# Extreme Weather Events - Rainfall

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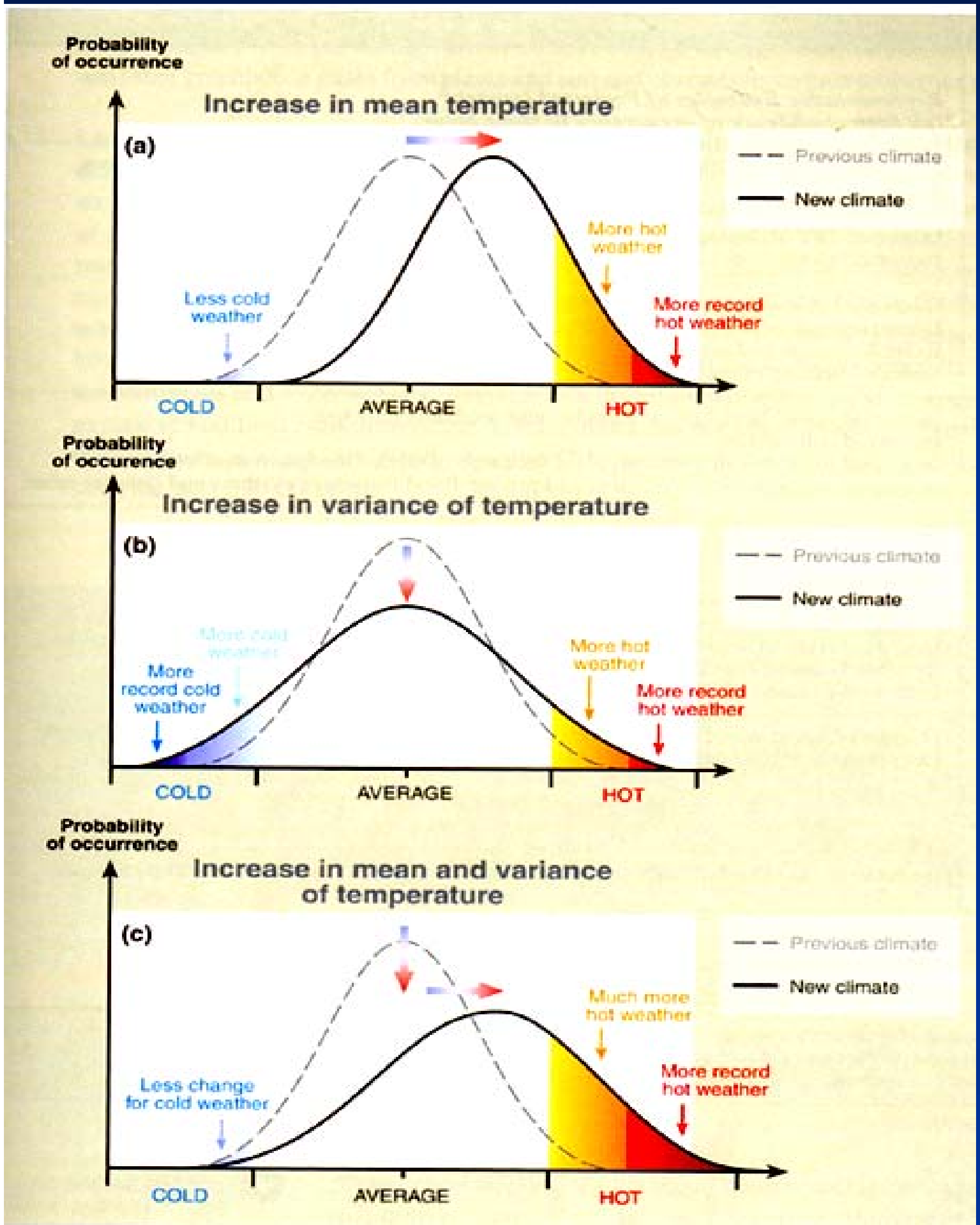
**Media briefing on climate change for South Asia**

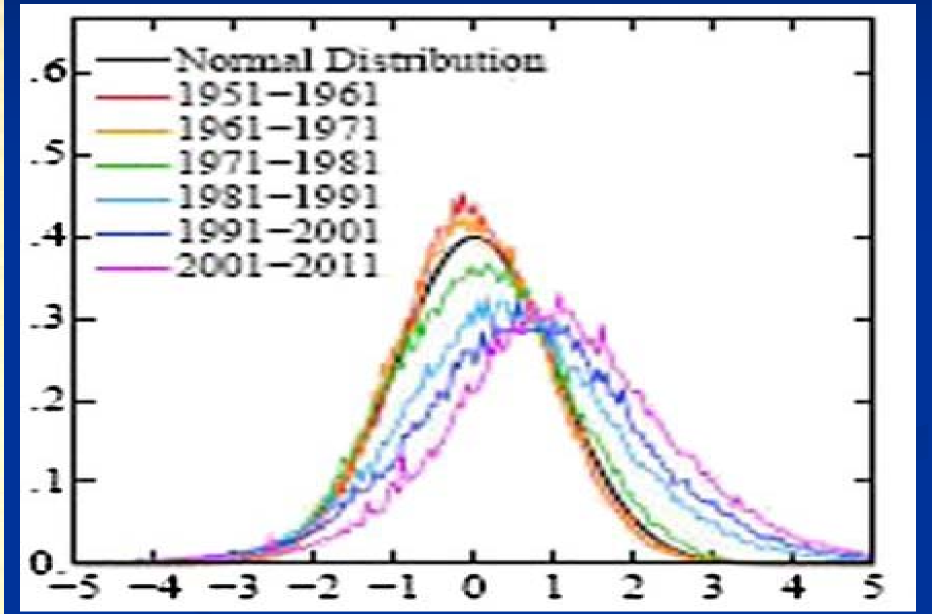
Centre for Science and Environment (CSE)
India Habitat Centre, New Delhi
18-19 September 2013

## Difference between natural climate variability and anthropogenic climate change

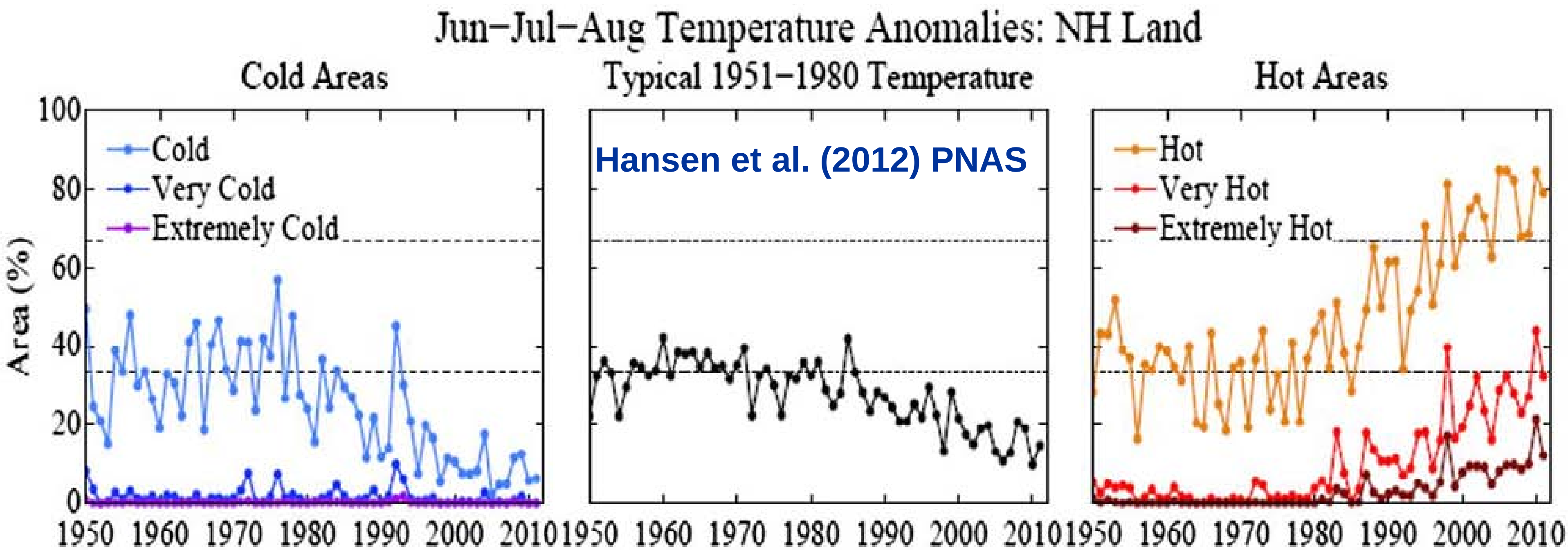
### Extremes are likely to rise

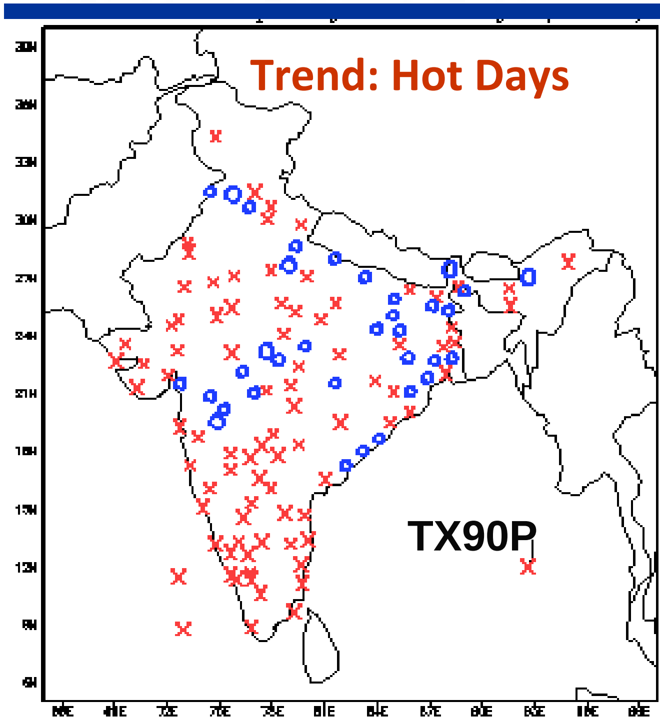


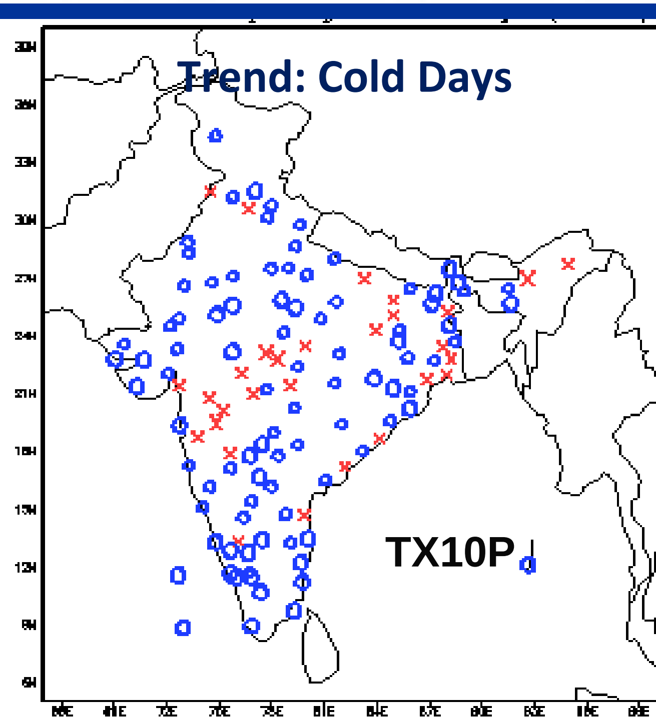

Distribution of temperature anomalies for northern summer (JJA): Global




Frequency of occurrence (y axis) of local temperature anomalies (relative to 1951 – 1980 mean) divided by local standard deviation (x axis) obtained by counting grid boxes with anomalies in each 0.05 interval. Area under each curve is unity – **Hansen et al. 2012 PNAS**




Trends in frequency of hot days (TX90p) and cold days (TX10p) for the period 1970-2003. Positive trends are shown by red cross (x) and negative trends by blue circles (o). Bigger crosses (X) and circles (O) are statistically significant trends

Revadekar et al. 2010, Natural Hazards

# Regional climate change projections over South Asia

## Reliable assessment of regional climate change

•High resolution is essential to represent processes properly on all ranges of possible statistical outcomes, especially climate extremes and their impacts

•Multi-model ensemble simulations necessary for reliable regional climate projections, and to Quantify and reduce uncertainties in regional climate projections

## Scientific challenges in modeling extreme precipitation events

•Relatively infrequent and inherently unpredictable

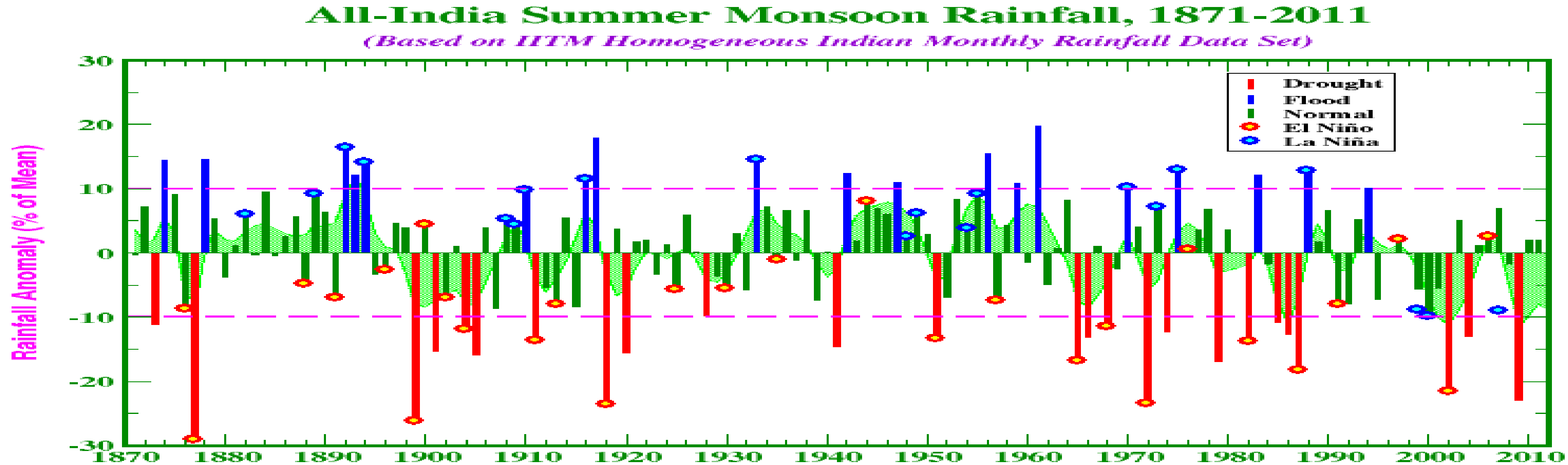
•Require large ensembles to simulate the statistics

