Parasitic Incidence (API), EIR, PR, Rainfall, Temperature.

DEVELOPMENT TOWARDS HEAT HEALTH WARNING SYSTEM TAILORED TO HUMAN THERMAL STRESS IN BANGLADESH

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ABSTRACT

In a warming world, heat waves are widely expected to increase in intensity, frequency, and duration, leading to increased heat stress on both humans and the environment across the globe. Bangladesh, already vulnerable to multiple climate change-related hazards in South Asia, is not an exception. Heatwaves are not only associated with a significant cause of hospitalization for elderly people and people with respiratory and cardiovascular diseases, but they will also impact the thermoregulatory processes of the body to anybody in the long run. To implement an early heat health warning system, the determination of heat stress is a primary requisite. This paper will focus on determining the heat stress index using a bioclimatic thermal index named PET (Physiologically Equivalent Temperature). PET is defined by the heat budget model of the human body with the combination of weather variables (temperature, relative humidity, wind speed, cloud coverage, etc.) and thus yields the actual physiological stress. PET is calculated by the latest version of the RayMan model (RayMan 1.2). For this study, to study the pattern of PET we have selected eight weather stations spreading across the country for three deadly heatwave events in 2021. To prepare an early warning system, we have used the forecasted weather variable from the Advanced Research Weather Research and Forecasting (ARW) model and calculate forecasted PET using the RayMan model. The skill of this early warning system will be presented in the talk.

Keywords: Heatwave, PET, RayMan model, WRF

CLIMATE CHANGE RESPONSES TO INCIDENCES OF LUNG CANCER: SCOPE OF NANOTECHNOLOGY FOR REMEDIATION

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ABSTRACT

Climate change has had a significant impact on the air we breathe. It impairs ozone and particle-induced air pollution, as well as the incidence of allergies. Furthermore, as a result of climate change, people's habitation patterns alter in many places, resulting in poor indoor air quality. As a result of low breathable air quality, the global population's risk of developing lung cancer has increased dramatically. Although nanoparticles are one of the causes of lung cancer due to climate change, nanotechnology is also employed in lung cancer treatment. Nanotechnological intervention has the ability to identify molecular alterations of small fractions of cancer-related cells with greater speed and sensitivity. In the treatment of lung cancer that are usually resistant to conventional therapy, nanoparticles represent a viable option. Magnetic nanoparticles were successfully employed to harm tumour cells in non- invasive ways. Novel nano-therapies are being developed to encapsulate a variety of ligands (DNA, RNA, antibodies) with the help of the large surface area of nanoparticles. It is possible to use these ligands for medicinal purposes or control the behaviour of other nano particles in vivo. A wide array of diverse combination of nano-features may be used to develop drugs in multi-modal manner for 'theranostic' actions. The energy absorption and re-radiation capabilities of nanoparticles can be strongly used to destroy cancerous lung tissues. In spite of all marvels, nanoparticles are yet to be fully utilised in lung cancer research, diagnosis and treatment. In the present paper a review has been made on the impact of climate change towards the prevalence of lung cancer & remediation of cancerous cell with the use of nanotechnology.

Keywords: Climate change, Lung cancer, Remediation, Nanotechnology

EMERGING INCIDENCES OF FLUOROSIS IN BARIND-SUB HIMALAYAN ALLUVIAL FANS OF WEST BENGAL, INDIA: NANO-TECHNOLOGICAL TREATMENT ADAPTATIONS AND INTELLIGENT HEALTH ANALYTICS

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ABSTRACT

Fluoride is an essential trace element of drinking water that acts beneficial to human beings within optimum limits (0.6 to 1.2 mg/l). But excess ingestion leads to acute fluorosis, while deficiency causes dental caries. The Barind alluvial aquifers of West Bengal (India) that characterizes the largest Pleistocene physiographic unit of Bengal Basin skirting the sub-Himalayan foothills, is reeling under fluoride pollution (7.58 mg/L) for several decades. A wide interplay of diverse geogenic and anthropogenic conditions has triggered fluoride leaching from host alluvium. Good correlation is deduced between fluoride and select hydro- chemical parameters that shed light onto fluoride geochemistry. But fluoride treatment in drinking water adopted so far under private-public initiatives proved expensive and failed to reach tangible results. The ground scenario of fluoride treatment and concurrent health remediation is thus turned into a burning socio-environmental and public health issue. In this paper, a novel de-fluoridation technique through selective adsorption by Mixed Metal Nano Oxides (MMNOs) has been successfully developed and validated for first time in field as part of environmental remediation of public water tube wells. These innovatively designed fluoride filters attached to community wells entail high fluoride nano-adsorption (2900-3000mg/Kg) under voluminous pumped flow conditions. The treatment is low-cost (20-30 paise/liter) and eco-friendly, and strongly advocates the marvels of MMNOs as effective commercial media for fluoride removal in public water supply schemes. This research further delves to form a strong connect between fluorosis epidemics and potable water quality by correlating the nano- treatment adaptations with clinical, medicinal and nutritional support system. The impacts of fluoridated and defluoridated water on pre- and post- mitigation health of beneficiaries are studied for creation of a compendium on Fluoride Health Analytics, AI-based Automated Monitoring, Early Warning Signs and Symptoms and Prediction of Fluorosis.

Keywords: Barind, fluoride filters, groundwater, nano-remediation.

DMC

Disaster Management and Climate Change

LANDSLIDE SUSCEPTIBILITY ZONATION: A CASE STUDY AT KANNAN DEVAN HILLS, KERALA, SOUTH INDIA

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ABSTRACT

Unusual precipitation over the mountains and concomitant landslides are one of the most widespread disasters on the planet. Every year, such landslides cause human casualties and economic losses in different parts of the world. This is particularly evident in tropical environments in light of the development and human settlement in the susceptible areas. In India, next to Himalayan region, the Western Ghats, the highly dissected terrain, is a part of the western mountain chain of peninsular India are enumerated as one of the country's major landslide prone areas. During the monsoon season, excessive rainfall causes landslides in the Western Ghats region. Very recently, the Pettimudi , in the Kannan Devan Hill (KDH) village (Munnar), Kerala's Idukki District, experienced its most destructive landslide in history on August 6, 2020. 72 people from lower socioeconomic classes died as a result of the slope failure. Aside from unusual rainfall being the primary cause of slope collapses, the current study focuses on exploring the other significant variables involved in landslides throughout KDH. The statistical study of drainage morphometric characteristics in the region and their association with slope failures indicates that 18.8 percent of the territory in KDH is in a high-risk zone and is vulnerable to landslides in the future. The study also confirms that there is a correlation between landslides and KDH drainage. The study highlights the efforts of government authorities and social organizations efforts in rehabilitating afflicted people in KDH coupled to the Pettimudi landslide event as well.

