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

Pankaj Kumar[1*], Aaquib Javed[1], Rupa Kumar Kolli[2], Disha Sachan[1], Anand Singh Dinesh[1], Midhun M.[1], Jyoti Sharma[1], R. K. Giri[3], Dushmanta R. Pattanaik[3], Sanjeev Kumar Jha[1], R Balasubramanian[4], G. D. Mishra[4]

[1] Department of Earth and Environmental Sciences, Indian Institute of Science Education and Research Bhopal, India.

[2] International Monsoons Project Office, Indian Institute of Tropical Meteorology, Pune, India.

[3] India Meteorological Department, Mausam Bhavan, New Delhi, India.

[4] India Meteorological Department, Bhopal, Madhya Pradesh, India.

*Corresponding Author: Pankaj Kumar

Email: kumarp@iiserb.ac.in

Associate Professor

Department of Earth and Environmental Sciences

Indian Institute of Science Education and Research Bhopal

Bhopal By-Pass Road, Bhauri. Bhopal - 462066. India

Homepage: http://home.iiserb.ac.in/~kumarp/index.html

ORCID: 0000-0003-1906-9852

What:

In its annual national symposium, TROPMET-22, the Indian Meteorological Society (IMS) brought together more than 600 participants, including eminent academicians, scientists, students, and industry personnel, to discuss recent developments and challenges in the weather and climate modeling and projections along with their application in the water and agricultural sectors over South Asia.

When:

29th Nov to 2nd Dec 2022

Where:

Bhopal, India

Early Online Release: This preliminary version has been accepted for publication in *Bulletin of the American Meteorological Society*, may be fully cited, and has been assigned DOI 10.1175/BAMS-D-23-0128.1. The final typeset copyedited article will replace the EOR at the above DOI when it is published.

1. Brief introduction and objective of the meeting

In recent years, human-induced changes to the climate have been witnessed in all parts of the world, such as heatwaves, droughts, floods, heavy precipitation events, and many more. These events have significant implications on the water, agricultural, and economic sectors, leading to changes in the hydrological cycle, water availability, water quality, and irrigation requirements. Advance prediction and accurate understanding of these events, how they are connected to other earth processes, and their changing relationship to climate change can potentially help to mitigate their impacts. Weather and climate modeling are critical tools that simulate the Earth's processes, satisfying all physical laws and providing insights into the physical mechanisms and attributes at the high spatiotemporal resolution responsible for all minor and major Earth system processes. These modeling efforts allow us to identify the driving factors and how they might change in the future. For instance, in the agricultural sector, the requirement is to identify the best crop varieties suited to changing climate conditions. Simulating different climate scenarios can provide farmers with regionally-tailored critical information to conduct their business. Considering these facts, the IMS held its annual national symposium on Tropical Meteorology (TROPMET-2022) from 29th November to 2nd December 2022, jointly hosted by the Indian Institute of Science Education and Research Bhopal and IMS-Bhopal Chapter. TROPMET is a series of annual flagship events of the IMS, with it being organized at the international level once every four years under the label INTROMET. Each year, TROPMET brings together a diverse group of experts, including climate scientists, agricultural scientists, local government bodies, academicians, policymakers, disaster management agencies, and other related sectors, to discuss and exchange knowledge and research for the benefit of society. This broad spectrum of participants in TROPMET-2022 packed 4 seminar halls on all 4 days of the symposium. The map (Figure 1) shows the number of participants from different parts of the country who participated in the event. Table 1 shows the category and number of participants who took part in the TROPMET-2022.

Table 1: Category and count of TROPMET-2022 participants

Category	Count
Plenary Speakers	8
Keynote Speakers	26

Accepted for publication in *Bulletin of the American Meteorological Society.* DOI 10.1175/BAMS-D-23-0128.1.

