Monsoon Mission

(With a Responsibility to improve monsoon weather/climate Forecasts):

Achievements and Road Ahead

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Associate Mission Director
Monsoon Mission

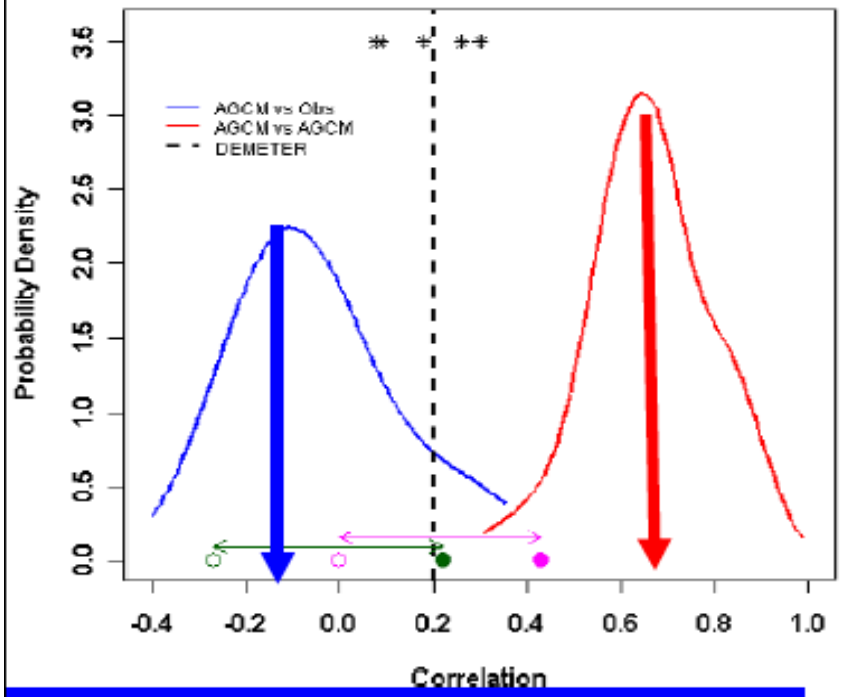
and all Members of Monsoon Mission
ESSO-IITM, ESSO-NCMRWF, ESSO-IMD, ESSO-INCOIS

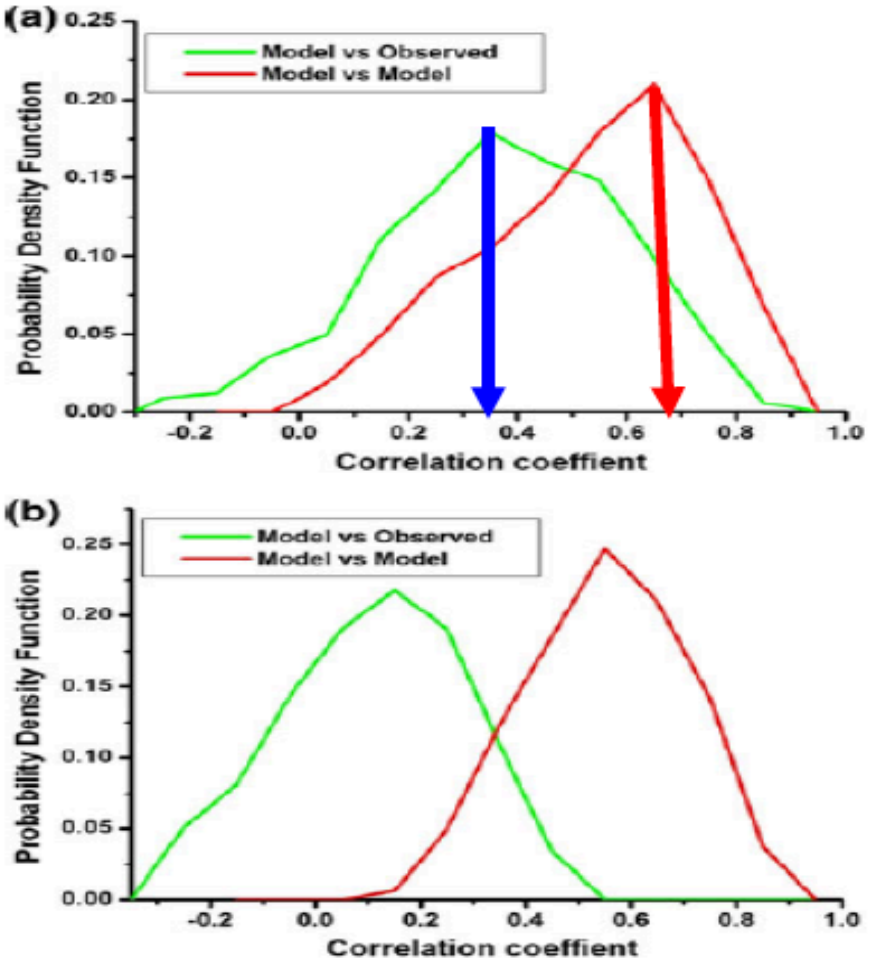
Outline

- Expectations
- Objectives of Monsoon Mission
- Milestones in Monsoon Mission
- Background
- Model selection and identified biases
- Developmental works
- Monsoon Mission model skill
- Future Direction

Potential Predictability VS Actual Prediction Skill of ISMR

Krishna Kumar et al , 2005, GRL





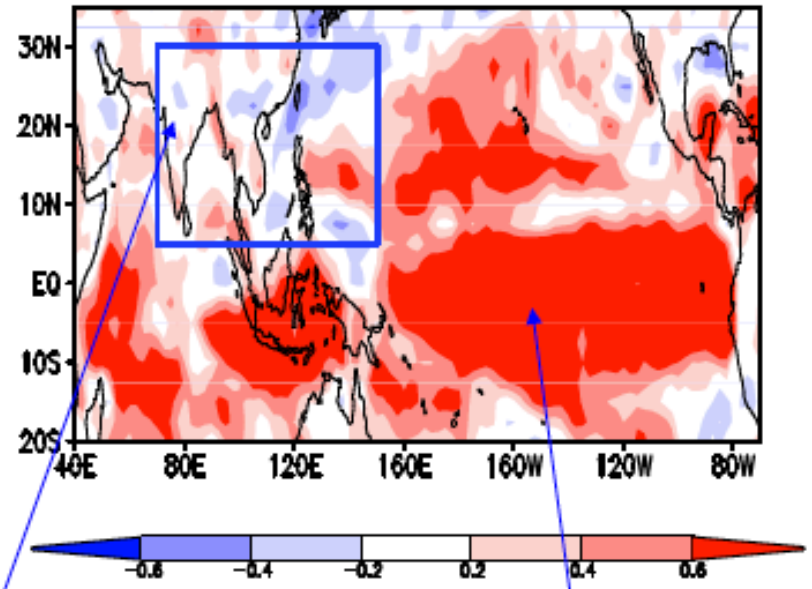
Rajeevan et al. 2011, Climate Dynamics

Fig. 13 PDFs of the correlation skill of ISMR based on a theoretical "perfect model" analysis (*red curve*) and based on the actual skill compared to the observed ISMR (*black curve*). **a** for the period 1960–1979 and **b** 1980–2005

Correlation Coefficients between the observation and prediction of precipitation using Multi models

Earlier version models

1979-1999

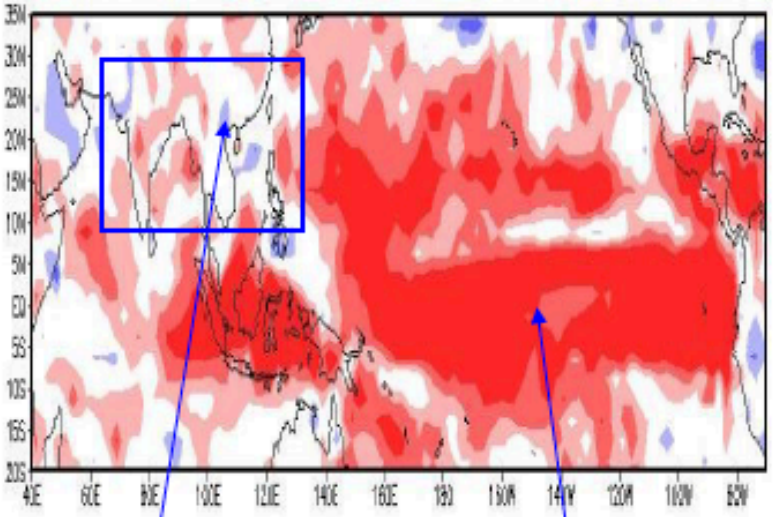


Poor skill

High skill

Latest models (ENSEMBLES)

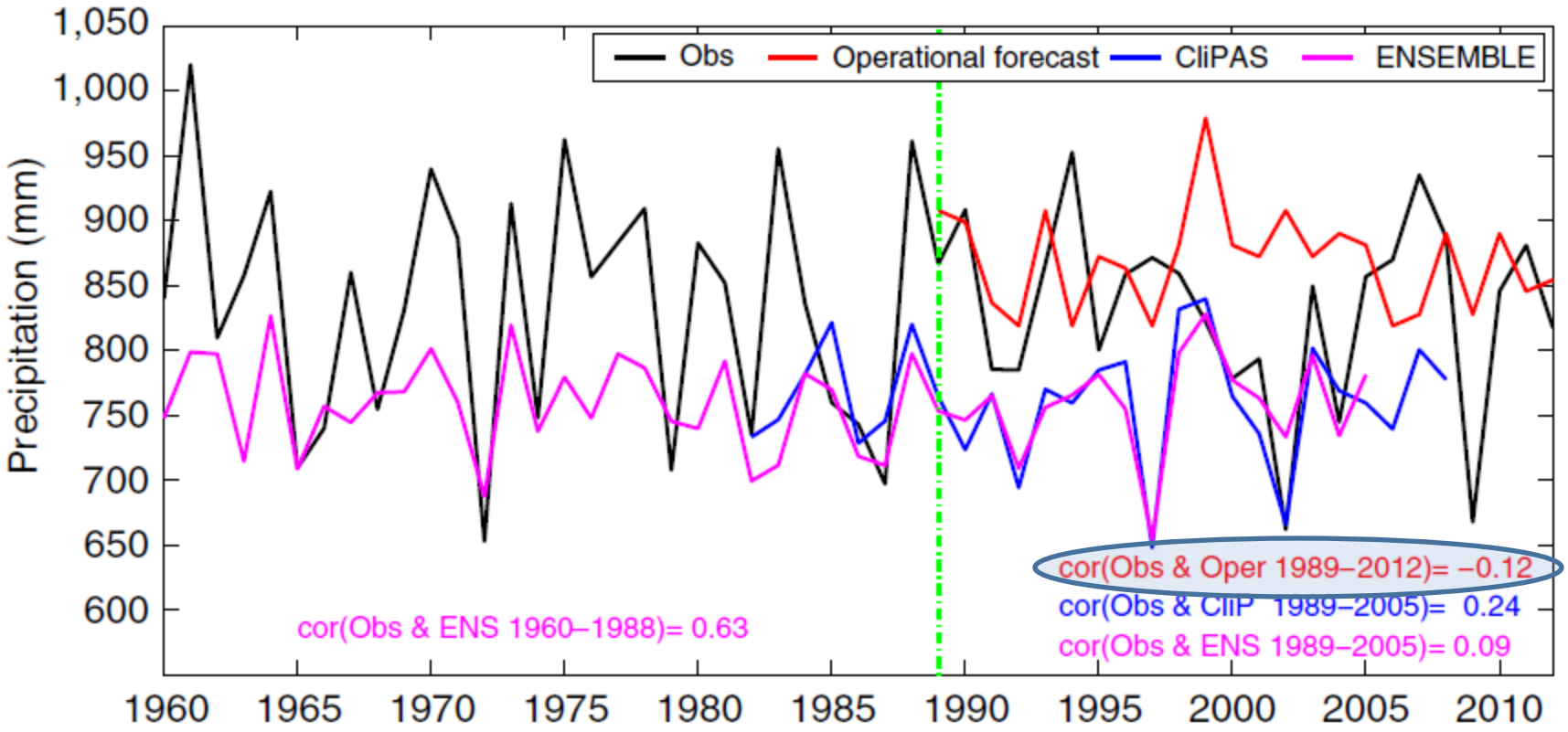
1979-1999



Improved skill

High skill

IMD Operational Model Prediction Skill of ISMR



Wang et al., (2015; Nature Communications)

Status of Indian Prediction System Prior to Monsoon Mission

- No coupled dynamical modelling System to make seasonal Forecasts
- No extended Range Dynamical Prediction System for predicting Active/break Cycles of Monsoon
- No expertize in handling coupled models in forecast mode
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- India's role in motivating monsoon research elsewhere in the globe was not significant
- No access to significant HPC resources to carryout the model development activities

The Statement

- It is important to borne in mind that whereas in research projects, the criteria for success is generally the demonstration of the potential for improvement in skill (with suggested changes in the model or more data on the clouds, ocean etc.), **the deliverable of a mission will have to be an unequivocal demonstration of improvement in skill**.