Keywords: Landslides of Kerala, Landslide susceptibility zonation, Frequency ratio, Drainage morphometric parameters, Statistical analysis.

Application of Artificial Intelligence for the Forecasting of Fog for the JPNI Airport Patna,India.

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ABSTRACT

Fog is one of the major weather hazards for aviation services i.e operations of Air Traffic Management. The persistence of Fog reduces the visibility of the atmosphere and severely impact flight operations. Therefore precise predictions of the fog are required for the Optimum operations of the aviation sector. Prediction of fog remains difficult even with the advancement of the Numerical Weather Prediction models and even guidance of fog prediction models. The biggest challenge in making weather forecasts is the complex and chaotic process of the atmosphere. This research paper tries to assess the ability of artificial intelligence to accurately forecast these weather for the JPNI Airport Patna, India. Artificial intelligence-based model prediction used the hourly synoptic data from January 2014 to July 2021. In Eastern India, fog leads to forms in stable and clear atmospheric conditions, low temperatures, supply of adequate humidity, and strong low-level inversion. Flexible inputs such as Dry Bulb Temperature, Wet Bulb Temperature, Dew Point Temperature, Relative Humidity, Total amount of cloud, Wind Direction, Wind Speed, Visibility, and Current Weather are used to predict Fog or No Fog events. In this research article, we assess parameter tuning in five algorithms as Distributed Random Forest (DFR), Deep Learning (DL), Gradient boosting Machine (GBM), Generalized Linear Model (GLM), and Extreme Randomized Tree (XRT). The optimum results were obtained from the Stacked Ensemble (SE) model with precise accuracy of more than 92% for forecasts one to three hours in advance.

Keywords: Fog Forecast, Artificial Intelligence, Machine Learning Algorithm, Deep Learning Algorithm, etc.

A Case Study: Extremely heavy rainfall over East Rajasthan during SW monsoon 2021

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ABSTRACT

Rajasthan lies over the northwestern part of India. It has an area of 3.42 lakh square kilometers. India meteorological department has divided the state for weather forecasting at subdivision level into East and West Rajasthan. It has a typical climatic condition with extreme hot temperature in the summer season at the same time extreme low temperature are also observed in the winter season.

Southwest monsoon plays a major role as far the irrigation is considered, still much of the area is dependent on rain for the cultivation of crops. During 2021 southwest monsoon entered East Rajasthan on 18 th June 2021 but after few spells of rainfall in the consecutive days, due to non-favorable Global features as well as no indication of rainfall in NWP models the furtheradvancement of southwest monsoon got delayed into the remaining parts of east as well as westRajasthan. Thus, the rainfall departure from the normal reached more than -30% in the East Rajasthan but with the formation of a low pressure system in the Bay of Bengal due the effect of which easterlies started reaching the East Rajasthan and at the same time a circulation was also present over the west Madhya Pradesh under the influence of these synoptic features some tehsils of east Rajasthan received extremely heavy rainfall of the order of greater than 250 mm for consecutive days which rose the rainfall departure from negative departure to positive. Even though the system was not located directly over the east Rajasthan it led to a massive rainfall. Sucha massive rainfall even though bring the statistical parameters near the normal or even greater butthey have a huge impact on the agriculture and the crop development process. Thus is a majorcause of concern to study.

POTENTIALITY OF SENTINEL -2 IN DROUGHT ASSESSMENT AND MONITORING

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ABSTRACT

The accelerating trend of climate change is intimidating to the existence of species on the earth. Climatic changes resulted in flash flooding, fluctuation in rainfall reception, growth of urban heat island, forest fire spreading and melting of polar ice cap. Low reception of rainfall and high per capita water consumption resulted in the declination of ground water level and surface soil moisture. In this study, change in surface soil moisture is estimated using Shortwave Infrared (SWIR) spectrum and Normalized Difference Vegetation Index (NDVI) on pre monsoon, monsoon and post monsoon period in the Okkiyam Maduvu watershed, Tamilnadu, India. The estimated soil moisture is validated with the insitu observation and coefficient of regression is observed to be 0.71. The study shows the potentiality of multispectral remote sensing in the assessment of drought.

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Keywords: Climate change, Surface Soil Moisture, SWIR, NDVI.

Climate Change Adaptation – Role of Satellite Data

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ABSTRACT

Weather and Climate has great influence on human civilization and activities. The human activities in the recent decades has raised emissions to the atmosphere due to burning coal, oil and gas, deforestation, increasing livestock farming, use of fertilizers containing nitrogen. Climate change is expected to have substantial adverse effects in India, mainly on agriculture, water storage in the Himalayan glaciers which are the source of major rivers and sea-level rise affecting coastal habitations. Another impact is increased frequency of floods and droughts, impacting India's food and water security. Adaptation to climate change requires adjustments by societies and ecosystems to limit the negative impacts of climate change and also to take advantage of opportunities provided by a changing climate. The various proactive actions planned include development of drought resistant crop varieties, improved flood management, Industries to reduce pollution, develop efficient water management systems, use of alternate energy sources such as solar, wind and ocean energy etc. With the availability of satellite remote sensing, new vistas have opened up to study the earth-atmosphere system in great detail and assess climate change and impacts. The operational satellites INSAT and IRS have heralded an era of space observations with high resolution observations of land, ocean and atmosphere. The IRS satellites are providing observations of parameters such as land use/cover, forest, water bodies, crops etc. while INSAT data has helped in studying various aspects of weather systems. Some of the unique studies are Hydrology and water balance, Drought and Flood mapping, Biosphere Monitoring, Mapping of Glacial Lakes & Water Bodies in Himalayas and Biodiversity Mapping. This paper highlights the role of multispectral high resolution satellite data in monitoring the climate change impacts and help in developing adaptation strategies through sustainable development models for managing agriculture and water resources.

