Seasonal Prediction of Indian Summer Monsoon

Part I: Why we get better skill with Feb. IC?

Part II: How to improve Indian Summer Monsoon Prediction in Coupled Models?

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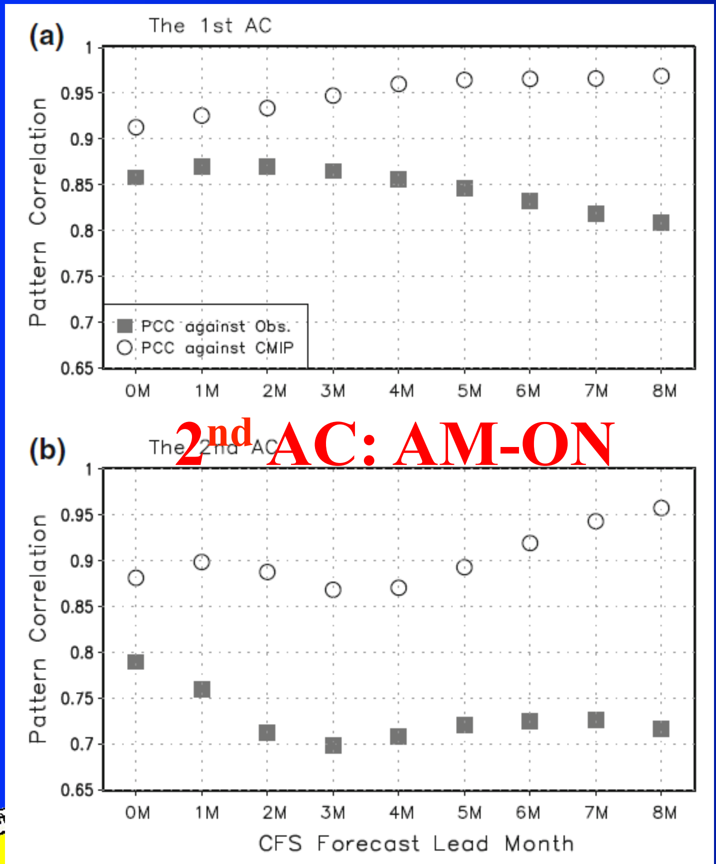
Outline

- Background
- Indian Summer Monsoon Prediction
- Prediction Skill with different Initial Conditions
- Why better skill with Feb. IC?
  - Improved Mean State?
  - ENSO-Monsoon Relation?
  - Indian Ocean SST-Monsoon Relation?

Background

Pattern Correlation Coefficient of 1st /2nd Annual Cycle modes in CFS at different Lead Months

1st AC: JJAS-DJFM



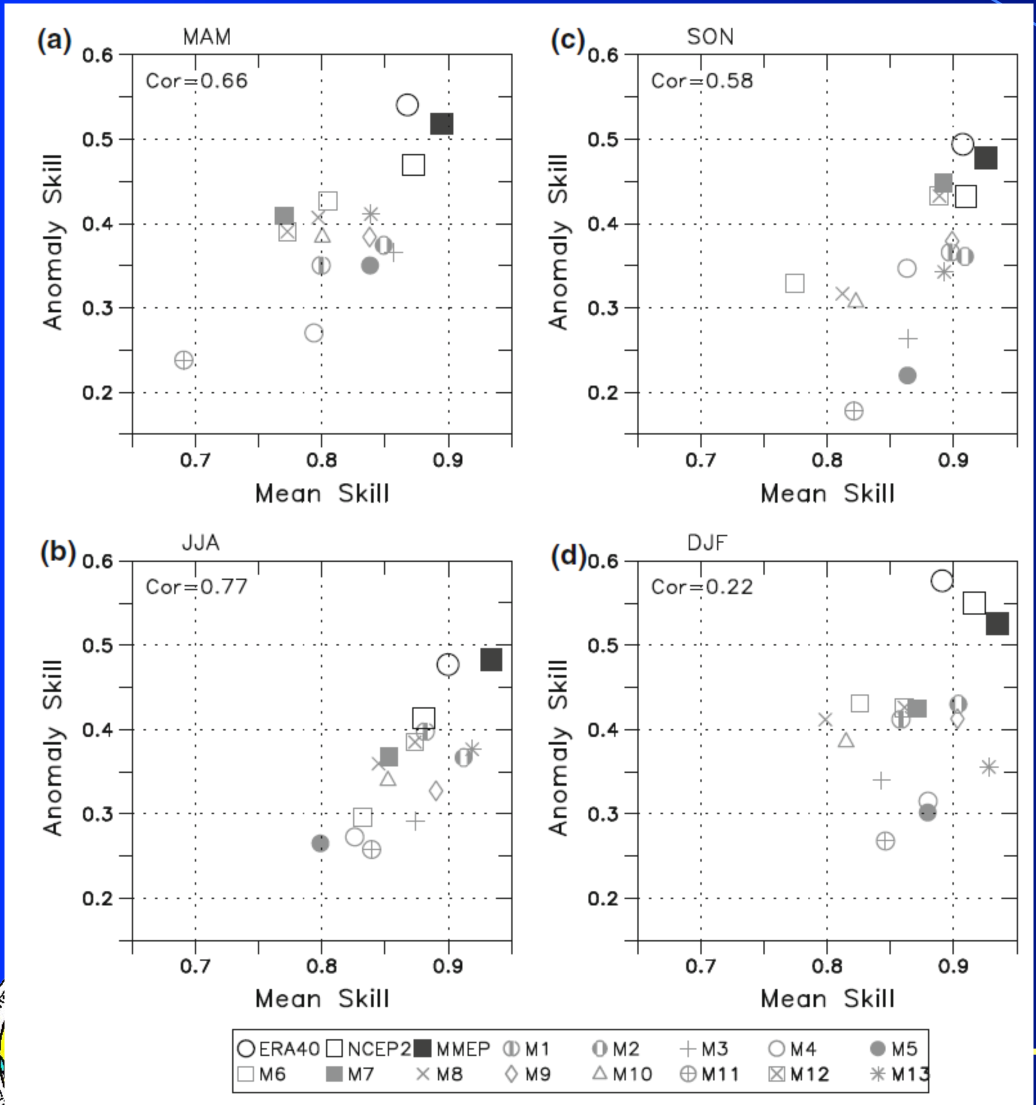
2nd AC: AM-ON

- **PCC decreases with increasing lead time against observations**

- **PCC increases with increasing lead time against its own free run.**

Reference: Lee et al., (2010)

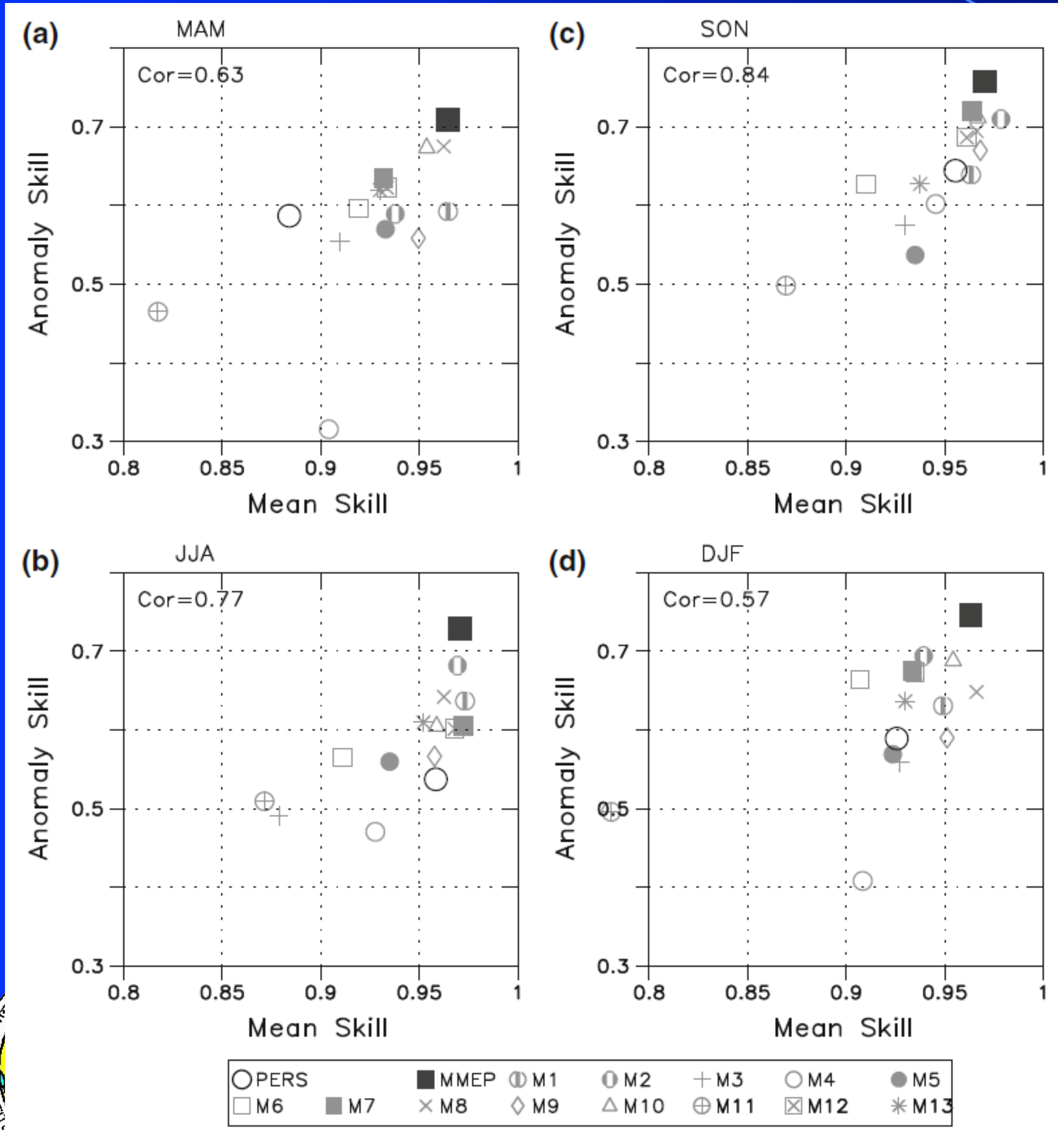
Mean Skill Vs. Anomaly Skill (for precipitation)



- During JJA the relation between mean seasonal cycle and interannual variability is very high.

Reference: Lee et al., (2010)

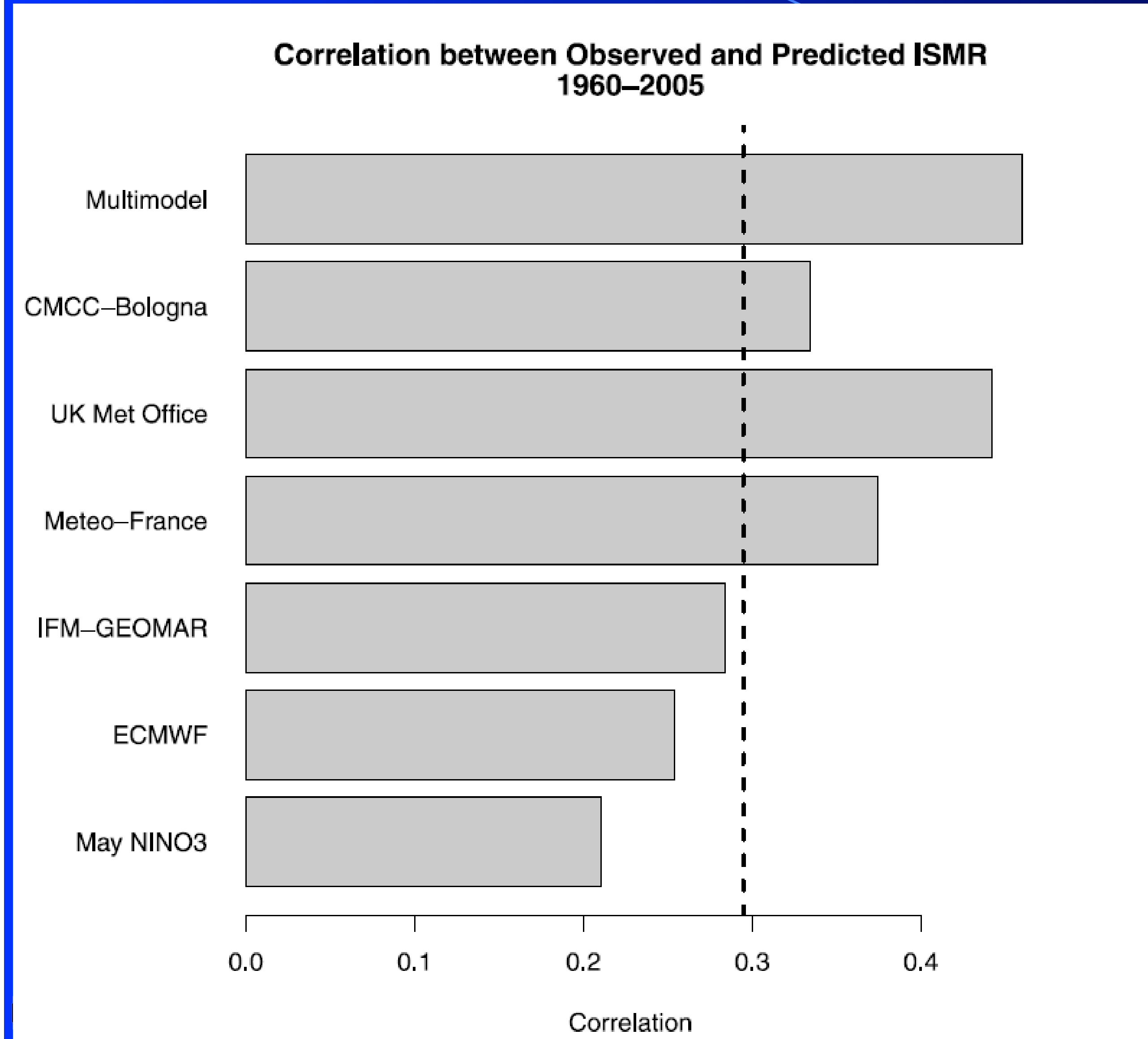
Mean Skill Vs. Anomaly Skill (for SST)