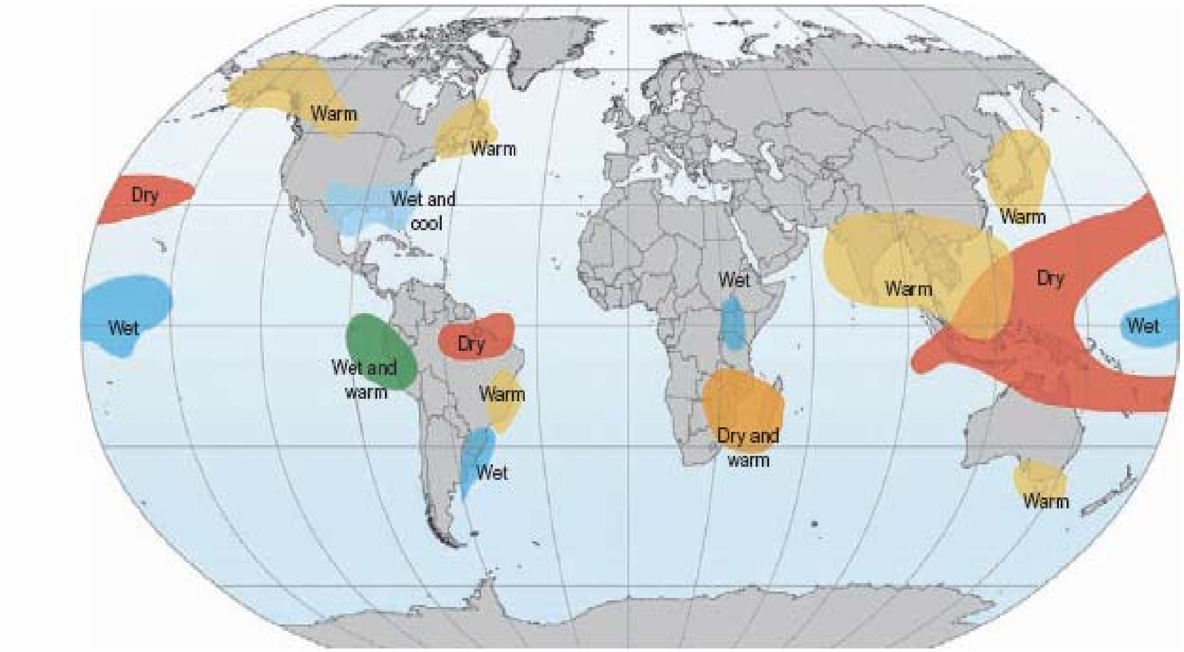
•Assess the impact of external drivers on their statistics

•Depend on dynamical processes that require relatively high resolution to represent them

# Influence of external drivers on extreme monsoons

Example: Indian monsoon droughts have often co-occurred with El Nino events




(Source: http://www.tropmet.res.in)

El Nino teleconnections

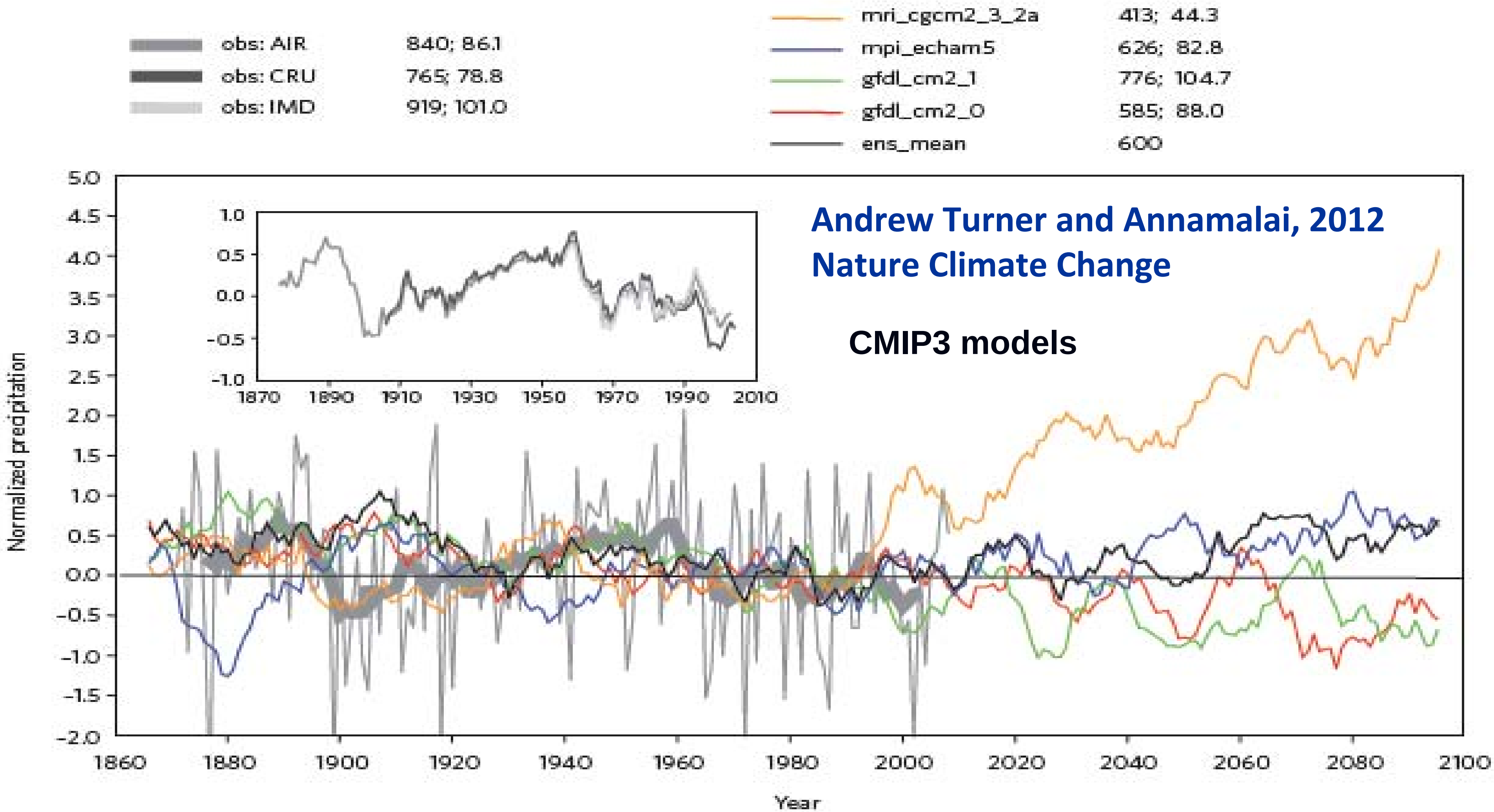
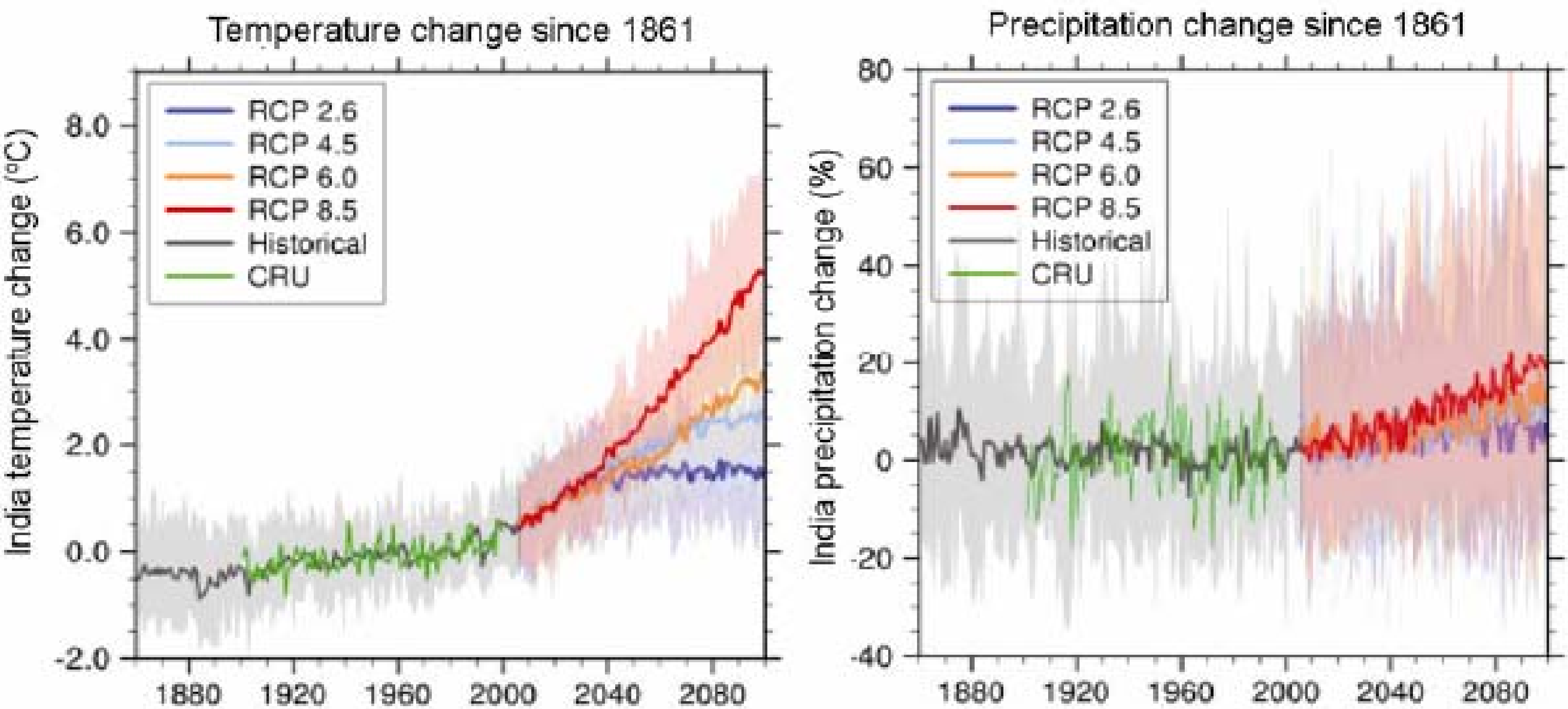


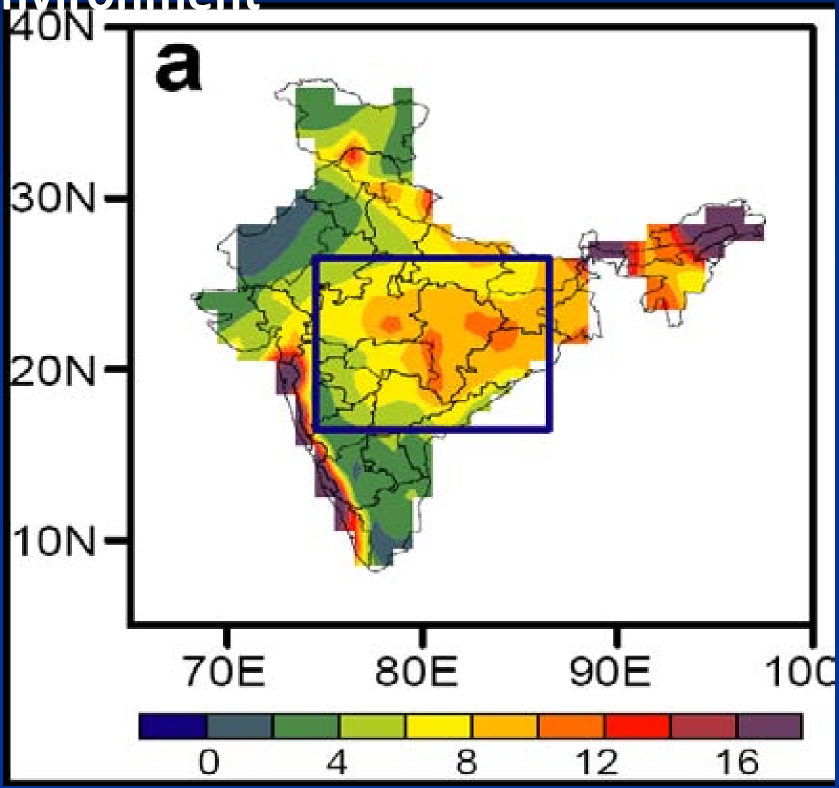

**Figure 2 | Historical and SRES A1B projection of South Asian monsoon rainfall.** Time series of mean summer (June–September) precipitation averaged over land points within 60–90° E, 7–27° N in the historical (20c3m; 1861–1999) and SRES A1B (2000–2100) future projection CMIP3 experiments. Only four models, shown[30] to have a reasonable simulation of the spatial pattern, seasonal cycle and interannual variability of monsoon rainfall, are depicted; the black curve shows their ensemble mean. Observations from the AIR index[28] based on gauge information are also shown for the 1871–2008 period as a proxy for South Asia rainfall. All curves are first normalized by their mean and standard deviation measured over 1961–1999 and are passed through an 11-year moving window. The faint black curve shows the observations without this smoothing. The inset compares the AIR with area-mean averages over the same domain as above from 1951–2004 IMD daily gridded data[31] and 1901–2009 monthly gridded CRU data[32]. The values listed in the legend are for June–September mean rainfall and interannual standard deviation, in mm. Obs, observations.

Multi-model climate change projections for India under representative concentration Pathways - Rajiv Chaturvedi et al. (2012) Current Science



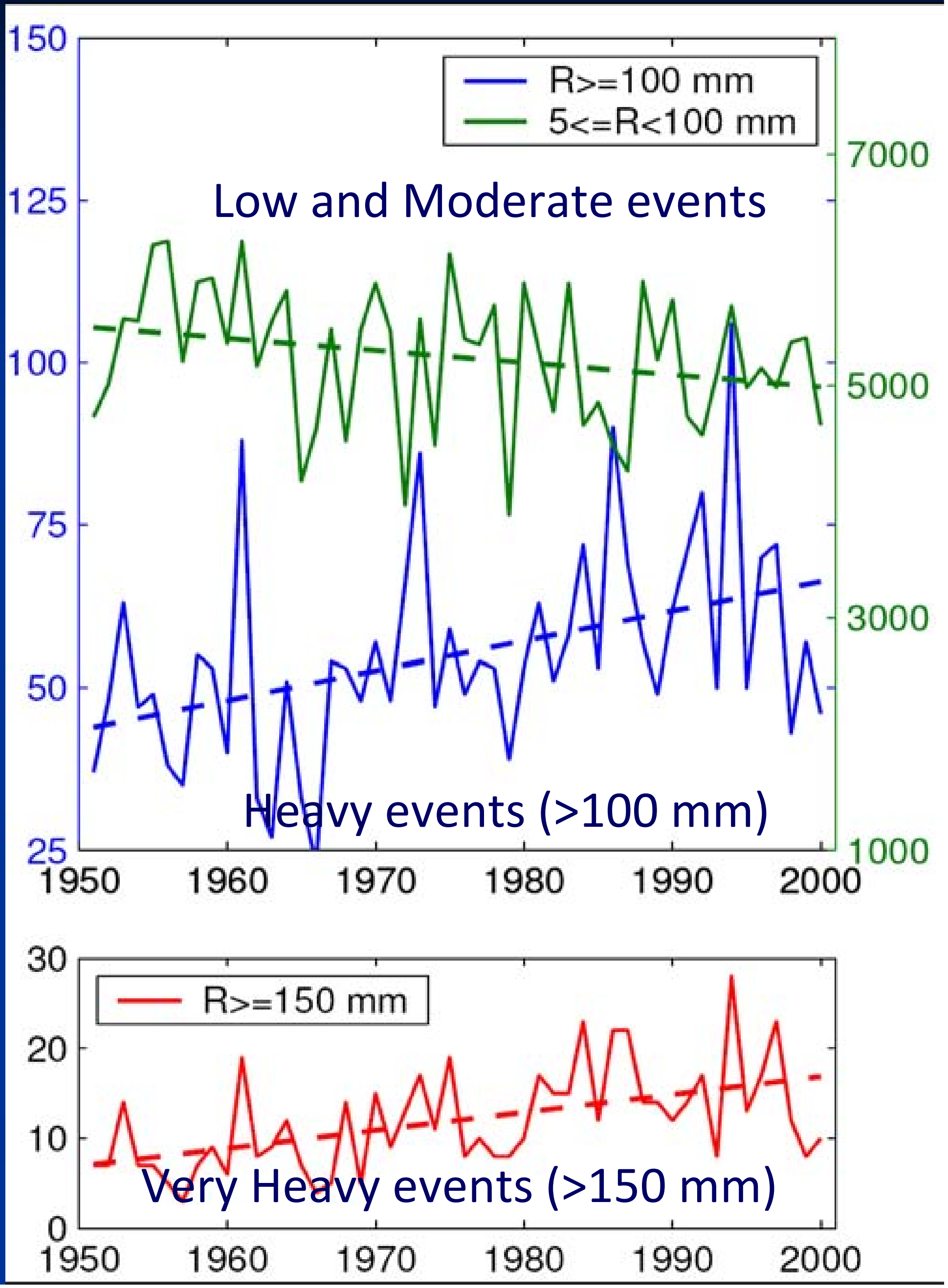

CMIP5 model-based time series of temperature and precipitation anomalies (historical and projections) from 1861 – 2099 relative to the 1961 – 1990 baseline for the RCP scenarios . Shaded areas represent the range of changes projected by the 18 models for each year. The model ensemble averages for each RCP is shown with thick lines. The observed temperature and precipitation trend from CRU is shown by the green line and the solid black line. ‘Historical’ refers to model ensemble values for historical simulations.

