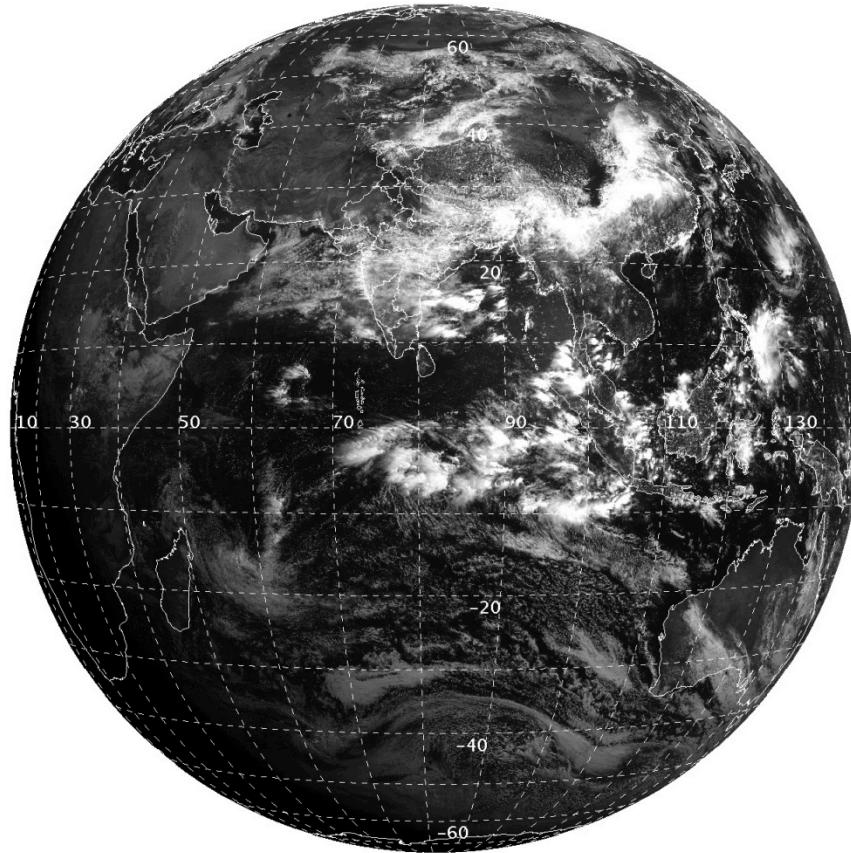


Monsoon Prediction: Seasonal



*Suryachandra A. Rao & Group Members
Indian Institute of Tropical Meteorology*

DEFINITIONS OF METEOROLOGICAL FORECASTING RANGES

1. Nowcasting

A description of current weather parameters and 0 -2 hours description of forecasted weather parameters

2. Very short-range weather forecasting

Up to 12 hours description of weather parameters

3. Short-range weather forecasting

Beyond 12 hours and up to 72 hours description of weather parameters

4. Medium-range weather forecasting

Beyond 72 hours and up to 240 hours description of weather parameters

5. Extended-range weather forecasting

Beyond 10 days and up to 30 days

6. Long-range forecasting

From 30 days up to two years

Two kinds of Atmospheric Predictability

Predictability of 1st kind

Originates from **Initial condition**

Deterministic forecast fails beyond two weeks due to the growth of errors contained in the initial states.

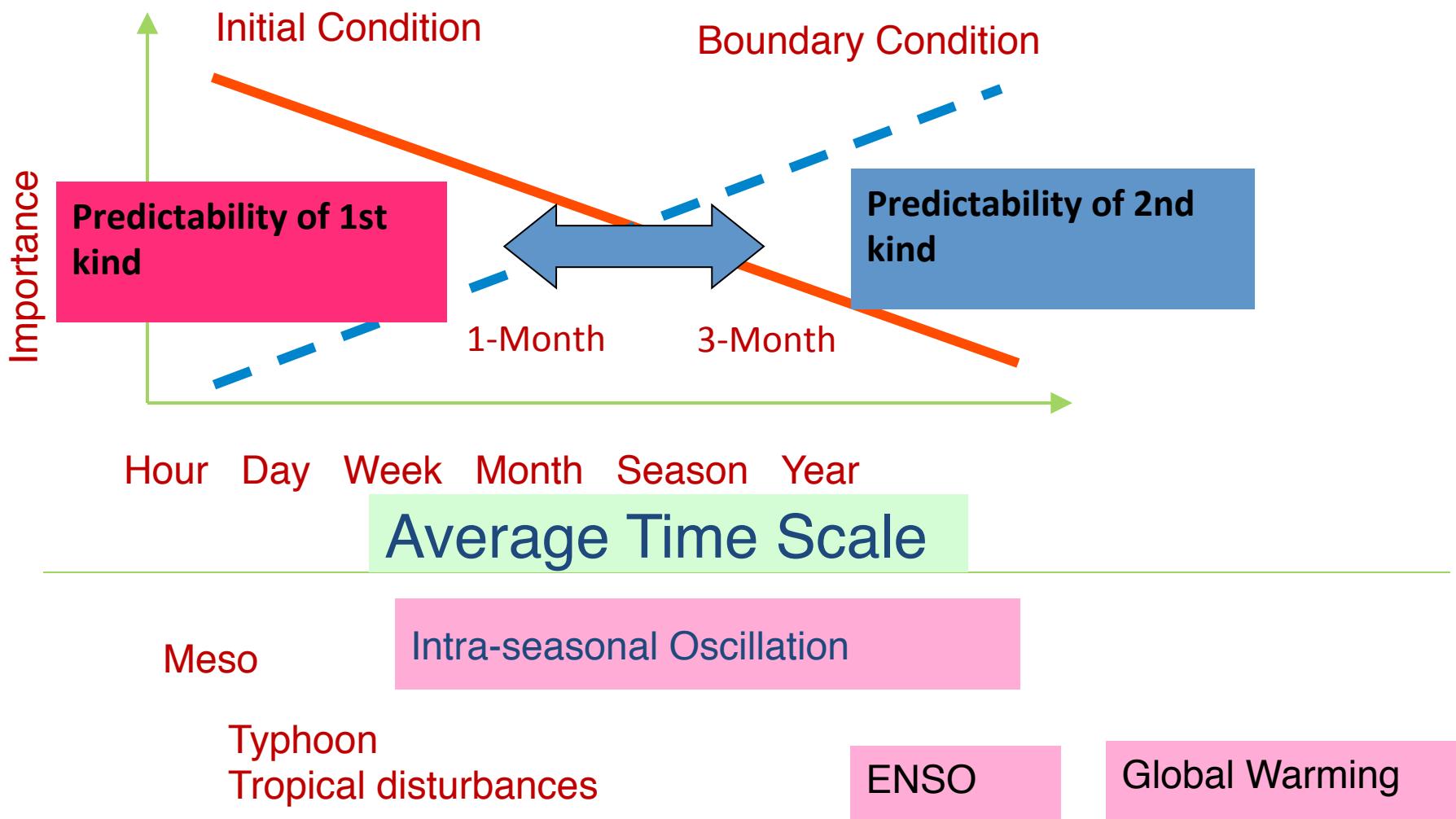
Chaotic behavior of atmosphere comes from its strong non-linearity.

Predictability of 2nd kind

Originates from **lower boundary condition**

Effective for longer time scale; Month to season

Relative importance of Initial Condition and Boundary Condition



Lower Boundary Condition of Atmosphere

- ◎ Ocean

- Sea Surface Temperature (SST)

- Sea Ice

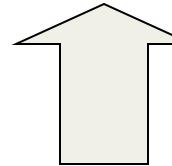
- ◎ Land Surface

- Soil Temperature

- Soil Moisture

- Snow Cover, Snow Depth

- Vegetation (Grass, Tree etc.)



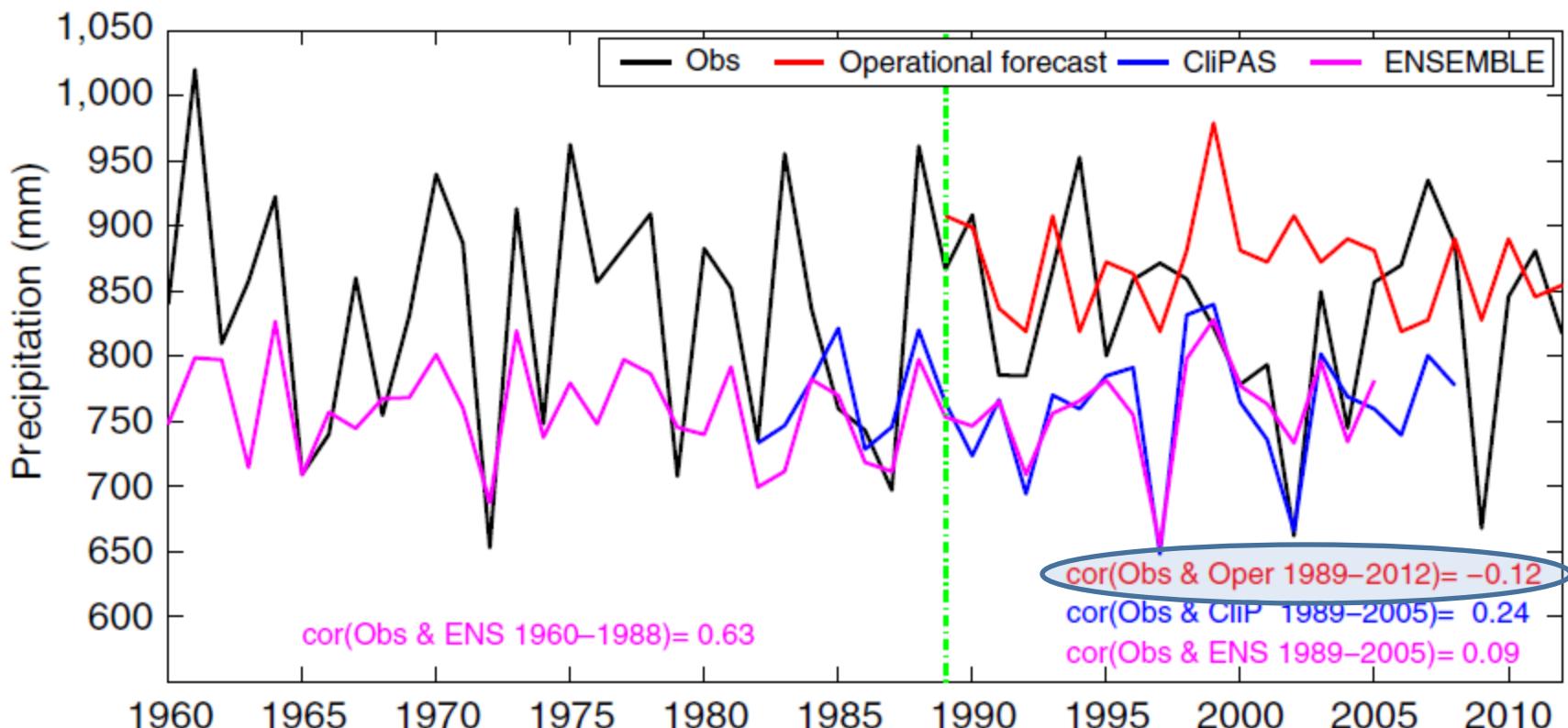
Most IMPORTANT
to the
atmospheric
variability !

