Large Scale DNS
(Expectations)

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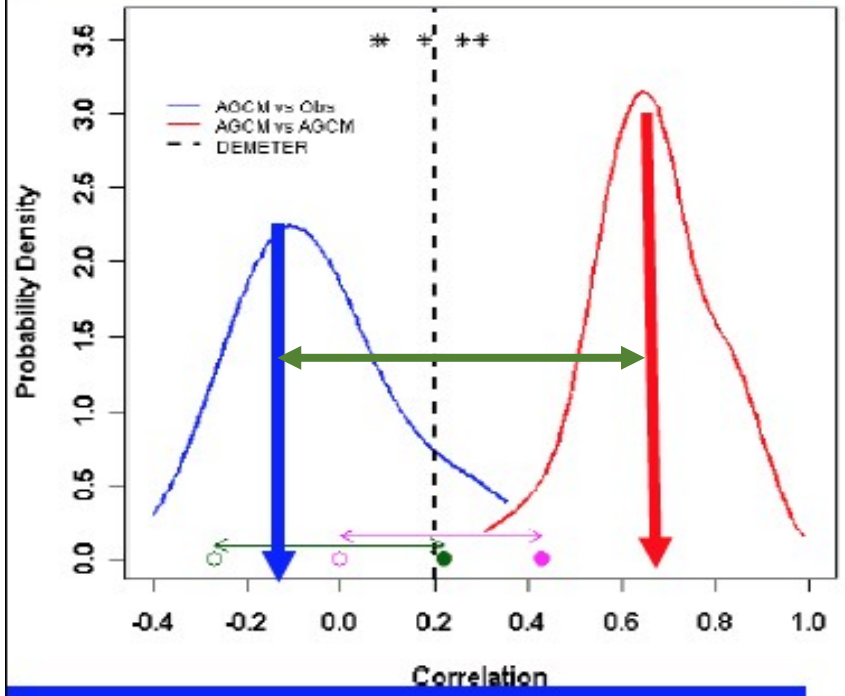
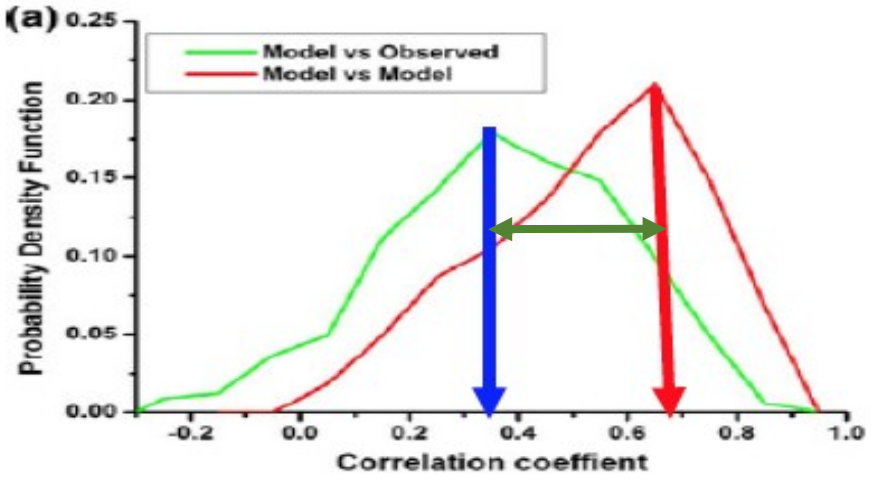
Outline

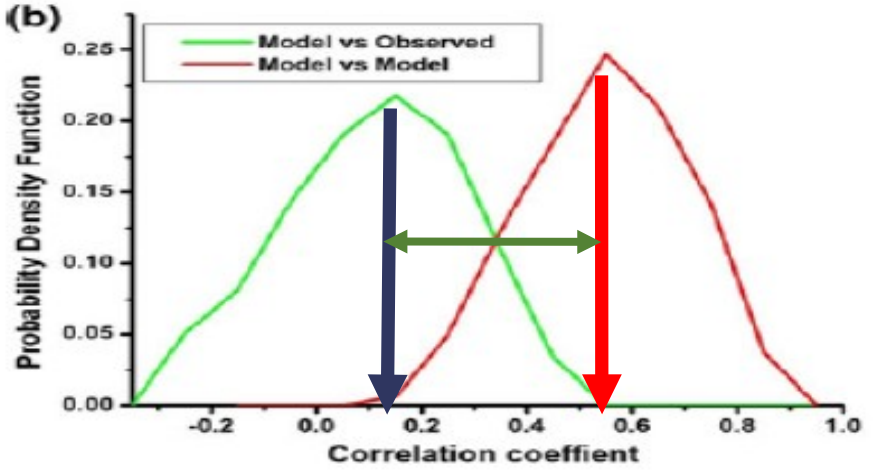
- Status of the state-of-the-art prediction System
- Model limitations
- How DNS/LES can help and what is needed?

Potential Predictability VS Actual Prediction Skill of ISMR

Krishna Kumar et al , 2005, GRL







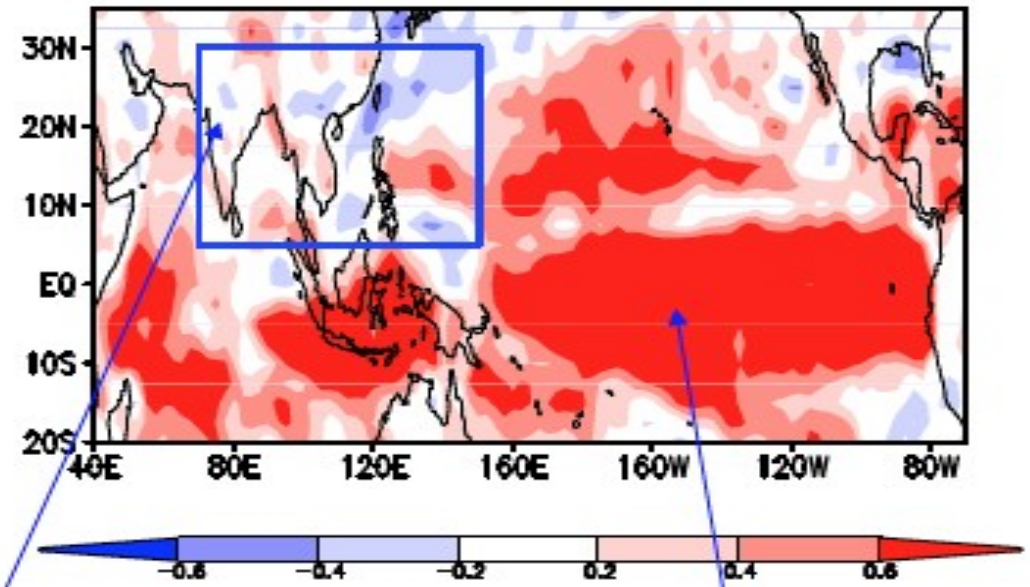
Rajeevan et al. 2011, Climate Dynamics

Fig. 13 PDFs of the correlation skill of ISMR based on a theoretical "perfect model" analysis (*red curve*) and based on the actual skill compared to the observed ISMR (*black curve*). a for the period 1960–1979 and b 1980–2005

