The Abdus Salam International Centre for Theoretical Physics

2356-21

Targeted Training Activity: ENSO-Monsoon in the Current and Future Climate

30 July - 10 August, 2012

ENSO-Monsoon Teleconnections in Coupled models

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ENSO-Monsoon Teleconnections in Coupled models

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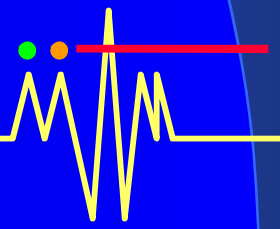
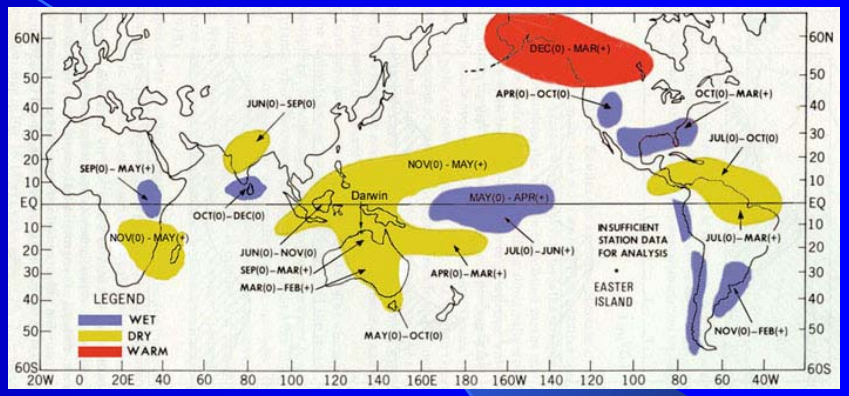
Outline

- Importance of ENSO-Monsoon Teleconnection
- What is known from observations and What is expected from Coupled Models?
- State of Coupled Models in capturing ENSO and Monsoon characteristics separately
- State of Coupled Models in capturing the teleconnection between them.
- CMIP5 model preliminary results



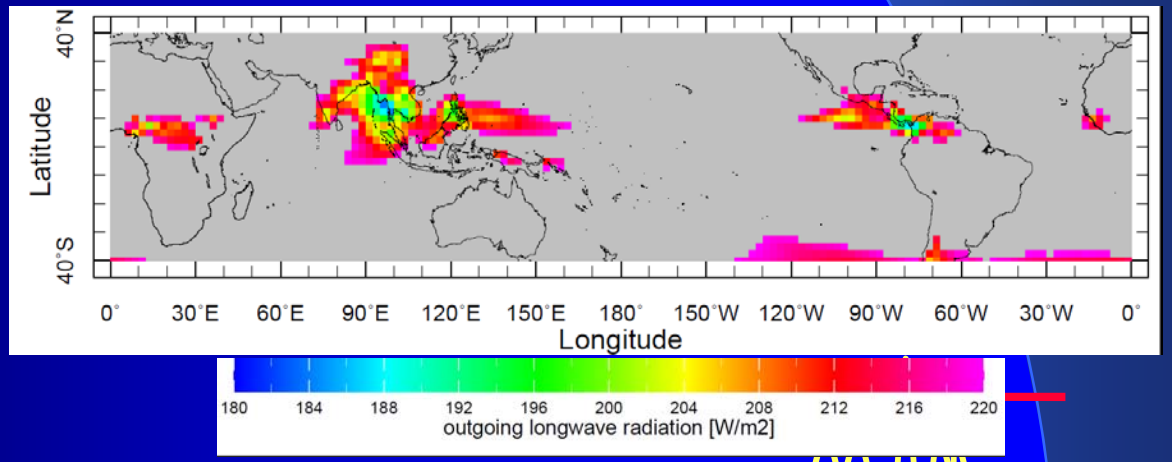
Importance of ENSO and Monsoon

ENSO is the most dominant modulator of weather/climate around the Globe on Seasonal time scales.

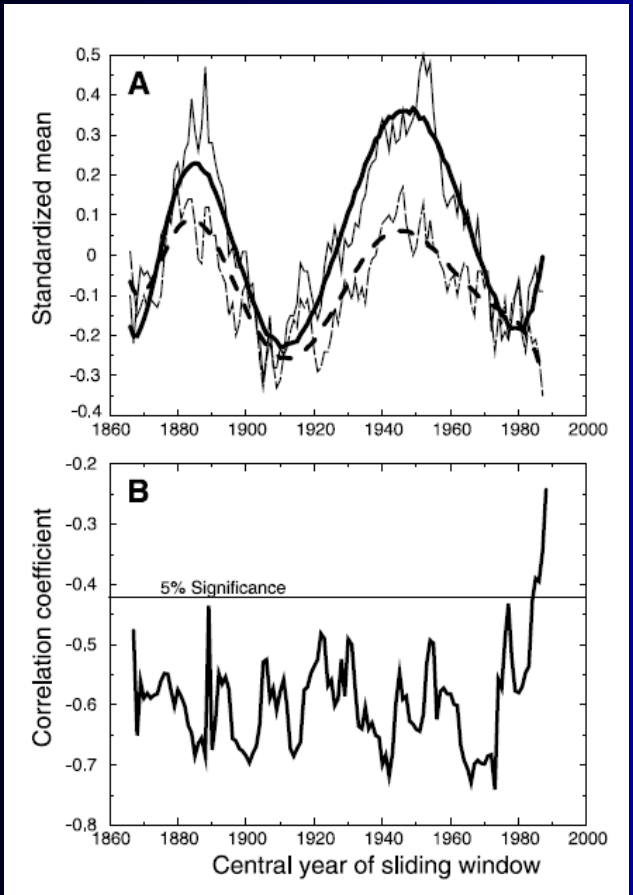


Piexoto, (1993)

- Monsoon region is the major heat source during summer months.

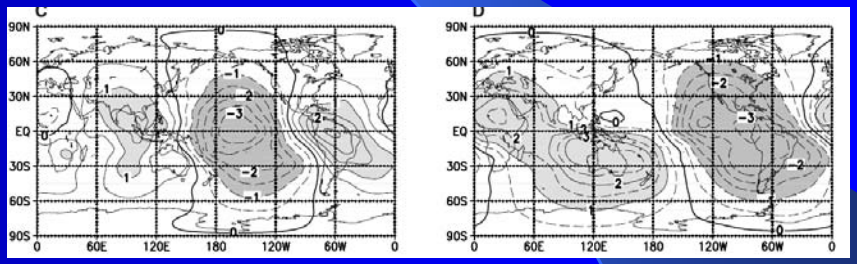


ENSO-Monsoon Teleconnection



21-yr sliding JJAS mean ISMR and Nino3 SST anomalies

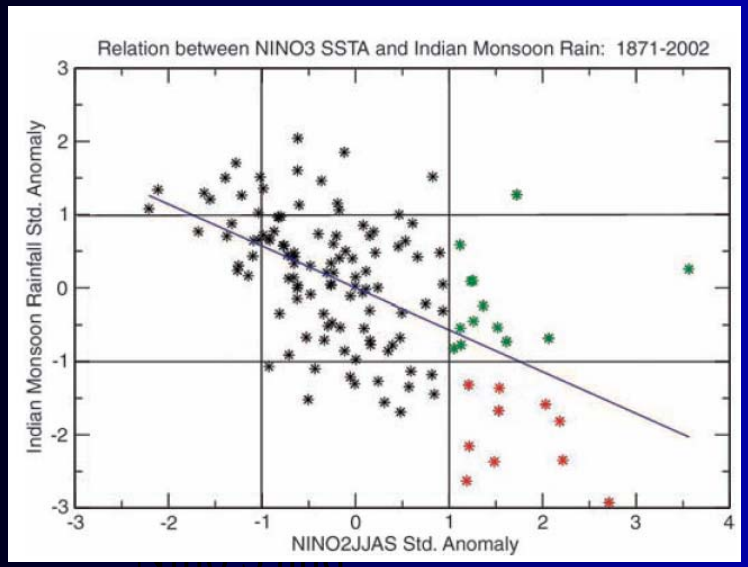
21-yr sliding correlation between JJAS mean and Nino3 SST anomalies



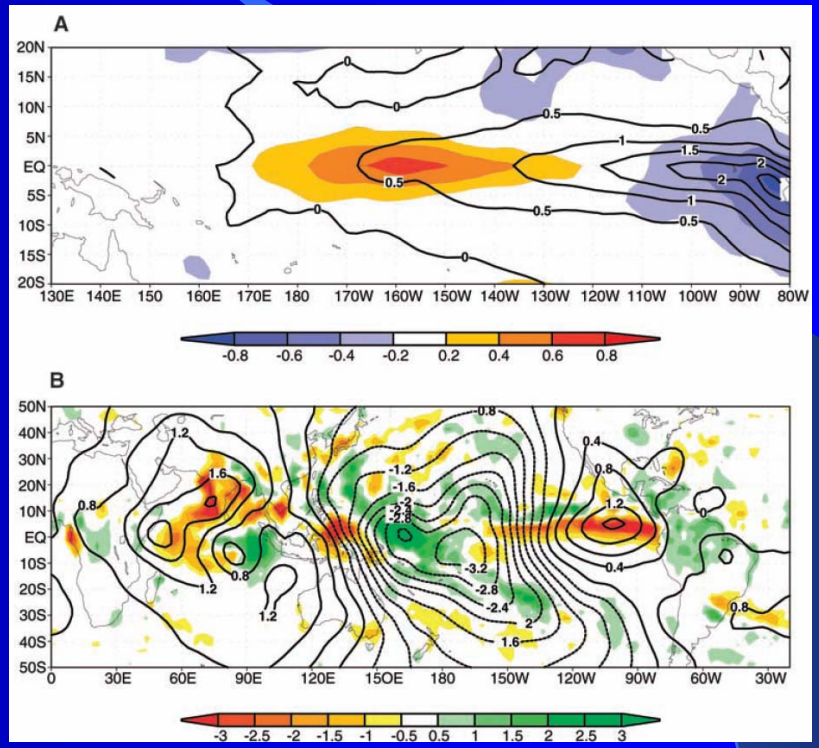
Correlation between Monsoon Rainfall and 200hpa Velocity Potential (a) 1958-80 (b)1981-1997

Kumar et al., (2006, 1999)

ENSO-Monsoon Teleconnection

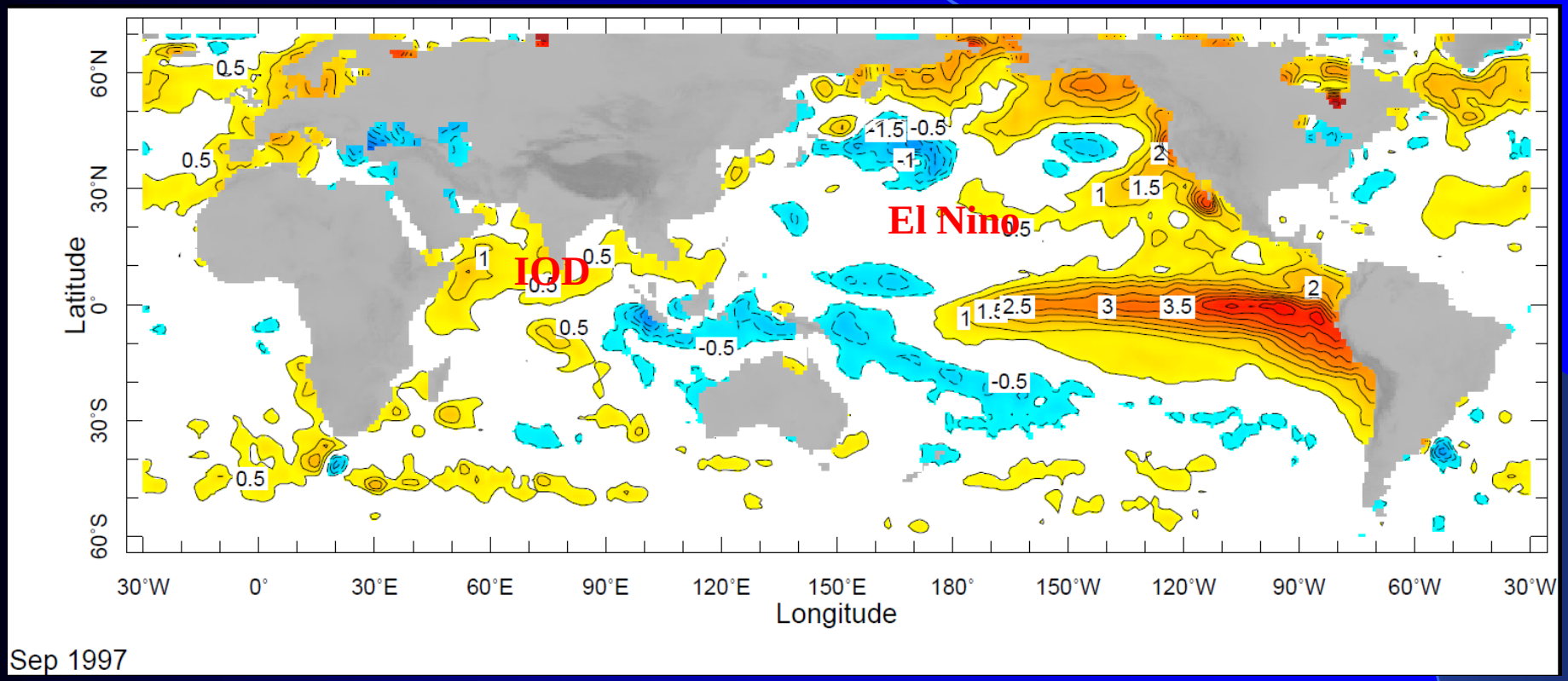


Nino 3 and ISMR



Kumar et al., (2006, 1999)

ENSO-Indian Ocean SST connection



Indian Ocean Dipole and Its influence on Indian Summer Monsoon

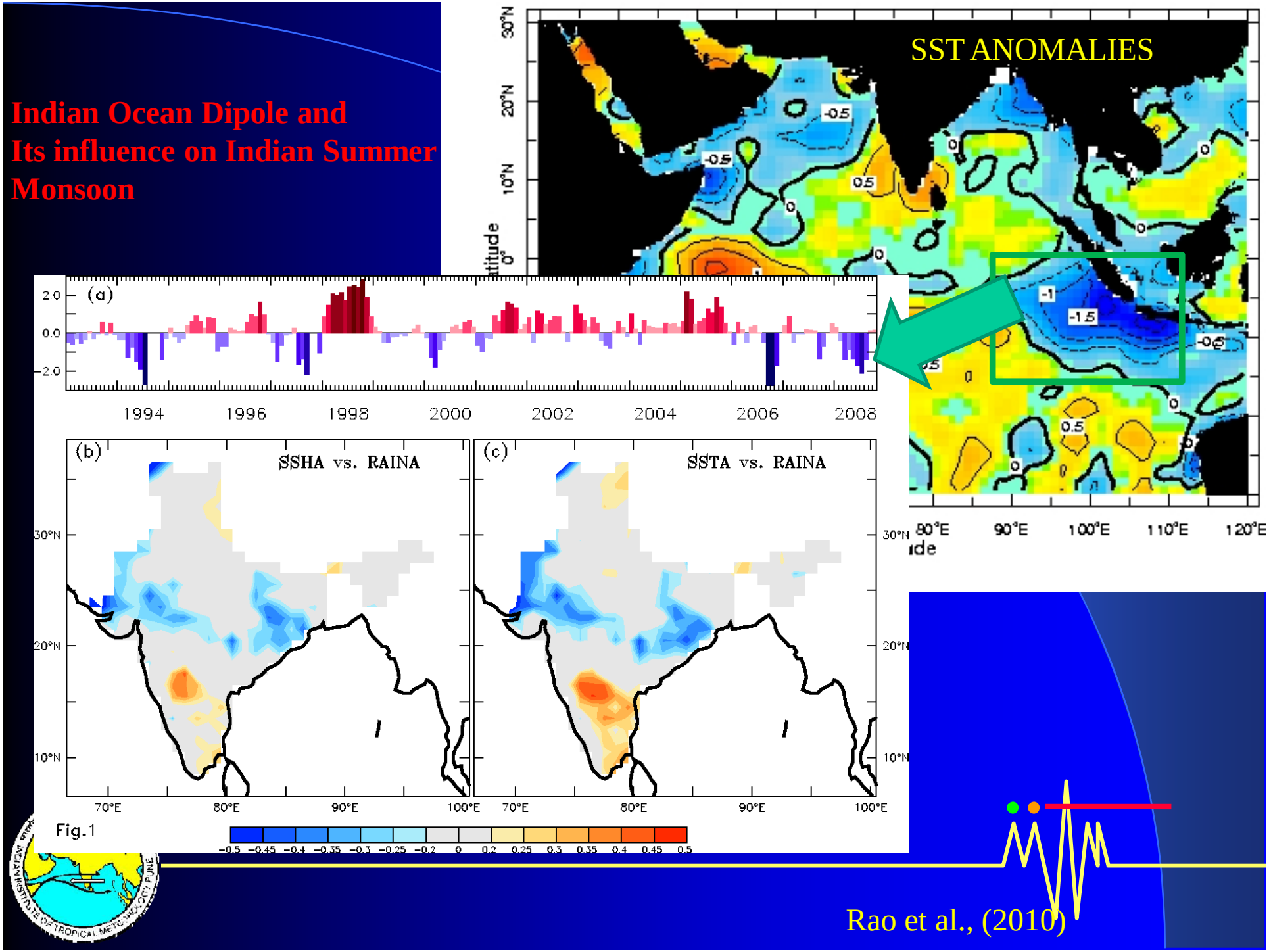
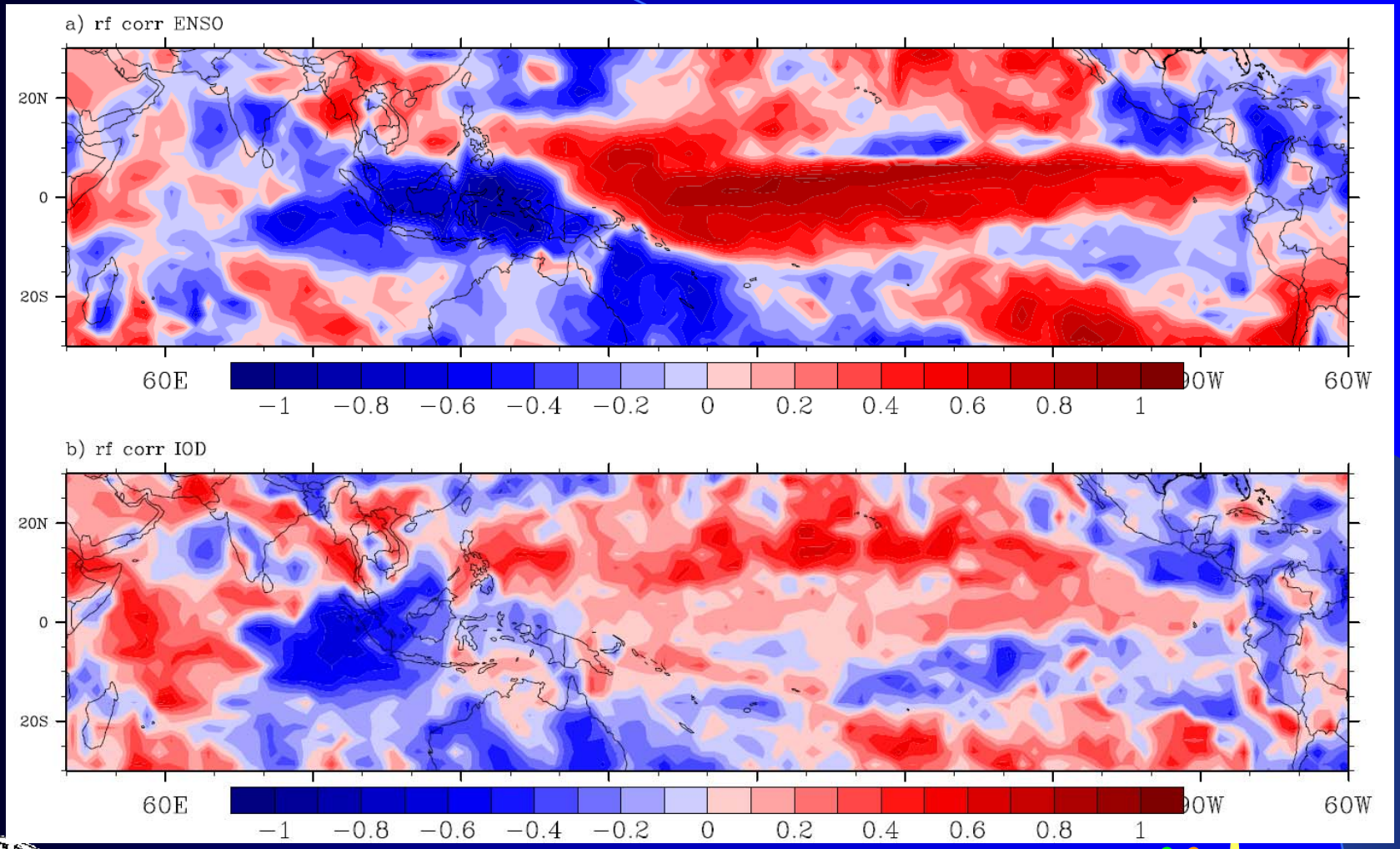


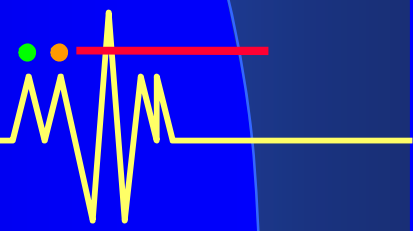
Fig.1

Rao et al., (2010)

ENSO, IOD SST connection with rainfall

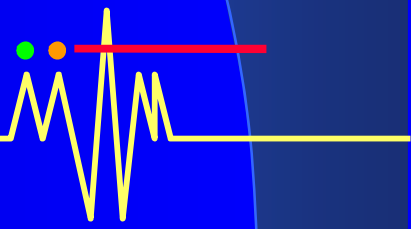


ENSO – MONSOON in a Single Coupled Model
CFS V1.0

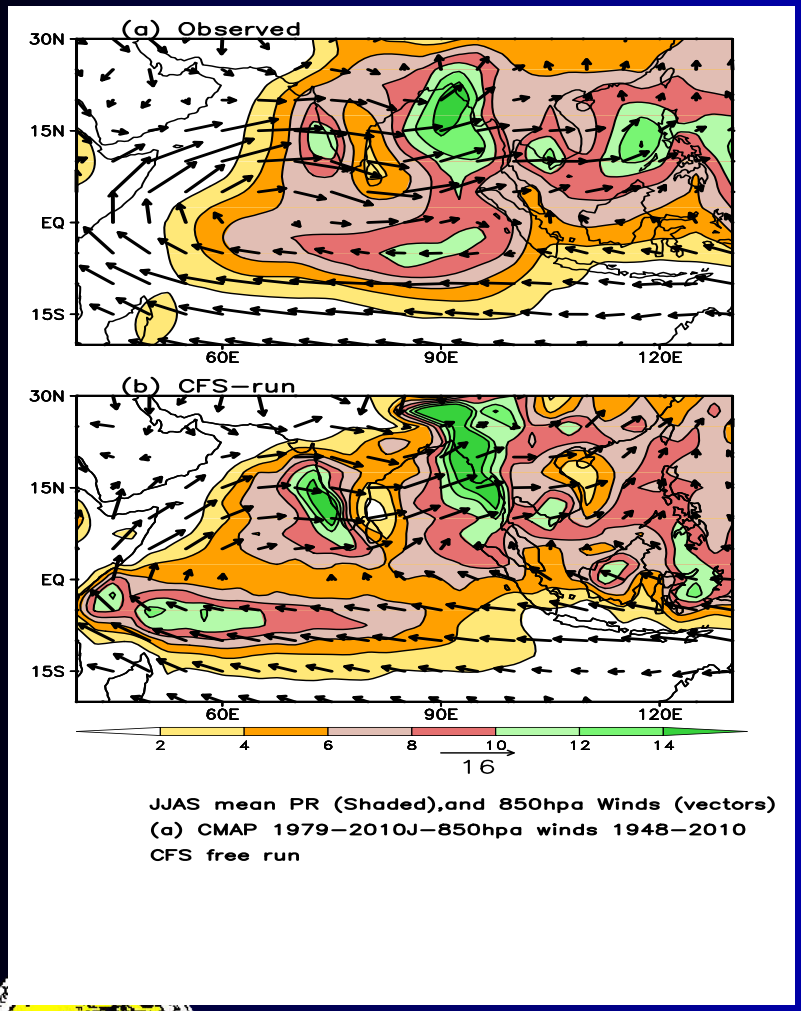


CFS T62L64

- **The NCEP CFS Components**
  - T62/64-layer version of the CFS
- Atmospheric **GFS (Global Forecast System) model**
  - – Model top 0.2 mb
  - – Simplified Arakawa-Schubert convection (Pan)
  - – Non-local PBL (Pan & Hong)
  - – SW radiation (Chou, modifications by Y. Hou)
  - – Prognostic cloud water (Moorthi, Hou & Zhao)
  - – LW radiation (GFDL, AER in operational wx model)
- GFDL **MOM-3 (Modular Ocean Model, version 3)**
  - – 40 levels
  - – 1 degree resolution, 1/3 degree on equator



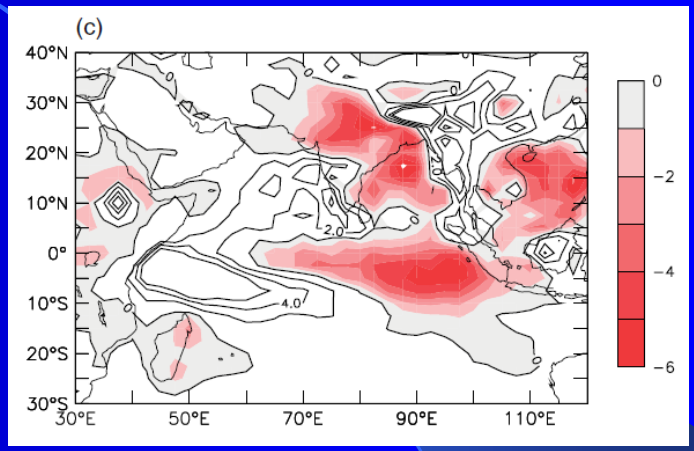
Model JJAS Rain Climatology



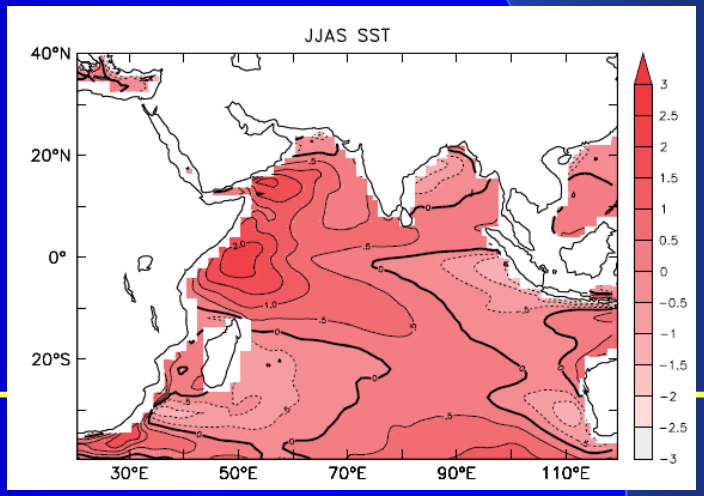
GPCP

CFS v1

Model Bias (CFSv1-GPCP)

