Ensemble Forecasts at Various Scales and their Applications

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Indian Institute of Tropical Meteorology, Pune
Ensemble Methods in Modelling and Data Assimilation
24-26 February 2020
Monsoon Mission Phase-I

Objectives

• To build a working partnership between the academic and R & D Organizations, and to improve the operational monsoon forecast skill over the country.

• To setup a state-of-the-art dynamical modeling framework for improving prediction skill of
  - Seasonal and Extended range predictions
  - Short and Medium range (up to two weeks) prediction

From research to operations & applications

Monsoon Mission Phase-II

Objectives

• To improve operational forecast skill over the country and develop relevant climate applications for agriculture, hydrology and power sectors.

• To develop and improve a state-of-the-art dynamical modelling framework for improving prediction skill of
  - Seasonal and Extended Range prediction
  - Short and Medium range (up to 2 weeks) predictions
High-resolution GEFS for short-range forecasting

- Initial conditions are from the Global Data Assimilation System
- Control analysis using Gridpoint Statistical Interpolation (GSI) and ensemble Kalman filter (EnKF) hybrid analyses
- The 20 ensembles from the EnKF scheme.
- These data assimilation systems are being run at NCMRWF
- Gain of 2 days lead time from the low resolution model
- The location and intensity of extreme rains as well as cyclogenesis events have been forecasted with some success at reasonable lead time.
Verification of Rainfall forecasts from GFS for JJAS (2012-2019) Monsoon Core Zone (18-28N, 66.5-88E)

- **Bias Score**: Frequency Bias
  - >1 implies model overestimates observed rain
  - >1 implies model underestimates observed rain

- **Probability of Detection (POD)**: Fraction of correct forecasts
  - 0 No Skill
  - 1 Perfect Score

- **False Alarm Ratio (FAR)**: Fraction of false alarms
  - 1 Worst
  - 0 Best

- **Critical Success Index (CSI)**: Threat Score
  - 0 No Skill
  - 1 Perfect Score
Probabilistic Quantitative Precipitation Forecast over River basin

PQPF generated from the 21 ensemble member based probabilistic forecast of GEFS at 12km with 10 days lead for specific rainfall threshold and for all Indian River basin
Percentile based extreme rain forecast

Extreme events on 17th Aug 2019

<table>
<thead>
<tr>
<th>Location</th>
<th>Rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jodhpur</td>
<td>105</td>
</tr>
<tr>
<td>Mount Abu Tehsil Sr (Rajasthan)</td>
<td>137</td>
</tr>
<tr>
<td>Amet</td>
<td>106</td>
</tr>
<tr>
<td>Srunagavapurukota (AP)</td>
<td>91.4</td>
</tr>
</tbody>
</table>

Based on GFST1534 hindcast and the rainfall and wind climatology, 90th and 95th percentile rainfall/wind is computed for each grid. Keeping this as reference, the percentile precipitation and wind forecast for 90th and 95th, are being prepared with 10 days lead for GFS 12km.
Development of Operational forecast of Thunderstorm/Lightning System for Thunderstorm Observation, Prediction and Monitoring (STORM)

<table>
<thead>
<tr>
<th>Large Scale Guidance: Probabilistic Prediction: GEFS</th>
<th>Prediction Tool utilizing IMD-WRF (3 Km) output</th>
</tr>
</thead>
<tbody>
<tr>
<td>• HEI (Hail Environmental Index) &gt;1</td>
<td>• LPI (Lightning Potential Index)</td>
</tr>
<tr>
<td>• SCP (Supercell Composite Parameter) &gt;1</td>
<td>• SCP (Supercell Composite Parameter)</td>
</tr>
<tr>
<td>• Layrh (Layer averaged Relative Humidity) &gt;80</td>
<td>• Layrh (Layer averaged Relative Humidity)</td>
</tr>
<tr>
<td>• Surface Wind Gust &gt;20kt</td>
<td></td>
</tr>
</tbody>
</table>

STORM is an acronym given to the MoES Severe thunderstorm Observation and Modelling programme of 2019. It was initiated on June 2018 and was handed over to IMD on 1 April 2019 with forecasting tools for forecasting lightning and lightning potential with dynamic model and forecasting probability of thunderstorm, Gusty wind, Hail from GEFS.
Evaluation of Wind forecast (WRF 3km) over Karnataka: Upper panel PDF of predicted and observed wind. Lower panel diurnal variation Good agreement with observations is seen.
The IITM MME (11 member) shows capability of better forecast in longer lead time as compared to EMWF forecast.