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

Earlier version models

1979-1999

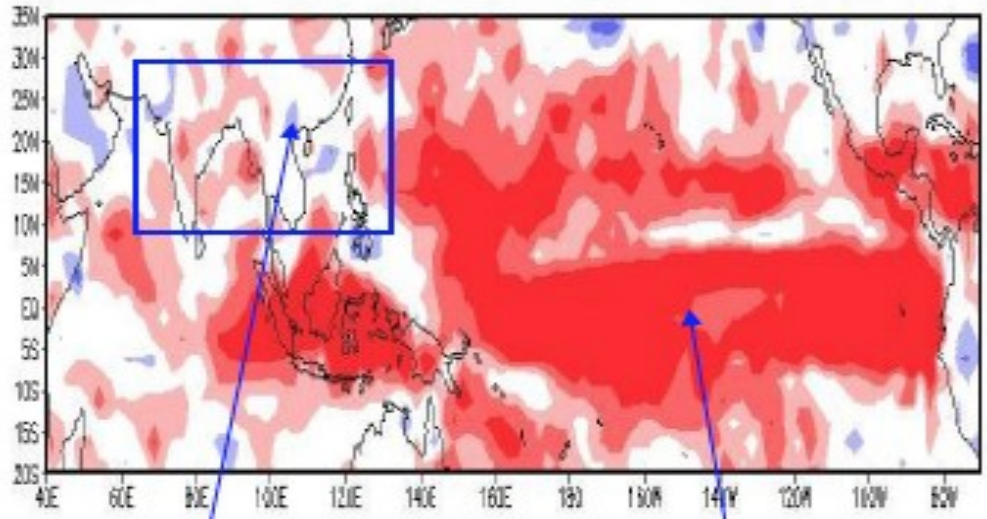


Poor skill

High skill

Latest models (ENSEMBLES)

1979-1999



Improved skill

High skill

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!

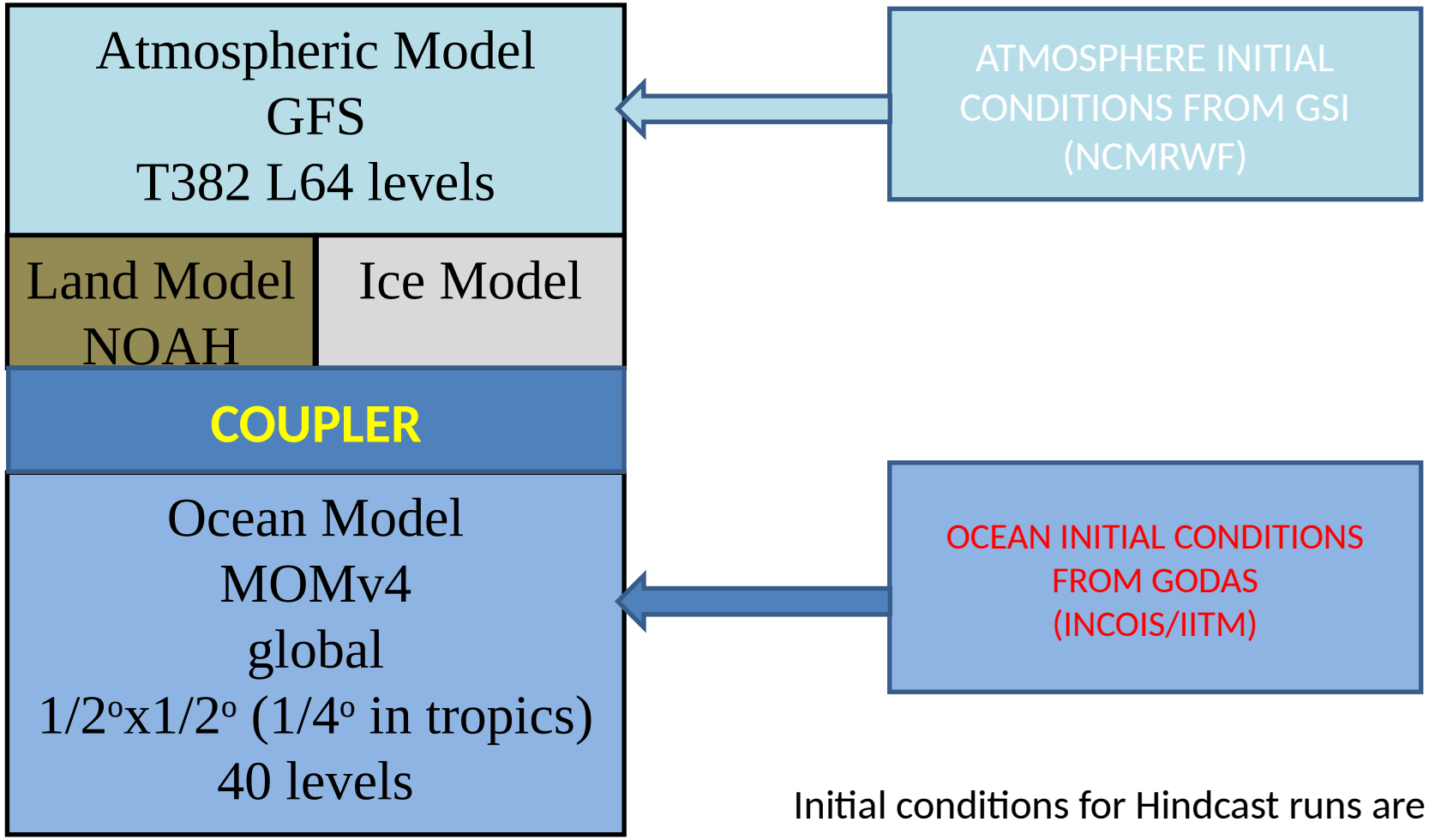
Developmental Activities under Monsoon Mission

- High Resolution Seasonal/Extended/Short Range prediction
- New LSM development
- Modified Zhao Carr cloud microphysics/ WSM6
- New Ocean model (MoM5) incorporation in CFS
- Revised SAS
- Super Parametrization-CFS
- Multi Cloud multi model stochastic parametrization in CFS
- LETKF coupled data assimilation

Improvements in monsoon characteristics due to developmental activities (Parametrization schemes, LSM, Ocean and resolution)

- Decreased dry bias over Indian Land mass
- Decreased cold tropospheric bias
- Decreased SST cold bias in tropics
- Improved representation of snow cover thickness and time of melting
- Improved ENSO characteristics and IOD characteristics.
- Improved teleconnections
- Better representation of extratropical and tropical interactions

IITM CFS Model: Seasonal Prediction



Initial conditions for Hindcast runs are obtained from CFSR

(Original model is adopted from NCEP)