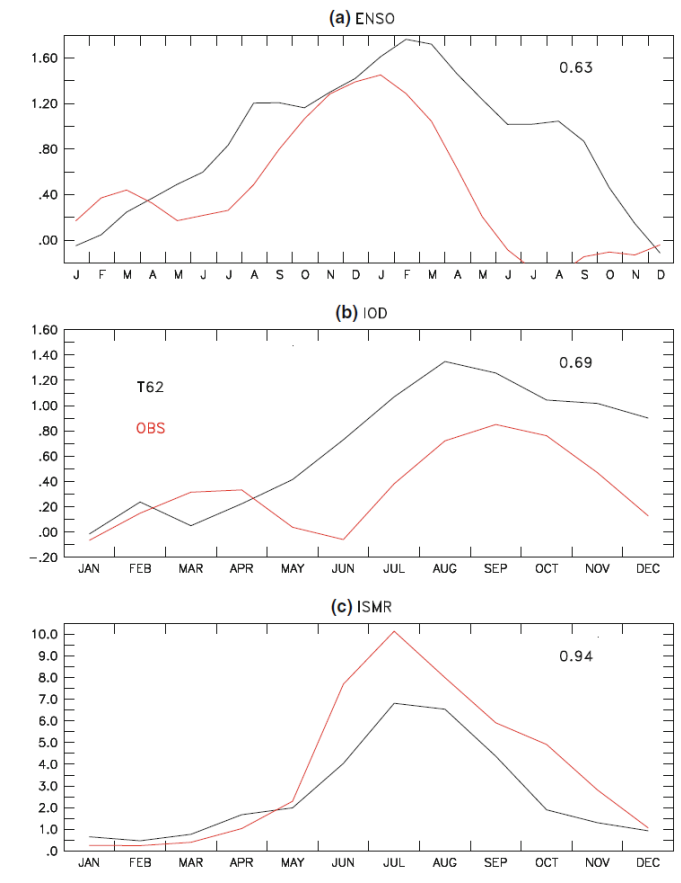


Model SST Bias (CFSv1-Reynolds)



Pokhrel et al., 2011 & Chaudhari et al., 2011

Seasonal Evolution of ENSO/IOD/ISMR

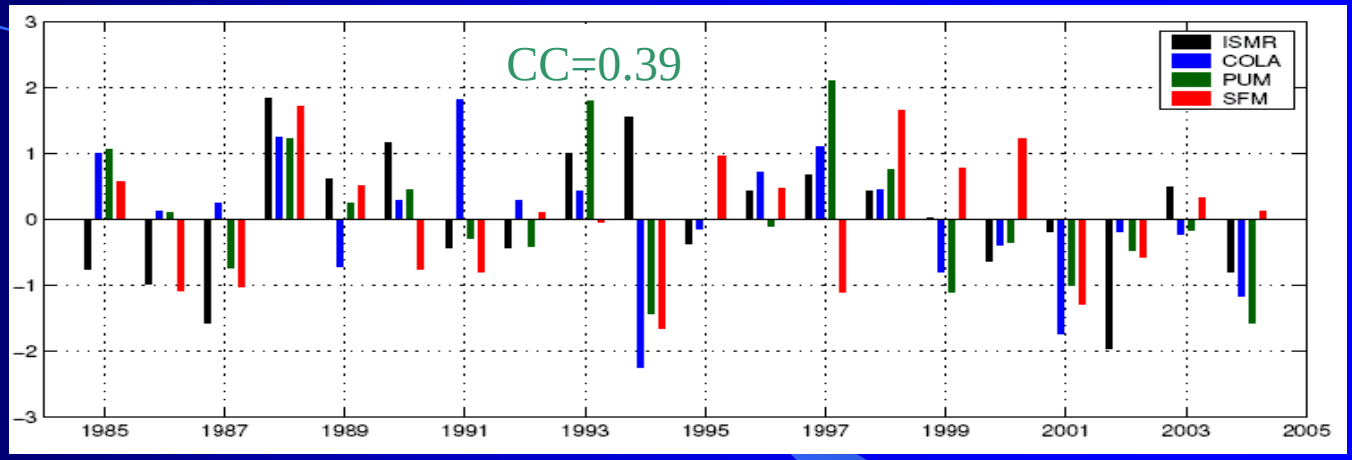


ENSO starts evolving early and decays late
Peaking is late in model

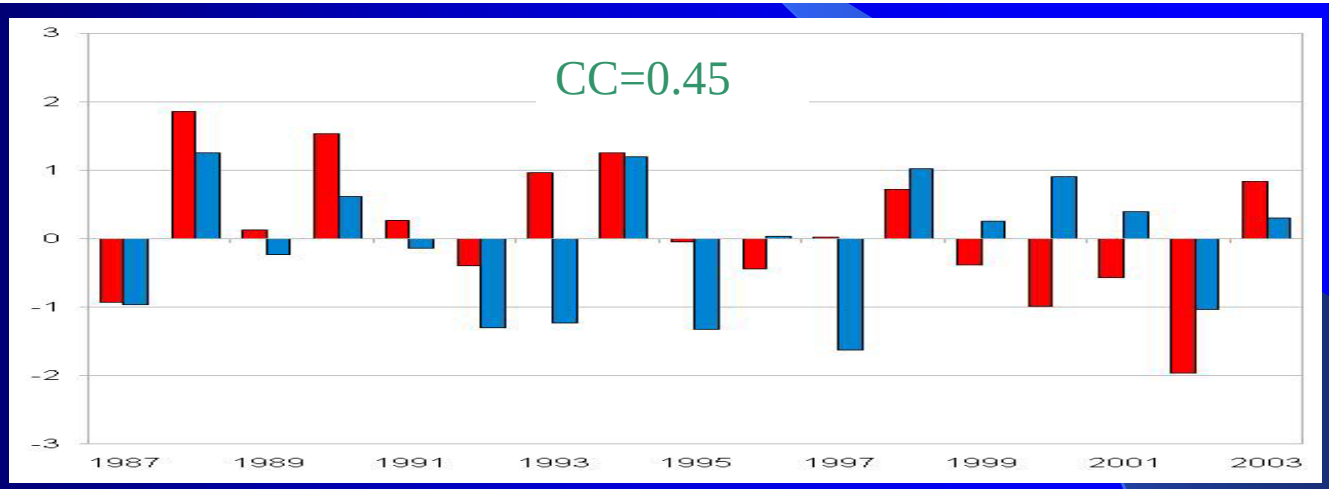
IOD starts evolving early and decays late
Peaking is early

ISMR underestimated

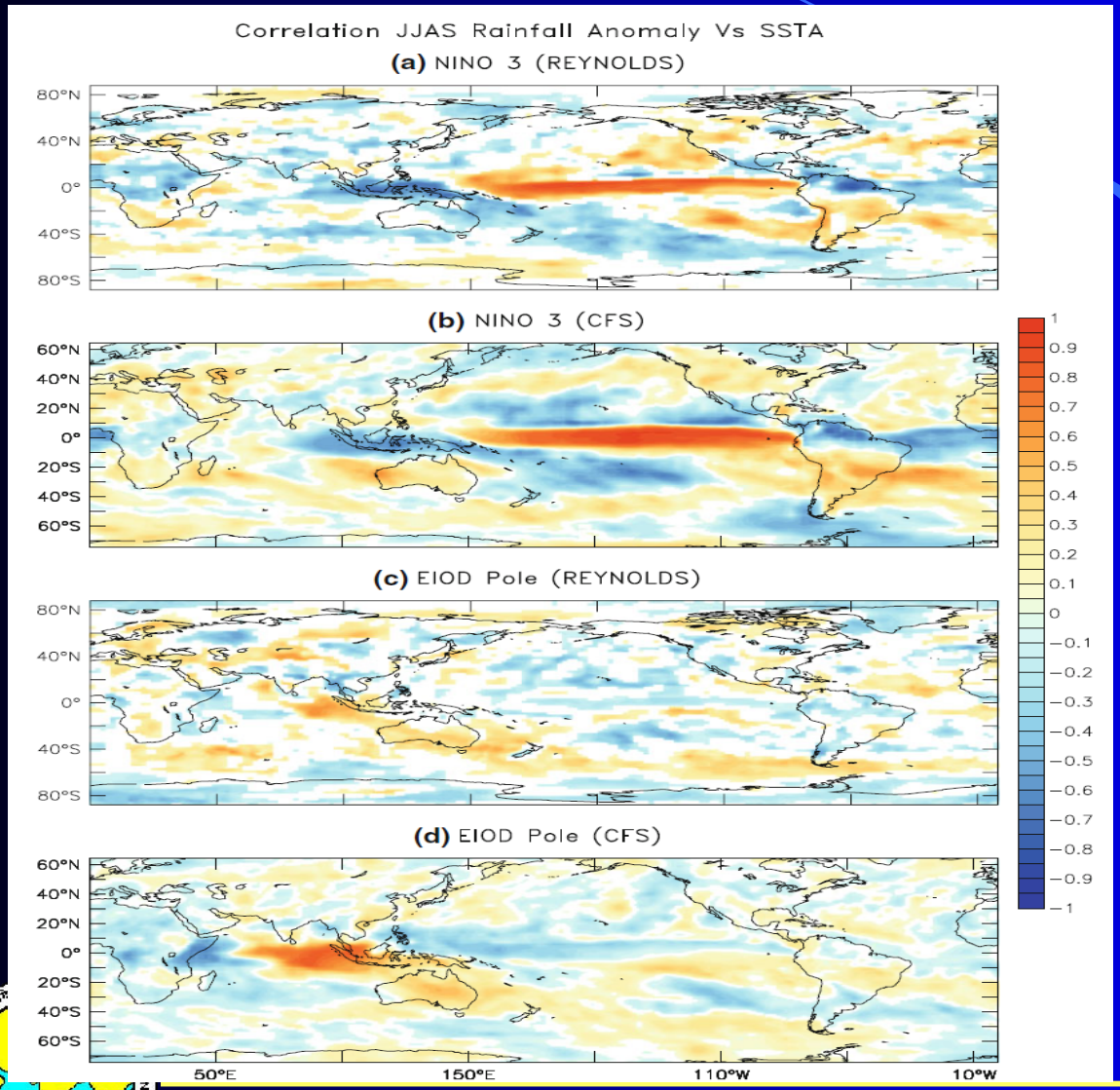
Dynamical AGCM
Potential Prediction Skill



Dynamical CGCM
CFS Prediction Skill
(T62L64)