Keywords: Climate Change, Climate Change Impacts, Satellite Observations, Adaptation

Numerical Simulation Studies of Flood Inundation and Run-up along Central and Northern Kerala

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ABSTRACT

The state of Kerala was in the shadow zone of several different natural disasters. But the Tsunami of 2004, Ockhi of 2017, Floods of 2018 and its replicated versions in the subsequent years exposed the vulnerabilities of the state. The impact of floods in 2018 was unprecedented and it exposed the urgent need for establishing a flood warning system. The main component of a flood warning system is the prediction of inundation and run-up along a bank. This investigation is an attempt to model the flood characteristics in terms of run-up and inundation along the banks of Chaliyar River pertaining to the district of Kozhikode in Northern Kerala and also along the banks of Periyar river along Central Kerala in Ernakulam District. The modelling was executed using a virgin model simulation exclusively including rainfall alone as input. The HEC - RAS and HEC - HMS model developed by US army corps of Engineering was used as it is a well calibrated and globally accepted model extensively used by several flood modellers across the globe. Besides an hypothetical non-virgin simulation with feeble external discharge scenarios was also simulated. The rainfall was bifurcated and classified into four modes like normal rainfall, moderate rainfall heavy rainfall and hypothetical rainfall. The rainfall data was interpolated from Central water Commission report on Kerala floods. The topographic data were downloaded from the USGS Earth Explorer website. By using these inputs, the run up and inundation for all the four scenarios were computed. The modelling results for northern Kerala predicted that only heavy rainfall events or Extreme Rainfall Events (ERE) could inundate the terrain. Dam discharges coupled with heavy rainfalls also can inundate the terrain to a larger extend. The investigation underscores that the banks of Chaliyar river are not vulnerable with reference to normal and moderate rainfall excluding dam discharges. In Central Kerala, the prominent locations from Cheranallur to Aluva all showed no run-up for normal rainfall. There was a significant change in the run up for moderate rainfall. The run up value came around 0.25 m. This value was constantly uniform from Cheranallur to Aluva. The moderate, hypothetical run up values were coming around 1.25 m and 2 m respectively. The simulated run up values highlighted that normal rainfall and moderate rainfall can create only insignificant run ups where

as heavy rainfall can lead to significant run up along both the terrains. The simulation executed in non-virgin mode predicted that prolonged rainfalls leading to extreme rainfall events can change the flood vulnerability of Kerala. Normal and moderate rainfalls are the usual pattern of rainfalls in Kerala. It is to be pertinently noted that 2018 onwards Extreme Rainfall Events (ERE) like the heavy rainfall in simulation studies is a reality. That was the reason behind computing non virgin simulations for heavy mode of rainfall. The investigation recommends the need of in-depth model computations in non linear mode incorporating all standard parameters and protocols with fine resolution data sets subject to field verification. It will ultimately help in generating model scenarios and for the creation of high vulnerability maps, as a prerequisite for accelerating mitigation strategies.

Keywords: HEC-RAS, Run up, ERE

Impact of Urbanization on Natural Disasters – A Case of Gangtok City

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ABSTRACT

The Indian Himalayan Region (IHR) has experienced rapid urban growth during the last three decades. However, unregulated growth has resulted in the environmental change, transforming the region (Walker, 2011).

Gangtok is prone to multiple-hazards like earthquakes, floods, and landslides. As the population growth of Gangtok has increased rapidly from 17% (2001) to over 271% (2011), it has further aggravated the risk by creating pressure on the land and simultaneously increasing the risk to disasters and their direct and indirect impacts. The twin challenges of dealing with extreme weather-related disasters and adapting to the impacts of climate change requires an integrated approach of both disaster risk management and climate change adaptation. The study was conducted by Integrated Research & Action for Development IRADe in association with G.B. Pant National Institute of Himalayan Environment (NIHE) in Gangtok Urban Agglomeration to assess the citizen perception on disasters and its association with climate change . The study examined various sectors extending from climate change pattern to compounding factors such as water and drainage. The study revealed that frequency of hazards like urban floods and landslides have increased. Moreover, changes in both, climatic factors such as heavy rains and the human induced factors such as rapid urbanization and deforestation have played major role in altering these hazards. Therefore, resulting in the increased vulnerability due to unplanned growth of the city. The effects are not confined to hazards but has also affected the overall environment of the city like water resources, air quality and green cover.

The study helped to identify ward level vulnerabilities and required preparedness is the critical to combat the current and future disasters.

Keywords: Climate change, Disaster Resilience, Urbanization, Adaptive Strategies

Wildfires as an impact of global climate change and anthropogenic activities-
A case study of Similipal Biosphere Reserve, Mayurbhanj, Odisha.

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ABSTRACT

Climate change has been a key factor in increasing the risk and extent of forest fire. Since the beginning of this year there has been a series of forest fire across the whole country. Forests are home to flora and fauna, build soil, regulate water flows, and provide quality water as well as small wood and timber. Odisha's total forest cover area is 50,347 sq km as per the 2020 survey which is nearly 32.33% of the total geographical area of 155.707sq. kms. Similipal, Asia's second largest Biosphere Reserve spread over an area of 4374 sq km in the district of Mayurbhanj. The problem of the study is a massive fire broke out in the month of February causing immense damage to the biosphere. A total of 348 fire points have been detected by the Forest Department. The hot climate and absence of post monsoon generated the wildfire. The primary reason behind this wildfire is mainly caused by human action is another thrust of the study. The local Adivasi people in the area torch the forest to clear the land for ease of Mahua flower and Kendu leaves collection and poaching. It was observed that the core area of the sanctuary was secured whereas the buffer zone and foot hills were adversely affected. The main purpose of this paper is to interpret the potential effects of climate change and fire regimes from the data collected of primary and secondary sources .The data has been analysed with the help of statistical methods and map generated using remote sensing and GIS. The degree of forest fire analysis and its frequency are very important factors for taking post preventive measures and conserve the Biosphere Reserve.

Keywords: Climate change, Forest fire, spatial analysis, Odisha.

Tropical Extreme Weather Event Management and Climate Adaptation via Supervised Computer Vision-based Algorithms

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ABSTRACT

Worldwide, the tropical regions frequently experience extreme weather events like hurricanes, typhoons, and monsoons. Due to climate change, these natural disasters have been increasing in the probability of occurrence as well as the severity of the impacts. It is crucial that robust pipelines are established to enable effective disaster management, which saves lives and minimizes economic loss. In this work, we discuss how computer vision-based methods can produce automated algorithms that can be deployed to assess the impacts of tropical weather events. In particular, we focus on how Earth observation data like high-resolution satellite imagery is a prime source of training data for machine learning models like convolutional neural networks. We experiment with training various convolutional neural networks with different criteria for optimization and input modalities for training data. The data sourced is primarily from the xBD dataset, developed by xView2, which includes Earth observation imagery from monsoons in India and Nepal. We find that ordinal cross-entropy loss is the loss function that yields the highest accuracy. Furthermore, the aspect of change detection over multitemporal scales (pre-disaster to post-disaster) is a crucial part of the training data that increases the efficacy of the model when captured. The aim of this study is to advance interpretable, state-of-the-art deep learning-based computer vision models for extreme event management in the tropics and to aid in the broader worldwide climate adaptation effort as carbon emissions continue to rise.

