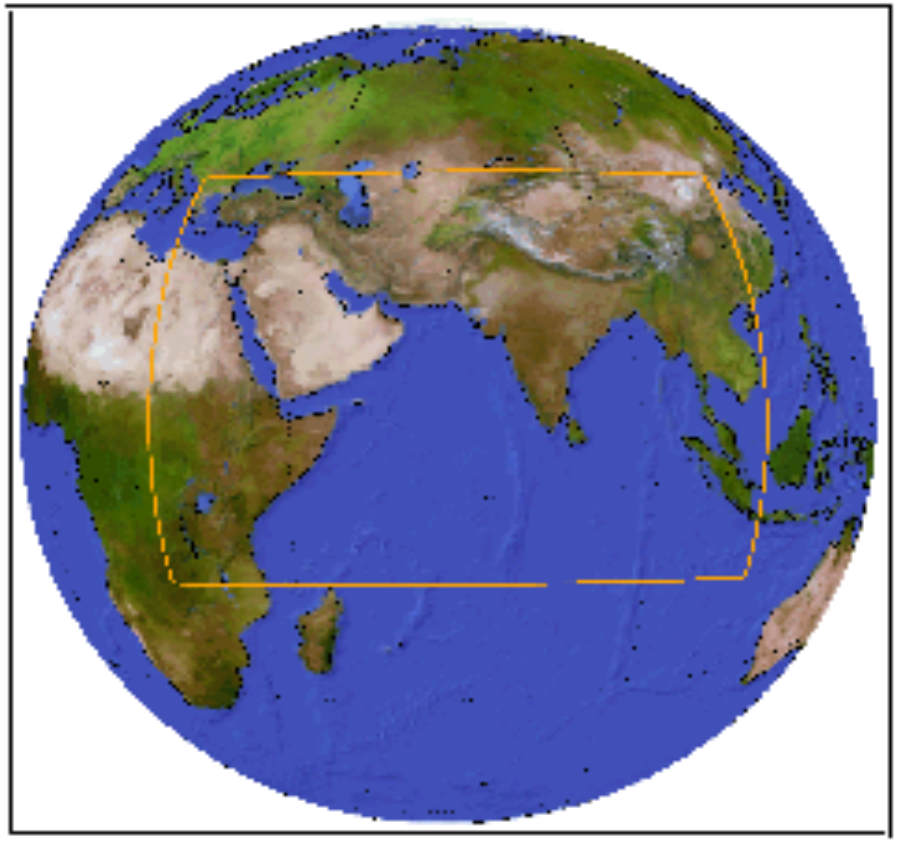


Regional Downscaling and High-Resolution (AGCM) Climate Simulations

Swapna Panickal
(Inputs from CORDEX Team, CCCR)

Centre for Climate Change Research
Indian Institute of Tropical Meteorology (IITM)

ICTP TTA: Monsoon in a changing climate, Italy, 31st-4th August 2017

Background

- **Regional downscaling methods are used to provide climate information at the smaller scales needed for many climate impact studies**

- **There is high confidence that downscaling adds value both in regions with highly variable topography and for various small-scale phenomena.**

- **Regional models necessarily inherit biases from the global models used to provide boundary conditions.**

- **However, several studies have demonstrated that added value arises from higher resolution of stationary features like topography and coastlines, and from improved representation of small-scale processes like convective precipitation.**

IPCC, WG1 Ch.9

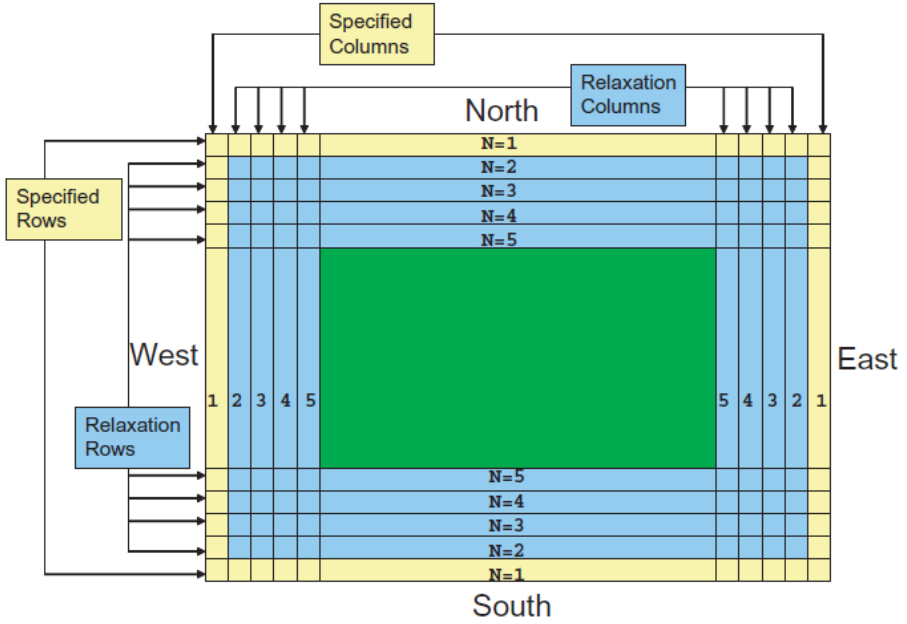
Outline

- **Dynamical Downscaling**
- **Co-ordinated Regional Climate Downscaling Experiment (CORDEX) South Asia from CCCR**
- **High Resolution Regional Climate Simulations for South Asia**
- **Tools for evaluation/visualization**
- **Future Road map**

Dynamical Downscaling

- **Dynamical downscaling uses a limited area, high-resolution model (a regional climate model, or RCM) driven by boundary conditions from a GCM to derive smaller-scale information**

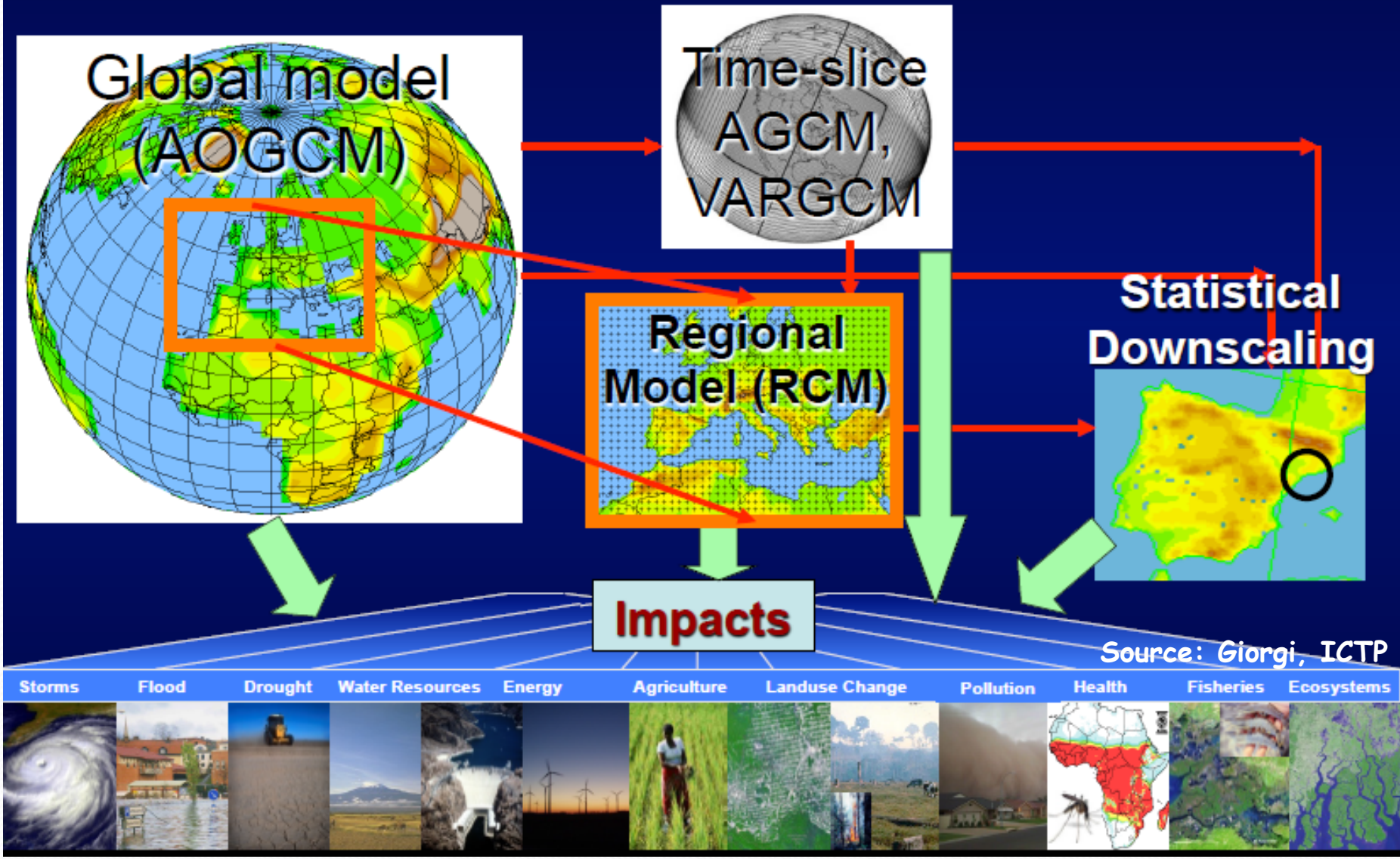
- **Lateral Boundary condition variables:**
  - **-Wind**
  - **-Temperature**
  - **-Water vapour**
  - **-Surface pressure**



Lower boundary condition variables:

- **SST**
- **Land Use & Land cover**

Downscaling regional climate information for impact assessment studies



Source: Giorgi, ICTP

Why regional downscaling is needed?

There are a number of uncertainties in our understanding of climate change in the 21st century. These can be summarized into terms of three questions:

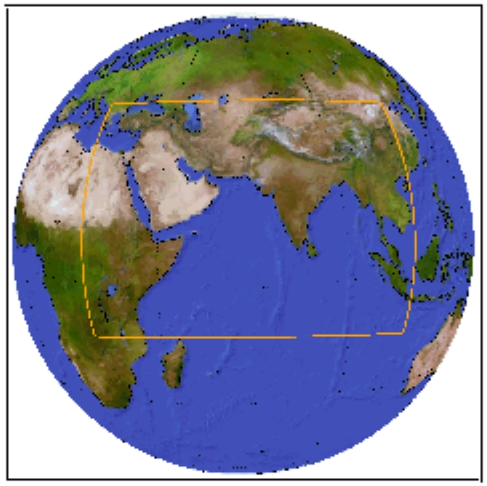
- **how will the external forcing of the climate system change in the future?**
- **how will changes in external forcing factors influence climate?**
- **to what degree is the future climate change signal masked/amplified by natural variability of the climate system?**

A common way to deal with these uncertainties is to perform several simulations constituting an ensemble

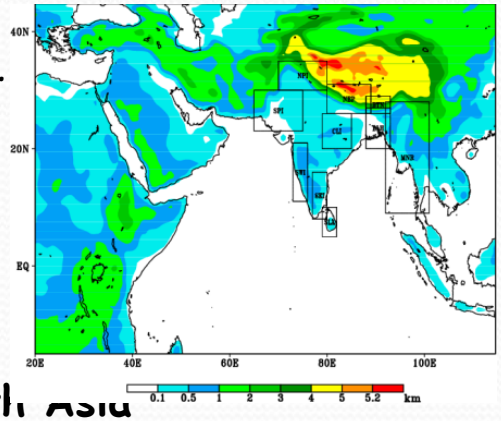
Uncertainties can be addressed by ;

- **Several different emission scenarios can be used to get an understanding on the uncertainty related to external forcing thereby sampling a multitude of possible outcomes such as the Representative Concentration Pathways (RCPs).**
- **Using multiple climate models or an ensemble of simulations with one model perturbed in its formulation of the physics, parts of the uncertainties related to how changes in forcing influence the climate can be assessed.**
- **Finally, to get an understanding on the natural variability one may use several simulations with one climate model under the same emission scenario differing only in initial conditions.**
    - **These uncertainties in long term regional climate projections need to be properly quantified and communicated for use in risk assessment and management studies.**

CORDEX South Asia Co-ordination



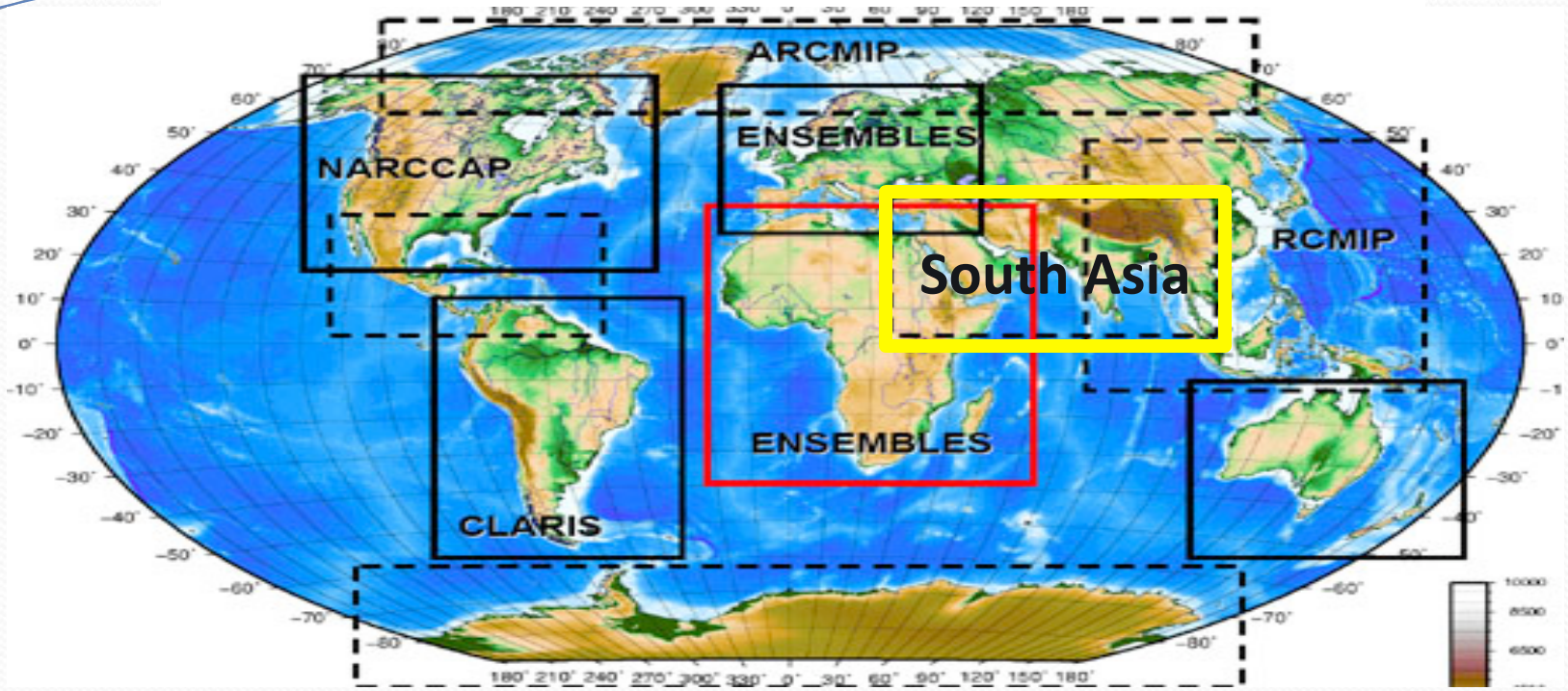
- **Development of multi-model ensemble projections of high resolution (50km) regional climate change scenarios for South Asia**
  - Generation of regional climate projections at CCCR-IITM
    - LMDZ variable grid global climate model
    - RegCM4 regional climate model
  - Co-ordination with partner 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

The CORDEX vision is to advance and coordinate the science and application of regional climate downscaling through global partnerships.



