South Asia Media Briefing Workshop
CSE, India Habitat Centre, New Delhi
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Monsoons and Extreme Weather Events in Changing Climate

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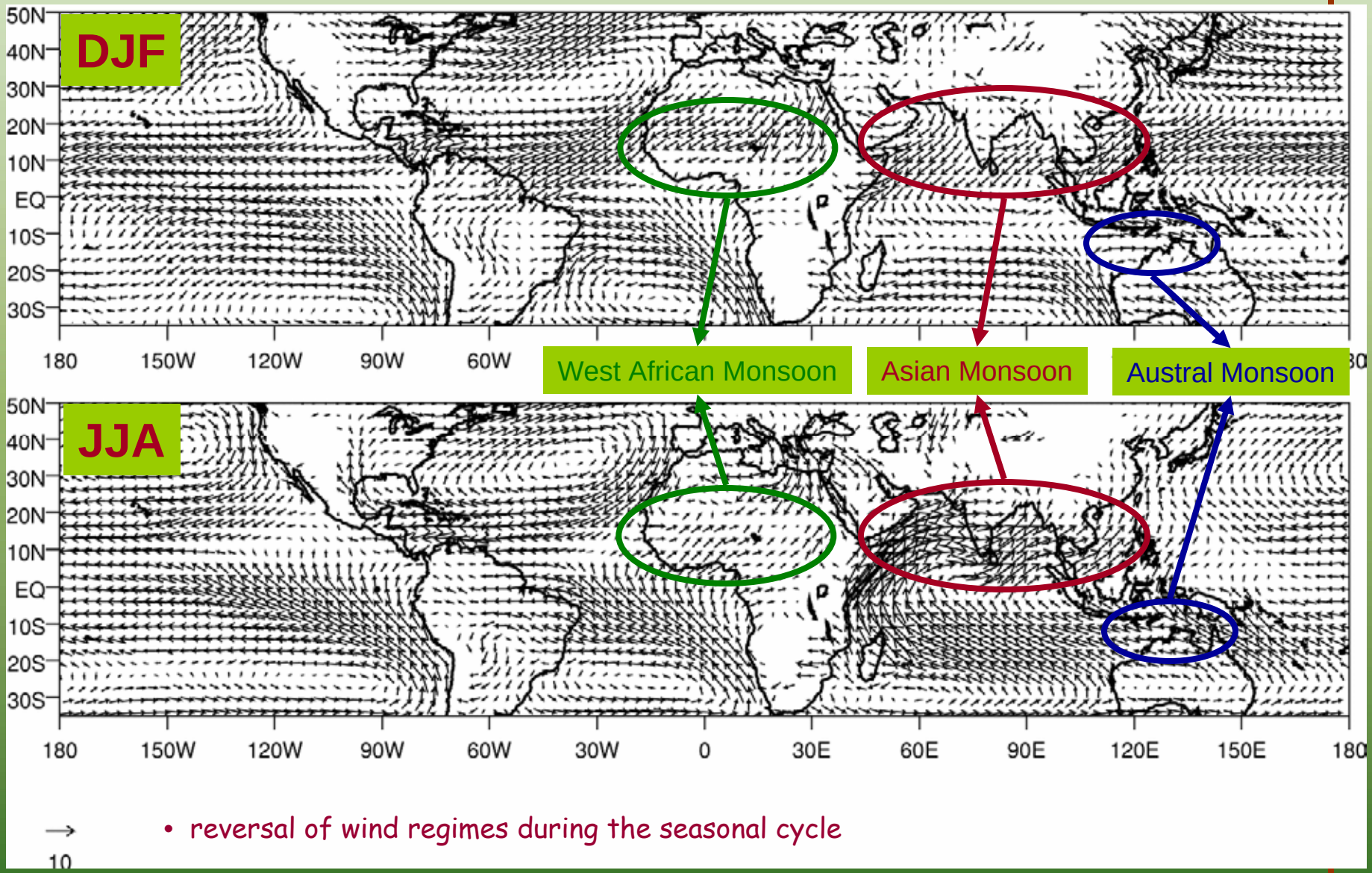
Indian Institute of Tropical Meteorology, Pune
(Ministry of Earth Sciences, Govt. of India)

Monsoon

- the dominant phenomena over much of Asia
- the factors that influence the monsoonal flow and precipitation are of central importance for understanding climate change in this region

- Key Processes
- Extreme Weather Events
- Skill of Models in Simulating Present Climate
- Climate Projections
- CCCR, IITM contributions for IPCC AR5

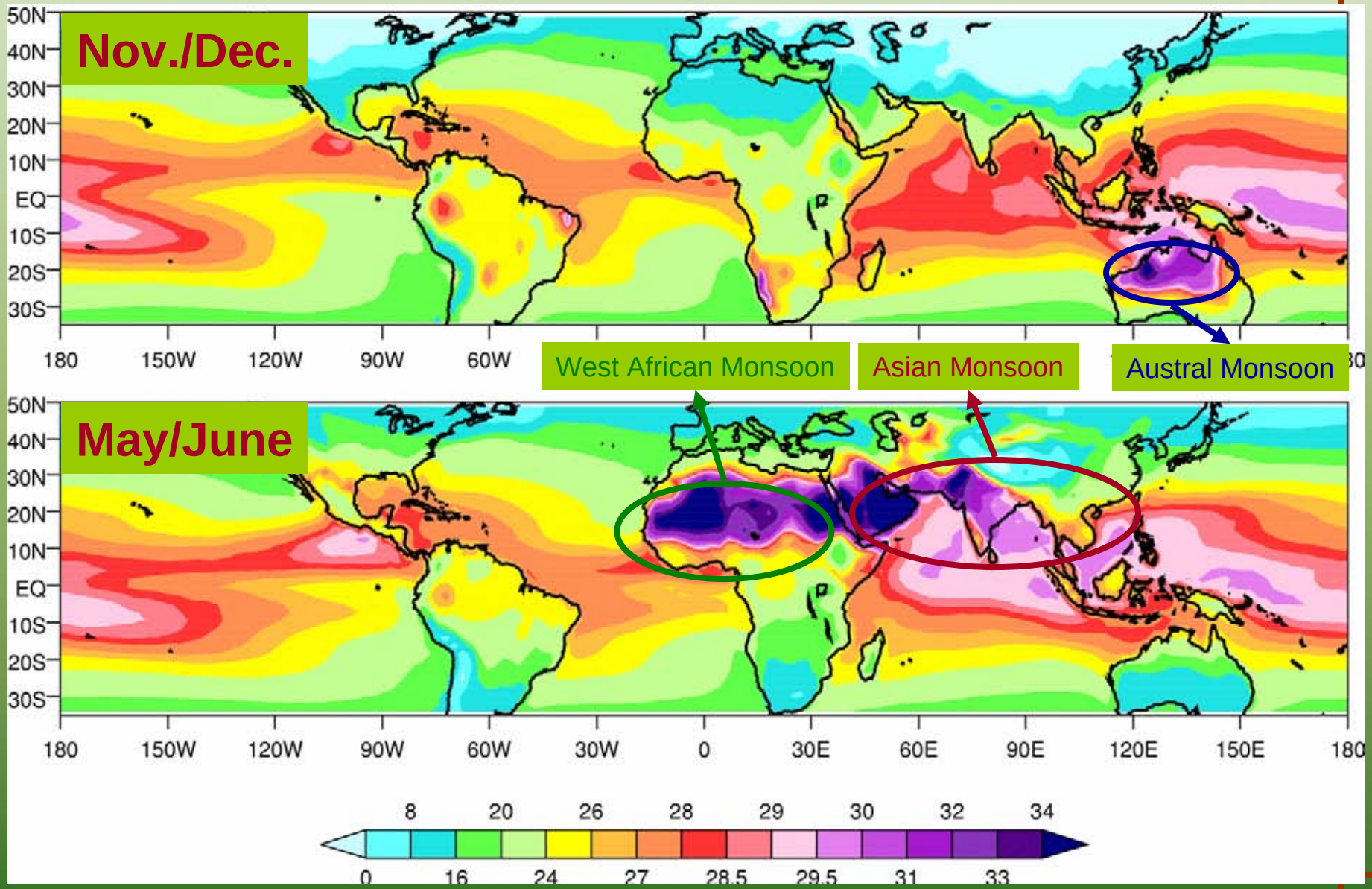
925hPa Circulation



- reversal of wind regimes during the seasonal cycle

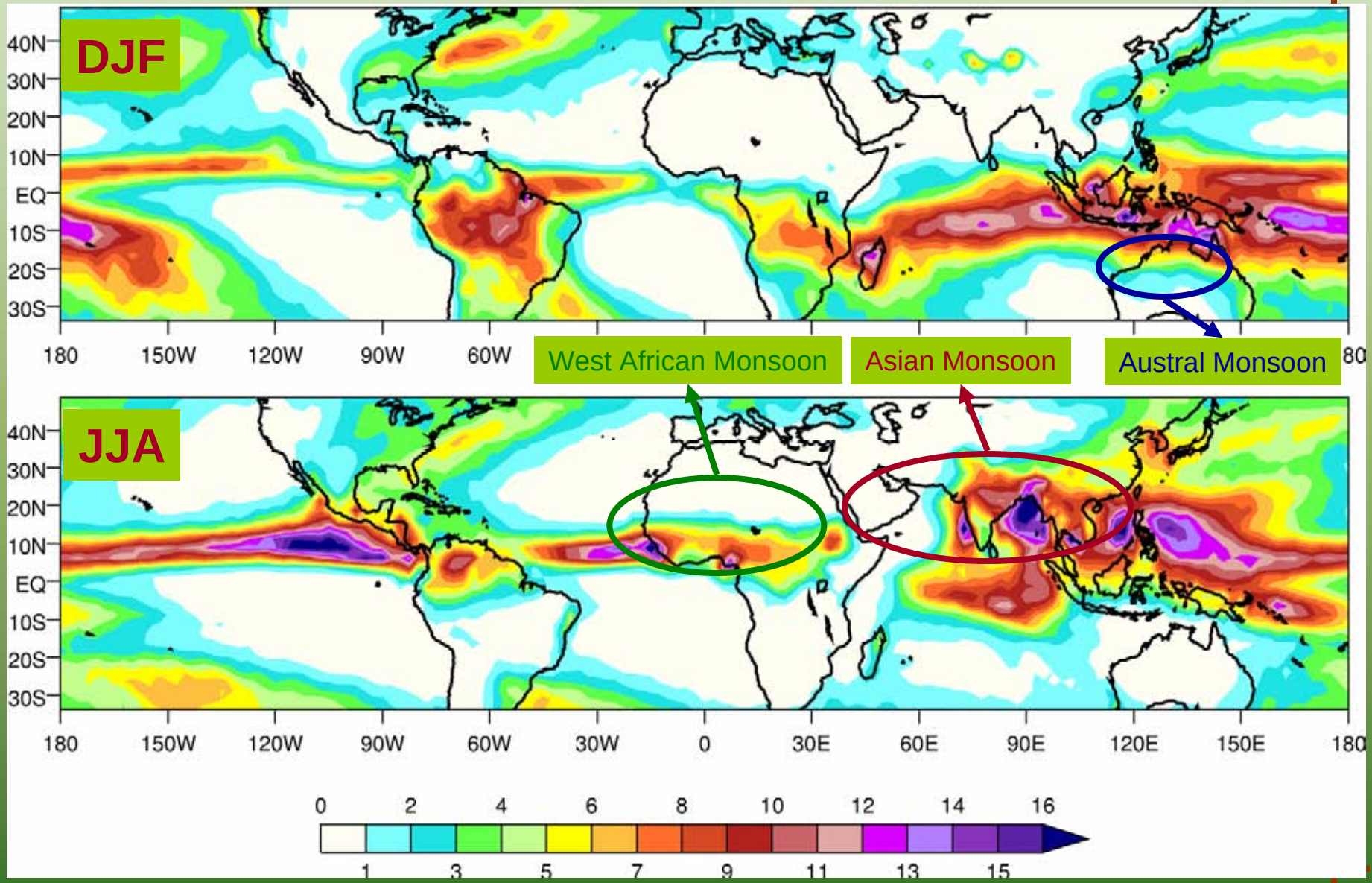
Courtesy: J.M. Slingo, Univ of Reading

Land/Sea Temperature contrasts



Courtesy: J.M. Slingo, Univ of Reading

Rainfall (mm/day)



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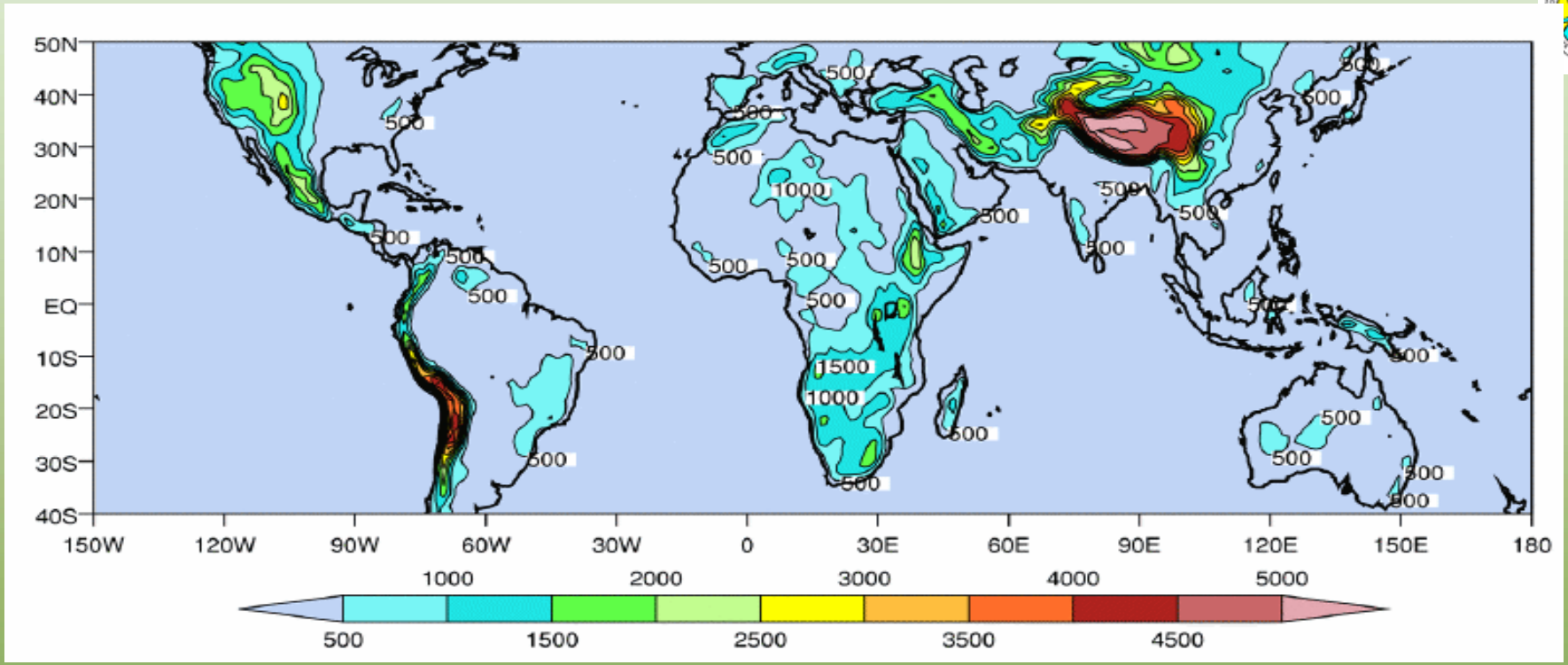
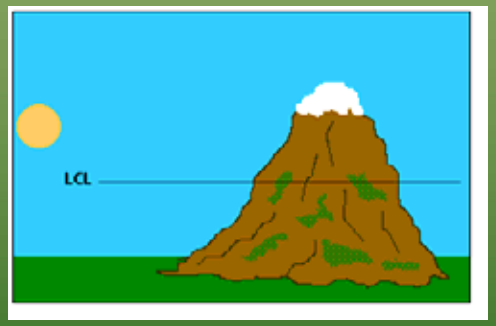
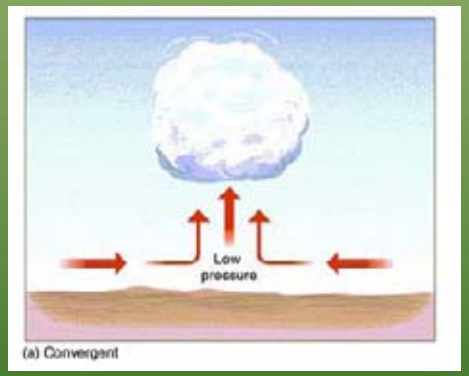


- Examples of dynamical forcing that can produce saturation include orographic lifting and large-scale convergence