Walker's Contributions

- Sir Gilbert Walker made significant contribution to long range forecasting research.
- He introduced the correlation and regression techniques and objective models.
- His research for global predictors led to the discovery of Southern Oscillation and North Atlantic Oscillation.
- His regression methods have been more or less followed by IMD for the operational work.



IMD Operational Model Prediction Skill of ISMR

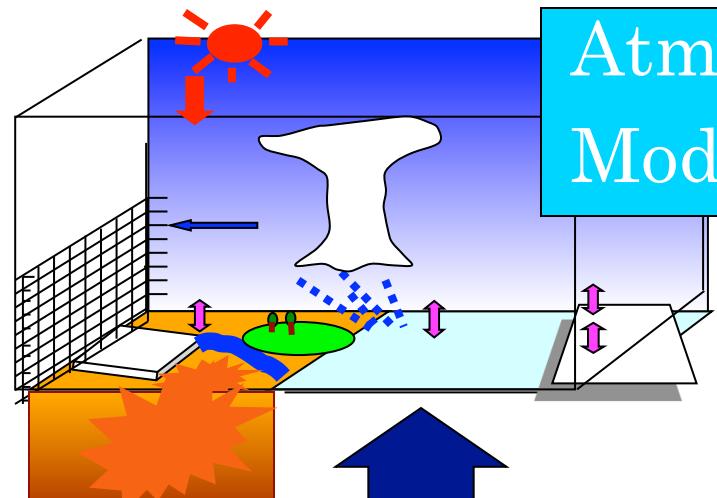


Two Methods for Numerical Seasonal Prediction

Past

Two-Tiered Way

Atmosphere-Land
Coupled Model



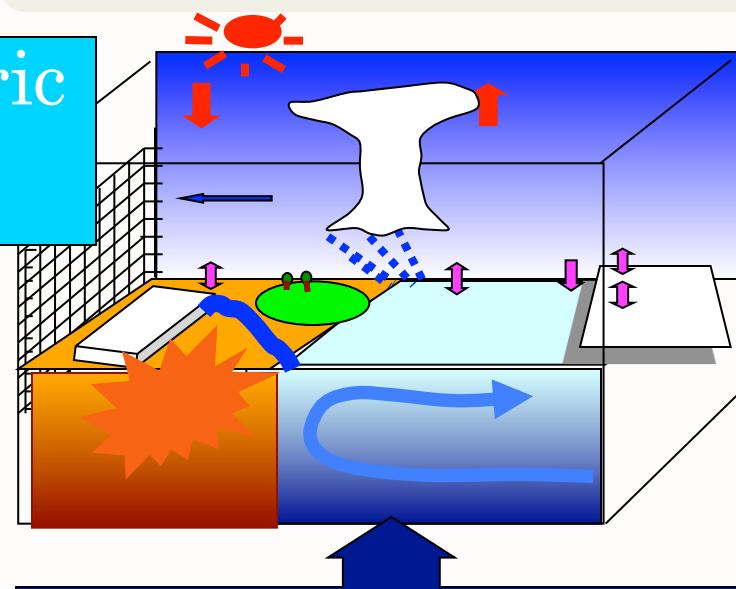
Atmospheric
Model

Separately predicted SST
is prescribed as boundary

Present

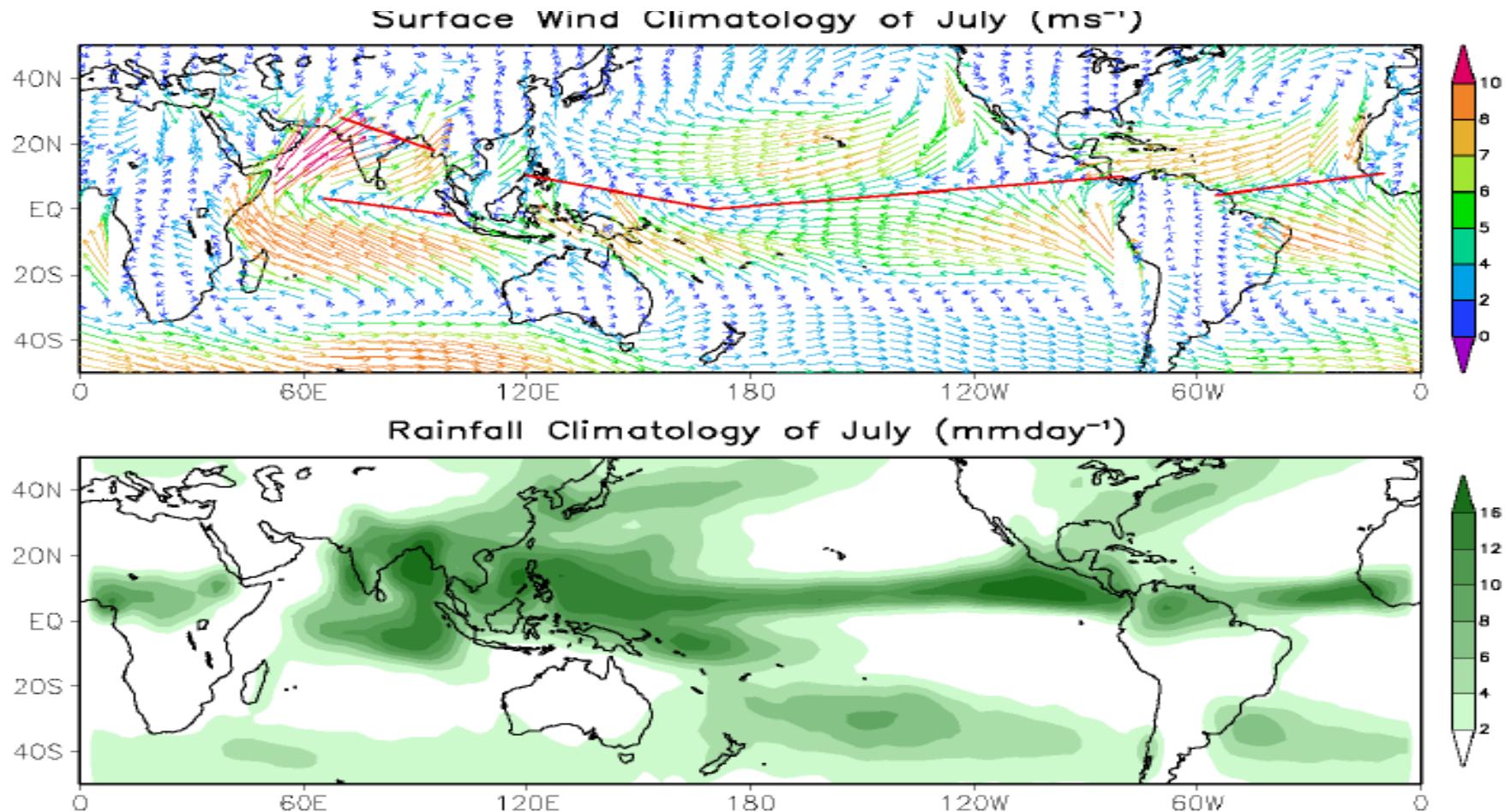
One-Tiered Way

Atmosphere-Land-Ocean Coupled
Model

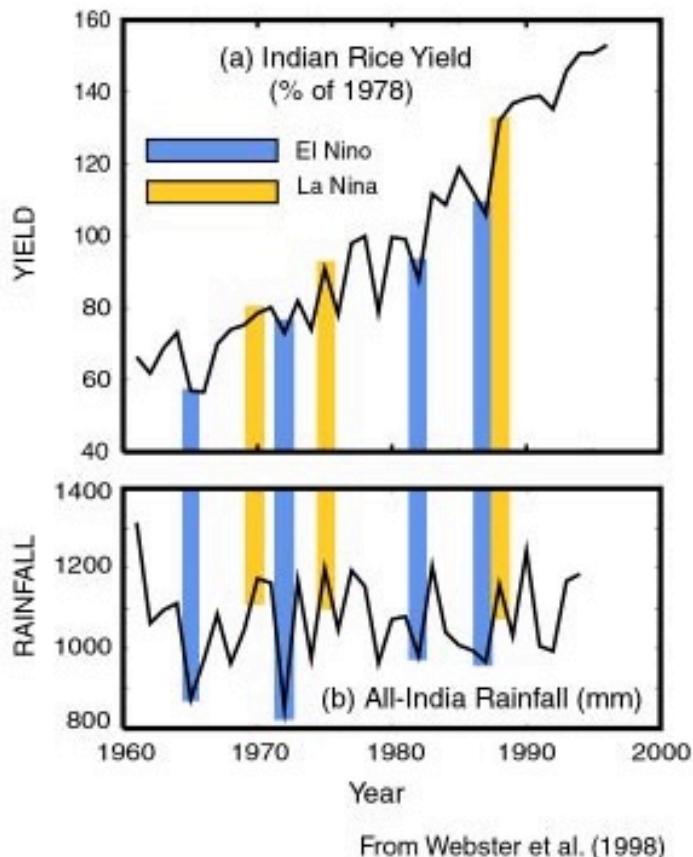


Ocean model is coupled

Monsoon

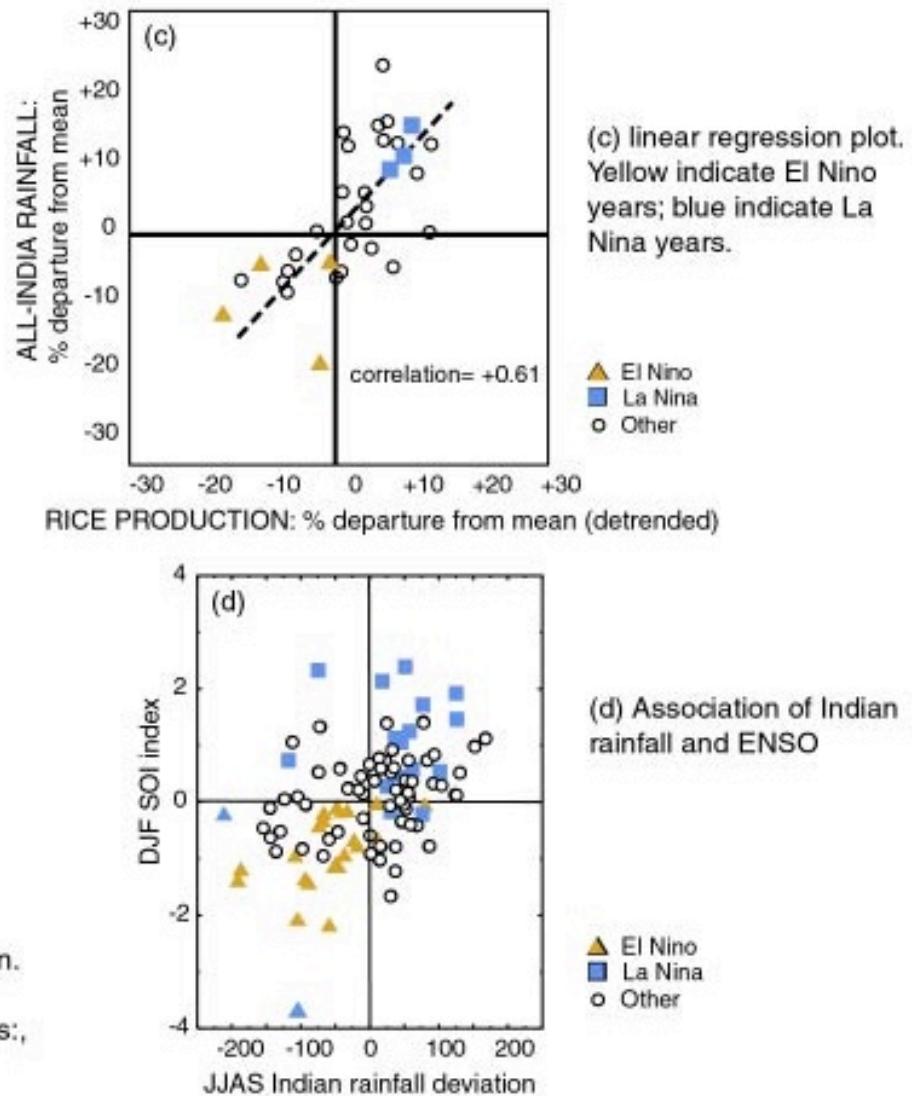


Indian Monsoon and Agriculture



(a) The relationship between Indian rainfall and rice production from 1960 to 1996 relative to 1978 production.

