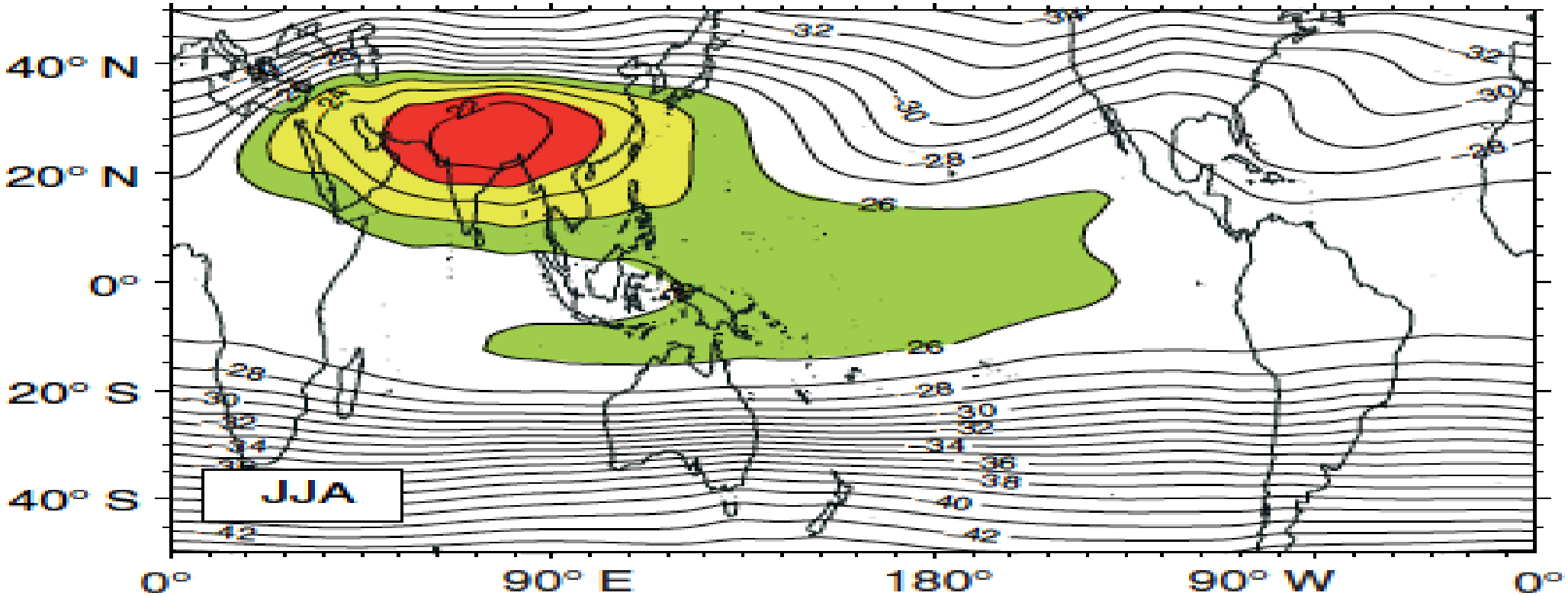
Predicting South Asian Monsoon through Spring Predictability Barrier



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WMO 2nd OCP, 30 May- 1 June, 2018