Invited Speakers	36
Oral Presentations	148
Lightning-talk Presentations	95
Poster Presentations	137
National Organizing Committee	49
Local Organizing Committee	24
Volunteers	68
Total	**591**

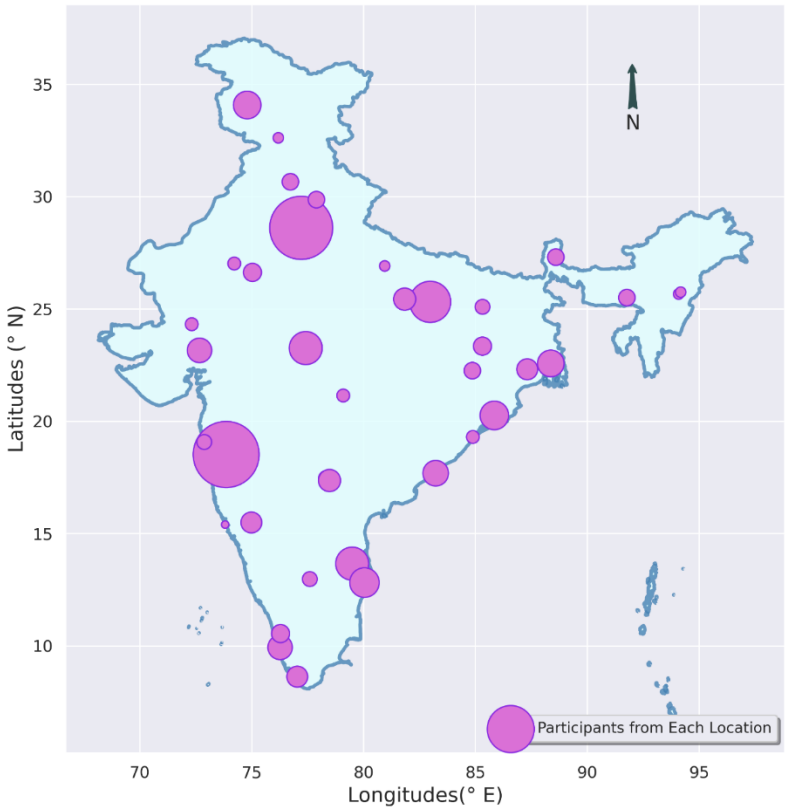

Fig. 1: Map showing the locations of attendees in TROPMET-2022; the size of the circles represents the number of participants.

2. Symposium Overview and Format

Accepted for publication in *Bulletin of the American Meteorological Society*. DOI 10.1175/BAMS-D-23-0128.1.

The symposium featured nine major themes, each with multiple sub-themes catering to diverse areas of expertise. A total of around 470 abstracts were received. A list of reviewers from various research domains were invited to review the abstracts. Finally, the abstracts were rationally distributed between oral and poster presentations based on the suggestions from experts. There were two plenary talks on each of the four conference days, followed by three to four parallel sessions. Each parallel session included keynote lectures, invited lectures, and student oral presentations. Each session was chaired and co-chaired by panelists, who were invited based on their expertise in the running themes and sub-themes. Apart from these, some special sessions addressing water and energy resource challenges were also conducted.

The major themes of the symposium are listed below:

i. Weather and Climate Processes (WCP)
ii. Climate Modeling, Prediction and Projections (CMPP)
iii. Applications of Weather and Climate in Hydrology (AWCH)
iv. Remote Sensing Applications in Weather and Climate Prediction (RAWCP)
v. Applications of Weather and Climate in Agriculture (AWCA)
vi. Climate Services (CS)
vii. Monsoon Prediction and Projection (MPP)
viii. Weather and Climate Extremes (WCE)
ix. Impact-based Weather and Climate Prediction (IWCP)

3. Takeaway Messages

3.1 Weather and Climate Processes (WCP)

During the session, subsurface modeling of ocean variables was the highlight of the discussion. However, it was unanimously agreed that more attention should be given to observing ocean variables. High-resolution modeling of the Himalayan region has shown great improvement in capturing the climatology, variability, and embedded extremes. One of the key aspects that emerged from the discussion was the identification of the varying relationship between climate variables with different climate teleconnection modes and their impacts.