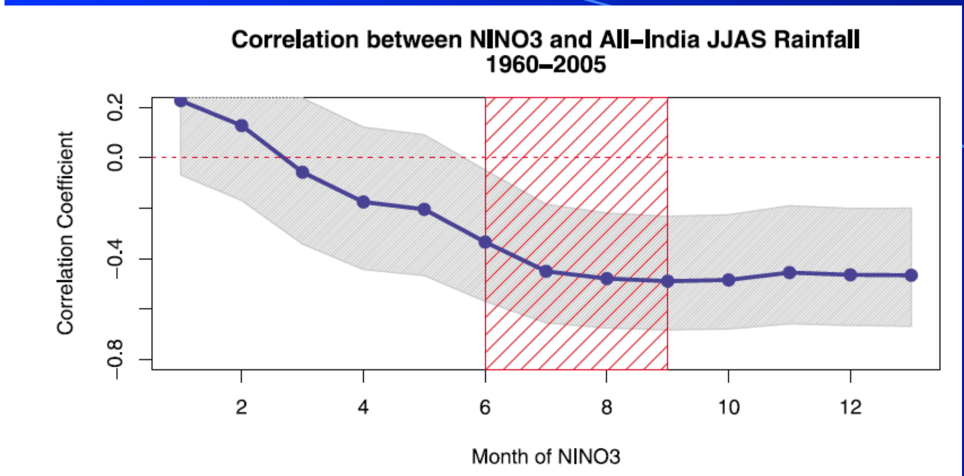
- Relation between mean skill and interannual variability skill is strong for SST

Reference: Lee et al., (2010)

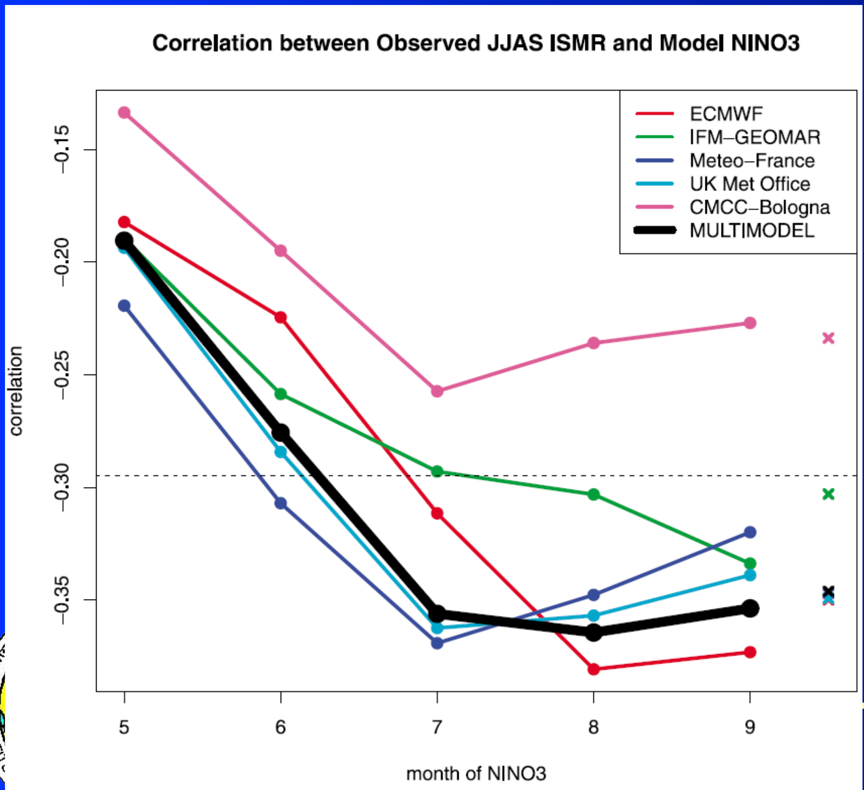
Prediction Skill (ACC) of Indian Monsoon Rainfall (Land rain aggregated between 70-90°E and 10°S-10°N) with different coupled models initialized with May IC.



Ref.: Delsole and Shukla, (2012)



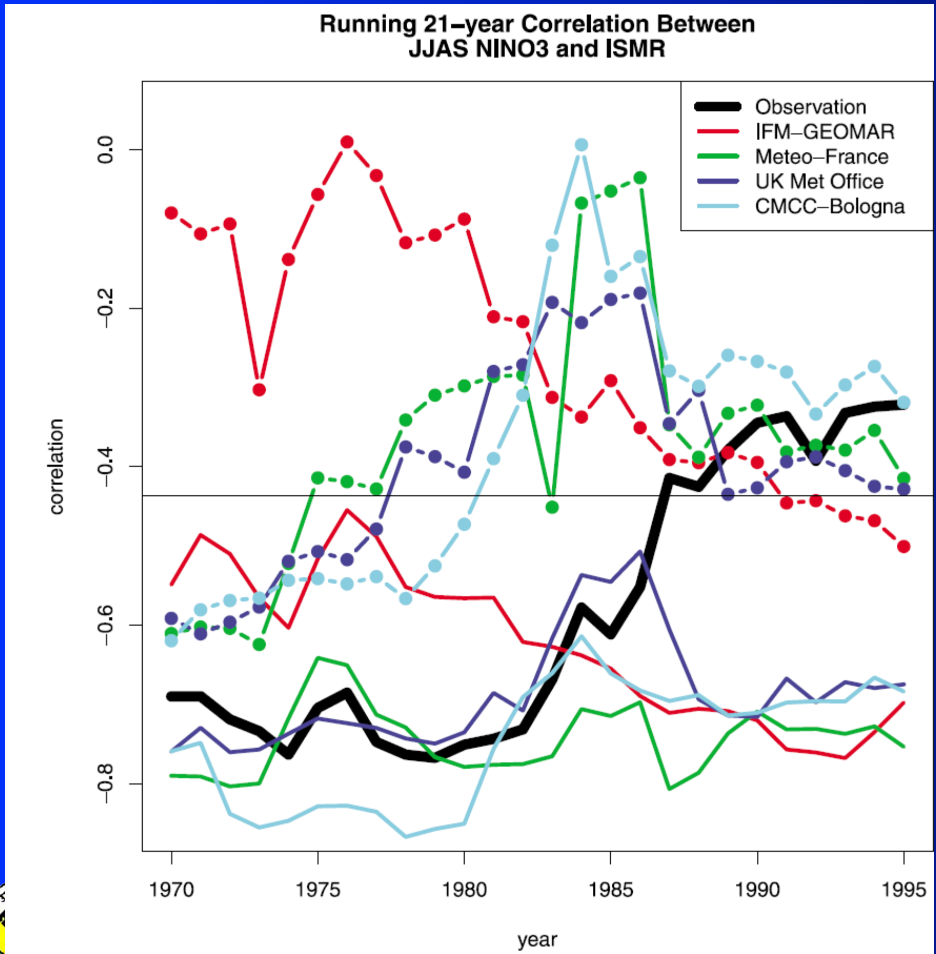
In real world ENSO-Monsoon relation is concurrent.



- Both UK met and Meteo-France are able to reproduce the observed relation.
- CMCC do not have good correlation between Nino3 and ISMR

Ref.: Delsole and Shukla, (2012)

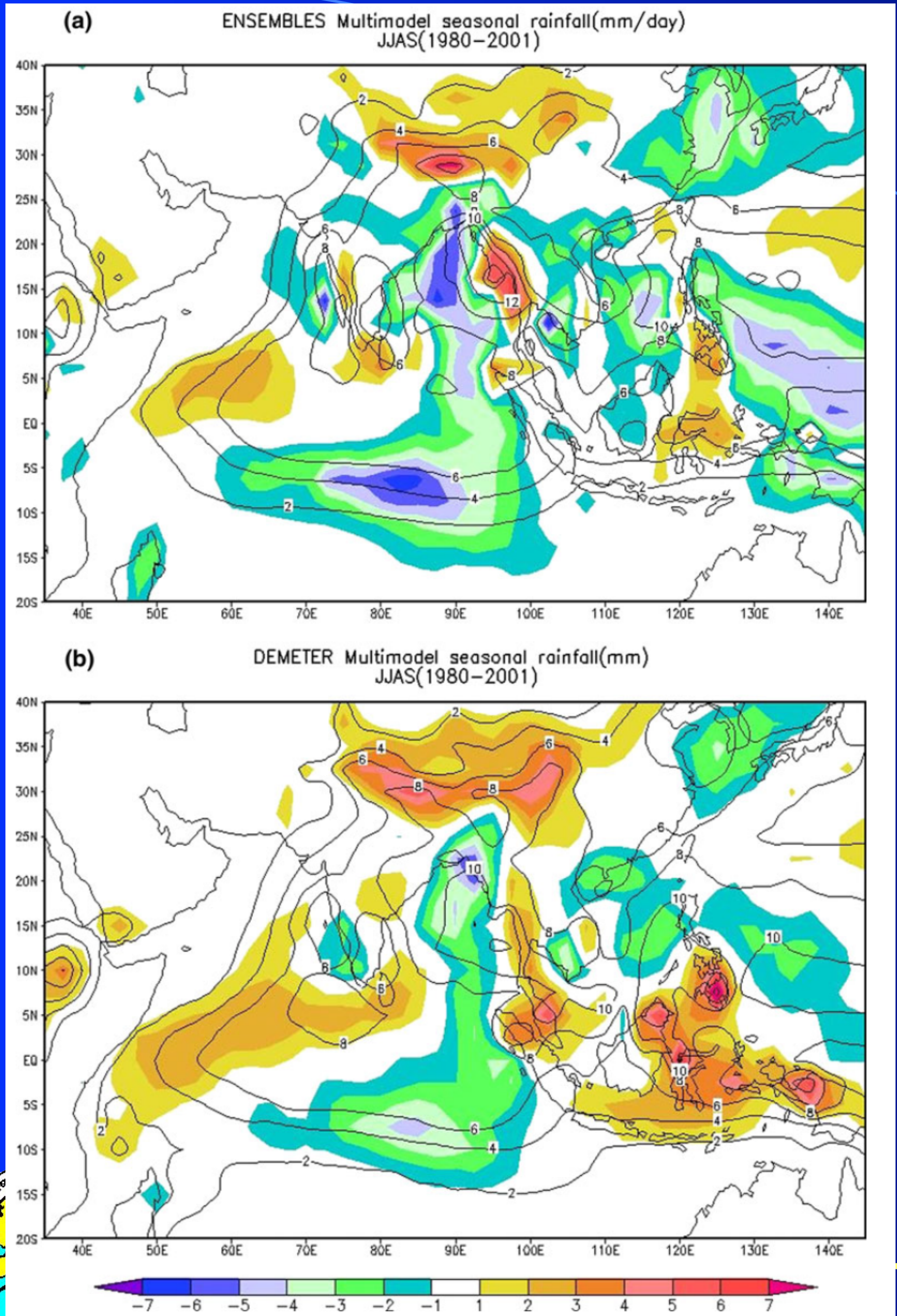
ENSO-MONSOON Relation in Coupled Models (Moving 21yr correlation)



All models show very good relation between Nino3 index and ISMR.

However, its' insignificance in recent times is not captured by the models.

Ref.: Delsole and Shukla, (2012)



Model Bias for Recent Coupled Models

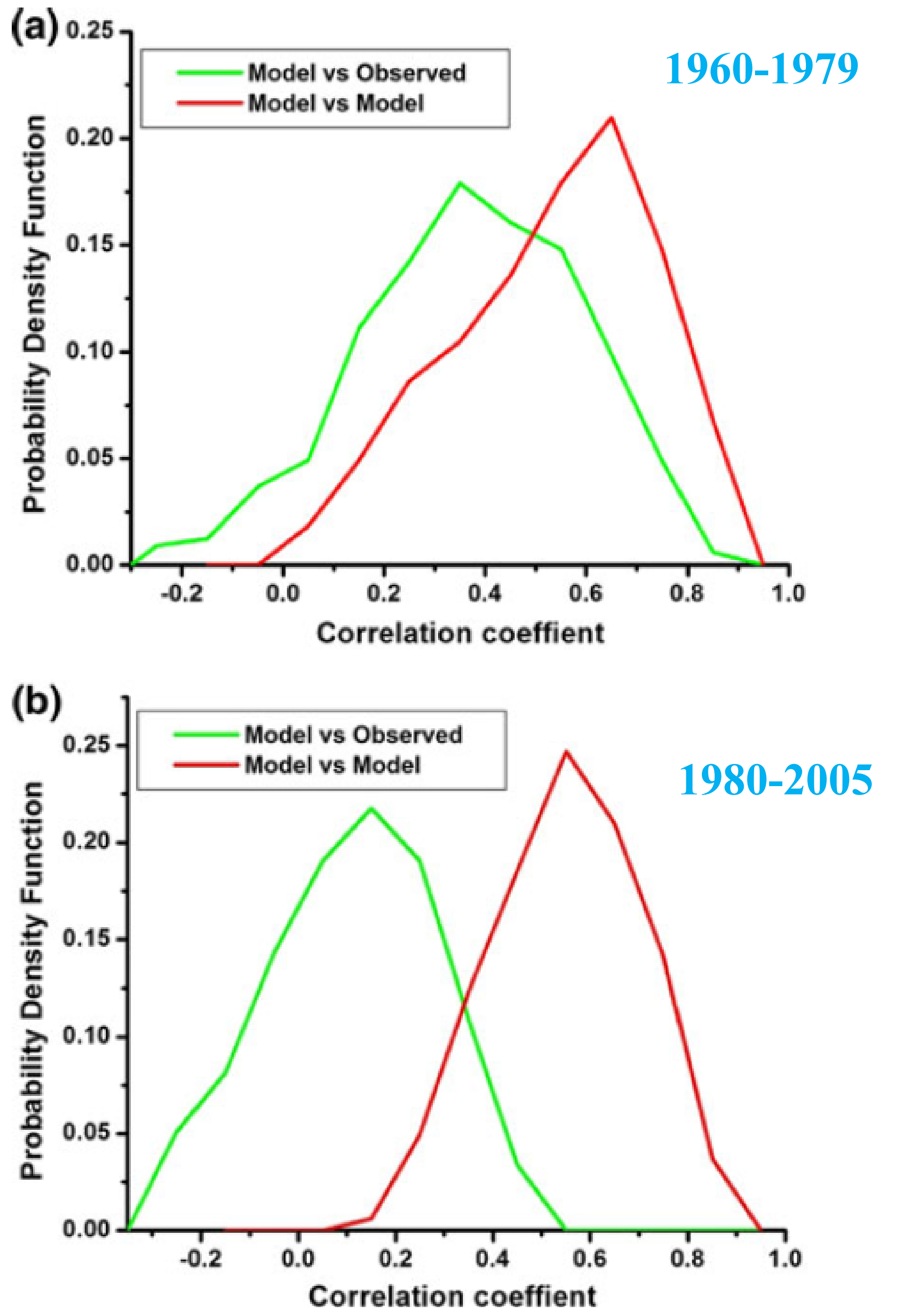
Model Bias for earlier Coupled Models

Ref: Rajeevan et al., (2012)