(b) the All-India rainfall Index for the corresponding years;:

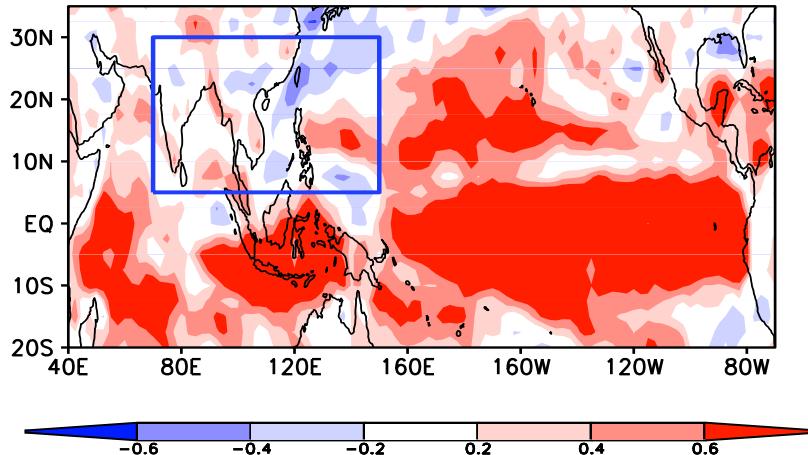


(d) Association of Indian rainfall and ENSO

Two-tier MME hindcast of summer Monsoon rainfall

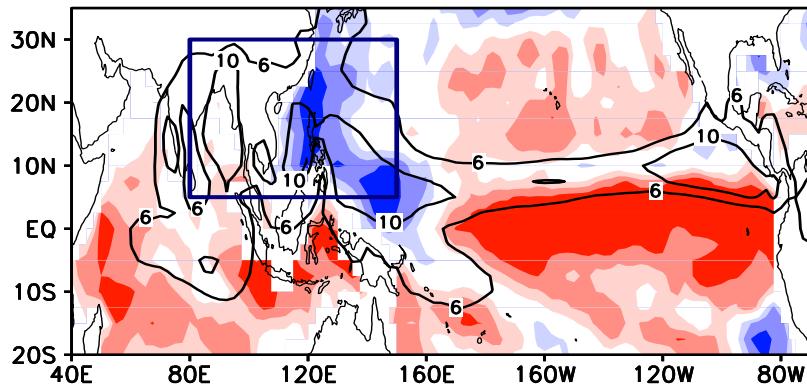
Hindcast Skill is nearly Zero in ASM region

5-AGCM EM hindcast skill (21Yr)

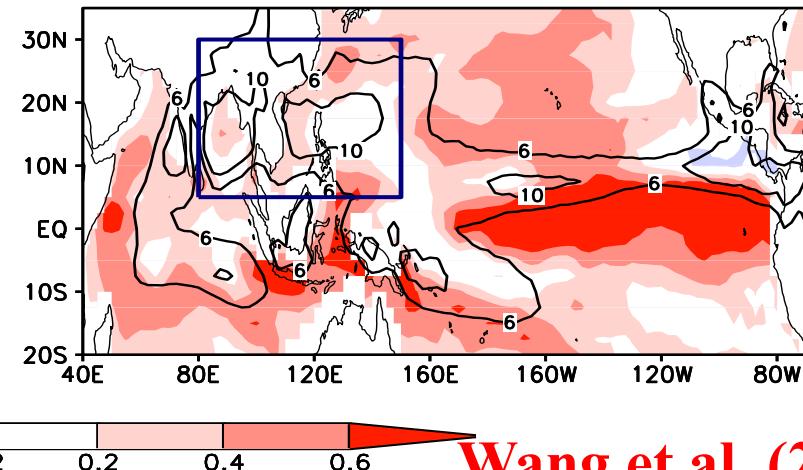


- Two-tier system was unable to predict ASM rainfall.
- TTS tends to yield positive SST-rainfall correlations in SM region that are at odds with observation (negative).
- Treating monsoon as a slave to prescribed SST results in the failure.

OBS SST-rainfall correlation



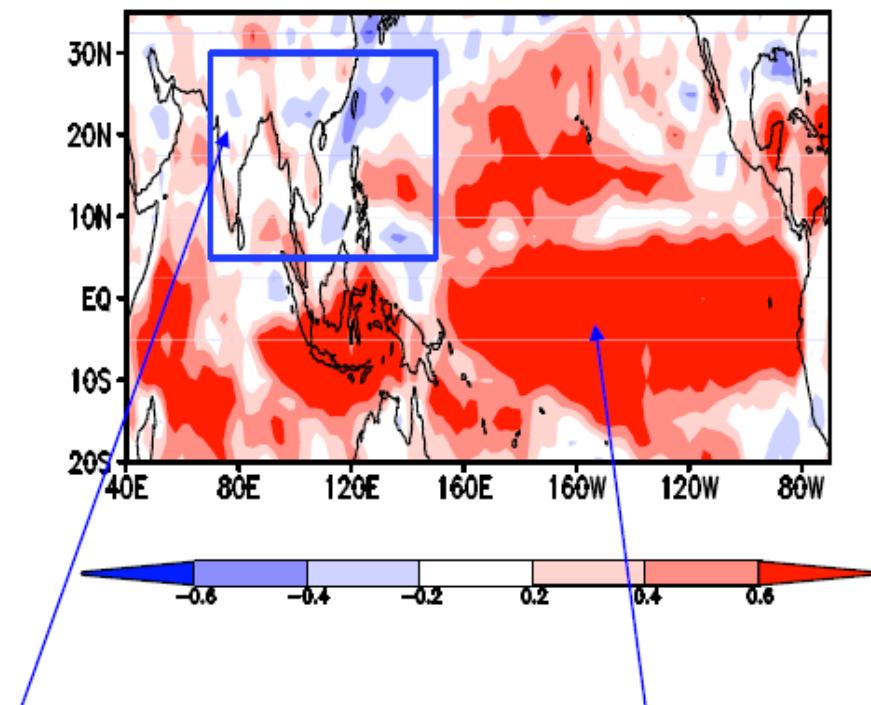
Model SST-rainfall correlation



Wang et al. (2005)

STATE OF THE ART COUPLED MODELS PREDICTION SKILL (Correlation between observed and Predicted) OF TROPICAL PRECIPITATION (Prior to Monsoon Mission)

Earlier version models
1979-1999

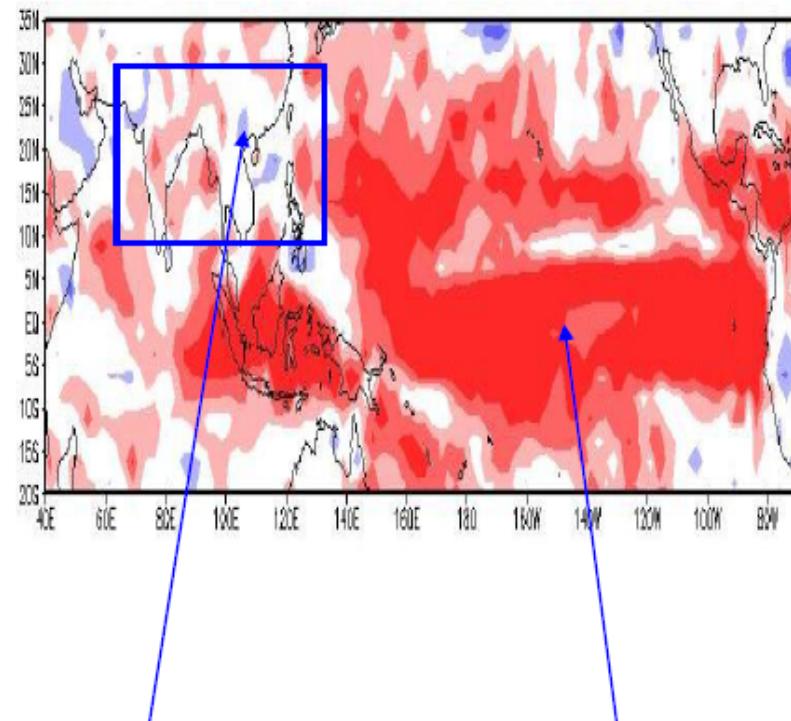


Poor skill

High skill

Preeti et al., (2009)

