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CONFERENCE REPORT

**Report on the International Conference on
Ensemble Methods in Modelling and Data Assimilation
(EMMDA)
(24-26 February 2020)**



Abhijit Sarkar, Akhilesh K. Mishra, Ashish Routray,
S. Indira Rani, A. Jayakumar, Mohana S. Thota,
K. Niranjan Kumar, Raghavendra Ashrit, Sumit Kumar,
Suryakanti Dutta, and E. N. Rajagopal

March 2020

**National Centre for Medium Range Weather Forecasting
Ministry of Earth Sciences, Government of India
A-50, Sector-62, NOIDA-201309, INDIA**

**Report on the International Conference on Ensemble Methods
in Modelling and Data Assimilation (EMMDA)
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An international conference on “**Ensemble Methods in Modelling and Data Assimilation (EMMDA)**” was organised by NCMRWF during 24-26 February 2020. The international conference was inaugurated by the Chief Guest Dr. M. Mohapatra, Director General of Meteorology, IMD & Permanent Representative to WMO on 24th February in the presence of Dr. Vipin Chandra, Joint Secretary, MoES, Prof. E. Kalnay, University of Maryland, USA, Dr. E.N. Rajagopal, Head, NCMRWF and Dr. Abhijit Sarkar, Conference Convener. The Chief Guest also inaugurated NCMRWF’s Data Web Portal, which provides, (1) **IMDAA Reanalysis Data**, a high resolution (12 km, 1-hourly) 40-year regional reanalysis over India, from 1979 to 2018 and (2) **NGFS Reanalysis Data**, a high resolution (25 km, 6-hourly) Global reanalysis, from 1999 to 2018.

The major themes of the conference were:

- Ensemble methods in Global Weather Prediction
- Ensemble methods in Data Assimilation
- Ensemble methods in Monthly and Seasonal Forecasting
- Convection Permitting Ensemble Prediction Systems
- Verification of Ensemble weather forecasts
- Applications of Ensemble weather forecasts

International scientists from UK Met Office, ECMWF, NOAA, KMA, BoM, NIWA, SAWS, TMD (Bangkok, Thailand), University of Maryland, University of Reading and Scuola Universitaria Superiore Sant’Anna, Pisa, Italy participated in the conference. The scientists from NCMRWF and several Indian academic & research institutes, the forecasters and the representatives of forecast user community took part in this conference. There were 17 international and 19 national speakers in the conference. Young Indian researchers showcased their research outcomes through 19 poster presentations. This conference provided a platform for discussions and deliberations on the present status, future prospects and optimum use of ensemble data assimilation technique and ensemble forecasting system.

The Unified Model Partnership supported the conference by providing wide publicity of EMMDA among the UM partners and sponsoring 6 participants from KMA, Met Office, BoM and SAWS. The presentations of the conference are available under “Scientific Program” Tab at <https://www.ncmrwf.gov.in/event/emmda/>

The Scientific Programme of the conference is given in Annexure-I. A session wise brief summary of the proceedings of the conference is presented below:

The theme of the first technical session was “Ensemble methods in Global Weather Prediction”. This session was chaired by Dr. Zoltan Toth, ESRL/NOAA, USA. The first speaker of the session was Prof. Eugenia Kalnay, University of Maryland who delivered a talk on “Can we Improve Substantially Weather Forecasts without Cheating?” In this talk she discussed about the Proactive Quality Control (PQC) methodology which is a fully flow dependent Quality Control based on Ensemble Forecast Sensitivity to Observations (EFSO). Major benefit of cycling PQC in sequential data assimilation framework was demonstrated in this talk. Dr. Warren Tennant of Met Office, UK was the next speaker of this session. In his talk he summarized recent developments in Global Ensemble Prediction System at Met Office. Recent upgradation of Met Office’s global ensemble system (MOGREPS-G) was nicely explained in his presentation. In the upgraded MOGREPS-G the En-4D-EnVar method has replaced the ETKF method for generating perturbed ensemble members. Next, Dr. M. Mohapatra, DGM, IMD talked about the use of probabilistic forecasting operational at IMD. He also explained how the forecasters of IMD use the forecast products of multi-model ensemble system. Application of High Resolution Ensemble Prediction system in predicting extreme rainfall events over Indian Region was presented by Dr. Parthasarathi Mukhopadhyay, IITM, Pune. He also explained the new approach of dynamical core in GFS; the TCO Grid. The last talk of this session was delivered by Dr. Joohyung Son, KMA, South Korea. Through her presentation she introduced the Korean Integrated Model (KIM) based Global Ensemble Prediction System and also highlighted some important results of the comparative study of the performances of KIM-GEPS and MOGREPS-G.

