Prediction of Extreme Events

Current Status and Future Pathways against the Backdrop of Climate Change

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Joint International Workshop on Prediction Skill of Extreme Precipitation Events and Tropical Cyclones: Present Status and Future Prospects (IP4), & Climate Change

What: This workshop was held as a follow-up to another workshop INTROSPECT 2017, to review the current status of forecasting extreme events and tropical cyclones particularly against the backdrop of climate change and to explore future pathways.

When: 25–28 November 2019

Where: Pune, India

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Against the backdrop of increasingly frequent extreme precipitation events and the increasing severity of tropical cyclones, it is time to evaluate current forecast systems and develop pathways for improving the accuracy and reliability of predicting these high impact weather events in a changing climate. In India recurring recent extreme precipitation events in August 2018 and 2019 in the southern Indian state of Kerala severely disrupted lives and caused immense damage of more than \$5 billion (U.S. dollars, 2018) to public properties. The Indian seas have experienced anomalously strong severe cyclones, such as Tropical Cyclone Ockhi (29 November–6 December 2017), at very low latitudes. There were other extreme rain events recently, such as flooding in the southern metropolis of Chennai during November and December 2015 as well as floods in the northern mountainous state of Uttarakhand in June 2013. For all of these events the existing forecast system provided useful guidance in the short-term (up to 10 days) and extended-range (up to 2–3 weeks) time scales. Though the short-range forecast succeeded in providing the guidance of ~3 days, it could not provide the probability of extremes associated with those events, with longer lead time. Therefore, there remains a most urgent need to provide these probabilities with longer lead times (~5–7 days).

Keeping in view the recent improvement in the forecast of extreme precipitation events and the forecast of tropical cyclones, the joint international workshop on “Prediction Skill of Extreme Precipitation Events and Tropical Cyclones: Present Status and Future Prospects (IP4), & Climate Change” was held in November 2019 at the Indian Institute of Tropical Meteorology, Pune, India (Fig. 1). The workshop included 31 invited talks covering different aspects of spatiotemporal ranges of forecasts, namely, subseasonal to seasonal, short-range weather forecasts, and climate projections. The details of the talks are mentioned in Table 1. The workshop was attended by experts from various operational forecasting centers.¹ Sixty students/postdocs/early career scientists also attended (see Fig. 2 for a group photo), and there were 22 posters presented (mentioned in Table 2). The posters were displayed on all four days of the workshops to allow students/postdocs/scientists maximum time for interactions. Workshop talks/proceedings were live streamed and remote viewers texted questions as a way to participate in the discussions.

Speaker presentations have been uploaded and are available online (www.tropmet.res.in/ip4/presentations.php). Also, all talks have been uploaded to the IITM YouTube Channel (www.youtube.com/watch?v=i8KKsKsz8Q4&list=PLgQCKqNw6z_CZUThN5-dvZC3qaCQDfJzX).

In the workshop, experts deliberated on forecast techniques such as the ensemble prediction system and its utility for extreme event forecasts. There was extensive discussion of the strength and deficiencies of cloud and convection parameterizations in the context of increasing resolution in future climate models. Experts also mentioned the strength of machine learning (ML)/artificial intelligence (AI) and emphasized their use in the gray areas of parameterization.

The following emerged as consensus recommendations from the workshop:

- Significant modeling development and improvement in forecast skill for extreme rain and tropical cyclones/hurricanes/typhoons have taken place in the last few decades. However, there is a need for further improvement in higher rainfall thresholds at longer lead times. Likewise, there is a need to improve tropical cyclone intensity forecasts.

¹ Centers represented at the workshop: European Centre for Medium-Range Weather Forecasts (ECMWF), National Centers for Environmental Prediction (NCEP), the Met Office (UKMO), Korean Institute of Atmospheric Prediction System (KIAPS), National Centre for Medium Range Weather Forecasting (NCMRWF), and India Meteorological Department (IMD) and also from research institutes/universities such as the Massachusetts Institute of Technology, Colorado State University, California Institute of Technology, Jet Propulsion Laboratory, University of Oxford, University of Victoria, National Center for Atmospheric Research, Indian Institute of Science (Bengaluru, India), The University of Tokyo, Sant’Anna University, Goddard Space Flight Center, University of Kyoto, IIT, Bhubaneswar, Space Application Centre, Indian Space Research Organization, Indian National Centre for Ocean Information Services (INCOIS), National Centre for Polar and Ocean Research (NCPOR), National Centre for Coastal Research (NCCR), and Indian Institute of Tropical Meteorology (IITM).