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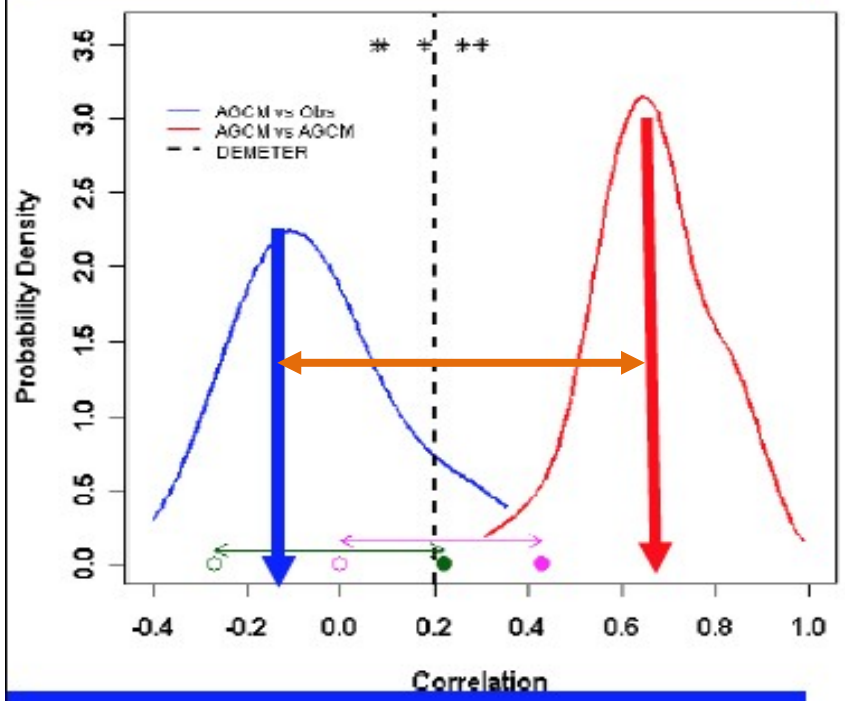