Main improvement is in Brier Skill Score for the Monsoon Zone.
Development of Ensemble Prediction

Each ensemble member is generated by slightly perturbing the initial atmospheric conditions with a random matrix (random number at each grid point) generated from a random seed. Fraction of the 24 hour tendency of different model variables are added to or subtracted from the unperturbed analysis with random perturbation between -1 and +1 times the 24 hour tendency so that the perturbation follow Gaussian distribution.

The perturbed IC,

\[ X'_{x,y,z,t} = X_{x,y,z,t} - p \ [r \ \Delta X_{x,y,z,t}] \]

where, \( \Delta X = X_{x,y,z,t} - X_{x,y,z,t-1} \); \( r \) -> taken from a random matrix and lies between -1 and +1; \( p \) -> tuning factor such that \( 0 < p \leq 1 \)

We perturb the wind, temperature and moisture fields and the amplitude of perturbation for all variables are scaled according to the magnitude of each variable at a given vertical level.

- It has the potential to generate infinite number of perturbed ICs.
- Amplitude of perturbation can be adjusted by changing the tuning factor.
- Sensitivity of perturbing each Individual variables can be evaluated.
Effect of perturbations in ERPAS

Initial condition of 1 May 2001

Without Q perturbed

With Q perturbed

P=1

P=.05

Growth of spread in rainfall over Monsoon zone
(high vs low perturbation)

✓ Improvement in model forecasts is seen with low values of perturbation.
Real-time Forecast Products: 2-3 weeks lead-time forecasts of Rainfall, temperature, humidity, large scale indices of intraseasonal oscillations, SPI etc.

Applications:

Monsoon: Onset and Withdrawal of monsoon, formation of low pressure system, propagation of convective phases, mid latitude intrusions

Agriculture: Draught Monitoring, Revival of Active Spells, Persistence of break spells, inputs to crop model, SPI.

Health: Cold Spells, heatwaves, local temperatures, guidance for vector borne diseases.

Hydromet: Flood Outlook and reservoir management.

Forecast Frequency Once per week; Ensemble member 16; Contributing models: CFSv2(T126 and T382); GFS(T126 and T382)
Meteorological forecasts from ERPAS

- **Rainfall**
- **Maximum & Minimum temperature**
- **Prediction of Cyclogenesis**

Cyclone Roanu in May 2016

- **Maximum Temperature (°C)**
  - Week 1 (21.05.2016 to 06.06.2016): Mostly normal to below normal 
  - Week 2 (07.06.2016 to 13.06.2016): Mostly normal to slightly normal

- **Minimum Temperature (°C)**
  - Week 1 (21.05.2016 to 06.06.2016): Mostly normal to slightly above normal 
  - Week 2 (07.06.2016 to 13.06.2016): Mostly normal to slightly below normal
Agricultural advisories based on ERPAS

National Agromet Advisory Service Bulletin
Based on
Extended Range Weather Forecast (ERFS)

Validity: 31 August to 13 September 2018
Date of issue: 31 August 2018

Kerala
Rainfall received during the period from 01 June to 30 August 2018 over Kerala is 2424.0 mm, which is 36% excess than normal. The extended range weather forecast provided for next two weeks (31 August to 6 September and 7 to 13 September) is below normal for both the weeks.

- To control rice bug, spray 2 ml malathion per litre of water. (Pesticides application should be done either before 9 am or after 3 pm). Otherwise, the pesticide application will adversely affect the pollination.
- Due to monsoon showers, there is a chance of Sigatoka disease in banana. As a precaution, spray Pseudomonas 20g/litre. In case of severe attack, spray 2 ml hexaconazole or 1 ml propiconazole per one litre of water by mixing it with a sticker and spray on both the surfaces of the leaf.
- Weather may be favourable for the soft rot disease in Ginger. Remove weeds and apply urea @ 33 kg per acre. To control soft rot, drench the soil with 1% Bonkemixure/0.3% monochlor.

Karnataka
Rainfall received during the period from 01 June to 30 August 2018 over different meteorological subdivisions of Karnataka viz., North Interior Karnataka is 281.5 mm (20% deficit), South Interior Karnataka is 563.9 mm (10% excess) and Coastal Karnataka is 2936.8 mm (7% excess). The extended range weather forecast provided from 31 August to 6 September and 7 to 13 September over all the sub-divisions of Karnataka is below normal for both the weeks.