ENSO-Monsoon-IOD-Teleconnection in CFS V1.0



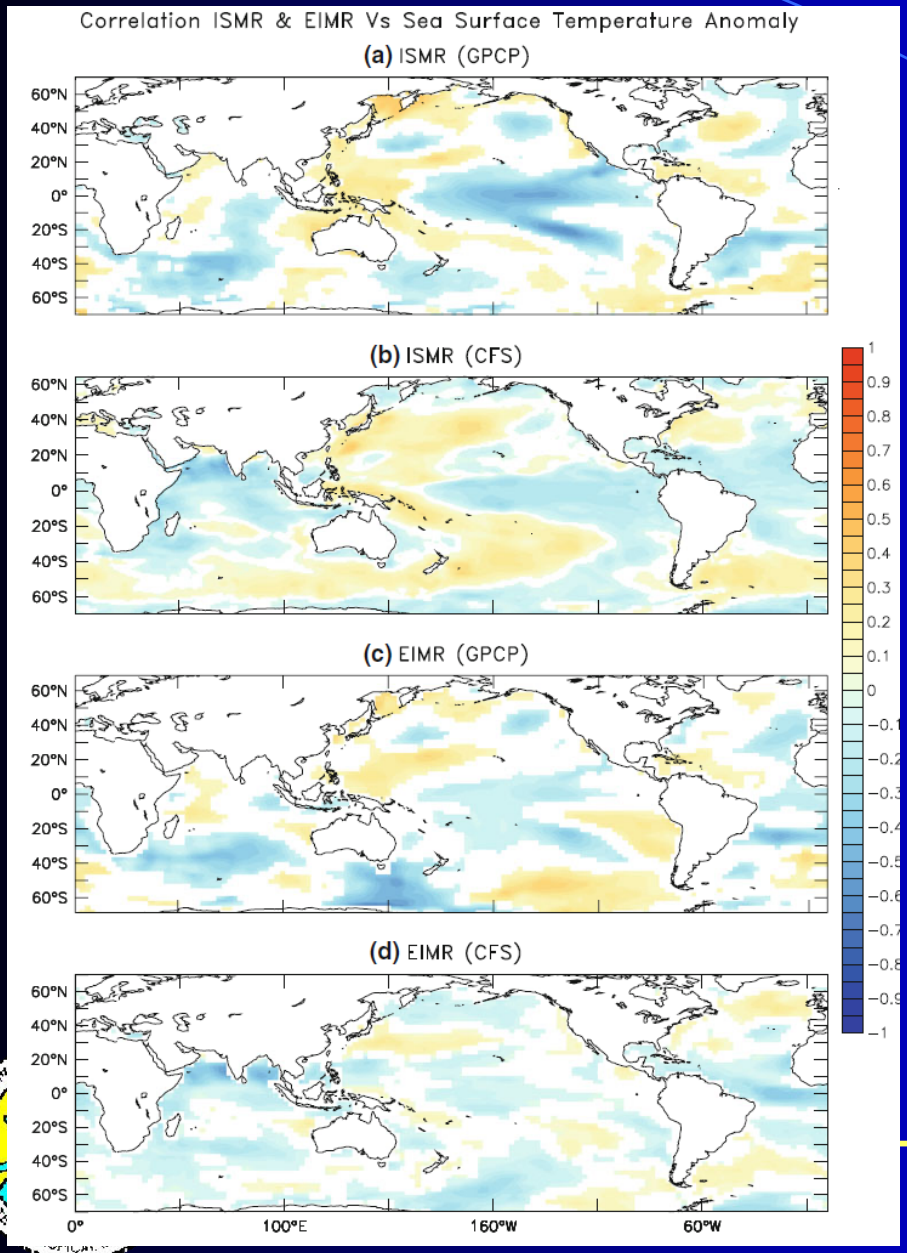
Nino3 Vs JJAS Rain Observations

Nino3 Vs JJAS Rain CFS V1

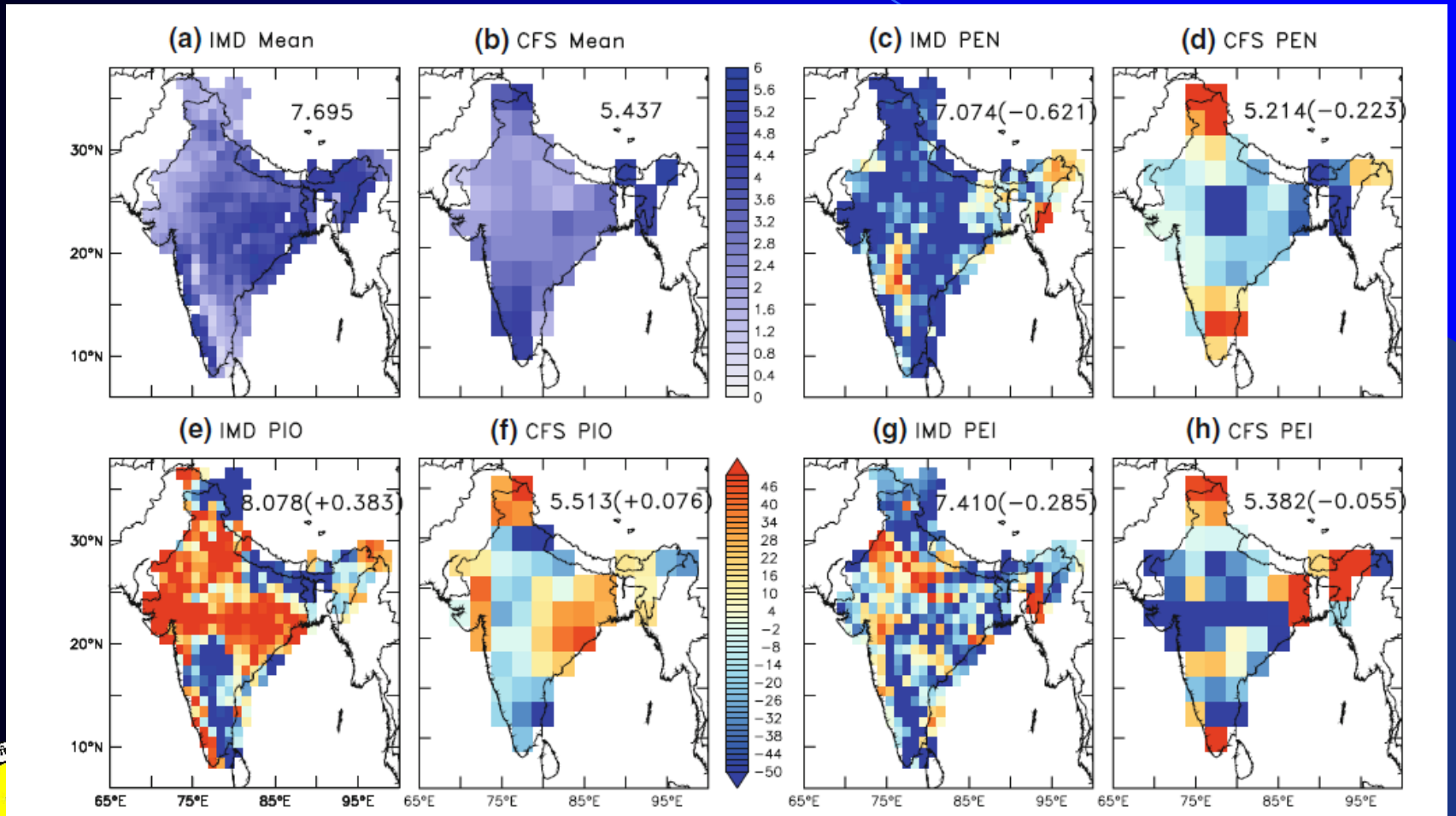
EIOD Vs JJAS Rain Observations

EIOD Vs JJAS Rain CFS V1

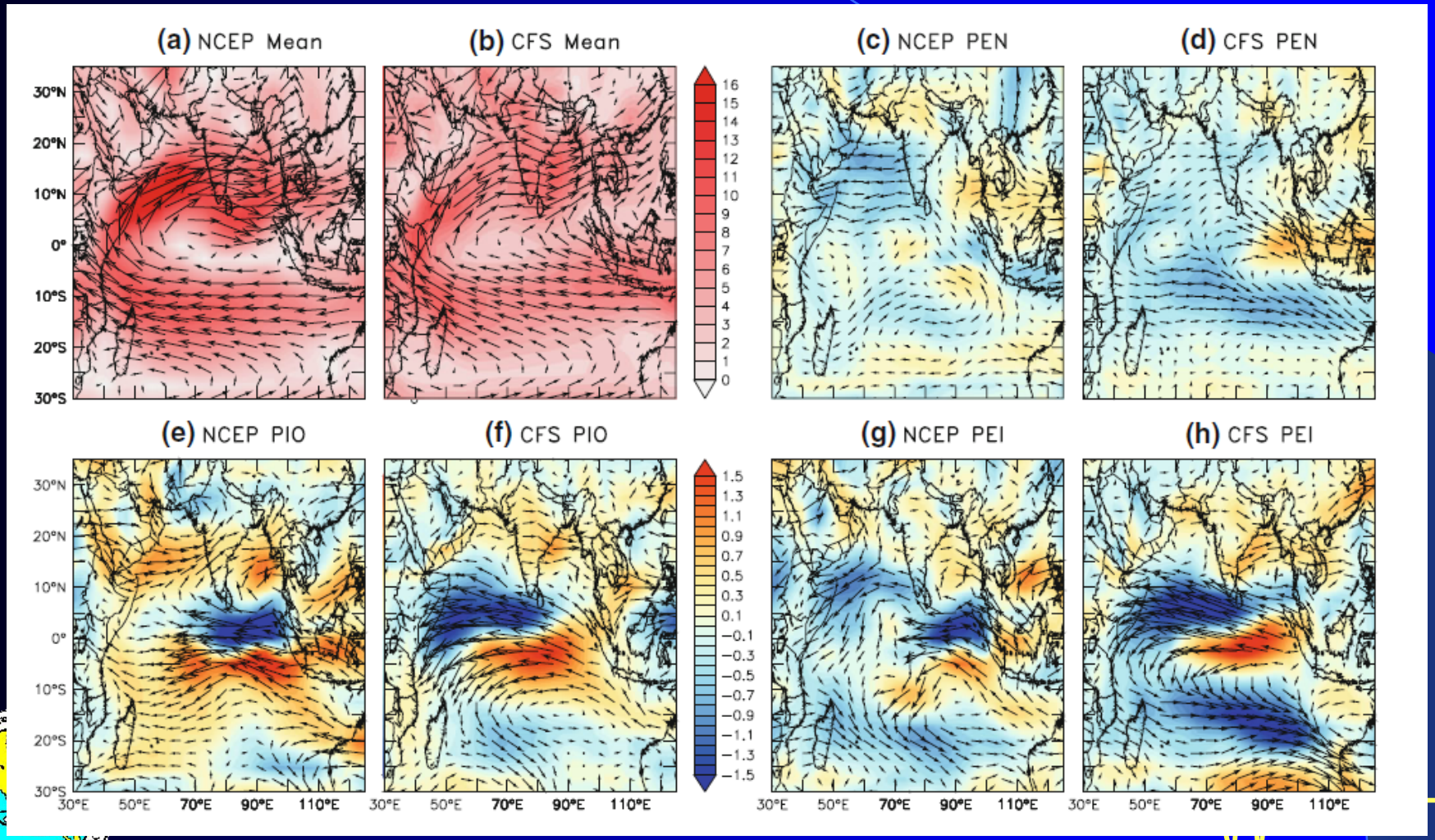
ISMR and SST correlation



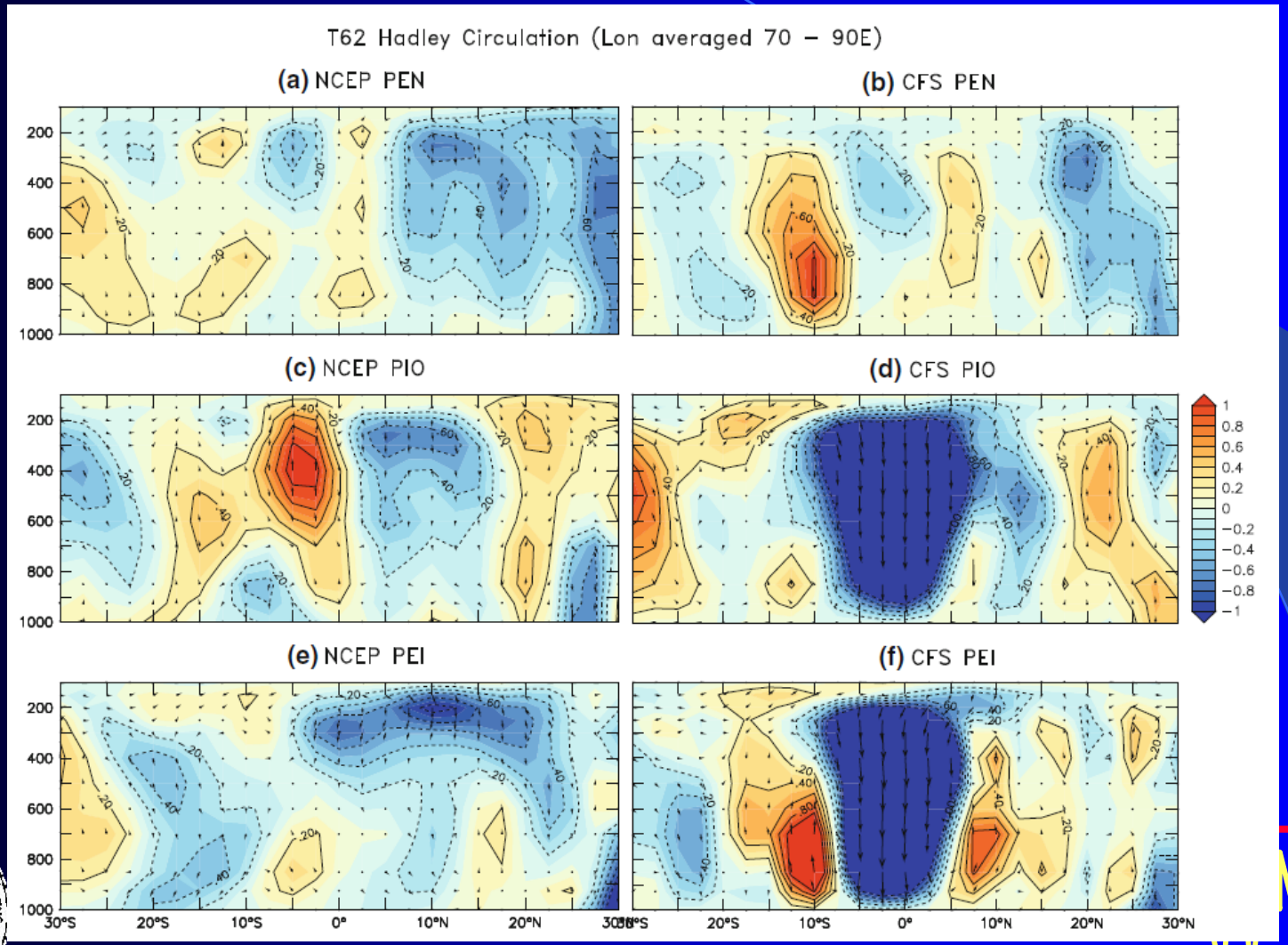
Combined Influence of ENSO and IOD



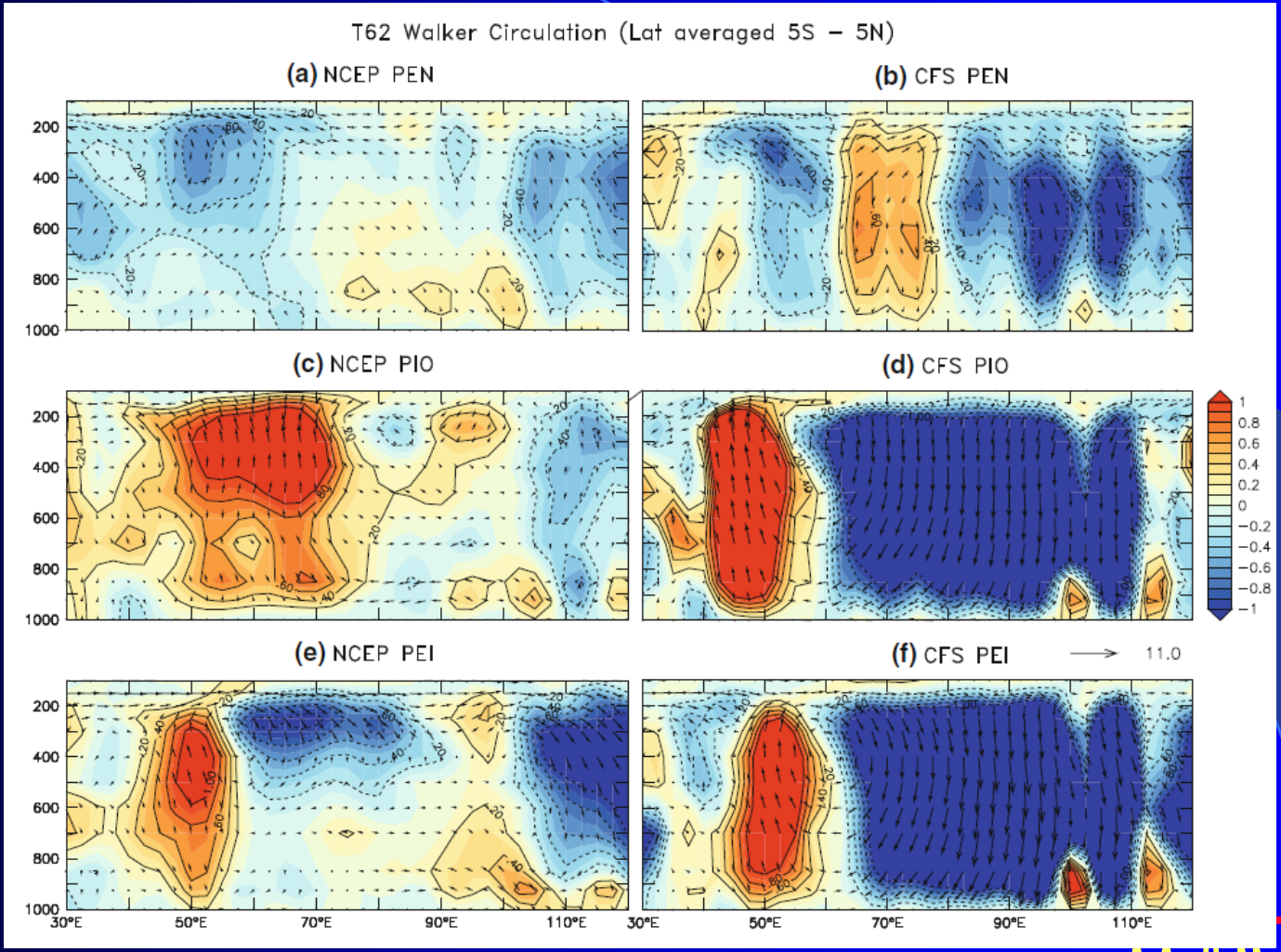
Surface winds during different phases



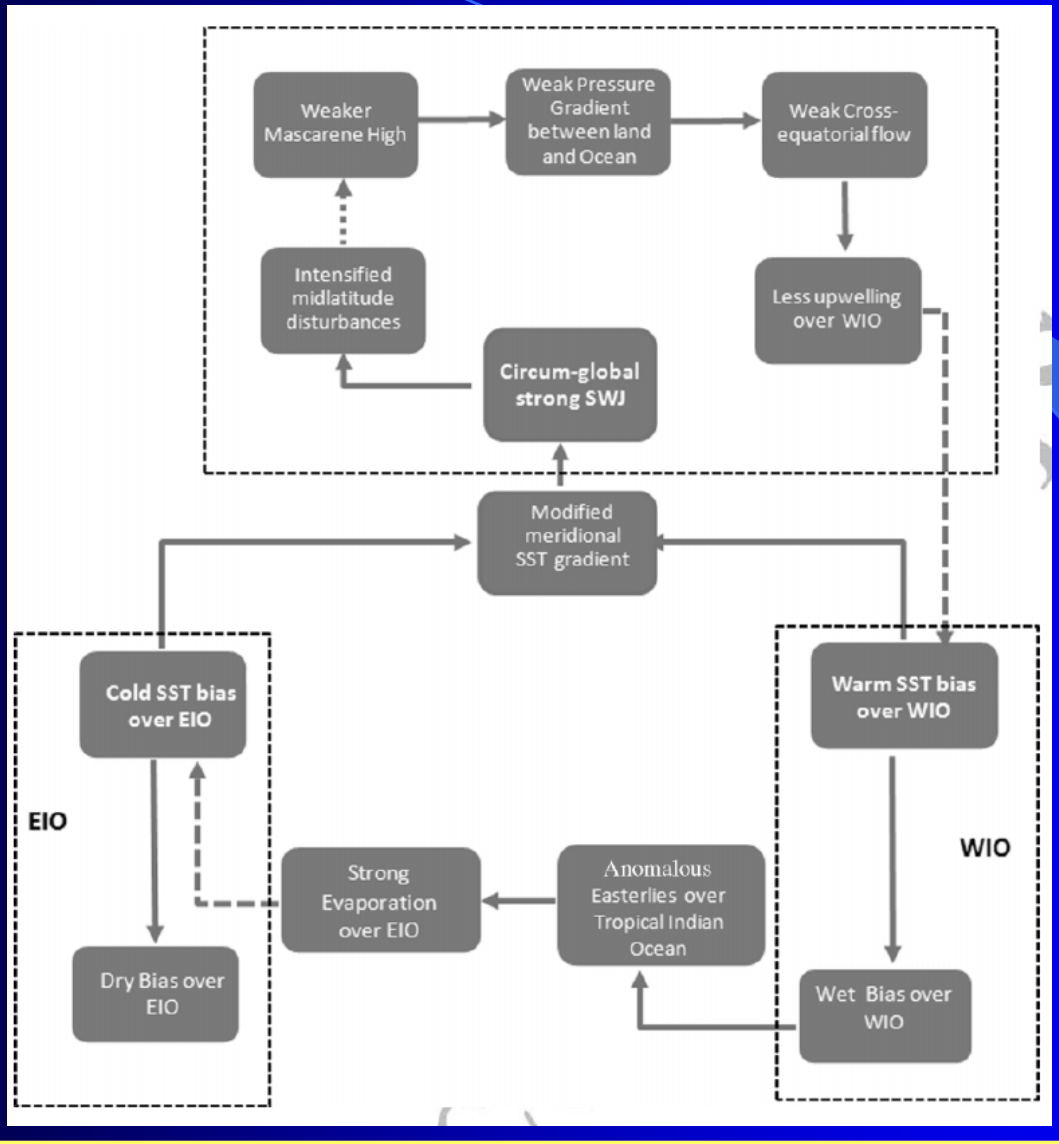
Local Hadley Cell during Different Phases



Walker Cell during Different Phases



One Bias leads to another….



Chaudhari et al., 2912)

ENSO-IO Teleconnection

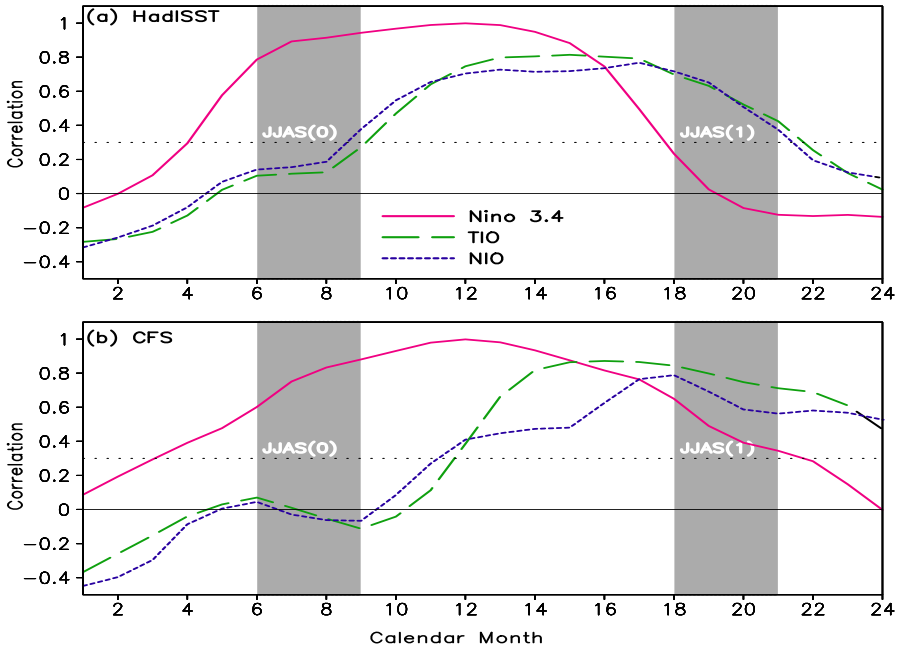
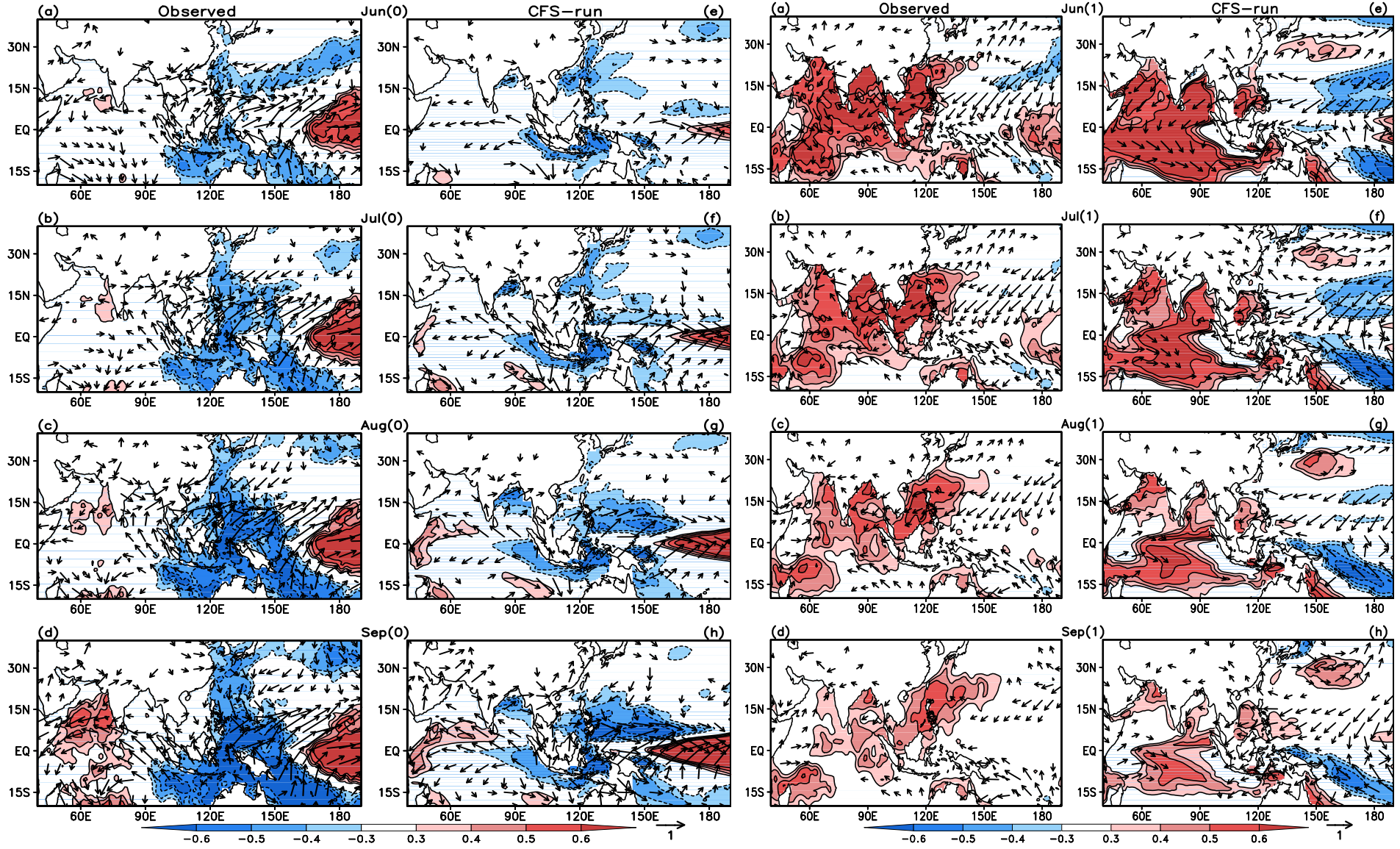


Figure 2. NDJ(0/1) Nino–3.4 SST index correlation with the TIO and NIO SST during the ENSO developing and decay year (a) ER–SSTand (The solid thick line is for the lagged autocorrelation of the Nino–3.4 SST index with its NDJ(0/1) values

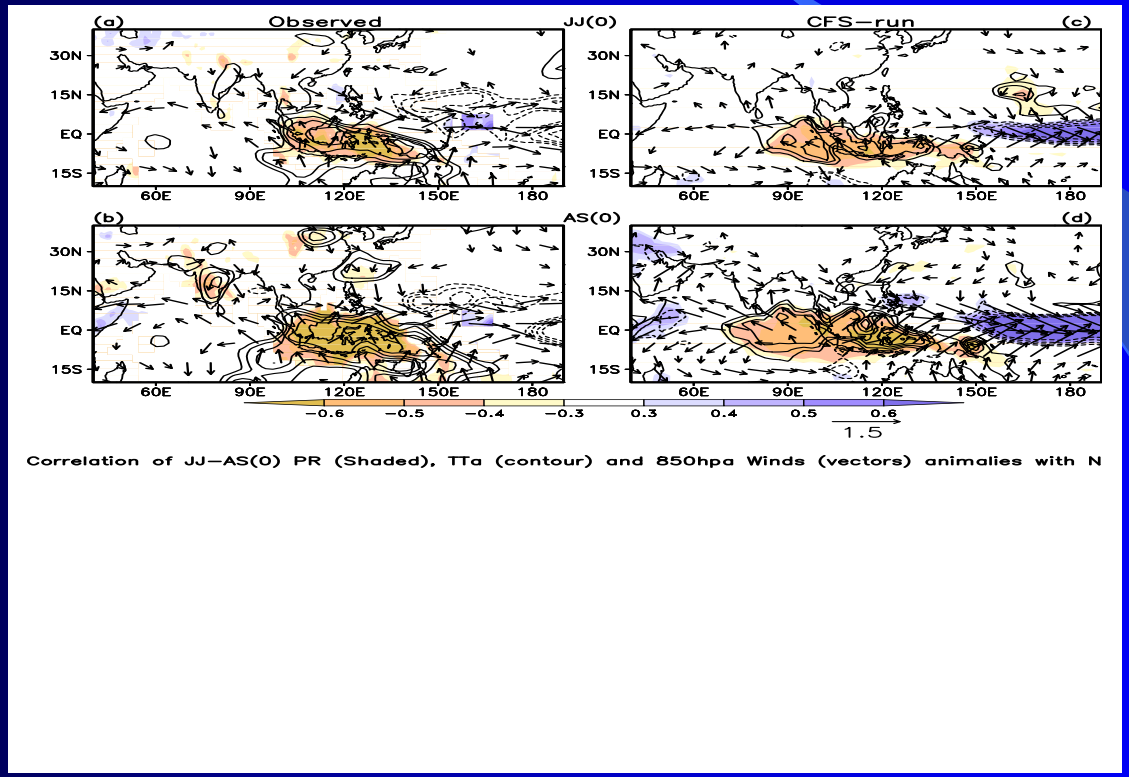
NDJ(0/1) Niño-3.4 SST index correlation with the TIO and NIO SST during the ENSO developing and decay year
(a) HadISST and
(b) CFS-free run.
The solid thick line (Magenta) is for the logged autocorrelation of the Niño-3.4 index with NDJ(0/1) values.

Jastin et al., (2012)

ENSO IO teleconnection during developing/decaying phase of El Nino

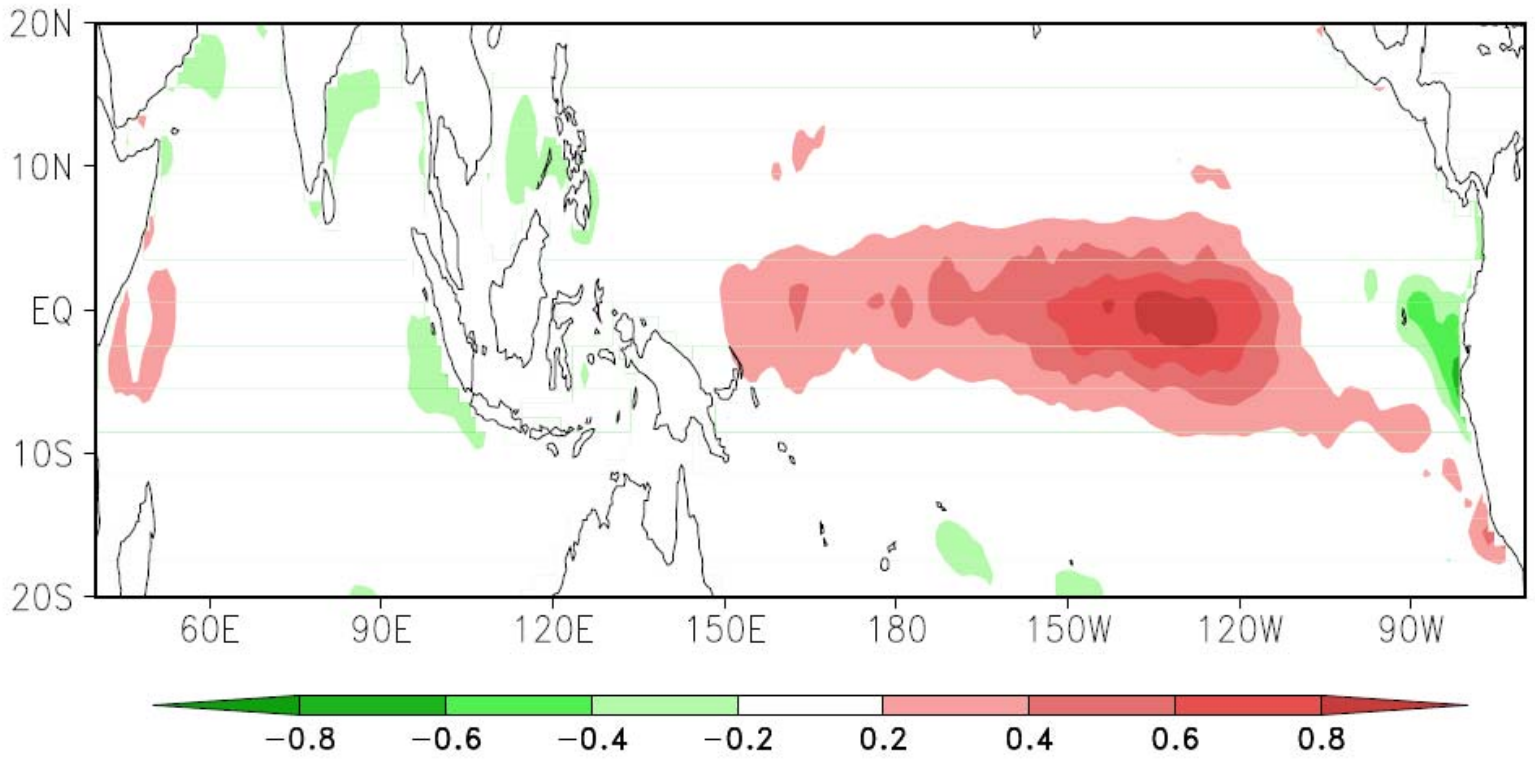


Nino3.4 (NDJ) correlation with JJ/AS rainfall



Correlation of JJ—AS(0) PR (Shaded), TTa (contour) and 850hpa Winds (vectors) animalies with N

The SST difference between Observed SST - Model Failed prediction years w.r.t ISMR



Monsoon in AR4 models

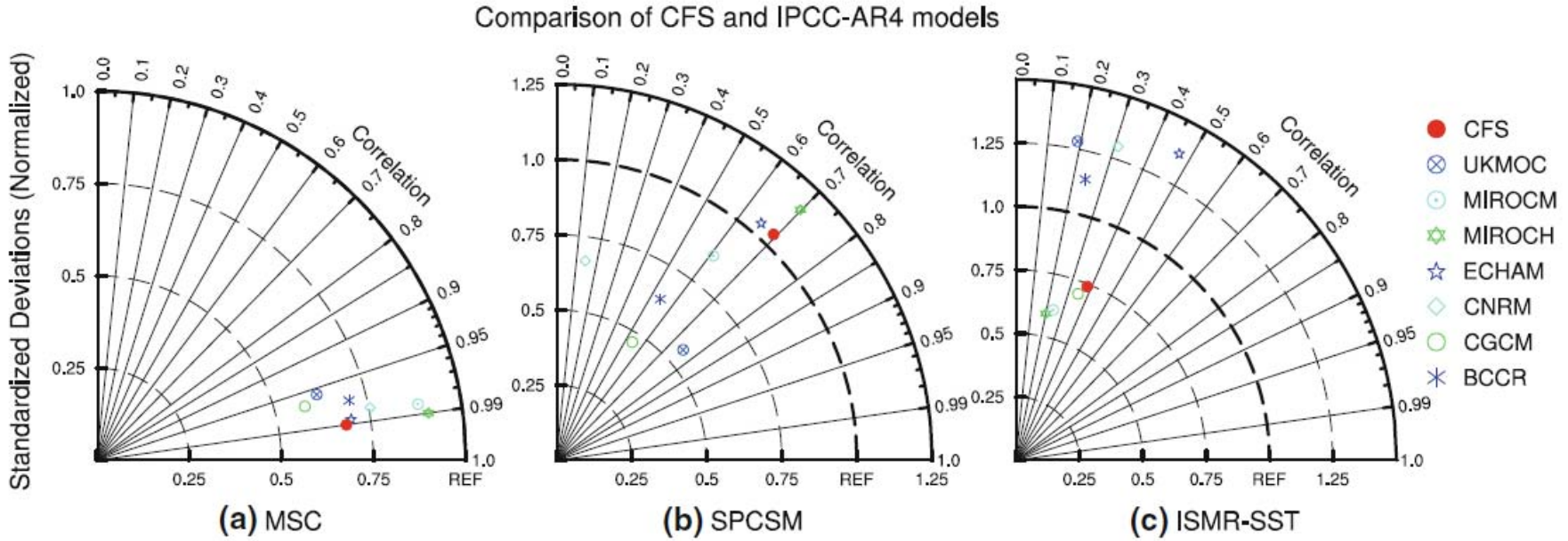


Fig. 1 Taylor diagram between CFS and IPCC-AR4 models for **a** mean seasonal cycle (*MSC*), **b** spatial pattern of climatological seasonal mean (*SPCSM*) and **c** ISMR–SST relationship comparison

ENSO-Monsoon Teleconnection in AR4 models

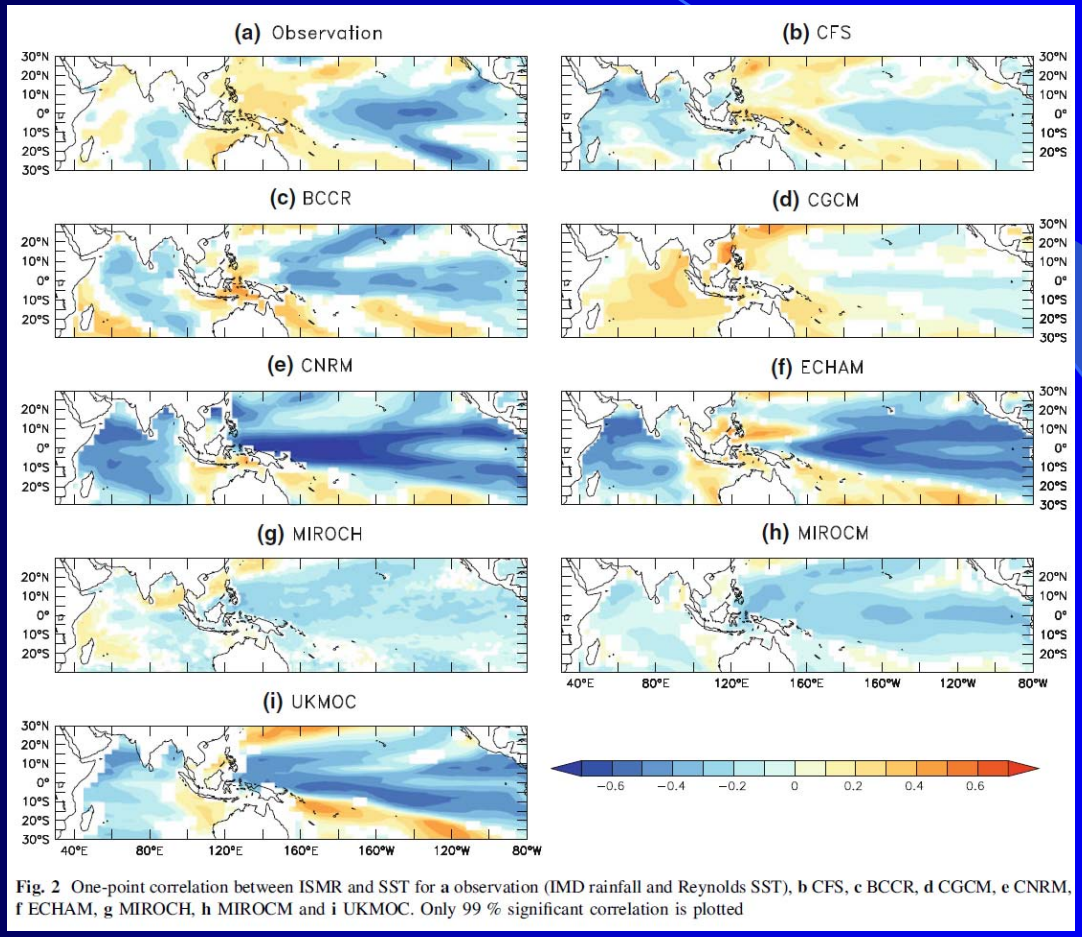
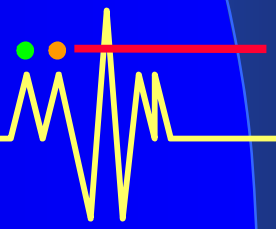