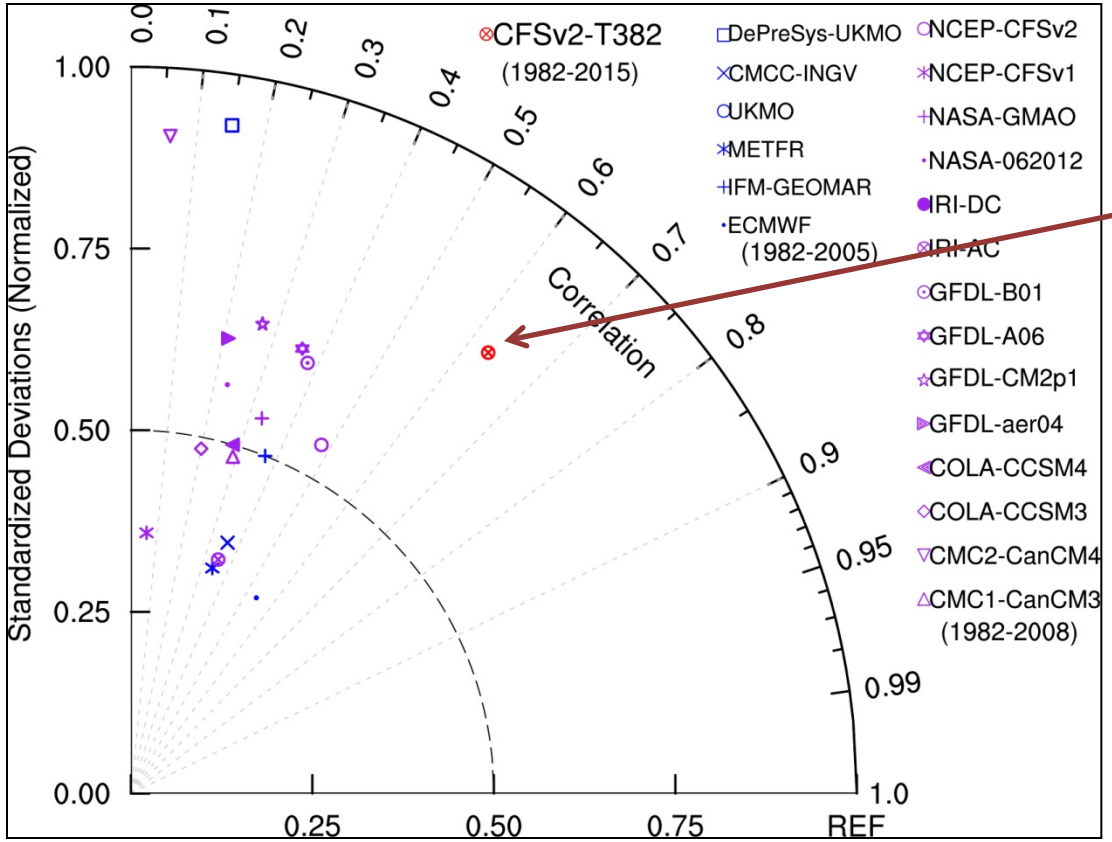
Thanks to WMO for Support

The Monsoon Mission

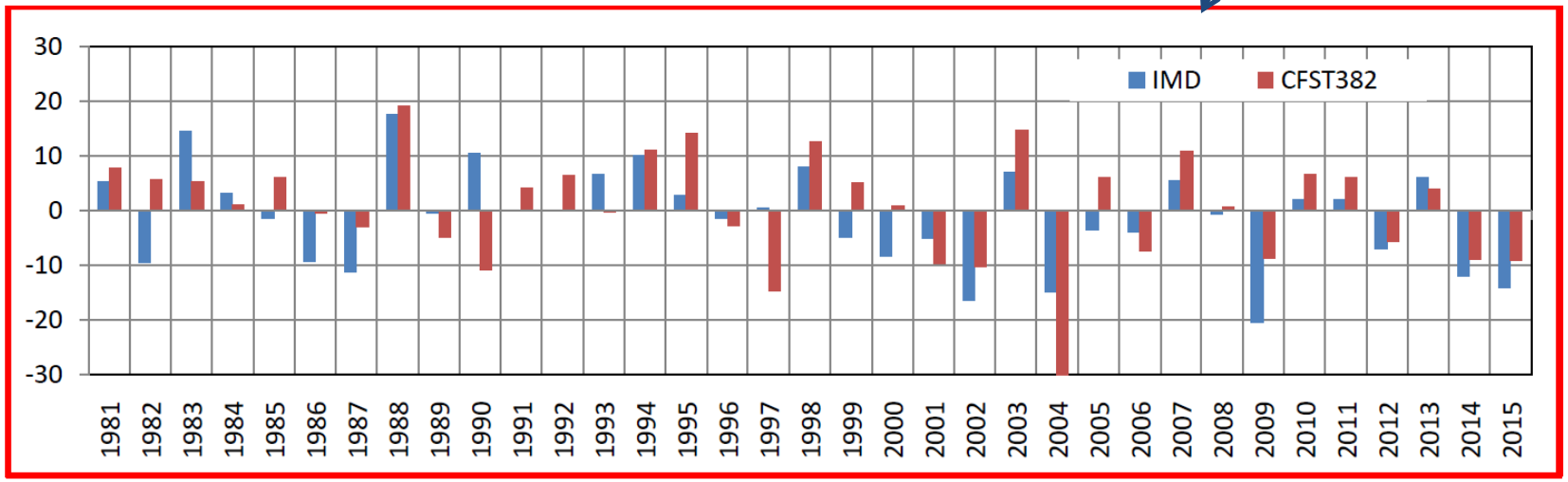
Aim: To Improve predictions Skill of South Asian Monsoon

- **Seasonal and Extended range predictions**
- **Short and Medium range (up to two weeks) prediction**

- 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 **(R2O and O2R approach).**
- Requirement :All research work must be on the Operational Modeling Framework!



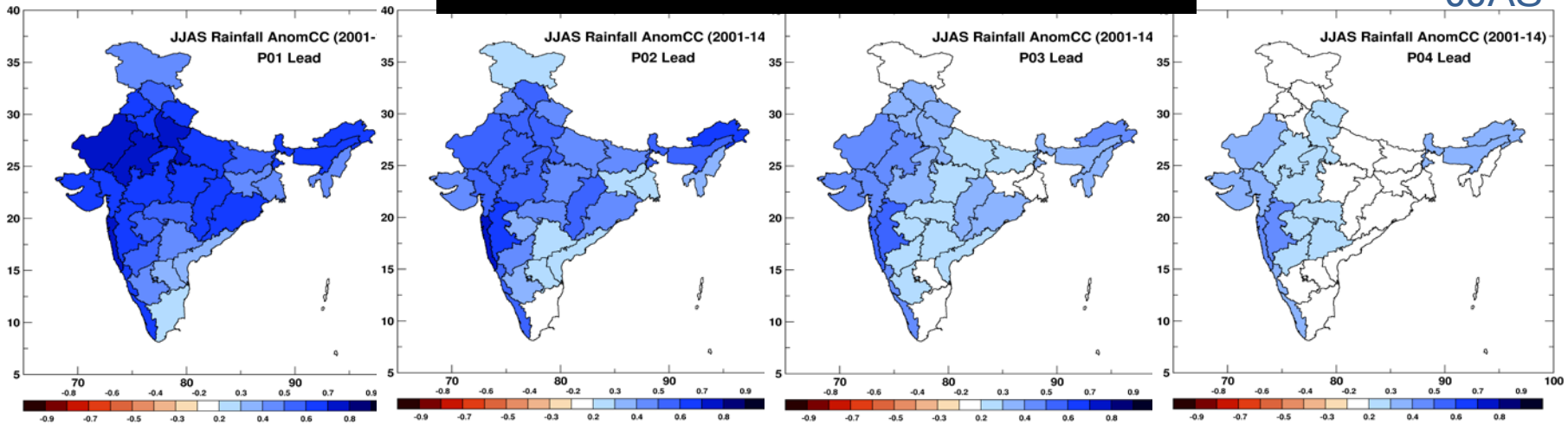
Monsoon Mission Model Performance (Prediction Skill as well as interannual variance) is better than other models for Indian Monsoon.