The Mission

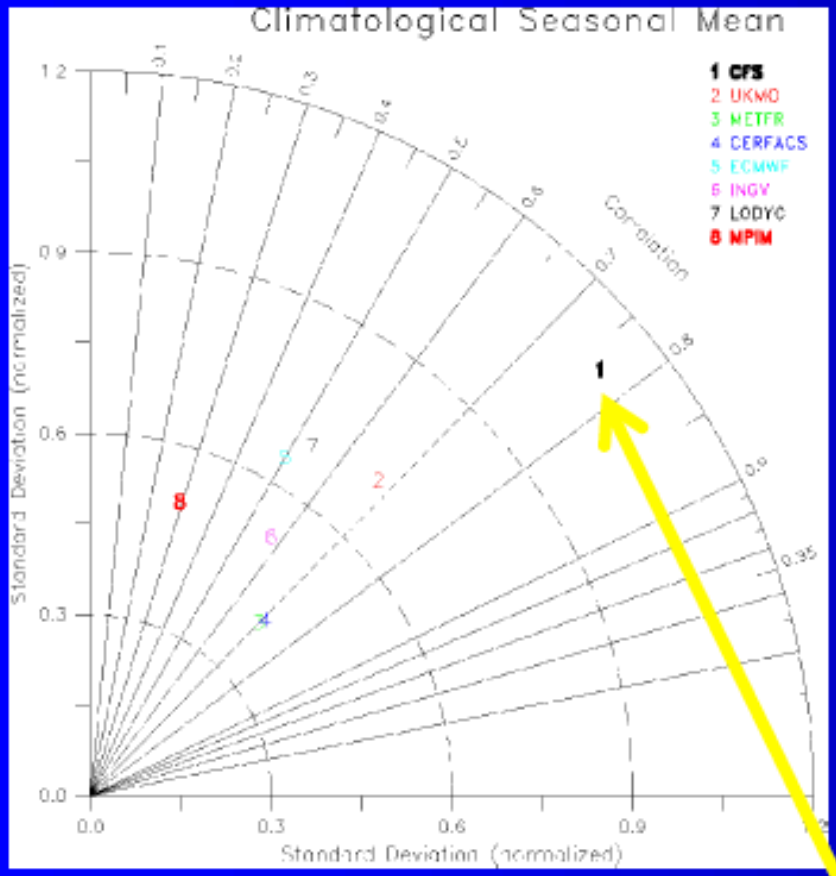
- The Mission's goal is to build a working partnership between the Academic R & D Organizations and the Operational Agency to leapfrog in improving monsoon forecast skill.
- Requirement :All research work must be on the Operational Modeling Framework!

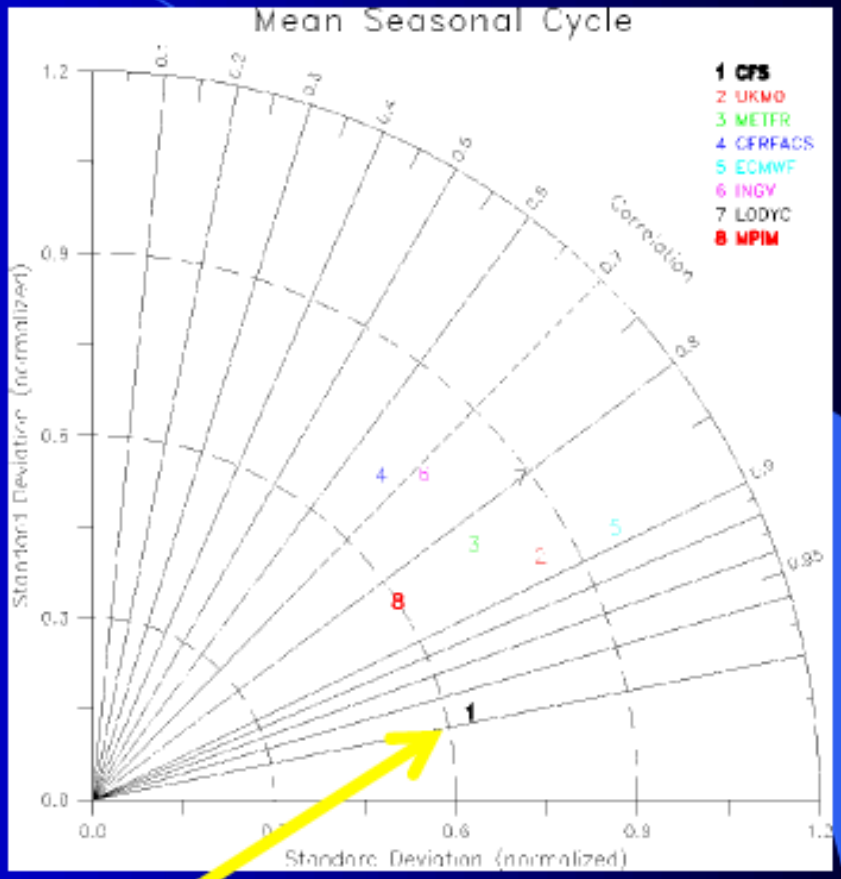
This is the challenge!

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 frame work for improving prediction skill of
  - Seasonal and Extended range predictions
  - Short and Medium range (up to two weeks) prediction

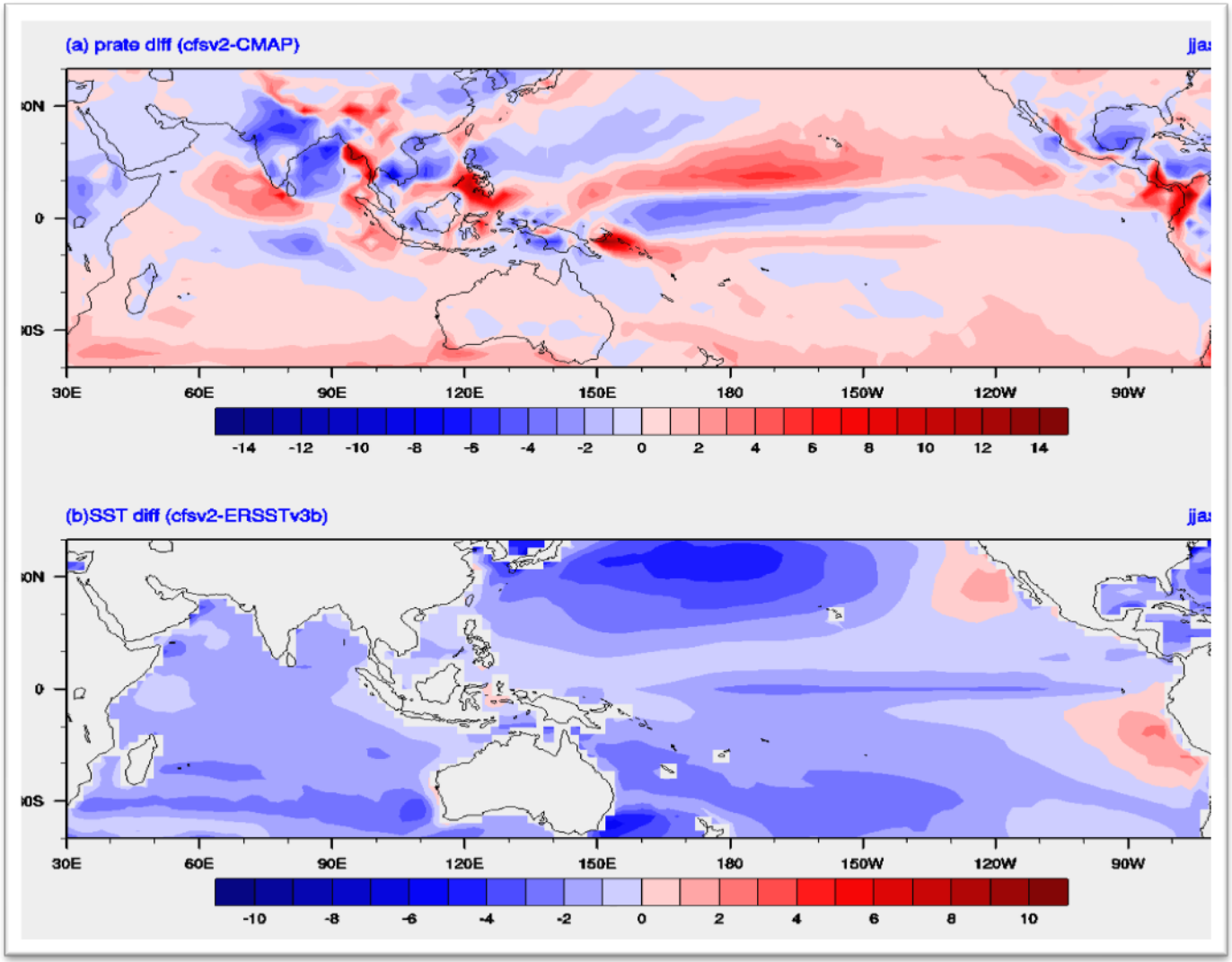
Skill of Various Models in Simulating the Climatological Seasonal Mean Monsoon





CFS Simulates Seasonal Cycle Better than Other Models

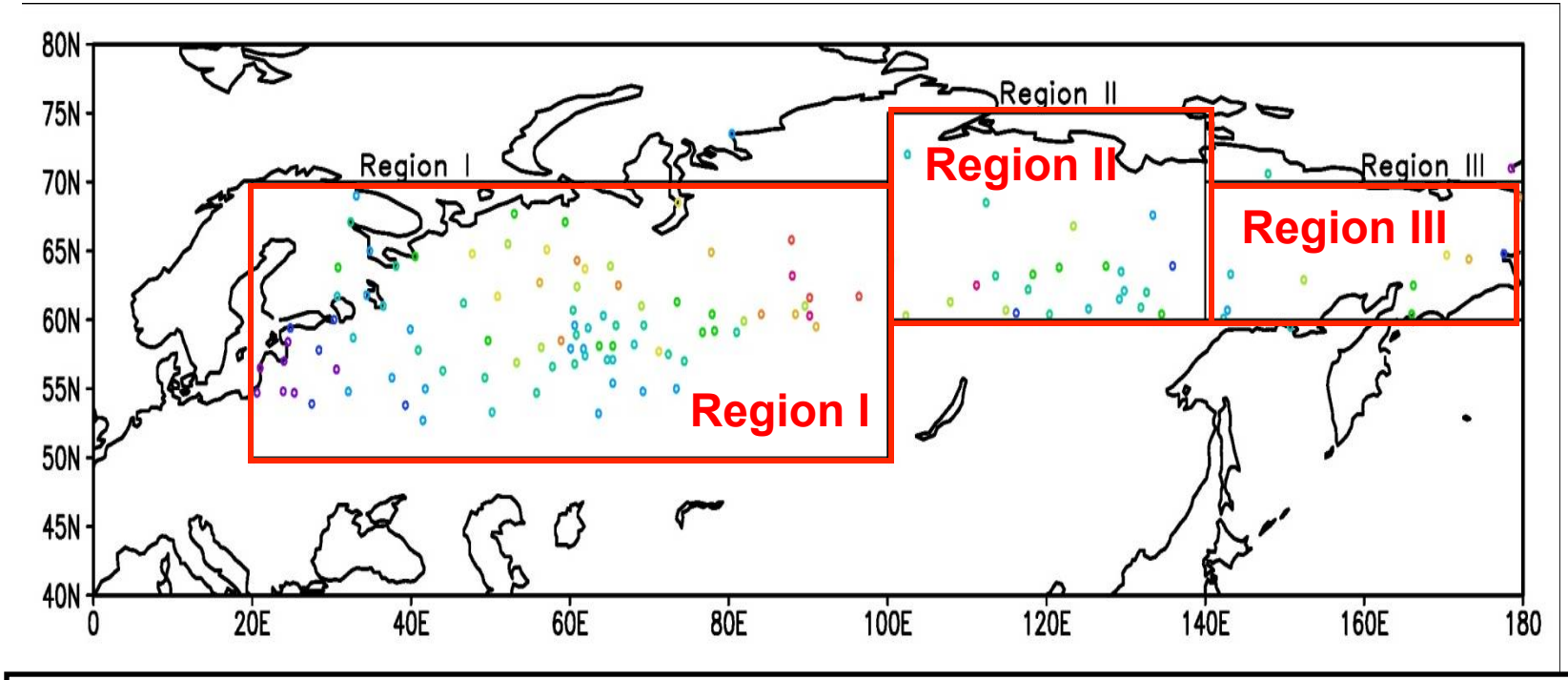
Last 20 years JJAS climatology difference between CFSv2 and Observation



