The Abdus Salam
International Centre
for Theoretical Physics

2356-18

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

30 July - 10 August, 2012

Indian monsoons: Variability and Prediction
(Part 2)

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Indian monsoons: Variability and Prediction

Part -II

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Dynamical Models

- They are physically based models describing the dynamics and physics of atmosphere and Oceans
- Three dimensional models
  - Regional or Mesoscale model
  - Atmospheric General Circulation Model
  - Coupled Atmosphere-Ocean Model
  - Earth system model

Dynamical Seasonal Forecasting Strategies

- Tier-1 Approach
  - Using an atmospheric general circulation model (AGCM) with prescribed SSTs (either persisted or predicted by another ocean model)
- Tier-2 Approach
  - Using a coupled atmosphere-ocean general circulation model (CGCM).
- Ensemble runs (with different initial conditions) are made to account for uncertainty.

Early AGCM (AMIP) results

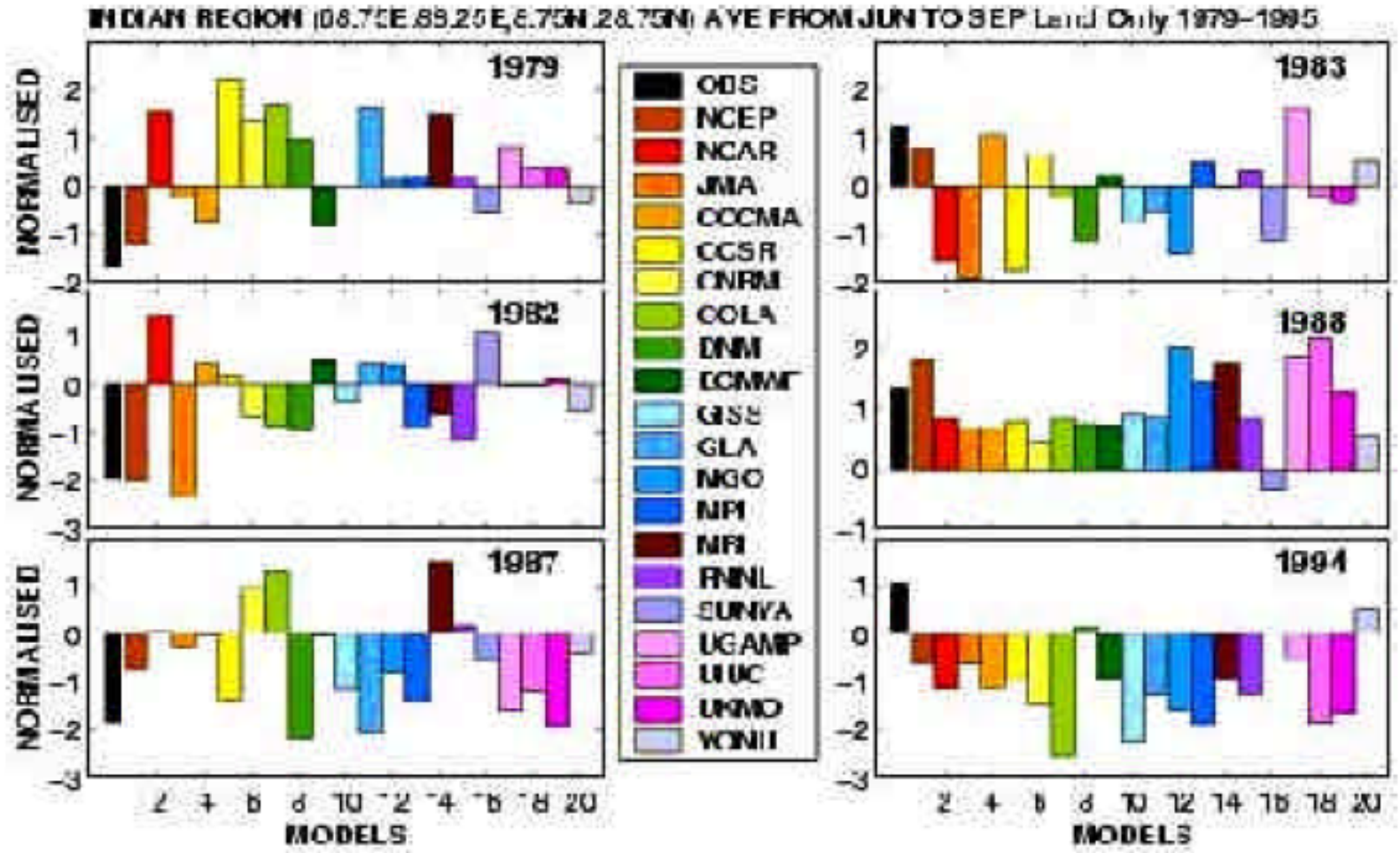
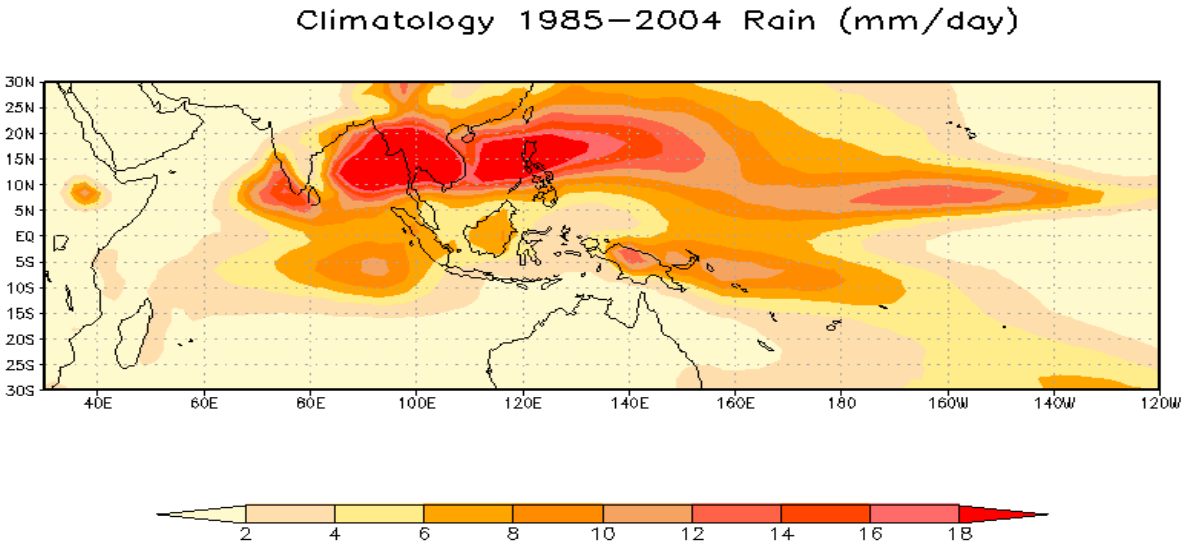


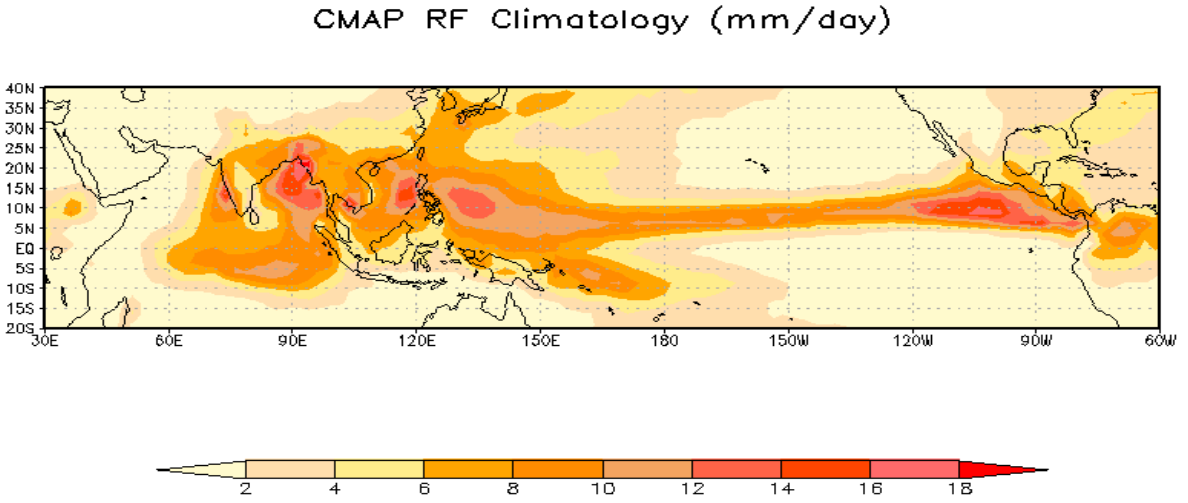
Figure 9. Normalized precipitation (June–September) anomalies in AMIP II models for the Indian region for 1979, 1982, 1983, 1987, 1988 and 1994 seasons.

Performance of an Atmospheric General Circulation model, SFM

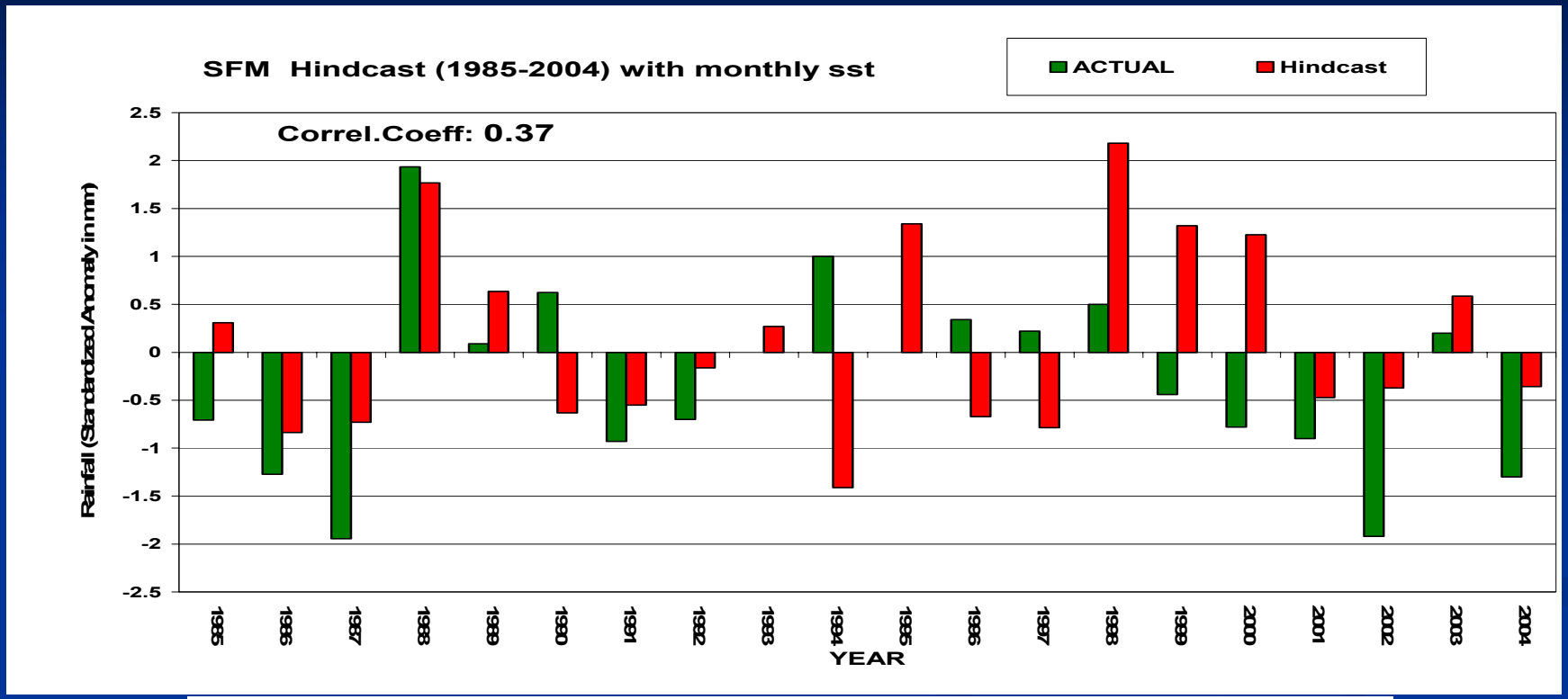
Model Climatology

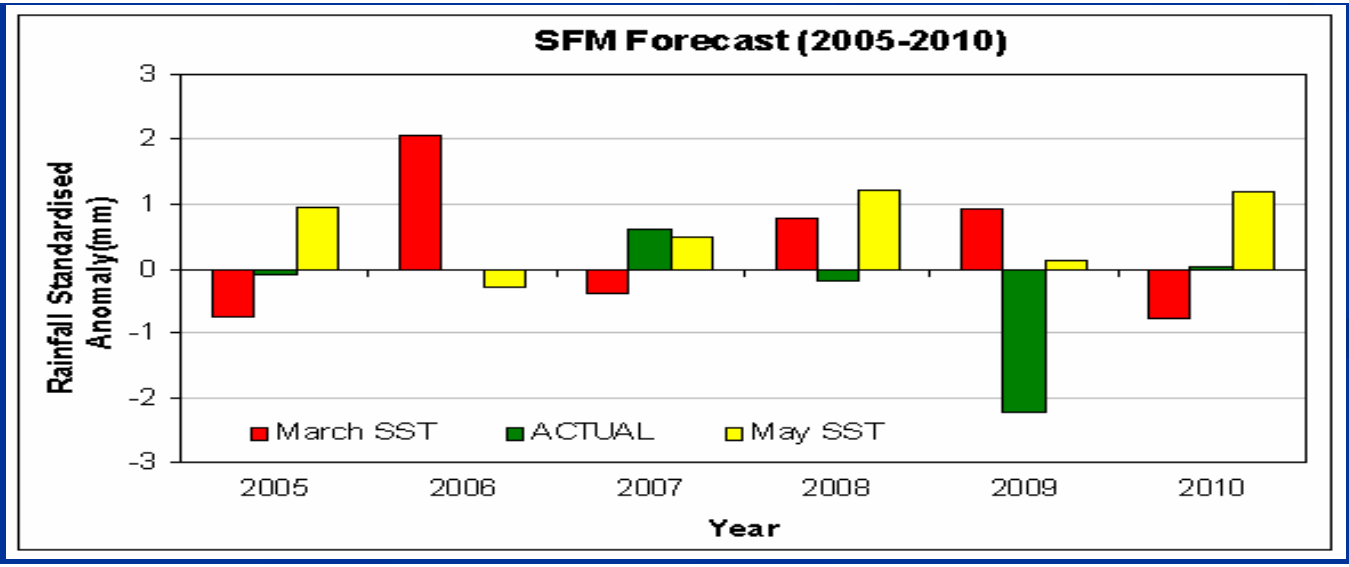


Observed Climatology



Hindcasts and forecasts from SFM for seasonal rainfall over the country as a whole



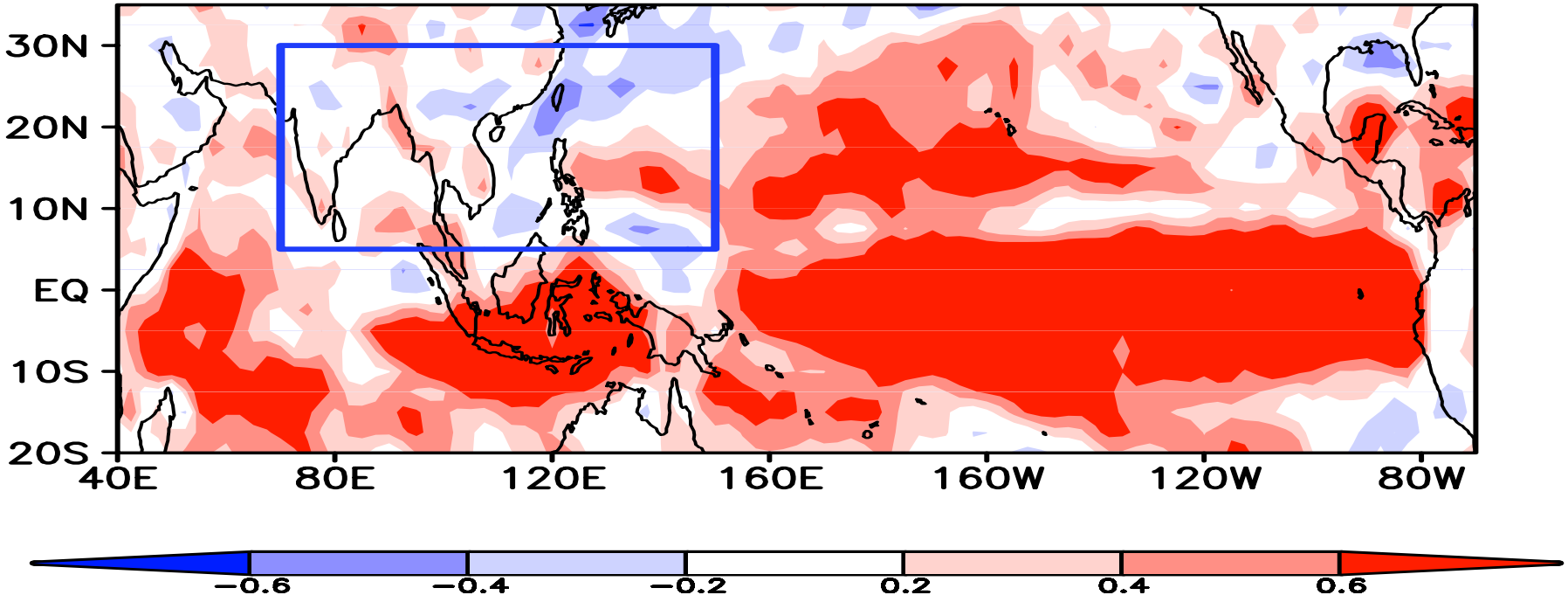


Problems of AGCMs : Strategic issue

- When forced by observed SST, AGCMs are unable to simulate with any accuracy of summer monsoon rainfall (Krishna kumar et al. 2005, Wang et al. 2005)

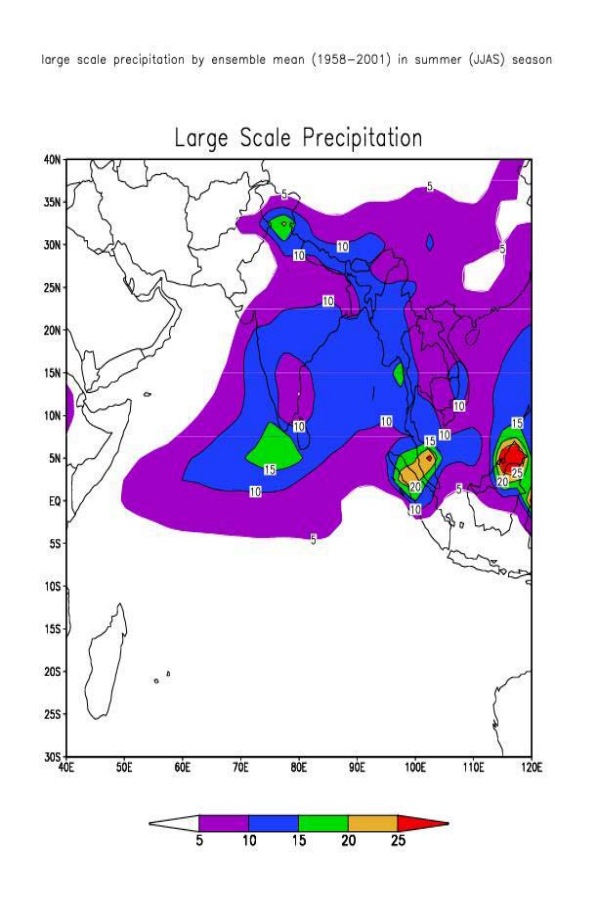
- Given the lower boundary forcing, why all AGCMs are unable to simulate monsoon rainfall anomalies correctly?