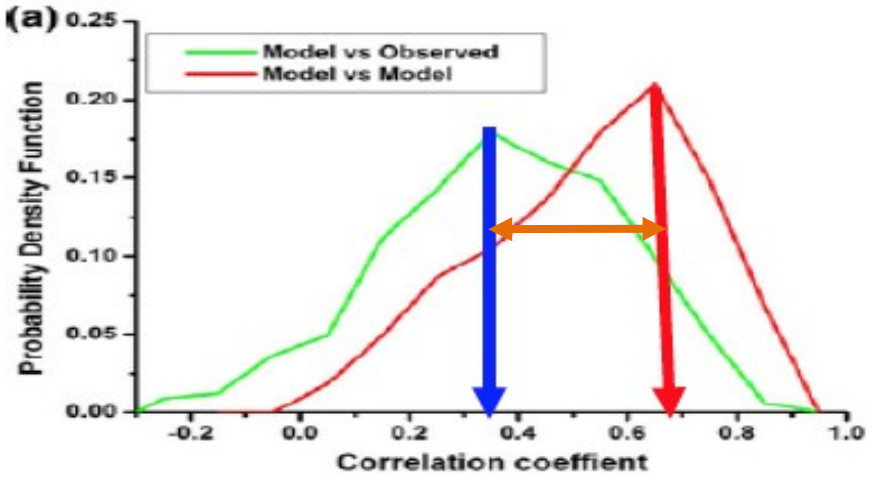

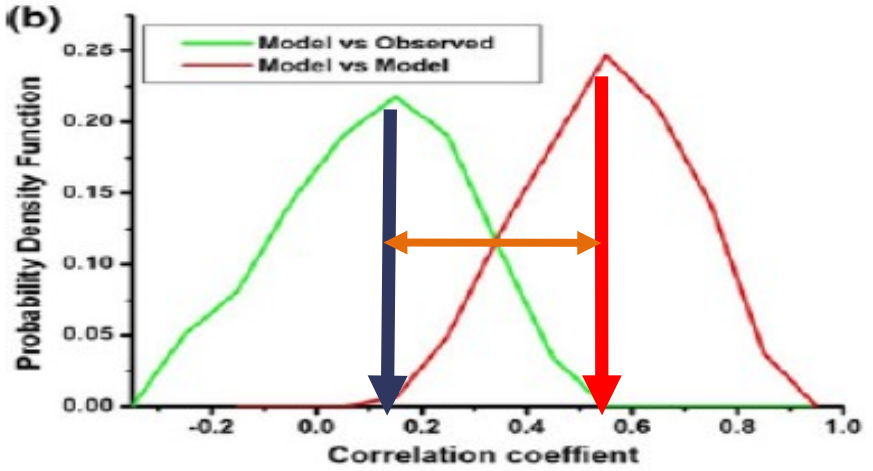

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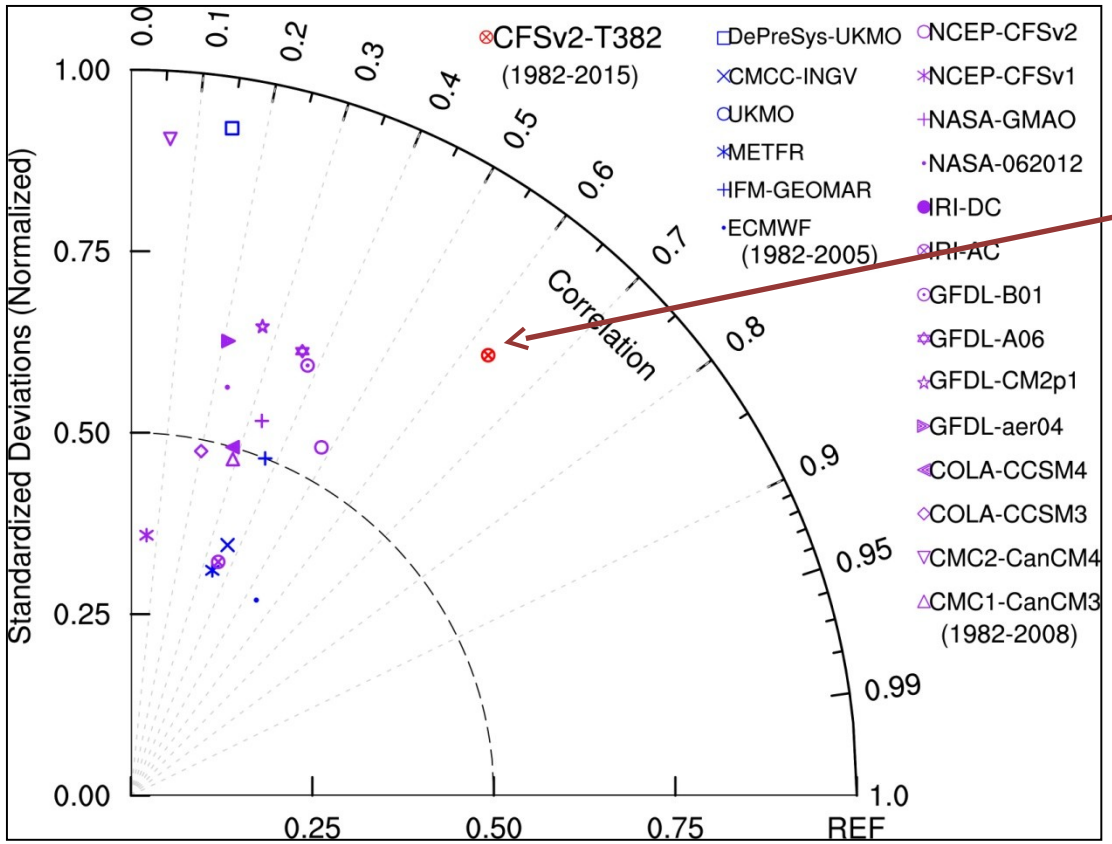
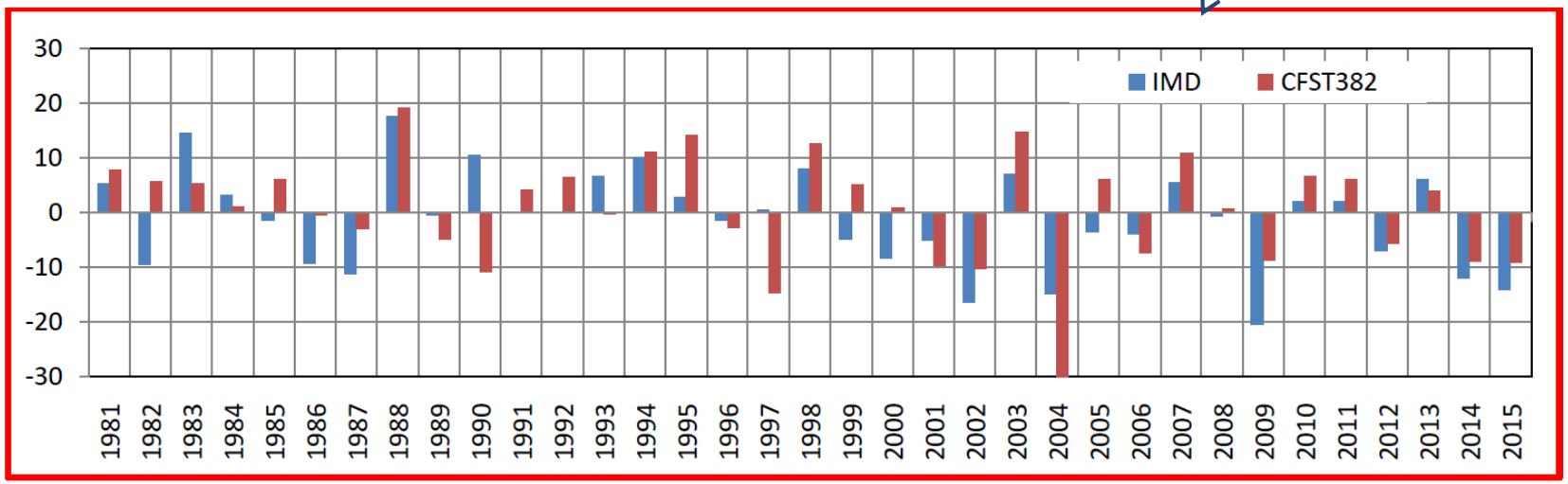
Fig. 13 PDFs of the correlation skill of ISMR based on a theoretical "perfect model" analysis (*red curve*) and based on the actual skill compared to the observed ISMR (*black curve*). a for the period 1960–1979 and b 1980–2005

Present Day Model Potential Skill vs Actual Skill

0.7 vs 0.64



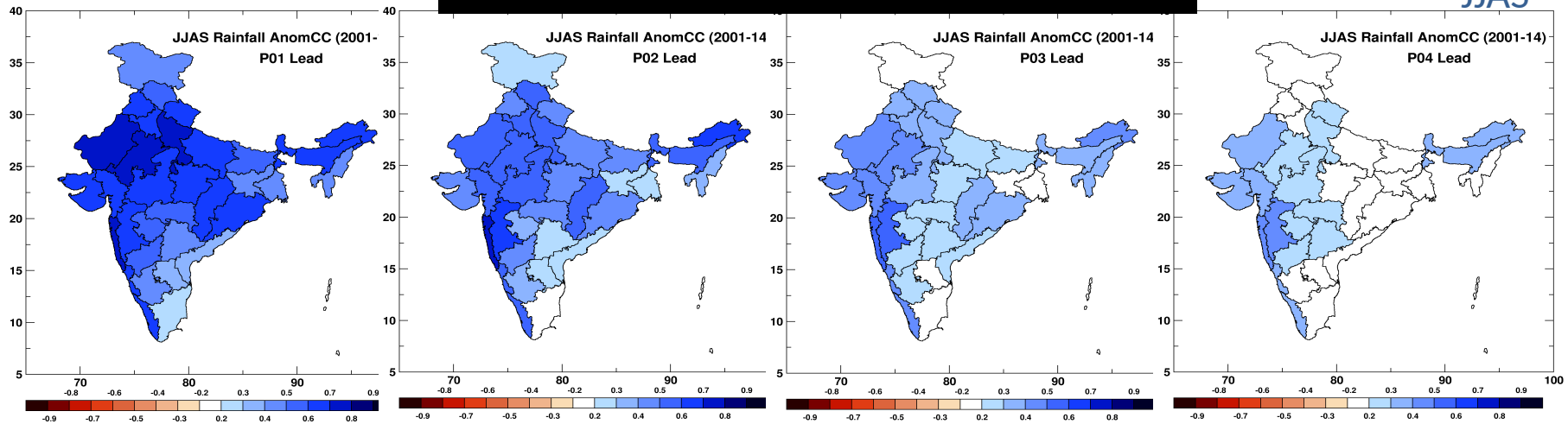
Monsoon Mission Model Performance (Prediction Skill as well as interannual variance) is better than other models for Indian Monsoon.