Precipitation Bias

SST Bias

Observed Snow Data

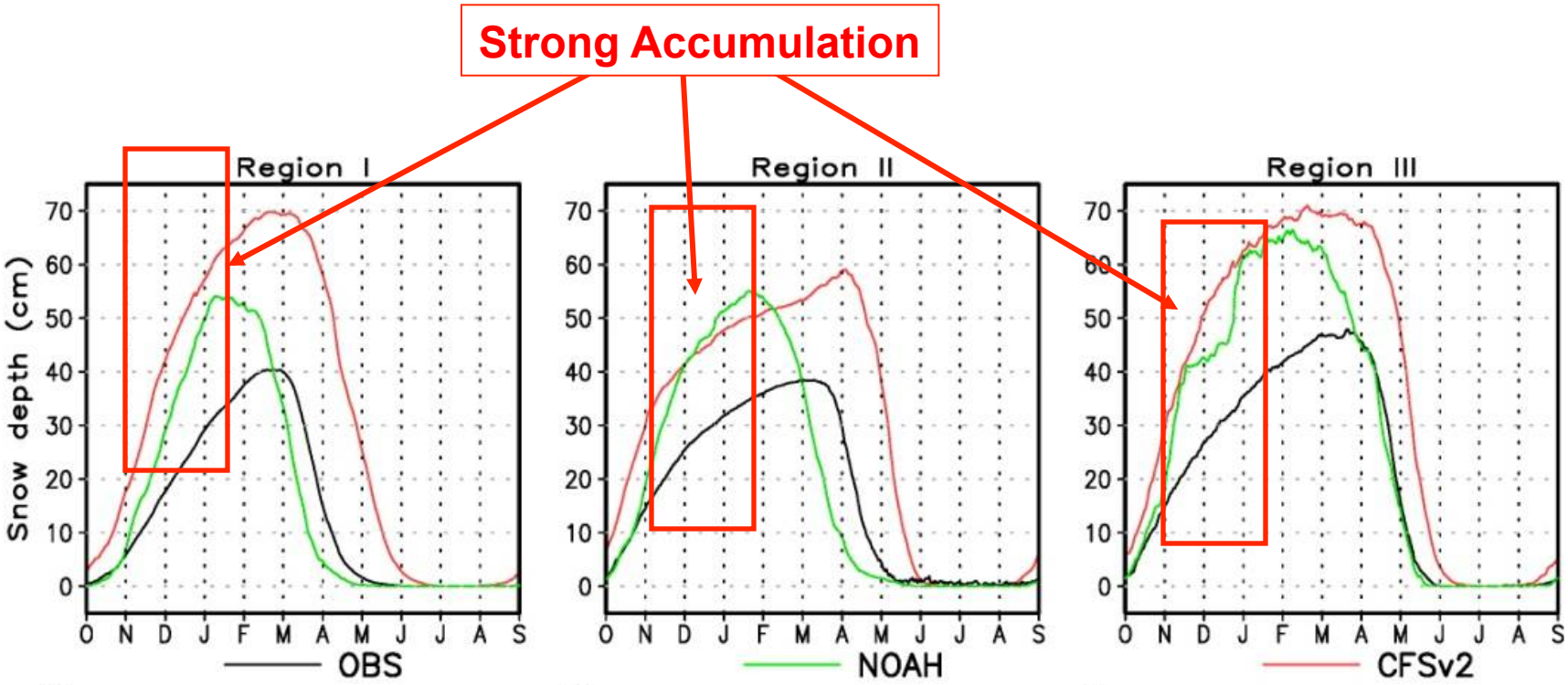


- **Snow from Historical Soviet Daily Snow Depth data (observed stations).**

- **The Eurasia is divided to 3 regions and they are**
  - **-> Region I (50-70N,20-100E, high snow depth, 129 stations)**
  - **-> Region II (60-75N,100-140E, low snow depth, 24 stations)**
  - **-> Region III (60-70N,140-180E , high snow depth, 10 stations)**

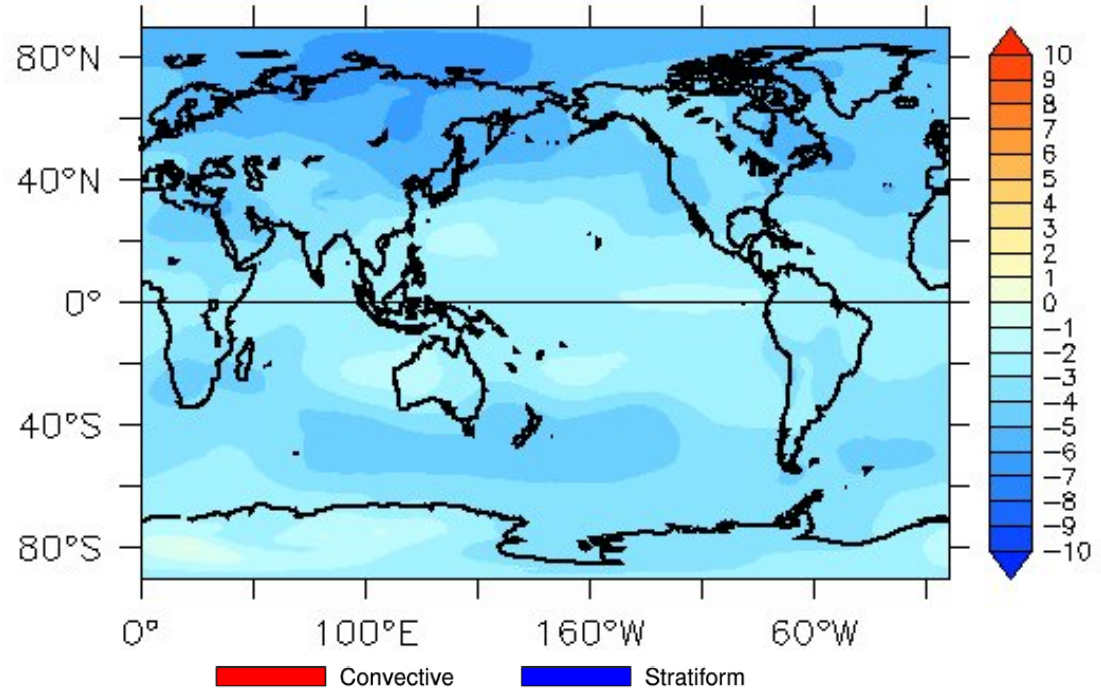
Source: Sujith and Saha

Observed & Simulated Snow Depth

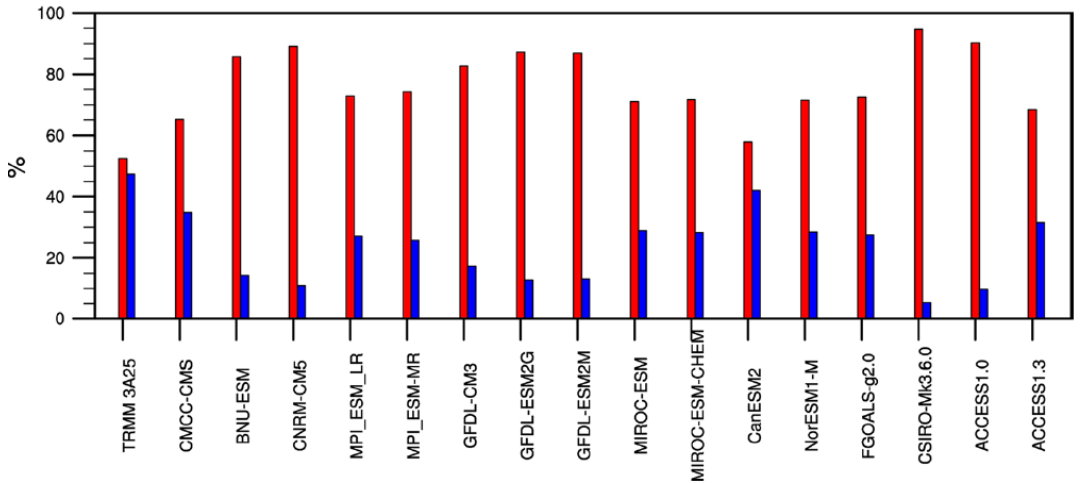


- CFS as well as stand-alone Noah LSM has tendency to accumulate more snow
- As the stand-alone LSM is forced with observed 2m air temperature, melting is controlled by forcing and hence it is close to observation

Last 20 years JJAS climatology difference between CFSv2 and Observation



Troposphere (600hpa-200hpa) Temperature Bias



Convective & Stratiform

Developmental Activities

- High Resolution Seasonal/Extended Range prediction
- New LSM development
- Modified Zhao Carr cloud microphysics/ WSM6
- New Ocean model (MoM5) incorporation in CFS
- Revised SAS
- SP-CFS
- Multi Cloud multi model stochastic parametrization in CFS
- LETKF coupled data assimilation

Developmental Activities

- Convective Parameterization (New SAS, Han & Pan, 2011; Ganai et al., 2014)
- Cloud Microphysics (Hazra et al., 2015; Abhik et al., 2016)
- Super Parametrization (Goswami et al., 2015)
- Improved snow physics in Land Surface Model Saha et al., (2017)
- High Resolution Model (Ramu et al., 2015)
- Stochastic Parametrization (Goswami et al., 2017)
- New Ocean model (in progress)
- EnkF coupled Data assimilation system (Kalnay et al., 2016)

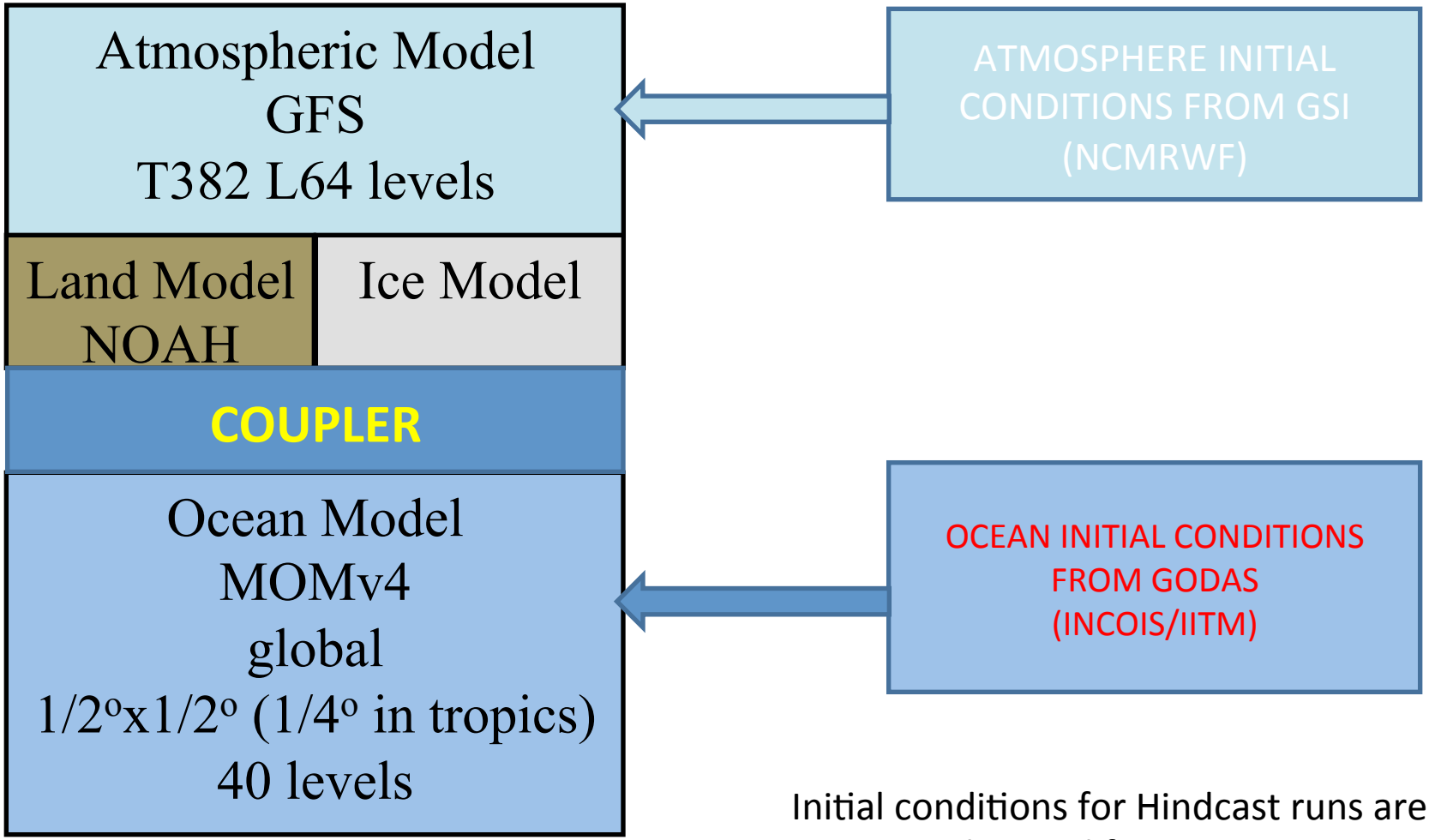
Improvements in monsoon characteristics due to developmental activities (Parametrization schemes, LSM, Ocean and resolution)