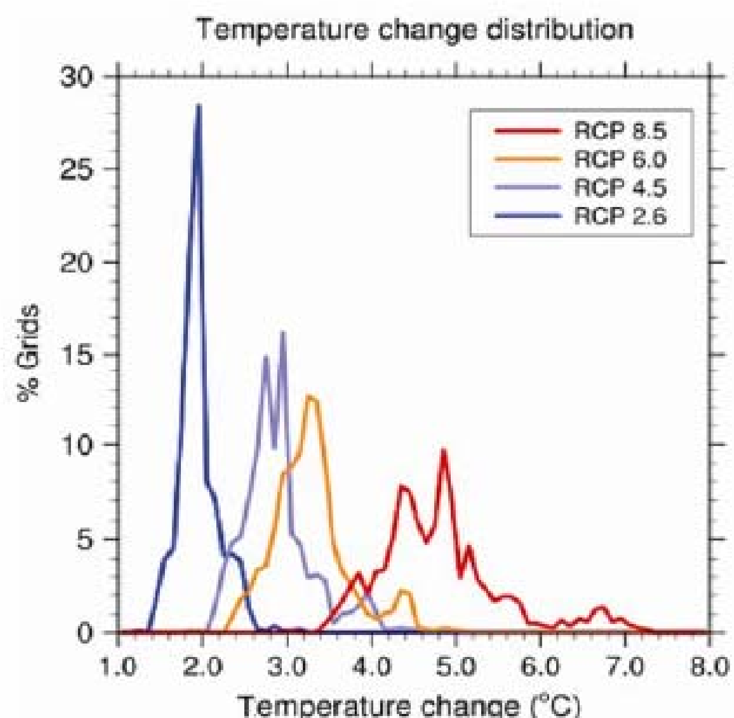
**Increasing Trend of Extreme Rain Events over India in a Warming Environment**

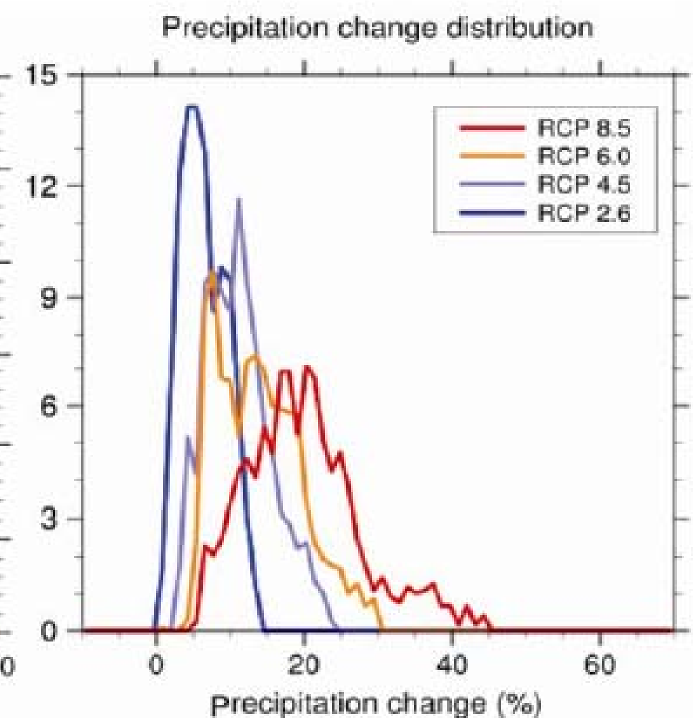



Goswami et al., Science, 2006

## Time series of count over Central India

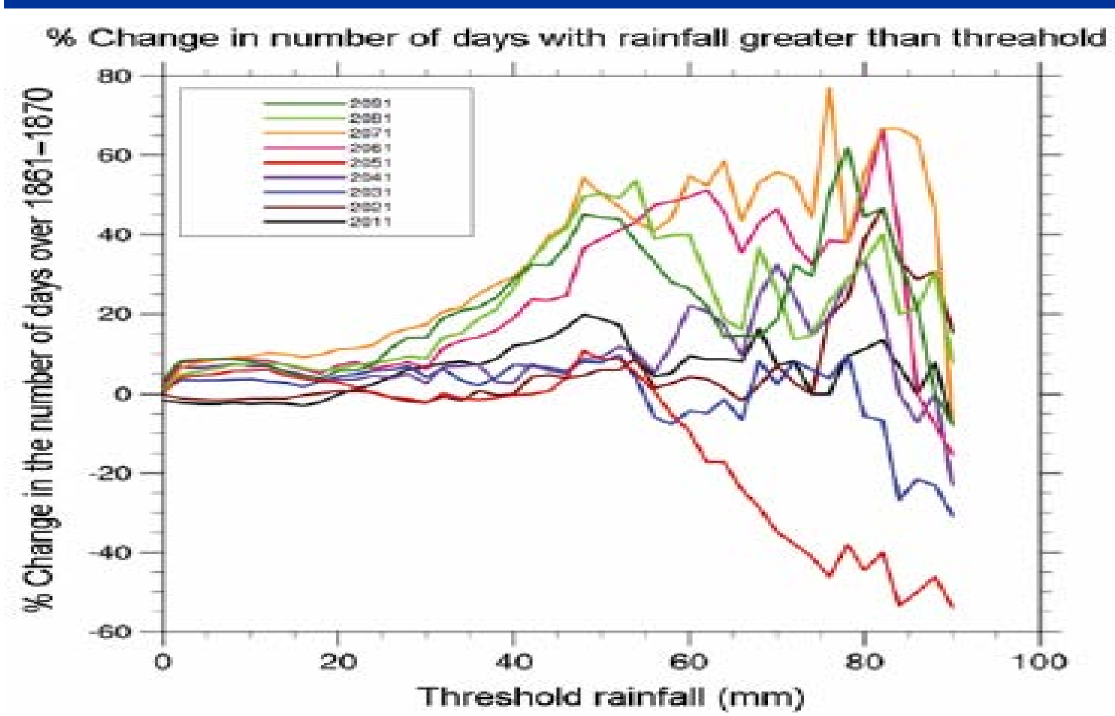





CMIP5 model ensemble-based grid-wise distribution of temperature & rainfall change under different RCP scenarios for India for 2080s (2070 – 2099) relative to the pre-industrial period (1861 – 1900)

**Chaturvedi et al. 2012**

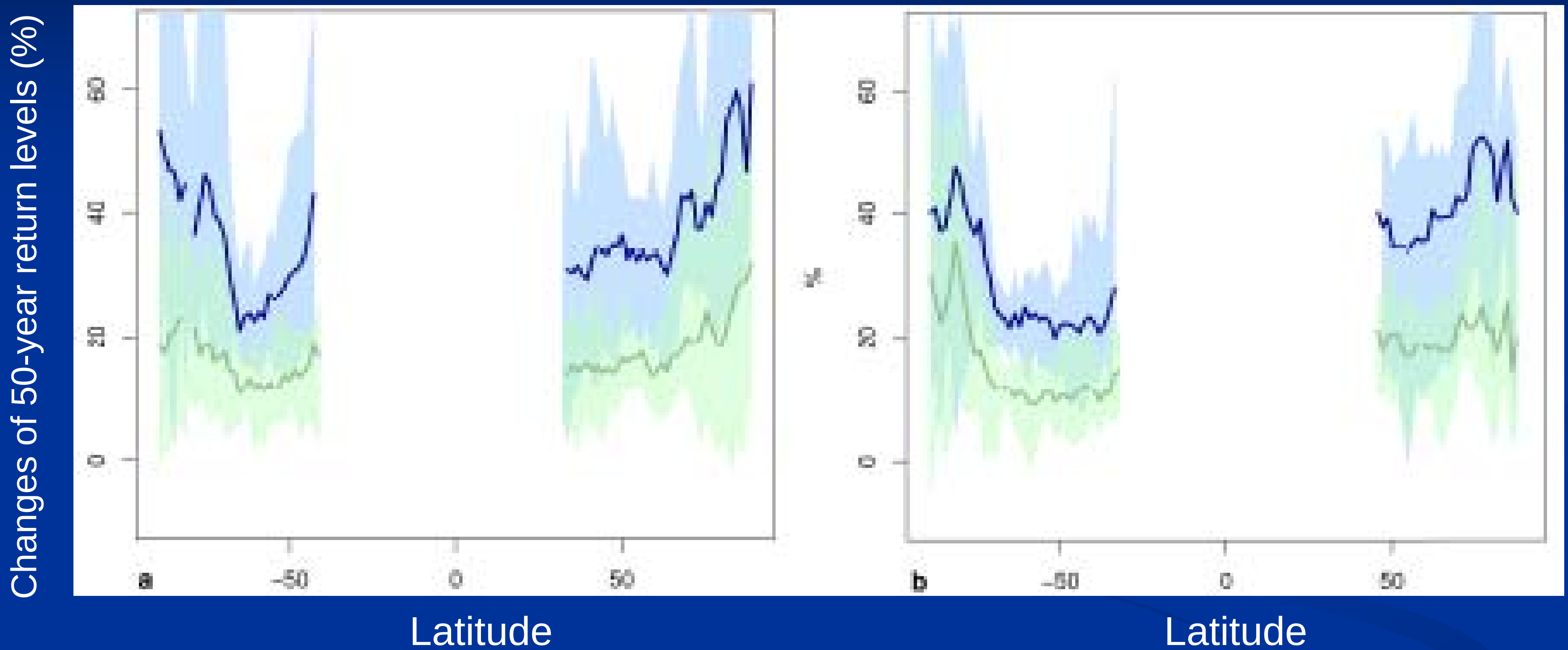



## CMIP5 models

Limitations of coarse resolution climate models in capturing high intensity ( > 100 mm / day) rainfall events over the Indian monsoon region and their change

Projected change in the frequency of extreme rainfall days for future decades relative to the 1861 – 1870 baseline based on the MIROC-ESM model for RCP4.5 scenario

# CMIP5 models don't provide reliable & consistent estimates of changes in precipitation extremes over tropics and subtropics



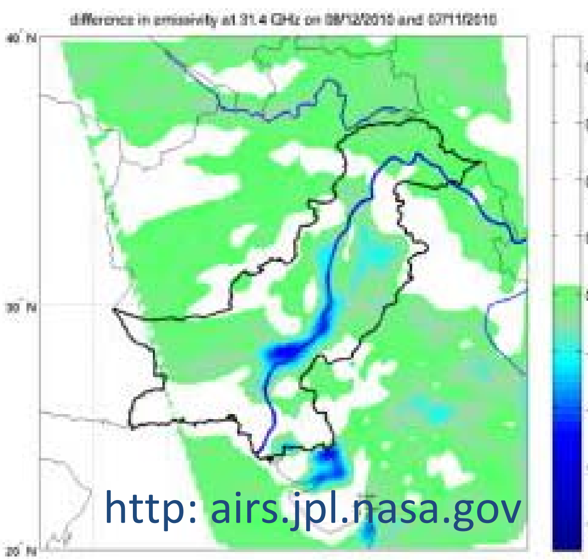

Zonal mean changes of the estimated 50-yr return levels (%) w.r.t 1966-2005 under RCP8.5 scenario (a) Winter (b) Summer. Blue and green lines represent the ensemble mean for the periods 2020 – 2059 and 2060 – 2099 respectively.

**Source: Andrea Toreti et al. Geophy. Res. Lett, 2013**

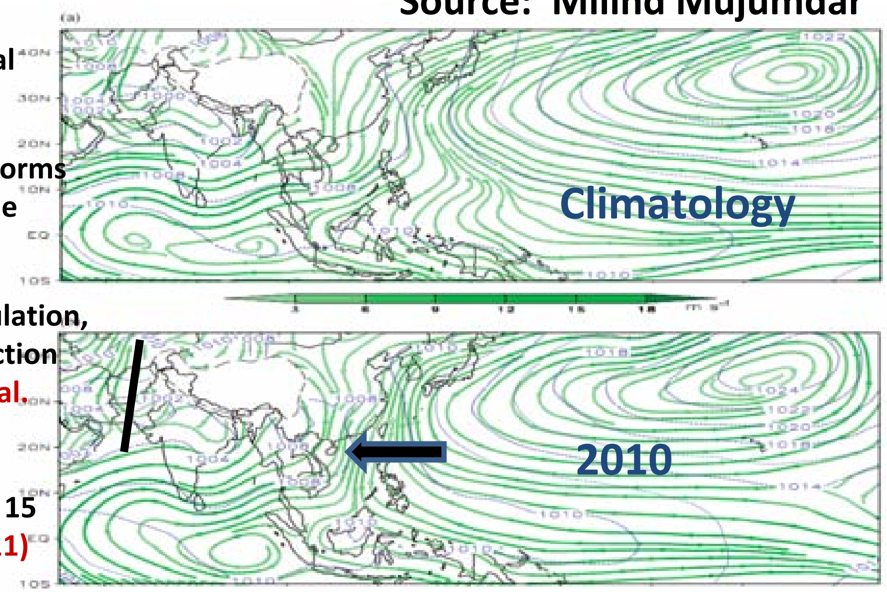
# Regional climate processes: Links between regional and large-scale variability

**Pakistan Floods 2010:** Extent of Pakistan floods detected by AIRS satellite. The Atmospheric Infrared Sounder, AIRS, in conjunction with the Advanced Microwave Sounding Unit, AMSU, senses emitted infrared and microwave radiation from Earth to provide a three-dimensional look at Earth's weather and climate

**Source: Milind Mujumdar**




- **Westward shift of sub-tropical High (Mujumdar et al. 2012)**
- **Westward displacement of storms and departure of synoptic scale circulation (Houze et al. 2011)**
- **Influence of midlatitude circulation, European blocking and interaction with tropical storms (Hong et al. 2011, Saeed et al.2011)**
- **Extended range prediction (~ 15 days lead) (Webster et al. 2011)**