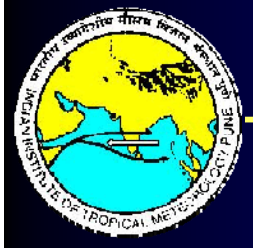
Fig. 2 One-point correlation between ISMR and SST for **a** observation (IMD rainfall and Reynolds SST), **b** CFS, **c** BCCR, **d** CGCM, **e** CNRM, **f** ECHAM, **g** MIROCH, **h** MIROCM and **i** UKMOC. Only 99 % significant correlation is plotted

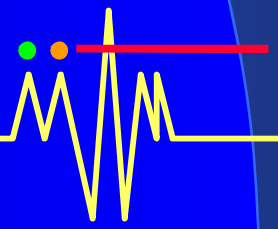
ENSO – MONSOON in Recent Operational Coupled Models



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 (0.25 – 0.5 L40)	Dynamical Sea ice and Land surface models

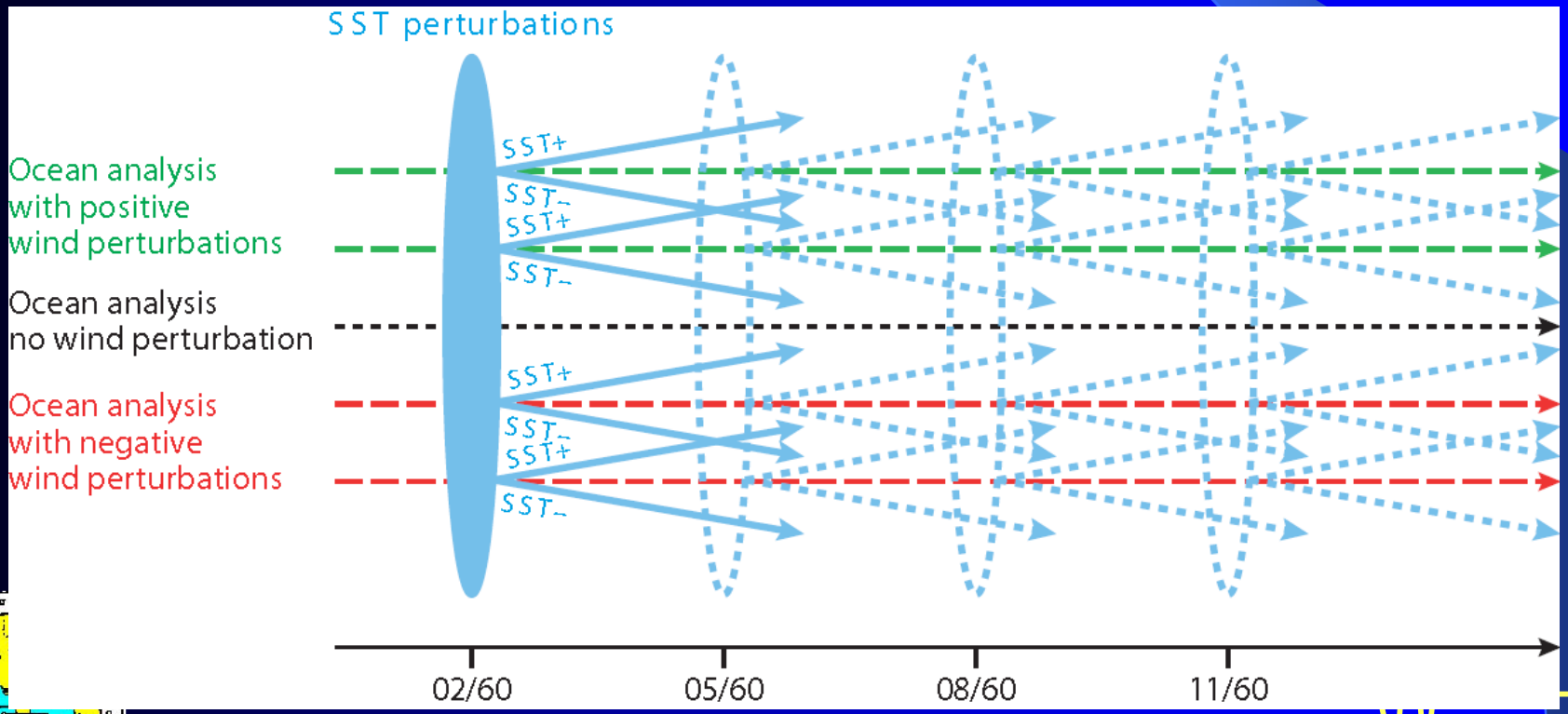




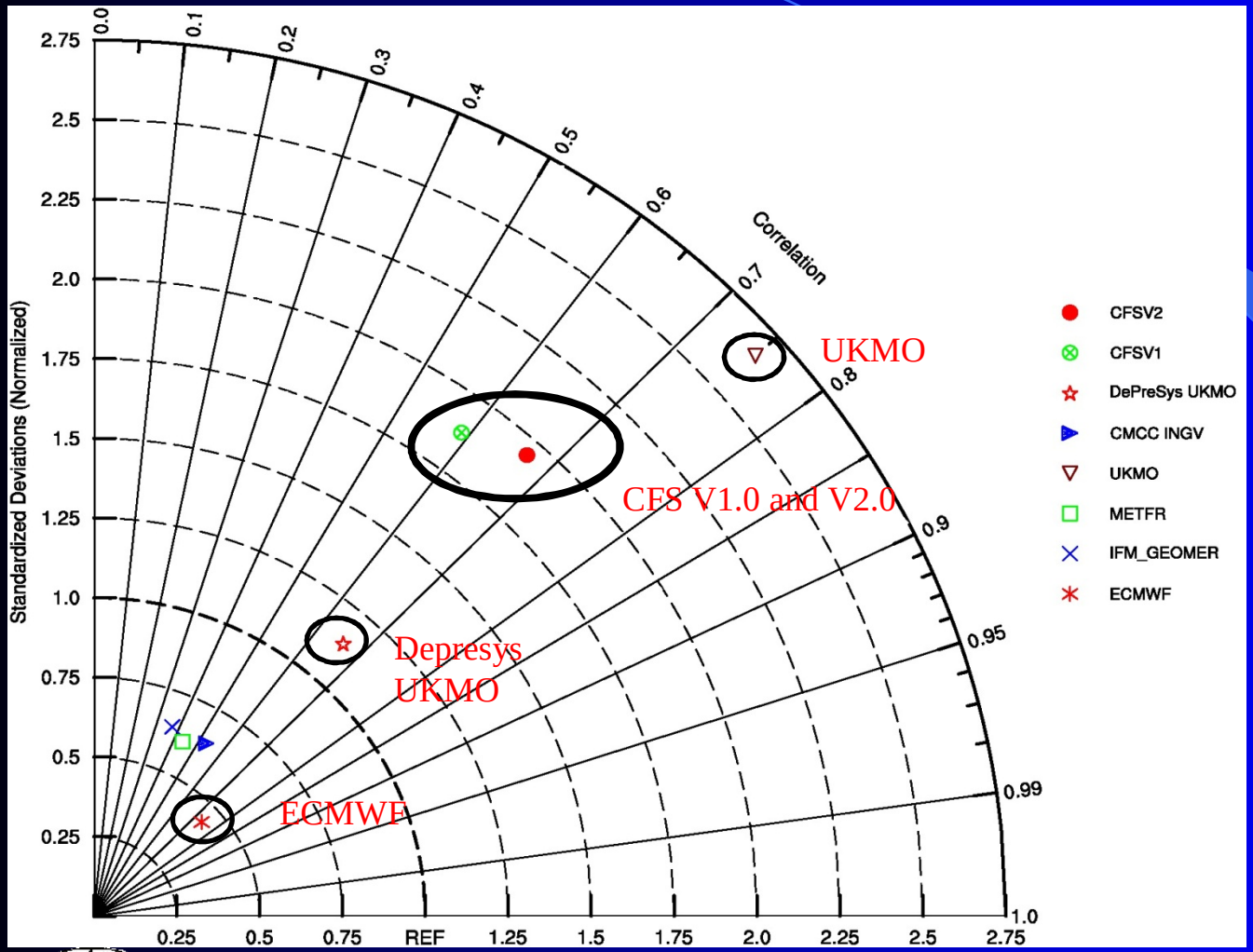
Details of Initialization (in ENSEMBLES)

Atmospheric IC:ERA-40 Operational Analysis
AMIP type Simulations

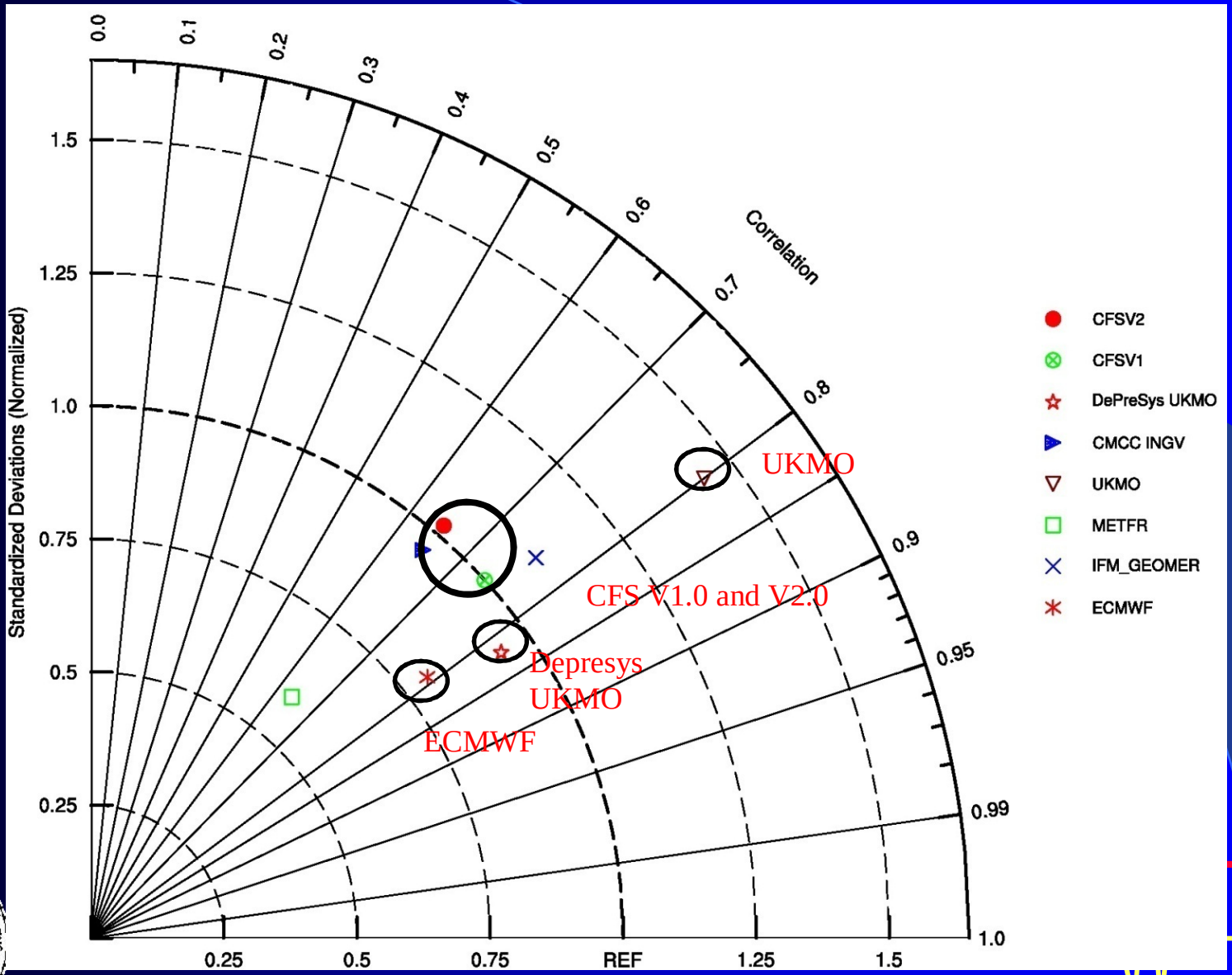
Ocean IC: **Ocean analysis with Wind/SST Perturbations**



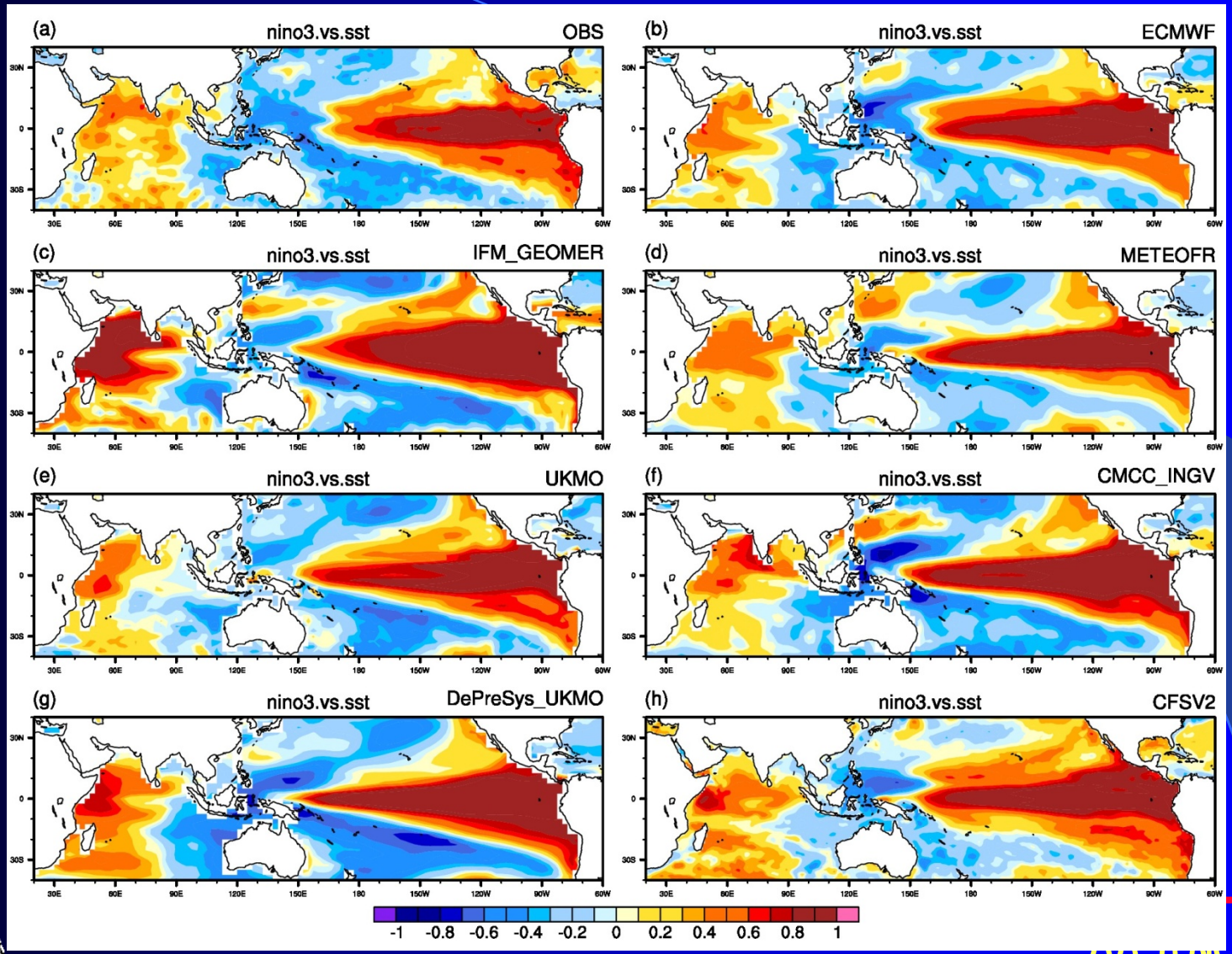
Rainfall Spatial Pattern (10N-30N; 70-100E)



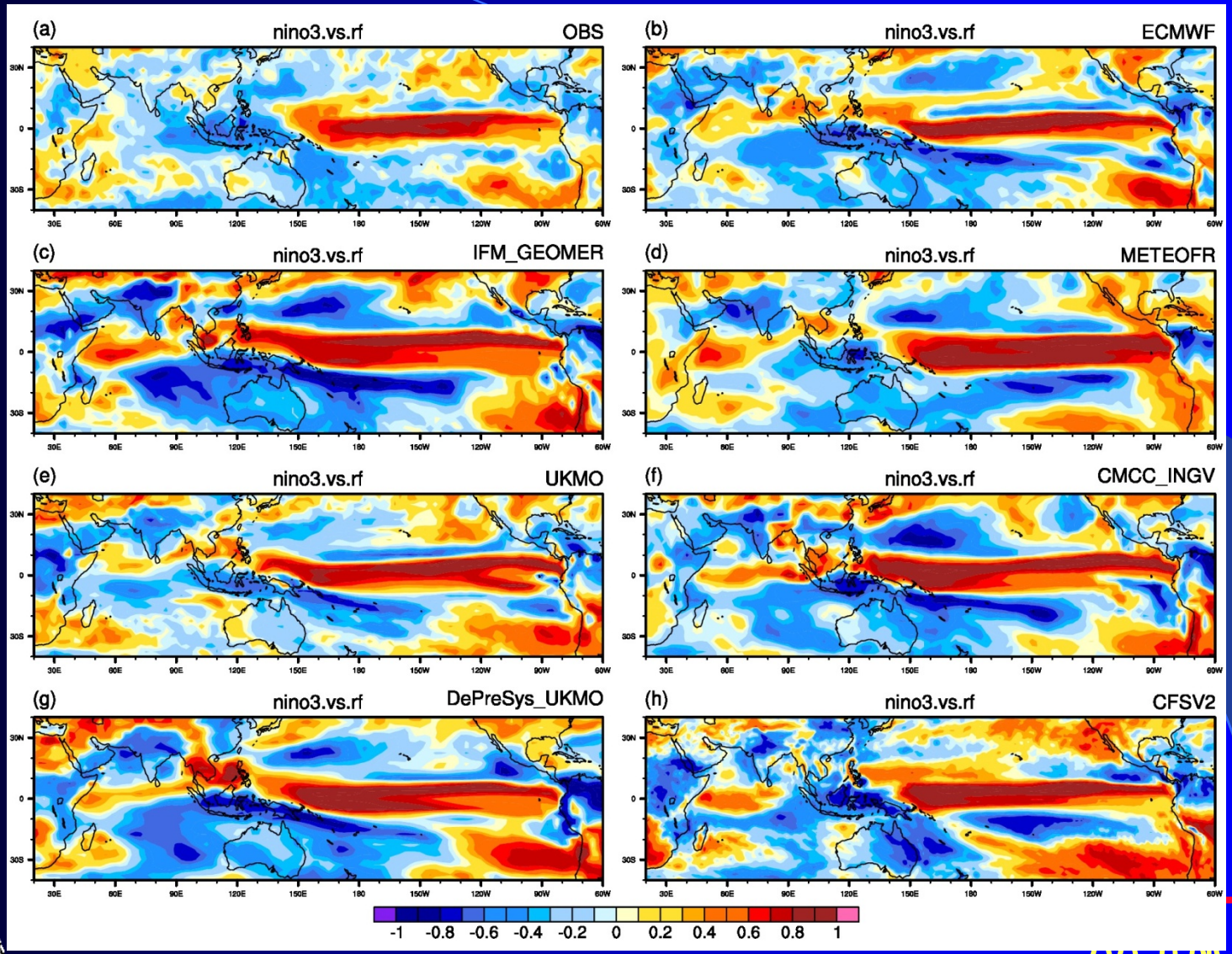
Spatial Pattern of Indian Land Rainfall



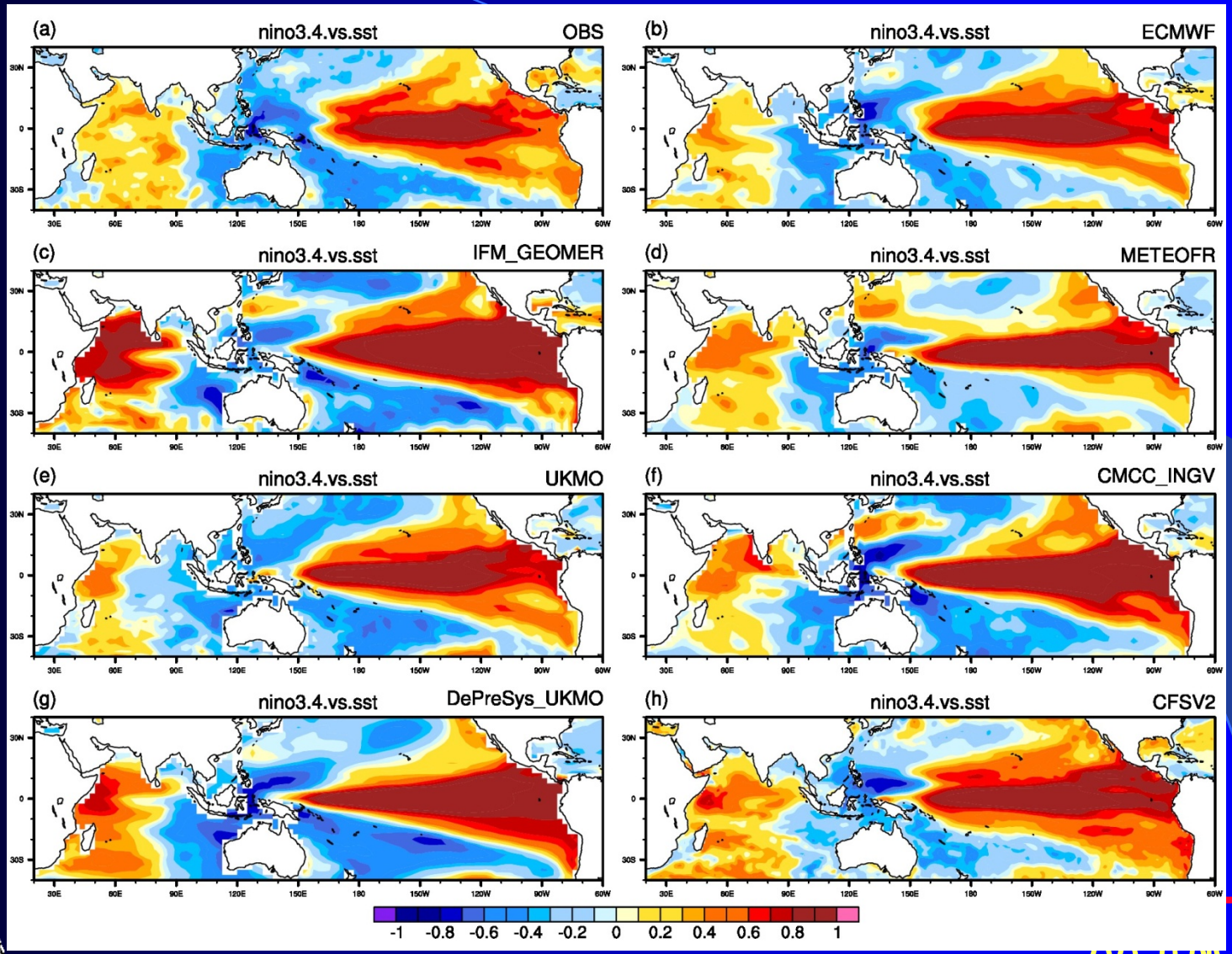
Nino 3.0 SSTA correlated with JJAS SST



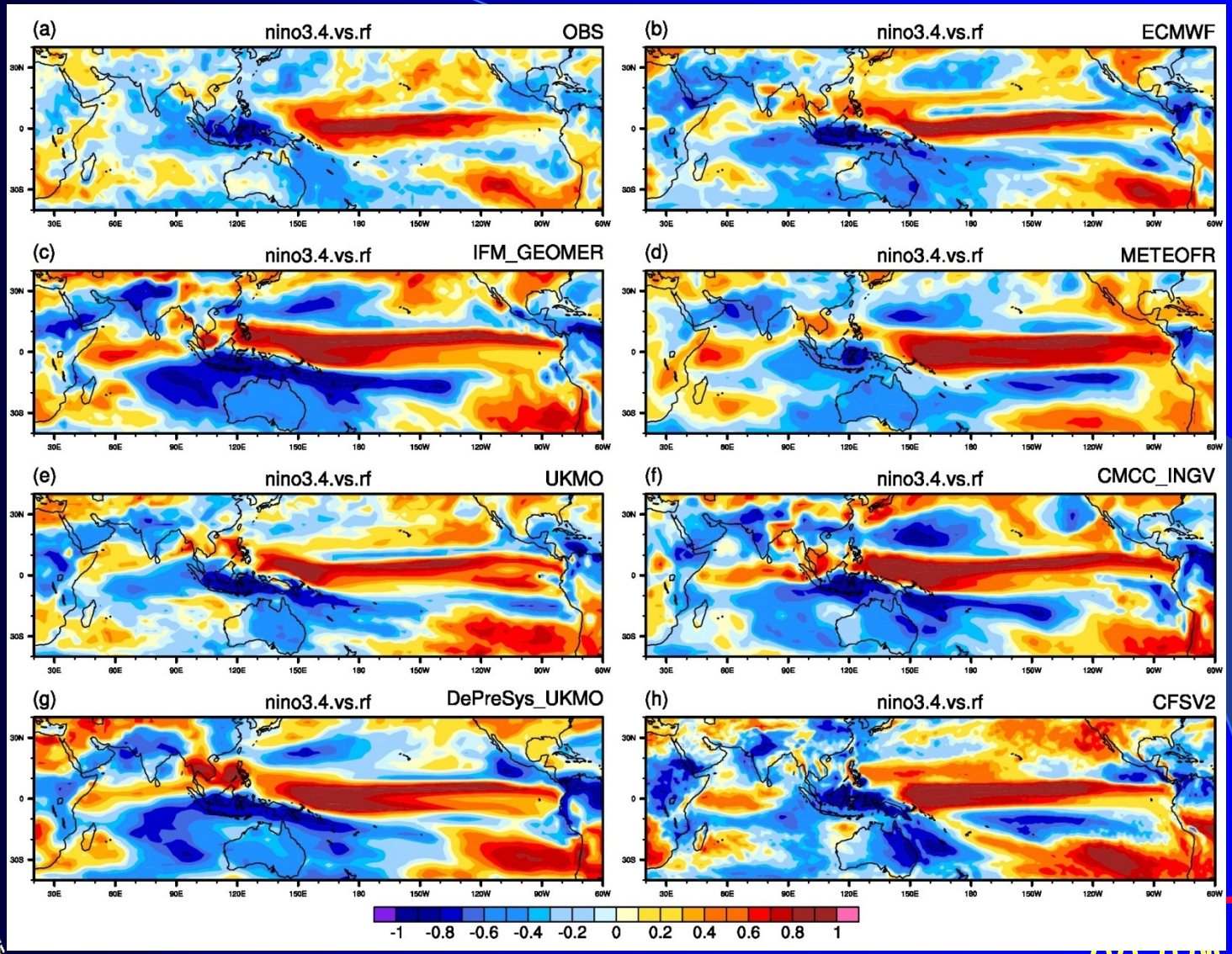
Nino 3.0 SSTA correlated with JJAS Rain Fall