High Resolution regional climate simulations for

1. Understanding Regional Climate Process
2. Improving climate models
3. Capacity Building
4. Providing evaluated high resolution regional climate projections for land-regions worldwide
5. Linking climate modelling better with regional impact, adaptation and vulnerability assessment

Centre for Climate Change Research

Indian Institute of Tropical Meteorology (IITM)

http://cccr.tropmet.res.in/globaldata/

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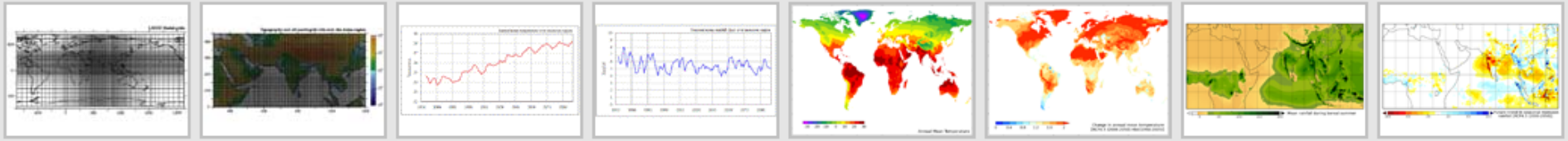
High Resolution Climate Change Simulation over South Asia



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.

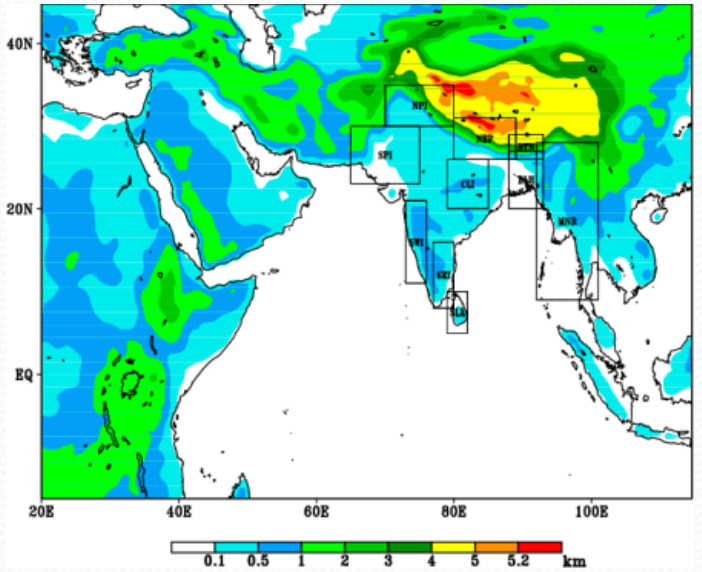
Monthly Data	Historical (1951-2005)	RCP 4.5 (2006-2095)
Rainfall (mm / day)	Download	Download
Surface Air Temperature (°C)	Download	Download

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

 Designed & Developed By Sandip Ingle, CCCR | Data Source : Dr. Sabin T.P., CCCR

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
REMO2009(MPI)	MPI Regional model 2009 (REMO2009; Weblink: http://cccr.tropmet.res.in/cordex/docs/REMO-CORDEX-DATA-WAS-IITM_4.pdf	MPI-ESM-LR (Giorgetta et al 2013)	Climate Service Center, Hamburg, Germany



http://cccr.tropmet.res.in/cordex/docs/Table_CORDEX_Expts_all.doc

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

CORDEX-South Asia Multi Models Output http://cccr.tropmet.res.in/cordex/files/downloads.jsp

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

Historical runs is available to download.

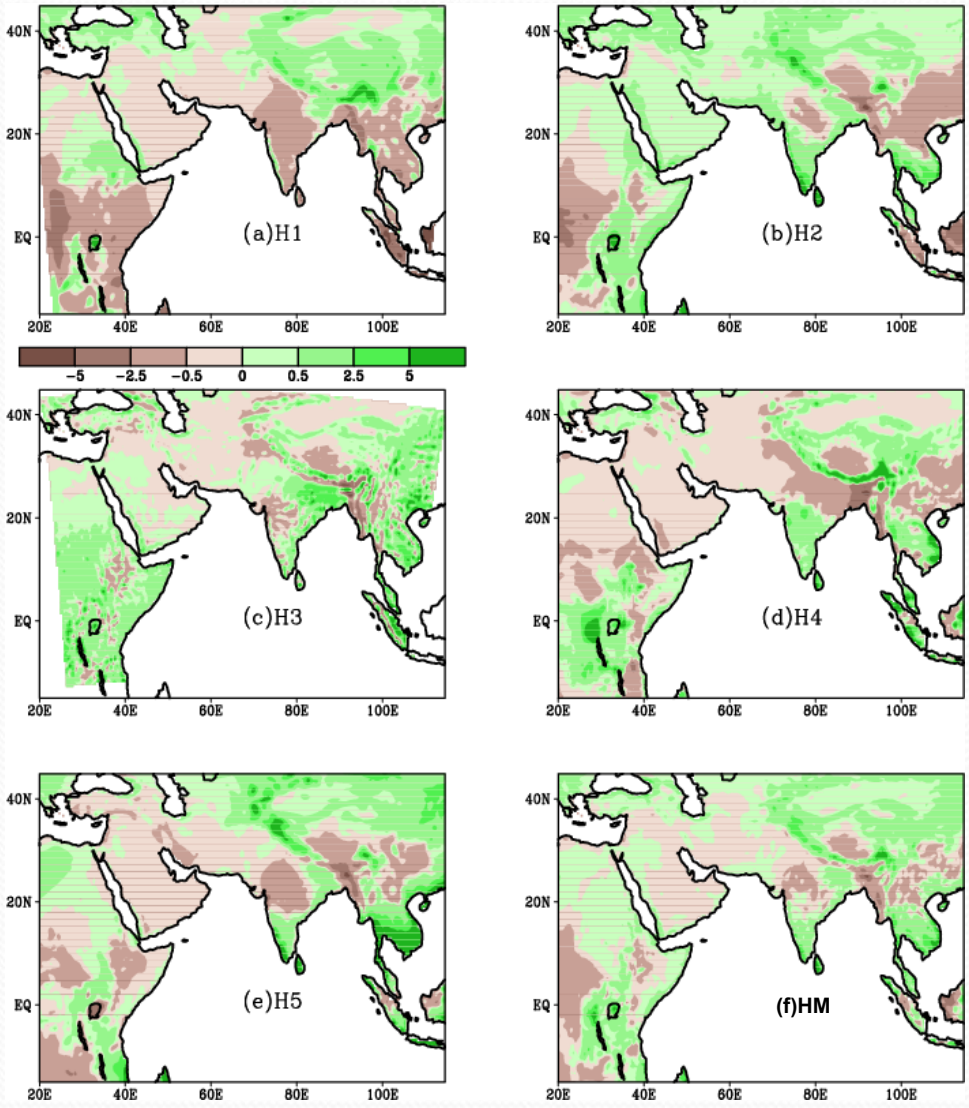
Experiment Name	Rain fall (pr)	Surface Air Temp (tas)	Surface Air Temp. Maximum (tasmax)	Surface Air Temp. Minimum (tasmin)	Sea-level Pressure (psl)	Surface Specific Humidity (huss)	Surface Zonal Wind (uas)	Surface Meridonial Wind (vas)	Downward Shortwave Radiation (rsds)
RCA4 (ICHEC)	✓	✓	✓	✓	✓	✓	✓	✓	--
RegCM4 (GFDL)	✓	✓	✓	✓	✓	✓	✓	✓	✓
RegCM4 (LMDZ)	✓	✓	✓	✓	✓	✓	✓	✓	✓
CCLM4 (MPI)	✓	✓	--	--	✓	✓	--	--	--
LMDZ4 (IPSL)	✓	✓	✓	✓	✓	✓	✓	✓	--
REMO2009 (MPI)	✓	✓	✓	✓	✓	✓	✓	✓	✓
CCAM (ACCESS)	✓	--	✓	✓	✓	--	--	--	--
CCAM (CNRM)	✓	--	✓	✓	✓	--	--	--	--
CCAM (CCSM)	✓	--	✓	✓	✓	--	--	--	--
CCAM (GFDL)	✓	--	✓	✓	✓	--	--	--	--
CCAM (MPI)	✓	--	✓	✓	✓	--	--	--	--
CCAM (BCCR)	✓	--	✓	✓	✓	--	--	--	--

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

High Resolution Regional Climate Simulations for South Asia

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



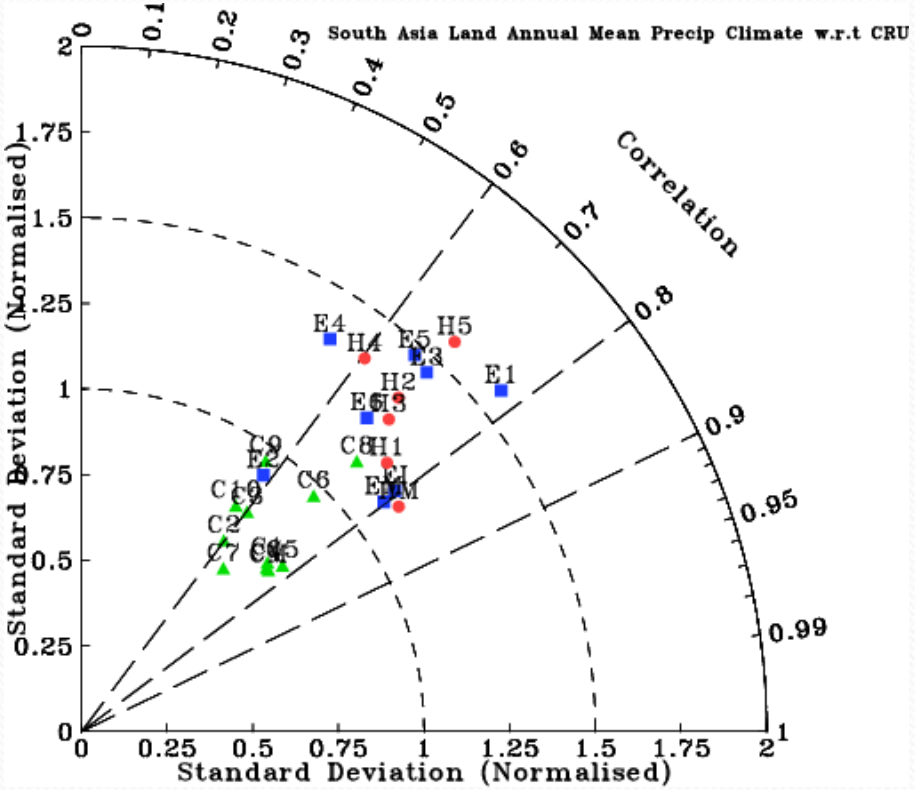
Model Label	Model Name & Version	Driving CMIP5 AOGCM
H1	COSMO CLM	MPI-ESM-LR
H2	ICTP RegCMv4.1	GFDL-ESM2M
H3	SMHI RCAv4	EC-EARTH
H4	IPSL LMDZv4	IPSL-CM5A-LR
H5	ICTP RegCMv4.1	LMDZ4

- 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)