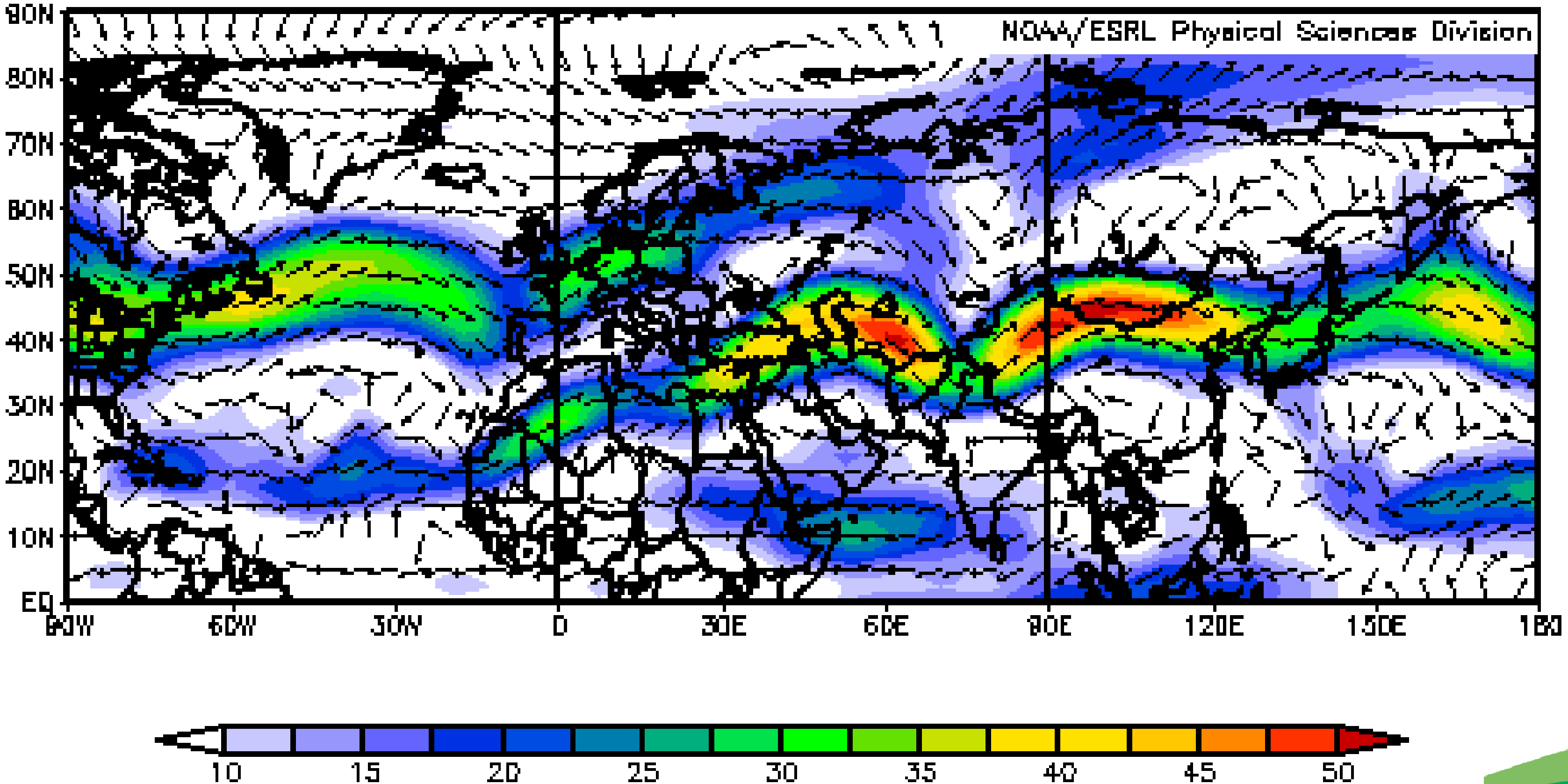


Imperial College London

The University of Reading

# Uttarakhand (India) floods 2013

## 200 hPa winds 14-18 June 2013

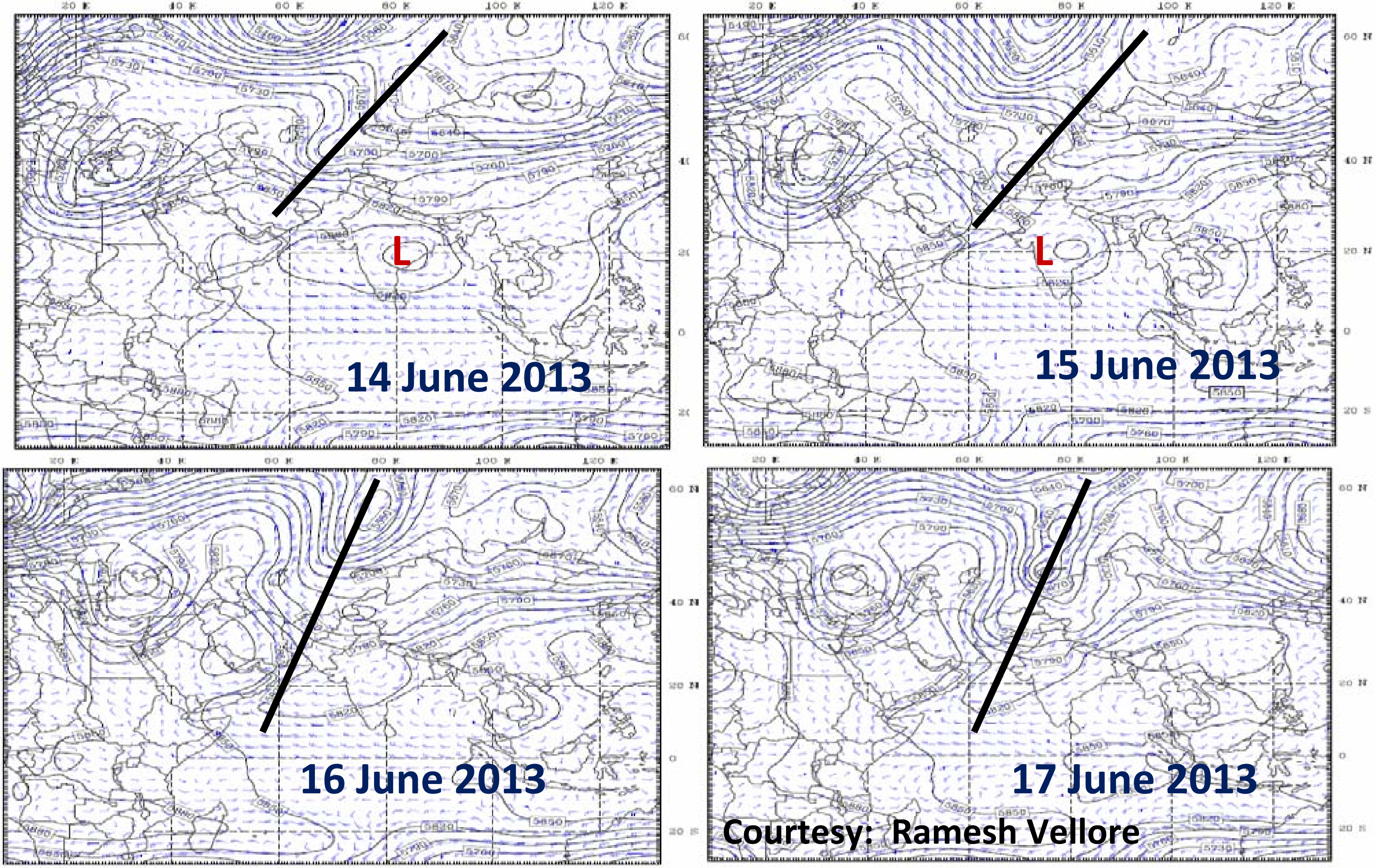



**Courtesy: Sir Prof. Brian Hoskins**

Grantham Institute for Climate Change

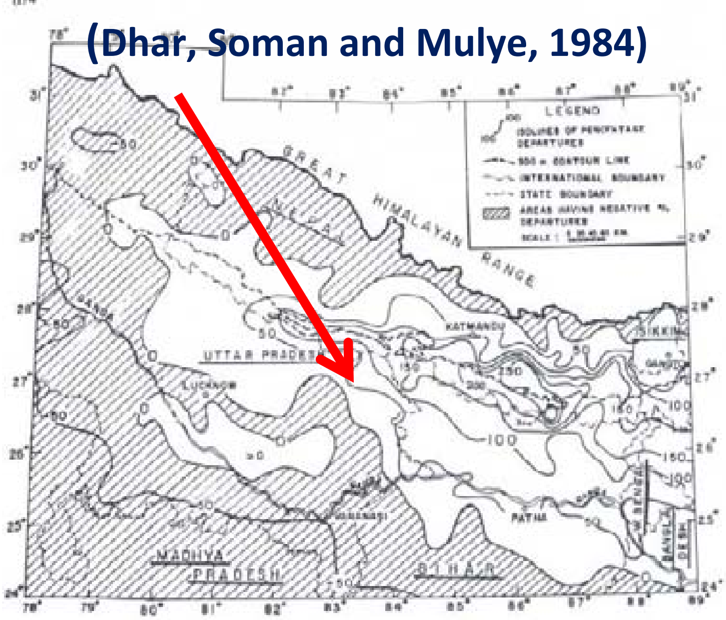
# Evolution of Uttarakhand heavy rainfall event (June 2013)

Interactions between southward intruding mid-latitude troughs and monsoon lows

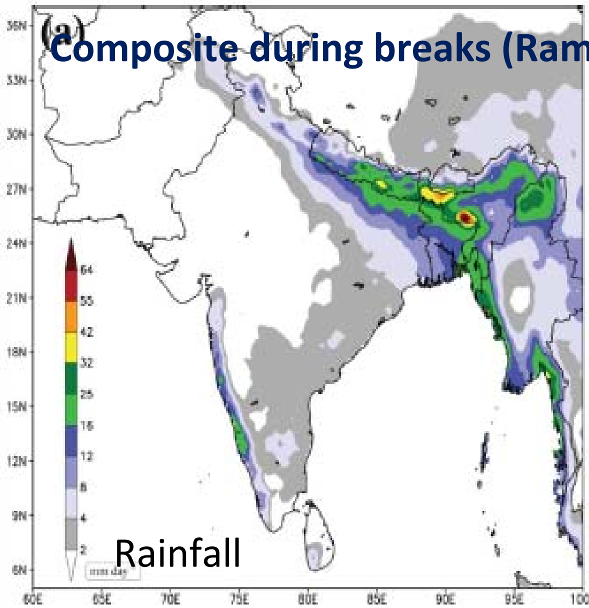


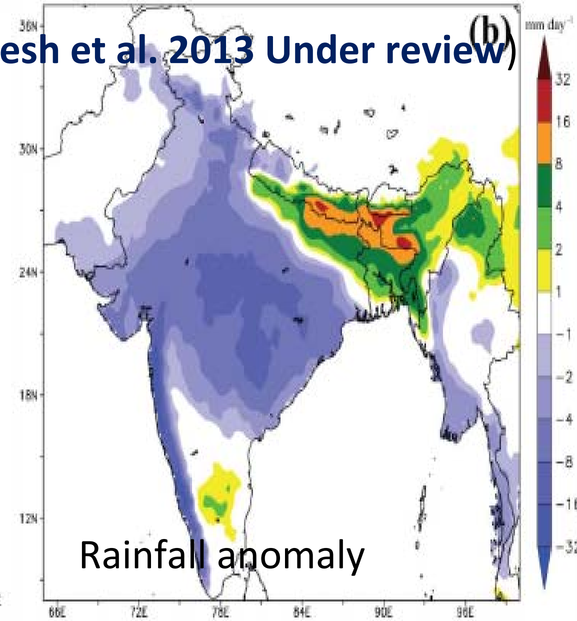
# Rainfall over the southern slopes of the Himalayas & adjoining plains during monsoon breaks

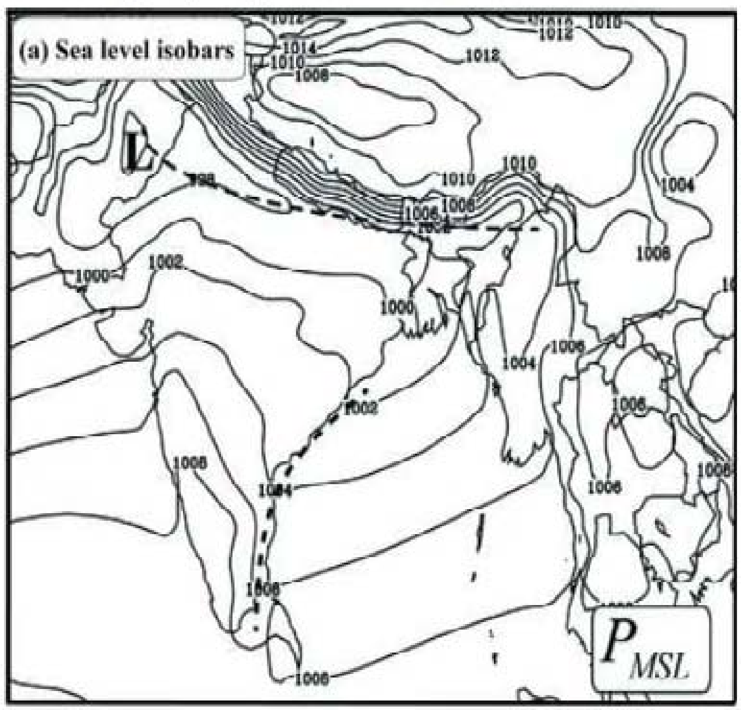
(Dhar, Soman and Mulye, 1984)

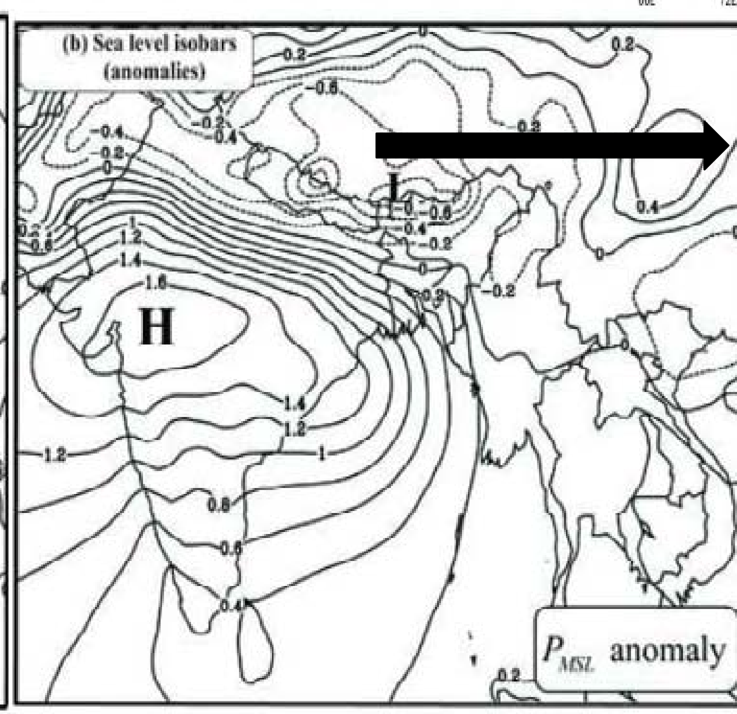



Composite during breaks (Ramesh et al. 2013 Under review)



