Synoptic Scale Systems and Extended Range Prediction

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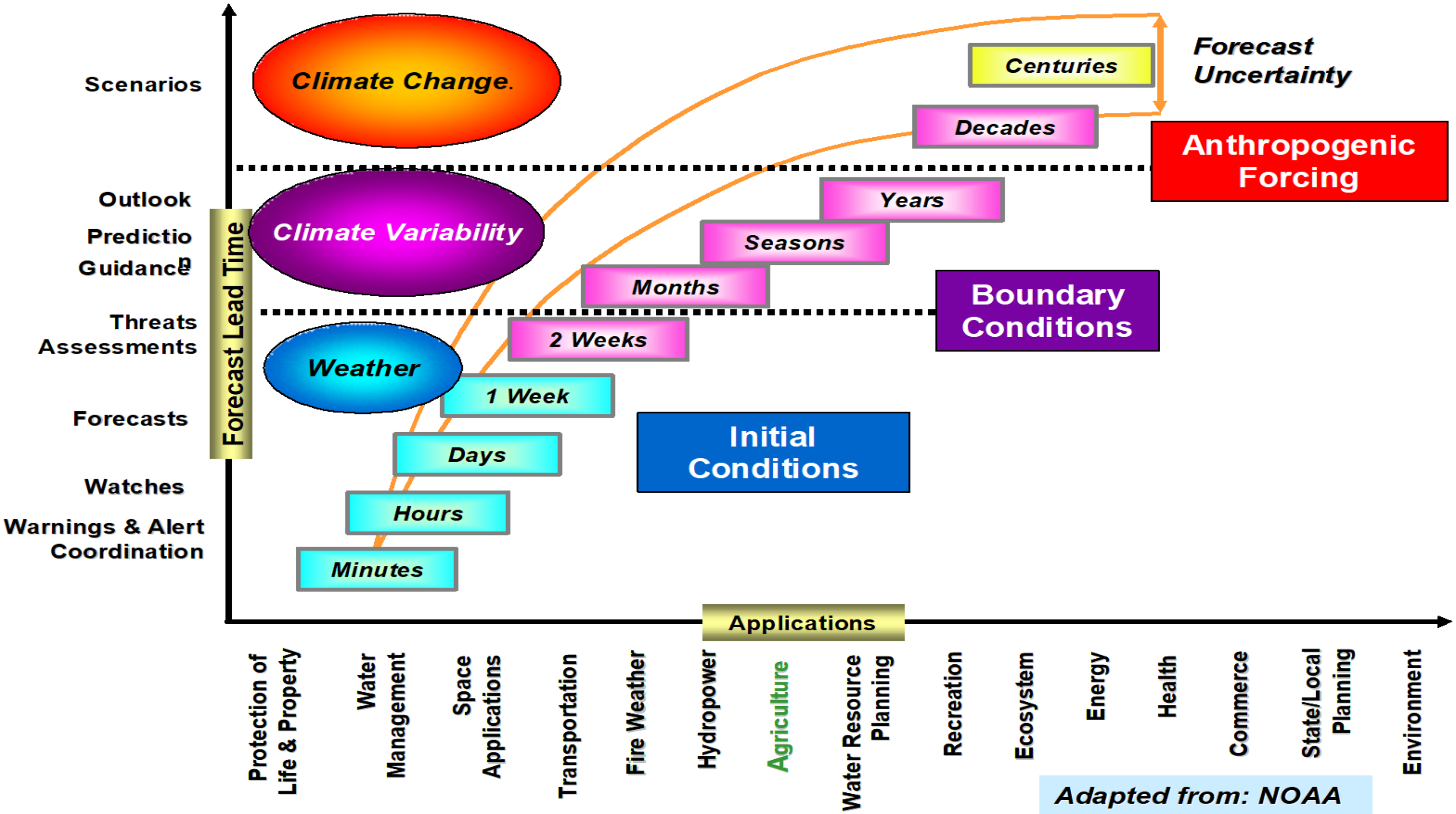
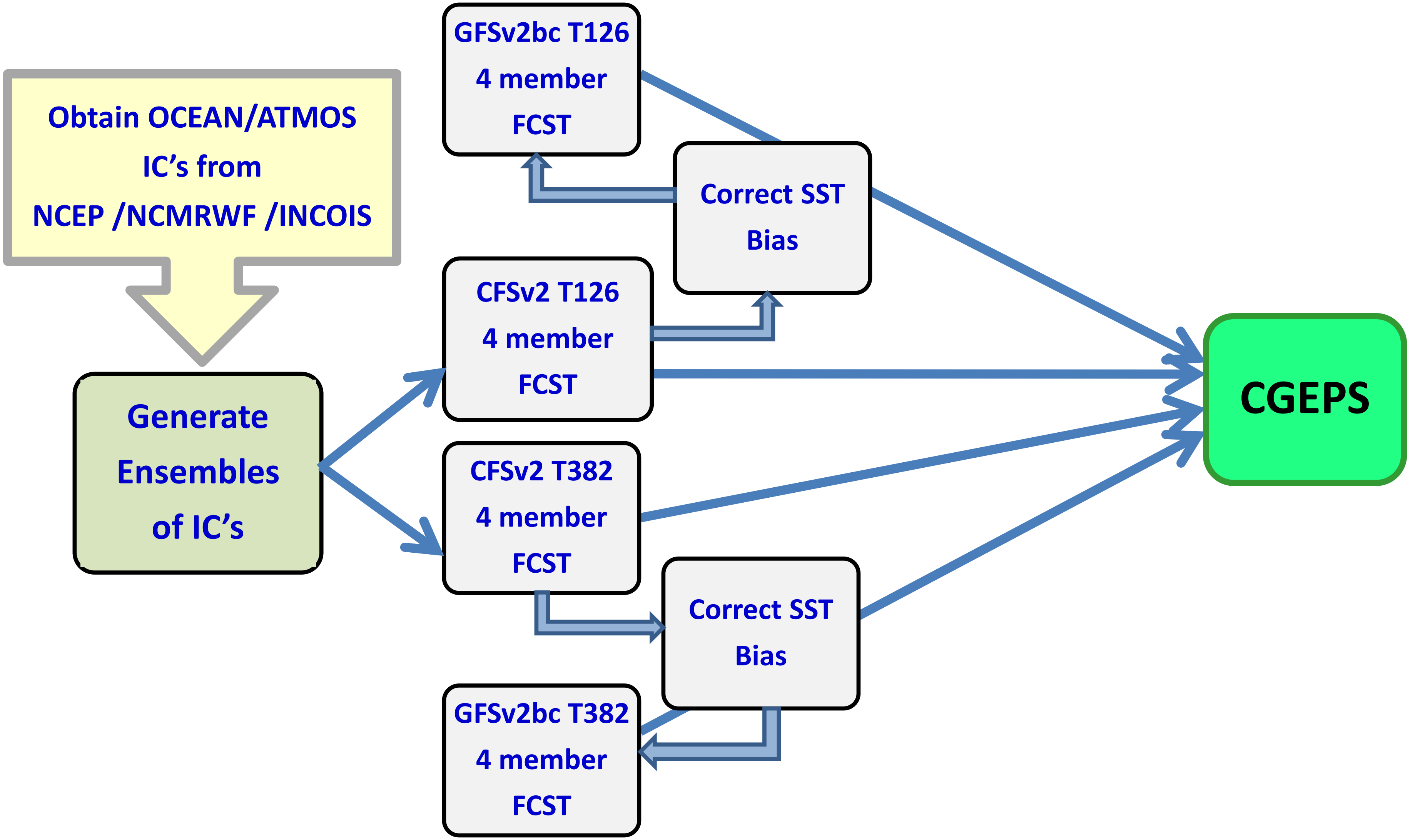
CLIMATE PREDICTION FRAMEWORK

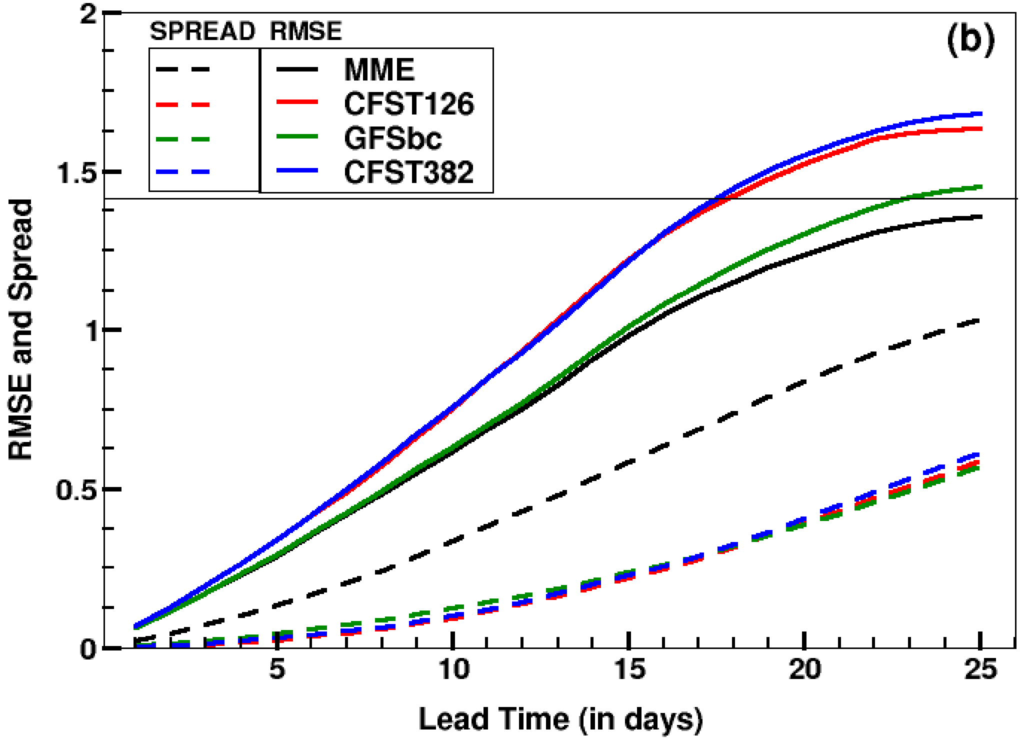


Weather • Climate • Water

IITM Ensemble Prediction System



RMSE and spread of MISO indices (IITM Research Report No. RR-128)