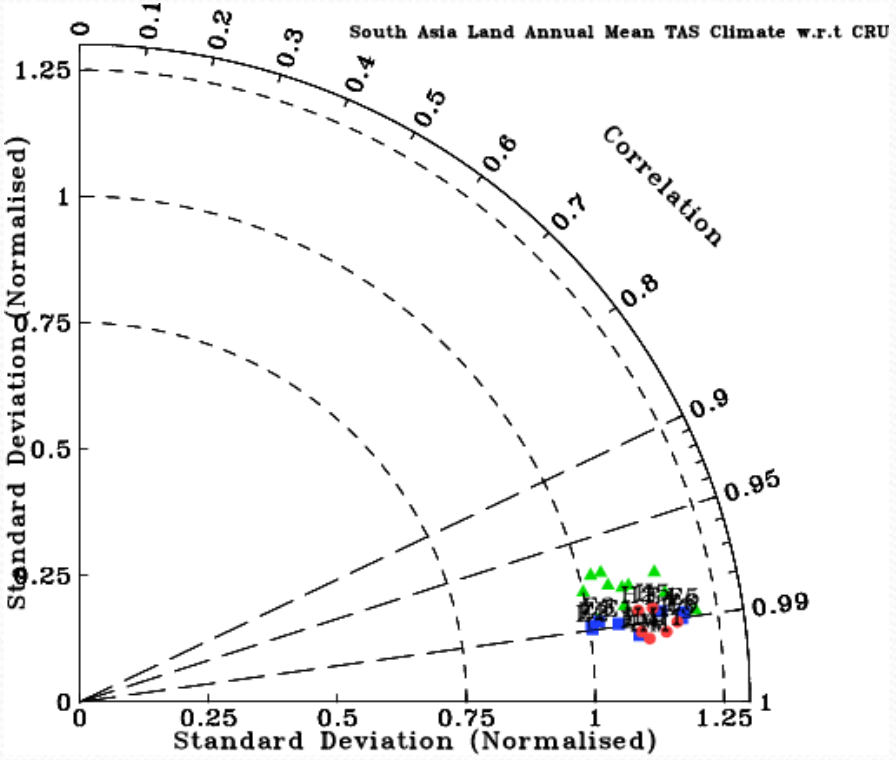
ICRC CORDEX 2013 (http://cordex2013.wcrp-climate.org/posters/P3_27_Sanjay.pdf)

Spatial pattern correlations and Standardized deviations of the simulated annual mean precipitation and surface air temperature

Precipitation



Surface Air Temperature

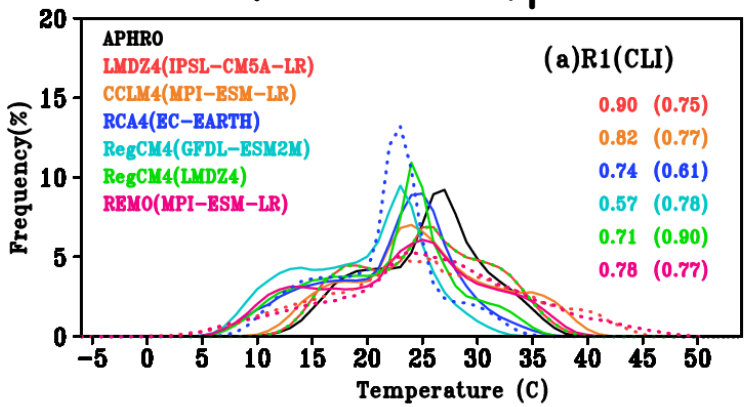


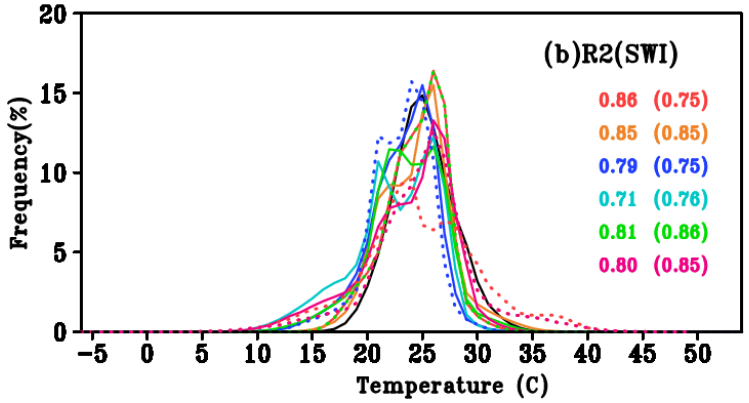
climatology (1990-2004) with respect to the observed (CRU) data over the South Asia land region (60°E-100°E; 5°N-35°N)

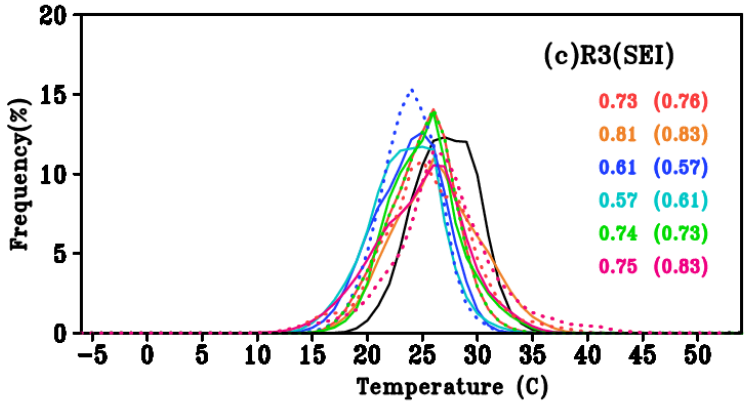
Sanjay et al. (http://cordex2013.wcrp-climate.org/posters/P3_27_Sanjay.pdf)

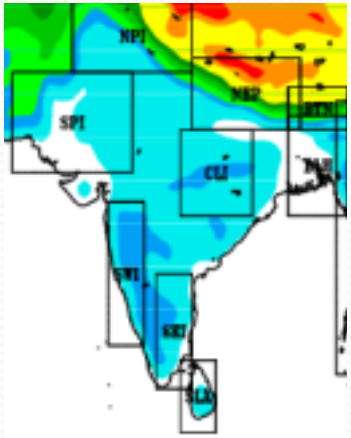
CORDEX South Asia 1986-2005 Daily Probability Density Functions

Surface Air Temperature

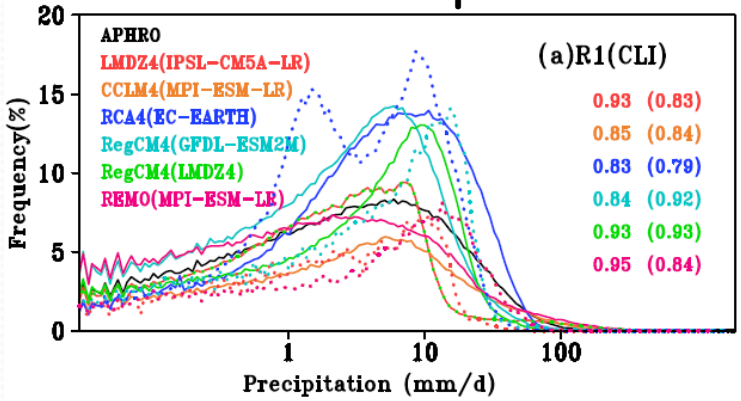


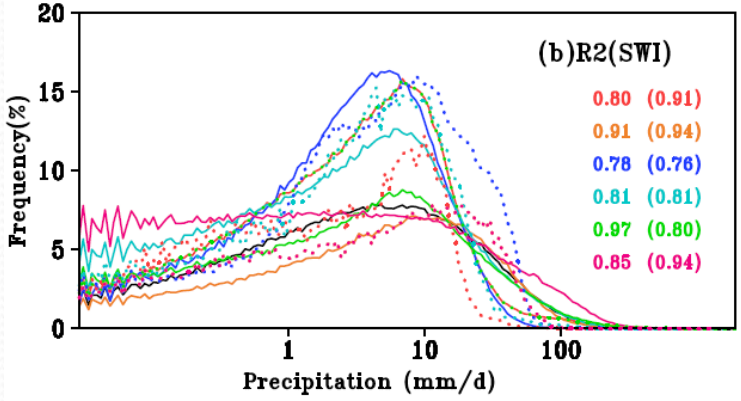


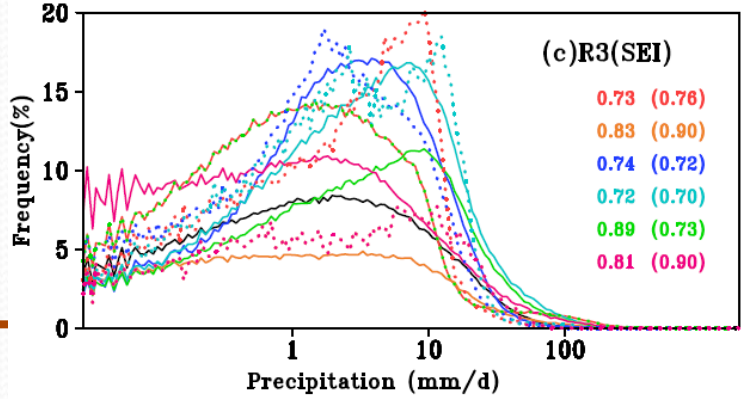




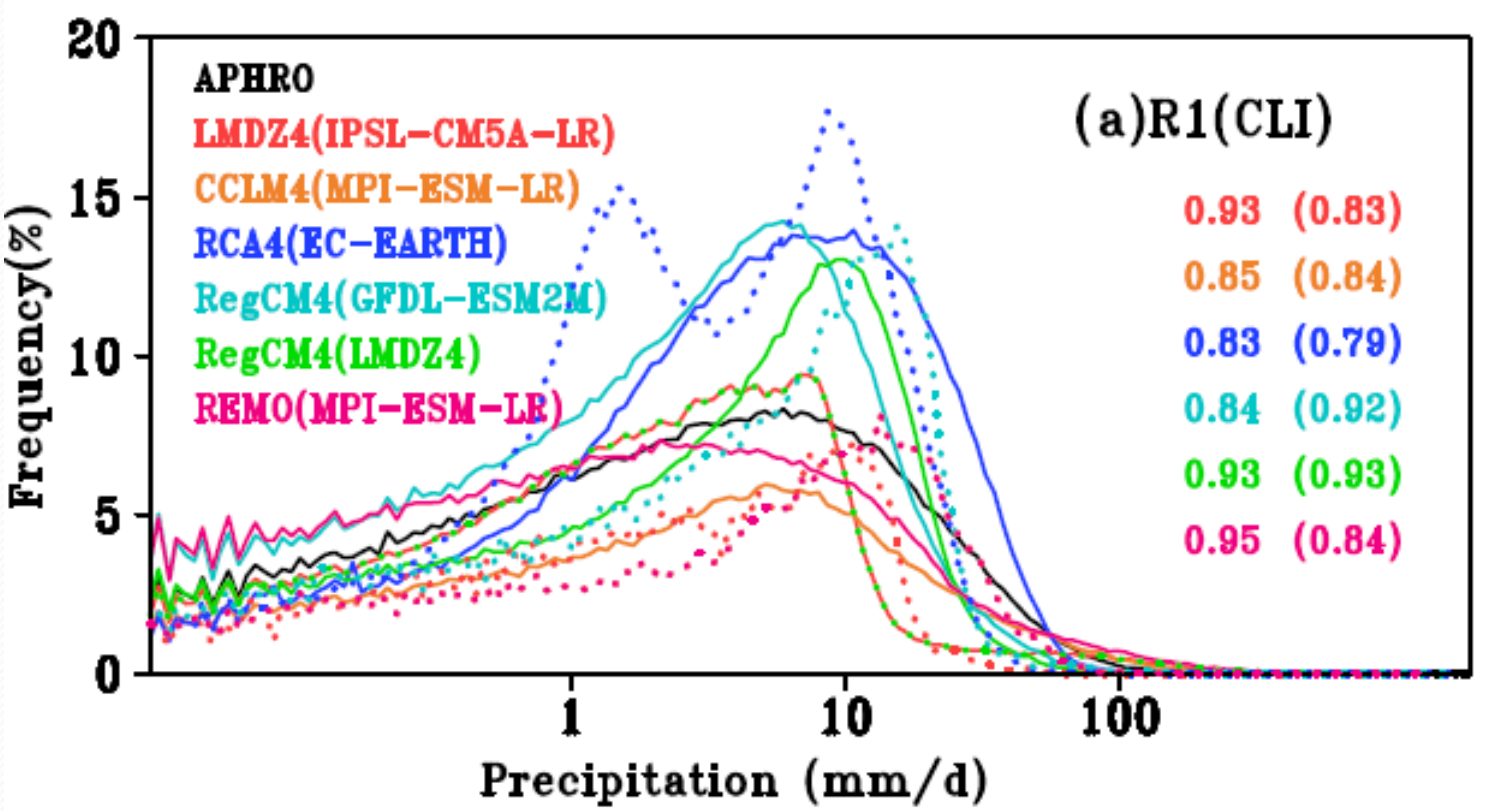
Total Precipitation





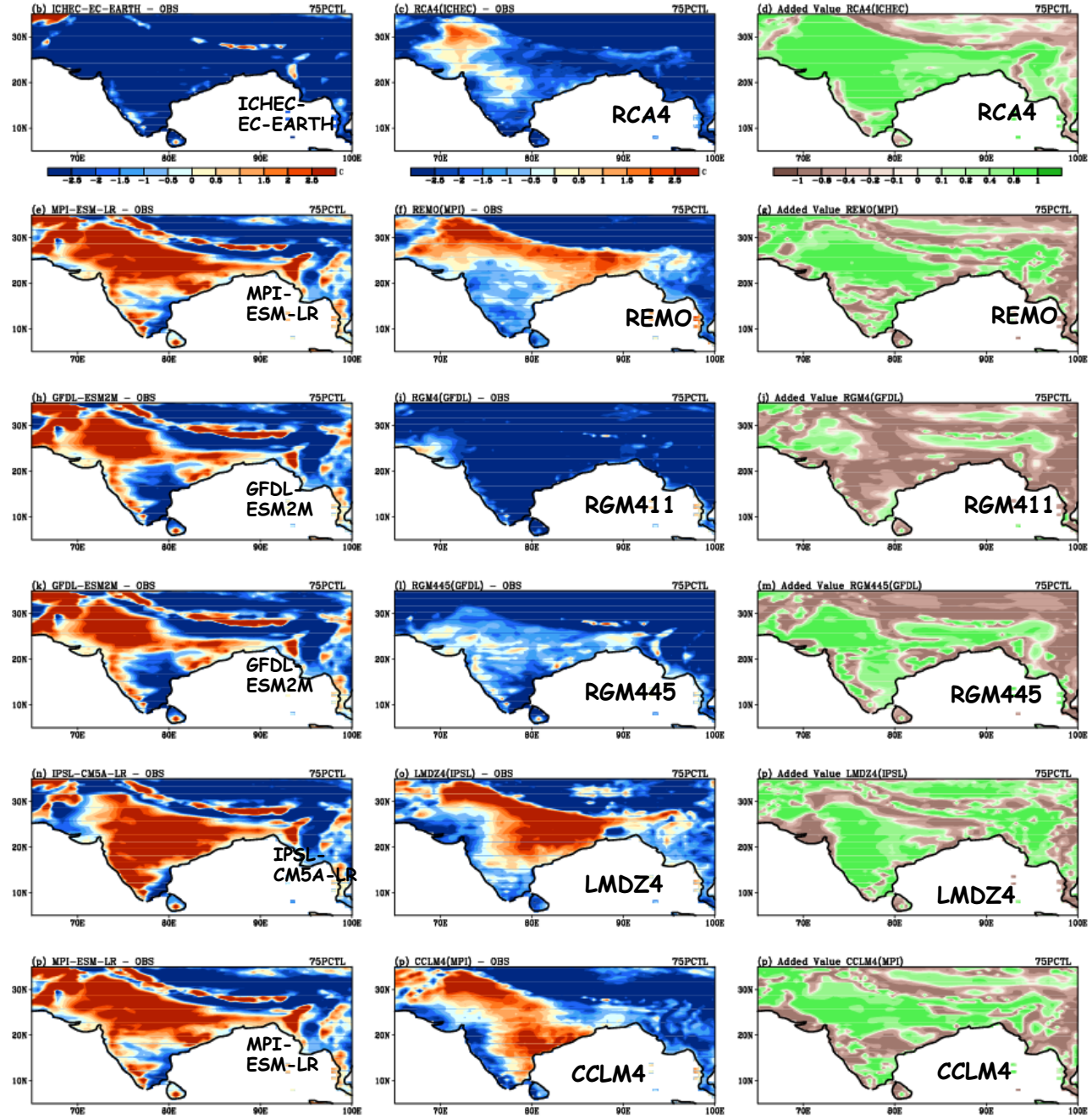


CORDEX South Asia 1986-2005 Daily Precipitation Probability Density Functions over Central India