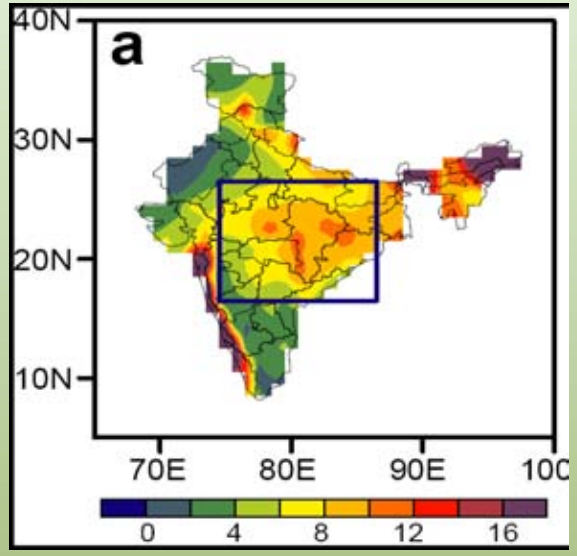




Monsoon Processes in Changing Climate

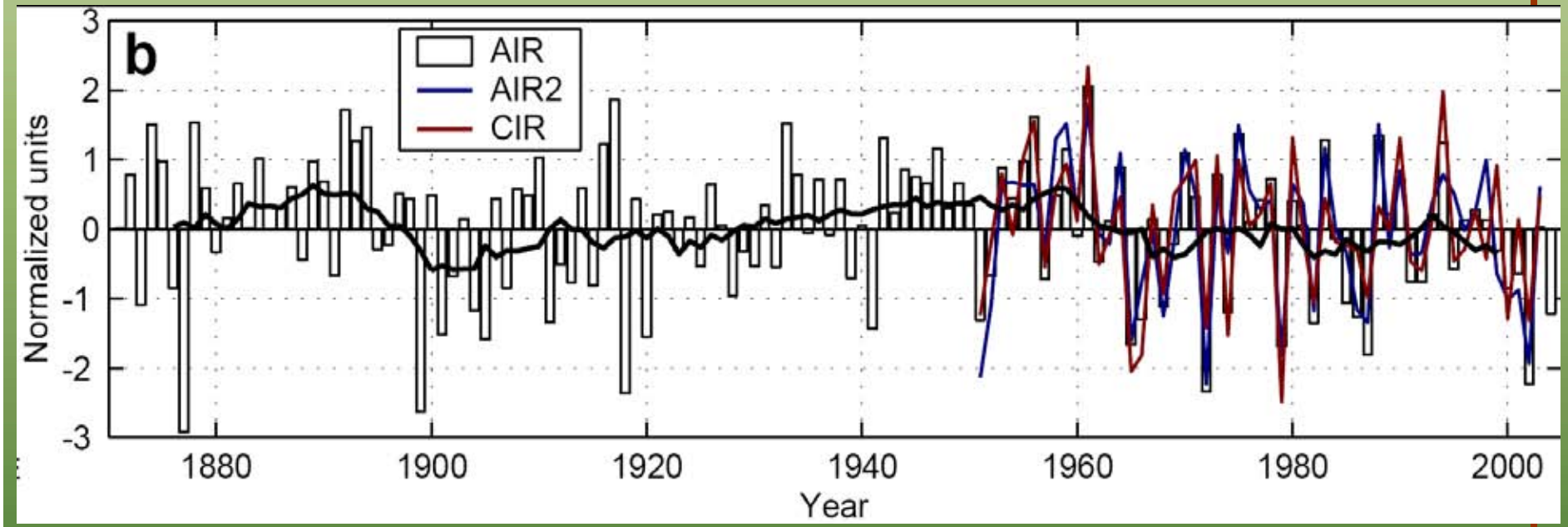
- Precipitation is affected both by the strength of the monsoonal flows and the amount of water vapour transported
- Monsoonal flows and the tropical large-scale circulation often weaken in global warming simulations
- However the monsoon precipitation is expected too increase due to the effect of enhanced moisture convergence in a warmer, moister atmosphere
- Impact of change in the ENSO-South Asian monsoon connection under GHG warming
- Link between Eurasian snow cover and the strength of the monsoon, with the monsoon strengthening if snow cover retreats
- Aerosols, particularly absorbing aerosols, further modify monsoonal precipitation
- Modifications of vegetation cover
- However, most emission scenarios suggest that future changes in regional climate are still likely to be dominated by increasing GHG forcing rather than changes in sulphate and absorbing aerosols, at least over the South Asian region
- The monsoon depressions and tropical cyclones generated over the Indian seas modulate the monsoon anomalies

All India summer monsoon rainfall variability



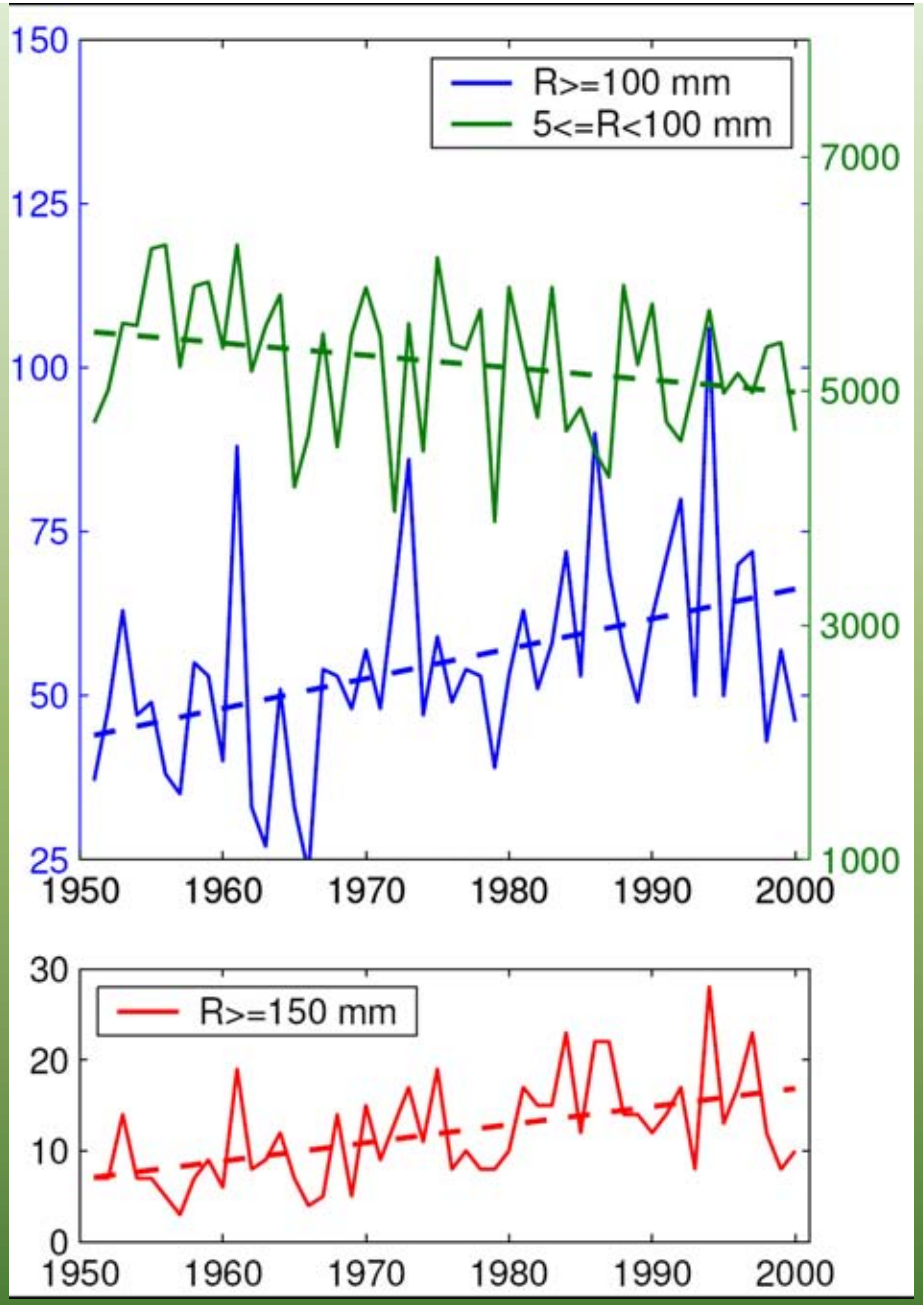
Climatological Mean (JJAS)

Interannual Variability



Goswami et al., Science, 2006

Time series of count over CI



Low & Moderate events

Heavy events (>10 cm)

V. Heavy events (>15 cm)

Challenges in assessment of future changes in South Asian monsoon rainfall

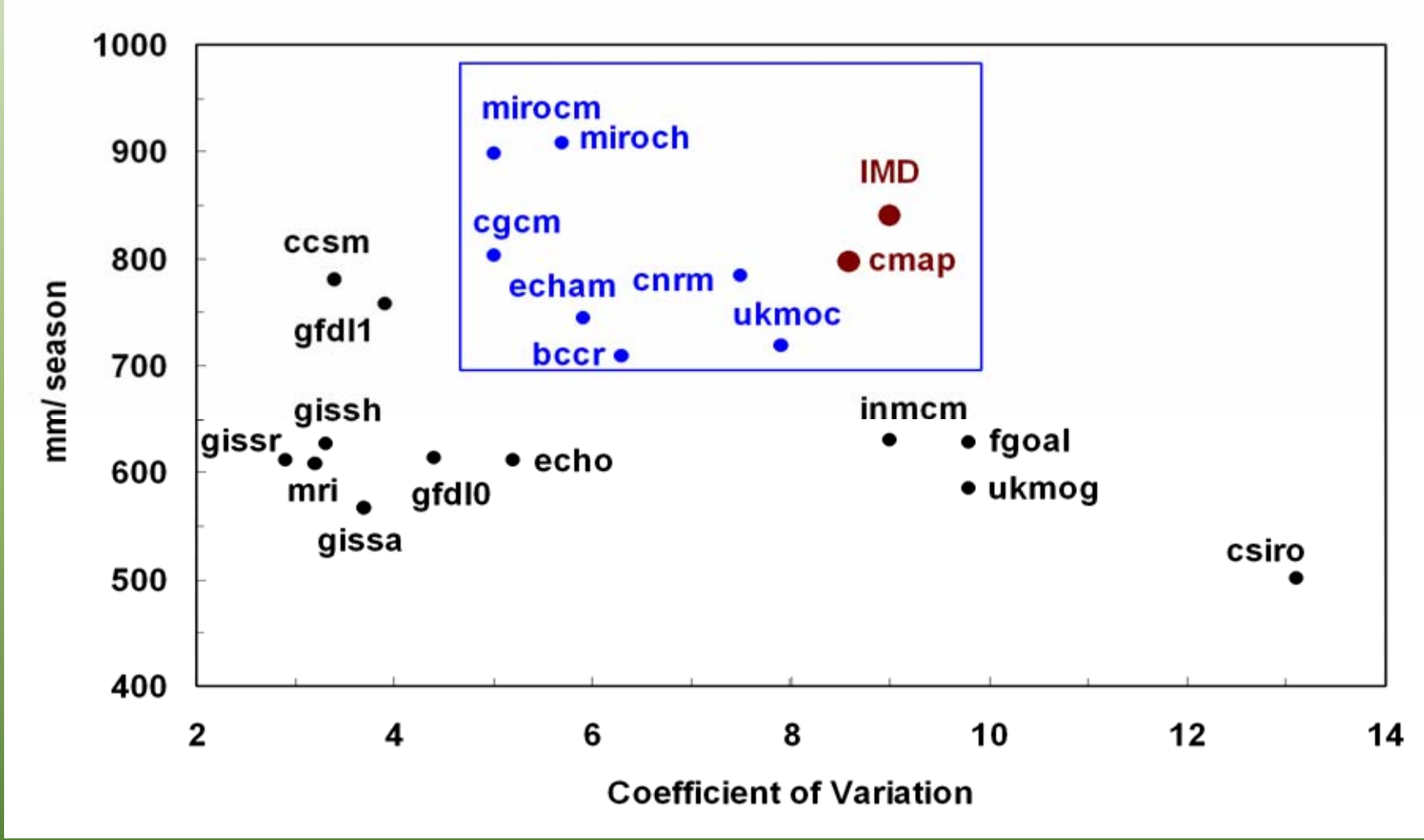
- Wide variations and uncertainties among the IPCC AR4 models in capturing the mean monsoon rainfall over South Asia
  (eg., Kripalani et al. 2007, Annamalai et al. 2007)

- Systematic biases in simulating the spatial pattern of present-day mean monsoon rainfall
  (eg., Gadgil and Sajani, 1998; Kripalani et al. 2007)

- **Realism of present-day climate simulation is an essential requirement for reliable assessment of future changes in monsoon**

South Asia

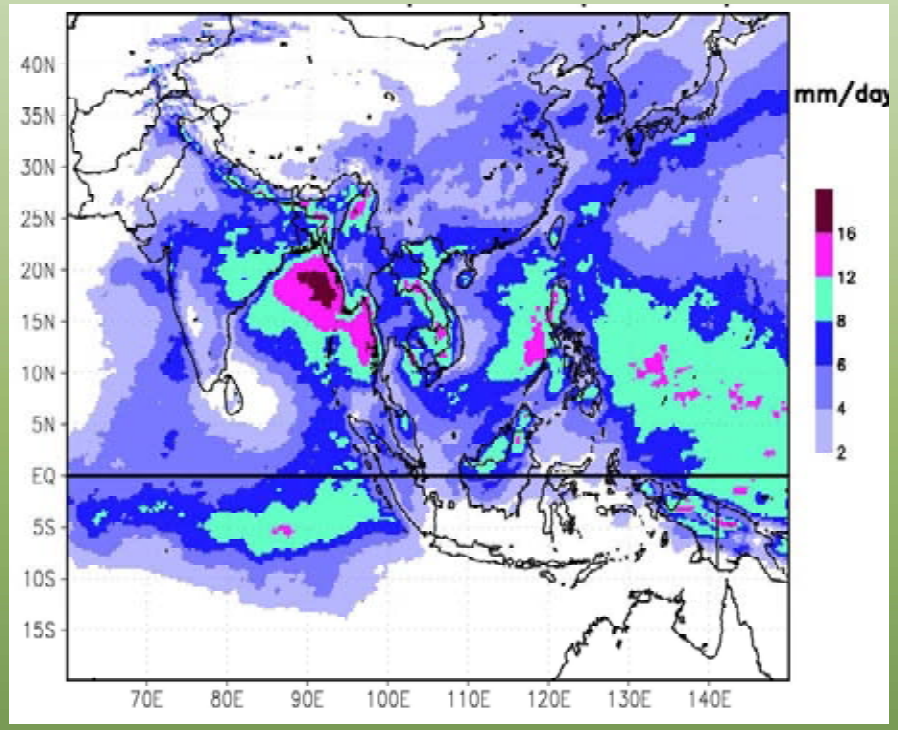
(5-35N, 65-95E))



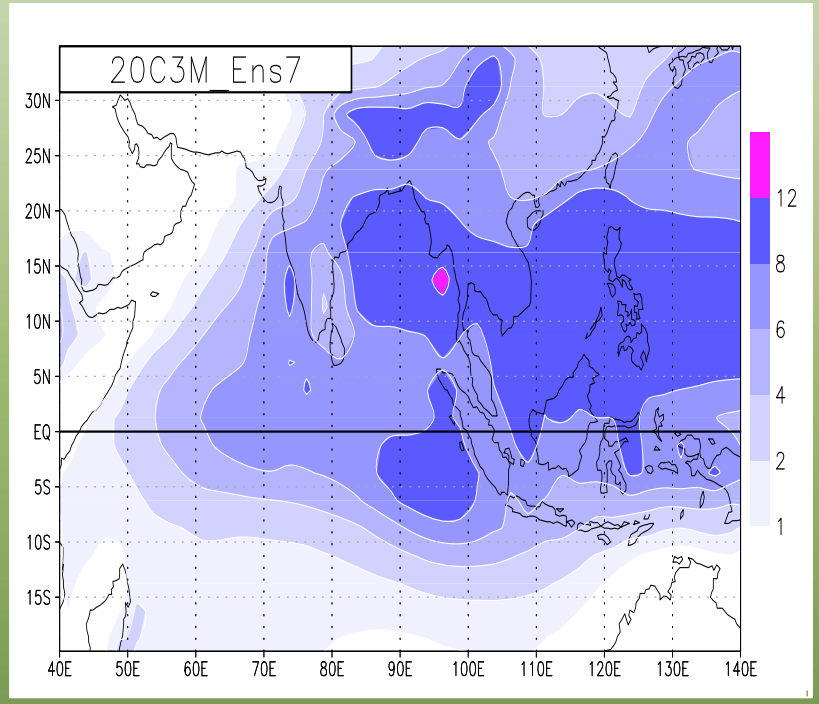
Kripalani et al. 2010

Summer monsoon precipitation

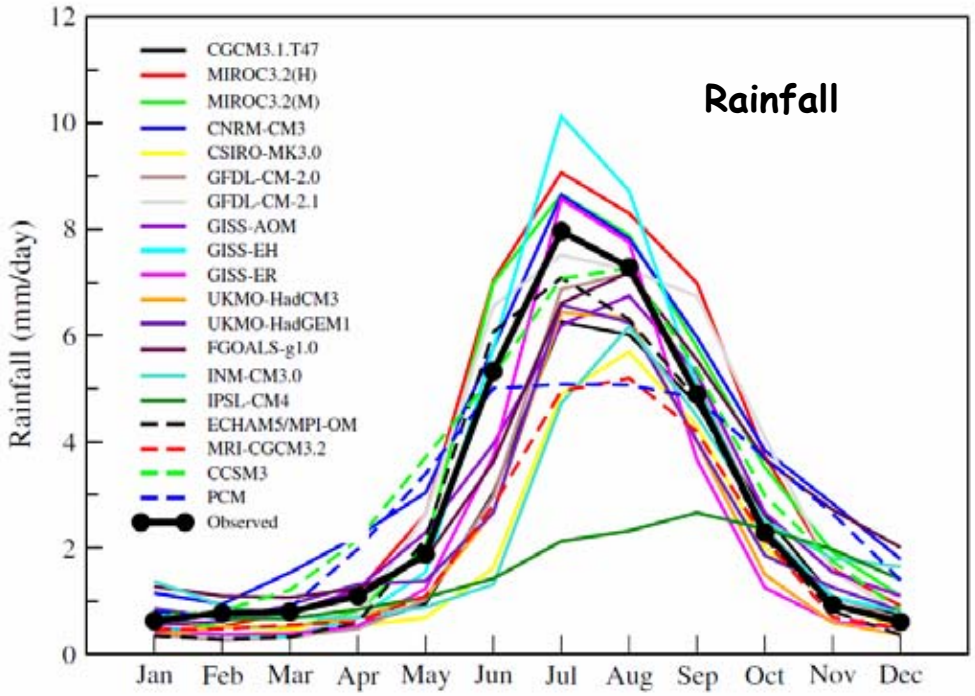
Observed rainfall (JJAS)