Bivariate RMSE: RMSE w.r.t. observation

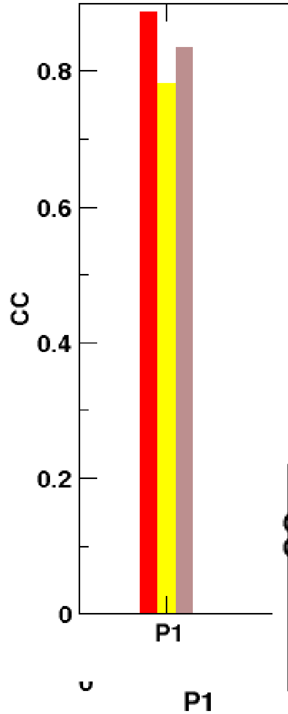
Bivariate Spread: Std. Dev of iindividual models w.r.t. Ensemble mean

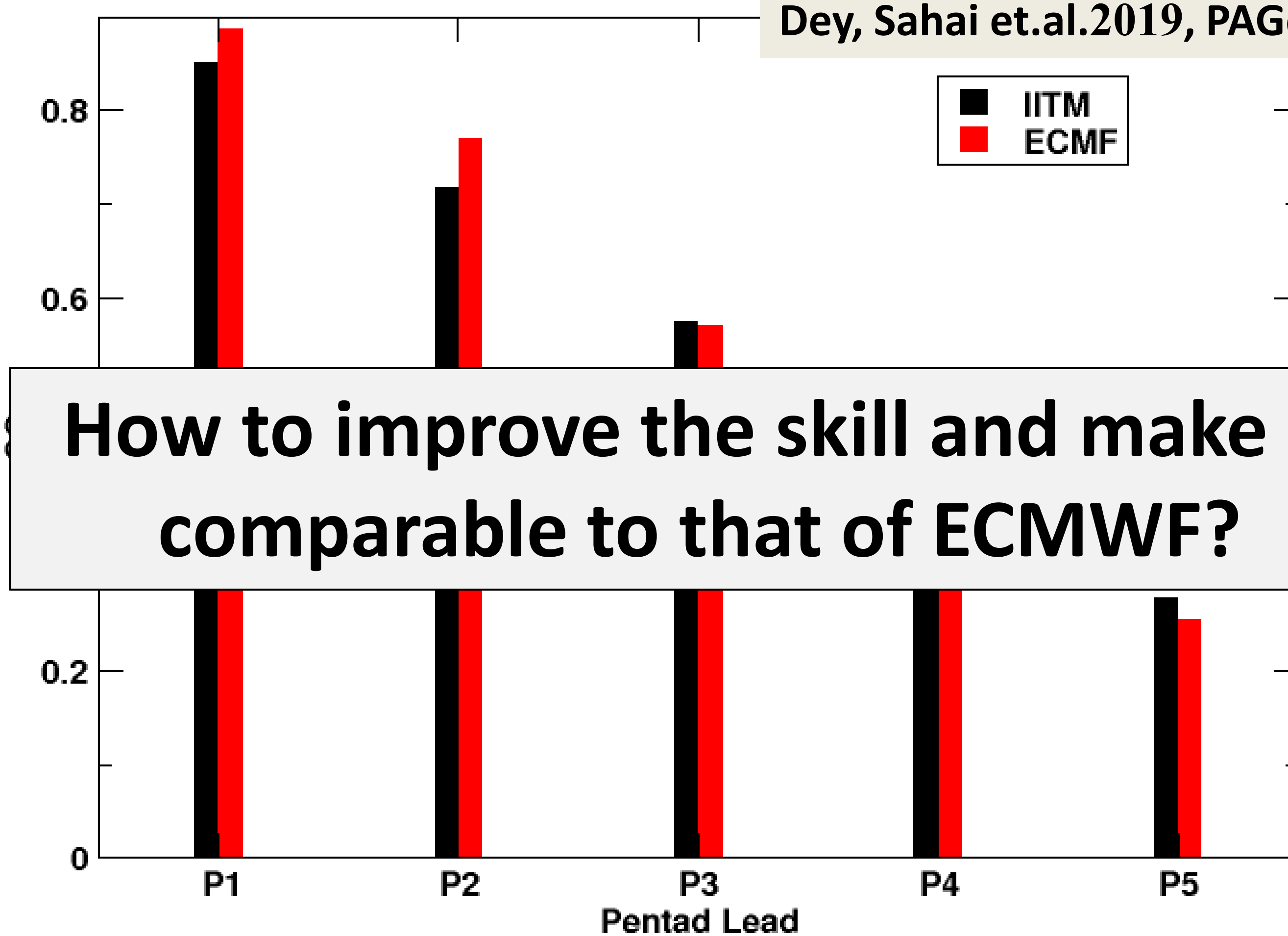
Considerable improvement in MME is contributed from the increased spread, which overcomes the under-dispersive nature of the individual models in EPS.

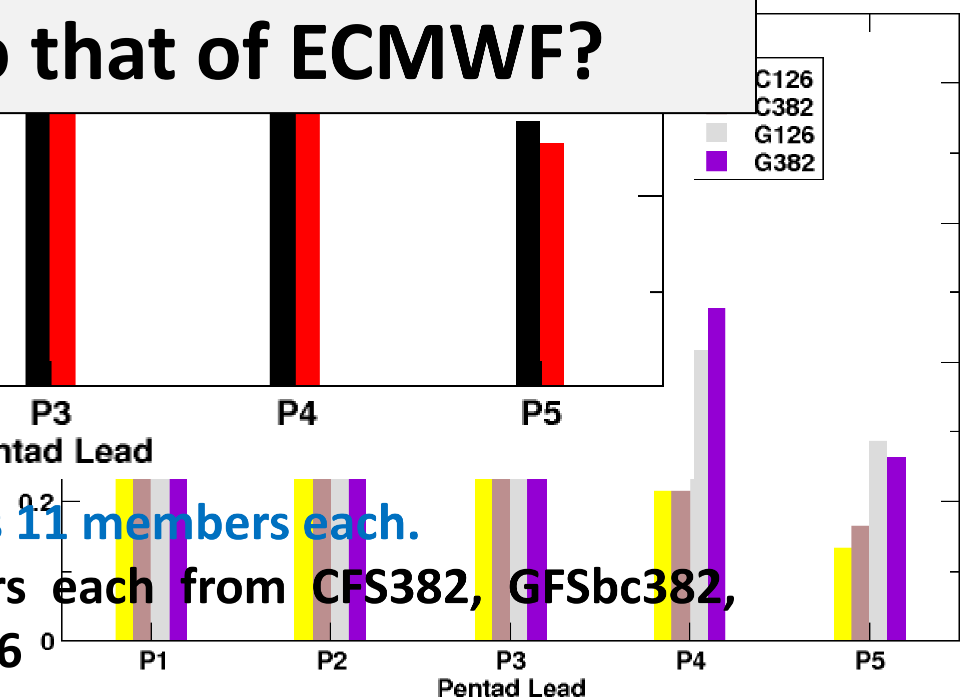
Abhilash, Sahai et al. 2015, JAMC; BAMS

Comparison of IITM-ERPS with ECMWF

Chattopadhyay, Sahai et. al. IITM RR-139
Dey, Sahai et.al.2019, PAGeoph







s much less
leads

How to improve the skill and make it comparable to that of ECMWF?

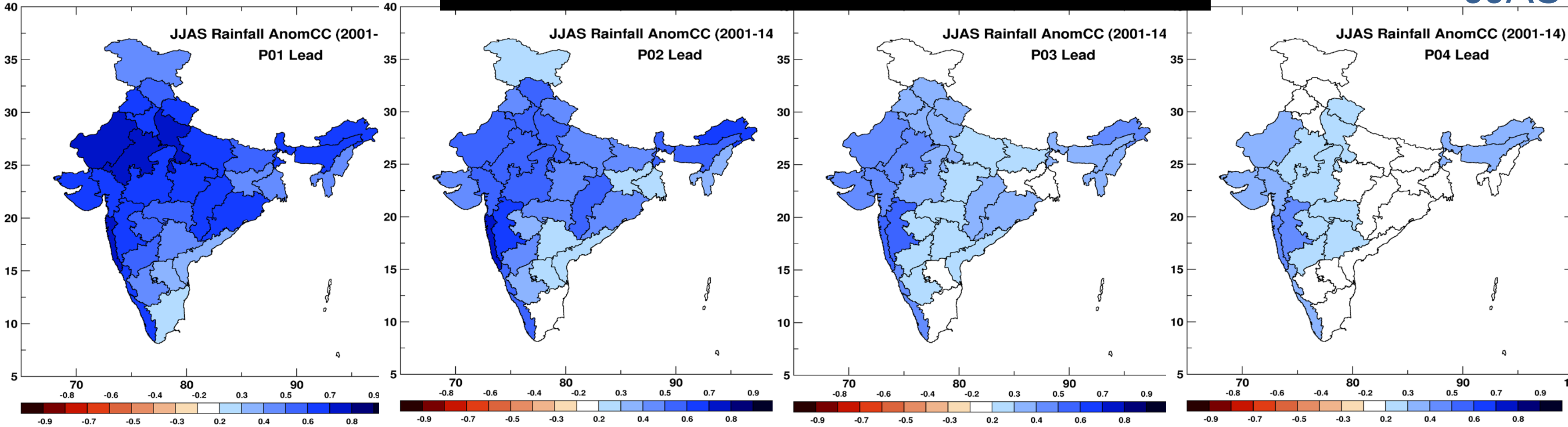
Both prediction systems has 11 members each.