Keywords: Climate change, Extreme Weather Event, Natural Disaster, Deep Learning, Artificial Intelligence

AMS

Adaptation, Mitigation, and Sustainable Development

TRANSPORTATION SYSTEM CONSTRAINTS IN A CLIMATE CHANGING SCENARIO: GEOSPATIAL ANALYSIS ON WEST COAST OF INDIA

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ABSTRACT

During the summer monsoon season, the west coast of India receives a significant amount of rainfall. Climate change has resulted in a possible deviation in the frequency and intensity of precipitation patterns in recent years, resulting in severe flooding. The western coastal plain (approximately 1400 km) is sandwiched between the Arabian Sea in the west and the Western Ghat Mountains in the east. Because of the potential for natural disasters, this region attracts a lot of attention. The road and railway network, which runs through highly uneven terrain, are part of the transportation system. The coastal plains are connected to other parts of peninsular India (Peninsular plateau) by mountain passes. These passages are critical for the distribution of essential supplies between the coastal plains and the rest of the country, especially since five of the country's major ports are located in this area. Flash floods, landslides, and other related disruptions to the region's transportation system are caused by unusually heavy rains. These unanticipated geohazards have a negative impact on commuters and the distribution of essential goods. The present study intends to identify the potential spots, with higher threat for transportation, geo-spatial solutions to minimize the constraints

Keywords: Climate change, Geo- hazards, Transportation system, Mitigation

ADAPTATION AND MITIGATION STRATEGIES AT FARM LEVEL TO MINIMIZE THE RISK : INTEGRATION OF MODELING AND STAKEHOLDER CONSULTATION APPROACH

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ABSTRACT

It is projected that by the end of the twenty-first century, average temperature over India is to rise by approximately 4.4°C relative to the recent past (1976–2005 average) under the RCP8.5 scenario. The year 2020 was the eighth warmest year on record since nation-wide records commenced in 1901. There has also been an increase in the occurrence of extreme weather events, such as heat waves and untimely intense precipitation, that affect agricultural production and thereby the food security and livelihoods of many small and marginal farmers, which is more than 90% of the total agricultural population of the country. Climate change has about 4-9 per cent impact on agriculture each year. Rice, wheat, maize and sorghum are the worst hit by this phenomenon. By 2030, rice and wheat are likely to see about 6-10 per cent decrease in yields. However, crops like potatoes, soybean, chickpea and mustard, on which climate change will have a neutral or positive impact. The adaptation and mitigation strategies should be concentrated at the local level. Hence, a study was conducted in Meerut District of Uttar Pradesh and Karnal District of Haryana, to understand the impact of climate change at local level by linking climate-crop-economic models with stakeholder participation under ICAR-AgMIP Collaborative study. This study shows that, under current production systems, although the magnitude of decline in net farm returns and per capita income may look small, it will adversely affect a large proportion of farms (49%–74%). The adaptation strategy for the current production system enhances rice yields by 6%–14% (APSIM and DSSAT) and wheat yields by 11%–18% (APSIM and DSSAT). These changes in the production system result in 11%–14% increase in mean net farm returns and 7%–8% increase in per capita income (APSIM and DSSAT), which result in 2%–3% decline in population poverty rate. Approximately 57%–62% of farms in the current production system would benefit from adoption of the adaptation strategy.

Keywords: Adaptation, Mitigation, Agricultural Pathway, Stakeholder

MICROTHERMAL ENVIRONMENT INFLUENCING MUSTARD APHID UNDER COMPANION CROPPING: A CLIMATE FRIENDLY APPROACH

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ABSTRACT

In recent past, different types of pest attack particularly the dreadful menace of mustard aphid, Lipaphis erysimi, potentially causing 100% yield loss in mustard have been increased due to gradual changes in thermal environment of the crop owing to interminable climate change conditions. Most farmers indiscriminately use synthetic insecticides which negatively impact the environment and calls for an eco-friendly solution. To encounter this situation, present investigation was carried out using companion cropping green technology involving two popular mustard cultivars (B-9, V1; B-85, V2) grown in combination with three companion crops (C1-Pea, C2-Marigold, C3-Garlic) and sole mustard (C4) under two planting arrangements viz. Border (A1) and Line (A2) in FRBD at Research Farm of BCKV, Kalyani, West Bengal during two consecutive rabi seasons of 2017-18 and 2018-19 to inspect the variability in microthermal environment under modified diverse mustard cropping system and its subsequent influence on mustard aphid dynamics. Results indicated that canopy temperature within mustard had lowered significantly in association with pea (C1) and marigold (C2) than sole mustard (C4). Maximum canopy temperature was recorded for B-85 (V2) and border (A1) arrangements kept the combined canopy quite cooler. Soil temperature at different depths (5 & 15 cm) stayed relatively higher under B-9 (V1) especially with border planting. Soil temperature was relatively optimum in rapeseed-mustard crop raised with pea (C1; 23.48 o C) and marigold (C2; 22.16 o C) than mustard-garlic (C3; 23.96 o C) and sole mustard (C4; 25.52 o C) combination. Weather based aphid forewarning models developed were able to explain 56.29% to 92.44% variability in aphid population with respect to canopy and soil thermal environment. Thus, it may be recommended that exploration of affordable alterations in crop microenvironment as an adaptation strategy against relentless climate change may amend the pest density and enhance crop yield to many extent at micro levels.

Keywords: Companion cropping, Microenvironment, Aphid dynamics, Adaptation, Climate change

CLIMATE CHANGE IMPACTS: MITIGATION AND ADAPTATION

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ABSTRACT

Every inhabitant on this planet is suffering from the impacts of climate change in one way or the other. What we have achieved through steady growth in economy, food production, and all modern infrastructure facilities the climate change washes out in no time. Climate change mitigation and adaptation can be supported by biodiversity conservation actions, enabling the permanence of mitigation and adaptation efforts.