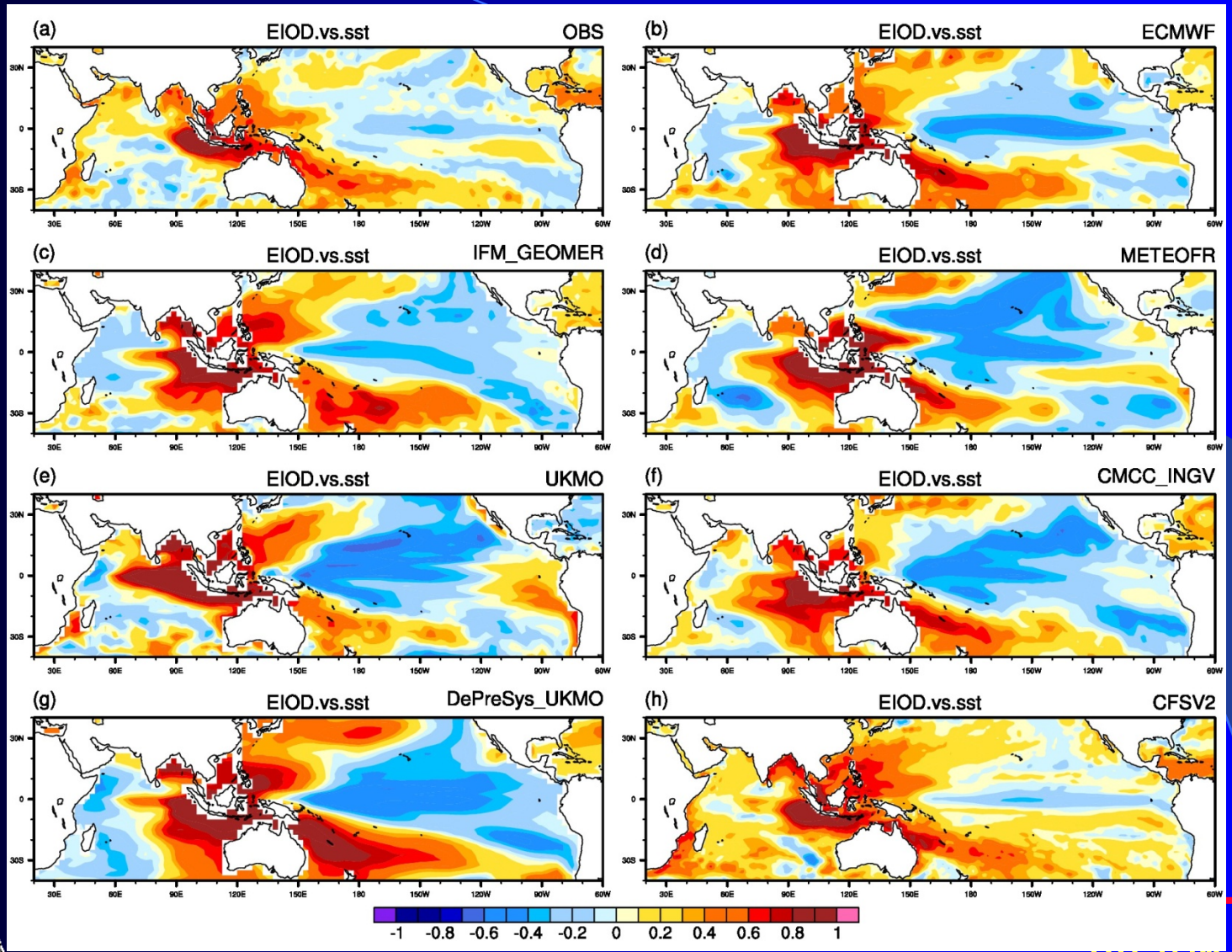
Nino 3.4 SSTA correlated with JJAS SST



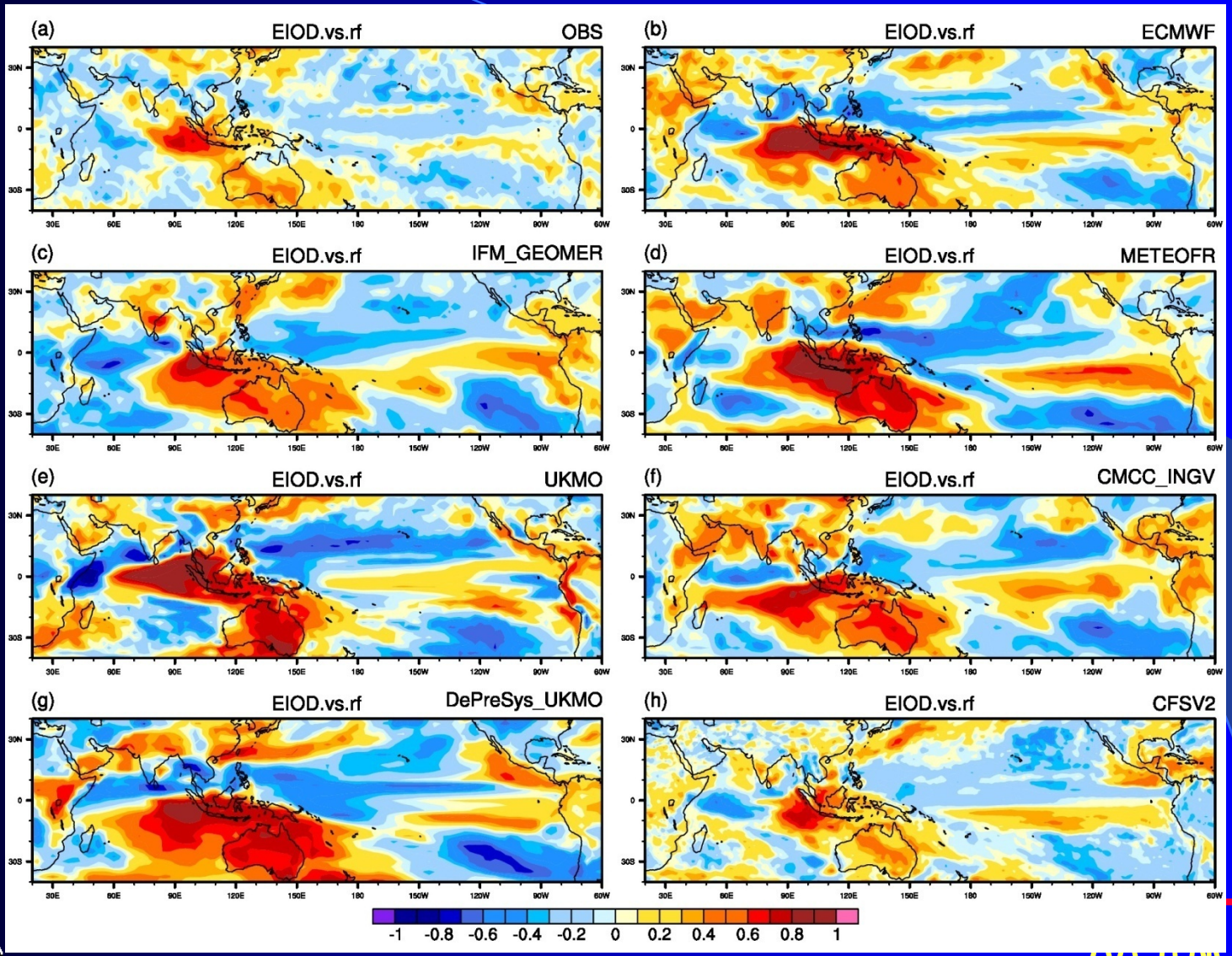
Nino 3.4 SSTA correlated with JJAS Rain Fall



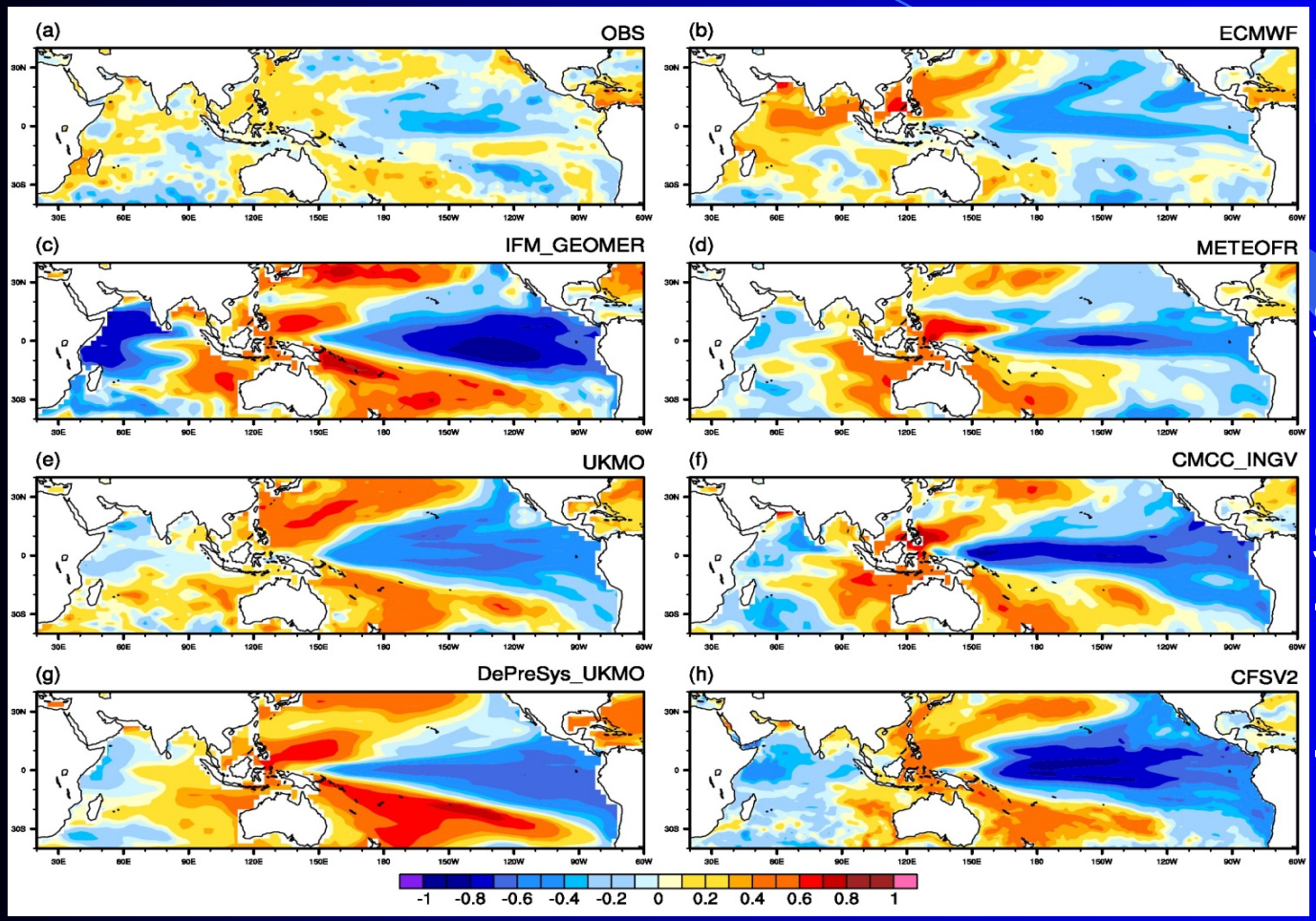
EIOD SSTA correlated with JJAS SSTA



EIOD SSTA correlated with JJAS Rain Fall

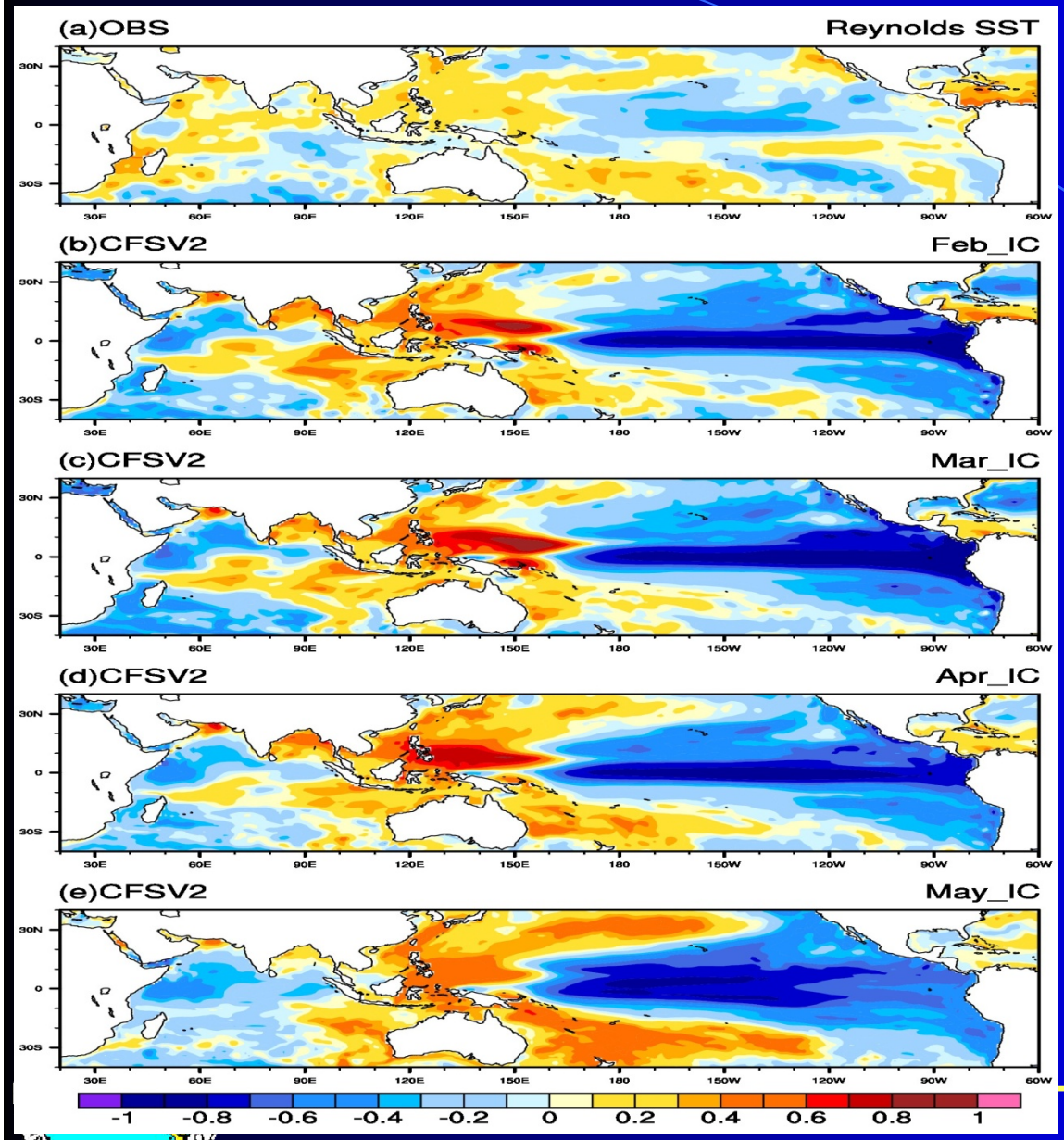


SST (JJAS) Correlated with Indian land points rainfall



Rainfall over India is strongly linked to Pacific SST in many models and Indian Ocean SST teleconnection is opposite to the observed

SSTA correlated with Land point precip



Observations

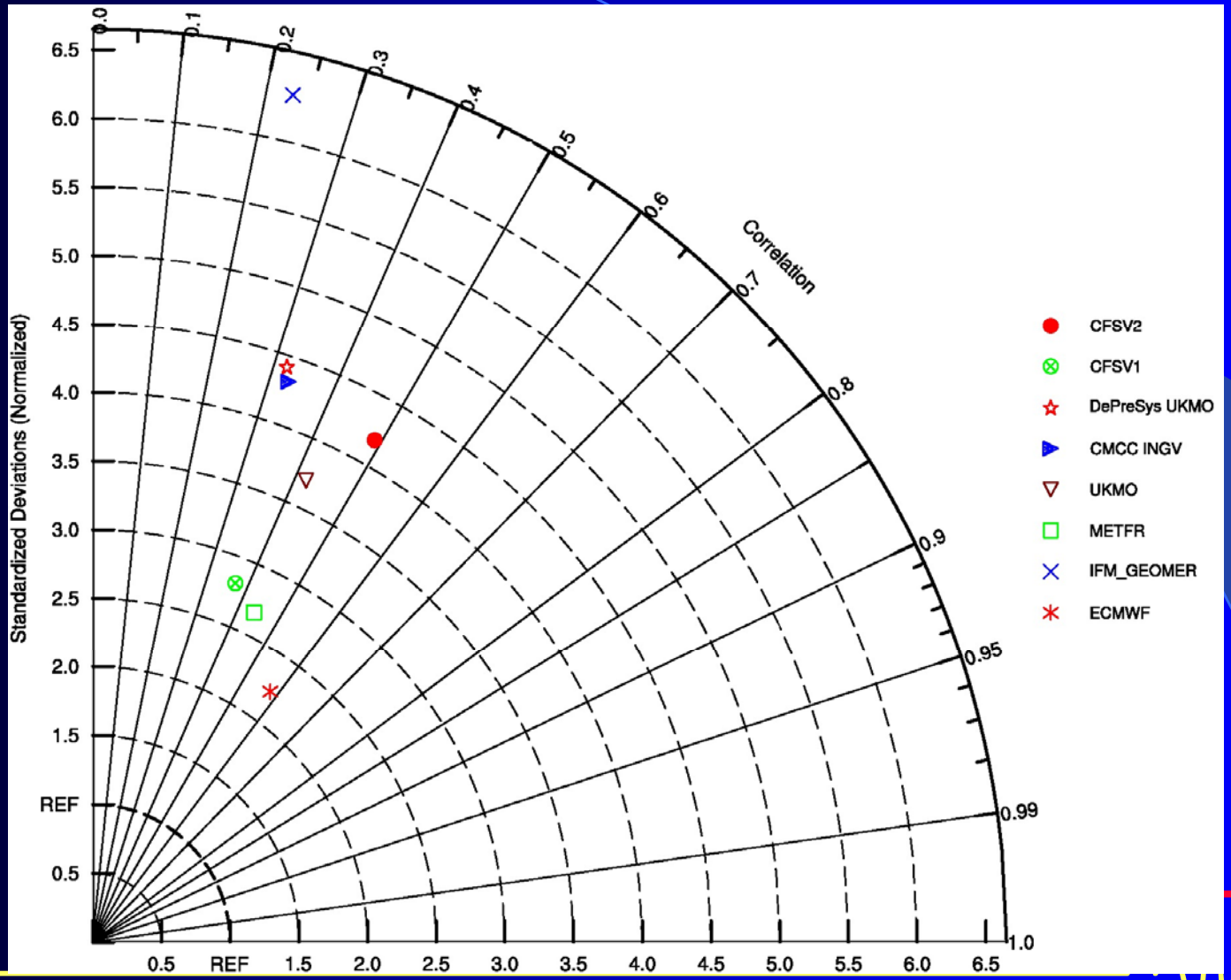
CFS v2 Feb. IC

CFS v2 Mar IC

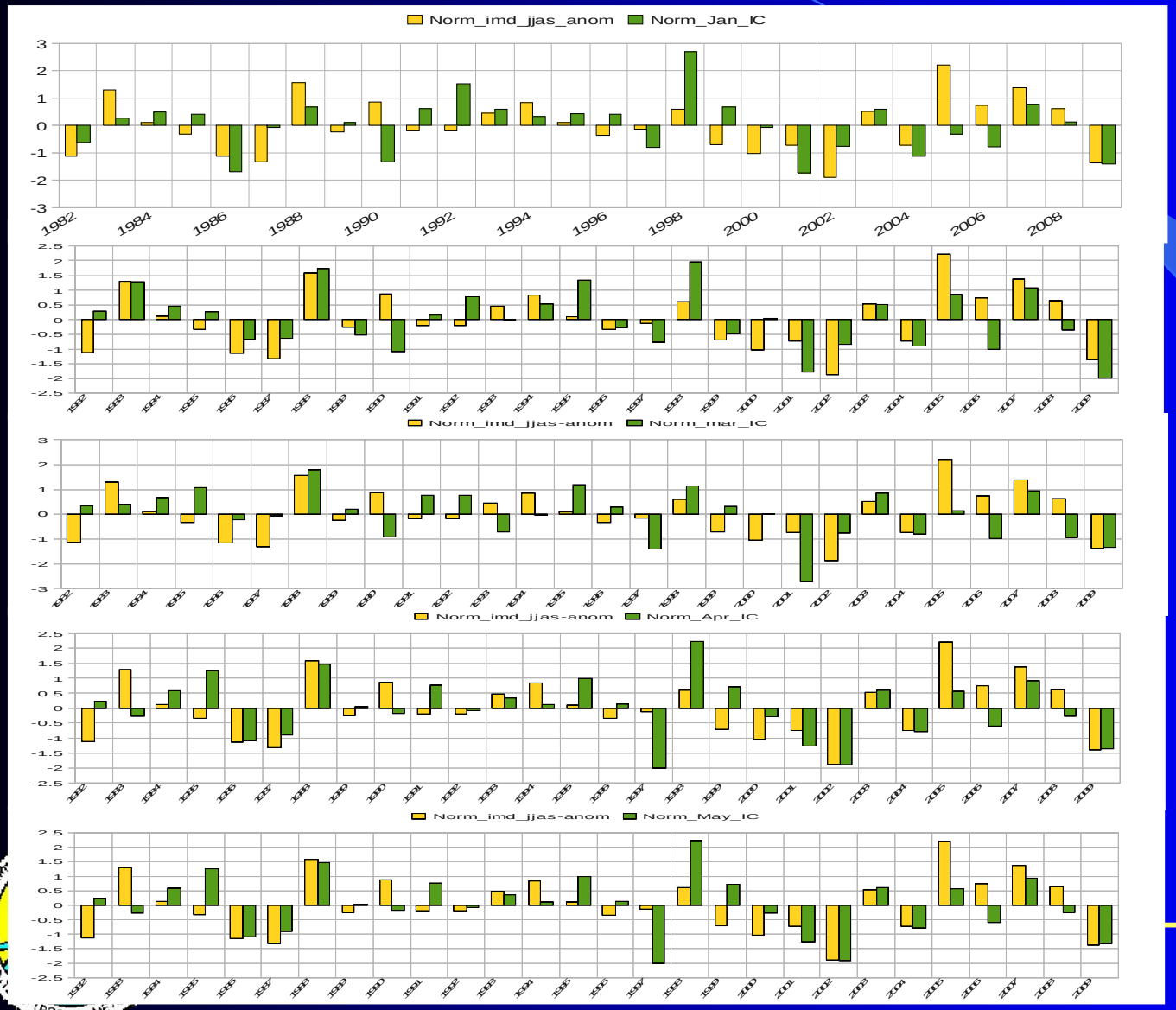
CFS v2 Apr IC

CFS v2 May IC

Spatial pattern of SSTA correlation with land points rainfall (JJAS)