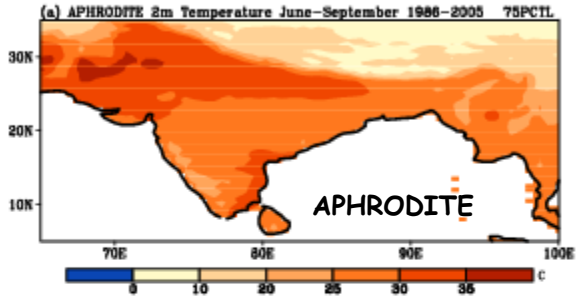


- A simple quantitative measure of how well each climate model can capture the observed PDFs (Perkins et a. 2007) for precipitation shows that over central India, 3 of the 6 RCMs improves than the driving CMIP5 AOGCMs.

CMIP5 CORDEX RCMs Added Value



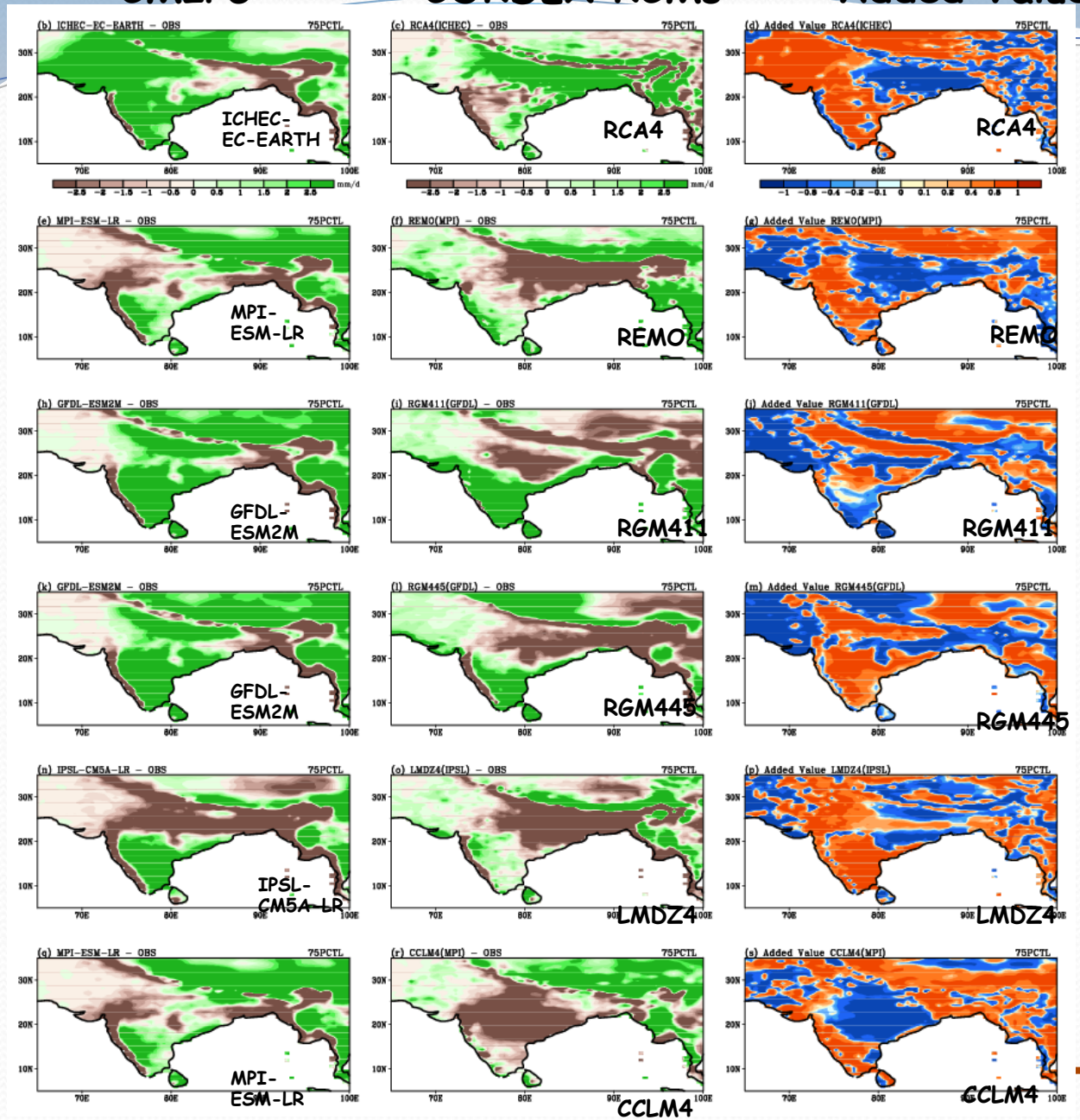
Historical Runs Driven with CMIP5 AOGCMS June-September Daily 75th Percentile 2m Temperature Bias w.r.t APHRODITE 1986-2005



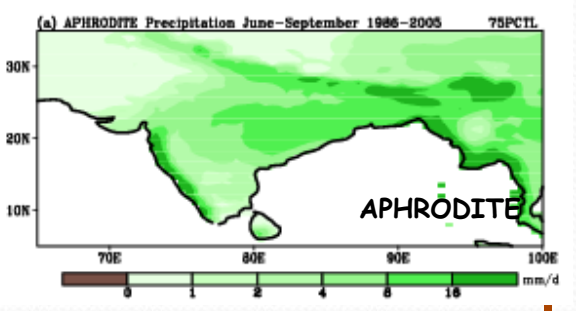
AV is positive where the RCM's squared error is smaller than the driving AOGCM's squared error.

Sanjay et al. under revision

CMIP5 CORDEX RCMs Added Value



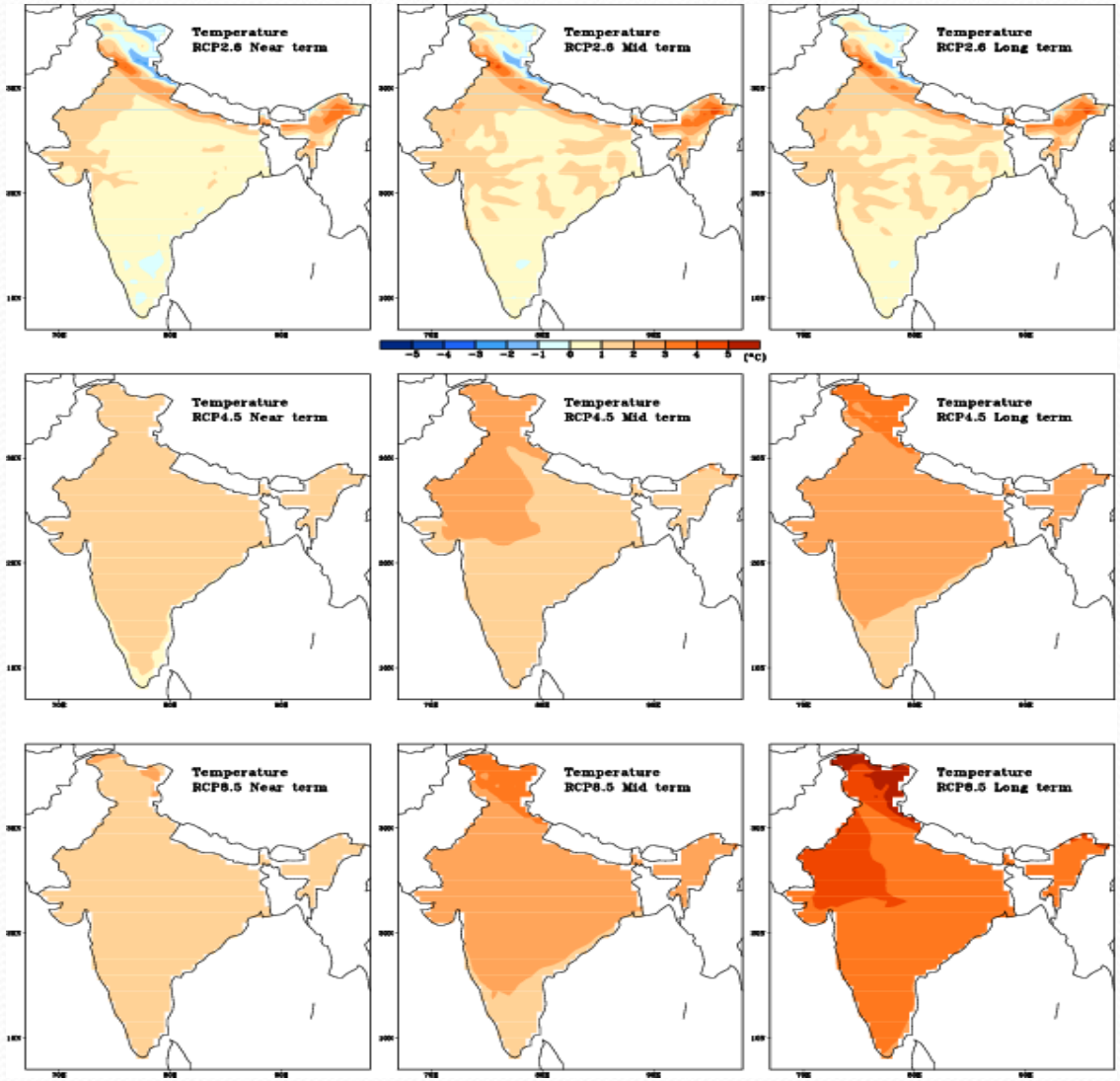
Historical Runs Driven with CMIP5 AOGCMS June-September Daily 75th Percentile Precipitation Bias w.r.t APHRODITE 1986-2005



Sanjay et al. under revision

CORDEX South Asia multi-RCM ensemble mean projections

Annual average surface air temperature



The all India mean surface air temperature change for the near-term period is projected to be in the range of 1.08°C to 1.44°C,

Larger than the natural internal variability

The RCP2.6 scenario shows increase of less than 1°C over most of India except in some areas

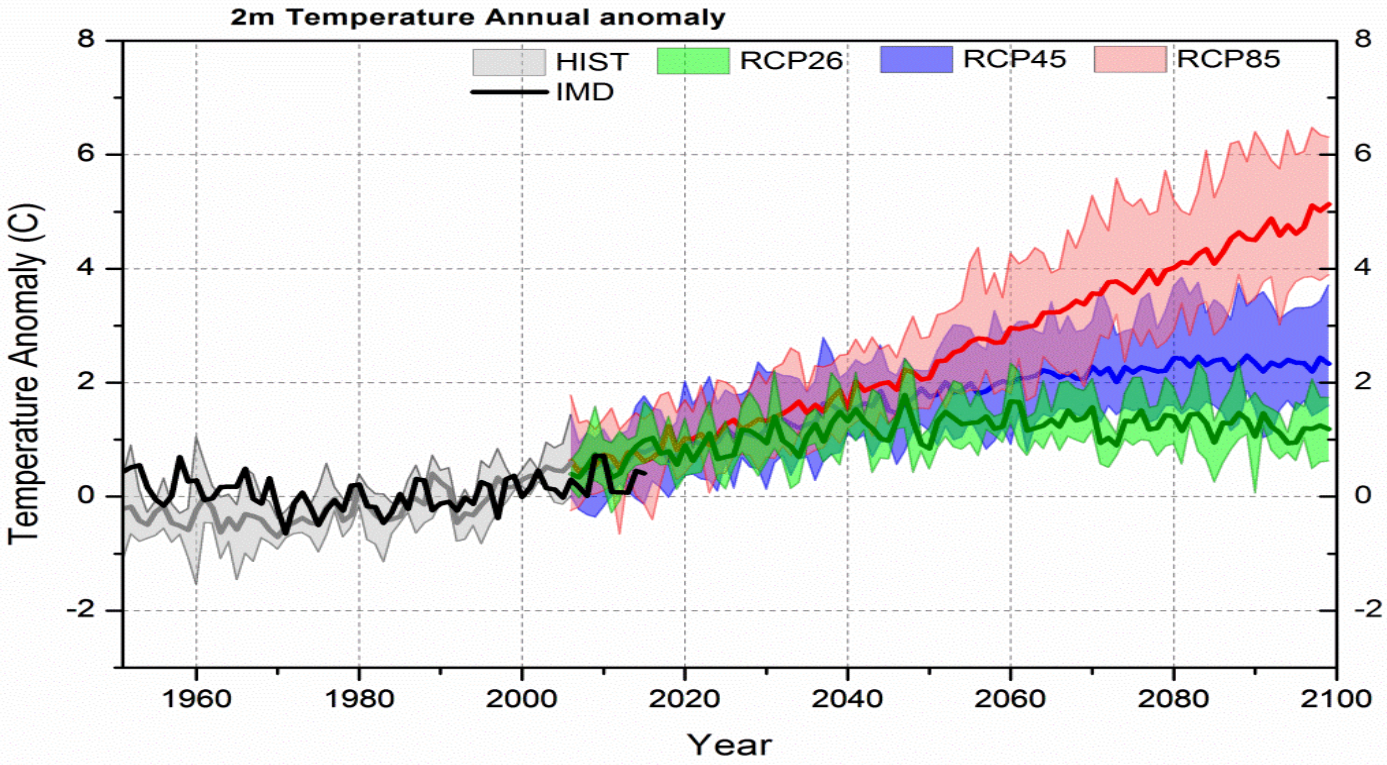
The RCP4.5 and RCP8.5 scenarios for the near-term change show similar increase of less than 2°C uniformly over the Indian land.