Latest models (ENSEMBLES)
1979-1999

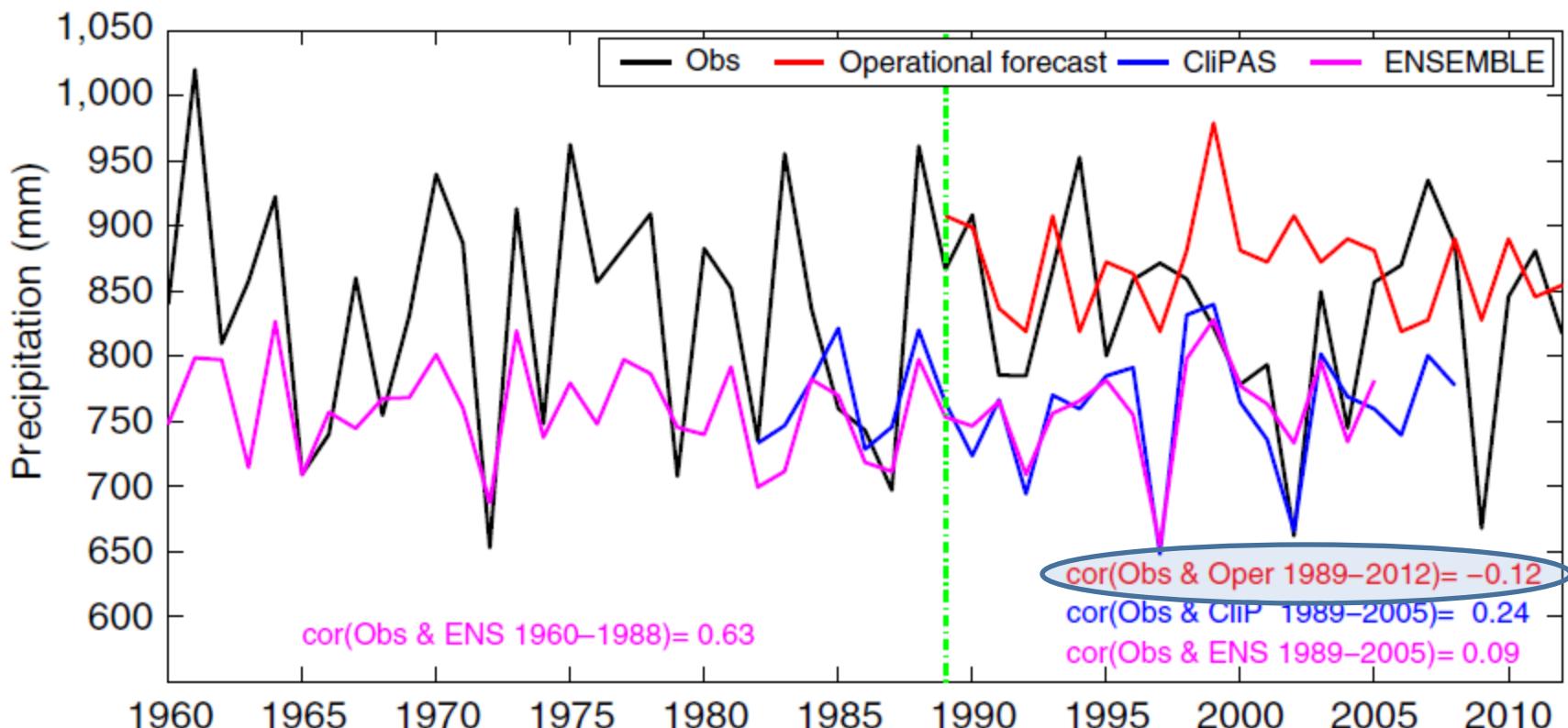


Improved
skill

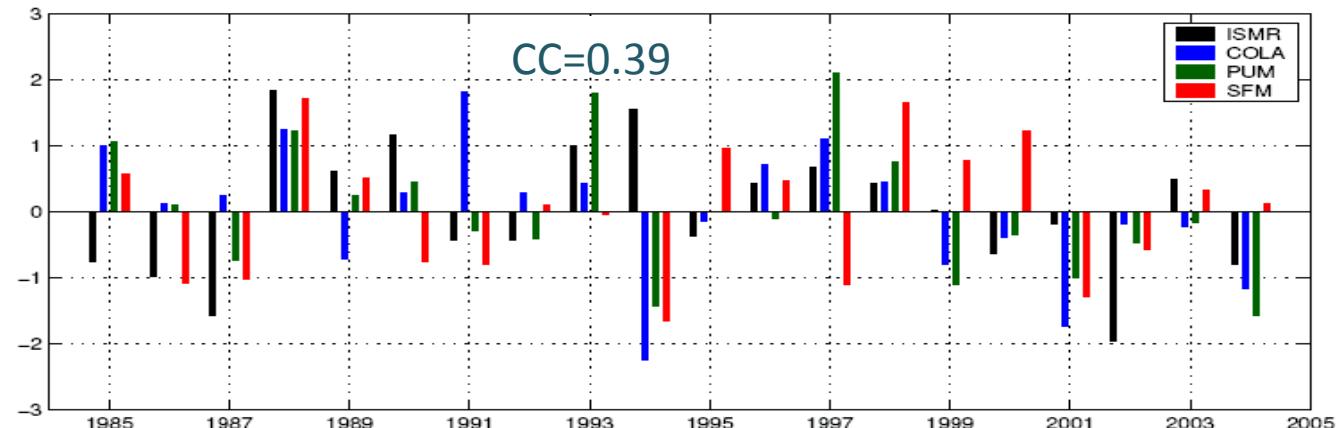
High skill

Rajeevan et al., (2011)

IMD Operational Model Prediction Skill of ISMR

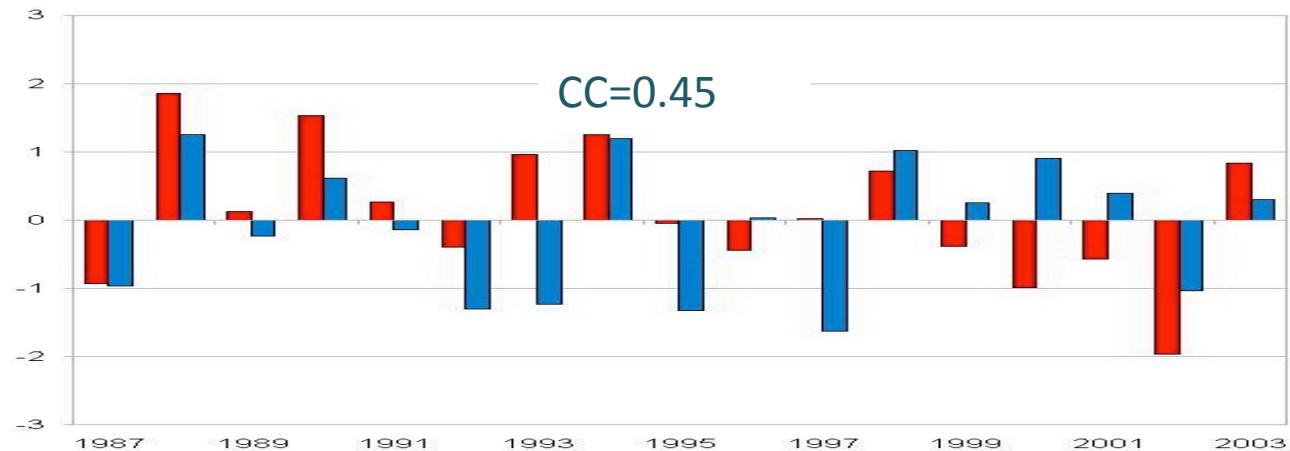


Dynamical AGCM
Potential Prediction Skill



Gadgil & Sreenivasan, (2012)

Dynamical CGCM
CFS Prediction Skill
(T62L64)



Rajeevan (Pers. Communication)
& Pattanaik and Arun Kumar (2014)

Major Biases in CFSv2

Main Biases:

Dry bias over India

Cold bias in SST

Cold land and trop. Temperature

Excess Eurasian snow

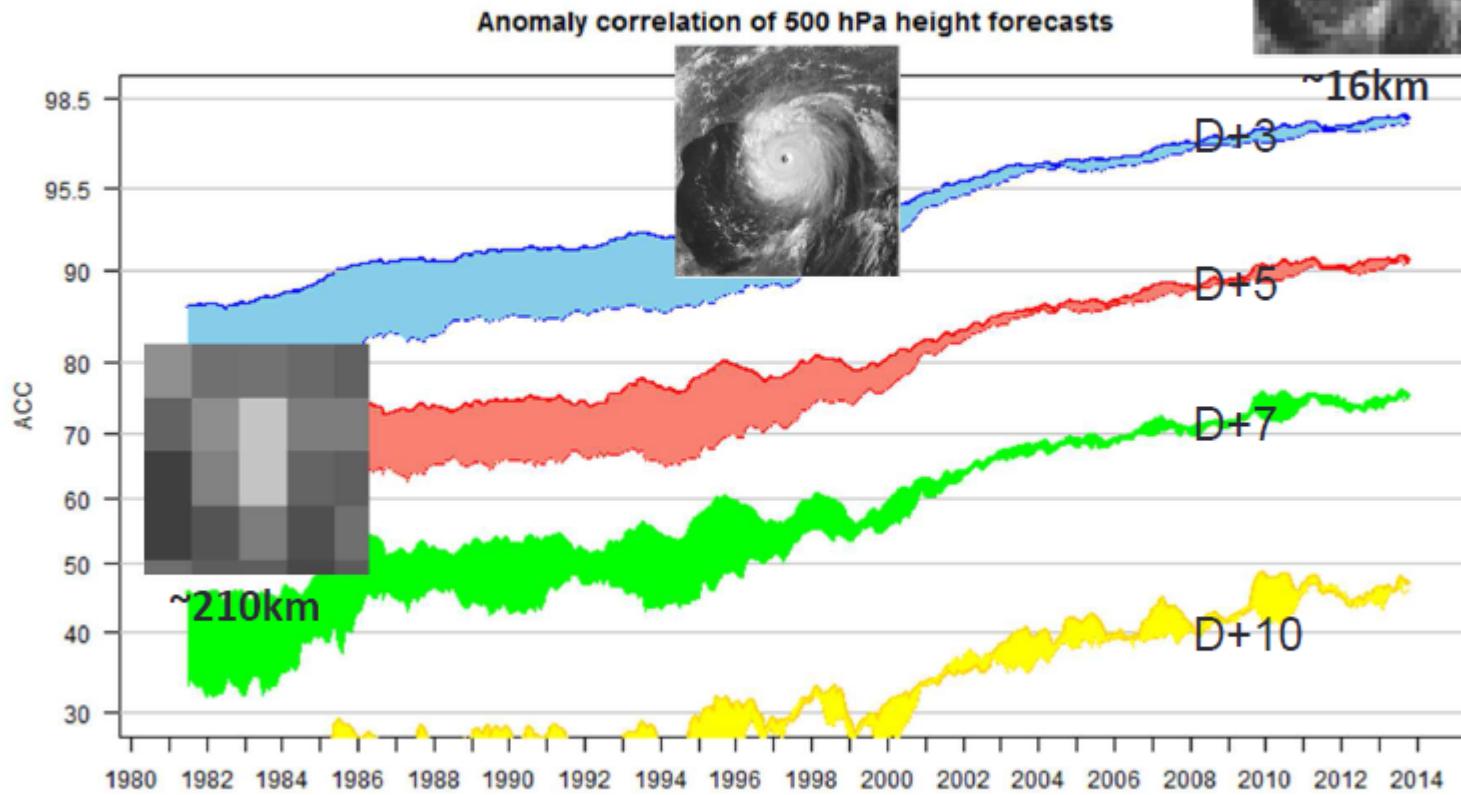
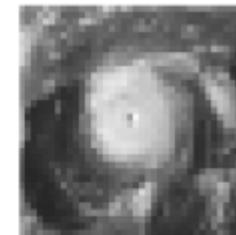
Excessive convective rainfall over tropics