Correlation Coefficients between the observed and MME hindcasted June-August precipitations (1979-1999)

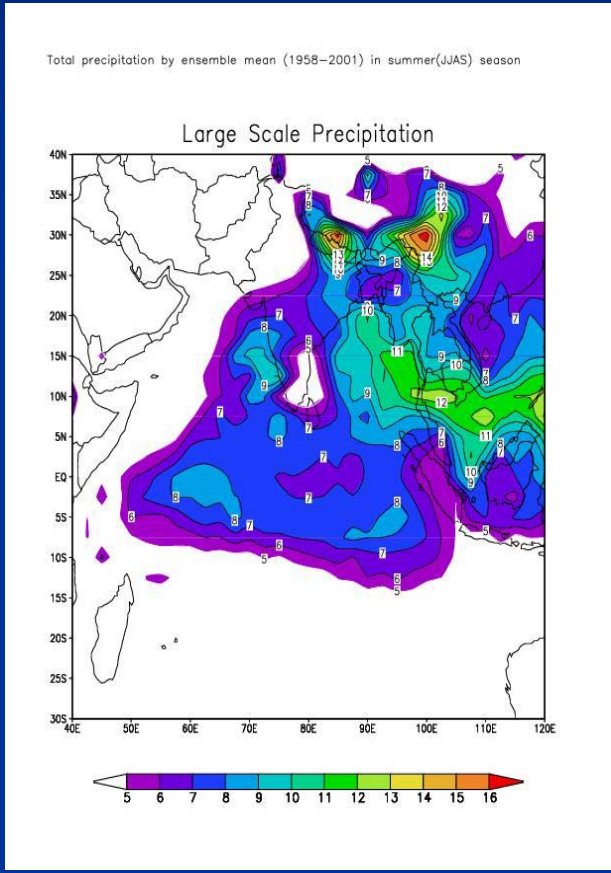


Wang et al. 2005 Geophys. Res.Letters

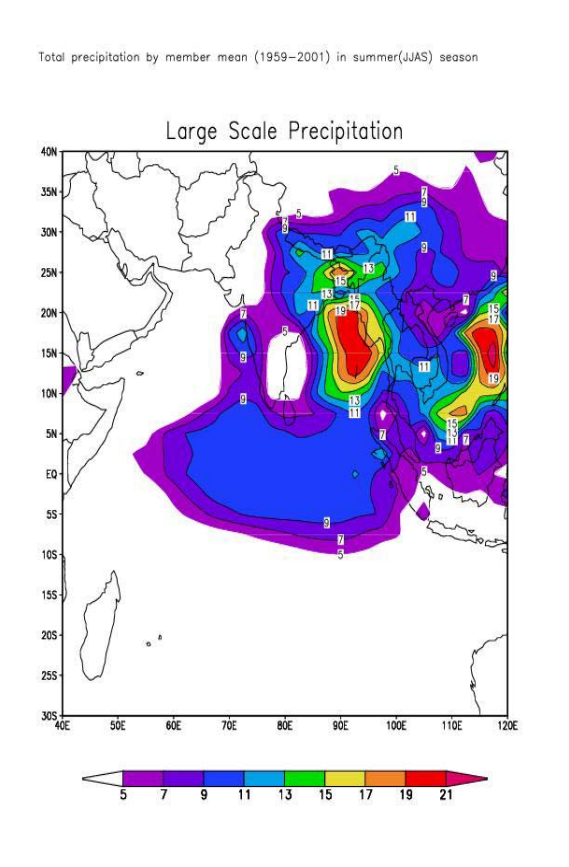
Early Couple Model Results (DEMETER)



ECMWF

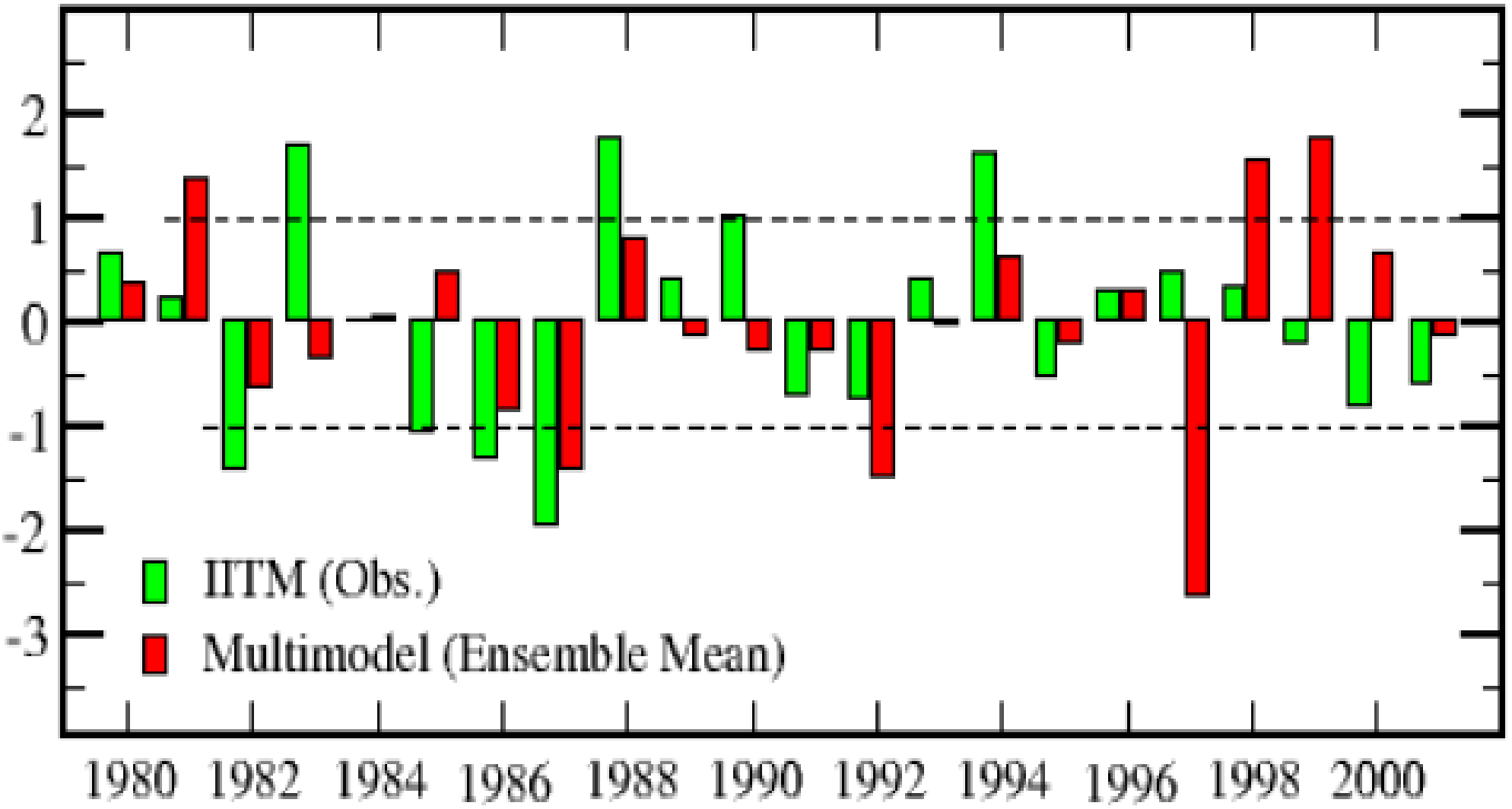


MeteoFrance



UK Met

DEMETER model forecasts



Preethi et al (2010), Climate Dynamics

ENSEMBLES project

- The Development of a European Multi-model Ensemble System for seasonal to inter-annual prediction (DEMETER) project (Palmer et al. 2004) provided an ideal opportunity to examine the simulation characteristics of the Indian summer monsoon.

- ENSEMBLE-based predictions of climate changes and their impacts (ENSEMBLES) is an EU-funded integrated project that intends to develop an ensemble prediction system for climate change based on the principal state-of-the-art, high resolution global models developed in Europe.

- The project has been designated to produce for the first time, an objective probabilistic estimate of uncertainty in future climate at the seasonal to decadal and longer timescales

ENSEMBLE Models

Table-1 Overview of the Models contributing to the ENSEMBLES seasonal forecasts

Partner	Atmospheric Model and Resolution	Ocean model and Resolution	Reference
ECMWF	IFS CY31R1	HOPE 0.3^0-1.4^0/L29	Balmaseda et al. (2008)
UKMO	HadGEM2-A N96/L38	HadGEM2-O 0.33^0-1^0/L20	Collins et al. (2008)
Meteo France	ARPEGE4.6; T63	OPA8.2; 2^0 /L31	Daget et al. (2009) and Salas Melia (2002)
IFM-GEOMAR	ECHAM5 T63/L31	MPI-OM1 1.5^0/L40	Keenlyside et al (2005) and Jungclaus et al. (2006)
CMCC-INGV	ECHAM5 T63/L19	OPA8.2 2^0/L31	Alessandri et al. 2010 b and Masina (2009)
DePreSys, UKMO	HadCM3 T42 L19	HadCM3 1.25^0/ L20	Gordon et al. (2000)

No models except the Depresys used the flux corrections.

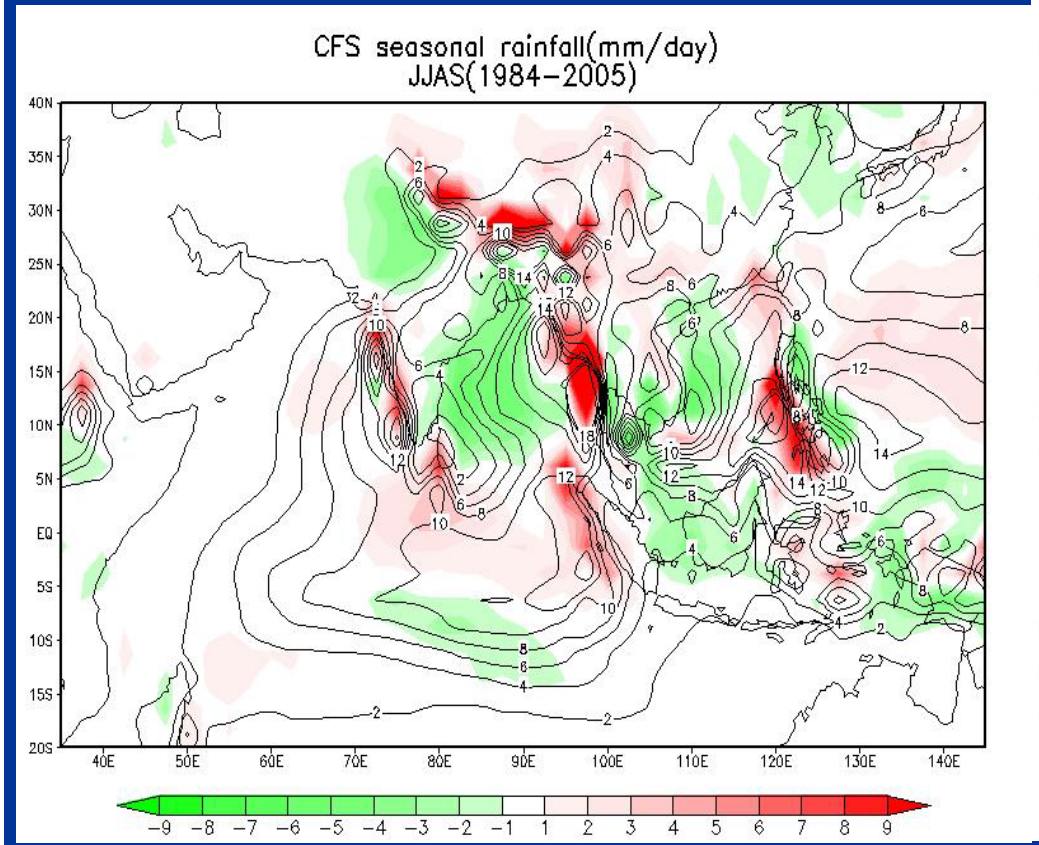
Depresys ensemble members are generated by perturbing parameters in the physical parameterization schemes.

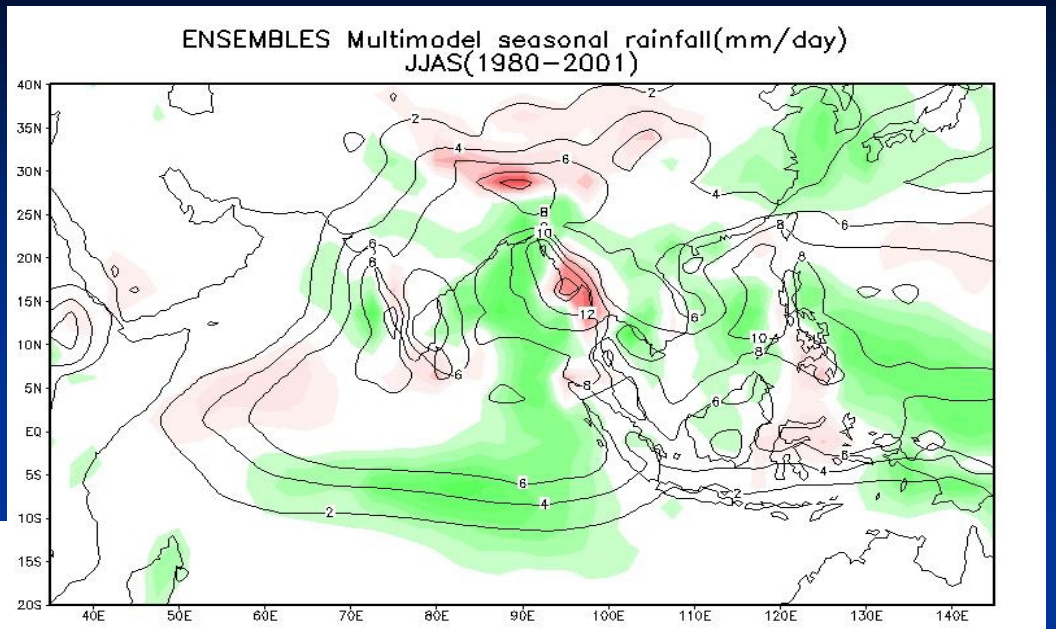
ENSEMEBLES models

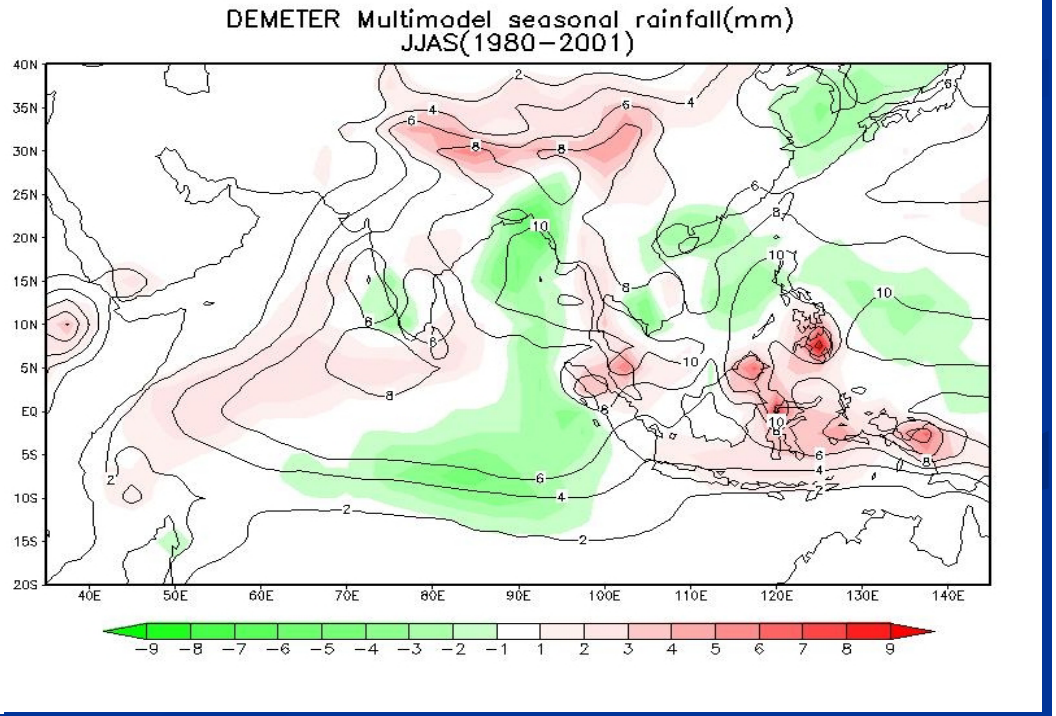
- Common hindcast period: 46 years (1960-2005)
- For each year, 7-month long seasonal forecasts starting from 1st February, **May**, August and November.
- 9 Ensemble Members
- Since DEMETER, the contributing seasonal prediction systems have improved in all aspects
  - increase in resolution
  - better representation of sub-grid physical processes
  - land surface process,
  - sea-ice
  - greenhouse gas boundary forcing
  - more widespread use of assimilation for ocean initialization

Both DEMETER and ENSEMBLES predict more rainfall over the equatorial Indian Ocean compared to observations.