Near-term (2016-2045) Mid-term (2036–2065) Long-term (2066–2095)

Sanjay et al., 2017

CORDEX South Asia multi-RCM ensemble mean projections

2m Temperature Anomaly



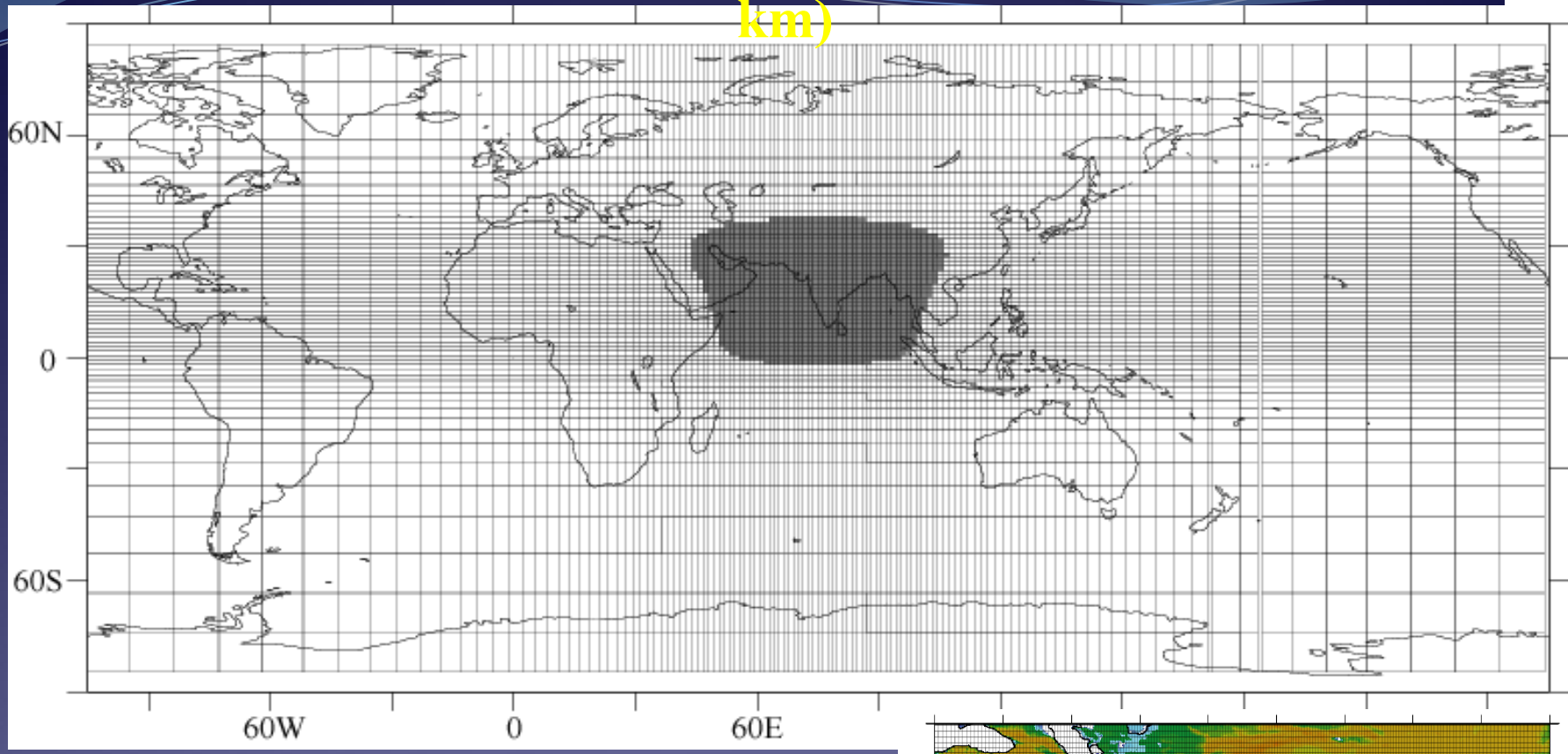
The all India averaged annual surface air temperature anomalies based on the IMD gridded data show steady long-term warming with interannual variations

A consistent and robust feature across the downscaled CORDEX South Asia RCMs is a continuation of warming over India in the 21st century for all the RCP scenarios

Sanjay et al., 2017

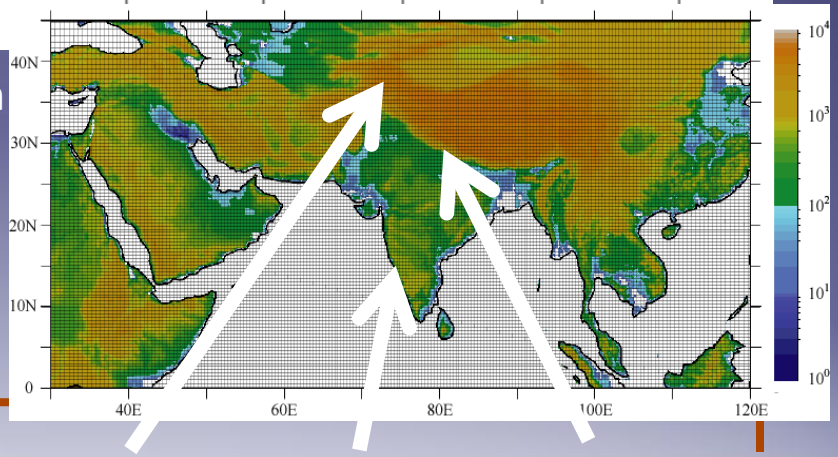
High Resolution Regional Climate Simulations for South Asia: A Variable Resolution (LMDZ) Approach

LMDZ grid setup for South Asia (shaded region has grid-size < 55 km)



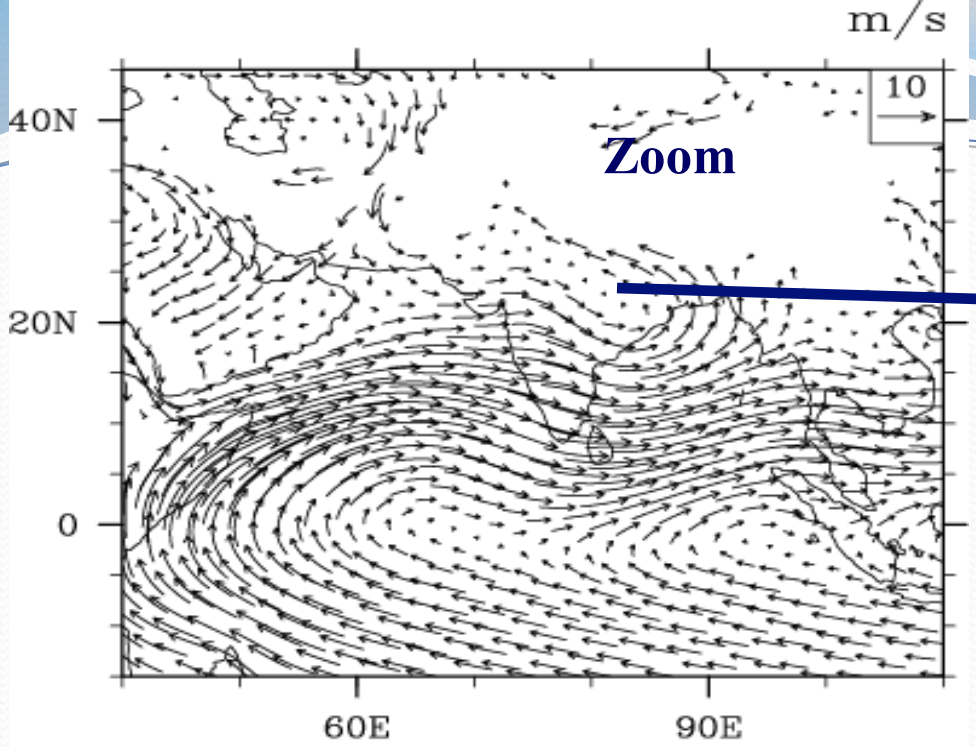
LMDZ global atmospheric model: Variable resolution with zooming capability

The resolution becomes gradually coarser outside the zoom domain.

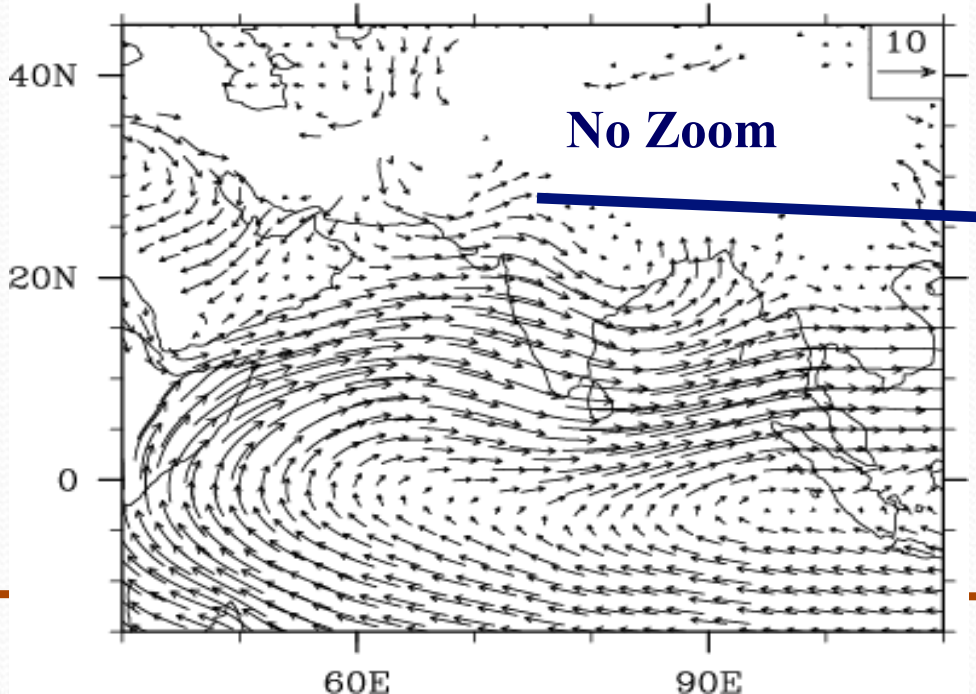


Curtesy : Sabin, CCCR

850 hPa winds (JJAS)