PURPOSE

Reduce hardships consequent to climate change, such as diseases, meeting dail life requirements, and loss of livelihoods . Adaptation is a measure of the extent to which a species or ecosystem is able to adjust to environmental change. Mitigation on the other hand is action taken to minimize negative climate impacts. Development which ensures ecosystem services or natural resources without deficit even to future generations is called sustainable development.

METHODS TO ACHIEVE SUSTAINABILITY

Clean technologies, policies and strategies fostering climate-friendly technologies and innovations, renewable energy, energy efficiency, sustainable cities, food systems, land use and restoration, sustainable forest management are among them.

ADAPTATION ACTIVITIES

Disaster preparedness, climate resilient infrastructure, improved drainage system, stress tolerant cultivars. Adaptation on local level perspectives, conserving biodiversity and ecosystem, and capacity building to cope with the crisis.

MITIGATION MEASURES

Reduce carbon, and stabilize greenhouse gases. Reduce waste by composting. Since agriculture and food production contribute to a major portion of carbon emission sustainable agriculture deserves priority.

CONCLUSION

Sustainable energy sources, consumption, lifestyle, businesses, infrastructure, tourism, transportation, all need to adopt carbon neutral pathways. Our future depends on the speed at which we transform to a low carbon sustainable economy.

Integration of Human Activities and Ecological Restoration on Climate Change

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ABSTRACT

Climate change is a continuous process. But after the industrial revolution and exponential growth in human population, the environment of the mother Earth started becoming polluted. Many forests were destroyed for accommodating human settlements and establishment of factories etc. This resulted in a sharp increase in various types of solid & Hazardous wastes and liquid waste. The prominent solid wastes are Municipal Solid Wastes, Plastic Wastes, Construction & Demolition Wastes (C & D wastes), electronic wastes, bio-medical wastes and Hazardous Wastes. Similarly there has been quantum jump in the industrial effluent and domestic wastewater. Both carbon dioxide and methane are greenhouse gases which are generated due to industrial, domestic and urban activities; these gases contribute to global warming and climate change. The total warming effect to the Earth's atmosphere from the rise in the concentration of GHG by humans from 1990-2019 has increased by 45 percent. So there is an urgent need for mitigation of ongoing environmental degradation. In order to improve it further, there should be action towards Ecological Restoration. The increase in atmospheric temperature is resulting in massive damage to Earth's ecosystem. Several agencies including 'United Nations Environmental Programme (UNEP)' are working under different national and international programmes for prevention and control of pollution and saving of natural resources through Circular Economy. Minimisation of waste materials through effective management is the best way to check the increase in the concentration of GHGs. The Concept & methodology of Cleaner Production will give a right direction to go for reduce, reuse, recycle and eco-friendly product design. There is a need of ecological restoration to get fresh air, clean and drinking water, green earth, flora & fauna for Environmental sustainability. In the present paper, discussions will be made on the increase in GHGs due to unscientific way of management of waste materials and measures to check their growth.

Key Words:- GHG (GreenHouse Gases), UNEP (United Nations Environmental Programme)

Assessing above ground carbon sequestration potential of coconut plantation at CRS, Aliyarnagar in Coimbatore

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ABSTRACT

Coconut plantations play a major role as a source of revenue to the country and as livelihoods to millions of people. Coconut palms, which can stay more than 50 years in the field, are capable for regulating atmospheric carbon by converting into biomass for a longer period of time. The field experiment was conducted at Coconut Research Station (CRS), Aliyarnagar in Coimbatore district in Completely Randomised Design (CRD) with six treatments and five replications. The non-destructive methods of Nareshkumar et al. (2008a) and Aexander Clark III et al. (1986) were used for studying the above ground carbon sequestration potential of coconut palms with different age, cultivar and management.

Thus the rate of above ground carbon sequestration potential of six year old dwarf & tall type coconut palm was estimated to 0.422 and 0.743t ha $^{-1}$ yr $^{-1}$ respectively, twelve year old dwarf & tall type coconut palm was estimated to 0.413 and 1.83 t ha $^{-1}$ yr $^{-1}$ respectively, eighteen year old, organically managed tall type palms was estimated to 1.854 t ha $^{-1}$ yr $^{-1}$. By multiplying the weight of carbon by the factor 3.6663, the weight of carbon dioxide sequestered in a coconut palm can be calculated. Thus the rate of above ground carbon dioxide sequestration potential of six year old dwarf & tall type coconut palm was calculated as 1.619 and 2.726t ha $^{-1}$ yr $^{-1}$ respectively, twelve year old dwarf & tall type coconut palm was calculated as 1.516t ha $^{-1}$ and 6.743t ha $^{-1}$ yr $^{-1}$ respectively, and an eighteen year old, organically managed tall type palms was calculated as 6.801t ha $^{-1}$ yr $^{-1}$.

Keywords: Biomass, carbon sequestration, non-destructive methods, organically managed

NET ZERO ENERGY AND SUSTAINABLE DESIGNED BUILDINGS A VIABLE ALTERNATIVE TO MITIGATE CLIMATE CHANGE

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ABSTRACT

Poor performing buildings such as residential, commercial, institutional are significantly contributing to the climate change indirectly or directly. During operational phase of buildings, applications such as cooling, heating, ventilations, lighting, appliances responsible for 80 % greenhouse gas emission out of total life cycle and 20 % amount is responsible in initial stage such as material manufacture, transportation, demolition and renovation. Hence, the buildings consume more than half amount of total energy generated in the country affecting climatic change. This side effects on climate will double or triple in coming decades due to several key factors as demand for buildings will increase. However, the existing knowledge, advanced design techniques, and research findings to fill this gap are important to reduce negative effects due to buildings on climate. This paper focuses on adaption of sustainable solutions in order to achieve net zero energy building. In order to mitigate energy consumption in buildings the techniques of renewable energy sources available on-site and off-site, electrical and thermal energy features have been discussed. The paper summarizes two case studies on sun based passive solution and their basic design for net zero energy building. This review paper findings and techniques proved to be essential and effective in order to reduce energy consumption cost, increase thermal comfort of residents and sustainable building practices.