North Interior Karnataka
- Sowing of desi cotton, castor, cowpea and horsegram as sole crop can be taken up in shallow black and red soils. Similarly, in medium black and deep black soils, sowing of Sunflower, Cotton and fodder crops may be opted.
- As below normal rainfall is forecasted, farmers are advised to provide desirable irrigation to crops.
- Vaccinate livestock against Foot and Mouth disease (FMD vaccination), Black Quarter disease (BC vaccination) and Anthracosis septicaemia.

South Interior Karnataka
- To control stem borer in Maize Spray Quinotriphon-25 EC @ 2ml/liter of water or Chlorothalonil -20 EC @ 2ml/liter of water.

Issued by
Indian Council of Agricultural Research (ICAR)
All India Coordinated Research Project on Agricultural Meteorology (AICRPM),
Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad.
&
Earth System Science Organization
India Meteorological Department

Strategic Agricultural Planning based on rainfall during next two weeks till 15th September 2018

Agronet Advisories

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Drought Monitoring

IMD’s Forecast Land Surface Products

- Land surface variables (soil moisture and runoff) were simulated using a well calibrated Variable Infiltration Capacity Model (VIC).
- Forcings from Medium range forecast model (GFS T1534) and Extended Range Forecast System were used to drive VIC.

Courtesy, Water and Climate Lab, IIT Gandhinagar
Improving Health Information using ERPAS

✓ Health Outlooks

Heat-wave and cold-wave forecasts

Weather Forecast

Health Outlook (IMD)

Challenges:

a. Health Data
b. Improved High Resolution forecasts

Research Effort:

Downscaling
High-resolution dynamical seasonal prediction system

- Reduced dry bias and better teleconnection
- Improvement in the interannual standard deviation from 0.4 (T126) to 0.5 mm/day (T382)
- Higher skill compared to the original T126 version
- Successful prediction of consecutive deficit monsoon years 2014 and 2015

Products and services in association with IMD

- ENSO-IOD Bulletin
- IMD-LRF
- Rainfall forecast over SASCOF
- Long Range Temperature forecast
R&D toward improving ISMR prediction and predictability

To test the impact of the progress made under MM, a series of hindcast experiments were carried out using seven versions of the MM model with mixed physics configurations, namely,

1) The **standard CFSv2** at T126 resolution with standard physics (CTL; Saha et al. 2014),
2) With the **high-resolution (T382)** MM model (Ramu et al. 2016),
3) With **revised SAS, improved cloud microphysics (WSM6)** and radiation (Abhik et al. 2017),
4) With **old snow model but new cloud microphysics parameterization** (MC; Hazra et al. 2017),
5) With **new snow model** combined with **new cloud microphysics** (SN-MC; Saha et al. 2019),
6) With the **revised convection parameterization scheme** (SAS2; Han and Pan 2011; Krishna et al. 2019), and
7) The **revised convection parameterization scheme and revised shallow convection scheme** (SAS2sc).
### Skill Improvements due to Developmental Activities