“Ensemble methods in Data Assimilation” was the theme of the Technical Session 2. There were four talks scheduled in the first part of this session which was chaired by Prof. Eugenia Kalnay. First talk of this session was delivered by Dr. Daryl Kleist from NCEP/NOAA, USA. Title of his talk was “Data assimilation for the Unified Forecast System: Plans for GFS Version 16 and Progress of JEDI”. Dr. Kleist began his talk by presenting an overview of NCEP’s operational Global Data Assimilation System (GDAS). He briefly described the hybrid 4D-EnVar and FV3 based 80-member ensemble Global Forecast System (GFS) running at 12 km horizontal resolution. He also gave an overview of NCEP’s proposed upgrade with 127 Layer model enabling new satellite channels (AMSU-A Channel 14 and ATMS Channel 15) ingested at upper level. Dr. Kleist also explained the proposed sustainable

production suite of Unified Forecast System at NCEP, Joint Effort for Data assimilation Integration (JEDI) and Joint Center for Satellite Data Assimilation (JCSDA). Second presentation of this session was by Dr. V. S. Prasad, NCMRWF. He gave a brief presentation on history of data assimilation at NCMRWF and current operational regional and global assimilation system. He demonstrated that the ingestion of radiance data from MT-SAPHIR resulted in 4% improvement in humidity forecast. The next talk was by Dr. John P. George on “Hybrid Variational-Ensemble Data Assimilation in the NCUM System and IMDAA Regional Reanalysis”. Dr. John explained the Hybrid variational Ensemble Data Assimilation used in NCUM-Global and 4D-Var used for IMDAA regional reanalysis. He discussed the hybrid and non-hybrid data assimilations and their biases. Last talk in this session was delivered by Dr. Prashant Kumar from Space Application Centre (SAC), India. In his talk on “Assimilation of INSAT-3D Thermal Infrared Window Imager Observation using Particle Filter” he discussed the challenges in satellite data assimilation. He also demonstrated how using particle filter one can select the ensemble. All the four talks were very well received and appreciated by the audience.

The second part of Technical Session 2 was chaired by Dr. Daryl Kleist, NCEP/NOAA, USA. First speaker of this session, Dr. Zoltan Toth, ESRL/NOAA spoke on the topic “Ensembles: A Critical Review”. Through this talk he opined that there is fundamental problem associated with the concept of ensembles and the perturbed members are worse than the control. He also conveyed that although the error in ensemble mean is smaller than that in control, ensemble mean contains less information. In the following talk Ji-Hyun Ha, KMA described the “Hybrid data assimilation in the KIM Forecasting System at KMA”. Dr. Ha pointed out that in KMA Hybrid 4D-EnVar replaced 3D-Var in 2017. The major developments are the increase of Ensemble-Background Error Covariance ratio and the increase of horizontal resolution of ensemble forecast. Although Hybrid 4D-EnVar works well, it tends to make the temperature increment colder in upper tropical region. The presentation also showed that increasing ensemble BEC ratio from 0.3 at the pole to 0.7 at the equator improves the model performance which resulted in improving the prediction of heavy rainfall and typhoon track on the Korean Peninsula. Dr. Amit Apte, ICTS, Bengaluru delivered a talk on “Hybrid particle-ensemble Kalman filter for Lagrangian data assimilation”. In this talk he proposed hybrid particle-Kalman filter in overcoming the challenges of “curse of dimensionality” and non-Gaussian distribution. The last talk of the day was delivered by Dr. Javier Amezcu, Reading University, UK through video conferencing. His talk was on “Assimilation of Atmospheric

Infrasound Data to Constrain Winds using an EnKF”. In his talk he demonstrated how the data assimilation method using an EnKF exploits acoustical infrasound from explosions to probe an atmospheric wind component from the ground up to stratospheric altitudes. It was claimed to be the first study demonstrating technique to implement assimilation of infrasound data into atmospheric models.