Keywords: Climate Change, Net Zero Energy Building, Sustainable Buildings, Mitigation & Adaptation

Challenges In Strategizing Adaptation, Mitigation, and Sustainable Development To Combat Consequences Of Climate Change

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ABSTRACT

Although world leaders have agreed to control greenhouse gases' emission, it is seen that the current rate of emission may not stop global climate change. Even if it will be controlled to some extent will not be in a comfortable range. It is apparent that a large coastal area throughout the world will be hit by the Sea Level Rise and the habitation will be fully disturbed and inundated. Three possible strategies viz. Protection, Accommodation and Relocation can be envisaged to combat with this unavoidable disaster. Each of these strategies will have different social and economic consequences, depending on the area and people thereof. When Sea Level Rise is inevitable, the world leaders will have to decide most optimized sustainable solutions, which will have least effect on the people. This paper describes the different consequences for the strategies with merits and demerits with illustrations and aims to find a common way out applicable to different parts of the world. Undoubtedly the acceptance of the strategies by concerned people will vary based on locations. Incidences of Extreme Weather Events in recent years has accelerated the need to concentrate in the matter. Also, an overall common revision of thoughts in reducing global warming and emissions has to be stressed upon to achieve a sustainable solution. Science has already proven that the principal cause of climate change is anthropogenic and hence anthropogenically acceptable solutions for adaptation, mitigation, relocation, whatsoever suits in particular region has been attempted to find. The extreme heat in last year, the wild bush fires and the catastrophic storms affecting low lying and island countries deserves more attention such the events can be minimized to the extent possible. As everything will depend on societal decisions few suggestions at local level have been included which can be accepted as global policies.

Keywords: Climate change, Sea Level Rise, Adaptation, Mitigation,

ROC

IMS-OSI joint session on Role of Ocean on Climate

Influence of climate modes on tropical cyclone activity in North Indian Ocean

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ABSTRACT

Tropical cyclones (TCs) are one of the most destructive weather systems with strong air-sea interactions over the warm tropical oceans. The North Indian Ocean (NIO) comprising the Bay of Bengal(BoB) and Arabian Sea (AS) hosts about 7% of total TCs that occur worldwide each year. The Bay of Bengal is more prone to cyclonic activity as compared to the AS. But the year 2019 was anomalous, where AS had witnessed five cyclones and BOB had only two. The warming of the Indian Ocean is one of the causative factors for the increasing frequency and intensity of cyclones in both the basins. In this study, we analyse the climatic factors such as El-Niño Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO) and Indian Ocean Dipole and their influence on the cyclonic activity in NIO. Climate teleconnections have considerable impact on the TCs over both the basins. The La-Niña enhances the formation of TCs in BOB as compared to El-Niño. The co-occurence of El Niño and positive IOD have a tendency for the formation of more cyclones in BoB. The years 1982 and 1997 are examples for such co-occurrence. Similarly, La-Niña co-occurring with negative IOD forms more cyclones in BoB. During a negative IOD year, the cyclones in BoB are found to be stronger than usual. Positive IOD has more effect on AS cyclones and more frequent storms can be observed, because the AS will be warmer than BoB. The co-occurence of El-Niño and positive IOD will contribute to a lesser number of cyclones in AS. The impact of ENSO on TCs over BoB is significant only in the warm phase of PDO. Positive IOD along with positive phase of PDO shows more cyclones in AS. La-Niña years exhibit more cyclones than El Niño in the warm phase of PDO.

Keywords: Tropical cyclone, Climate teleconnections, Cyclone Frequency, Intensity

Extreme wind-wave projections for the Indian Ocean under a changing climate

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ABSTRACT

Impact of global warming and climate change have increased the risk of extreme ocean waves and its vulnerability along coastal regions. The Coordinated Ocean-Wave Climate Projections (COWCLIP) project is aimed to generate global wave climate projections and its assessment on wind-wave driven feedback to the coupled earth system. Wave simulations carried out under the COWCLIP framework can be used to skill assess the wave climate for the Indian Ocean (IO) with ERA5 datasets for the historical period. Models such as MRI-CGCM3, ACCESS1.0, INMCM4, HadGEM2-ES, and BCC-CSM1.1 are considered as the best-performing models in representing the past wind-wave climate over the IO region. In addition, the multimodal ensemble mean constructed using the above mentioned five best-performing models are chosen to analyze the futuristic wave projections. Generalized Extreme Value (GEV) analysis is a powerful tool to understand the seasonal climatology and variability of extreme waves and winds over the IO region. Study revealed that regions over the northern IO, northwestern Arabian Sea (AS) and central portions over Bay of Bengal (BoB) experience the highest wave activity during the JJA (June-July-August) season in the future. Considering the RCP4.5 (Representative Concentration Pathway) scenario, the end-century projections reveal drastic change in extreme waves by about 1 m over regions northeast Bay of Bengal, western tropical IO, and southern IO regions. Analysis based on probability density for extreme waves (> 4 m) in future signifies an increase for the AS under the RCP8.5 scenario forcing. SST projections also show an increment over the entire AS during the DJF (December-January-February) and JJA seasons ranging between 1.5°-2°C, and hat is 0.5°C greater than in BoB region. Projected decline in winds over western tropical IO during JJA and SON (September-October-November) seasons is consistent with weak SLP (Sea Level Pressure) variations and warmer oceans over that region.

Keywords: Climate change, CMIP5, RCP, Extreme waves

Interannual Variability of Mesoscale Eddies in the Bay of Bengal

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ABSTRACT

In the north Indian Ocean, robust eddy-mean interaction facilitated by the horizontal density gradient dominates circulation in the Bay of Bengal. However, the interannual variability of mesoscale eddies in the bay is still unclear. Here, we have used Sea Level Anomaly (SLA) data using satellite gridded merged altimeter product (AVISO) to estimate eddy formation in the bay using an eddy detection algorithm developed by Mason et al., 2014. We have calculated Eddy number and associated eddy radius and amplitude using the algorithm daily in the Bay of Bengal (78°E - 98°E, 3°N - 23°N) region within 1° x 1° grid box. We have investigated Spatio-temporal variabilities of mesoscale eddies in the bay from January 1993 to December 2016. We have defined mesoscale eddy with eddy amplitude (radius) of more than 5 cm (50 km) and a life cycle of more than 28 days. Our analysis shows the dominance of cyclonic eddies over anticyclonic eddies annually. For estimating eddy variability concerning different seasons, we have defined spring (February-April), summer (June-August) and winter (October-December). Among three seasons, we observe a maximum eddy number (cyclonic and anticyclonic) during summer compared to spring and winter. Our analysis also shows significant interannual variability associated with eddy numbers in the Bay of Bengal. We have found the role of IOD (Indian Ocean Dipole) compared to ENSO (El Niño and the Southern Oscillation). During the negative IOD years, the cyclonic eddies formation is more than those in positive IOD years. Likewise, in positive IOD years, the anticyclonic eddies generation is more than those in negative IOD years. Due to the strong relationship between IOD and rainfall, cyclonic eddy number variabilities are positively correlated with 5-90 rainfall variabilities (JJA variabilities) during p-IOD years.

