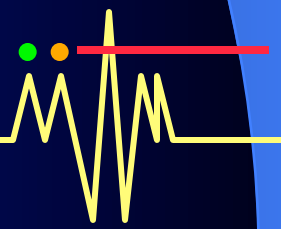
Opportunities and Challenges in Monsoon Prediction in a Changing Climate:(OCHAMP-2012) A Report

B.N.Goswami

Indian Institute of Tropical Meteorology (IITM), Pune

Outline

- **Background of the Conference : IITM's Golden Jubilee**
- **Conference Statistics**
- **Highlights of the Conference**
- **Summary of the Panel Discussion**



Background

- As a part of celebration of Golden Jubilee Year (1962-2012) of IITM a conference on Opportunities and Challenges of Monsoon Prediction in a Changing Climate (OCHAMP-2012) was proposed by IITM during 21-25 February, 2012.
- Strong support from WCRP/WWRP made the Conference truly International !
- With support from Ministry of Earth Sciences (MoES), Govt. India and ICTP, Trieste, we added a Training component by inviting a large number Ph.D students and early career scientists to interact with the Experts.

Inauguration of OCHAMP by WMO Secretary General

Participants

IITM in Evolution






1959 IMD sows seed	1962 the Birth	1962-70 Nurtured by IMD	1971 Autonomy	1972-2005 Identity Established	2006-2011 Fast Growth & Maturity

Proposal for the Institute of Tropical Meteorology

At the Third Session of WMO Congress in May 1959 following Resolution was adopted:

"Resolution 22 (CG-II)
Research Institute for Tropical Meteorology

The Congress, considering,

(1)The urgent need for research work in tropical Meteorology especially as regards developing forecasting techniques,

(2) The limited facilities and resources available in tropical countries for carrying out search,

(3) The great economic value of improved Met. Services in the tropics for public transport, agriculture, public health, water resource development and many other branches of the national economy,

DECIDES that the World Met. Organization should do everything possible to initiate, sponsor and encourage the establishment and operation of one or more research institute for tropical meteorology &

DECIDES the Executive Committee to take all possible steps to implement the above decision"

Resolution 22 (CG-II) adopted at the Third Session of the WMO Congress

No.B86400

India Meteorological Department

From

The Director General of Observatories
Lodi Road, New Delhi.

To

The Secretary to the Government of India,
Ministry of Transport and Communications
Department of Communications & Civil Aviation)
New Delhi.

Dated New Delhi, the 9th June 1961

Subject:- Third Five Year Plan – Development of Research Organization: INSTITUTE OF TROPICAL METEOROLOGY, SMALL RESEARCH UNITS AT REGIONAL CENTRES.

Sir,

I have the honour to forward herewith proposals concerning scheme No.12 "Development of Research Organization: Institute of Tropical Meteorology, Small Research Units at Regional Centres" included in the third Five Year Plan of the department, for administrative approval of Government. The justifications for the scheme together with details of the phased programme are given below:-

A. INSTITUTE OF TROPICAL METEOROLOGY

1. Need for a meteorological research Institute. Ever since its inception in 1875, the India Meteorological Department has been engaged in the study of meteorology as a science in addition to rendering service to various interests who require meteorological information and advice and warnings. In the years upto 1940, departmental officers, though few in number, could spend a fair part of their time in research work connected with the synoptic, climatological and physical aspects of the atmosphere and make significant contributions to the science of meteorology. The increase in knowledge of the characteristics and behaviour of the atmosphere over India derived from such research work was applied to improve the technical service to various interests including shipping, aviation and the public.

With the rapid development of transport and communications over land, sea and air, and more particularly in the air, demands for met. service have increased considerably during the last 20 years and more specially in the last 5 to 10 years. Though a large addition to the strength of the department has taken place in the last 20 years, most of the time officers and staff is spent in rendering service to various

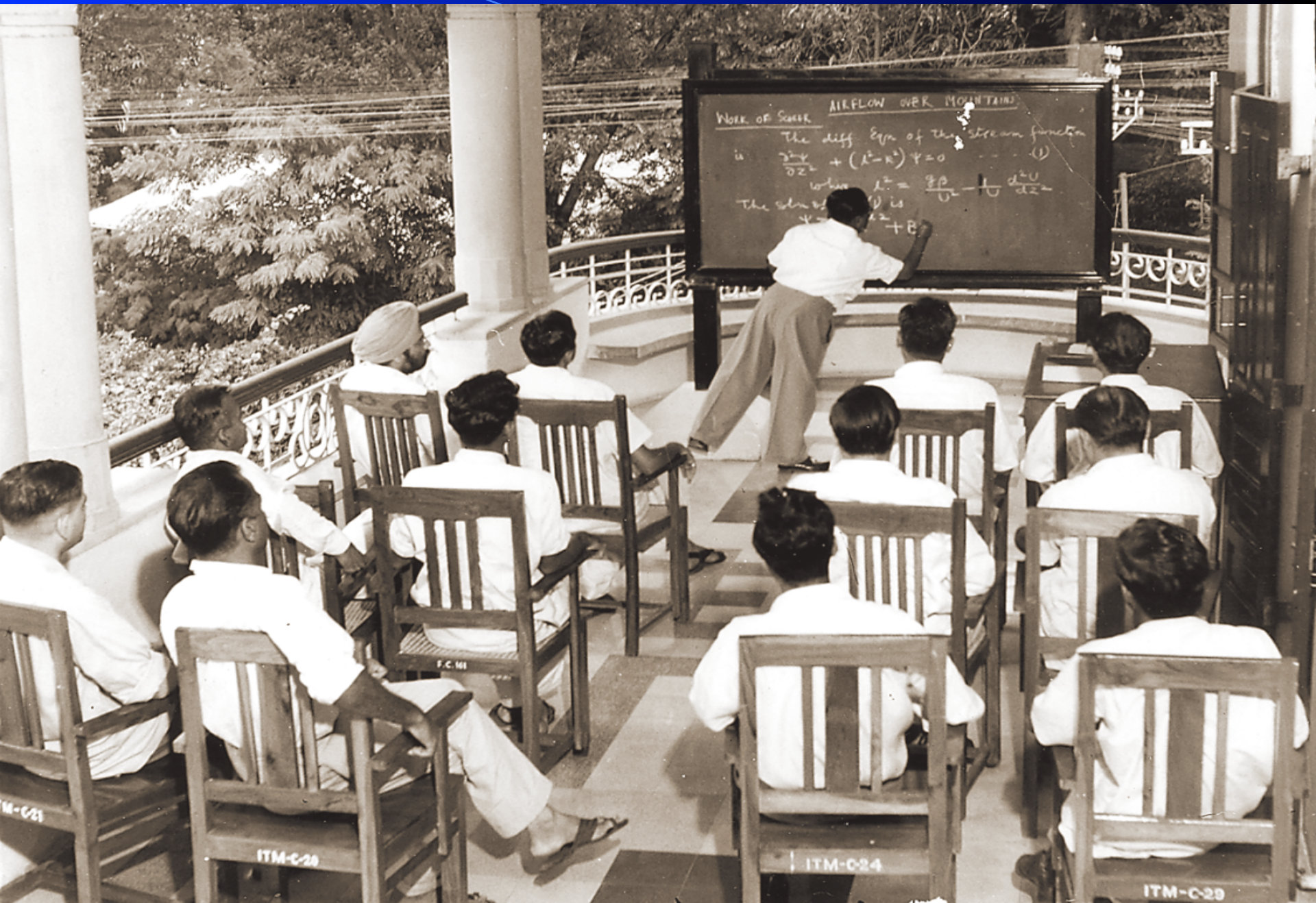
.. 2

Birth of the Institute

- IMD received the formal approval of the Govt. of India in February 1962 as one of the schemes under the Third Five Year Plan.
- The Institute was formally established on 17th November 1962 with the posting of Prof. P.R. Pisharoty as its Director.
- The ITM was established as a distinct unit of the India Meteorological Department for research in Meteorology and Atmospheric Science.
- ITM started functioning in Ramdurg House, a building of IMD adjacent to its main office.

IITM in Ramdurg House

Seminar Verandah



HPC Building

‘SHISHIR’ : CCCR Housing Complex

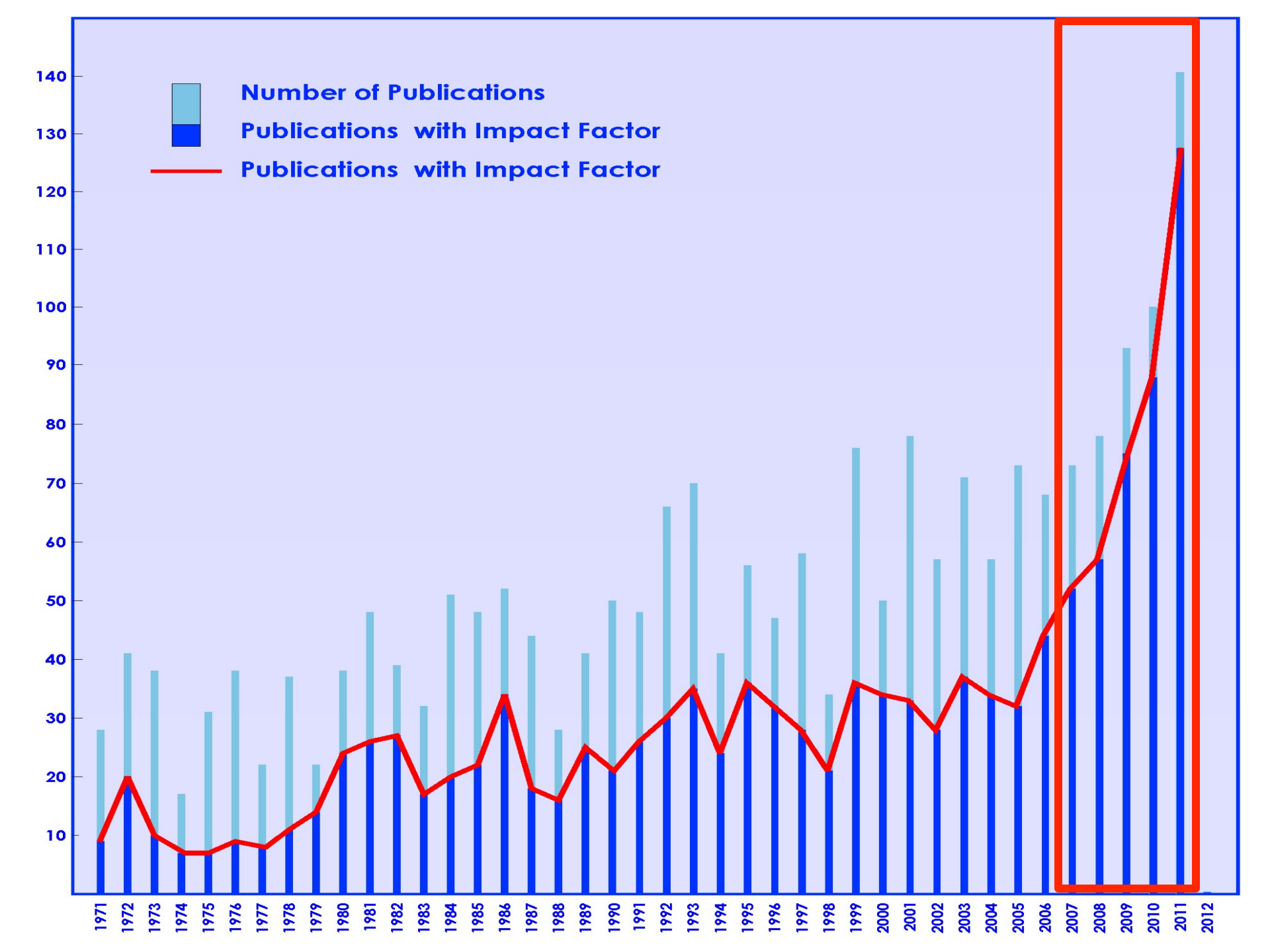
Seminar Halls and Training Facility

HPC with peak performance 70TF

Mobile Doppler LIDAR Profiler

Mobile X-Band Doppler Dual Polarized Radar

Microwave Radiometer Profiler


Number of Publications
Publications with Impact Factor
Publications with Impact Factor
140
130
120
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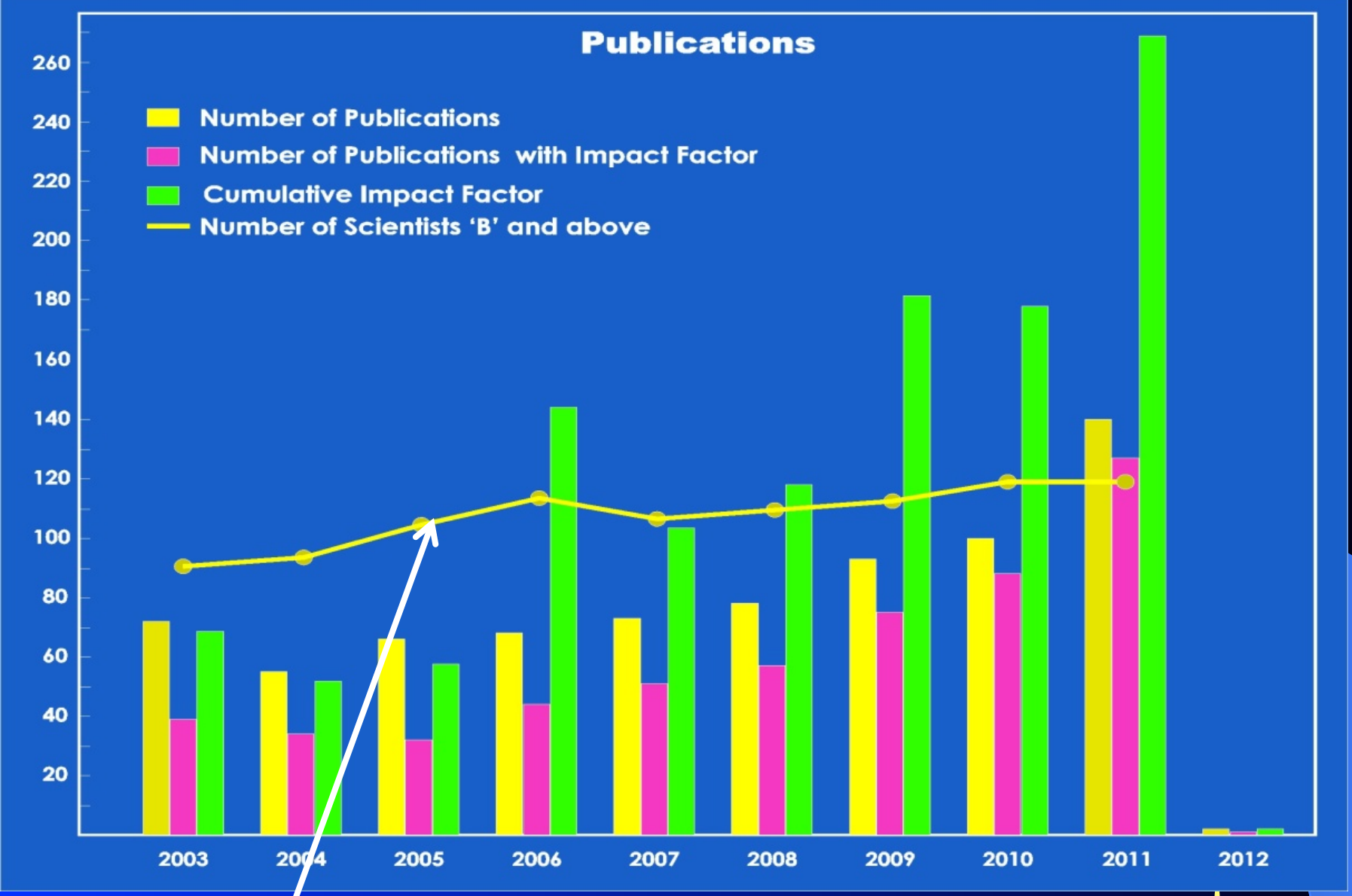