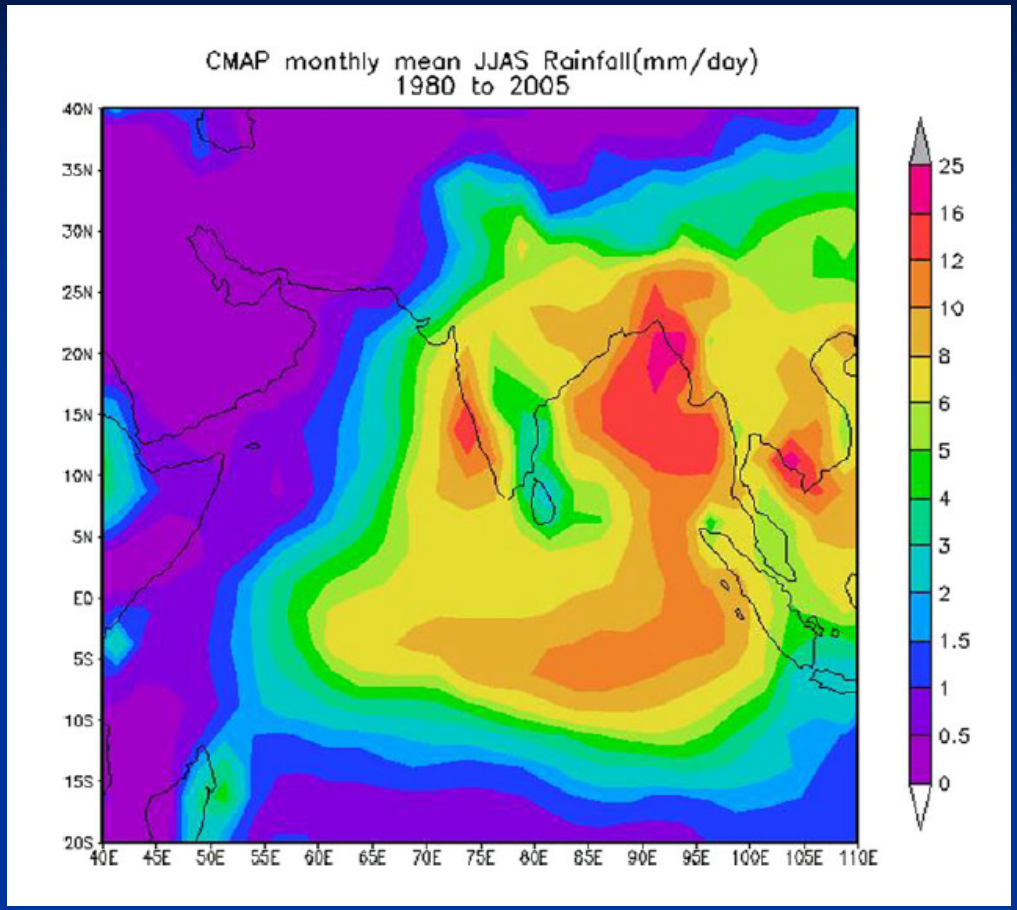
CFS model has a dry bias over northern plains of India. Along the west coast, CFS predicts more rainfall

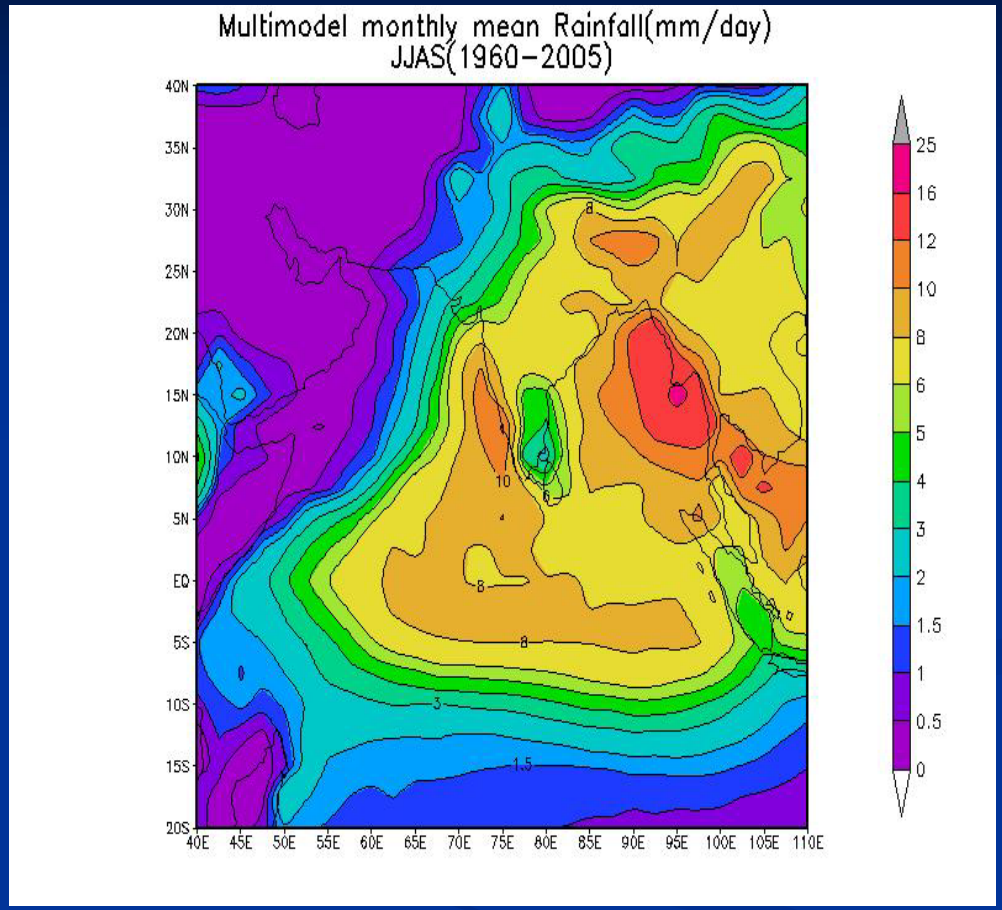






Performance of the Latest Coupled Models

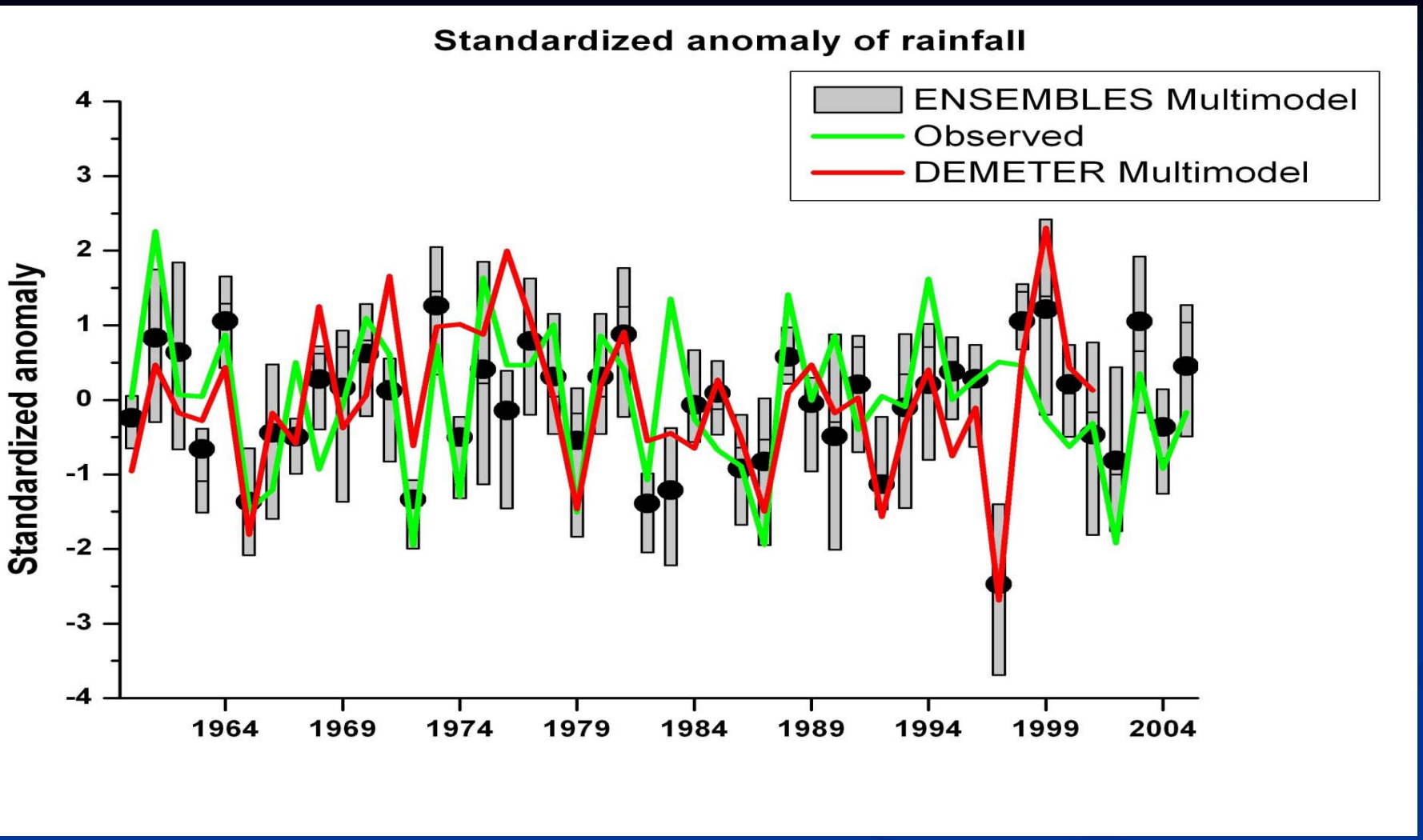




Observed monsoon rainfall climatology

State-of-the-art Climate Models (ENSEMBLES)

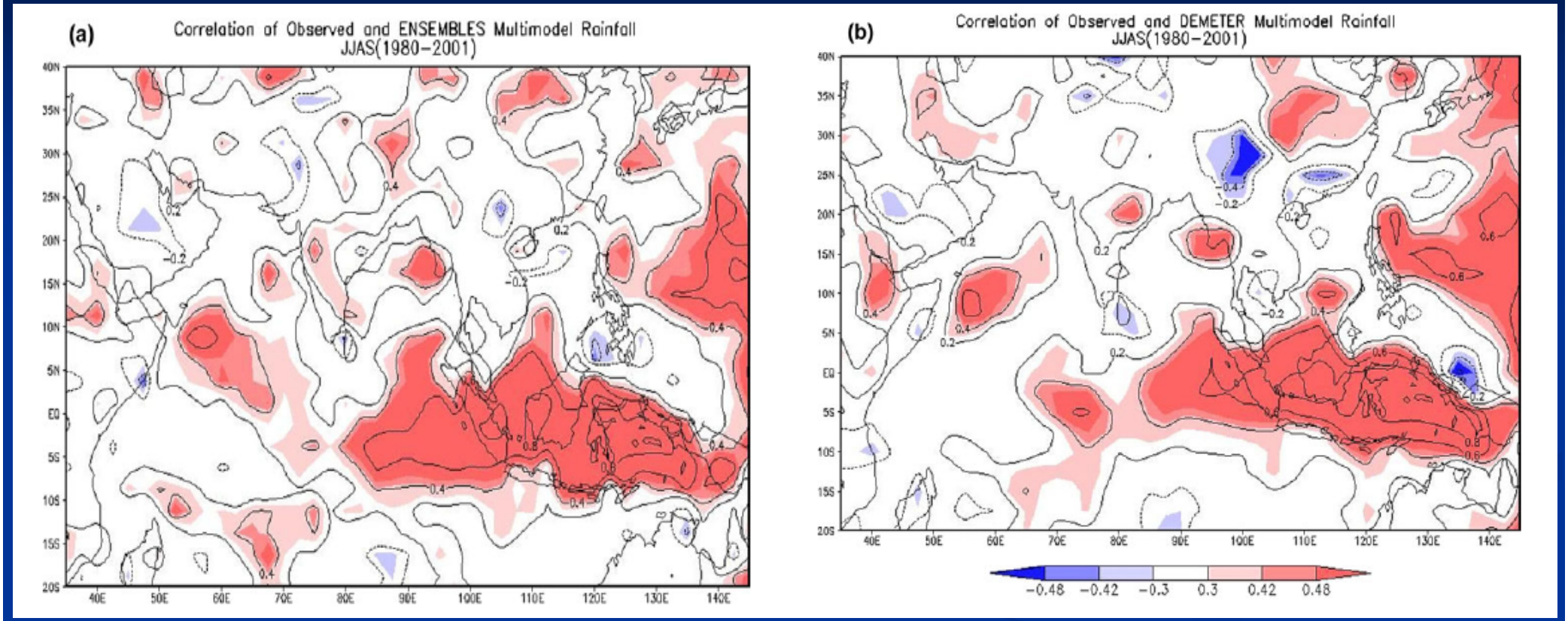
Rajeevan et al. 2011, Climate Dynamics



In comparison with DEMETER, ENSEMBLES results improved in drought years like 1972, 1974 and 1979 and excess monsoon year like 1961. Problem remains for years like 1983 and 1997

Rajeevan et al. Climate Dynamics, 2011

Correlations



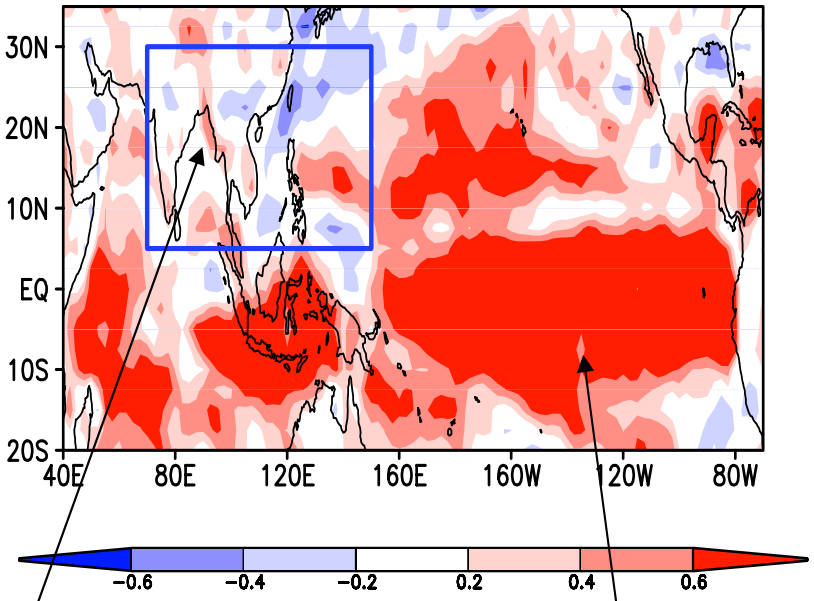
ENSEMBLES DEMETER

Rajeevan et al. Climate Dynamics, 2011

Correlation Coefficients between the observation and prediction of precipitation using Multi models