- Decreased dry bias over Indian Land mass
- Decreased cold tropospheric bias
- Decreased SST cold bias in tropics
- Improved representation of snow cover thickness and time of melting
- Improved ENSO characteristics and IOD characteristics.
- Improved teleconnections
- Better representation of extratropical and tropical interactions

Working Partnership

- Total No. of Projects Funded: 37 main projects + 3 sub projects
- Total # of Publication (so far): ~180
- Total # of Ph.Ds (so far): ~10
- Total # of young scientists trained abroad: 10
- Total No. of Project Staff Worked in these projects
  - » PIs/CoPIs = > 50
  - » Project Fellows/PDFs = > 50
  - » Indian Staff outside of India = ~10

IITM CFS Model: Seasonal Prediction



Initial conditions for Hindcast runs are obtained from CFSR

(Original model is adopted from NCEP)

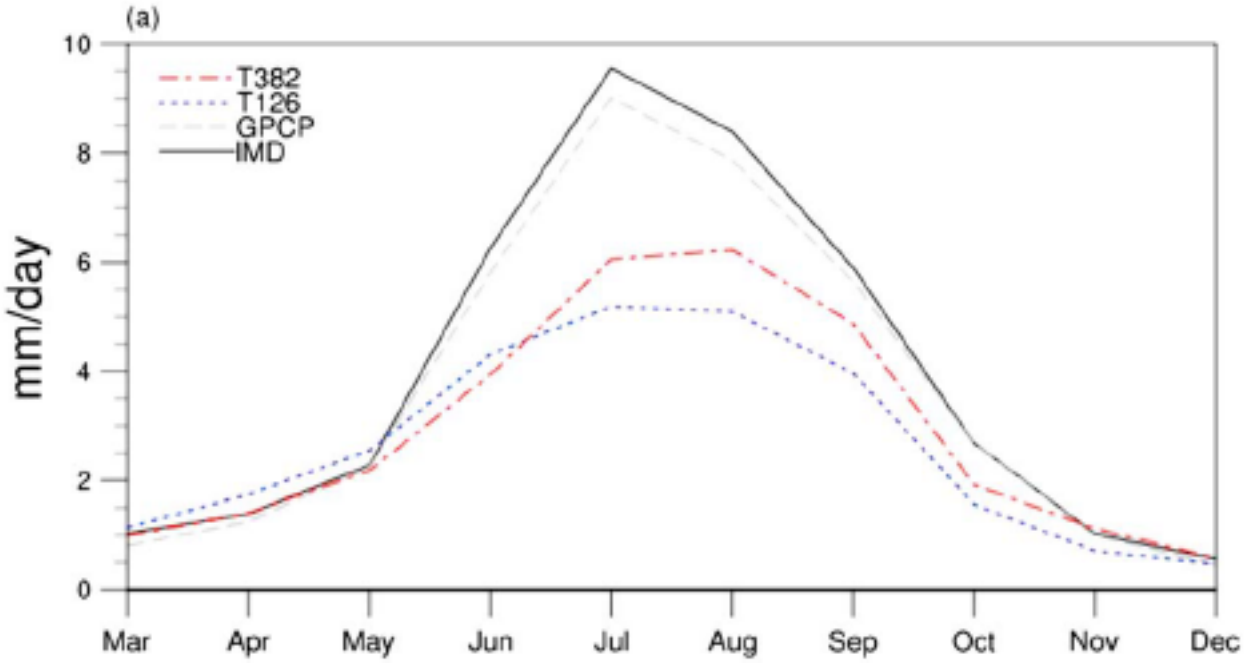
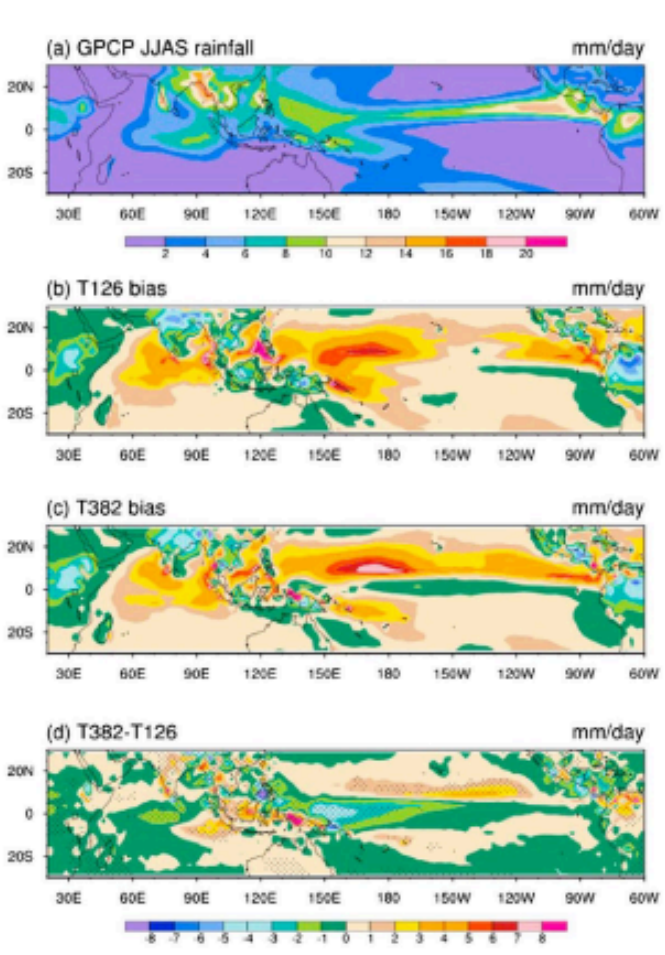
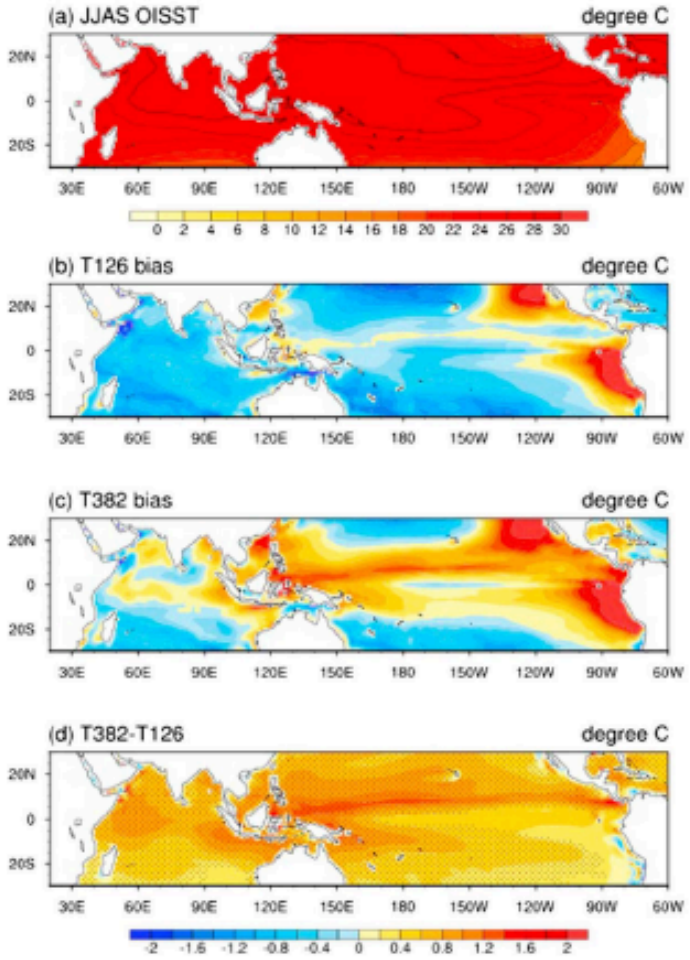


Figure 1. Annual cycle of Indian landmass rainfall simulated in T382 and T126 hindcast runs along with observations.

SST/Rainfall Bias in T126 and T382

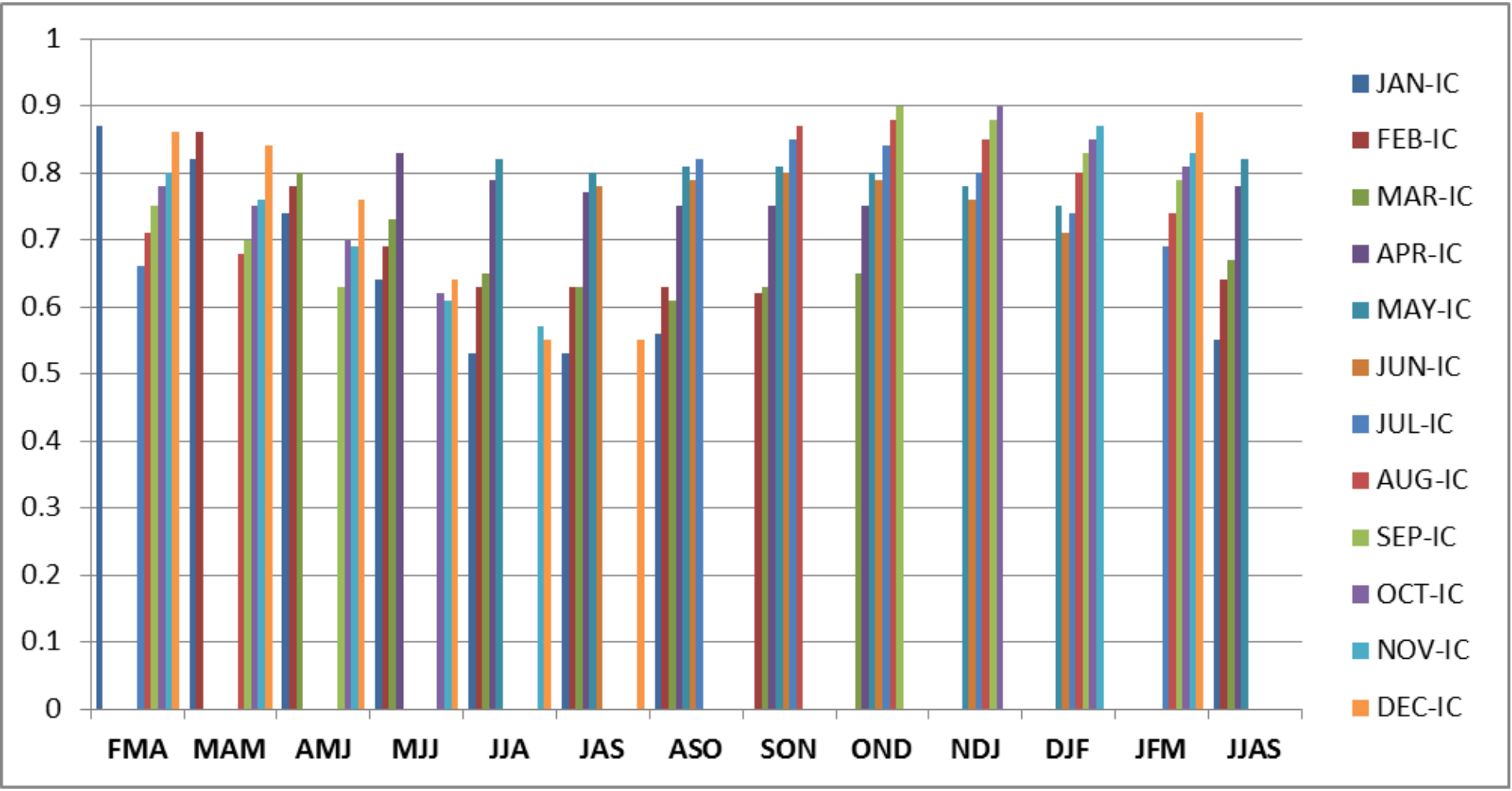




Ramu et al., (2016, JGR)