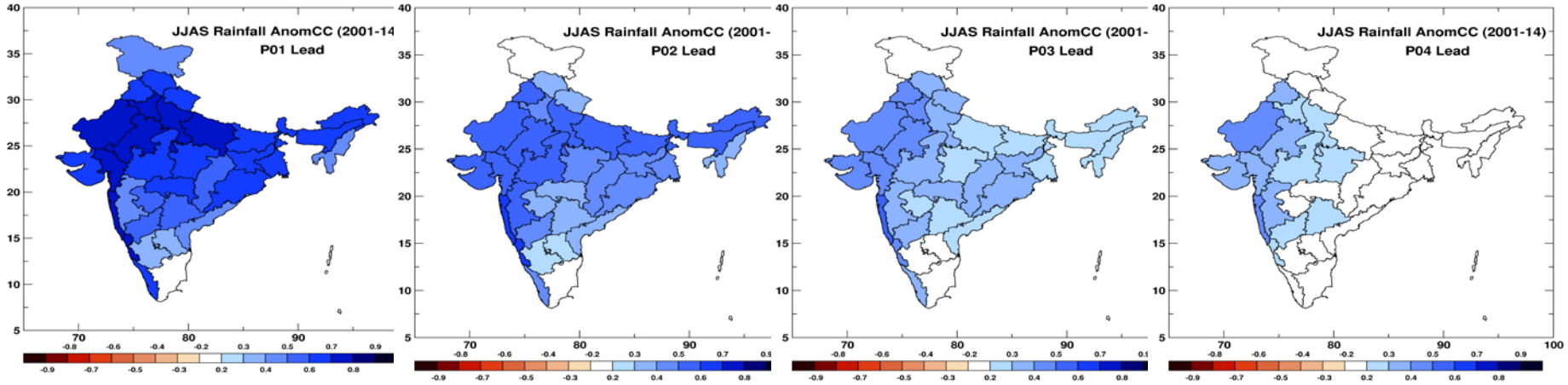
Subdivision Wise Statistics

ECMF MME

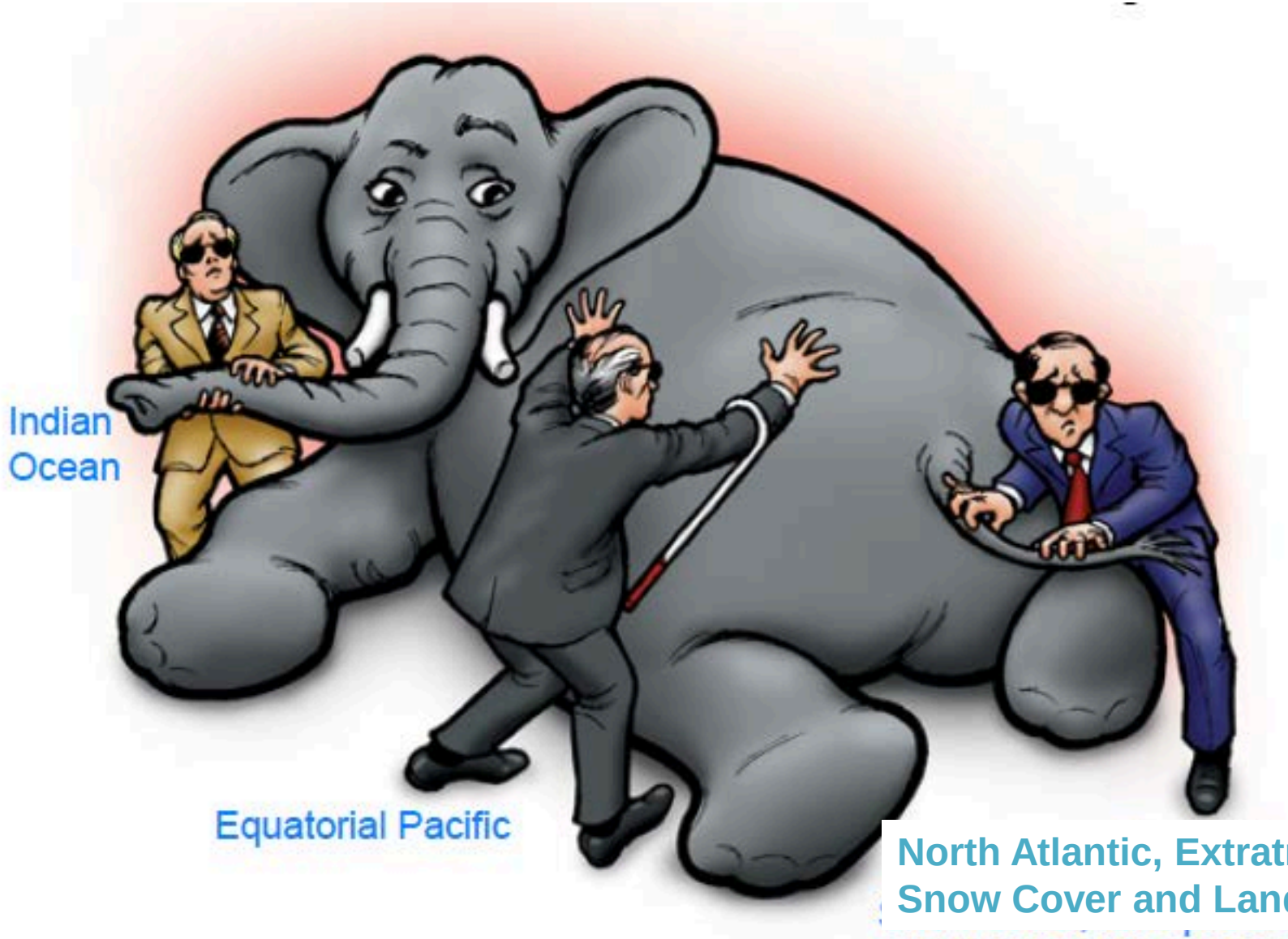
JJAS



IITM MME

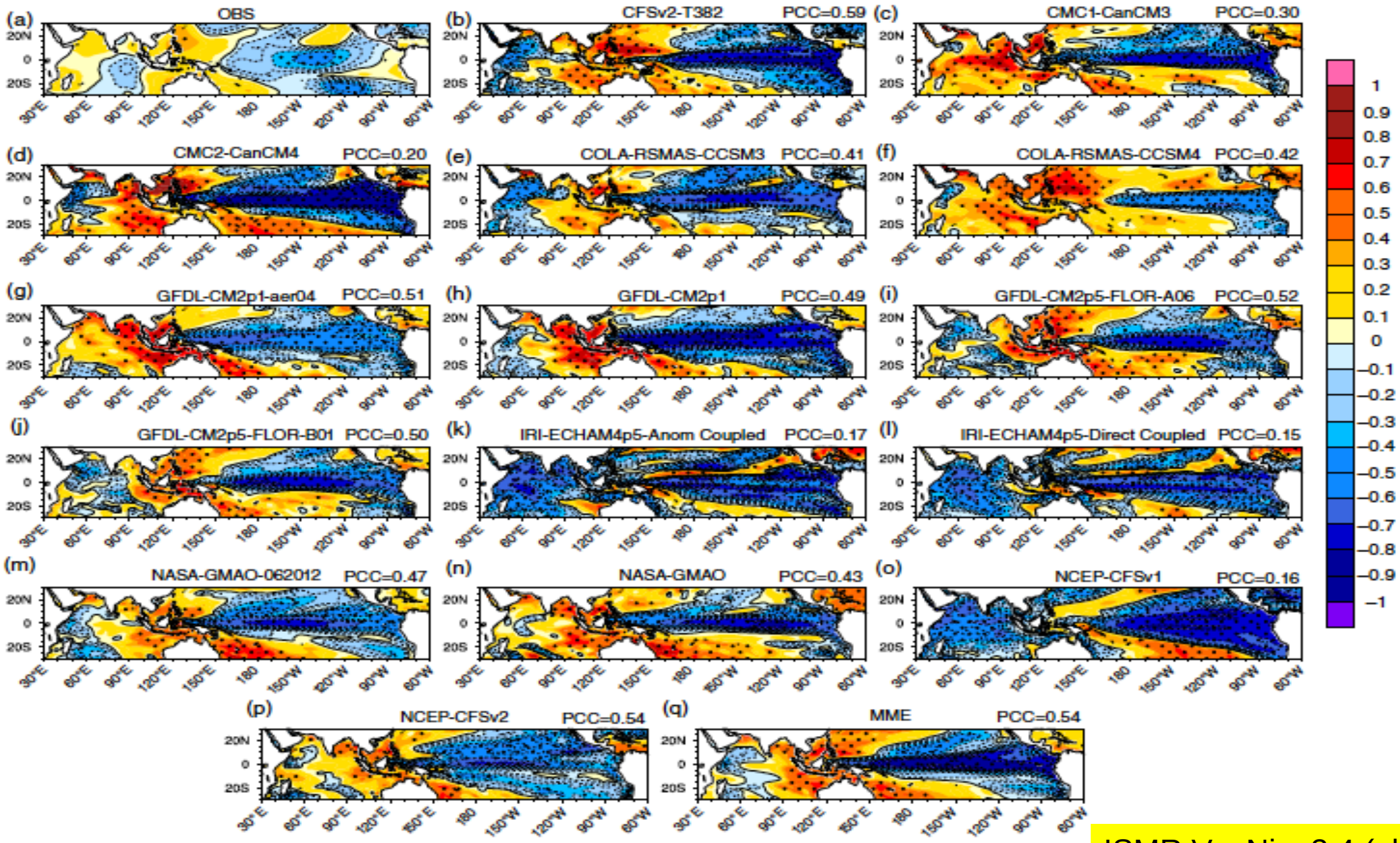


Source of Monsoon Variability/Predictability?