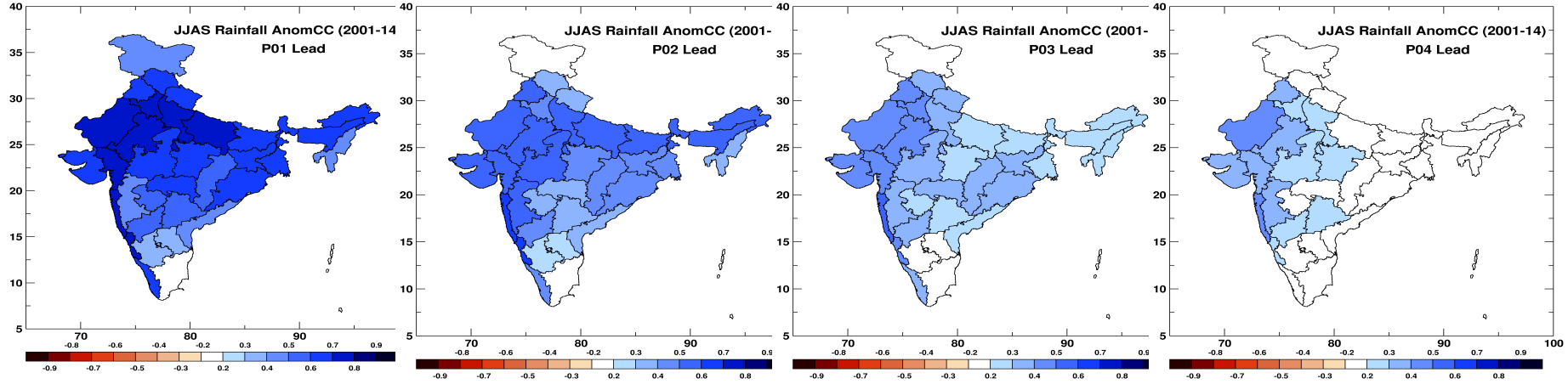
Subdivision Wise Statistics

ECMF MME

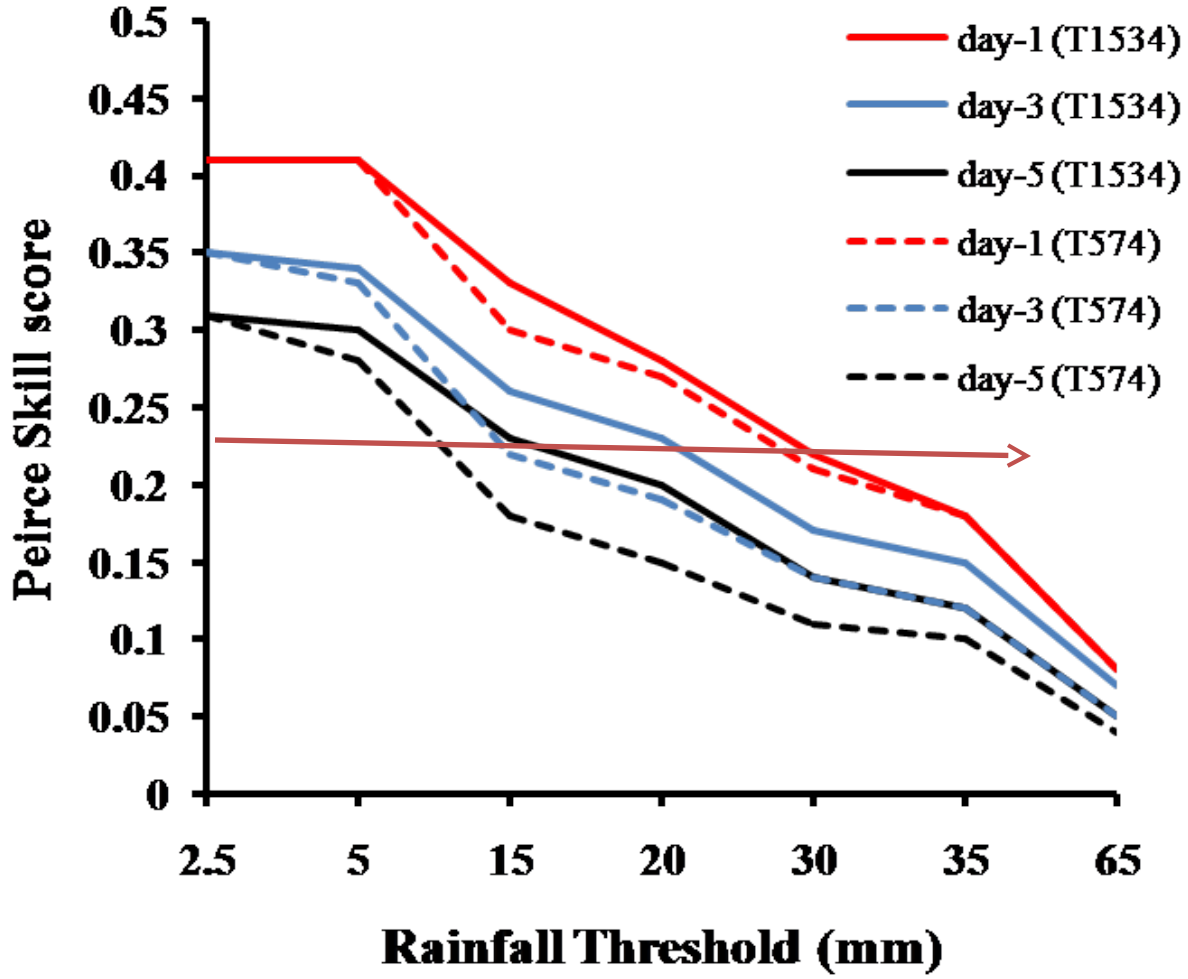
JJAS



IITM MME



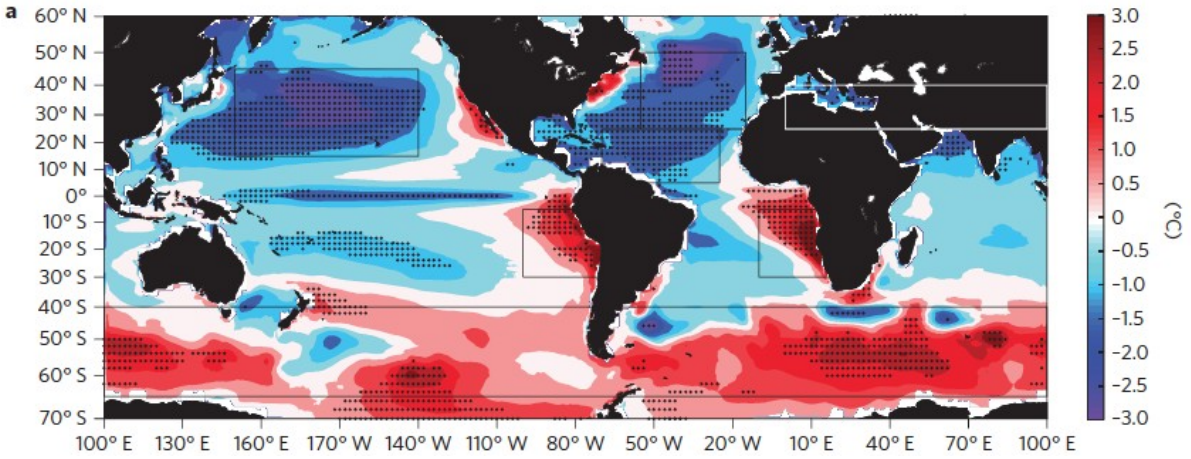
High Resolution global 12.5 km model gives better skill (The skill of GFS T574 with 3 day lead is now extended to 5 days with T1534 ~12.5 km global GFS



How Forecast Errors evolve?