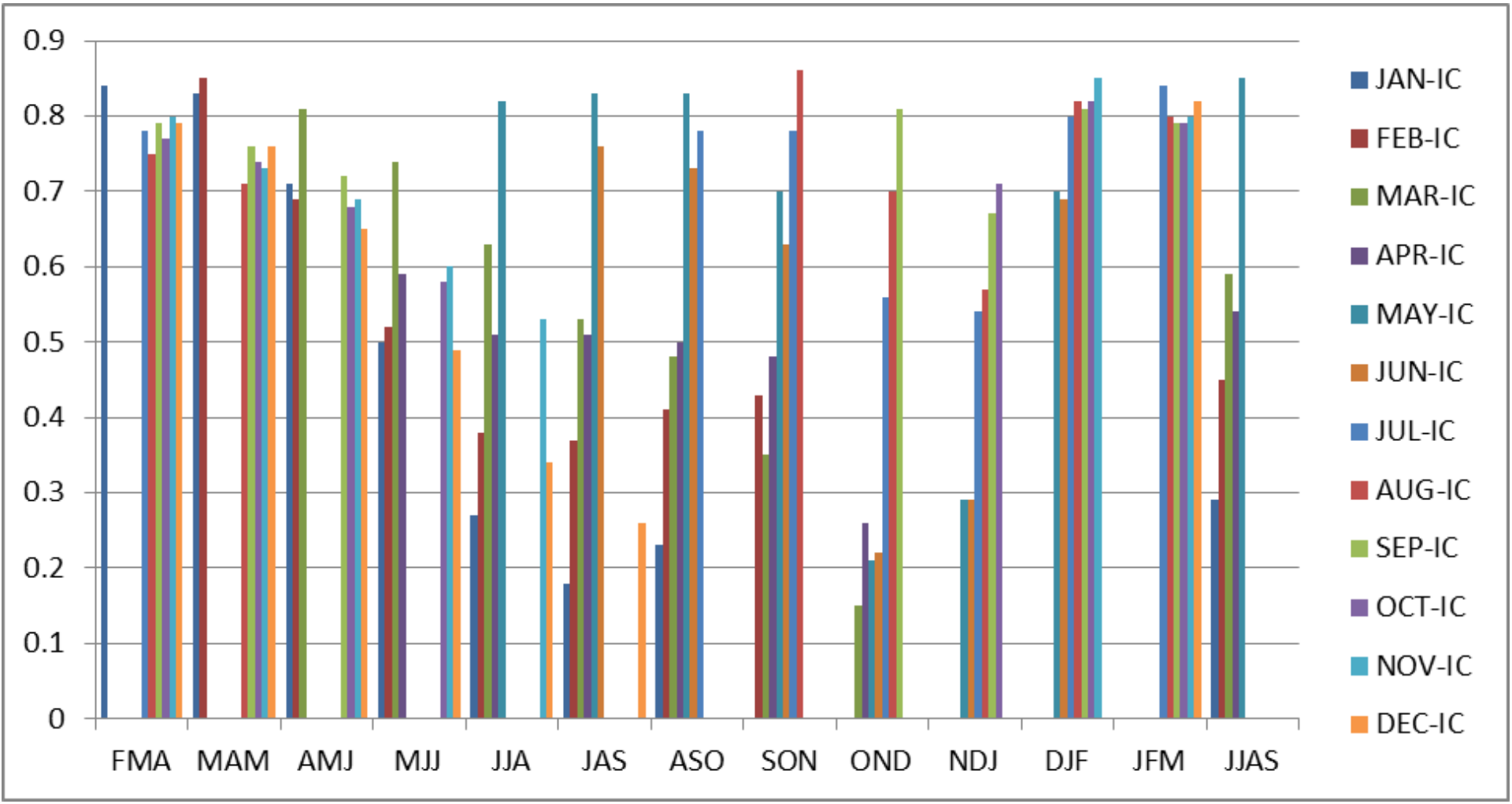
CFSv2 Prediction Skill

Anomaly Correlation Coefficient (ACC): NINO 3.4

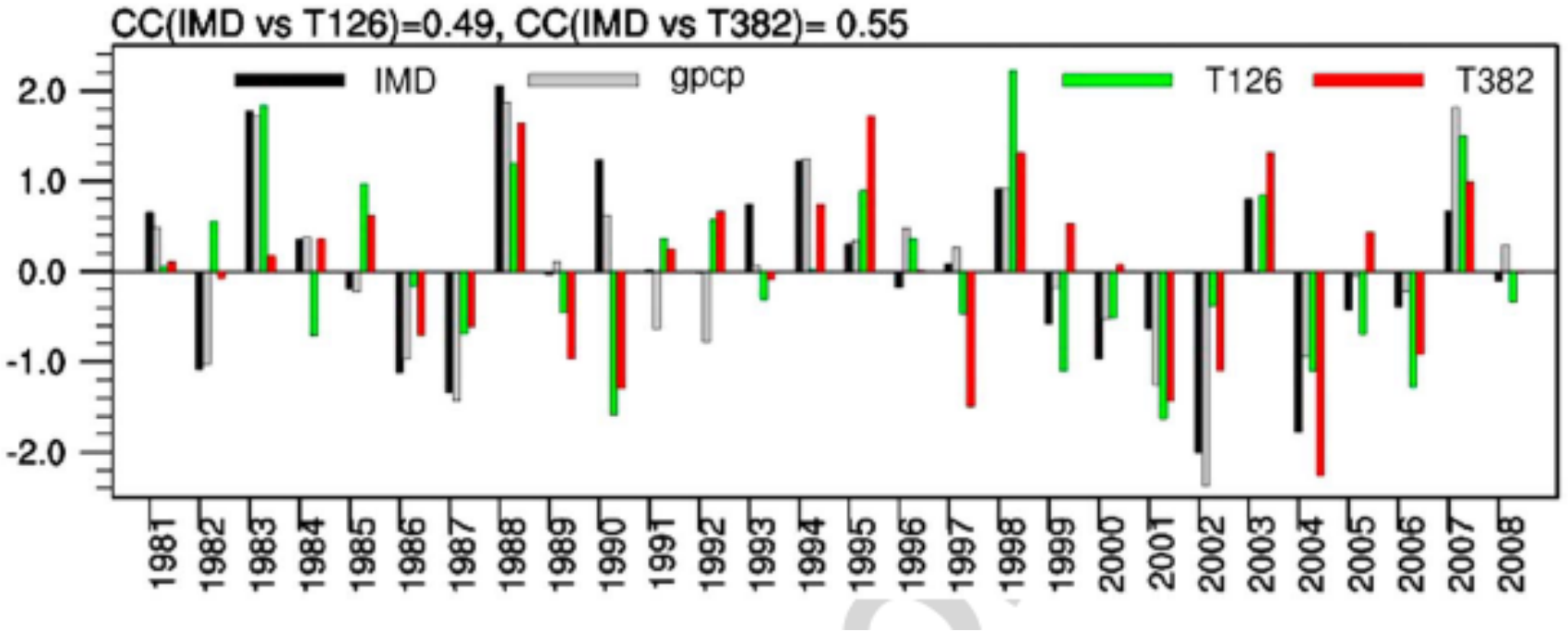


CFSv2 Prediction Skill

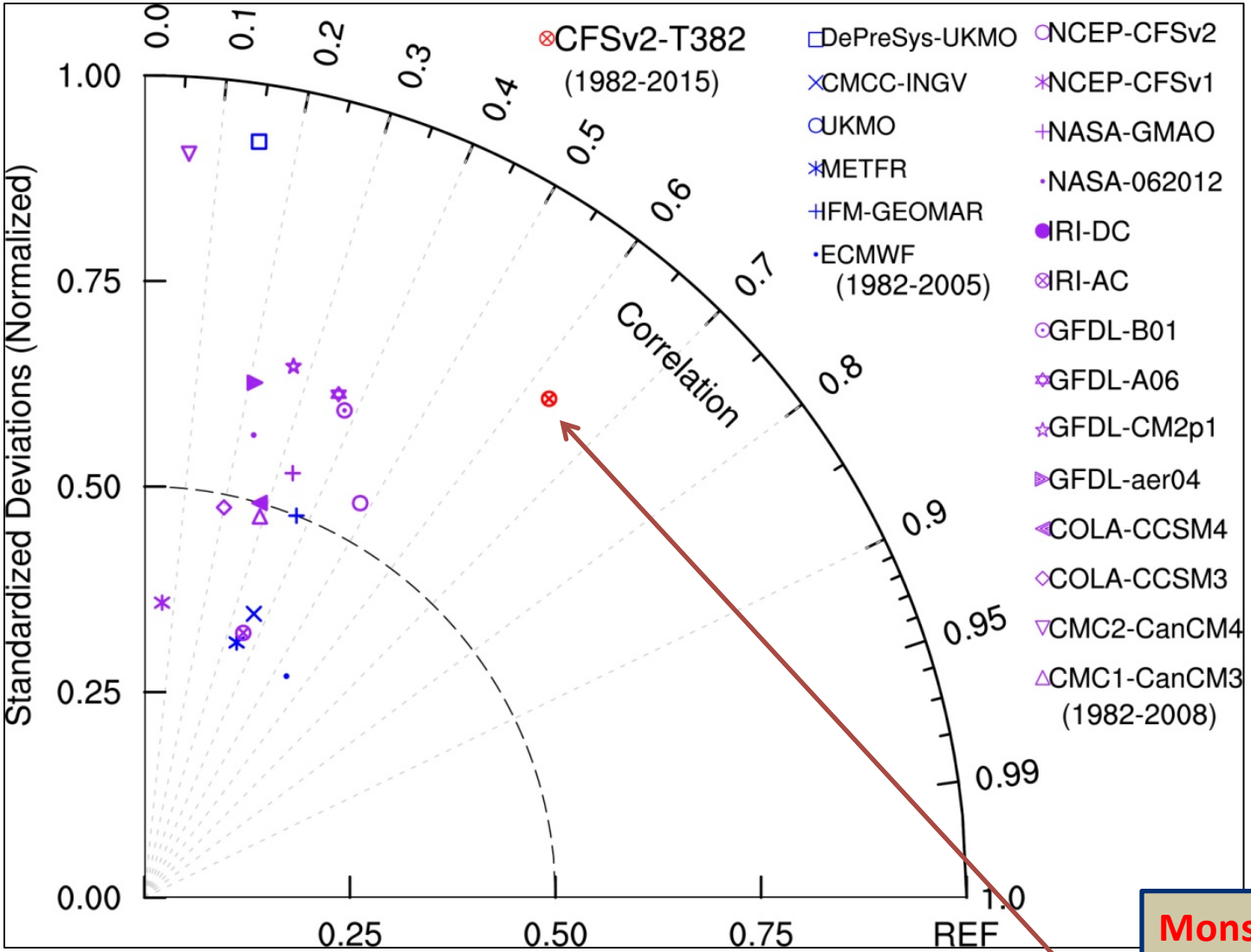
Anomaly Correlation Coefficient (ACC) : IOD East Box



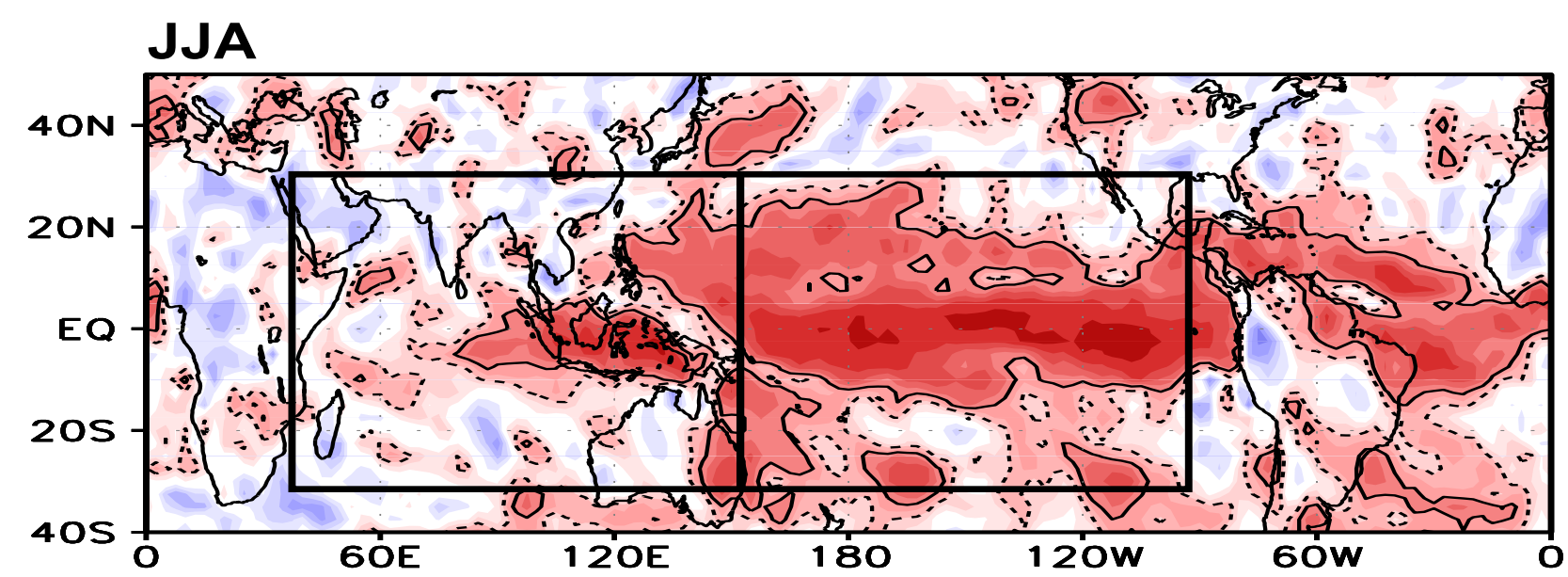
Prediction Skill in IITM CFS



Ramu et al., (2016)