IITM-MME uses 3 members each from CFS382, GFSbc382, GFSbc126 and 2 from CFS126

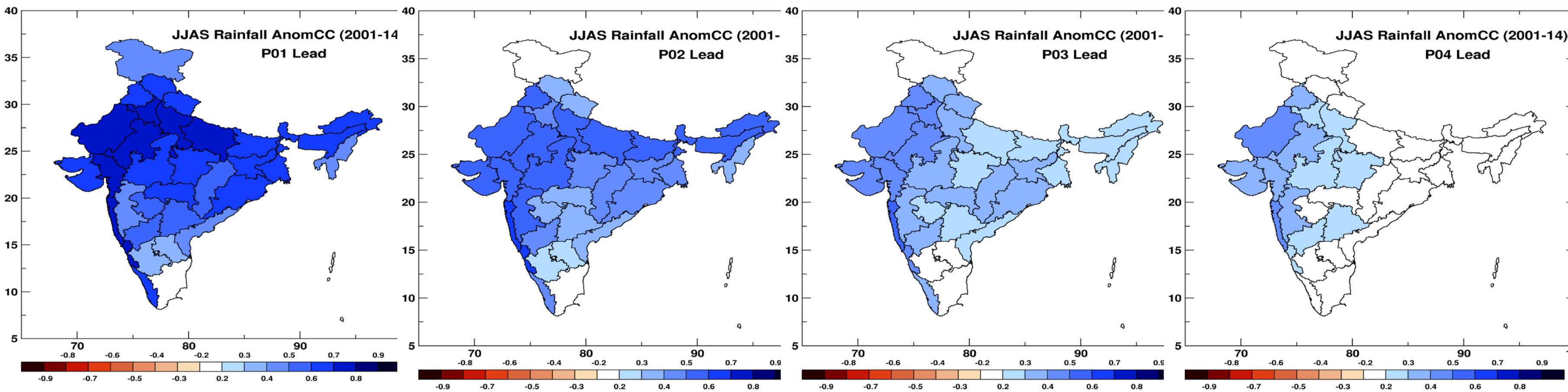
Subdivision Wise Statistics

ECMF MME

JJAS



IITM MME

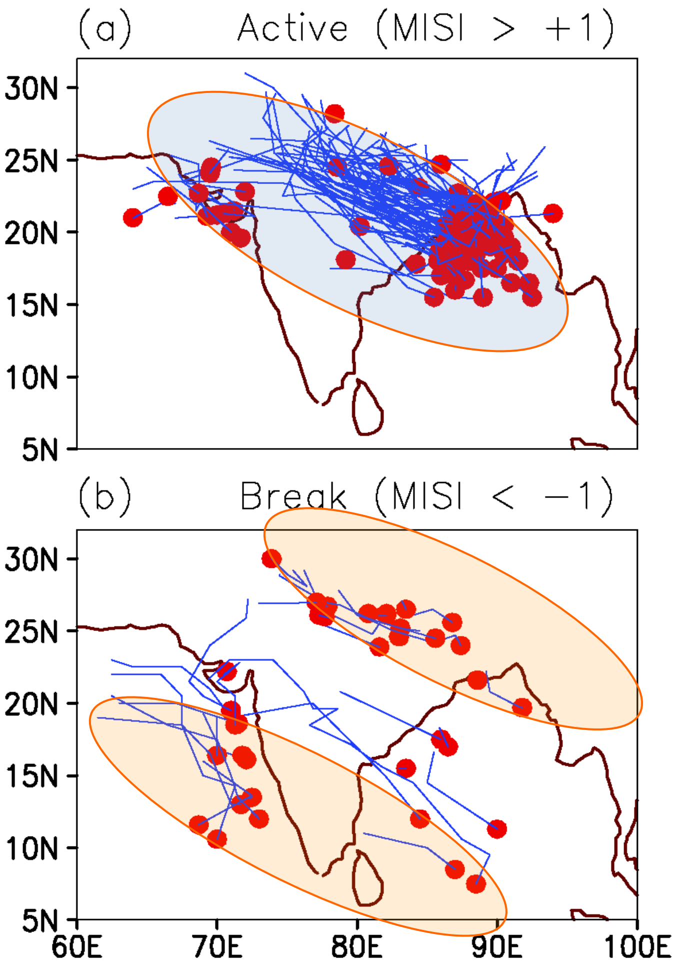


Chattopadhyay, Sahai et. al. IITM RR-139

Issues with extended Range

Cascade of Error in both directions determines the extended range predictability

Mean Back Ground-MISO and Synoptic Scale



Goswami et al. 2003, *GRL*, 30, doi:10.1029/2002GL016734

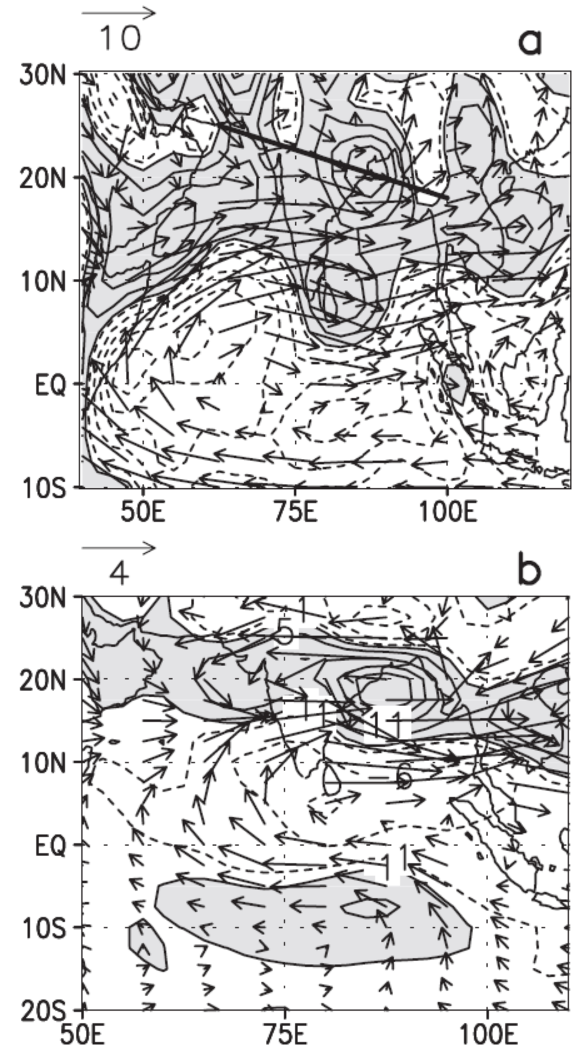


Figure 5. (a) Long term seasonal (June–September) mean vector winds (ms^{-1}) at 850 hPa and associated relative vorticity ($10^{-6}s^{-1}$). Thick line indicates the approximate location of the monsoon trough. (b) Active minus break composite wind anomalies (ms^{-1}) and associated relative vorticity ($10^{-6}s^{-1}$) at 850 hPa during the 40 year period (1954–1993). The region of positive vorticity is shaded with minimum contour of 1 units and contour interval of 5 units in both panels.

Association between droughts and very long breaks (VLB)

Drought Years	Long breaks identified from IMD rainfall data	Drought Years that co-occurred with ElNino (E) / No ElNino (NE)
1951	-	-
1965	2-15 Aug	E
1966	2-12 Jul	NE
1968	22 Aug-5 Sep	E
1972	12 Jul-4 Aug	E
1974	26 Aug-8 Sep	NE
1979	13-29 Aug	NE
1982	27 Jun-8 Jul	E
1985	-	-
1986	23 Aug-8 Sep	NE
1987	16-26 Jul	E
2002	2-31 Jul	E
2004	26 Aug-5 Sep	E

List of drought years (below 10% of its long period average) during the period 1951-2004

- VLBs are identified when the standardized rainfall anomalies, averaged over the Indian core region is below -1.0 for a duration of more than 10 days.
- It may be noted that 85% of ISM droughts during this period are associated with at least one VLB.
- Hence VLBs in the monsoon are responsible for ISM droughts.

Joseph, Sahai et al., 2009, ClimDyn

Modulation of monsoon ISOs by ENSO

		No. of days per events at each SOM node (El-Nino; *La Nina*)	Correlation of the cumulative rainfall anomalies associated with the days clustered at each SOM node with ENSO Index
Method-1*	Break	12.95; *6.27*	-0.53
	Active	6.67; *12.07*	-0.35
Method-2#	Break	11.87; *7.84*	-0.38
	Active	9.55; *8.65*	-0.07

*With ENSO effect on seasonal mean

#Without ENSO effect on seasonal mean

Particular MISO phases are preferred during ENSO years, that is, the canonical break phase is preferred more in the El Niño years and the typical active phase is preferred during La Niña years.

