Extended range prediction of Indian summer monsoon : Current Status

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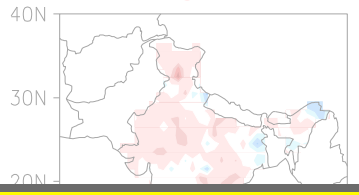
17th CMMAP Meeting 5-7 Auggust 2014, Colorado

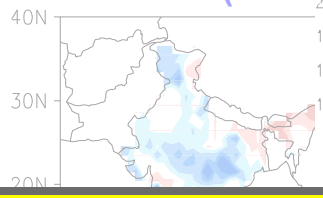
Background and Motivation

Spatial Variability

Drought (2002)

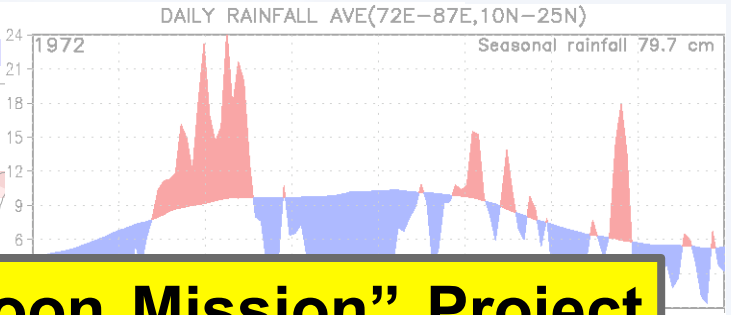


Flood (1961



Seasonal JJAS rainfall anomaly dur
floo
yea

Temporal Variability



0 cm

Hence, under the "National Monsoon Mission" Project of Govt. of India, IITM has adopted Climate Forecast System (CFS) coupled model from NCEP for seasonal and extended range prediction of Indian summer monsoon under Indo-US collaboration.

may not be useful for agricultural planning.

Seasonal rainfall anomalies are nearly homog

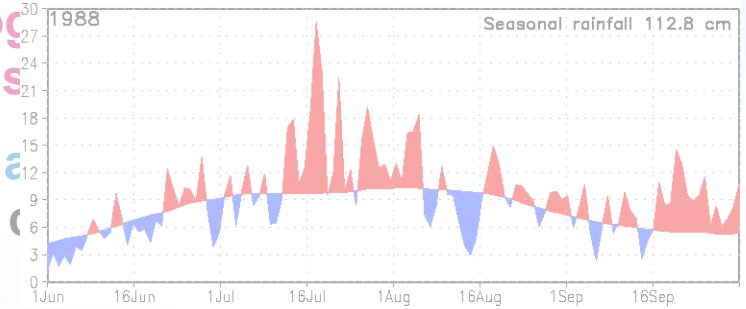
Therefore, in addition to the seasonal mean

All India rainfall, we need to predict some aspects of monsoon 3-4 weeks in advance on a relatively smaller spatial scale that will be useful for farmers.

But, mostly (~70%) monsoon years are normal a

rainfall anomalies are inhomogeneous over the c

degree of spatial variability !!!

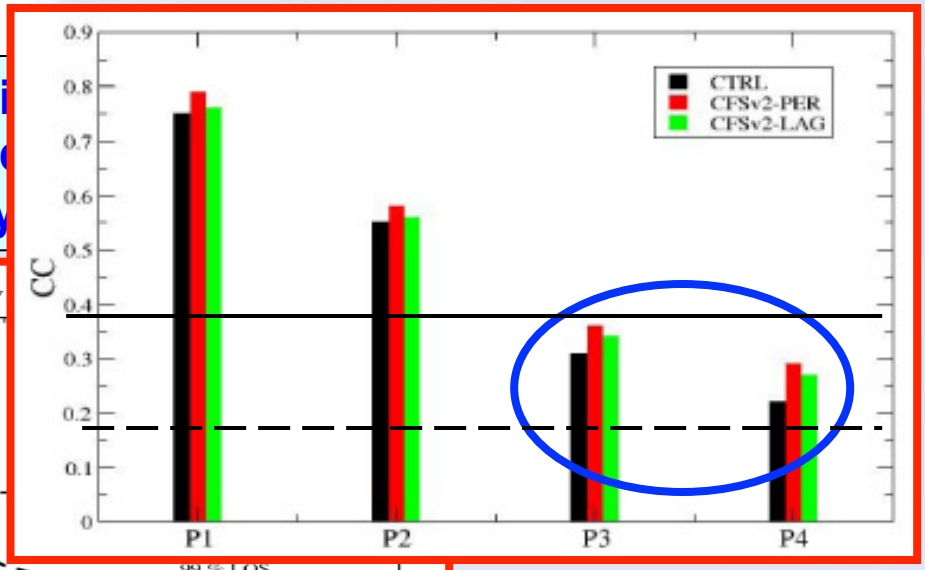


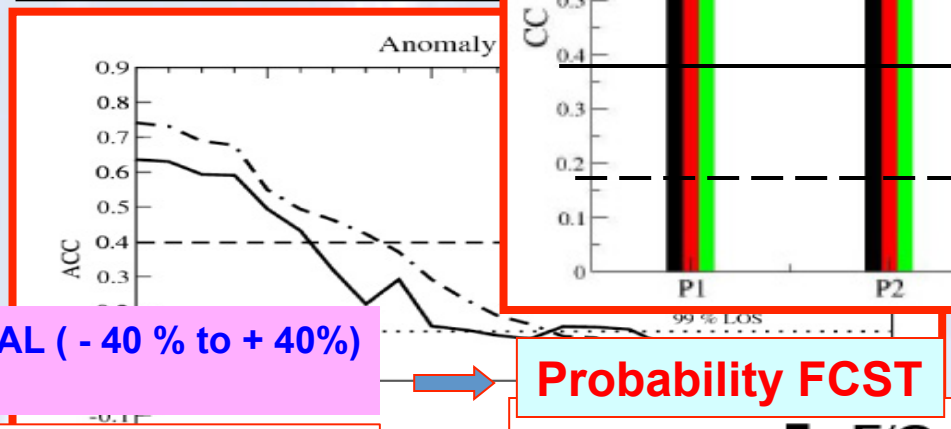
Adding to this is the variability of rainfall on temporal scales.....

Background and Motivation

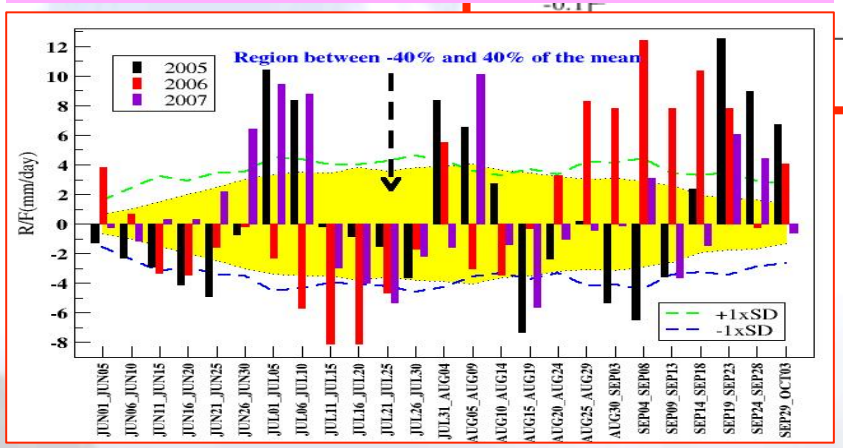
Some kind of averaging is required to remove the high frequency weather noise, prediction on pentad scale extends the skill

As useful skill of dai
drops by 7-9 days,
no longer valid bey

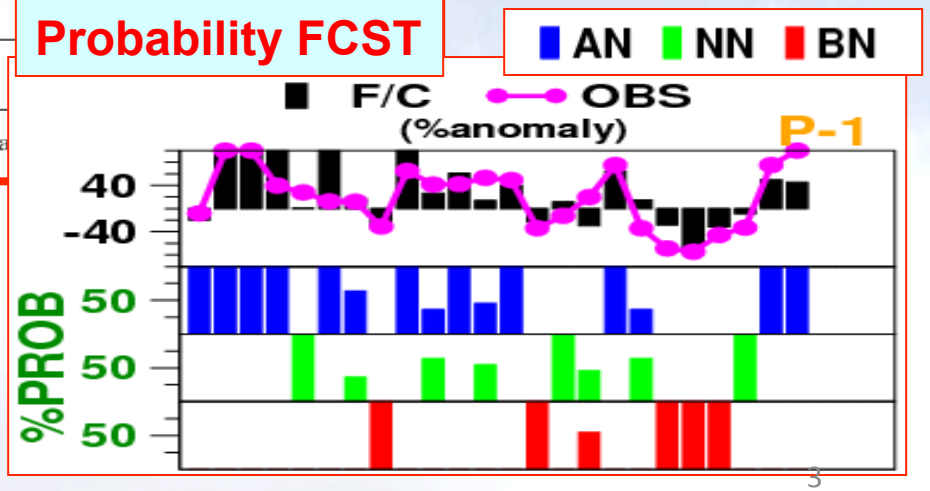




ACTIVE (> 40 %),NORMAL (- 40 % to + 40%)
BREAK (< 40 %)



Probability FCST

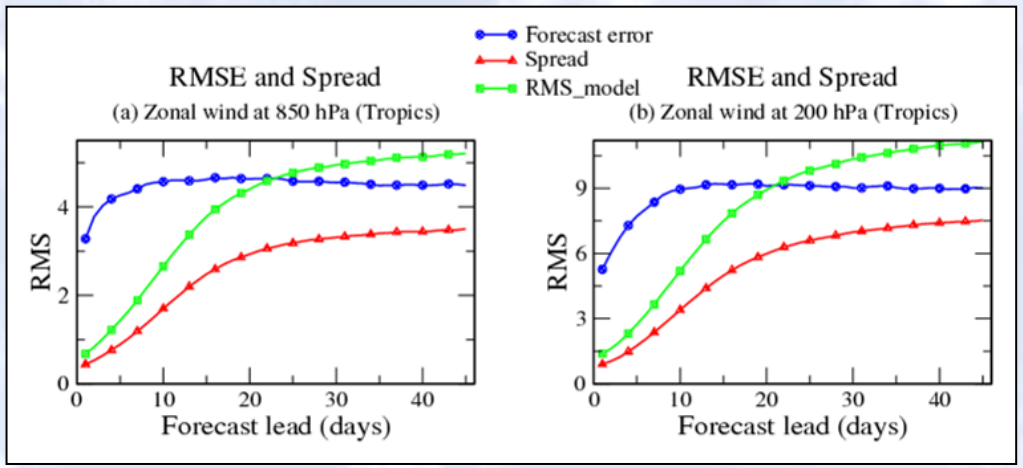


Abhilash et al., 2014

Development, Testing, tuning and reliability of Ensemble Prediction System (EPS)

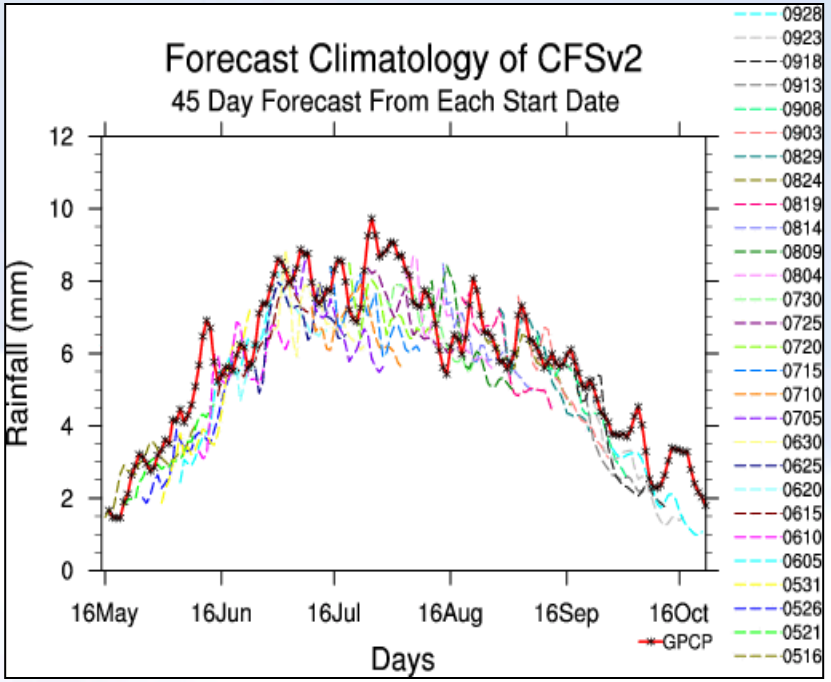
- ***It has the potential to generate infinite number of ensembles.***
- ***Amplitude of perturbation can be adjusted by changing the tuning factor.***
- ***Sensitivity of perturbing each Individual variables can be evaluated.***