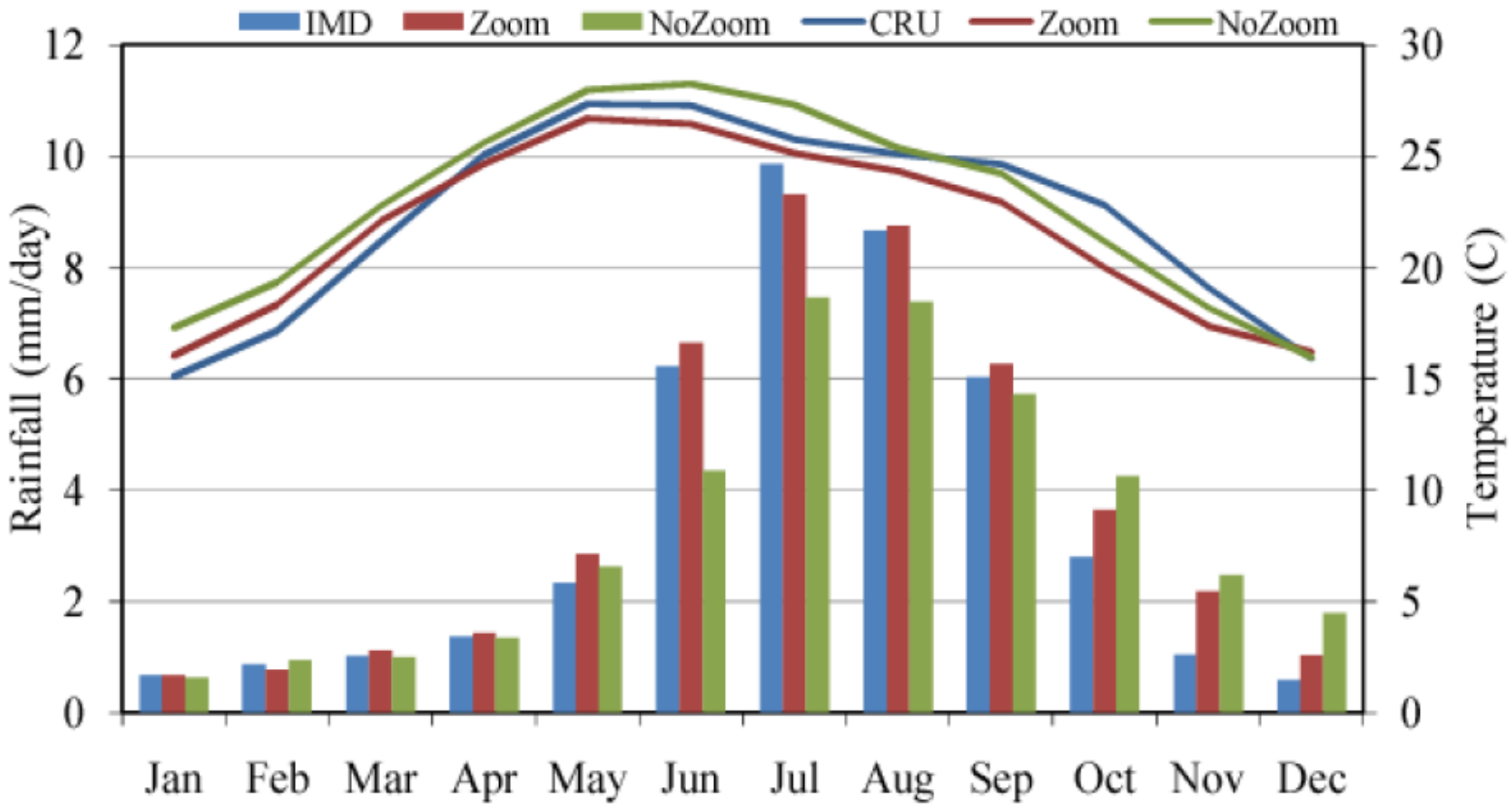


Cyclonic turning of moist winds from Bay of Bengal



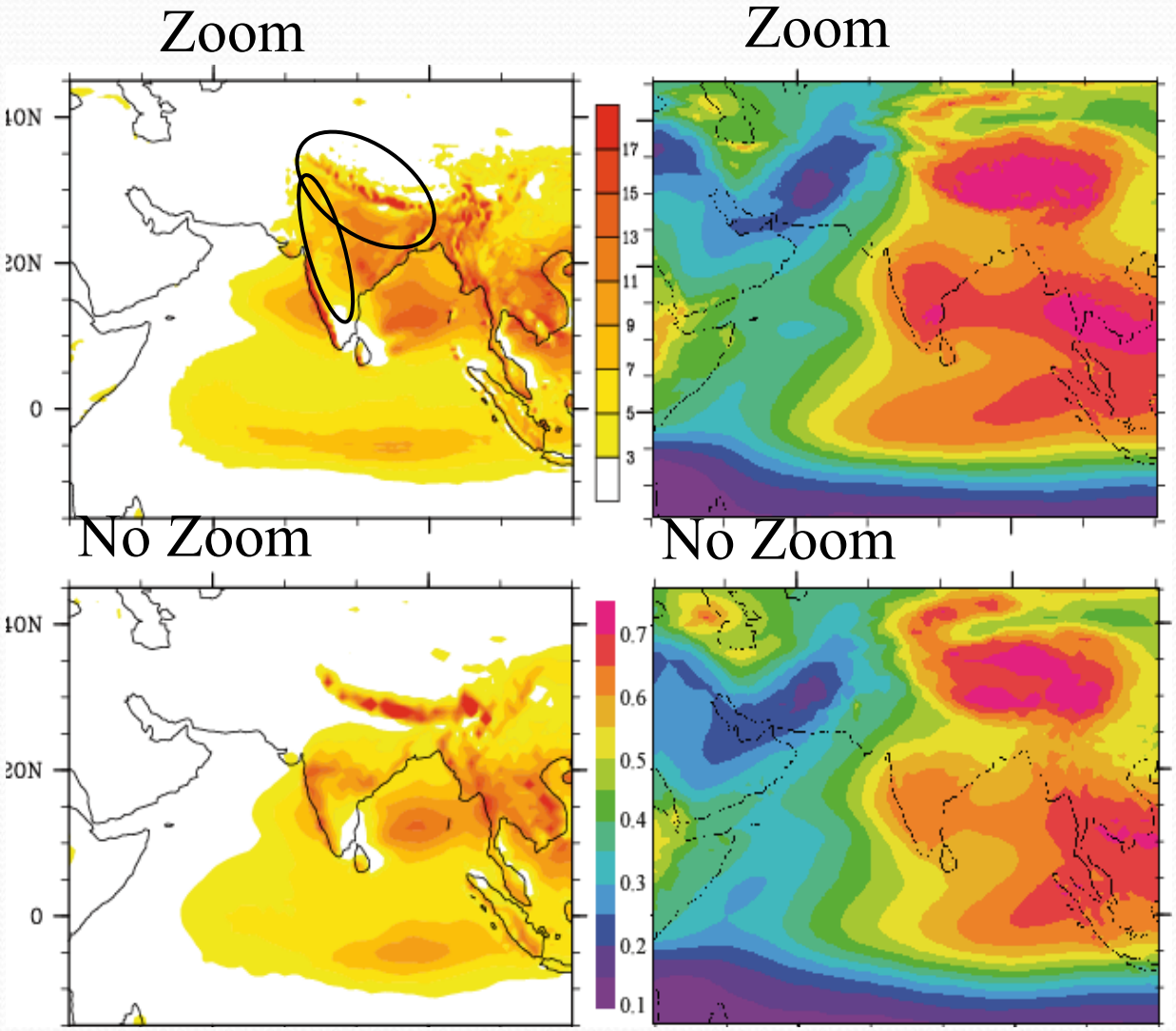
Dry westerly winds from Indo-Pak and adjoining areas

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



Monsoon rainfall (JJAS)

Relative Humidity 500 hPa



Zoom simulation able to capture finer details of the regional precipitation variability

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:

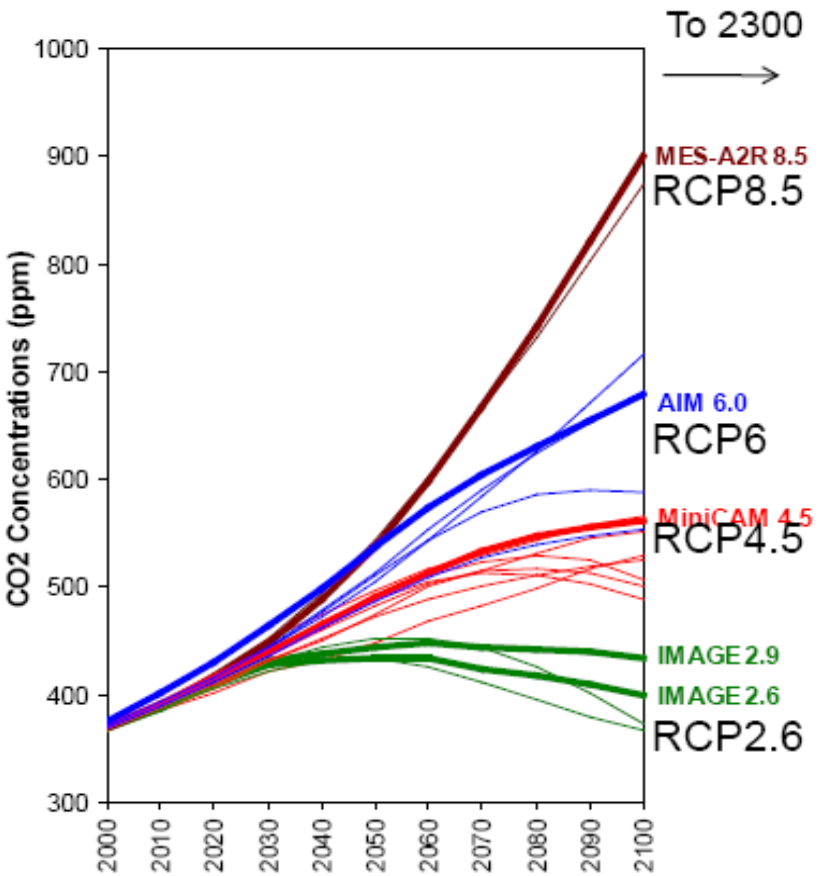
Future projection run which includes both natural and anthropogenic forcing based on the IPCC AR5 RCP4.5 climate scenario. The evolution of GHG and anthropogenic aerosols in RCP 4.5 scenario produces a global radiative forcing of + 4.5 W m^{-2} by 2100

GHG only (1950-2005)

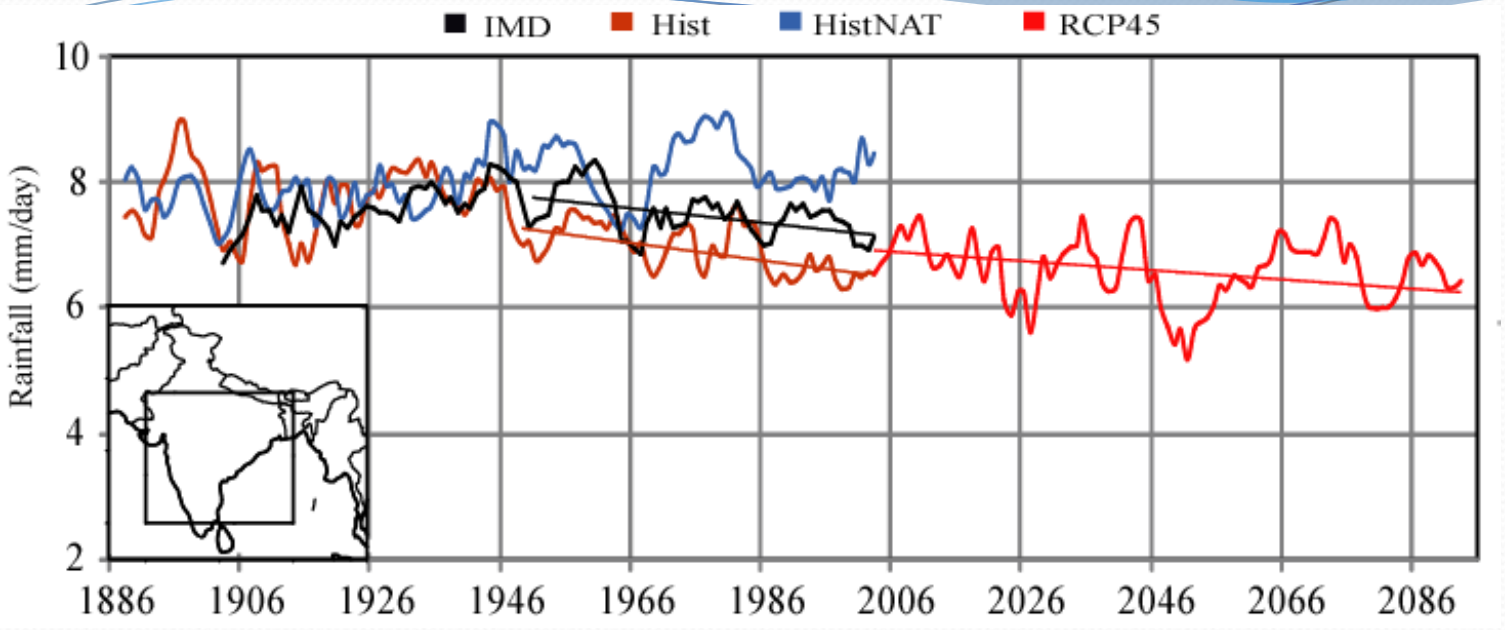
Natural and GHG-only forcings. Land use and aerosol fields set to 1886 values

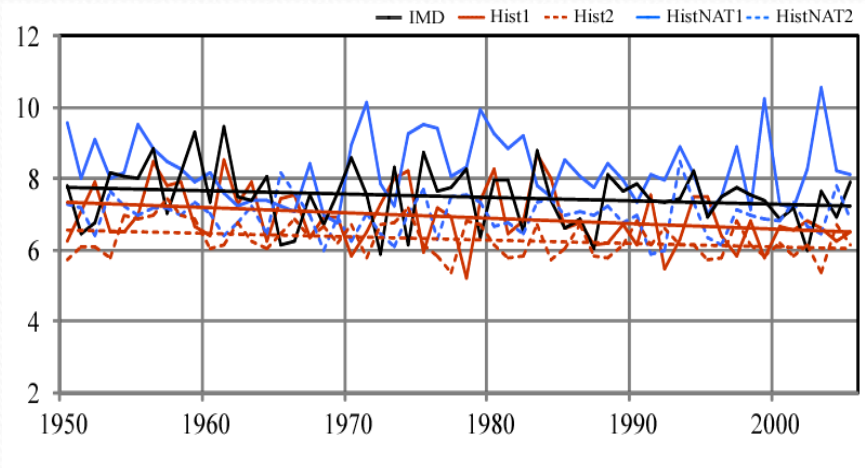
Pre Industrial GHG (1950-2005)

Includes Natural variations, Aerosol forcing and Land-use change. The concentration of GHGs are set to 1886