The first day’s proceedings were followed by the Conference Dinner hosted by Secretary, MoES at India Habitat Centre, New Delhi.

The second day of the conference started with the third part of the Technical Session 2, which was chaired by Dr. E. N. Rajagopal, Head, NCMRWF. The first speaker of the day was Mr. Robert Maisha, SAWS, South Africa. In his talk on “Ensemble forecasting and Data assimilation at SAWS” he discussed about the downscalers and Convective Scale Ensemble Prediction System (CSEPS) of SAWS. He also emphasized the importance of stream flow data for hydrology/climate change and flood predictions. Dr. Arya Paul, INCOIS then delivered a talk on “LETKF-ROMS: An improved predictability system for the Indian Ocean”. He discussed about the implementation of LETKF in ROMS over Indian region in which 80 member ensembles have been used with two different mixing schemes (KPP and MY). LETKF method shows the improvement over Northern Indian Ocean and degradation over Head Bay of Bengal region. The third talk of the session was delivered by Dr. Deepak Subramani, IISc, Bengaluru on “Probabilistic Forecasting and Bayesian Data Assimilation using Dynamically Orthogonal Equations”. This talk was mainly based on Bayesian approach in probabilistic forecasting. In this talk he discussed about, which Bayesian approach is better and talked about the estimation of initial condition and dynamical uncertainty in the model. Finally, he gave a glimpse of Machine Learning (ML) and Artificial Intelligence (AI) in predicting the Ocean state variables like SST and SSH. In the last talk of the session Dr. Siva Reddy Sanikommu, KAUST described the “Efforts on Developing Efficient Ensemble Data Assimilation System for the Red Sea at KAUST”. He discussed about the uncertainties in the background error covariance matrix and the Ensemble Optimal Interpolation (EnOI) methods which are prone to spurious errors. He also emphasized the importance of flow depended ensembles and the importance of subsurface observations in Ocean data assimilation.

The Technical Session 3 on “Ensemble Methods in Monthly and Seasonal Forecasting” was chaired by Dr. Warren Tennant, Met Office, UK. The first talk of this session was delivered by Dr. Harry H. Hendon BoM, Australia on “Overview of BoM

Operational S2S Ensemble Prediction Systems and Future Plans”. The performance of upgraded operational model ACCESS-S1 system based on UKMO-GC2 relative to previous low resolution POAMA system was presented in this talk. The sub-seasonal predictability with MJO and IOD teleconnections was reported with new ACCESS-S1 model. Further, plans for upgrades to new ACCESS-S2 and ACCESS-S3 system during the next 5 years were also discussed. Dr. A K Sahai, IITM, Pune was the next speaker in this session who presented the performance of sub-seasonal prediction of Indian summer monsoon from the IITM ensemble prediction system. It was emphasized in his talk that the coupled models are required for a better realistic simulation of monsoon intra-seasonal oscillations. Further, the predictions of the extreme weather from the ensemble prediction system were also presented in this talk. The next speaker, Dr. Suryachandra Rao, IITM presented ensemble seasonal prediction of Indian summer monsoon (ISM). The complexity of prediction of ISM with respect to El Nino Southern Oscillation (ENSO) was discussed in his talk. He also pointed out the reduced predictability of El Nino in recent decades. Dr O. P. Sreejith, IMD, Pune discussed the present operational seasonal forecast system of India Meteorological Department (IMD). He discussed about the dynamical and statistical models used for the long range forecast of monsoon rainfall. He also discussed about the seasonal climate outlook for south Asia. Dr. Pil-Hun Chang, KMA, South Korea presented the climate prediction system (GloSea5) operational at KMA. He discussed about the ensemble prediction system that uses time-lagged ensemble approach. He presented the results of seasonal probability prediction from GloSea5 based on reliability categories. He indicated that the better representation of land initialization may have played major role in improving the reliability. Prof. Roberto Buizza, ECMWF/Sant’ Anna, SAS, Italy delivered the next talk on “Data Assimilation and Ensembles: Two Invaluable Tools to Increase Predictability and Quantify Uncertainty” through video conferencing. Prof. Buizza talked about understanding the evolution of complex systems and emphasized that the prediction of their evolution requires the adoption of appropriate tools, approaches and methodologies. He presented some examples of weather prediction, where complexity is evident both when we try to understand and predict the small-scale, high-frequency variations (e.g., extreme events such as hurricanes) or the large-scale, low-frequency features (e.g., continental-scale anomalies). The last talk of this session was delivered by Dr. A K Mitra, NCMRWF on “NCMRWF Coupled Ensemble Extended Range Prediction System”. He presented the state-of-art global coupled seamless modelling system implemented at NCMRWF along with the ocean initialization system. He also informed that a regional high resolution mesoscale coupled system was being tested for Indian domain under the WCSSP-India project. The skill of the