Spread-Error relationship

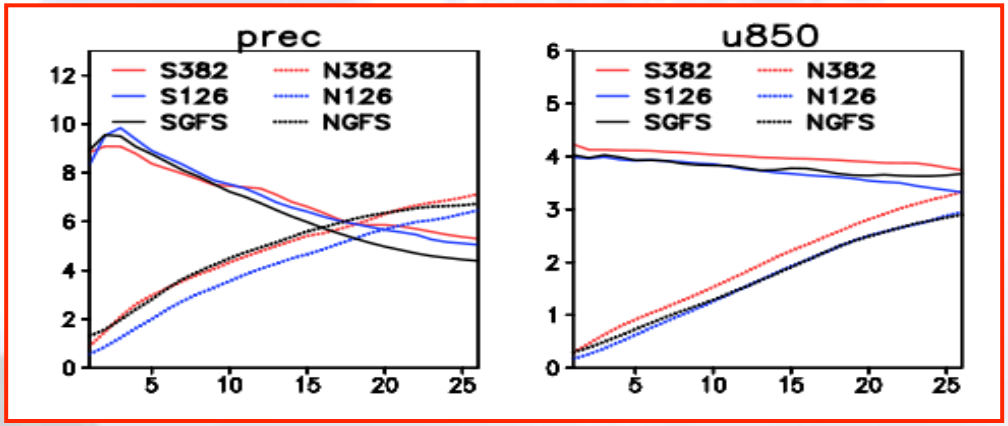


Reliability of the EPS

Lead-dependant climatology



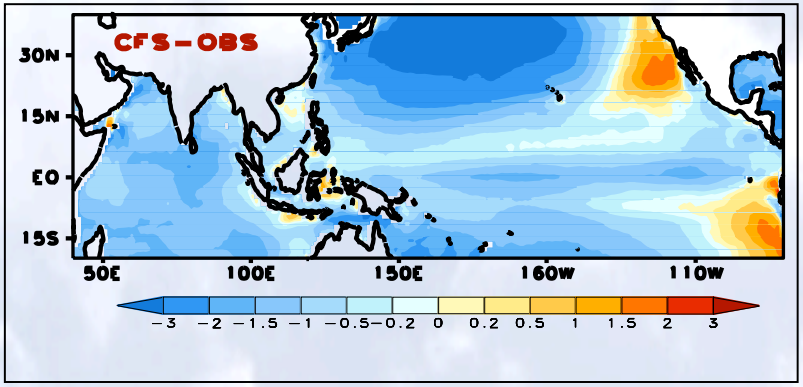
SNR and Predictability

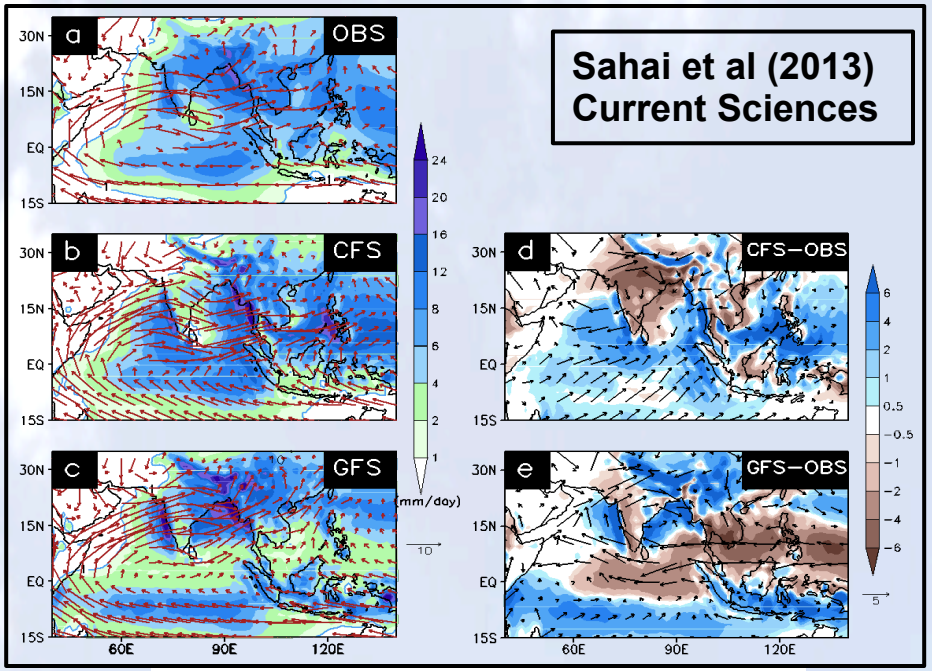


Abhilash et al., 2013a

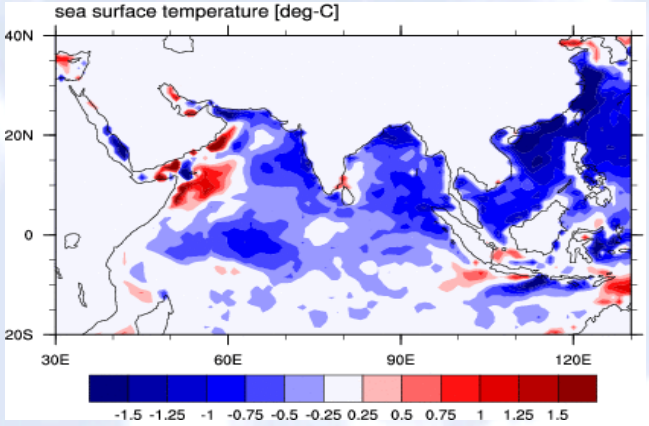
Background

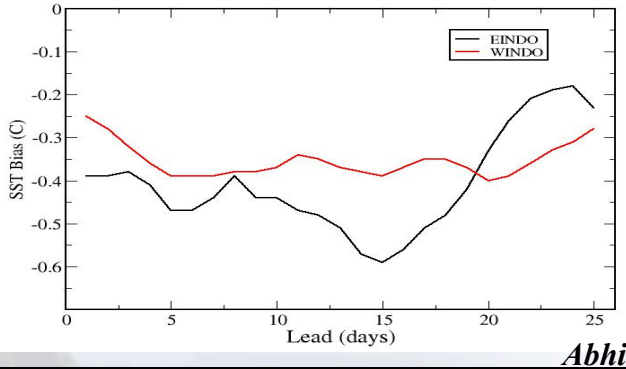
SST Bias from Long Simulation





SST Bias
20 day Lead

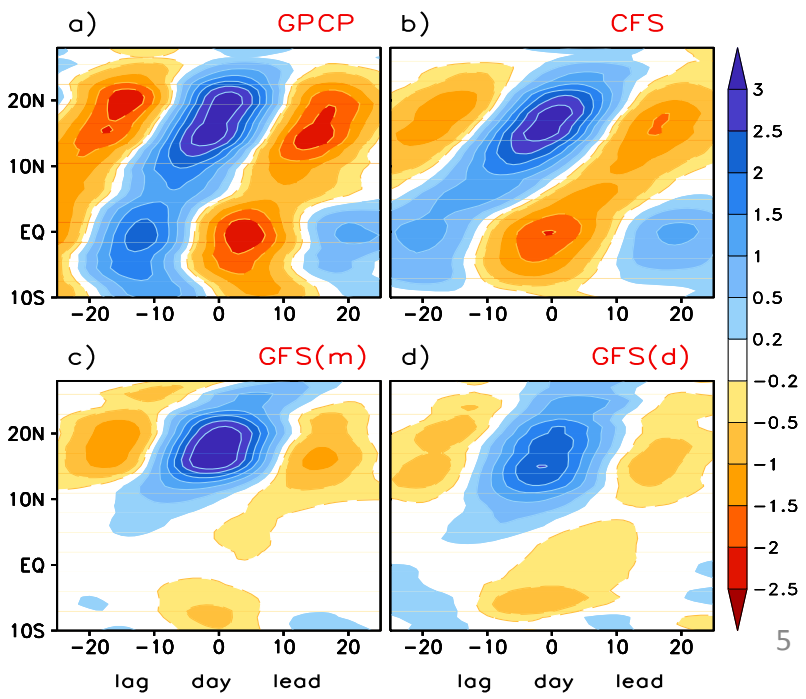




Lead Dependant Bias

Abhilash et al., 2013c

Northward propagation of ISO



Optimization of the EPS and Strategy for real-time prediction

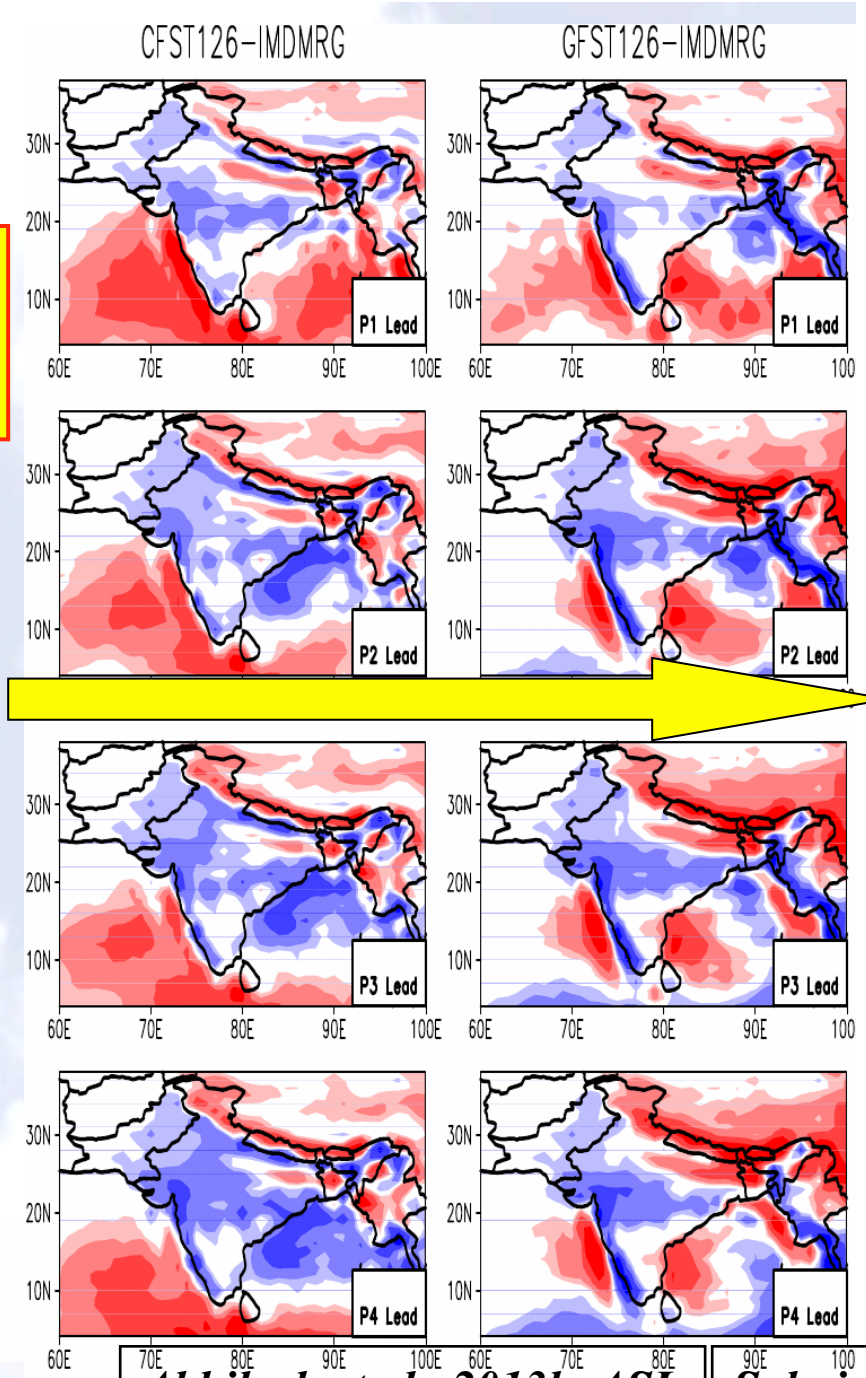
❖Does Stand Alone GFS foreced with bias correction in forecasted SST from CFS improves the ERP skill?????

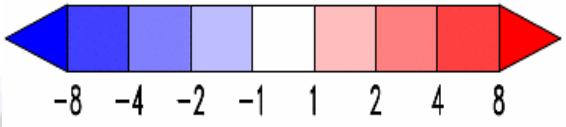
❖How important is model resolution in ERP ?????

Model	Resolution	Forecast Lead	Hindcast period
CFSv2	T126~100km	45 days	2001-2012 (28 Start dates in one year during monsoon season)
CFSv2	T382~35km	45 days	-do-
GFSv2bc (Forced by Bias corrected CFSv2 SST)	T126	45 days	-do-

GFSv2bc Seasonal (JJAS) Climatology is better than CFS126

Spatial pattern of T382 seasonal climatology has further improved

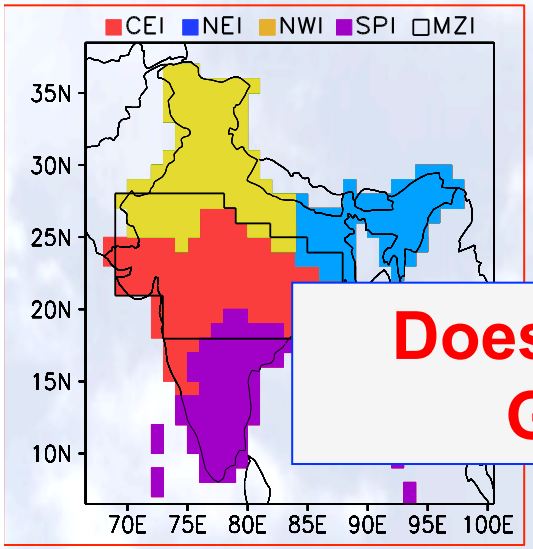


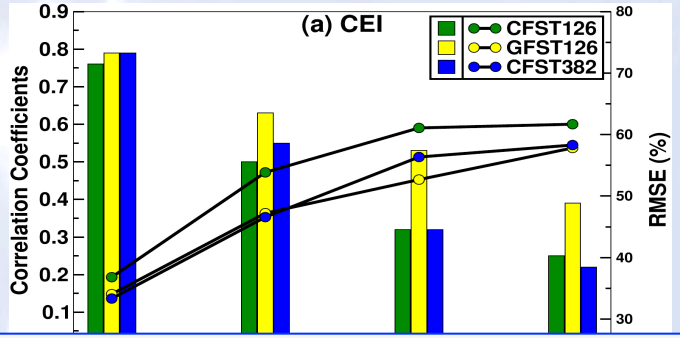


Abhilash et al., 2013b, ASL

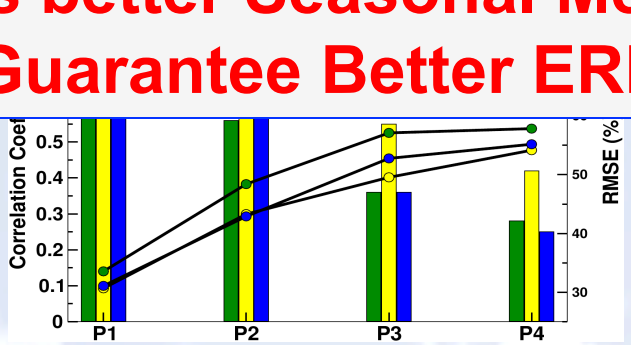
Sahai et al., 2014, Clim. Dy

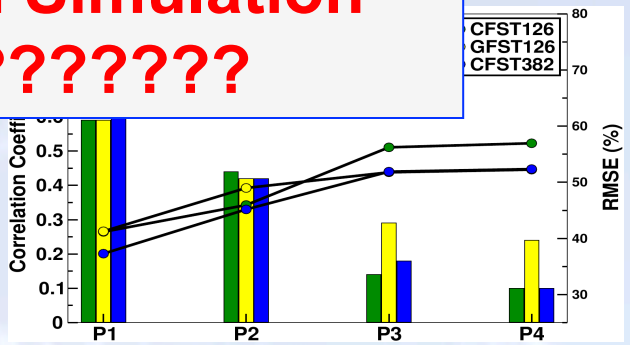
Model evaluation is done for both Actual Pentad mean rainfall averaged over 5 Homogeneous region as well as for large scale MISO



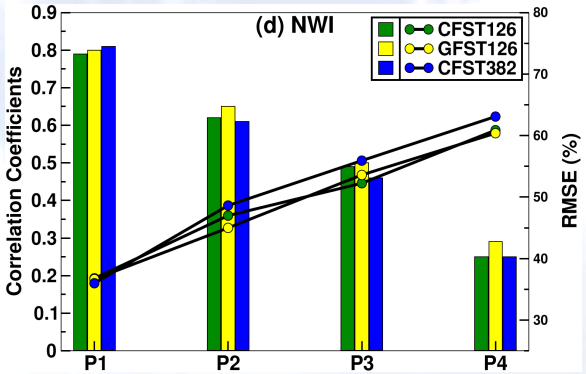


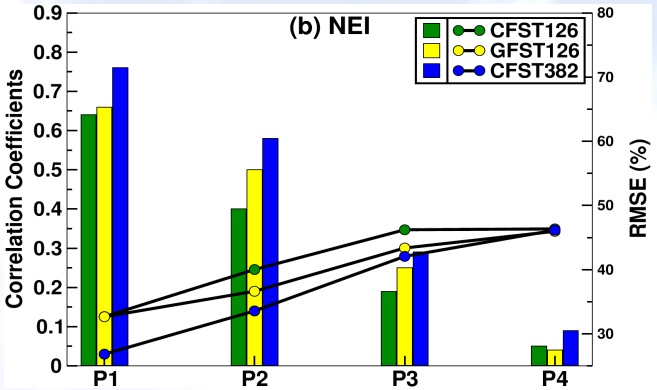
Does better Seasonal Mean Simulation Guarantee Better ERP ???????



