Symposium on Climate Change at India Geospatial Forum
12 February 2015, International convention centre, Hyderabad

The high resolution regional Climate projections for south Asia

मिलिन्द मुजुमदार

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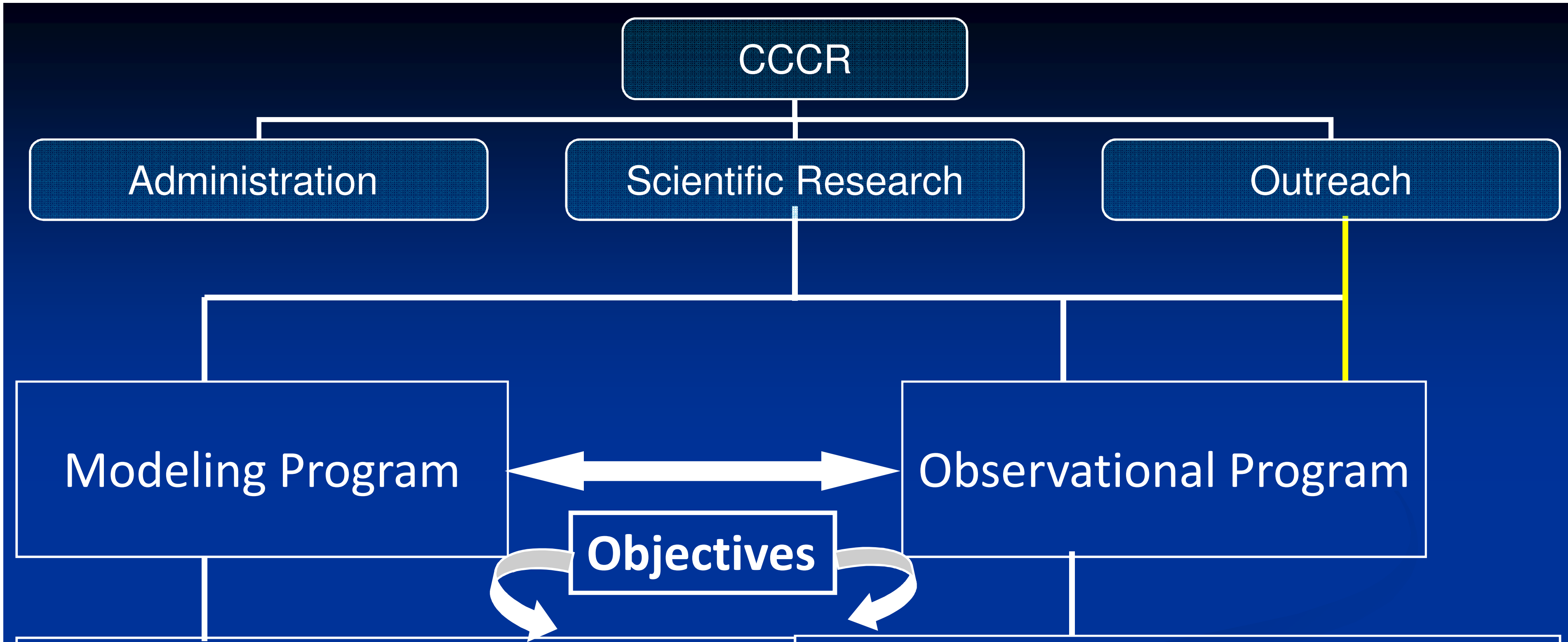
http://www.tropmet.res.in

Acknowledgements: Ministry of Earth Sciences (MoES), IITM

Research Activities

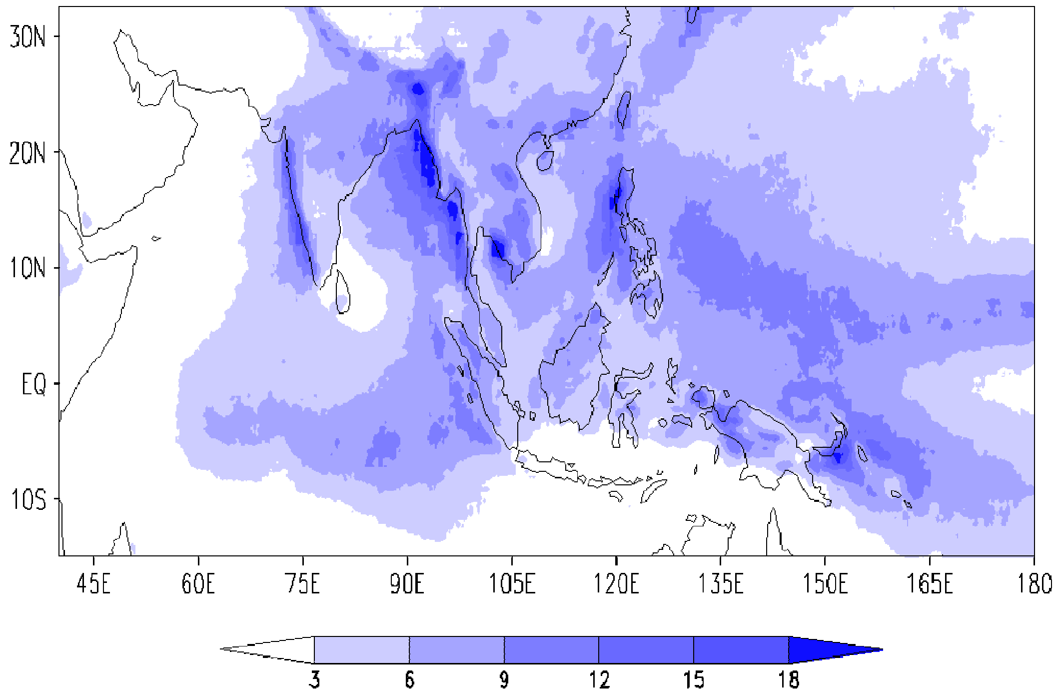
Centre for Climate Change Research (CCCR)
http://cccr.tropmet.res.in

Indian Institute of Tropical Meteorology (IITM), Pune
www.tropmet.res.in



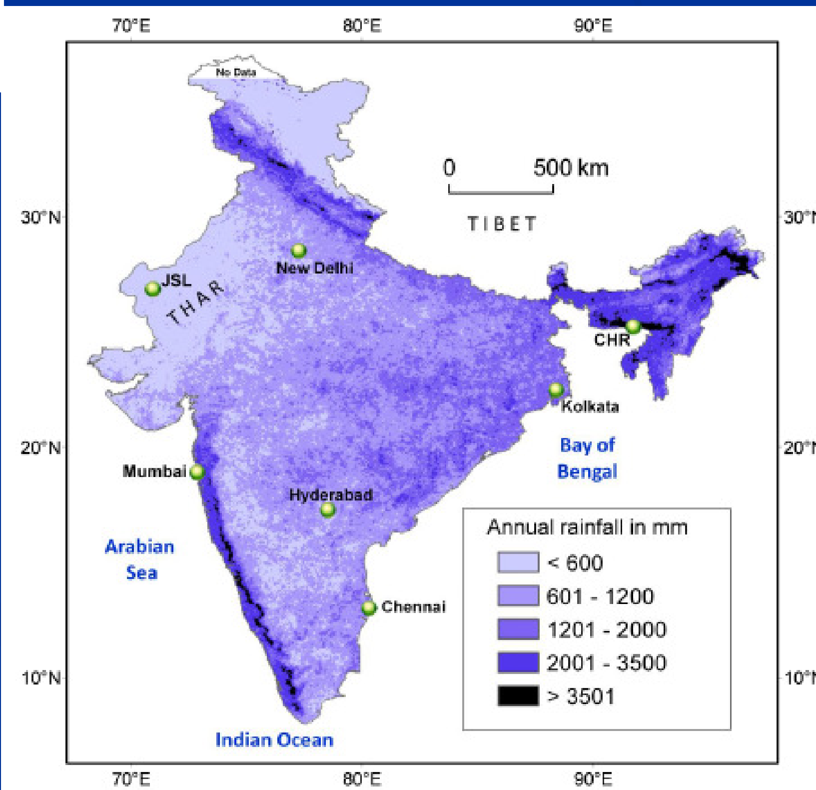
- Development of a Global Earth System Model to address the Attribution & Projection of global and regional climate change – (Long-term)
- To develop regional climate change scenarios over South Asia using High-resolution Regional Climate Models ; quantify uncertainties for providing reliable inputs for impact assessments. Contribute to IPCC AR5 – (Short-term)

- To understand Past Changes in Monsoon Climate using Multiple Proxy Records. Reconstruction of monsoon indices back to a few thousand years
- Co-ordinate the MoES flux network program to measure GHG flux variations across diverse ecosystems and vegetation types over India
- To promote Outreach and Training for Capacity Building in Climate Change Research and Dissemination of Information



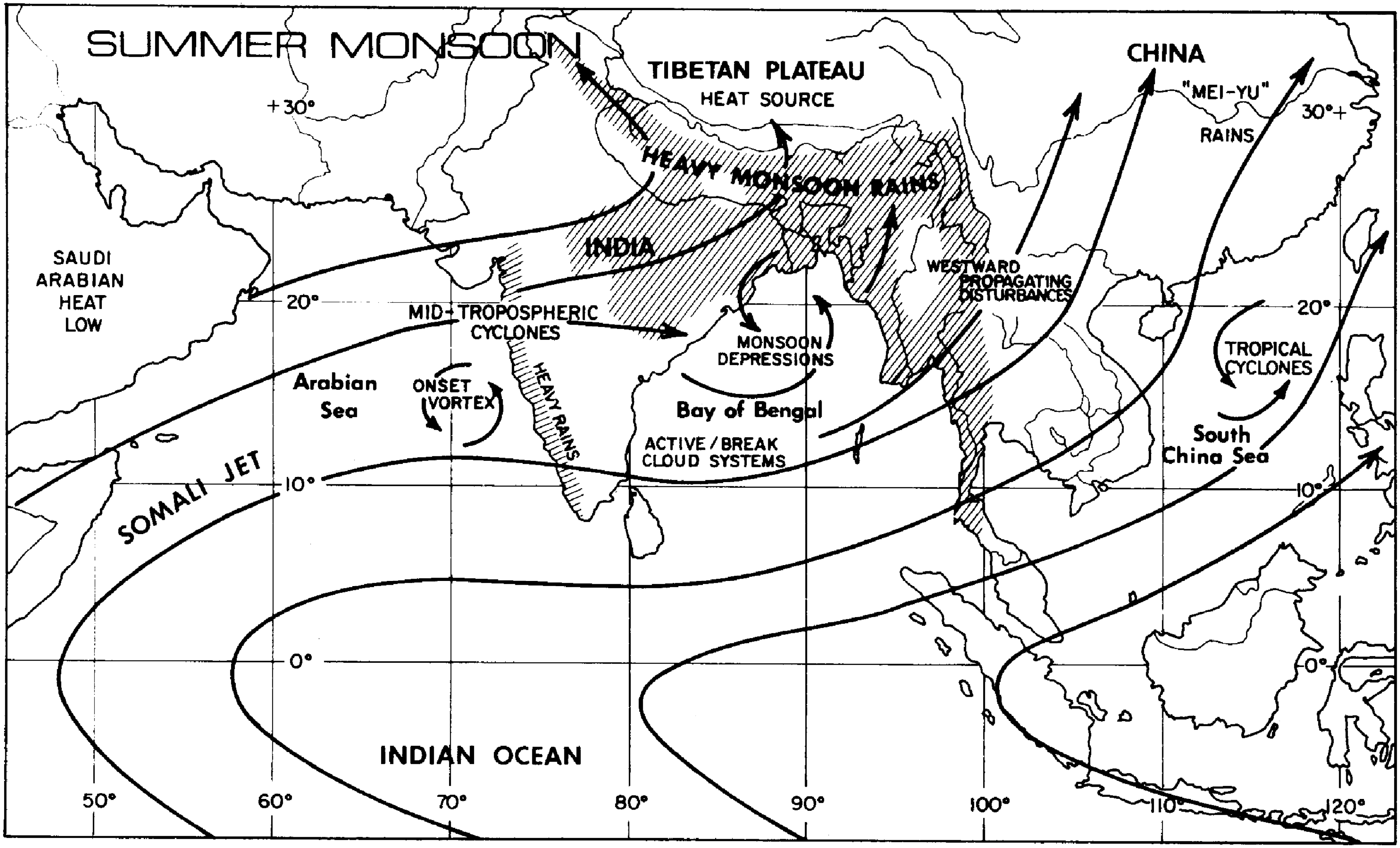
Spatial distribution of mean summer monsoon (JJAS) rainfall rate in mm day^{-1} based on TRMM 3B42