5-year running mean of seasonal (JJAS) monsoon precipitation

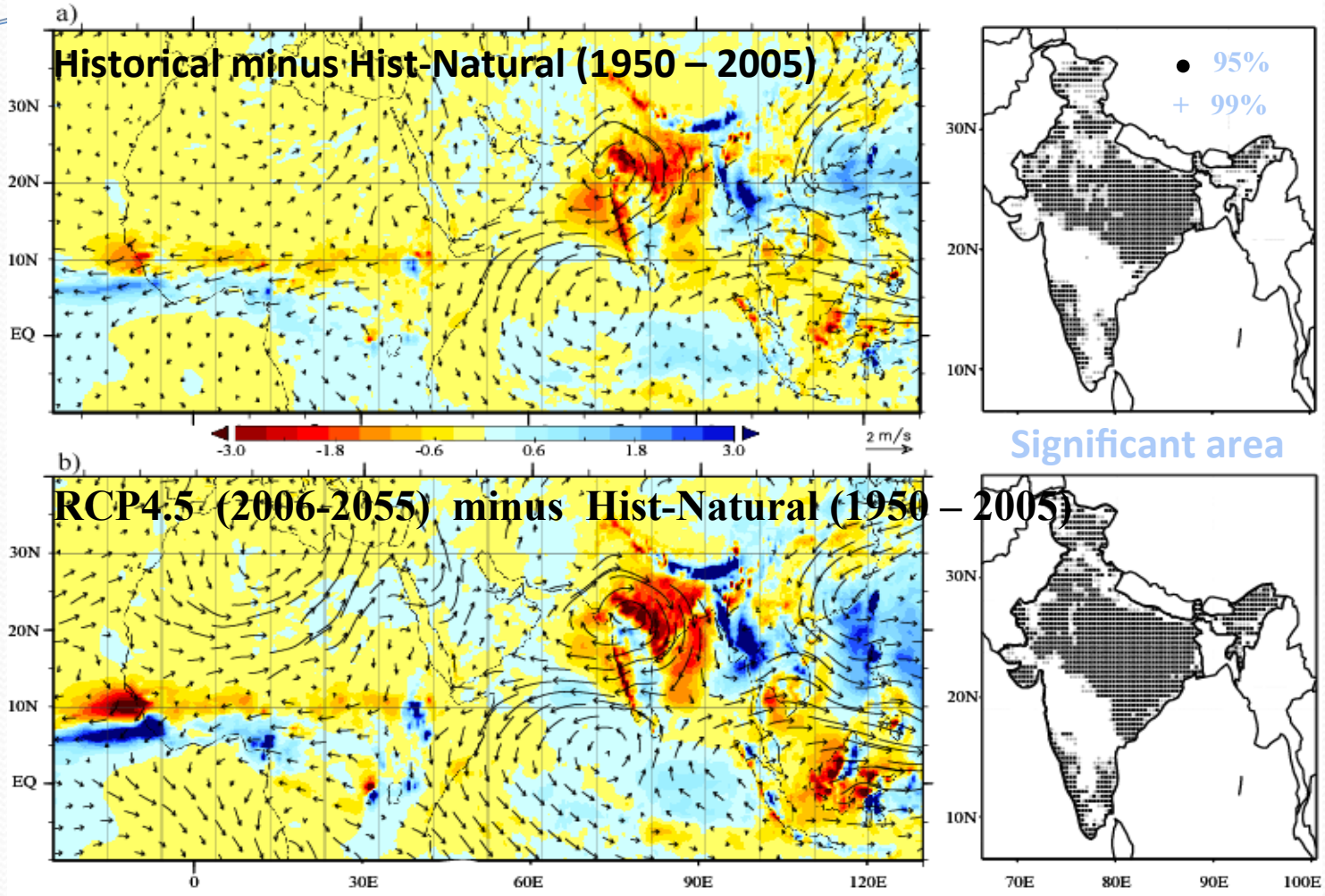




Further, the HIST1 and HIST2 simulations show significant decrease of monsoon rainfall over the Indian land region during 1951-2005 by ~16% and ~9% respectively which are conspicuously absent in HISTNAT1 and HISTNAT2.

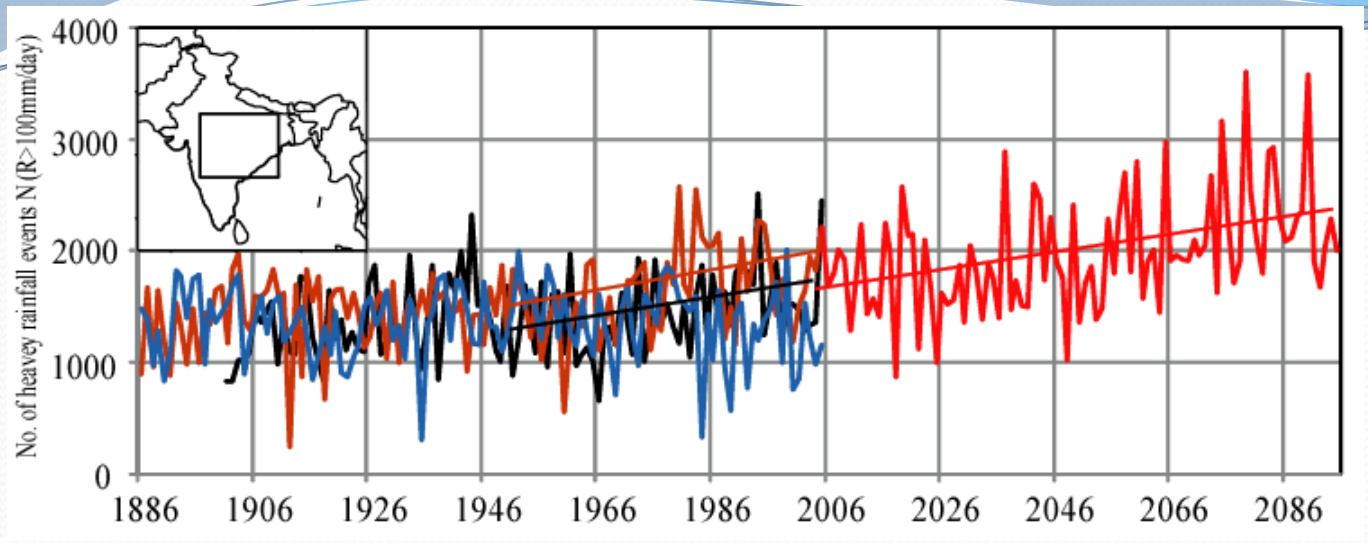
	Rainfall trend	Mean rain	% change	P value
IMD dataset	-0.55 (55 years)$^{-1}$	7.5	-7%	P < 0.01
HIST1	-1.1 (55 years)$^{-1}$	6.9	-16%	P < 0.01
HIST2	-0.55 (55 years)$^{-1}$	6.3	-9%	P < 0.01
HISTNAT1	-0.03 (55 years)$^{-1}$	8.3	-0.3%	P = 0.54
HISTNAT2	- 0.1 (55 years)$^{-1}$	6.9	-1%	P = 0.2
RCP4.5	-1.1 (55 years)$^{-1}$	6.6	-17%	P < 0.01
RCP4.5	-0.29 (90 years)$^{-1}$	6.6	-5%	P < 0.01

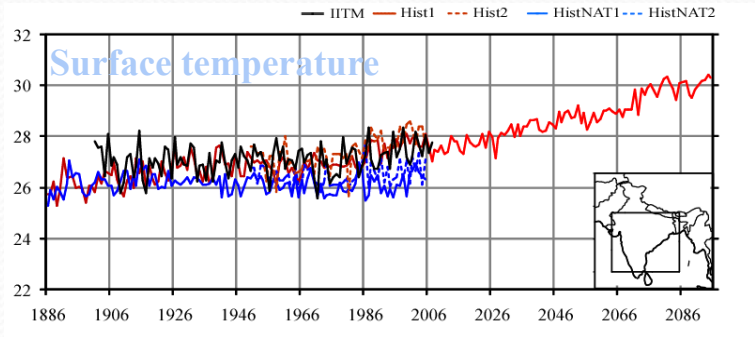
Difference in JJAS rainfall and wind at 850 hPa

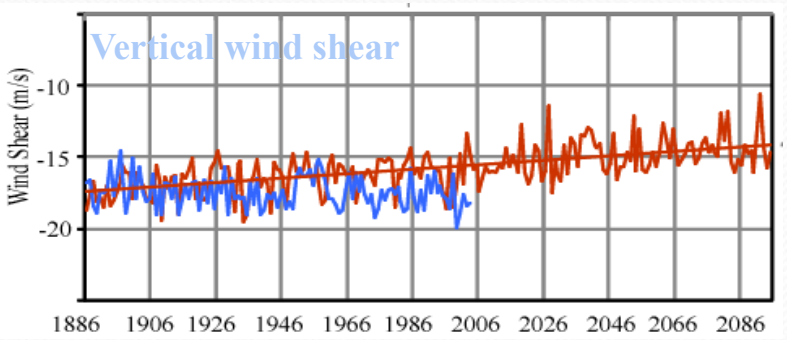


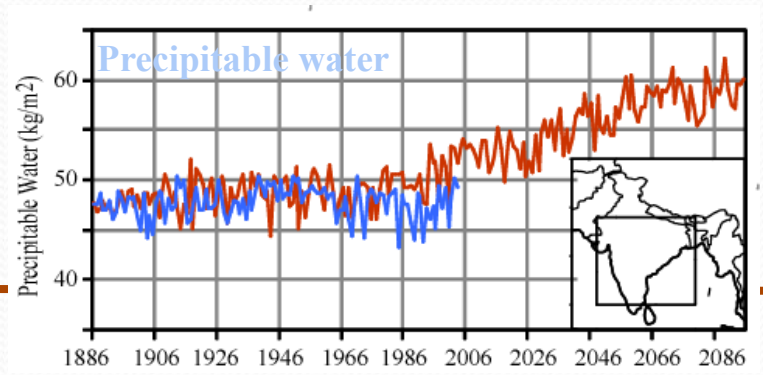
Widespread negative anomalies of rainfall over the IGP and mountainous west-coast. The simulations also depict anomalous precipitation enhancement over southeastern China and adjoining areas, which is again consistent with the observed pattern.

Time series of Extremes in precipitation (>100mm/day over MT region)









With rising surface temperatures, the simulated atmospheric moisture content over the subcontinent increased substantially by ~24% during 1886-2095. The vertical wind shear reduced nearly by the same amount. Such a weakly sheared environment with high humidity levels favors enhanced localized convection and leads to the increasing frequency of precipitation extremes .

Highlights:

- **The LMDZ experiments realistically simulate the mean monsoon precipitation.**

- **The high resolution leads to a realistic representation of the heavy orographic precipitation of Western Ghats and north-eastern India.**

- **The zooming provides a key value-addition especially in terms of the observed coupling between wind and precipitation over the MT region.**

- **Recent trend in monsoon precipitaion and extremes events are also well simulated by the model.**

Climate Data Evaluation Tools

Centre for Climate Change Research

Indian Institute of Tropical Meteorology, Pune, India

Thanks to: S. Ingle, M. Mujumdar

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

About Climate Data Portal http://cccr.tropmet.res.in/home/old_portals.jsp

The CCCR Climate Data Portal is designed to facilitate the dissemination of climate information using a publicly accessible FTP and web-based interface. click here

CORDEX-South Asia Multi Model Output http://cccr.tropmet.res.in/home/ftp_data.jsp

Evaluation Runs (1989 - 2008) | Historical Runs (1950 - 2005) | RCP4.5 Scenario Runs | RCP8.5 Scenario Runs

Historical (1950-2005)

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)	✓	✓	✓	✓	✓	✓	✓	✓	--
REMO2009 (MPI)	✓	✓	✓	✓	✓	✓	✓	✓	✓
CCAM(ACCESS)	✓	--	✓	✓	✓	--	--	--	--
CCAM(CNRM)	✓	--	✓	✓	✓	--	--	--	--
CCAM(CCSM)	✓	--	✓	✓	✓	--	--	--	--
CCAM(GFDL)	✓	--	✓	✓	✓	--	--	--	--
CCAM(MPI)	✓	--	✓	✓	✓	--	--	--	--
CCAM(BCCR)	✓	--	✓	✓	✓	--	--	--	--

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
REMO2009(MPI)	MPI Regional model 2009 (REMO2009; Weblink: http://cccr.tropmet.res.in/cordex/docs/REMO-CORDEX-DATA-WAS-IITM_4.pdf	MPI-ESM-LR (Giorgetta et al 2013)	Climate Service Center, Hamburg, Germany

http://cccr.tropmet.res.in/home/docs/cordex/Table_CORDEX_Expts_all.doc

Development of CCCR-IITM Earth System Grid Federation (ESGF) node

Thanks to:

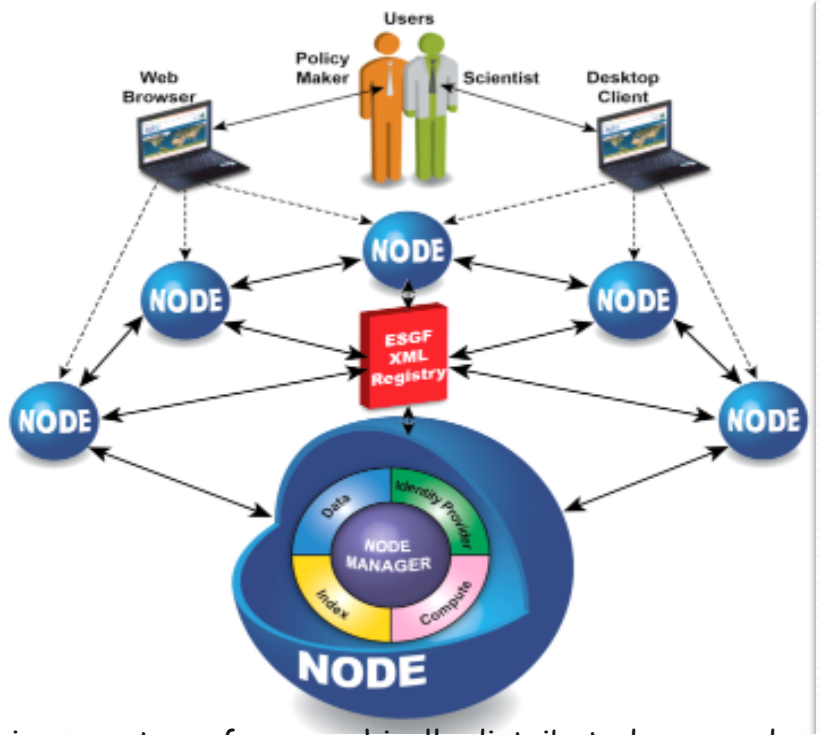
Sandip Ingle, R.Mahesh (CCCR, IITM)

Prashanth Dwarakanath (NSC, SMHI)

Nikulin Grigory (SMHI)

- Archival, Management, Retrieval and Dissemination of CORDEX South Asia and CMIP6 datasets

- ESGF is an international collaboration for the software that powers most global climate change research, notably assessments by the IPCC



Using a system of geographically distributed peer nodes—independently administered yet united by common protocols and interfaces—the ESGF community holds the premier collection of simulations and observational and reanalysis data for climate change research