No. of Scientists remains roughly constant

New Initiatives

Centre for Advanced Training in Earth System Science and Climate (CAT-ESSC)

- To attract good students for doing Ph.D in Climate Science, a 'Job-linked Training Program'.
- 20-30 Trainees every year will be inducted to jobs in different MoES organizations after going through a 3 Semester Training. Continue to do Ph.D while on job.
- 2nd Batch has just been selected
- We are happy to see that some very good students are attracted

New Initiatives

The Monsoon Mission

- **Mission mode project to deliver quantifiable improvement in skill of prediction of monsoon on short, medium and seasonal time scale.**
- **Build partnership with academic and R & D organizations to work on improving skill of 'Operational Modeling Systems'**
- **A five year project. Govt. has allocated about $80 million to the project, about 50% of which will be available for funding projects**
- **Open to International Partners as well!**

Conference Statistics

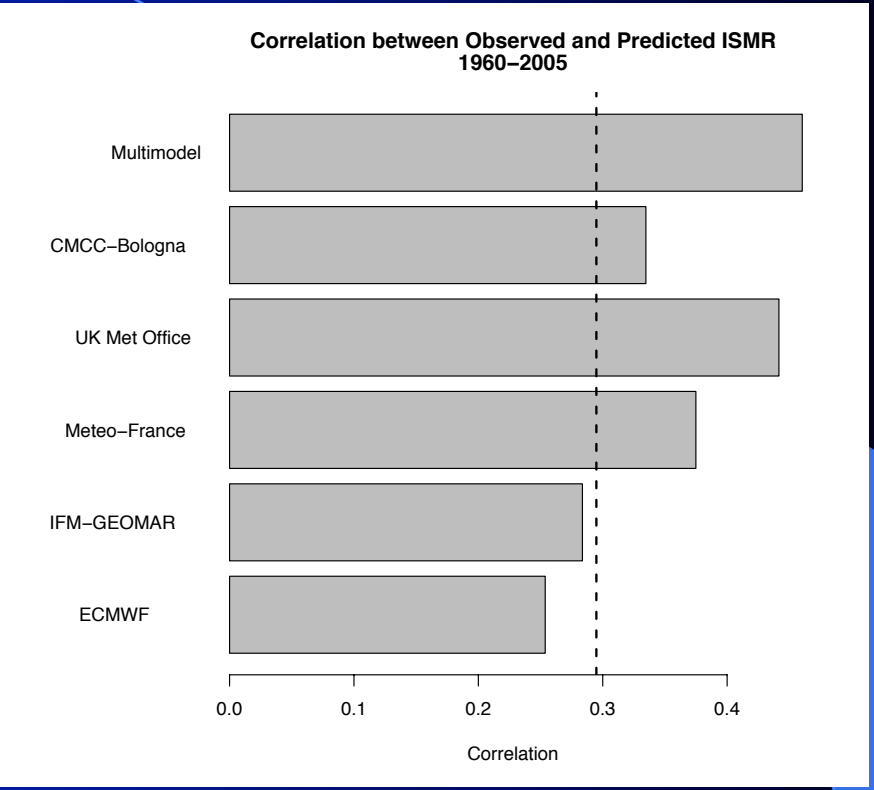
- Total number of Plenary Sessions:7
  - Exclusive time for Posters in each Session
- Total no. of Participants: 340
- Oral Presentations: 57
- Poster Presentations: 235
- No. of Graduate Students/ Early Career Scientists attended: 150
- Participants from outside India: 58

Major Opportunities: Prediction and Predictability of Monsoon

- **Prediction and Predictability of Monsoon:**
  - **The skill of coupled O-A models for predicting ISMR has become equal to or better than statistical models in recent years (Shukla / Goswami)**
  - **Predictions of high-frequency extreme events show skill and sufficient lead to for utility (Webster)**
  - **Reliable skill of Monsoon ISOs from coupled O-A models is achieved up to 2/3 weeks (Goswami)**

Major Opportunities: Prediction and Predictability of Monsoon (Seasonal)

Seasonal mean predictions skill of coupled O-A models for predicting ISMR for 1960-2005 is significant at 95% and they are consistently improving. On the otherhand statistical models are not showing any improvement,



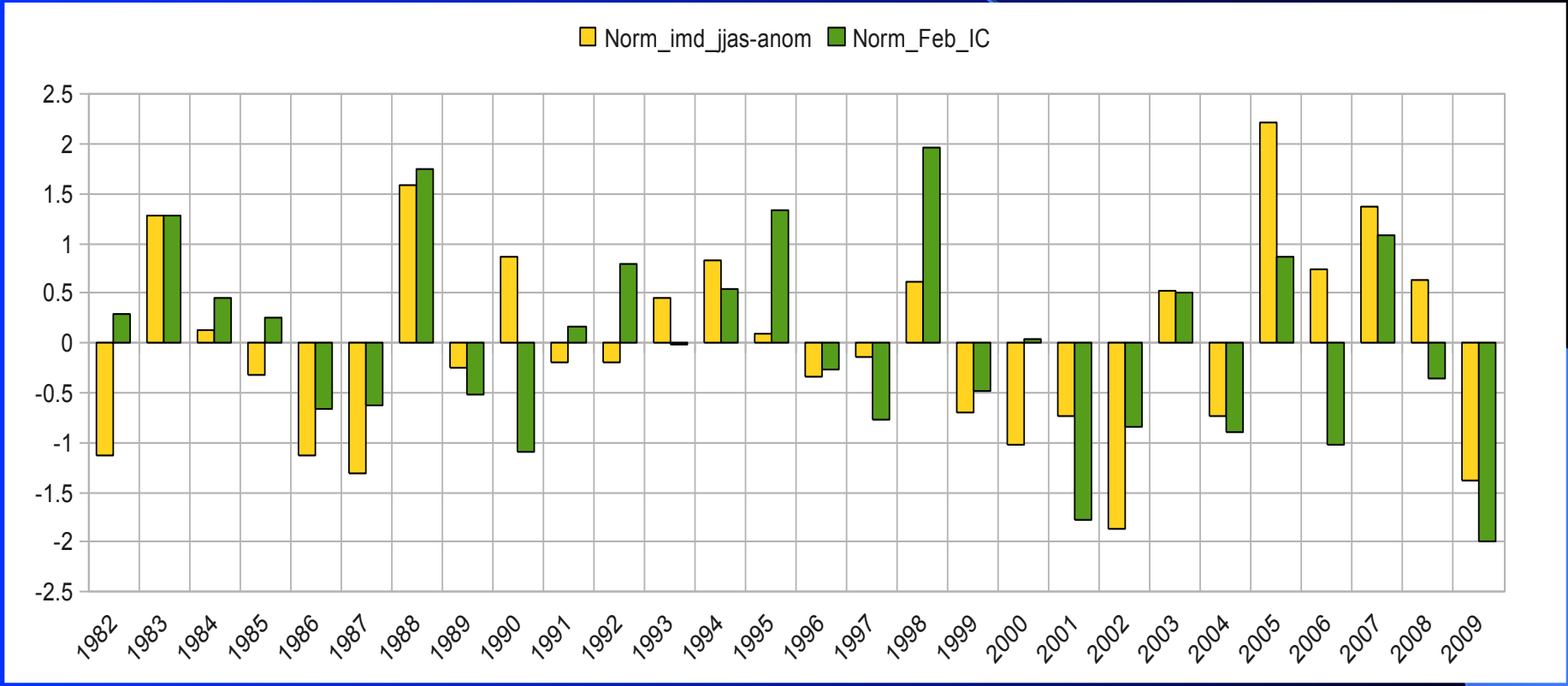
For 1960-2005 Obs,

CC (April Nino3, ISMR): −0.18

CC (May Nino3, ISMR): −0.21

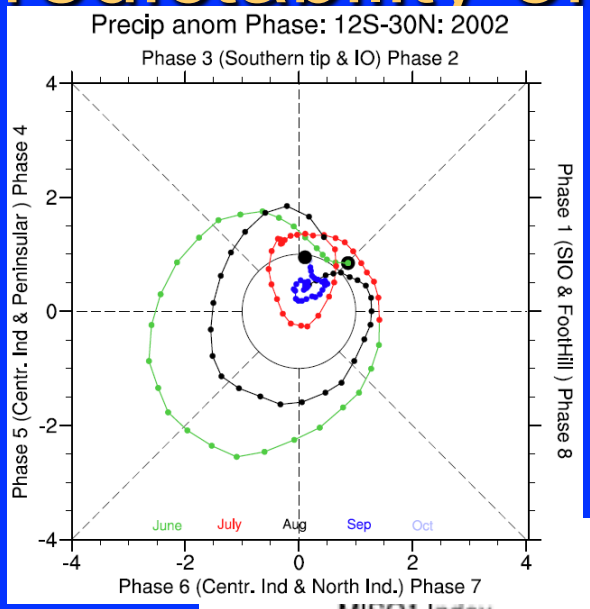
Delsol and Shukla ., 2011 GRL

Forecast skill of AIR in CFSv.2 with Feb I.C. ; Corr=0.59

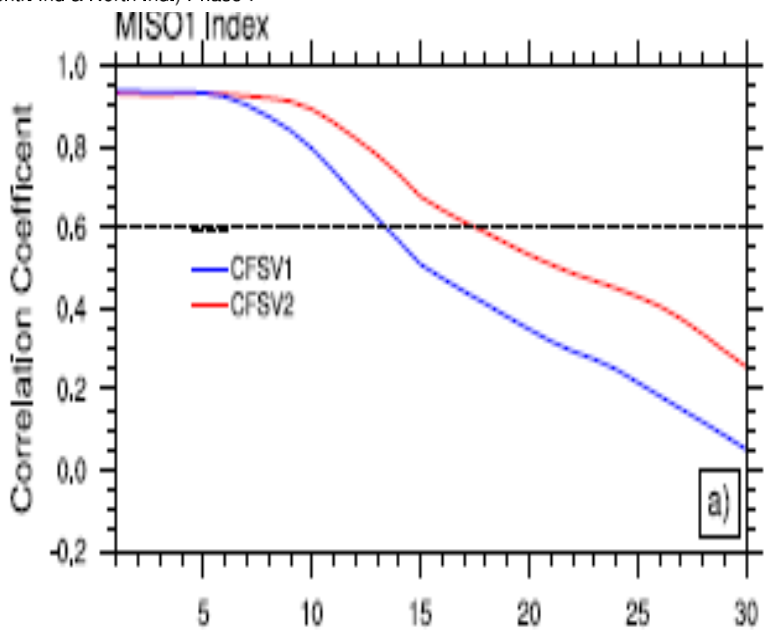


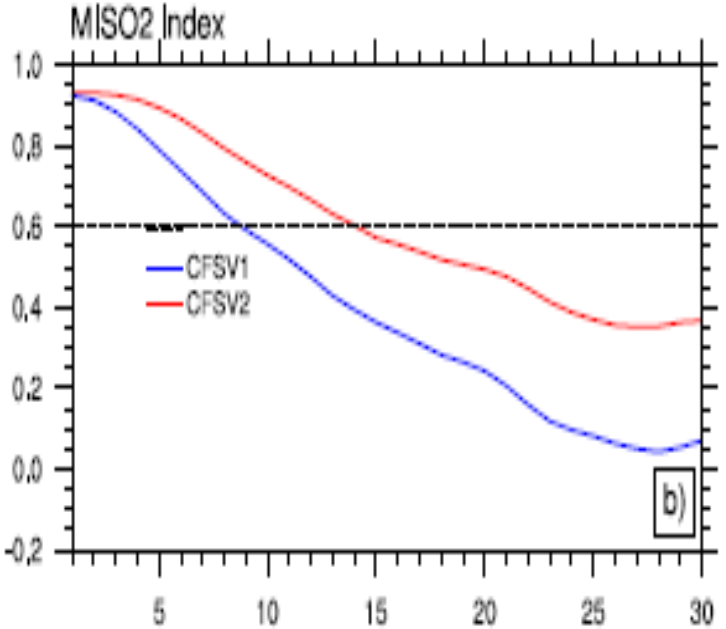
Rao, A.S. et al. 2012, Manuscript under review

Major Opportunities: Prediction and Predictability of Monsoon (Intraseasonal)



Skill of Asian Summer monsoon rainfall on ISO scale showed improvement in CFS V2.0 Model