Attempts to reduce these biases

- Convective Parameterization (New SAS, Han & Pan, 2011; Ganai et al., 2014)
- Cloud Microphysics (Hazra et al., 2015; Abhik et al., 2016 communicated)
- Super Parametrization (Goswami et al., 2015)
- Improved snow physics in Land Surface Model Saha et al., (2016. to be submitted)
- **High Resolution Model (Ramu et al., 2015)**
- Stochastic Parametrization (in progress)
- New Ocean model (in progress)

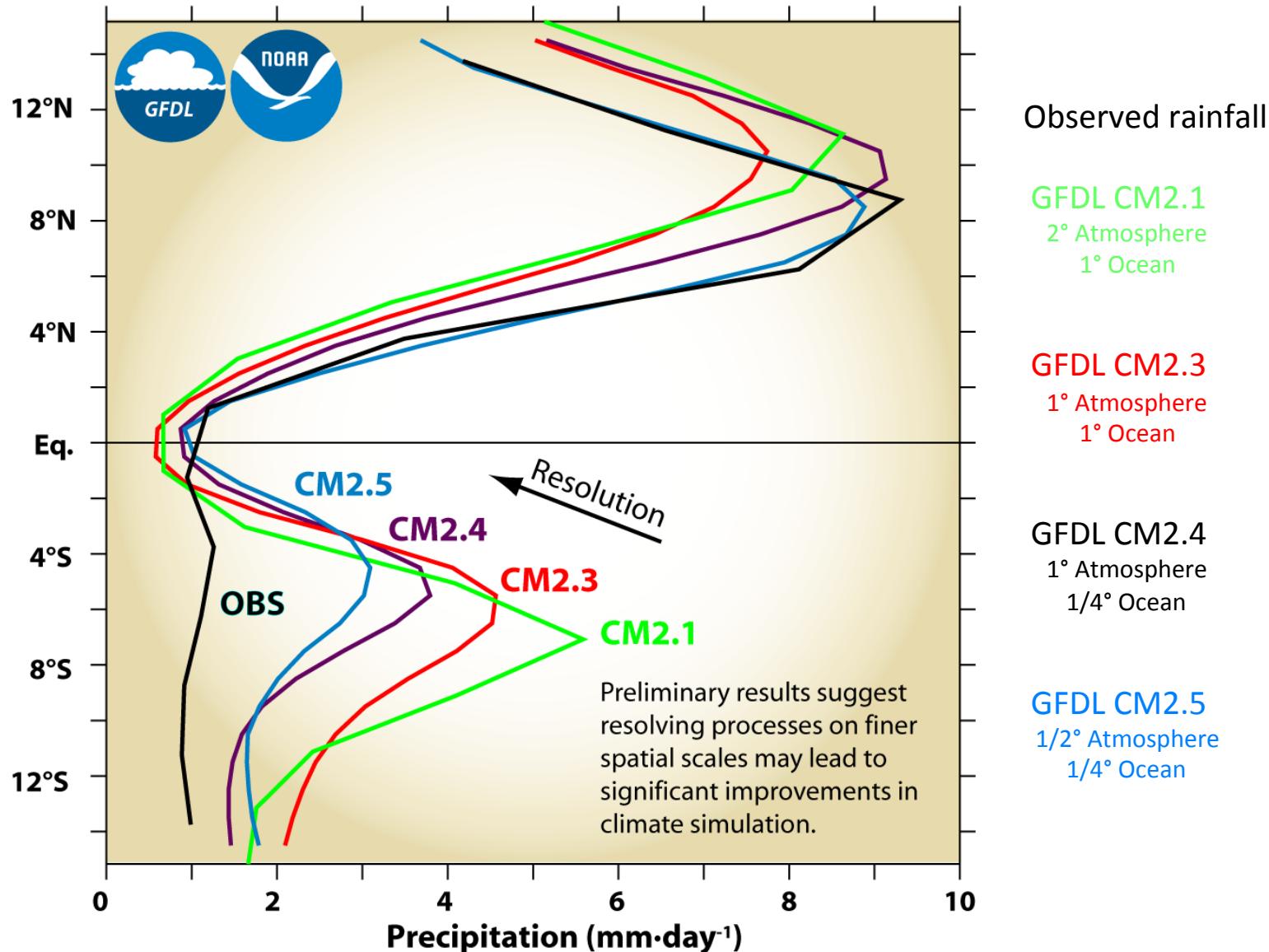
Importance of High Resolution

Evolution of ECMWF scores comparison
northern and southern hemispheres



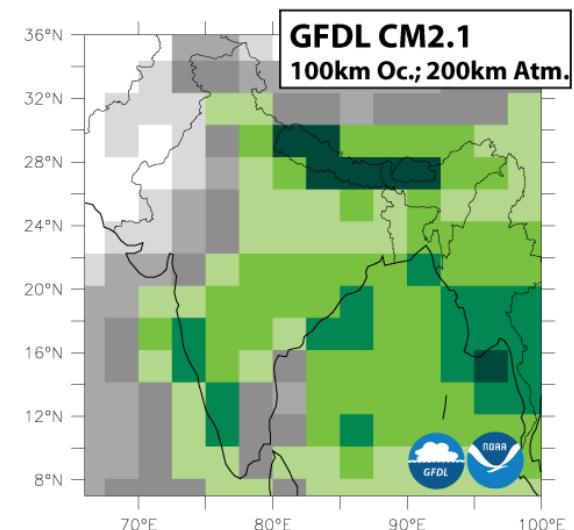
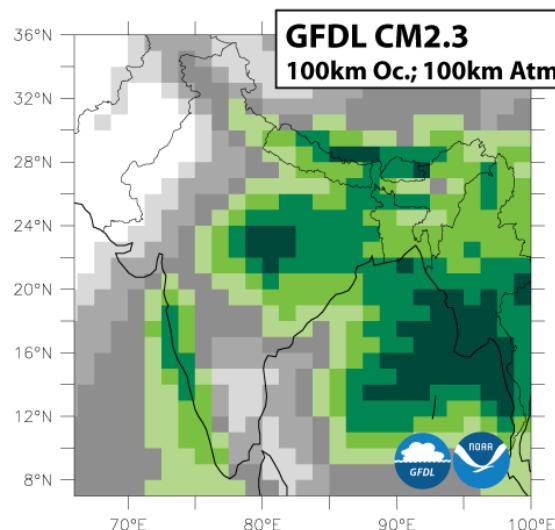
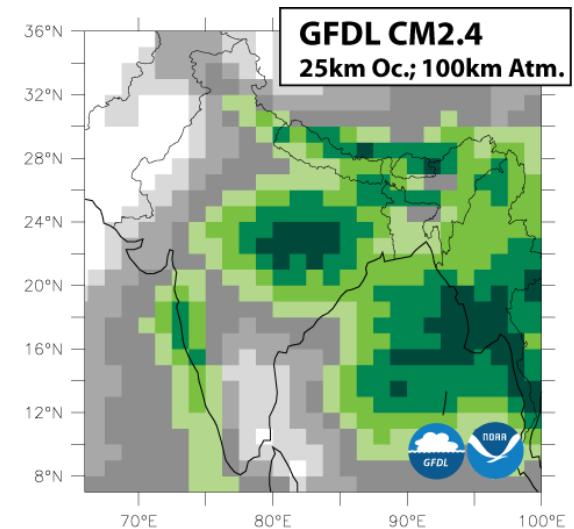
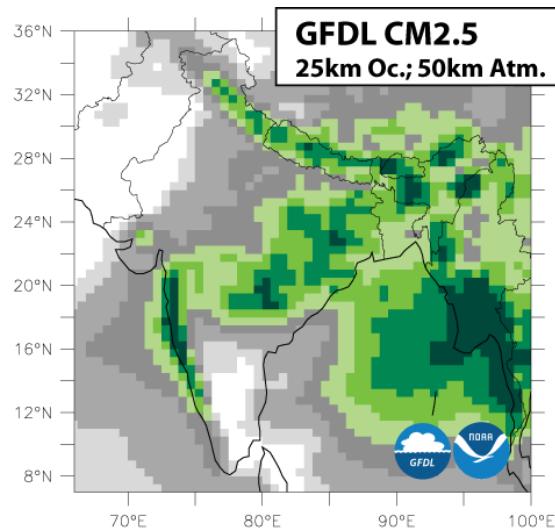
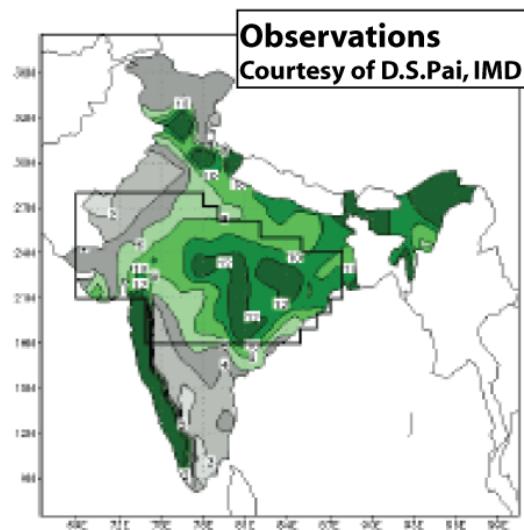
Courtesy of ECMWF. Adapted and extended from Simmons & Hollingsworth (2002)

GFDL Coupled Model East Pacific Precipitation (150°W-90°W)



Courtesy: Gabriel Vecchi (GFDL)