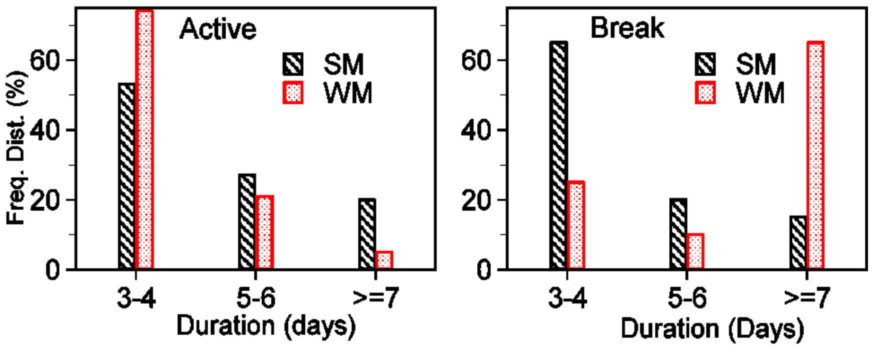
Interestingly, if the ENSO effect on seasonal mean is removed, the preference for the break node remains relatively unchanged; whereas, the preference reduces/vanishes for the active node.

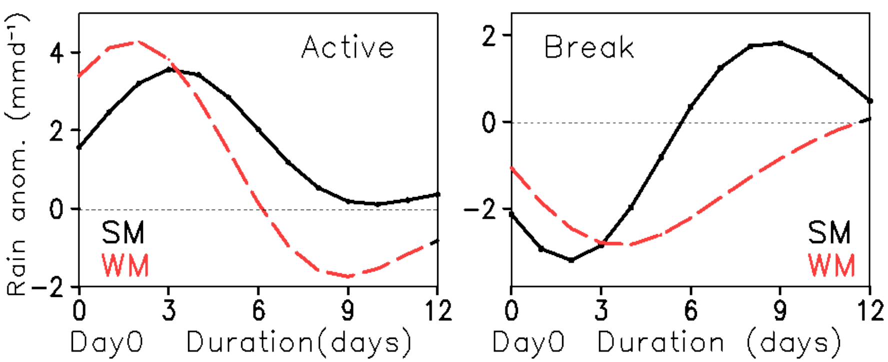
The results indicate that the El Niño–break relationship is almost independent of the ENSO-monsoon relationship on seasonal scale whereas the La Niña–active association seems to be interwoven with the seasonal relationship.

Joseph, Sahai et al., 2011, JGR

Asymmetry in MISO during Extreme Monsoon

Frequency and duration of active/break spells

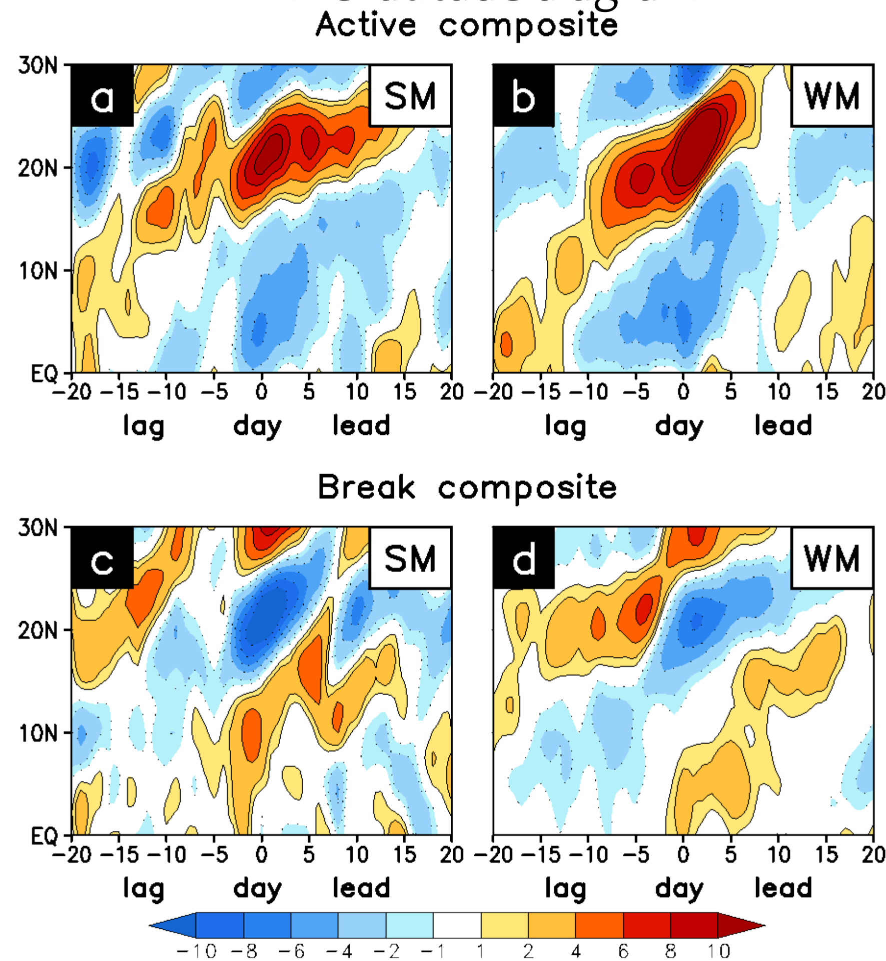




Long active spells (>5 days) → SM (~47%)
Short active spells → WM (~73%)
Prolonged break spells → WM (65%)

Sharmila, Sahai et al., 2014, I.J.Clim

Time-latitude diagram

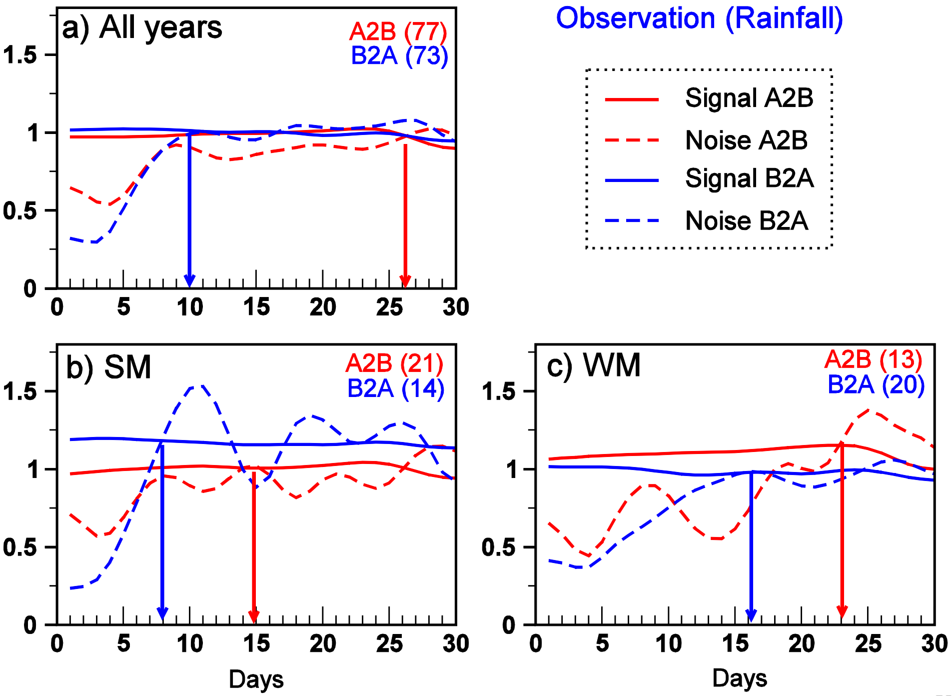


SM→ Slow (fast) propagation during active (break) phase
WM→ Fast (slow) propagation during active (break) phase

Potential Predictability of MISO during Extreme Monsoon

Estimated Observed Potential Predictability of Active/Break Spell Transitions

Potential Predictability of Active/Break Cycle over Central India



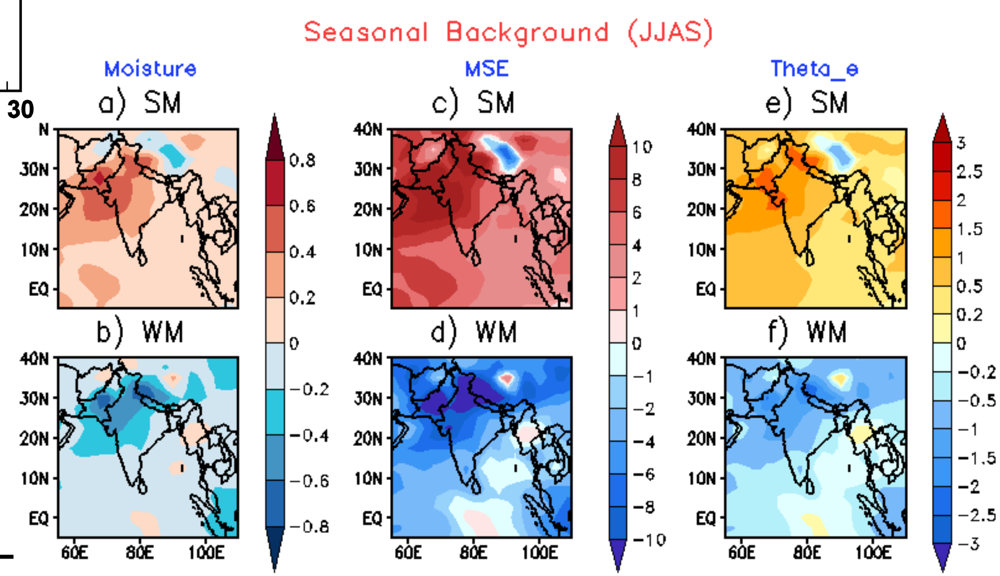
Observation

SM: A2B → 15 days
B2A → 8 days

WM: A2B → 23 days
B2A → 16 days

Phase dependent potential predictability of A2B and/or B2A phase transitions is considerably asymmetric during SM and WM years.