3.2 Climate Modeling, Prediction, and Projections (CMPP)

Accepted for publication in *Bulletin of the American Meteorological Society.* DOI 10.1175/BAMS-D-23-0128.1.

The session featured India's contribution to the Coupled Model Intercomparison Projects Phases 6 and 7 in the form of IITM-ESM (Indian Institute of Tropical Meteorology - Earth System Model), which is an indigenously developed climate model and a part of the Intergovernmental Panel on Climate Change's report in connection with the south Asian monsoon. The session also highlighted the importance of the modeling community in improving the effectiveness of global and regional models. However, more emphasis was given to setting up fully functional coupled Regional Earth System Models. Model performance was discussed in the context of sub-seasonal to seasonal prediction and climate change projection. The expert's conversation further highlighted that the existing climate modeling framework could be enhanced using emerging AI/ML techniques. The availability of vast amounts of weather and climate data has motivated the use of these data-driven artificial intelligence methods to unravel the complexities of the phenomenon. Potential applications of AI/ML in climate modeling include data assimilation, downscaling and bias correction, and hybridization between physics-based and machine-learning models.

3.3 Applications of Weather and Climate in Hydrology (AWCH)

The session primarily discussed statistical hydrology and rainfall forecasting over the major Indian river basins and highlighted the increase in hydrological extremes such as floods, landslides, and glacial lake outbursts due to climate change and their underlying drivers. One of the key issues raised was the altered hydrologic regimes as a consequence of anthropogenic disturbances and climate change, especially in the high-altitude regions of India. The session enabled a discussion on sustainable agricultural practices and potential local adaptation strategies to reduce the effects of severe weather phenomena.

3.4 Remote Sensing Applications in Weather and Climate Prediction (RAWCP)

The session covered the discussion on various satellite products that have been developed with the aid of advanced sensor technology and retrieval algorithms. The focus was on assessing the satellite products' efficiency in terms of precipitation accuracy, rain type classification, physio-chemical properties of atmospheric particles and their sources, concentration, determination, mineralogy, mixing state, and other relevant parameters. The broad implication on direct or indirect radiative effects and climate change were discussed. The session also discussed the uncertainty in the newly

Accepted for publication in *Bulletin of the American Meteorological Society.* DOI 10.1175/BAMS-D-23-0128.1.

developed datasets by integrating satellite products with ground-based data by hybrid assimilations methods. However, it was concluded that there is a need for more ground and air-based observations to generate products with a micro-level focus.

3.5 Applications of Weather and Climate in Agriculture (AWCA)

During the session, experts engaged in thorough discussions on agrarian matters and agreed on the notion that the Agri-Food systems must embody sustainability, inclusivity, resilience, and adaptability to climate change while providing adequate, safe, and nutritious foods for healthy diets for present and future generations. The vulnerability assessment of Indian agriculture to climate change revealed that more than 50% of the districts are in a very high risk-to-risk bracket, posing a challenge to minimize soil erosion, excess, and deficit water management, and avoid biotic and abiotic stresses in plants. Studies on sustainable crop management practices in extreme climatic conditions in India have shown that utilizing agricultural machinery can help address the negative impact of climate-induced externalities on crop performance and reduce risks related to adverse meteorological events on farmers' revenue. An Agricultural Model Intercomparison and Improvement Project (AgMIP) Regional Integrated Assessment Framework was also discussed for the Indian scenario.

3.6 Climate Services (CS)

Climate services refer to providing climate information to aid decision-making. It requires active participation from users and providers, streamlined access to the information, and the ability to fulfill the users' requirements. In this session, the experts discussed the available multi-agency capacities in the country to deliver climate services. Specifically, how National Framework for Climate Services is assisting all the sectors (government, the Public Sector Units, the public, and the private sector) in integrating and mainstreaming high-quality climate services into the decision-making process, enabling them to manage the risks and opportunities associated with climate variability and change, including coping with extremes. Moreover, the key highlights were to identify gaps and specific elements for strategic and action plans and fostering multi-agency collaboration.