Annual rainfall over India in mm



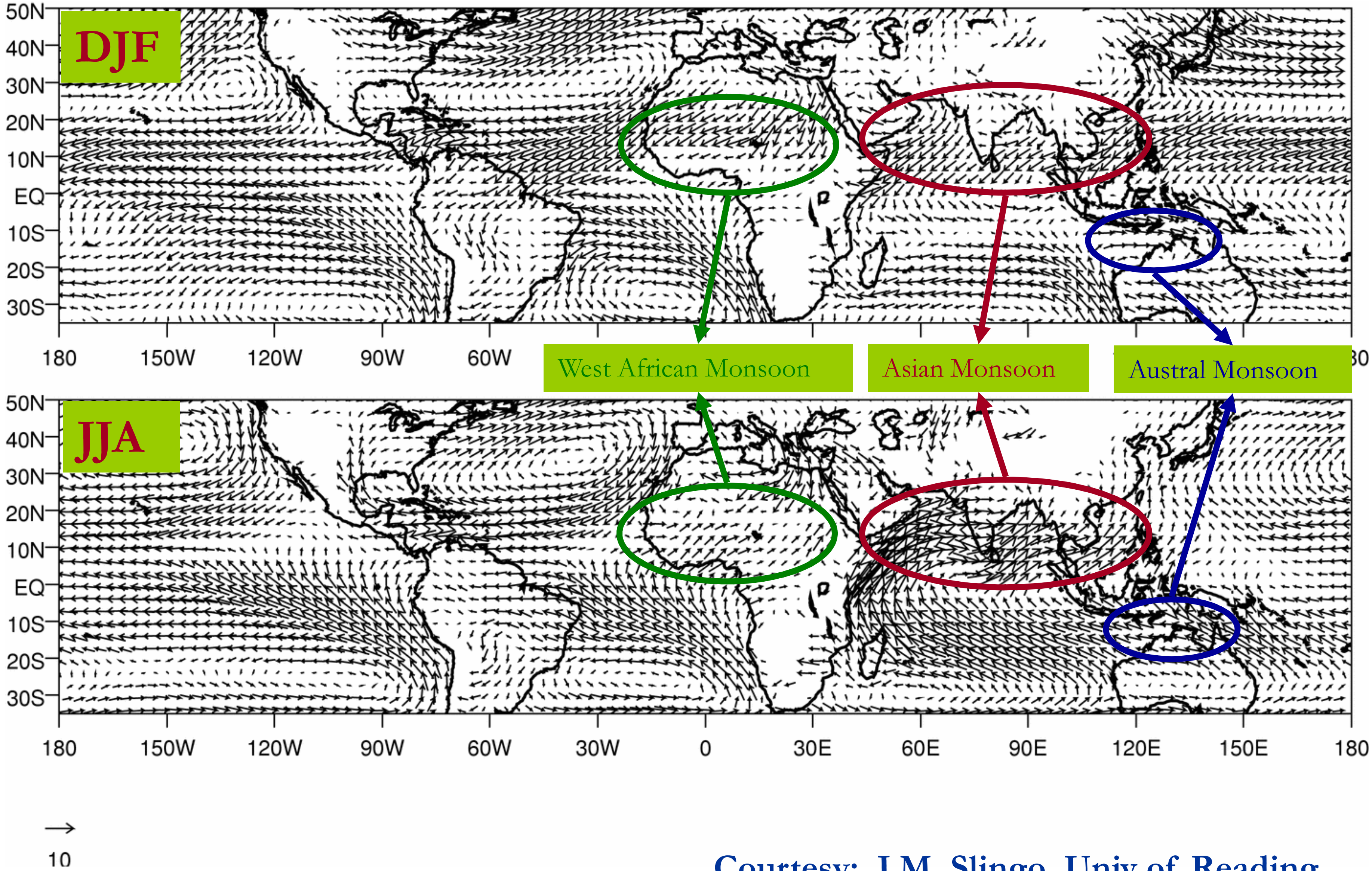
Rainfall from TRMM satellite. Data source: http://www.geog.ucsb.edu/~bodo/TRMM/)

A.K. Singhvi and R. Krishnan (2014): Chapter in book 'Landscapes and Landforms of India' – Springer Verlag



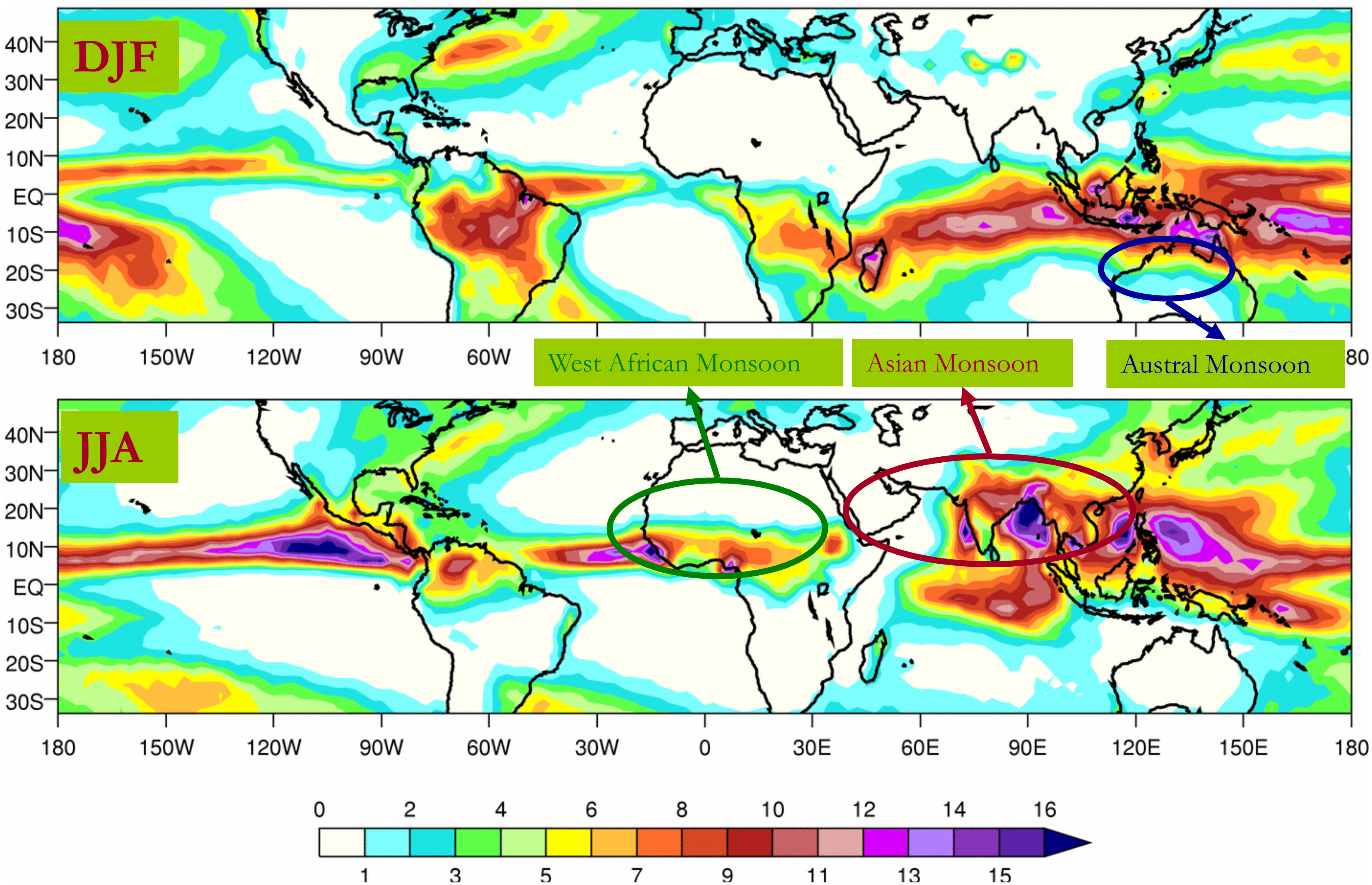
Primary synoptic and smaller-scale circulation features that affect cloudiness and precipitation in Summer monsoon region. Locations of June to September rainfall exceeding 100 cm over the land West of 100^{o}E associated with the southwest monsoon are indicated (Rao, 1981). Those over water areas and east of 100^{o}E are omitted.

Winds at 925hPa



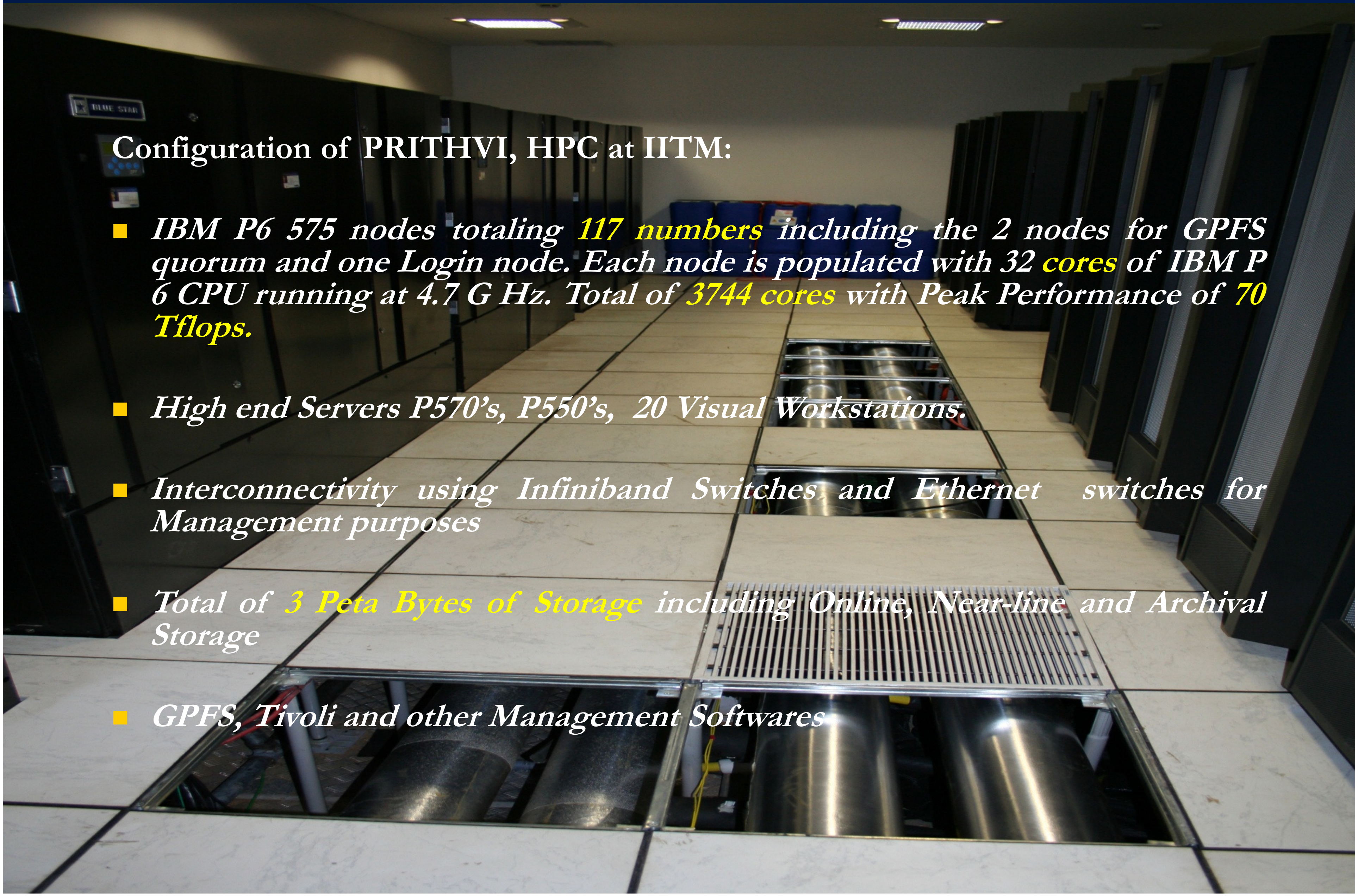
Courtesy: J.M. Slingo, Univ of Reading

Rainfall (mm/day)



Courtesy: J.M. Slingo, Univ of Reading

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*

Inauguration of New High Performance Computing System (790 Teraflop)

1st Largest Computing Capability in Country

New augmented HPC, named as "AADITYA" at IITM was inaugurated by the hands of Dr. Shailesh Nayak, Hon'ble Secretary of the Ministry of Earth Science (MoES), Chairman, Earth System Science Organization (ESSO) on 28 February 2014.

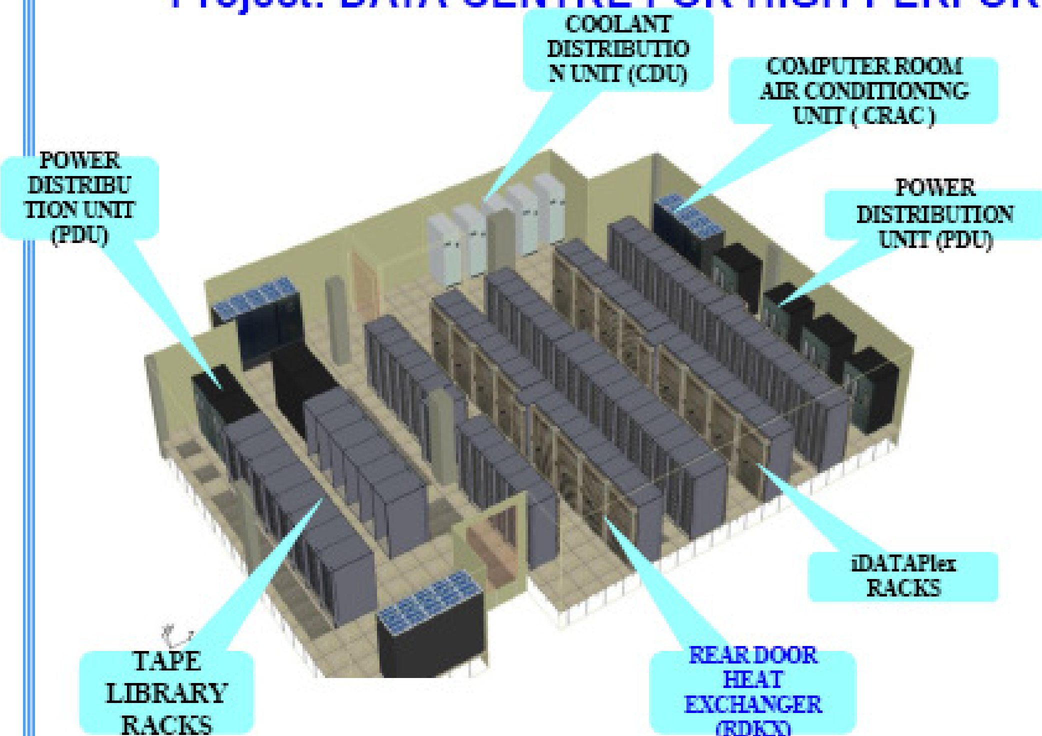
The Aaditya HPC is a Highly Parallel Supercomputing System built on IBM System X technology. The compute performance is more than 790 Tera Flops with Intel Sandy bridge Processors. There are 2384 compute Nodes with each node have 2 number of 8 core Processors (Intel Xeon E5-2670 2.6GHz cache 20MB) and the Memory is 4 GB DDR3 per core and 64 GB per node. The total RAM/Memory of the cluster is more than 150 Tera bytes. The System is having a 6 Peta bytes disk based storage solution built on IBM GSS technology with read & write performance of about 100 GB/sec.