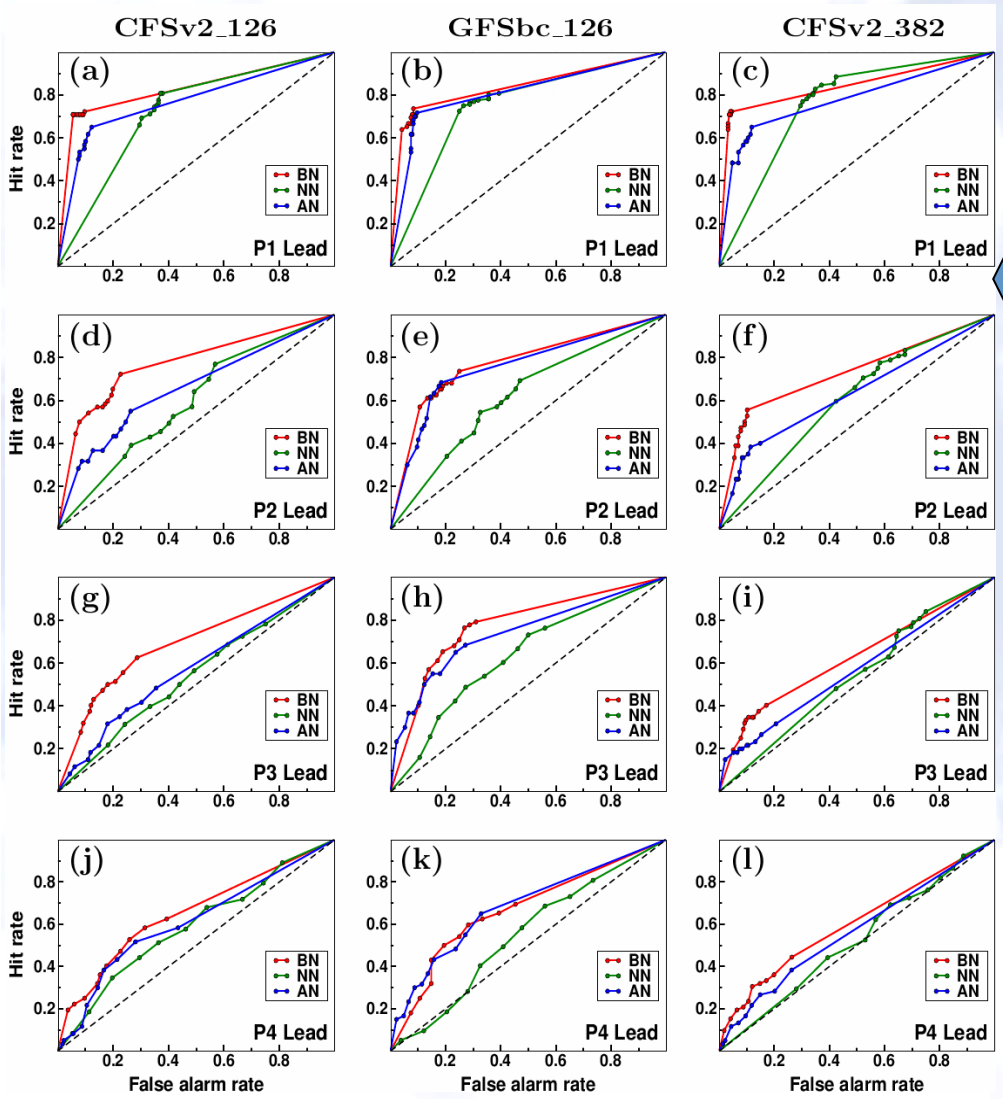


T382 skill is better over NEI



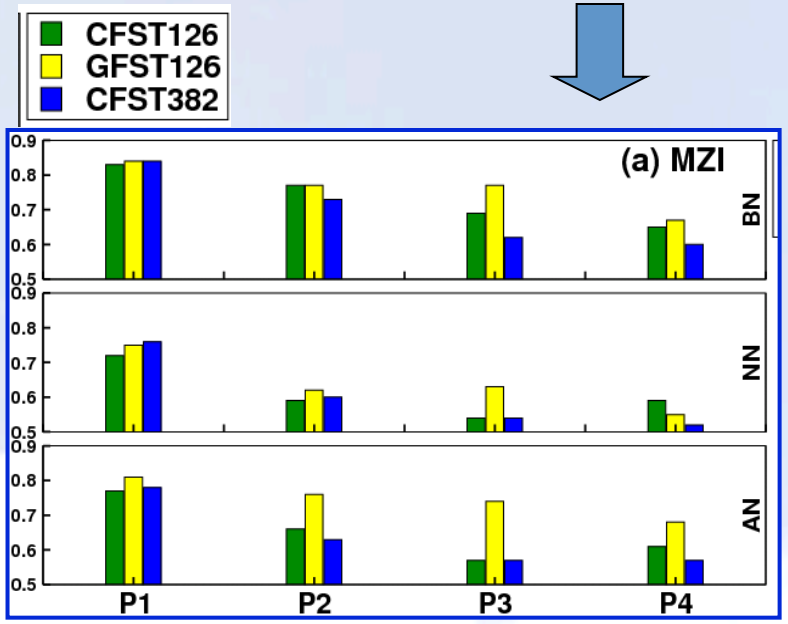


Skill Statistics: CC at different pentad lead over MZI, CEI, NWI, NEI, SPI



ROC over MZI For AN, NN, BN categories

AUC over MZI For AN, NN, BN categories

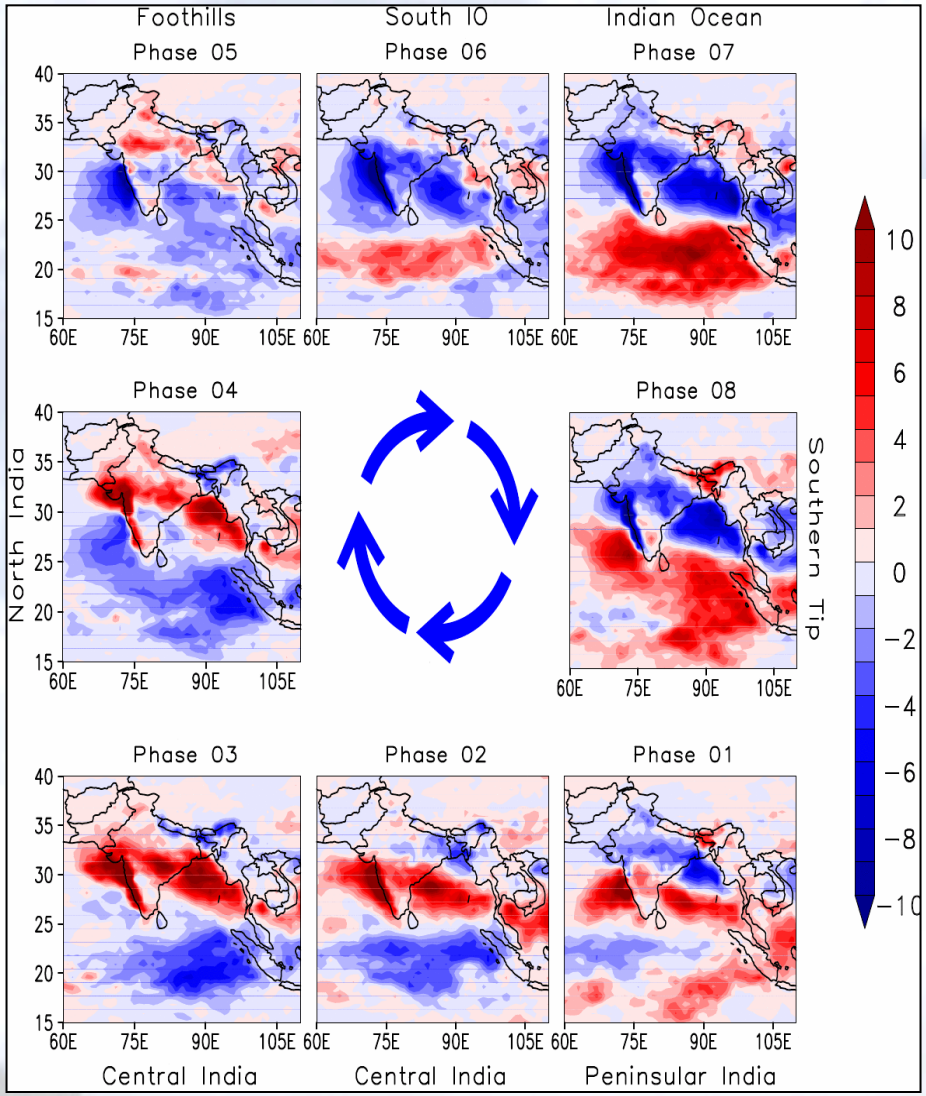


Borah et al, 2013

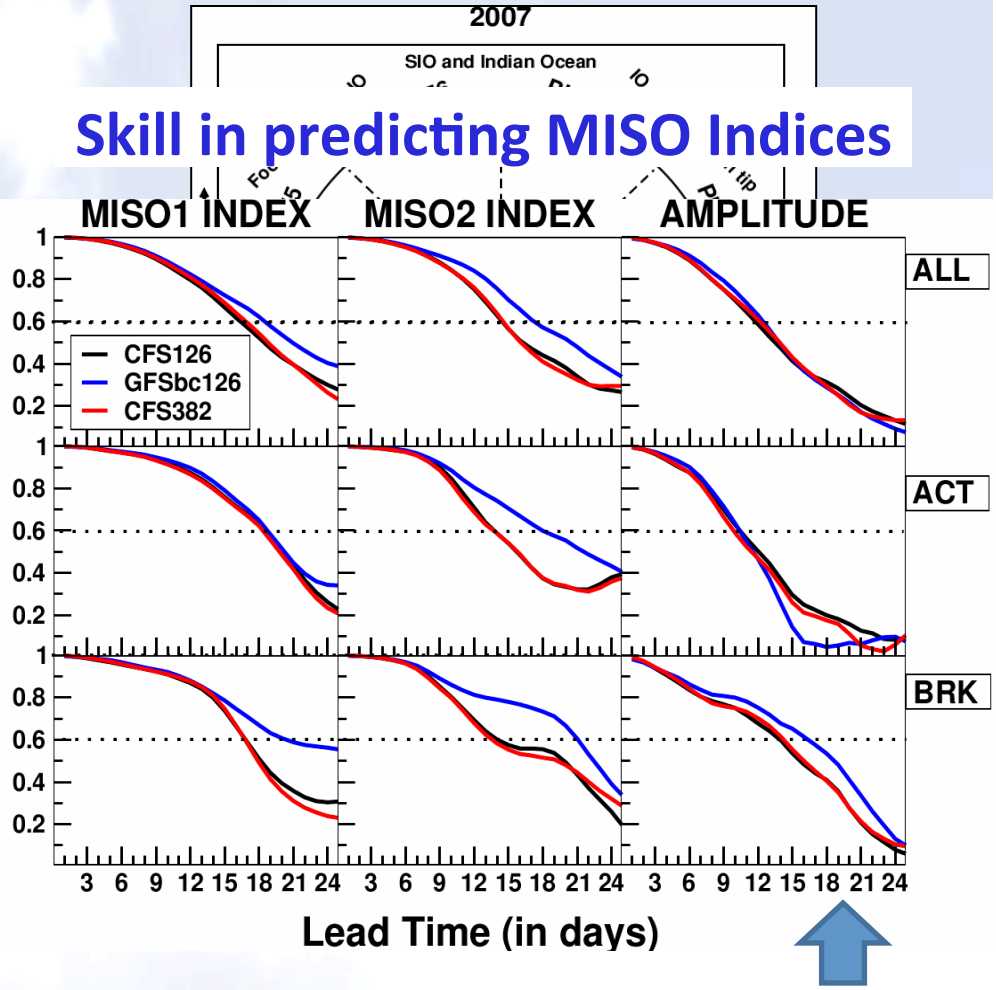
Optimization of Low frequency component over Indian region

RMM----------→ BSISO----------→ MISO--- (*Suhas et al., 2013, Goswami et al., 2013*)

Eight Phase evolution of MISO



Skill in predicting MISO Indices



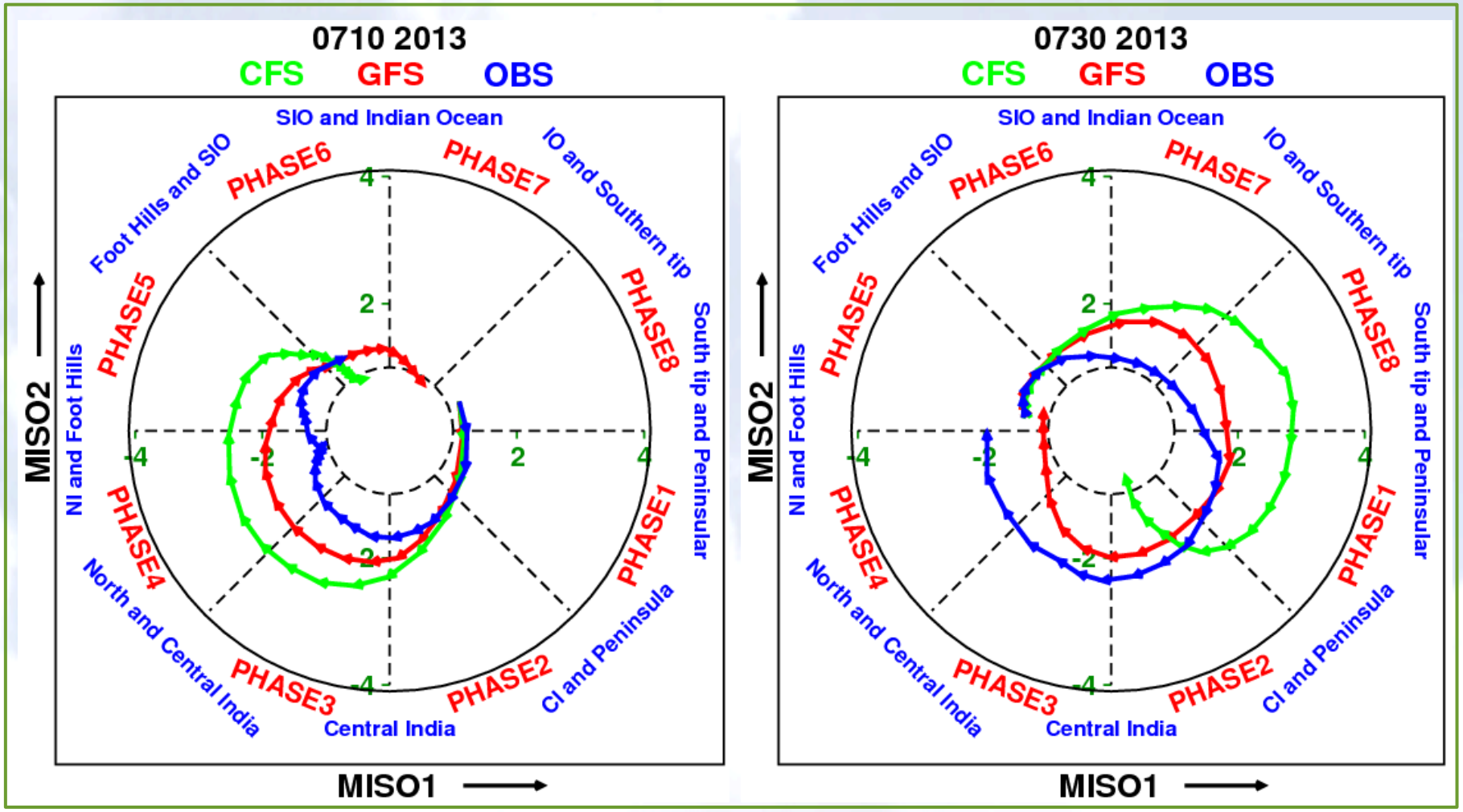
Correlations between the MISO1 and MISO2 index and the MISO amplitude as a function of lead-time.

Outcome of the experiments

Bias Correction as well as High Resolution

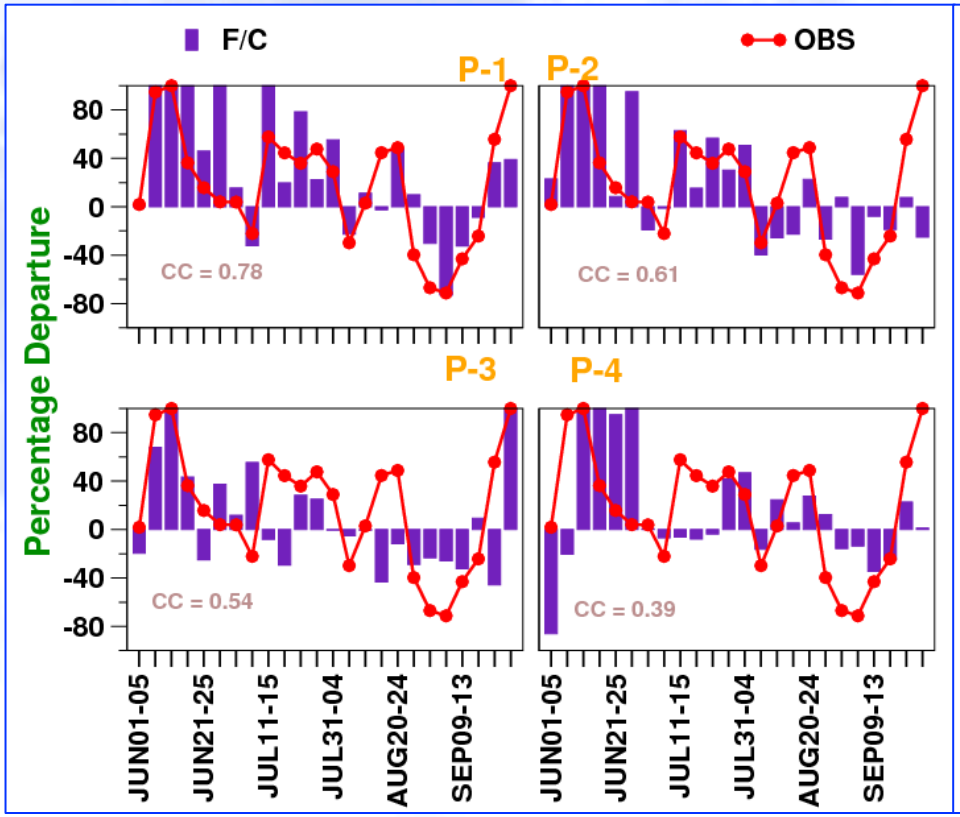
- The dry bias over the Indian land region slightly reduced in all lead pentads in the bias corrected GFSv2 compared to CFSv2T126. While T382 run exhibit large reduction in climatological biases … But no significant operational usefulness of CFST382 forecast over T126 forecast of MISO.
- The pentad lead prediction skill of ensemble mean deterministic and probabilistic forecasts from GFSv2bc is significantly higher than CFSv2, both T126 and T382, for all lead pentads.
- GFSv2 is superior to CFSv2 in predicting large-scale low-frequency components of MISO and is clearly an artifact of correcting the SST bias. Biases are similar in T126 and T382 resolutions.
- The real-time dissemination of extended range (~3 weeks) forecast in the high resolution NCEP CFSv2 framework could be a challenging task for the operational forecasters, owing to time constraints and computational management.