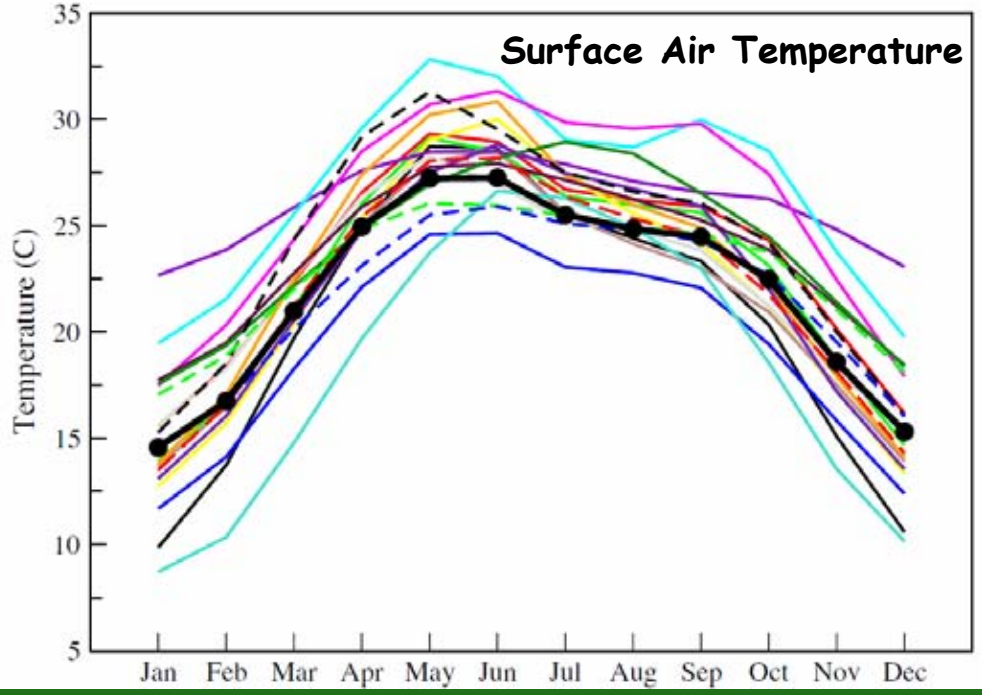


IPCC models: 20C3M 1979-1998



The 20c3m simulations attempt to replicate the overall climate variations during the period ~1850-present by imposing each modeling groups best estimates of natural (eg., solar irradiance and volcanic aerosols) and anthropogenic (eg. GHG, sulfate aerosols and ozone) during this period. Seven 20C3M models (GFDL CM2.0, GFDL-CM2.1, MPI-ECHAM5, MRI, MIROC3-HIRES, HadCM3, NCAR-PCM – Source: J. Shukla)



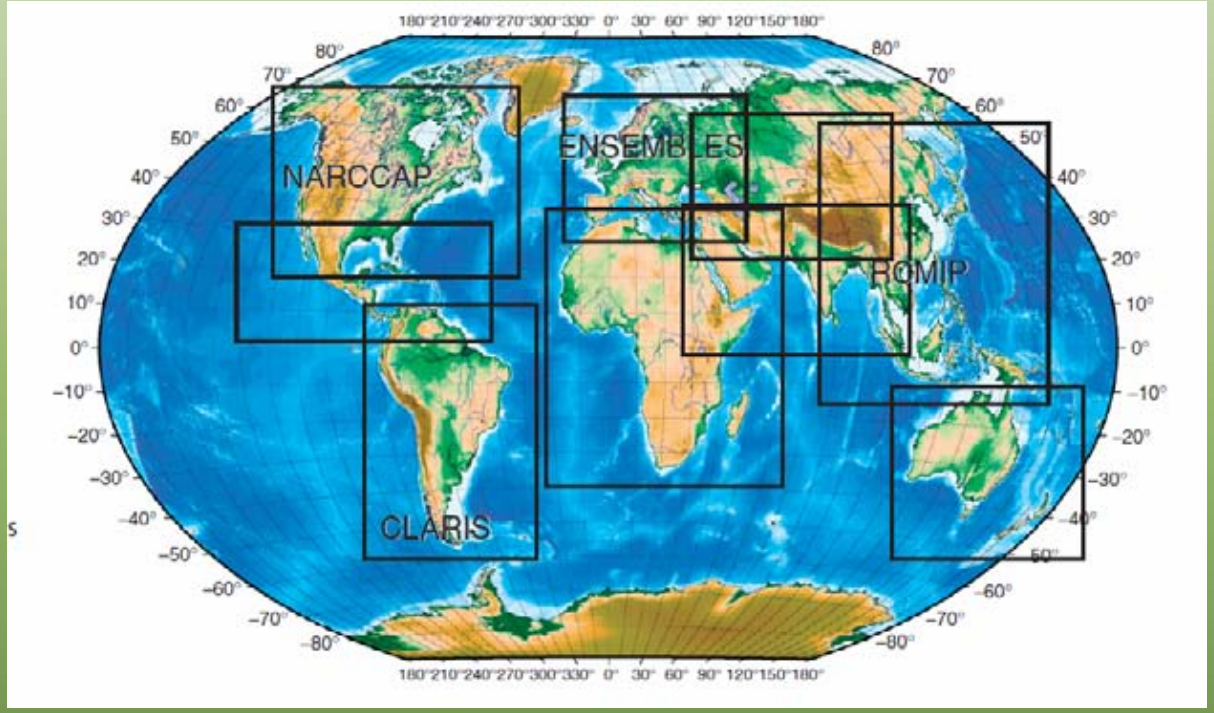


IPCC AR4 models area-averaged annual cycles over South Asia (1979-2000)

Regional Climate Downscaling

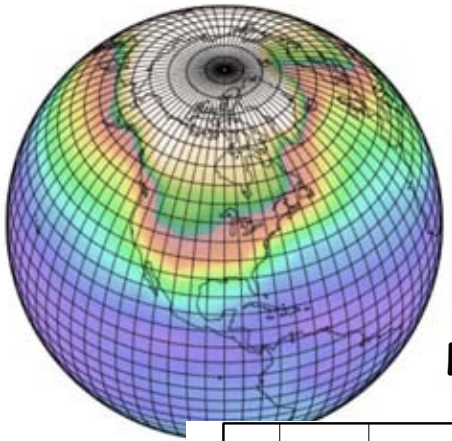
- In IPCC AR4, the Atmosphere-Ocean General Circulation Models (AOGCMS) constitute the primary tool for capturing the global climate system behaviour
- The spread within an ensemble of AOGCMs is often used to characterise the uncertainty in projected future climate changes
- However over South Asian monsoon region the spread remains large
- Due to the significant complexity of the AOGCMs and the need to provide multi-century integrations, horizontal resolutions of AR4 AOGCMs range from 400 to 125 km
- Generating information below the grid scale of AOGCMs is referred to as downscaling
- **Dynamical downscaling** uses high-resolution climate models to represent global or regional sub-domains, and uses either observed or lower-resolution AOGCM data as their boundary conditions
- These models are formulated using physical principles, which increases confidence in their ability to downscale realistically future climates

- The regional climate model (RCM) is a model of the atmosphere and land surface, of limited area and high resolution and locatable over any part of the globe

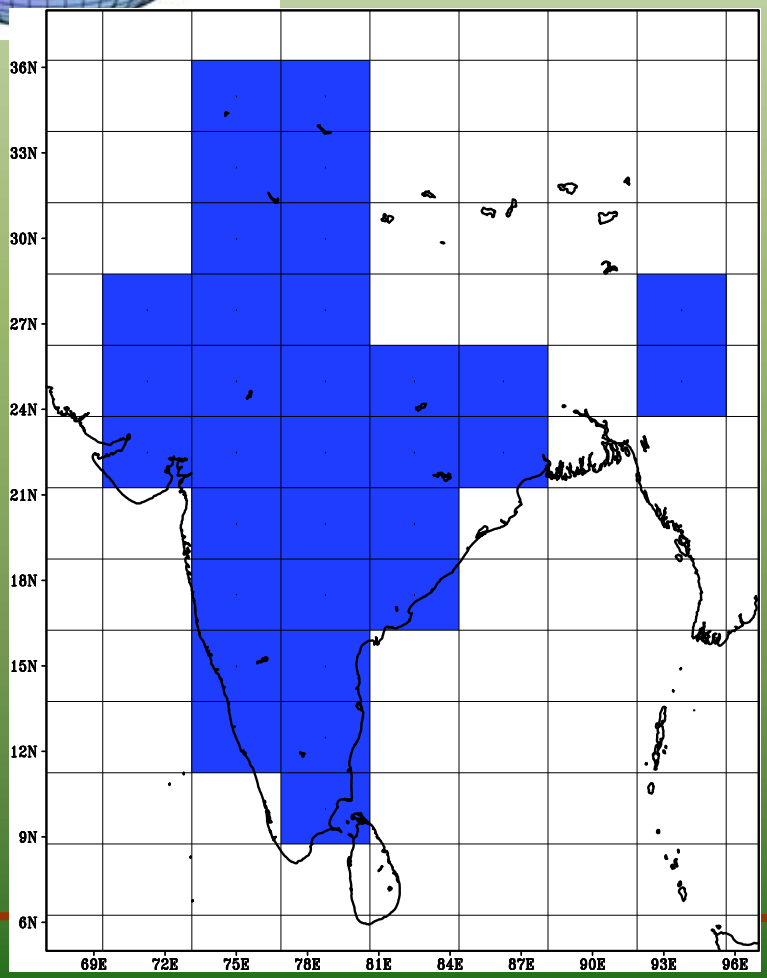


Drawbacks

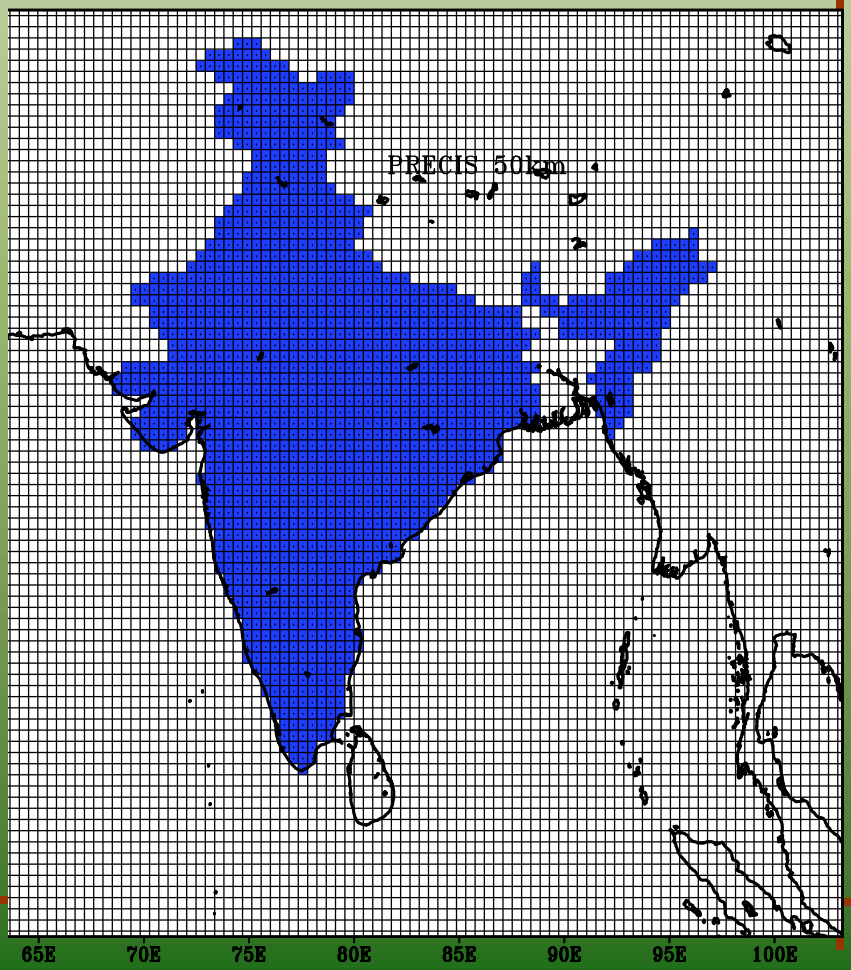
- Computational cost
- Validity of parametrization schemes in future climate



HadCM3 (3° x 2.5^{o})



PRECIS (0.44^{o} x 0.44^{o})



imd-hadcm3-grid.eps, Thu Aug 21 09:11:07 2008

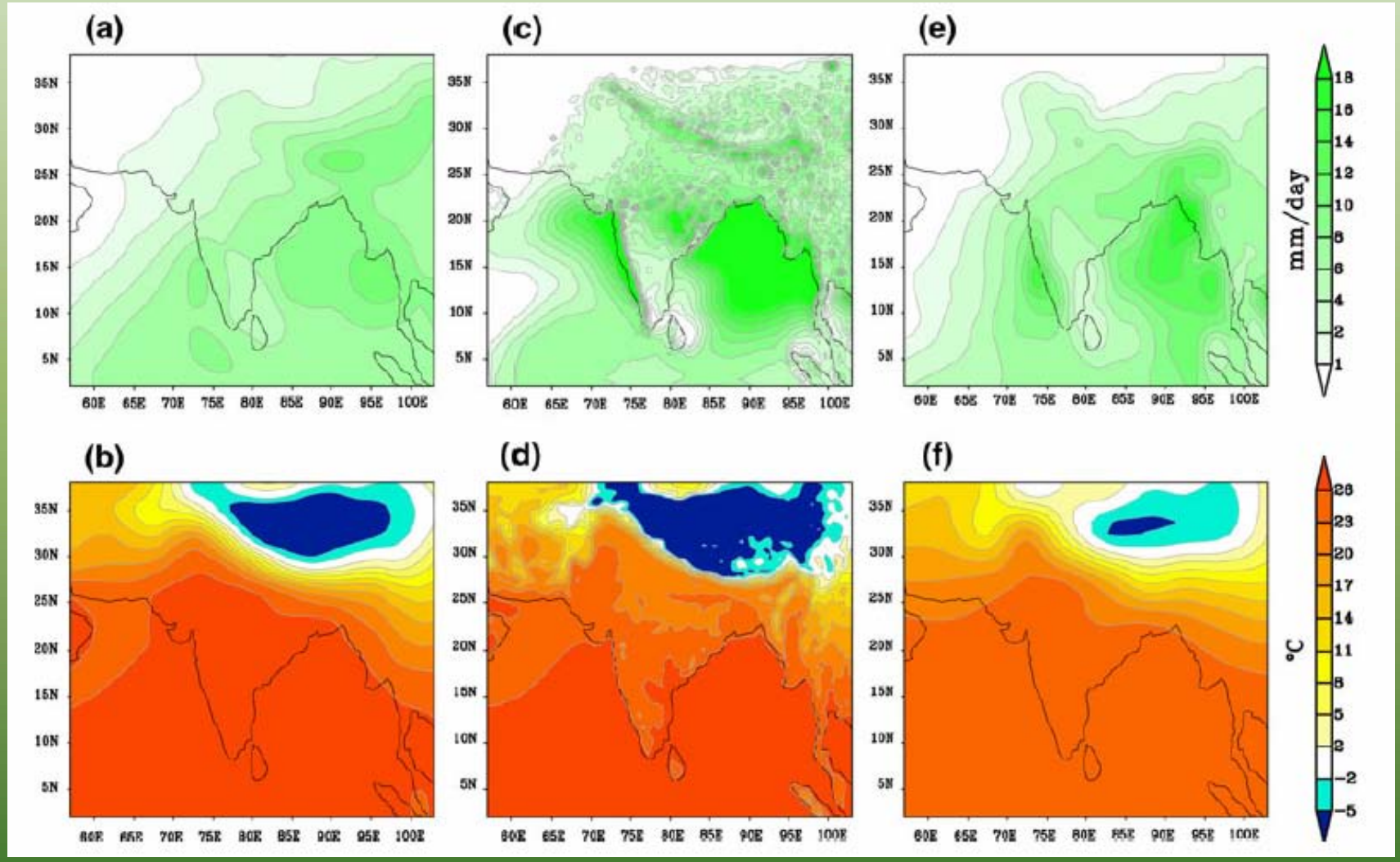
Summer monsoon climate over India by a high-resolution regional climate model

Krishna Kumar et al. (2010)