Keywords: Mesoscale Eddies, Bay of Bengal (BOB), Indian Ocean Dipole (IOD) mode, El Niño Southern Oscillation (ENSO)

OCEAN WARMING INDUCED BY KELVIN WAVE ACTIVITY IN ARABIAN SEA AND ITS IMPLICATION ON ENHANCED TROPICAL CYCLONE ACTIVITY

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ABSTRACT

The Indian Ocean is a sink for the accumulation of ocean heat that is evident in the near sub-surface and deeper layers from the year 2000 onwards. In a historical perspective, the Arabian Sea (AS) was a less active region in terms of tropical cyclogenesis and tropical cyclone activity. However, during the recent decades the tropical cyclone activity have enhanced over the AS basin, and the recent years have witnessed intense tropical cyclones that made landfall over the west coast of India. This study investigated the possible causative factors and physical mechanisms responsible for enhanced ocean warming in the AS basin. Various datasets such as Altimetric observations and Reanalysis products were using in the study. The ORAS5 Ocean Heat Content (OHC), derived meridional and zonal heat transport, currents, temperature, salinity, Outgoing Long Wave Radiation (OLR) and air-sea fluxes were used to quantify warming at water depths of 700 m (D_{700}) and 300 m (D_{300}) and its variability during the past four decades. Study signifies that the highest variability in OHC occurred over the western side of the Indian Ocean and the Southern Indian Ocean sectors. Increased warming in AS basin has a correlation with decreased OLR during the past 20 years. Inferences from altimetric observations reveal strengthening of downwelling Kelvin wave propagation causing warming over the eastern AS by transporting low-saline water from Bay of Bengal leading to stratification of water column. Rossby waves associated with deepening of thermocline causes warming in southern AS during its propagation. Heat budget analysis reveal that surface heat fluxes play an important role in warming over AS during the pre-monsoon season. Increasing (decreasing) trend of surface heat fluxes (vertical entrainment) during the period 2000–2018 play a significant role in warming over the southeastern Arabian Sea.

Keywords: Ocean Heat Content, Arabian Sea, Heat transport, Kelvin wave, Rossby wave

VARIABILITY OF CLOUD FRACTION OVER DIFFERENT SECTORS OF THE INDIAN OCEAN

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ABSTRACT

Clouds play a crucial role in Earth's climate by influencing the radiation budget and hydrological cycle. The variability of clouds is one of the prominent sources of uncertainty in assessing the impact of climate change. The complex microphysical processes and multiple variables associated with clouds pose a challenge in accurately simulating clouds and their variability. In view of the sparse ground-based measurements of clouds, the satellite and reanalysis data products are widely used to understand cloud variability. The present study utilises ERA5 reanalysis data for 40 years (1979-2018) to examine the variability and trends in clouds over different sectors of the northern Indian Ocean. The reanalysis data has a resolution of 0.25°×0.25° with values at an hourly interval. In the last four decades, the total cloud fraction increased by 4-6% over the Indian Ocean. While the low-level clouds were found to decrease, there was an increase in mid-level and high-level clouds over the Indian Ocean. Over the equatorial Indian Ocean, the high-level clouds showed a significant increasing trend. The seasonal variability of cloud fraction over different regions of the Indian Ocean are discussed in relation to the variations in vertical wind and sea surface temperature (SST). The results highlight the varied response of clouds to SST in different seasons with a maximum during the pre-monsoon (March-May) season.

Keywords: Cloud fraction, Sea surface temperature, Cloud variability, Indian Ocean

HIGH WAVE AND CURRENT OBSERVATION DURING TAUKTAE CYCLONE IN ARABIAN SEA

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ABSTRACT

Tropical cyclones are a major hazard in coastal regions, both in terms of loss of life, damages to properties and economic. The extensive coastal belt of India is very vulnerable to these tropical cyclones. Tropical cyclones over the Arabian Sea in the pre-monsoon season (May–June) have intensified since 1997. It is unusual for a storm formed over the Bay of Bengal to move across southern India and re-intensify over the eastern Arabian Sea (Cyclone Ockhi). It is also notices since 2017 onwards coastal flooding events are frequent happening in the southern part of the West coast of India due to increase in wave intensity. The National Institute of Ocean Technology (NIOT) had installed and maintaining 5 pairs of HF Radar along Indian coast for surface current and wave measurements and also carrying out various shallow water oceanographic measurements for monitoring of coastal process variation due to changes in climate & environmental conditions. Extremely Severe Cyclonic Storm Tauktae is a tropical cyclone in the Arabian sea during 14th to 19th May, 2021 and Tauktae began to parallel the coast of the Indian states of Kerala, Karnataka, Goa and Maharashtra, before rapidly intensifying into a very severe cyclonic storm, early on 16th May 2021. Early on 17th May, it neared the coast of Gujarat, making landfall very close to one of the HF Radar remote site (Jegri Light House). The maximum wave height (Hmax) observed was 7.81 m on 14-May-2021 at 23:51 hours and significant wave height (Hs) was 4.13 m on 15th May2021 at 02:21 hours during Tauktae cyclone off Trivandrum coast observed by GPS based Directional Wave rider Buoy around 20m water depth. The maximum observed Hs at Kanyakumari Wave rider Buoy (WRB) and Kollam WRB are 3.79m and 4.66 m respectively by INCOIS. Two HF Radar systems operated by NIOT at Gujarat Coast (Jegri and Wasi Borsi light house) have captured various signatures of the cyclone in the surface current patterns up to 200km offshore and Wave parameters in the nearshore area. The significant variation in wave height was observed when the cyclone reached near to HF Radar site Wasi and Jegri on 17th May afternoon. HF radar sites Wasi Borsi and Jegri located very close to the cyclone track and land fall has measured maximum wave height about 13.4m and 10.6m respectively. Similarly, the maximum surface current observed about 360cm/s. The details of wave and current observed and its analysis is reported in this study.