North Atlantic, Extratropical SST,
Snow Cover and Land Processes

ENSO Monsoon Relation

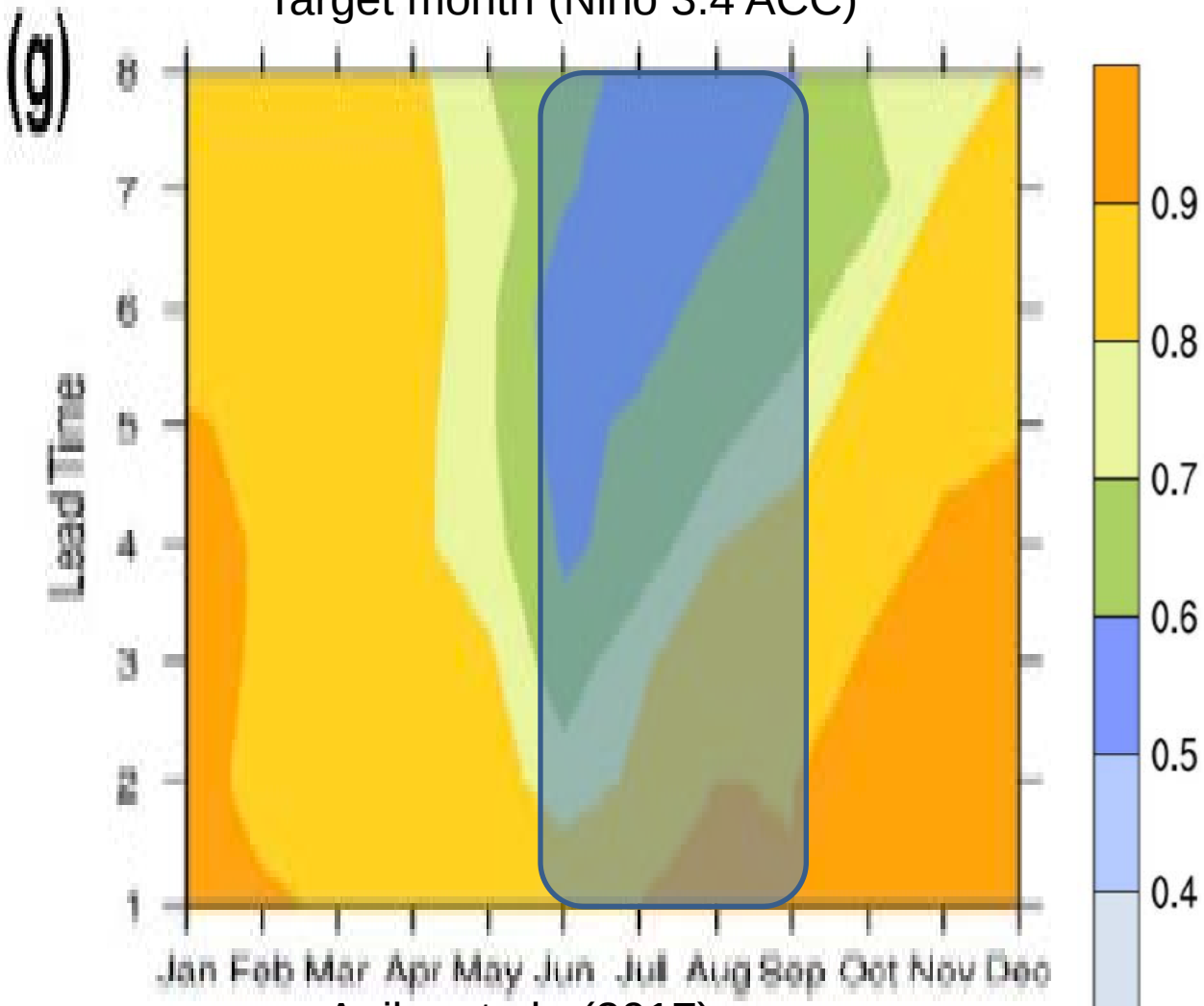


Pillai et al., (2017)

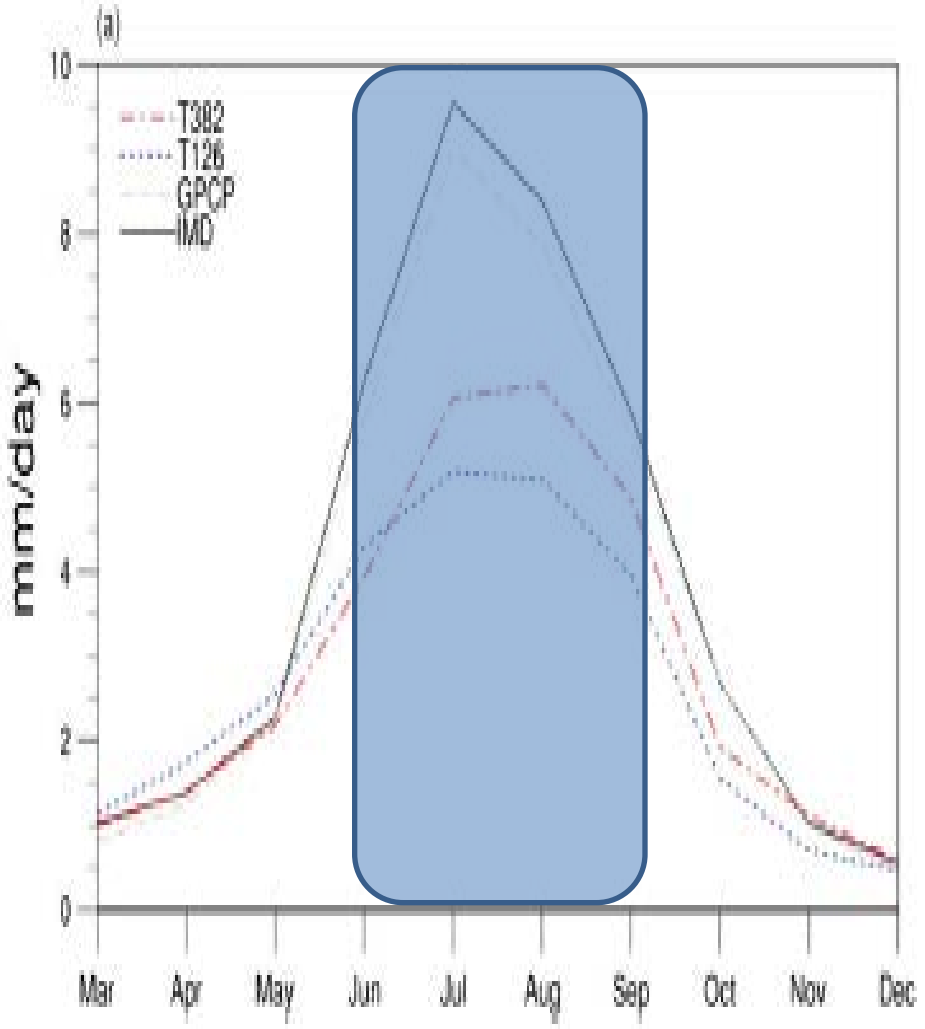
ISMR Vs. Nino3.4 (obs.)= -0.5
In models = -0.65 to -0.85