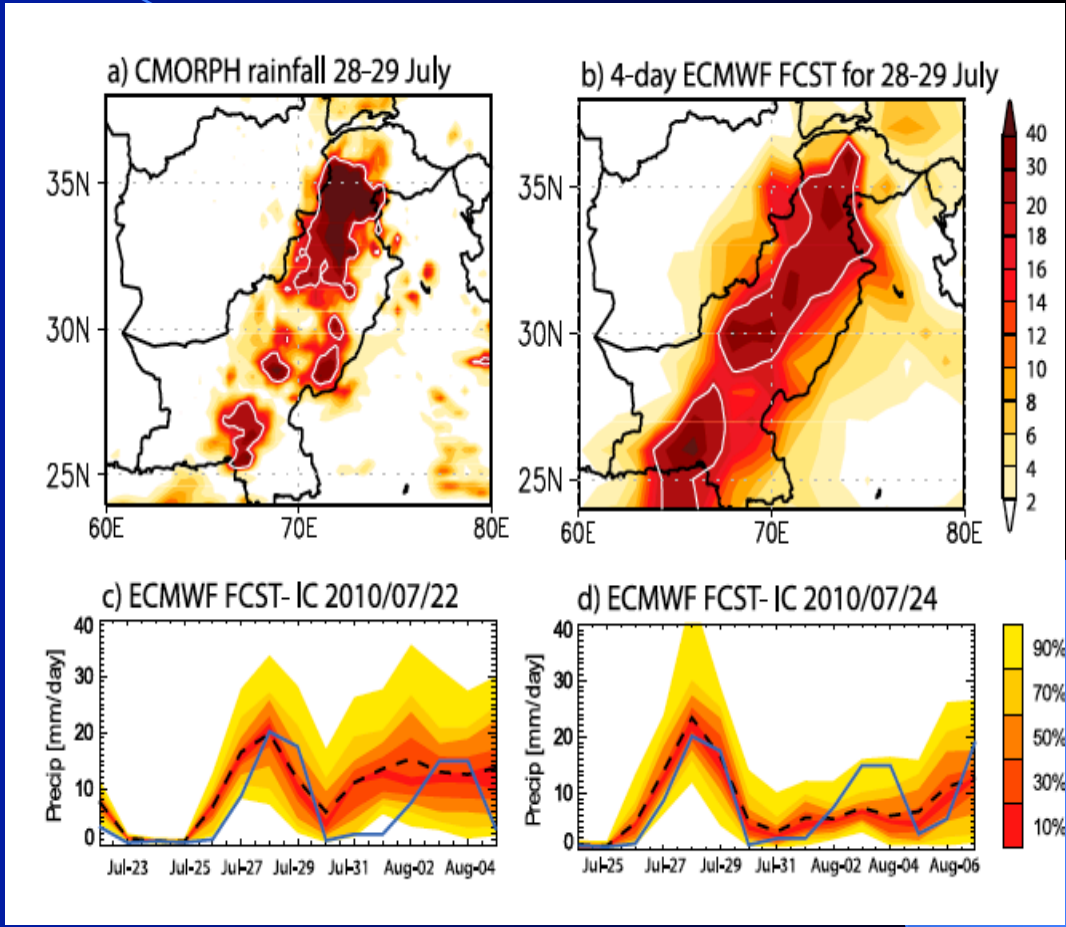


- Suhas et. al. 2012, Clim. Dyn
- Goswami et al. 2012 submitted to MWR

Major Opportunities: Prediction and Predictability of Monsoon (Medium Range)

Predictions of high-frequency extreme events show skill at sufficient lead to be useful (Webster)

- Precipitation forecasts (made 6 and 4 days in advance) of the major northern July precipitation event compare well with satellite observations
- White contour shows 20 mm/ day

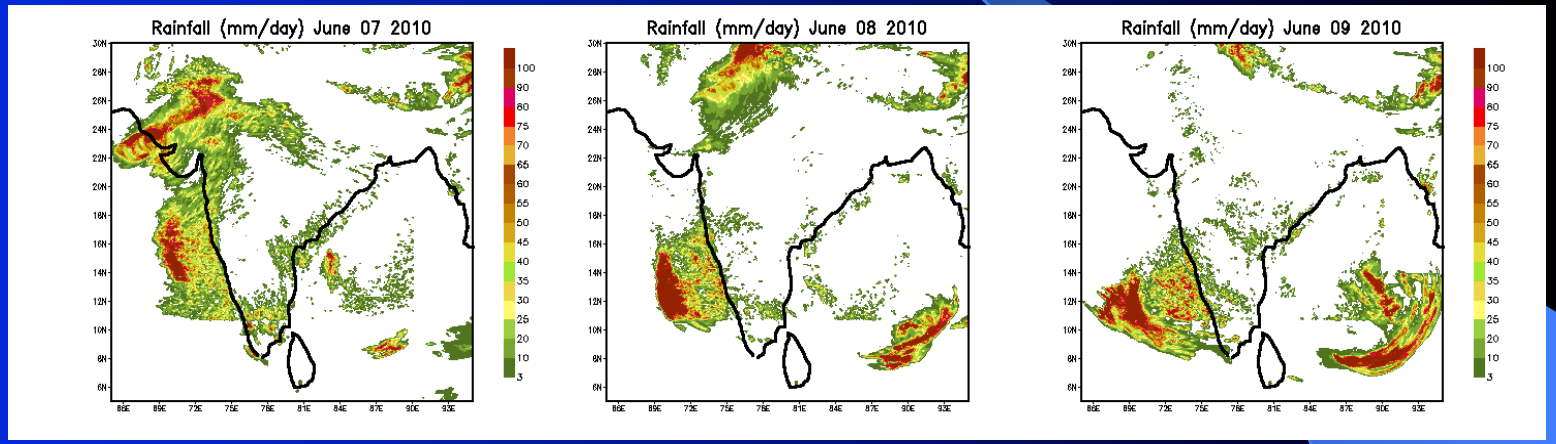


Webster et al. 2011 GRL

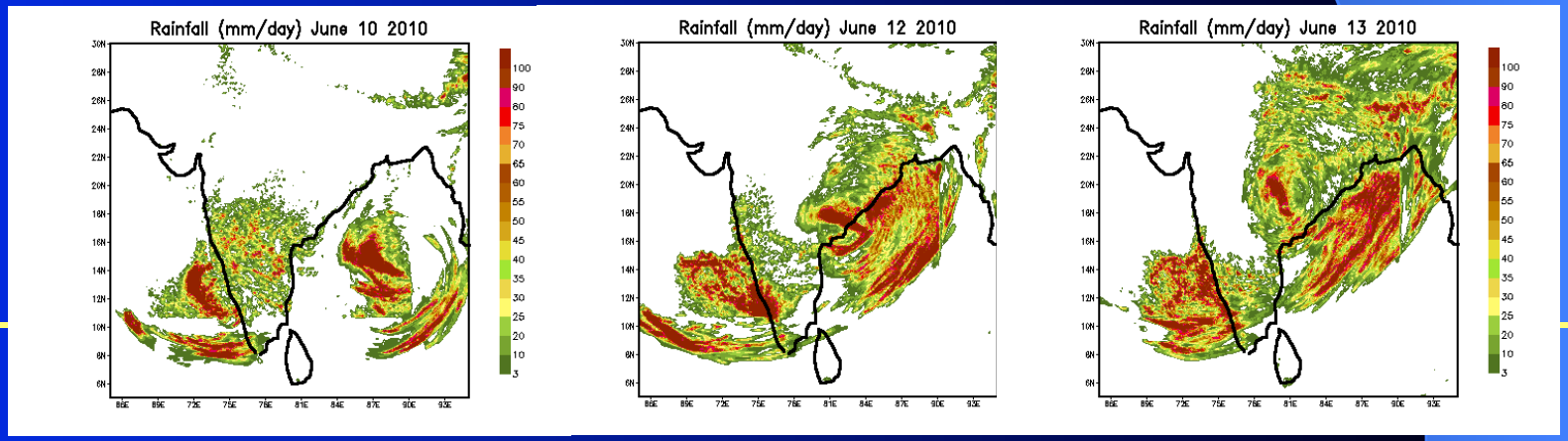
Emerging Understanding: Role of Aerosols on Monsoon Depressions

Role of aerosols and cloud microphysics on decreasing trend of Monsoon Depressions (TNK)

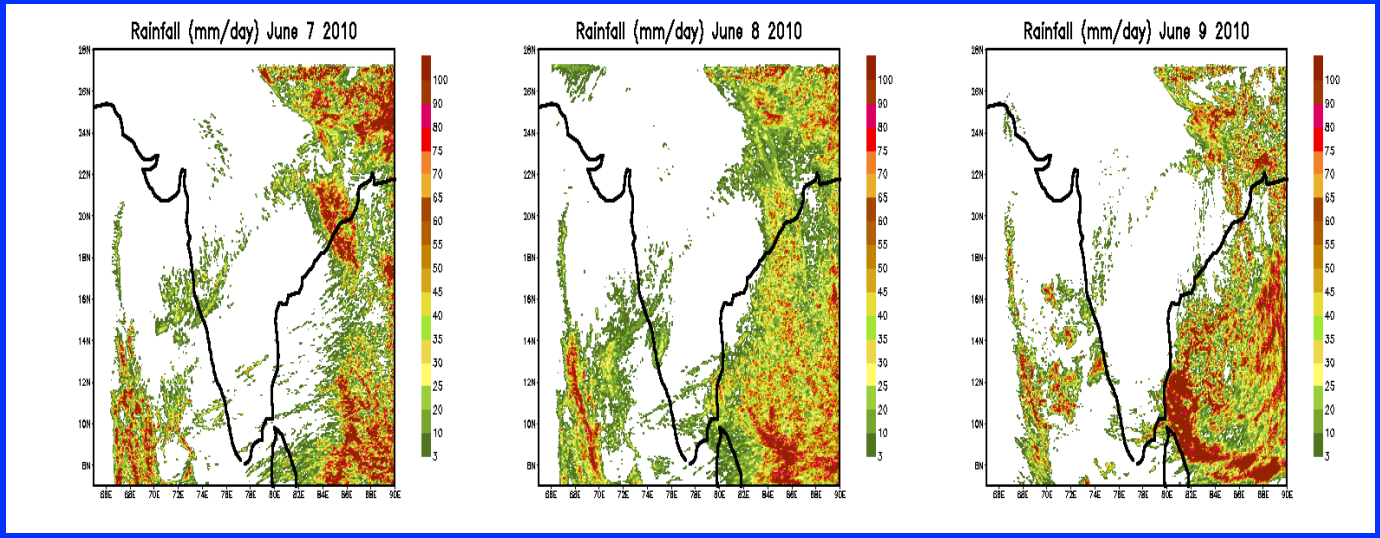
WRP-Chem model



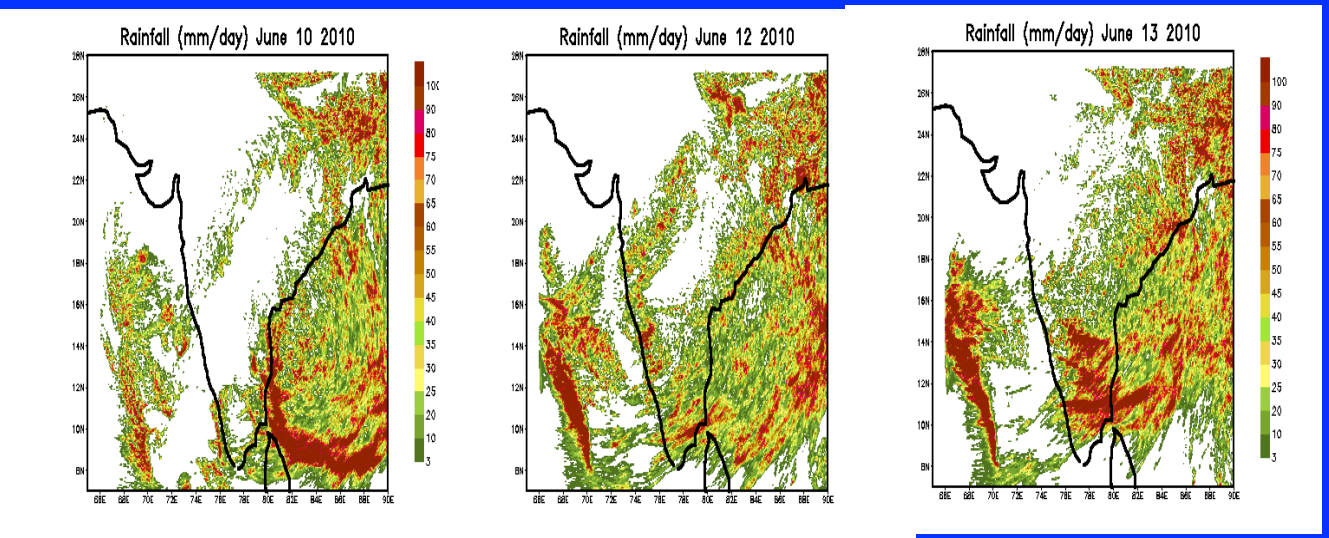
RAINFALL FROM THE CONTROL EXPERIMENT



Emerging Understanding: Role of Aerosols on Monsoon Depressions



RAINFALL FROM THE MODIFIED CCN EXPERIMENT



The organization of convection around a monsoon depression starts to collapse as widespread convection (not on the scale of the depression) as a result of an enhanced population of CCN in the form of fine drops.

Aerosol-Dynamics Interaction affects MISO Predictability

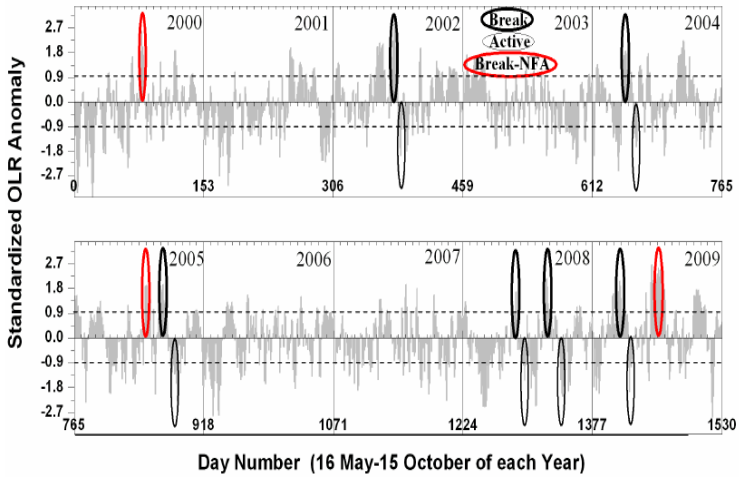


Fig. 2 Standardized OLR anomalies for the period 2000-2009. Long break cycles (thick black solid circles) followed by active spells (thin black circles) together with those breaks immediately not followed by active episodes (thick red circles).