The anomalously high (low) background instability could reduce (enhance) the predictability limit through modulating the growth of error considerably during phase transitions of SM (WM) years.



Sahai et al., 2017, Nat. Haz

Relative Importance of Synoptic Scale and MISO and its representation in prediction 2015 Monsoon

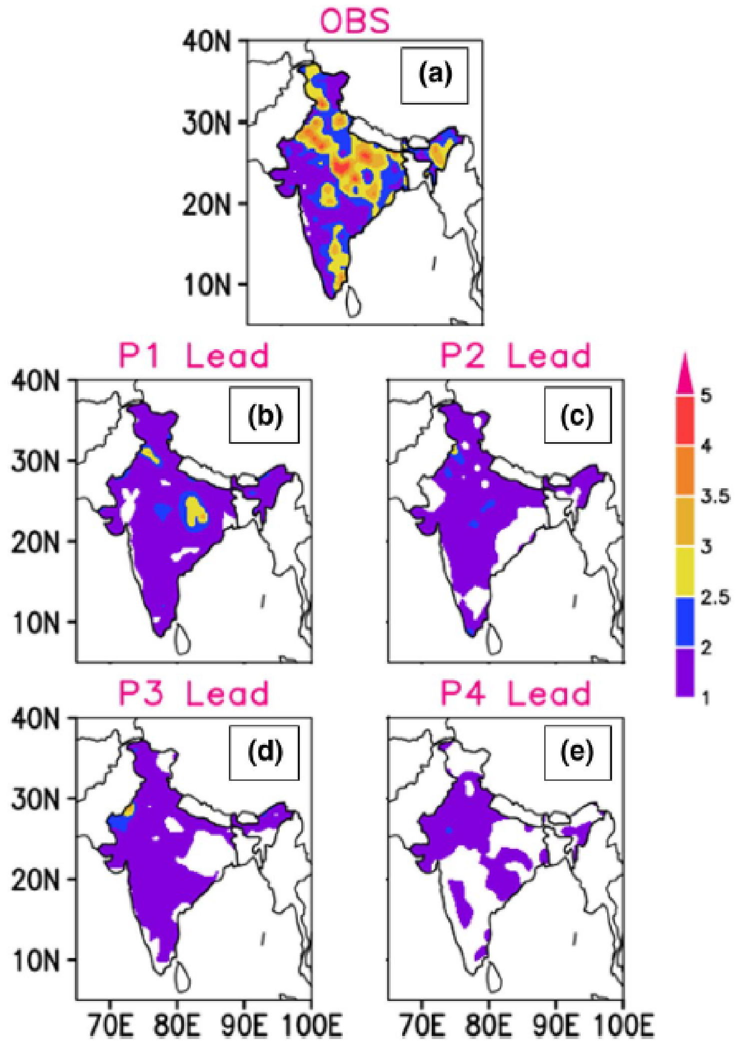
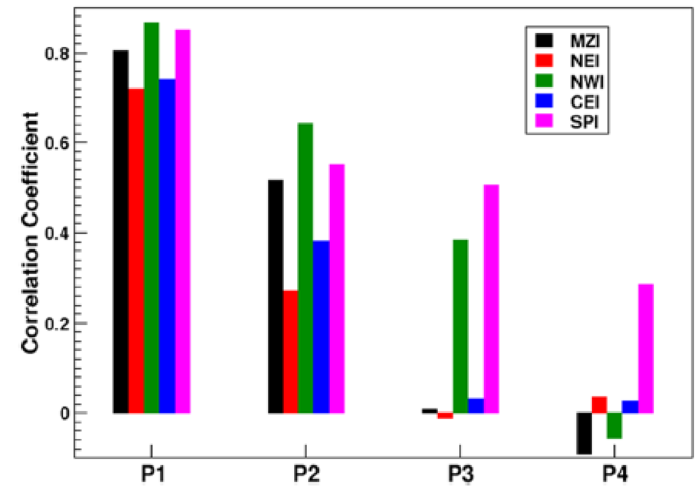


Fig. 8 Ratio of the synoptic to ISO variance during JJAS for the year 2015: **a** observation, **b–e** P1 to P4 leads respectively as predicted by MME



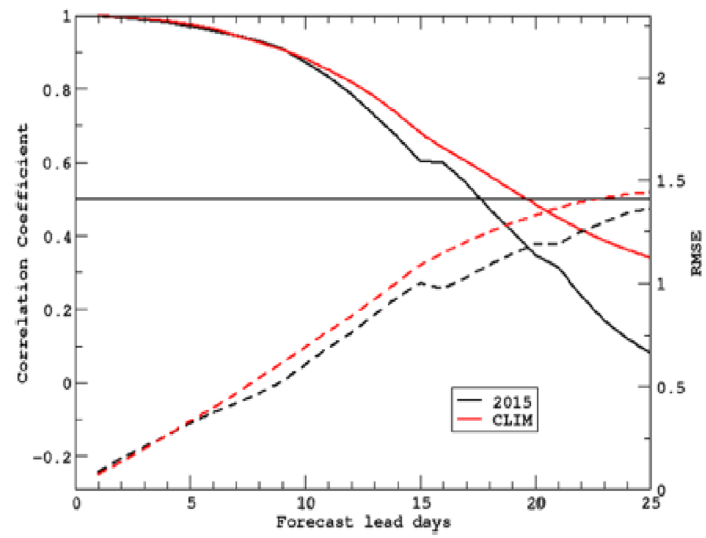
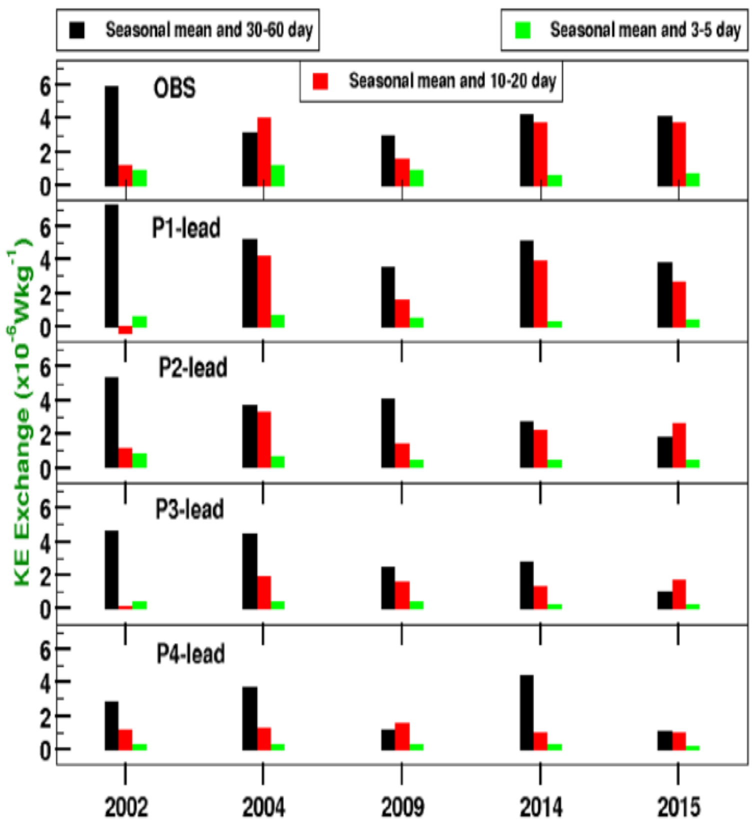


Fig. 6 Bivariate correlation and RMSE of predicted and observed MISO indices during 2015

Abhilash et al., 2018 Clim. Dyn

Fig. 9 Kinetic energy exchanges through the mean–wave interactions of the seasonal mean interacting with the synoptic scale(3–5 day) and low frequency (10–20 and 30–60 day) oscillations at different pentad leads of MME forecasts of CFSv2 along with the ERA reanalysis for the deficient years during 2001–2015



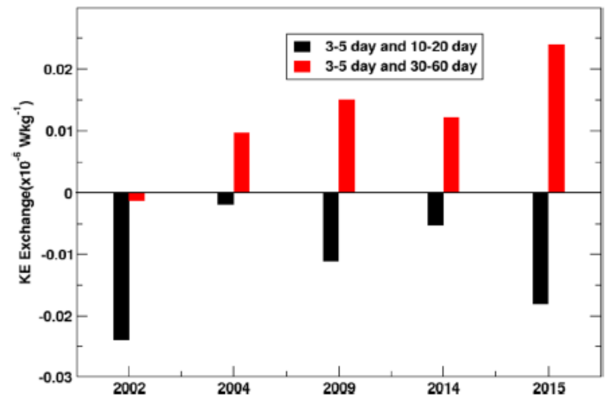


Fig. 10 a–e Kinetic energy exchanges through the non-linear wave–wave interactions of the synoptic scale(3–5 day) wave interacting with the low frequency (10–20 and 30–60 day) oscillations for the deficient years during 2001–2015. The plot is based on ERA reanalysis