3.7 Monsoon Prediction and Projection (MPP)

In this session, the added value and fidelity of several high-resolution Regional Earth System Models, CMIP5/6 simulations, and their projection of the Indian Summer Monsoon were demonstrated. Furthermore, the experts agreed on the importance of

Accepted for publication in *Bulletin of the American Meteorological Society.* DOI 10.1175/BAMS-D-23-0128.1.

evaluating and improving the accuracy of sub-seasonal to the seasonal medium-range weather forecast and prediction of the Indian Summer Monsoon rainfall to deliver more reliable agro-meteorological services to minimize agricultural losses. Using data-driven AI/ML techniques for improved prediction skills, data downscaling and assimilation techniques, bias correction, and prediction of extremes could be a potential way forward. The experts also emphasized that detailed investigations are required into lesser-known teleconnections that affect the Indian Summer Monsoon Rainfall, such as Eurasian Snow Cover Fraction, Southern Indian Ocean, North Atlantic Oscillation, Pacific-Japan pattern, and Tropical Indian Ocean warming, Southern Annular Mode teleconnection. By better understanding these teleconnections, more accurate predictions of Indian Summer Monsoon Rainfall can be delivered to benefit the hydrological and agricultural sectors.

3.8 Weather and Climate Extremes (WCE)

The Indian subcontinent, due to its geographical location and varied topography, experiences a diverse range of weather and climate extremes which are increasing in frequency, intensity, and duration. A broad discussion on the impacts of heatwaves, cold waves, drought, flash floods, and heavy rainfall on human health and agricultural productivity was held in this session. The ocean extremes, such as Marine heatwaves and cold spells, were also part of the detailed discussion. Interestingly, lightning and thunderstorms became an appropriate source of stimulating discussions because of their increased activity and higher risk of death than other extremes in recent periods. Additionally, experts discussed how such extremes are affected by the continuous and unremitting warming of the planet.

3.9 Impact-based Weather and Climate Prediction (IWCP)

Impact-based weather and climate prediction provide forecasts and information about the potential effects of weather and climate events on different sectors of society and human activity. The advantages of 4D data assimilation over other existing techniques for the numerical simulation of tropical cyclones were briefly discussed during the session. Additionally, experts discussed the crucial role of integrating Artificial Intelligence and Machine Learning techniques in Global and Regional Ensemble Prediction Systems to predict extreme weather events more accurately.

4. Conclusion

Accepted for publication in *Bulletin of the American Meteorological Society.* DOI 10.1175/BAMS-D-23-0128.1.

This national symposium, TROPMET-2022, brought together a diverse group of experts in the fields of climate science, agriculture, policymaking, and disaster management to discuss and exchange knowledge on the impacts of climate change and weather events. Overall, the symposium highlighted the importance of knowledge-sharing, collaboration between different sectors, and the need for further research to bridge knowledge gaps in regional observations, model biases, and understanding of local-scale processes. It emphasized the significance of improved observations and data assimilation techniques to enhance our understanding of weather and climate dynamics at different scales. Multi-agency collaboration was identified as crucial for delivering tailored climate products to end-users and addressing the challenges posed by climate change, especially in the agricultural sector. The symposium's success was attributed to the support of various government departments and institutions, as well as sponsors who contributed to the event.

Acknowledgments

We thank the following departments from the Government of India for their support: Science and Engineering Research Board, Department of Science and Technology, Ministry of Earth Science, India Meteorological Department. We would also like to thank the following sponsors: National Institute of Ocean Technology, Indian Institute of Tropical Meteorology, National Centre for Polar and Ocean Research, NetApp, ReNew Power, SGS Weather, Environmental Planning and Coordination Organisation (EPCO) Government of Madhya Pradesh, National Bank for Agriculture and Rural Development (NABARD), Greenko Group, Adani Renewables, and SO-Wertz.

Accepted for publication in *Bulletin of the American Meteorological Society.* DOI 10.1175/BAMS-D-23-0128.1.