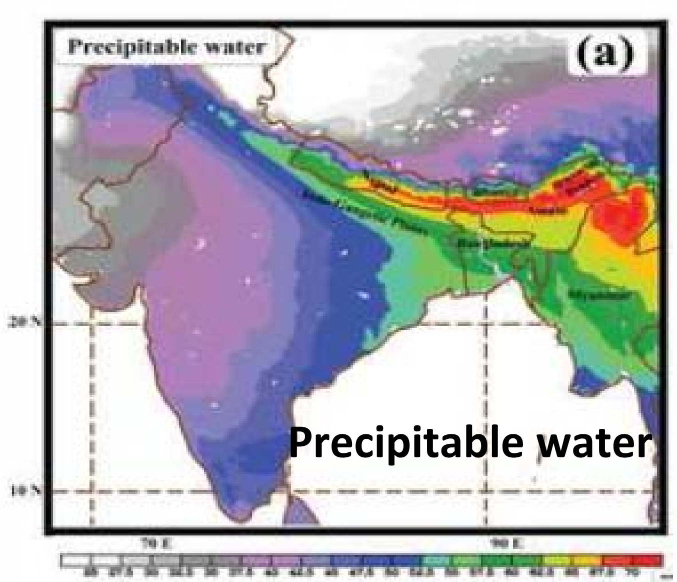



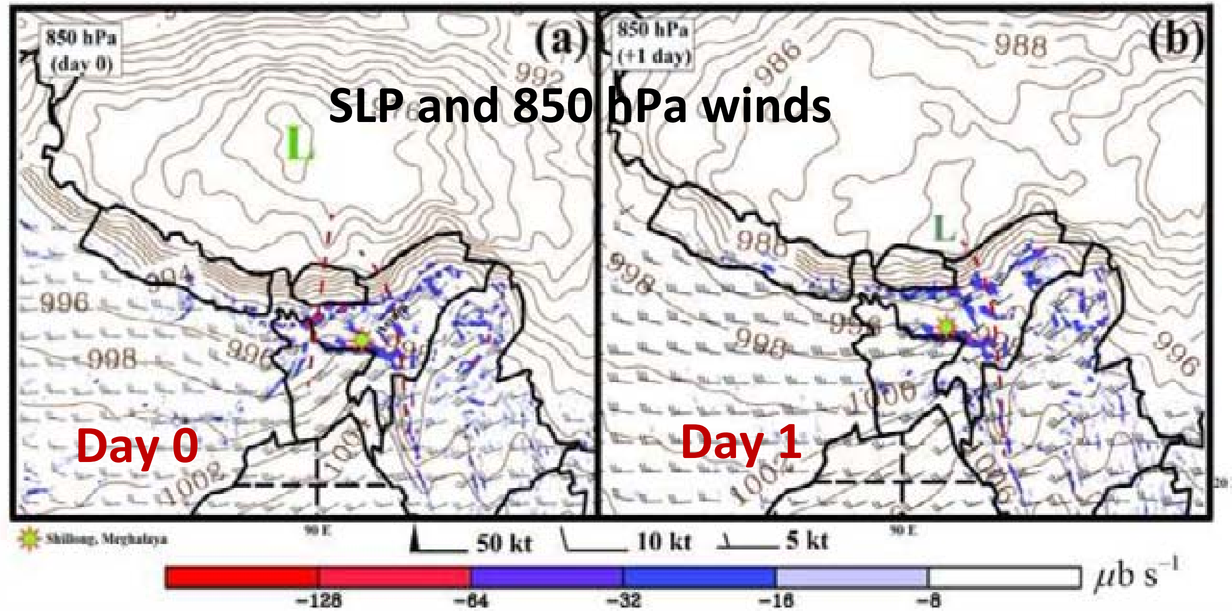



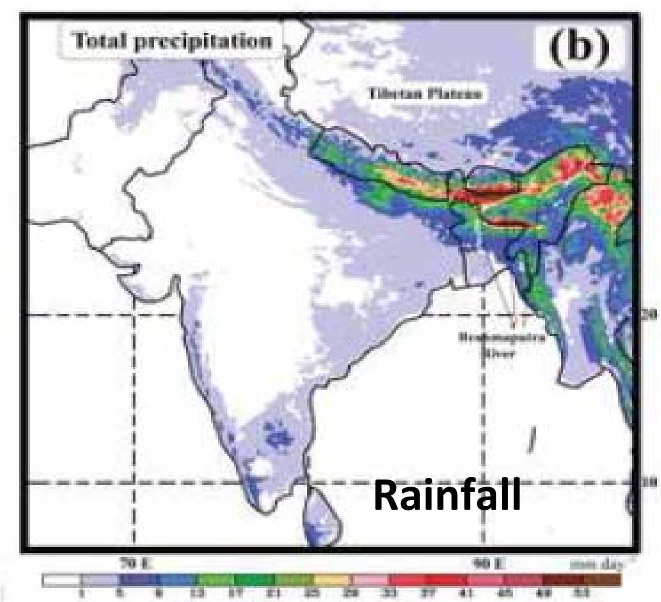

Anomalous northward shift of monsoon trough

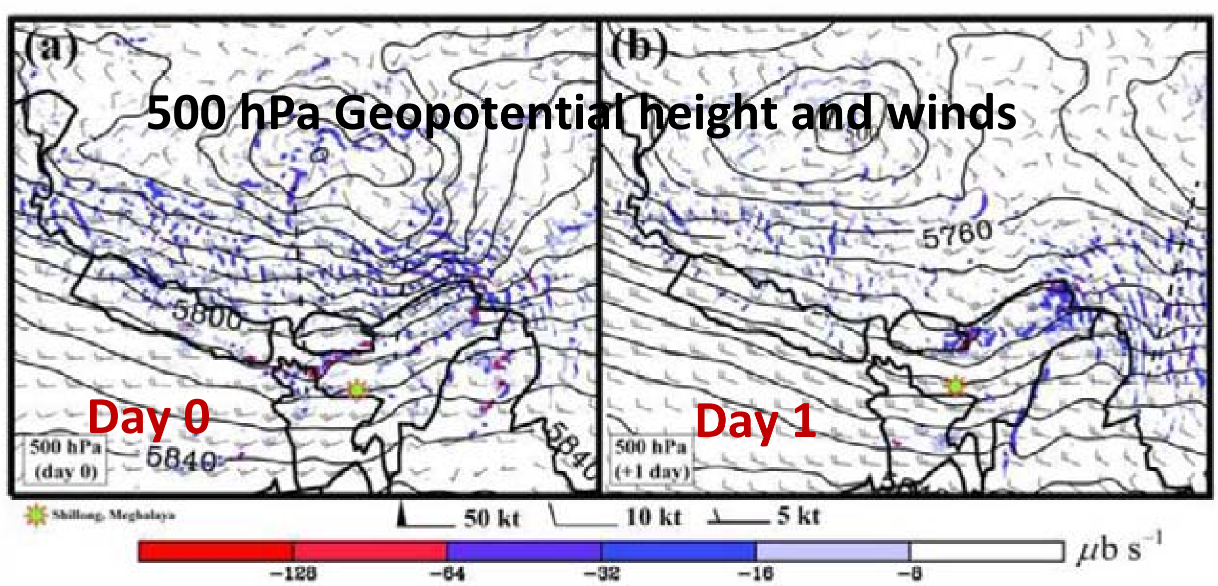
Ramesh et al. 2013

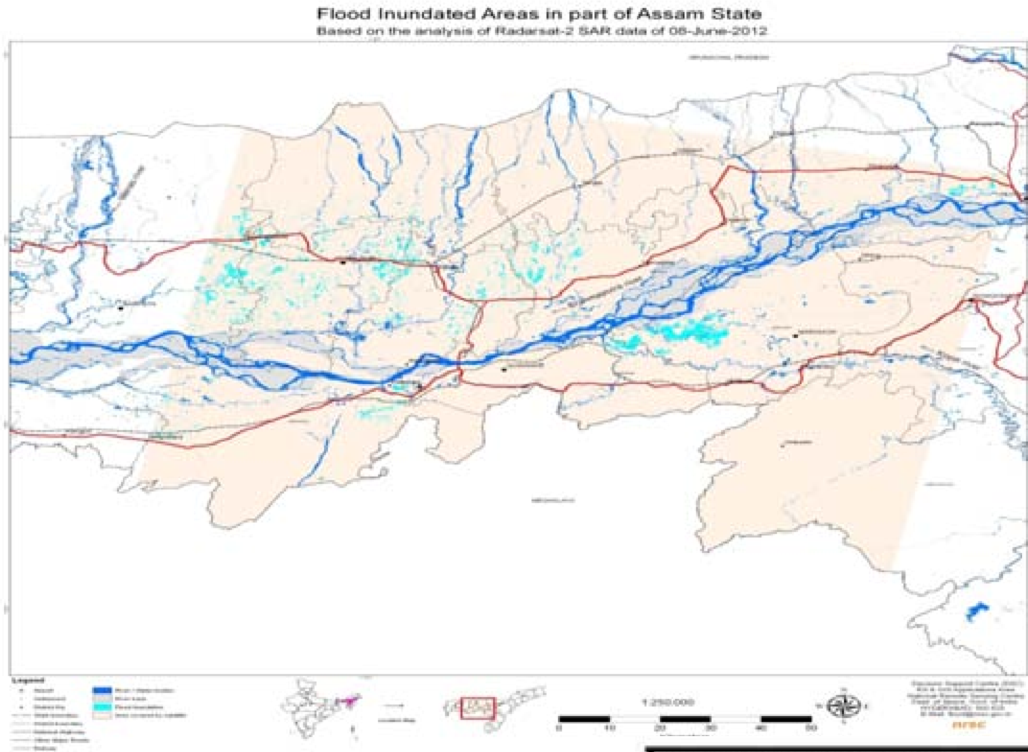
# Monsoon break simulation by WRF high-resolution (10 km) model - Courtesy: Ramesh Vellore



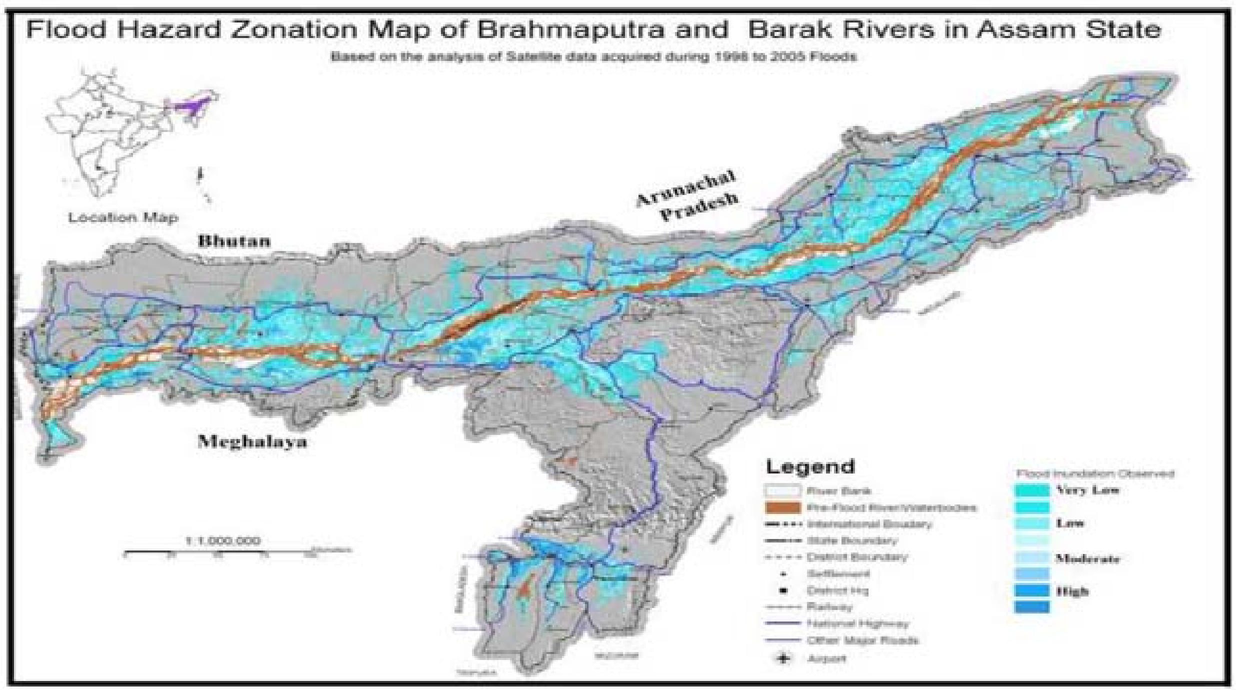






Flood Inundated Areas in part of Assam State: 8 June 2012 - Analysis of Radarsat SAR data

Flood Hazard Zonation Map of Brahmaputra and Barak Rivers in Assam State – Based on analysis of satellite data during 1998 – 2005 floods

Courtesy: National Remote Sensing Centre, India



# World Climate Research Programme (WCRP)

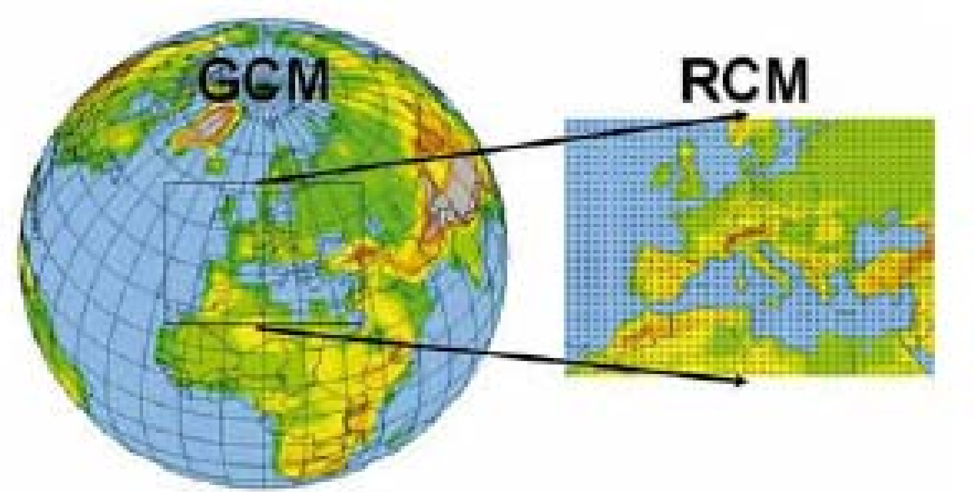
WCRP CORDEX

**Providing global coordination of Regional Climate Downscaling for improved regional climate change adaptation and impact assessment**

## What is Regional Climate Downscaling?

A Global Climate Model (GCM) may provide a prediction for an area of 300km by 300km covering what could be a vastly differing landscape (from very mountainous to flat coastal plains for example) with greatly varying potential for floods, droughts or other extreme events. Regional Climate Models (RCM) instead can provide information on a much smaller area allowing for more precise information foran effective impact and adaptation assessment and planning, which is vital in many vulnerable regions of the world.

*From the picture on the right you can see how although the GCM covers the whole globe the level of detail is relatively low whereas a RCM can provide much higher level of detail (or resolution) over a smaller region such as Europe or Africa.*



## Why do we need Regional Climate Downscaling?

Global Climate Models (GCM) can provide us with projections of how the climate of the earth will change in the future. These results are urging the international community to take decisions on climate change mitigation. However, the impacts of a changing climate, and the adaptation strategies required to deal with them, will be on a more regional scale. This is where Regional Climate Downscaling (RCD) has an important role to play by providing projections with much greater detail.

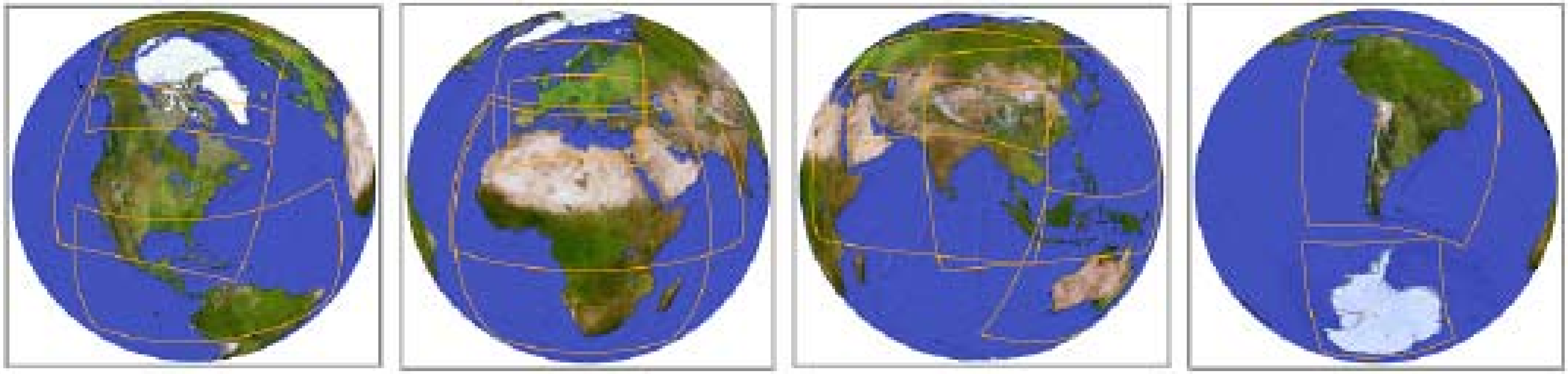
**Impacts of changing climate are pre-dominant at regional scales !**

## What is CORDEX?

The RCD techniques available, their applications, and the community using them are broad and varied, and it is a growing area. The Coordinated Regional Climate Downscaling Experiment (CORDEX) was launched by the World Climate Research Programme (WCRP) to create a framework for evaluating and comparing these various techniques that are in use all over the world. It is envisaged that CORDEX will also contribute to the WMO Global Framework for Climate Services by providing climate predictions at the regional scale and will increase the capacity to downscale the global climate predictions. Further the CORDEX community supports activities in developing regions and also provide opportunities for young scientists to further their experience and knowledge base.

http://wcrp.ipsl.jussieu.fr/cordex/

# CORDEX communities across the globe



- EURO-CORDEX
- MED-CORDEX
- CORDEX-Africa
- South Asia CORDEX
- South America CORDEX
- North America CORDEX
- Arctic CORDEX
- MENA-CORDEX
- Australasia CORDEX
- East Asia CORDEX
- Central America CORDEX
- CORDEX Antarctica

*•Better understand regional climate processes and improve climate models*

*•Produce reliable high-resolution regional climate change scenarios globally, thereby contributing to the IPCC AR5 and to the climate community beyond the AR5*

*•Evaluate regional climate model performance through a set of experiments aiming at producing regional climate projections*