Seasonal Prediction Skill of ISMR (all India land points averaged) in ENSEMBLES

	Mean rainfall (cm)	Coefficient of variation CV (%)	Correlation coefficient 1960–2005
Observed	82.9	11.9	1
ECMWF	93.2	4.5	0.37
IFM-GEOMAR	79.8	5.7	0.34
MF	45.0	8.2	0.34
HadGEM2	80.0	12.2	0.39
CMCC-INGV	91.0	5.4	0.39
HadCM3	65.6	8.9	0.27
ENSEMBLES MME	75.8	5.7	0.45
DEMETER MME (1960-2001)	76.0	4.3	0.28
IMD's operational Forecasts	–	–	0.29 (1988–2010)

Ref: Rajeevan et al., (2012)



Probability Density Function of Prediction skill (ACC)

- Potential predictability of ISMR is decreasing in present state of the art coupled models

Ref: Rajeevan et al., (2012)

Present Study

Details of Latest Models

	Atmosphere	Ocean	Other details
ECMWF	IFS CY 31 R1 (T159 / L62)	HOPE (0.3° – 1.4° / L29)	
UK Met Office	Had GEM2-A (N96 / L38)	HadGEM2-O (0.33°-1° / L20)	Fully interactive sea ice
MetFrance	ARPEGE 4.6 T63	OPA 8.2 (2° / L31)	GELATO sea ice model
IFM – GEOMAR	ECHAM 5 (T63 / L31)	MPI OMI 1.5° / L40	
CMCC - INGV	ECHAM 5 (T63 / L19)	OPA 8.2 (2° / L31)	Dynamical snow-sea ice model and land surface model
DePreSys-UKMO	HadAM3 (2.5°-3.75° / L38)	HadOM (1° / L 40)	Perturbed parameter
CFS v2	GFS (T126/L64)	MOM4 (0.33 – 1°/L40)	Dynamical Sea ice and Land surface models

Details of Initialization (in CFS V2.0)
(May Initial Conditions)

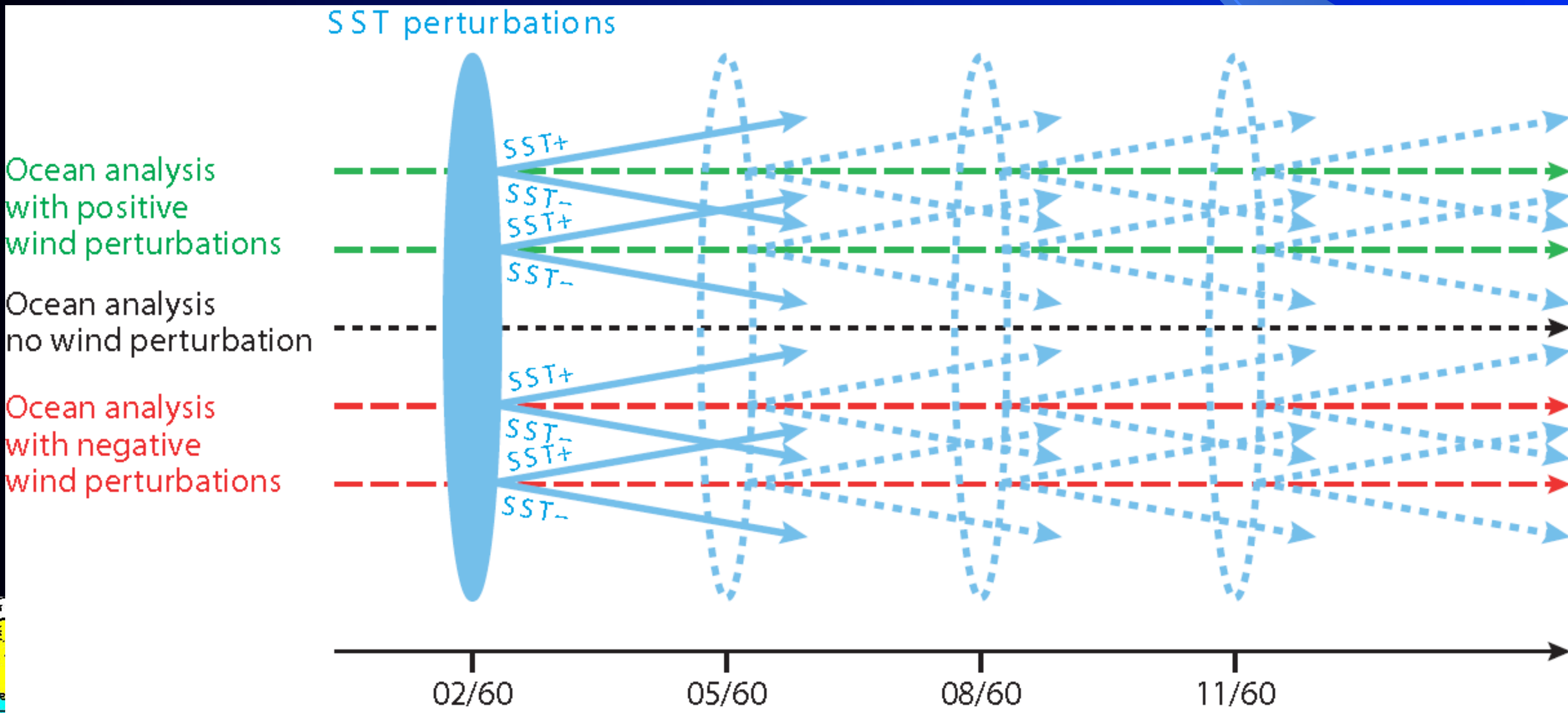
Month	Day	Hour
5	11	0, 6, 12, 18
5	16	0, 6, 12, 18
5	21	0, 6, 12, 18
5	26	0, 6, 12, 18
5	31	0, 6, 12, 18
6	5	0, 6, 12, 18

CFS V2.0 hindcast results are evaluated for Feb., Mar., Apr., May., Initial Conditions.

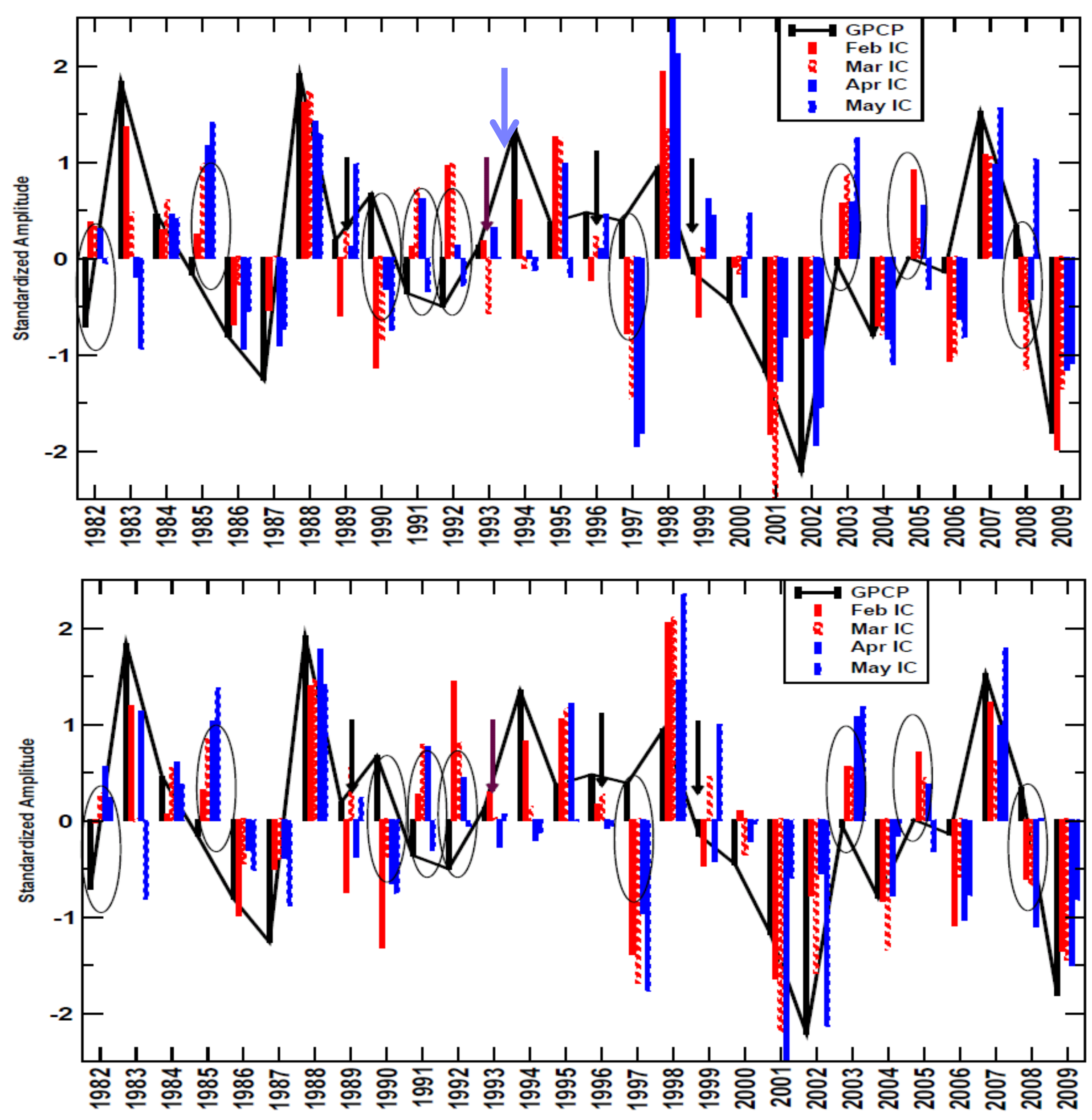
Details of Initialization (in ENSEMBLES)

Atmospheric IC:ERA-40 Operational Analysis
AMIP type Simulations

Ocean IC: Ocean analysis with Wind/SST Perturbations



Rainfall Interannual variability



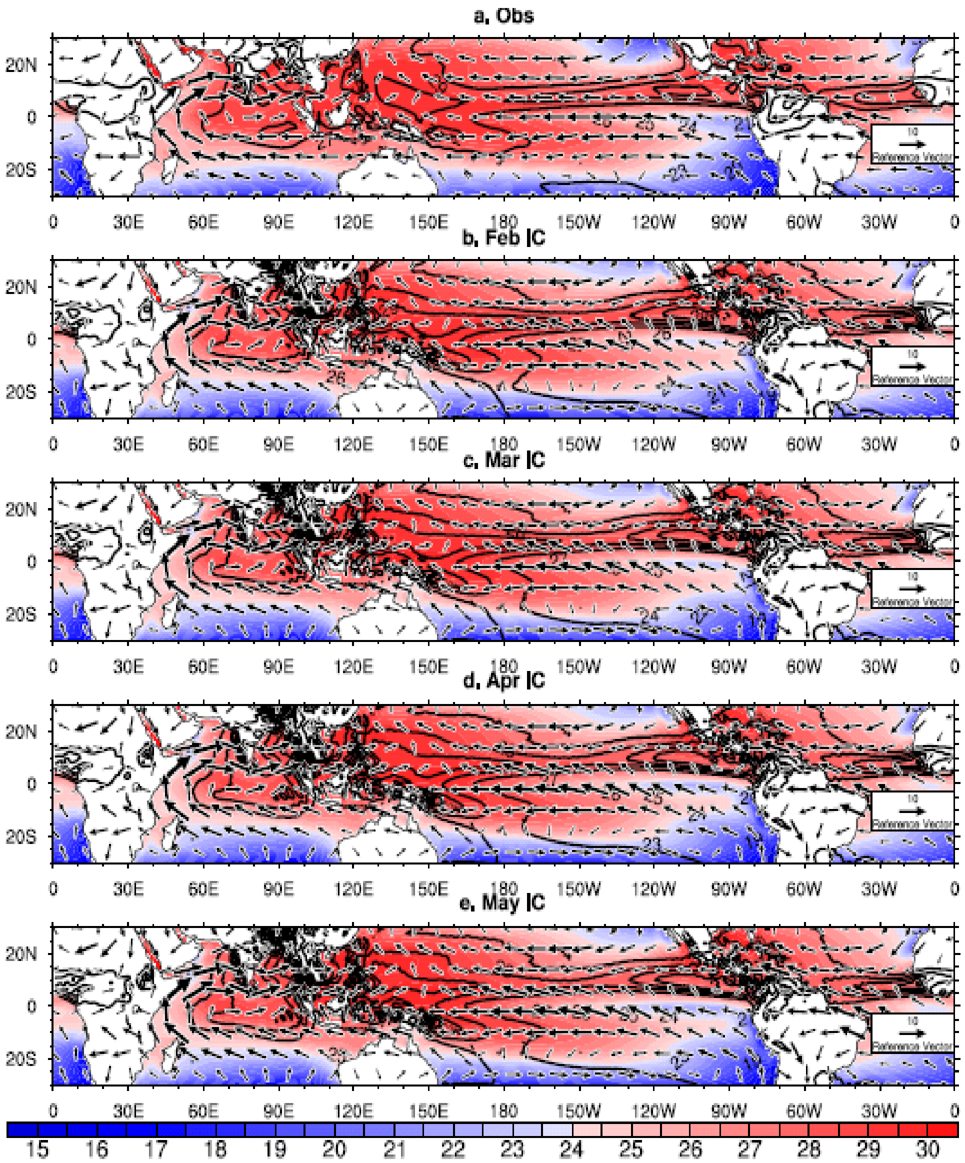
Top pannel : Interannual variability of ISMR anomaly in observation (GPCP) and different initial condition hindast runs.

Ovals marks the years when the forecast goes entirely wrong. Arrows marks the year when at least one forecast is wrong. (bottom) Same as above but using monthly startified ensembles.