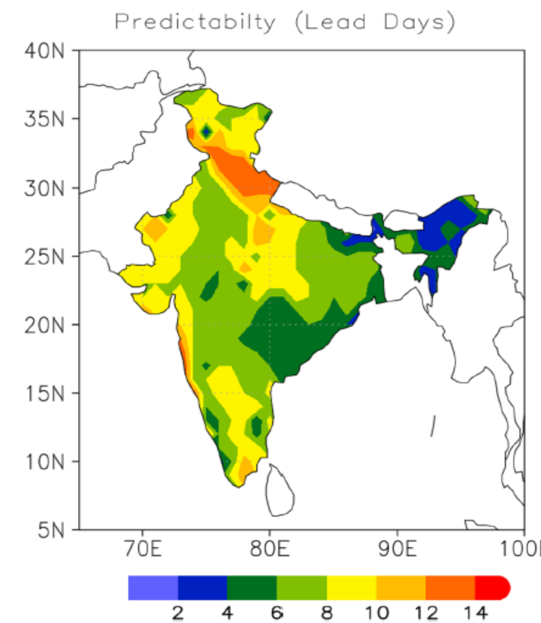


Fig. 7 The lead (in days) at which signal to noise ratio becomes less than one from the MME forecast during 2015 monsoon season

Abhilash et al., 2018 Clim. Dyn

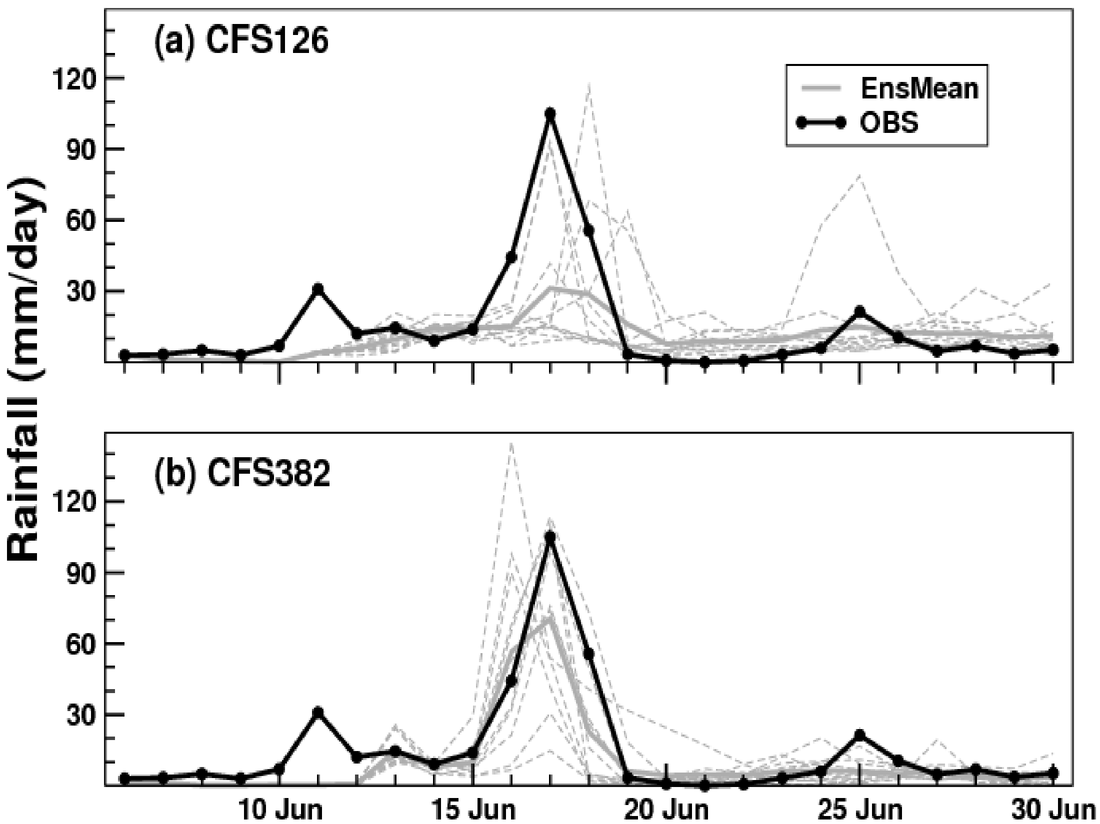
Observation

- **The case study of 2015 reveals that the scale interaction can play a dominant role in determining the long range predictability.**
- **Seasonal mean background as well as teleconnection patterns also determines the frequency and duration of active break spells**

Example of Extended Range Forecast of Synoptic events when large scale is better Captured

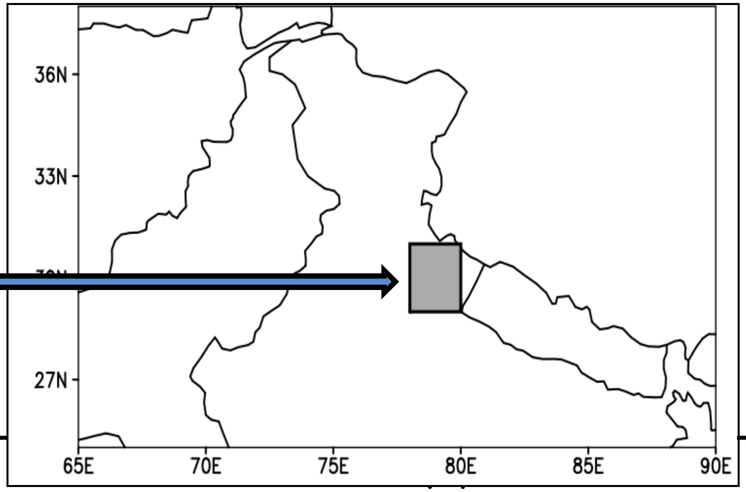
- **Uttarakhand extreme event**
- **Mount Abu extreme event**

Extended range prediction of Uttarakhand rainfall event by (a) CFS126 and (b) CFS382 from 05 June initial condition.



The heavy amount of rainfall (~110mm) over Uttarakhand was predicted somewhat reasonably (~70mm) by CFS382; however, the amount (~30-35mm) is underestimated by CFS126

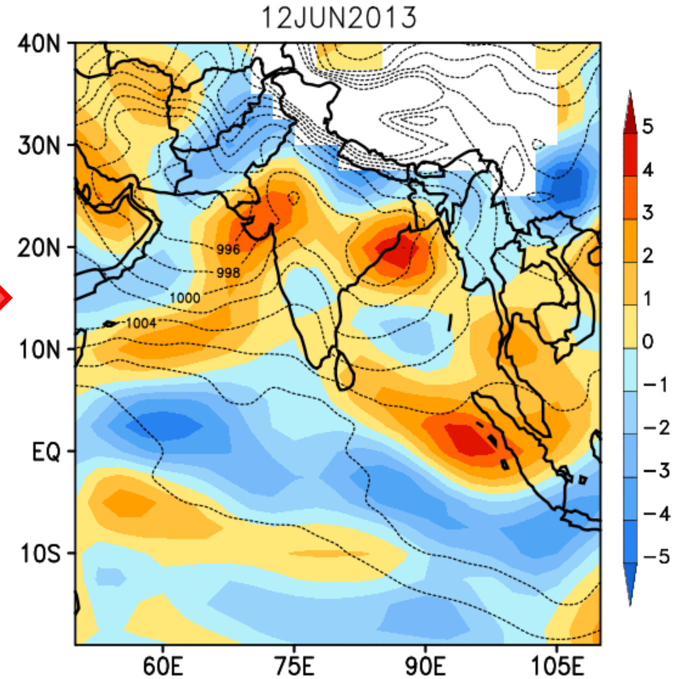
The region where rainfall values are averaged



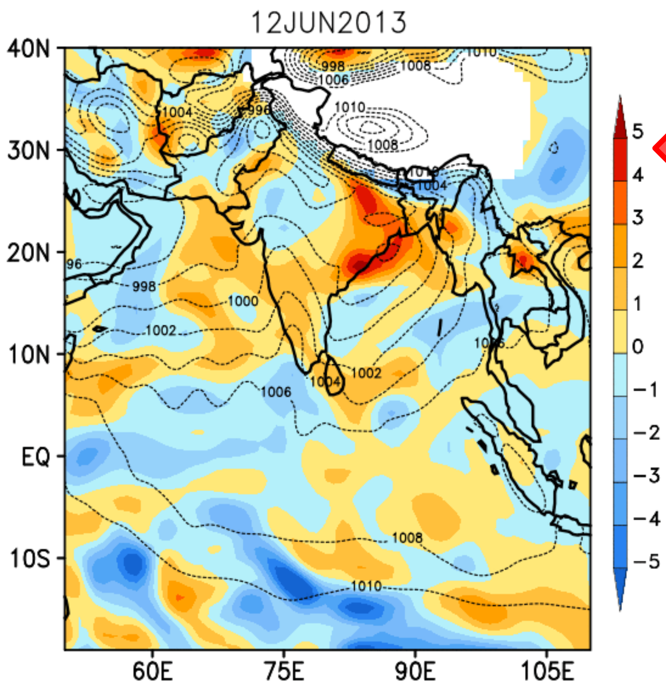
Evolution of Potential Vorticity (PV; x10^{-7} s^{-1}) anomalies at 700 hPa and mean sea level pressure

The development and northwestward movement of the low pressure system in BoB is predicted reasonably well by both CFS126 and CFS382, with CFS382 performing slightly better.