*•Quantify and understand the uncertainties in regional climate projections*

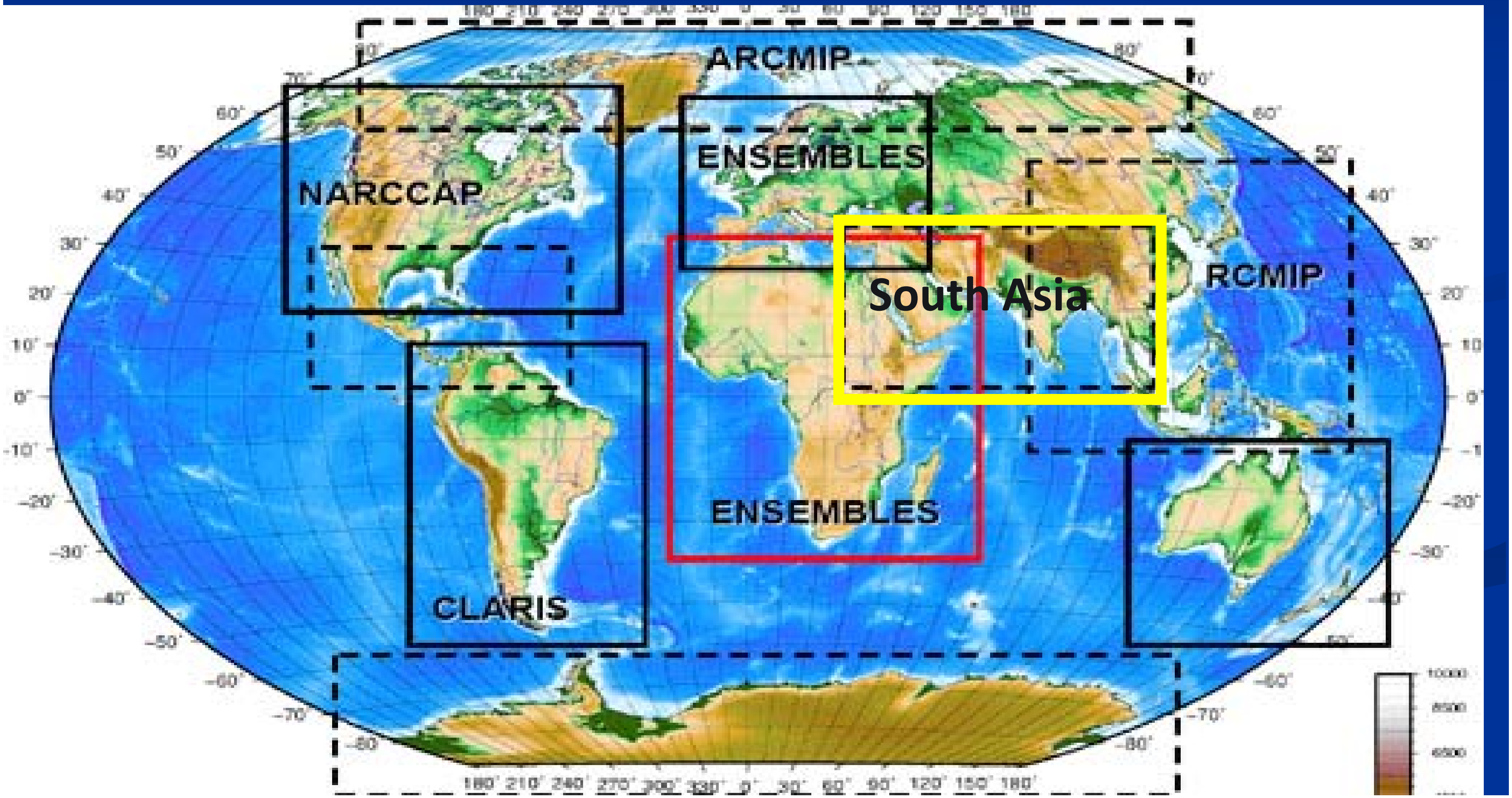
*•Link climate modeling better with regional impact, adaptation and vulnerability assessment*

*•Integrate the regional downscaling activities, facilitate cross-fertilization of scientific expertise and engage the community of regional scientists for further capacity building in the region*

# WCRP CORDEX South Asia

Co-ordinated Regional Downscaling Experiment – CORDEX South Asia

**(CORDEX South Asia – led by CCCR, IITM)**



# CORDEX: Model Experiments

- Evaulation / Baseline run with ERA – Interim boundary conditions (1989 – 2008)
- Historical run (1950 – 2005)
- Future projection : 2005 - 2100 (eg., RCP 4.5, 6.0, 8.5 Scenario)

## Participating Modeling Groups

- LMDZ model (~ 35 km ) CCCR (IITM), IPSL
- RegCM model (~ 50 km) CCCR (IITM)
- HadRM3P model (~ 50 km) CCCR (IITM), Hadley Centre
- WRF model (~ 50 km) - CCCR (IITM), BCCR and TERI
- MRI model (~ 20 km) global model (MRI, Japan)
- RCA model (~ 50 km) Rossby Centre, Sweden
- COSMO-CLM (~ 50 km) University of Frankfurt, Germany
- CCAM model ( ~ 50 km) CSIRO, Australia

# Understanding regional climate change over South Asia

High resolution (~ 35 km) dynamical downscaling at CCCR, IITM

***Historical (1886-2005):***

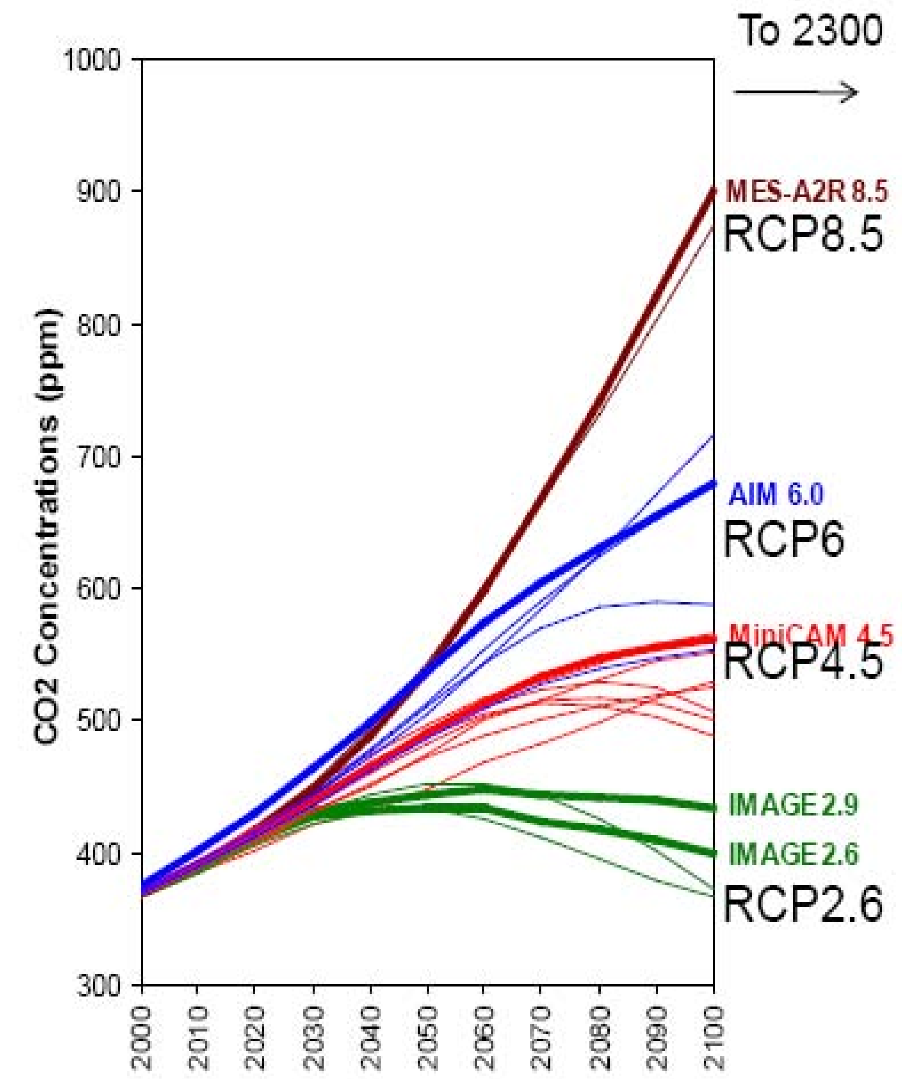
*Includes natural and anthropogenic (GHG, aerosols, land cover etc) climate forcing during the historical period (1886 – 2005) ~ 120 years*

***Historical Natural (1886 – 2005):***

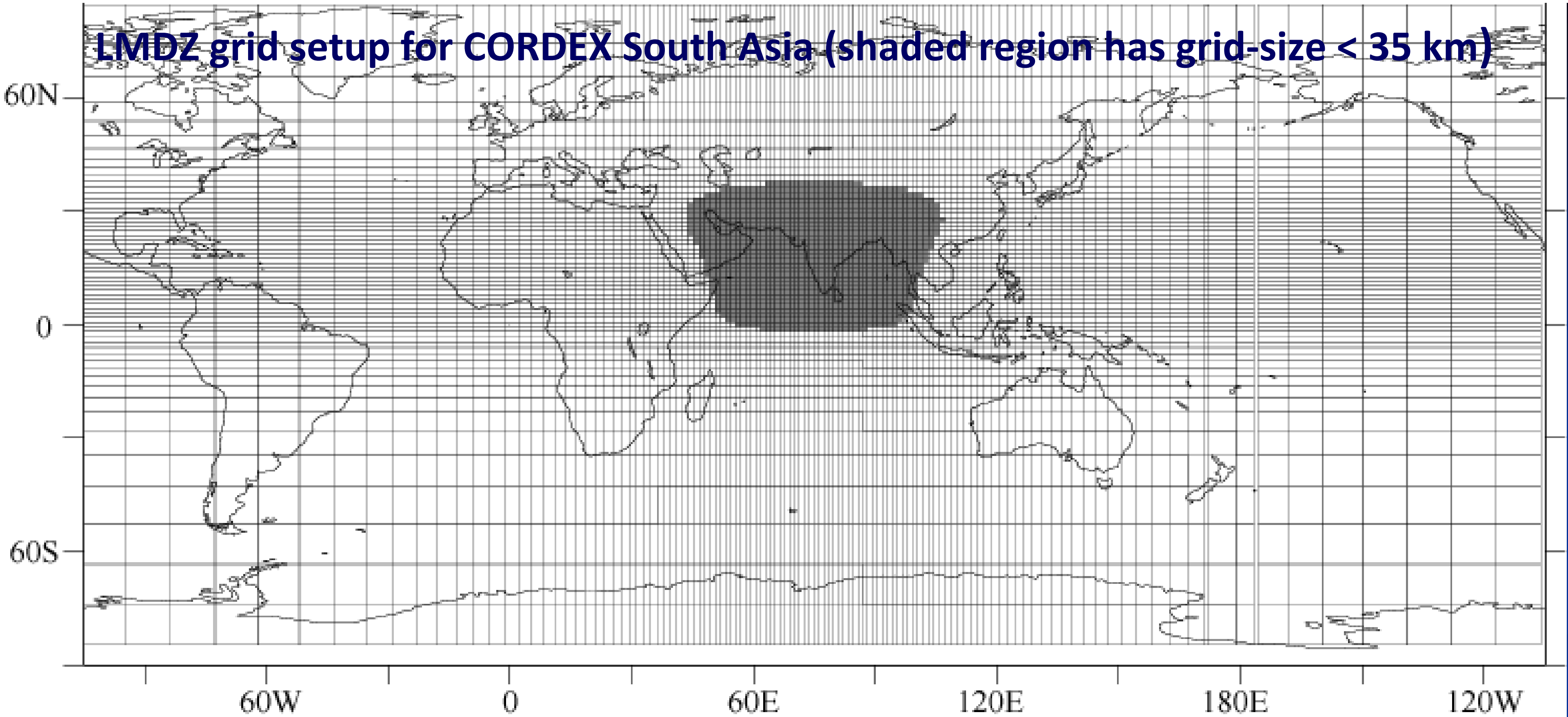
*Includes only natural climate forcing during the historical period (1886– 2005) ~ 120 years*

***RCP 4.5 scenario (2006-2100) ~ 95 years:***

*Future projection run which includes both natural and anthropogenic forcing based on the IPCC AR5 RCP4.5 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*



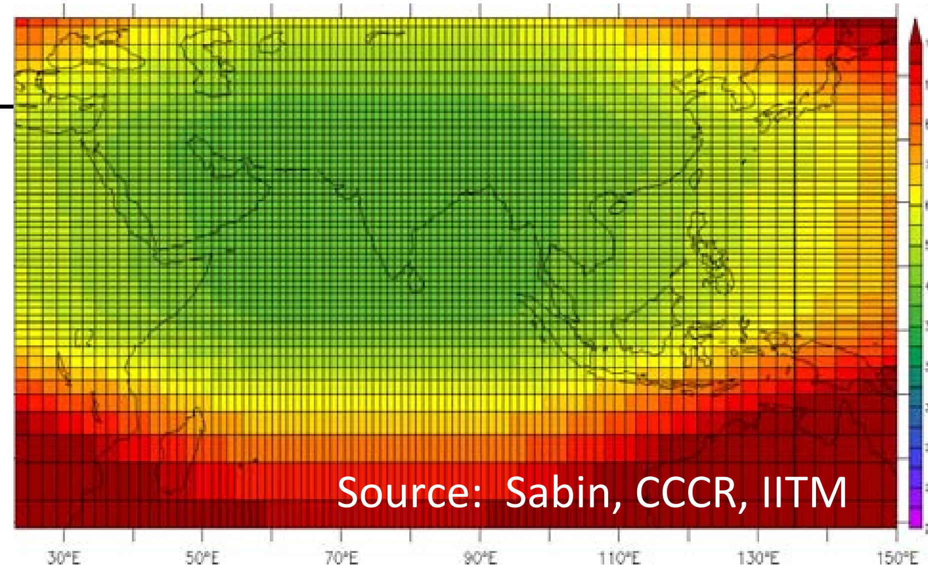
# LMDZ grid setup for CORDEX South Asia (shaded region has grid-size < 35 km)




Clim Dyn
DOI 10.1007/s00382-012-1658-8

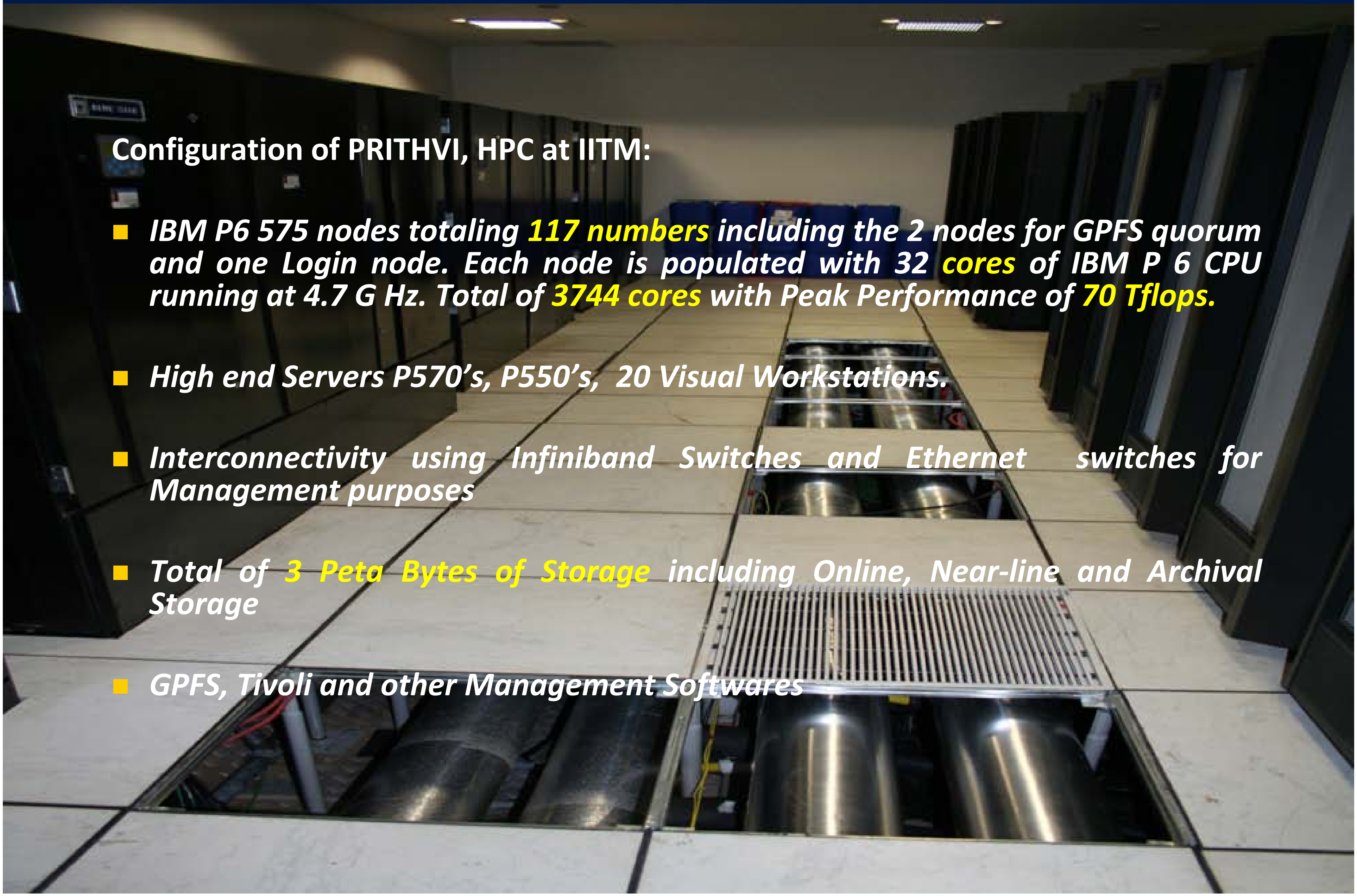
## High resolution simulation of the South Asian monsoon using a variable resolution global climate model