Enhanced Resolution and Coupling Improve Monsoon Representation

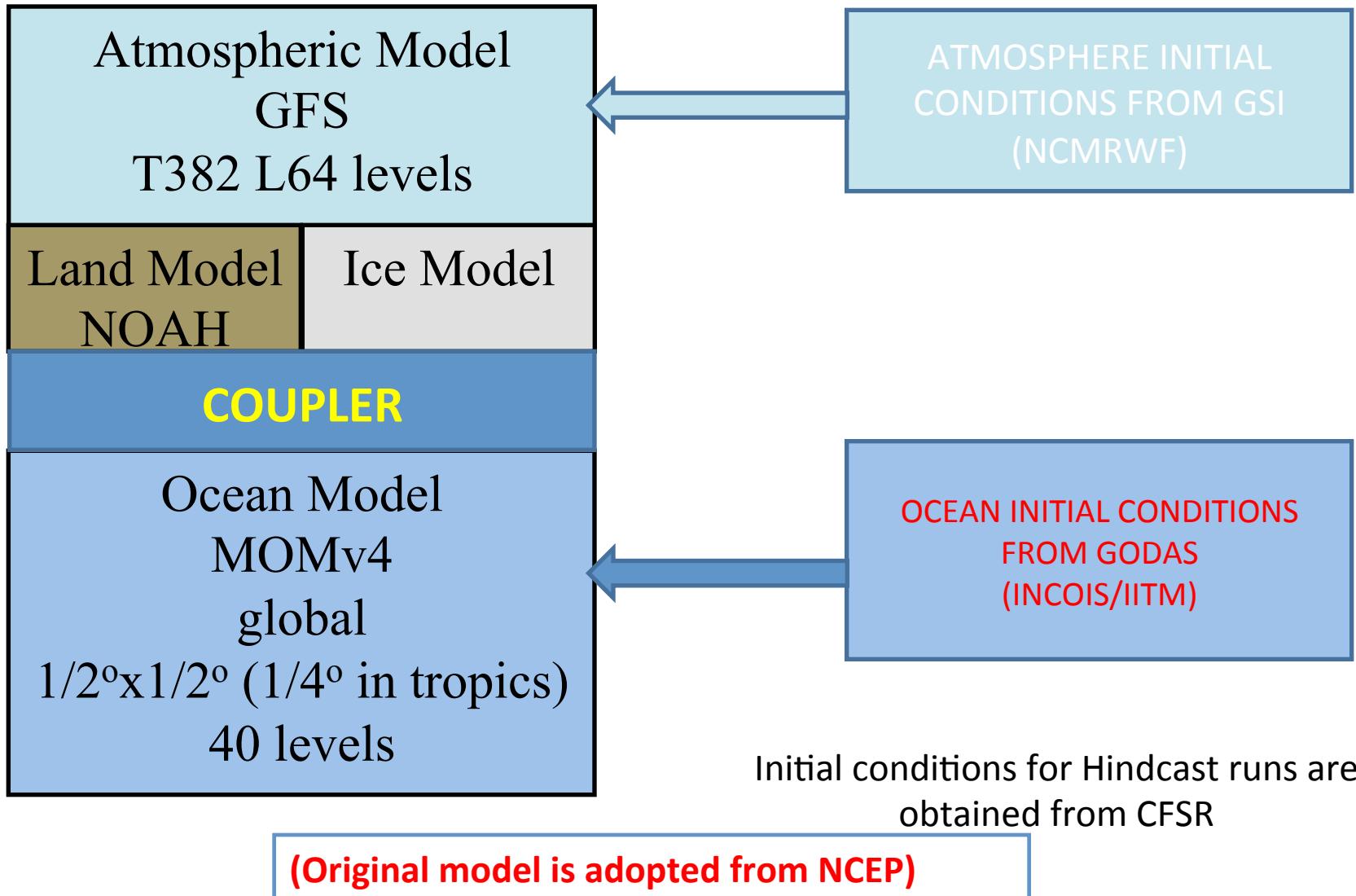


July-August Mean Rainfall (mm/day)

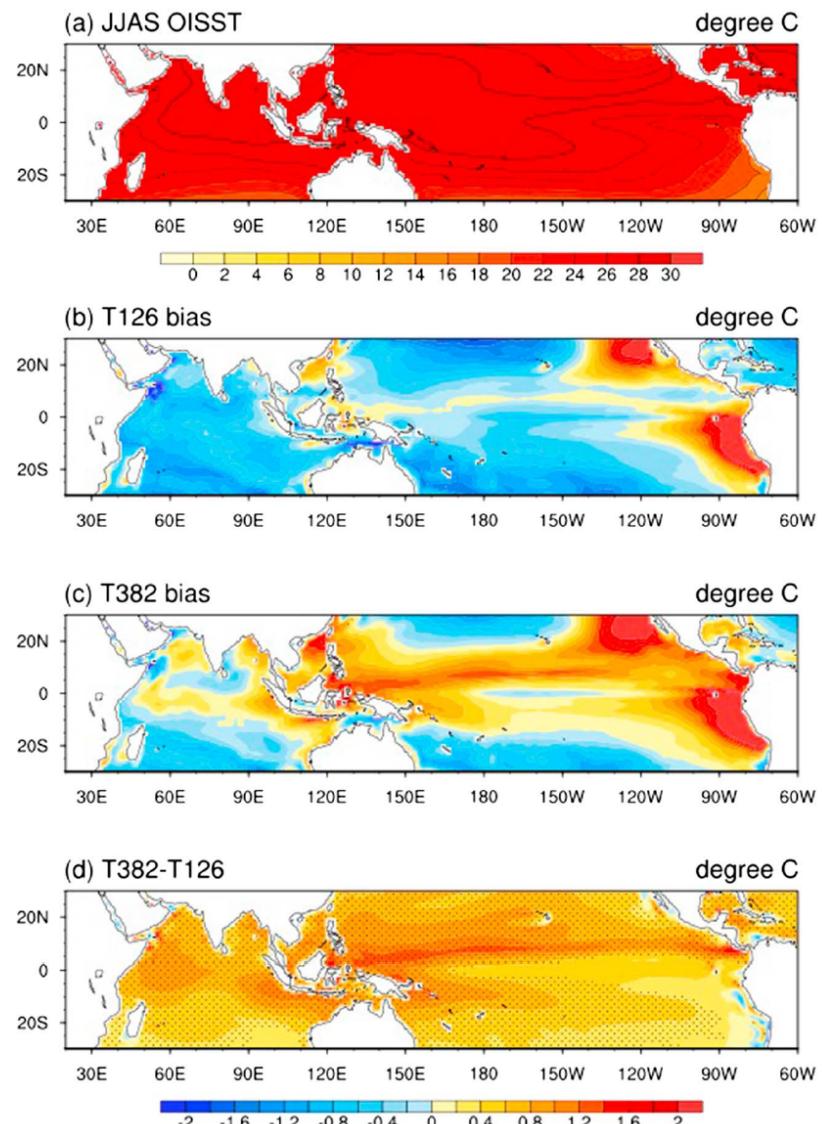
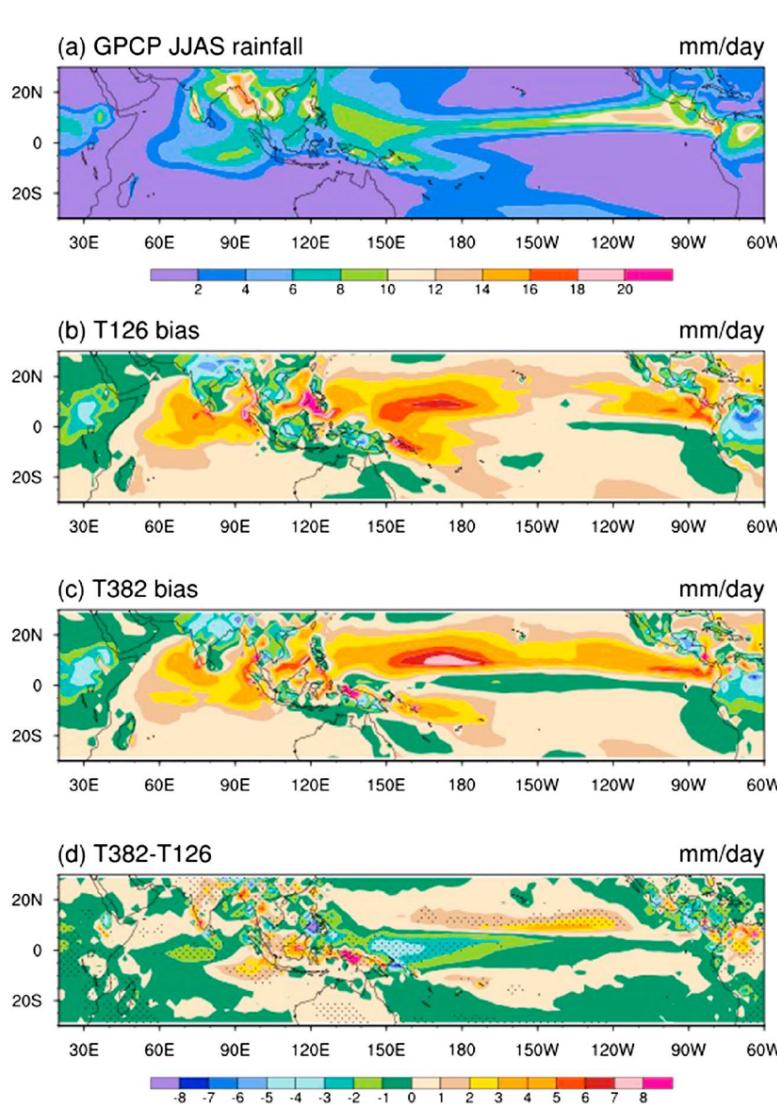