model with respect to the seasonal rainfall, temperatures including the polar sea ice forecast skill of the model was also discussed in this presentation.

The Technical Session 4 on “Convection Permitting Ensemble Prediction Systems” was chaired by Dr. Harry H. Hendon, BoM, Australia. Out of four talks of this session two were through video conferencing. Dr. Stuart Webster, Met Office, UK was the first speaker and in his talk he gave an “Overview of Convection Permitting Ensembles Work at the Met Office” through video conferencing. Apart from describing the complexity of Met Office Regional Ensemble system, he also showed results of sensitivity experiments like the influence of initial conditions, LBCs and physics on the ensemble spread. Second remote talk of this session was delivered by Dr. Stuart Moore, NIWA, New Zealand. He described New Zealand’s convective scale ensemble system known as NZENS. Prof. Suneet Diwedi, Allahabad University spoke on “Energetically Consistent Stochastic and Deterministic Kinetic Energy Backscatter Schemes for Atmosphere–Ocean Models”. He explained how stochastic kinetic energy backscatter scheme improves predictability of low resolution numerical forecast model. The last talk of this session “Understanding the Predictability of Extreme Weather Events using Ensemble-based Data Assimilation” was delivered by Dr. Govindan Kutty, IIST, Thiruvananthapuram. In this talk he showcased the benefits of using ensemble Kalman filter based data assimilation system in predicting the extreme events like cyclone Nargis and Uttarakhand rainfall episode.

The Technical Session 5 on “Verification of ensemble weather forecasts” was chaired by Dr. Michael Naughton, BoM, Australia. The first talk of this session was remotely presented by Dr. Martin Leutbecher, ECMWF on “An overview of ensemble forecasting system operational at ECMWF”. He emphasized the fact that ensemble size and spatial resolution are both important and specific application decides the optimal configuration. Next, Dr. Raghavendra Ashrit, NCMRWF presented the applications of spatial verification methods like CRA for ensemble forecasts. He also highlighted the benefits of using spatial techniques over traditional verification scores. The last talk of the day was delivered by Dr. Abhijit Sarkar, NCMRWF. He compared the performances of Regional and Global Ensemble Prediction Systems of NCMRWF by verifying various parameters with observations. He showed that regional ensemble prediction system has better skill in predicting extreme rainfall events in the short range compared to the global system.

The second day's proceedings were followed by a special dinner hosted by DGM, IMD at India Habitat Centre, New Delhi.