T. P Sabin · R. Krishnan · Josefine Ghattas ·
Sebastien Denvil · Jean-Louis Dufresne ·
Frederic Hourdin · Terray Pascal



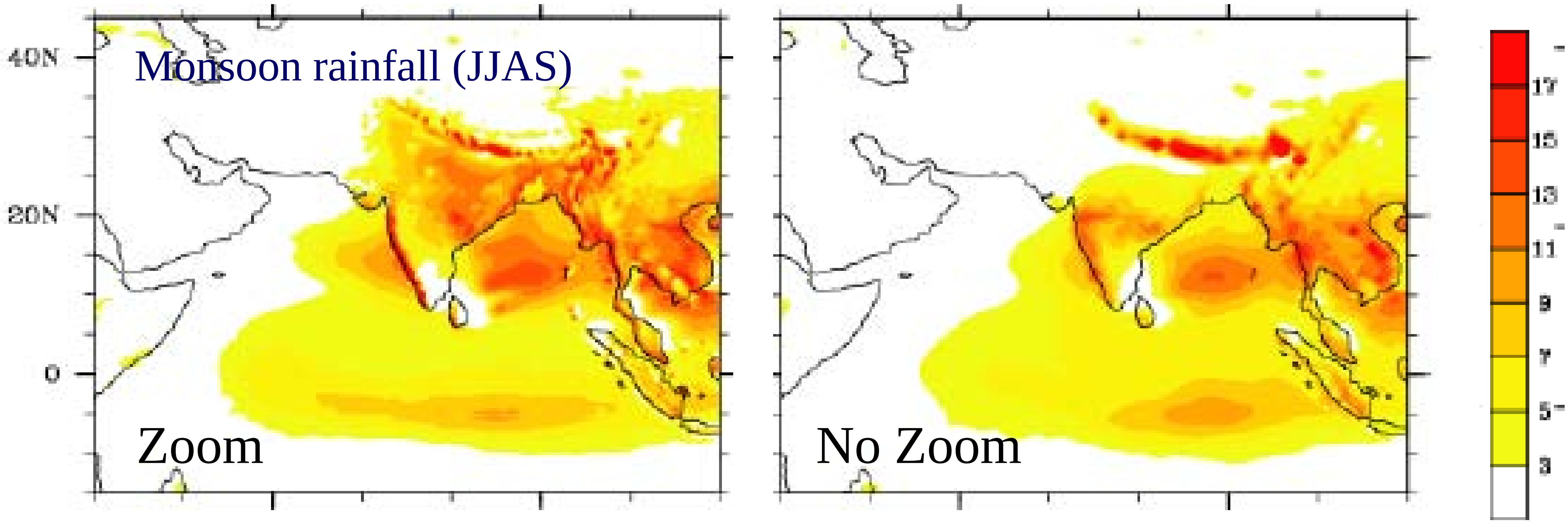

Source: Sabin, CCCR, IITM

## PRITHVI (High Performance Computing System) , IITM, Pune

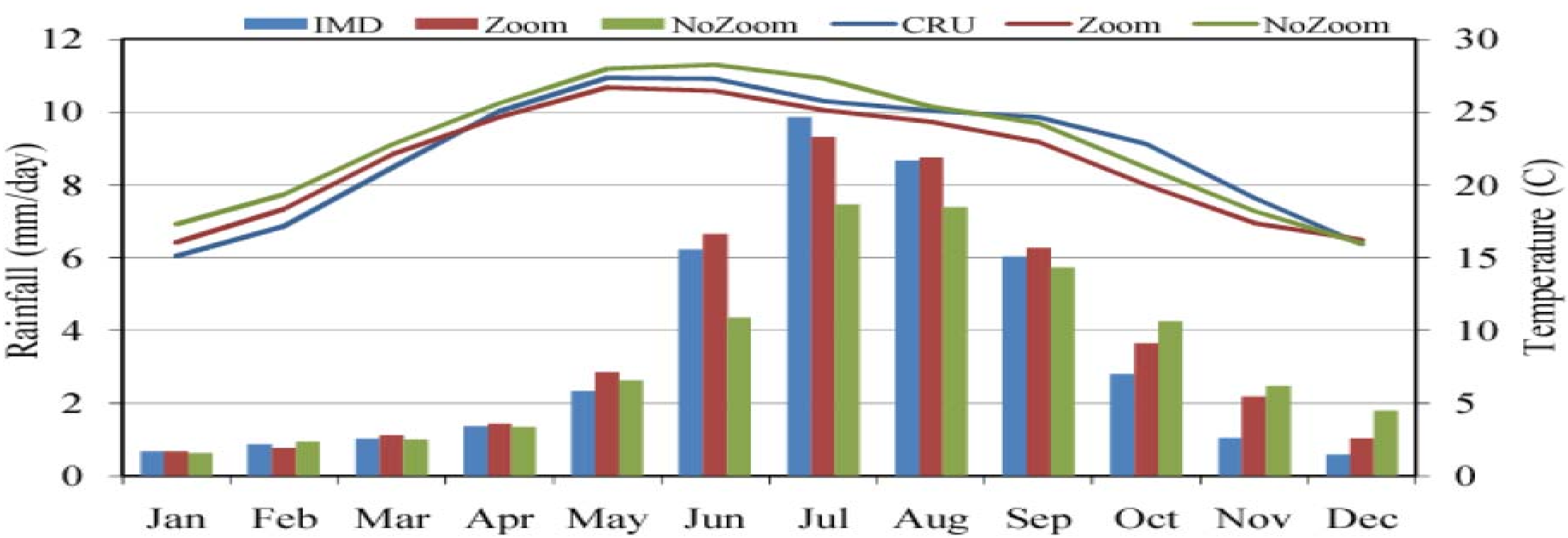


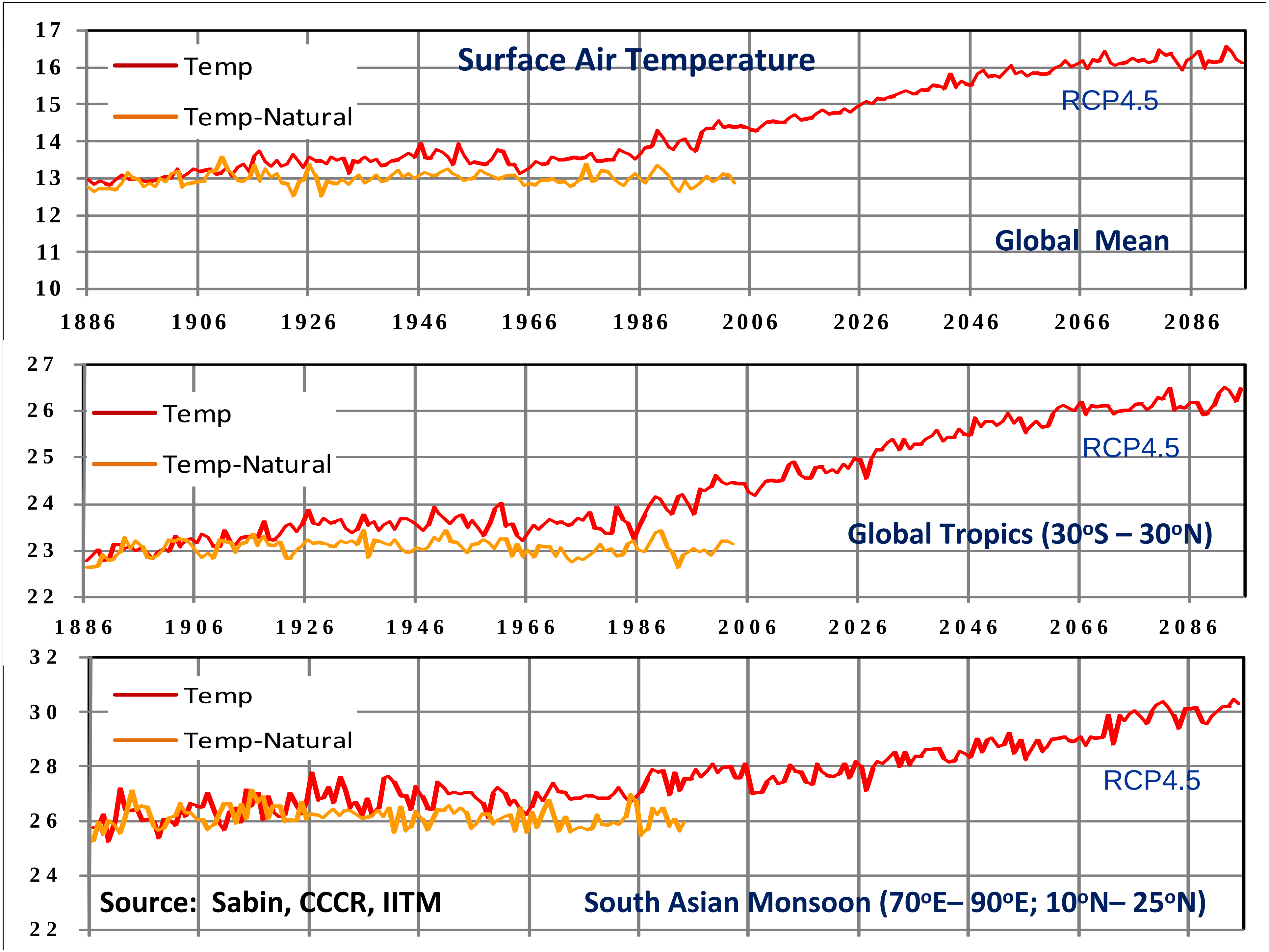
**Configuration of PRITHVI, HPC at IITM:**

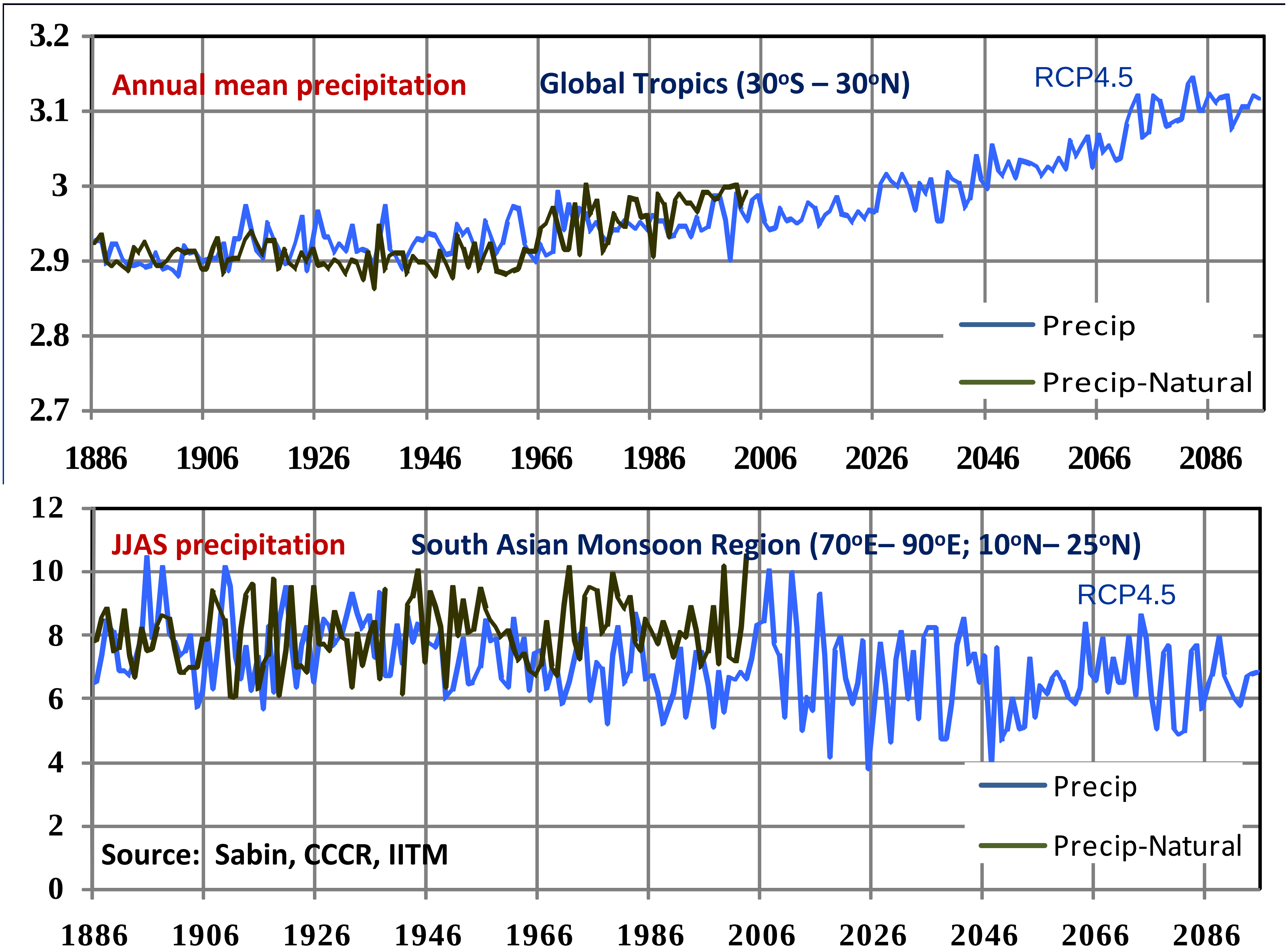
- *IBM P6 575 nodes totaling 117 numbers including the 2 nodes for GPFS quorum and one Login node. Each node is populated with 32 cores of IBM P 6 CPU running at 4.7 G Hz. Total of 3744 cores with Peak Performance of 70 Tflops.*
- *High end Servers P570's, P550's, 20 Visual Workstations.*
- *Interconnectivity using Infiniband Switches and Ethernet switches for Management purposes*
- *Total of 3 Peta Bytes of Storage including Online, Near-line and Archival Storage*
- *GPFS, Tivoli and other Management Softwares*