Spring Predictability Barrier and Monsoon

Target month (Nino 3.4 ACC)



Anika et al., (2017)



Potential and actual Skill (1982-2015) of ISMR and SST indices during JJAS with ICs from different months

Table 1 Potential skill and actual skill of JJAS mean SST indices and ISMR for CFSv2 T382 hindcasts from Feb to May initial conditions

IC (months)	Indices							
	Nino3		EMI		EEIO SST		ISMR	
	Pot. skill	Actual skill	Pot. skill	Actual skill	Pot. skill	Actual skill	Pot. skill	Actual skill
Feb	0.86	0.66	0.70	0.66	0.75	0.35	0.70	0.55
Mar	0.90	0.70	0.78	0.68	0.76	0.55	0.72	0.40
Apr	0.92	0.80	0.85	0.70	0.78	0.58	0.72	0.38
May	0.95	0.85	0.89	0.71	0.84	0.80	0.70	0.30

As lead time decreases actual prediction skill increases

As lead time decreases actual prediction skill decreases

Pillai et al (2017a)

Prediction Skill of ISMR in CFS V2 (1982-2015)

Model	Feb. IC	Mar. IC	Apr. IC	May IC
T382	0.55	0.50	0.40	0.28
T126	0.49	0.40	0.39	0.23

Similar behavior is noticed in:

ENSEMBLES: METEO FRANCE and INGV (Chattopadhyay et al., 2015)
NMME : CanCM3, GFDLCM2, IRI_ECHAM4 Coupled, NASA GMAO (Pillai et al., 2017b)

Reference Data: IMD

Pillai et al (2017a)

References

1. Chattopadhyay R, Rao SA, Sabeerali CT, George G, Rao DN, Dhakate A, Salunke K (2015) Large scale teleconnection pattern of Indian summer monsoon as revealed by CFSv2 retrospective seasonal forecast runs. Int J Climatol. doi:10.1002/joc.4556

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3. Pillai PA, Rao SA, George G, Rao DN, Mahapatra S, Rajeevan M, Dhakate A, Salunke K (2016) How distinct are the two flavors of El Niño in retrospective forecasts of climate forecast system version 2 (CFSv2)?. Clim Dyn 48:3829–3854. doi:10.1007/ s003821-26-016-3305-2

4. **Shukla RP, Huang B, Marx L, Kinter JL, Shin CS (2017) Predictability and prediction of Indian summer monsoon by CFSv2: implications of initial shock effect. Clim Dyn. doi:10.1007/s00382-017- 3594-0 (online)**

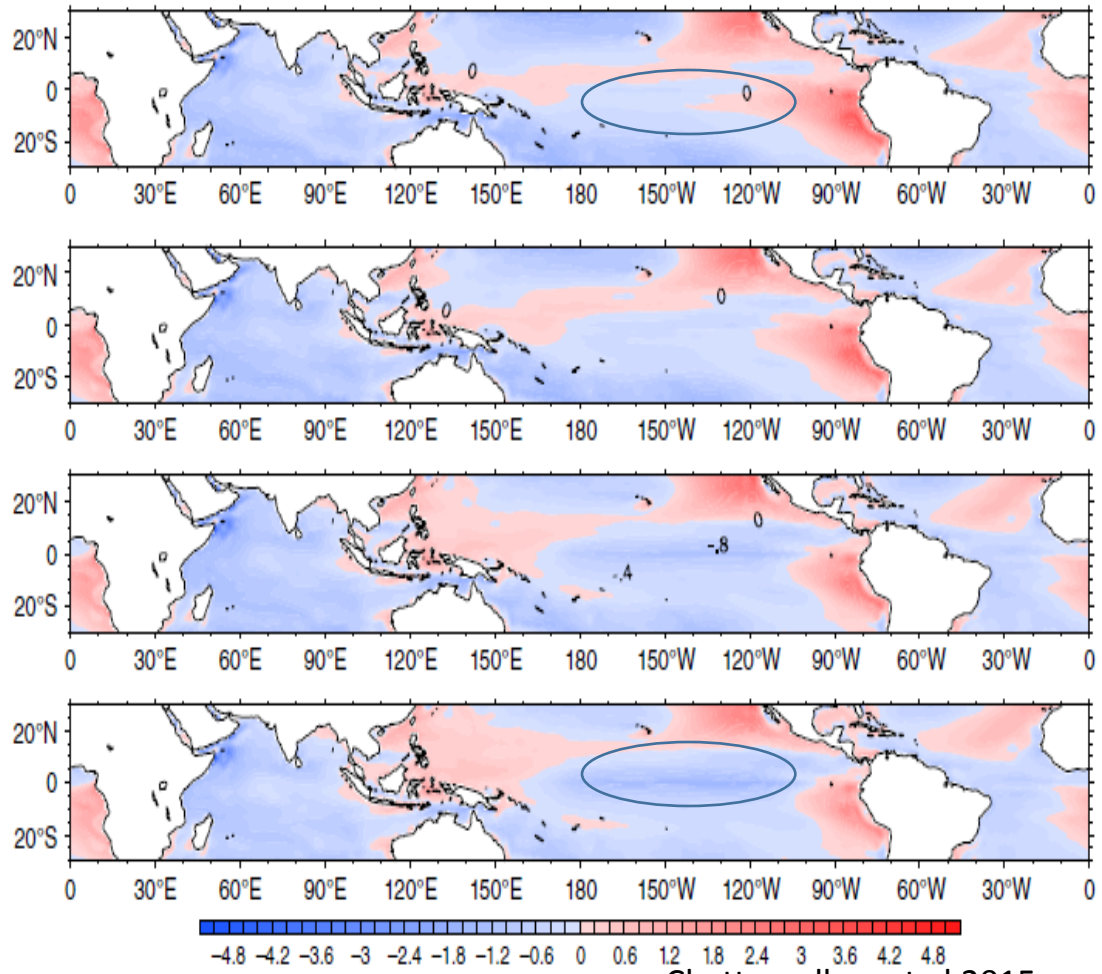
5. Ramu D.A., Suryachadra A. Rao, Pillai P., Pradhan M., George G., Nagarguna Rao D., Mahapatra S., Pai D.S., Rajeevan M (2017). Prediction of seasonal summer monsoon rainfall over homogenous regions of India using dynamical prediction system. J. Hydrol. 546, March 2017, DOI:10.1016/j.jhydrol.2017.01.010, 103–112.

6. Pillai PA, Rao SA, Das RS, Dhakate A, Salunke K (2017a). Potential predictability and actual skill of Boreal Summer Tropical SST and Indian summer monsoon rainfall in CFSv2-T382: Role of initial SST and teleconnections . Clim.Dyn (online) DOI 10.1007/s00382-017-3936-y

7. Pillai PA, Rao SA, Ramu DA, Pradhan M, George G (2017b) . Seasonal prediction skill of Indian summer monsoon rainfall in NMME models and Monsoon Mission CFSv2 DOI: 10.1002/joc.5413. International journal of climatology.