Secretary, MoES
Powering ON the India's
Fastest Super Computer
AADITYA, 28th Feb. 2014

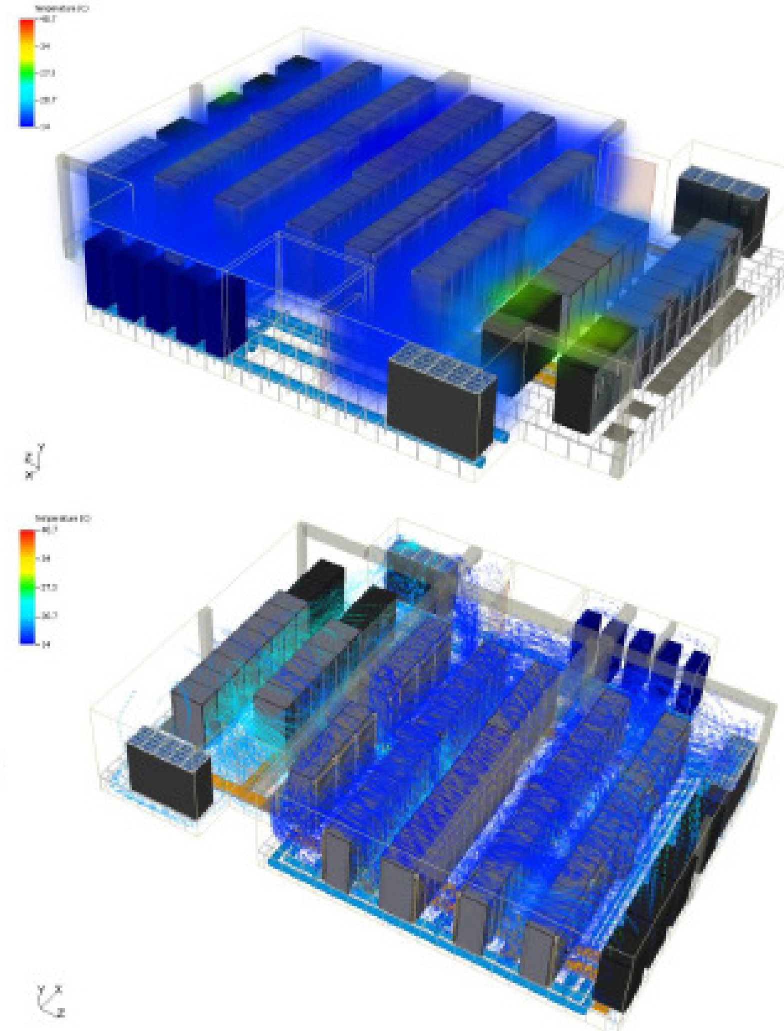
HPC Data Center
AADITYA

INDIAN INSTITUTE OF TROPICAL METEOROLOGY (IITM)

Project: DATA CENTRE FOR HIGH PERFORMANCE COMPUTING (HPC), PUNE



Data Centre – First Floor



Computational Fluid Dynamic (CFD) Analys

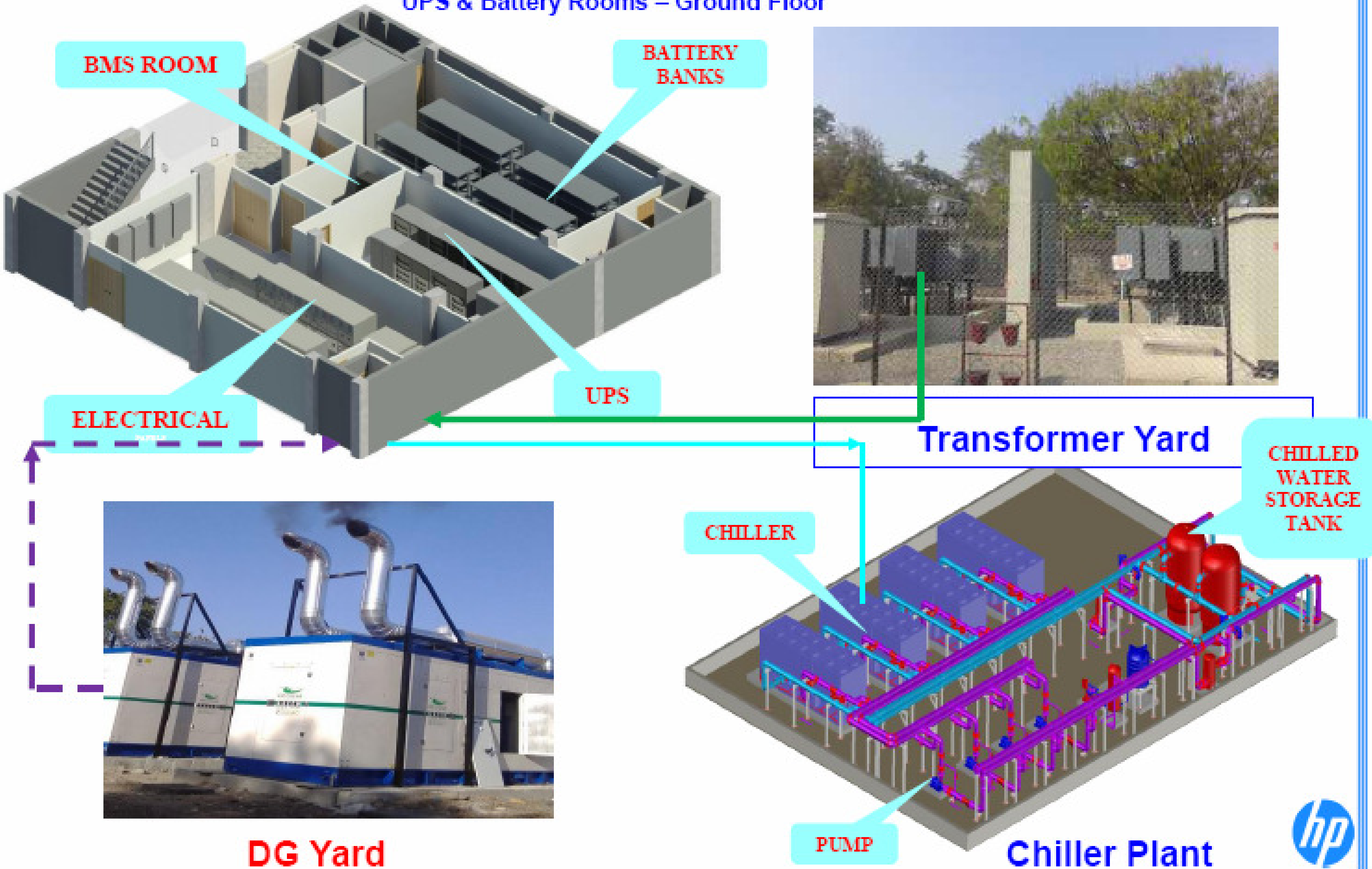
KEY HIGHLIGHTS

- 760 TF HPC Data Center with 1 PB storage
- iDATAplex racks with rear door heat exchanger cooling
- Storage, IB and Tape Library
- 2 X 2.5 MVA Transformers N + N
- 6 X 625 KVA dedicated diesel generators
- 4 X 175 TR Air cooled chillers N + N
- 6 X 500 KVA UPS with 15 minutes battery backup N + N

INDIAN INSTITUTE OF TROPICAL METEOROLOGY (IITM)

Project: DATA CENTRE FOR HIGH PERFORMANCE COMPUTING (HPC), PUNE

UPS & Battery Rooms – Ground Floor



IPCC AR5:

- There is high confidence that large-scale patterns of surface temperature are well simulated by the CMIP5 models

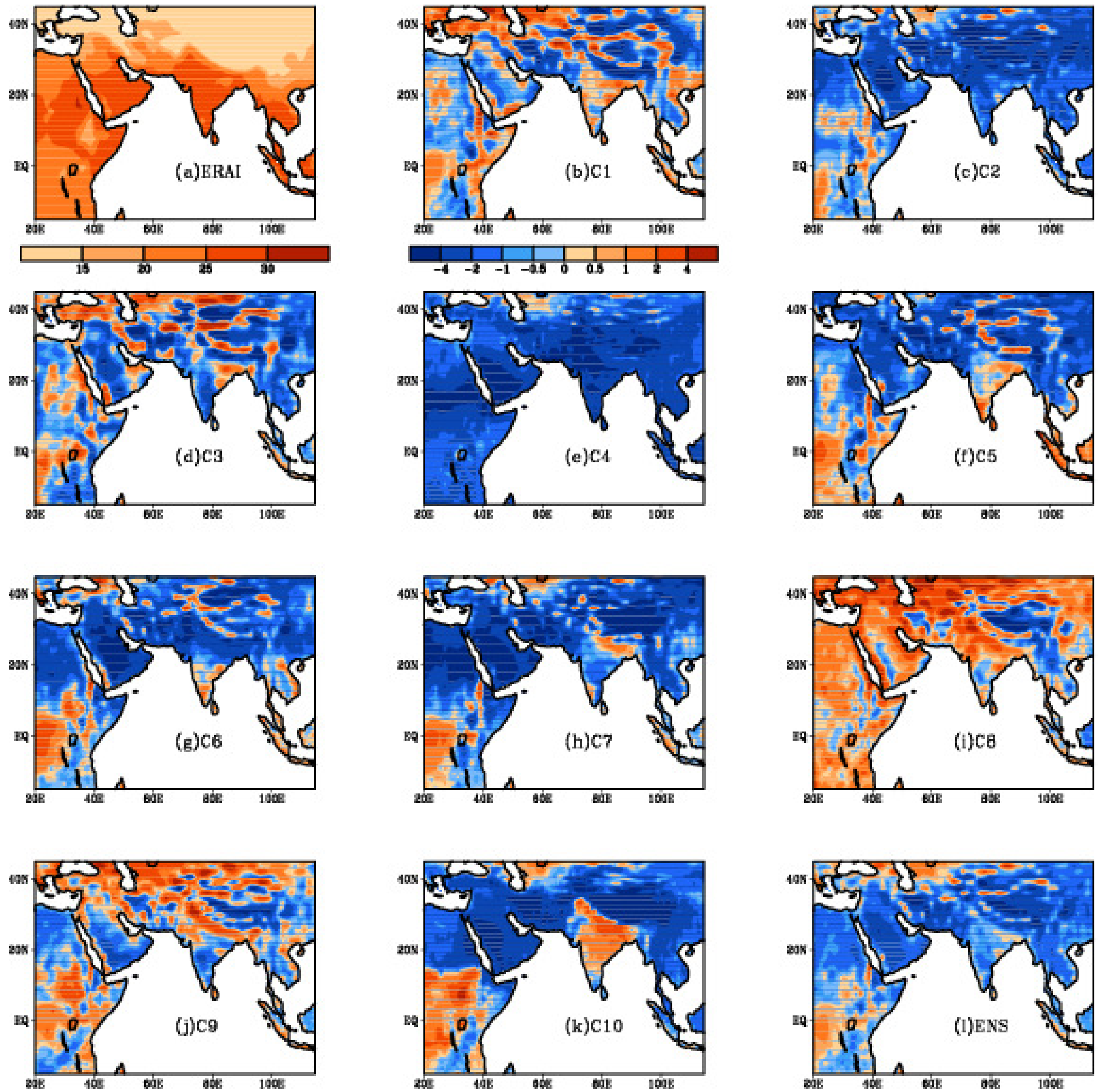
- **In certain regions this agreement with observations is limited, particularly at elevations over the Himalayas**

- **The broad-scale features of precipitation as simulated by the CMIP5 models** are in modest agreement with observations, but **there are systematic errors in the Tropics**