AI:B

AI:B-A

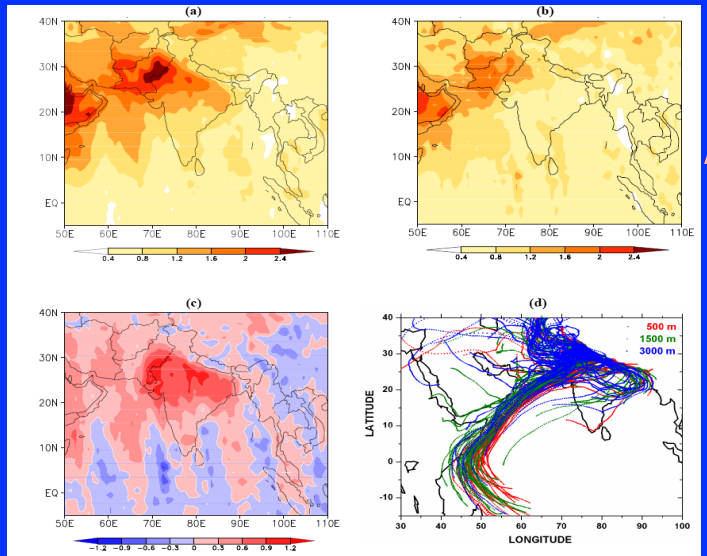
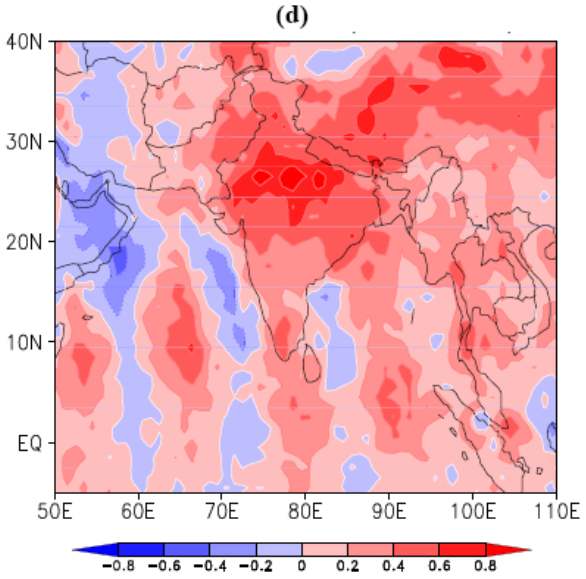


Fig. 5 Composite Aerosol Index during BFA cases: **(a)** breaks **(b)** actives **(c)** break minus active and **(d)** breaks composite of seven-day back-trajectories ending at 0000 UTC at the receptor point (80°E; 28°N) over the Indo-Gangetic Plain for the altitudes 500, 1500 and 3000 m.

AI:A



AI BFA-BNFA

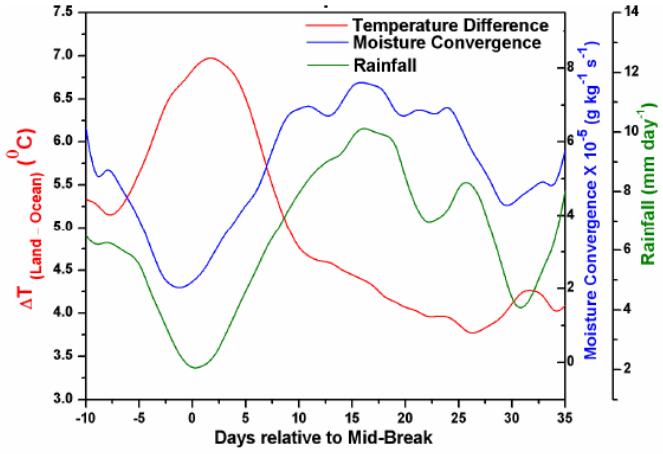


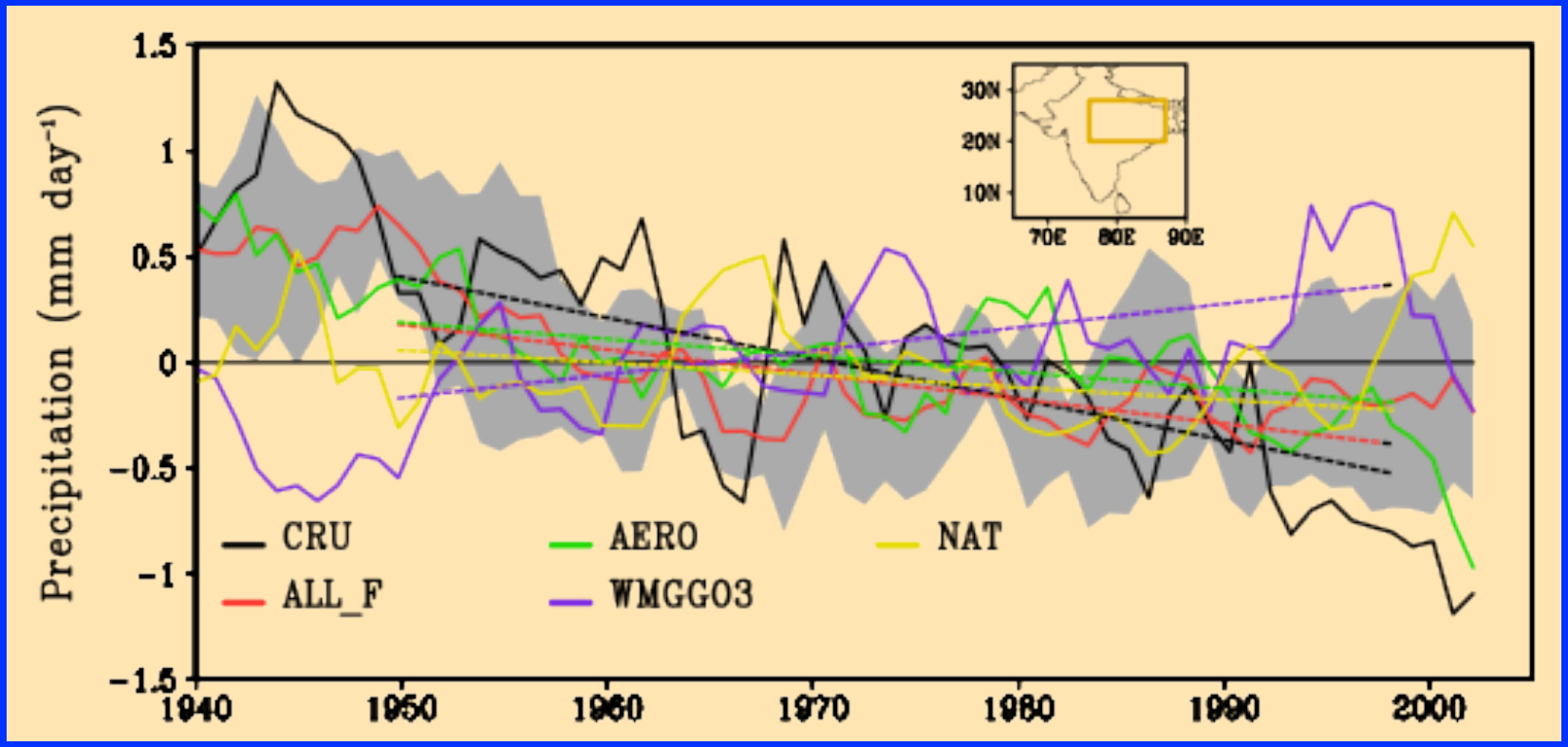
Fig. 6 (b) Composites of time evolution of temperature difference at 925 hPa between Land and Ocean, moisture convergence at the same level and rainfall w.r.t. the mid-day of BFA breaks composite.

Manoj et al. 2011, Climate Dynamics

Emerging Understanding: Aerosols masking the GHG warming?

GRDL CM3 Simulation: S. ASIA Rainfall

Linear trends of average JJAS rainfall over central-northern Indian (mm day^{-1})



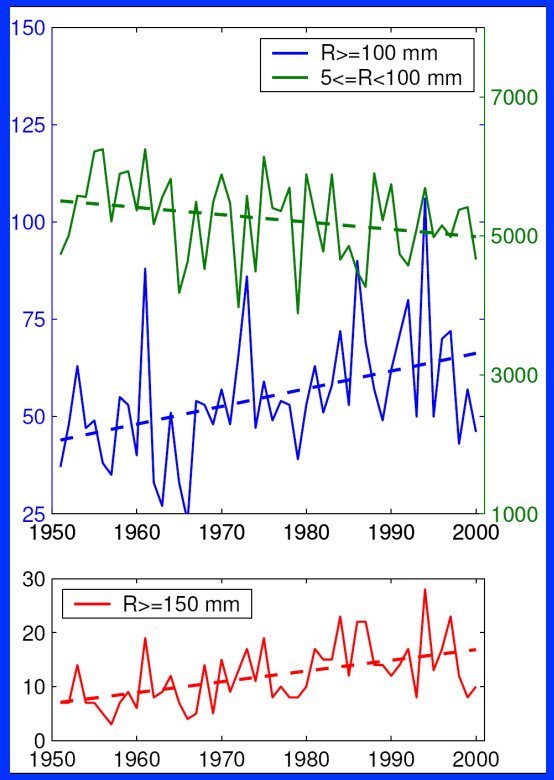
Some questions remain:

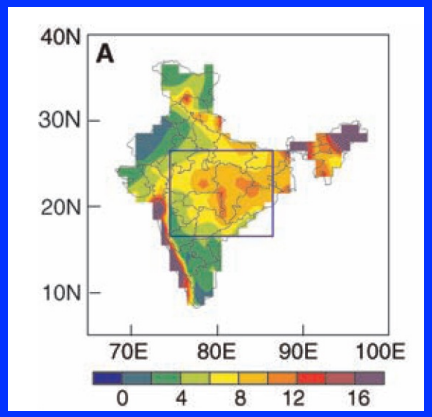
Ramaswamy

Decreasing trend is primarily in the eastern part of India

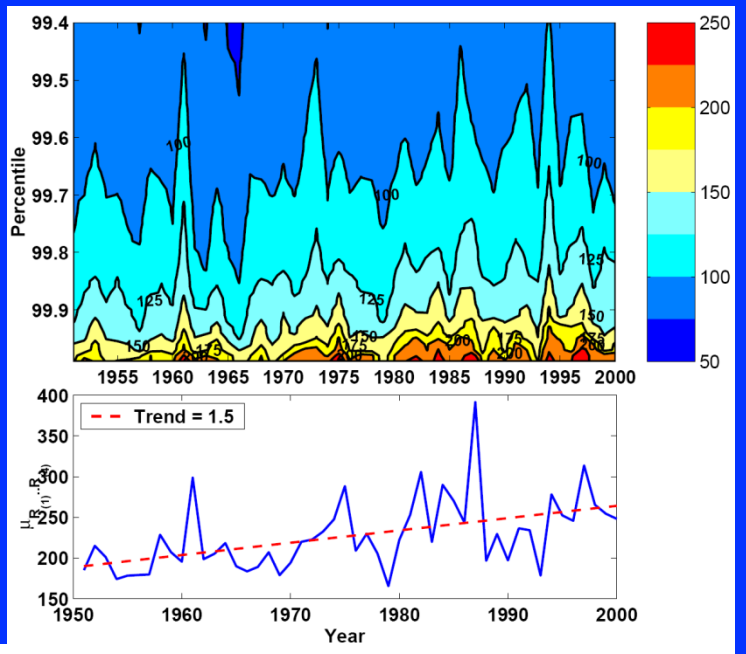
How dependent is the result on this model?