The third day of the conference started with Technical Session 6 on “Applications of Ensemble Weather Forecasts”, which was chaired by Prof. A. Chandrasekar, IIST, Thiruvananthapuram. There were six talks in this session. Prof. Eugenia Kalnay, University of Maryland, USA covered two topics. The first topic was “Leveraging oscillatory modes to improve forecasts of chaotic processes, with applications to the Indian monsoon”. In this talk she suggested that the data driven method predicted the Monsoon Intra-Seasonal Oscillations (MISO) better than the CFS. She commented that MISO had 14% daily variances and an error reduction was 7% or more depending on the region using the oscillatory modes. She suggested that DA should be able to formally combine the model and machine learning. Her second talk was on “Results from the assimilation of Altimeter Absolute Temperature (ADT) in CFS using LETKF”. She suggested that localizing the ADT at sea surface is not a good choice, because the assimilation of non-local observations in EnKF is a non-trivial problem. Preliminary results showed largest improvement over the shallow water at the Tropics and deep layers at the Northern Hemisphere and improvement was not observed over the Southern hemisphere in temperature and salinity forecasts. Next, Dr. Michael Naughton, BoM, Australia delivered a talk on “BoM's Development and Use of Ensembles in NWP and applications”. His presentation covered ACCESS-global, city Hybrid En-4DVAR system and their applications to extreme weather like bushfire, floods, storms, etc. He also mentioned about the IMPROVER, a post processing & verification tool for greater automation of products and alerting, STEPS- a statistical ensemble for nowcasting and seamless prediction, Calibrated Thunder, stream flow forecasting, TC bias correction etc. Prof. Ravi S. Nanjundiah, IITM delivered a talk on “Ensemble Forecast and their Application from Short Range to Seasonal Scales”. He described the achievements in the first and second phases of Monsoon Mission project, the STORM project and the applications in the renewable energy sector. One of the highlights of his talk was that the IITM's MME extended range prediction system was comparable to ECMWF system in longer lead time. Applications of IITM ensemble system in different fields like monsoon onset and withdrawal, agriculture, cyclogenesis, hydrology, health, etc. were also discussed. Later Dr. S.C. Kar, NCMRWF delivered a talk on the probabilistic predictions for Hydrology applications. He emphasised the importance of the deterministic action at the user end from the probabilistic forecasts, particularly for the hydrological applications. Next, Prof. C. Balaji, IIT Madras, delivered talk on “Ingesting Multi-

satellite Radiances to Improve the Predictability of Regional NWP Model”. The main objective of his research work was to improve the forecast skill of the WRF model by assimilating the radiance observations from the MT-SAPHIR and INSAT-3D satellites through EnKF analysis system for simulation of tropical cyclone Vardah over Bay of Bengal. He concluded that the assimilation of INSAT-3D radiance observations had more positive impact than the MT-SAPHIR radiance on the simulation of Vardah cyclone. Finally, Dr. Boonlert Archevarahuprok, TMD, Thailand, gave an overview of “TMD’s Numerical Weather Prediction System”. The presentation mainly discussed the establishment of computing facilities and NWP modelling system to predict extreme weather systems like heavy rainfall, flood, cyclones, etc. over Thailand region.

Young researchers of NCMRWF and other Institutes showcased their research works during the conference through poster exhibition. All together 19 posters were exhibited during the conference. The poster presenters summarized their works through brief oral presentations after the Technical Session 6. These presentations got huge appreciation and encouragement from the senior scientists present in this conference.

The concluding session had a panel discussion under the chairmanship of Prof. Ravi Nanjundaiah, Director, IITM. The other panel members were Prof. Eugenia Kalnay, University of Maryland, USA, Dr. Zoltan Toth, ESRL/NOAA, USA, Dr. Harry H. Hendon, BoM Australia, Dr. Warren Tennant, Met Office UK, Dr. Daryl Kleist, NCEP/NOAA, USA, Prof. C. Balaji, IIT Madras and Dr. E.N. Rajagopal, Head, NCMRWF.

The panel discussion began with opening remarks from the Chairperson. He thanked all the speakers for high quality presentations and stimulating discussions on ensemble methods in Modelling and Data Assimilation. He noted that while there have been improvements in ensemble modelling, there is need to develop improved forecasts and applications. Reflecting on the EMMDA conference Prof. Kalnay, expressed happiness over the progress made in recent years. She further added that, now modelling and DA tools are available for the research community to collaborate and that best way to improve is through international collaboration. Prof. Balaji, emphasized on the use of Machine Language (ML) & Artificial Intelligence (AI) to improve the model initial conditions. He further reiterated the need for network of radars for improved monitoring and forecasting in general. Specifically he pointed to the turbulence forecasting and how it could be improved using the advanced ML tools. He also suggested that a national level (i) PhD fellowship program and (ii) Post-Doctoral Fellowship program should