Monitoring of MISO and verification

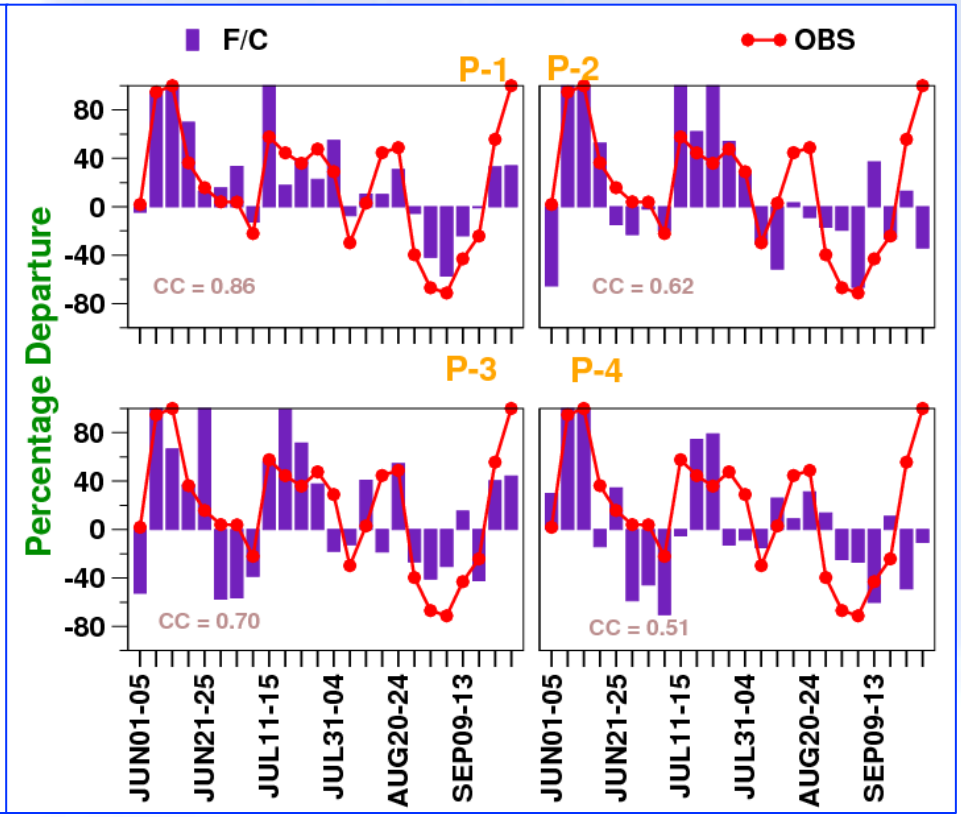


Observed and Predicted percentage anomalies are shown for 2013 over Monsoon Zone

CFS

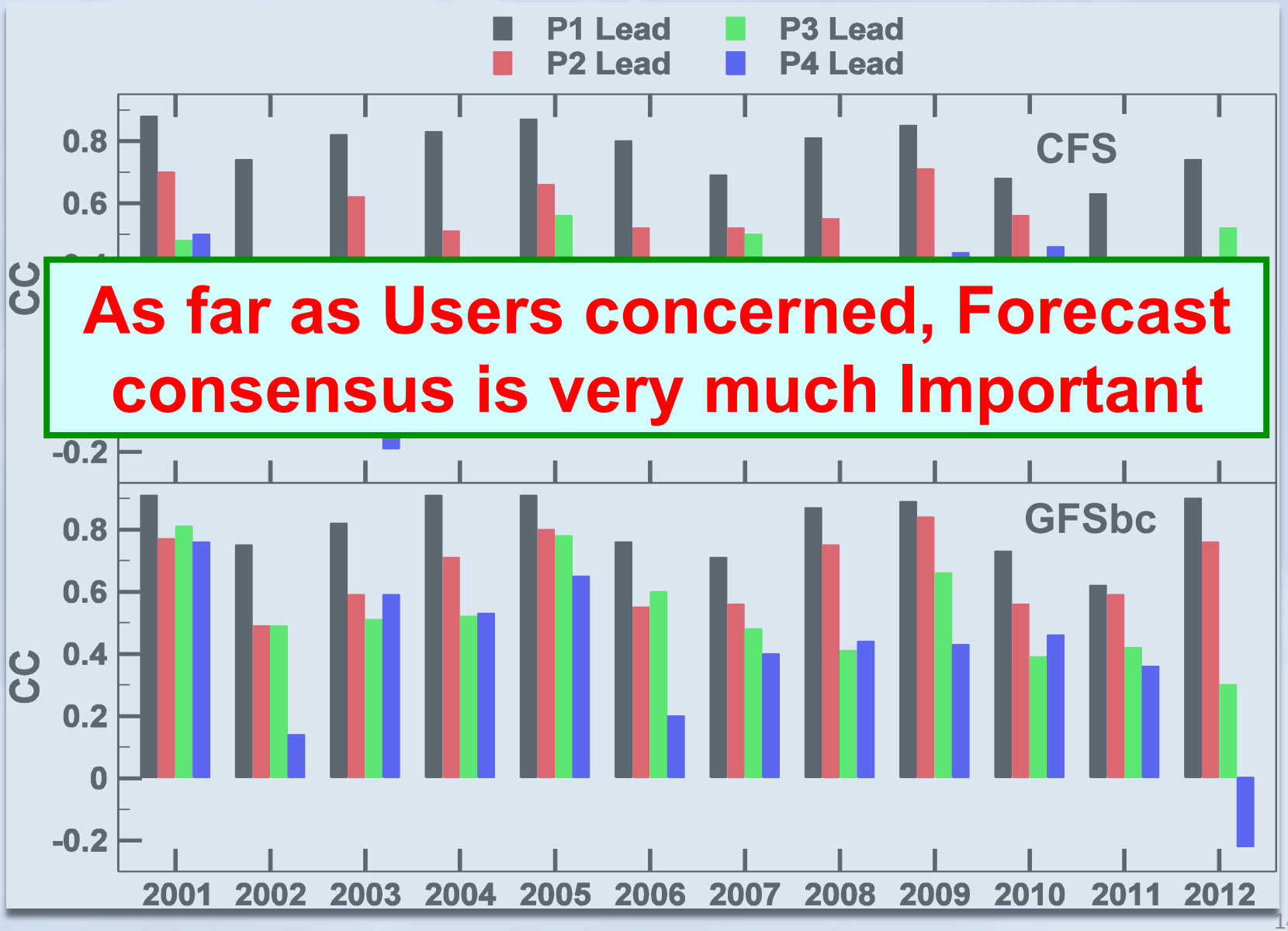


GFS



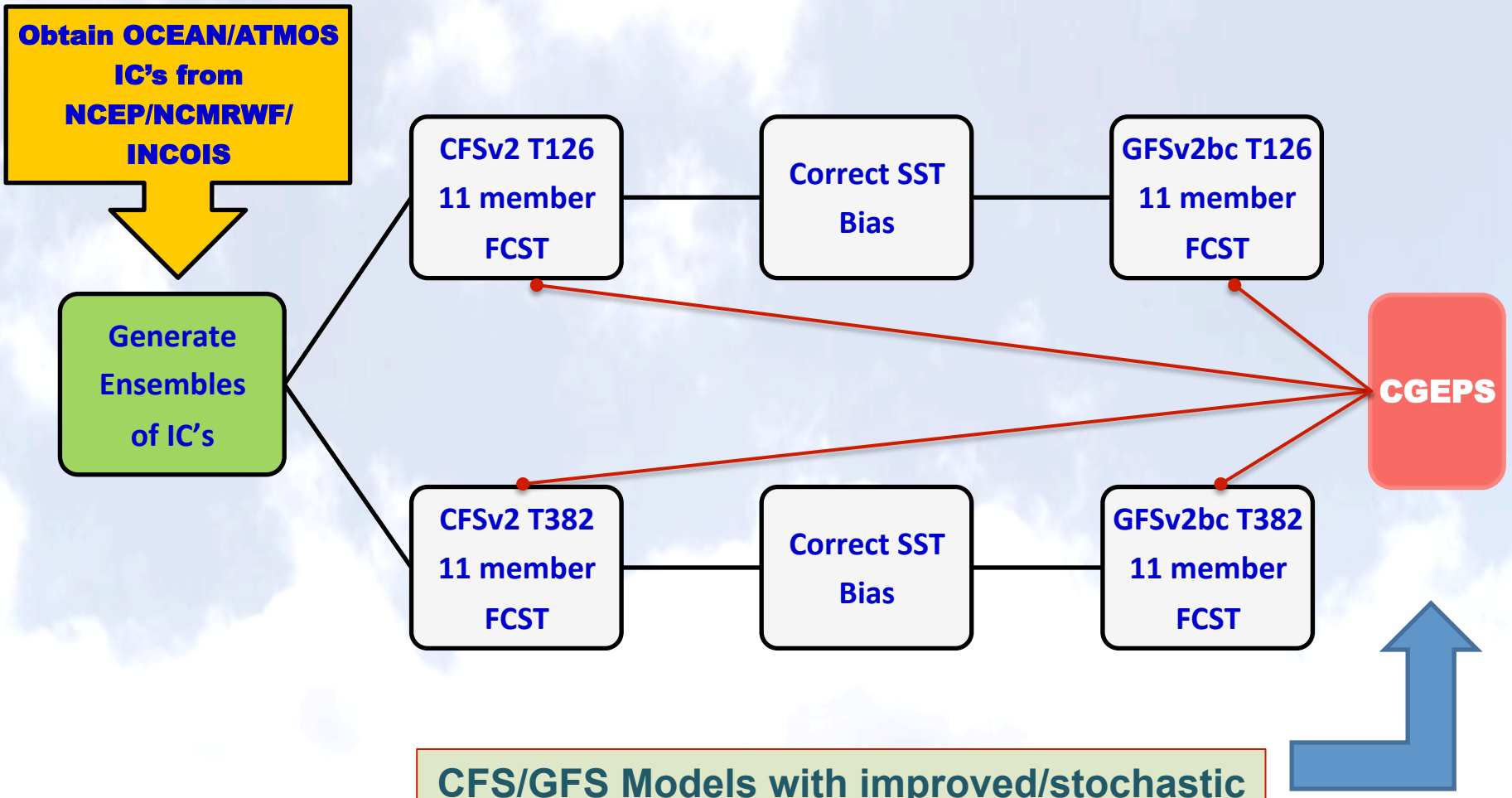
Both the models performed differently from Event-to-Event

Inter-annual variation in skill of individual models

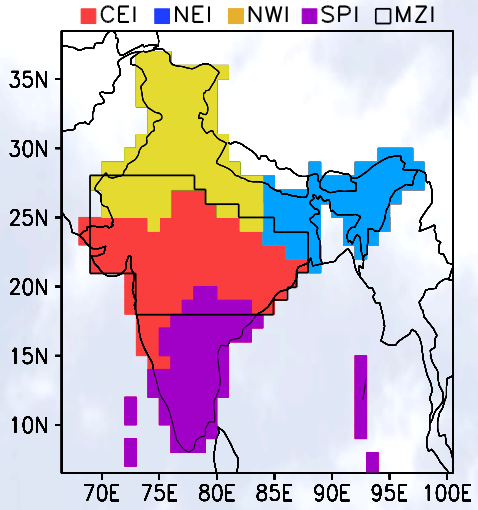


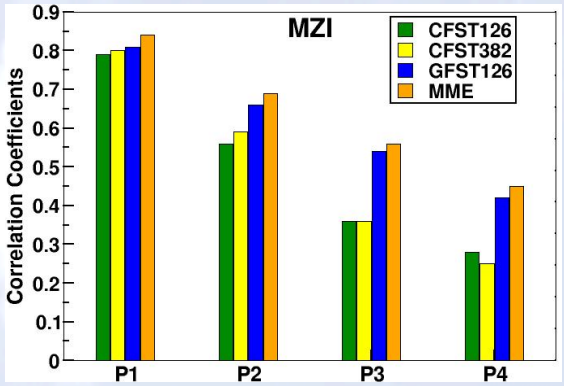
As far as Users concerned, Forecast consensus is very much Important

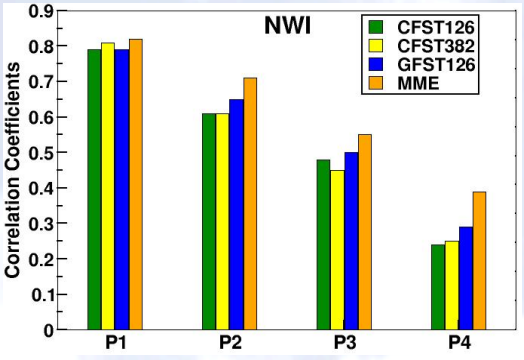
Towards the development of
CFS Grand Multi Model Ensemble (CGMME) Prediction System

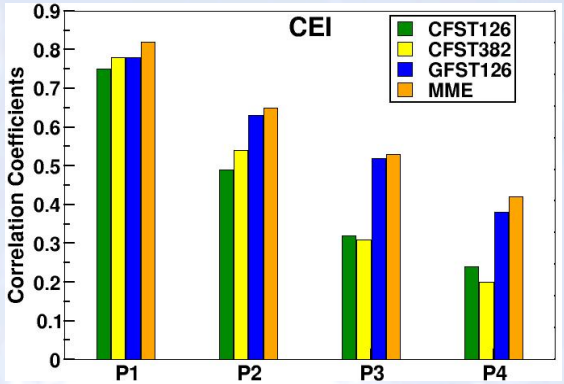


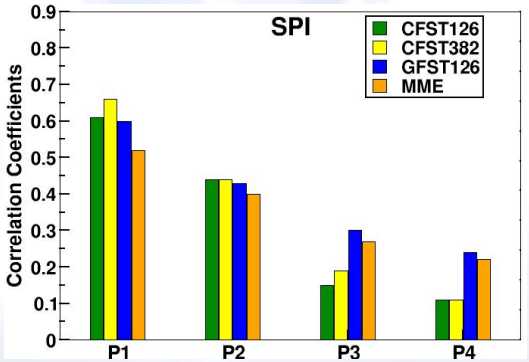
Preliminary results from MME:

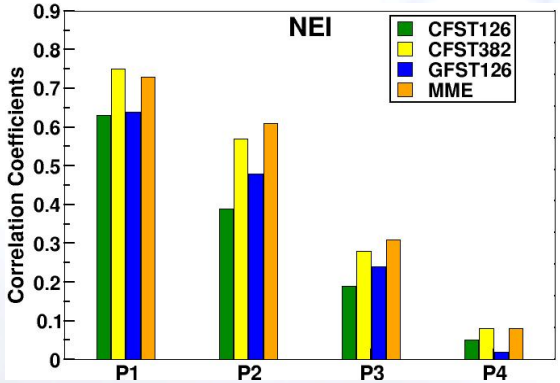












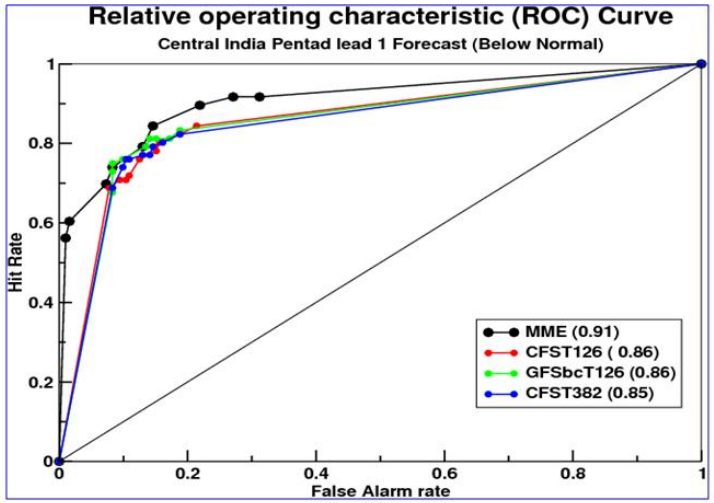


Fig. 7: ROC for Below normal

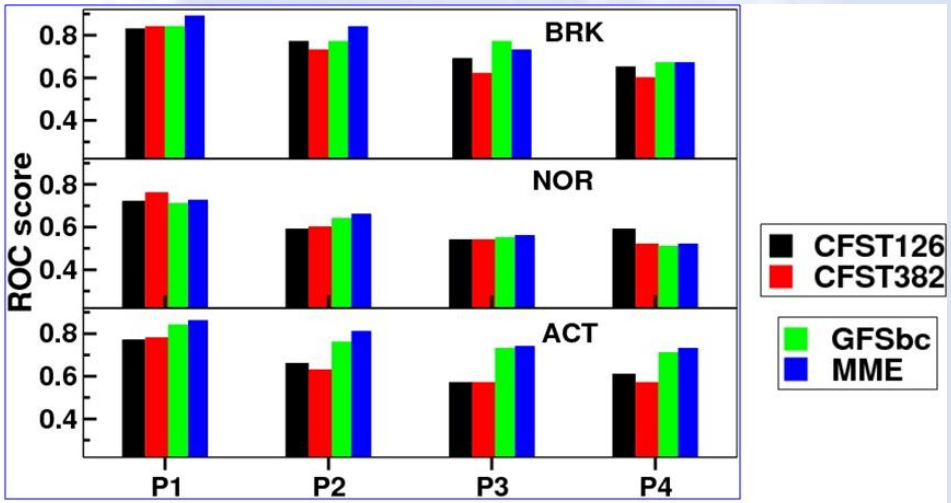


Fig. 8: Area Under ROC

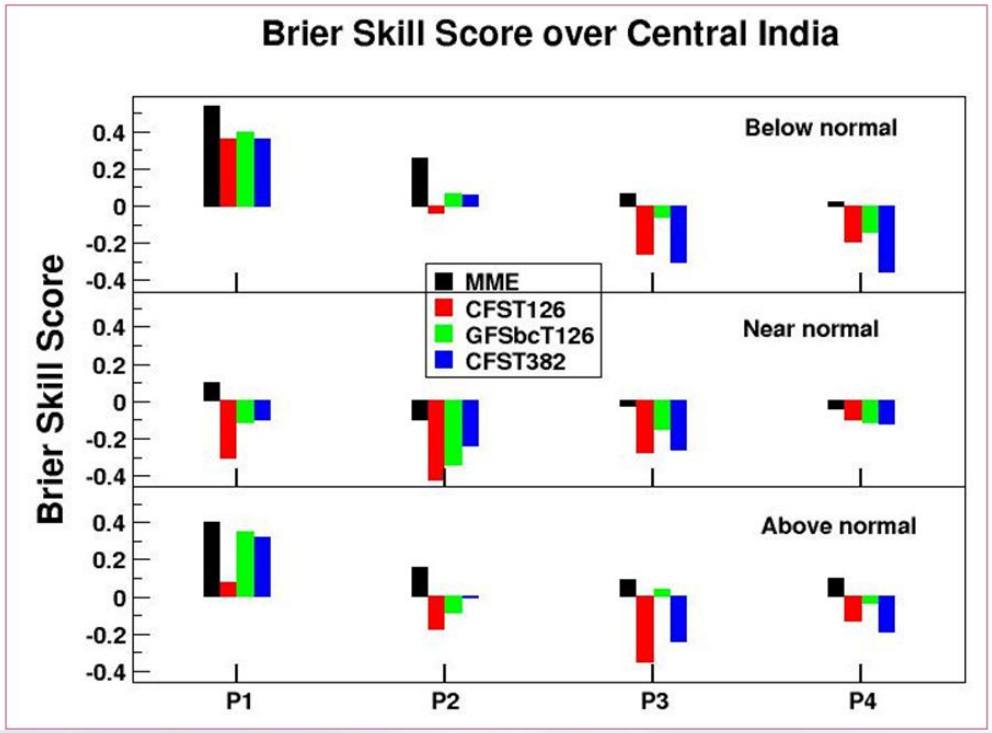
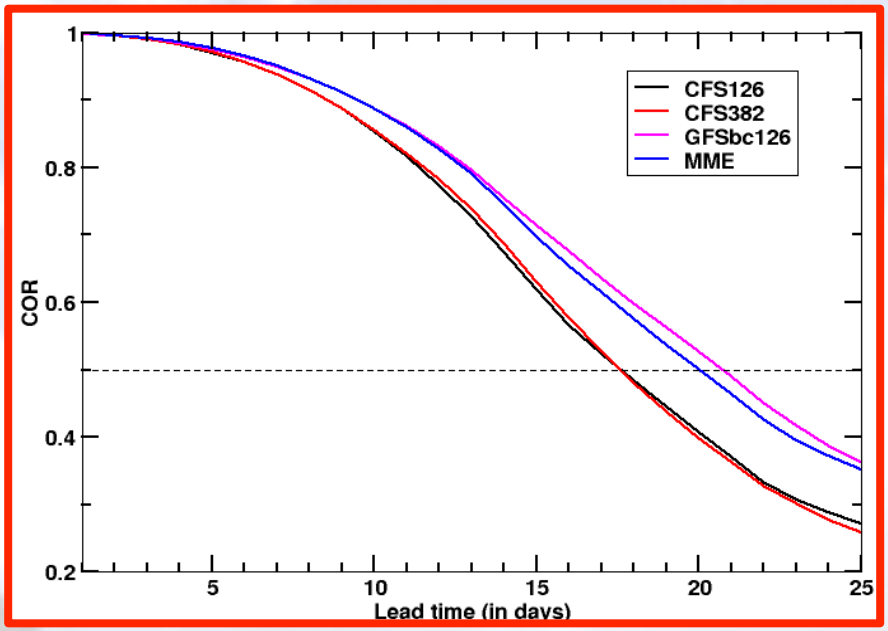


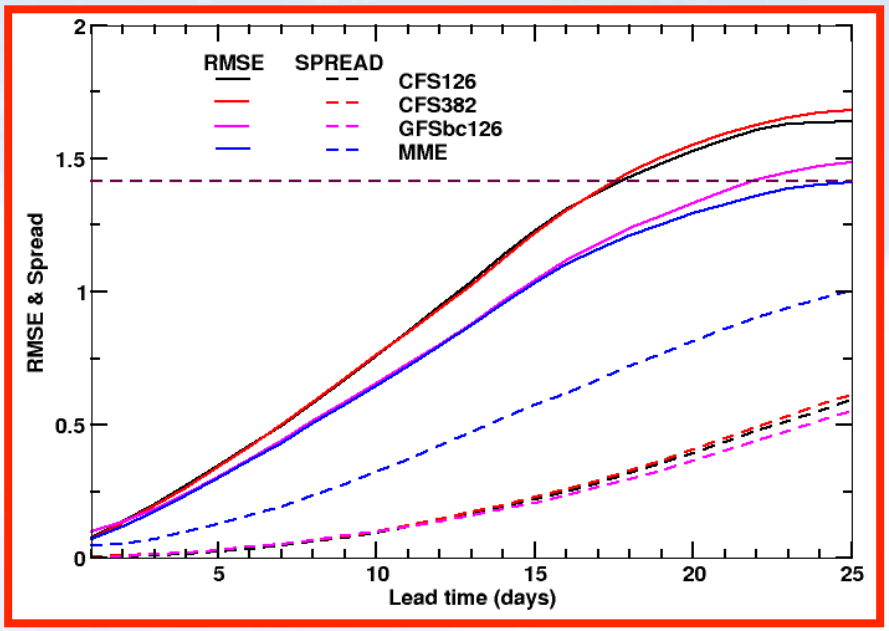
Fig. 9 BSS of active, break and normal categories

Standard Forecast Verification: Bivariate correlation and RMSE

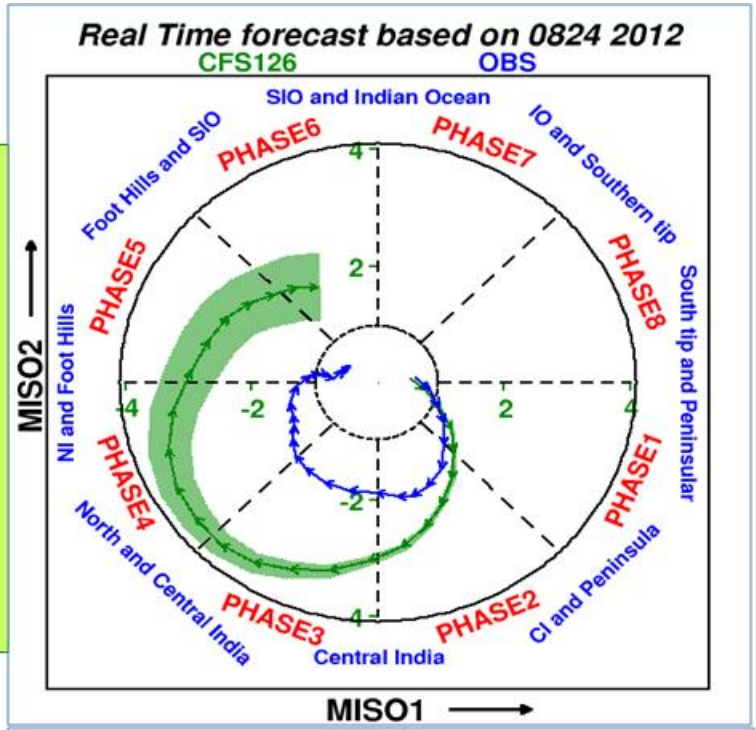
$$cor(\tau) = \frac{\sum_{t=1}^{N}\left(a_1(t)b_1(t,\tau)+a_2(t)b_2(t,\tau)\right)}{\sqrt{\sum_{t=1}^{N}\left[a_1^2(t)+a_2^2(t)\right]}\sqrt{\sum_{t=1}^{N}\left[b_1^2(t,\tau)+b_2^2(t,\tau)\right]}}$$

$$RMSE(\tau) = \sqrt{\frac{1}{N}\sum_{t=1}^{N}\left\{\left[a_1(t)-b_1(t,\tau)\right]^2+\left[a_2(t)-b_2(t,\tau)\right]^2\right\}}$$