Key words: Surface Current, Waves, HF Radar

INCREASING SWELL WAVE POWER AND ITS SPATIAL VARIABILITY IN THE INDIAN OCEAN

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ABSTRACT

The impact of climate change has direct consequences on surface winds and wind-generated waves over the global oceans. In this context, the global wave power has also increased in magnitude that is visible and more prominent over the higher latitudinal regions. Therefore, a proper understanding and detailed analysis of swell wave power in a changing climate, its characteristics over different ocean basins, and knowledge on the mutual interaction between distant swells and local wind-waves over a region is still not fully understood. This study aims to understand the potential of swell wave power in the Indian Ocean (IO) and Southern Ocean (SO) sectors. Spatial distribution of swell wave energy over different geographic regions in the IO and its long-term trend was analyzed using 42 years (1979–2021) of ERA5 Ocean Wave Reanalysis product. Findings from the study signifies dominance of about 73% swell wave power in the extra-tropical south IO, whereas for other regions it is about 90%, 81%, and 91% for the tropical south IO, Arabian Sea, and Bay of Bengal respectively. The overall distribution is more extensive in the eastern IO sector in terms of propagation and directional characteristics of swells reaching the North Indian Ocean (NIO). Findings from the study also postulates that the extreme swell wave power is increasing in a changing climate and evident during all the seasons, especially over wider coverage in the tropical IO belt, with the highest in the extra-tropical region. Detailed investigation of swell wave power for the NIO during the southwest monsoon season showed a gradual trend in the spatial distribution of swells in concurrence with the regions having higher winds (> 10 m/s). Spatial trend distribution using linear regression and correlation analysis for swell wave energy and associated wind stress reveal changing monsoonal climate over the NIO region.

Role of eddies on tropical cyclone induced phytoplankton blooms in North Indian Ocean

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ABSTRACT

Tropical cyclones (TC) are extremely destructive weather systems occurring in warm tropical oceans which can alter the dynamics of the physical and biological state of oceans. The North Indian Ocean comprising of Bay of Bengal (BoB) and Arabian Sea (AS) are conducive to tropical cyclone activity. BoB is a comparatively low productive oceanic basin due to stratification induced by huge riverine influx whereas AS is more productive due to monsoonal winds and winter convection. However, TC can bring nutrient-rich subsurface water into the surface and thus enhance phytoplankton yield. In this study, we analyse the role of eddies in enhancing the phytoplankton blooms induced by Tropical cyclones. We analyse the 7-day composite of Sea Surface Height Anomaly (SSHA) before and during the cyclone passage in BoB and AS to understand the role of eddies on cyclone induced phytoplankton blooms. The cold-core eddies (negative SSHA) tend to enhance the phytoplankton blooms, whereas warm-core eddies (positive SSHA) tend to suppress the phytoplankton blooms. Our analysis shows the presence of cold-core eddy before the passage of cyclone Phailin (2013), Madi (2013) and Hudhud (2014) and warm-core eddy before the passage of cyclone Vardah (2016) at the float location. We also analyse the impact of El-Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) on phytoplankton blooms. The magnitude of bloom is higher in the positive IOD years in BoB and higher in negative IOD years in AS. The El-Niño, La-Niña, IOD years are dominated by cold-core eddies in BoB and warm-core eddies in normal years. In AS, the La-Niña, IOD and normal years are dominated by cold-core eddies, whereas El-Niño years are dominated by warm-core eddies. The characteristics of phytoplankton blooms in AS and BoB are in contrast with the differences in Sea Surface Temperature in AS and BoB in IOD years.

Keywords: Tropical cyclone, Phytoplankton bloom, Eddy, ENSO

An overview of the role of oceanic iodine emissions in a changing climate

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ABSTRACT

Iodine is found naturally dissolved in the seawater as iodide (I^-) and iodate (IO^-_3). The interaction of gas-phase ozone (O_3) with I^- at the sea surface leads to inorganic iodine emissions that photolyse to produce atmospheric iodine. Atmospheric iodine is known to cause significant loss of tropospheric O_3 via catalytic reaction cycles. Self-reactions of iodine in the atmosphere leading to the formation of higher iodine oxides are known to act as cloud condensation nuclei (CNN) and eventually affect the radiation budget. A gap in observational data of atmospheric concentration and oceanic iodine emissions is a major constraint in predicting the change in iodine emissions or its biogeochemical cycling in the future. Until recently, this lack of observational data on atmospheric iodine mostly belonged in the Indian and the Southern Ocean marine environment. Indian Scientific Expeditions to the Southern Ocean conducted in the Indian and Southern Ocean water between 2015–2020 reported the ubiquitous presence of iodine oxide, up to ~1 pptv in the marine boundary layer. Recent studies focused on climate change impact of marine iodine emissions and atmospheric iodine shows that the increasing anthropogenic emission of tropospheric O_3 has increased the iodine emissions threefold over the twentieth century. In the polar regions, the primary source of atmospheric iodine is the biological production under sea ice. Amplifying effects of climate change in the polar region have caused rapid melting of the sea ice, thus increasing iodine emissions. Increased iodine emissions are reported for a 25% increase in modelled tropospheric ozone loss rate in the North Atlantic region since 1950. A recent chemistry-climate model study using an iodine chemistry module reported an additional 1.5–2.5% reduction in the ozone column globally. However, the lack of observational data for iodine species brings uncertainties in estimating the impact of iodine on the future climate.

Keywords: Marine iodine emissions, climate change, tropospheric ozone.

CHLOROPHYLL DISTRIBUTION OVER THE INDIAN OCEAN FROM CMIP5 MODELS AND A REGIONAL ECO-SYSTEM MODEL

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ABSTRACT

Chlorophyll (Chl-a) concentration simulated by 16 CMIP5 global climate models and a regional eco-system model are compared with European Space Agency's Ocean Color-Climate Change Initiative (OC-CCI) derived Chl-a over the Indian Ocean. This study aims to identify the cases of successful Chl-a concentration simulation by global and regional models, considering satellite-derived Chl-a as a benchmark. Eight years of Chl-a data (1998–2005) from OC-CCI over the Indian Ocean are utilized for validation. The correlation between model and satellite Chl-a is used to classify global climate models into three groups identifying their performance over the Indian Ocean in simulating the Chl-a concentration. The correlation between model and satellite-derived Chl-a are used to provide quantitative information about the inter-comparison. The climatological means for different seasons and years are examined to understand the interannual and seasonal variations in the correlation coefficients for Chl-a. The latitudinal and longitudinal variations in Chl-a simulated by models are also analysed and compared with corresponding variations observed by satellites. The study highlights the regional deficiency in CMIP5 climate models in simulating Chl-a and the need for improved coupled physical-biogeochemical models over the tropical Indian Ocean, which can be achieved from a regional eco-system model.

Keywords: Chlorophyll, CMIP5 models, ecosystem model, Indian Ocean

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