

Dynamic Downscaling to Study Climate Change Impacts on Water Resources in India **RPD-2**

IIT Delhi

IIT Madras

Anna University, Chennai

Banaras Hindu University, Banaras

Partners

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- **BHU Varanasi:**
 - Rajesh Kumar Mall, DST Mahamana Centre of Excellence for Climate Change Research, Banaras Hindu University

Objectives

1. To produce the downscaled climate data (at ~50km) under future scenarios to carry out river basin impact studies.
2. To build capacity within the country to carry out dynamical downscaling.
3. To train manpower to be able to perform dynamical downscaling as well as in utilization of downscaled output.

Downscaling Models Chosen

- Global Climate Model at High Resolution
 - CAM5 (Community Atmospheric Model Version 5” from National Center for Atmospheric Research) **IITD**
- Nested Regional Climate Models:
 - WRF (“Weather Research & Forecast” Model from National Center for Atmospheric Research) **IITM**
 - PRECIS (“Providing REgional Climates for Impacts Studies” from UK Met Office Hadley Centre) **Anna U**
 - RegCM4.6 (“Regional Climate Model Version 4” from ICTP, Trieste) **BHU**

Summary of Downscaling Simulations

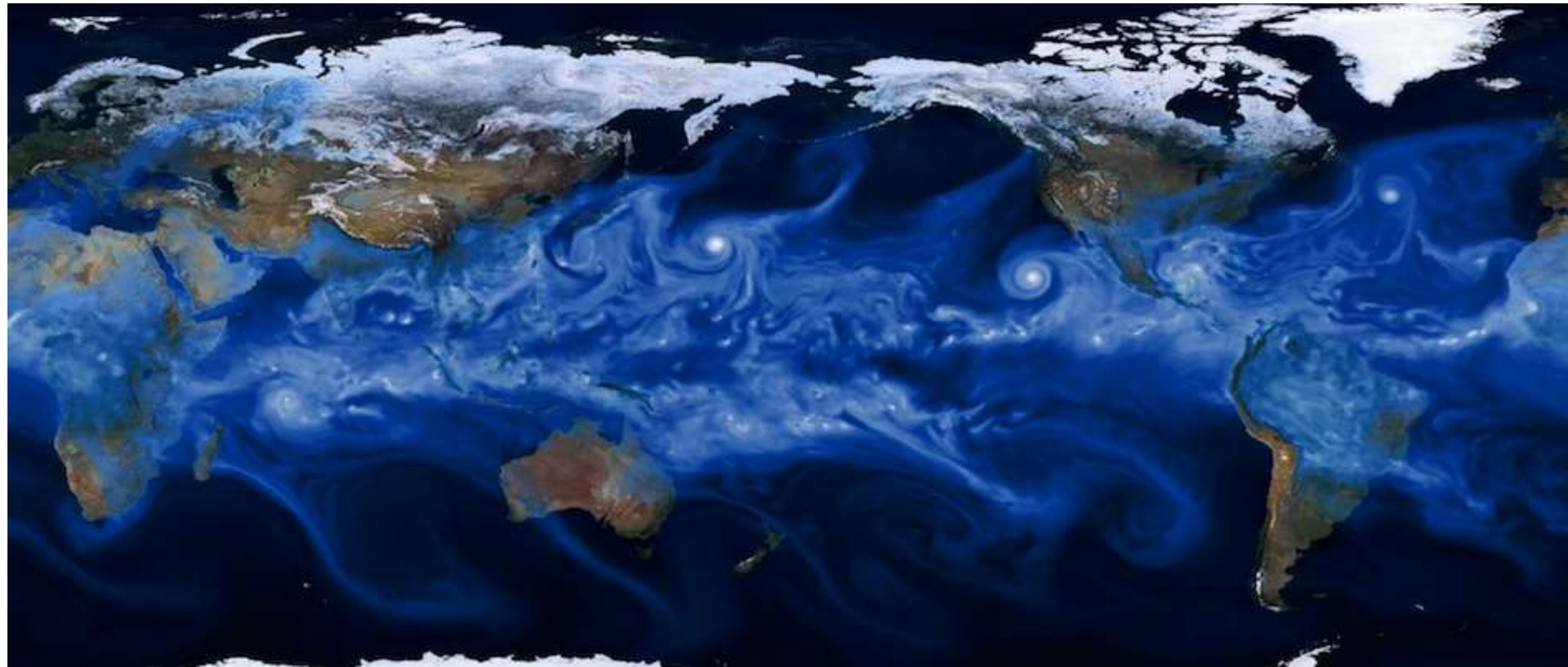
S. No.	Institution	Downscaling Model	Downscaled Resolution	CGCM to be downscaled	Scenario Runs planned	Years	Domain
1	IIT Delhi	CAM5	~50km	CCCMA-CanESM2, CNRM-CM5, MIROC5, MPI-ESM-LR, NorESM1-M.	Historical, RCP4.5, and RCP8.5	Historical: 1950-2005 RCP scenarios: 2006-2100	Entire Globe
2	IIT Madras	WRF	25km	CanESM2 and NorESM1	Historical, RCP4.5, and RCP8.5	Historical: 1950-2005. RCP scenarios: 2006-2100	Entire Country
3	Anna University	PRECIS	25 km	HADGEM2-ES	Historical, RCP4.5, and RCP8.5	Historical: 1970-2005 RCP scenarios: 2006-2100	Entire Country
4	BHU	RegCM4.6	25 km	MPI-ESM-LR and NorESM1-M	Historical, RCP4.5, and RCP8.5	Historical: 1950-2005 RCP scenarios: 2019-2100	Entire Country

Deliverables

- Variables (Minimum list):
 - Daily Rainfall
 - Daily Max and Min Temperatures
 - Daily RH
 - Daily Solar Radiation
 - Daily Wind Speed
- Data Format
 - netCDF format (On model grid)
 - Example scripts to extract as text inputs needed for hydrologic modelling.