Model ISMR SKILL with different IC. (against IMD bold; GPCPC parenthesis) Period: 1982-2008

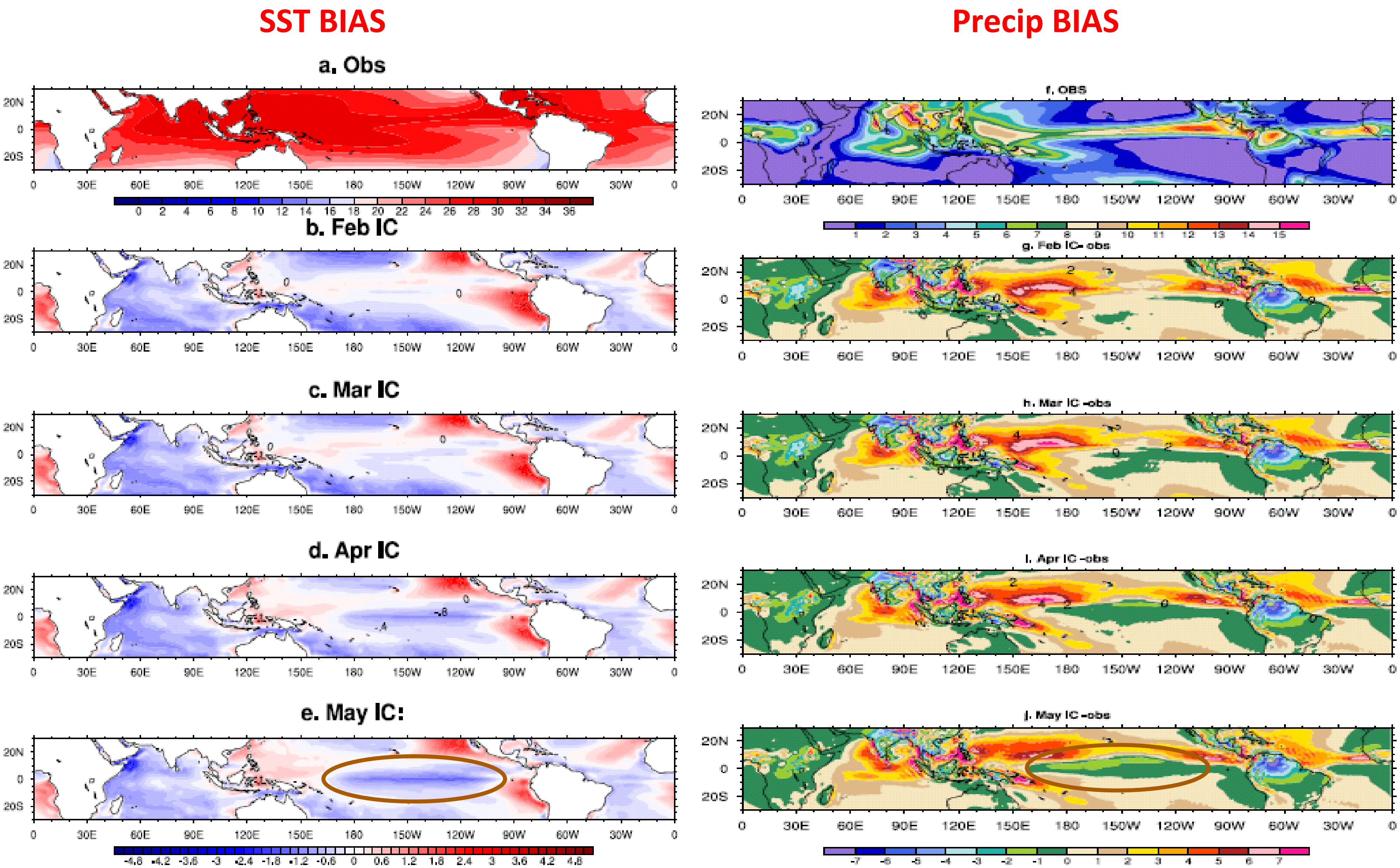
Model	Feb. IC	Mar. IC	Apr. IC	May IC.
CFS V2. (Mid Month release)	**0.52** (0.60)	**0.28** (0.44)	**0.48** (0.55)	**0.33**(0.45)
CFS V2. (Monthly strtified)	**0.58** (0.57)	**0.57**(0.57)	**0.55**(0.56)	**0.43**(0.49)
Meteo-France	**0.40**			**0.20**
INGV	**0.40**			**0.30**
UKMO	**0.30**			**0.30**

Basic State and Bias



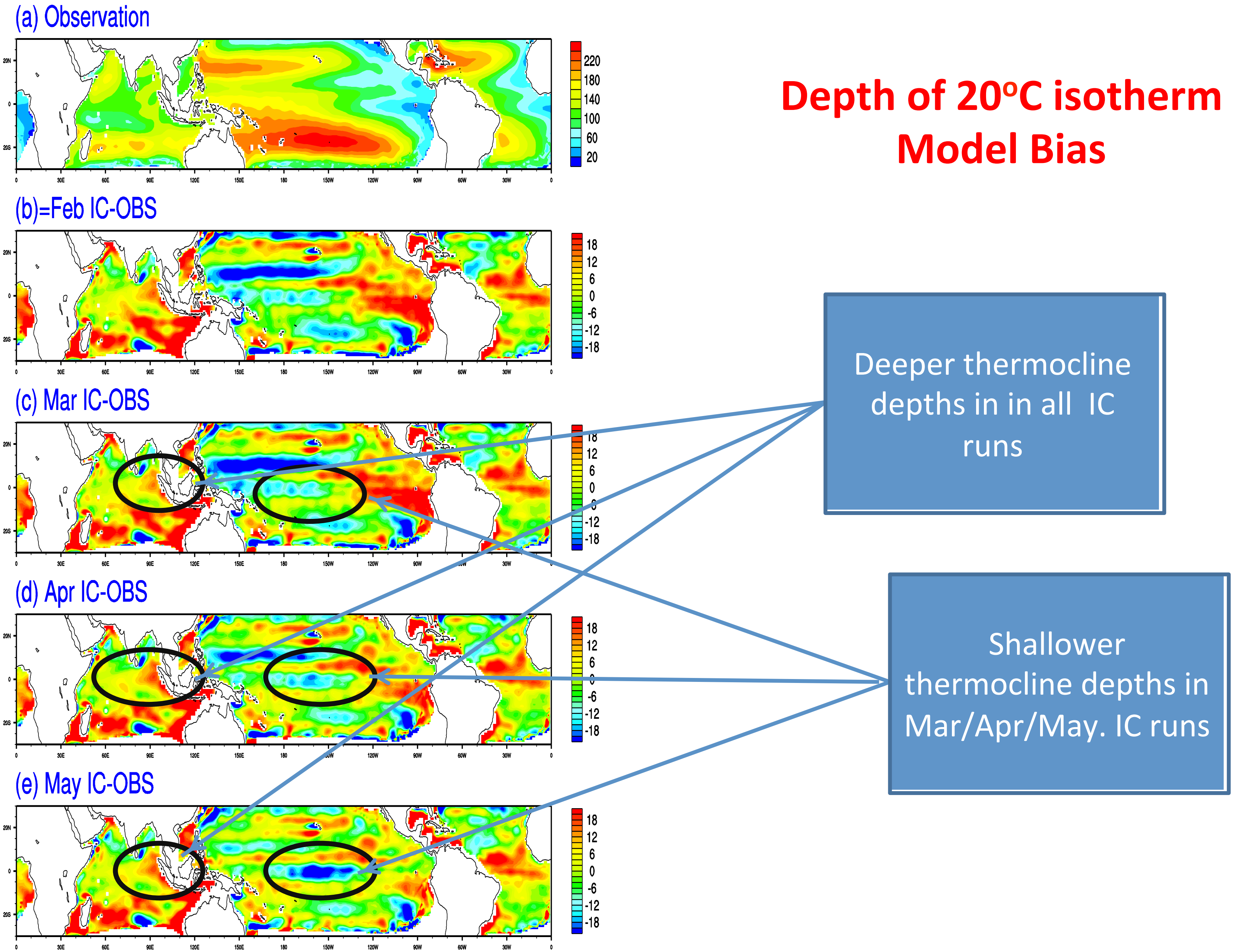
MEAN STATE

The JJAS averaged climatology for SST (shaded), precipitation(contours) and wind vectors at 850hPa. The observed fields are shown in top panel (a), while the JJAS ensemble mean of the CFS runs from different months are shown in rows below(b-e). The runs from the months for each initial conditions are mentioned at the top of each panels. (units SST: C,precipitation: mm day−1)

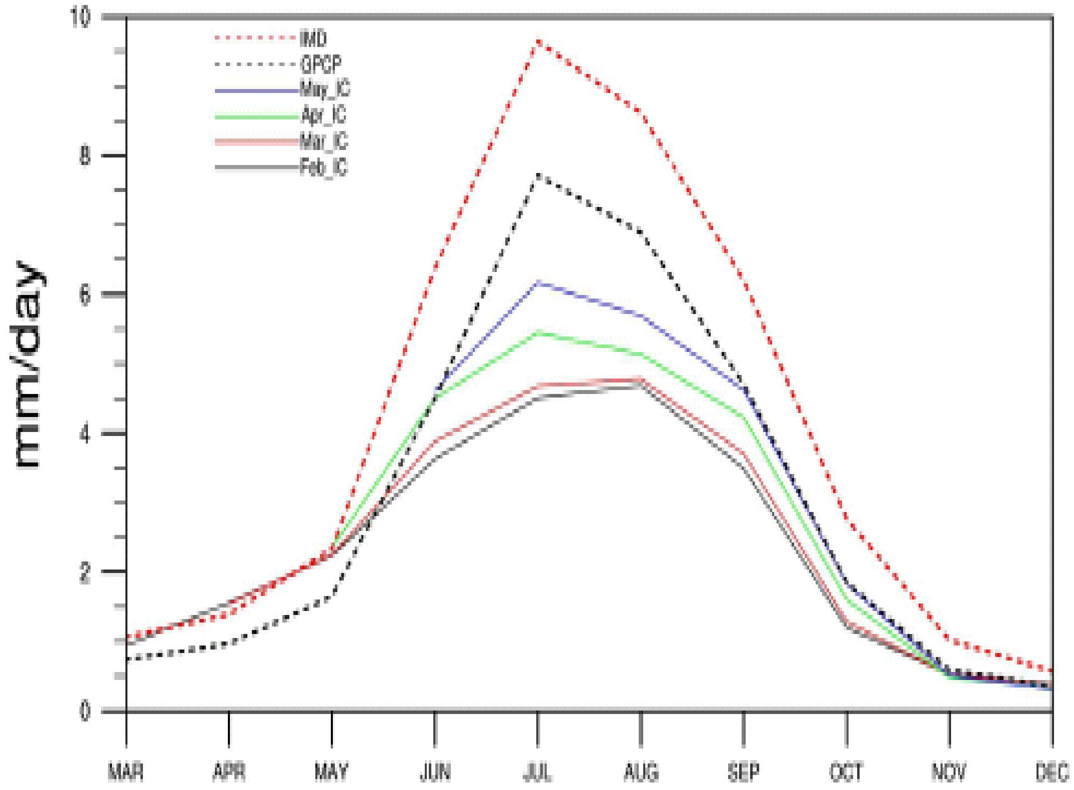


The JJAS climatology from Observed SST (a), and the climatological bias from observation for the CFS derived SST for Feb, Mar, Apr, May initial condition runs (b-e).(f-j) same as (a-b) but for precipitation

Depth of 20°C isotherm Model Bias



Seasonal Cycle of Rainfall Over Indian Land Mass



Significant improvement Is seen in rainfall simulation over India as lead time decreases.

The Bias Structure indicate that there is appearance of cool SST BIAS and dry rainfall bias: Change in spatial Bias structure from Feb IC → May IC

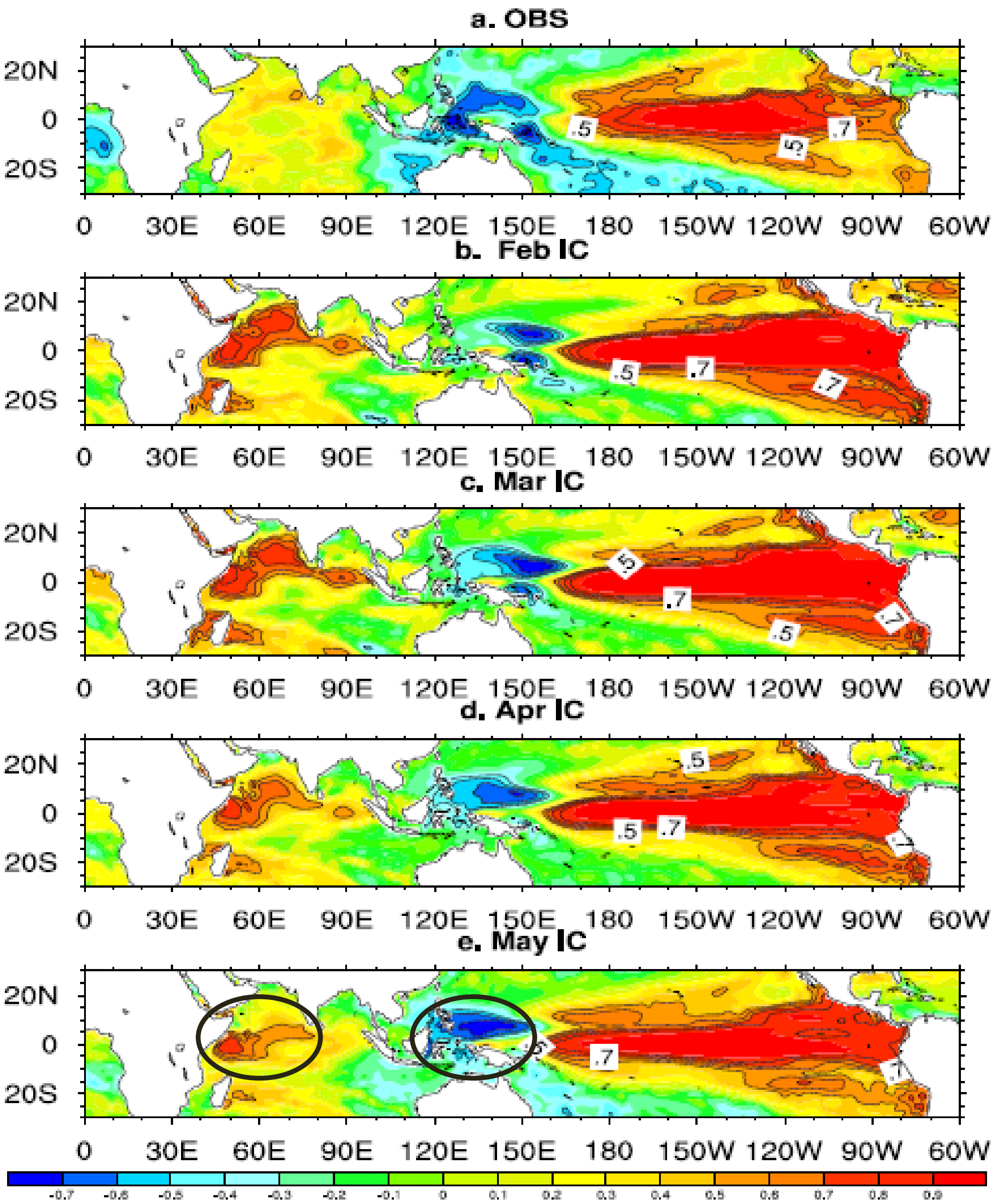
On the Other hand Indian Ocean biases are decreasing from Feb IC → May IC

This lead dependent skill is important and it is clear that the skill of ISMR is better from Feb IC.