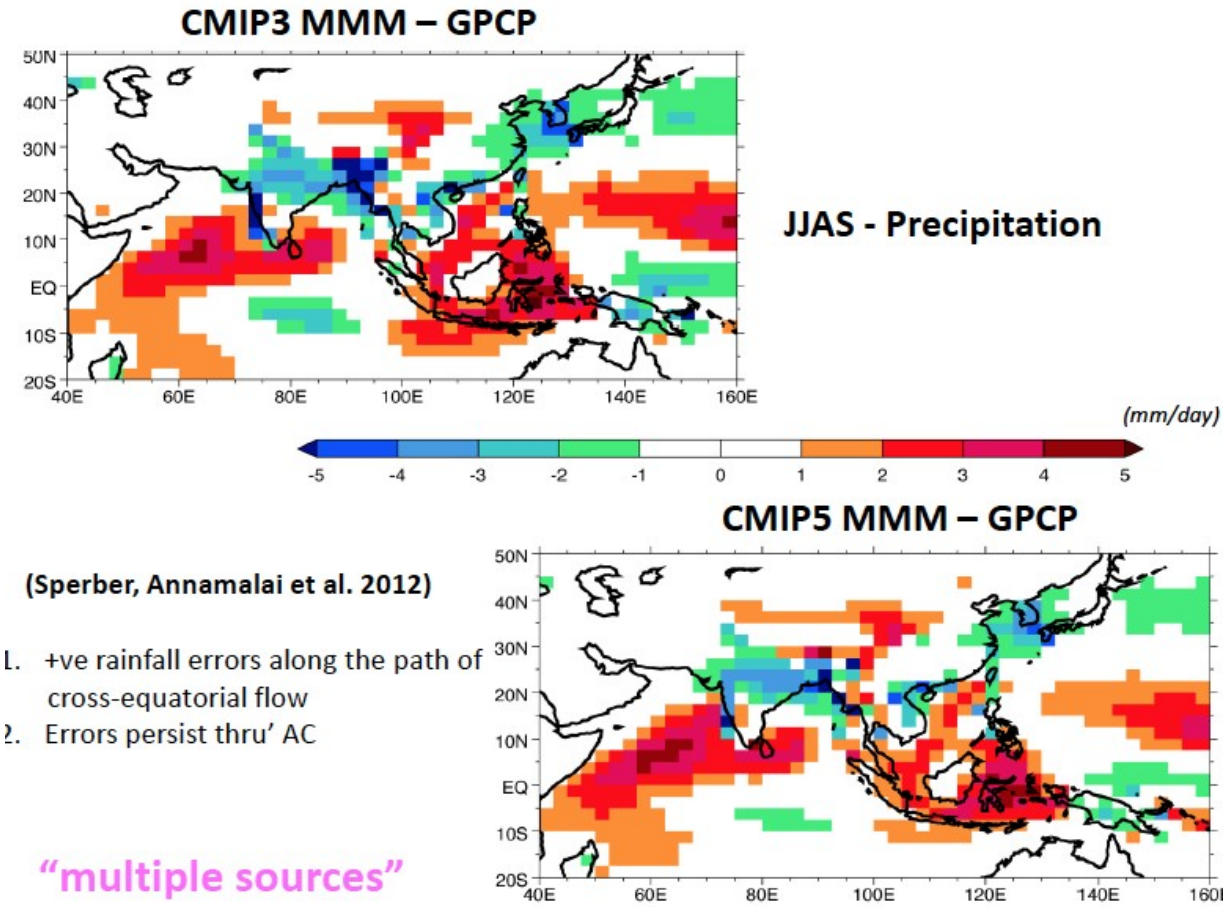
- **Combined effects of inadequate and incomplete observations**
  - ✓ Data Assimilation methods
  - ✓ Ensemble Prediction
  - ✓ More relevant and accurate observations
- **Model deficiencies**
  - ✓ Numerical methods
  - ✓ Approximations made in formulation of the model equations
  - ✓ Spatial Resolution
  - ✓ Sub-grid Scale Parametrization

Systematic Model Biases in CMIP5 models



SST Bias (Wang et al., 2014)

Rainfall bias (Sperber et al., 2012)



(Sperber, Annamalai et al. 2012)

1. +ve rainfall errors along the path of cross-equatorial flow
2. Errors persist thru' AC

"multiple sources"

What is involved in resolving all scales (Ocean Model)?

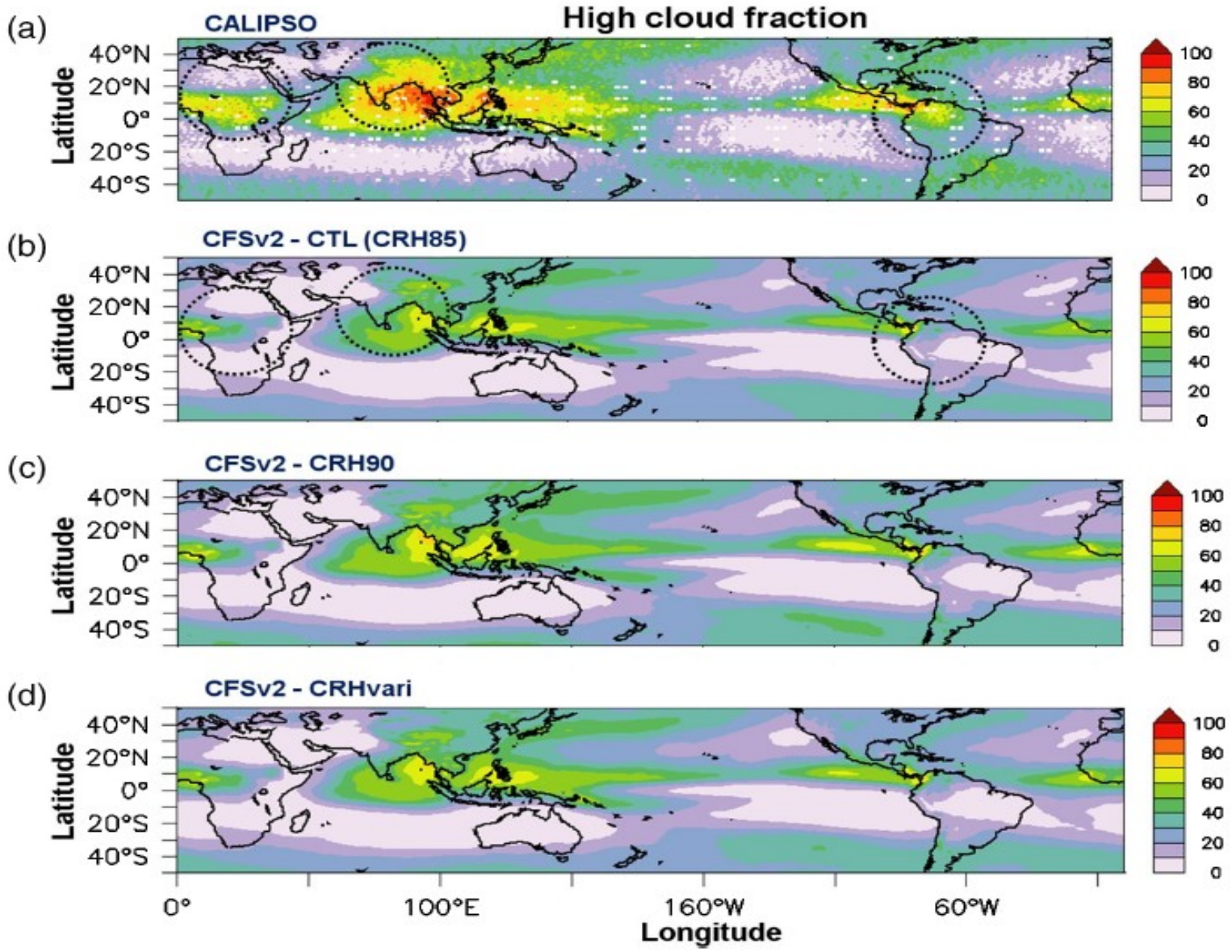
- Temporal resolution : 1 second
- Spatial resolution : 10^{-3} m
- Volume of the Ocean: 1.3×10^{18} m^3
- Integration duration : Millennium
- Total # time steps : 3×10^{10}
- Total # grid cells : 1.3×10^{27} (Which is 10^4 times more than an Avogadro's number)

A computer to calculate these many integrations is not available at present. Even if it is made available it is impossible to complete the simulations in reasonable time.