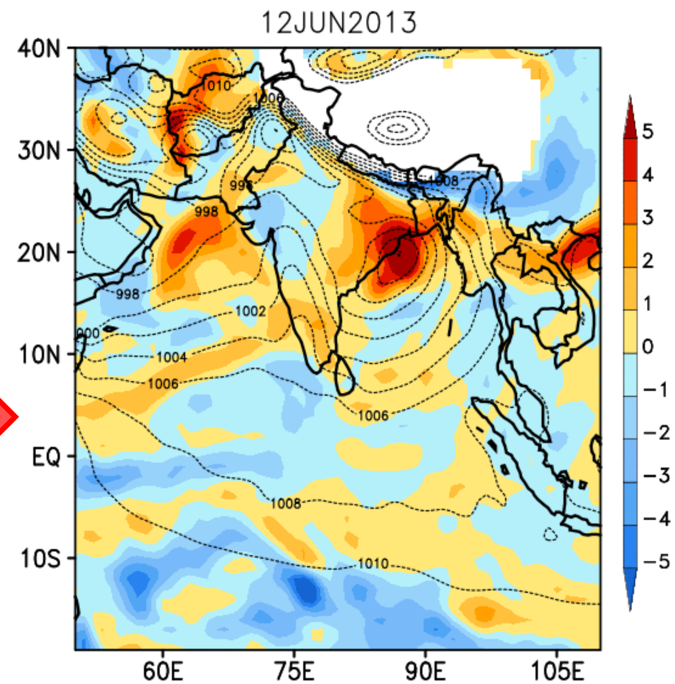
OBS



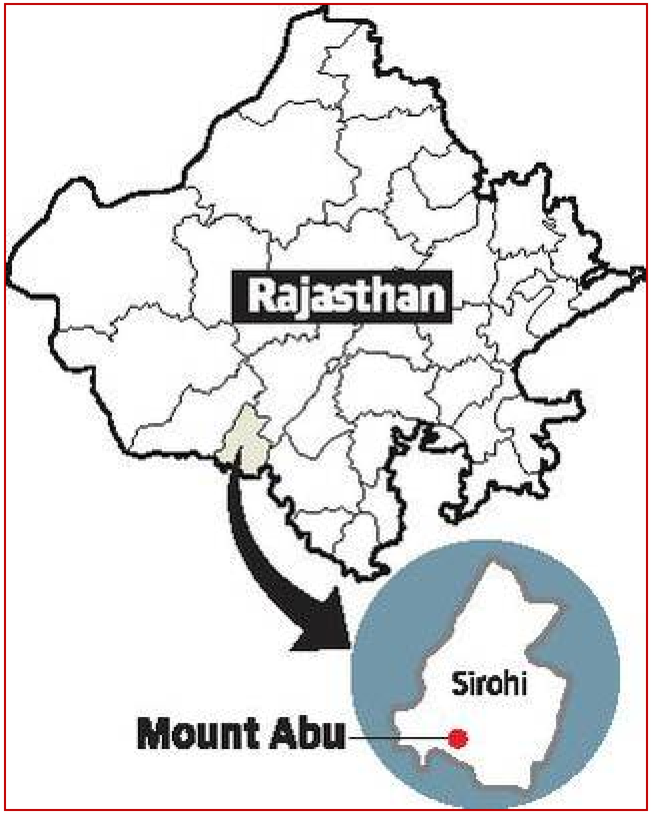
CFS126



CFS382

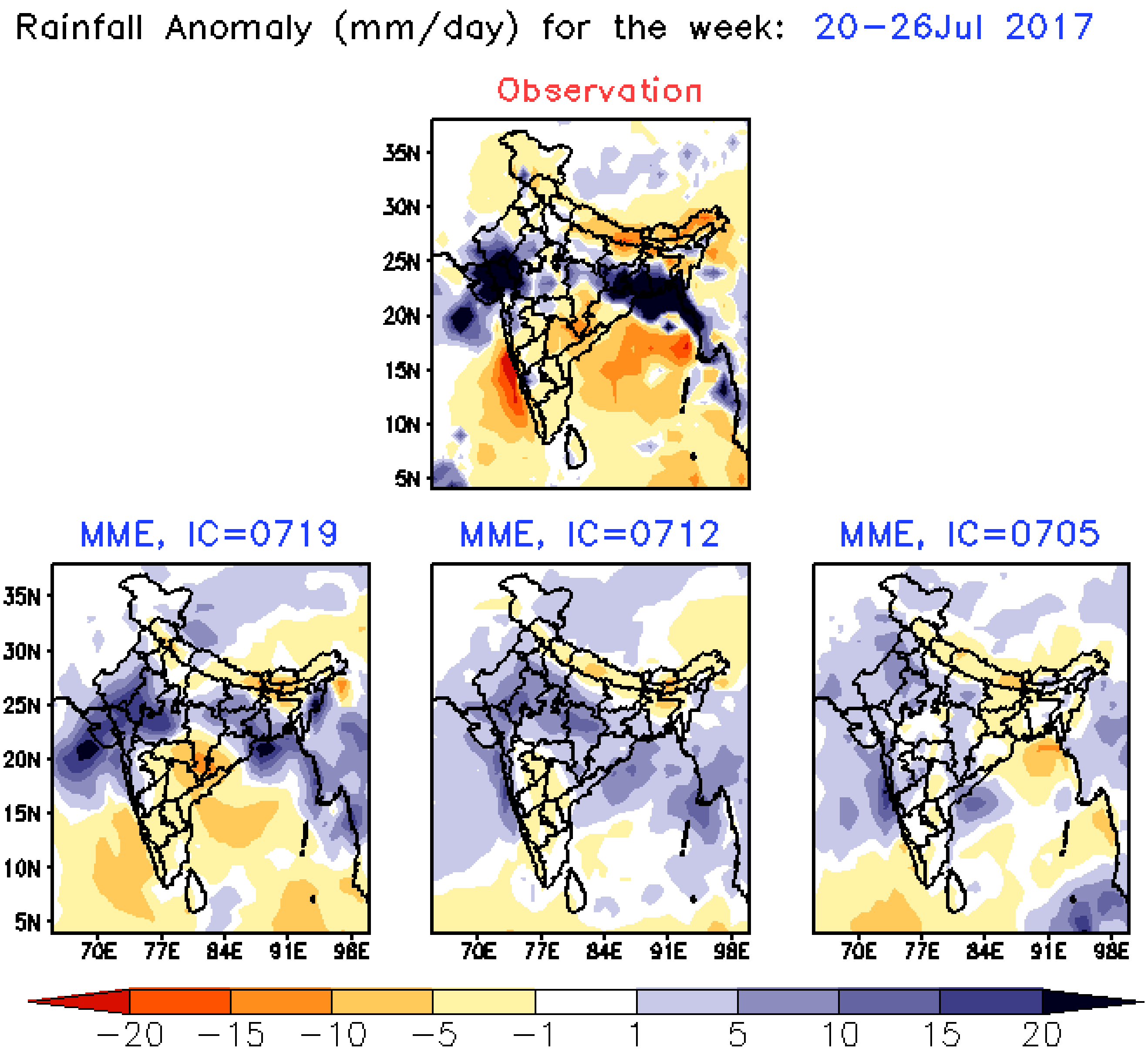


Mount Abu, 26 July 2017



Mount Abu reportedly received the heaviest rainfall in over 300 years in the last 24 hours. (770 mm) in 24 hours)

ERF forecast – ICs 19, 12 and 05 July, 2017

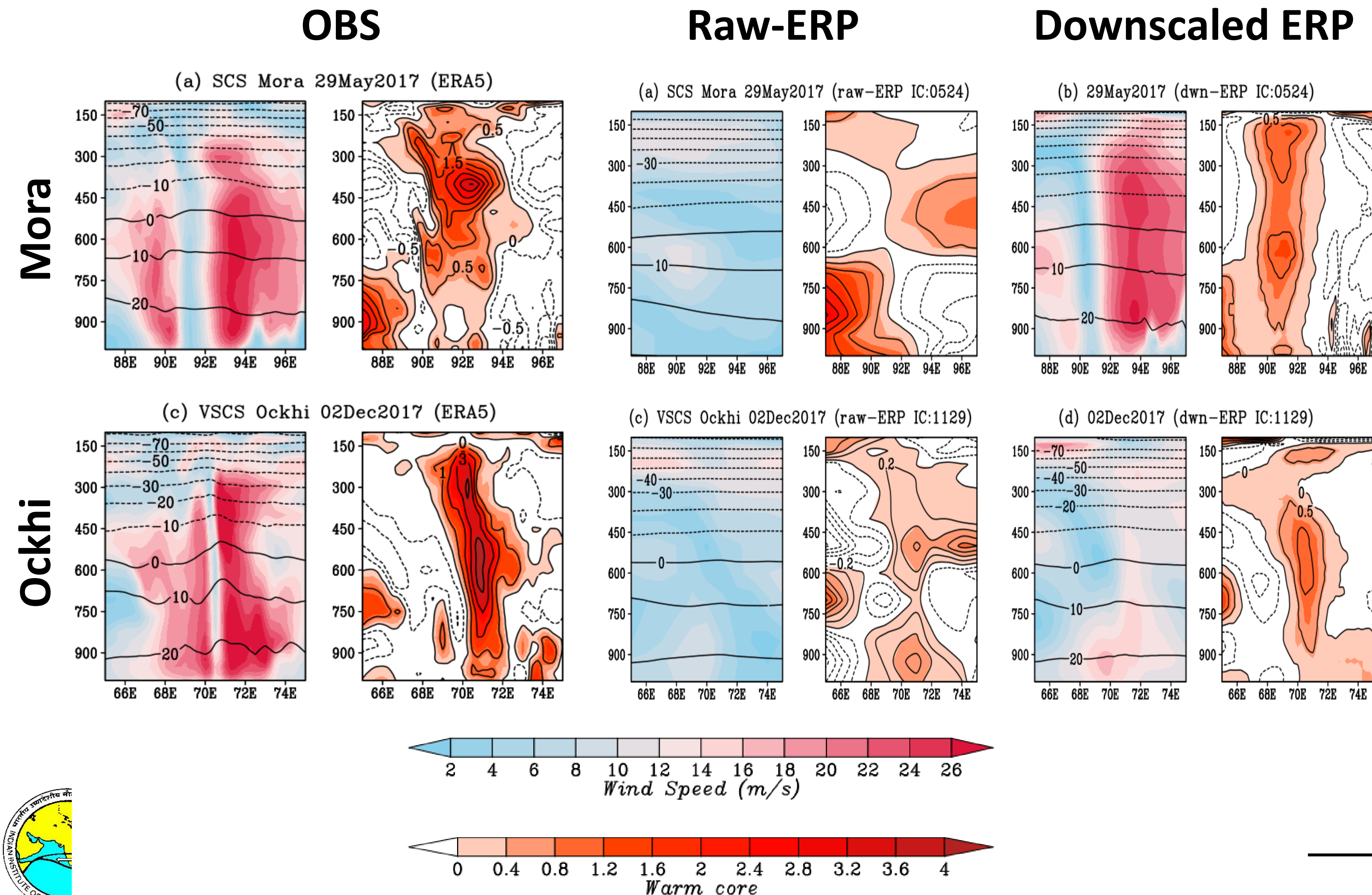


Dynamical Downscaling

Weather Research and Forecasting-Advanced Research WRF version 4.0 (Skamarock et al., 2019) is used to downscale the forecast outputs from the ERP system.