IPCC-AR4 models
Ensemble mean

PRECIS

Observed



Summer monsoon climate over India by a high-resolution regional climate model

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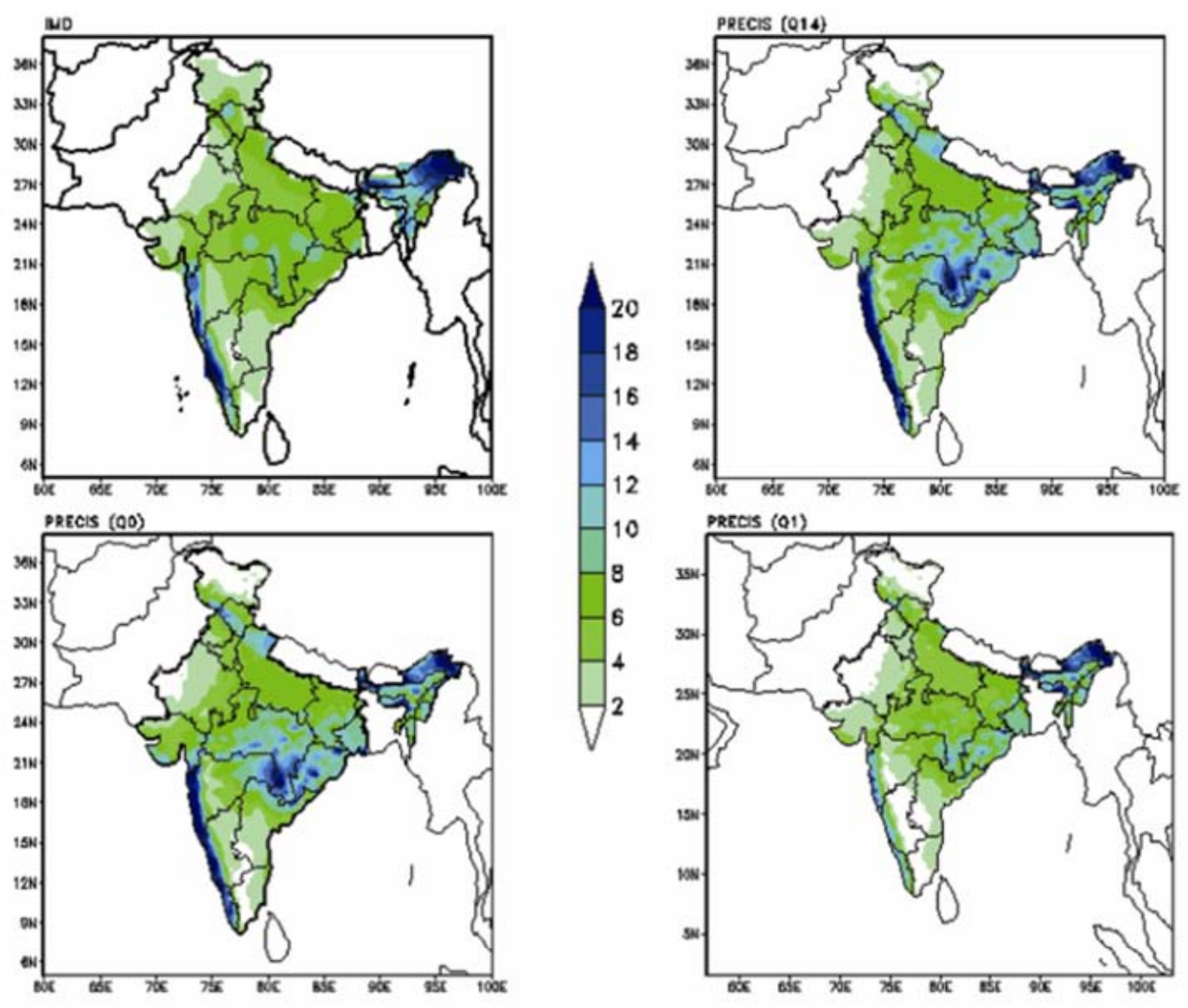
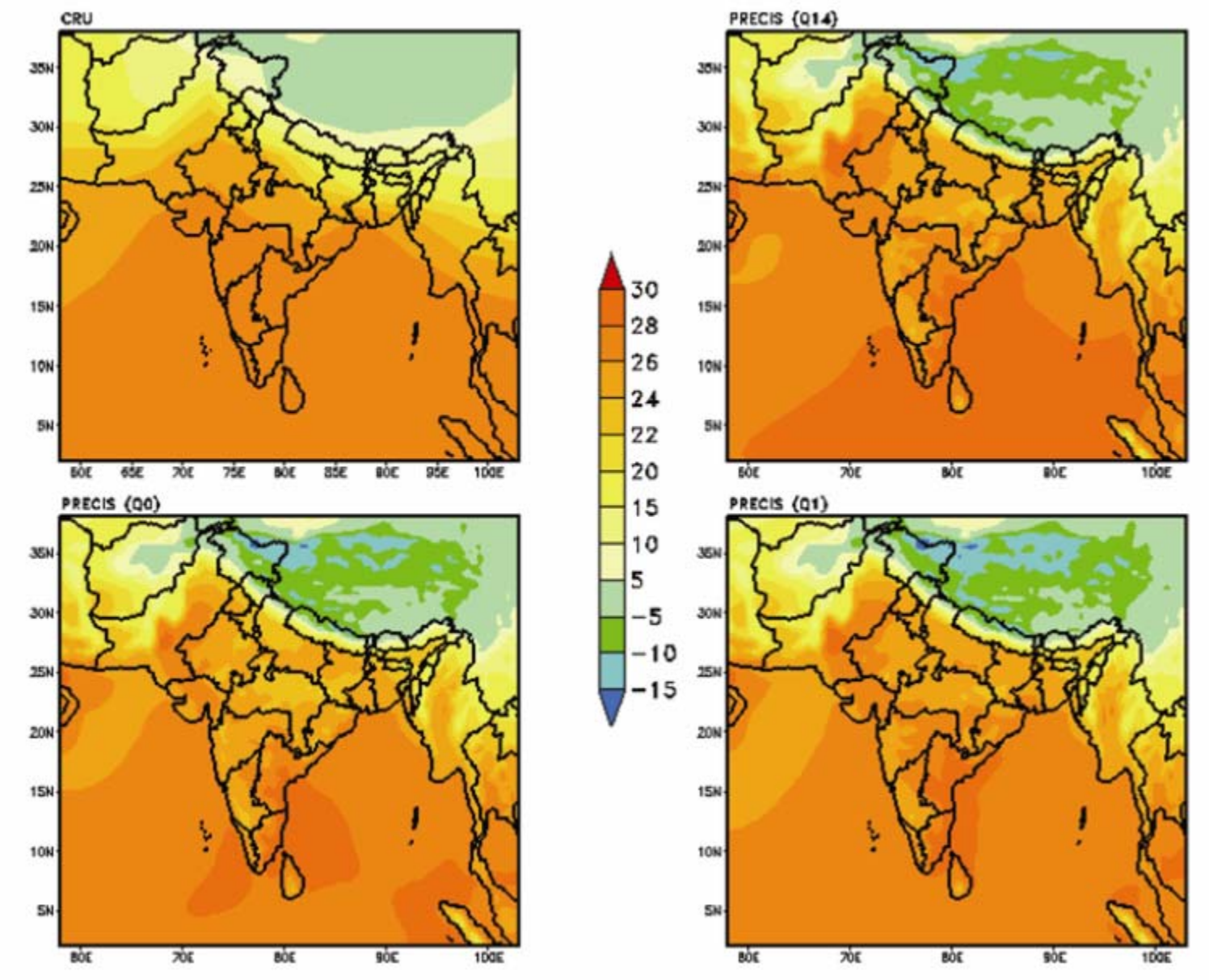


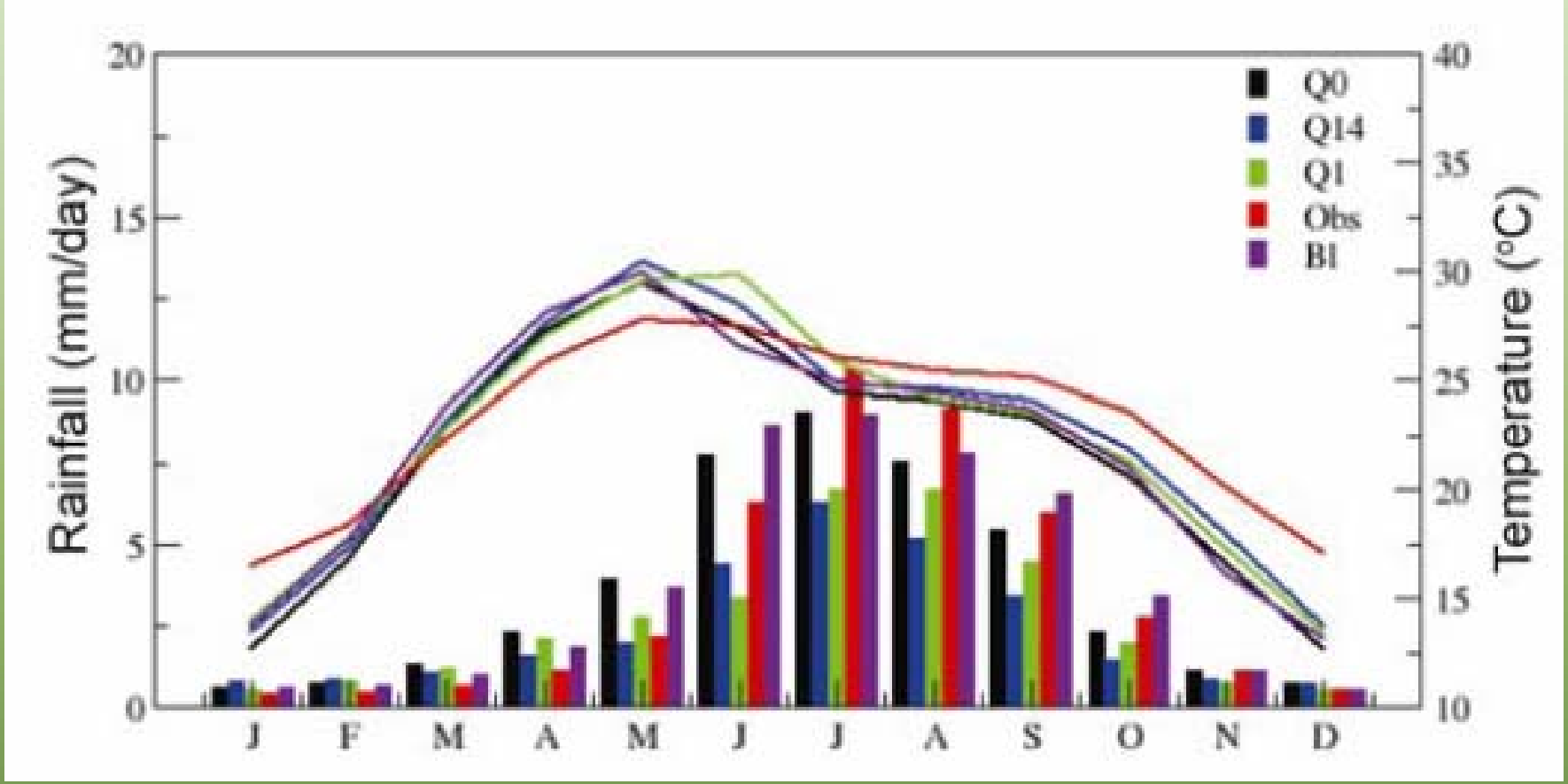
- PRECIS (Providing REgional Climates for Impact Studies)
- 3 simulations driven with HadCM3 QUMP lateral boundary conditions
- 1961-1990 climatology

Mean annual surface air temperature simulated in PRECIS



Krishna Kumar et al. (2011)

PRECIS area-averaged annual cycles over India (1961-1990)



Krishna Kumar et al. (2011)

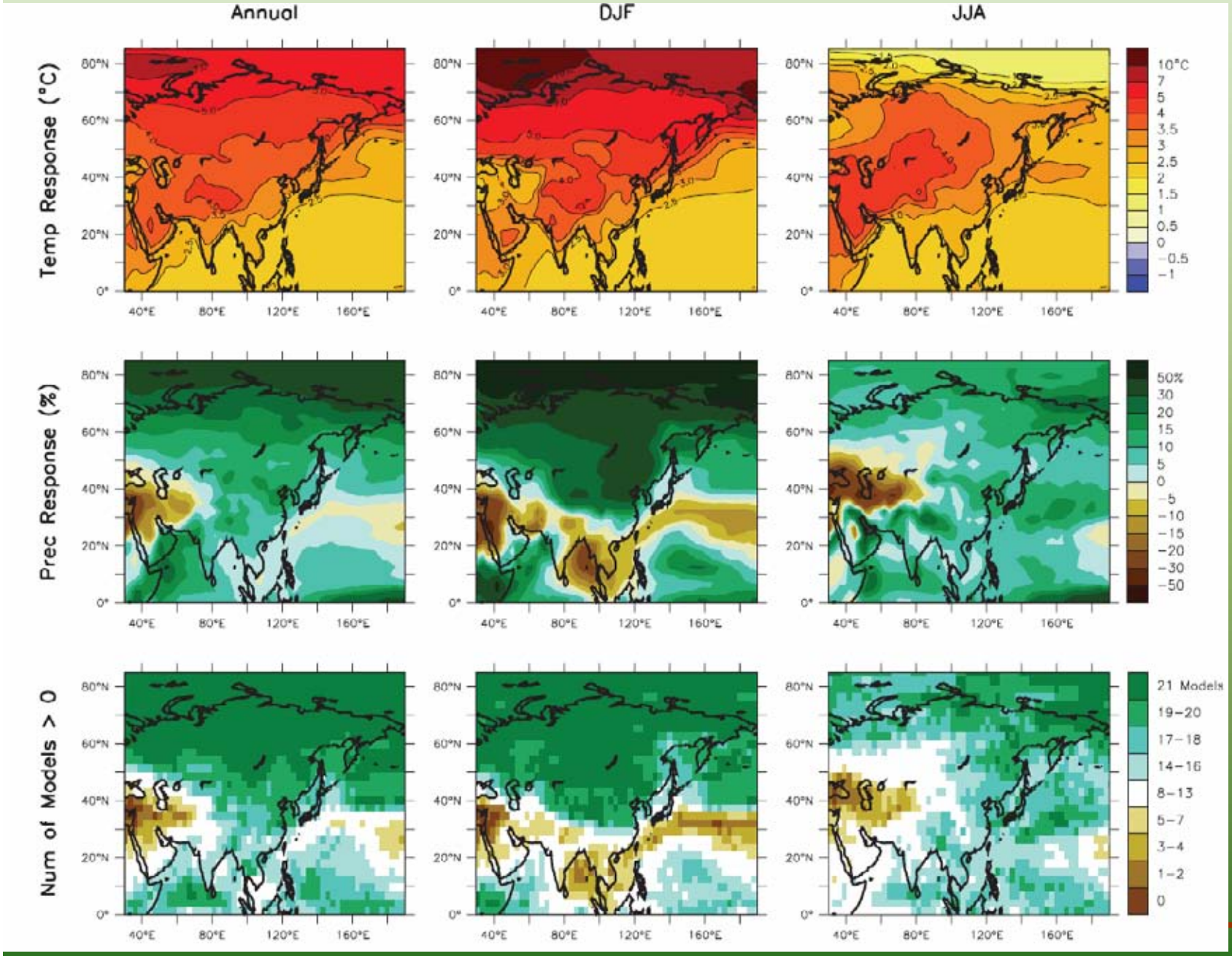
Regional Climate Projections

IPCC AR4 projected climate change for South Asia:

- Warming during this century (3.3°C) is likely to be above the global mean (2.5°C)
- It is very likely that there will be fewer very cold days
- Summer precipitation is likely to increase (11% with large inter-model spread)
- An increase in the frequency of intense precipitation events in parts of South Asia is very likely
- Extreme rainfall and winds associated with tropical cyclones are likely to increase
- Monsoonal flows and the tropical large-scale circulation are likely to be weakened
- Sources of uncertainty
  - Non availability of detail assessment of the projected changes in regional climatic means and extremes
  - Substantial inter-model differences in representing monsoon processes
  - A lack of clarity over changes in ENSO

IPCC 2007

Temperature and precipitation changes over Asia

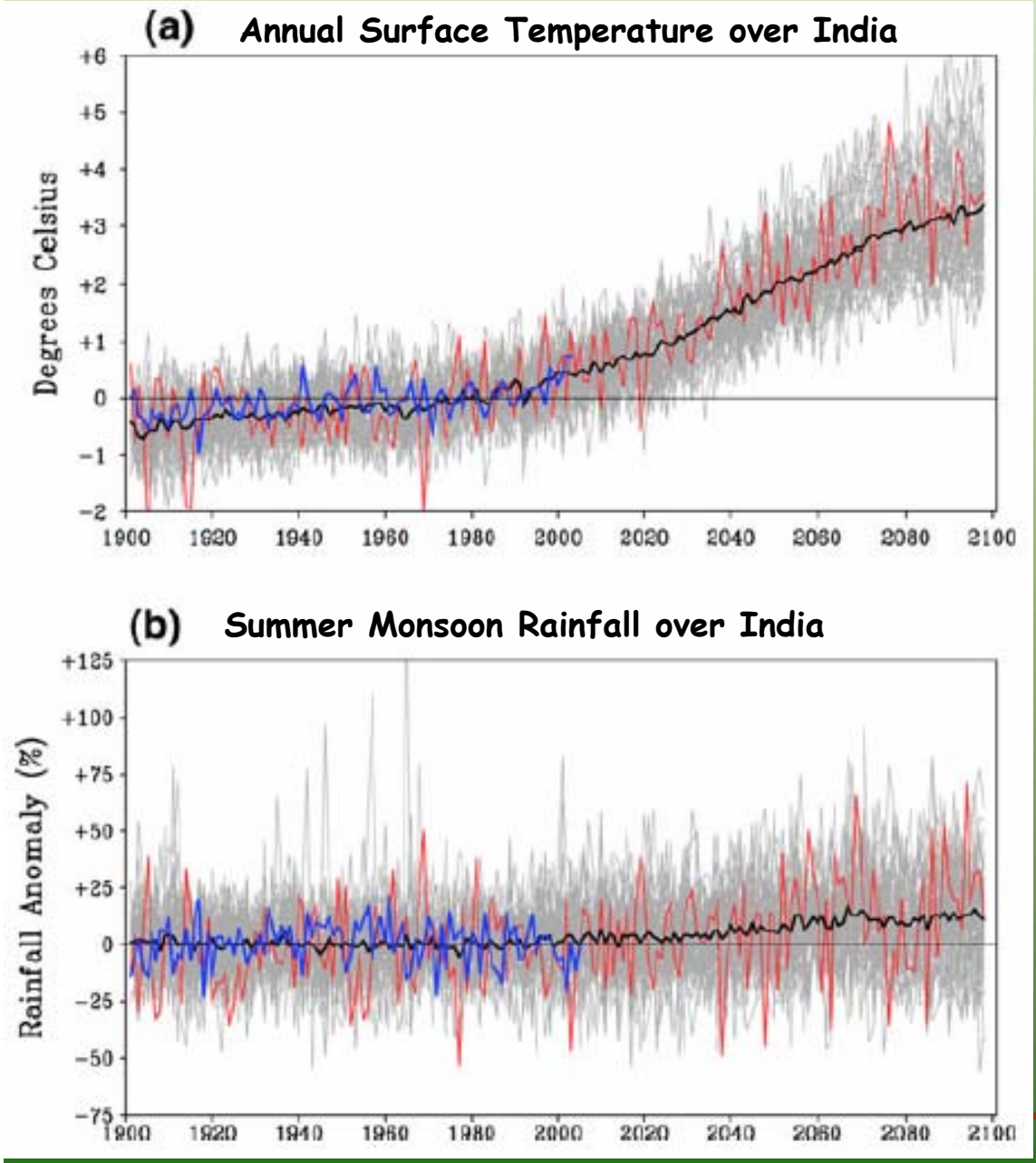


Changes between 1980 to 1999 and 2080 to 2099

Christensen et al.(IPCC,2007)

IPCC-AR4 A1B Simulations (1901–2098)

Krishna Kumar et al. (2010)



- Indian temperatures during the late 21st Century will very likely exceed the highest values experienced in the 130-year instrumental record of Indian data

- Seasonal Indian monsoon rains in the latter half of the 21th century may not be materially different in abundance to that experienced today
- Such an assessment comes with considerable uncertainty

Simulated projections for summer monsoon climate over India by a high-resolution regional climate model (PRECIS)

Krishna Kumar et al. (2011)