be launched under MoES to promote R&D in Ensemble Methods. Dr. Tennant opined that we need good models and well calibrated ensembles using Bias Correction. He pointed out that for a good ensemble prediction system, the deterministic model has to be good. Giving the example of TIGGE, he pointed out that not all the ensemble models were well calibrated and emphasized the need to obtain appropriate spread which can be achieved only by generating realistic perturbations. Expressing agreement, Dr. Hendon mentioned that at BOM, efforts were first invested in improving the deterministic model biases.

Reacting to the discussions, Dr. Toth, highlighted that improvements in the ECMWF forecast skill is due to the efforts of global community, which encompasses, scientific contributions, technological/infrastructure advances and also outreach. He also expressed importance and potential of coupled DA and ensemble. Further, he added that with increase in the HPC capability, the grid resolution increases by factor of 2 and in 5-10 years we are likely to see 1-2 km resolution global models. However, he emphasized the need to communicate “Predictable and Unpredictable” aspects to public and on generating the ensembles statistically. Dr. Rajagopal, shared the NCMRWF experience of improved performance in ensemble by increasing grid resolution (from 33 km to 12 km) despite reducing the number of ensemble members (from 44 to 22). Further, he mentioned about the availability of two ensemble systems GEFS and NEPS with MoES which could be optimally used to generate probabilistic forecast products and the need for effective communication of probabilistic forecasts to users. He also touched upon some concerns and challenges that NCMRWF plans to work in the near future which included, efficient compute node usage, generating ensemble hindcasts, use of TIGGE data for R & D and attracting youngsters to work on ensembles.

Following the remarks from all the panel members, the session was opened for comments and suggestions from the delegates in the audience. Dr. Suryachandra Rao, IITM, wanted to know how to improve the spread in the forecasts as models tend to be under dispersed. In reply, Dr. Tennant, opined that it is important to get the rain bearing systems correct in the models by getting the model physics correct. Reacting to the discussions, Stuart Webster, Met Office UK through video conference expressed opinion that for improved forecast products there is need to use both convective scale ensembles (for improved representation of convection) and better post-processing systems. Several of the participants from the audience pointed out that the University education needs to introduce (i) ensemble forecasting methods (ii) coupled NWP and (iii) use of simple toy models (easily portable version of UM and WRF model) for effective learning.

In his concluding remarks, the Chairman listed out some of the key points including (i) continued collaboration (ii) use of AI and ML in forecasting and (iii) improved & smart use of HPC for DA and Modelling e.g., GPUs, Accelerators and tailoring codes for new & emerging HPC technologies.

The conference came to conclusion with final remarks by Head, NCMRWF, thanking all the international participants for attending in person and also those who could manage to attend through Video Conference. He also expressed gratitude towards all the participants for their participation and their lively discussions. He also thanked all the internal committees and administration of NCMRWF for successful organization of EMMDA conference.

The Major Recommendations of the conference are summarised below:

- 1) More national and international collaborations are required for improving modelling and DA systems based on ensembles.
- 2) Wider use of Machine Learning (ML) and Artificial Intelligence (AI) in modelling and DA should be encouraged in India.
- 3) Improvements in model physics and in generation of perturbations in initial conditions are needed.
- 4) Interpretation of EPS forecast products and effective communication of EPS forecasts to the users & decision makers are essential. It is essential to communicate “Predictable and unpredictable” aspects of an EPS to the users.
- 5) Convective scale ensembles (for improved representation of convection) and better post-processing systems are required.
- 6) Optimum use of HPC for DA and Modelling with GPUs, Accelerators and development of tailor made new codes for new and emerging technologies are essential.
- 7) Availability of two ensemble systems GEFS and NEPS under MoES should be optimally combined to generate probabilistic forecast products. Ensemble hindcasts are essential for generating high resolution model’s climatology.
- 8) There is an urgent need to introduce NWP modelling, ensemble methods and coupled modelling in University curriculum to create trained young scientists in these fields.
- 9) A national level Post-Doctoral Fellowship program under MoES to promote R&D in ensemble methods in modelling and DA systems would be highly useful.