The ERP output variables such as winds, relative humidity, temperature and surface variables like sea-surface temperature, mean sea level pressure, surface pressure, soil-moisture and soil-temperature are bias corrected at all vertical levels before giving them as boundary conditions to WRF.

Vertical Profiles of Cyclones at Mature Stage



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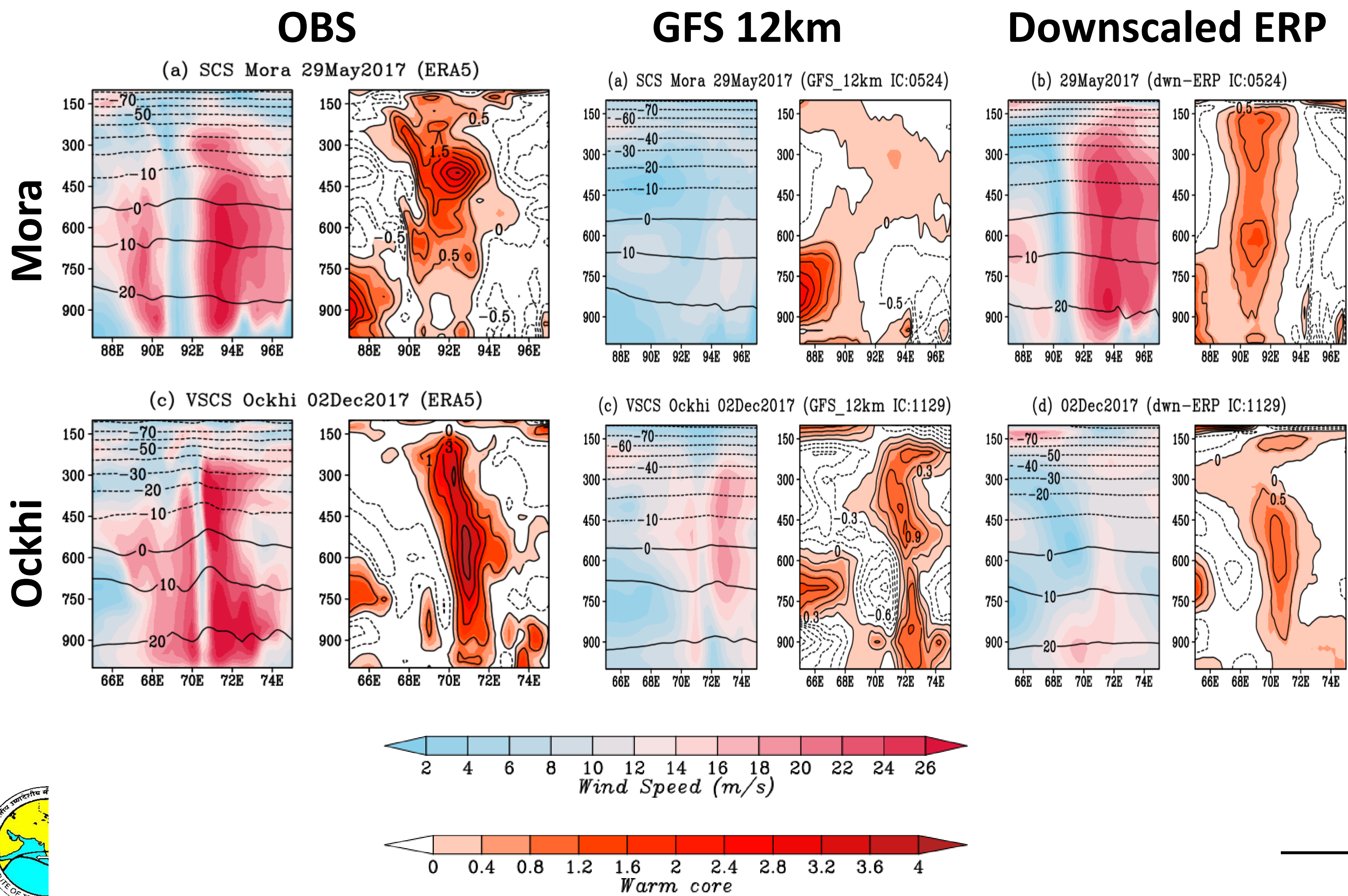
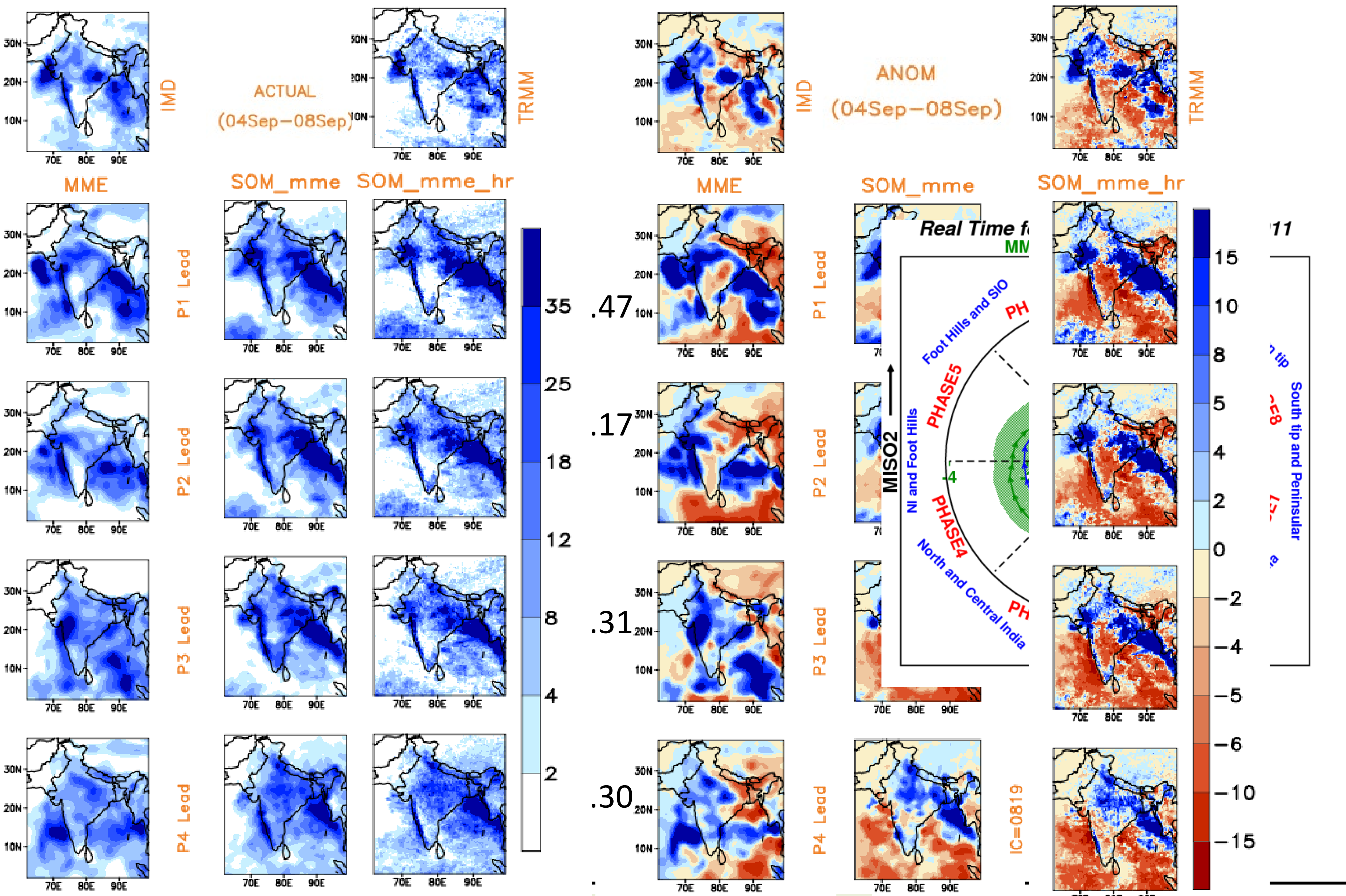


SOM based Bias correction and Downscaling: Application to ERP of Mahanadi flood in September 2011



Sahai et al 2016, Clim. Dyn.

Conclusion

- Extended range prediction implies the prediction of the low-frequency oscillations.
- Predictability of such low-frequency oscillations are limited by synoptic scale systems during the monsoon season
- However, under certain instances when the synoptic scale systems develops over a systematic development of monsoon mean low frequency background, operational predictability of such synoptic scale system is improved.