<table>
<thead>
<tr>
<th>RUN (Ensembles)</th>
<th>Hindcast Period</th>
<th>Resolution</th>
<th>AISMR (GPCP), (% improvement over CTL)</th>
<th>Nino 3.4</th>
<th>IOD East Pole</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTROL (10)</td>
<td>2003-2017 (2016)T126</td>
<td>0.33 (0.49, +9%)</td>
<td>0.53</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>NCEP CTL (10)</td>
<td>2003-2017 (2016)T126</td>
<td>0.42 (0.45)</td>
<td>0.57</td>
<td>0.76</td>
<td></td>
</tr>
<tr>
<td>CFS-NCEP (10)</td>
<td>1981-2017 T126</td>
<td>0.29</td>
<td>0.53</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td>COLA-CFS (10)</td>
<td>2003-2017 T126</td>
<td>0.60 (+81%)</td>
<td>0.61</td>
<td>0.62</td>
<td></td>
</tr>
<tr>
<td>SAS2 (10)</td>
<td>2003-2017 T126</td>
<td>0.54 (+63%)</td>
<td>0.70</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>SAS2sc (10)</td>
<td>2003-2017 T126</td>
<td>0.63 (+91%)</td>
<td>0.54</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>NCEP SAS2 (10)</td>
<td>2003-2017 T126</td>
<td>0.70 (+37%)</td>
<td>0.66</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td>NCEP SAS2sc (10)</td>
<td>2003-2017 T126</td>
<td>0.40 (-5%)</td>
<td>0.63</td>
<td>0.68</td>
<td></td>
</tr>
<tr>
<td>CFS-ALBEDO (10)</td>
<td>1982-2014 T126</td>
<td>0.11 (-56%)</td>
<td>0.64</td>
<td>0.31</td>
<td></td>
</tr>
<tr>
<td>INCOIS-T382 (14)</td>
<td>2003-2017 T382</td>
<td>0.47 (+42%)</td>
<td>0.49</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td>NCEP-T382 (10)</td>
<td>1981-2017 T382</td>
<td>0.51 (+76%)</td>
<td>0.53</td>
<td>0.54</td>
<td></td>
</tr>
<tr>
<td>NCEP Multi Cloud MP (10)</td>
<td>1982-2014 T126</td>
<td>0.45 (+7%)</td>
<td>0.58</td>
<td>0.43</td>
<td></td>
</tr>
<tr>
<td>NCEP WSM6 (10)</td>
<td>1981-2012 T126</td>
<td>0.61 (+64%)</td>
<td>NA</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>CFS-ICE-Micro (16)</td>
<td>1981-2010 T126</td>
<td>0.70 (+59%)</td>
<td>0.58</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>CFS-Hydrology (10)</td>
<td>1981-2017 T126</td>
<td>0.48 (+65%)</td>
<td>0.54</td>
<td>0.61</td>
<td></td>
</tr>
</tbody>
</table>

**AISMR: All India Summer Monsoon Rainfall (Averaged over Indian Land Mass)**

- **9% Improvement** is achieved due to indigenous ICs
- **60-90% Improvement** is achieved due to revised SAS of Han & Pan (2011)
- **42-75% Improvement** is achieved due to increased resolution
- **60-65% Improvement** is achieved due to In-house Developments (LSM, Microphysics, WSM6 and Hydrology)

Core Time = 65 Years (567522 Hours)
T126 (6 Nodes: 9 months in 7 hours)
T382 (10 Nodes: 9 months in 40 hours)

Runs carried out on Aditya indicated by *
All the runs are using INCOIS-NCMRWF initial conditions, unless indicated by #.
Initialized with Feb. IC and skills are shown for JJAS
Forecast Products using Seasonal forecasts (IMD)

Maximum Temperature

PRESS RELEASE
New Delhi, 01 April, 2019

Government of India
Ministry of Earth Sciences (MoES)

INDIA METEOROLOGICAL DEPARTMENT
Seasonal Outlook for the Temperatures during April to June, 2019

Highlights

- The April to June (AMJ) season average maximum temperatures are likely to be warmer than normal by 0.5°C over most of the meteorological subdivisions from central India and some subdivisions from northwest India. Near normal maximum temperatures are likely in the remaining subdivisions.
- The seasonal average minimum temperatures over West Rajasthan are likely to be above normal by more than 1°C.
- Above normal heat wave conditions are likely in the core heat wave (MHW) zone during the season (April to June).

1. Background

Since 2016, India Meteorological Department (IMD), has been issuing seasonal forecast outlooks for sub-divisional seasonal temperatures over the country during both hot and cold weather seasons. These seasonal outlooks are based on model simulations from the Monsoon Mission Coupled Forecasting System (MMCF5) Model developed under the Monsoon Mission project. This year IMD had issued temperature outlook for the hot weather season of March to May on 1st March, 2019. IMD has now prepared an updated seasonal outlook for the average temperatures during the hot weather season of April to June, 2019.

The MMCF5 has a spatial resolution of about 38 km and improved modules of physics. The model climatology was prepared based on retrospective forecasts for 27 years (1982-2008). The seasonal temperature forecast outlook for the period December 2019 to February 2020 presented here is prepared using MMCF5 simulations based on the 2019 November initial condition. The forecast was prepared using 36 ensemble member forecasts. The model forecasts and forecasts were bias corrected using the probability distribution function (pdf) method. The model hindcasts show moderate skill over many subdivisions over northwest and central India during the period 1983-2008.

Minimum Temperature

PRESS RELEASE
New Delhi, 29 November, 2019

Government of India
Ministry of Earth Sciences (MoES)

INDIA METEOROLOGICAL DEPARTMENT
Seasonal Temperature Outlook during December 2019 to February, 2020

Highlights

- The upcoming winter season (December to February) is likely to experience warmer than average minimum temperatures over most parts of the country except over northermost parts of India, thus indicating a warmer winter season over the country.