IIT Delhi

The Community Atmosphere Model Version 5 (CAM5)

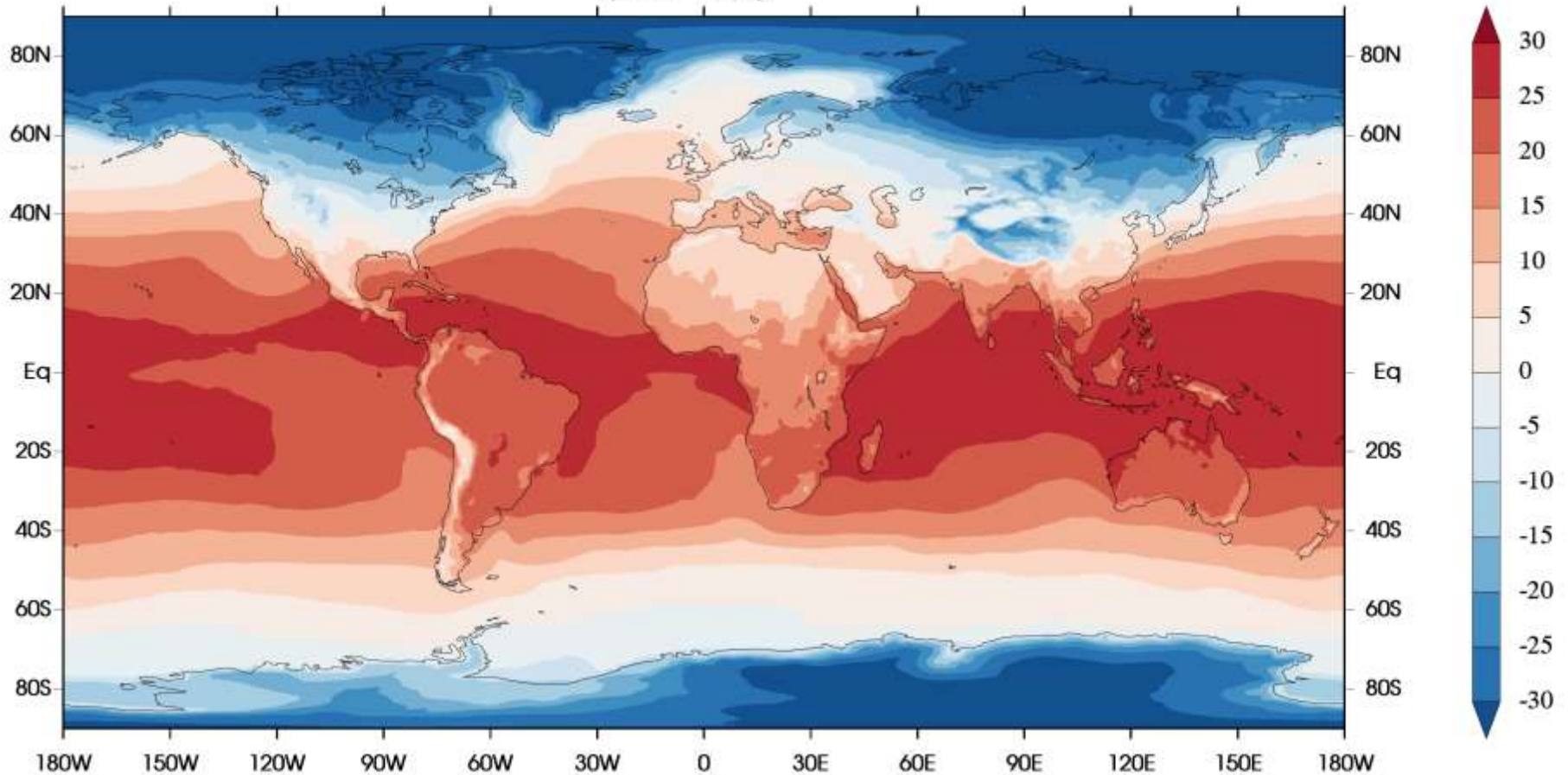


- ~3 mb model top pressure
- Choice of 0.5°, 1°, 2° horizontal resolution
- Choice of 30 or 60 vertical layers
- 30-minute time step
- Finite volume (Fv) dynamical core
- Community Land Model (CLM4.5)
- UW moist turbulence
- UW shallow convection
- UW macrophysics
- Zhang-McFarlane deep convection
- *Morrison-Gettelman* 2-moment stratiform microphysics
- RRTMG radiation scheme
- Choice of 3-mode Modal Aerosol Model (MAM3), 7-mode (MAM-7)