Earlier version models

1979-1999

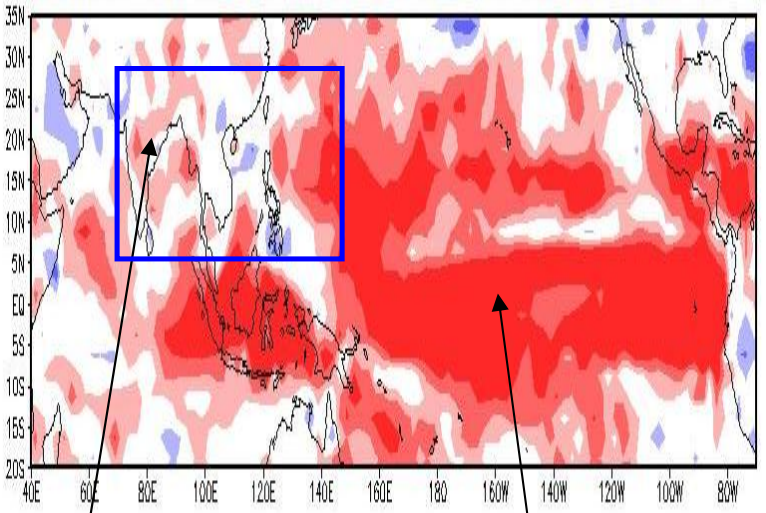


Poor skill

High skill

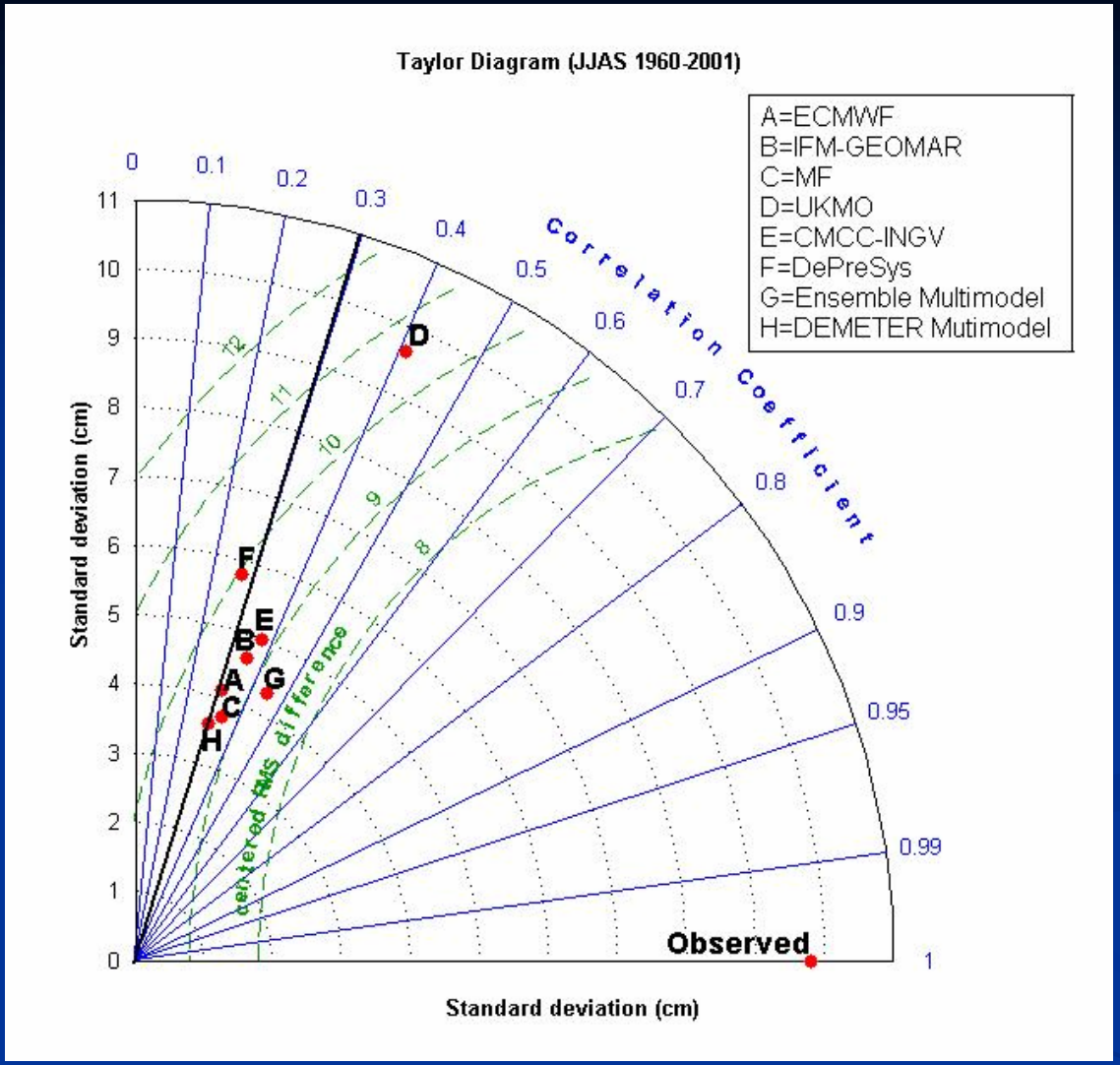
Latest models (ENSEMBLES)

1979-1999



Improved skill

High skill



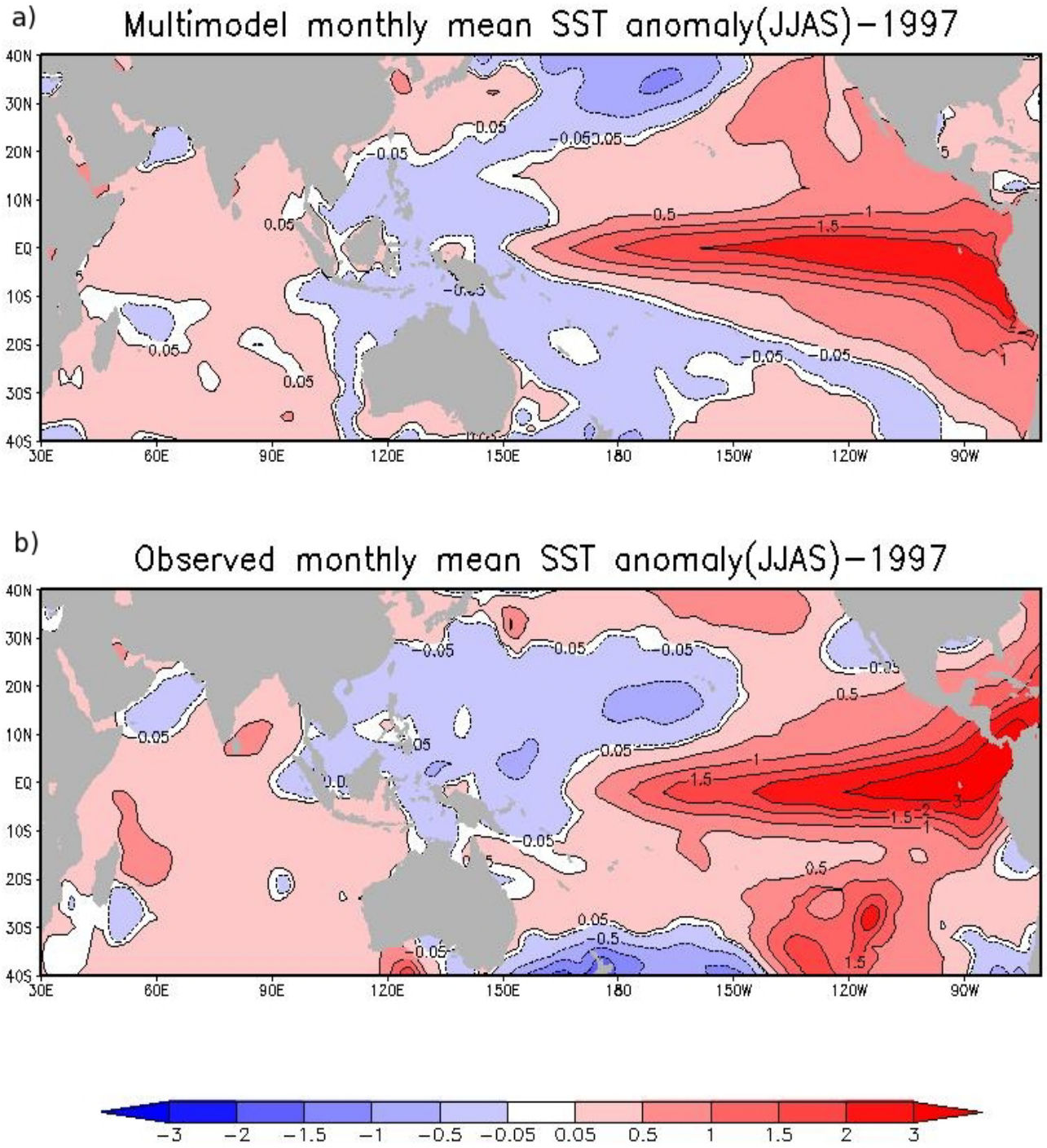
In comparison with DEMETER, ENSEMBLES MME has better prediction skill. Each of ENSEMBLES models except Depresys showed better skill than the DEMETER MME.

Comparison of performances of different climate models

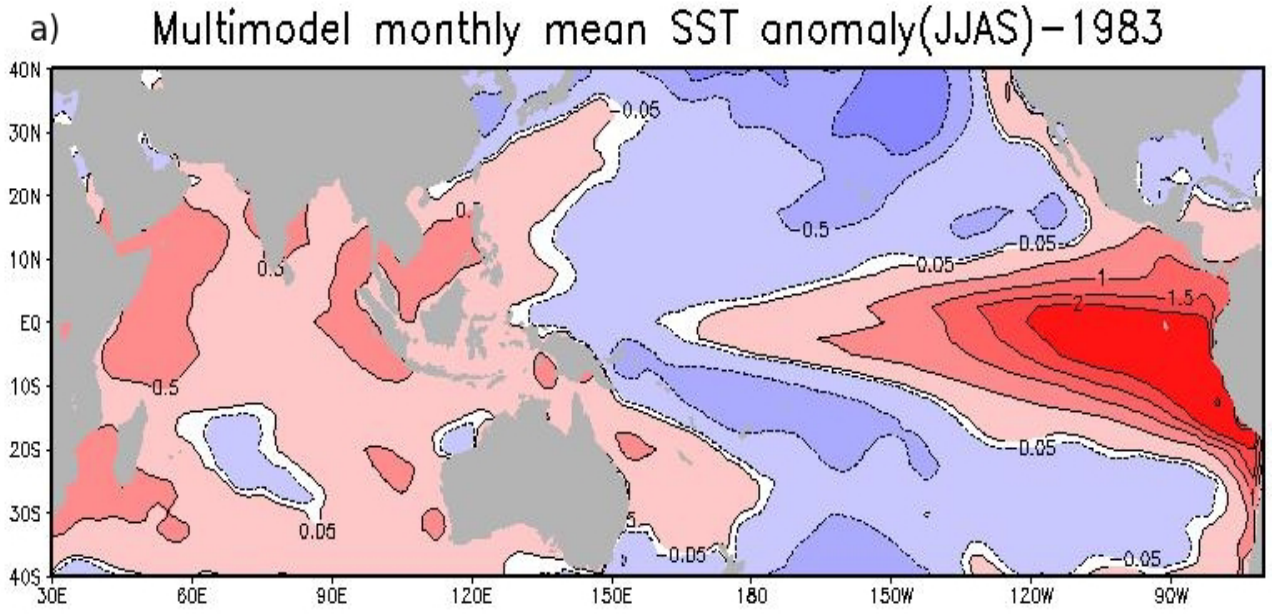
Forecasting system	Period	Correlation Coefficient (between Actual and predicted monsoon rainfall)
Earlier Generation Models (DEMETER)	1960-2001	0.28
Latest Models (ENSEMBLES)	1960-2005	0.49
NCEP CFS V2 (IITM Pune)	1984-2005	0.41
IMD STATISTICAL FORECASTING SYSTEM	1988-2011	0.23

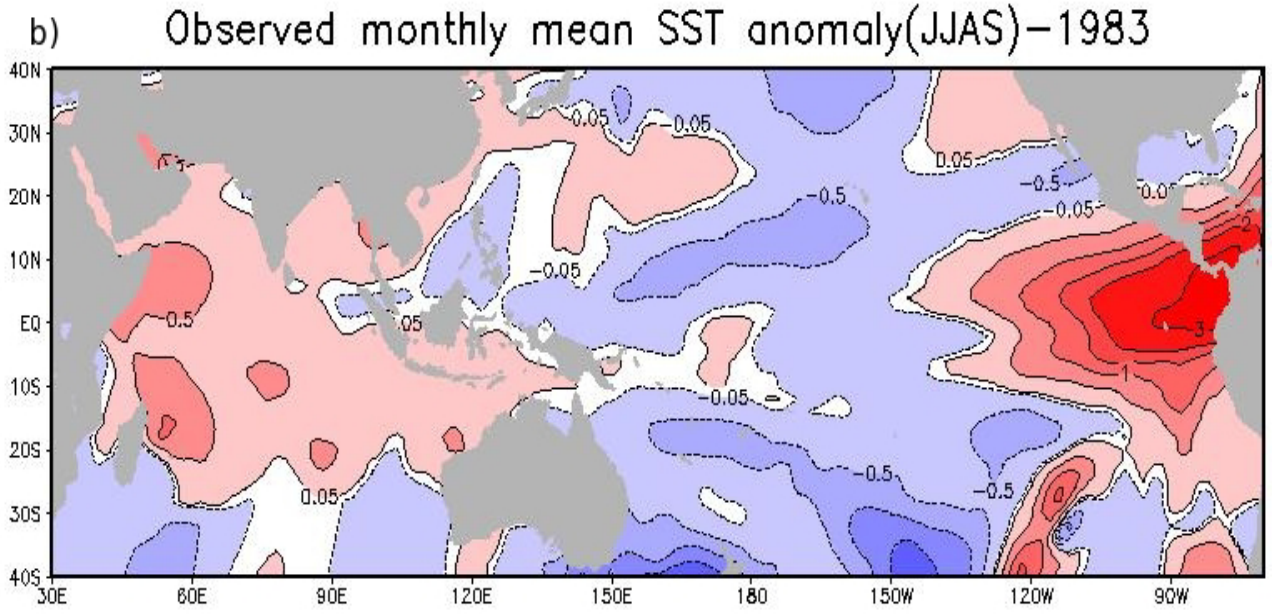
ENSEMBLES predict an extended warming into central Pacific Ocean during the 1997 El Nino.

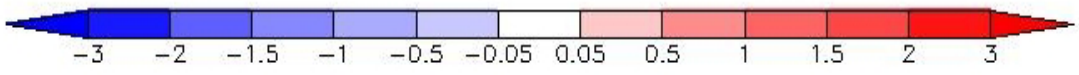
Indian Ocean Dipole (IOD) signal is missing from the model predictions



In 1983, the MME showed an extensive warming (remnant of 1982 El Nino), but observations showed warming only off the coast of Peru.