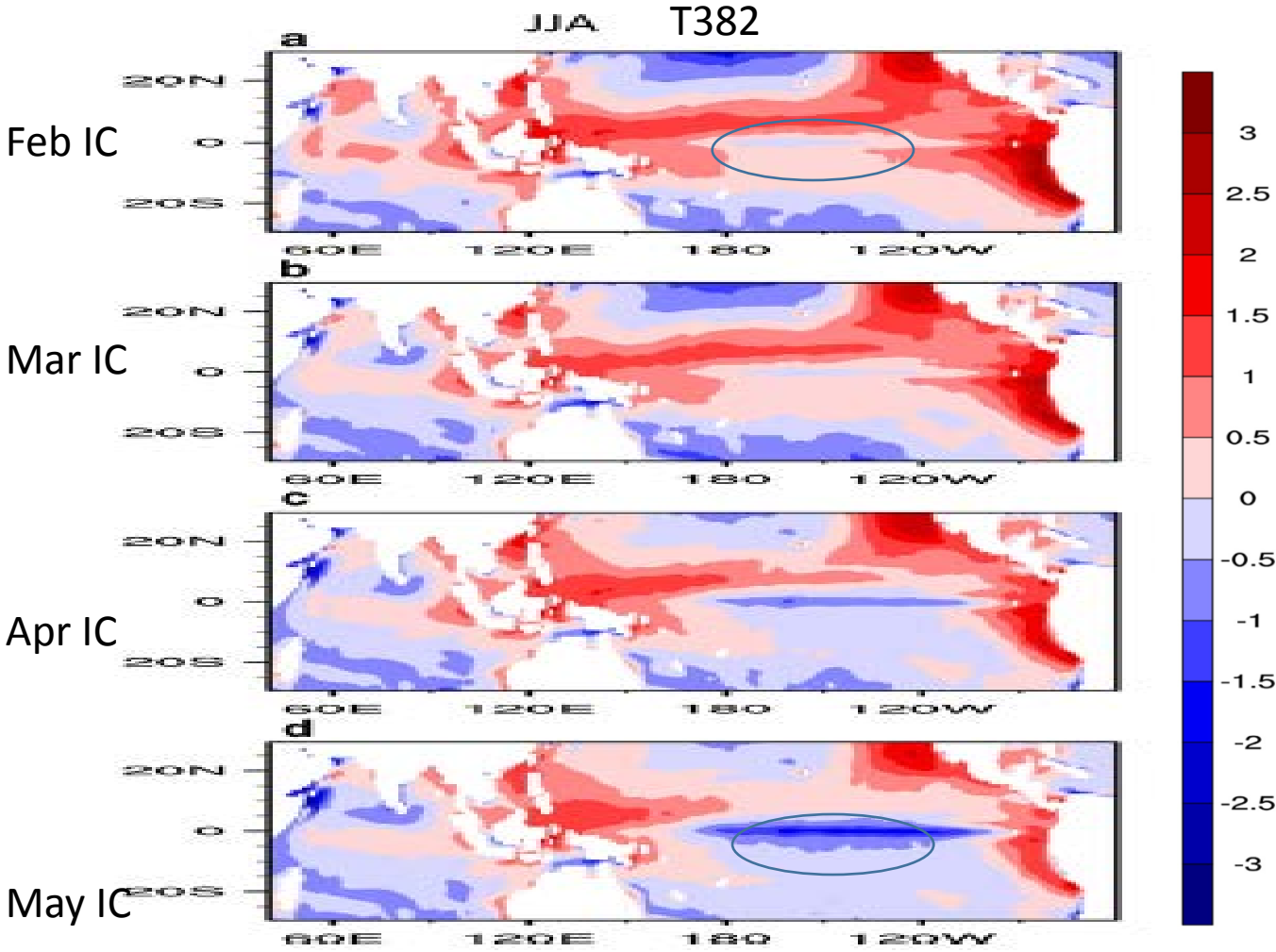
JJAS Biases

T126



Chattopadhay et al 2015

T382



Feb IC

Mar IC

Apr IC

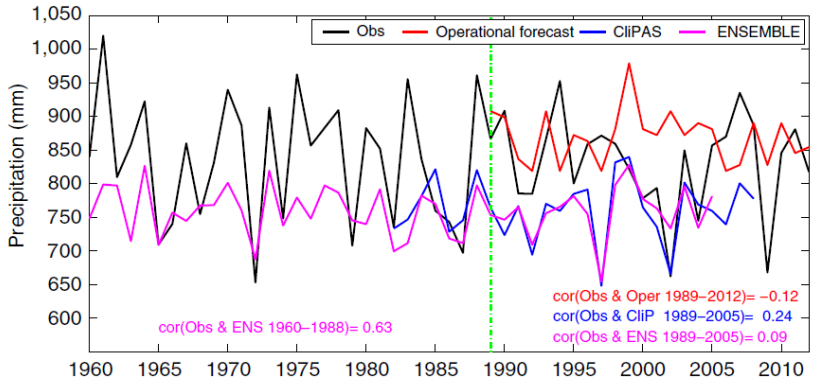
May IC

Pillai et al 2016

➢ **Reduced cold bias in the central Pacific ensures better ENSO- Monsoon teleconnection in Feb IC hindcasts comapred to other ICs**

El Nino Flavors and their teleconnections

➢Distinguishing both flavors of ENSO are needed for the accurate prediction of Monsoon rainfall in the recent period (Wang et al 2015)