Annexure-I

Scientific Programme of International Conference EMMDA

Day 1: 24 February 2020		
8:30 – 9:30	Registration	
9:30 – 10:30	Inaugural Session	
10:30 – 11:00 High Tea		
11:00 – 13:00: Technical Session 1 - Ensemble Methods in Global Weather Prediction		
Chairperson: Zoltan Toth, ESRL/NOAA, USA		
11:00 – 11:30	Eugenia Kalnay, UoM	Can We Improve Substantially Weather Forecasts without Cheating?
11:30 – 12:00	Warren Tennant, Met Office, UK	Recent Developments in Global Ensemble Prediction at Met Office
12:00 – 12:20	Mrutyunjay Mohapatra, IMD	Probabilistic Forecasting in IMD: Current Status and Future Scope.
12:20 – 12:40	Parthasarathi Mukhopadhyay, IITM	Performance of High Resolution Ensemble Prediction System in Predicting Extreme Events over Indian Region.
12:40 – 13:00	Joohyung Son, KMA	Introduction to Korean Integrated Model (KIM) based Global Ensemble Prediction System.
13:00 – 14:00 Lunch		
14:00 – 15:30: Technical Session 2 - Ensemble Methods in Data Assimilation – 1		
Chairperson: Eugenia Kalnay, University of Maryland, USA		
14:00 – 14:30	Daryl Kleist, NCEP/NOAA	Data Assimilation for the Unified Forecast System: Plans for GFS Version 16 and Progress of JEDI.
14:30 – 14:50	V.S. Prasad, NCMRWF	4D-Ens-Var Analysis System at NCMRWF
14:50 – 15:10	John P. George, NCMRWF	Hybrid Variational–Ensemble Data Assimilation in the NCUM NWP System and IMDAA Regional Reanalysis
15:10 – 15:30	Prashant Kumar, SAC	Assimilation of INSAT-3D Thermal Infrared Window Imager Observation using Particle Filter
15:30 – 16:00 - Tea and Poster Session		
16:00 – 17:40: Technical Session 2 - Ensemble Methods in Data Assimilation – 2		
Chairperson: Daryl Kleist, NCEP/NOAA, USA		
16:00 – 16:30	Zoltan Toth, ESRL/NOAA	Ensembles: A Critical Review
16:30 – 17:00 Via Video Conference	Javier Amezcua, Reading University UK	Assimilation of Atmospheric Infrasonic Data to Constrain Winds using an EnKF
17:00 – 17:20	Ji-Hyun Ha, KMA	Hybrid Data Assimilation in the KIM Forecasting System at KMA
17:20 – 17:40	Amit Apte, ICTS, Bengaluru	Hybrid Particle-ensemble Kalman Filter for Lagrangian Data Assimilation.
19:30-21:30 - Conference Dinner hosted by Secretary, MoES at India Habitat Centre, New Delhi		