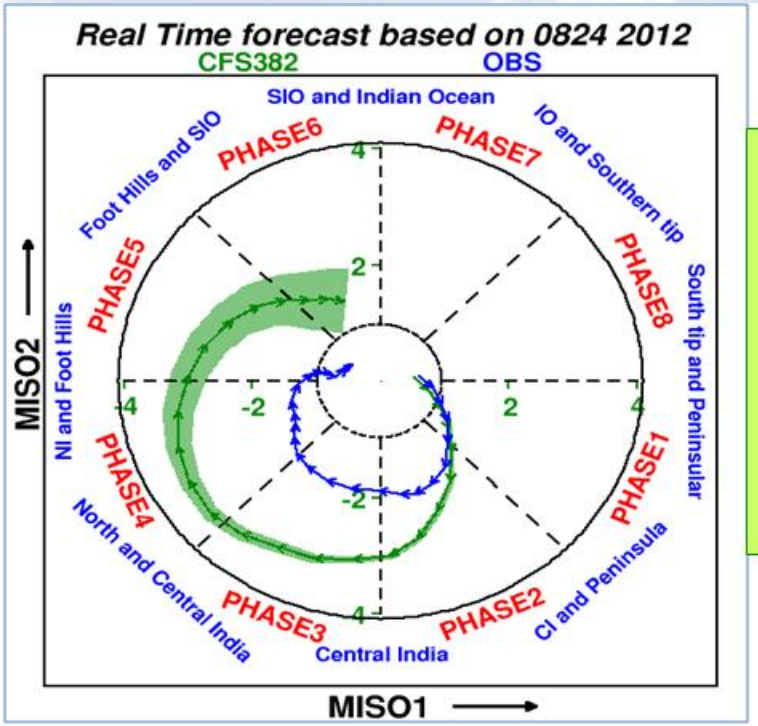




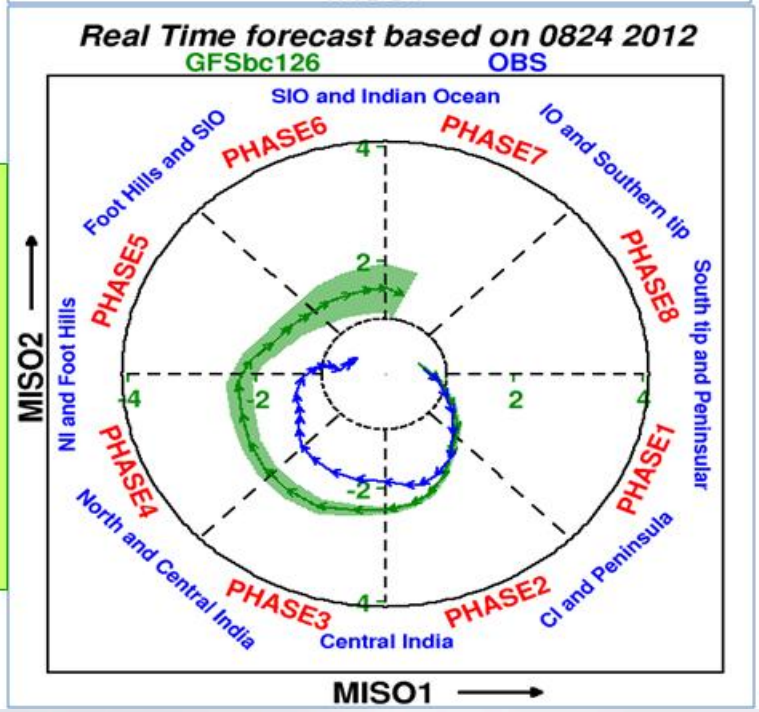
CFSv2_T126



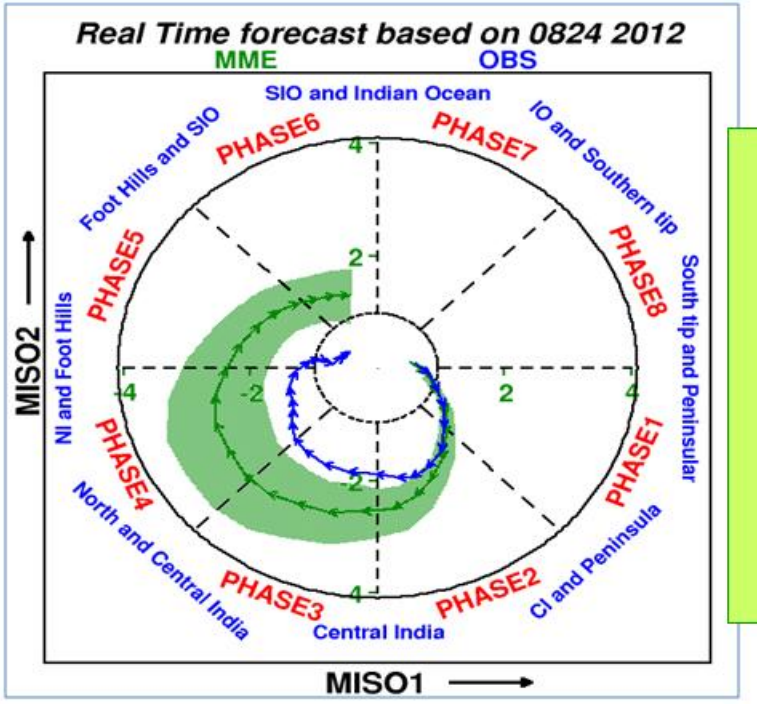
CFSv2_T382



GFSv2_T126

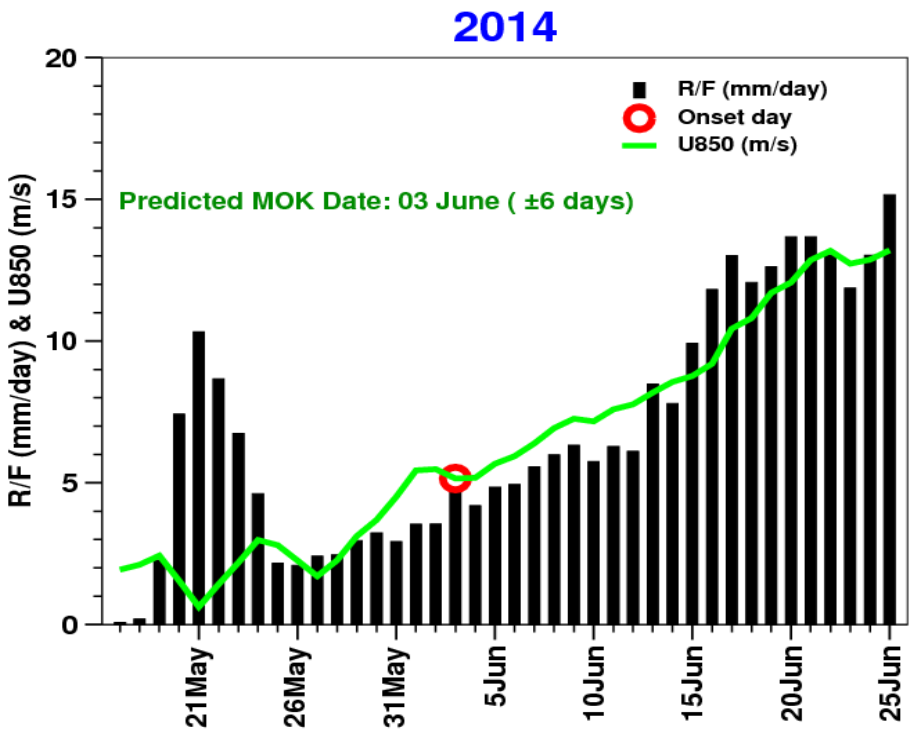


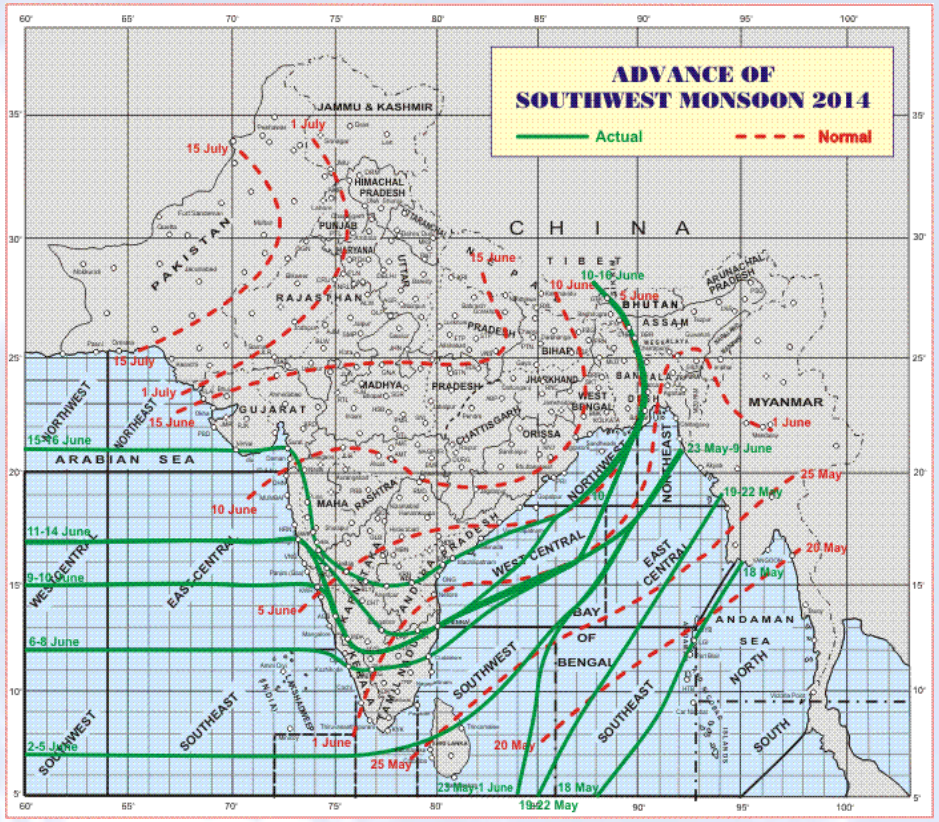
MME(CGEPS)



Highlights of 2014 Real-time prediction

Monsoon Onset over Kerala



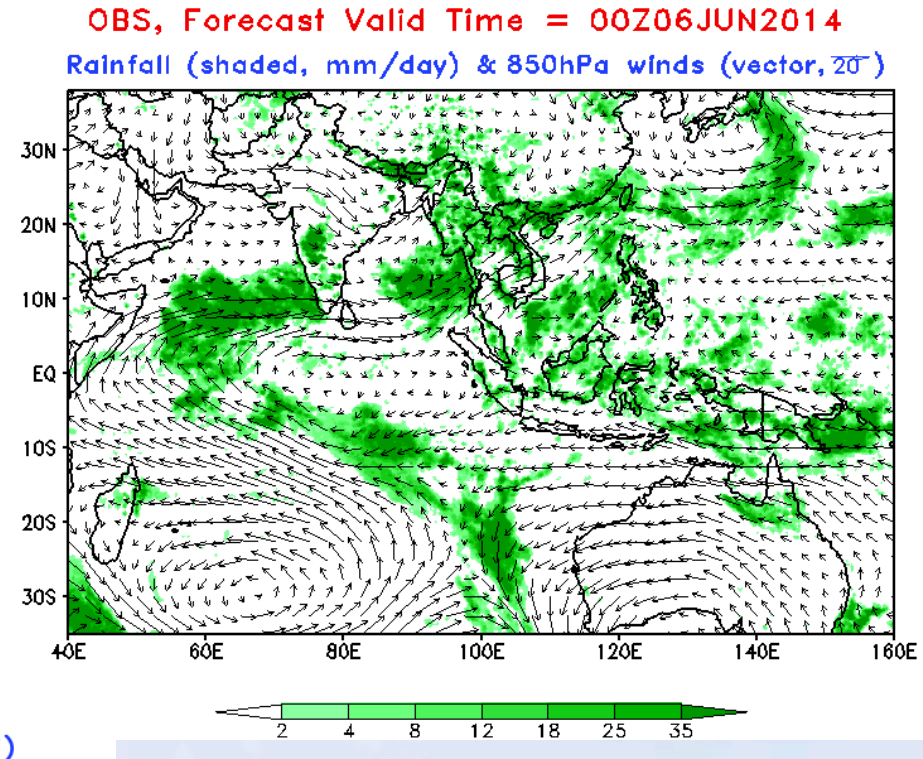


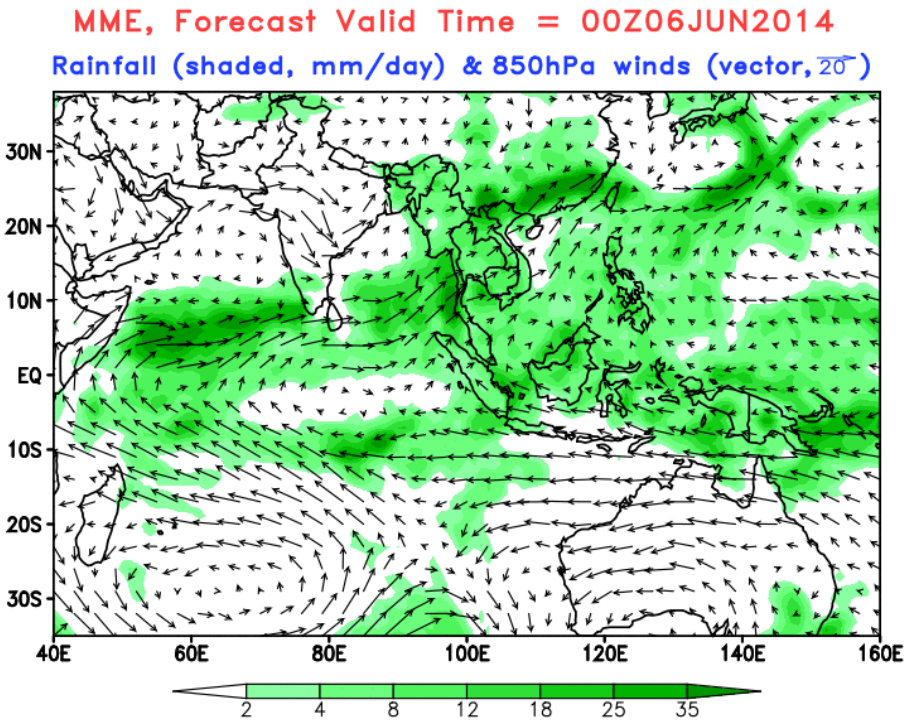
IMD Declared MOK: 06 June
Predicted MOK : 03 June
from 16 May IC

Real-time experimental CGMME forecasts from IITM can be accessed at : http://www.tropmet.res.in/erpas/

