

way, and would help accomplish the target of precaution drug inclusion at any rate 50% of the populace with indicative CVD. The World Heart Federation (WHF) could unite specialists from around the world to improve admittance to prescriptions for CVDs and specifically to help a polypill procedure for auxiliary avoidance of CVDs by leading support exercises, backing the consideration of the polypill on the WHO Essential Medicines List. They can be accomplished by taking part in correspondence endeavours and fitting them with other related activities; for example, the new Coalition for Access to NCD Medicine and Products.

It may well be assessed that if just 50% of individuals with either hypertension or diabetes are treated with a poly-

pill, about 2–4 million unexpected deaths, heart failure and stroke could be forestalled on a yearly basis. This could be useful in ensuring the well-being of individuals who have less access to medical facilities. Later, polypills with more up-to-date statins could additionally diminish LDL cholesterol and blood pressure, and lessen the danger of CVDs by more than 50%. Polypill companies would also have to look for Controllers' endorsement to sell their pills in different nations, and those generic medication creators may group with large insurers to offer the treatment. Also, the purpose of giving out a polypill in financially weak networks may strike some as paternalistic. That worry should be weighed against the risks of proceeding with the current course, with extending well-

being incompatibility among low and high-financial status networks. A system based on polypill may well benefit all networks, but it seems reasonable to start with networks where requirements and limitations may be more notable. Many people are open to down-to-earth ways to deal with improving their cardiovascular well-being, including the utilization of a polypill. At any rate, realization of the current preliminaries should stimulate the enormous use envisaged to contrast a methodology based on polypills and the best accessible options.

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MEETING REPORT

Modelling atmospheric–oceanic processes for weather and climate extremes*

A rapid increase in the frequency of extreme weather events has been seen over India in recent decades. Countries in Asia are witnessing increasing number of extreme weather events such as typhoons, cyclones and threats of exacerbating these events (due to warming climate) on mankind are looming large. The events like the recent floods over Kerala and Tamil Nadu, drought in Assam, extreme rainfall in Mumbai, etc. are causing huge damage to property and result in loss of lives. An important step in the short-term mitigation of weather extremes is that we should be able to reliably predict such events well in advance. The prediction of tropical weather is a challenge due to the inherent uncer-

tainty of the atmosphere and especially the extremes due to gaps in the proper understanding of the processes involved.

With this vision in mind, an international workshop was organized in 2019 which brought together both academic and operational researchers from India and abroad to facilitate an understanding of the challenges in operational forecasts of extreme weather events with a focus on atmospheric–oceanic processes in the tropical climate, particularly in Asia.

The workshop received overwhelming response with around 100 submissions from several countries (Indonesia, Malaysia, Singapore, Bangladesh, Thailand, China, Saudi Arabia and Japan), especially from research students and early career scientists. There were 42 poster presentations and about 25 oral presentations.

M. Rajeevan (Secretary, Ministry of Earth Sciences, Government of India) in the inaugural address highlighted increasing occurrences of extreme weather and emphasized challenges in accurately predicting the same with further need to augment the research efforts in this direction. The first technical session on the first day of the workshop was based on challenges in operational forecasts of extreme weather events. U. C. Mohanty (IIT Bhubaneswar), who was the key-

note speaker of the session, presented an assessment of observations and predictions of extreme weather events over India, viz. tropical cyclones over the Bay of Bengal, severe thunderstorm and lightning. He mentioned that the Hurricane Weather Research and Forecasting (HWRF) model system has achieved significant improvement in track prediction, occurrence of thunderstorms over the Bay of Bengal's basin because of higher model resolution, improved physics, assimilation of satellite data, impact of Doppler radar reflectivity and radar position, and representation of large-scale synoptic conditions and other features.

Muhammad Firdaus Ammar Bin Abdullah (Malaysian Meteorological Department) presented a case study of an extreme rainfall event over Kuala Lumpur, Malaysia, which was analysed using Weather Research and Forecasting (WRF)-1 km model to study the impact of terrain in shaping the synoptic factors. He stressed upon the need for an enhanced systematic observation network in the region for improving the forecast of extreme events.