WG1 Ch.9

- **Efforts towards robust national climate change information**

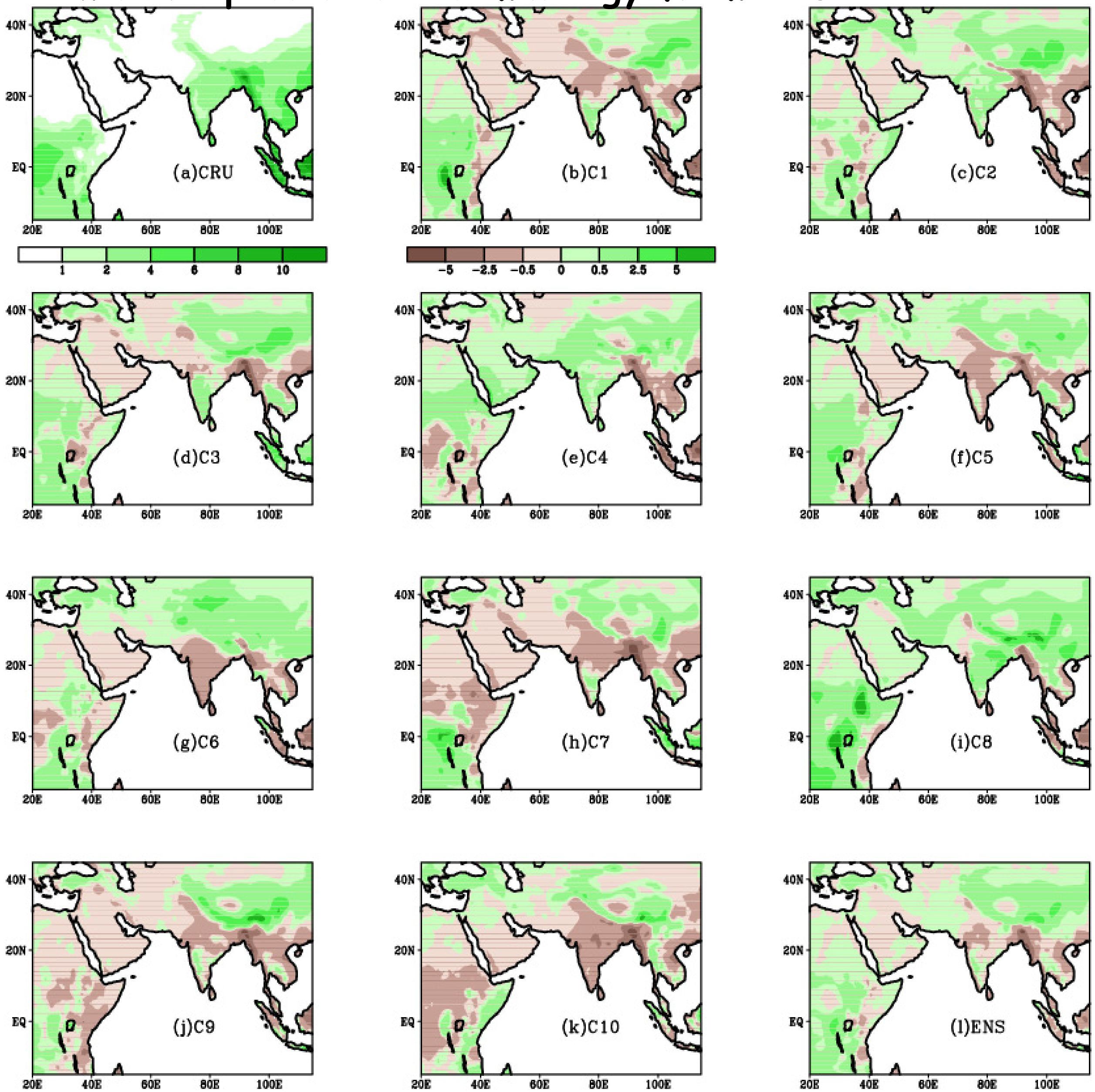
Annual Mean surface (2m) Air Temperature (°C) for the period 1990-2004
CMIP5 Historical Experiments Multi-Model Bias
with respect to the climatology from ERA-Interim



Subset of CMIP5 AOGCMs.

Model Label	CMIP5 Model Name
C1	CanEsm2
C2	GFDL-CM3
C3	**GFDL-ESM2M**
C4	**EC-EARTH**
C5	HadCM3
C6	HadGEM2-ES
C7	**IPSL-CM5A-LR**
C8	MIROC5
C9	**MPI-ESM-LR**
C10	MRI-CGCM3

Annual Mean Precipitation (mm d^{-1}) for the period 1990-2004
CMIP5 Historical Experiments Multi-Model Bias
with respect to the climatology from CRU



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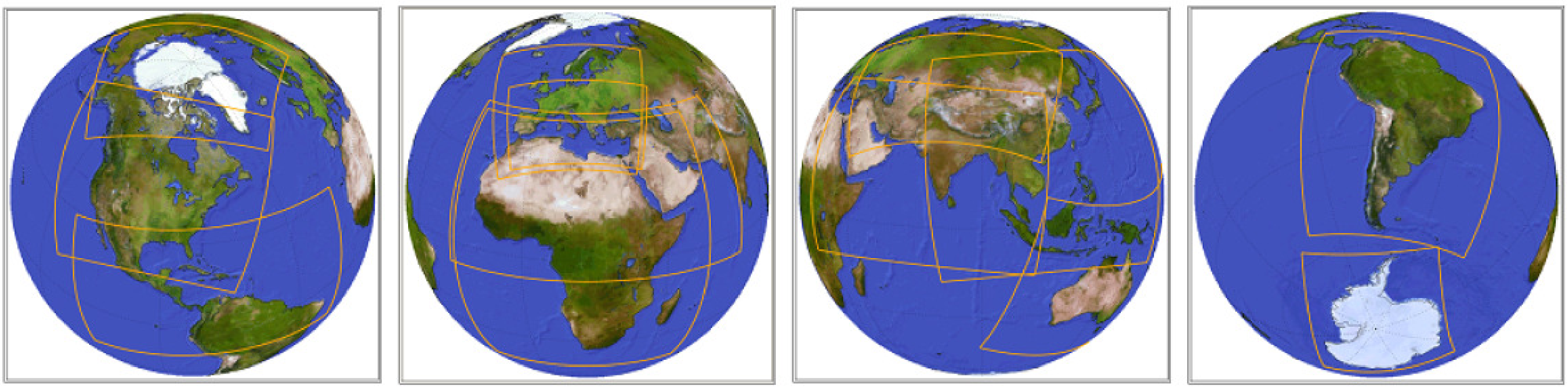
C9	**MPI-ESM-LR**
C10	MRI-CGCM3

WCRP
World Climate Research Programme
CORDEX
Coordinated Regional Climate Downscaling Experiment

CORDEX is providing global coordination of Regional Climate Downscaling for improved regional climate change adaptation and impact assessment.

CORDEX is a project of the WCRP Group on Regional Climate (WGRC)

The CORDEX community



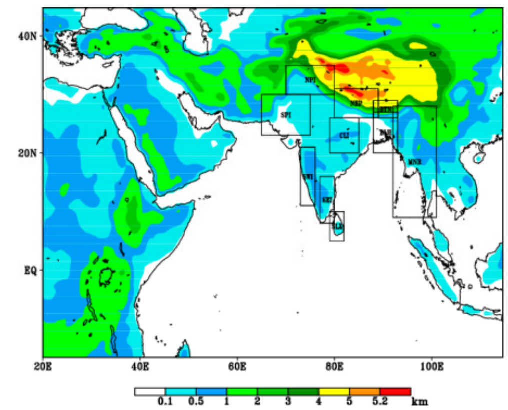
The CORDEX community has grown to now include 13 domains;

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

http://wcrp-cordex.ipsl.jussieu.fr/images/pdf/newsletters/newsletter1_january2013.pdf

CORDEX South Asia Co-ordination

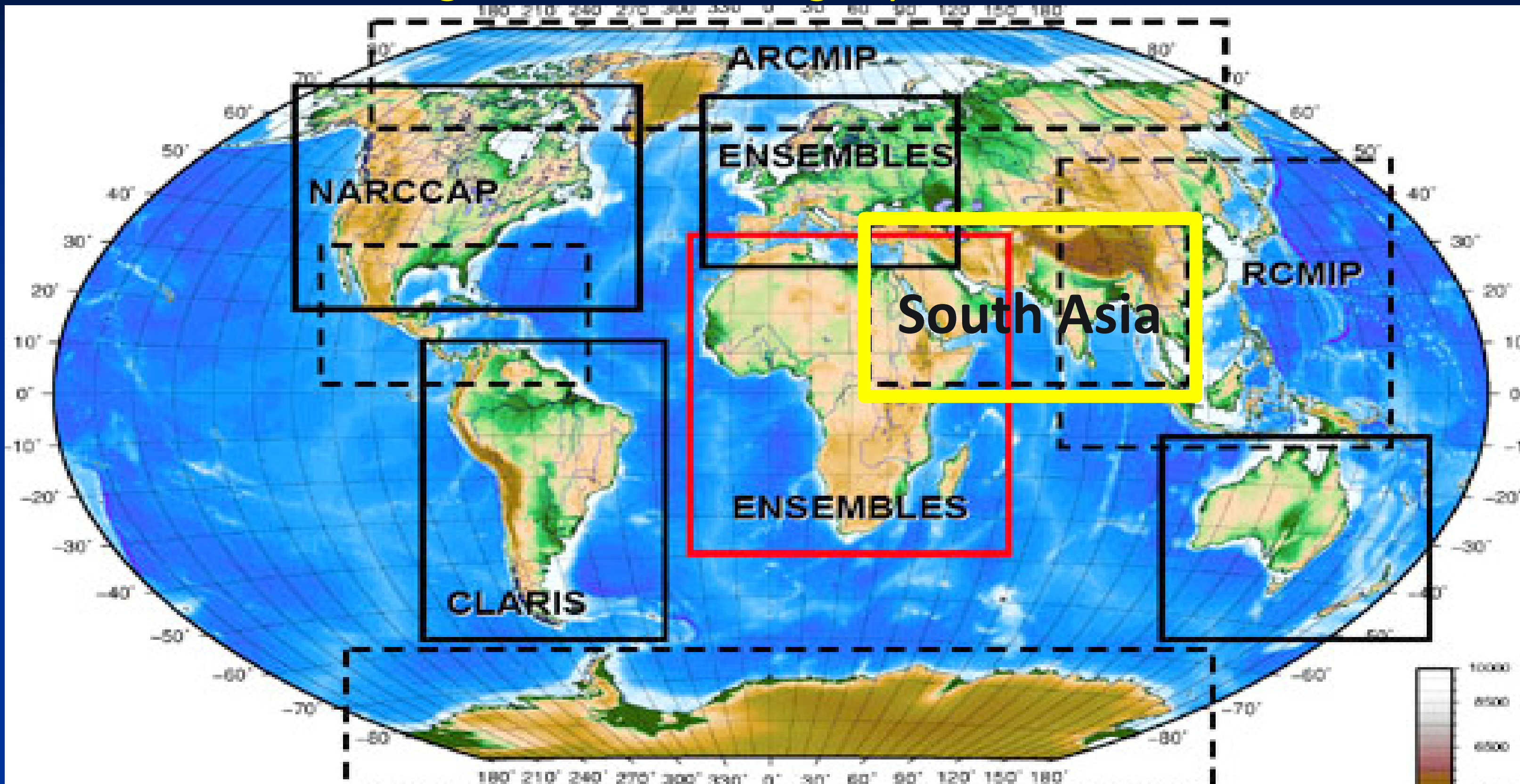
- **Development of multi-model ensemble projections of high resolution (50km) regional climate change scenarios for South Asia**
    - Generation of regional climate projections at CCCR-IITM
        - LMDZ variable grid global climate model
        - RegCM4 regional climate model
    - Co-ordination with partner institutions for multi-model ensemble projections – SMHI, IAES, CSC, CSIRO, ICTP…



- **Development of an Earth System Grid (ESG) node at CCCR-IITM for CORDEX South Asia**
    - Archival, Management, Retrieval, Dissemination of CORDEX South Asia data
- **Evaluation of regional climate projections over South Asia**
    - to provide relevant and reliable regional climate change information for effective harnessing of science-based climate information by Vulnerability, Impact & Adaptation (VIA) community
- **Development of regional capacity for assessment of regional climate change**

WCRP CORDEX South Asia – led by CCCR, IITM

Co-ordinated Regional Downscaling Experiment – CORDEX South Asia



- *Better understand regional climate processes and improve climate models*
- *Develop 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*
- *Develop regional capacity for assessment of regional climate change with higher level of confidence of model-based projections and judgment of regional experts*
- *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*

CORDEX: Model Experiments

- Evaluation / 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)
- PRECIS 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
- REMO model (~ 50 km) Max Planck Inst, Hamburg
- ***CCAM model (~ 50 km) CSIRO, Australia***

Centre for Climate Change Research (CCCR)

http://cccr.tropmet.res.in/cordex/files/downloads.jsp

CORDEX-South Asia Multi Models Output

Historical (1950 – 2005) | Evaluation Run (1989 – 2008) | RCP 4.5

Variable name (Monthly and Daily)	SMHI-RCA4	IITM-RegCM4-GFDL	IITM-RegCM4-LMDZ	COSMO-CLM	IITM-LMDZ
Institute's / Data Providers	Rossby Centre, SMHI	CCCR-IITM, Pune	CCCR-IITM, Pune	Goethe Inst - Univ. of Frankfurt	CCCR-IITM, Pune
Rainfall (pr)	✓	✓	✓	✓	✓
Surface Air Temperature (tas)	✓	✓	✓	✓	✓
Surface Air Temp. Maximum (tasmax)	✓	✓	✓	--	✓
Surface Air Temp. Minimum (tasmin)	✓	✓	✓	--	✓
Sea-level Pressure (psl)	✓	✓	✓	--	✓
Surface Specific Humidity (huss)	✓	✓	✓	--	✓
Surface Zonal Wind (uas)	✓	✓	✓	--	✓
Surface Meridional Wind (vas)	✓	✓	✓	--	✓
Downward Shortwave Radiation (rsds)	--	✓	✓	--	--