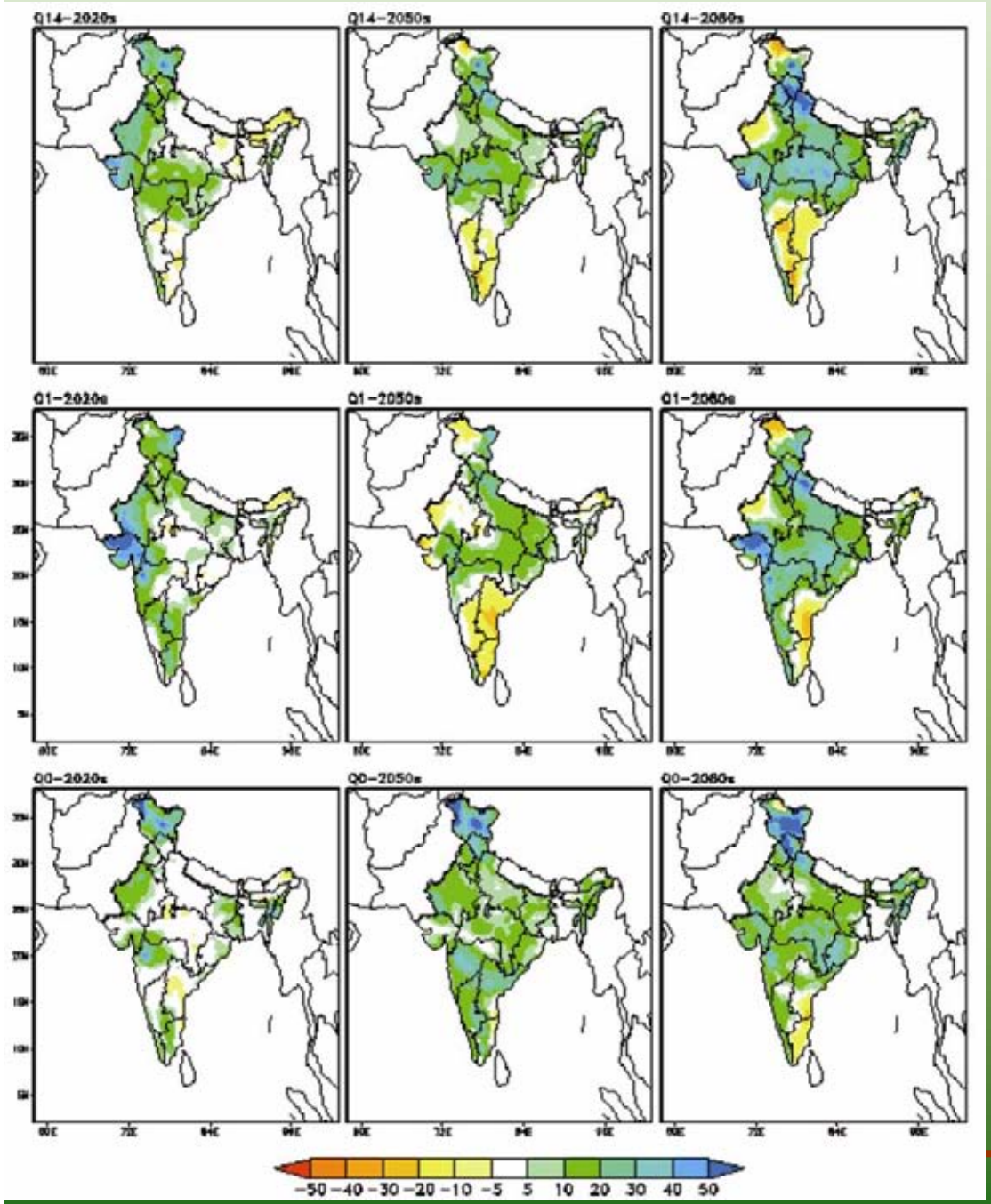
- The model projections indicate significant warming over India towards the end of the 21st century

- The summer monsoon precipitation over India is expected to be 9–16% more in 2080s compared to the baseline (1970s, i.e. 1961–1990) under global warming conditions

- Also, the rainy days are projected to be less frequent and more intense over central India

- The analysis of temperature extremes indicates that both the daily maximum and minimum temperatures may be intense in the future under global warming conditions

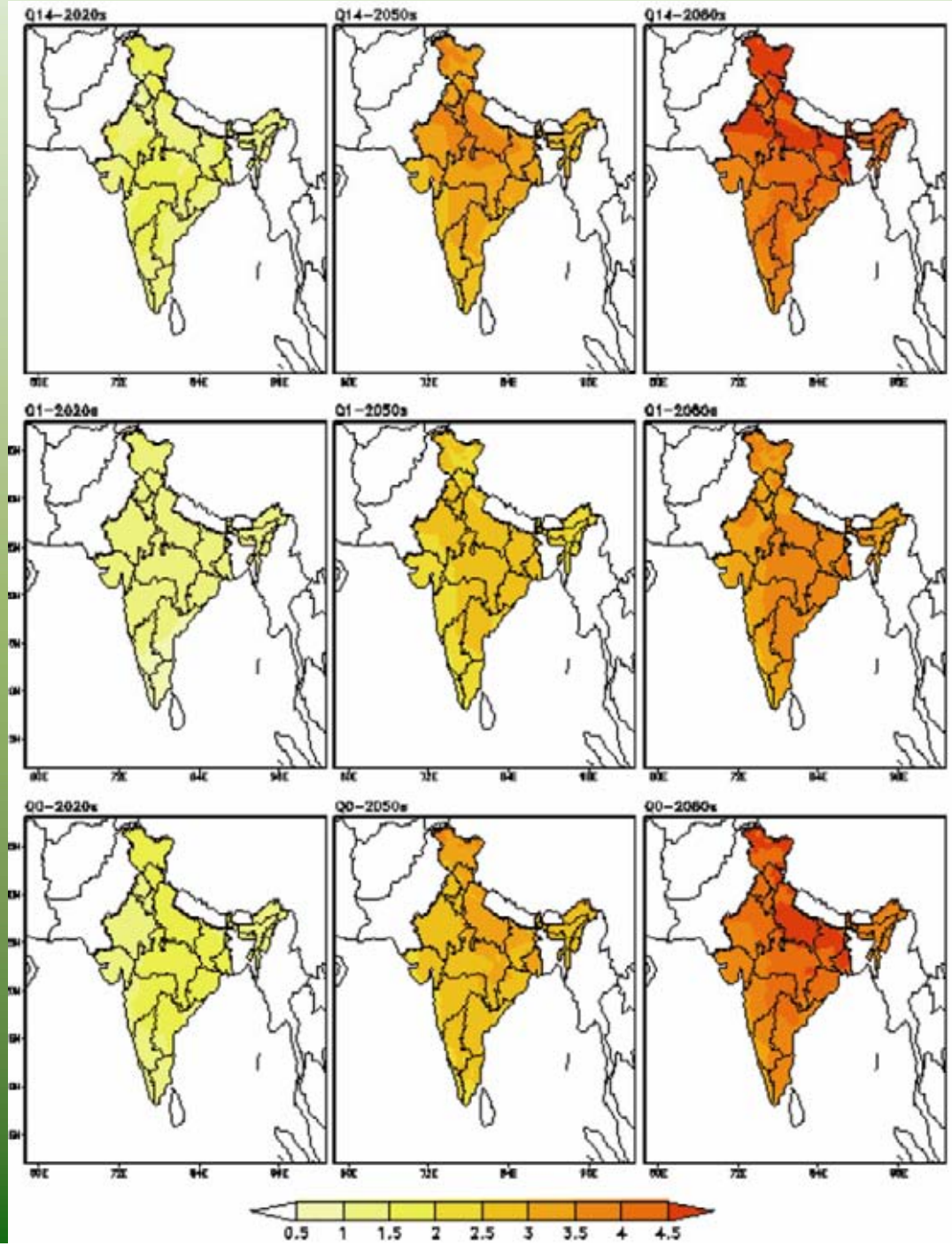
- Changes in the night-time temperature extremes may be more intense than those of daytime temperatures.



PRECIS A1B scenario projected future changes in mean monsoon precipitation (%) in the 2020s, 2050s and 2080s with respect to the baseline period of 1961–1990

- Towards the end of the century, precipitation may increase by ~ 15% (with an inter-ensemble spread 9-16%)
- On smaller regional scale, some regions may experience slightly lower rainfall compared to the baseline period in the future

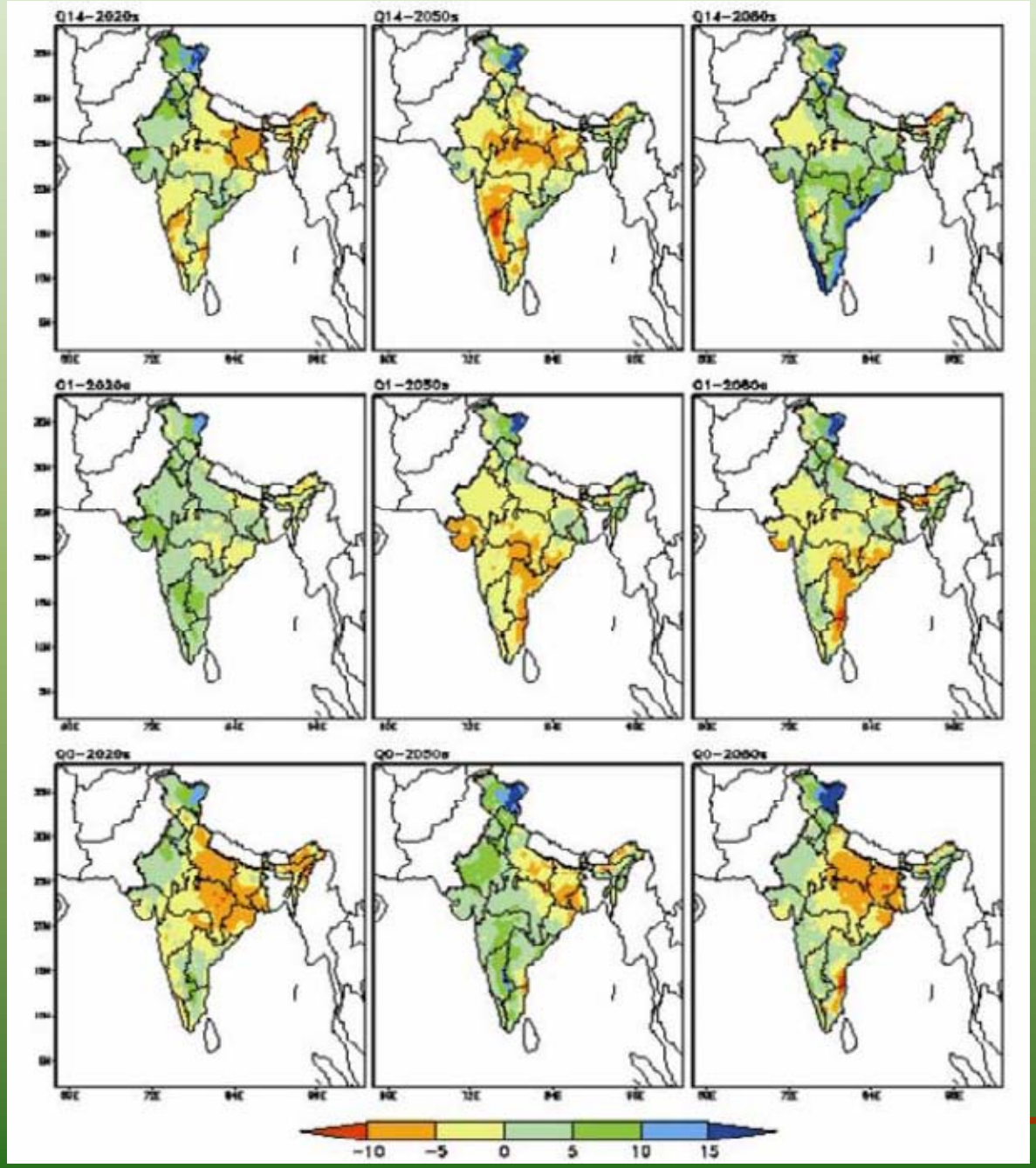
Krishna Kumar et al. (2011)



PRECIS A1B scenario projected future changes in mean annual surface air temperature (°C) in the 2020s, 2050s and 2080s with respect to the baseline period of 1961–1990

- Towards the end of the century all three simulations indicate a significant rise (~4 ° C)

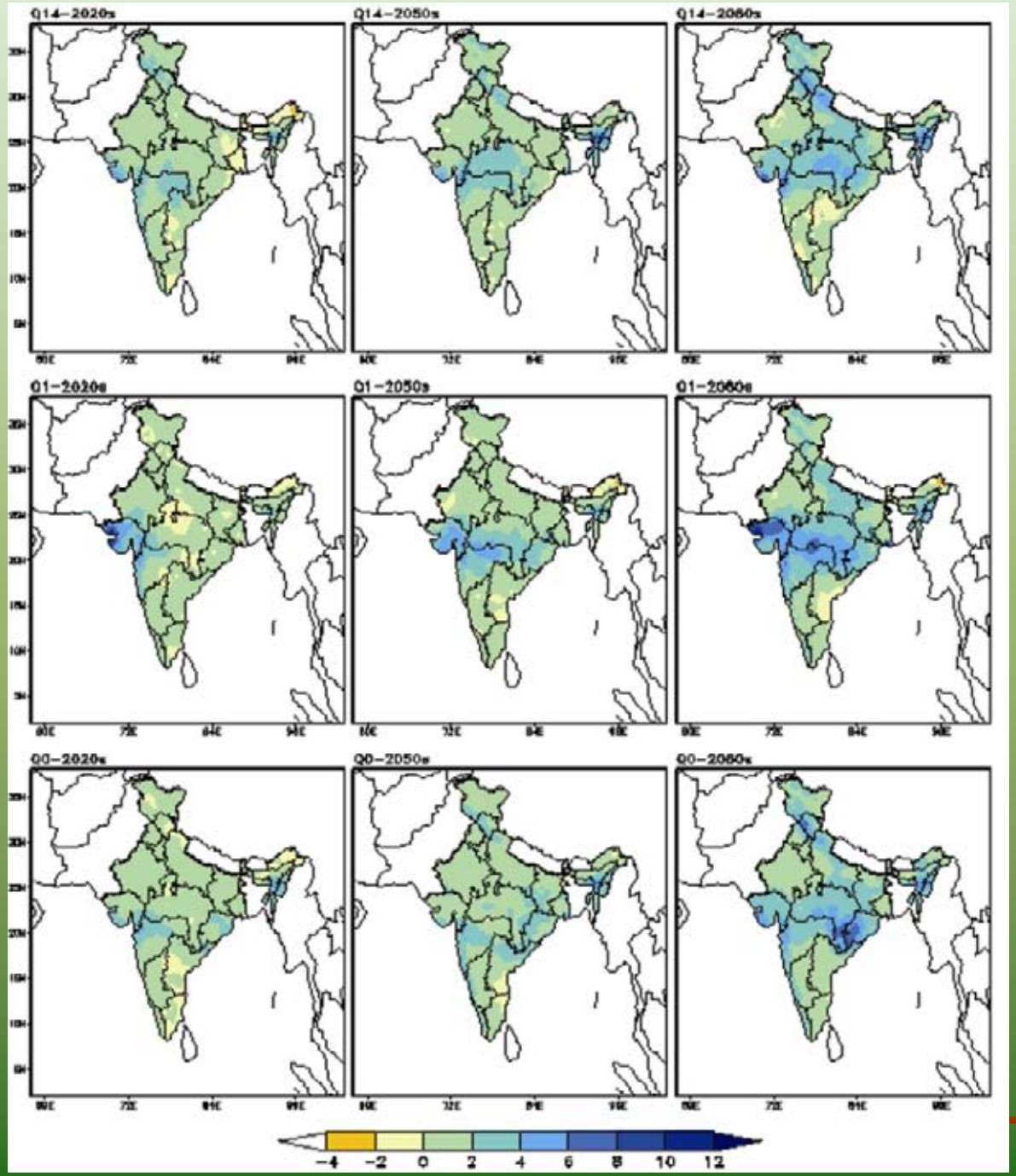
Krishna Kumar et al. (2011)



PRECIS A1B scenario projected future changes in the number of rainy days in the 2020s, 2050s and 2080s with respect to the baseline period of 1961-1990

- Uncertainty in the projection of changes in the number of rainy days

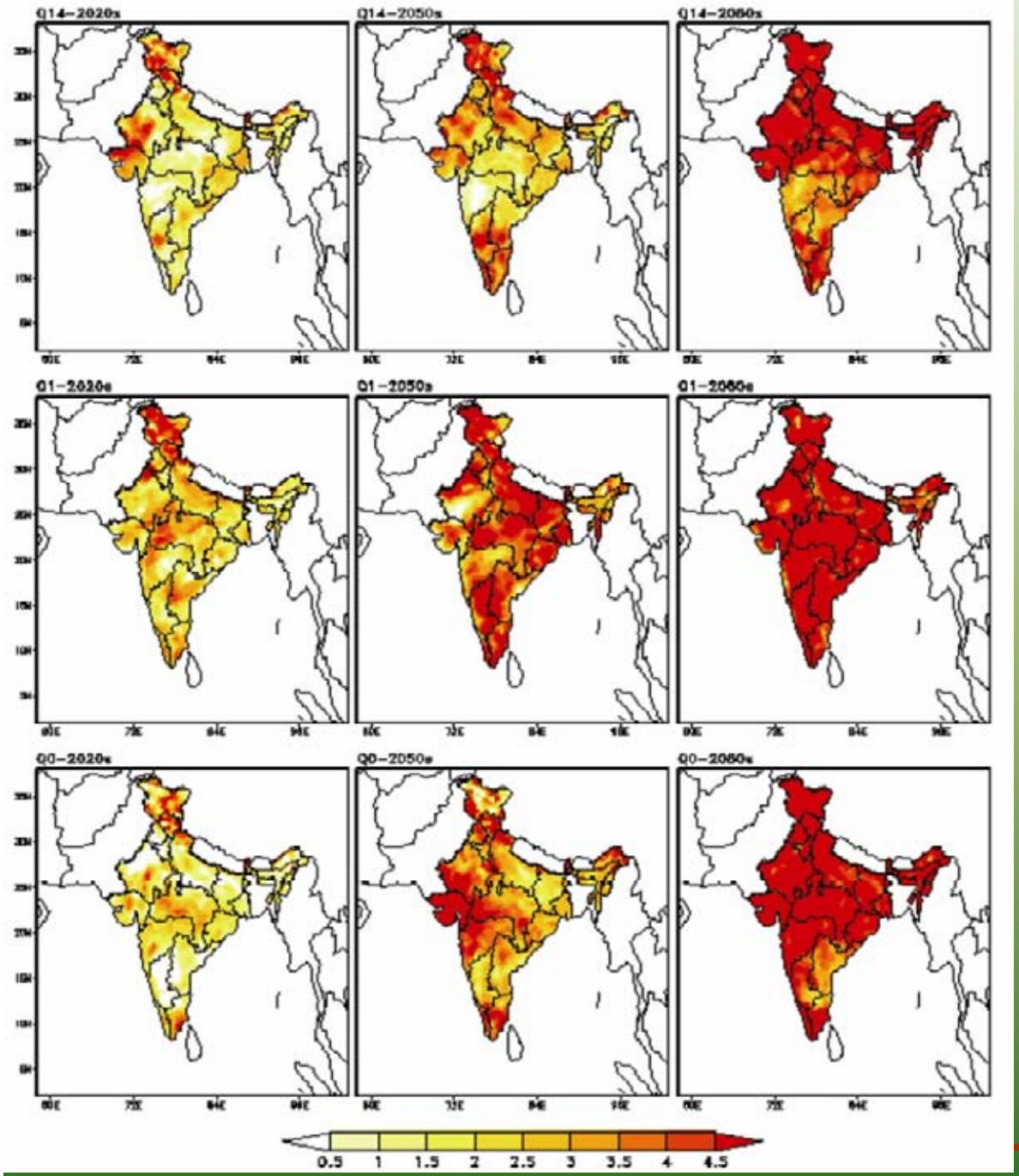
Krishna Kumar et al. (2011)



PRECIS A1B scenario projected future changes in the intensity of rainfall on a rainy day (mm/day) in the 2020s, 2050s and 2080s with respect to the baseline period of 1961–1990

- The intensity of rainfall on a rainy day is likely to be higher in the future

Krishna Kumar et al. (2011)



PRECIS A1B scenario projected future changes in the daily lowest minimum temperature(°C) in the 2020s, 2050s and 2080s with respect to the baseline period of 1961–1990

- Night-time temperature extremes more intense than those of daytime temperatures

Questions : On Attribution?