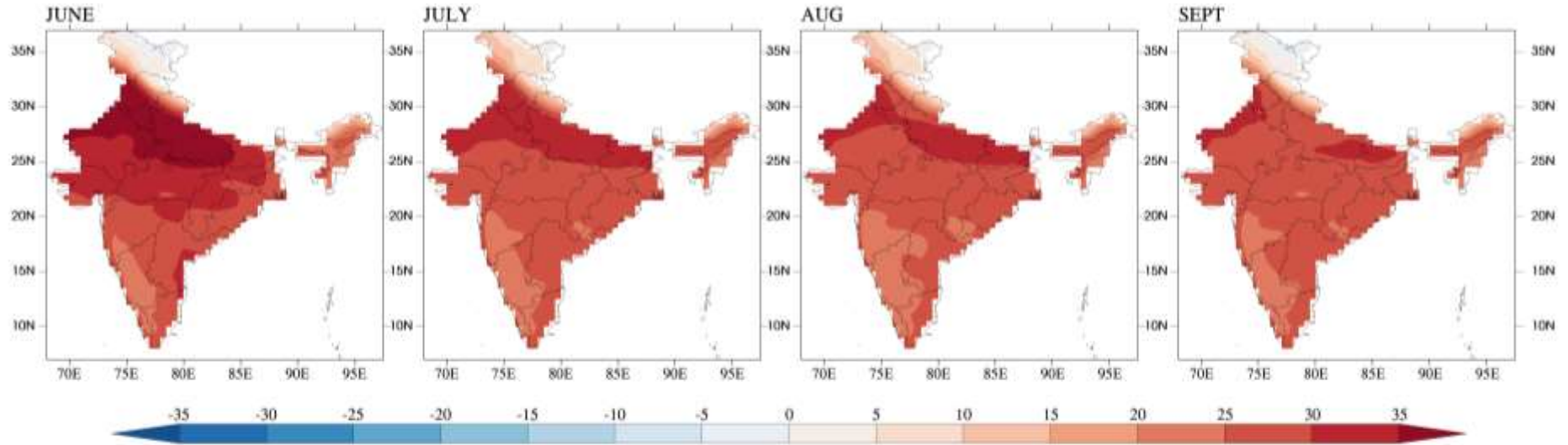
Progress

- Five GCMs to be chosen from CCCMA-CanESM2, CNRM-CM5, MIROC5, MPI-ESM-LR, NorESM1-M.
- Computing time allocation for Rs. 25 Lakhs on IITD Supercomputer PADUM
- Storage server finalized and purchase process to be completed in a week or so.
- Two research scholars currently working on this project
- Historical simulations being carried out.

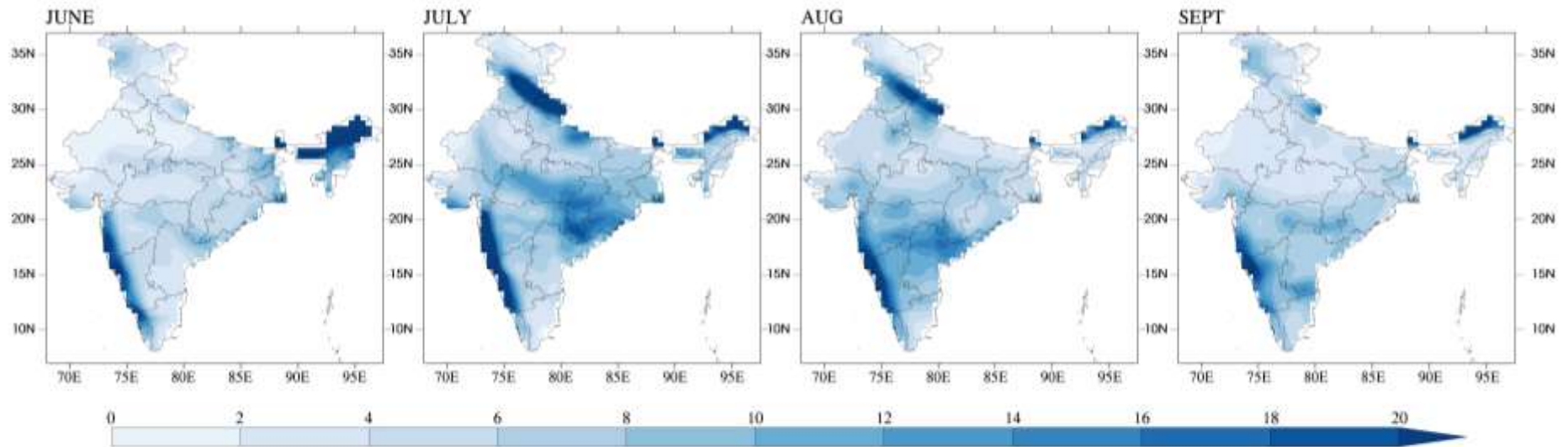
Annual mean of 2-m Air Temperature (°C)
(1951-1953)



Surface Air Temperature (mean) °C



Rainfall mm/day



IIT Madras

Methodology

RCM

WRF model has been chosen by the IIT Madras group to carry out the dynamical downscaling of the two GCMs (CanESM2 and NorESM1).

The first time-slice is chosen to be a recent period with sufficient observations (1950-2005). The two GCMs selected are used for estimating the future change in the climate(2006-2100) under RCP 4.5 and 8.5 scenarios.