What Parametrizations are used in climate models?

- Unresolved Turbulent transfer processes in the boundary layer and the free atmosphere.
- Convective and stratiform clouds
- Precipitation
- Radiative transfer and heating
- Heat and water storage
- Exchanges between land surface and atmosphere

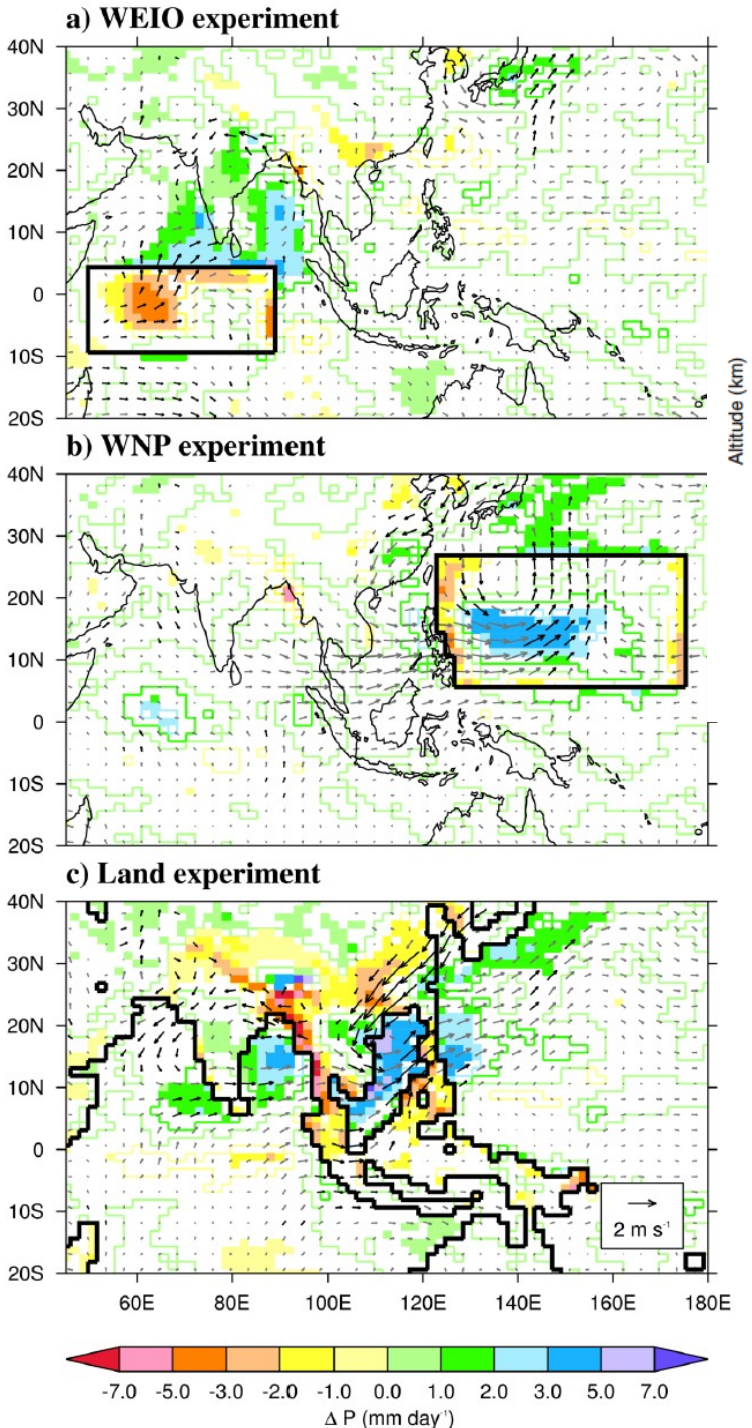
Impact of critical relative humidity on High cloud Simulations?

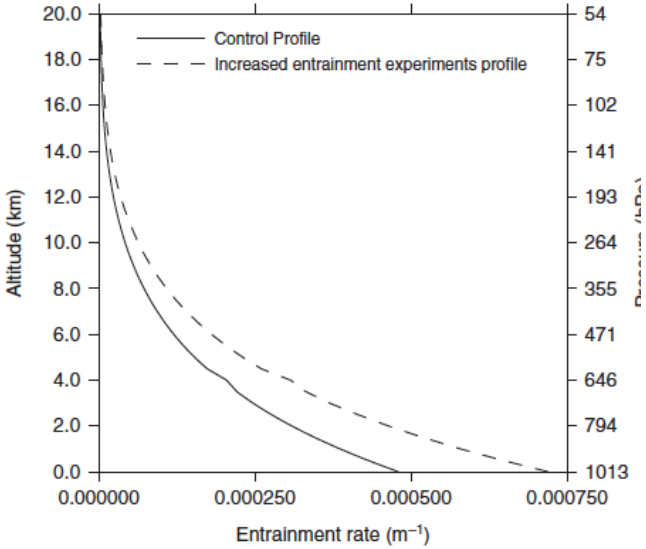


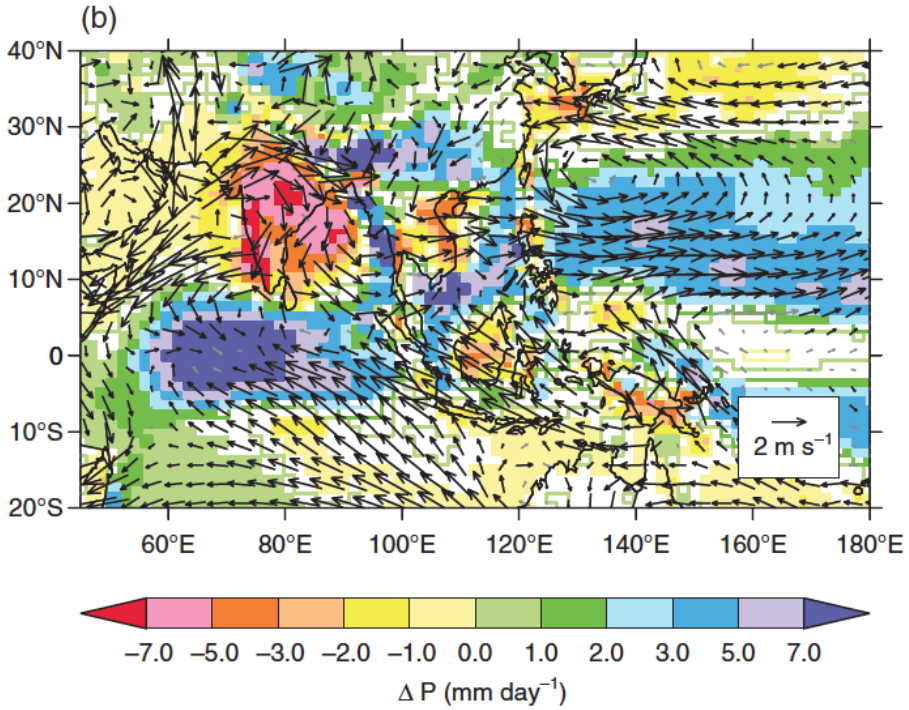
Control (CTL) run: value of RHcrit is set as 85, 85, 85% for low, mid, highlevels, respectively (default values specified in CFSv2).
CRH90 run: value of RHcrit is set as 90, 90, 90%.
CRHvari run: value of RHcrit is set as 88, 90, 89%.