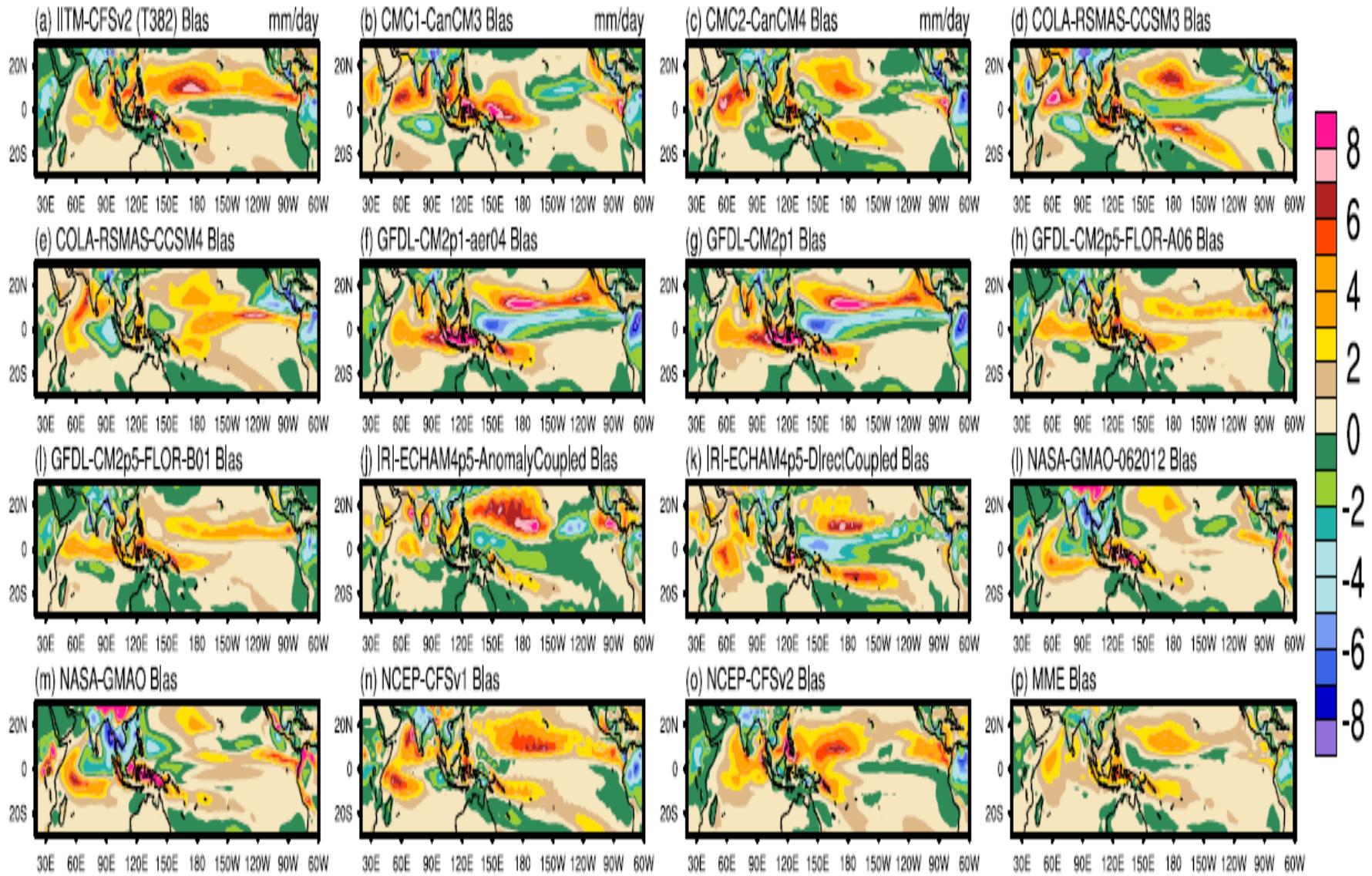
Courtesy: Gabriel Vecchi (GFDL)