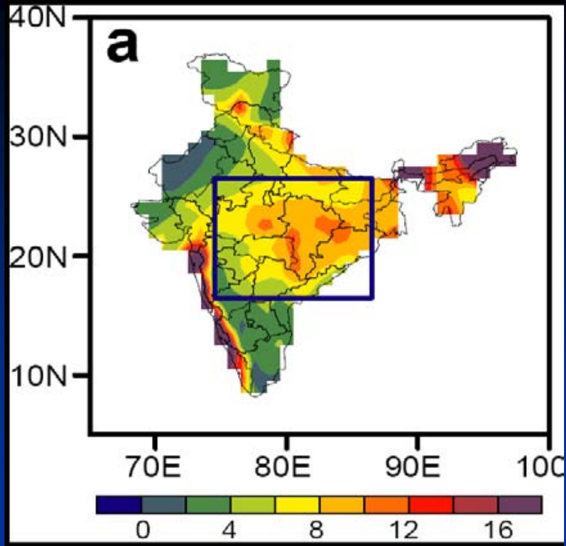

**Mean annual cycles of rainfall (mm day $^{-1}$) and surface temperature ($^{o}$C) over the Indian landmass from the zoom and no-zoom runs**

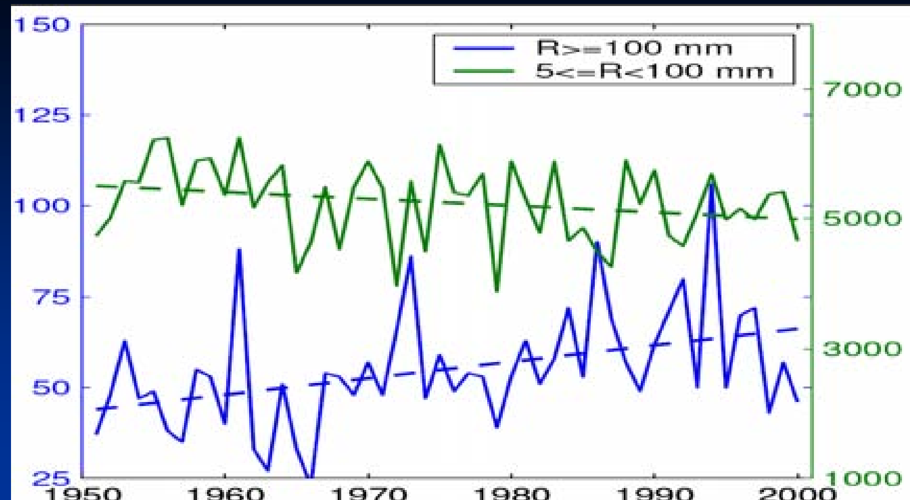



Surface Air Temperature
Temp
Temp-Natural
RCP4.5
Global Mean
Global Tropics (30ºS – 30ºN)
South Asian Monsoon (70ºE– 90ºE; 10ºN– 25ºN)
Source: Sabin, CCCR, IITM
1886
1906
1926
1946
1966
1986
2006
2026
2046
2066
2086

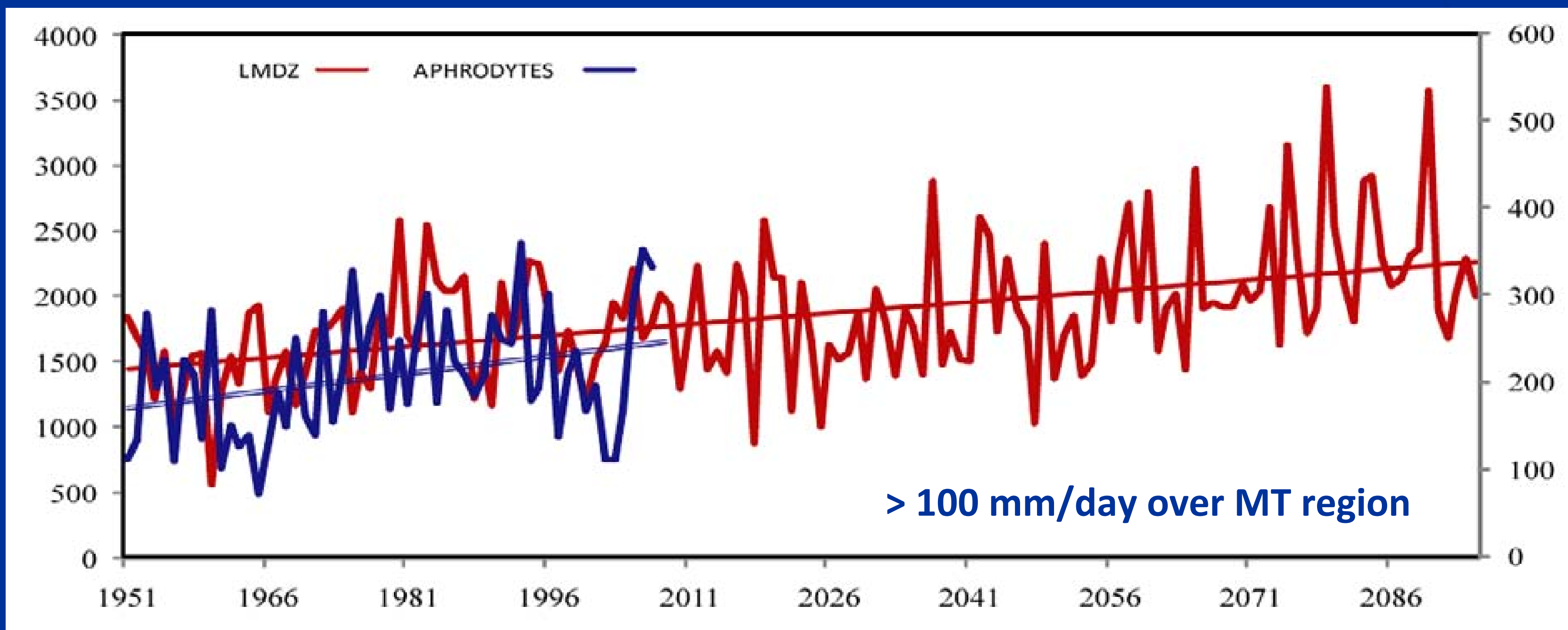


Annual mean precipitation
Global Tropics (30°S – 30°N)
RCP4.5
Precip
Precip-Natural
3.2
3.1
3
2.9
2.8
2.7
1886
1906
1926
1946
1966
1986
2006
2026
2046
2066
2086
JJAS precipitation
South Asian Monsoon Region (70°E– 90°E; 10°N– 25°N)
RCP4.5
Precip
Precip-Natural
12
10
8
6
4
2
0
Source: Sabin, CCCR, IITM
1886
1906
1926
1946
1966
1986
2006
2026
2046
2066
2086



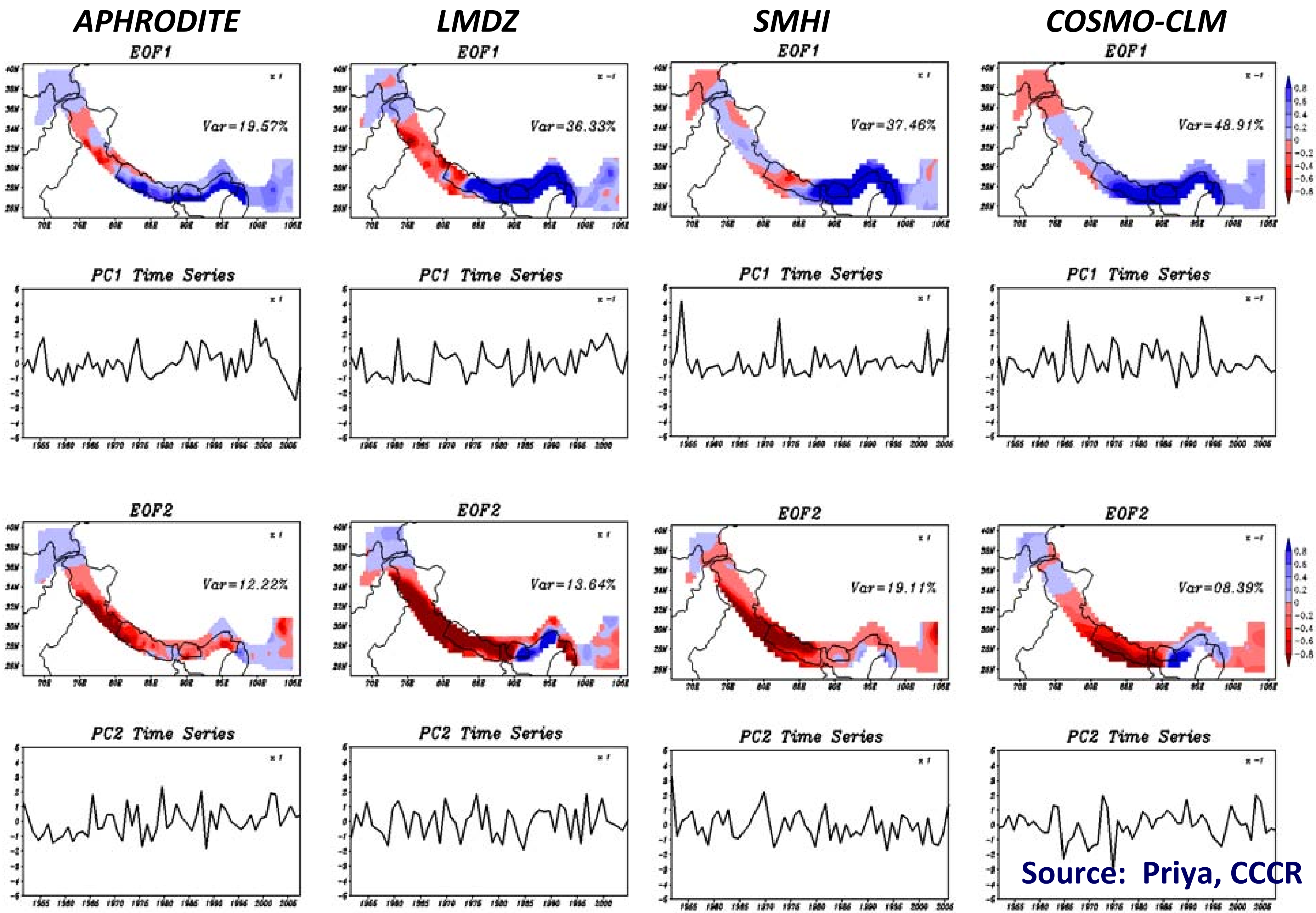




Goswami et al., Science, 2006




Source: Sabin, CCCR, IITM

# Patterns of rainfall variability over Himalayas from multiple models




Source: Priya, CCCR

# Announcement of CORDEX South Asia dataset dissemination: 12 Sept 2013

Updated on 03 Sept 2013

## CORDEX-South Asia Multi-Model Output

Historical (1950 – 2005)
Space required for each variable is approx 4 GB

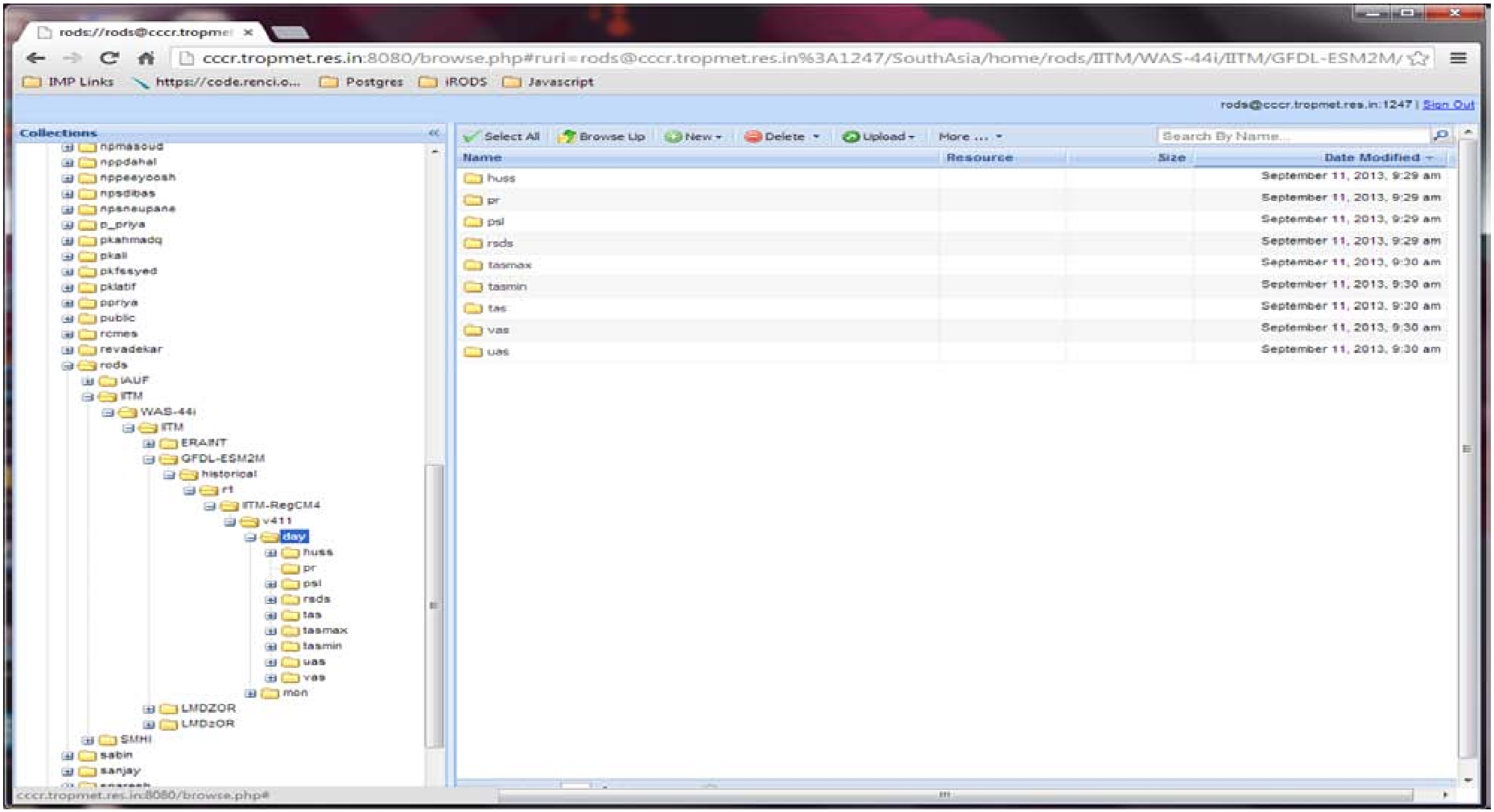
| Variable name (Monthly and Daily) | SMHI-RCA4 | RegCM4-GFDL | RegCM4-LMDZ | COSMO-CLM | LMDZ |
|---|---|---|---|---|---|
| Rainfall (pr) | Y | Y | Y | Y | Y |
| Surface Air Temperature (tas) | Y | Y | Y | Y | Y |
| Surface Air Temp. Maximum (tasmax) | Y | Y | Y | -- | Y |
| Surface Air Temp. Minimum (tasmin) | Y | Y | Y | -- | Y |
| Sea-level Pressure (psl) | Y | Y | Y | -- | Y |
| Surface Specific Humidity (huss) | Y | Y | Y | -- | Y |
| Surface Zonal Wind (uas) | Y | Y | Y | -- | Y |
| Surface Meridional Wind (vas) | Y | Y | Y | -- | Y |
| Downward Shortwave Radiation (rsds) | -- | Y | Y | -- | -- |

Courtesy: Sandip Ingle, Milind Mujumdar, CCCR

# CORDEX South Asia multi-model data

## Centre for Climate Change Research (CCCR)
## Indian Institute of Tropical Meteorology, Pune

## CCCR Data Portal http://cccr.tropmet.res.in:8080/



# Summary

•Reliable projections of regional climate change , changes in extremes and their impacts - Scientifically challenging

•**CORDEX South Asia:** A framework for addressing regional climate and monsoonal issues under changing climate

•CORDEX South Asia multi-model high-resolution simulations at IITM and Partner Institutions
- Evaluation run, Historical runs and future scenarios eg. RCP4.5.

•Multi-model Analysis: Evaluation of model performance, Quantify uncertainties in regional climate projections

•Develop synergistic linkage between climate downscaling and VIA user communities in Asia through direct user engagement

•Archival and dissemination of CORDEX South Asia multi-model outputs - CCCR, IITM

•Development of regional capacity - CORDEX training workshops in South Asia, East Asia and South East Asia in 2013, 2014 and 2015

•Framework for developing an ESG node at CCCR, IITM for CORDEX South Asia

# Thank you