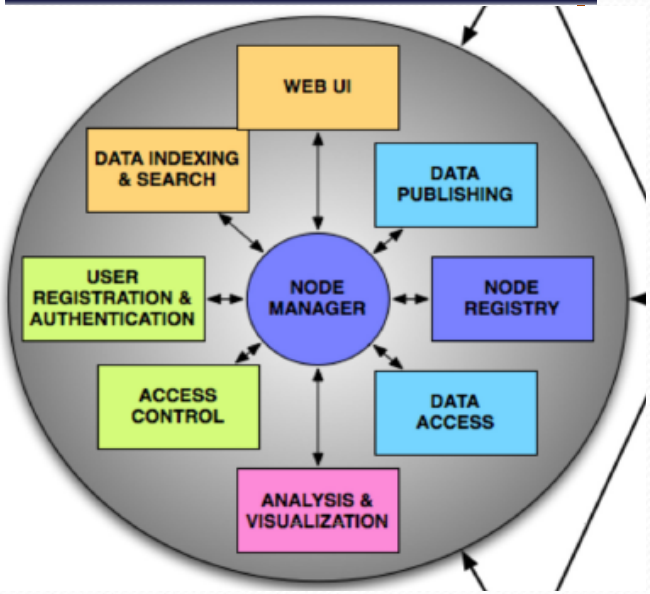
http://esgf.llnl.gov/mission.html

ESGF Earth System Grid Federation

CCCR Centre for Climate Change Research - IITM

Peer Nodes

- ANL Node
- BADC Node
- BNU Node
- CCCR-IITM Node
- CMCC Node
- DKRZ Node
- DMI Node
- E_INIS-ICHEC Node
- IPSL Node
- NASA-GSFC Node
- NASA-JPL Node
- NCI Node
- NERSC Node
- NOAA-ESRL Node
- NOAA-GFDL Node
- ORNL Node
- PCMDI Node
- PIK Node
- SMHI-LIU-NSC Node
- UIO Node
- UNICAN Node



The quality checked CORDEX-South Asia Data are published on the CCCR-IITM Earth System Grid Federation (ESGF) Data Node

The ESGF maintains a global system of federated data centers that allow access to the largest archive of climate data world-wide

http://cccr.tropmet.res.in/home/cordexsa_datasets.jsp

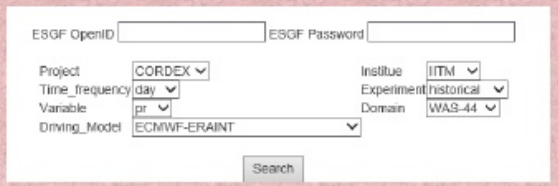
CORDEX South Asia RCM	RCM Description	Contributing CORDEX Modeling Center	Driving CMIP5 AOGCM (see details at https://verc.enes.org/data/enes-model-data/cmip5/resolution)	Contributing CMIP5 Modeling Center
IITM-RegCM4 (6 ensemble members)	The Abdus Salam International Centre for Theoretical Physics (ICTP) Regional Climatic Model version 4 (RegCM4; Giorgi et al., 2012)	Centre for Climate Change Research (CCCR), Indian Institute of Tropical Meteorology (IITM), India	CCCma-CanESM2	Canadian Centre for Climate Modelling and Analysis (CCCma), Canada
			NOAA-GFDL-GFDL-ESM2M	National Oceanic and Atmospheric Administration (NOAA), Geophysical Fluid Dynamics Laboratory (GFDL), USA
			CNRM-CM5	Centre National de Recherches Me´te´orologiques (CNRM), France
			MPI-ESM-MR	Max Planck Institute for Meteorology (MPI-M), Germany
			IPSL-CM5A-LR	Institut Pierre-Simon Laplace (IPSL), France
			CSIRO-Mk3.6	Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia
SMHI-RCA4 (6 ensemble members)	Rossby Centre regional atmospheric model version 4 (RCA4; Samuelsson et al., 2011)	Rosssy Centre, Swedish Meteorological and Hydrological Institute (SMHI), Sweden	ICHEC-EC-EARTH	Irish Centre for High-End Computing (ICHEC), European Consortium (EC)
			MIROC-MIROC5	Model for Interdisciplinary Research On Climate (MIROC), Japan Agency for Marine-Earth Sci. & Tech., Japan
			NOAA-GFDL-GFDL-ESM2M	NOAA, GFDL, USA
			CNRM-CM5	CNRM, France
			MPI-ESM-LR	MPI-M, Germany
			IPSL-CM5A-MR	IPSL, France
MPI-CSC-REMO2009 (1 ensemble member)	MPI Regional model 2009 (REMO2009; Teichmann et al., 2013)	Climate Service Center (CSC), Germany	MPI-ESM-LR	MPI-M, Germany

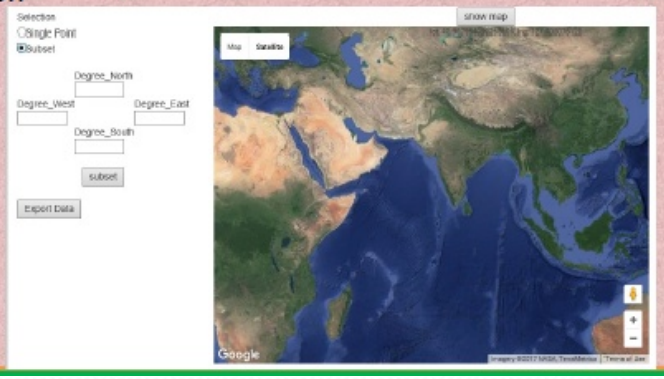
CORDEX South Asia Data Access and Analysis Tools

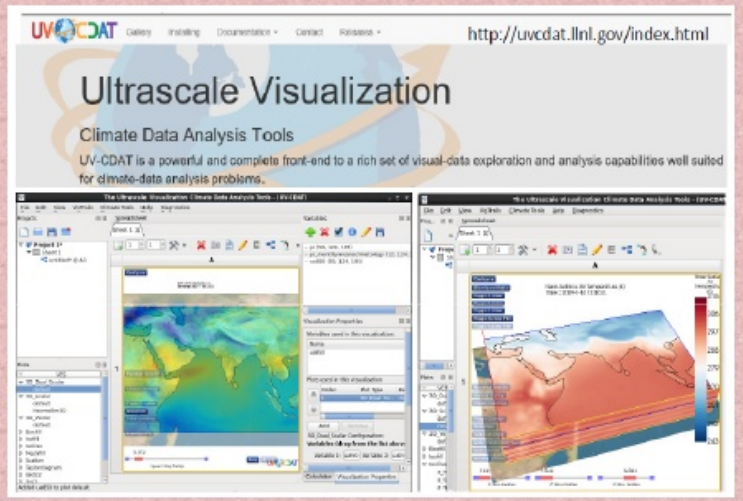
ESGF Data Extraction Tool

http://cccr-dx.tropmet.res.in:8000/projection/

Web Interface based on python developed by CCCR-IITM for users to explore and remotely access subsets of CORDEX South Asia datasets published on ESGF







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The Ultrascale Visualization Climate Data Analysis Tools - (UV-CDAT)

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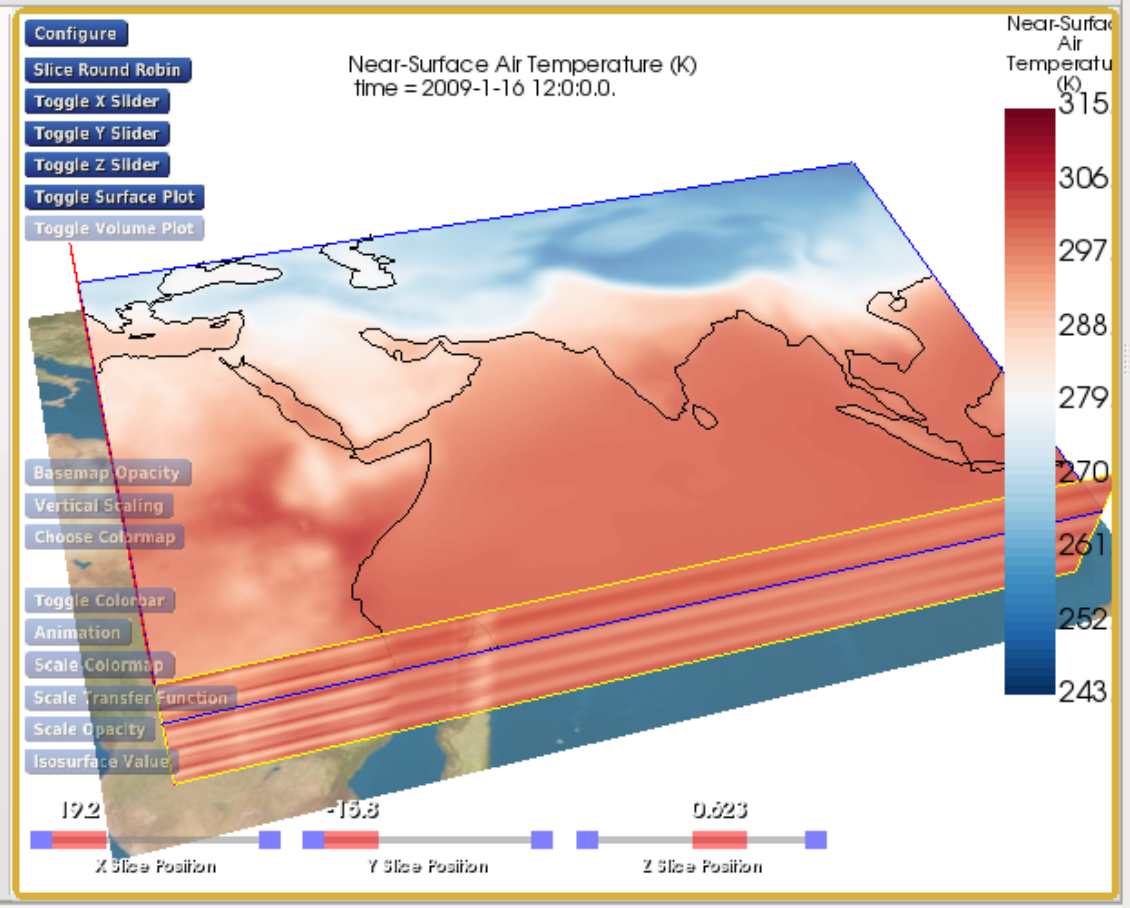

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-- tas_tropical (59, 124, 195)
-- tas_monthlymeansclimatology (12, 124,

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Y Slice -15.75

Z Slice 0.01

Apply Reset

Calculator Visualization Properties

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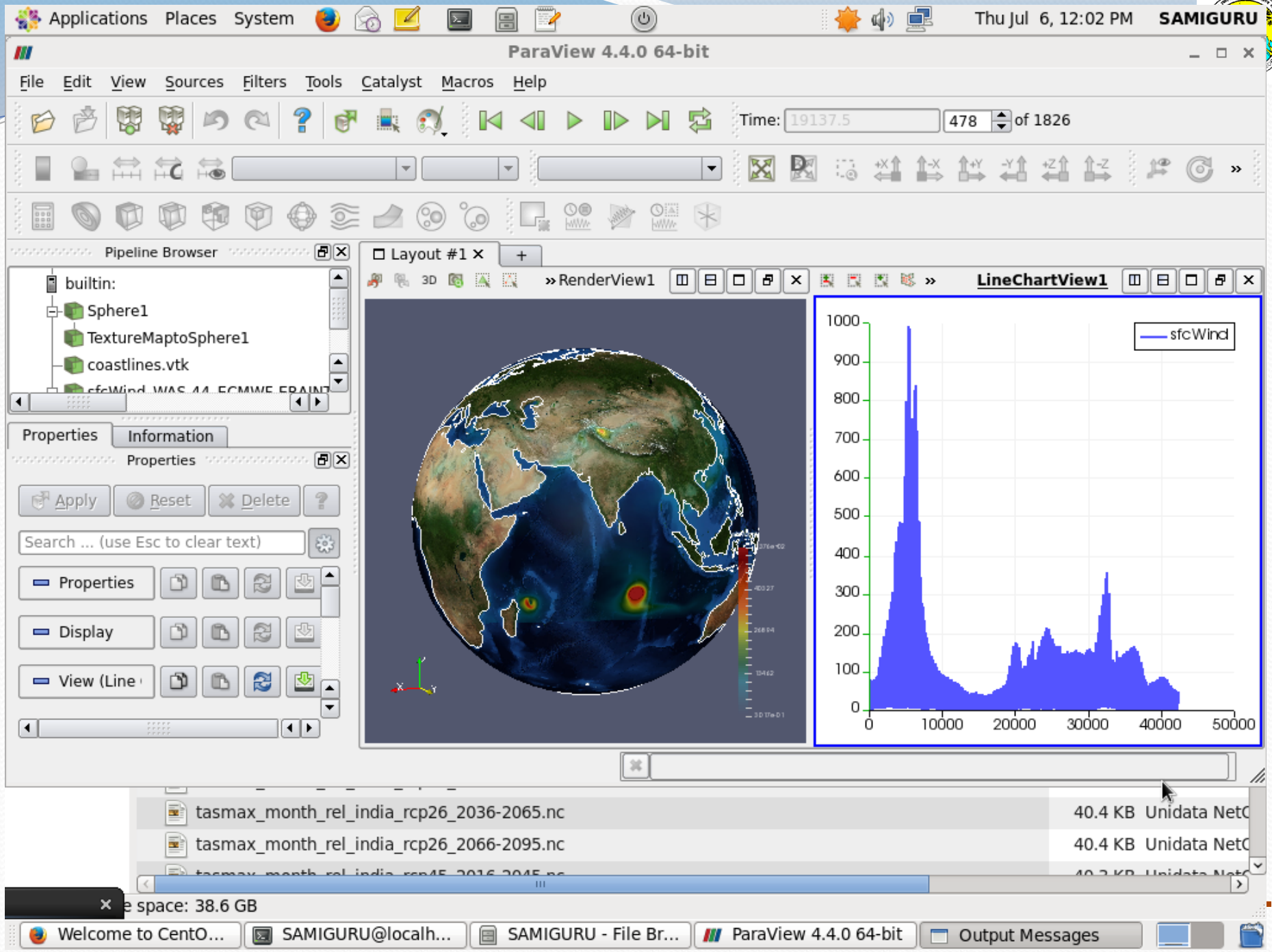
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Output Messages

Thank You