Progression of ISM from 05 June 2014 IC

NCEP/TRMM Analysis

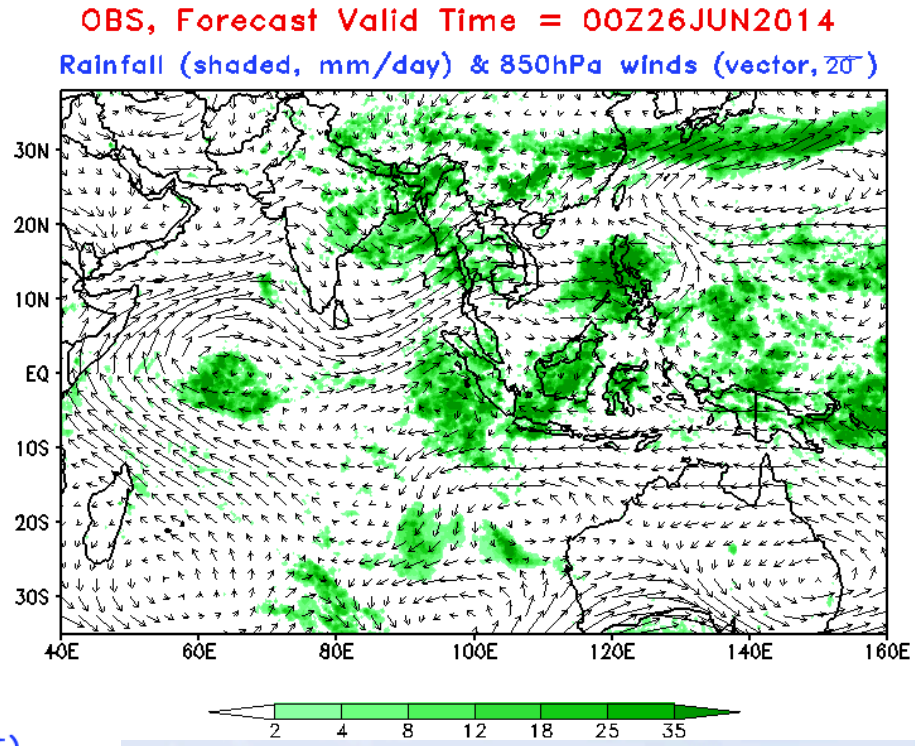


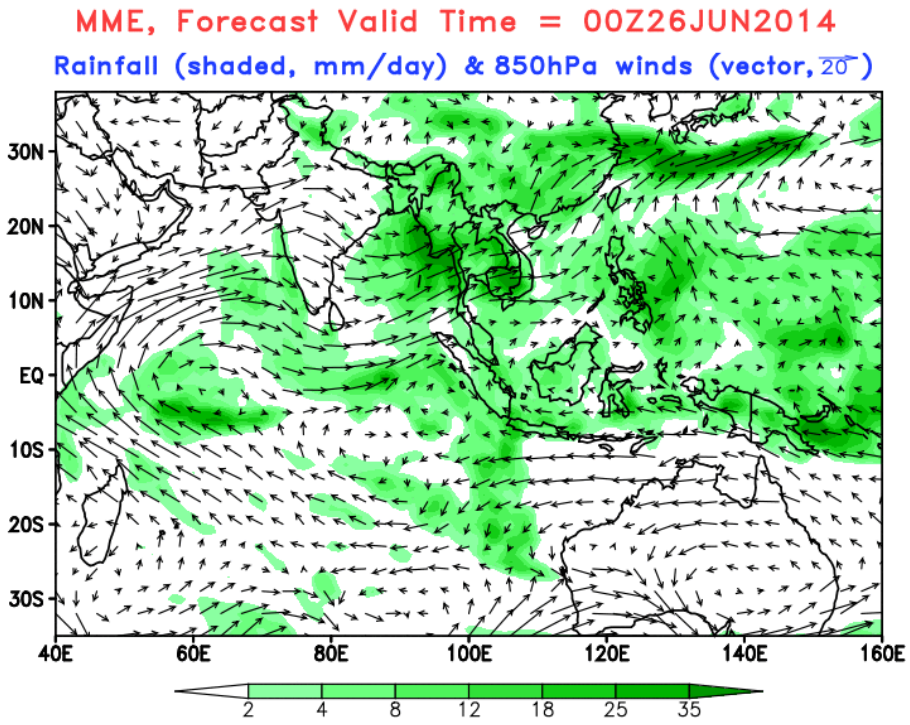


MME

Revival of ISM from 25 June 2014 IC

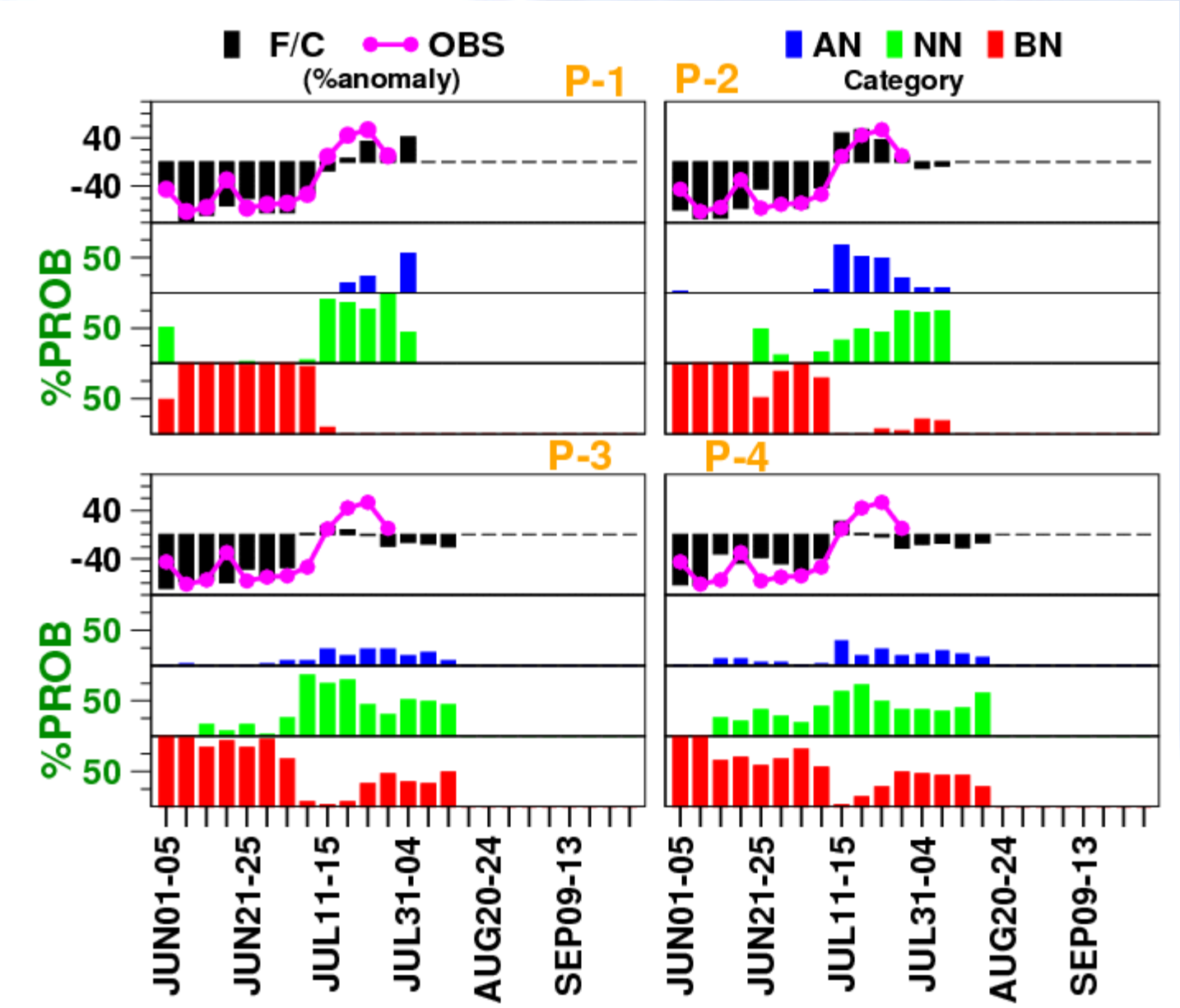
NCEP/TRMM Analysis



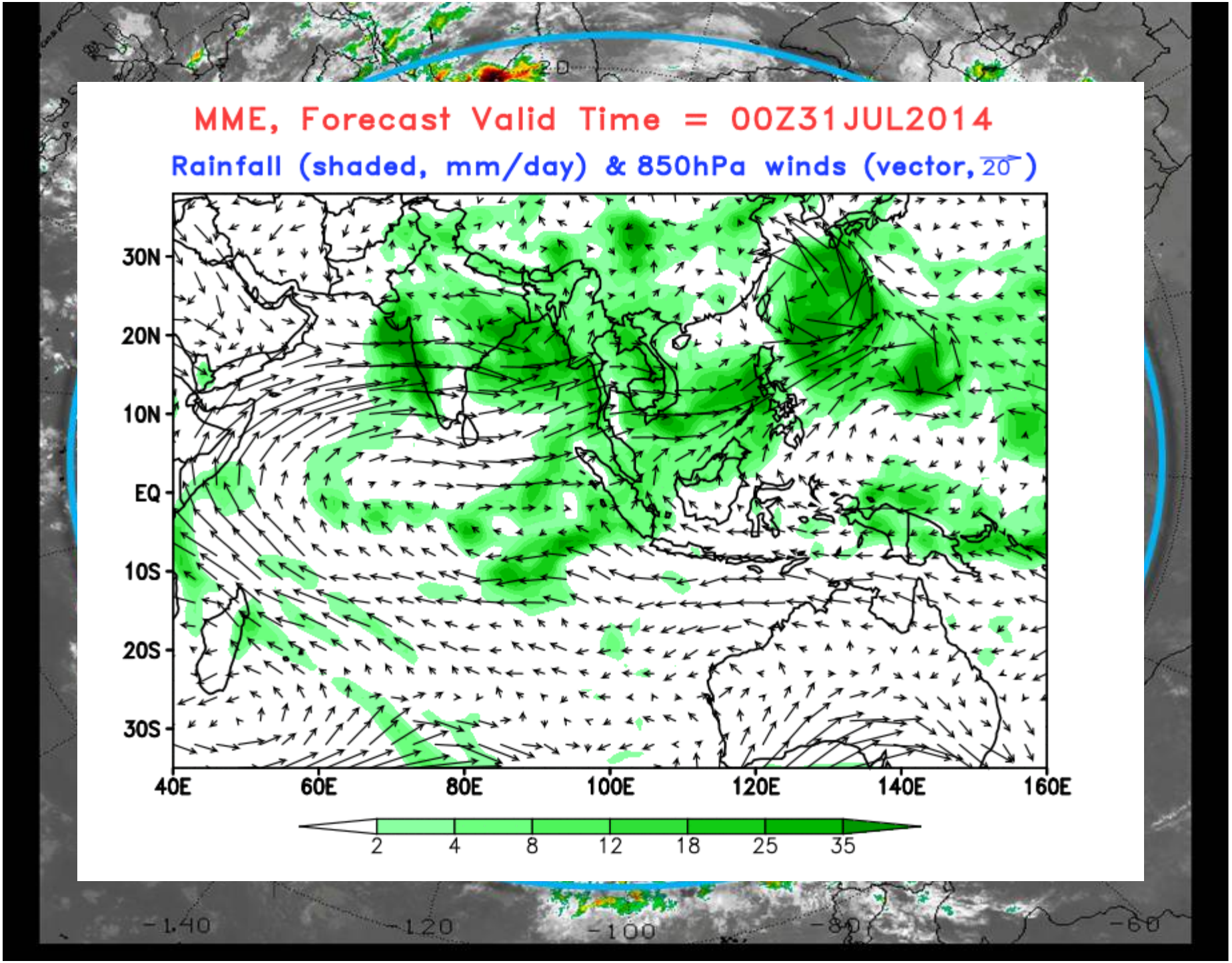


MME

Verification of area averaged rainfall over homogeneous regions predicted by MME



MZI


MME, Forecast Valid Time = 00Z31JUL2014
Rainfall (shaded, mm/day) & 850hPa winds (vector, 20)
30N
20N
10N
EQ
10S
20S
30S
40E
60E
80E
100E
120E
140E
160E
2
4
8
12
18
25
35

History of Evolution of the ERPS at IITM

2011: Implemented the EPS using CFSv2T126 in real-time for internal experimental prediction.

2012: Started issued the CFSv2T126 forecasts to IMD on experimental basis

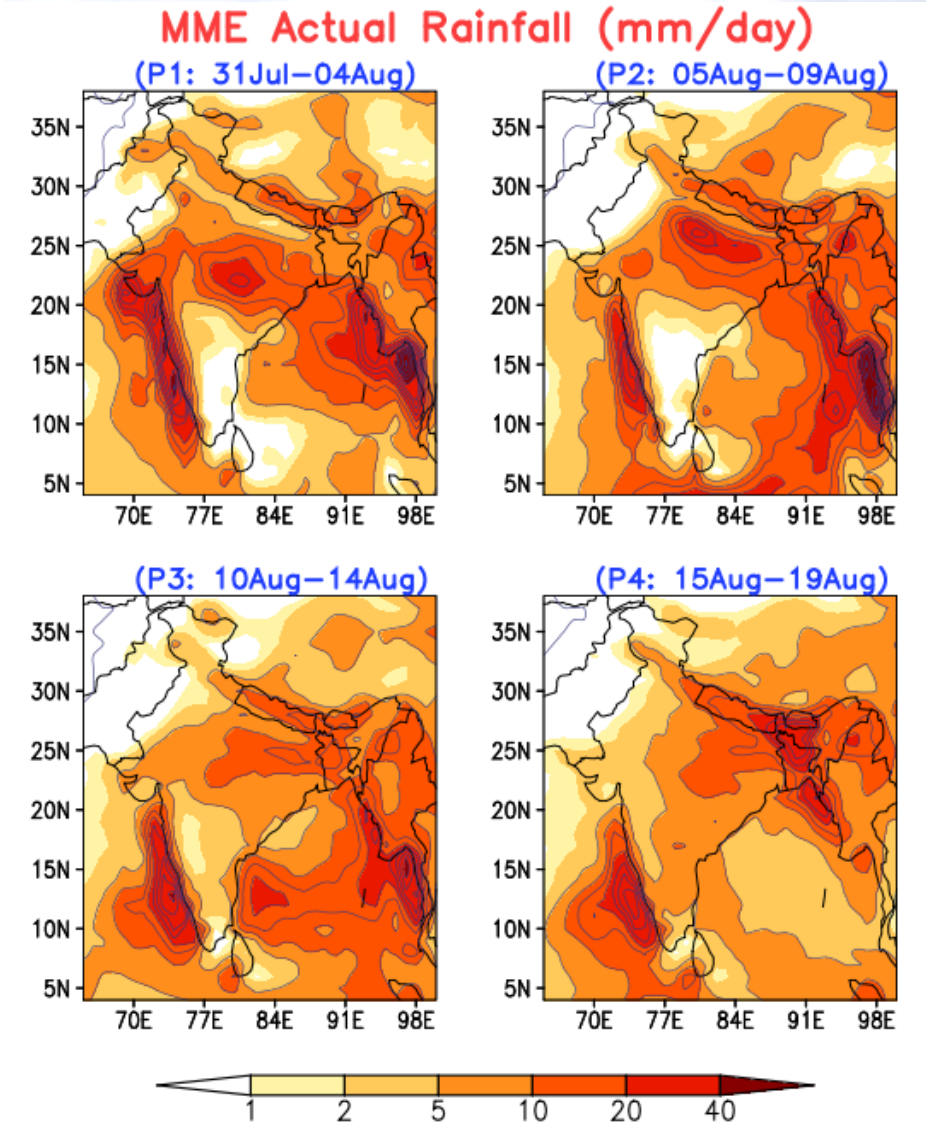
2013: The forecasts with CFSv2T126 and GFSbc were made available publicly in our web-site. Several user agencies started using the products in real-time mode.

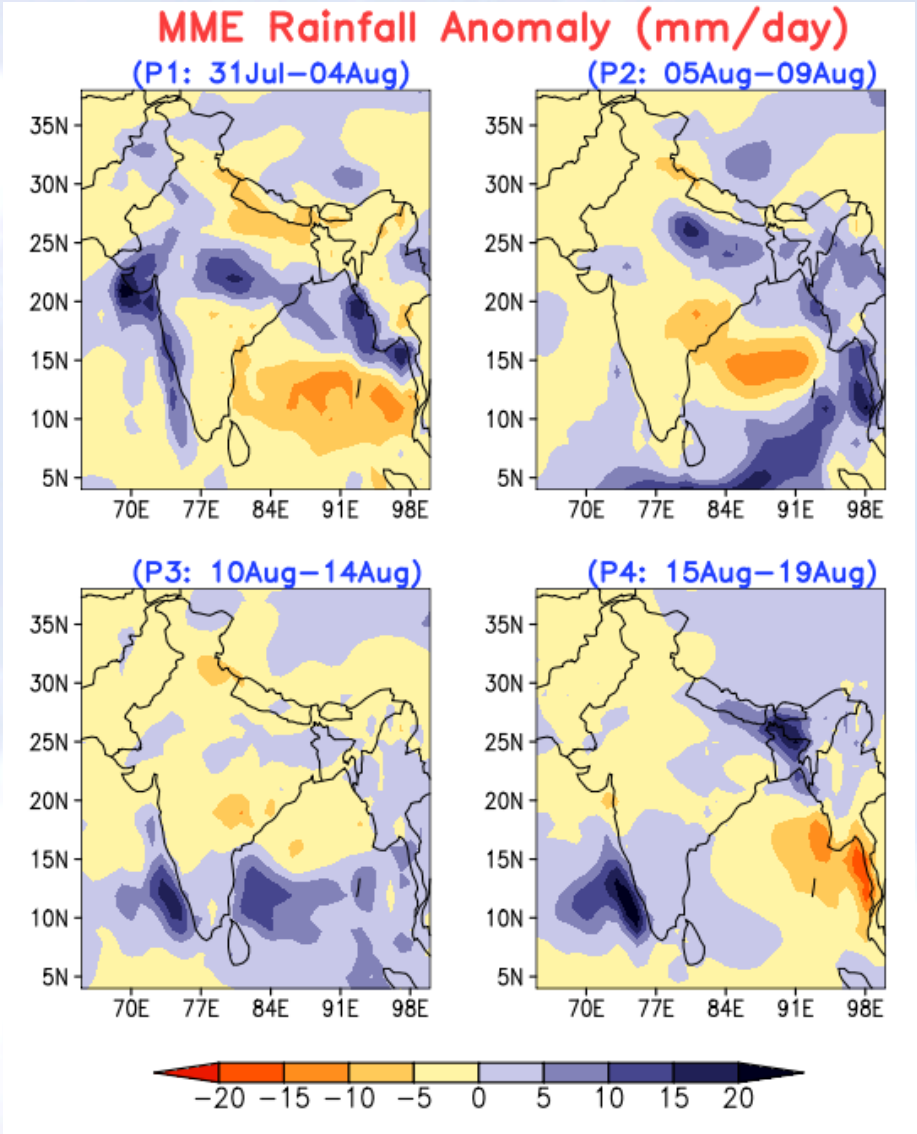
2014: Implemented the CGMME in the operational mode and the forecasts are made available in http://www.tropmet.res.in/erpas/

Thanks……

Any Queries???

Pentad wise rainfall predicted by MME



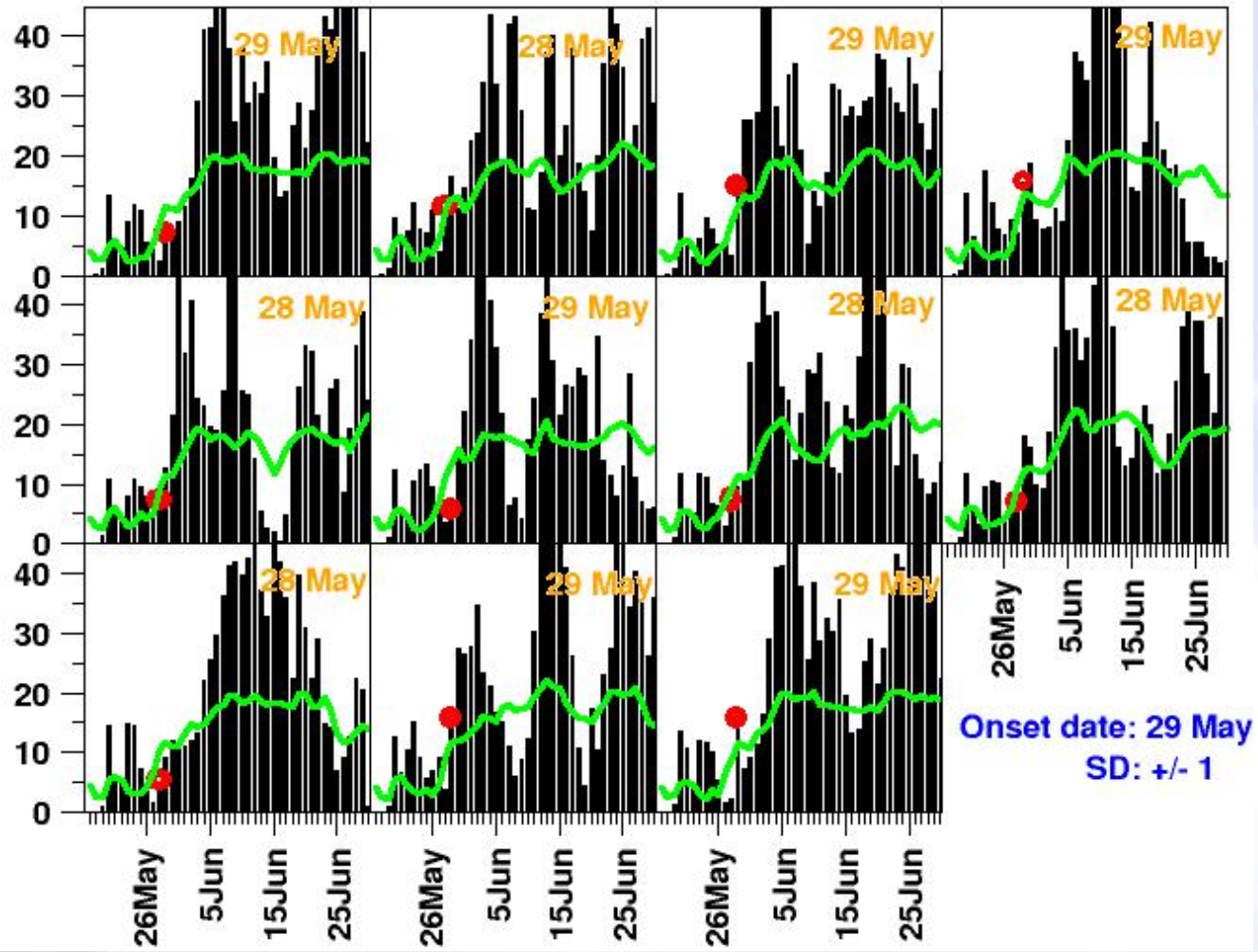


Highlights of 2013 Real-time prediction

Forecast of Monsoon Onset over Kerala

Based on 16 May 2013: 29 May 2013

Onset declared by IMD: 1st June 2013

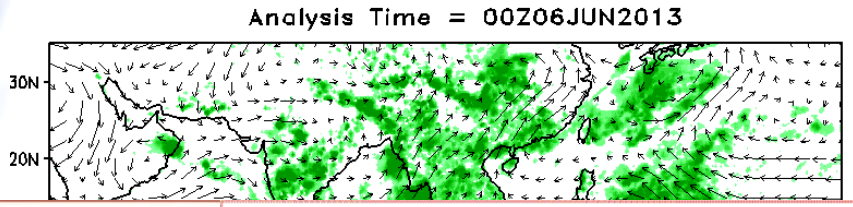


Onset date forecasts are obtained from each 11 member of CFSv2 45 day forecast. Then ensemble mean is given as the final forecasted onset date.