Improved Understanding: Asian Monsoon in a Changing Climate

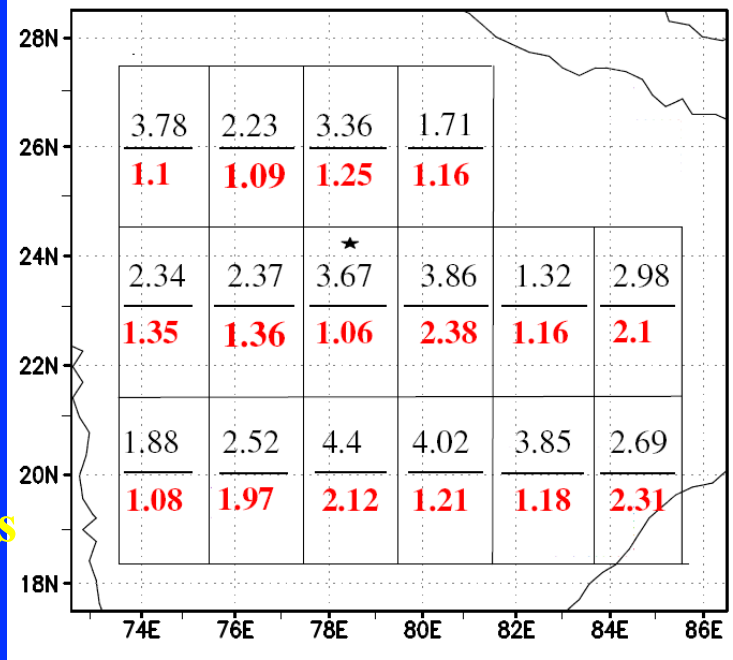




Goswami et al, *Science 314, 1442 (2006);*



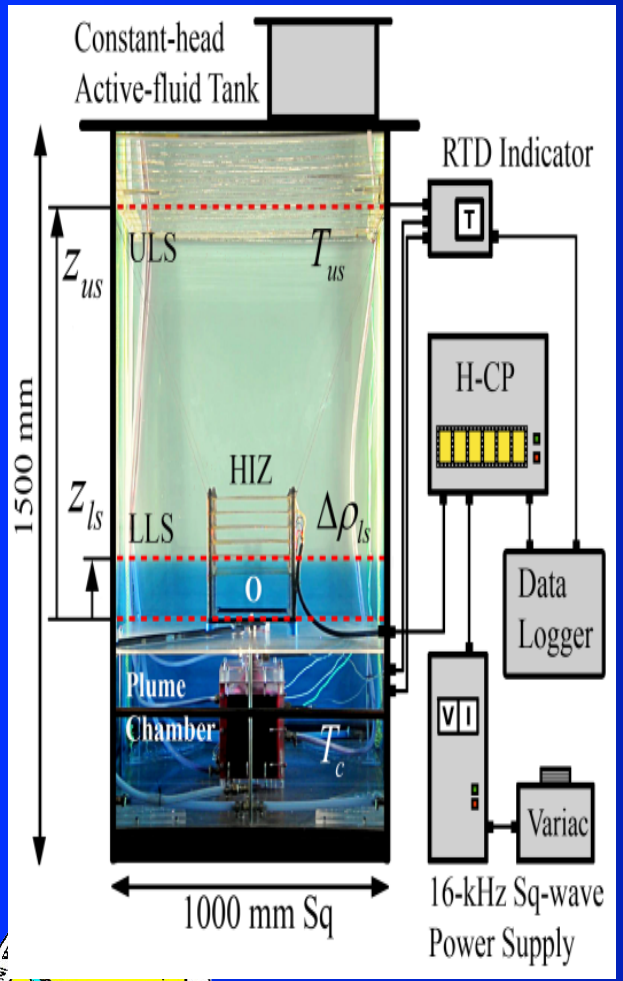
Mani et al. 2009, GRL

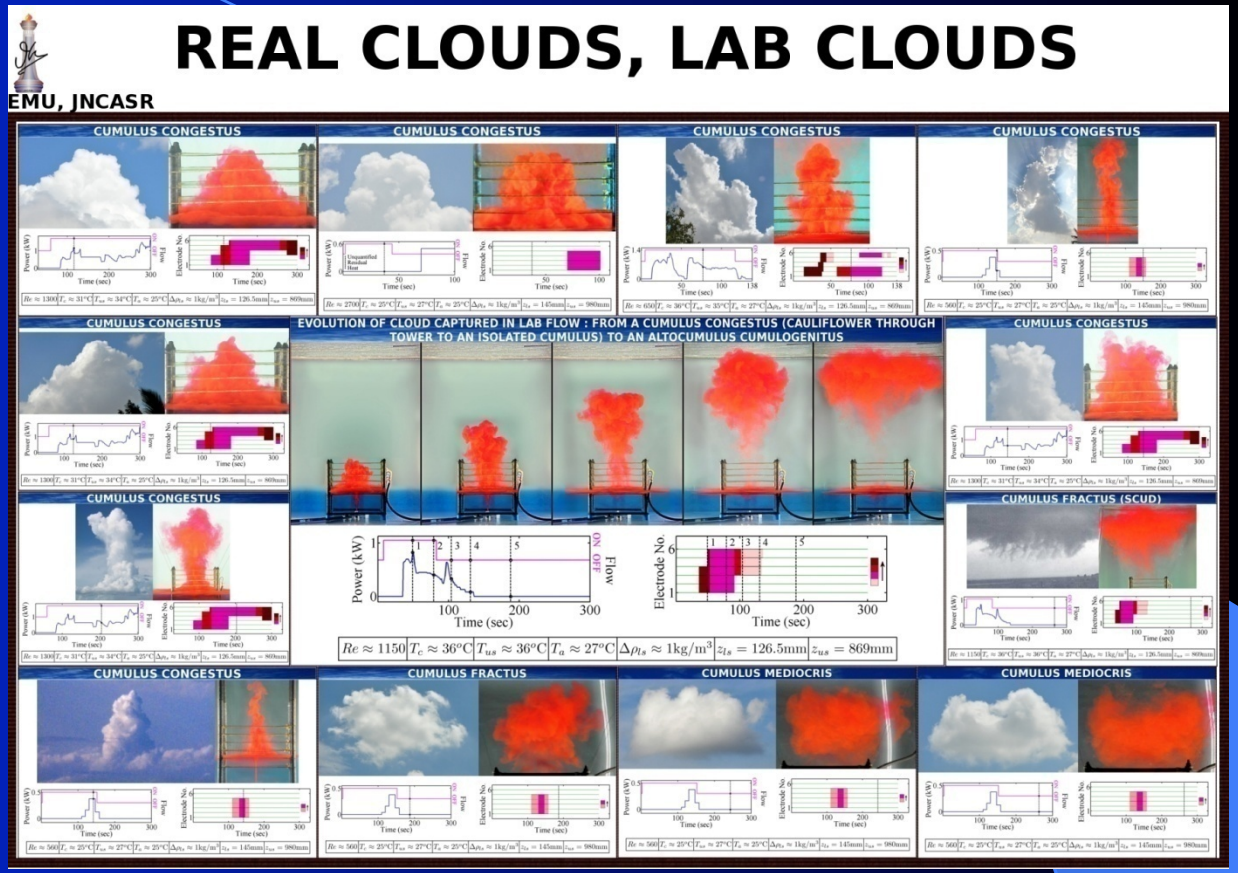


Error doubling Time for the last two quarters (1953-1978 and 1979-2004)

Improved Understanding: Laboratory Simulation of Cumulus Congestus Clouds

The Apparatus





The present technique has the capability to provide precise entrainment data on cumulus cloud flows, and hence to help in devising better cumulus parameterization schemes.

Vybhav Rao et al. (2012), Narasimha et al. PNAS, 2011

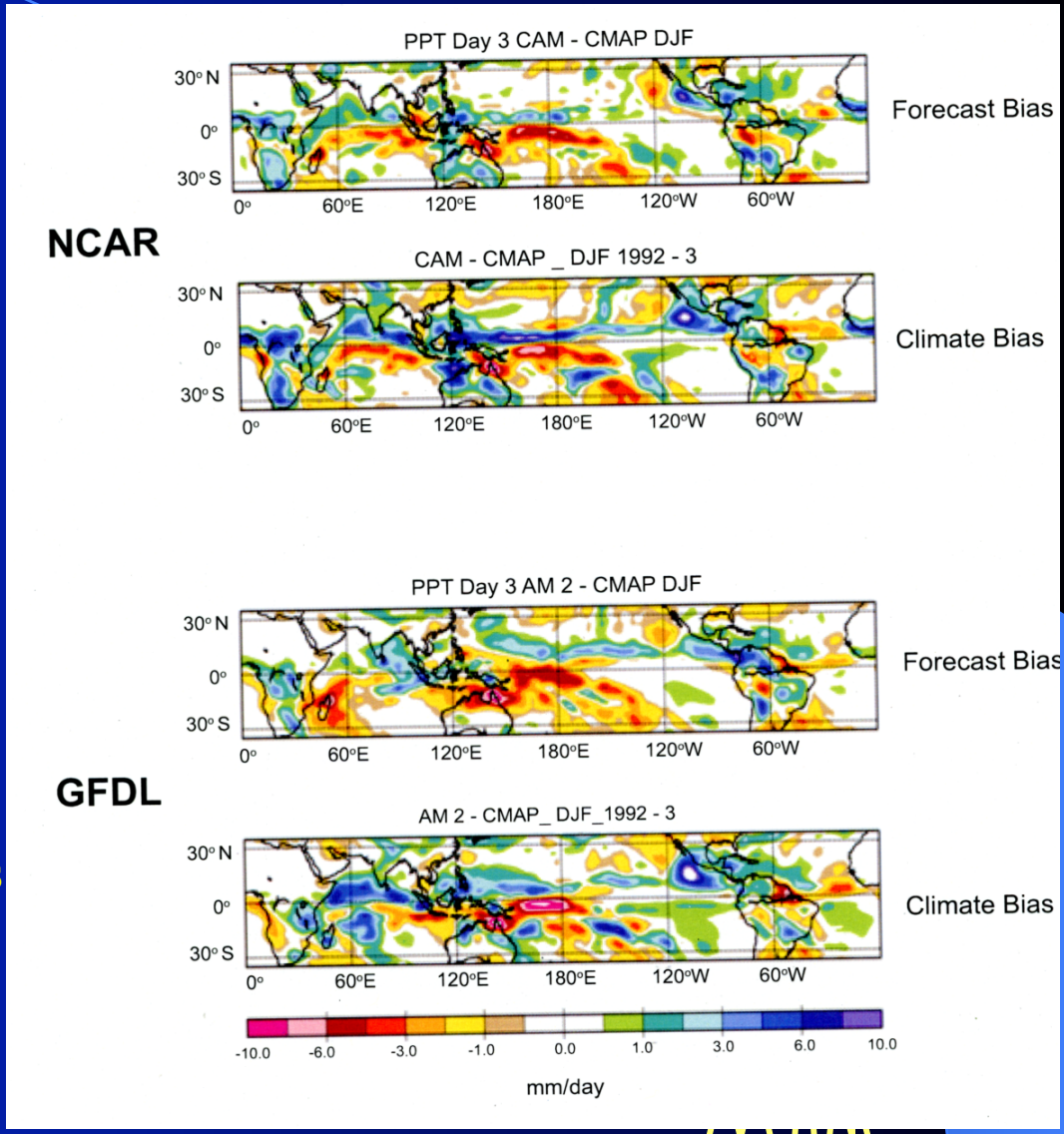
Challenges: Multiscale Organization of Tropical Convection and the Intersection of Weather & Climate

Tropical precipitation errors -- similar in weather & climate models -- appear within a few days (Monciref)

Challenges in this area are formidable, convective organization being a relatively new one, e.g.,

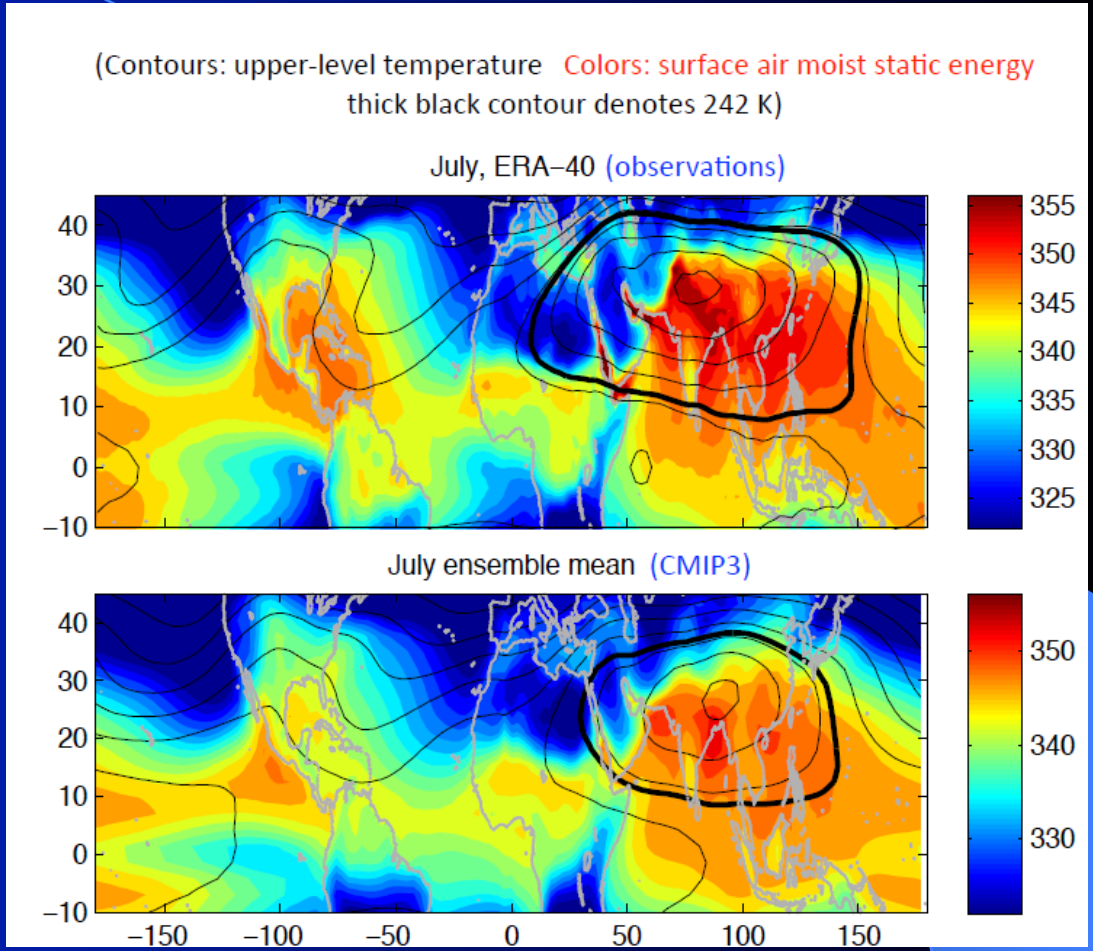
a) Mesoscale parameterizations for traditional climate models, superparameterizations and global CSRMs being experimental testbeds

b) 'High-resolution' issues where cumulus parameterization and explicit mesoscale circulations sit (uncomfortably) side-by-side are new parameterization considerations



Challenges: Biases in AR4 models due to smooth orography

IPCC AR4 models exhibit strong bias in simulating thermodynamic maximum and is due to insufficient blocking by Hindu Kush range (too weak, too oceanic and persists in AR5 also; Bill Boos)

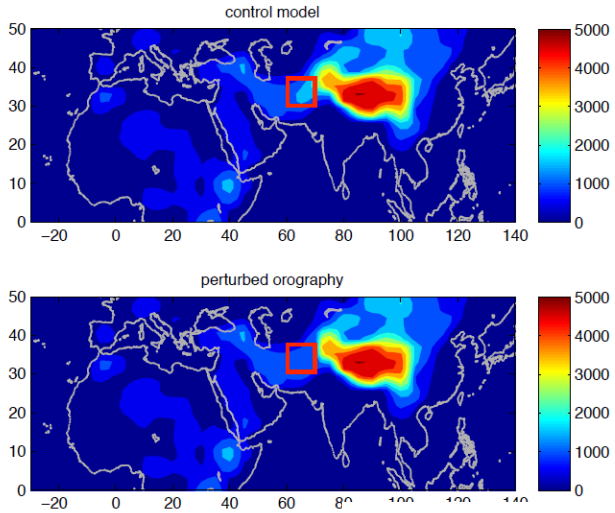


Asian thermal maximum too oceanic and too weak . Asian upper level temperature maximum doesn't penetrate far enough into Africa. North American "ridge" too weak. Model upper---level Temperature too cool