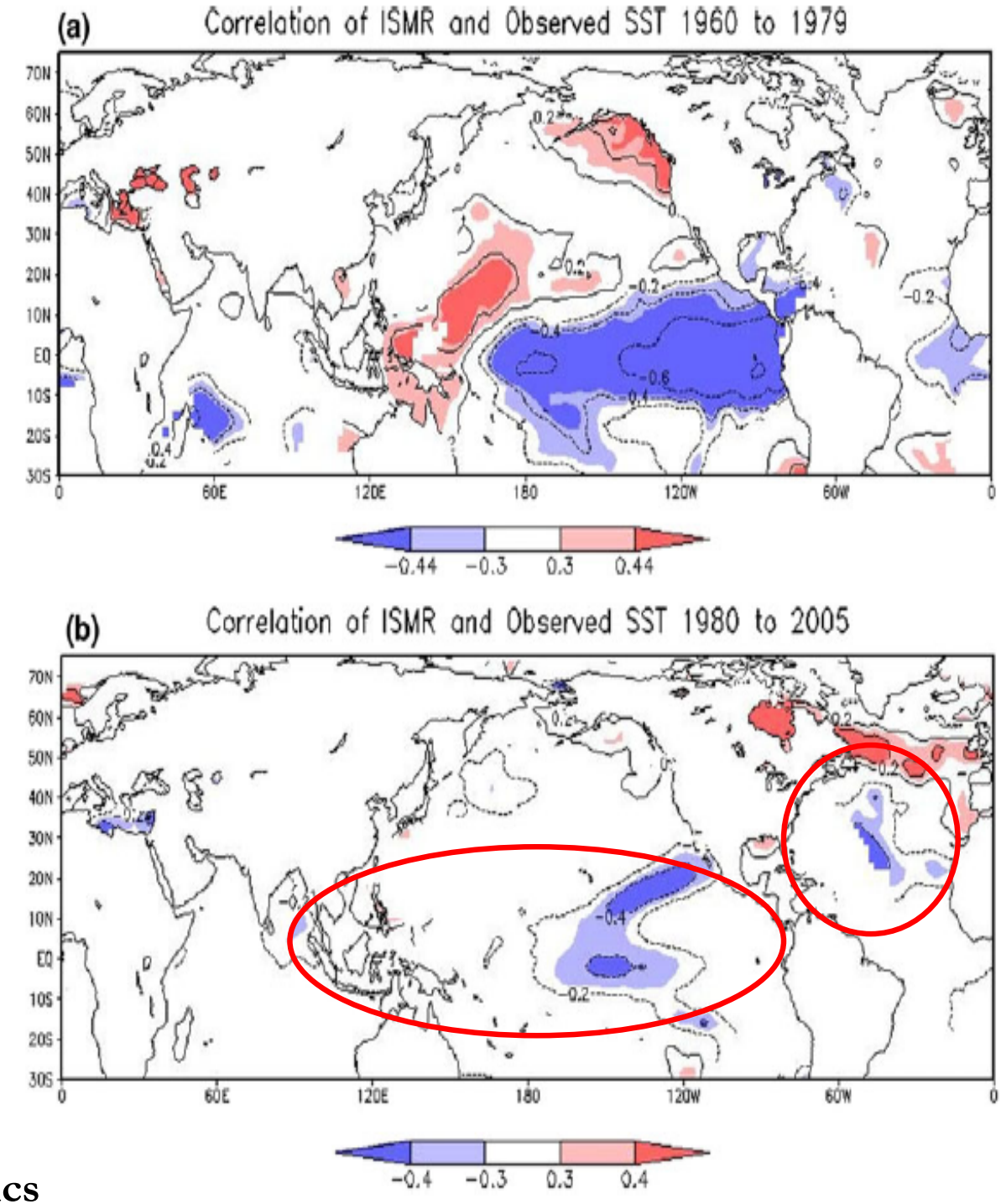




Monsoon Tele-connections

ENSO-Indian monsoon teleconnection has weakened during the recent decades

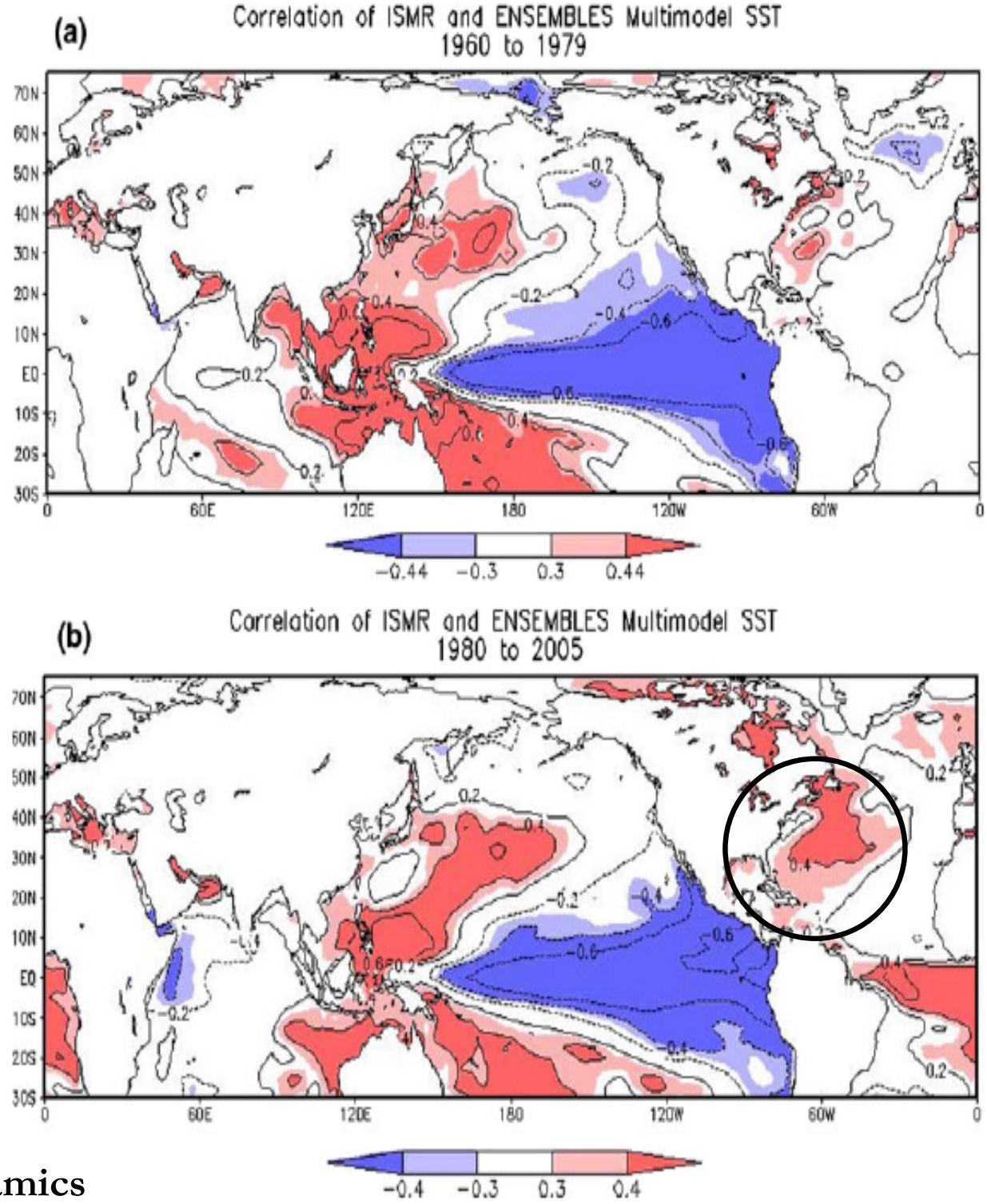
North Atlantic teleconnection has strengthened during the recent decades



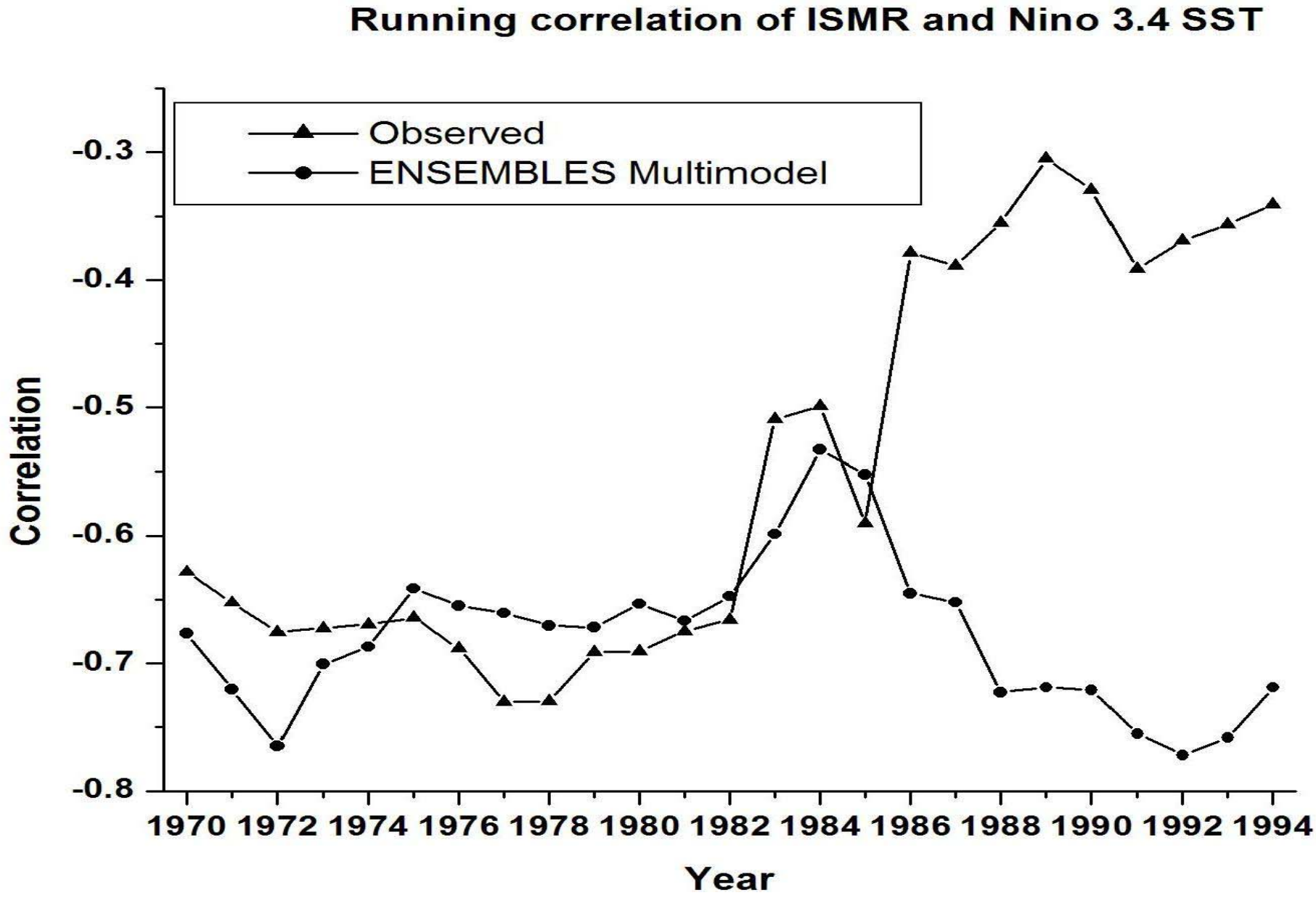
Rajeevan et al. 2011, Climate Dynamics

ENSEMBLES could not capture the recent weakening of the ENSO-Indian monsoon teleconnection.

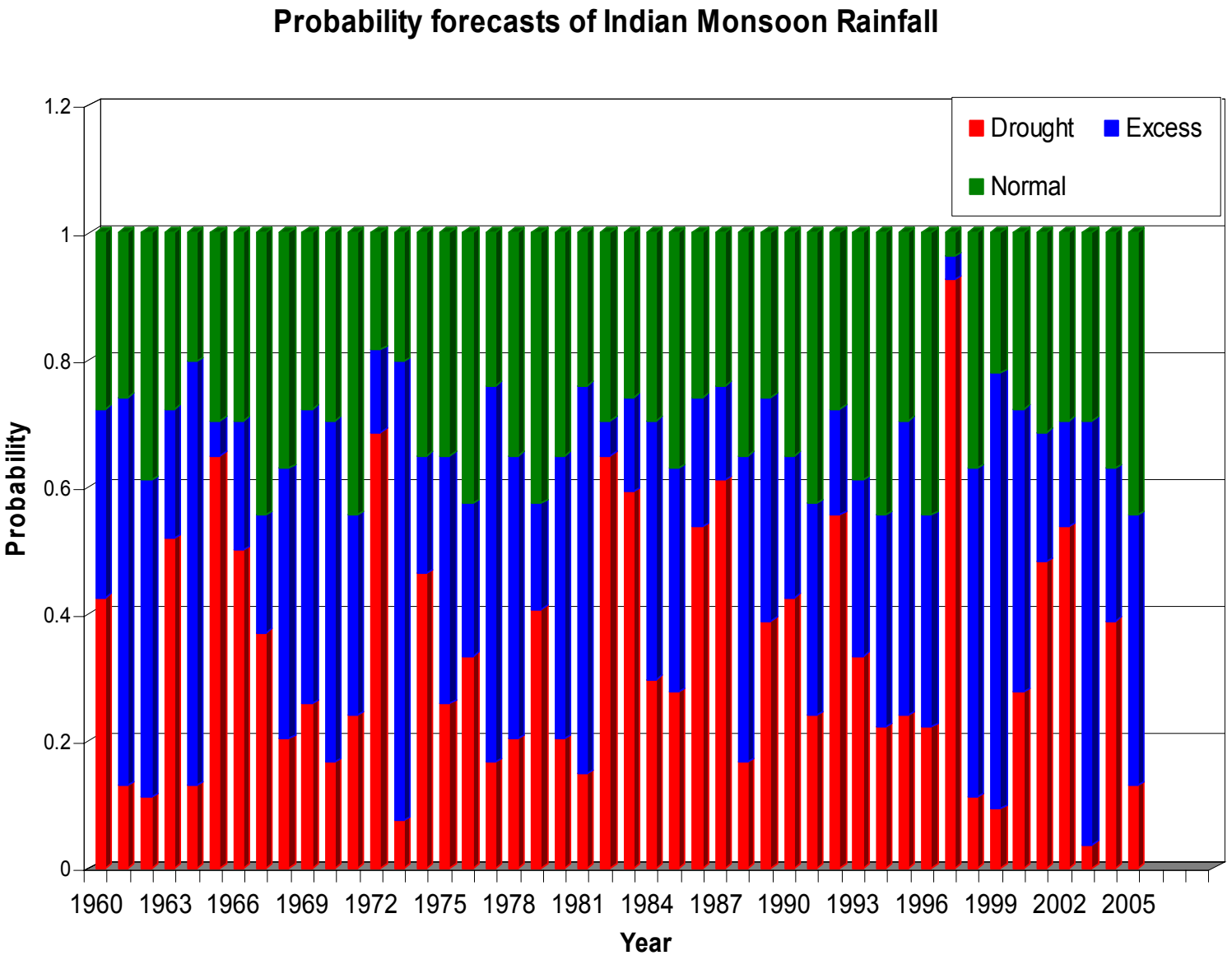
Correctly captures the north Atlantic teleconnection



Rajeevan et al. 2011, Climate Dynamics



ENSEMBLES could not capture the recent weakening of the El Nino- Indian monsoon relationship



Brier Skill Score

Drought: 0.201

Excess : 0.060

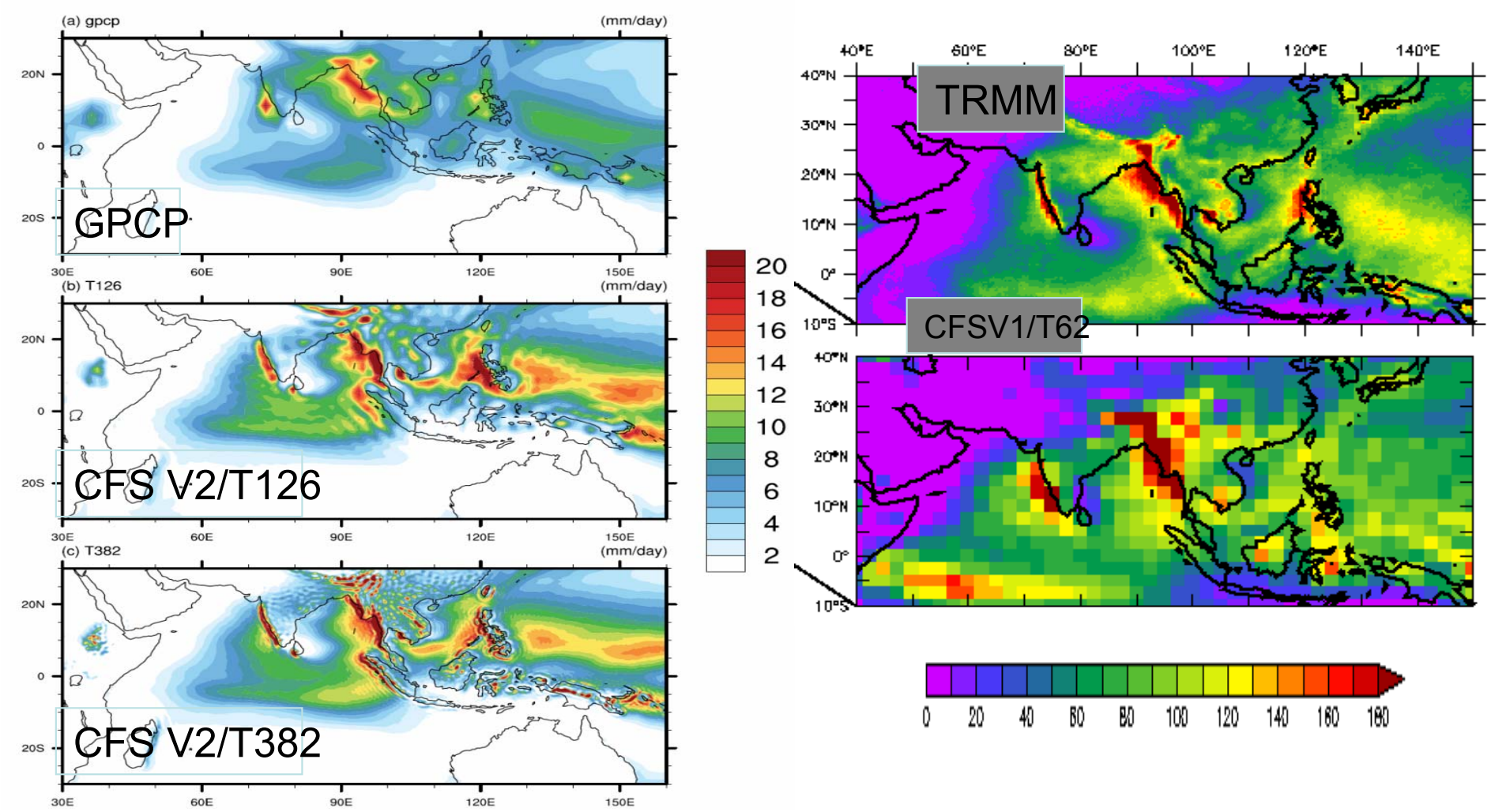
Normal= -0.002

Positive skill for probabilistic forecasts of droughts

Monsoon Mission

- Ministry of Earth Sciences, Government of India recently launched the Monsoon Mission with an objective of improving monsoon forecasts in all time scales from short range to seasonal.
- Development of a dynamical prediction systems
- NCEP CFS V2.0 for extended range to seasonal forecasts
- UKMO Unified Model for short range to medium range forecasts

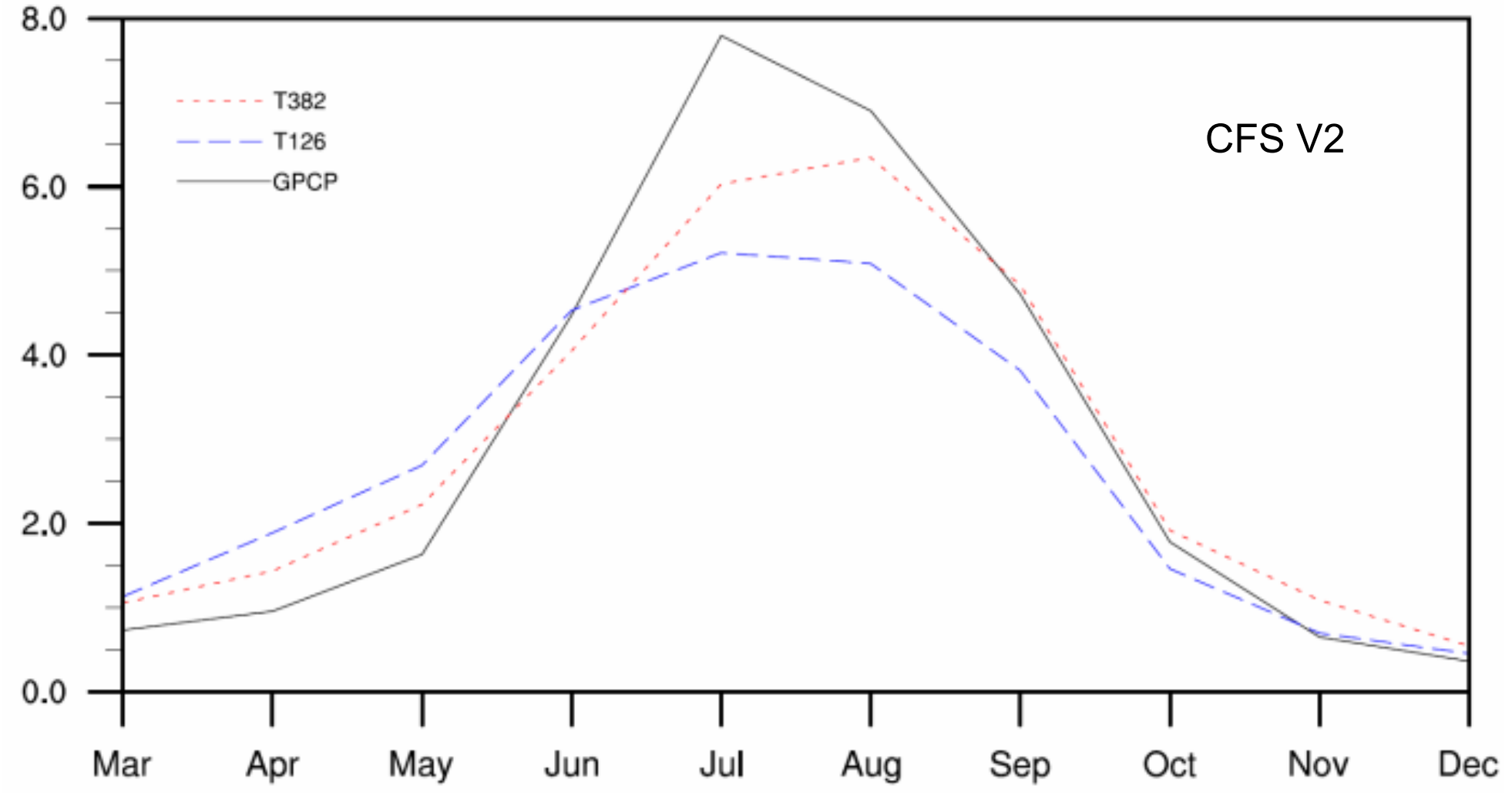
JJAS Mean of all the models Used in this Prediction