A horizontal resolution of 25km (inner domain) has been chosen so as to capture the local sub-grid scale features and dynamics and for assessment of impact of climate change on the water resources of Indian river basins.

BIAS ADJUSTMENT

Downscaled Daily rainfall and temperature data would be assessed for bias. Any bias would be adjusted based on the widely accepted Quantile-Quantile mapping technique

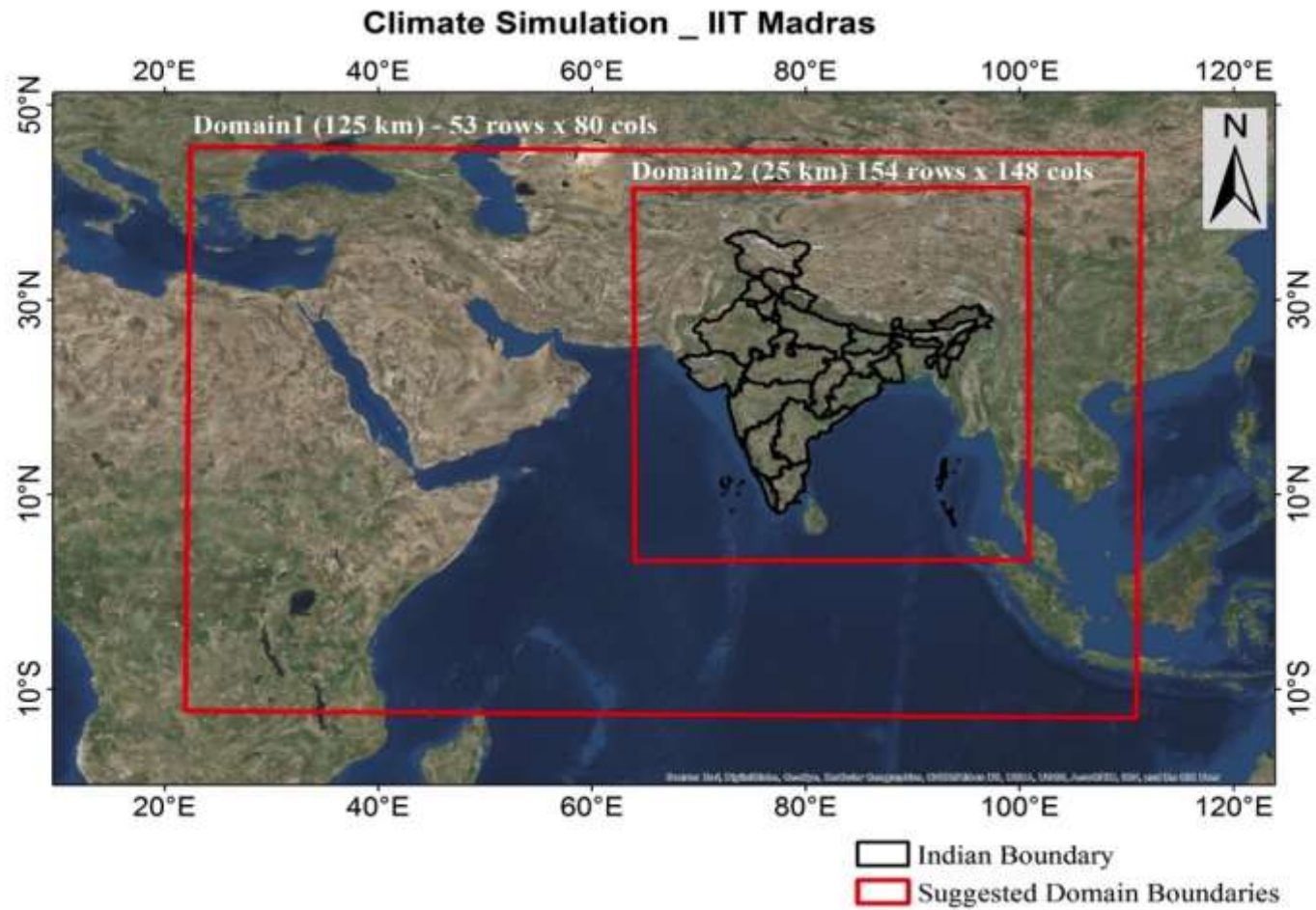


Fig1: Map showing the domains used in WRF

Resources

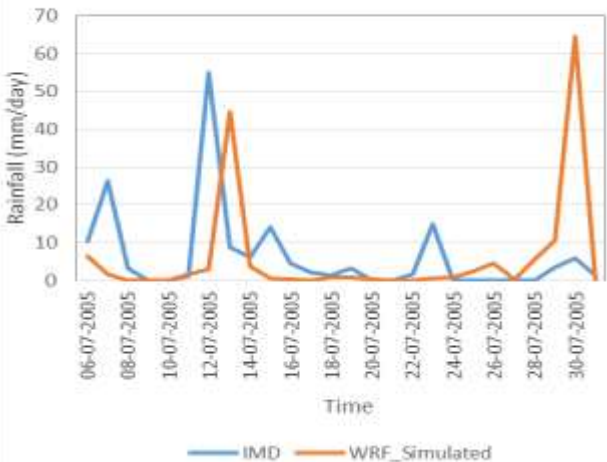
- Access to the VIRGO super cluster of IIT Madras
- Access to the IITM Pune super cluster is being explored
- Orders have been placed for two servers each with 28 cores, 128 GB RAM, and Intel Xeon Gold 2.2GHz processor and 6TB storage
- Two Research Scholars have started working on this project