Prediction Skill of ISMR in CFS V2.0



CFS v2 Jan IC
Correlation = 0.37

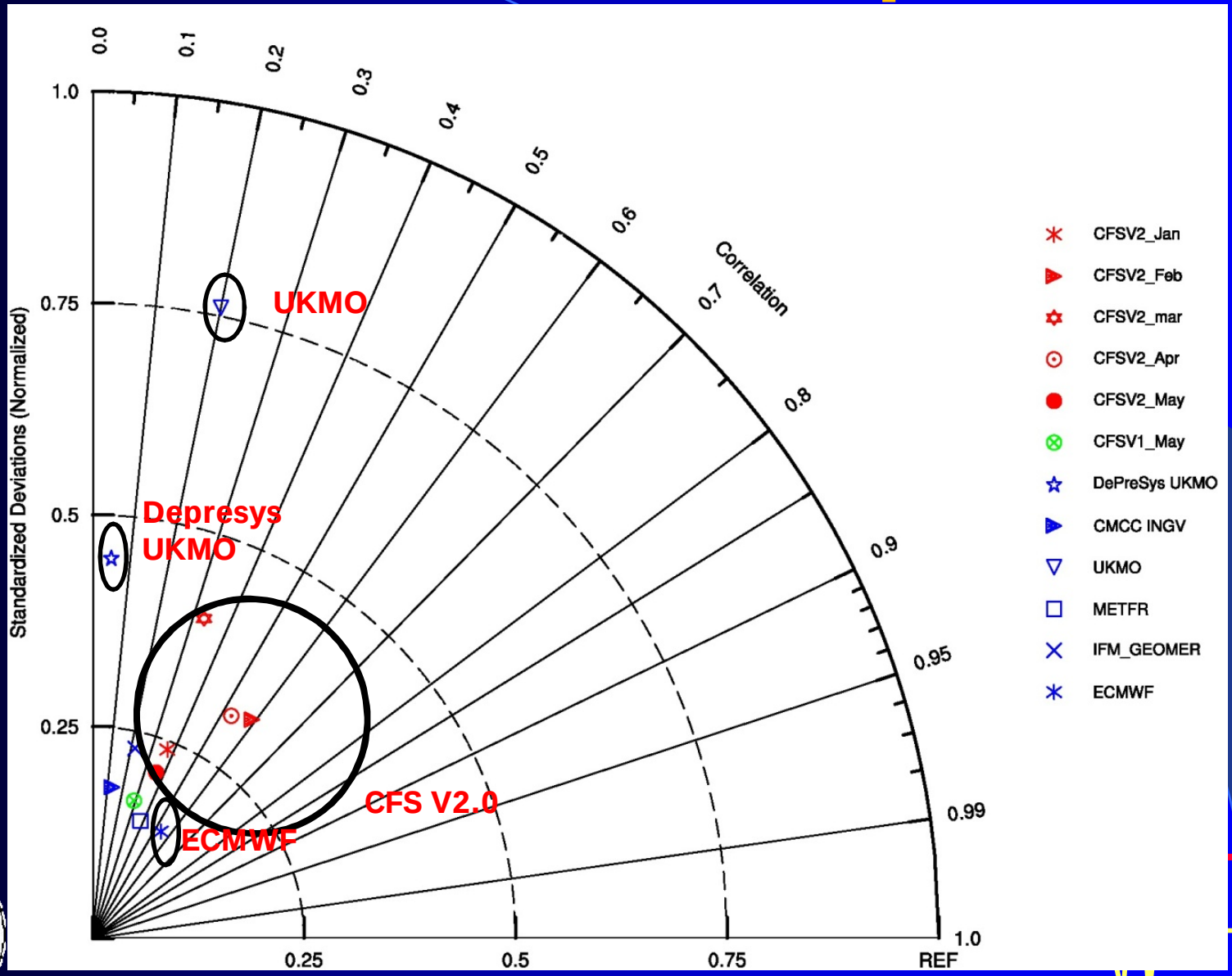
CFS v2 Feb IC
Correlation = 0.59

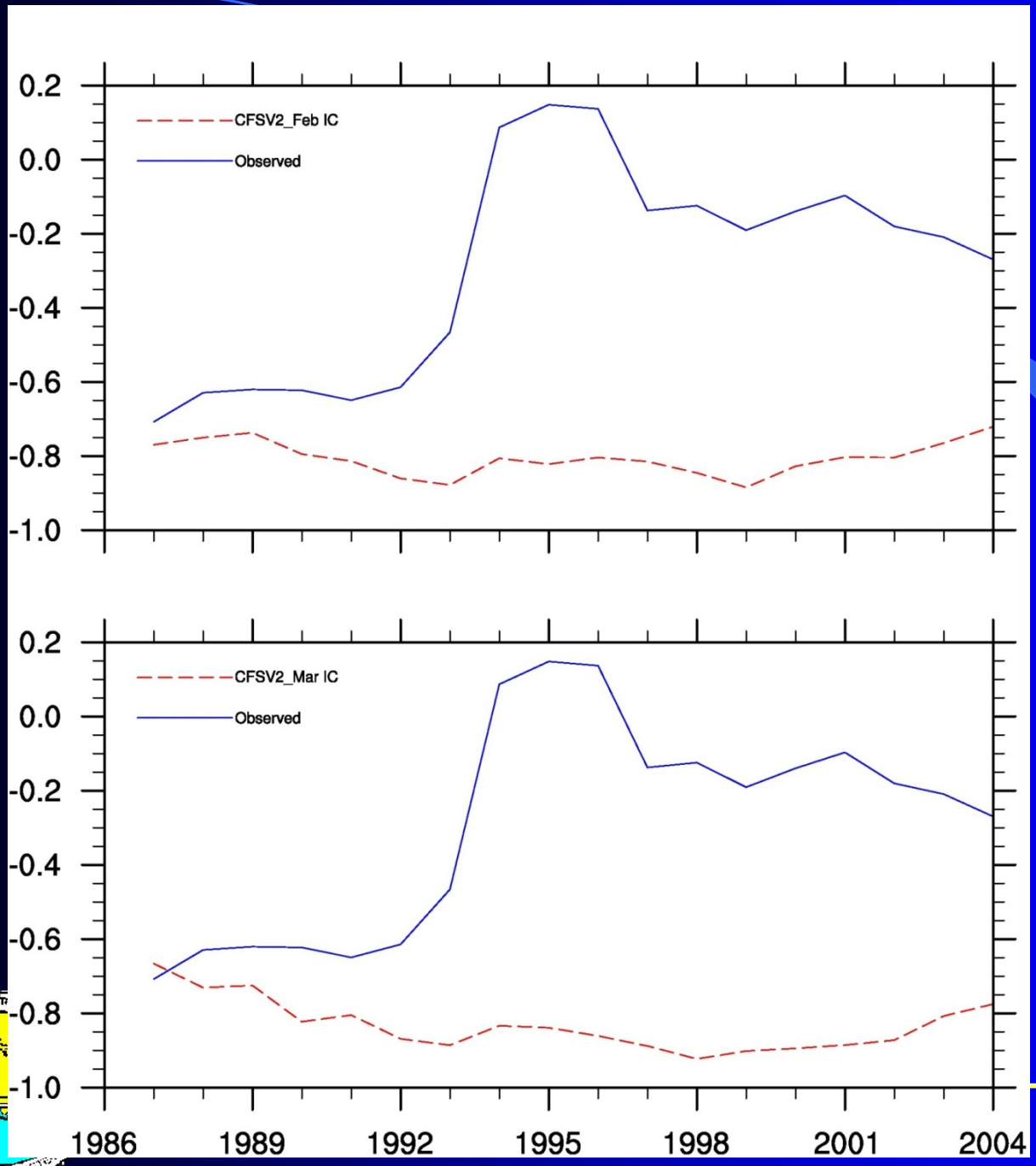
CFS v2 Mar IC
correlation = 0.33

CFS v2 Apr IC
Correlation = 0.53

CFS v2 May IC
correlation = 0.36

Rainfall skill Land points

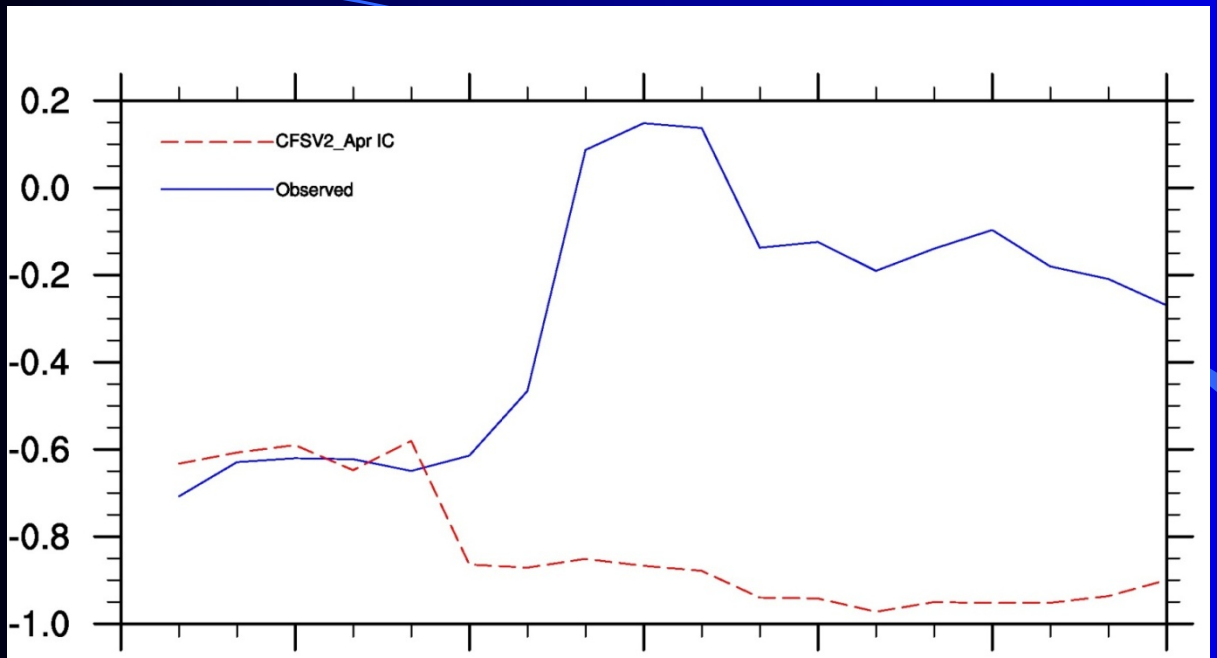




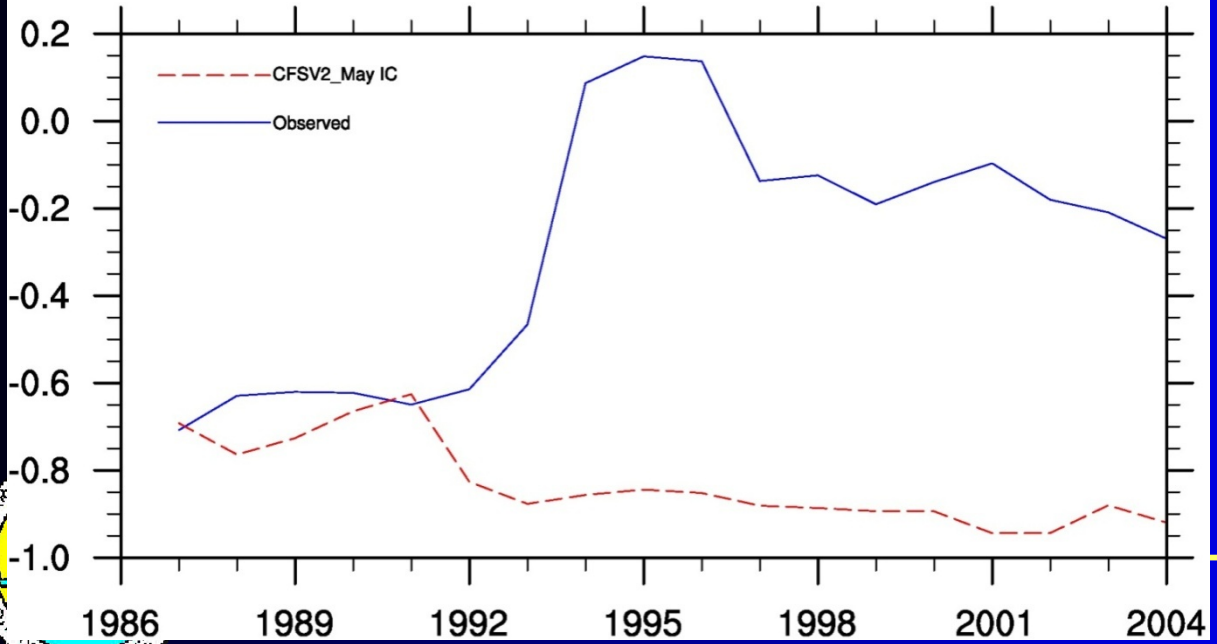
11 year running correlation b/w ISMR and Nino3.4 SST anomaly CFS V2 (JJAS)

Feb IC

Mar IC

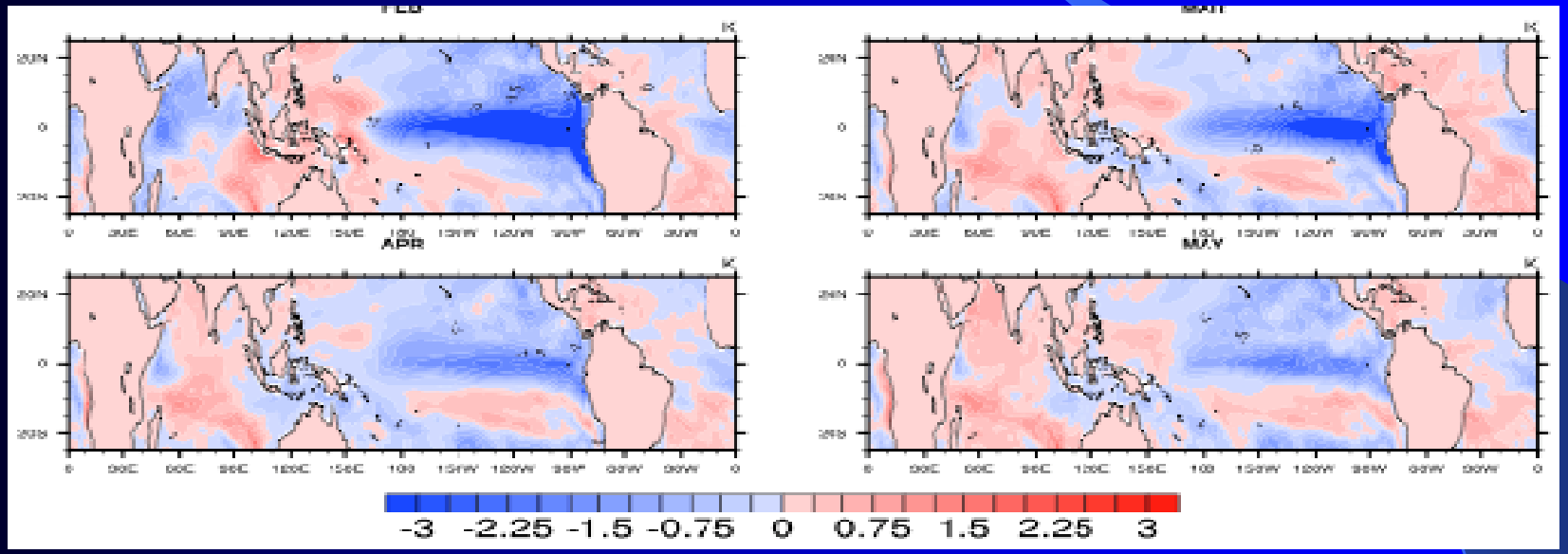

0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
CFSV2_Apr IC
Observed

Apr IC


0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
CFSV2_May IC
Observed
1986
1989
1992
1995
1998
2001
2004

May IC

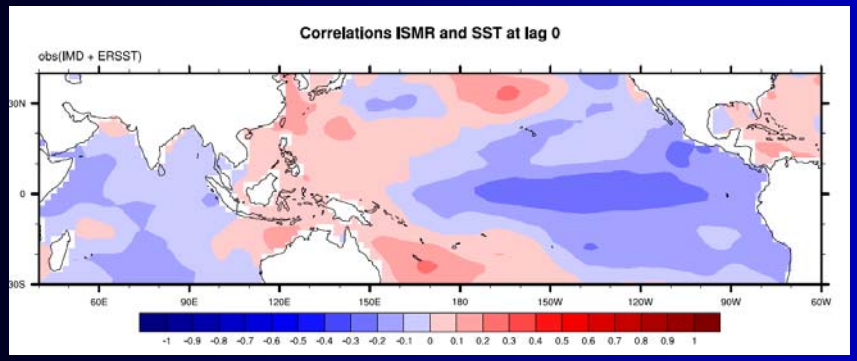
SST Composite for correct model predictions



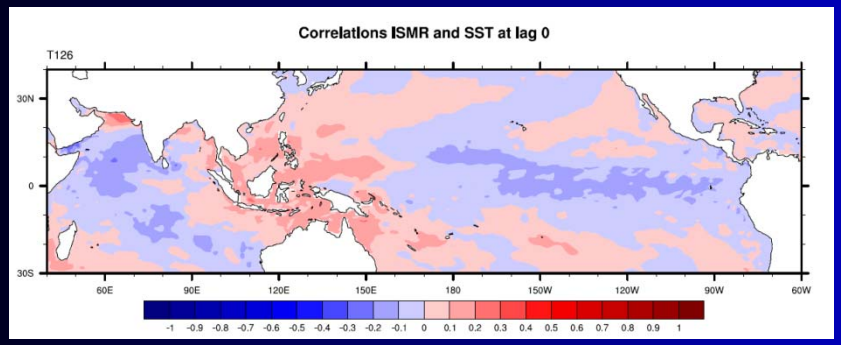
Rajib et al., 2012, Submitted

MONSOON-SST Teleconnetions at diff. resolutions

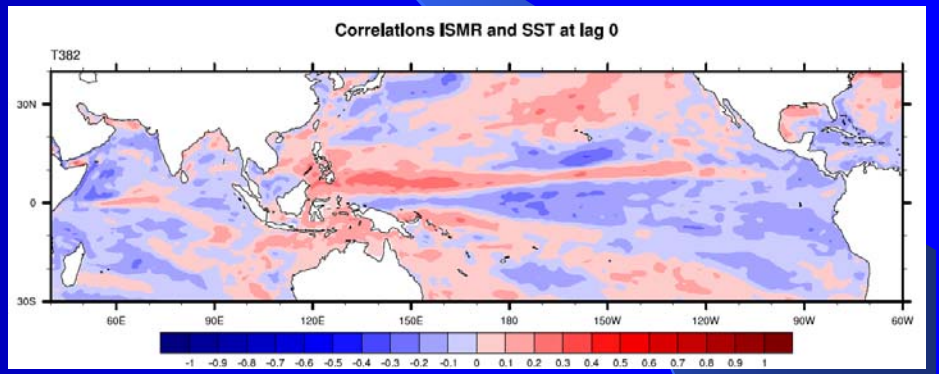
Observations



T126

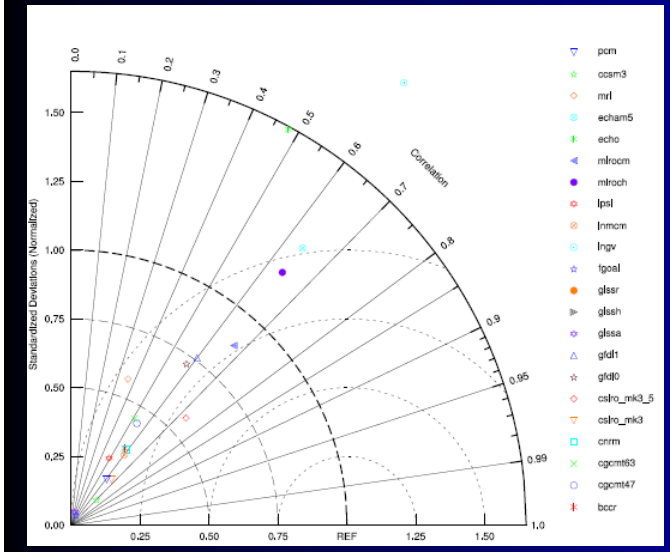


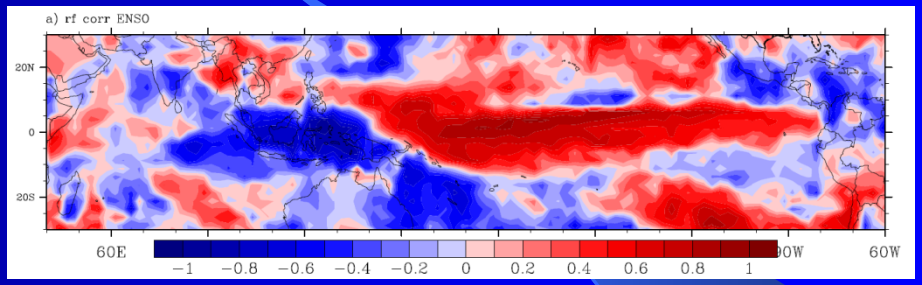
T382

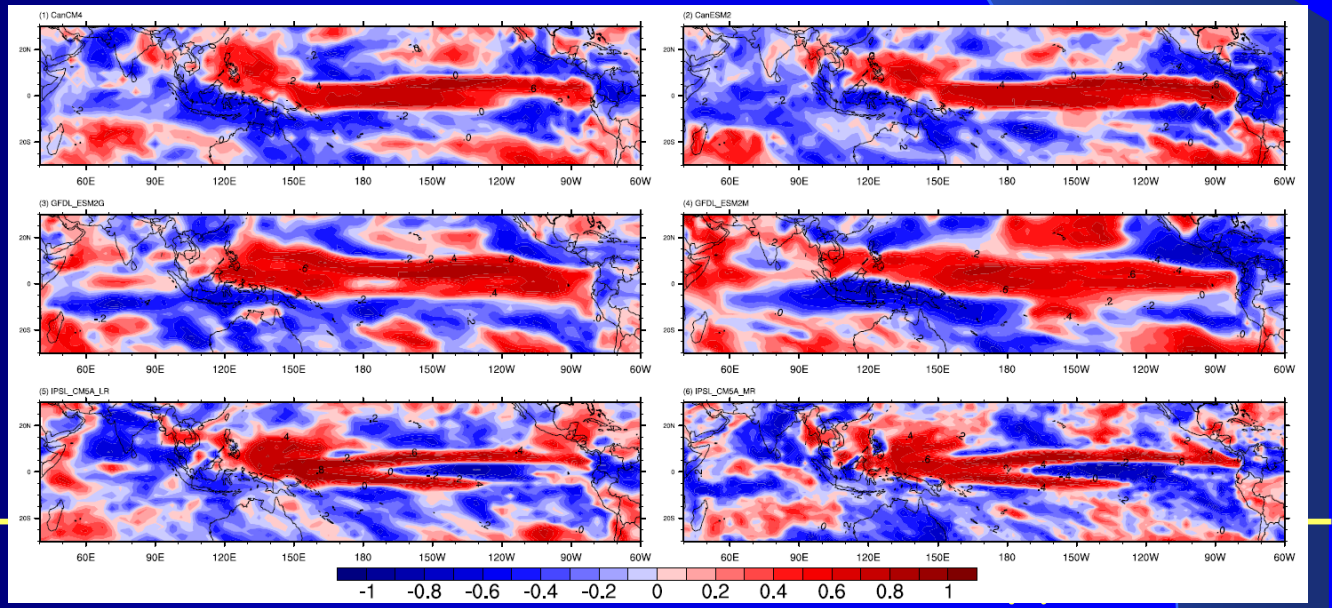


Rao et al., 2012, (Submitted)