- How much of the observed variability of the mean Indian Summer Monsoon rainfall due to Climate Change?
- How much of the observed increase in temperature over India been decreased by increasing presence of aerosols?

Questions : On Projections of Monsoon

- What will happen to the monsoon hydrological cycle 50-100 years from now under different scenarios? In particular, will the quantum of seasonal mean rainfall increase or decrease and if so by how much?
- What is the uncertainty in these projections? Can we quantify this uncertainty?
- How can we reduce this uncertainty?

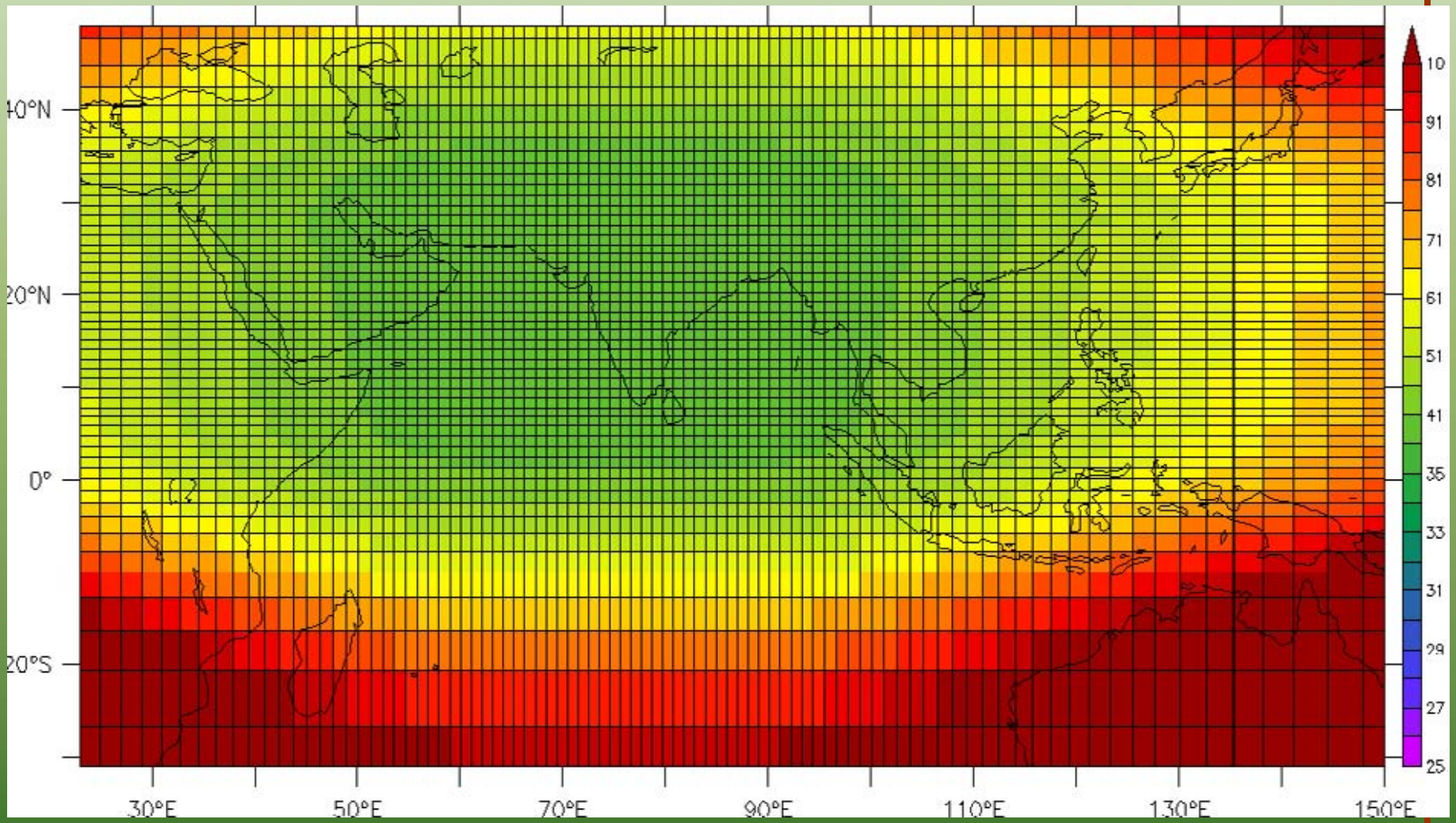
Strategy on Regional Climate Change Research at IITM

Centre for Climate Change Research (CCCR)
Ministry of Earth Sciences, Govt. of India

- **To build capacity in the country in high resolution coupled ocean-atmosphere modelling to address issues on Attribution and Projection of regional Climate Change**
  - **Earth System Model (ESM)**
- **To provide reliable input for Impact Assessment studies**
  - **Dynamic downscaling of regional monsoon climate using high resolution models; quantification of uncertainties**
- **Observational monitoring: Network with other Institutions**

High resolution dynamic downscaling of monsoon climate change scenarios and quantification of uncertainties

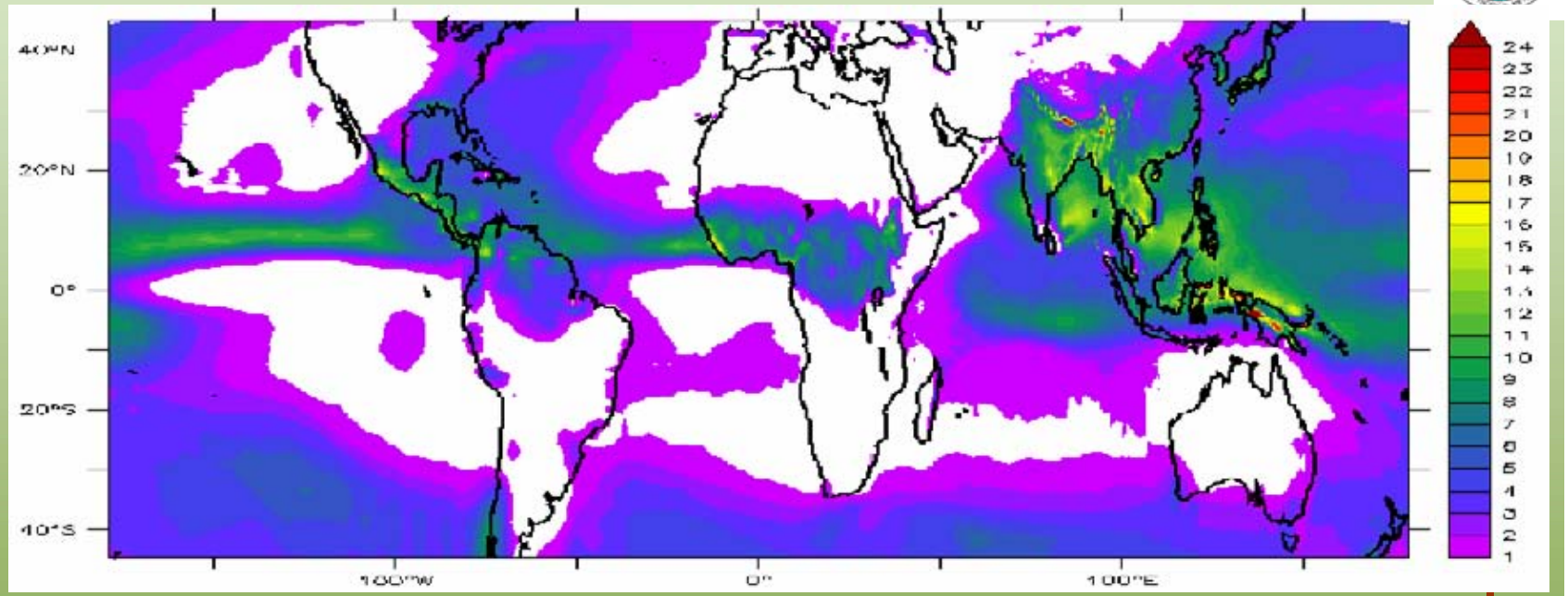
LMDZ global atmospheric model: Variable resolution with zooming capability



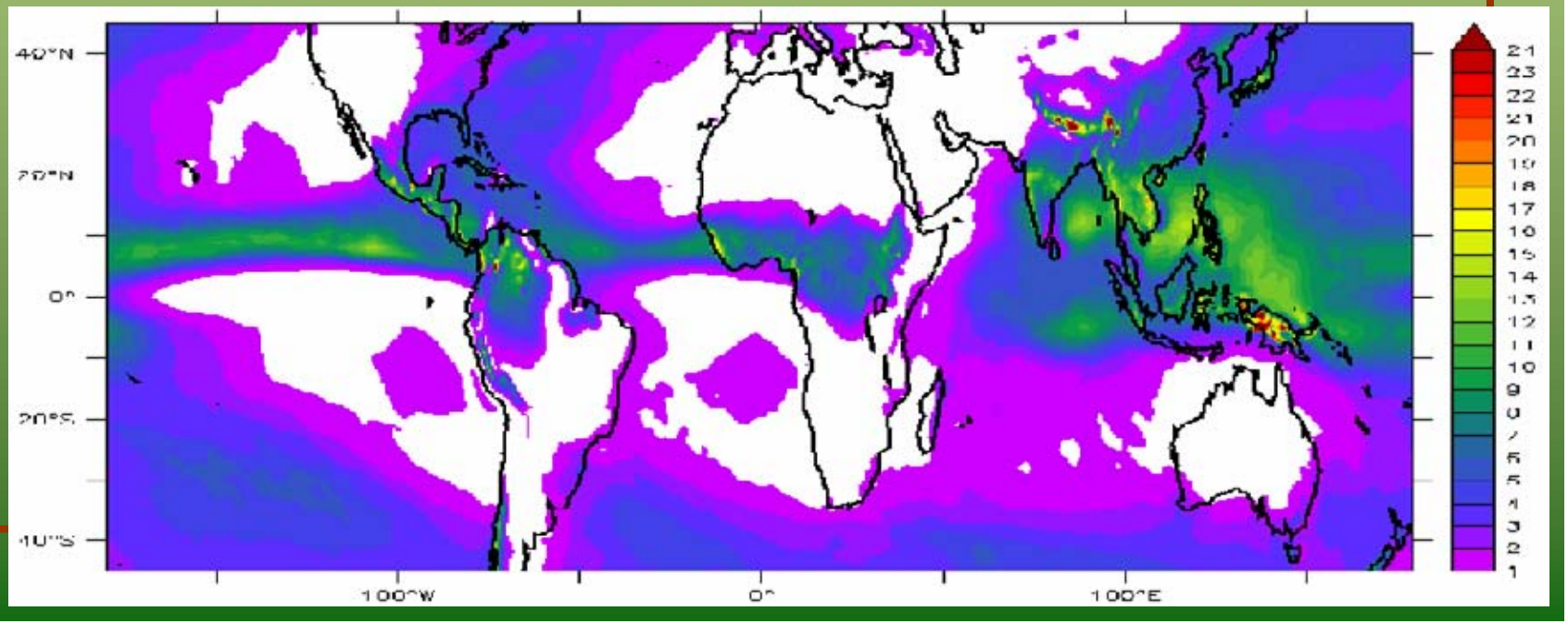
Source: Sabin, CCCR

GCM simulated precipitation for JJAS season: Zoom and No Zoom runs

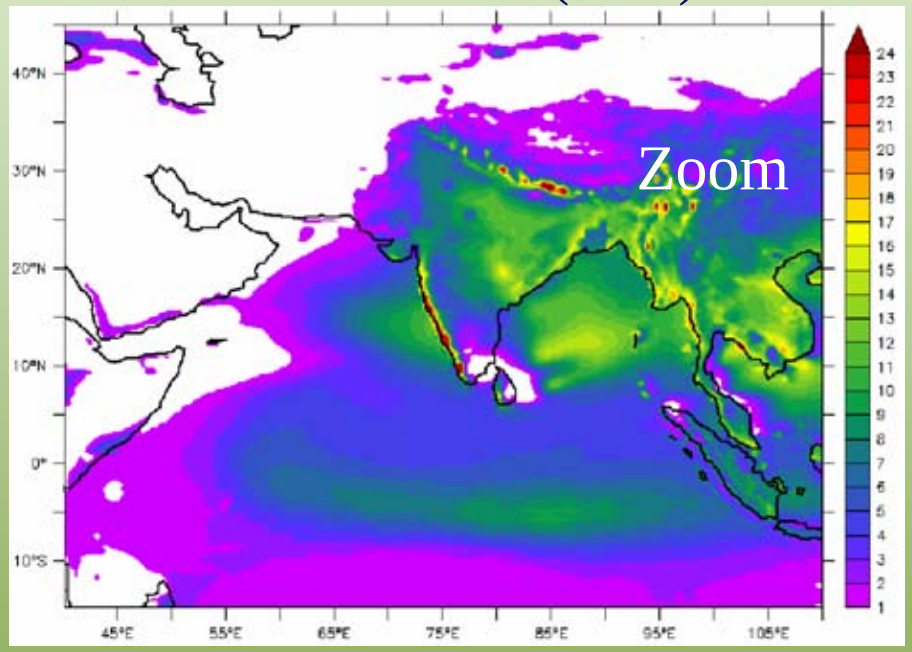
Zoom

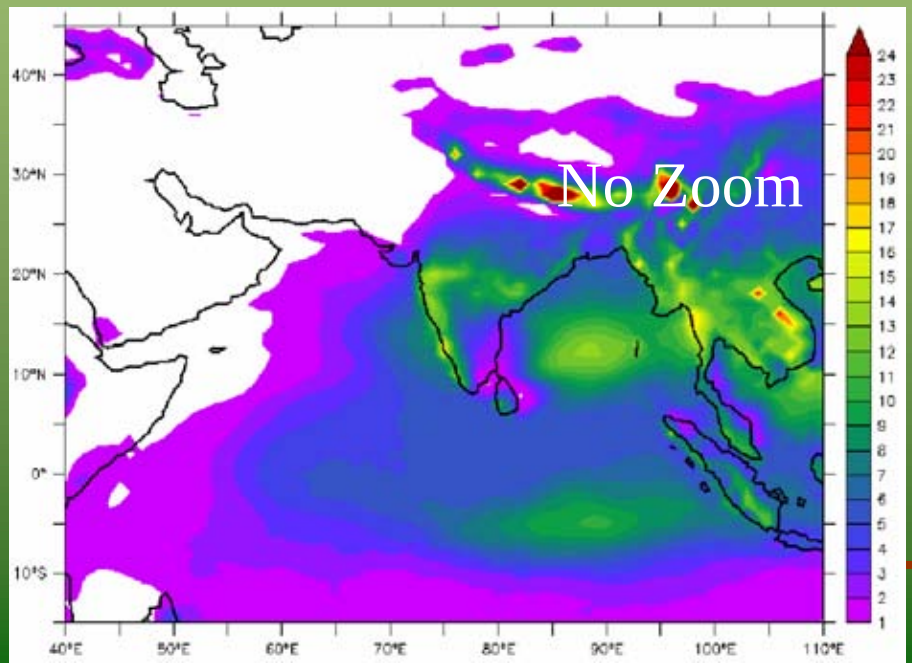


No Zoom

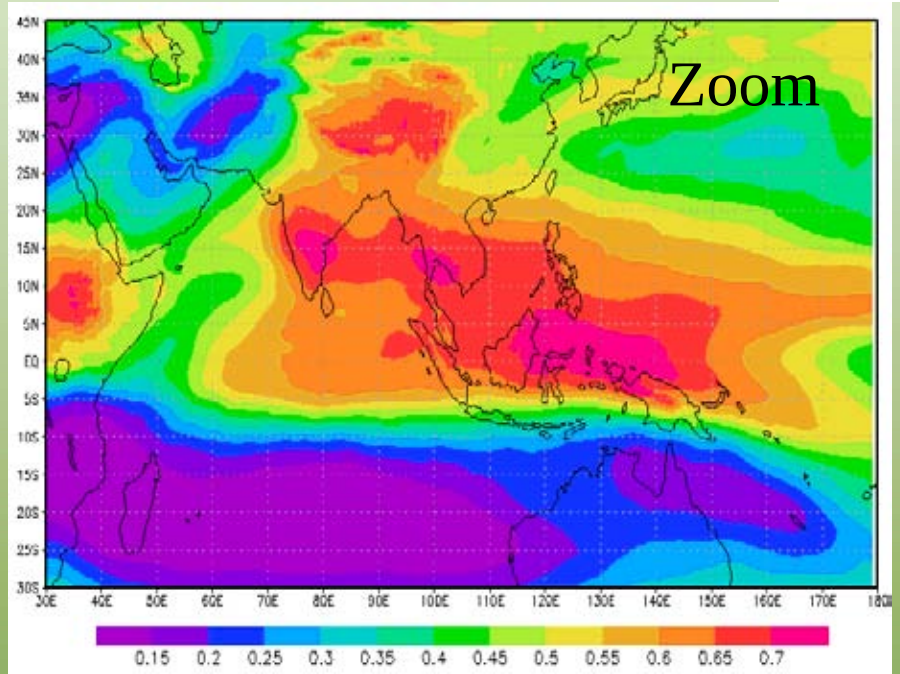


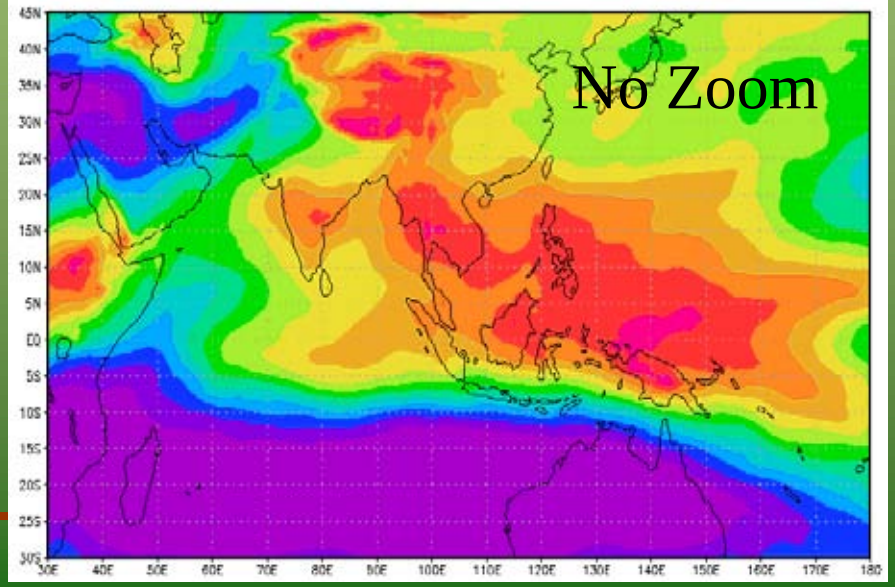
Monsoon rainfall (JJAS)