To download the data please click here

Regridding script example, click here to download | script

Table: List of CORDEX South Asia Regional Climate Model (RCM) Experiments

Experiment Name	RCM Description	Driving GCM	Contributing Institute
CCLM4(MPI)	COnsortium for Small-scale MOdelling (COSMO) model in CLimate Mode version 4.8 (CCLM; Dobler and Ahrens, 2008)	Max Planck Institute for Meteorology, Germany, Earth System Model (MPI-ESM-LR; Giorgetta et al 2013)	Institute for Atmospheric and Environmental Sciences (IAES), Goethe University, Frankfurt am Main (GUF), Germany
RCA4(ICHEC)	Rossby Centre regional atmospheric model version 4 (RCA4; Samuelsson et al., 2011)	Irish Centre for High-End Computing (ICHEC), European Consortium ESM (EC-EARTH; Hazeleger et al. 2012)	Rosssy Centre, Swedish Meteorological and Hydrological Institute (SMHI), Sweden
CCAM(ACCESS)	Commonwealth Scientific and Industrial Research Organisation (CSIRO), Conformal-Cubic Atmospheric Model (CCAM; McGregor and Dix, 2001)	ACCESS1.0	CSIRO Marine and Atmospheric Research, Melbourne, Australia
CCAM(CNRM)		CNRM-CM5	
CCAM(CCSM)		CCSM4	
CCAM(GFDL)		GFDL-CM3	
CCAM(MPI)		MPI-ESM-LR	
CCAM(BCCR)		NorESM-M	
LMDZ4(IPSL)	Institut Pierre-Simon Laplace (IPSL) Laboratoire de Me´te´orologie Dynamique Zoomed version 4 (LMDZ4) atmospheric general circulation model (Sabin et al., 2013)	IPSL Coupled Model version 5 (IPSL-CM5-LR; Dufresne et al. 2013)	Centre for Climate Change Research (CCCR), Indian Institute of Tropical Meteorology (IITM), India
RegCM4(LMDZ)	The Abdus Salam International Centre for Theoretical Physics (ICTP) Regional Climatic Model version 4 (RegCM4; Giorgi et al., 2012)	IPSL LMDZ4	CCCR, IITM
RegCM4(GFDL)	ICTP RegCM4	Geophysical Fluid Dynamics Laboratory, USA, Earth System Model (GFDL-ESM2M-LR; Dunne et al. 2012)	CCCR, IITM

- **CORDEX South Asia data (50km) is available on the CCCR-IITM Climate Data Portal (non-ESG):**

http://cccr.tropmet.res.in/cordex/files/downloads.jsp

CORDEX-South Asia Multi Models Output

Historical (1950 – 2005) | Evaluation Run (1989 – 2008) | RCP 4.5 | RCP 8.5

Experiment Name	Rain fall (pr)	Surface Air Temp (tas)	Surface Air Temp. Maximum (tasmax)	Surface Air Temp. Minimum (tasmin)	Sea-level Pressure (psl)	Surface Specific Humidity (huss)	Surface Zonal Wind (uas)	Surface Meridonial Wind (vas)	Downward Shortwave Radiation (rsds)
RCA4 (ICHEC)	✓	✓	✓	✓	✓	✓	✓	✓	--
RegCM4 (GFDL)	✓	✓	✓	✓	✓	✓	✓	✓	✓
RegCM4 (LMDZ)	✓	✓	✓	✓	✓	✓	✓	✓	✓
CCLM4 (MPI)	✓	✓	--	--	✓	✓	--	--	--
LMDZ4 (IPSL)	✓	✓	✓	✓	✓	✓	✓	✓	--
CCAM (ACCESS)	✓	--	✓	✓	✓	--	--	--	--
CCAM (CNRM)	✓	--	✓	✓	✓	--	--	--	--
CCAM (CCSM)	✓	--	✓	✓	✓	--	--	--	--
CCAM (GFDL)	✓	--	✓	✓	✓	--	--	--	--
CCAM (MPI)	✓	--	✓	✓	✓	--	--	--	--
CCAM (BCCR)	✓	--	✓	✓	✓	--	--	--	--

Model experiment details please click here "List of Experiments" NEW!

NEW! Dear Users, IRODS Server is under maintenance for upgradation, Data is available on FTP Server ftp://cccr.tropmet.res.in, For more details please email us : cccroutreach@tropmet.res.in

Regridding script example, click here to download | script

Thanks to:

Sandip Ingle
J. Sanjay

Centre for Climate Change Research

Indian Institute of Tropical Meteorology (IITM)

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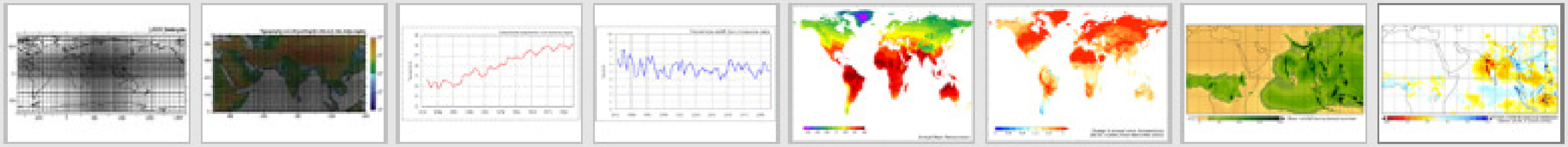
High Resolution Climate Change Simulation over South Asia

Click to enlarge



High-resolution simulations of 20th century climatic variations and future climate projections have been developed at CCCR-IITM, using a global climate model with telescopic zooming (~ 35 km in longitude x 35 km in latitude) over the South Asian region.

These high-resolution simulations, which were performed on the PRITHVI High Performance Computing (HPC) facility at IITM, offer new opportunities to better understand several key regional scientific issues concerning climate change over South Asia - e.g., Monsoons, precipitation extremes, heat waves, droughts and floods, changes in cyclonic weather systems, hydrological cycle etc.

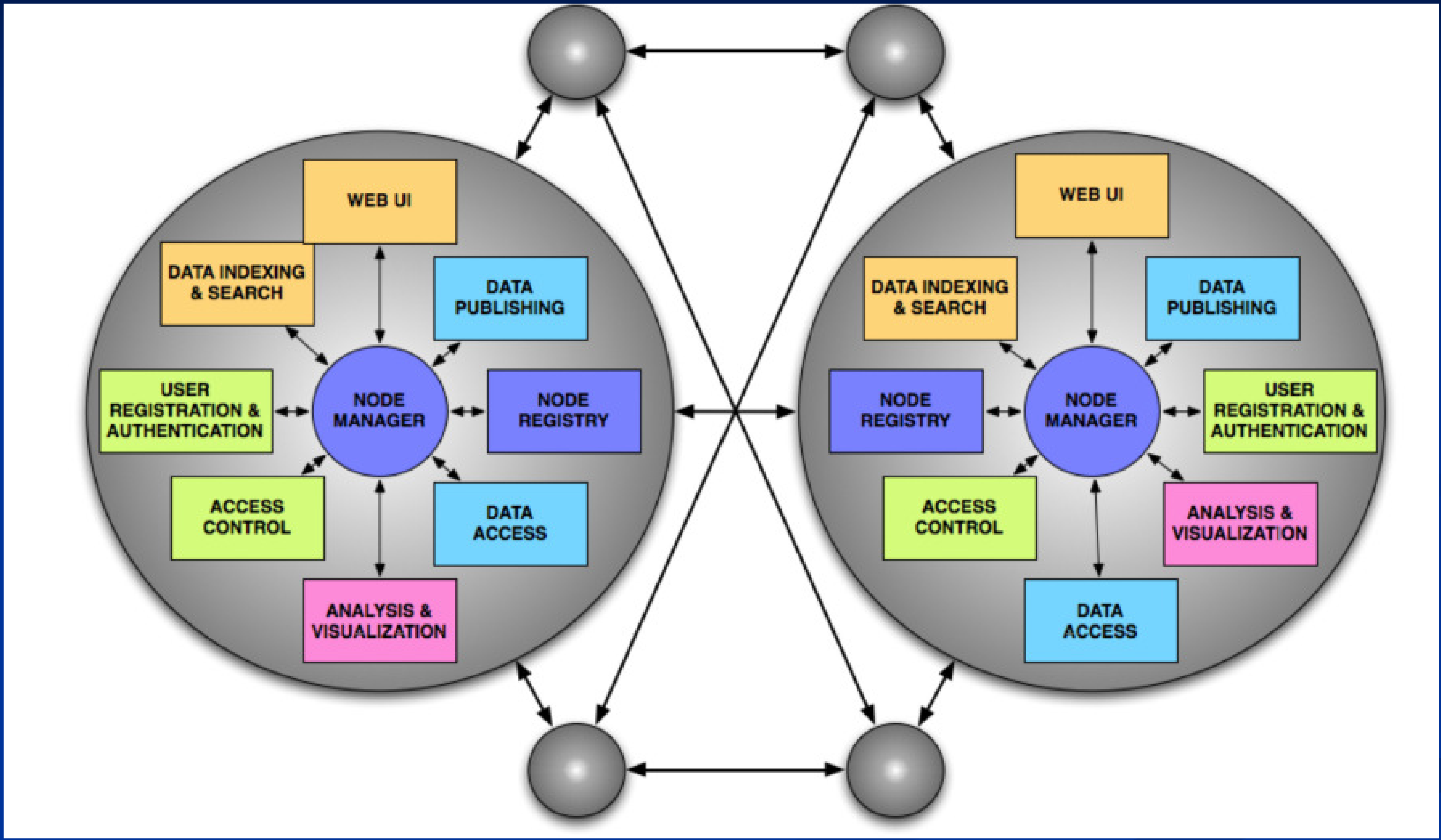
A variable resolution global modeling framework, based on the Laboratorie Dynamique Meteorologie (LMD, France) atmospheric general circulation model (GCM), has been employed for this purpose under a scientific collaboration between CCCR-IITM and LMD.

Monthly outputs of simulated rainfall and surface air temperature for the historical period (1951 - 2005) and 21st century RCP4.5 scenario projection for the period 2006-2095 are presently made available for downloads.

Monthly Data	Historical (1951-2005)	RCP 4.5 (2006-2095)
Rainfall (mm / day)	Download	Download
Surface Air Temperature (°C)	Download	Download

To Download Global Data Click here : ftp://esg-cccr.tropmet.res.in/Global-Data/

Earth System Grid Federation (ESGF) Node Design



http://esgf.llnl.gov/node-design.html

http://esg-cccr.tropmet.res.in/esgf-web-fe/

Thanks to:

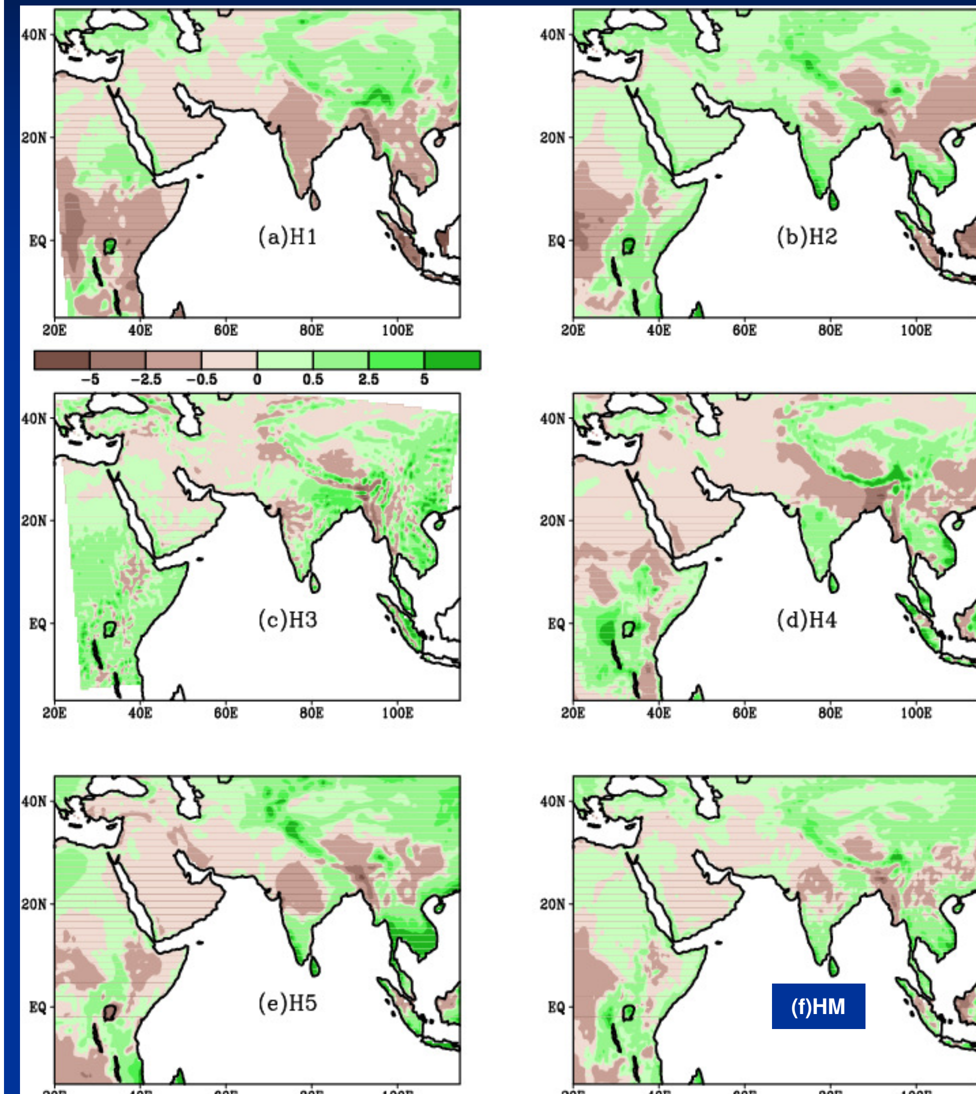
Sandip Ingle (CCCR, IITM)

Prashanth Dwarakanath (NSC, SMHI)

Nikulin Grigory (SMHI)