Challenges: Biases in AR4 models

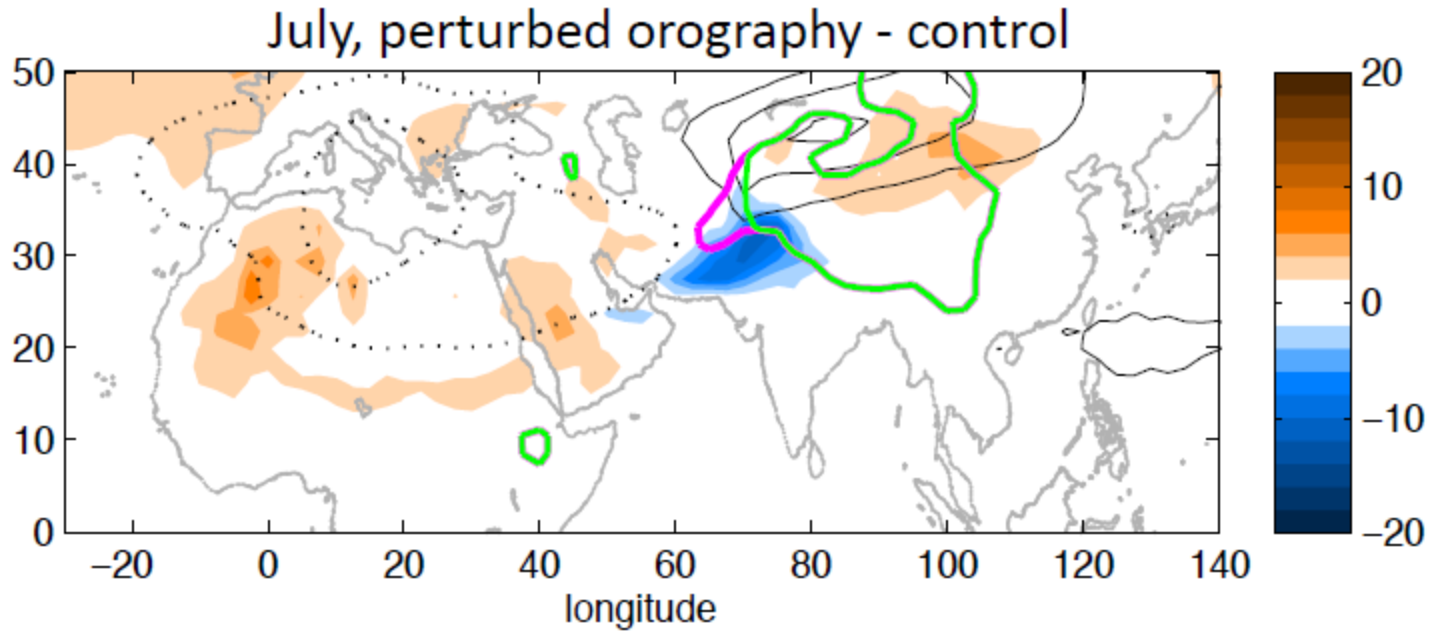
Try to recreate bias in a "good" model

- NCAR model has thermal maxima near observed location over N. India
- We rerun this model with slight reduction in height of Hindu Kush range



Modified topography recreates the bias

Errors in surface *h (colors)* and upper---tropospheric temperature (contours, negative dashed) green and magenta contours are 1.5 km surface altitude in control and perturbed model

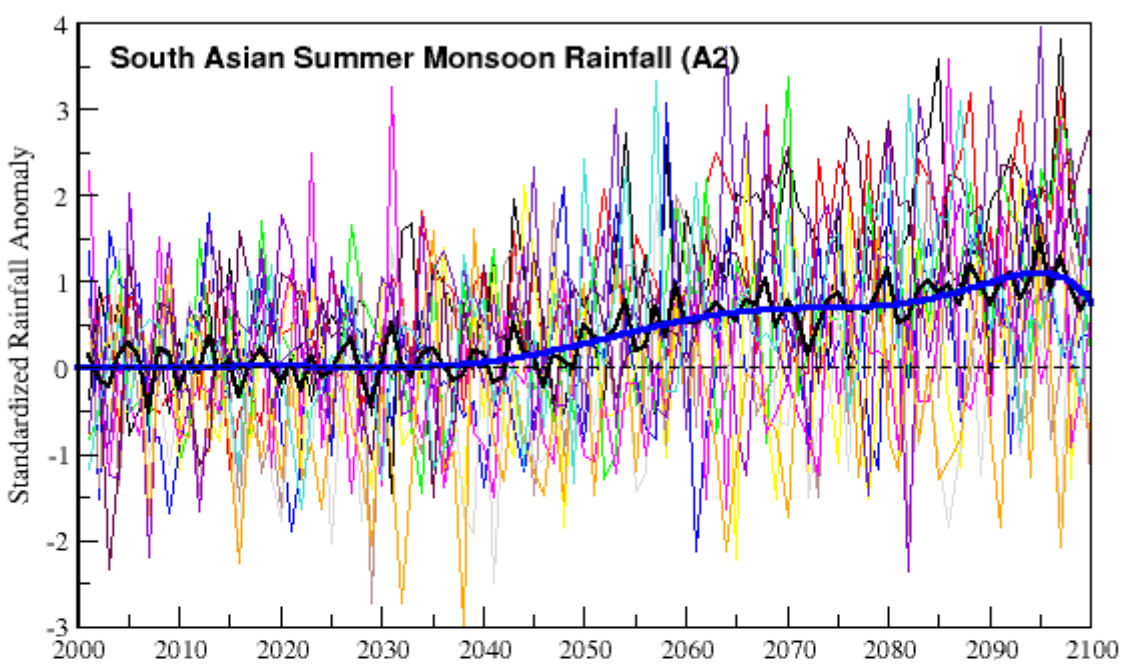


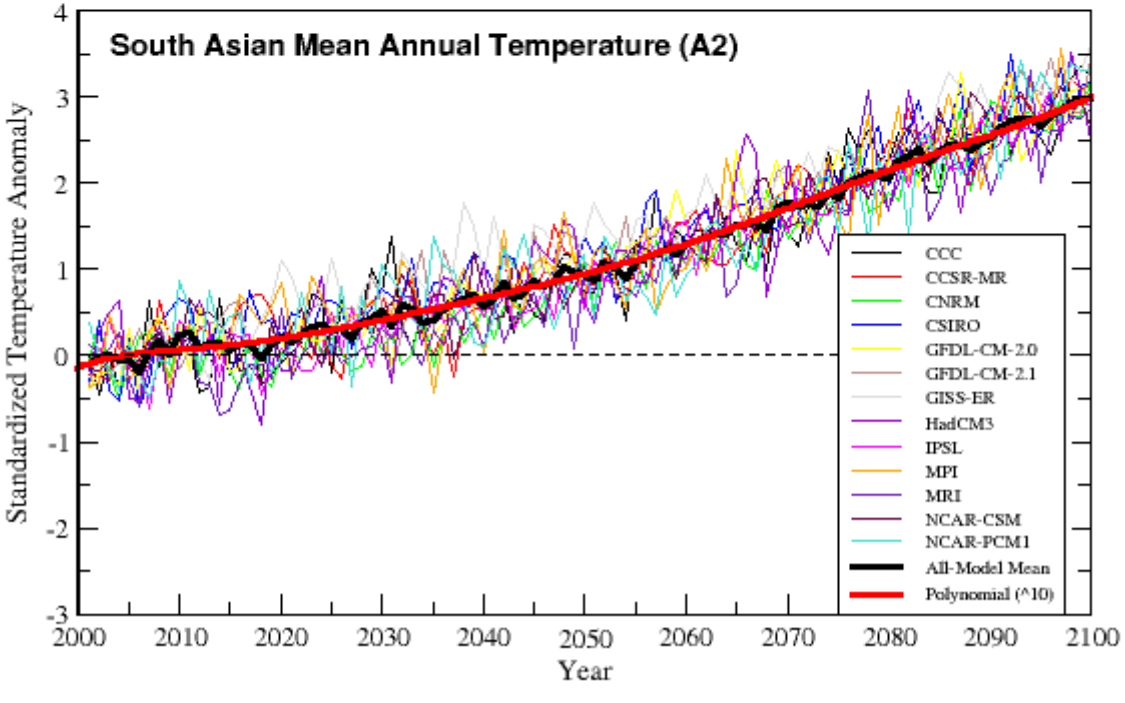
Challenges: Monsoon Projections

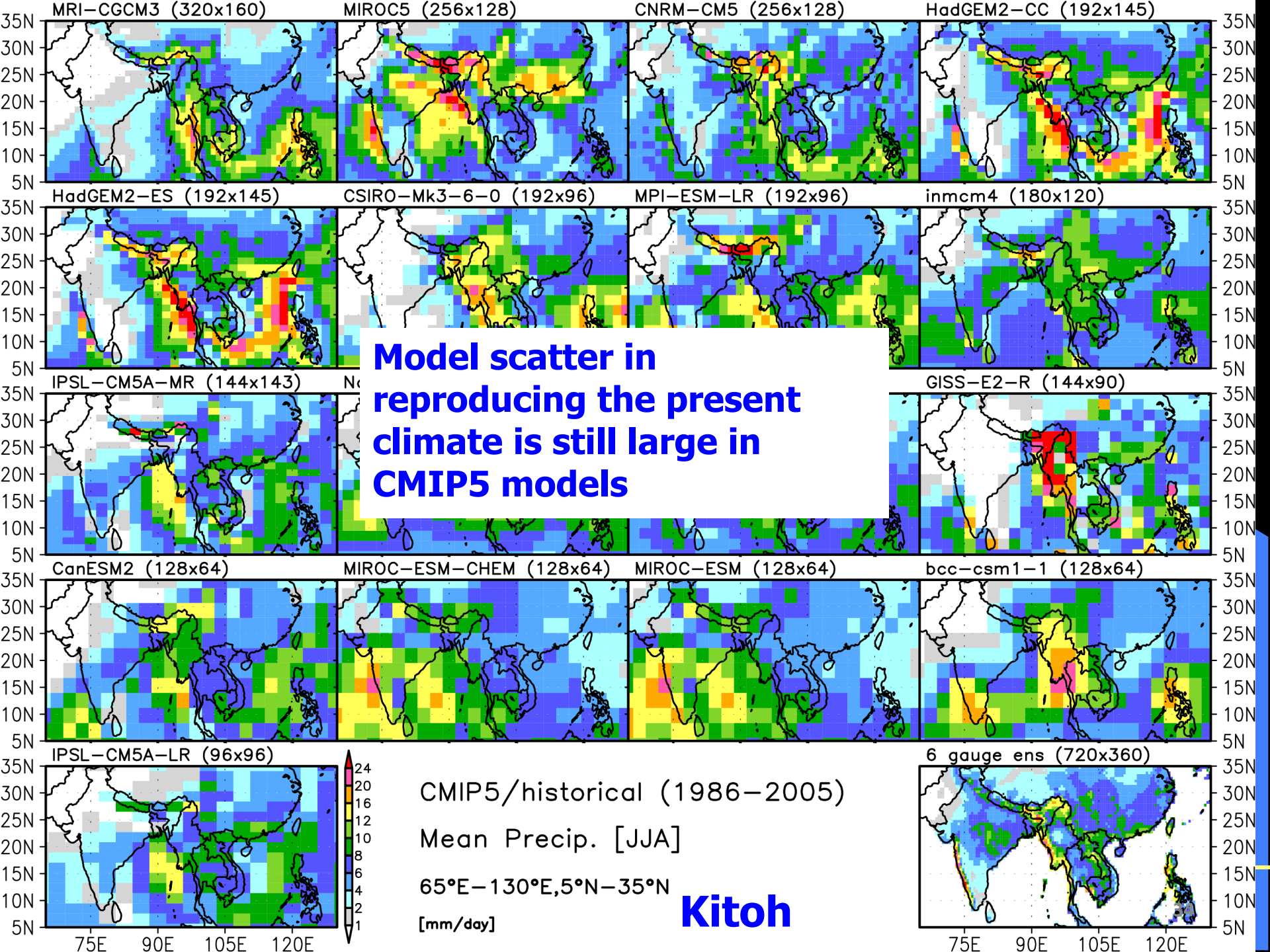
CMIP3 models

Future Scenarios for Summer Monsoon Rainfall and Annual Temperature over South Asia under A2 Scenario (High Emissions) based on IPCC AR4 Simulations of AOGCMs

(Anomalies relative to current period)