Aspects of seamless modelling system for weather/climate were elaborated by A. K. Mitra (NCMRWF, Noida). He discussed how NCMRWF aims to have a

*A report on an International Workshop on 'Modelling Atmospheric–Oceanic Processes for Weather and Climate Extremes', organized by the Centre for Atmospheric Sciences (CAS) of Indian Institute of Technology Delhi (IIT Delhi) in collaboration with the Asian Network on Climate Science and Technology (ANCST), during 28–29 March 2019. The workshop was hosted by IIT Delhi. MAPEX 2019 is a key activity of the Special Topic Group on 'Atmosphere–Ocean Interactions' of ANCST. The key sponsoring organizations from Government of India included MOES, SERB and DST.

seamless model framework across all the processes from subseasonal to seasonal scale to adapt to climate variability, and presented a case study of dust storm in Agra on 3 May 2018 which was well captured by NCMRWF after incorporation of regional data assimilation in the model. Manish Modani (The Weather Company, IBM, USA) talked about the numerical weather prediction at IBM/The Weather Company, which incorporates data assimilation from a variety of observations, including satellites, conventional (METARs, SYNOPs, cell-phone pressures, radiosondes) and radar. The forecast output has numerous applications like consumer, aviation, energy demand and insurance.

The next session was about mechanisms, drivers and feedbacks in atmospheric–oceanic processes leading to extremes. The keynote speaker, A. Chandrasekar (Indian Institute of Space Science and Technology, Thiruvananthapuram) presented a case study of 4DVAR assimilation in WRF model for simulating 350 mm rainfall in Uttarakhand during June 2013. He concluded that 4DVAR allows the observations to be distributed over a period of time and is consistently better all along picking the right amount of intensity and can be used in extreme rainfall events.

The second keynote speaker, A. D. Rao (IIT Delhi) spoke about the storm surges associated with cyclonic wind stress and related inundation, particularly in the Indian coast. He discussed the importance of inflow angle of cyclone and correct onshore topography in the correct prediction of storm surges. S. Sijkumar (VSSC) presented a case study of *Ockhi* cyclone and spoke about the influence of atmospheric waves on the cyclogenesis of *Ockhi*. Ashok Karumuri (University of Hyderabad) examined the heavy rainfall event in Chennai in 2015 and explained that ENSO is positively correlated to the northeast monsoon. He concluded that sea surface temperature (SST) had more effect on Chennai rainfall along with effects of urbanization-related land use-land cover changes which were captured in sensitivity experiments carried out with the WRF model. Ramesh Vellore (IITM, Pune) mentioned that northeast India is experiencing a larger number of extreme events of late and more monsoon breaks are expected in future. He observed that during monsoon break, there is a slight southward shift to the

tropical easterly jet and there is a coupling of the Siberian anti-cyclone and low troughs.

The third and last session of day 1 of the workshop was on the role of environmental factors on extreme weather events. Edwin Aldrian (BPPT, University of Indonesia, Jakarta, Indonesia), Vice-Chair of the IPCC Working Group I, the keynote speaker of the session, described that wetting (drying) trend in rainfall amount was found over the northern (southern) part of Indonesia. Yuya Takane (National Institute of Advanced Industrial Science and Technology, Japan) explored the importance of positive feedback in urban warming with regard to the use of air-conditioners (ACs) in megacities which can cause additional urban warming amounting up to approximately 20%. He stressed that this feedback should not be neglected in future urban climate projections, mainly in hot cities with large usage of ACs. Bala Subrahmanyam (VSSC, Thiruvananthapuram) presented performance evaluation of COSMO (Consortium for Small-scale Modelling) during the passage of *Ockhi* over the Arabian Sea. He noted that while the formation of a deep depression in Comorin Sea and its intensification into a cyclonic storm was evident from model simulations, the unexpected rapid intensification of *Ockhi* was not captured well by the model. Hari Prasad Dasari (King Abdullah University of Science and Technology, Saudi Arabia) demonstrated a study of the planetary boundary layer (PBL) height characteristics and its variability at different timescales over the Arabian Peninsula based on high-resolution assimilative WRF regional simulations. He observed that during El-Niño, the Red Sea Convergence Zone moves northward leading to the occurrence of heavy rainfall in the northern region.