CORDEX South Asia RCM historical simulations driven with CMIP5 AOGCMs

The biases in simulated annual mean precipitation (mm d^{-1}) for 1990-2004 against the CRU data



Model Label	Model Name & Version	Driving CMIP5 AOGCM
H1	COSMO CLM	MPI-ESM-LR
H2	ICTP RegCMv4.1	GFDL-ESM2M
H3	SMHI RCAv4	EC-EARTH
H4	IPSL LMDZv4	IPSL-CM5A-LR
H5	ICTP RegCMv4.1	LMDZ4

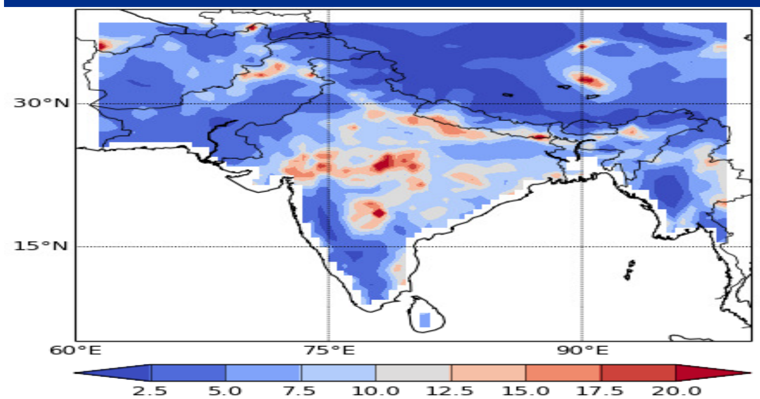
- The individual RCM bias vary from dry to wet over central India in the historical simulations: H1 (Fig. a) to H4 (Fig. d)
- The spatial distribution of the bias is similar for the two simulations H2 (Fig.b) & H5 (Fig.e) with the ICTP RegCM RCM driven with different global models (LMDZ4 & GFDL-ESM2M)

ICRC CORDEX 2013 (http://cordex2013.wcrp-climate.org/posters/P3_27_Sanjay.pdf)

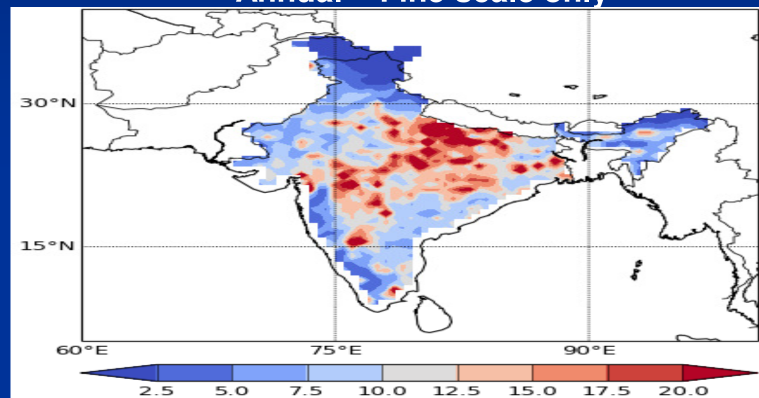
Uncertainties in Estimating Spatial and Interannual Variations in Precipitation Climatology in the India-Tibet Region from Multiple Gridded Datasets

- Signal-to-Noise ratio defined as the multi-data ensemble mean divided by the inter-data spread
  - **Satellite based (GPCP, TRMM) + Rain gauge based (CRU, UDEL, APHRODITE, GPCC and IMD)**

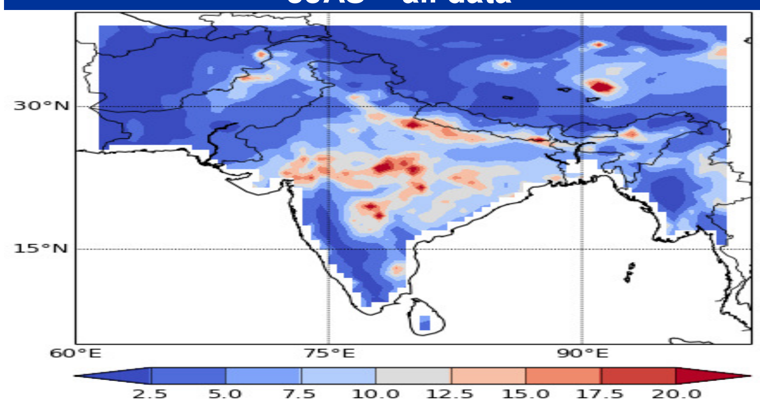
Annual – all data



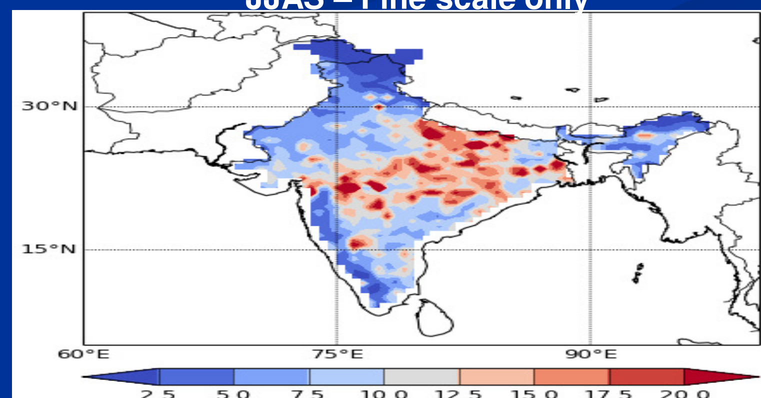
Annual – Fine scale only



JJAS – all data



JJAS – Fine scale only

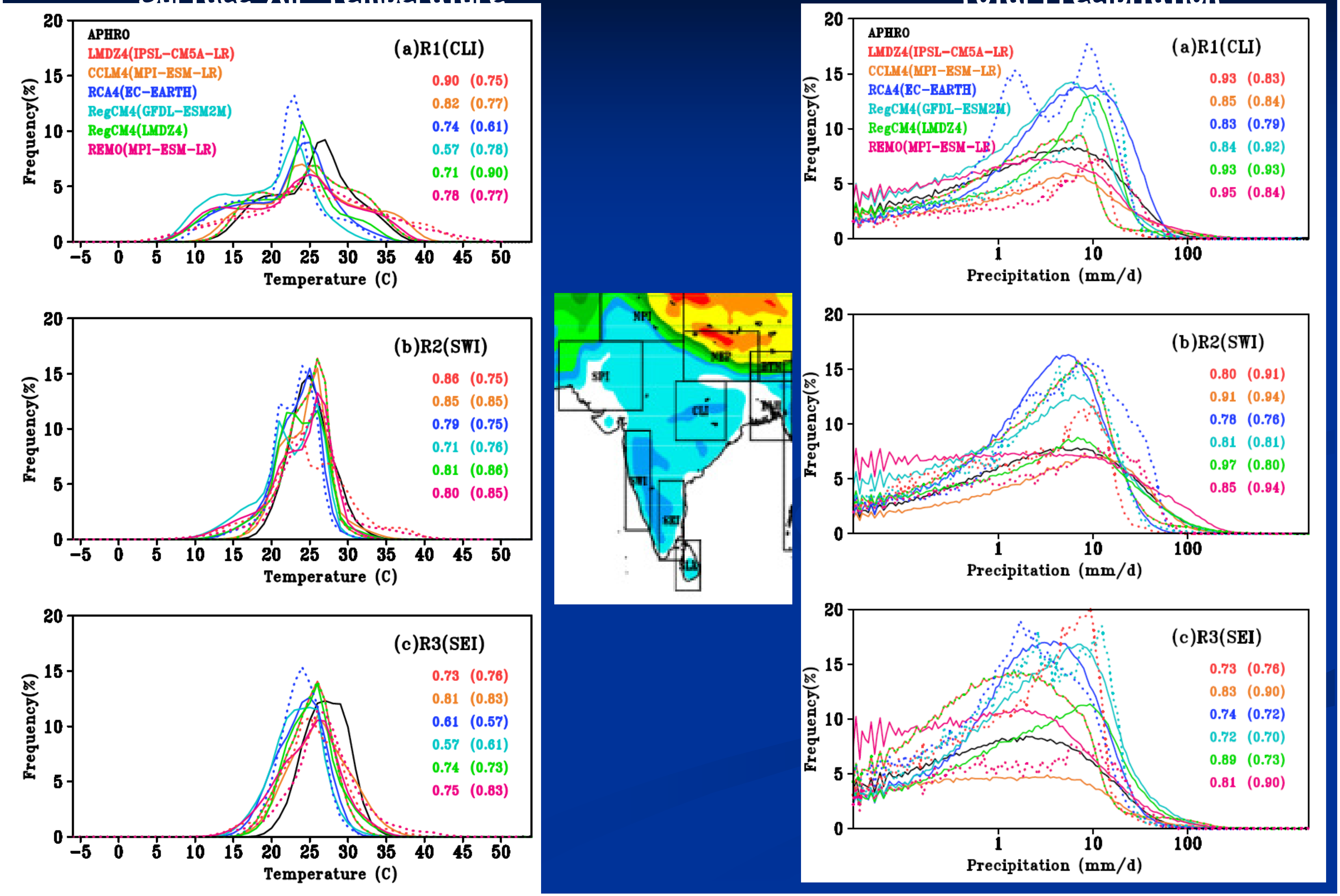


Ref: **J.Kim, J.Sanjay, C.Mattmann, M.Boustani, M.V.S.Ramarao, R.Krishnan, D.Waliser**. (Under Review)

CORDEX South Asia 1986-2005 Daily Probability Density Functions

Surface Air Temperature

Total Precipitation



Reliability of regional and global models to simulate precipitation extremes over India

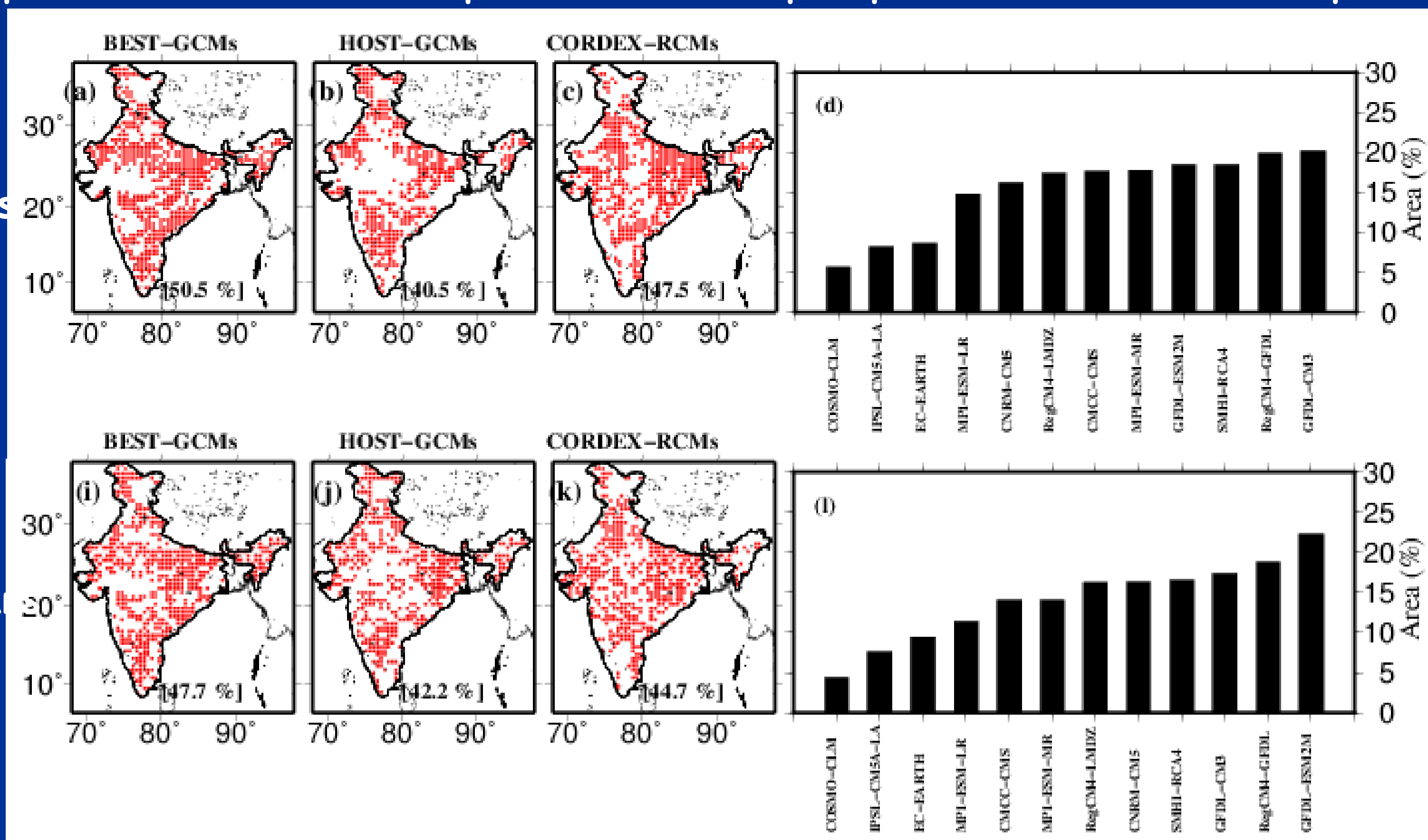
Bias in Annual Maximum Precipitation
w.r.t APHRODITE for 1961-90

Grid cells (in red) where models show appropriate bias (± 10%) for hydrologic design purpose for 1 day precipitation maxima at return period of:

Models & the area (%) where bias is appropriate for design purpose for 1 day precipitation maxima at return period of:.