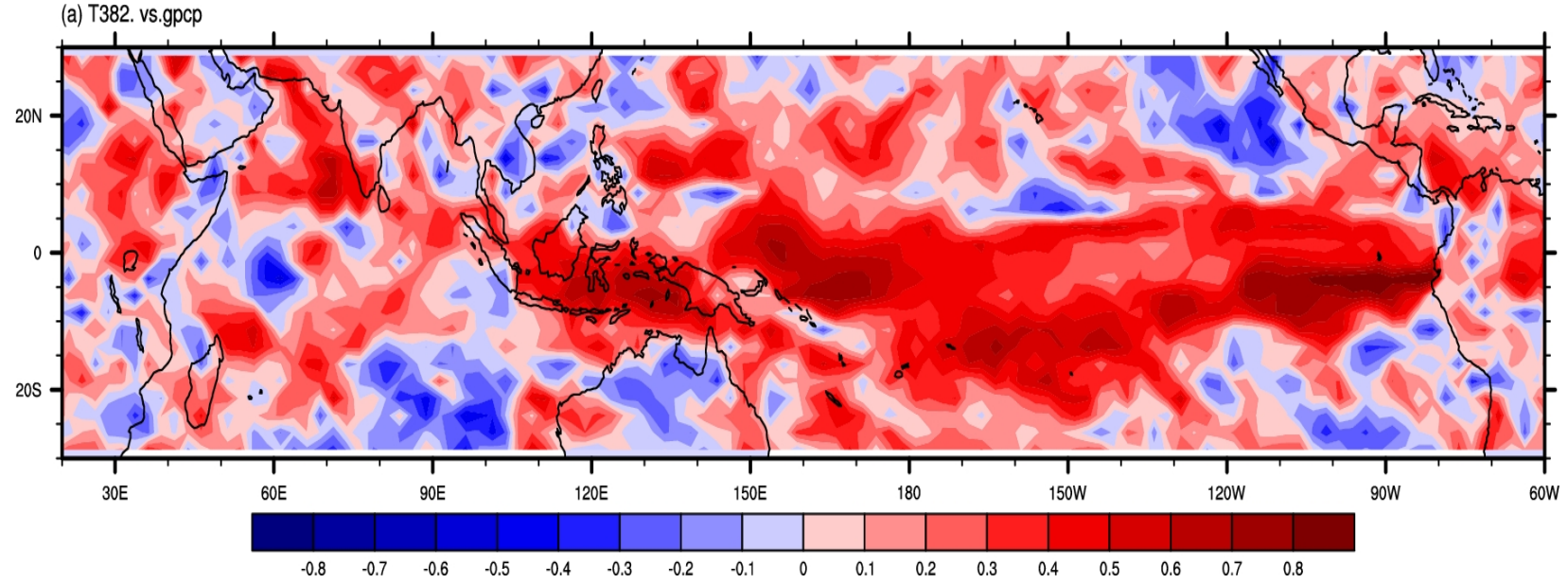


Monsoon Mission Mode Performance (Prediction Skill as well as interannua variance) is better than other models for Indian Monsoon.



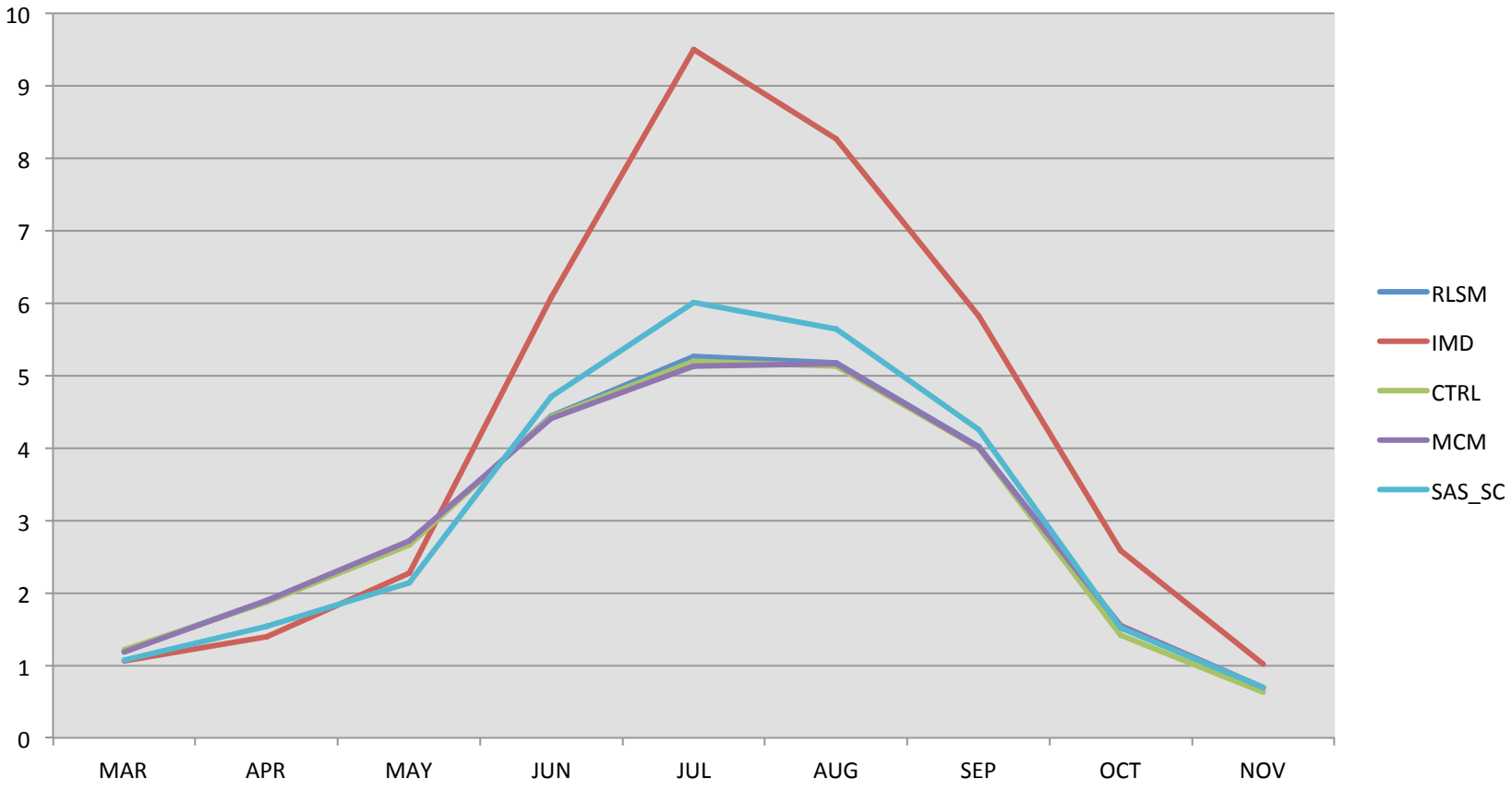
2005

Past to Present



2016

Improvements in ISMR with different developmental activities



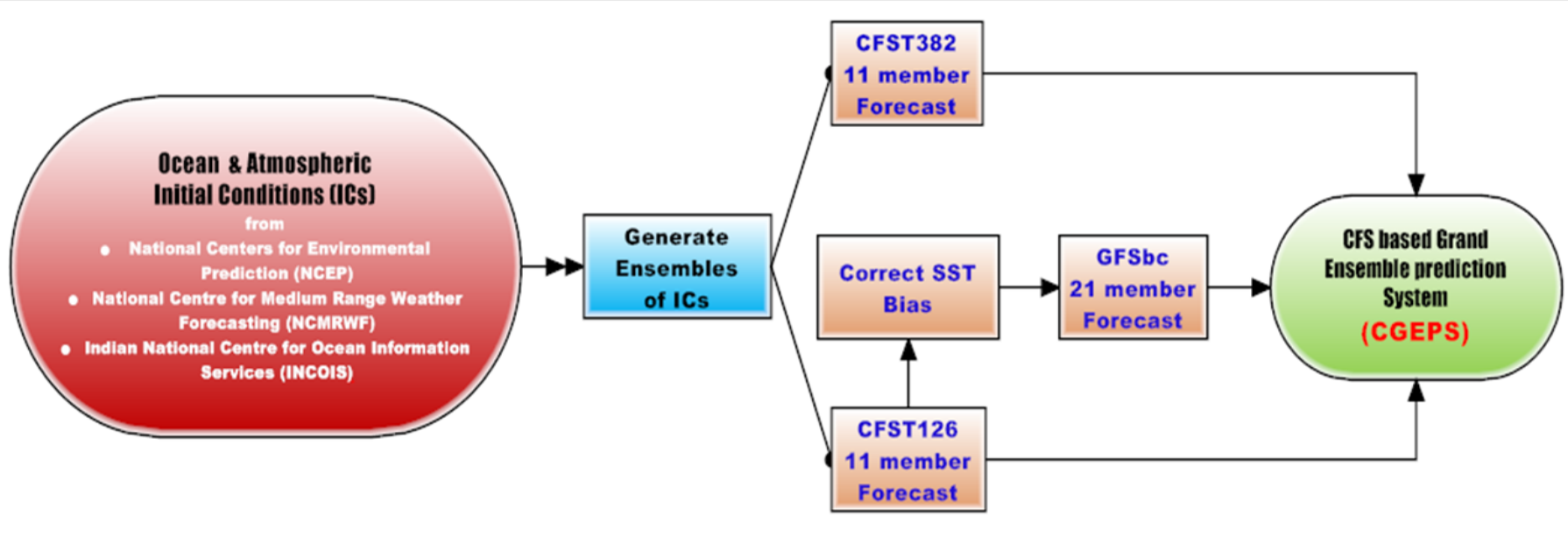
ISMR SKILL: Hindcast period 1981-2010
Towards Monsoon Mission Model

	CTL Original CFS	Modified SAS	Mod. SAS+ ZC	MCM
IMD	0.48	0.51	0.55	0.49
GPCP	0.43	0.55	0.64	0.55

Resolution: T126L64
 # Ensembles: 6
ICs : Feb. IC
Other Developments needs to be incorporated: LSM, MOM5, WSM6, Impact of Coupled Data assimilation, Stochastic Parametrization, Other international PIs works

Generation of Multi-model Ensemble (MME) Forecasts from CFS Grand Ensemble Prediction System (CGEPS) using CFST126, CFST382 & GFSbc

For forecast consensus, MME has been formulated from CGEPS using 21 ensembles of GFSbc, 11 ensembles each of CFS126 and CFS382.



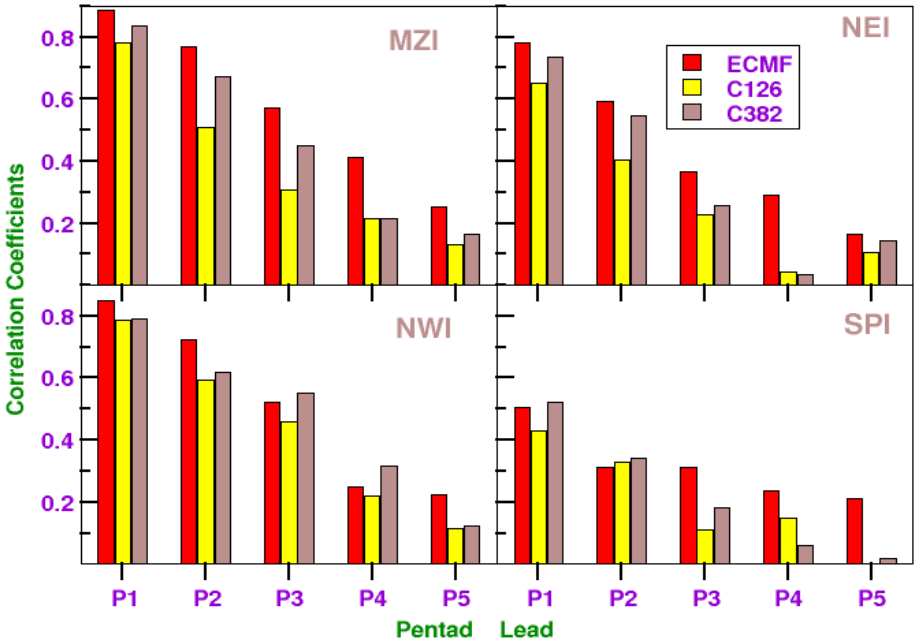
Hence, total 43 ensemble members were produced independently from 3 variants of CFS model to generate the CGEPS and forecast consensus is done by making simple average among the members.