What controls the large lead time skill?

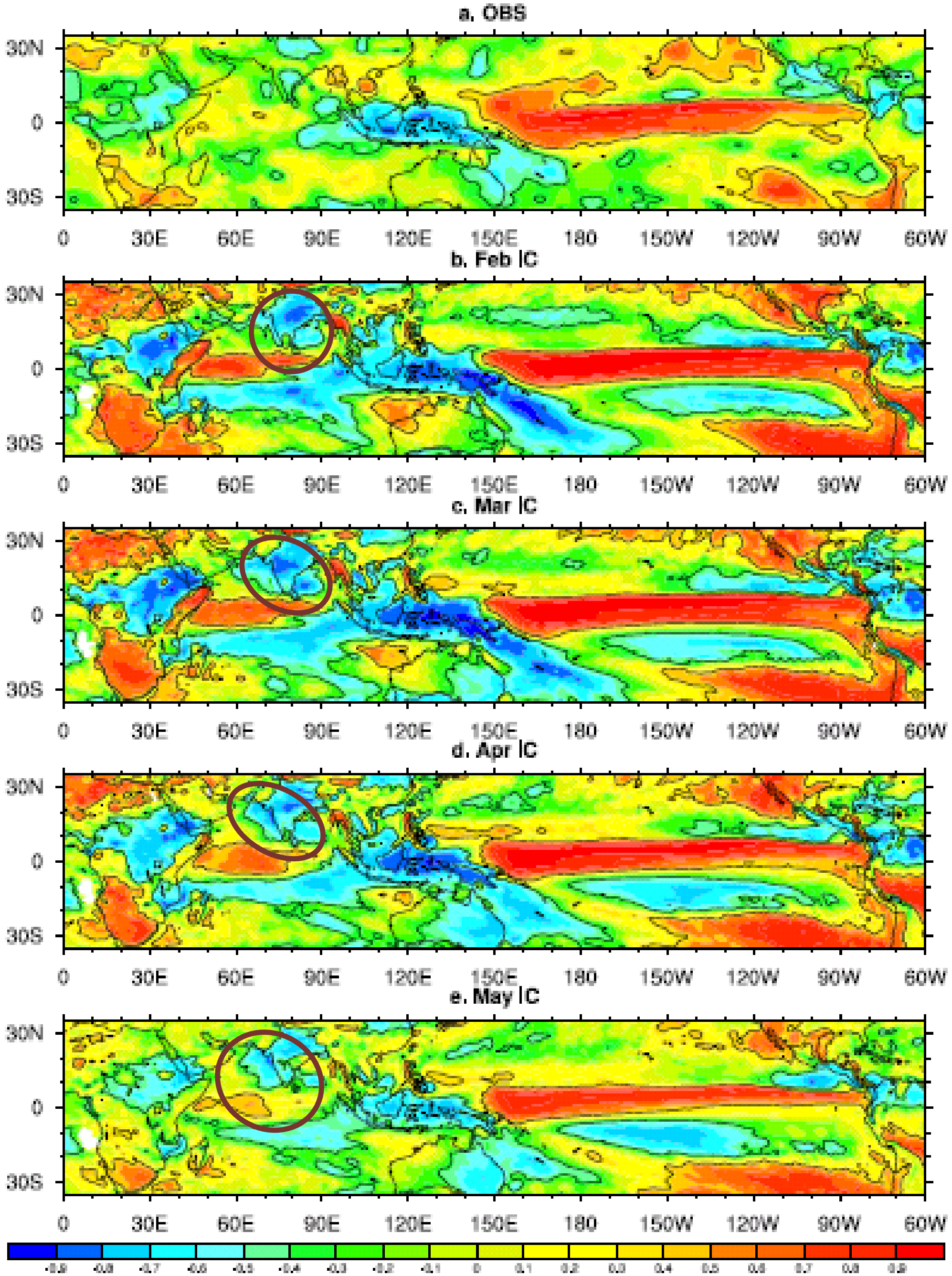
The IAV of ISMR largely depends on the teleconnection e.g. ENSO teleconnection and Indian Ocean teleconnection.

We need to look into the teleconnection aspect to understand this skill.