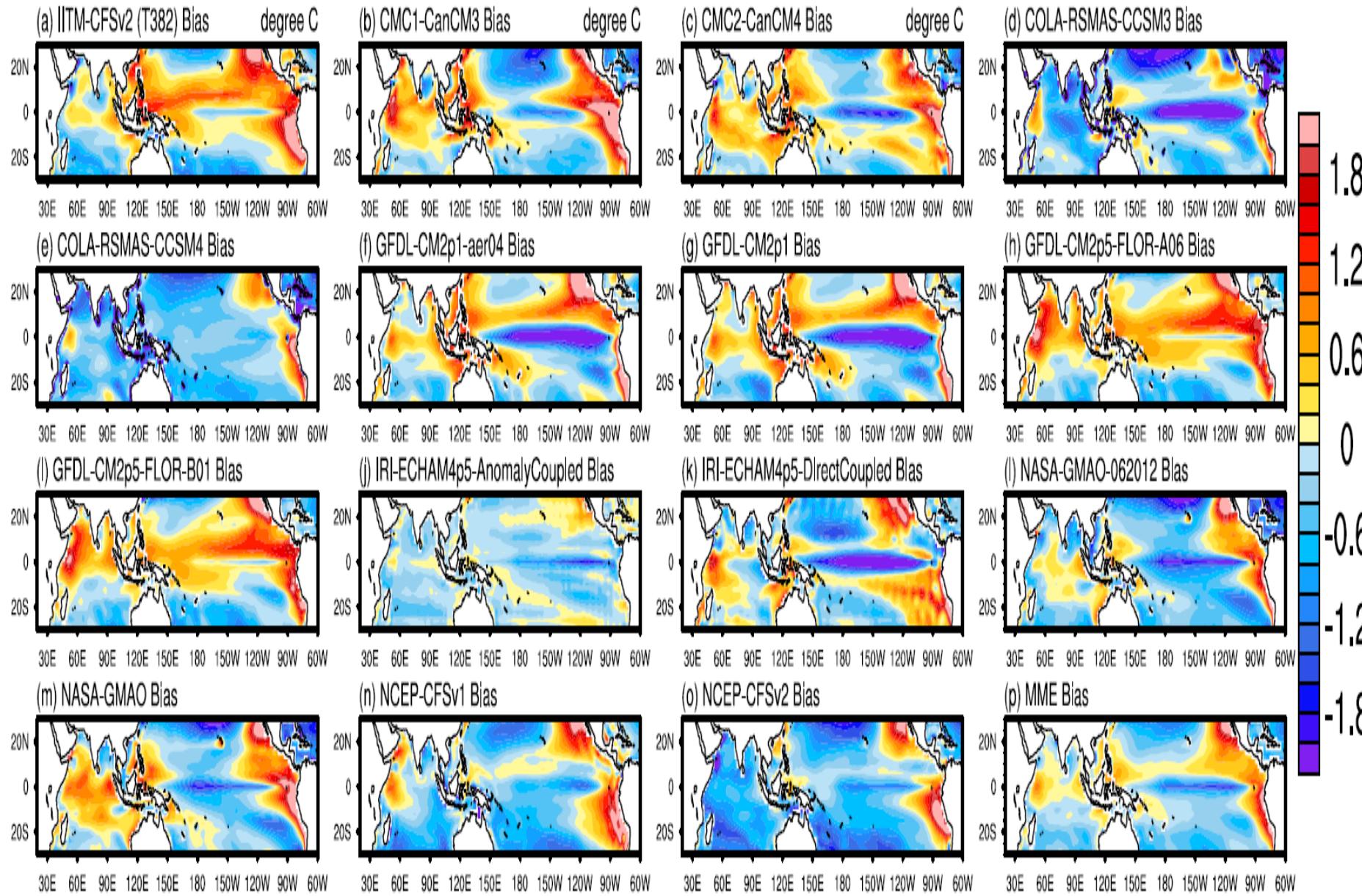
IITM CFS Model: Seasonal Prediction



SST/Rainfall Bias in T126 and T382

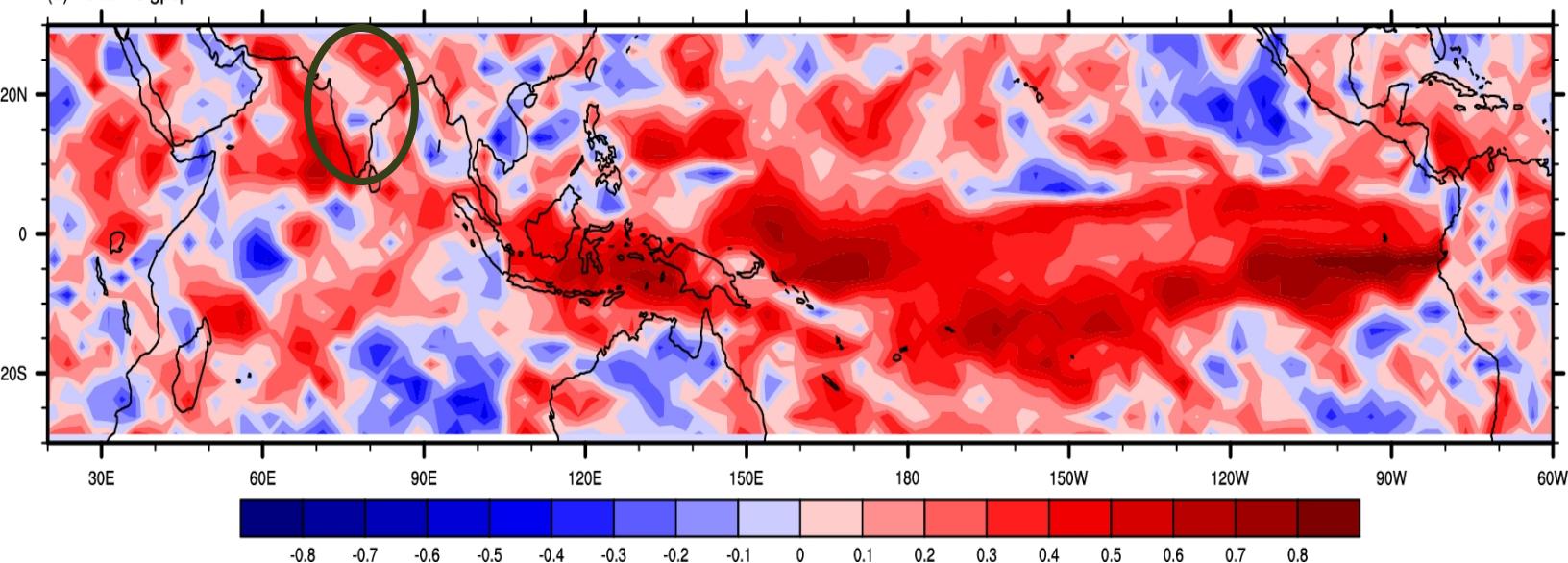






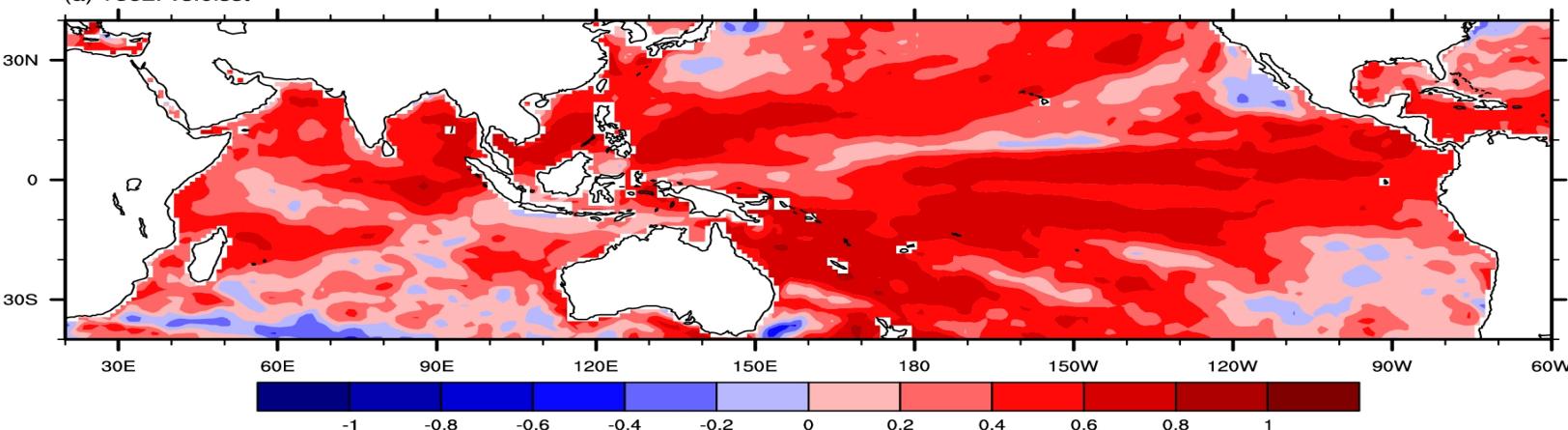
T382L64 Skill of Rainfall/SST

(a) T382. vs.gpcp

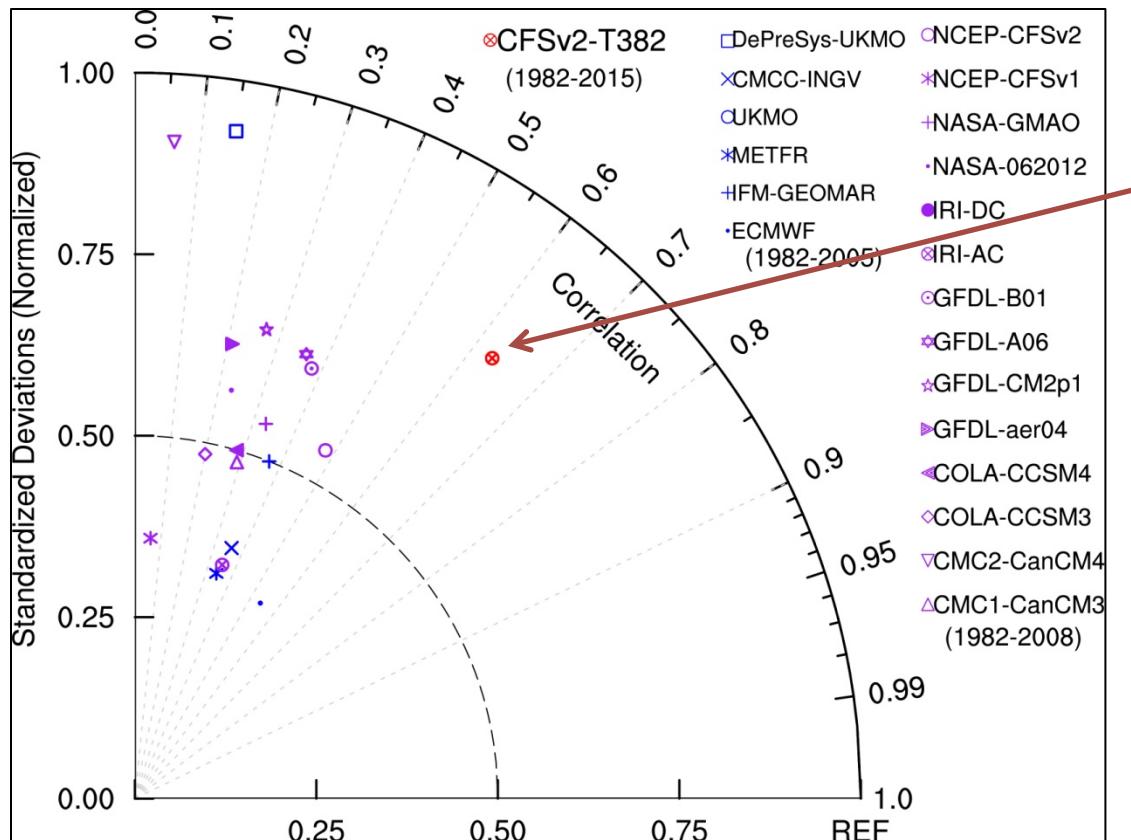


GPCP VS
T382

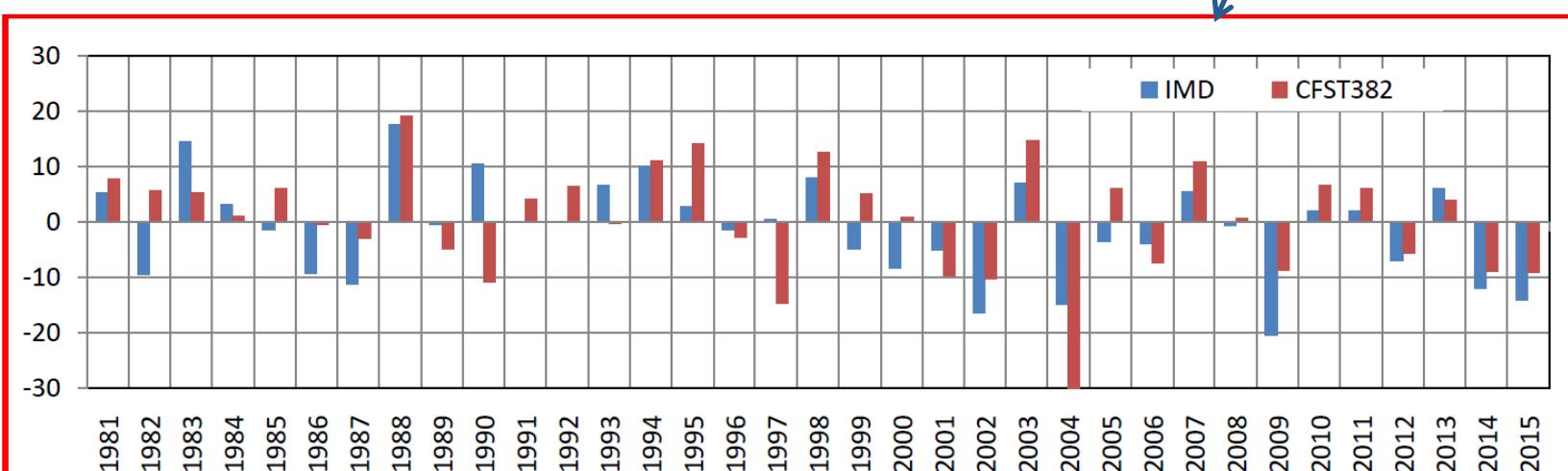
(a) T382. vs.oisst



ERSST VS
T382



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



Prediction Skill of Monsoon Rainfall in 5 Homogenous Regions

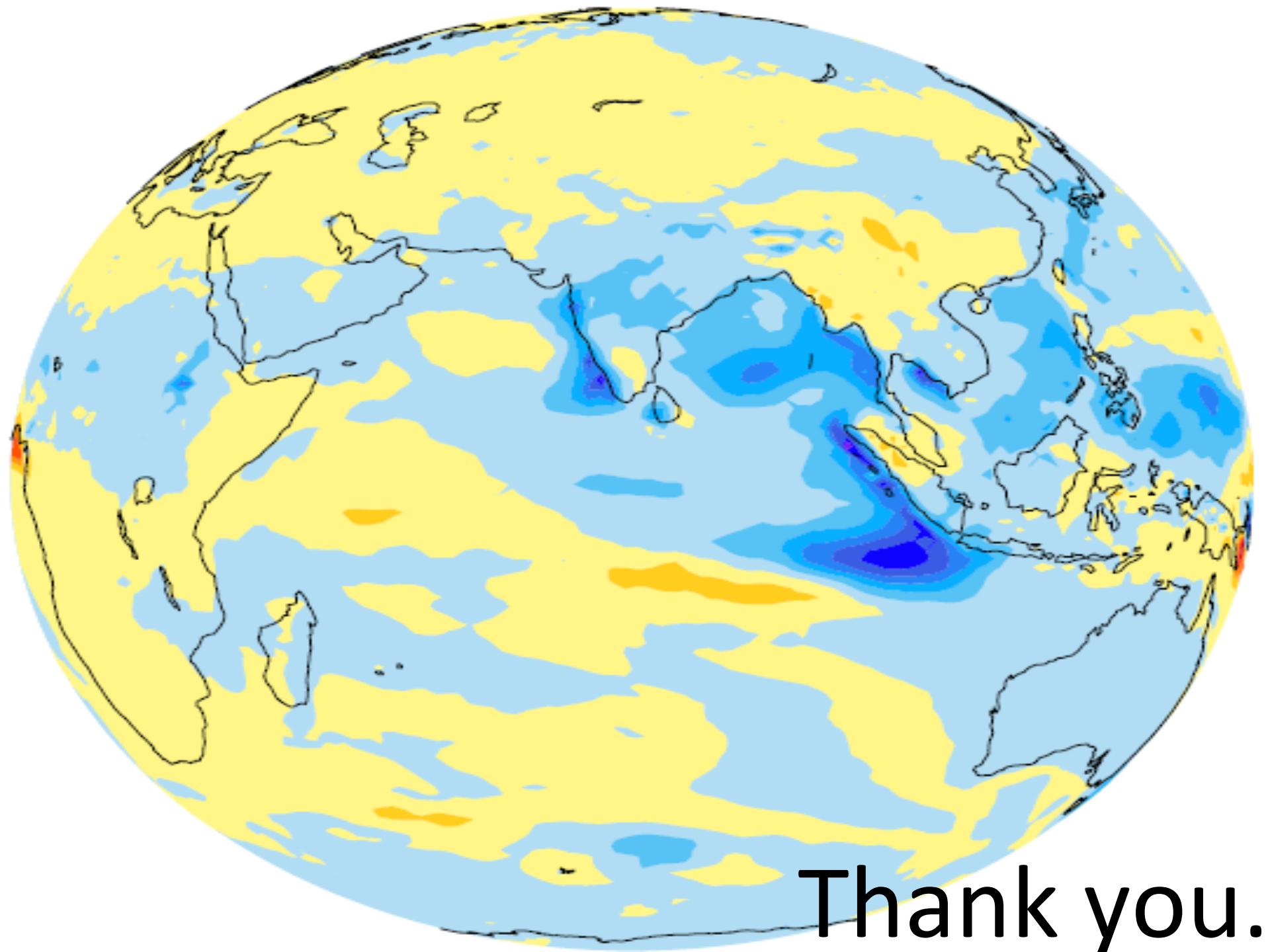
ISMР Skill (correlation between model JJAS rainfall and observation rainfall) for all the homogenous regions over India. Green colour indicate indicates 95% confidence level. February IC during 1981-2008.

Region	T126 ($\approx 100\text{km}$)	T382($\approx 38\text{km}$)
Central North East Indian (CNEI)	0.22	0.43
North East India (NEI)	0.08	0.45
North West India (NWI)	0.21	0.41
West Central India (WCI)	0.14	0.22
South Peninsular India (SPI)	0.43	0.26

Impact of the New SAS on Indian Summer Monsoon Prediction in CFS V2

	ORIG	NEWSAS
AILR (IMD)	0.30	0.37
AILR (GPCP)	0.34	0.52
NINO 3.4	0.55	0.56
NINO 3	0.54	0.58
NINO 4	0.50	0.48
IOD E	0.49	0.61
IOD W	0.59	0.33

Following Han and Pan (2011) and Ganai et al (2014)'s long integrations with new SAS, we have tested impact of new SAS Parametrization on seasonal prediction. [Ens. Size:5, Period: 1982-2008] Phani et al., (2016, Submitted)



Thank you.