- The path ahead for further improvement could include increasing model resolution in a coupled ocean–atmosphere framework along with suitable physics for high resolution and further application of AI/ML in the representation of physical processes.
- Use of improved and latest assimilation techniques involving data from remote sensing/satellites, particularly of low-level winds, was mentioned as one of the key aspects in improving model initial conditions vis-à-vis the skill of the forecast.
- Apart from improving the parameterization of important physical processes such as clouds and convection, special effort should be made to improve the cloud-radiative feedback in the model; for climate change it needs to account for cloud–aerosol–climate feedback. The understanding of warm and cold rain processes and their representation in climate models is one of the key gap areas where further research is needed.
- Against the backdrop of climate change, the increase of intense tropical cyclones (category 5), extreme rain events, rapid warming of the Indian Ocean, and sea level rise were highlighted and their consequences to society were discussed. It was recommended that models should be equipped for the representation of related processes so as to make the projections of these parameters more reliable.

Fig. 1. Indian Institute of Tropical Meteorology, Pune, India, the venue for the workshops.

Fig. 2. Attendees of the joint International Workshop on Prediction Skill of Extreme Precipitation Events and Tropical Cyclones: Present Status and Future Prospects (IP4), & Climate Change.

Table 1. Invited speakers in IP4 and the Climate Change Workshop.

Speaker No.	Speaker	Title
1	Prof. Graeme Stephens, JPL	How bad will future rains be? Some reason to expect progress and some thoughts on cloud-convection feedbacks
2	Prof. Ravi S. Nanjundiah, IITM	Unified parameterization of moist convective processes in a GCM—Few findings from CRM and LES
3	Dr. Peter Bechtold, ECMWF	Simplistic view of convection and waves in the IFS and in the Indian Ocean
4	Dr. Ken Mylne, UKMO	Ensemble forecasting for high-impact weather, with emphasis on India
5	Dr. Yuejian Zhu, NCEP	An assessment of predictability and prediction of FV3 GEFS for extreme event and uncertainty
6	Prof. Tim Palmer	Stochastic parameterization and extreme rainfall prediction
7	Dr. Kazuo Saito, Univ. of Tokyo	LETKF perturbations by ensemble transform in a cloud resolving model
8	Prof. David A. Randall, CSU	A new framework for convection parameterizations
9	Prof. Kerry Emanuel, MIT	Toward advanced probabilistic forecasting of tropical cyclone conditions and tropical cyclones and climate change: TC risk in India
10	Dr. Georg A. Grell	NWP prediction at ESRL/GSD: Development of physics parameterizations for global and regional modeling
11	Dr. Boualem Khouider, UVIC	A unified shallow–deep mass-flux convective parameterization using a stochastic multicloud plume model
12	Dr. Wei-Kuo Tao, NASA GSFC	Goddard mesoscale model simulations of impact weather systems
13	Dr. Roberto Buizza, Sant’Anna University	Ensembles: Invaluable tools to predict extremes
14	Dr. Atul Kumar Sahai, IITM	Development of extended range prediction system for tropical cyclones, extreme rainfall events and monsoon active spells
15	Dr. Arindam Chakraborty, CAOS, IISC	Interaction between extreme rainfall and quasi-periodic components of monsoon
16	Dr. Jimmy Dudhia, NCAR	Large-eddy simulation of idealized hurricanes at different sea surface temperatures
17	Prof. Song-You Hong, KIAPS	A non-hydrostatic spectral-element dynamic core for global weather forecasting
18	Prof. G S Bhat, CAOS, IISC	Wind extremes over Indian landmass
19	Dr. Ziad S. Haddad, NASA JPL	Using information in satellite passive microwave radiances, with or without geostationary IR, to improve analysis and forecasting of convective storms
20	Dr. Shoichi Shige, Univ. of Kyoto	The importance of warm-rain processes in heavy rainfall events: Lessons learned from the development of satellite rainfall retrievals
21	Dr. P. A. Francis, INCOIS	Intense rainfall events in the west coast of India
22	Dr. E. N. Rajagopal, NCMRWF	Tropical cyclone prediction current status and future roadmaps and heavy rainfall prediction current status and the future
23	Dr. U. C. Mohanty, IIT Bhubaneswar	Recent developments in prediction of tropical cyclones over north Indian Ocean
24	Dr. Parthasarathi Mukhopadhyay, IITM	Recent developments in short range forecasting, challenges and future roadmaps
25	Dr. Lucas Harris, GFDL	S2S prediction of tropical cyclones and the MJO at GFDL
26	Dr. Mrutyunjay Mohapatra, IMD	Cyclone warning system in India
27	Dr. C. M. Kishtawal, ISRO	Heavy rainfall prediction using satellite observations
28	Dr. R. Krishnan, CCCR, IITM	Understanding the Indian monsoon response to anthropogenic GHG and aerosol forcing: Lessons learned
29	Dr. Abhishek Chatterjee, INCOIS	Interannual/decadal variability of south tropical Indian Ocean: Natural vs forced response
30	Dr. Parmanand Sharma, NCPOR	Himalayan cryosphere in a changing climate of India
31	Dr. Satya Kiran Raju, NCCR	Assessment of shoreline changes along Indian coast

Table 2. Papers presented as posters at the workshops.