Nino 3.4 SST vs global SST teleconnection

Note the change in teleconnection pattern

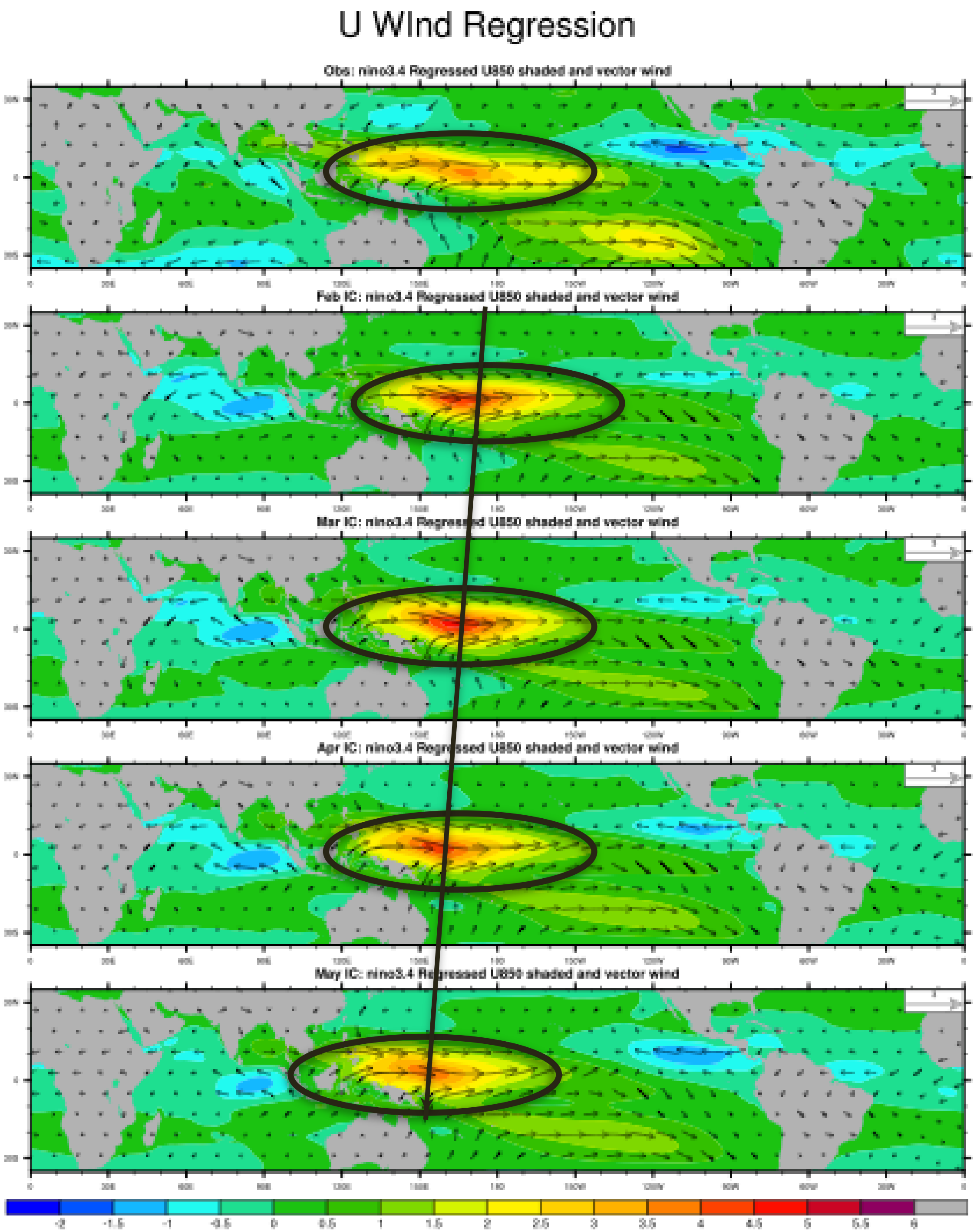


Correlation between Nino 3.4 SSTA and global Rainfall

Nin 3.4 SST with
wind at 850hpa regression

Notable shift in the region
of convergence

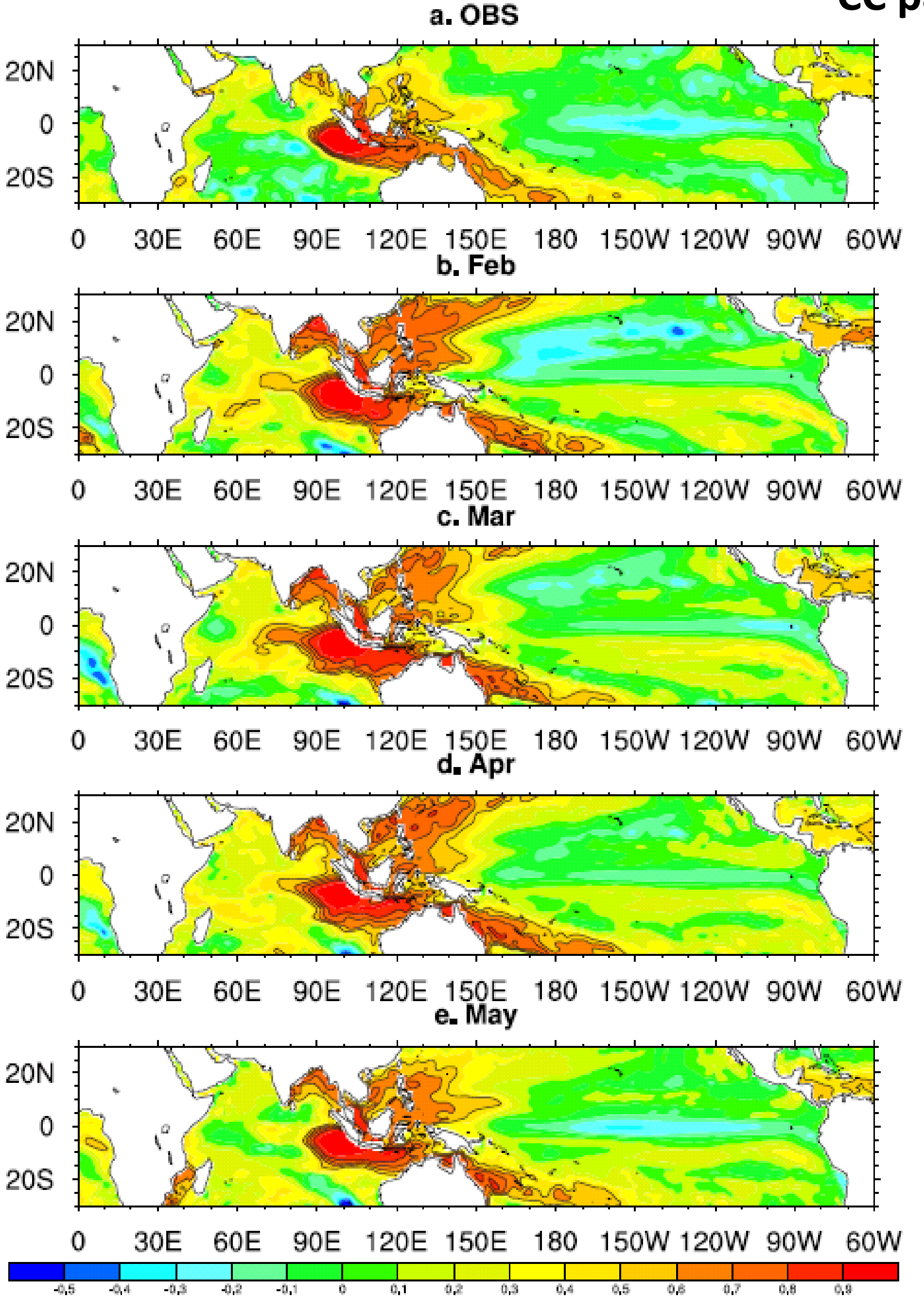
The cross panel line shows shift

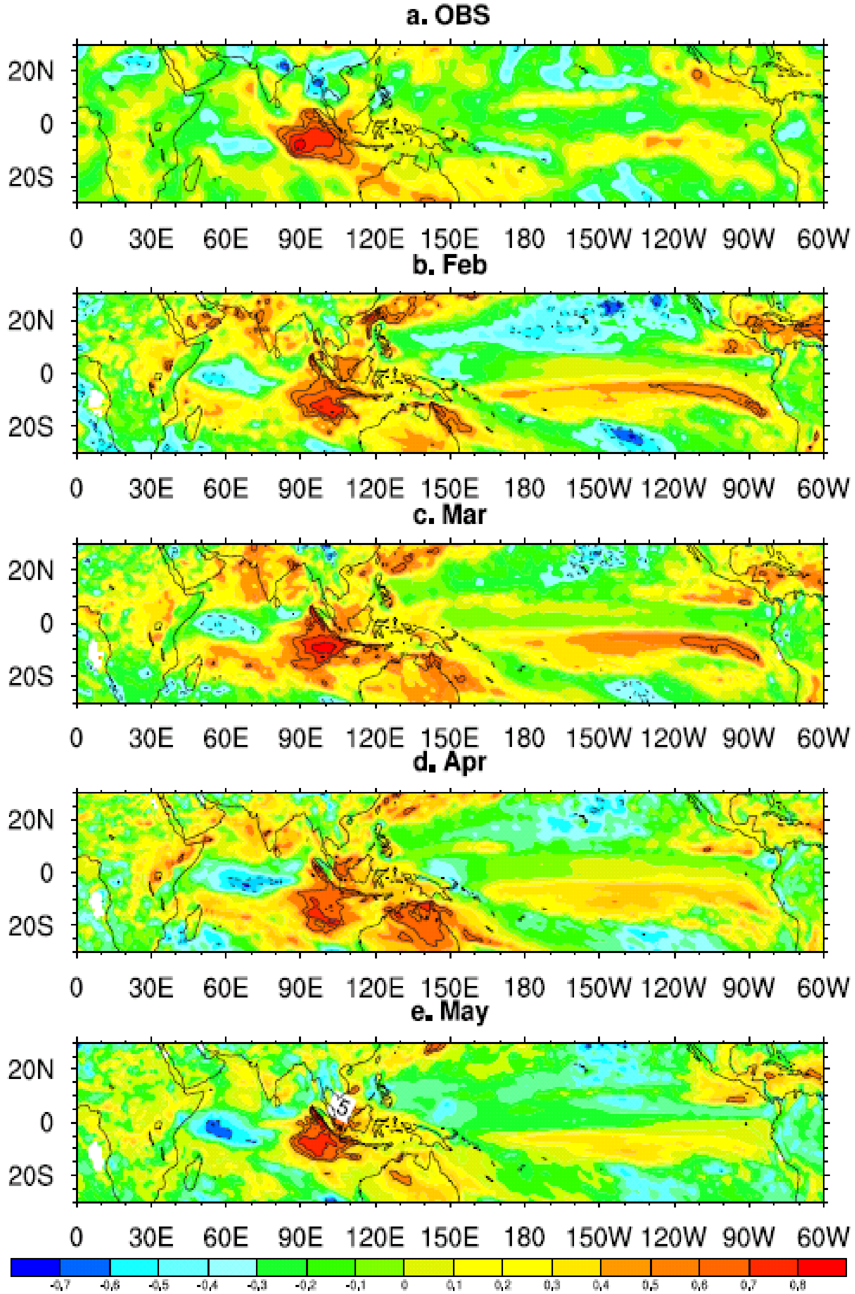


IODE SST with global SST

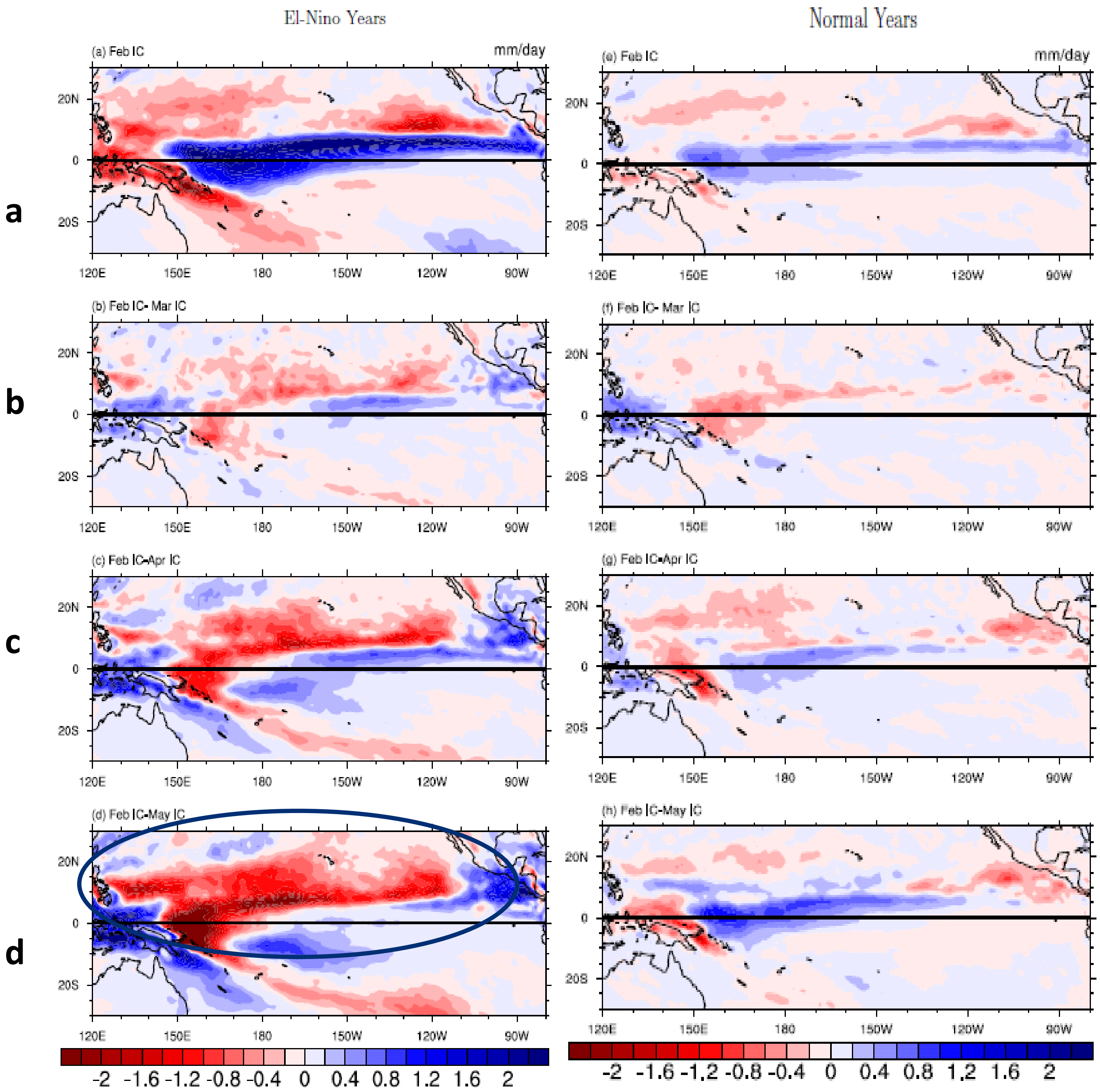
CC pattern

IODE SST with global RF



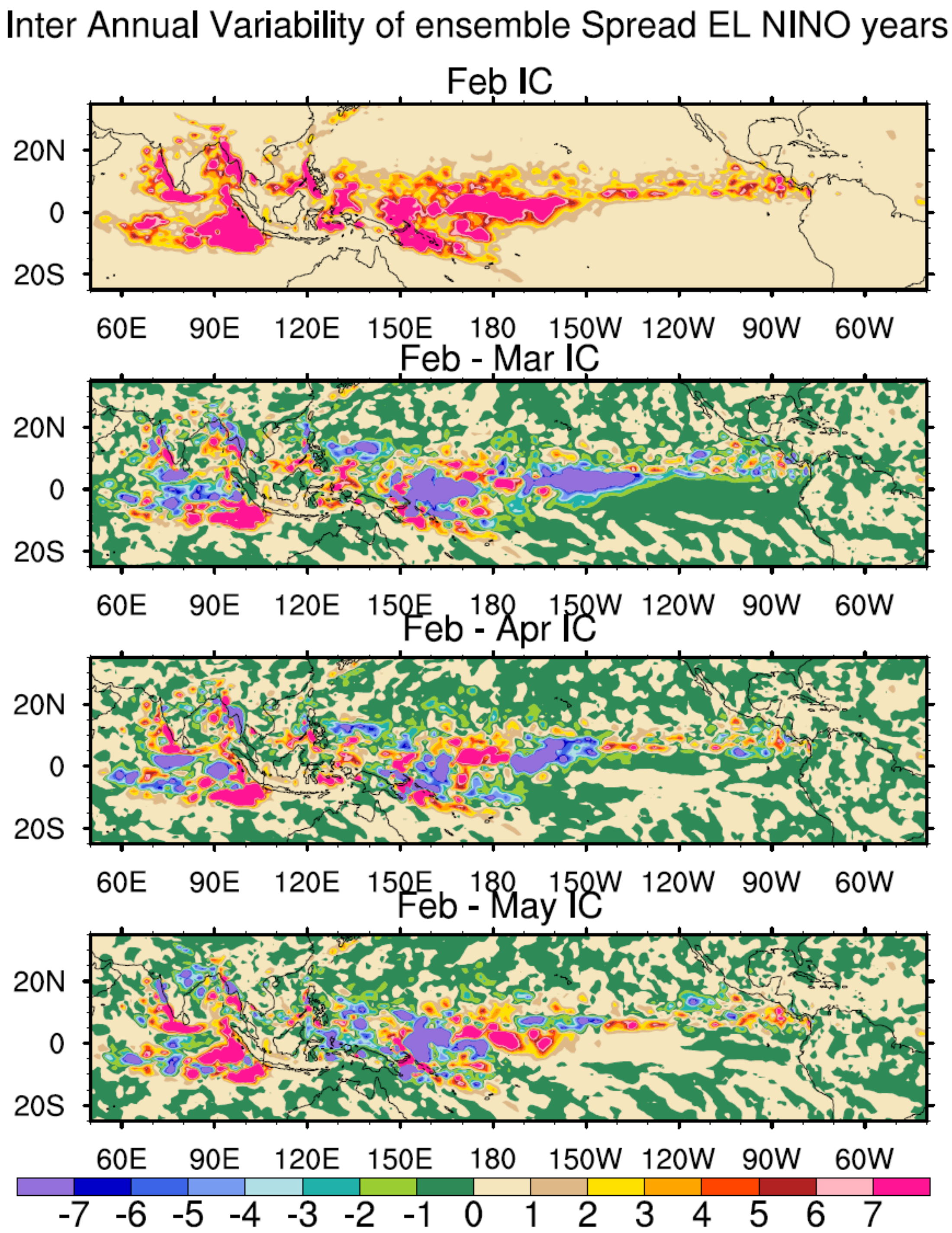


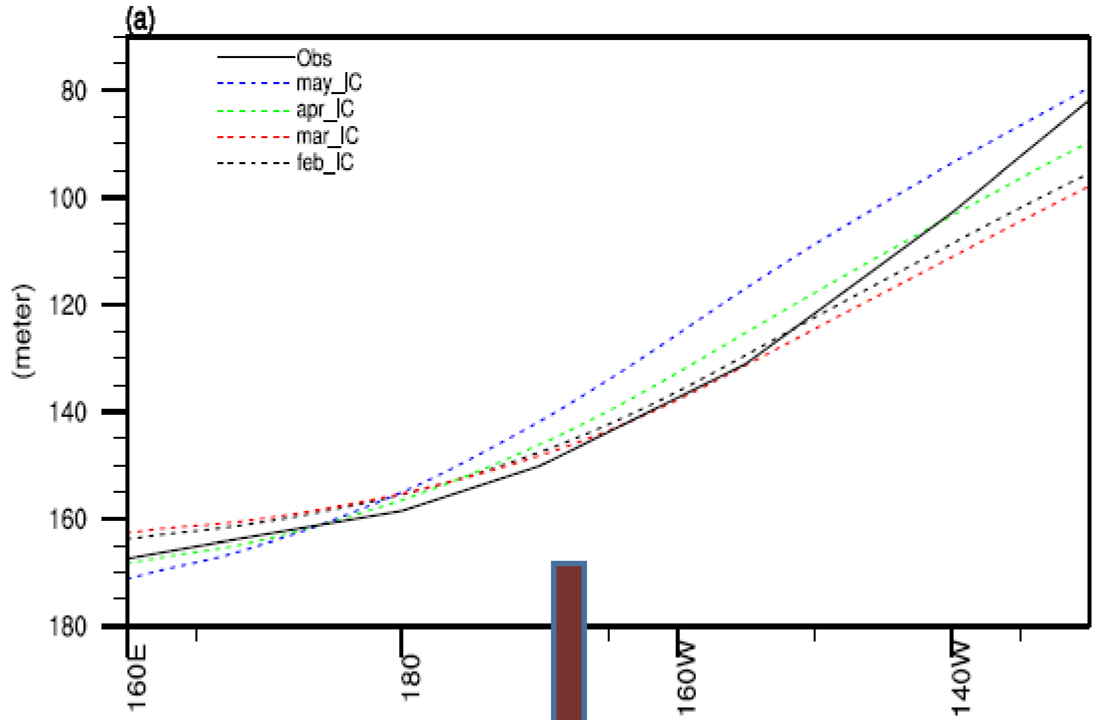
The Teleconnection plot shows shift in teleconnection pattern This is more evident in EL-Nino and normal years.



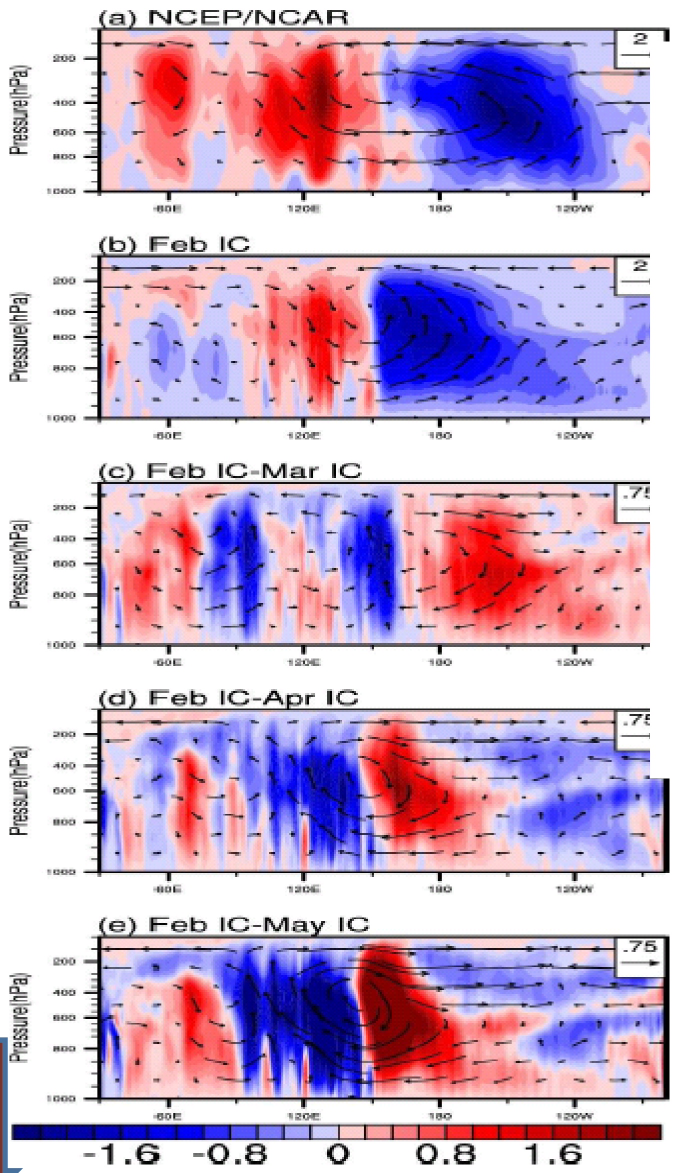
Composite of seasonal (JJAS) mean precipitation anomalies (mm day-1) for El Nino years (1982, 1987, 1991, 1997, 2002, 2004) in Feb IC hindcast run.