Day 2: 25 February 2020		
09:00 – 10:20: Technical Session 2 - Ensemble Methods in Data Assimilation – 3		
Chairperson: E. N. Rajagopal, NCMRWF		
09:00 – 09:20	Robert Maisha, SAWS, South Africa	Ensemble Forecasting and Data Assimilation at SAWS.
09:20 – 09:40	Arya Paul, INCOIS	LETKF-ROMS: An Improved Predictability System for the Indian Ocean
09:40 – 10:00	Deepak Subramani, IISc	Probabilistic Forecasting and Bayesian Data Assimilation using Dynamically Orthogonal Equations.
10:00 – 10:20	Siva Reddy Sanikommu, KAUST	Efforts on Developing Efficient Ensemble Data Assimilation System for the Red Sea at KAUST.
10:20 – 10:50 – Tea and Poster Session		
10:50 – 14:30: Technical Session 3 – Ensemble Methods in Monthly and Seasonal Forecasting		
Chairperson: Warren Tennant, Met Office, UK		
10:50 – 11:20	Harry H. Hendon, BoM	Overview of BoM Operational S2S Ensemble Prediction Systems and Future Plans.
11:20 – 11:40	A K Sahai, IITM	Ensemble Prediction System for Sub-seasonal Variability
11:40 – 12:00	A Suryachandra Rao, IITM	Ensemble Seasonal Prediction of Indian Summer Monsoon
12:00 – 12:20	O. P. Sreejith, IMD Pune	Present Operational Seasonal Forecast System of IMD
12:20 – 12:40	Pil-Hun Chang, KMA	Climate Prediction System. of KMA: Current Status and Plans
12:40 – 13:40 - Lunch		
13:40 – 14:10	Roberto Buizza, ECMWF/Sant'Anna SAS, Pisa	Data Assimilation and Ensembles: Two Invaluable Tools to Increase Predictability and Quantify Uncertainty
Via Video Conference		
14:10 – 14:30	A K Mitra, NCMRWF	NCMRWF Coupled Ensemble Extended Range Prediction System.
14:30 – 16:10: Technical Session 4 - Convection Permitting Ensemble Prediction Systems		
Chairperson: Harry Hendon, BoM, Australia		
14:30 – 15:00	Stuart Webster, Met Office, UK	Overview of Convection Permitting Ensembles Work at the Met Office
Via Video Conference		
15:00 – 15:30	Stuart Moore, NIWA, New Zealand	Convective scale ensembles at NIWA.
Via Video Conference		
15:30 – 15:50	Suneet Diwedi	Energetically Consistent Stochastic and Deterministic Kinetic Energy Backscatter Schemes for Atmosphere –Ocean Models
15:50 – 16:10	Govindan Kutty, IIST, Thiruvanthapuram	Understanding the Predictability of Extreme Weather Events using Ensemble-based Data Assimilation
16:10 – 16:40 - Tea and Poster Session		
16:40 – 17:50: Technical session 5 - Verification of Ensemble Weather Forecasts		
Chairperson: Michael Naughton, BoM, Australia		
16:40 – 17:10	Martin Leutbecher, ECMWF	Ensemble Forecasting at ECMWF.
Via Video Conference		
17:10 – 17:30	Raghavendra Ashrit, NCMRWF	Application of Spatial Verification Methods for Ensemble Rainfall Forecasts over India.
17:30 – 17:50	Abhijit Sarkar, NCMRWF	Verification of Regional Ensemble Prediction System of NCMRWF (NEPS-R)
19:30-21:30 Special Dinner hosted by DGM, IMD at India Habitat Centre, New Delhi		

Day 3: 26 February 2020**09:00 – 11:40: Technical Session 6 - Applications of Ensemble Weather Forecasts****Chairperson: Prof. A. Chandrasekar, IIST, Thiruvananthapuram**

09:00 – 09:30	Eugenia Kalnay, UoM	(i) Leveraging oscillatory modes to improve forecasts of chaotic processes, with applications to the Indian monsoon (ii) Effective Assimilation of Altimetry Observations with the CFS-LETKF System
09:30 – 10:00	Michael Naughton, BoM	BoM Development and Use of Ensembles in Numerical Weather Prediction and Applications.
10:00 – 10:20	Ravi S Nanjundiah, Director, IITM	Ensemble Forecast and their Application from Short Range to Seasonal Scales
10:20 – 10:40	S. C. Kar, NCMRWF	Probabilistic Predictions for Hydrology Applications.

10:40 – 11:00 – Tea and Poster Session

11:00 – 11:20	C Balaji, IIT-Madras	Ingesting Multi-satellite Radiances to Improve the Predictability of Regional NWP Model
11:20 – 11:40	Boonlert Archevarahuprok, TMD	TMD's Numerical Weather Prediction System

11:40 – 13:00: Poster Presentations**13:00 – 14:00 – Lunch****14:00 – 15:00: Concluding Session**

Panel discussion	Chairperson: Ravi S Nanjundiah Panel members: E. Kalnay, Z. Toth, Harry Hendon, W. Tennant, Daryl Kleist, C. Balaji, and E. N. Rajagopal
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15:00 - 15:30 Tea