1. Background

Since 2016, India Meteorological Department (IMD), Ministry of Earth Sciences (MoES) has been issuing seasonal forecast outlooks for sub-divisional scale temperatures over the country for both hot and cold weather seasons based on predictions from the Monsoon Mission Coupled Forecasting System (MMCF5) Model developed under the Monsoon Mission project. IMD has now prepared seasonal outlook for the sub-divisional average temperatures during the upcoming winter season of December 2019 to February 2020 and the same is presented here.

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ENSO-IOD bulletin

Earth System Science Organization (ESSO)
Ministry of Earth Sciences (MoES)
India Meteorological Department

El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) Bulletin

December 2019

Highlights

Currently, warm ENSO-neutral conditions are prevailing over equatorial Pacific Ocean and the latest MMCF5 forecast indicates cooling of SSTs in coming season and ENSO-neutral conditions are likely to continue during DIP season and the strength of positive IOD conditions is likely to weaken and turn into neutral IOD conditions during DIP season.

1. Current Sea Surface Temperature (SST) Conditions over Pacific & Indian Oceans

During November, warmer than normal SST anomalies were observed over west central parts (over and around the equatorial Pacific zone) of the equatorial Pacific Ocean and cooler than normal SST anomalies were observed over east equatorial Pacific Ocean (Fig 1a). Positive SST anomalies were observed over most parts of the north Pacific Ocean and central parts of south Pacific Ocean. Negative SST anomalies were observed in some isolated region of north central Pacific and over larger area of eastern part of southern Pacific Ocean. As compared to the same month, warming of SSTs was observed over eastern equatorial Pacific Ocean as well as parts of north Pacific Ocean. However, cooling of SSTs is seen over most of the western Pacific Ocean and south Pacific Ocean (Fig 1b).

Warmer than normal SST anomalies were observed over most parts of North and West Indian Ocean. Positive IOD pattern with positive SST anomalies were observed over west Indian Ocean and negative IOD pattern over eastern and southeast Indian Ocean on north coast of Australia and near monsoon region (Fig 1c). As compared to the same month, cooling of SSTs was observed over most parts of the Arabian Sea, Bay of Bengal and central parts of south Indian Ocean (Fig 1d).

1.1 El Niño Southern Oscillation (ENSO) conditions over the Pacific Ocean

The monthly time series of Niño4.4 SST anomalies for the last 12 months from December 2019 to November 2020 (Fig 2a) suggests that El Niño conditions from December 2019 have continued till June 2020. During July, El Niño conditions turned into El Niño Neutral conditions and it continued thereafter. Since September there has been notable increase in SST anomalies over the equatorial Pacific Ocean. Currently overall equatorial conditions remain El Niño. Further, positive SST anomalies over the Pacific Ocean and negative SST anomalies over western equatorial Pacific Ocean above the 20°C isotherm (Fig 2b) with increased magnitude spread over east of 160°W (at around 10°N) and negative SST anomalies were observed over parts of central equatorial Pacific Ocean near 140°W.

1.2 Indian Ocean Dipole (IOD) conditions over the Indian Ocean

The composite index for the last 12 months suggests that (Fig 3a) IOD conditions since December 2019 continued till April 2020. During March or May 2019, neutral IOD conditions again turned into positive IOD conditions and continued thereafter till the November 2019. However, in pact the value of positive IOD is slightly reduced.

Positive subsurface temperature anomalies (Fig 2c) were seen over the parts of west
Application of seasonal prediction output for reservoir management

Mula reservoir (Calibration parameters: 66)

<table>
<thead>
<tr>
<th>WRF_OML</th>
<th>CFSv2 (T382)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSE</td>
<td>0.682</td>
</tr>
<tr>
<td>PBIAS</td>
<td>-0.028</td>
</tr>
<tr>
<td>R²</td>
<td>0.682</td>
</tr>
</tbody>
</table>

Spin-up period: 1985-1987
Calibration period: 1988-2004
Validation period: 2005-2013

- Lower values of Percentage Bias and Higher values of NSE and R² indicated that the SWAT model simulated inflow within acceptable level of accuracy for monthly simulation
- Positive values of PBIAS for CFSv2T382 shows under-prediction of reservoir inflow, which is improved in WRF OML due to the reduced dry bias
CFSv2 Model hindcast skill of SPI3 and SPI6 index for June, July, August and September month of summer monsoon season (Bias corrected CFSv2 rainfall forecast data)