25 years

25 years



100 years

100 years

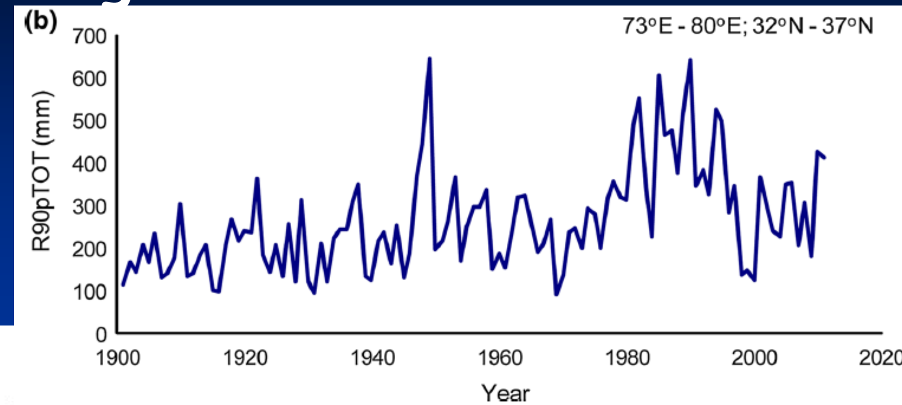
Ref: **Mishra V, D. Kumar, A.R. Ganguly, J. Sanjay, M. Mujumdar, R. Krishnan, R. D. Shah JGR 2014**

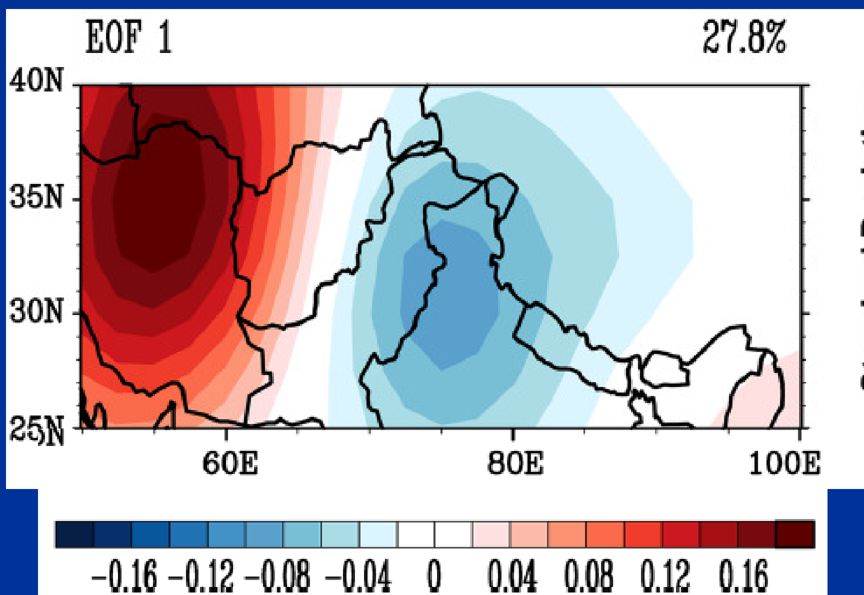
Important Scientific Results and Future Plans

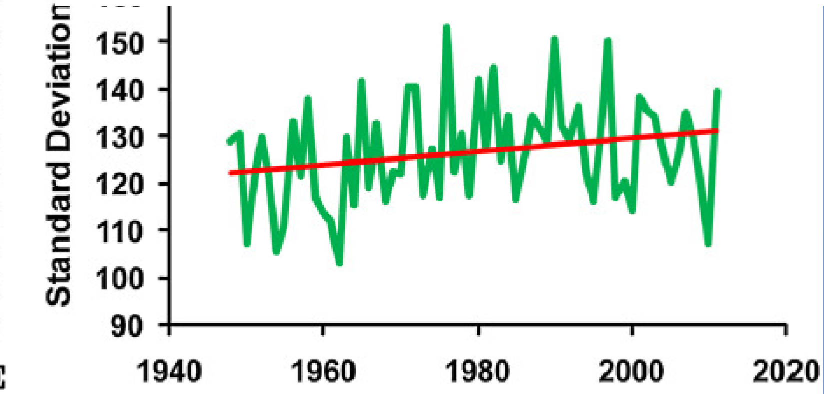
- **Development of Flagship Pilot Studies**
  - These case studies are needed to address particular issues such as:
    - Better identification and illustration of the added value of regional downscaling (both dynamical and statistical)
    - More process-based analysis, in particular by using high quality observations deriving from special programs
    - Use of multiple downscaling techniques in an ensemble approach
    - Better analysis of the effects of regional forcings, such as land-use and aerosols
    - Development of end-to-end (climate to end-users) projects.
      - Initiated State Action Plan on Climate Change (SAPCC)
        - A group of experts identified to work on all the states for a uniformly co-ordinated SAPCC
          - Dr. Mrs. Ashwini Kulkarni, IITM, Pune – CORDEX data and analysis
          - Prof. Vimal Mishra, IIT, Gandhinagar – Hydrology
          - Prof. Subimal Ghosh, IIT, Mumbai – Statistical downscaling
          - Prof. Subhakar Karmakar, IIT, Mumbai – Vulnerability Analysis

Changes in western disturbances over the Western Himalayas in a warming environment

- Latitude weighted EOF/PC analysis of daily high-frequency geopotential height anomalies at 500 hPa for the DJFMA season based on NCEP/NCAR reanalysis data for the period (1948–2011).

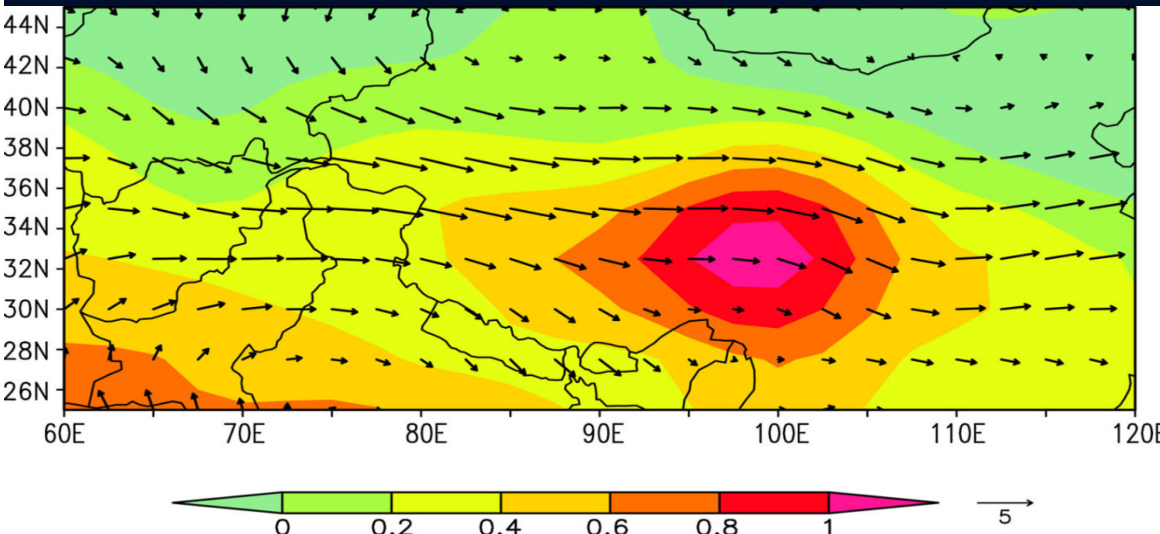






- The PC1 time series considered as a measure of western disturbances activity over the western Himalayas shows increasing trend significant at 5% level

Ref: **Madhura, R. K., R. Krishnan, J. V. Revadekar, M. Mujumdar and B. N. Goswami, Changes in western disturbances over the Western Himalayas in a warming environment.** ***Clim. Dyn.,2014***



Difference plots [(1980–2011) minus (1948–1979)] showing the change in DJFMA mean temperatures at 500 hPa (shaded) and vertical wind shear (vectors) computed as the vector difference of winds (200 hPa minus 700 hPa).

- The elevation dependency of the climate warming signal over the Tibetan Plateau and Himalayan region has introduced zonally-asymmetric changes in the DJFMA circulation through modifications in the middle and upper tropospheric temperatures over the Eurasian region.

- This pronounced mid-tropospheric warming has led to enhanced meridional temperature gradients and increased baroclinicity over Northern Indian sub-continent.

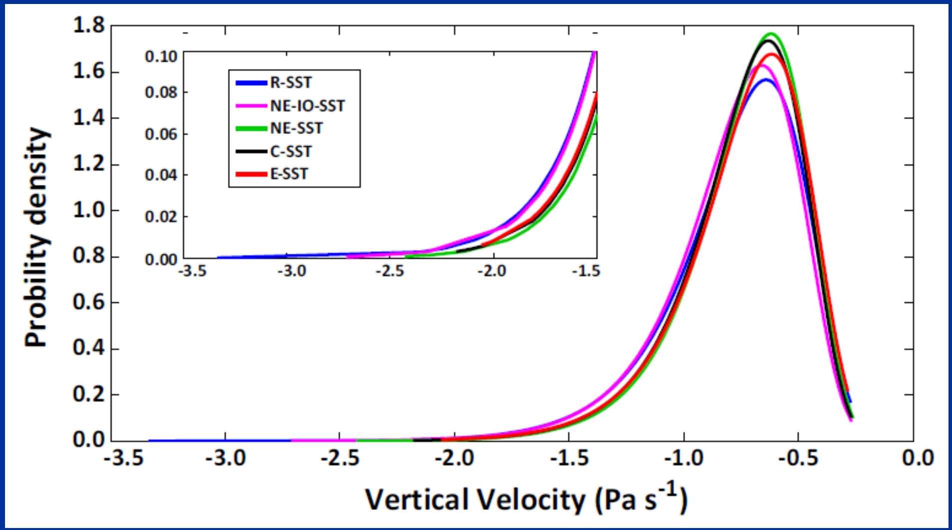
- This increase of the baroclininc instability of the westerly winds has in turn enhanced the variability of WD activity which has resulted in to higher propensity of heavy precipitation events over the WH.

Madhura et al. (2014)

Impacts of Indo-Pacific sea surface temperature anomalies on the summer monsoon circulation and heavy precipitation over northwest India-Pakistan region during 2010

- The simulations using a very high resolution AGCM and observed SSTs could realistically capture the large-scale features

- ENSO and ENSO-unrelated SST boundary conditions derived from the inverse linear modeling approach of Compo and Sardeshmukh (2010).



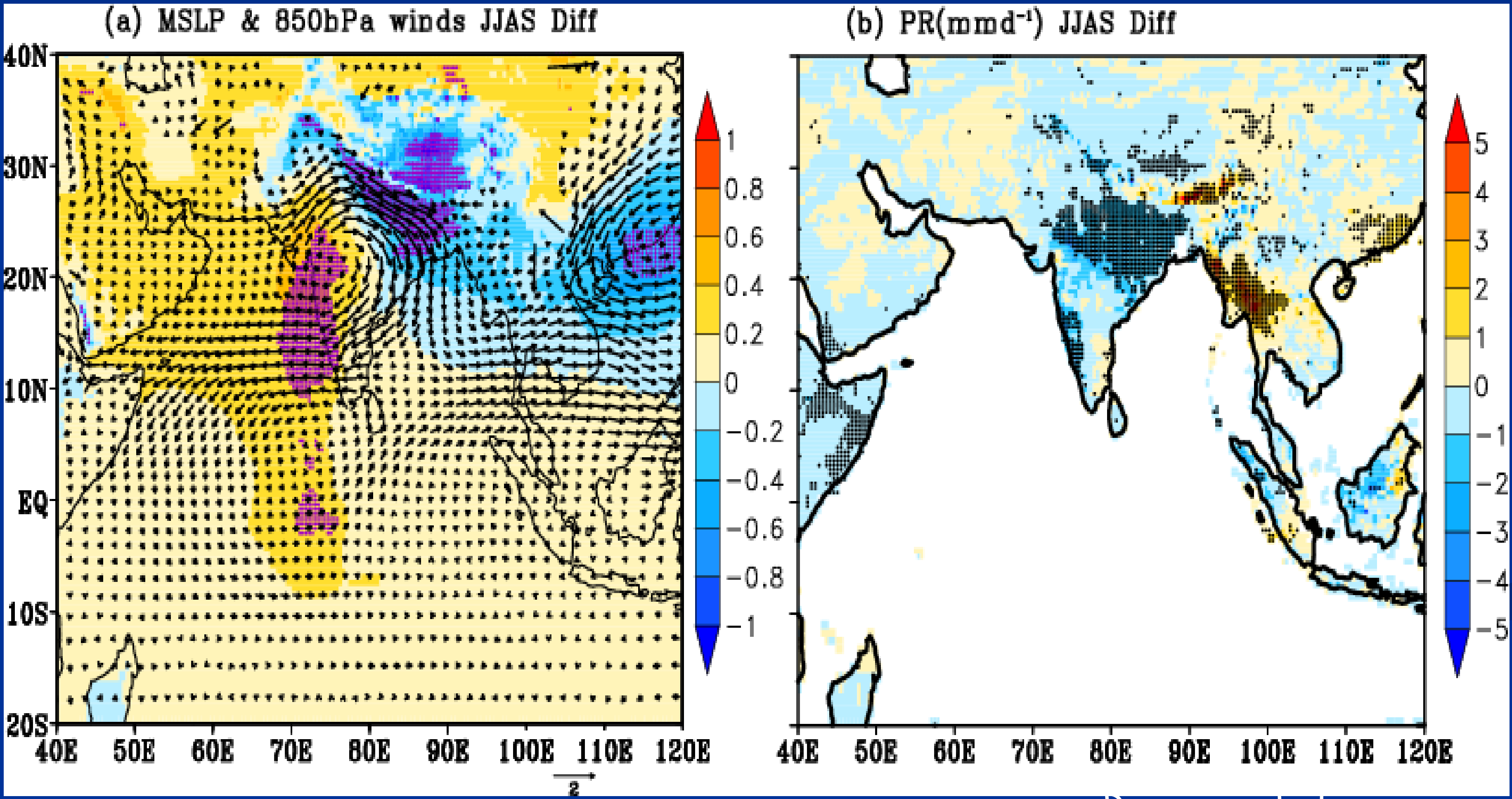
Fitted Weibull Probability Density Function (PDF) of minimum daily mid-tropospheric (500 hPa) vertical velocity (unit: Pa s^{-1}) time series extracted from the northwest Pakistan region (70°-74°E; 30°-36°N) during JJAS

- Tropical Indo-Pacific SST anomalies are an important factor in determining the heavy precipitation over northwest Pakistan and adjacent Indian region.