Abhilash et al. 2015,

Extended Range

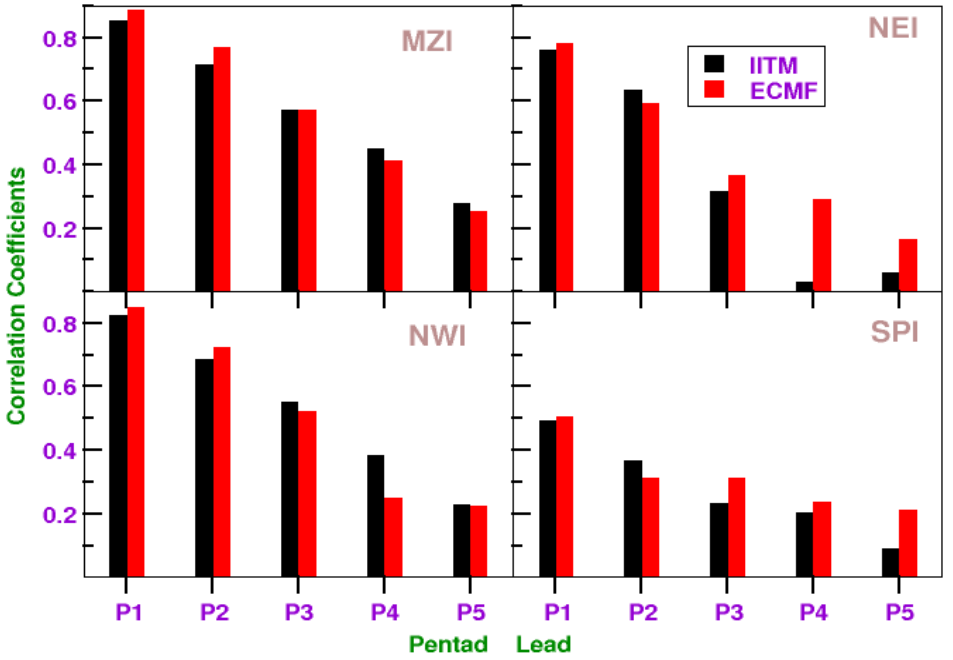
ECMWF vs CFS

Individual Skill



Skill statistics is based on:
11 members of both Models

MME Skill

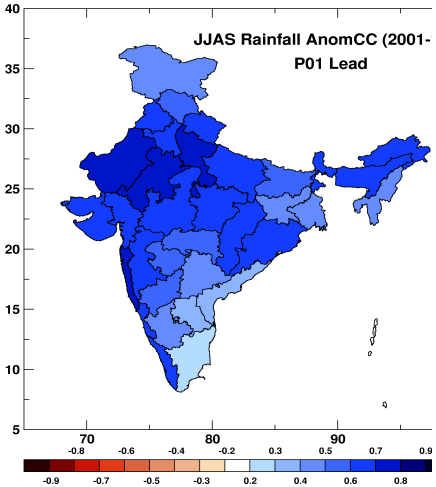


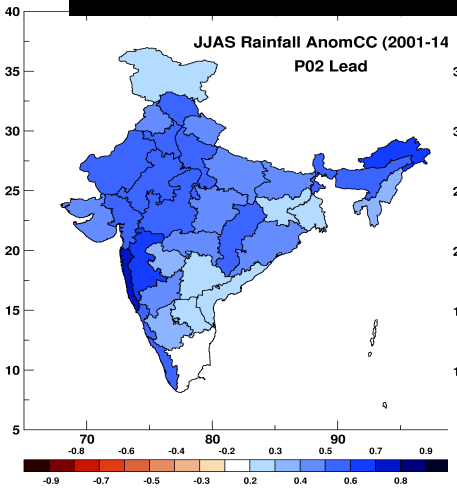
Forecast is given in Pentad (5 day) averaged lead-time: P1 means 1-5 day average..etc.

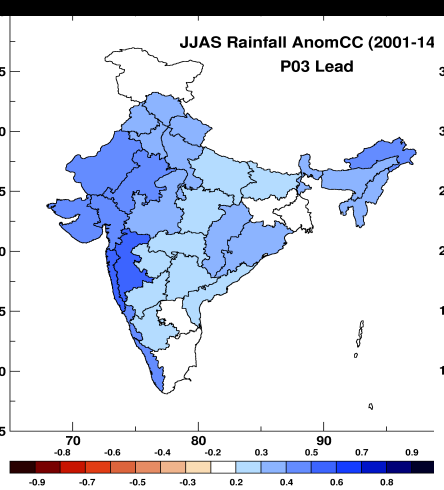
Subdivision Wise Statistics

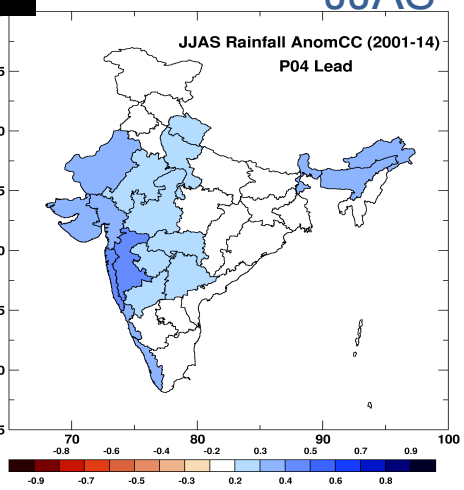
ECMF MME

JJAS

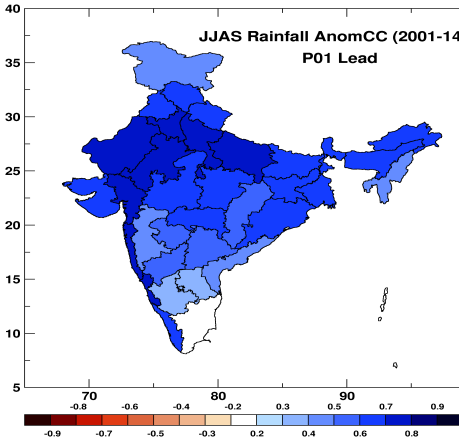


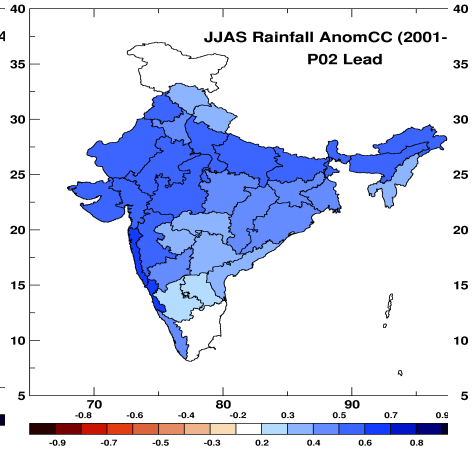


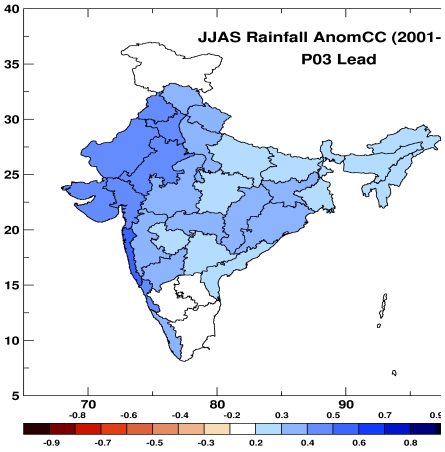


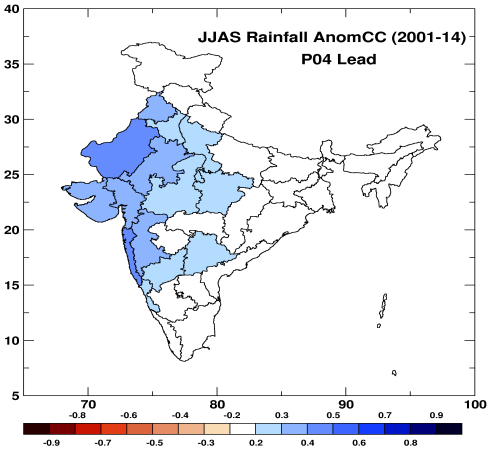


IITM MME



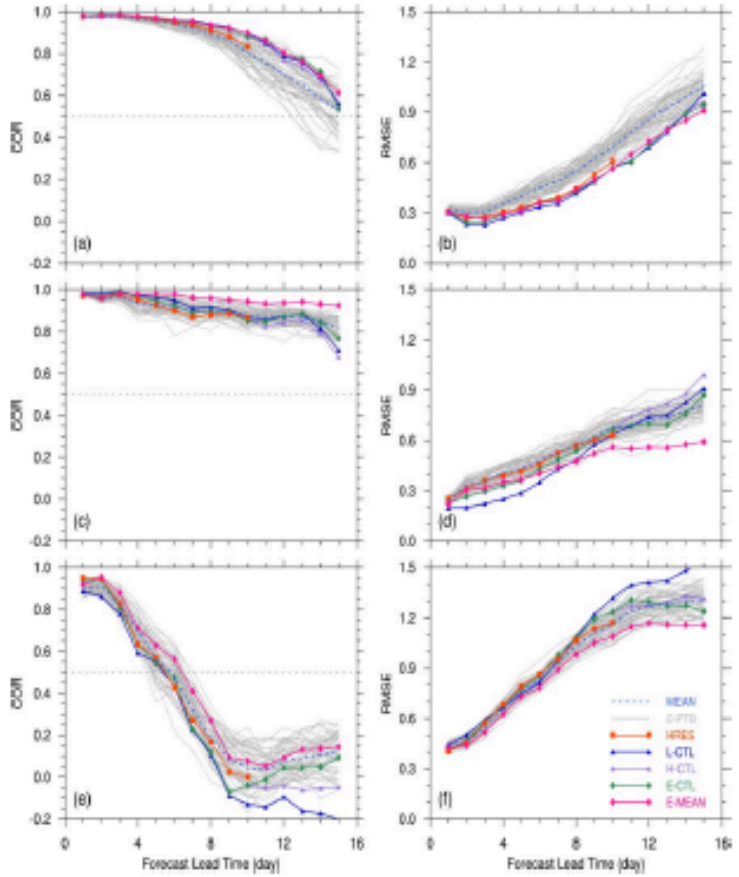






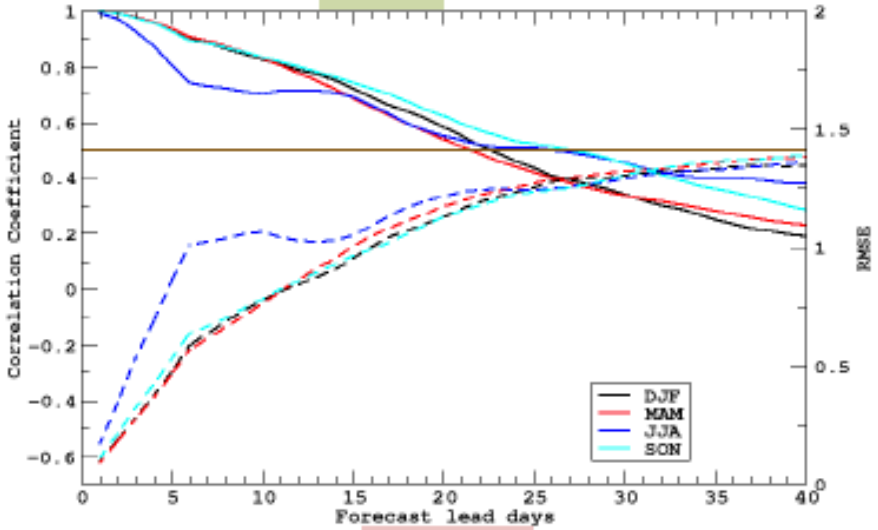
Prediction of MJO

ECMWF

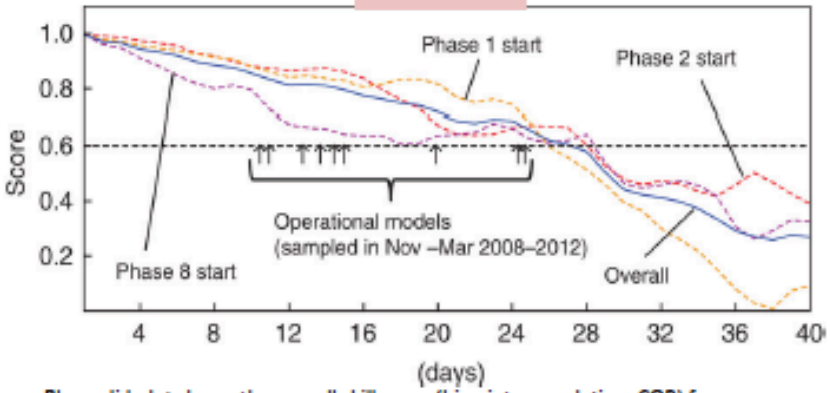


Jian Ling, Peter Bauer, Peter Bechtold, Anton Beljaars, Richard Forbes, Frederic Vitart, Marcela Ulate, and Chidong Zhang, 2014: Global versus Local MJO Forecast Skill of the ECMWF Model during DYNAMO. Mon. Wea. Rev., 142, 2228–2247.doi: http://dx.doi.org/10.1175/MWR-D-13-00292.1