(b, c, and d) bias of composite precipitation anomalies corresponding to El Nino years from Feb IC for the Mar IC, Apr IC, and May ICrespectively.


Inter Annual Variability of ensemble Spread EL NINO years
Feb IC
Feb - Mar IC
Feb - Apr IC
Feb - May IC
20N
0
20S
60E
90E
120E
150E
180
150W
120W
90W
60W
-7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7

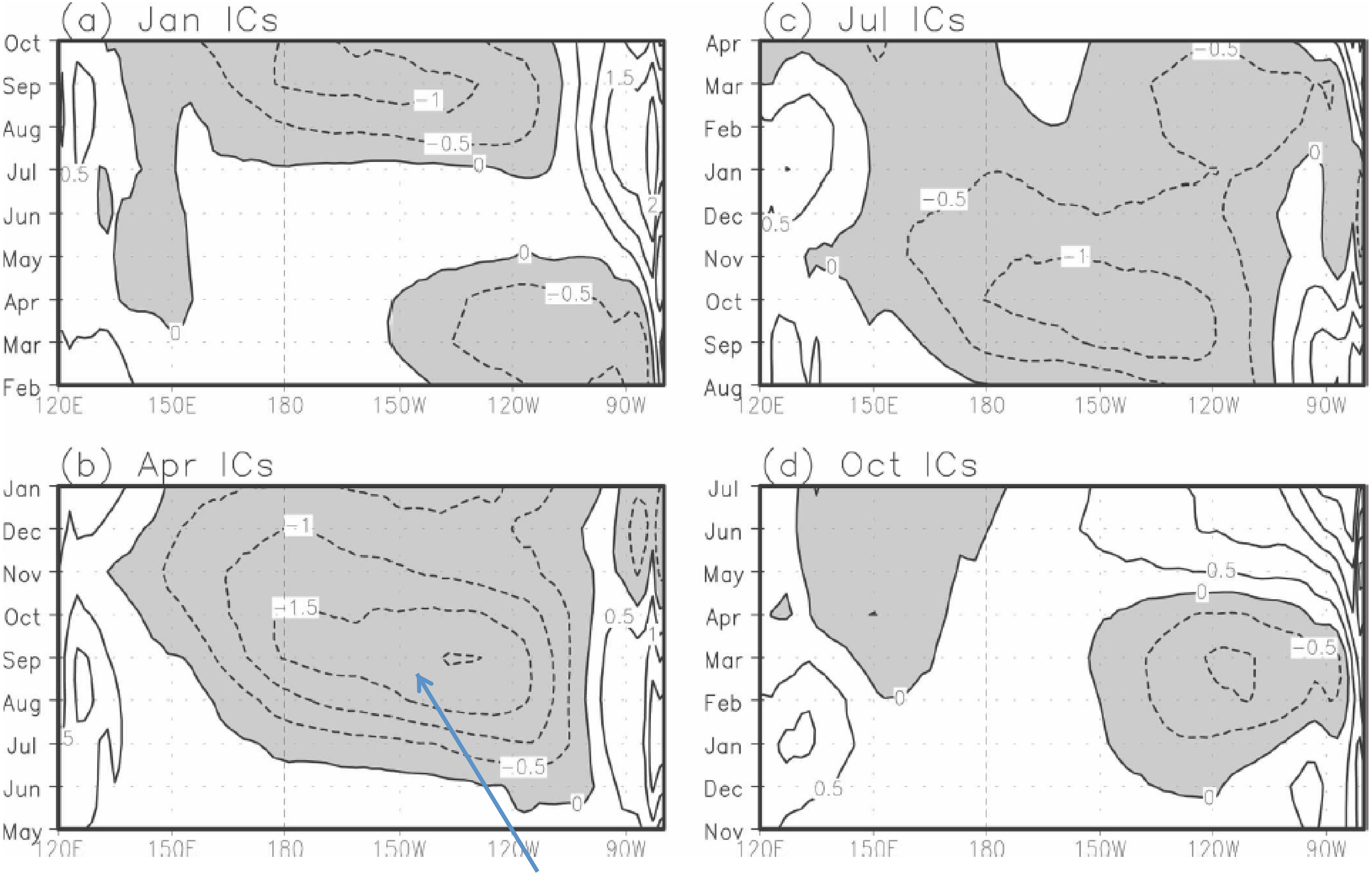


Zonal profile (meridionally averaged over 5^0S-5^0N) of climatological JJAS mean D20 isotherm (depth of 20 degree isotherm) for the different initial condition (Feb IC, Mar IC, Apr IC and May IC) runs of CFSv2 along with observation.



Composite of Walker Circulation during El Nino years in (a) NCEP reanalysis, (b) Feb IC hindcast run. (c, d, e) Difference of composite Walker Circulation from Feb IC run for the Mar IC, Apr IC and May IC runs respectively.

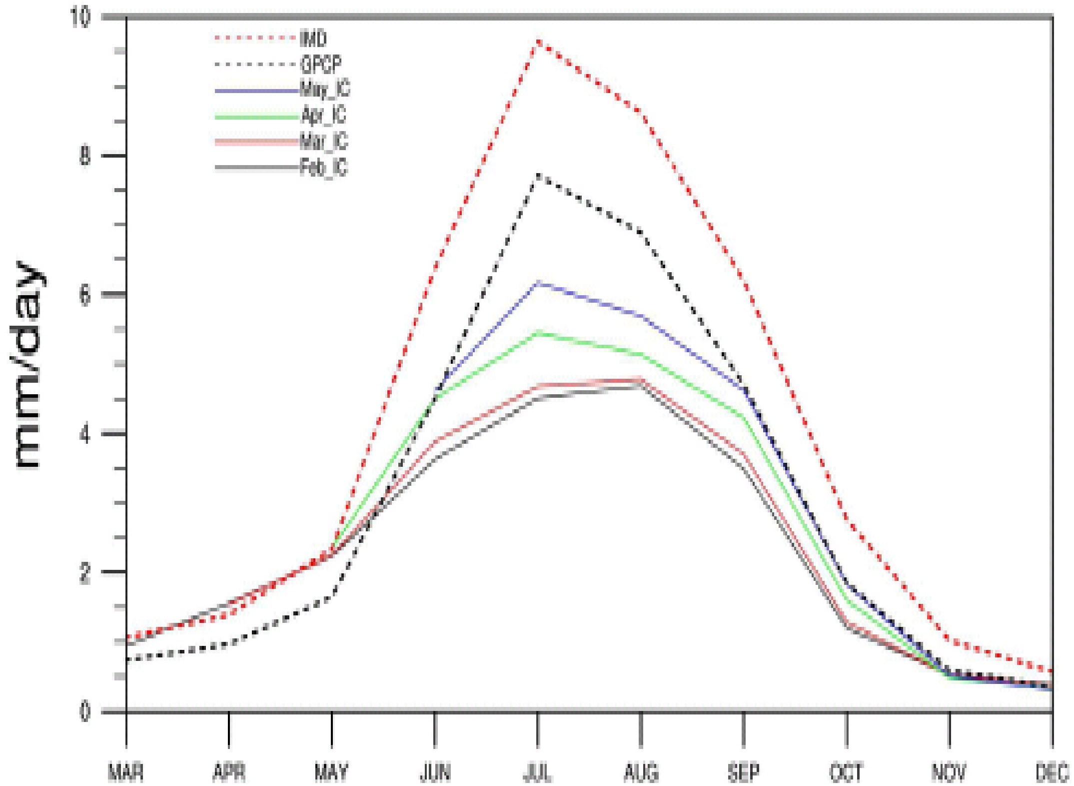
Model Bias in CFS



Relatively Large Bias in JJAS when model is Initialized with Apr. IC

Ref. Saha et al., (2006)

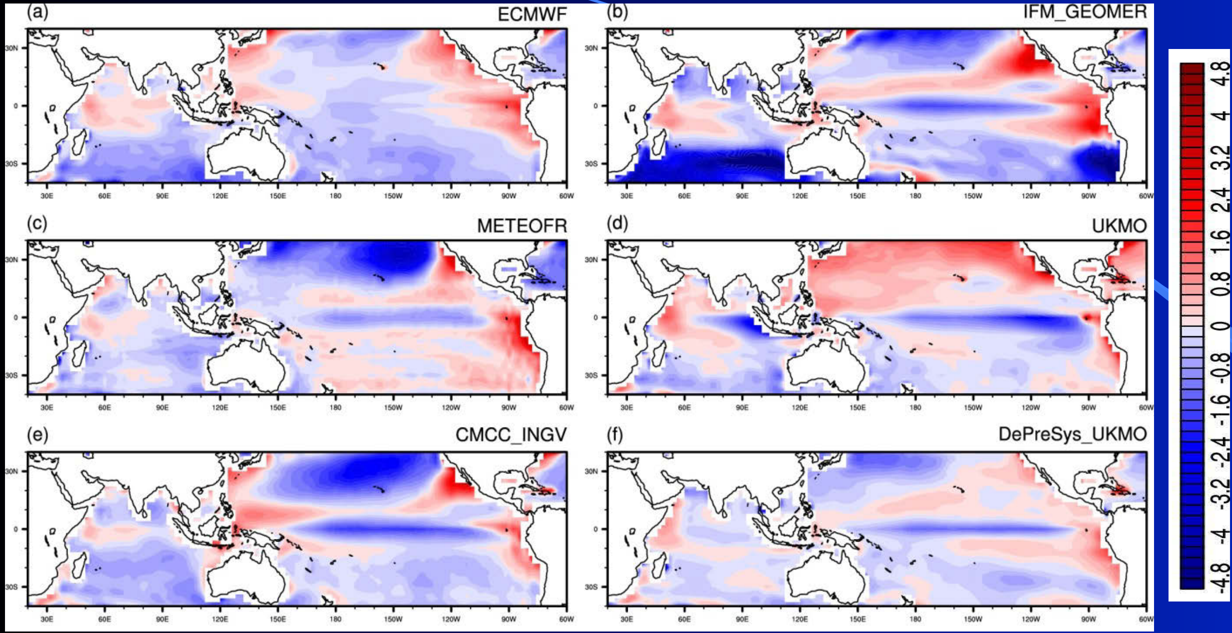
Seasonal Cycle of Rainfall Over Indian Land Mass



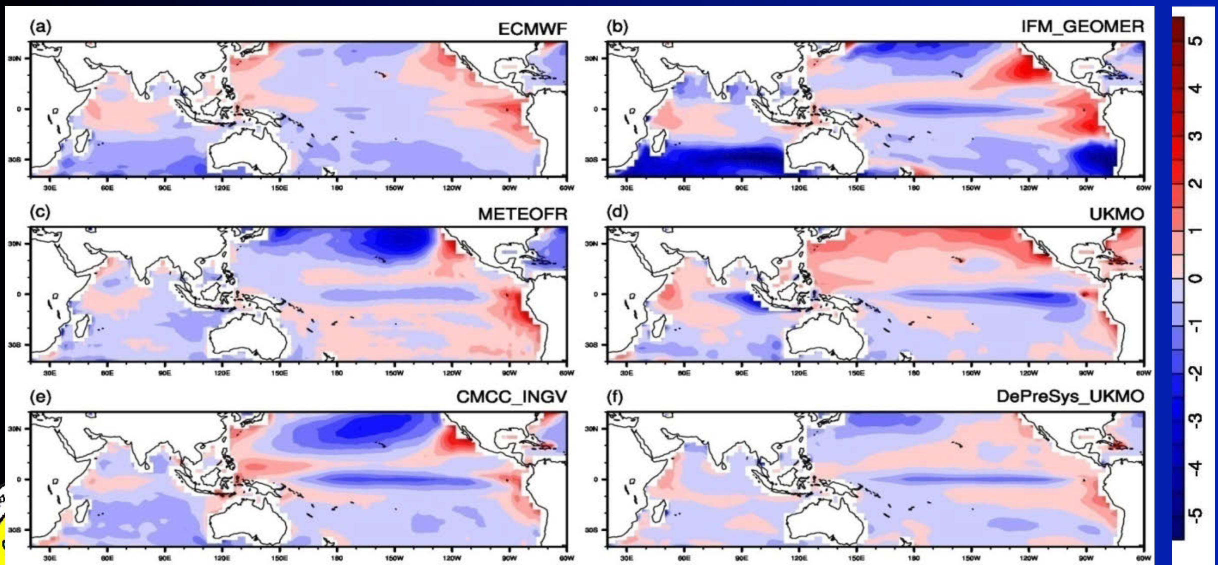
Significant improvement is seen in rainfall simulation over India as lead time decreases.