Speaker No.	Name of the poster	Author details
1	Potential vorticity (PV) analysis of Kerala flood 2018 and 2019 using NCMRWF Unified Model (NCMU)	A. Jayakumar, Claudio Sanches, Timmy Francis, Saji Mohandas, Vivek Singh, Prince Xavier, Sean Milton, and E. N. Rajagopal
2	A case study of extremely cyclonic Storm Fani (2019) from the prediction view of high resolution regional model	Shyama Mohanty, R. Nadimpalli, A. Sharma, A. K. Das, and U. C. Mohanty
3	Contribution of cyclonic disturbances to rainfall over India in recent climate condition	Kasturi Singh and Dr. Jagabandhu Panda
4	Adjusting WRF Model parameters using adaptive surrogate model based optimization to improve heavy rainfall forecast during Indian monsoon	Sandeep Chinta and C. Balaji
5	A preliminary study for GPM radar reflectivity assimilation in WRF Model for tropical cyclones	Baki Harish, C. Balaji, and Balaji Srinivasan
6	Analysis of monthly and daily annual extreme precipitation for Vadodara due to urbanization	Dr. Sanskriti Mujumdar
7	Assimilation of the rain gauges measurements using particle filter	Prashant Kumar
8	Heavily precipitating midtropospheric cyclones in the Indian summer monsoon	Ayantika Dey Choudhary, R. Krishnan, M. V. S. Ramarao, R. Vellore, M. Singh, and B. Mapes
9	Advancement in the algorithm of physical initialization in numerical models	Bappaditya Nag and T. N. Krishnamurti
10	Latest approaches of thunderstorm/lightning and severe weather forecasting using high resolution numerical model and GFS-GEFS	Madhuparna Halder, Radhika Kansae, P. Mukhopadhyaya, Subhadeep Halder, A. C. Pandey, Manoj Domkawale, and S. D. Pawar
11	Operational GFS/GEFS(T1534) prediction of tropical cyclones over north Indian Ocean during 2018 and 2019	Medha Deshpande, Radhika Kanase, R. Phani Murali Krishna, and P. Mukhopadhyay
12	Assimilation of DWR radial wind with regional GSI in improving TC prediction over Bay of Bengal	Sujata Pattanayak and V. S. Prasad
13	Investigation of two simultaneously intense tropical Cyclones Luban and Titli over north Indian Ocean	G. Mani Kranthi, Medha Deshpande, and Emmanuel Rongmie
14	Physical processes associated with the genesis of SCS Mora 2017 over the north Indian Ocean	R. Emmanuel, Medha Deshpande, and G. Mano Kranthi
15	Appraisal of data assimilation techniques for dynamical down-scaling of the structure and intensity of tropical cyclones	Pampi Malakar, Amit P. Kesarkar, Jyoti Bhate, and Deshmukhya
16	Oceanic subsurface impact on tropical convection	Supriya Ovhal, Sreenivas Pentakota, and Aditi Deshpande
17	Performance of regional climate model in simulating Indian summer monsoon rainfall and surface temperature over India and sub region	Shruti Verma, R. Bhatla, and Manas Pant
18	Electric forces in the realm of precipitation formation in tropical cloud	Dipjyoti Mudiari, Sunil D. Pawar, Anupam Hazra, and B. N. Goswami
19	Extreme events associated with lightning over India: A challenge for modeling study	Greeshma M. Mohan, K. Gayatri Vani, Chandrima Mallik, Dipjyoti Mudier, and other collaborators
20	The Hurricane Weather Research and Forecasting (HWRF) modeling system for forecasting of tropical cyclones over NIO	Akhil Srivasatava, Arun Sharma, Ananda Kumar Das, Sudheer Joseph, and V. S. Prasad
21	An improved index for capturing the genesis and evolution of north Indian Ocean tropical cyclones	Saranya Ganesh, A. K. Sahai, S. Abhilash, Sushmitha Joseph, and Manpreet Kaur
22	Intense rainfall conditions over Indo-Gangetic Plains under the influence of Madden Julian oscillation	Madhu Singh, R. Bhatla, S. Mandake, and P. Gautam