IITM



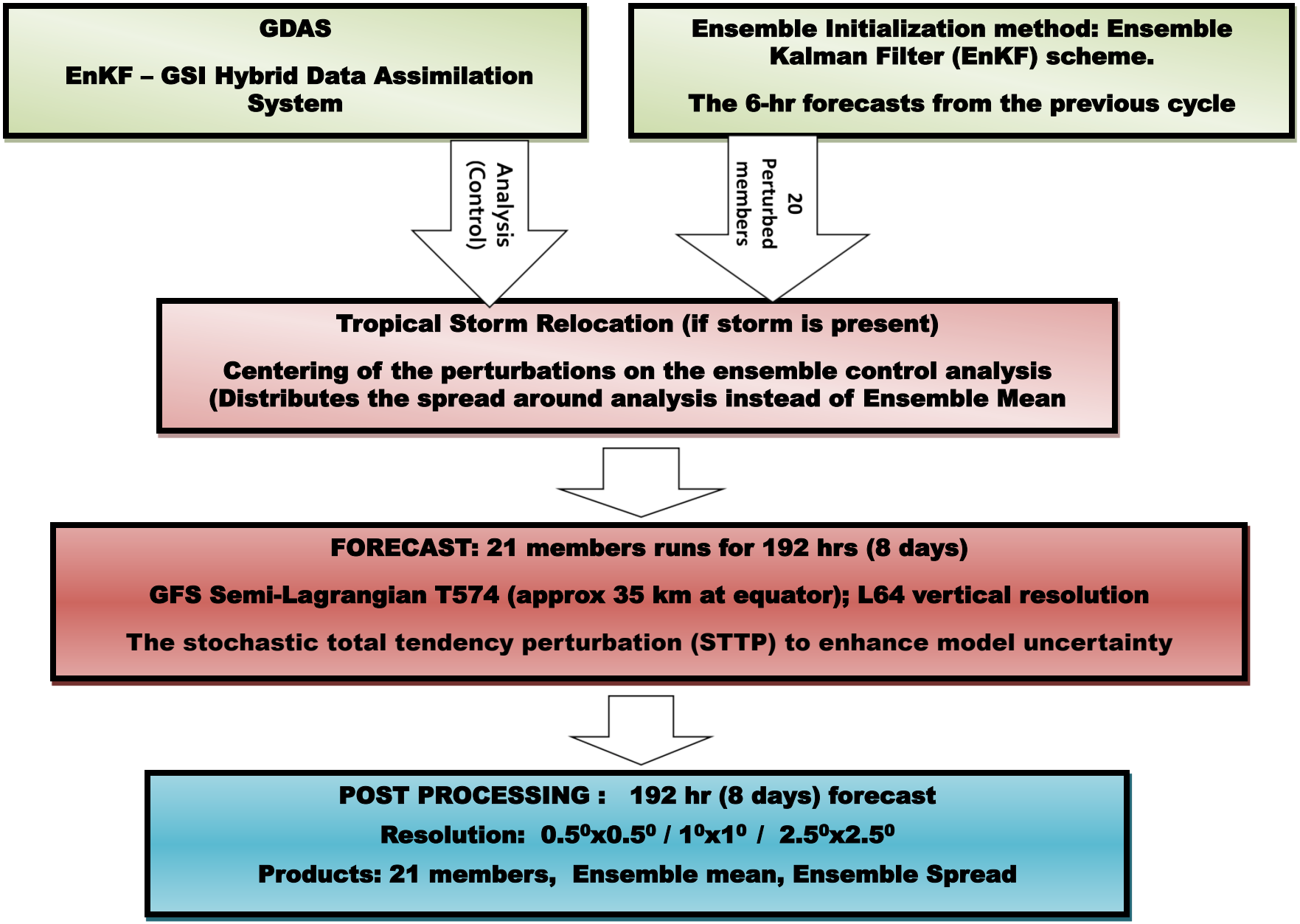
NICAM



Blue solid plot shows the overall skill score (bivariate correlation; COR) for all 54 simulations. Broken plots show COR for groups of simulations initialized at phase 8 (purple, 17 members), phase 1 (orange, 18 members) and phase 2 (red, 19 members). Arrows indicate the durations COR>0.6 is maintained by recent operational models

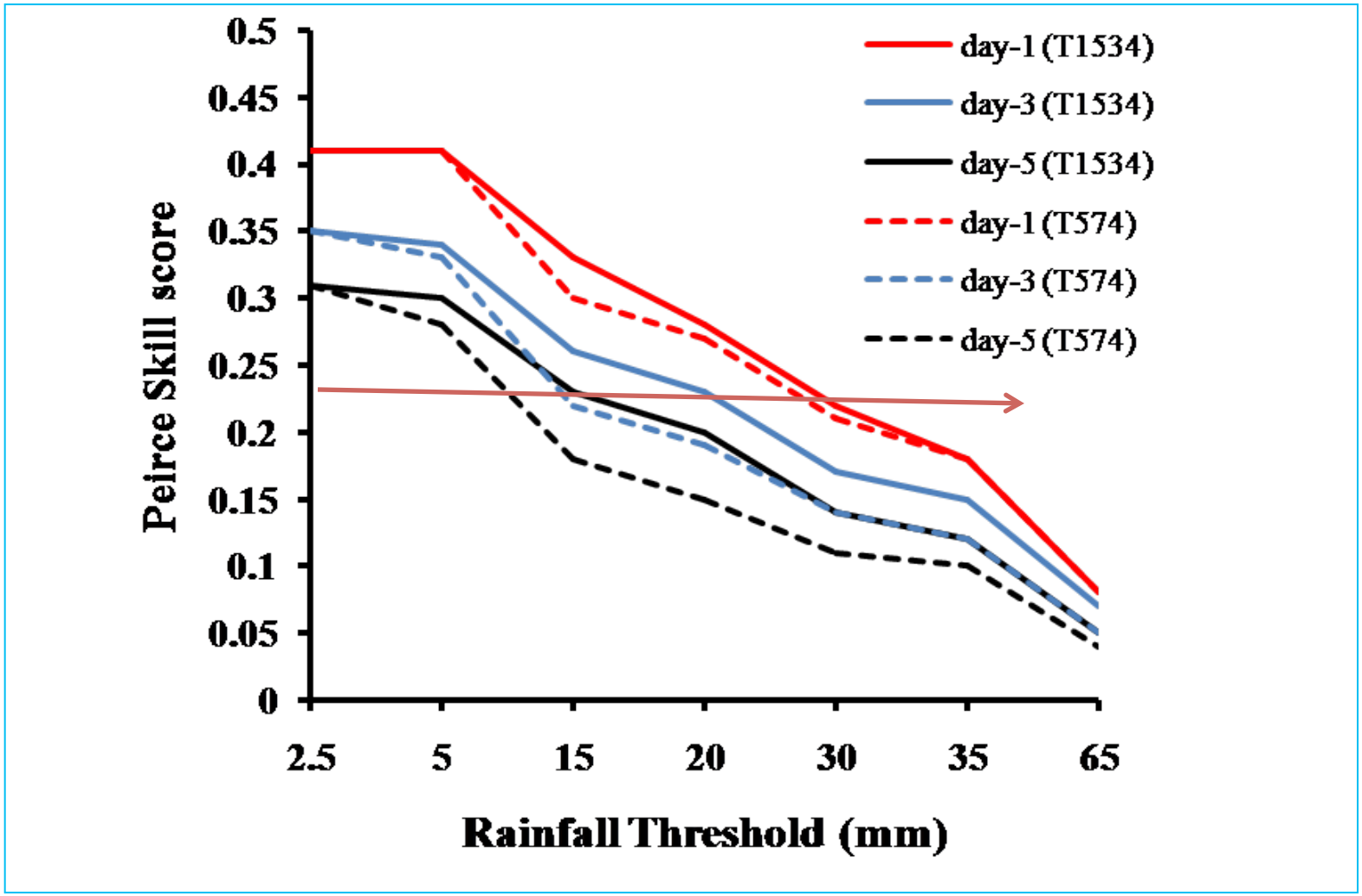
Miakawa et al., Nature Comm (2014).,5, doi:10.1038/ncomms4769

SCHEMATIC OF GEFS (SL) T574 L64 RUNNING AT IITM



Peirce Skill Score

3rd day skill of GFS T574 is now equivalent to 5th day skill of GFS T1534



UKMO Model is also selected for Monsoon Mission

- NCUM DA – Hybrid 4D-Var (44 member ETKF) operational from 1 Sept. 2016
- NCUM-Global Model (17 km/L70) operational from 1 June 2015
- NCUM-Regional Model (4 km/L70) operational from 1 July 2015
- NCUM-Regional Model (1.5 km/L70) – trialing for select cases for Indian Domain/sub domains
- NCUM- 44 member Global EPS (33 km/L70) operational from 1 Nov. 2015
- Ocean Initialisation based on NEMOVar was implemented at NCMRWF with a visit of a young scientist to NCOF/Met Office during March-May 2016 and now it is running in real-time using UKMO observational datasets.
- Coupled Model (UM [60kmL85] & NEMO [25 kmL75]) was implemented in Nov. 2016 at NCMRWF for coupled NWP for week-2 forecasts.

IMDAA

- Currently 10 year reanalysis (1979-1988) is on-going in 5 streams at Met Office and NCMRWF
  - 3 streams (1983-84, 1985-86 & 1987-88) at NCMRWF have completed 14 months in each stream
  - Ingest of INSAT-3D CSBT and Megha-Tropiques SAPHIR radiances in NCUM successfully done through IMDAA project's young scientist training - Operational from 1 Sept 2016
- Regional DA – Assimilation system (3D-Var) for 4-km regional NCUM has been implemented. Successfully assimilated radial wind observations from Indian DWRs
- Forecast Sensitivity to Observations (FSO) system has been setup and is being used for monitoring the impact of observations on the forecasts

Status of Indian Prediction System

Prior to Monsoon Mission

- No coupled dynamical modelling System to make seasonal Forecasts
- No extended Range Dynamical Prediction System for predicting Active/break Cycles of Monsoon
- No expertize in handling coupled models in forecast mode
- No expertize in developmental activities involving coupled models
- No coupled data assimilation system
- India's role in motivating monsoon research elsewhere in the globe was not significant
- No access to significant HPC resources to carryout the model development activities

Monsoon Mission

- Coupled dynamical modelling System to make seasonal Forecasts of ISMR with better prediction skill.
- First extended Range Dynamical Prediction System for predicting Active/break Cycles of Monsoon.
- High resolution ensemble based prediction system (T574) has been setup. Efforts are underway to setup T1534 ensemble prediction system soon.
- Significant work has been done to reduce coupled model biases and incorporated new physics and modules in coupled models.
- Tightly coupled data assimilation system being setup
- Significant HPC resources were put in place

What Needs to be Achieved in Future?

Achieved

- Reduced Biases
- Bias in Indian Ocean teleconnections are improved
- All forecasts are done separately
- Running separately a high resolution short range forecast system

To be achieved

- Biases still exist (further reduction required)
- Phase of the IO Teleconnections are still opposite
- Needs to develop a seamless prediction system
- Develop unified model by incorporating regional model

Road Ahead: Extremes and Applications

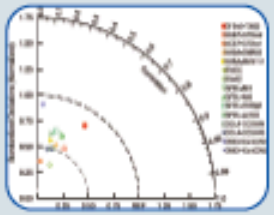
- Fully develop the Monsoon Mission Model by incorporating all changes carried out by various PIs of monsoon mission.
- Develop a unified model based on the above model by incorporating the regional model in the above model so that extremes can be predicted with improved accuracy and seamlessly
- Operationalize coupled ocean-atmosphere data assimilation system by carrying out vigorous tests on usability to different predictions.
- Appropriate dynamical core developments will be taken up to scale up the model at very high resolutions
- Develop Weather and Climate applications (For Agriculture, Hydrology etc.)

Achievements

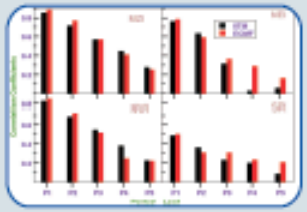
Nodal Agency

Monsoon Mission
Model Development

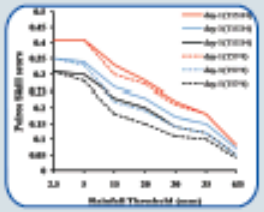
1. Best seasonal prediction model in the world for predicting monsoon rainfall with the highest resolution of 38 km, so far unparalleled.



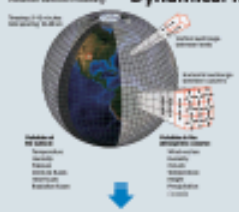
2. Skillful prediction of monsoon active/break cycles at extended range: at par with the best in the world.



3. Very high resolution (~27 km) weather forecasts at short and medium range resulted in gain of 2 days lead time.

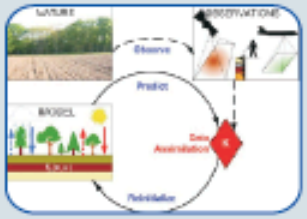


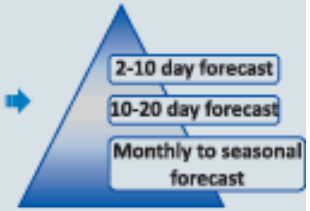
Dynamical Model



4. Coupled data assimilation system: Improves the quality of initial conditions required by dynamical model.

5. Transferred all the forecast models to IMD to operationalize.





6. Setting up of High Performance Computing System (1.2 PF)

Thank You


Evaluation of forecast information
Discussions with farmers (ICRISAT)
THANK YOU