Seasonal Mean Rainfall (cm)

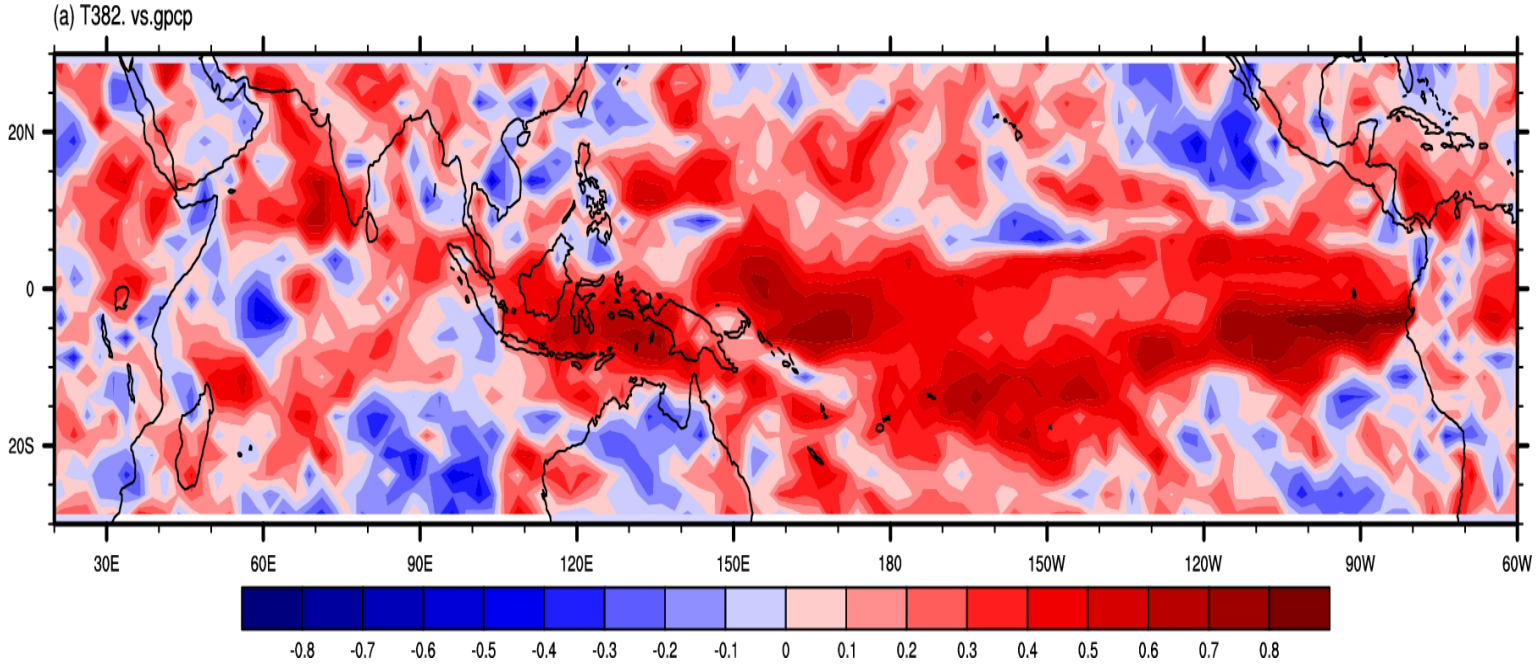
Seasonal Total Rainfall (cm)

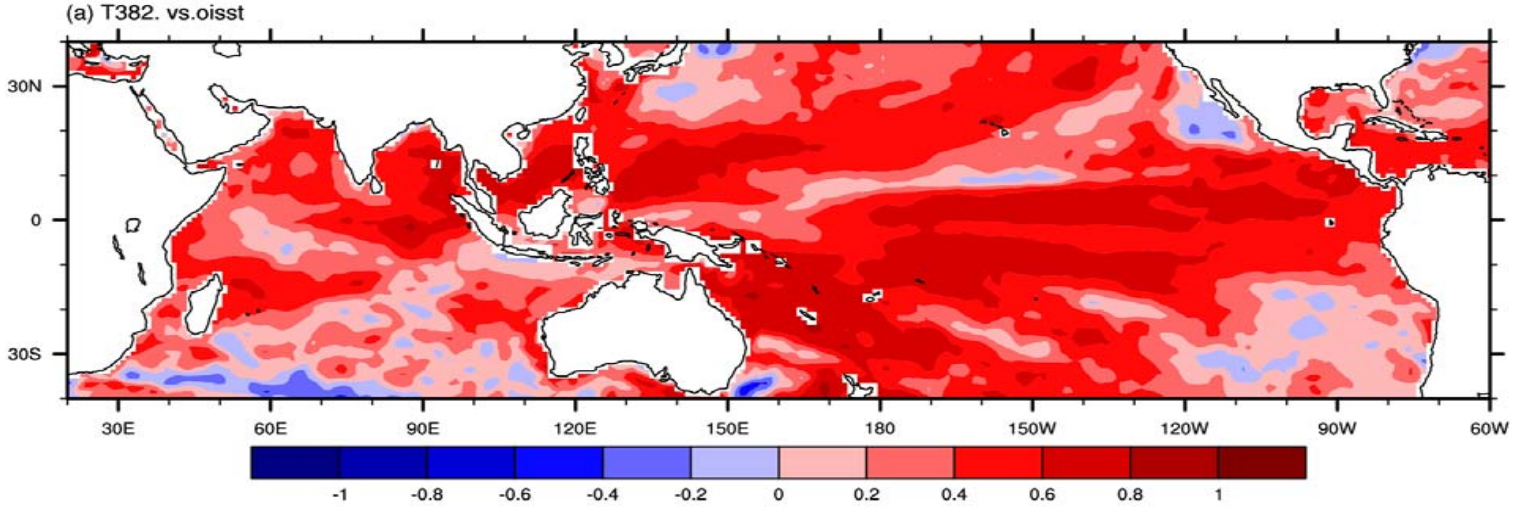
Annual Cycle of ISMR



The dry bias over land is reduced from about 50% to about 25% in the T382 version.

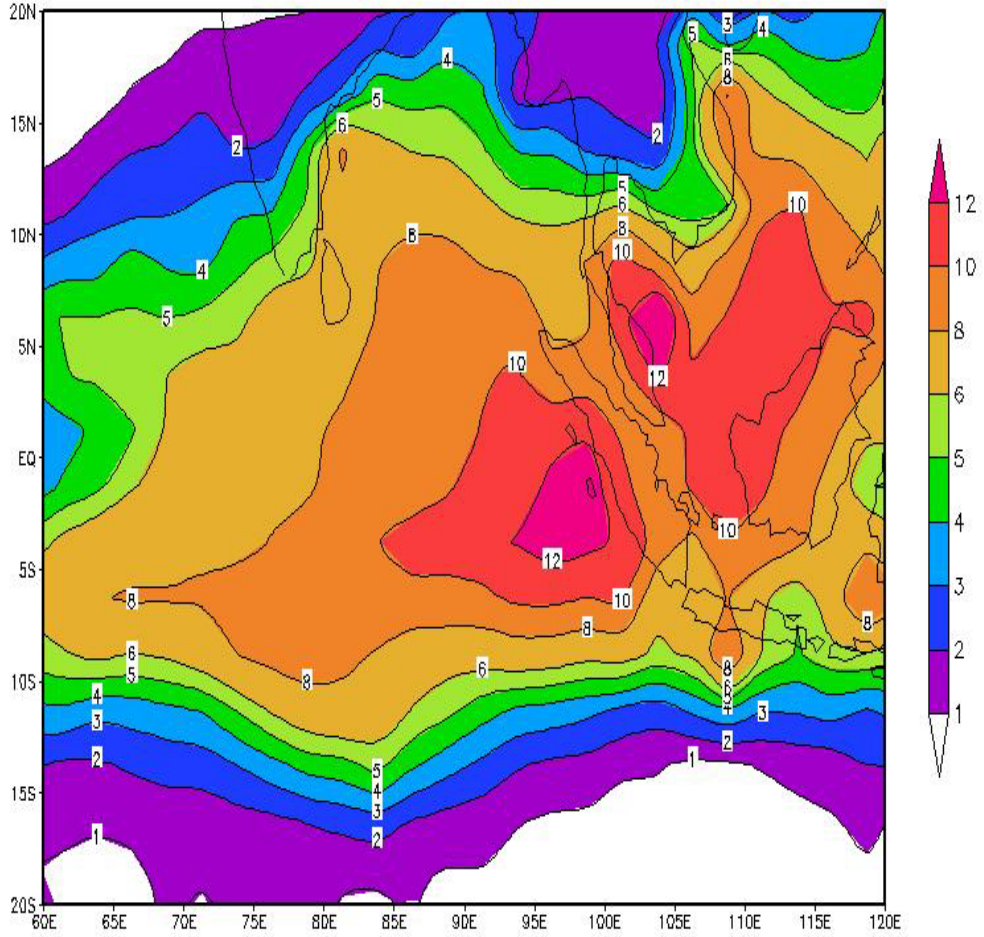
T382L64 Skill of Rainfall/SST



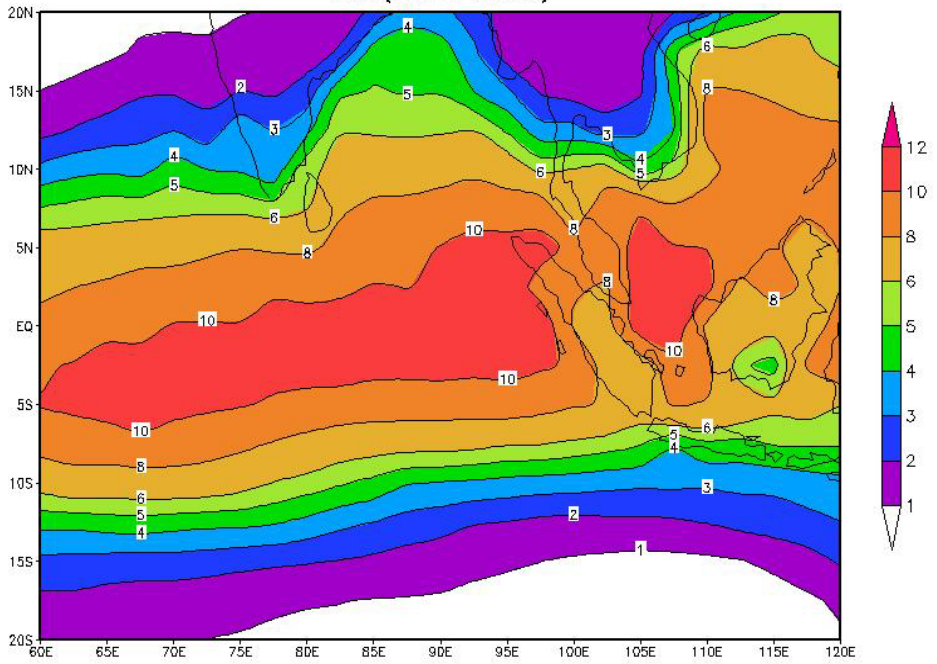


Dynamical predictions of NE Monsoon

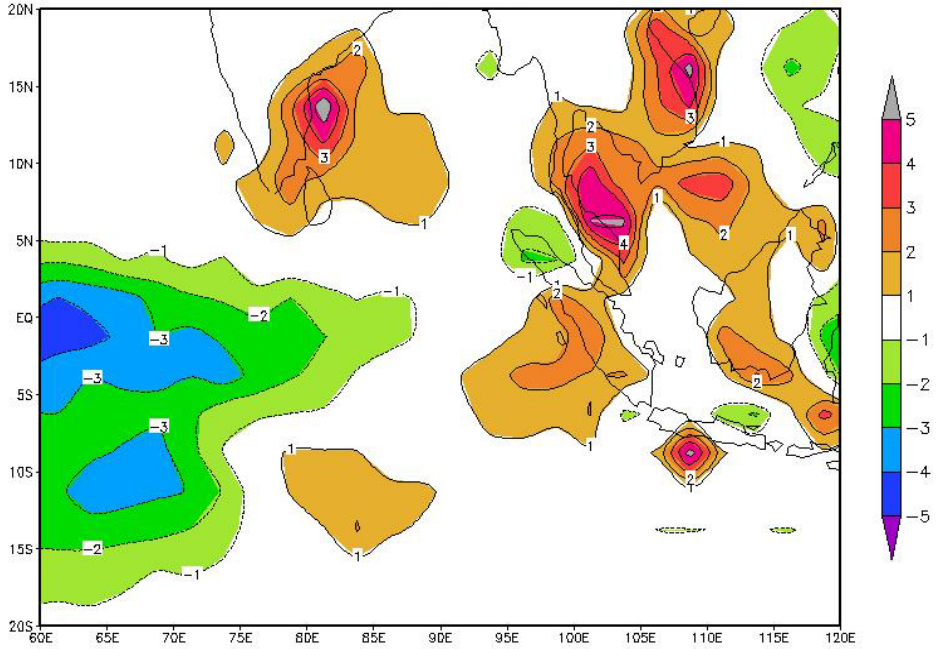
CMAP monthly mean OND Rainfall(mm/day)
1979 to 2005



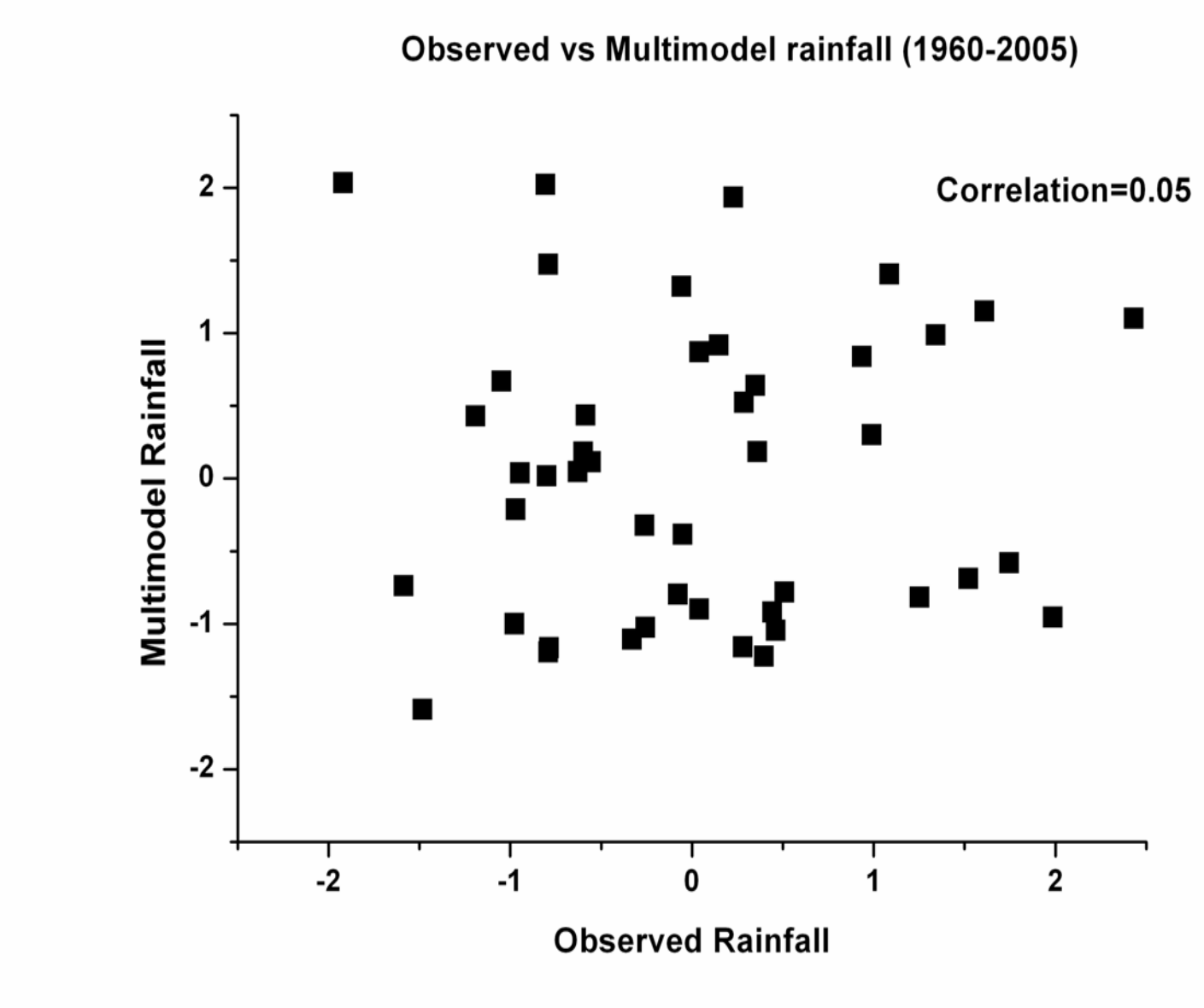
Multimodel monthly mean Rainfall(mm/day)
OND(1979-2005)