Source: Hazra et al., (2015)

Impact of entrainment rate on Simulations (Rainfall) ?







Effect of locally-targeted increases in the entrainment rate on JJAS precipitation. Despite both being moist tropical oceans, changing the entrainment rate in the WEIO and WNP has the opposite impact on precipitation.

Source: Bush et al., (2013) ; Andrew Turner

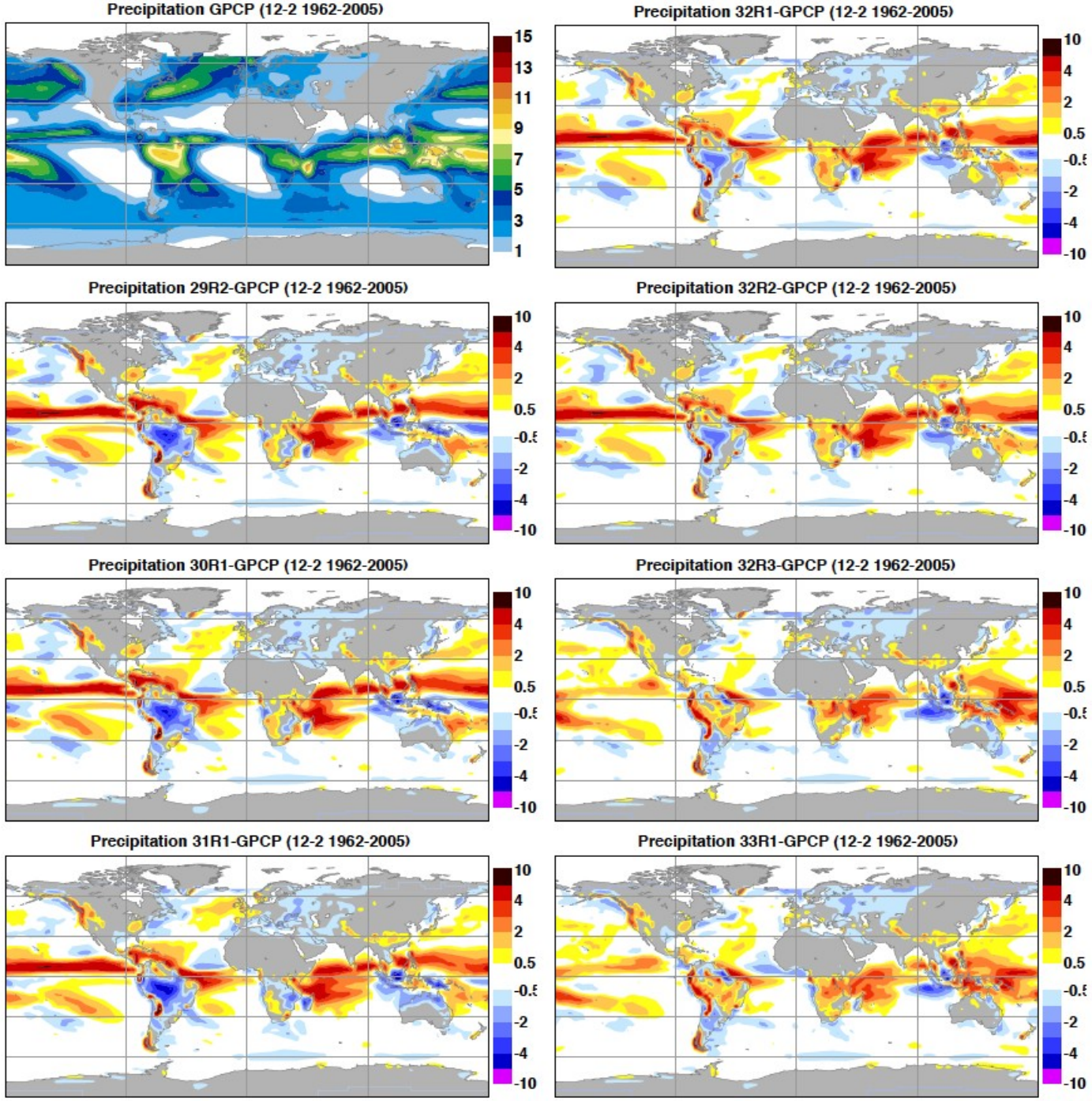
Similar attempts at ECMWF

Table 1: Main characteristics of the datasets used in this study. Values of the resolution given in parentheses are approximate values in degrees latitude/longitude.

Cycle	Introduced	Modifications
29R2	2005/06/28	Modification to convection scheme
30R1	2006/02/01	Increased vertical resolution (L60 to L91)
31R1	2006/09/12	Revised cloud scheme (ice supersaturation + numerics);
		implicit computation of convective transports;
		introduction of turbulent orographic form drag (TOFD) scheme;
		revised parameterization of sub-grid scale orographic drag
32R1	not operational	New short-wave radiation scheme;
		introduction of McICA cloud radiation interaction
		MODIS land surface albedo;
		retuned ice particle size;
		retuning of GWD (increase by a factor of two)
32R2	2007/06/05	Minor changes to the forecast model
32R3	2007/11/06	New formulation of convective entrainment and relaxation time scale;
		reduced vertical diffusion in the free atmosphere;
		modification to GWD scheme at the top of the model;
		new soil hydrology scheme
33R1	2008/06/03	Slightly increased vertical diffusion;
		increased orographic form drag;
		retuned entrainment in the convection scheme
		bugfix scaling of freezing term in convection scheme
		changes to surface model

Source: Jung et al., (2008)

Response of Precipitation to various developmental activities in ECMWF



Summary

Small Scale Simulations (both DNS and LES) should be focused toward decreasing the uncertainties in the parametrization used in climate models.

- **Large scale simulation group should carryout a detailed process-based analysis of systematic model biases and identify the lacuna of the parametrization scheme used.**

- **Small Scale Simulations group take a clue from the large scale simulations (particularly the systematic biases in the climate models) and design and carryout the experiments in such a manner which will help large scale groups to fine tune the parametrization schemes.**

Thank You