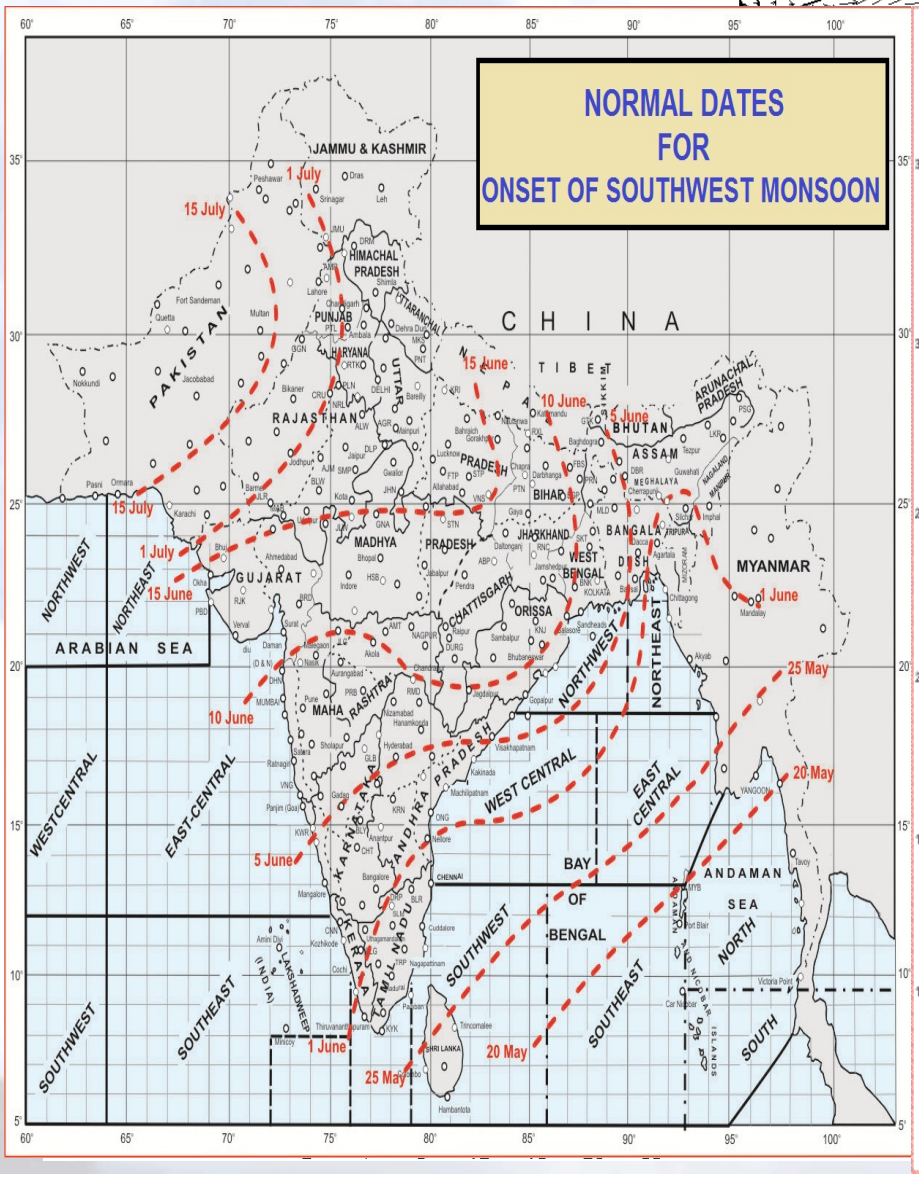
Y axis on each panel is in mm/day for rainfall (bars) and m/s for 850hPa wind(green line).

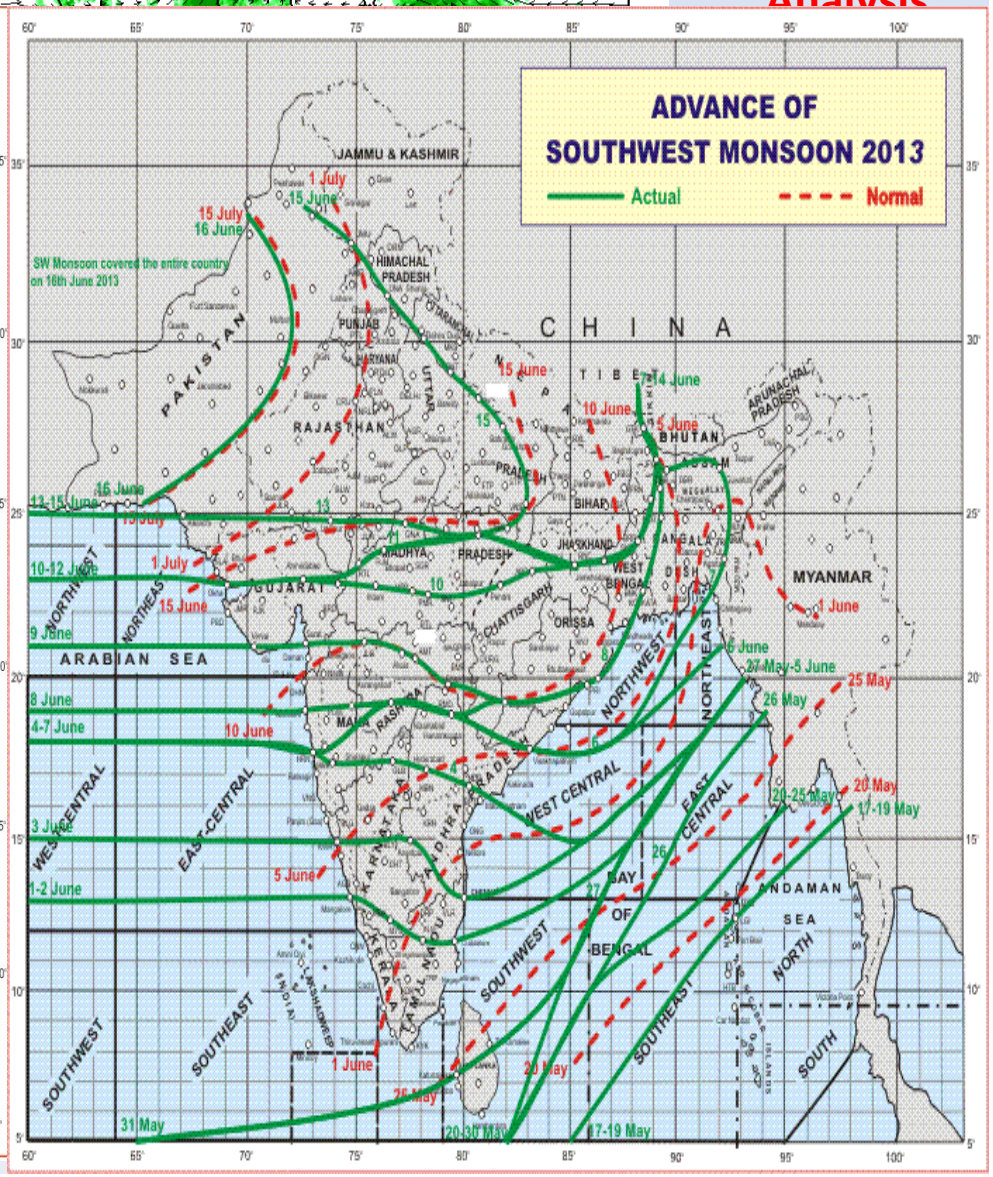
Red circle is the onset date and also written at the top of each panel

Rapid advancement of monsoon was well-predicted from 5 Jun IC



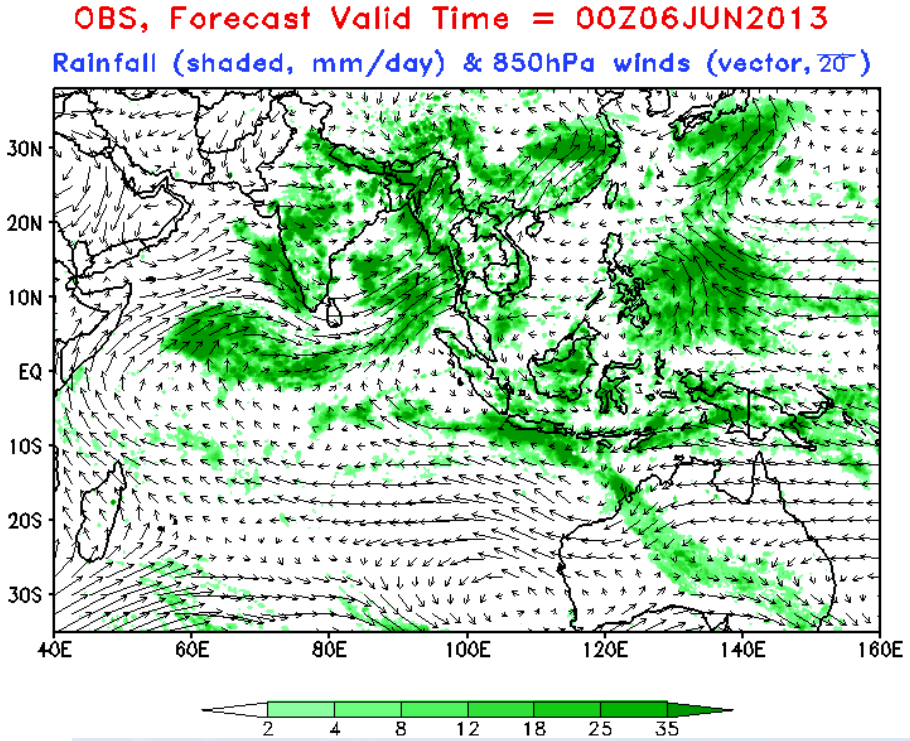
NCEP/TRMM Analysis

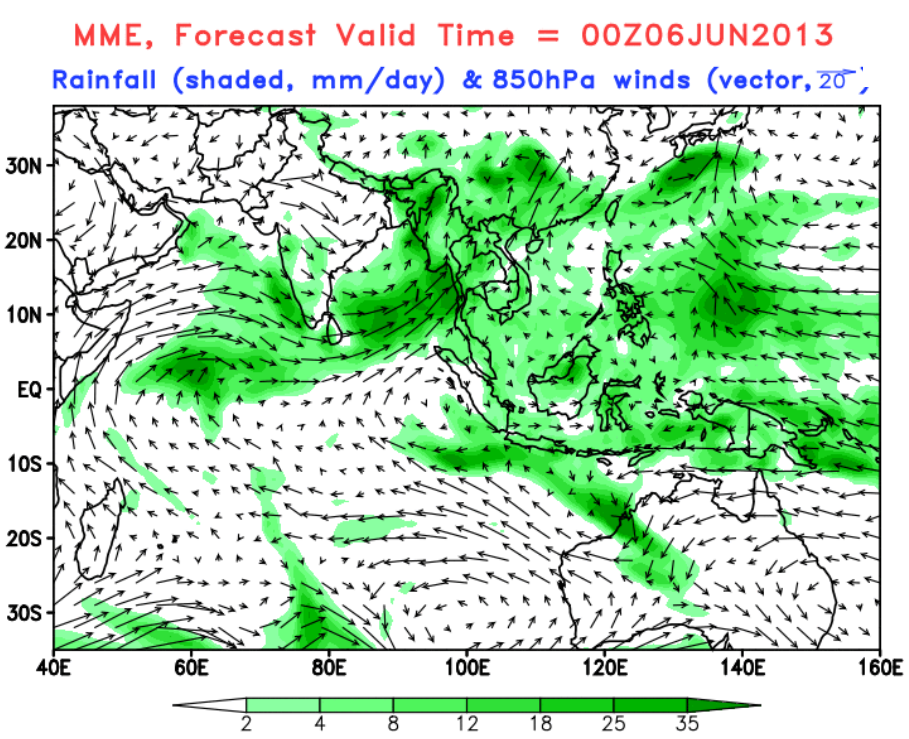




Progression of ISM from 05 June 2013 IC

NCEP/TRMM Analysis

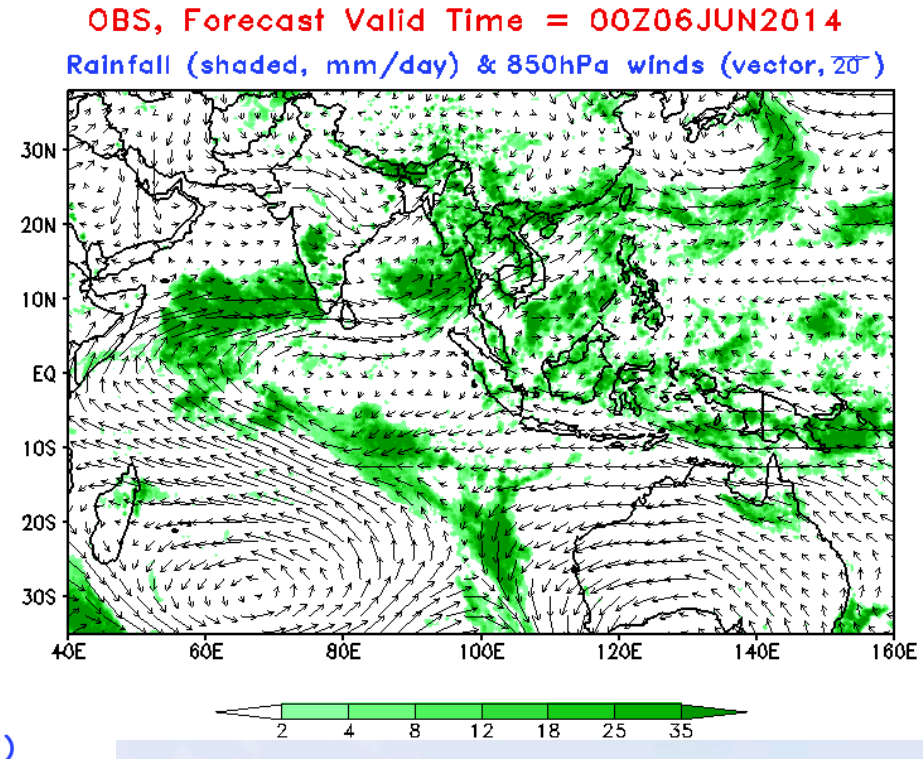


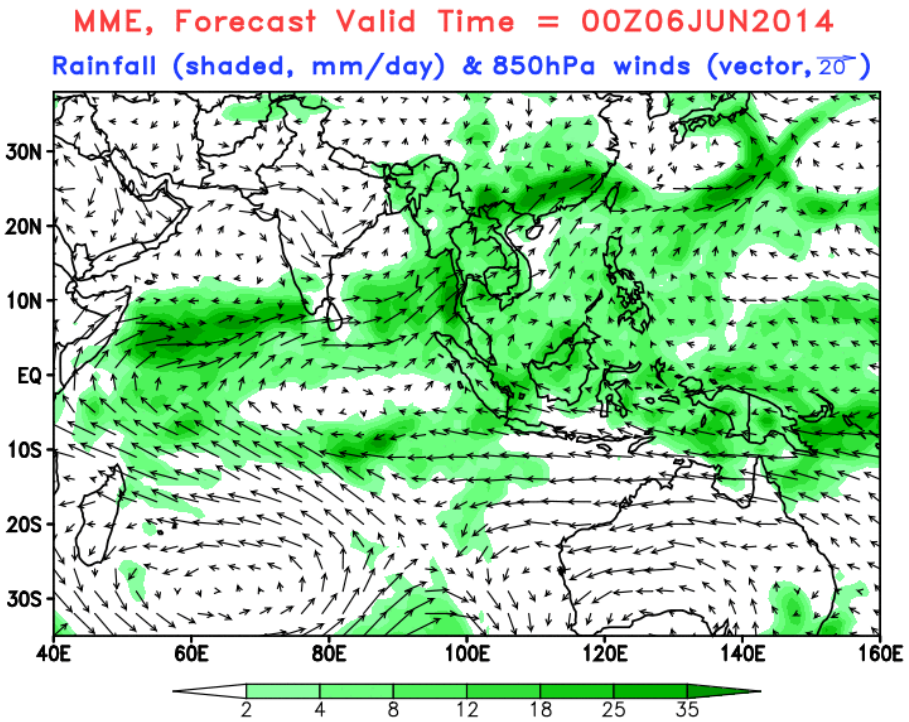


MME

Progression of ISM from 05 June 2014 IC

NCEP/TRMM Analysis





MME

How MISO is computed:

(ref: Suhas etal., 2012)

- **Extended EOF analysis is carried out similar to Wheeler and Hendon 2004 using standardized rainfall anomalies up to lag -15 days, averaged between 60-95E for the latitudes -12 to 30. The rainfall anomalies for the lag days are appended side by side to create the extended data matrix.**
- **The EOF analysis is carried out using IMD-TRMM merged data from 1998-2011. The real time data for 2013 is projected onto the EOFs created from the 14 years of past data.**
- **The amplitude of EOF1 and EOF2 (PC1 and PC2) are plotted in a PC1/ PC2 phase space similar to Wheeler Hendon 2004 to get an idea of the evolution of ISO and its strength.**

Strategy and highlights of 2013 Real-time prediction

Model has been integrated for 45 days for each 11 ICs at five day intervals starting from 16th May (Eg: 16May, 21May, 26May, 31May, 05Jun.....etc) at CFS T126 resolution and bias corrected SST from CFSv2 has been used to force GFSv2bc.

Forecast & Verification

- **Monsoon Onset over Kerala (MOK) was predicted well from 16 May initial conditions (29 May 2013).**
- **Rapid advancement of 2013 monsoon and the incidence of Uttarakhand heavy rainfall event was predicted well in advance by the models from 05 June initial conditions.**
- **Prediction of reduced rainfall activity in the end of August helped Pune Municipal Corporation in planning their road-repairing works.**
- **The revival of monsoon was well predicted from 08 September initial conditions, which helped IMD in declaring the withdrawal of monsoon.**
- **The extended range forecasts were widely utilized by Agromet Division of IMD to prepare the fortnightly agromet advisory bulletins**