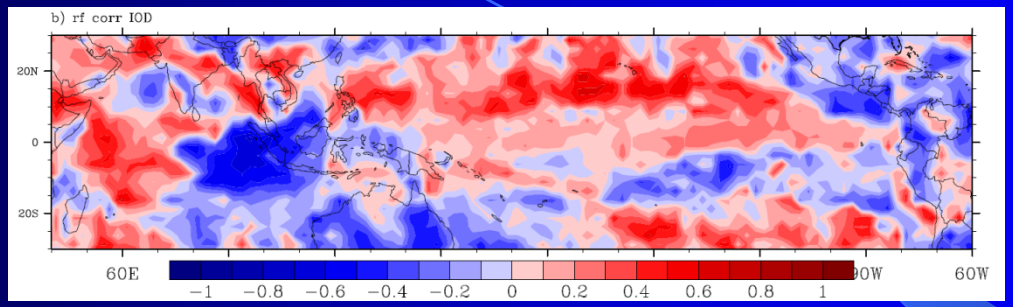
ENSO-MONSOON in CMIP5

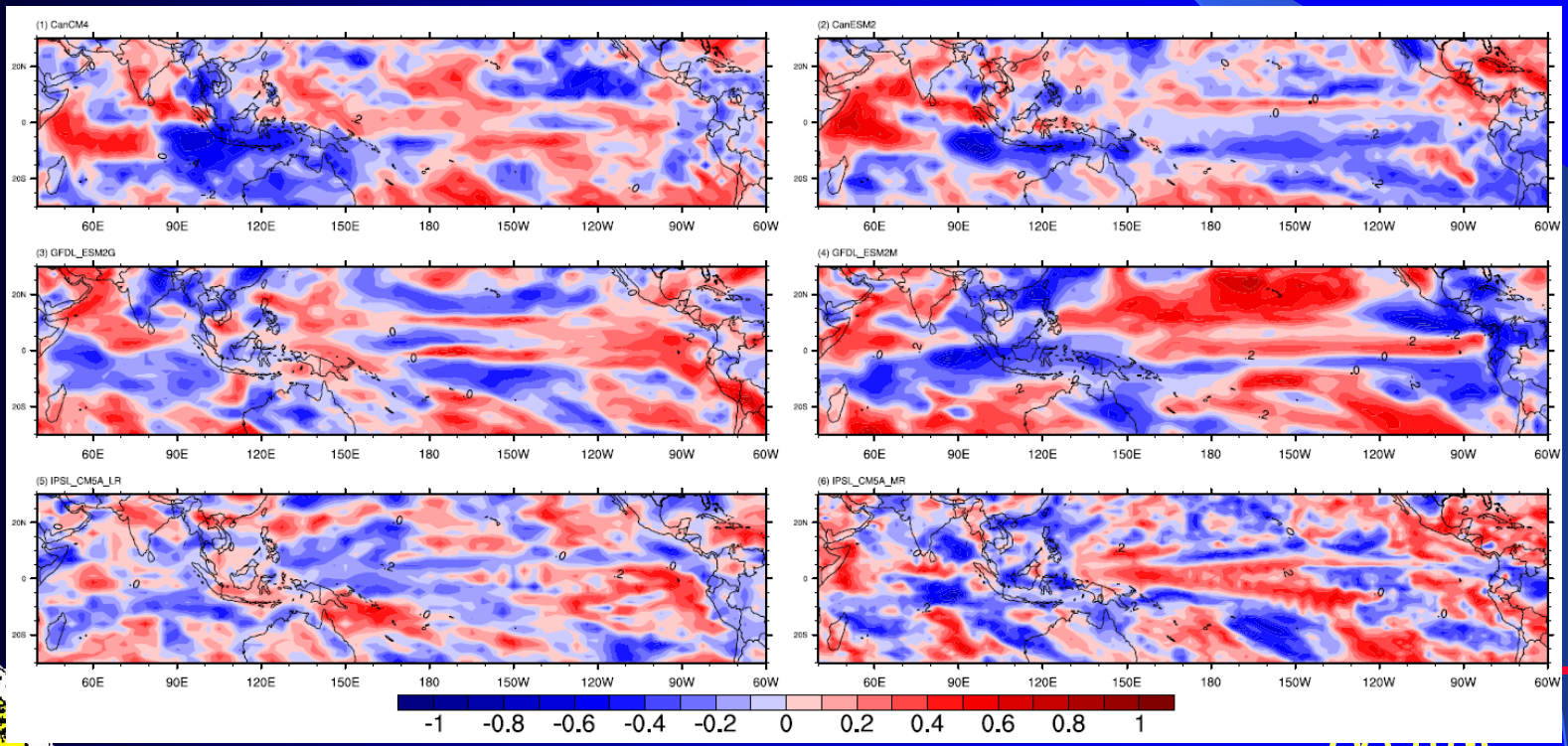






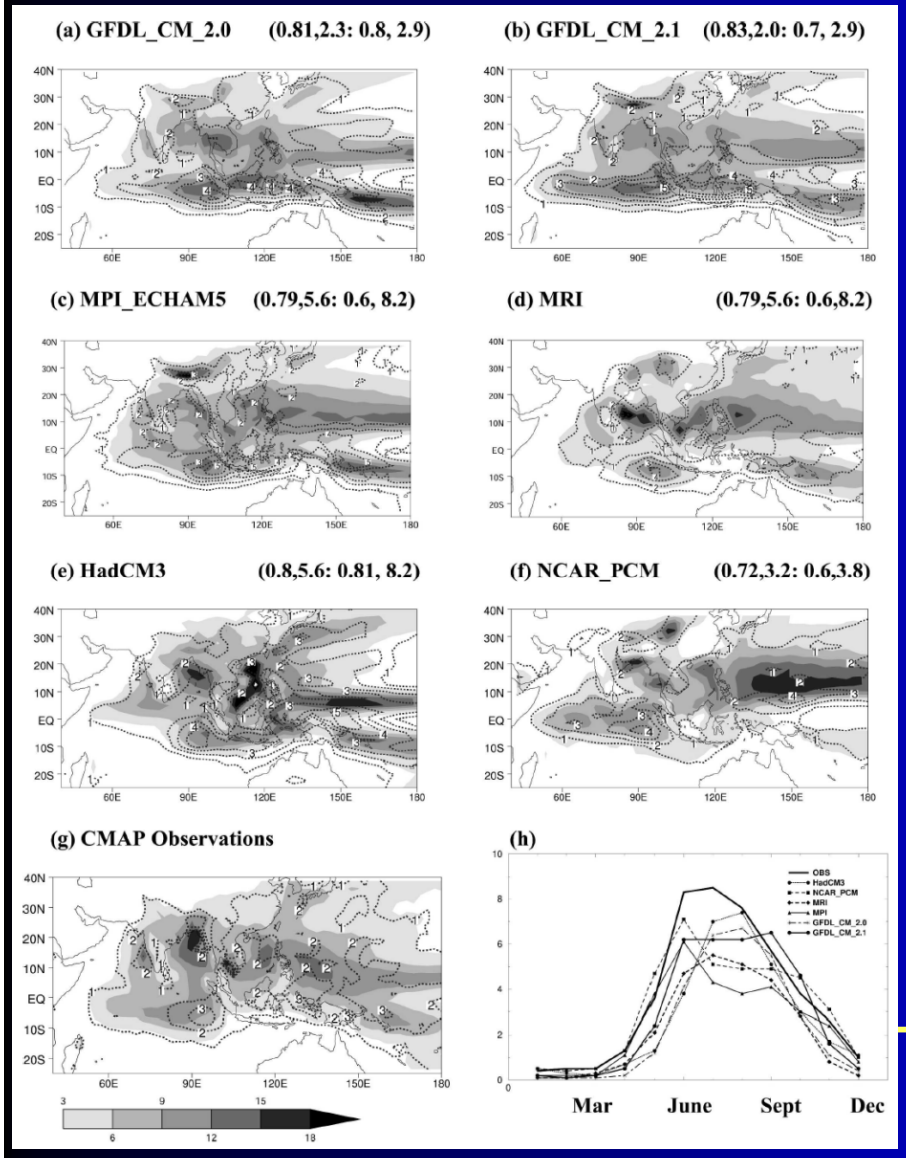
IOD-MONSOON in CMIP5



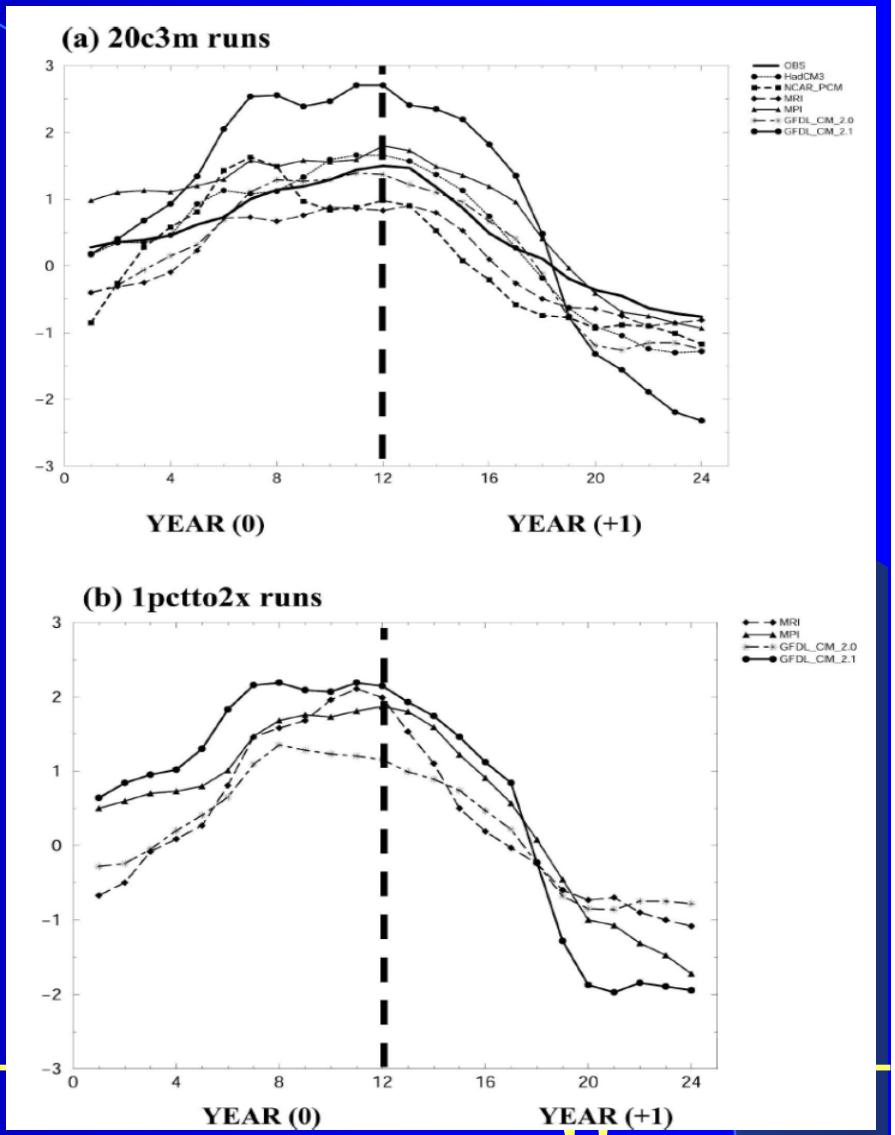


Monsoon in AR4 models and 2XCO2 expts.

Monsoon in different Models



Nino 3.4 SST evolution



Annamalai et al., (2007)

Teleconnections

20c3m Simulations

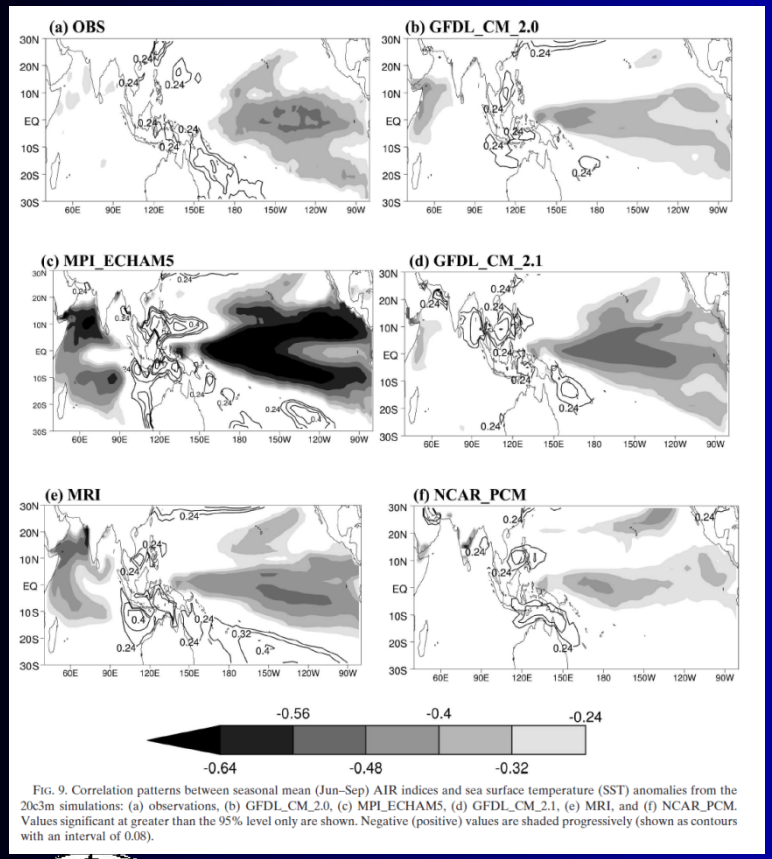
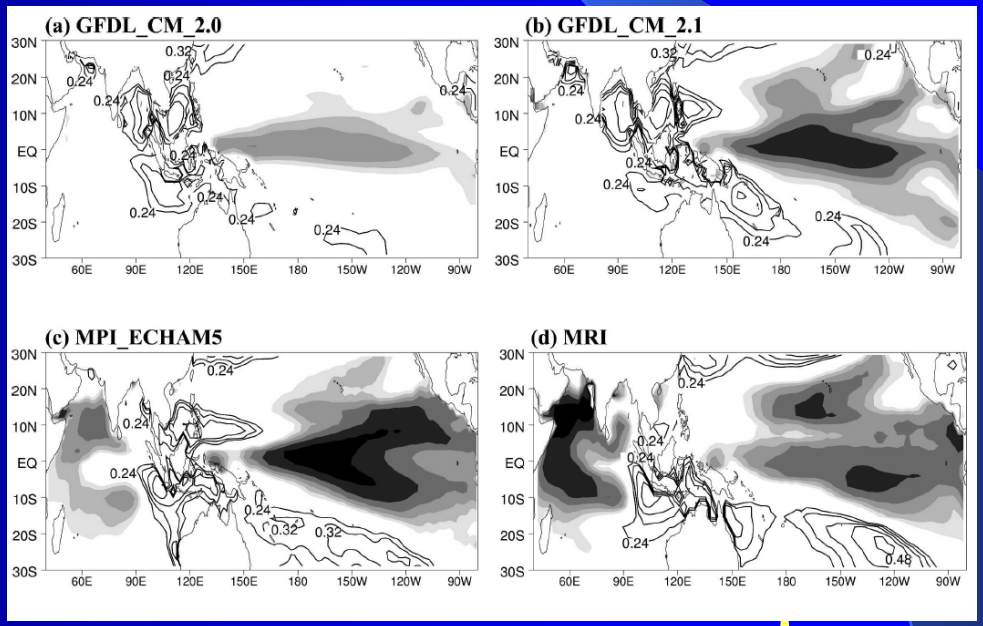


FIG. 9. Correlation patterns between seasonal mean (Jun–Sep) AIR indices and sea surface temperature (SST) anomalies from the 20c3m simulations: (a) observations, (b) GFDL_CM_2.0, (c) MPI_ECHAM5, (d) GFDL_CM_2.1, (e) MRI, and (f) NCAR_PCM. Values significant at greater than the 95% level only are shown. Negative (positive) values are shaded progressively (shown as contours with an interval of 0.08).

1pctto2x Simulations



Teleconnections in 2XCO$_2$ expt.

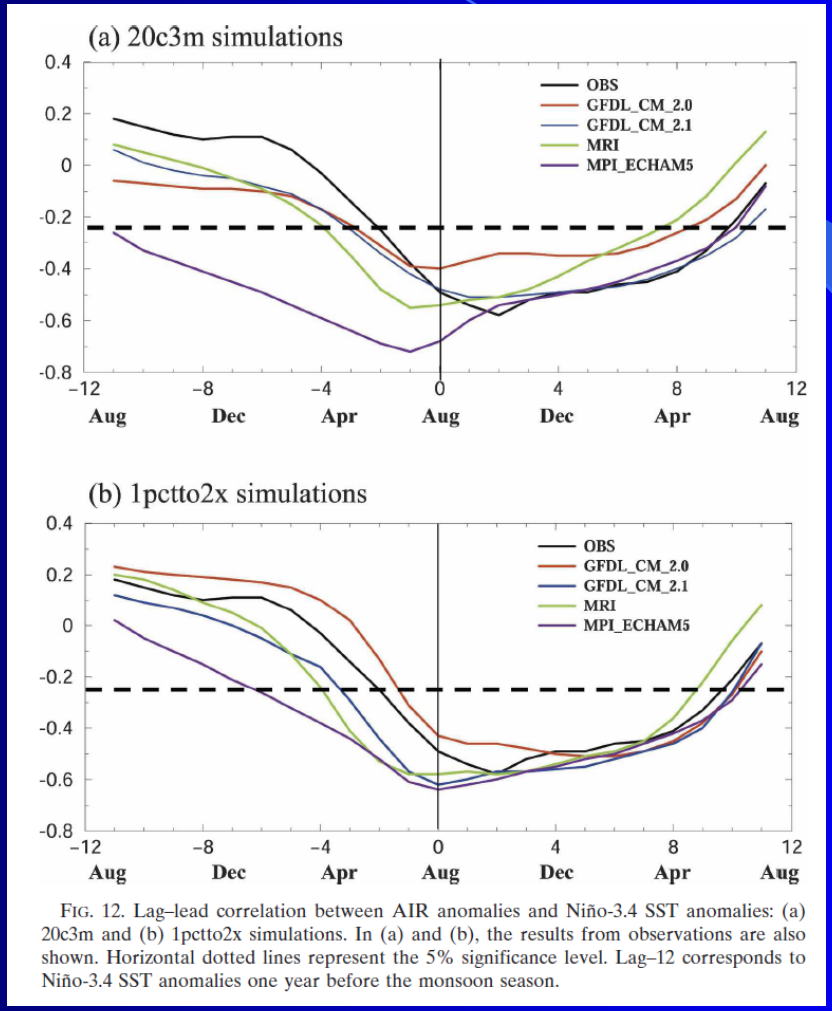
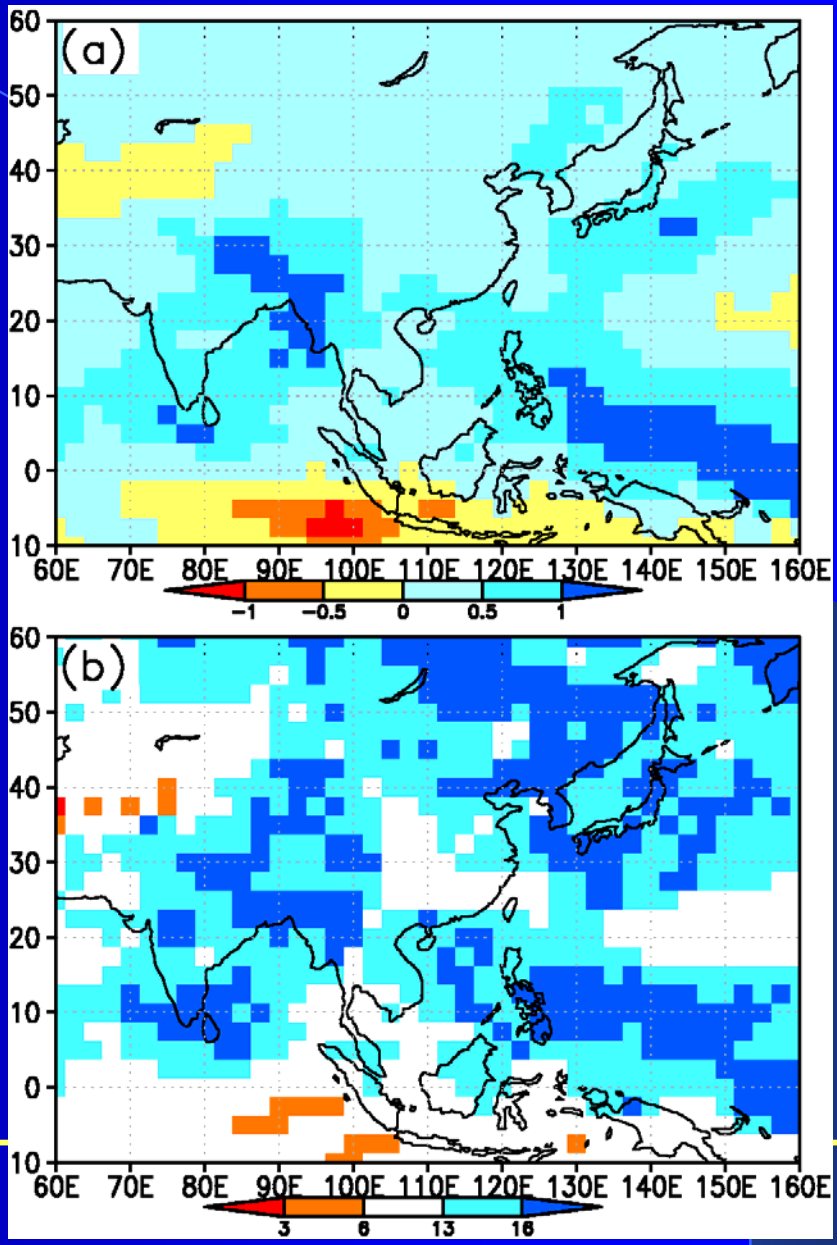


FIG. 12. Lag–lead correlation between AIR anomalies and Niño-3.4 SST anomalies: (a) 20c3m and (b) 1pctto2x simulations. In (a) and (b), the results from observations are also shown. Horizontal dotted lines represent the 5% significance level. Lag–12 corresponds to Niño-3.4 SST anomalies one year before the monsoon season.

Challenges: Uncertainty in AR3 models remained in AR5 models.

18 models mean

Number of models (out of 18) with precipitation change greater than 0



Source: Kitoh

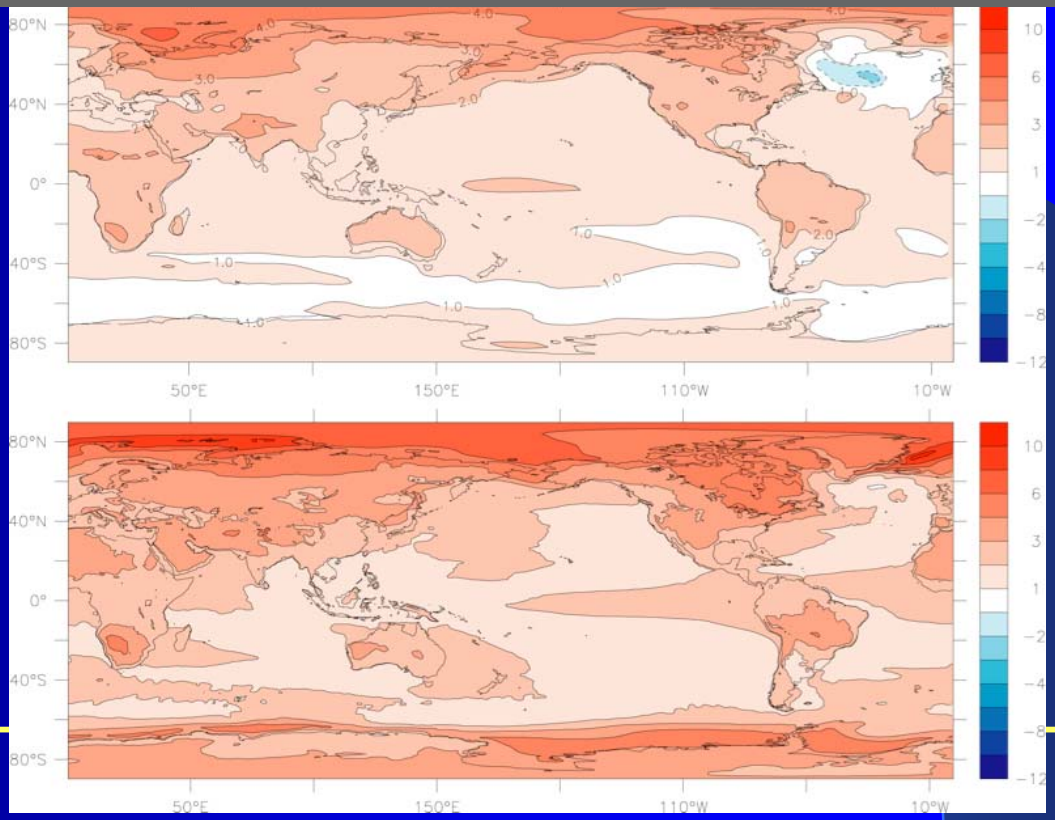
Major Challenges

- **Climate change Projections**
  - **Response of increased CO2 in coupled models at different resolution is different (Vechhi)**

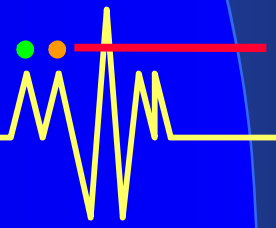
Global Surface Temperature Response to 2xCO_2

CM 2.1 (Low Res.)

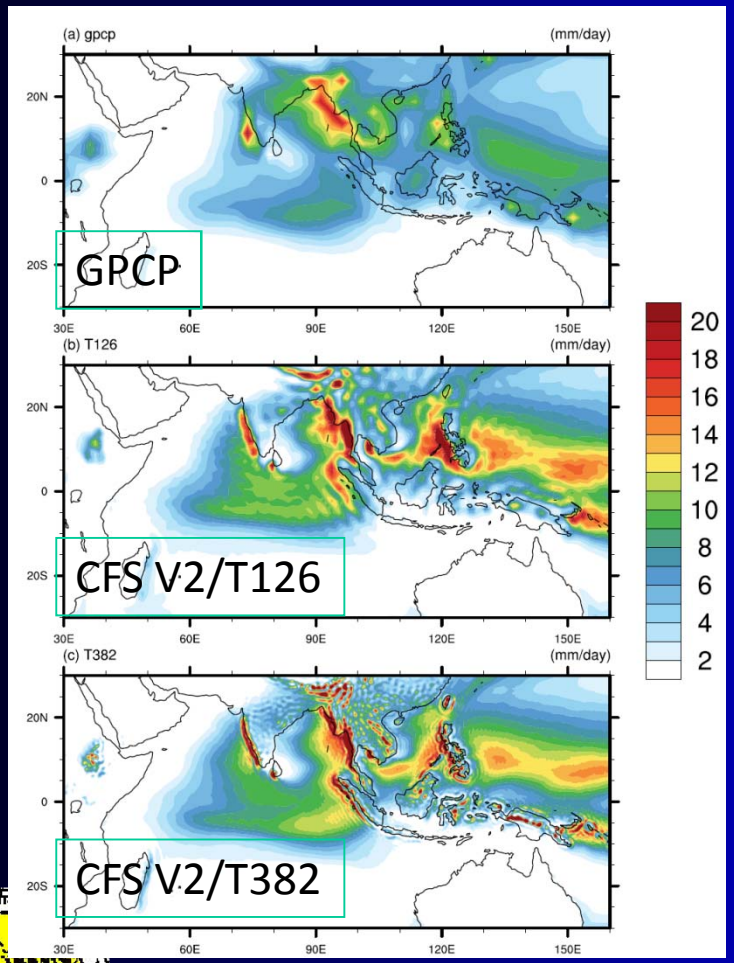
CM 2.5 (High Res.)