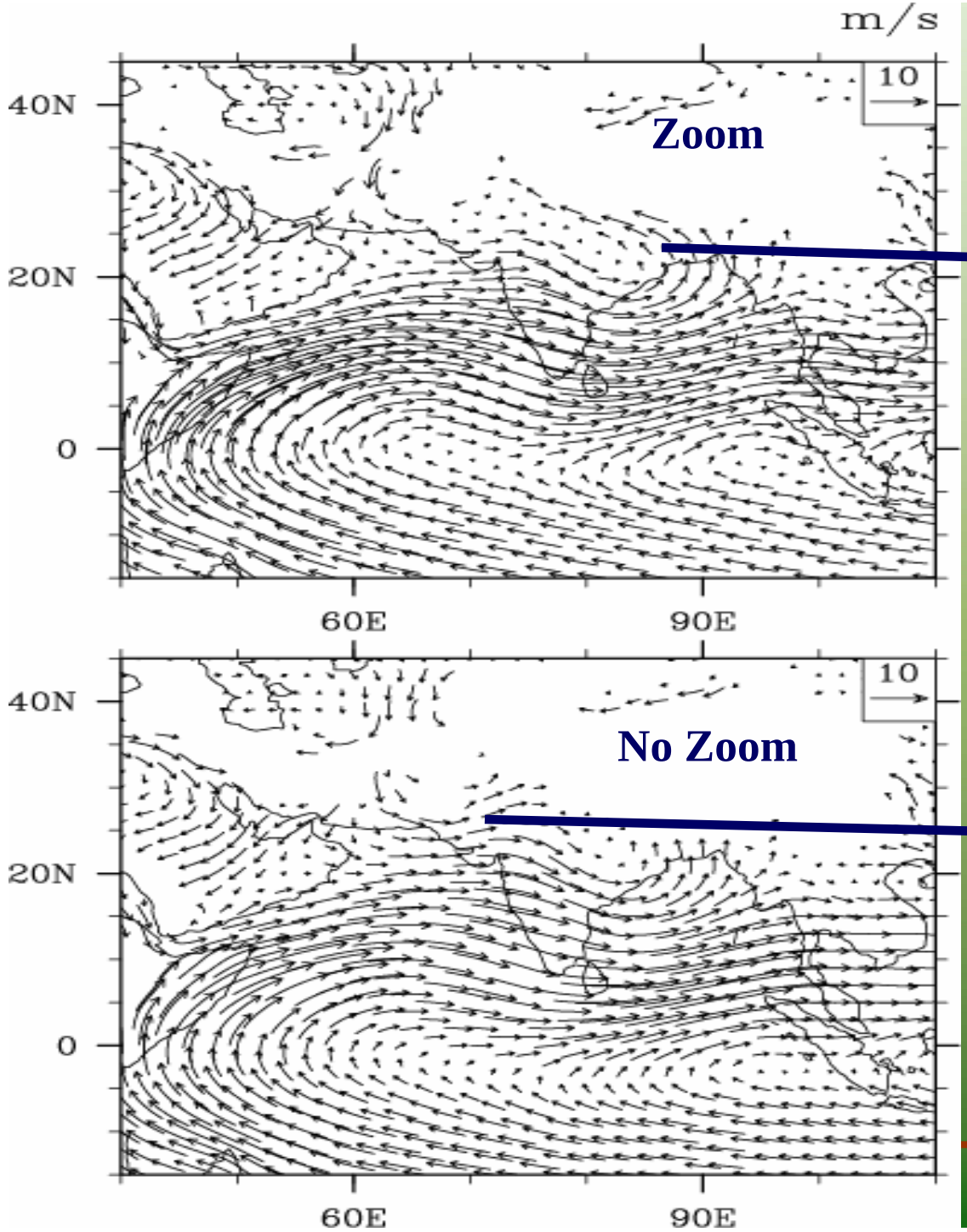


Relative Humidity 500 hPa (JJAS)





850 hPa winds (JJAS)



Cyclonic turning of moist winds from Bay of Bengal

Dry westerly winds from Indo-Pak and adjoining areas

High resolution (~ 35 km) dynamical downscaling simulations using LMDZ over South Asia at CCCR

Historical (1886-2005): *Includes natural and anthropogenic (GHG, aerosols, land cover etc) climate forcing during the historical period (1886 – 2005) ~ 120 years*

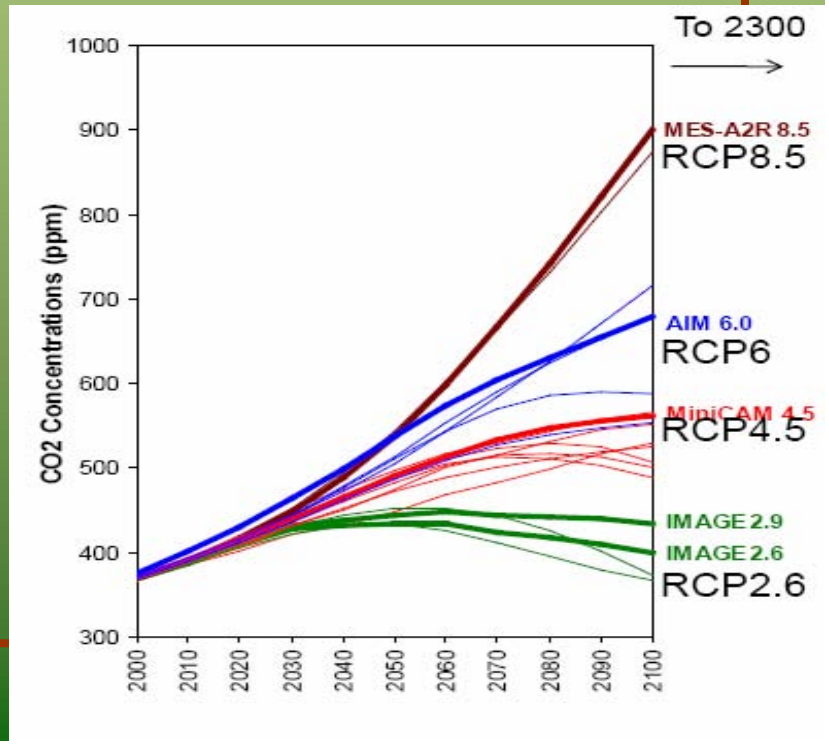
- *Completed ~ 35 years of integration. Full period will be completed by early 2012*

Historical Natural (1886 – 2005): *Includes only natural climate forcing during the historical period (1886– 2005) ~ 120 years*

- *Completed ~ 20 years of integration. Full period will be completed by early 2012*

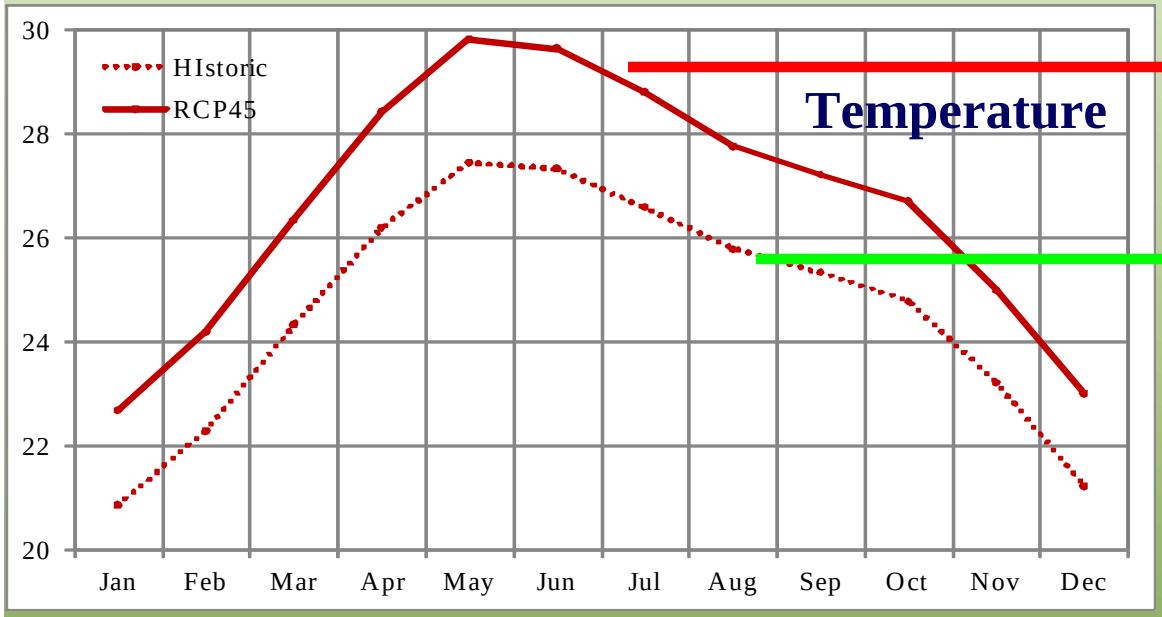
RCP 4.5 scenario (2006-2100) ~ 95 years: *Future projection run which includes both natural and anthropogenic forcing based on the IPCC AR5 RCP 4.5 climate scenario . The evolution of GHG and anthropogenic aerosols in RCP 4.5 scenario produces a global radiative forcing of + 4.5 W m^{-2} by 2100*

- *Completed about 35 years of integration. Full period will be completed by early 2012*



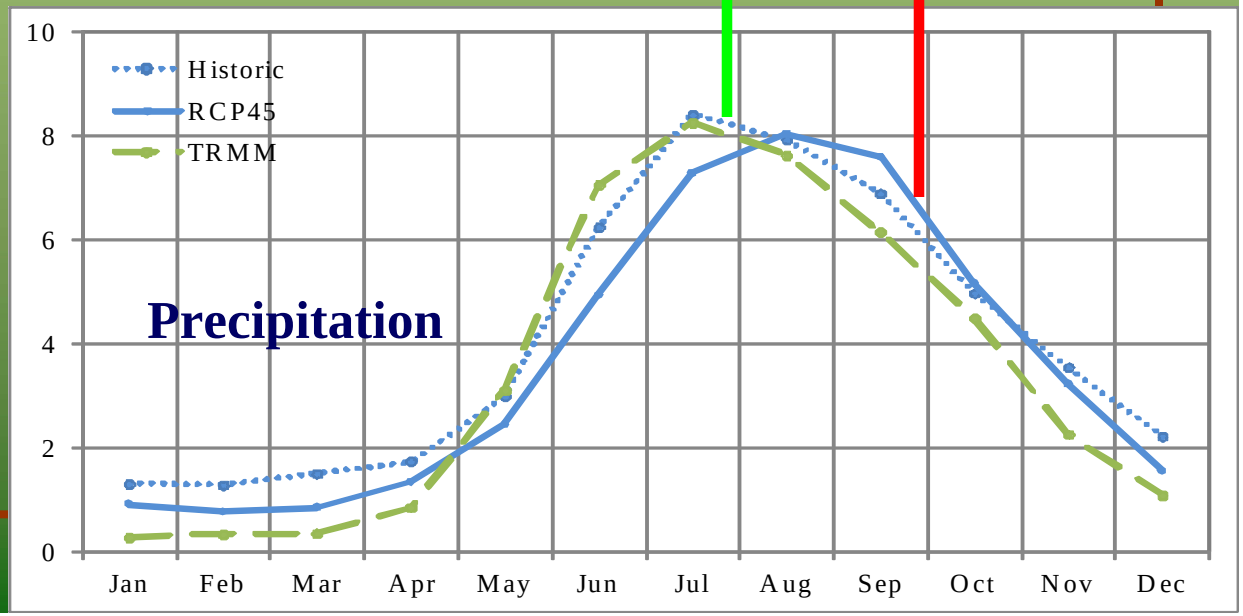
Annual cycle of precipitation and surface temperature over South Asian region

High resolution (~ 35 km) model simulations



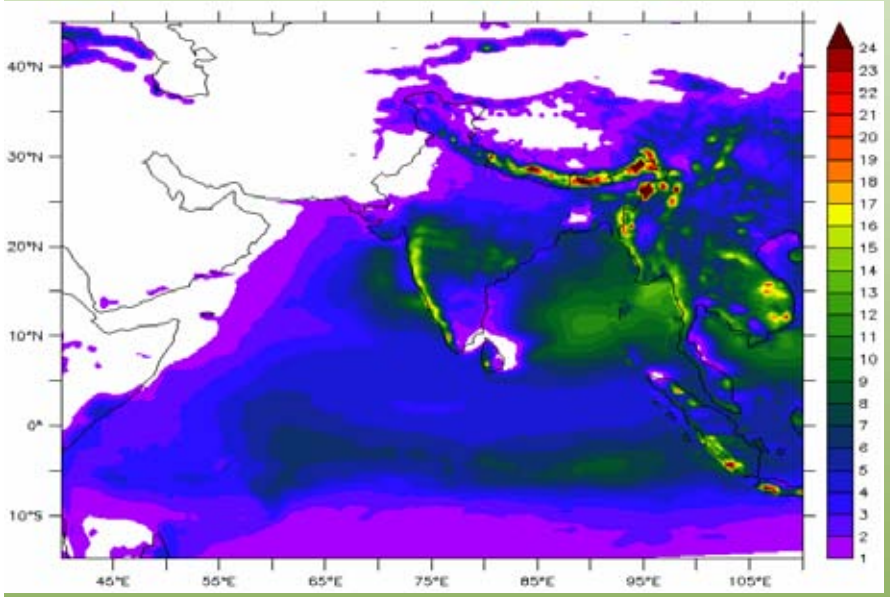
RCP4.5

HIST

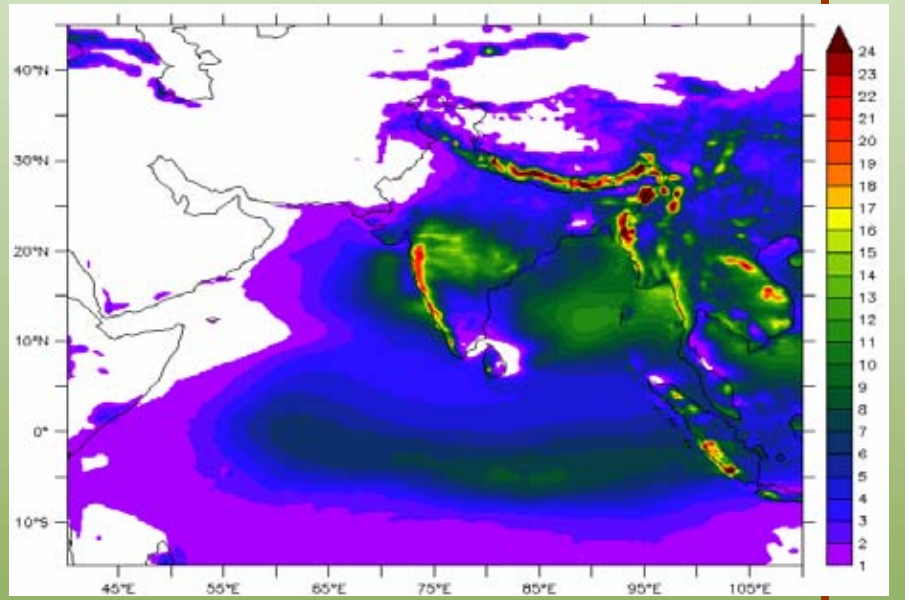


Monsoon rainfall (JJAS)