Ref: **Priya P., M.Mujumdar, T.P.Sabin, T.Pascal and R.Krishnan (JClim - Accepted)**

Recent Past Summer Monsoon Season Climate Response to Anthropogenic Forcings

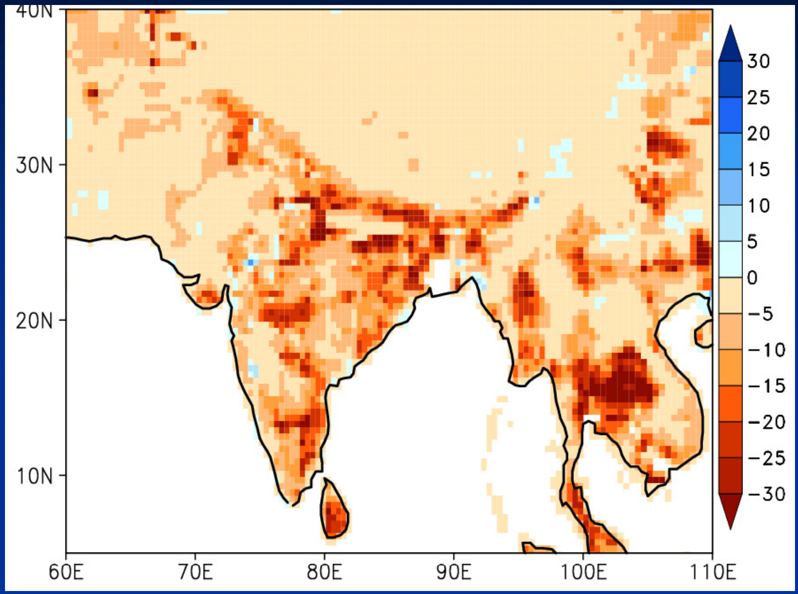
- LMDZ variable grid global climate model simulated long-term mean (1951-2005) difference between the response to combined natural and anthropogenic forcings (HIST), and natural forcings only (NAT)
-



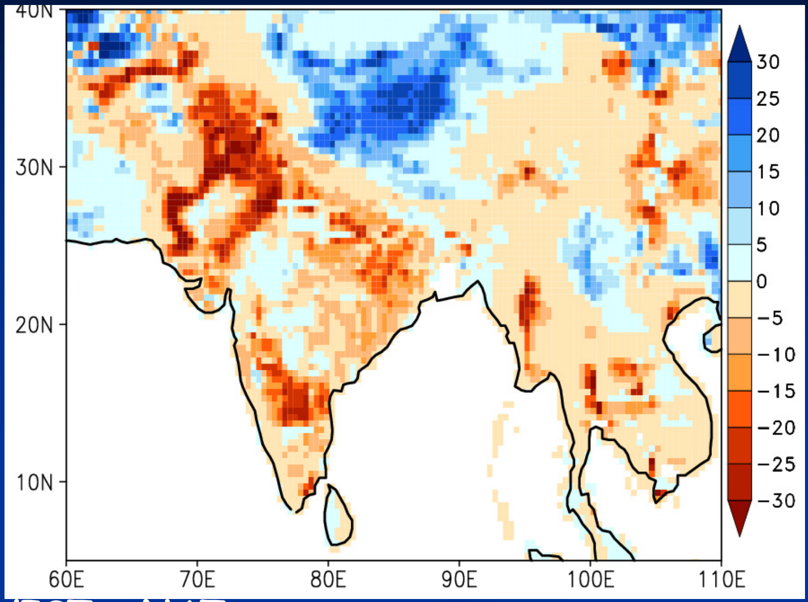
Ramarao et al.

LMDZ Land Cover Land Use Mean Change (1951-2005)

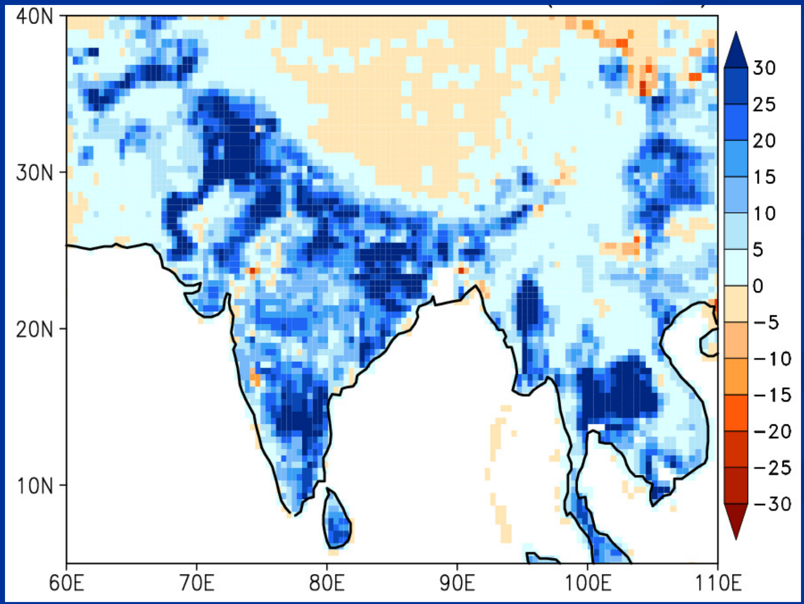
Tree Fraction (%) HIST – NAT



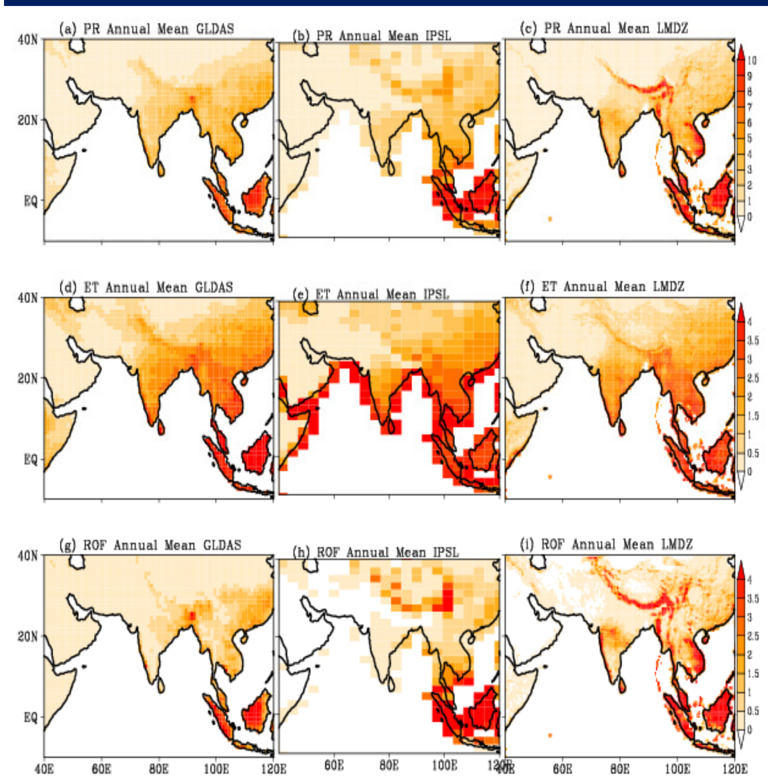
Grass Fraction (%) HIST – NAT



Crop Fraction (%) HIST – NAT



Surface Water Balance over India

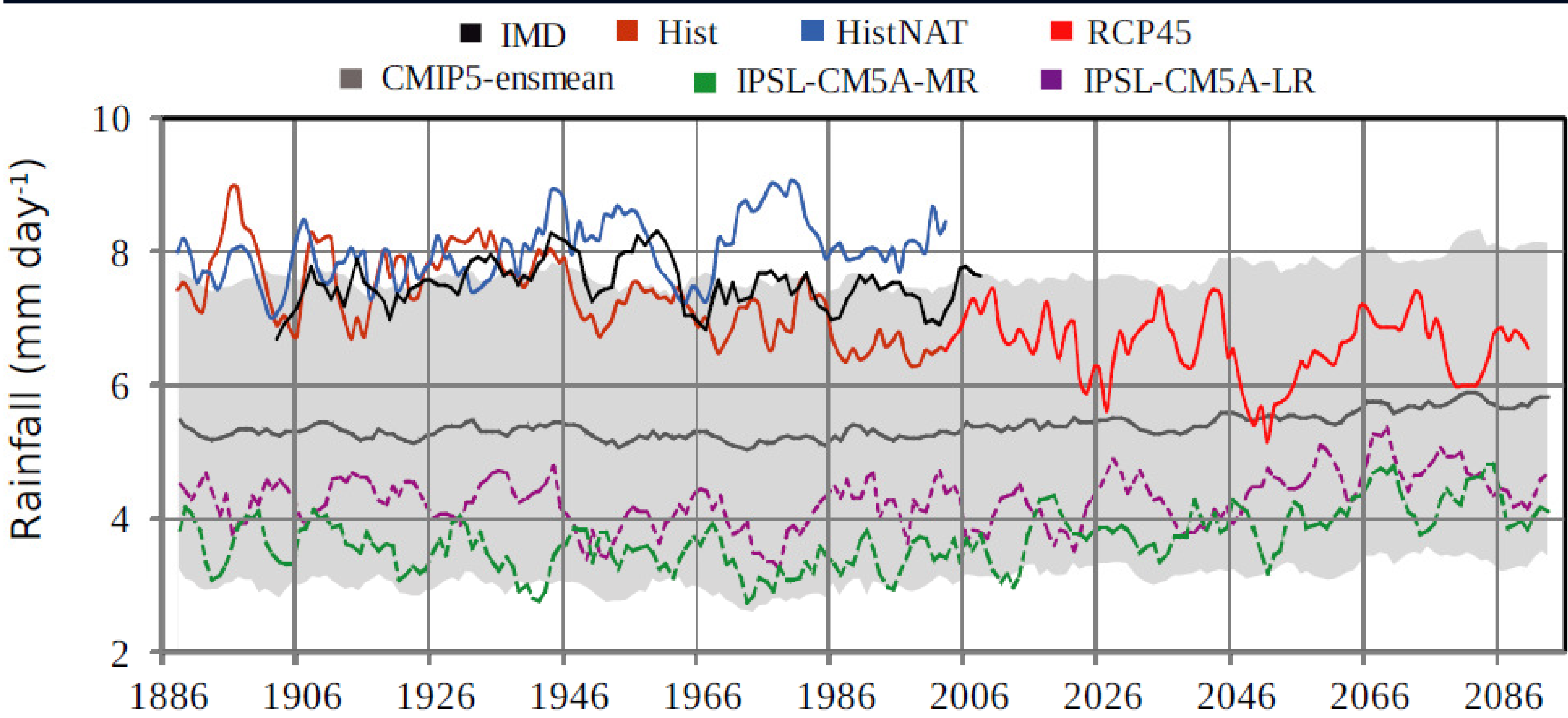


Long term annual means and interannual variability in mm d^{-1} for precipitation (P), Evapotranspiration (ET), runoff (R) and P-ET during 1979-2005 averaged over the domain 70°-90°E;10°-28°N.

	GLDAS		IPSL		LMDZ	
	Mean	Stdev	Mean	Stdev	Mean	Stdev
P	2.63	0.61	1.81	0.29	2.97	0.61
ET	1.99	0.43	2.25	0.11	1.92	0.23
R	**0.65**	0.18	**0.28**	0.10	**1.06**	0.37
P-ET	**0.64**		**-0.44**		**1.05**	

- Consistent water balance in the high resolution simulation with the LMDZ model provides confidence in assessing the surface hydrological response to changing climate over India

Ramarao et al.



- The observed decreasing trend in Indian precipitation captured by the LMDZ model simulation with all forcing (Hist)
- The LMDZ model with only natural forcing (HistNAT) indicates strong decadal scale variability
- Earlier studies reported the reasons for decadal scale variability on PDO and NAO

Climate projections and Geo-Informatics

- Maps are worth thousands words. Outputs of climate projections can be effectively presented in interactive digital maps using GIS.
- Such maps can be investigated in relation to various boundaries, population intensity, digital elevation model etc. so as to formulate focused policies for adaptation
- These maps can be disseminated for vulnerability impact and assessment (VIA) using state of the art Information Technology (IT) infrastructure. Many open source database and map and web servers facilitate this.
- Coupling of GIS, Climate projections and IT can be extremely helpful in developing robust VIA systems which are of tremendous utility for developing adaptation policies.

Thank you