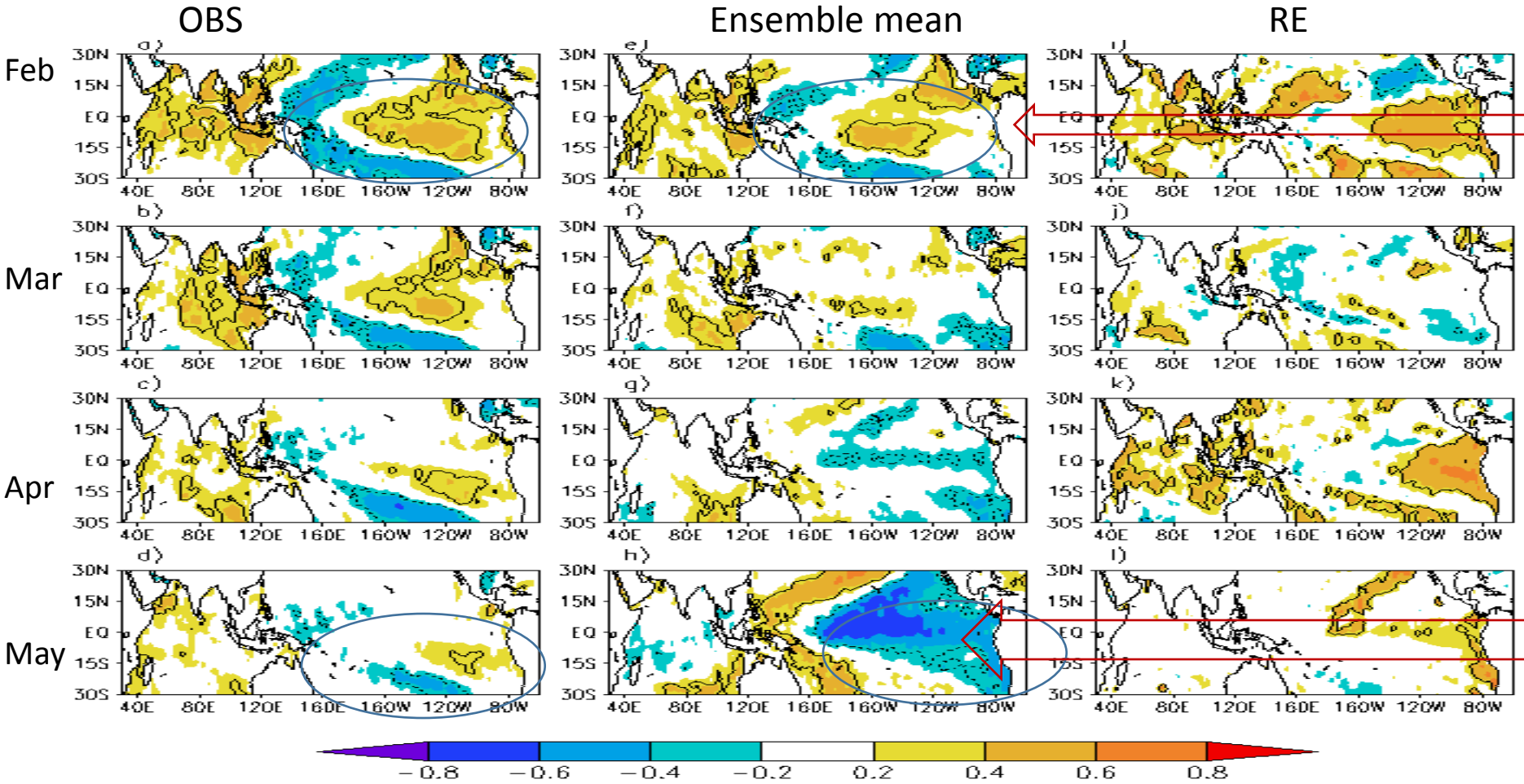
Seasons	JJA			SON		
ICs for model	Obs.	T126	T382	Obs	T126	T382
	-0.07			0.27		
Feb IC		0.64	**-0.107**		0.73	0.72
Mar IC		0.72	0.32		0.86	0.76
Apr IC		0.8	0.35		0.91	0.8
May IC		0.87	0.3		0.92	0.72
June IC					0.9	0.78

➢ Both flavors of El Nino can be distinguished, only when Nino3 and EMI are un related (Hendon et al (1999).

➢ In CFSv2, Feb IC of T382 is only able to distinguish ENSO flavors.

Pillai et al (2016)

Role of initial SSTA ISMR prediction



Off- equatorial SST pattern in Feb for both observations and model.

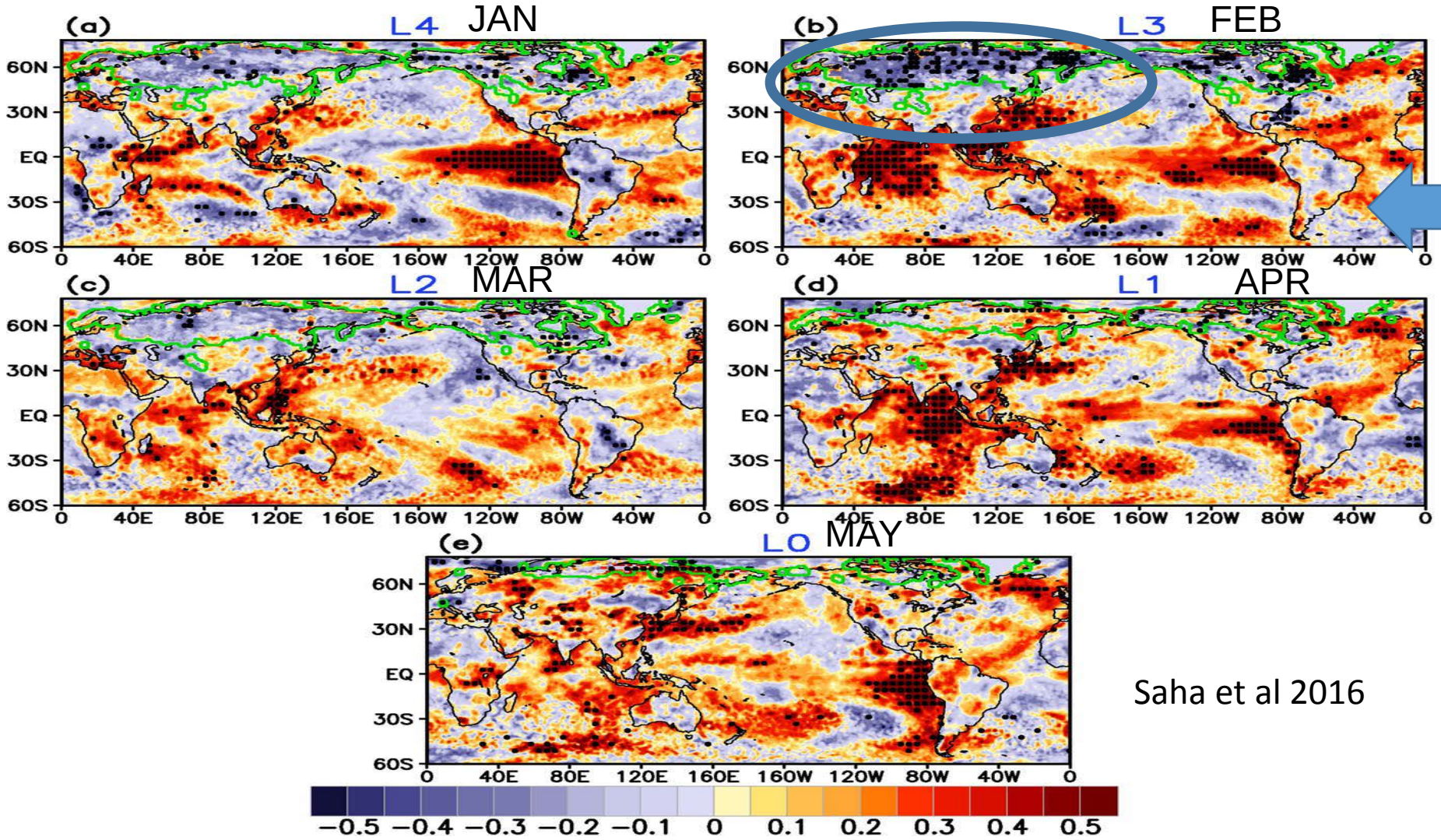
Instead of weakening El Nino pattern in April and May, model produces strong La Nina

Fig. Correlation between JJAS ISMR and SST anomalies of Feb to May initial months for observation, ensemble mean and RE values

Initial role of SST is captured in Feb IC . So less error in prediction and better skill for Feb IC

RE: Relative Entropy is difference between the probability density function of prediction and observations and is used to assess the predictability of each prediction.

Pillai et al 2017a



Role of initial SST , soil moisture (top one layer) and snow water equivalent (over land) is proper in Feb IC (L3). Thus the error from initial conditions are minimum for Feb IC leading to higher skill of ISMR.