MRI−CGCM3 (320x160)
MIROC5 (256x128)
CNRM−CM5 (256x128)
HadGEM2−CC (192x145)
HadGEM2−ES (192x145)
CSIRO−Mk3−6−0 (192x96)
MPI−ESM−LR (192x96)
inmcm4 (180x120)
IPSL−CM5A−MR (144x143)
GISS−E2−R (144x90)
CanESM2 (128x64)
MIROC−ESM−CHEM (128x64)
MIROC−ESM (128x64)
bcc−csm1−1 (128x64)
IPSL−CM5A−LR (96x96)
6 gauge ens (720x360)
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5N
75E
90E
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120E
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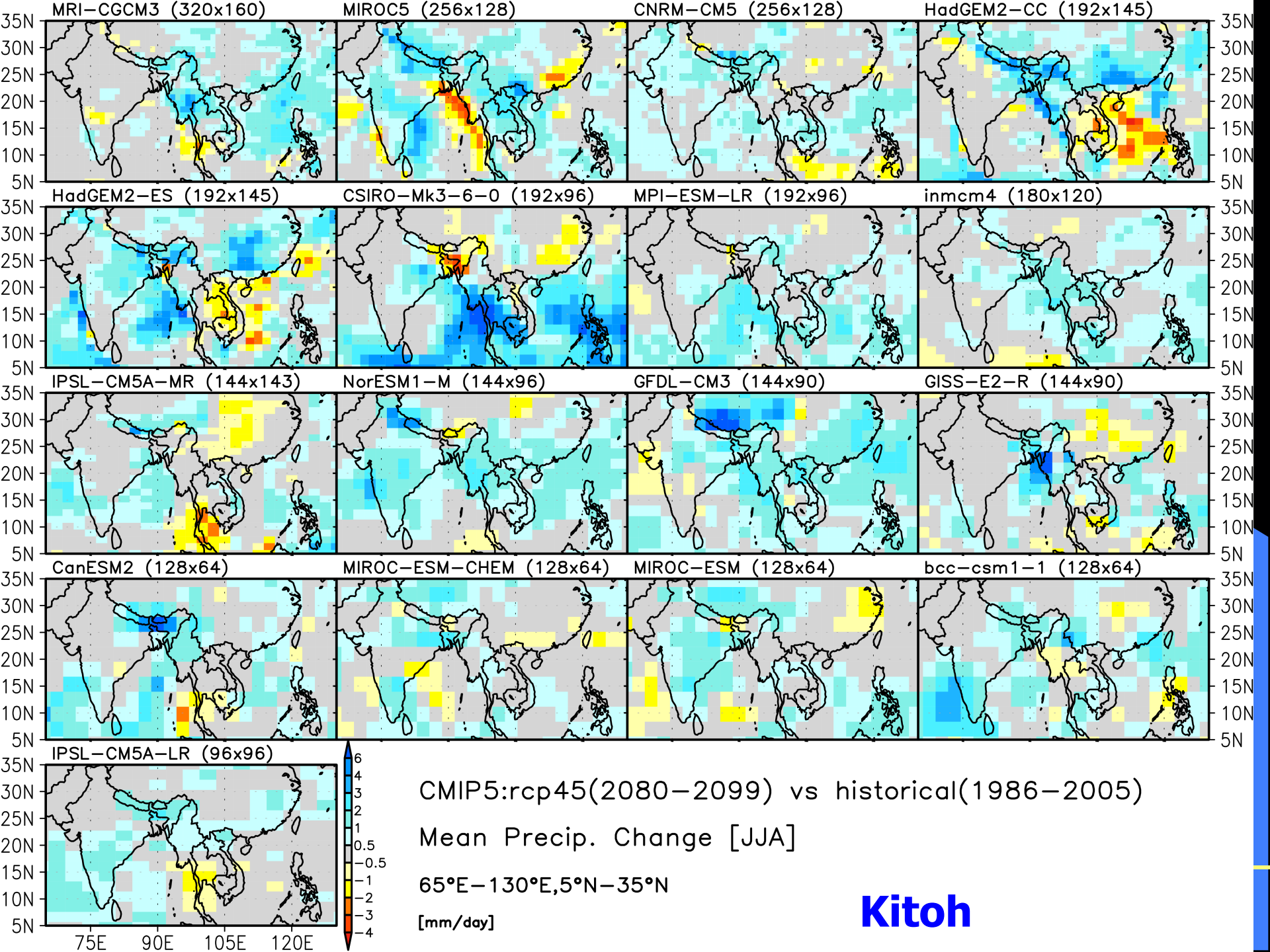
Model scatter in reproducing the present climate is still large in CMIP5 models
CMIP5/historical (1986−2005)
Mean Precip. [JJA]
65°E−130°E,5°N−35°N
[mm/day]
Kitoh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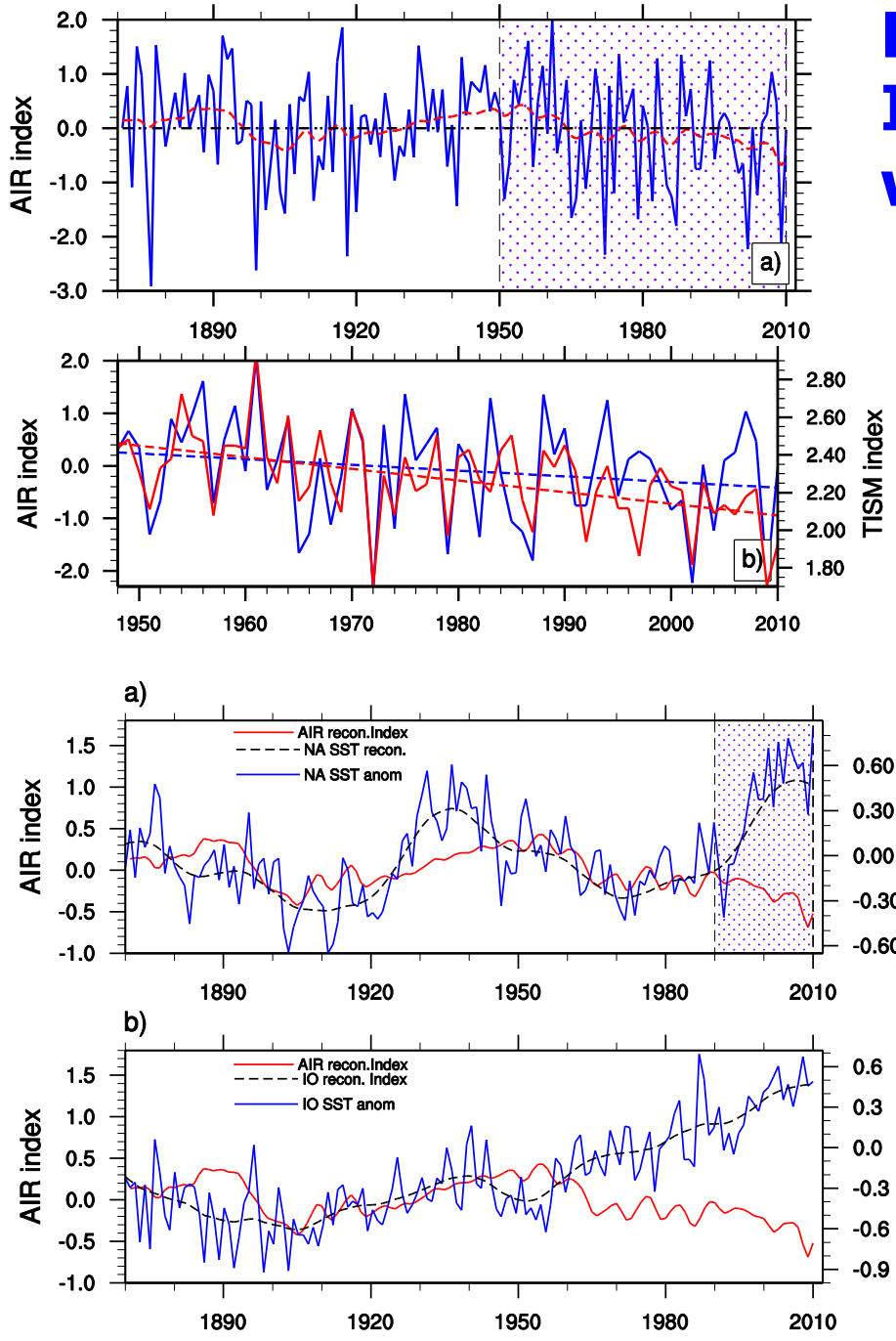
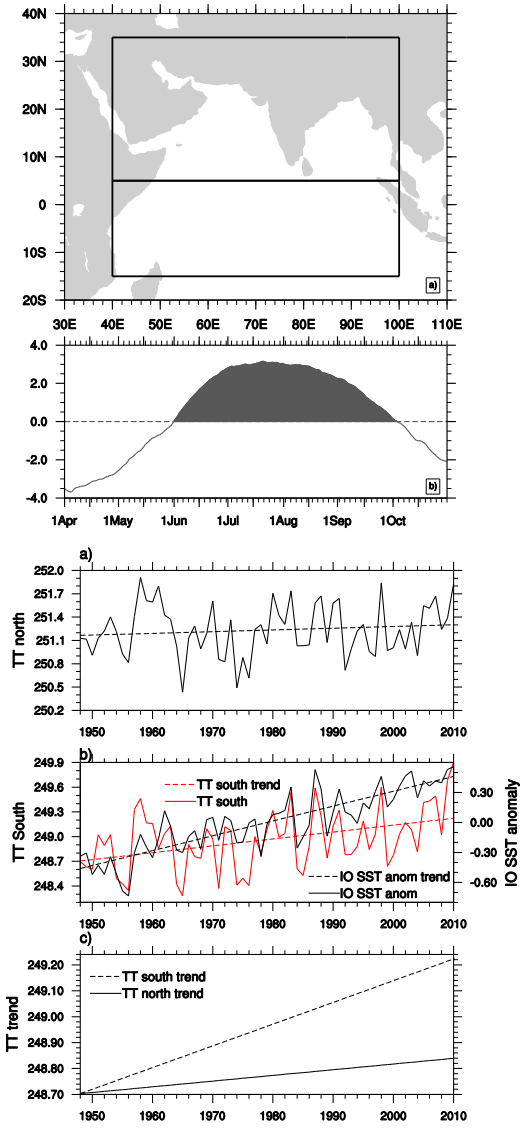
MPI−ESM−LR (192x96)
inmcm4 (180x120)
IPSL−CM5A−MR (144x143)
NorESM1−M (144x96)
GFDL−CM3 (144x90)
GISS−E2−R (144x90)
CanESM2 (128x64)
MIROC−ESM−CHEM (128x64)
MIROC−ESM (128x64)
bcc−csm1−1 (128x64)
IPSL−CM5A−LR (96x96)
35N
30N
25N
20N
15N
10N
5N
75E
90E
105E
120E
6
4
3
2
1
0.5
−0.5
−1
−2
−3
−4
CMIP5:rcp45(2080−2099) vs historical(1986−2005)
Mean Precip. Change [JJA]
65°E−130°E,5°N−35°N
[mm/day]
Kitoh

Recent decrearing trend of ISMR seems to be driven by warming of the IO!





Goswami et al. 2012

Panel Discussion

Recommendations of the Conference

- **Coupled Models for Monsoon Prediction**: Has shown some measurable progress. Must focus on further improvement to realize the potential predictability.
- **How to Improve the Parameterization schemes:** Formulation of clouds is largest source of biases in models. New observations required to better understanding to lead to new ideas on parameterization.
- **Uncertainty in Aerosol's Role**: Considerable uncertainty on how it influences monsoon. A model inter-comparison project suggested
- **New observations:** What is one single observation missing currently to give a quantum jump in tropical weather prediction?

Some Feedbacks

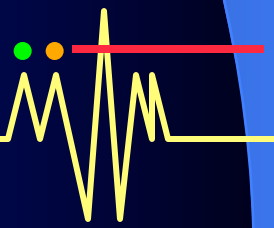
T.Yasunari,

"I really enjoyed this meeting which was one of the most exciting monsoon meeting I have ever joined."

J. Shukla

"the most stimulating monsoon conference that I have ever attended."

Thank you



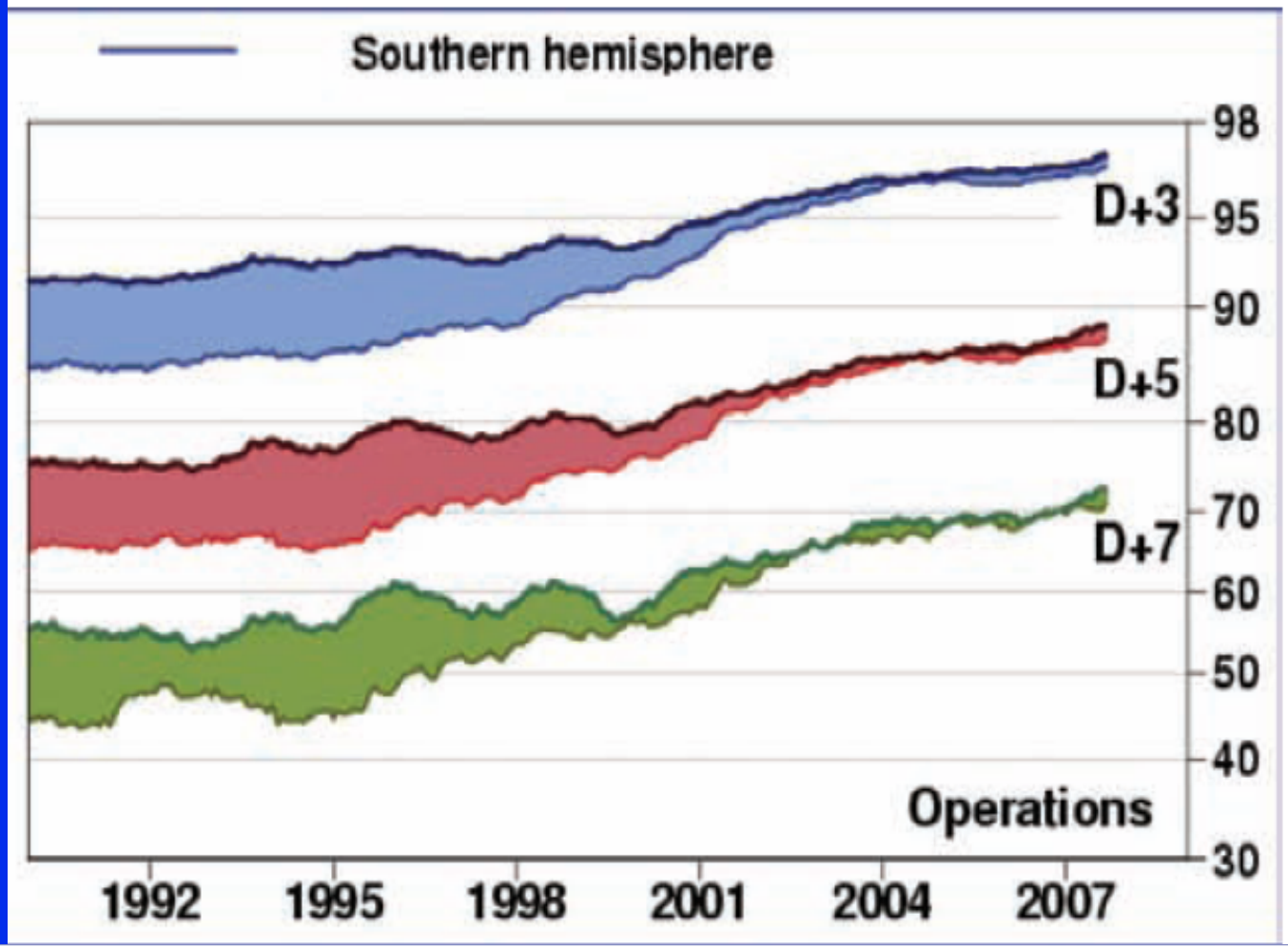


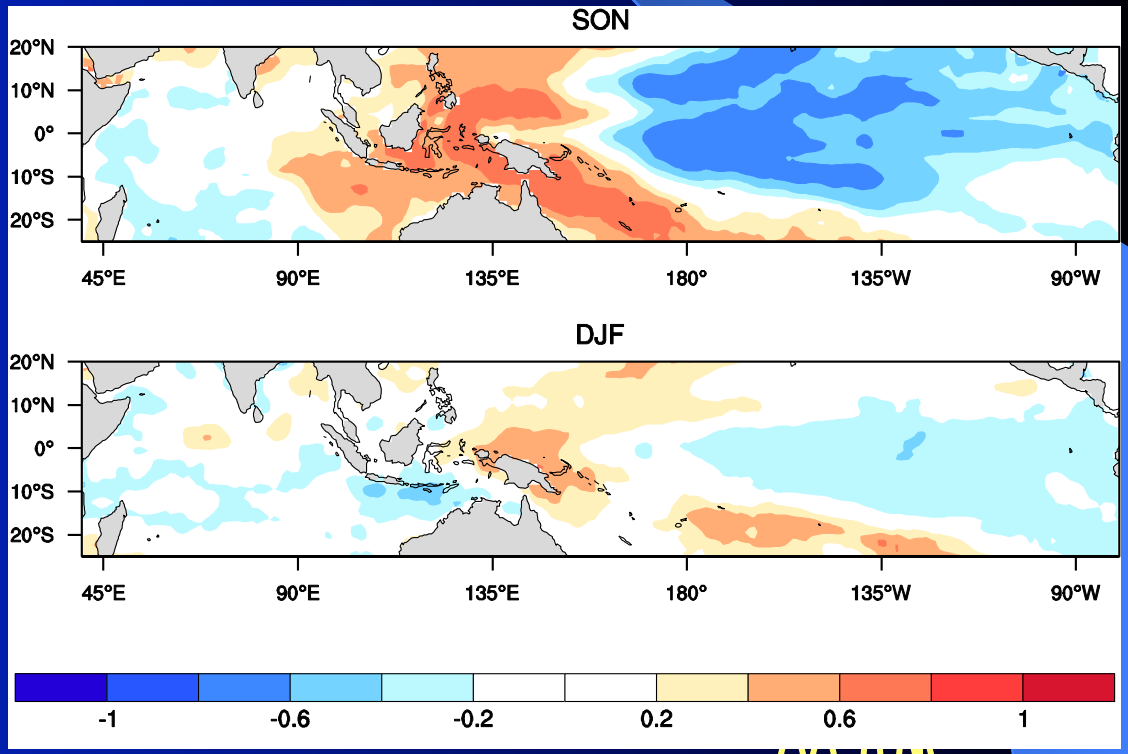
Figure 3. Improvements in medium-range NWP forecast skill; 12-month running mean of anomaly correlation (%) of 500hPa height forecasts. (left) Forecasts based on the ERA-40 system (i.e. initial conditions and associated model) – illustrates impact of additional data sources. (right) Forecasts based on the operational system at the given time – illustrates combined impacts of additional data sources, advances in data assimilation and model improvements. Courtesy of Adrian Simmons by way of Martin Miller.