The Monsoon Mission CFSv2 is able to simulate the short term drought indices and it can be useful for the meteorological drought planning purpose.
Conclusions

- A high-resolution global coupled model is now issuing operational seasonal forecasts of Indian summer monsoon rainfall with high skills (>0.6) over the Indian land region
- A new operational extended-range coupled prediction system yields prediction skills comparable with the leading operational centers in the world
- A very high-resolution probabilistic short-range prediction system based on GEFS (~12.5 km, Table 2) and a deterministic GFS (semi-Lagrangian at 12.5 km) are providing skillful forecasts.
- Numerous model developmental activities have been carried out, not only to reduce the systematic model biases but also to improve the prediction skill of the monsoon weather and climate
- These operational forecasts are being employed for variety of applications (health, reservoir inflow prediction, hydrological forecasts, agricultural practices, renewable energy sector.... *Endless Possibilities*)
THANK YOU
Any Questions?
Extra Slides
Improving Cloud Microphysics constrained with Indian data

Ganai et al. 2019

CFSv2 with RSAS-WSM is able to better simulate
- The large-scale organized northwest-southeast tilted structure of rain band
- Reasonable large-scale or stratiform rainfall associated with the northward propagating strong BSISO events
- The pressure-latitude profiles of cloud liquid water (CLW) and cloud ice (CLI) show more realistic steady northward propagation

Observation based hypothesis
Jiang et al. 2011
Abhik et al. 2013
Rajeevan et al. 2013

Implementation in GFS and reproducing the observed profiles

Implementation of modified WSM6 in CFSv2. Improvement of mean state and ISV
Abhik et al. 2017

Modification with CAIPEEX

Higher CC and intranual variance

RSAS-ZC:
Zhao and Carr (ZC) cloud microphysics scheme with simplified Arakawa-Schubert (RSAS) convection scheme.

RSAS-WSM:
Six-class WRF single moment (WSM6) cloud micro-physics scheme with Revised SAS (RSAS) convection scheme.

Lag composite of CLW (shaded) and CLI (red contour, solid (+ve) and dashed (-ve)) during strong event averaged over 70E-90E, corresponding rainfall anomalies plotted in the bottom in each plot.
Figure 6 Taylor diagram showing the skill of ISMR prediction using reforecasts from control run (CTL) and the developmental activities under MM, namely the revised microphysics (WSM6) along with revised convection (SAS2) and a modified radiation scheme, new cloud physics parameterization (MC), the new snow model (SN) and MC together (SN-MC), the revised convection parameterization scheme (SAS2) and SAS2 with revised shallow convection scheme (SAS2sc). The improvement in skill over the CTL run is notable in the experiments. The period of the hindcast is 1981-2010. The axes denote the ratio of standard deviation of the simulated ISMR to the observed.
The Impact of Modified Fractional Cloud Condensate to Precipitation Conversion Parameter in Revised Simplified Arakawa-Schubert Convection Parameterization Scheme on the Simulation of Indian Summer Monsoon and Its Forecast Application on an Extreme Rainfall Event Over Mumbai

Malay Ganu1,2, R. P. M. Krishna1, Snehla Turkey3, P. Mukhopadhyay1, M. Mahakuk1,2, and Ji-Young Han1

1Indian Institute of Tropical Meteorology, Pune, India. Department of Atmospheric and Space Sciences, Savitribai Phule Pune University, Pune, India. 3Korea Institute of Atmospheric Prediction Systems, Seoul, South Korea

Citation:

(a)

(b)

(c)

(d)

(e)
Time Line of development of IITM ERPS using CFSv2

2011: Ensemble Prediction System developed, [Abhilash et al., 2014, IJOC]

2012: Bias Correction of CFS forecasted SST implemented [Abhilash et al., 2014, ASL; Sahai et al., 2013, Curr. Sci.]

2013: High Resolution CFST382 implemented [Sahai et al., 2014, CIDy; Borah et al., 2014, IJOC]

2014: CFS based Grand EPS Implemented [Abhilash et al., 2015, JAMC; Sahai et al., 2015, Curr. Sci.]

2015: Forecast for winter and other seasons started

2016: Forecast for Heat Waves started, ERP System transferred to IMD