CMAP monthly mean bais OND Rainfall(mm/day)
1979 to 2005

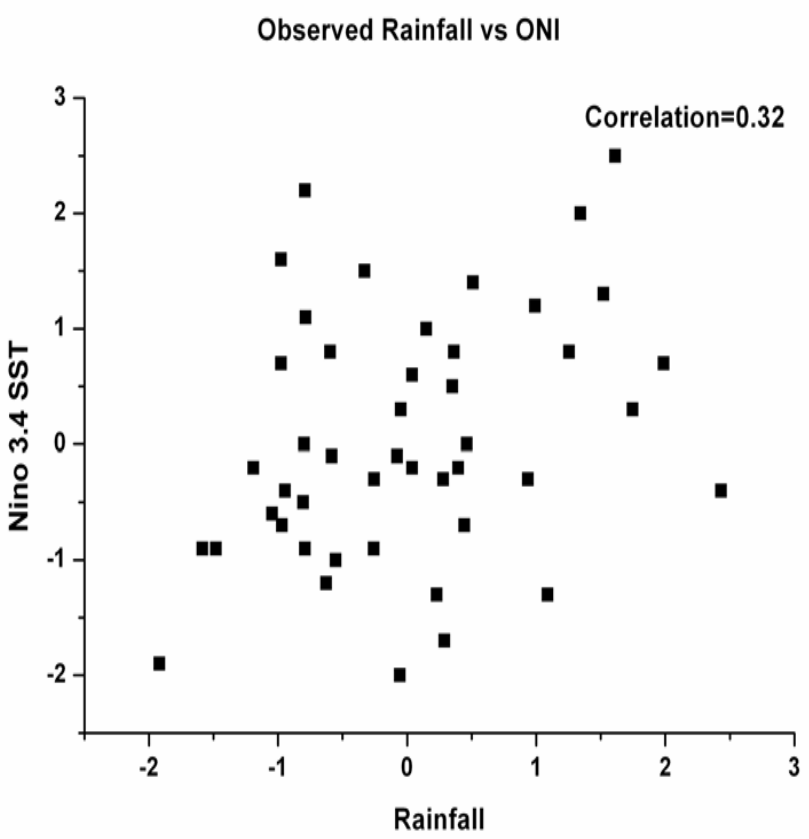


Model Skill (CC)

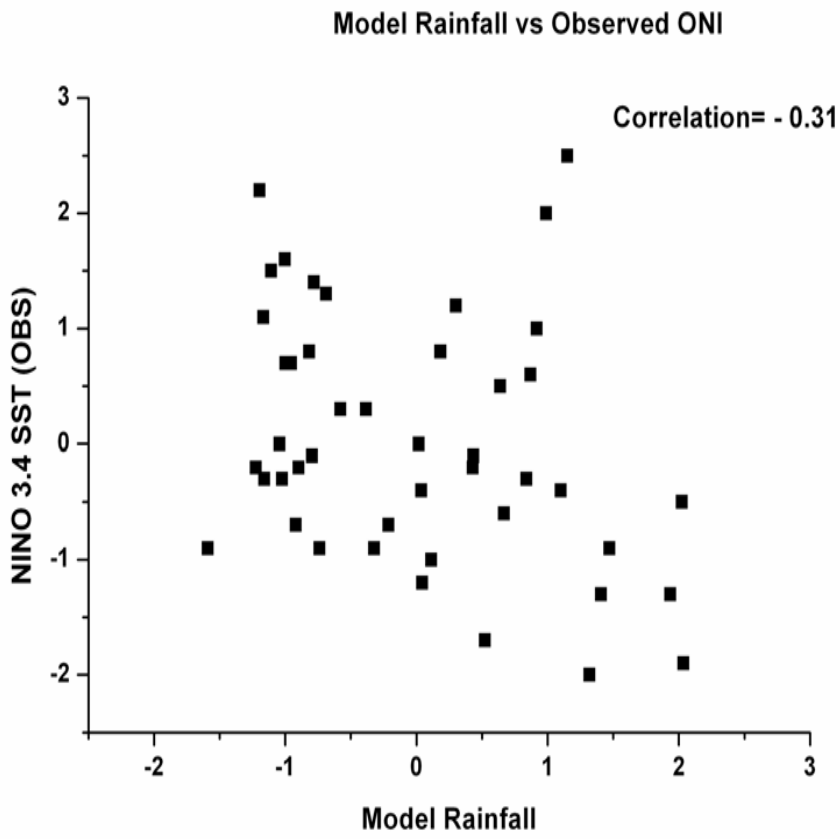


Correlations with Nino 3.4

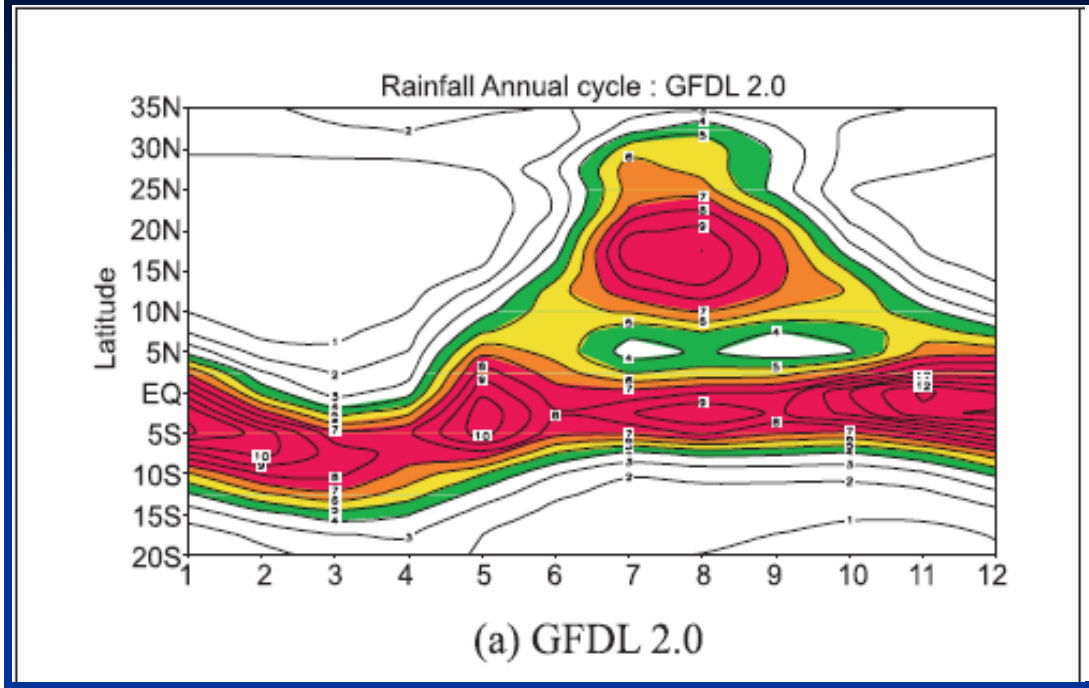
Observations



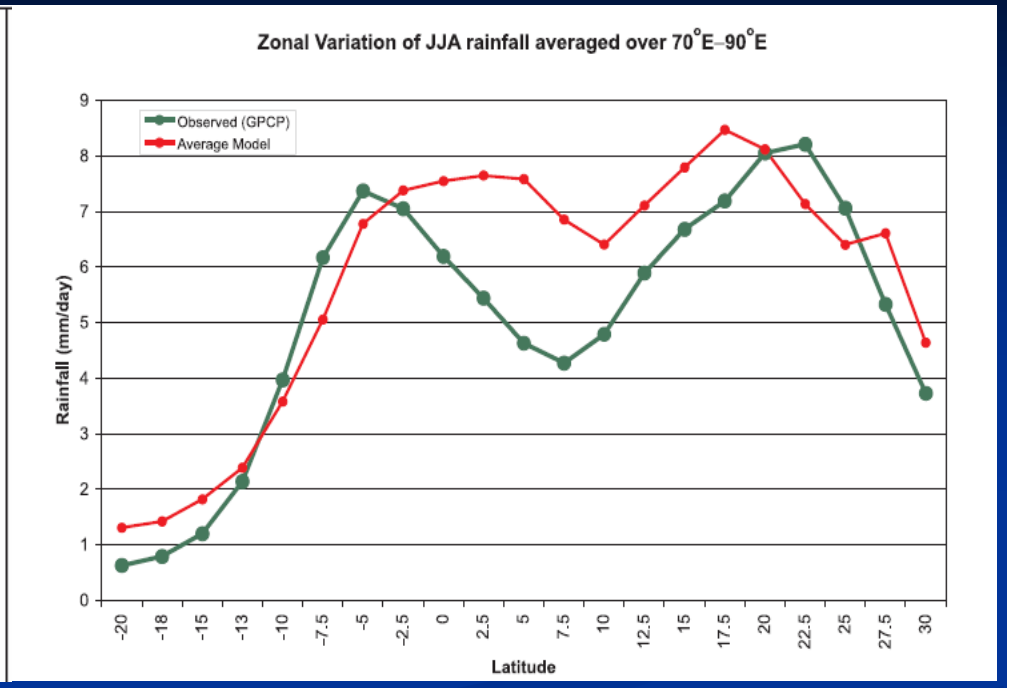
ENSEMBLES MME



Issues with the Coupled Dynamical Models

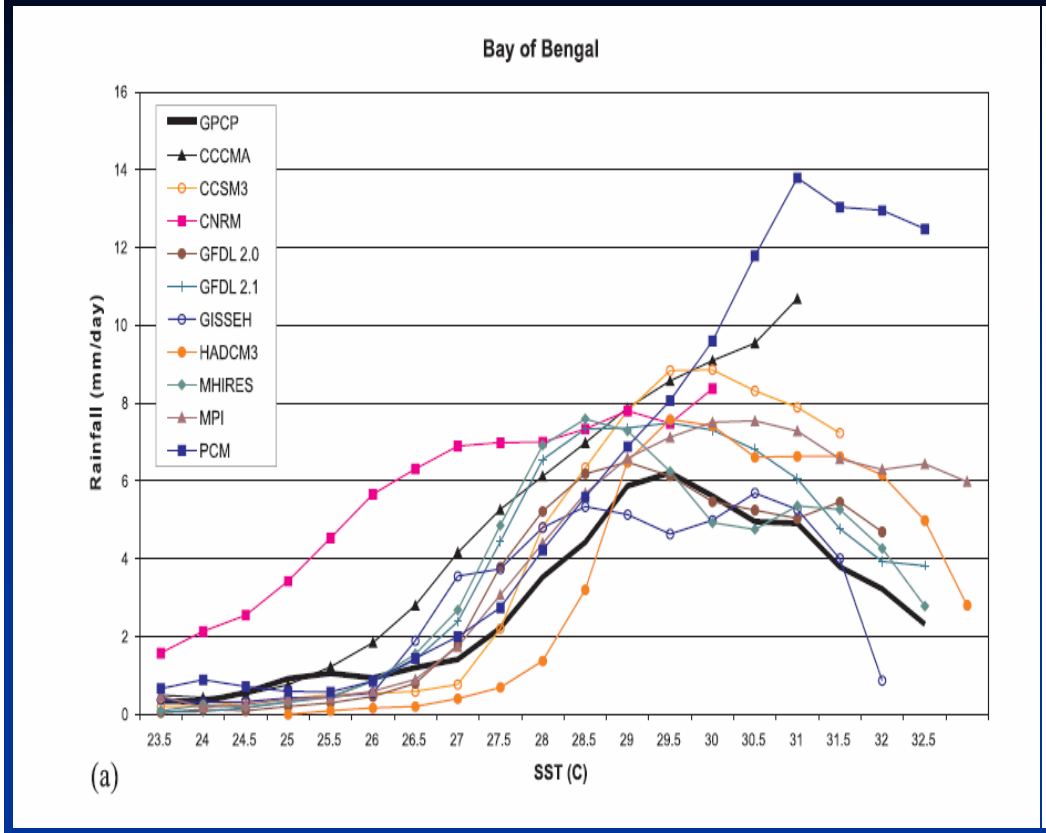


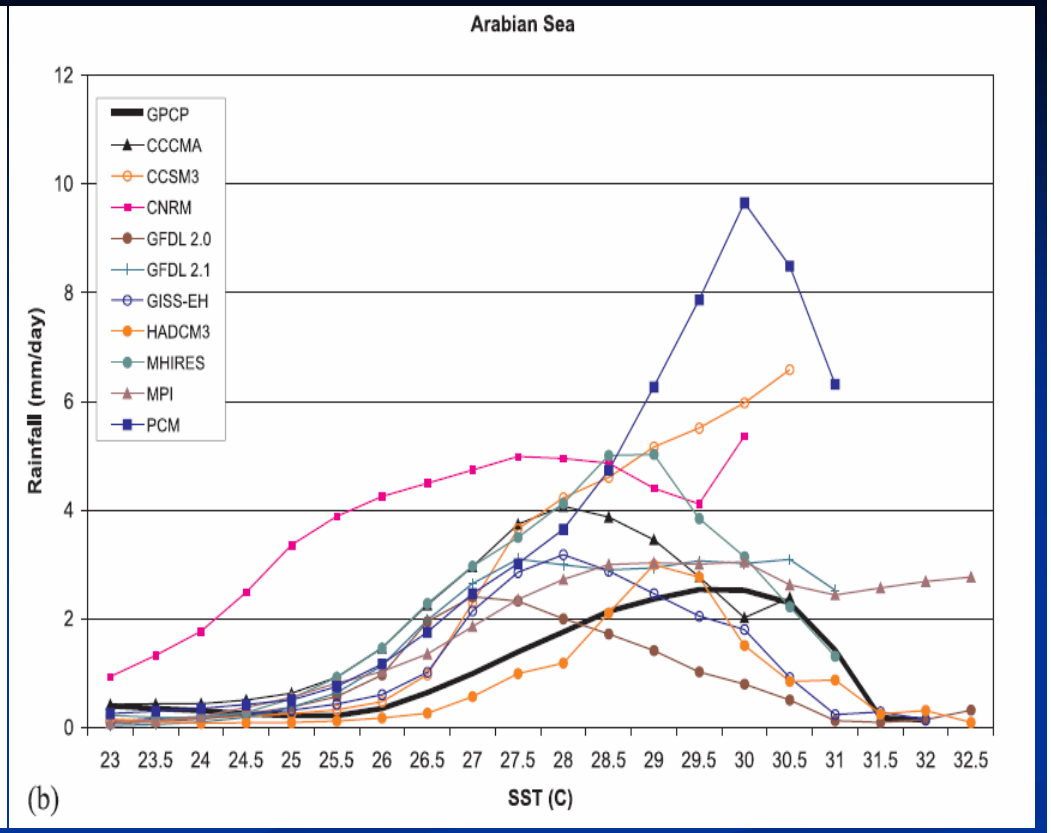
(a) GFDL 2.0



Best of best IPCC models also showed excessive rainfall over the equatorial Indian Ocean.

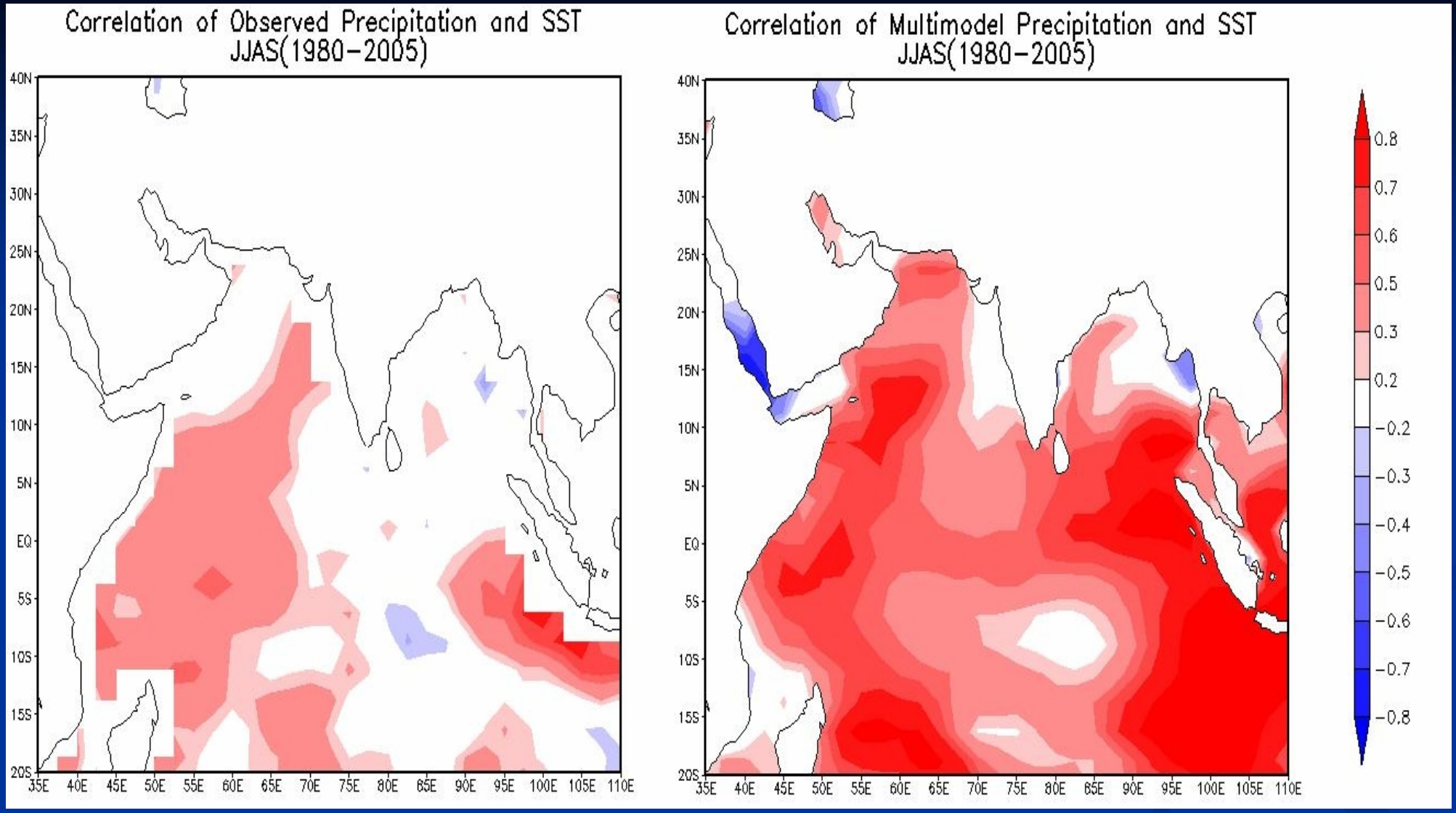
Rajeevan and Nanjundiah (2009), in " Current Trends in Science" Indian Academy of Sciences.