Downscaling using WRF

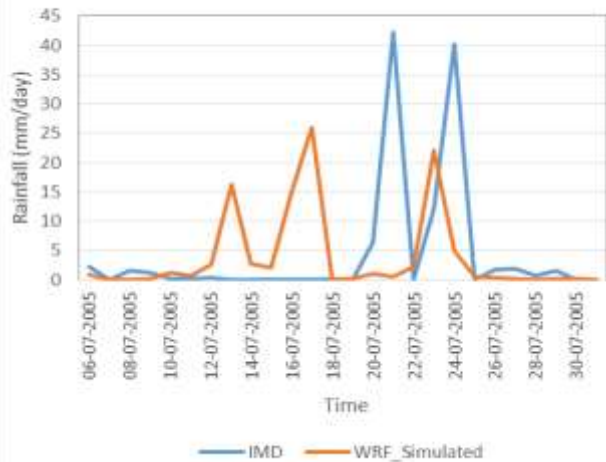
- Model physics options are being checked for robustness with downscaling reanalysis data with WRF
 - ERA-Interim
 - NCEP
 - MERRA
 - JRA-55
- Comparing the downscaled reanalysis with the IMD gridded data

Preliminary Results: Rainfall (July 2005)

Delhi City



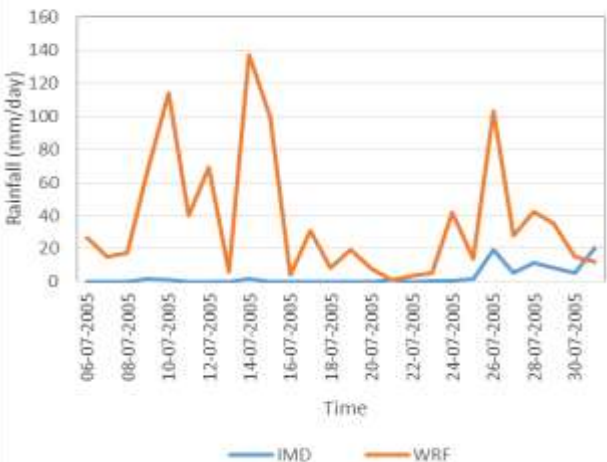
Chennai City



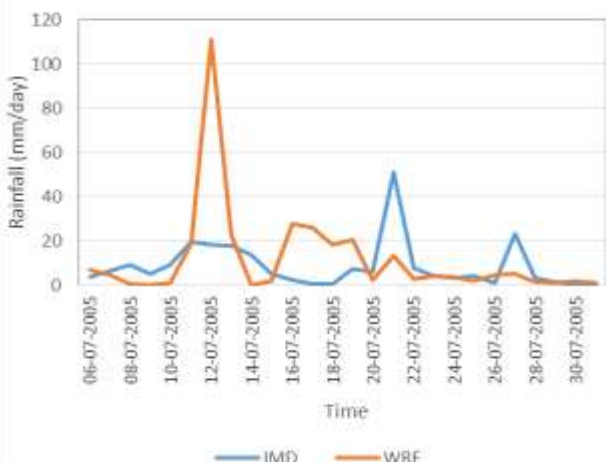
Mumbai City



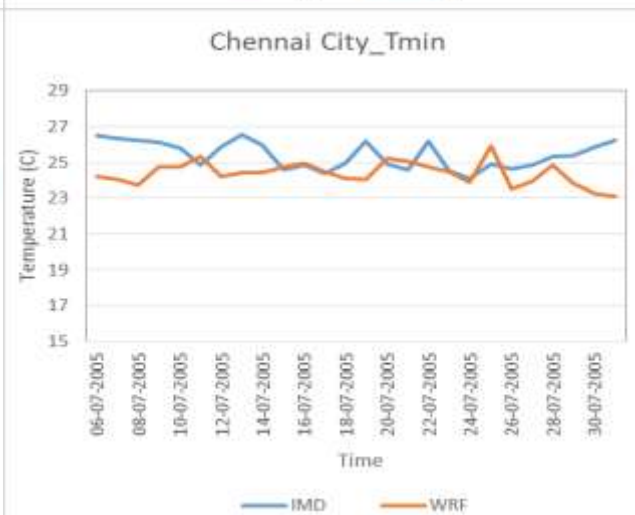
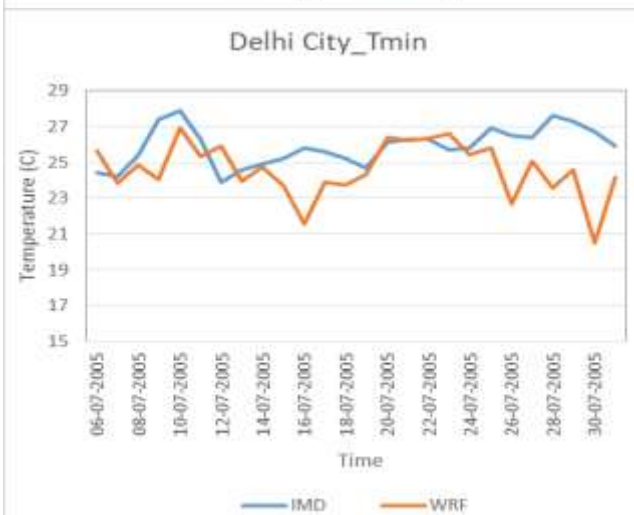
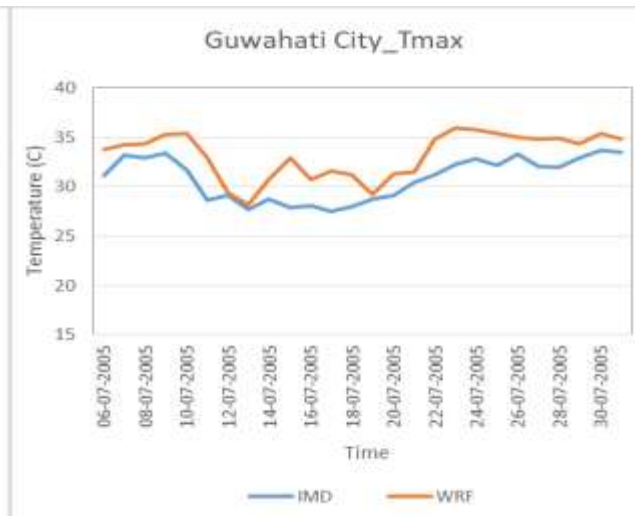
Thiruvananthapuram City