The second day of the workshop had two sessions of scientific talks and a poster presentation session. In the first session entitled ‘Observations, diagnostic analysis and case studies for extremes’, there were two keynote speakers. The first keynote speaker, G. S. Bhat (Indian Institute of Science (IISc), Bengaluru) talked about wind extremes over India and pointed out that although the wind extremes events (other than cyclones) cause serious damage to both life and property of common people, there is not much research done in this direction.

Since such events last for only a short duration (<10 min), averaging of the *in situ* data will result in loss of signal. Thus, these wind gusts around dust-storm periods still remain a challenge for the modelling community. Bhat highlighted that lack of observational data of wind gusts/dust storms (especially within the height of near-surface turbulent layer) is a serious issue for the study and modelling of these events. The second keynote speaker, S. S. V. S. Ramakrishna (Andhra University, Visakhapatnam) discussed North Indian Ocean severe cyclones and the associated physical processes. He observed that cyclonic storms over the Indian Ocean region show a decreasing trend in the recent decade, whereas the severe cyclonic storms exhibit an increasing trend. He noted that the Noah land surface model scheme gives better results for cyclone simulations using WRF model. Sensitivity studies showed that incorporation of real-time SST improved cyclone track prediction from the WRF model. Also, initial thermodynamic sounding can play an important role in accurate cyclone simulation and prediction.

The next talk in this session was delivered by Sheeba Nettukandy Chenoli (University of Malaya, Kuala Lumpur). She presented case studies of extreme rainstorms that caused devastating flooding across the east coast of Peninsular Malaysia during the NE monsoon in 2014. She discussed that ENSO events are found to be a regulating factor for the rainfall events over this region. Combined action of cold surges (northeastern surge) and easterly surge intensifies the extreme rainfall events. Further, during El-Niño, the Siberian high was found to be weaker and neutral events experienced strongest cold surges.

The second technical session of the day was on ‘Assessment of projected changes of extremes in warming climate’. The first keynote speaker D. Sengupta (IISc) gave a talk entitled ‘River water and Bay of Bengal cyclones’. He discussed the response of the Bay of Bengal to the passage of cyclone *Phailin* in October 2013, with the help of open-ocean mooring observations and a one-dimensional model. Prior to *Phailin*, salinity stratification was very high at the base of a shallow, fresh layer coming from the Ganga–Brahmaputra–Meghna river; a deep, nearly isothermal layer lay underneath. Vertical mixing due to

enhanced vertical shear of near-inertial currents deepens the mixed layer from 10 m to at least 50 m; sea surface salinity increases by 1.6 psu, but SST does not decrease. The combined effects of shallow stratification and deep warm layer inhibit mixed layer deepening and SST cooling. Sengupta inferred that cyclones may intensify rapidly over low-salinity riverwater in the Bay of Bengal.

The second keynote speaker Someshwar Das (Central University of Rajasthan Ajmer) talked about modelling and forecasting of severe storms over the Himalaya and adjoining regions. He presented case studies of observations and simulation of cloudbursts, Nor'westers and desert storms. Taking a case study of Nepal, he explained the series of synoptic conditions that lead to cloudburst which include: (i) equatorward intrusion of upper-level westerly trough; (ii) upper level jet entrance regions closer to the Himalaya; (iii) positive potential vorticity anomaly associated with steep tropopause fold and interaction with elevated topography, and (iv) monsoon trough shift over the Himalaya. He also demonstrated performance of WRF model and the European Centre for Medium-Range Weather Forecast (ECMWF) forecast for precipitation associated with cloudbursts. Das summarized that though models are able to predict the signature of rainstorms fairly well, the skill of predicting precise location, time and intensity needs improvement. Further, assimilation of Doppler radar and satellite data improves the prediction.