Too stronger coupling of SST-rainfall in the IPCC coupled climate models

Rajeevan and Nanjundiah (2009), in " Current Trends in Science" Indian Academy of Sciences.

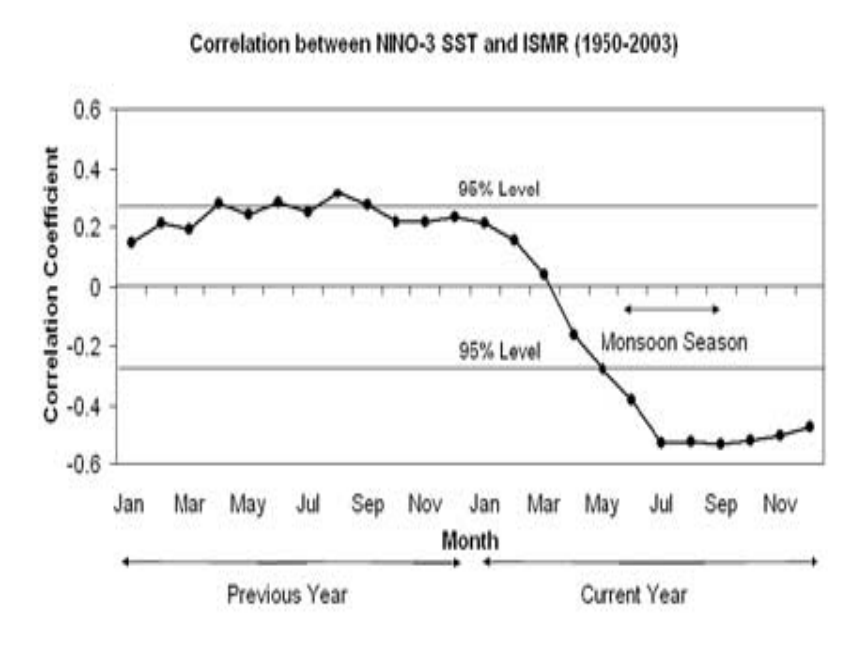


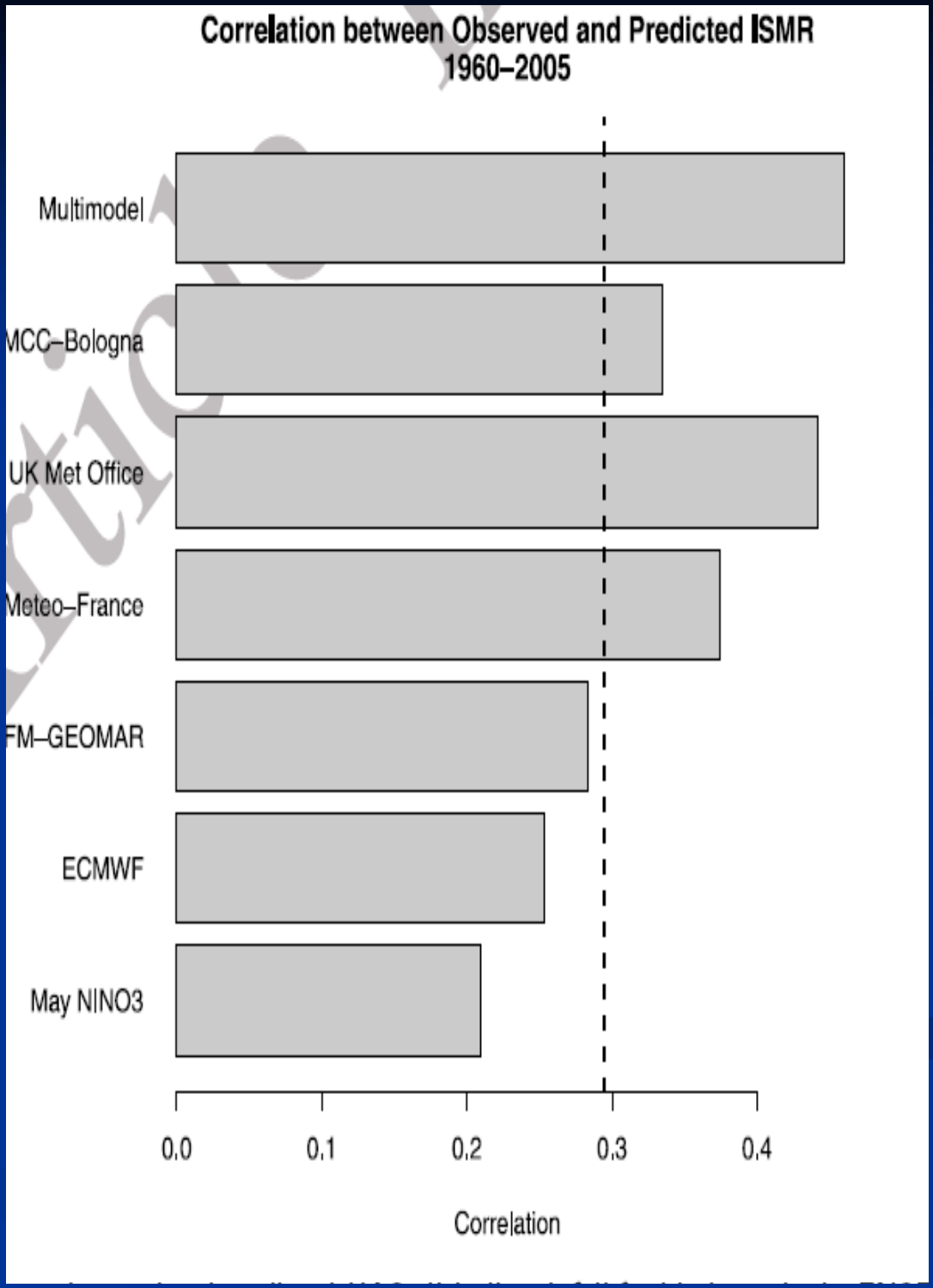
Observations

ENSEMBLES

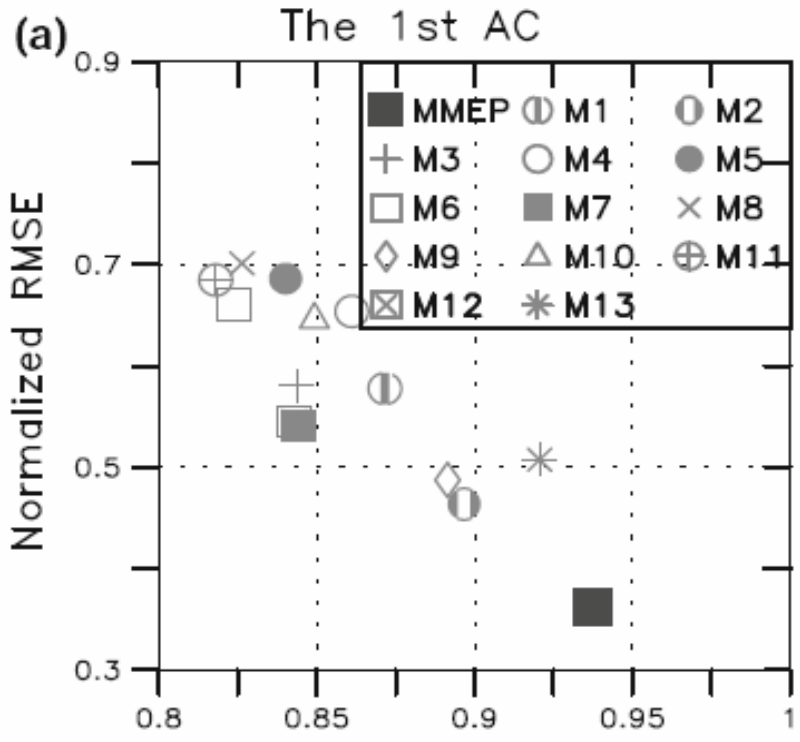
Too stronger local air-sea coupling over the Indian ocean in the models

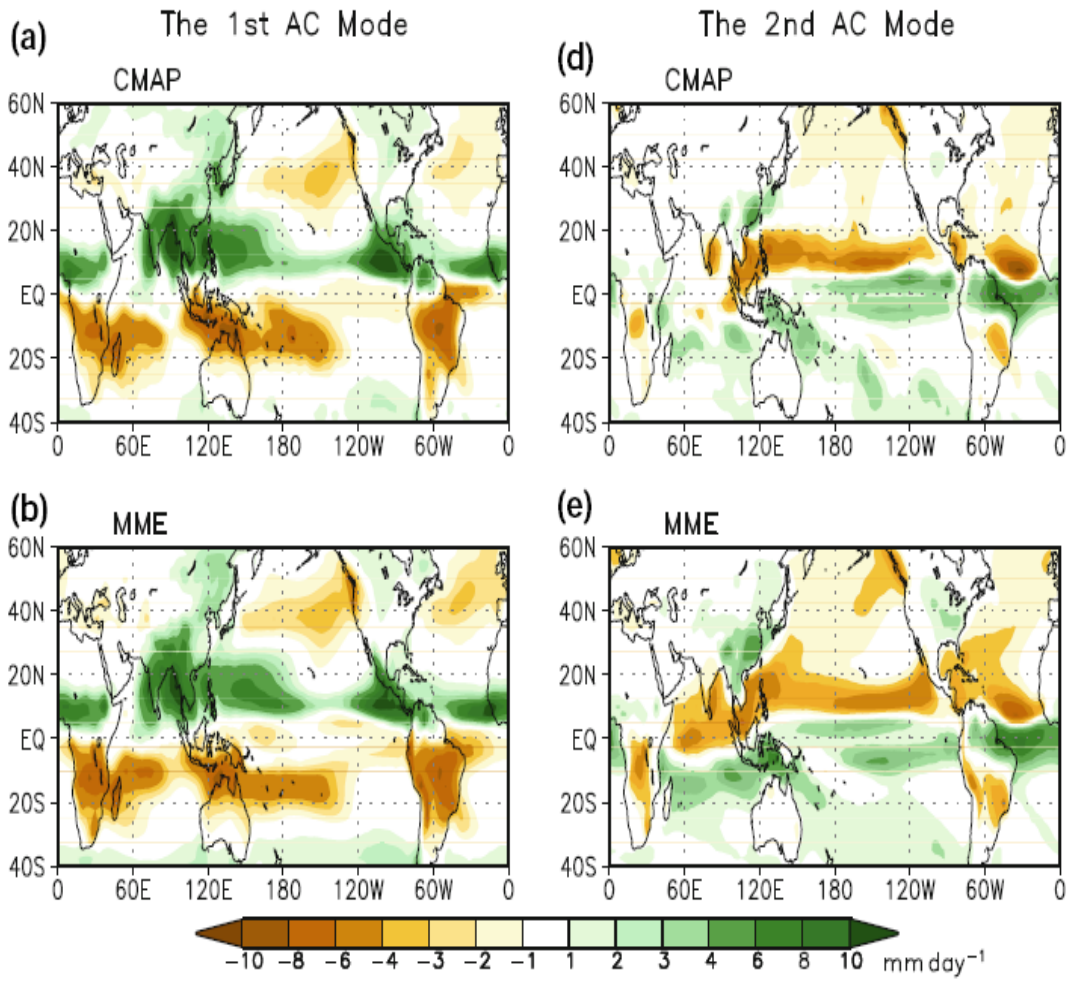
Delsole and Shukla 2012





Dynamical models have better capability to estimate the influence of simultaneous SSTs

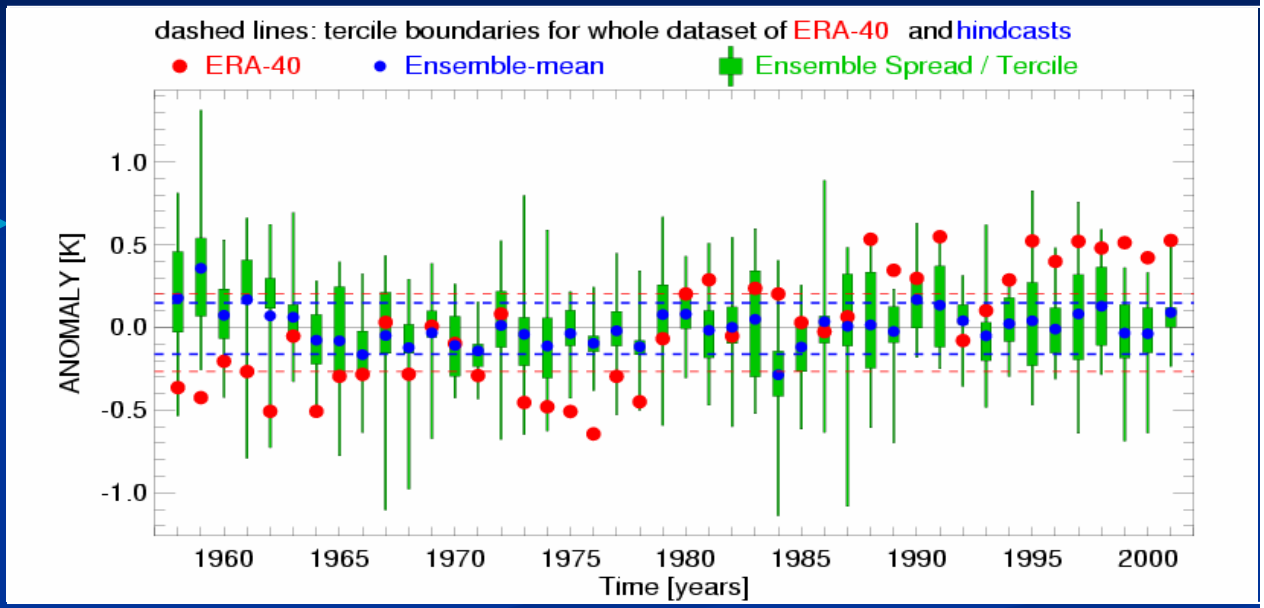




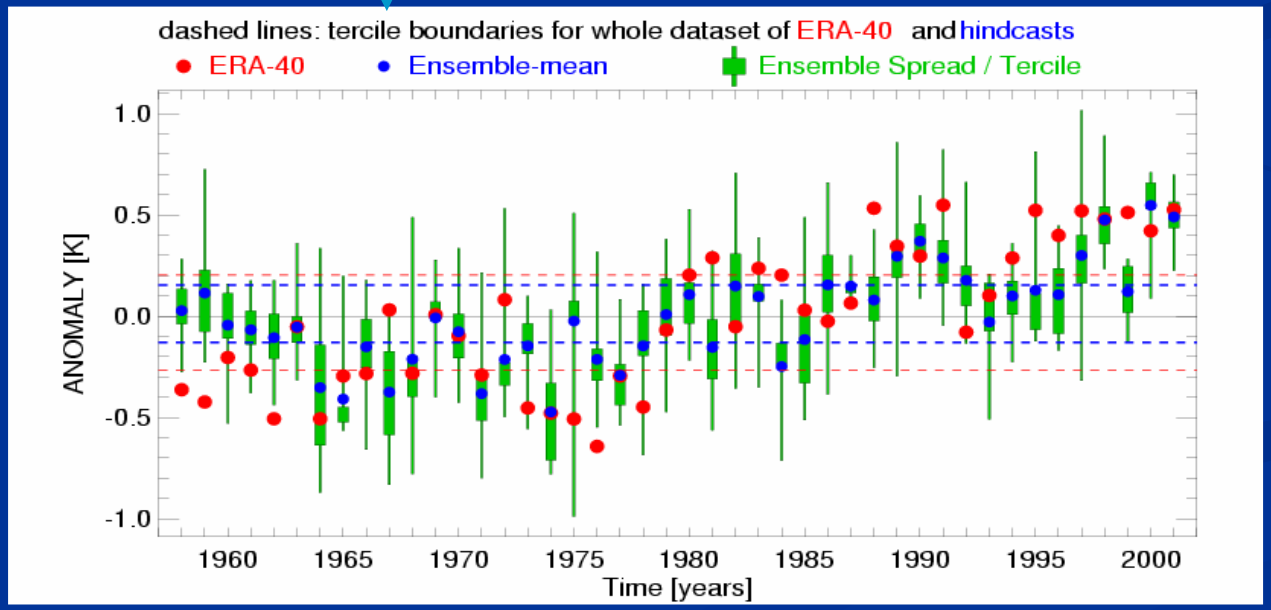
Lee et al 2010, Climate Dynamics

GHG effect in seasonal forecasts

Constant GHG
Correlation = 0.29



Variable GHG
Correlation = 0.68



Francisco J Doblas-Reyes
ECMWF
WCRP workshop on seasonal Prediction, Barcelona, 2007

Conclusions

- The skill of dynamical models in predicting Indian summer monsoon rainfall has been improving over the years, which gives us a hope to make use of them for operational forecasts
- However, we need to continue research towards reduce uncertainties and errors in the model, thus improving the prediction skill
- Monsoon Mission initiated by the Govt of India is focusing on this aspect. We expect very useful results from the monsoon mission.