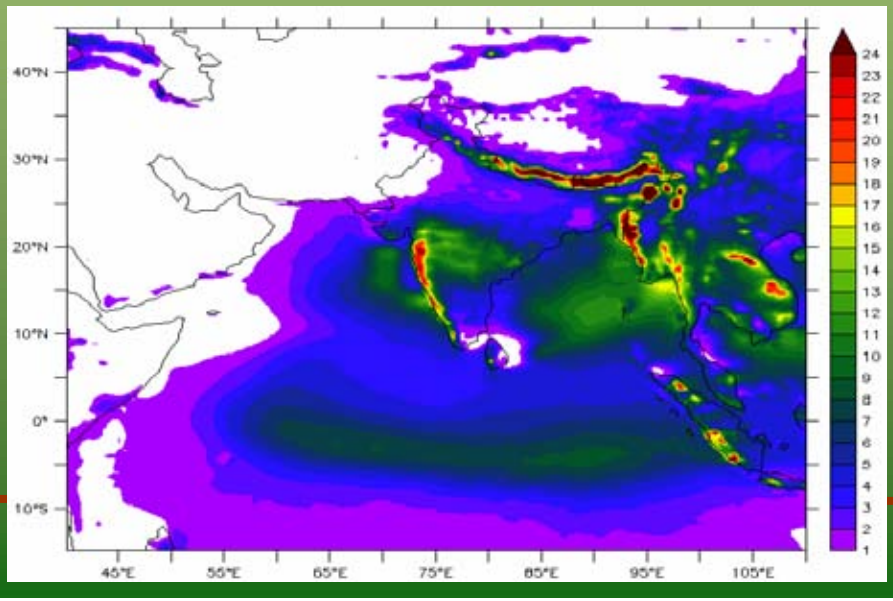
HIST-Nat



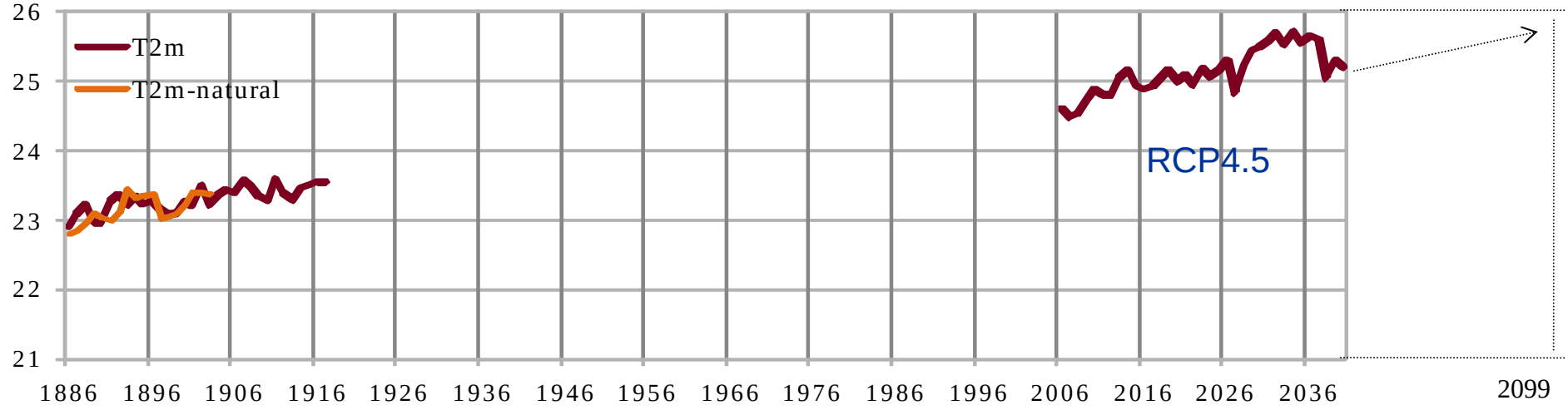
HIST



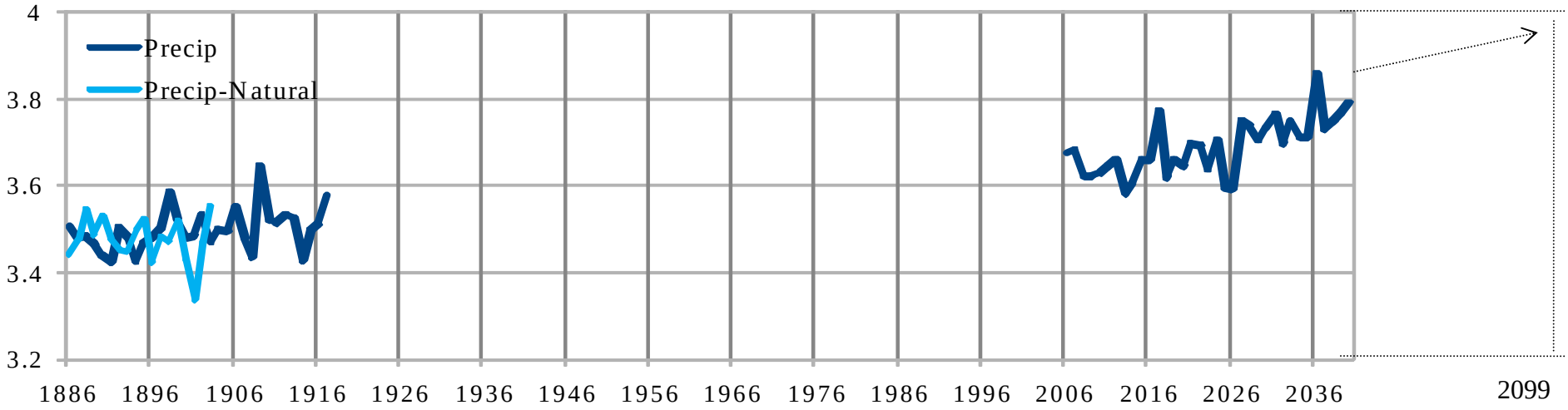
RCP4.5



Annual mean precipitation and surface temperature
Global Tropics: 30°S-30°N

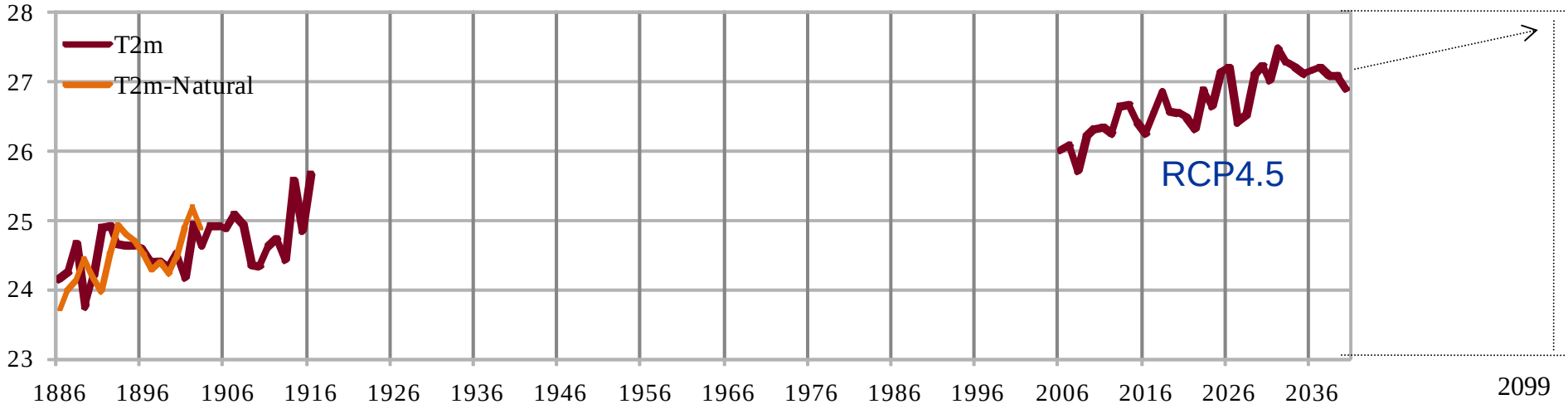


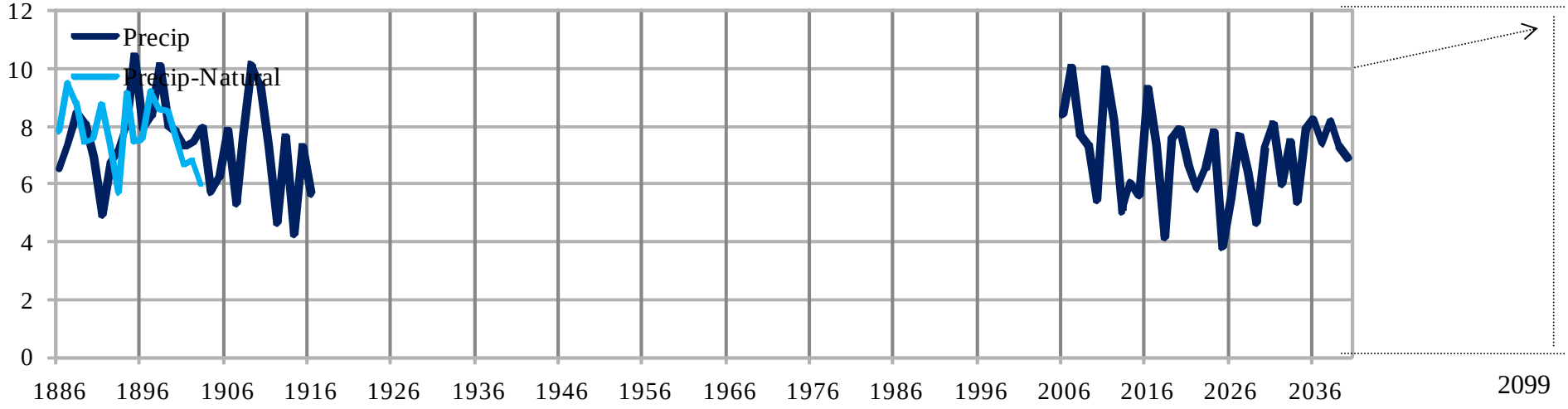
Historical and RCP runs are ongoing and expected to be completed by Jan 2012



High resolution (~ 35 km) simulations over South Asia

Precipitation and surface temperature over monsoon region (JJAS)
70°E-90°E ;10°N-25°N

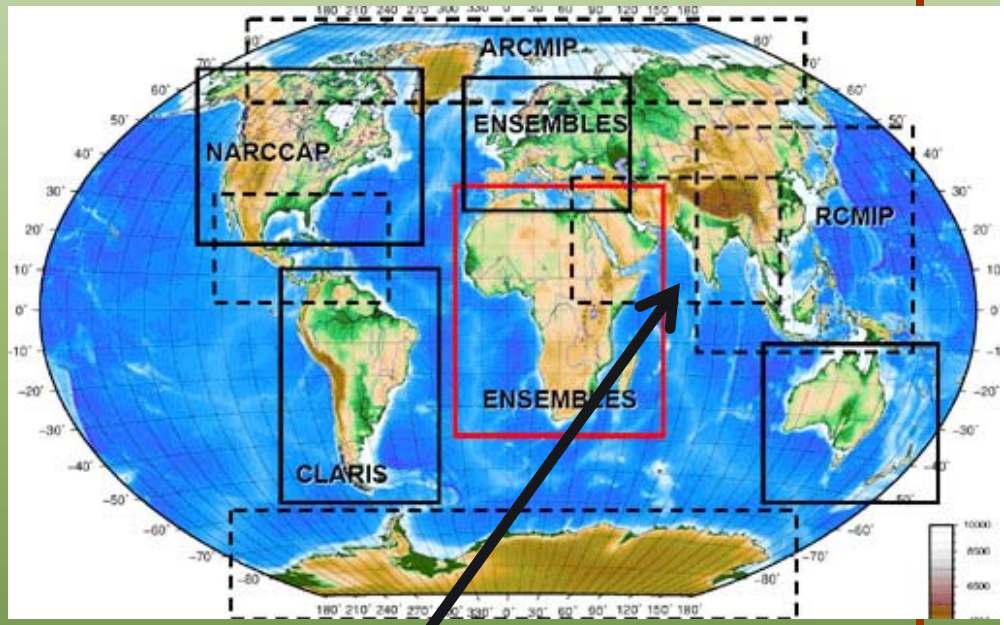




Co-ordinated Regional Downscaling Experiment (CORDEX)

To be co-ordinated by CCCR (Region: South, Southeast and West Asia)

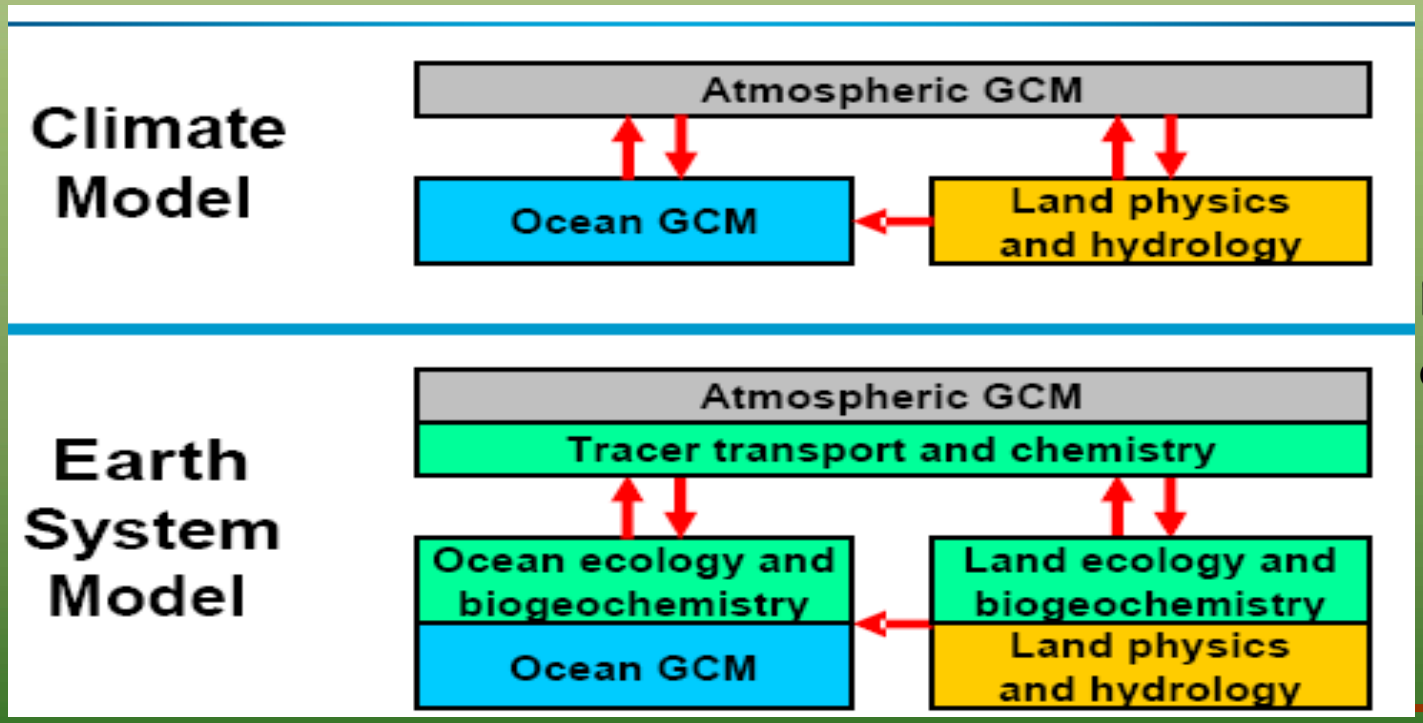
- LMDZ: High resolution zooming (~ 35 – 50 km) over CORDEX domain
  - Historical run (1886– 2005) ongoing ~35 years completed so far. Deadline early 2012
  - RCP4.5 (2006-2100) ongoing ~ 35 years completed so far. Deadline early 2012
  - Historical Natural (1886-2005) ongoing ~ 20 yrs completed so far. Deadline early 2012
- WRF (~ 50 km)
  - Two members 19 years (1989: 2007) baseline simulations using ERA Interim LBC completed
  - Future climate simulations: Require LBCs from CMIP5 models
- RegCM (~ 50 km)
  - One members 19 years (1989 – 2007) baseline simulation using ERA Interim LBC completed
  - Future climate simulations: Require LBCs from CMIP5 models
- PRECIS (~ 50 km)
  - QUMP runs (1960 – 2100): 3 members are completed and 2 more realizations are ongoing
  - Two additional QUMP runs to be completed by end of 2011.



Domain

Ongoing efforts towards development of Earth System Model (ESM) to address the Scientific Challenges of Global Climate Change and the Asian Monsoon System

- Plan to include ESM components in the CFS-2 coupled ocean-atmosphere model
- CFS-2 coupled ocean-atmosphere model simulations on HPC
- Fidelity of CFS-2 coupled model in capturing the global and monsoon climate
- Ocean Biogeochemistry Module coupled to MOM4. Runs are ongoing on HPC
- Aerosol Transport Module coupled to AGCM. Runs are ongoing on HPC



Basic structure of ESM

First Announcement and Call for Abstracts

IITM Golden Jubilee International Conference on

Opportunities and Challenges in Monsoon Prediction in a Changing Climate (OCHAMP) 21-25 February 2012 Pune (INDIA)

Conference Webpage

http://www.tropmet.res.in/ochamp

Introduction

Indian Institute of Tropical Meteorology (IITM) in collaboration with WMO's World Climate Research Programme (WCRP) and World Weather Research Programme (WWRP) proudly announces the International Conference on Opportunities and Challenges in Monsoon Prediction in a Changing Climate (OCHAMP-2012), 21-25 February, 2012 at IITM, Pune, INDIA. The five-day Conference is being organized to commemorate the Golden Jubilee of the Indian Institute of Tropical Meteorology (IITM) and will be dedicated to Monsoon Prediction in a Changing Climate. The focus of the five-day long event will be on the advances made and challenges faced in predicting the global monsoon (especially the Asian Monsoon) in a changing climate.

Themes of the Conference

1. Prediction and Predictability of the Monsoon
2. Observing Monsoon Variability and Processes
3. Modeling the Monsoon and its Variability
4. Monsoon in a Changing Climate
5. Tropical Clouds, Aerosol and Monsoon
6. Role of Indian Ocean on Asian Monsoon
7. Past as a mirror for future: Monsoon as Tipping point

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Dr. Jianping Li, IAP, China
Dr. A. Suryachandra Rao, IITM, India
Prof. Bin Wang, IPRC, USA
Prof. Tetsuzo Yasunari, NU, Japan

Summary

- Finite computing resources limit the spatial resolution of state-of-the-art global climate simulations to hundreds of kilometres

- In neither the atmosphere nor the ocean are small-scale processes such as convection, clouds and ocean eddies properly represented

- Climate simulations are known to depend, sometimes quite strongly, on the resulting bulk-formula representation of unresolved processes

- To improve global and regional predictions of climate change, we need to be continually improving our understanding and modelling of the Atmosphere, Oceans, Cryosphere, and Land surface

Thanks

- CSE Media Briefing Organisers
- Dr. R. Krishnan, Dr. K. Ashok & scientists in CCCR, IITM