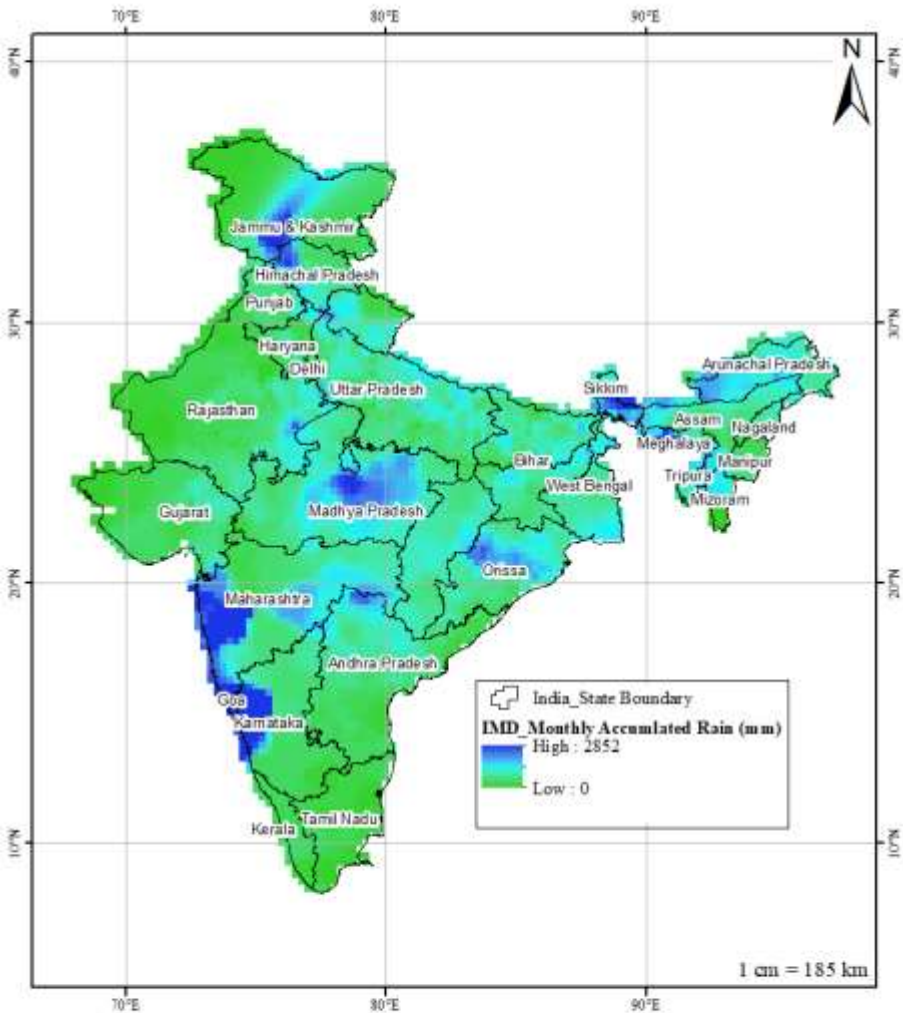


Guwahati City

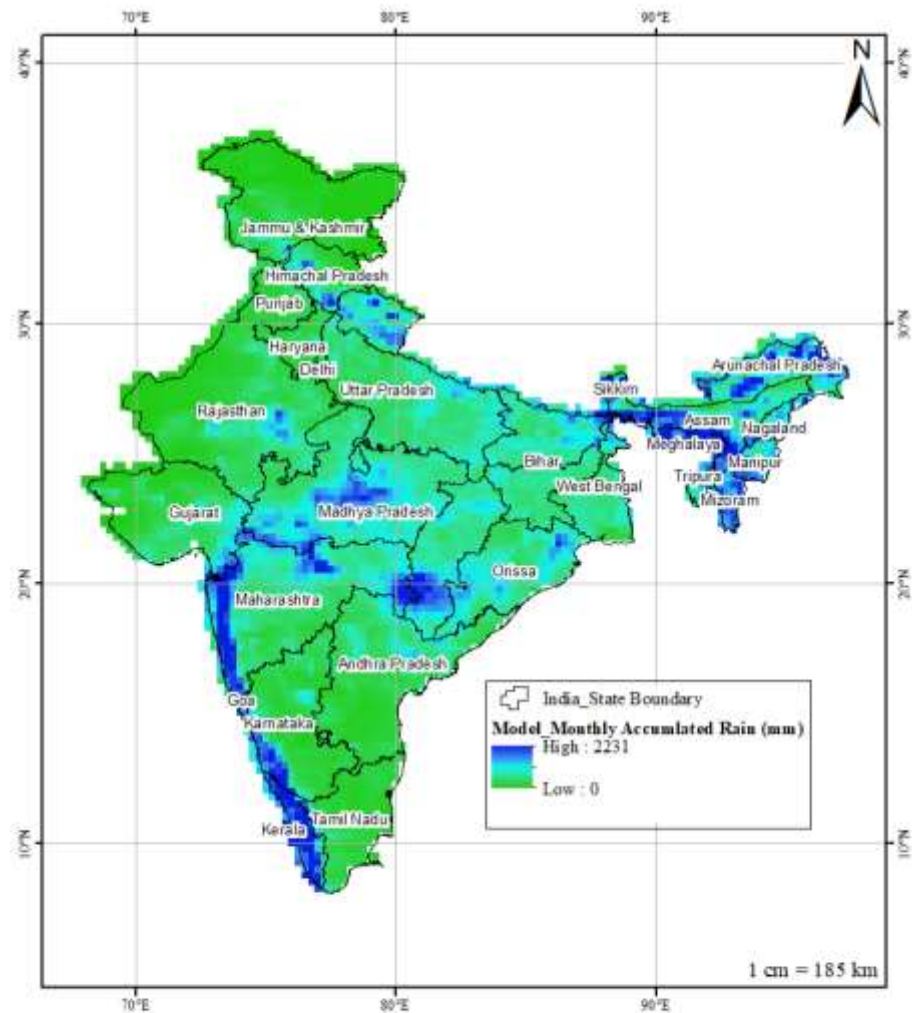


Preliminary Results: Temperature (July 2005)





IMD gridded rainfall July 2005



WRF downscaled rainfall July 2005
(from ERA-Interim)

Progress

- Conducted preliminary study on the performance of CMIP5 GCMs in simulating Indian summer monsoon.
- CanESM2 and NorESM1 GCMs were selected to provide initial and boundary conditions to the Weather Research and Forecasting (WRF) model.
- These GCMs were selected for downscaling to complement the data from CORDEX South-Asia as well as their performance in simulating the Indian Summer Monsoon (Anand et al., 2018; Sengupta and Rajeevan 2013)