Saha et al 2016

Correlation of RE of ISMR with SST, Soil Moisture and Snow Water Equivalent

RE: Relative Entropy is difference between the probability density function of prediction and observations and is used to assess the predictability of each prediction.

Role of initial SST anomalies and initial error in CFSv2-T382

Indices	Nino3		EMI		EEIO SST		ISMR	
IC (months)	AE	C	AE	C	AE	C	AE	C
Feb.	0.48	0.63	-0.03	0.75	0.40	0.48	0.04	0.64
Mar	0.38	0.64	-0.03	0.60	0.30	0.60	0.03	0.62
Apr	0.58	0.65	-0.08	0.51	0.40	0.52	0.19	0.08
May	-0.01	0.83	0.17	0.50	0.19	0.87	0.36	0.06

Table :correlation of RE with absolute error(AE) and RE contribution to predictability (C)

Small error and higher skill for ISMR in Feb IC and that for ENSO and IOD in May IC

Indices	Nino3		EMI		EEIO SST		ISMR	
IC (months)	Pot. skill	Actual skill	Pot. skill	Actual skill	Pot. skill	Actual skill	Pot. skill	Actual skill
Feb.	0.86	0.66	0.70	0.66	0.75	0.35	0.70	0.55
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May	0.95	0.85	0.89	0.71	0.84	0.80	0.70	0.30

Pillai et al 2017a

Table: Potential skill and actual skill for all ICs

When AE is small and C is higher , actual skill and potential skill are higher and close to each other

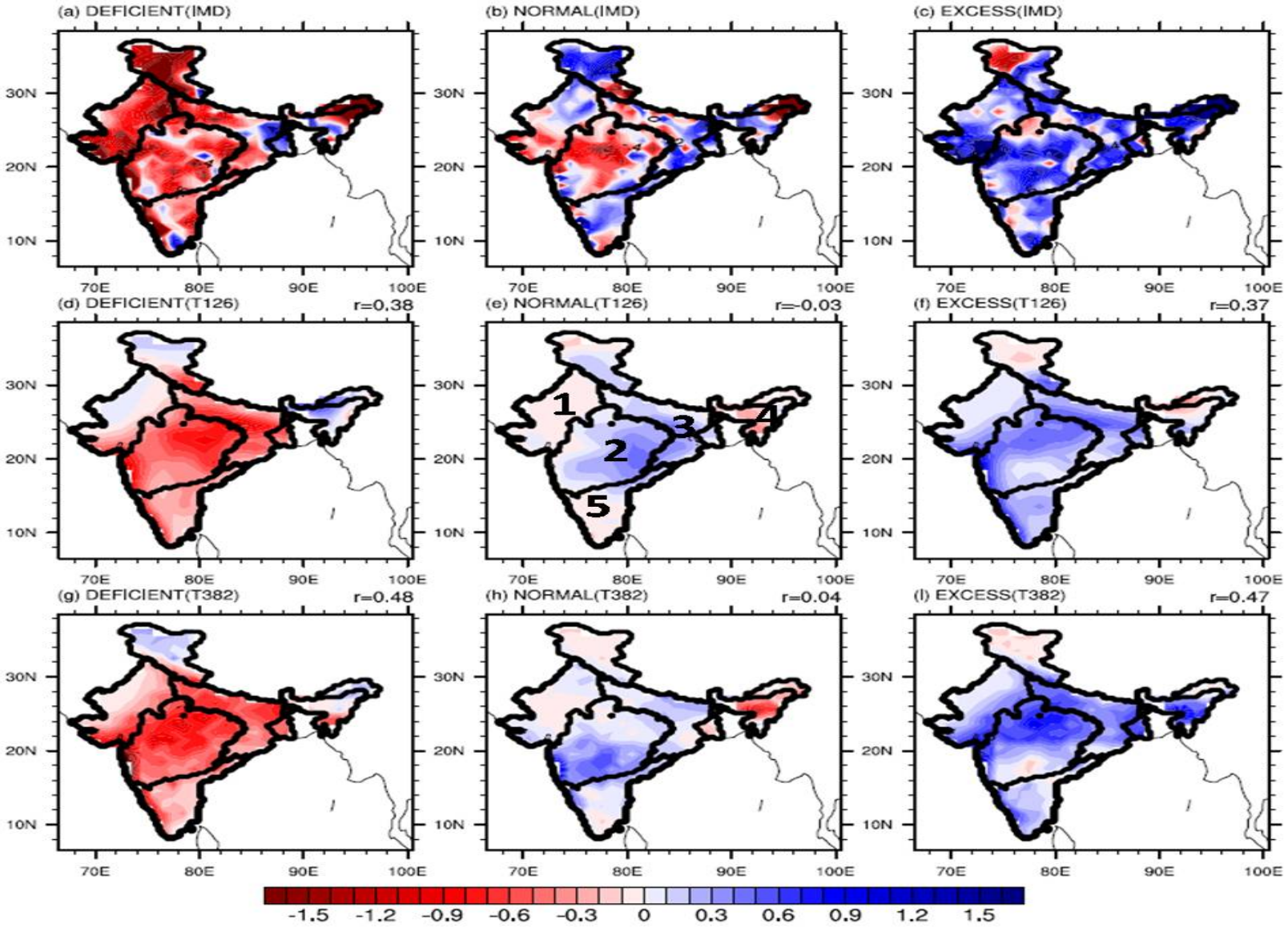

Fig. spatial distribution of rainfall anomalies in deficient, normal and excess monsoon years

Deficient and excess years spatial pattern is proper in Feb IC hindcasts with a pattern correlation of around 0.5 for CFSv2-T382.

Ramu et al 2017

	Predictability experiments (perfect model scenario)	Real CFSv2_rev (1979–2008) reforecasts		
	Ensemble mean of five members	Ensemble mean of four members	Ensemble mean of eight members	Ensemble mean of twelve members
Feb IC	0.54	0.44	0.49	0.49
May IC	0.73	0.34	0.40	0.39

Shukla et al (2017)

"The above results demonstrate that CFSv2 has higher skill using May IC than Feb IC in predictions in the perfect model scenario and perfect ocean initial state. **Why, then, is there higher prediction skill in the NCEP CFSv2 hindcasts initialized with Feb IC than the hindcasts initialized with May IC, as reported in Chattopadhyay et al. (2015) and Saha et al. (2016)?** One fundamental difference between the predictability runs and the hindcasts is that the latter are strongly influenced by the model climate drift, including a large initial shock (Zhang 2011a , b), while those influences are practically absent in the former. Therefore, we hypothesize that the stronger influence of the initial shock in the May CFSv2 hindcasts is the main reason for its reduced prediction skill."

Summary and Conclusions

- There are other factors (other than ENSO) that influence Monsoon predictability
- Getting the other factors reasonable in the model provides better prediction skill at longer leads
  - Flavors of El Nino
  - Reduced biases in Central tropical Pacific
  - Snow/Soil moisture and extra tropical SSTs
  - Less initial shock due to Feb. ICs
  - Once we get the reasonable prediction skill for monsoon the model is expected to get better skills for other regions also like north America, Australia and Africa (not shown here)

Thank you!