Coefficient of Variance:
GPCPC: 10.00
Feb. IC: 10.05
Mar. IC: 10.80
Apr. IC: 08.30
May IC.: 06.30

JJAS SST mean bias for ENSEMBLE MODELS



(Feb. IC)



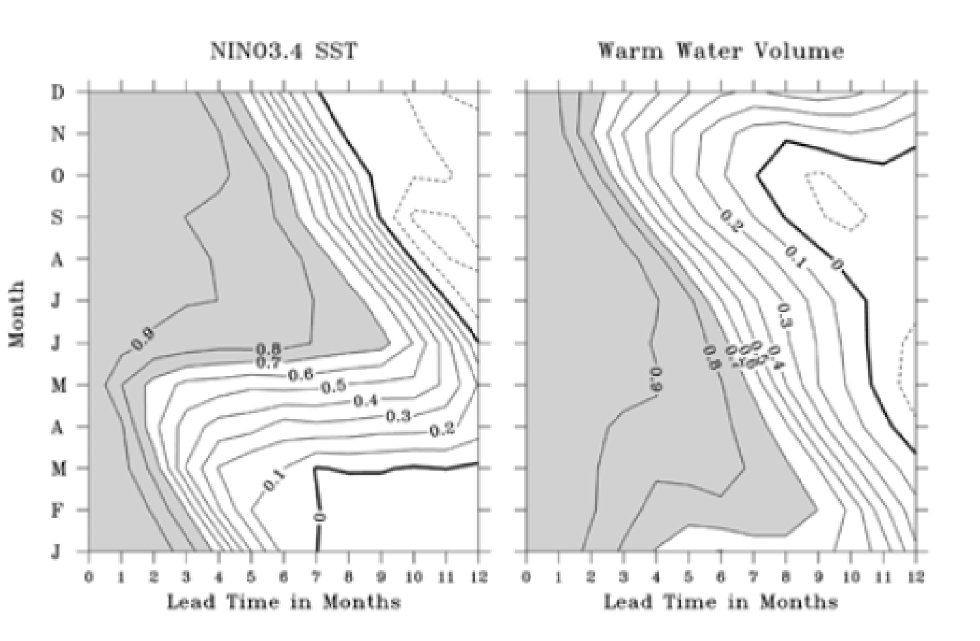
(May. IC)

Cold bias in eq. Pacific cold tongue is noticed in many models

Spring Predictability Barrier

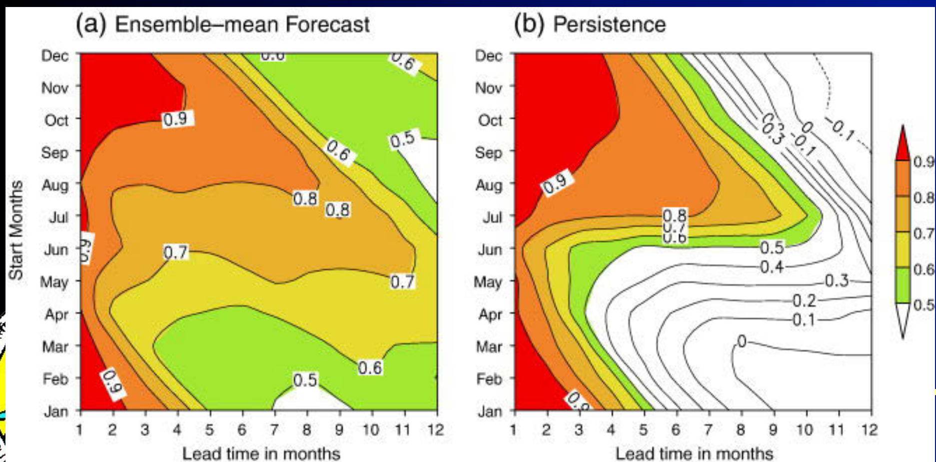
- If forecasts are made before and through the spring, ENSO predictions tend to be much less successful. This is popularly known as "Spring Predictability Barrier"

Spring Persistence Barrier in ENSO prediction



SST auto correlations clearly suggest that autocorrelations drop significantly when Starting month is Mar/Apr/May .

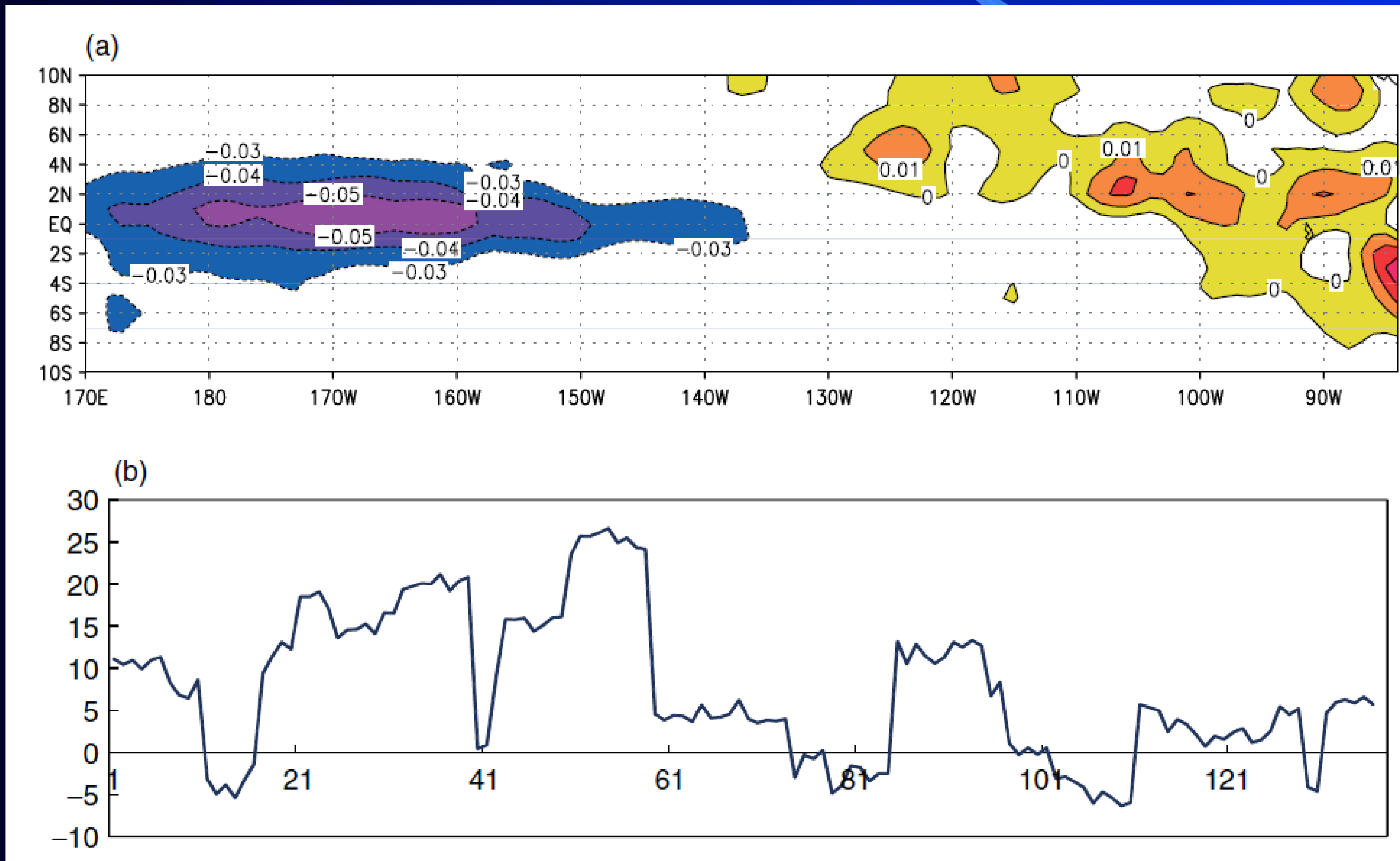
However, the same is not seen for WWV



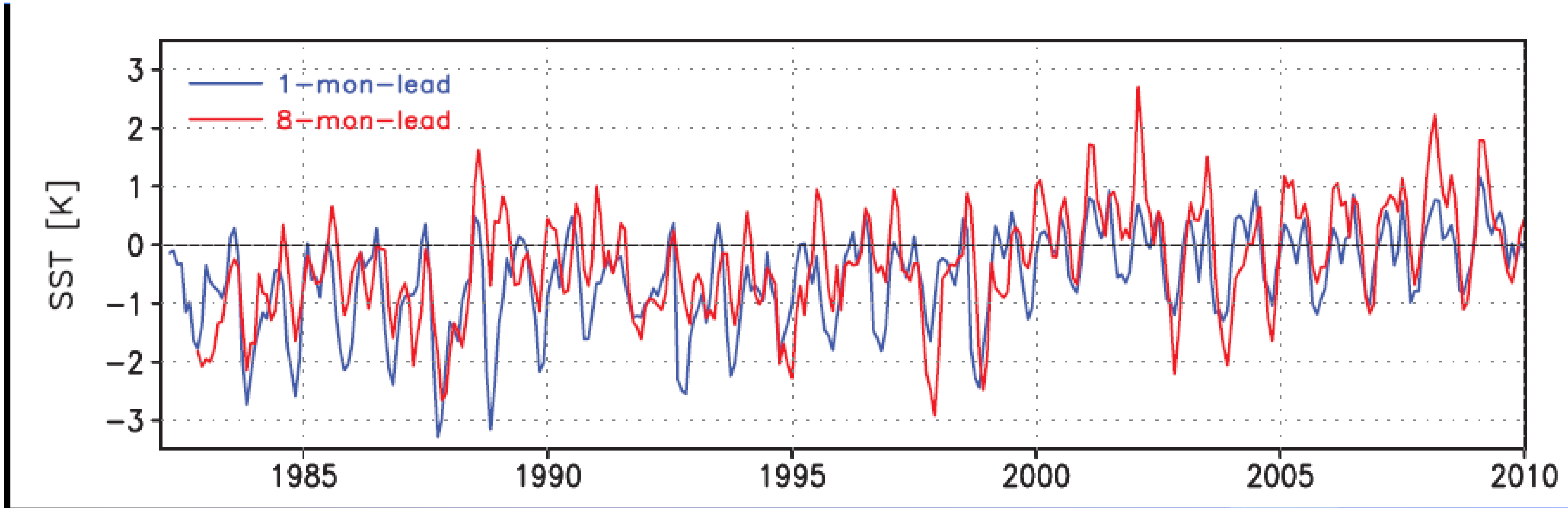
Real Model Forecast

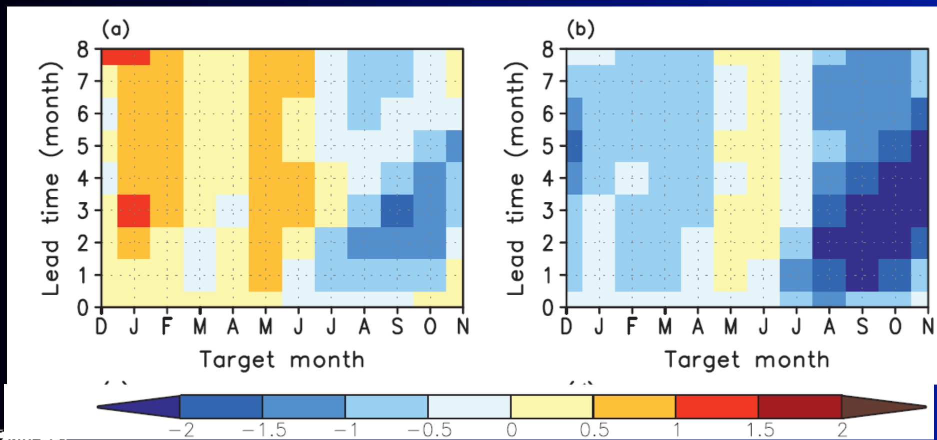
Ref: McPhaden, (2003)

1st S-EOF mode of model Errors for Spring Barrier Period.



Reference: Duan and Wei (2013)

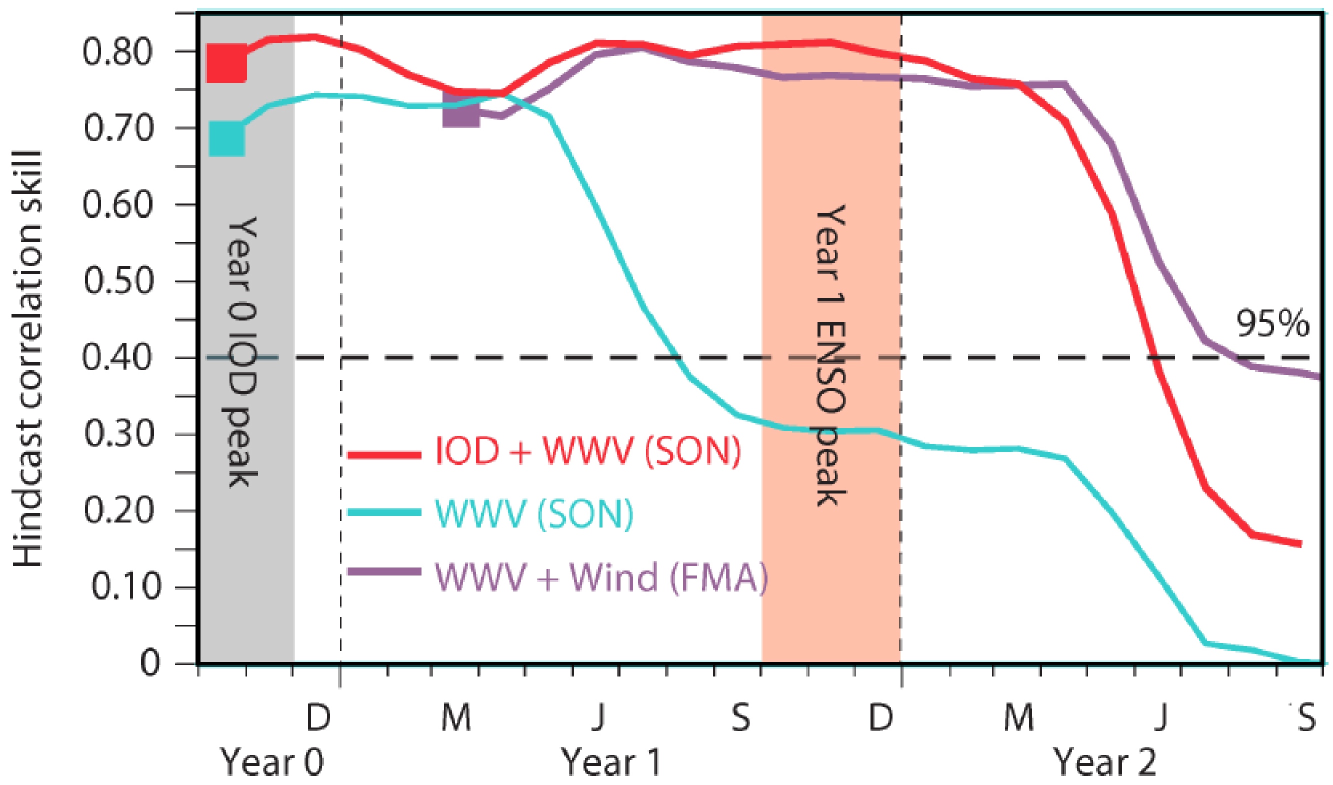




- Top pannel model error in Nino 3.4 region
- Bottom pannel (a) model bias prior to 1999 (b) after 1999

Ref: Kumar et al., (2012)

Predictability of NINO34 from the Warm Water Volume (WWV) and the Indian Dipole Mode Index (DMI) 14 months in advance, i.e. beyond the winter-spring barrier (Izumo et al. 2010)



Results based on satellite-era SST data over 1981-2008

Hypothesis

- In spite of improved simulations in Indian Ocean with short lead times, ISMR skill drops gradually from Feb. to May due to large biases in tropical Pacific Simulations in May.
- Large biases in tropical Pacific simulations, particularly during El Nino years is due to spring predictability barrier.
- Recent studies show evidences if Indian Ocean simulations are better captured, then influence of predictability barrier will reduce.