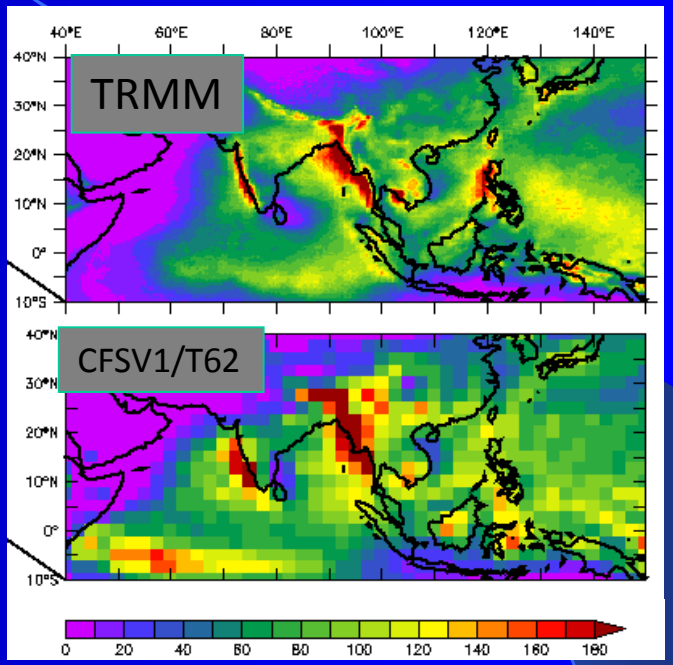
Monsoon 2012 Prediction Using T382 CFS V2



JJAS Mean of different resolution models of CFS

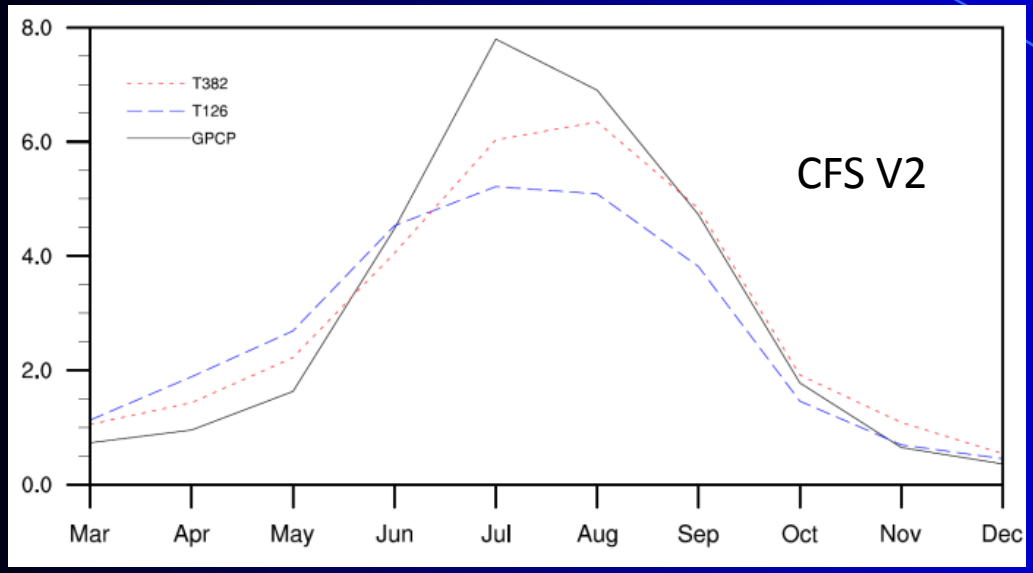


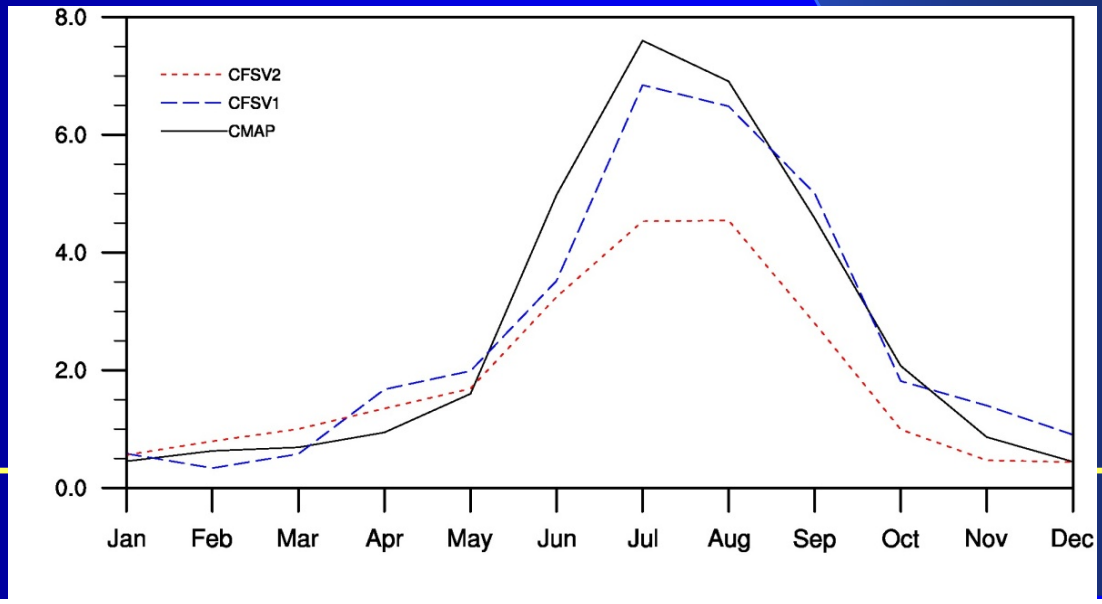
Seasonal Mean Rainfall (mm/day)



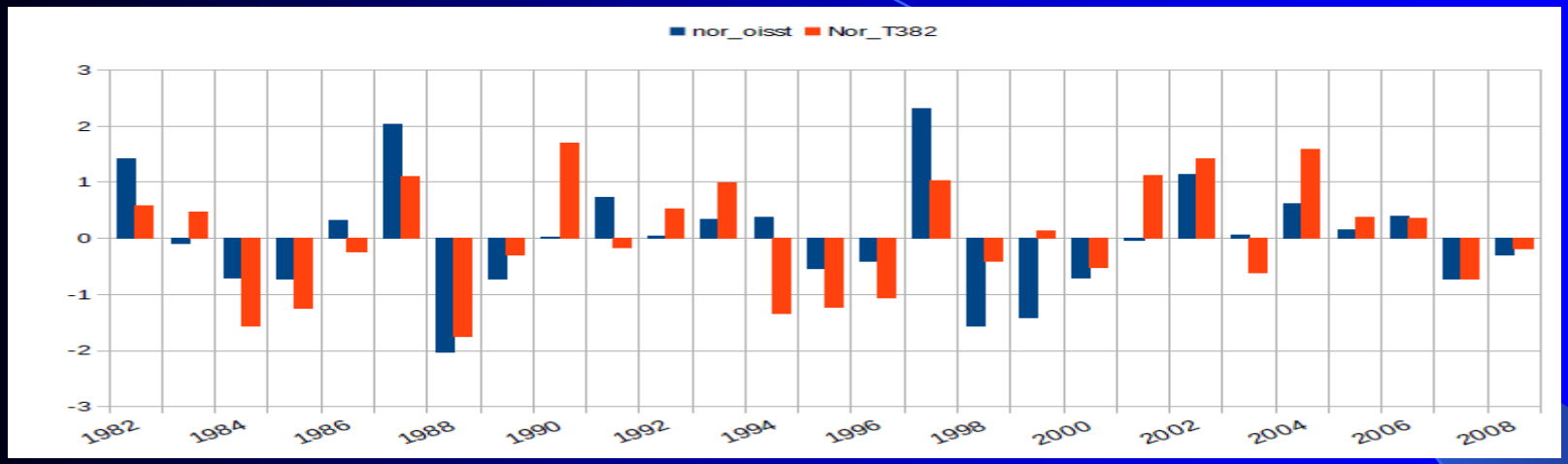
Seasonal Total Rainfall (cm)

Annual Cycle of ISMR

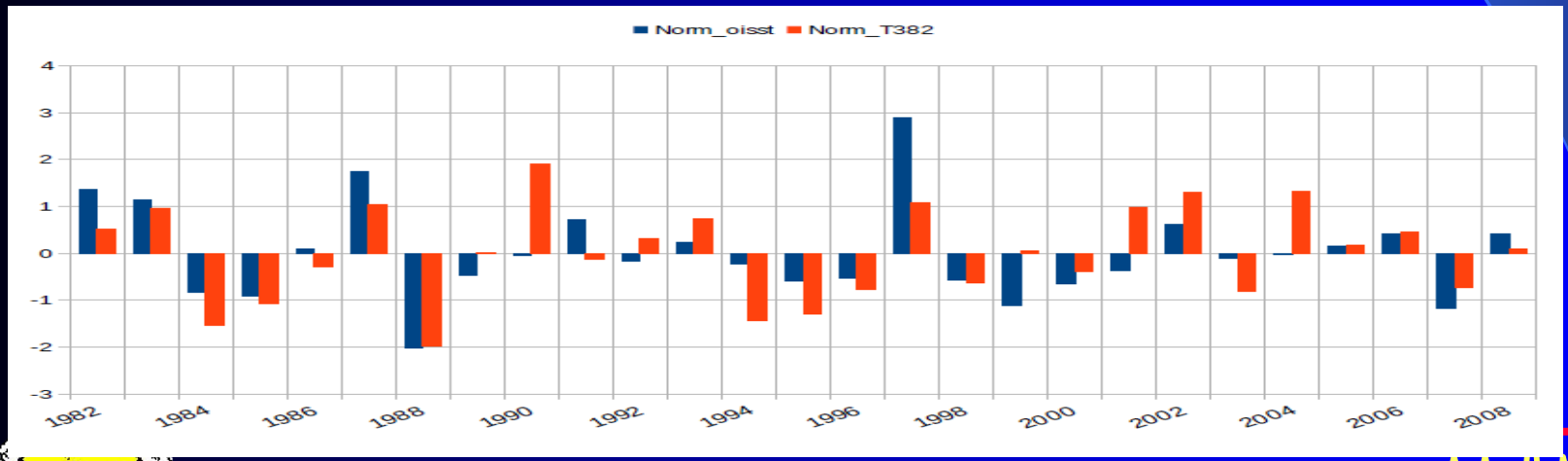




T382L64 Skill of SST indices in JJAS

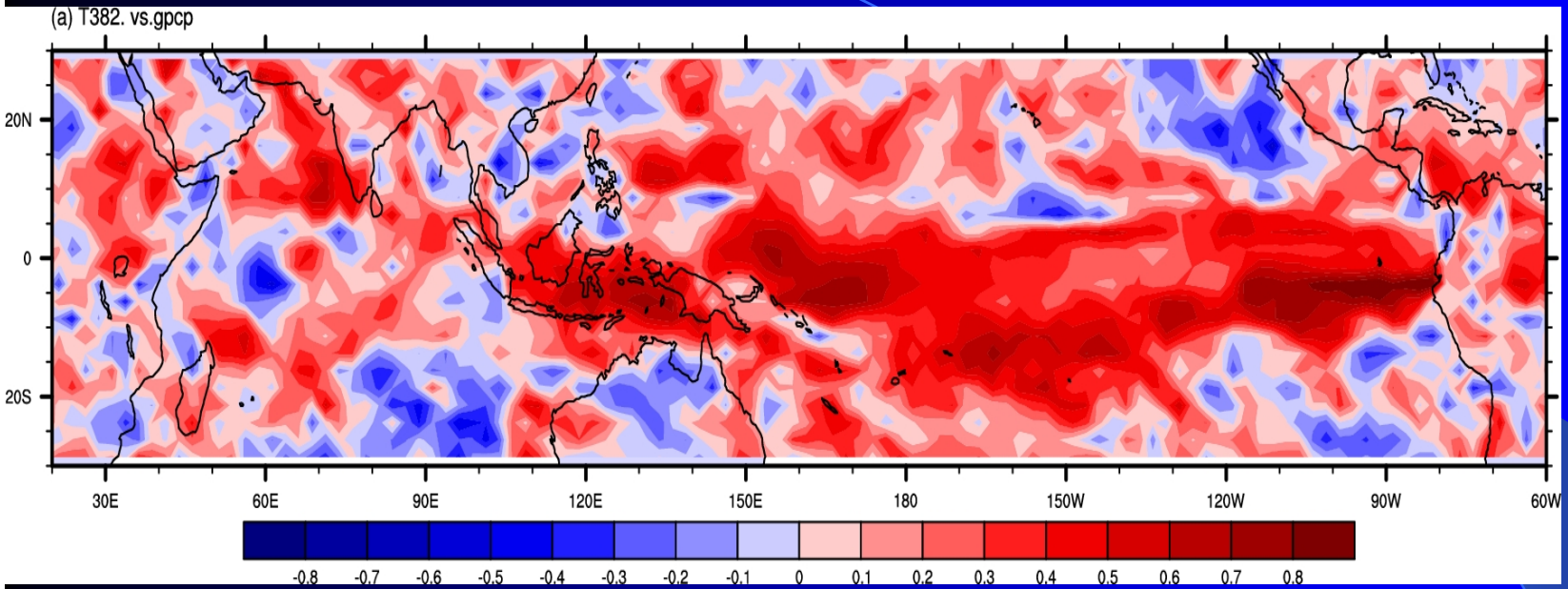


Nino 3.4
C.C=0.62

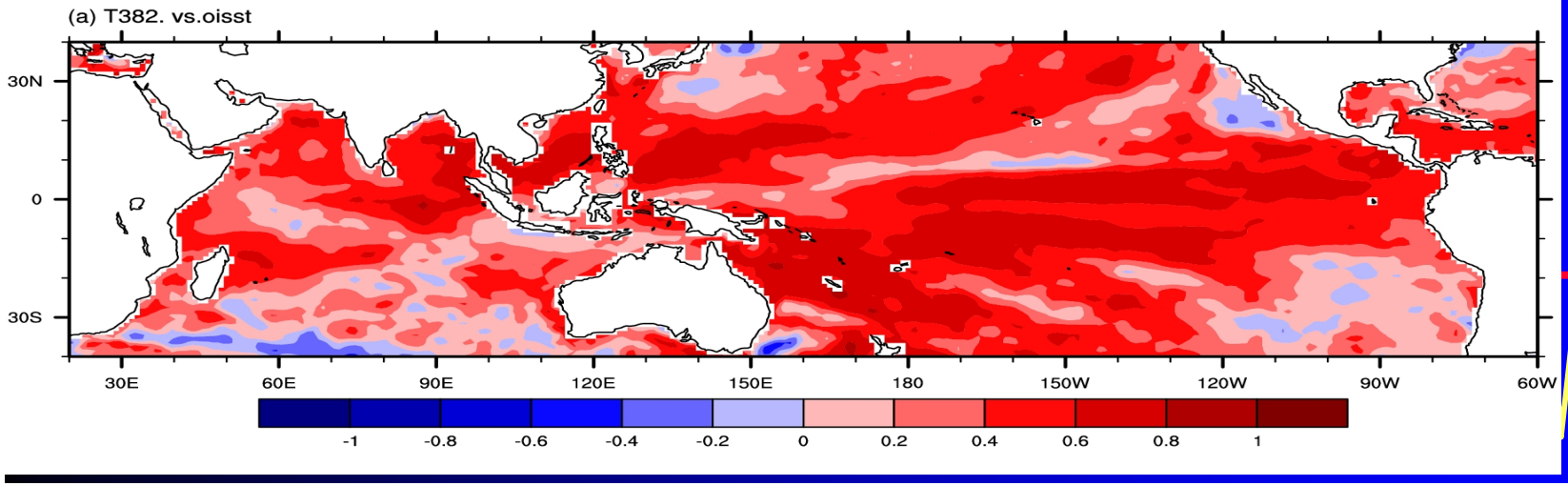


Nino 3
C.C=0.64

T382L64 Skill of Rainfall/SST

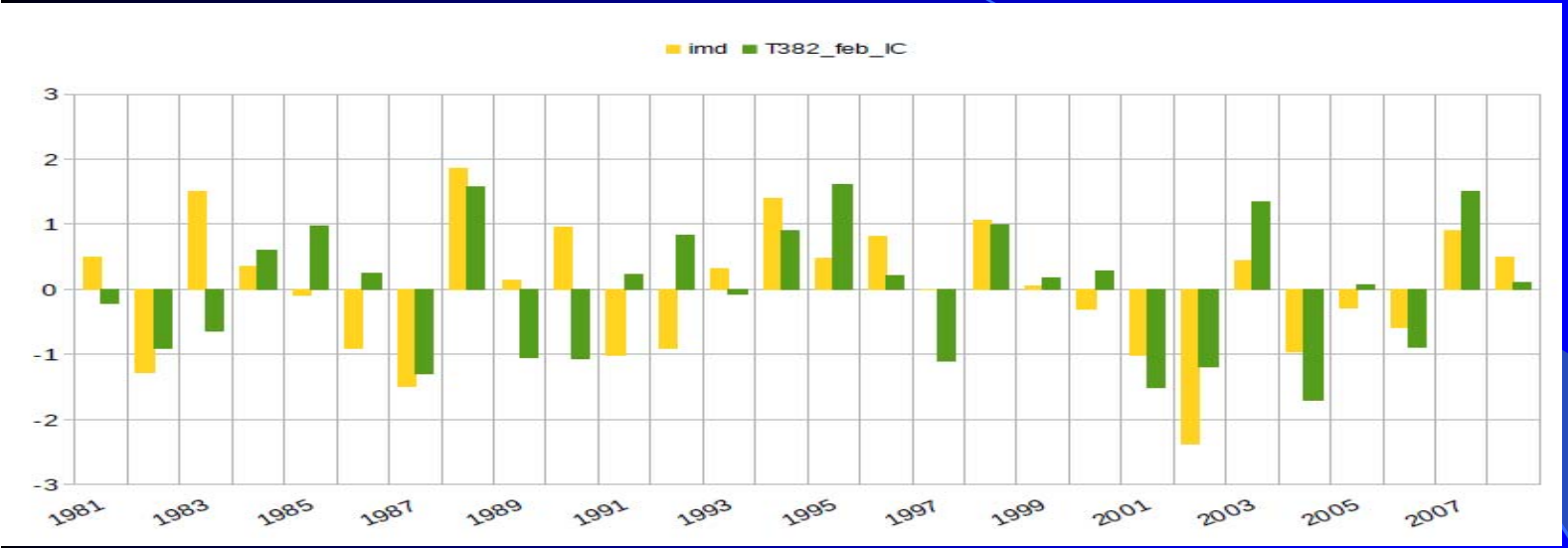


GPCP VS T382

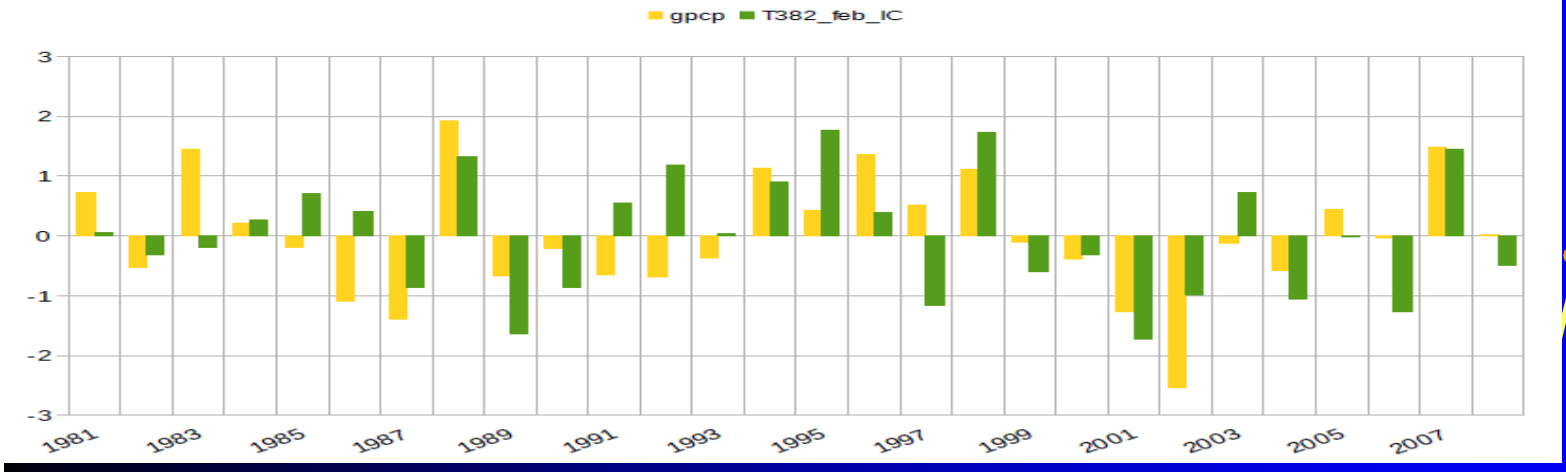


ERSST VS T382

T382L64 Skill of Rainfall



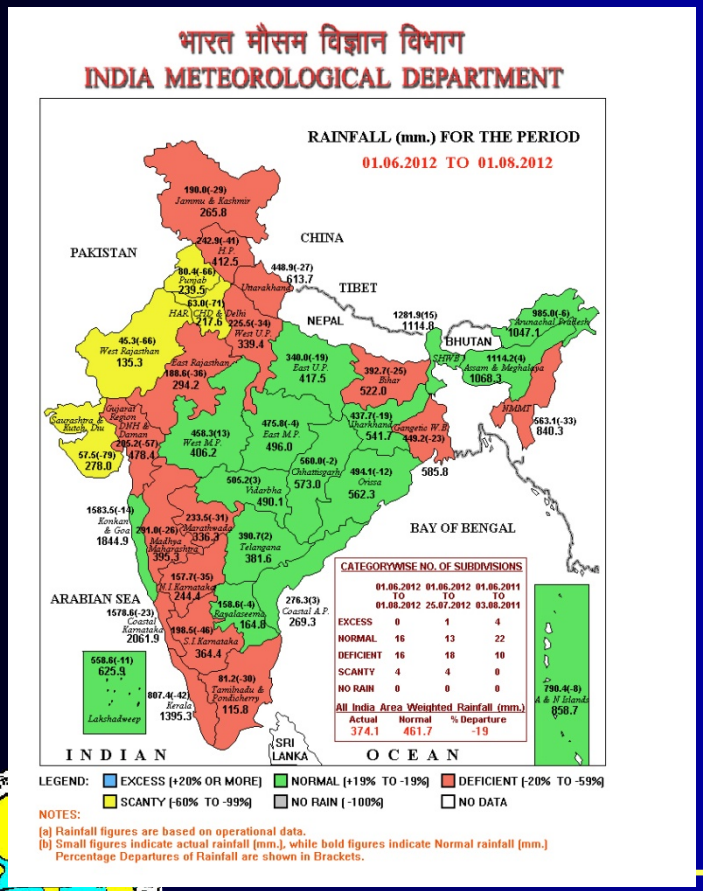
Rainfall avg.
Indian Land
Points
C.C=0.53



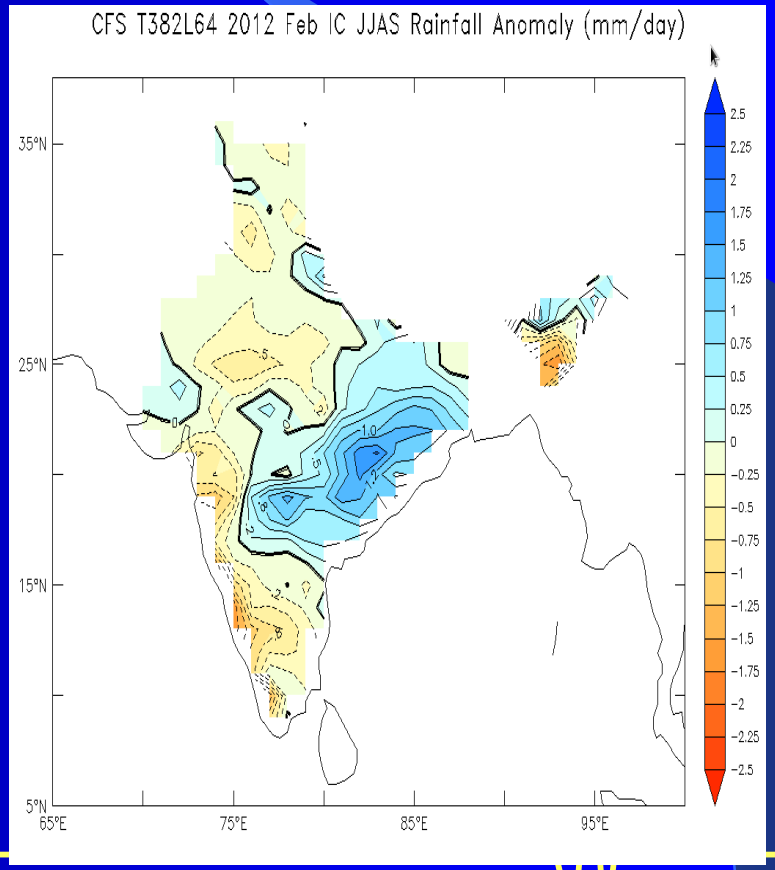
Rainfall avg.
5-30N;70-100E
C.C=0.53

Monsoon 2012 Prediction

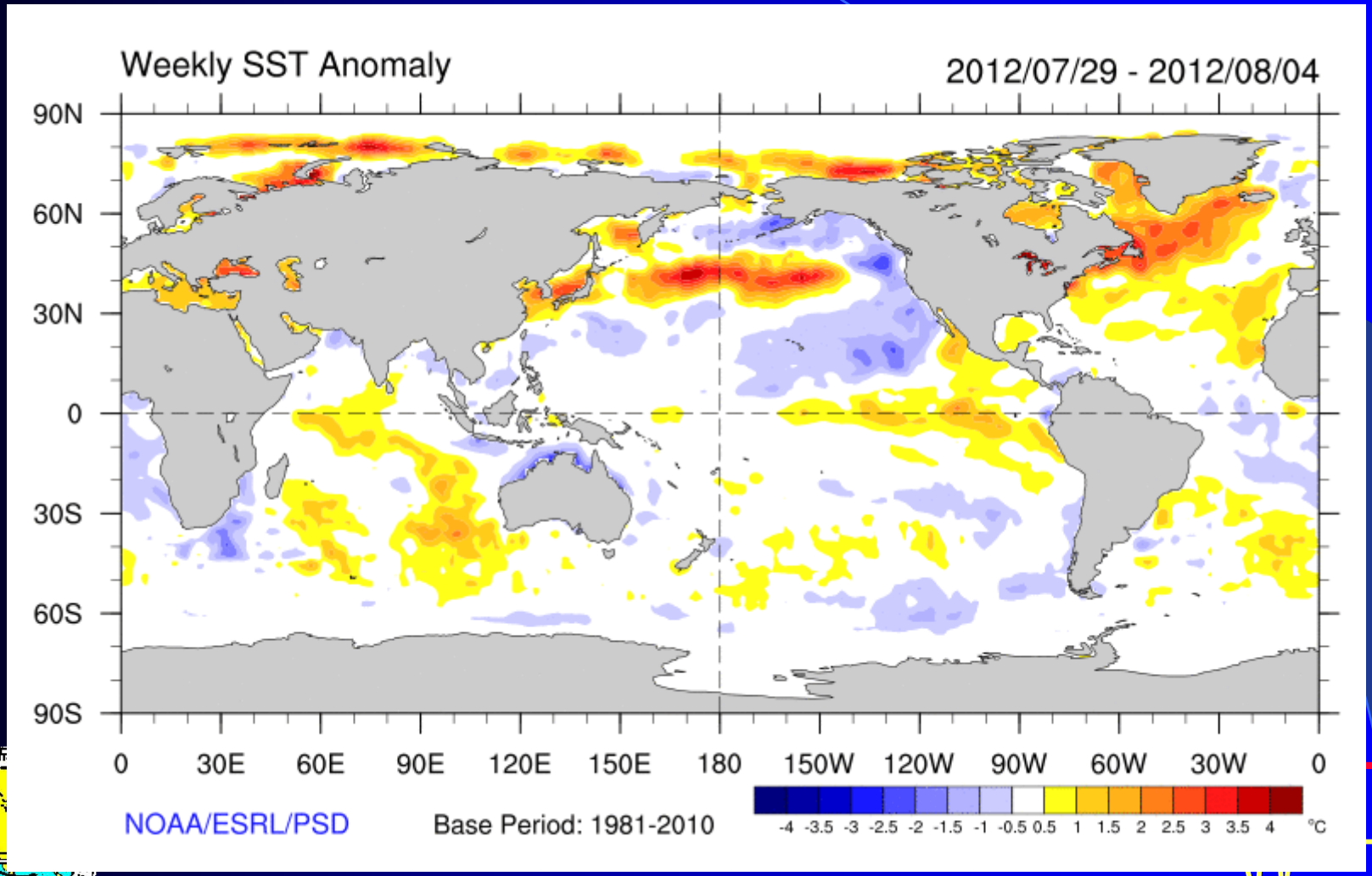
Observed till 01 Aug, 2012



T382 Predicted, JJAS 2012
Using Feb. IC.



Current SST Conditions



Conclusions

- ENSO-Monsoon Teleconnections is ean essential element for better prediction skill of Indian Monsoon Rainfall.
- Even good predictive models do not capture ENSO/Monsoon characteristics properly.
- Lot of uncertainty in how ENSO-monsoon relation will vary in future climate.
- Coupled models have shown promising results for improved prediction of Monsoon

Thank you