- The historical run is with the above GCMs forcing for the period 1950-2005.
- The two future scenarios will be from:
 - RCP 4.5 from 2006-2100
 - RCP 8.5 from 2006-2100
- The model validation will be performed by comparing the WRF simulated variables with possible networks of meteorological weather stations such as gridded weather data such as IMD $0.5^\circ \times 0.5^\circ$ rainfall data and APHRODITE $0.25^\circ \times 0.25^\circ$ rainfall data

Anna University

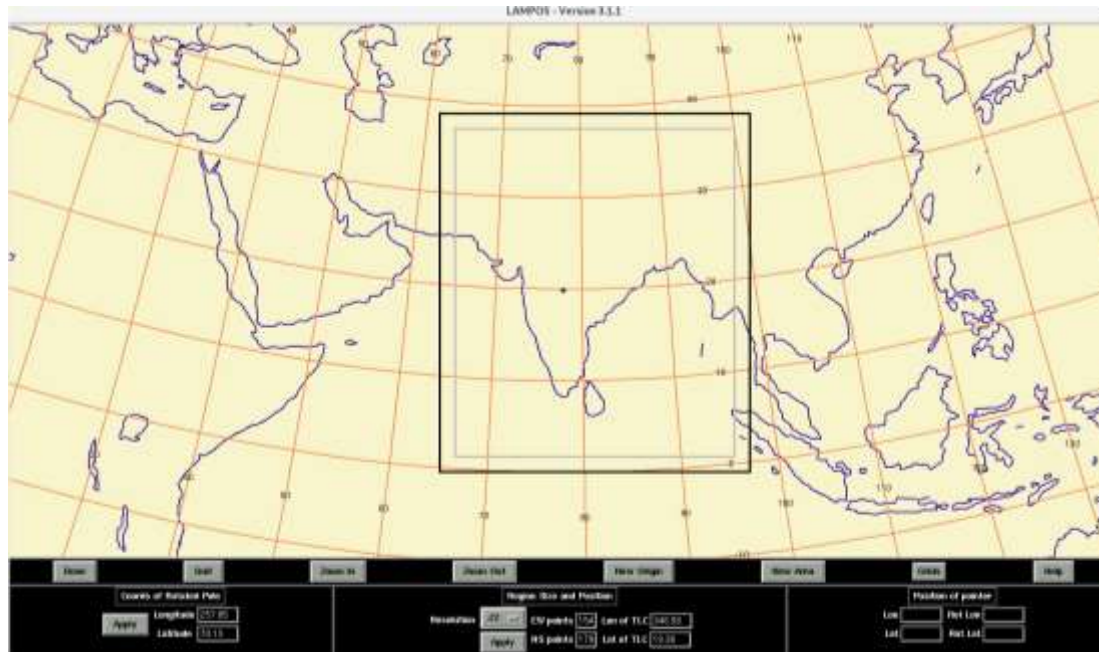
PRECIS-Providing Regional Climate For Impact Studies