R. K. Jenamani (India Meteorological Department, Delhi) explained in detail about large-scale and meso-scale process that have been found to lead to extreme dense fog/smog spells across the Indo-Gangetic Plain and at the Indra Gandhi International Airport in Delhi. He presented a case study of application of a model for predicting the onset of fog and discussed the forecasting challenges.

Amita Prabhu (IITM, Pune) presented a case study of analysing the influence of low-frequency wintertime Eurasian snow forcing on summer monsoon rainfall over NE India (NEISMR) through the north Atlantic SST bridge. She discussed that while the summer monsoon rainfall over major parts of India (excluding the NE region) appears to be related with events in the Southern Hemisphere, namely the southern annular mode through the Pacific SSTs, the variation of

NEISMR appears to be related with events in the Northern Hemisphere through the Arctic oscillation, Eurasian snow and Atlantic SSTs.

The final talk of the session was delivered by Anurag Kandya (Pandit Deendayal Petroleum University, Gandhinagar). He presented a comprehensive study of the dynamics of urban heat island (UHI) effect in the megacity of Delhi during 2001–2018. Kandya revealed that Delhi as whole has experienced a warming trend for the annually averaged night-time land surface temperature during 2003–2018. About 26% of Delhi has witnessed an increasing trend in the night-time UHI intensities. He stressed the importance of UHI mitigation measures to take forward the concept of sustainable cities.

The poster session on the second day included posters from students and early-career researchers. The posters included interesting studies on multi-faceted aspects of extreme weather such as the use of numerical weather prediction models to study extremes, role of air-quality parameters like aerosols, observational analysis of extremes and various indices, heat stress, evaluation of weather and climate models along with atmospheric chemistry models, and many others. The works of these young minds were well received and appreciated by many senior scientists and researchers.

The final session of the day was a panel discussion chaired by K. J. Ramesh (IMD, Delhi), Akhilesh Gupta (Department of Science and Technology (DST), Government of India (GoI)), Swati Basu (Office of the Principal Scientific Adviser to GoI), R. K. Mehajan (DST, GoI) and Manju Mohan (IIT Delhi).

Some of the key recommendations from the panel discussion are as follows:

(i) Encouragement of efforts amongst premiere and older institutions with newer universities and institutions for collaborative research projects.

(ii) The operational models to be available to the research community with test data for initial/boundary conditions and validation for incessant model development activities. Model inter-comparison exercises shall be conducted periodically amongst the user community and operational agencies.

(iii) Automatic weather station measurements utilized for routine forecasts shall be upgraded for research purposes

to include radiation, flux-tower measurements and other state-of-the-art equipment.

(iv) Observational network shall be enhanced keeping in view the area most impacted by extreme weather events such as extreme rainfall, drought, cyclones, thunderstorms, fog, etc.

(v) Focus on research aspects such as data assimilation with satellite products.

(vi) The observational data (Doppler Weather Radar (DWR), satellite, networks, field campaign, etc.) available with academic institutions, operational agencies, space and other research organizations could be integrated through coordinated efforts and be brought on a common platform through a designated agency for this purpose.

(vii) Research efforts for bridging the huge gap between data availability (both from newer technological platforms such as DWR, satellites, etc. and routine networks), and its utilization for improving scientific understanding and incorporation in operational models.

(viii) Enhancement of capacity-building programmes in meteorology and related fields.

(ix) Suitable career avenues with schemes for attracting bright students and early career researchers in a sustainable manner should be created.

(x) Greater cooperation amongst Asian nations facing extreme weather situations for sharing of model data, observations, experiences, etc. as also collaborative projects shall be enhanced.

(xi) Parameterization of microphysics, land-surface processes, boundary layer, aerosol–cloud interactions, convective processes, etc. shall be based on locally developed parameterizations.

(xii) Implementing seamless high-resolution models effective at the local scale for research and operational purposes to be adopted to take care of local, regional and large-scale circulations.

(xiii) City-scale forecast model development for extreme weather events to be given high priority.

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