Improved Understanding: Role of local air-sea interactions on monsoons

Local air-sea interaction acts to promote rainfall/SST variability and predictability in Australian pre-monsoon, but acts to damp SST/rainfall post onset (Hendon)

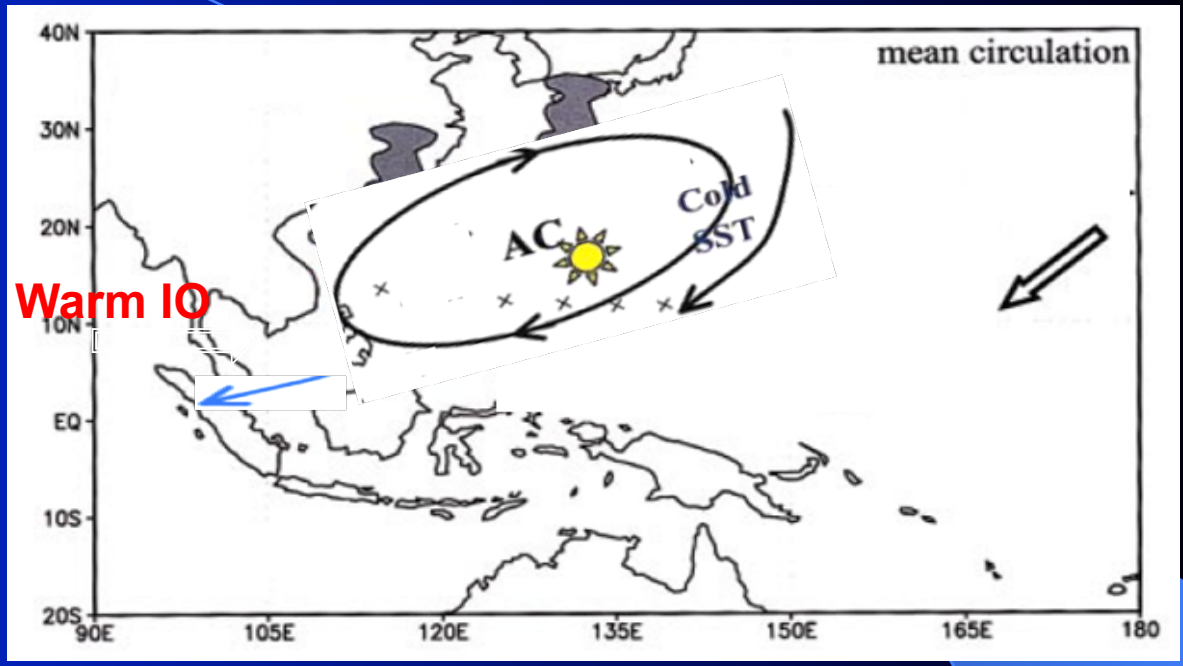
Observed gridded SST correlated with Australian averaged rainfall (north of 25S) 1980-2008. ***Strong ENSO-like correlation in pre-monsoon transition season***

Much weaker correlation, especially locally, during monsoon



Improved Understanding: Variability and predictability of West North Pacific High

West North Pacific High variability/ Predictability: WNPAC induces SST cooling via evaporation/ entrainment. Cold SST and Southward cold dry advection suppress convection, enhancing WNPAC (Wang)

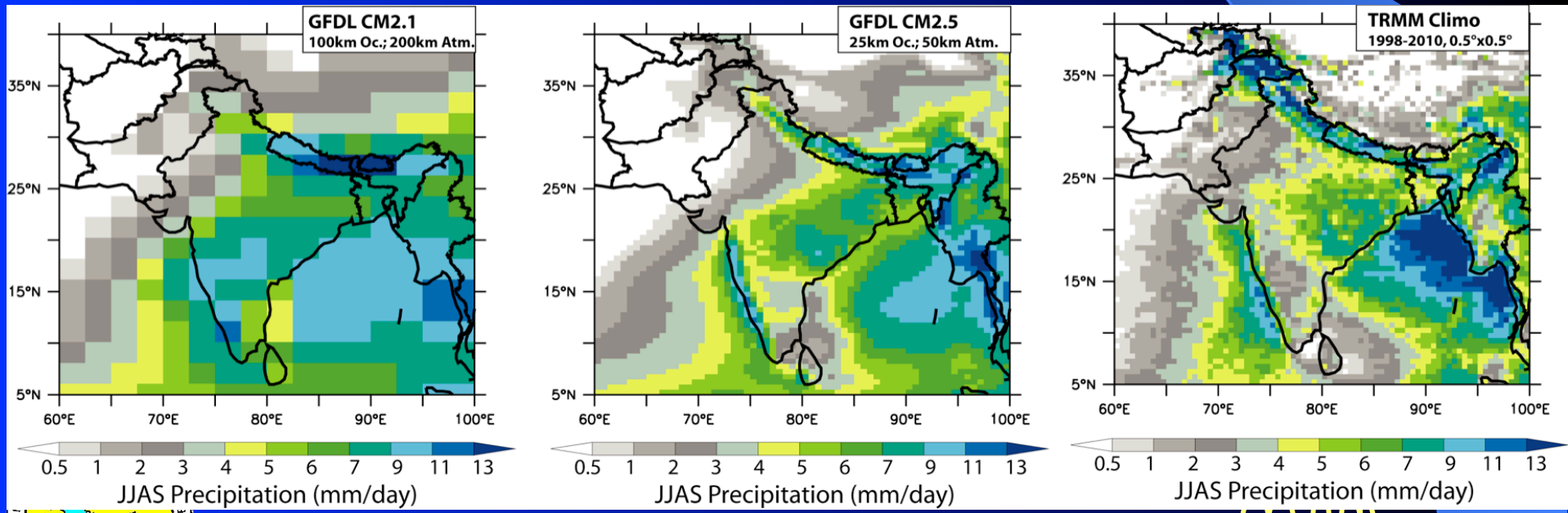


1) WNPAC induces SST cooling via evaporation/entrainment
2) Cold SST and Southward cold dry advection suppress convection, enhancing WNPAC

Major Challenges: Climate Change Projections

- **South Asian Monsoon rainfall simulation improves with resolution of the coupled models (Vechhi)**

CM2.1(lo-res) **CM2.5(hi-res)** **TRMM(1998-2010)**

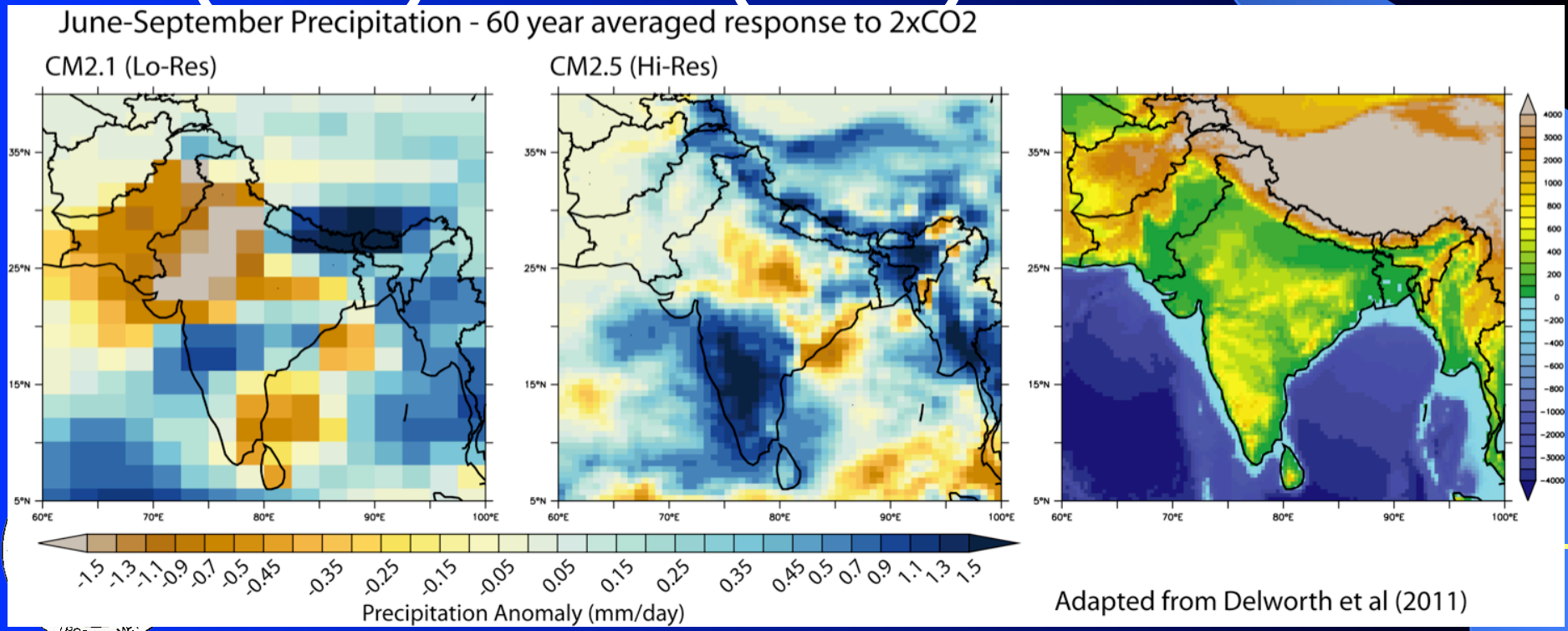


Major Challenges: Climate Change Projections

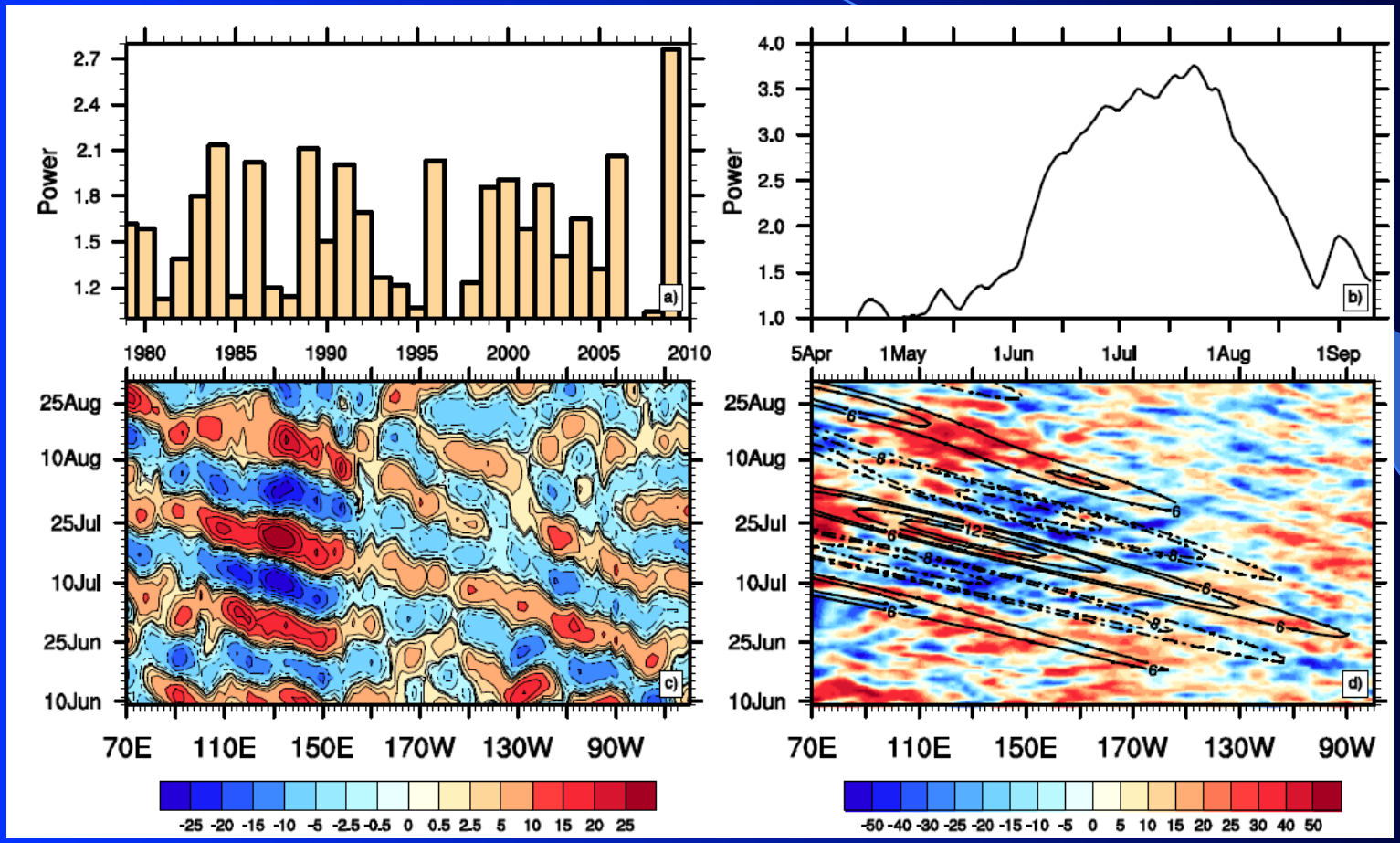
- **Response of increased CO2 in coupled models at different resolution is different (Vechhi)**
- **Response model dependent, hi-res model shows orographically-tied features**

Why is this difference?

CM2.1(lo-res) CM2.5(hi-res)



Improved Understanding: Indian Summer Monsoon
Active/Break spells influenced by Equatorial Rossby waves



Neena et al. 2011, JGR

Atmospheric internal dynamics ,through equatorial Rossby waves originating from tropical Pacific, appears to be modulating monsoon ISOs even during non El Nino years.