The screenshot displays the PRECIS 2.0.0 software interface. The window title is "PRECIS 2.0.0". The menu bar includes "File", "Region Tools", "Configuration", "Monitor", and "Help". The interface features the Met Office Hadley Centre logo on both sides. The central area shows the "PRECIS Version 2.0.0" title. On the left, there is a map of India. The main configuration panel lists the following details:

- Name:
- RunID:
- Region: INDIA
- Resolution: 0.22° (25 km), 150 x 160
- RCM: HadRM3P
- GCM: HadGEM2-ES (akwsl)
- Scenario: rcp4.5
- Start date: 2005/12/1
- Run length: 95 years, 1 month, 0 days
- Calendar: 360 day year
- Output: Hourly and Daily surface & upper air data plus climate meaning
- Land surface: MOSES2
- Description:

On the right side, there are three large buttons: "Run PRECIS" (green), "Monitor PRECIS" (yellow), and "Stop PRECIS" (red). At the bottom, there are five smaller buttons: "New Region", "Edit Region", "Models", "Time", and "Output".

DOMAIN SELECTION



Model Details :

DOMAIN : INDIA (Extents: 3.5° N to 38.5° N , 62.5° E to 101.6° E in rotated pole)

RESOLUTION : 0.22° (25 Km),

GCM : HADGEM2-ES,

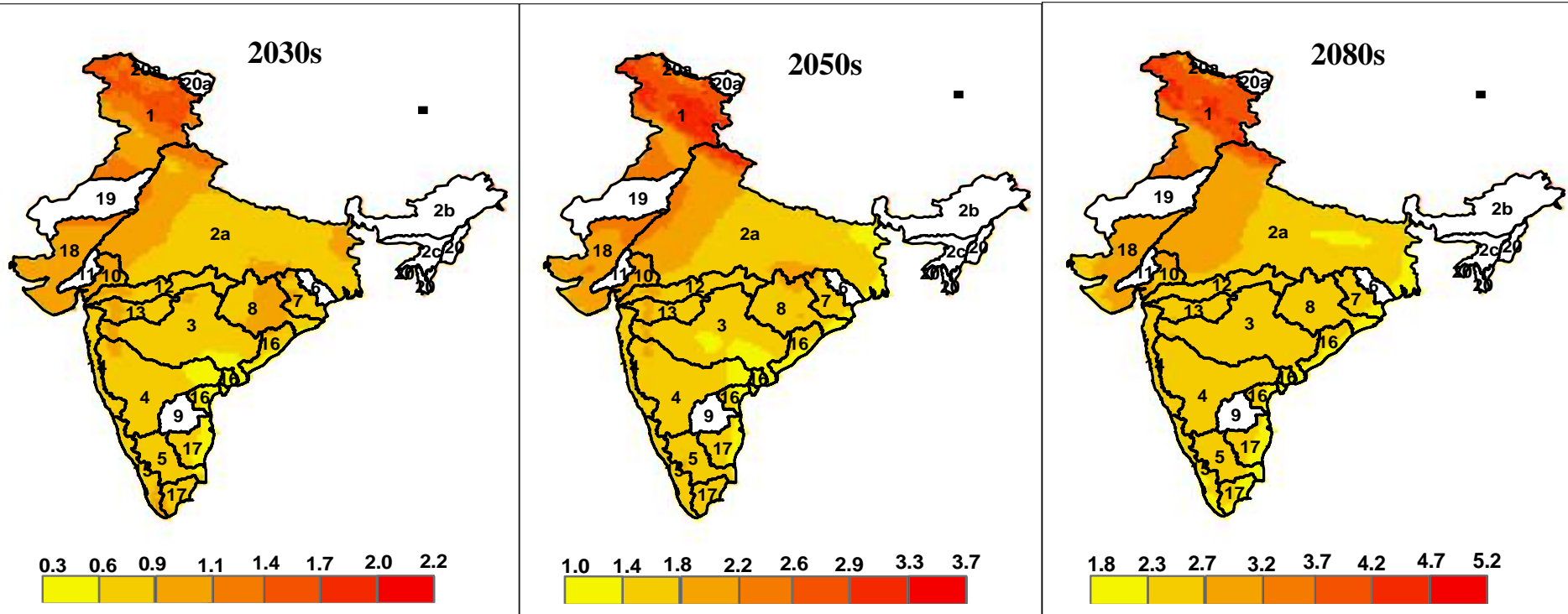
SCENARIOS : RCP 4.5 and RCP 8.5

HISTORICAL : 1970 to 2000,

PROJECTIONS : 2005 to 2099

➤ 1 Research Associate, 1 SRF and 1 JRF were appointed in this project on 10th May 2018.

MAXIMUM TEMPERATURE PROJECTIONS FOR INDIA USING RCP 4.5



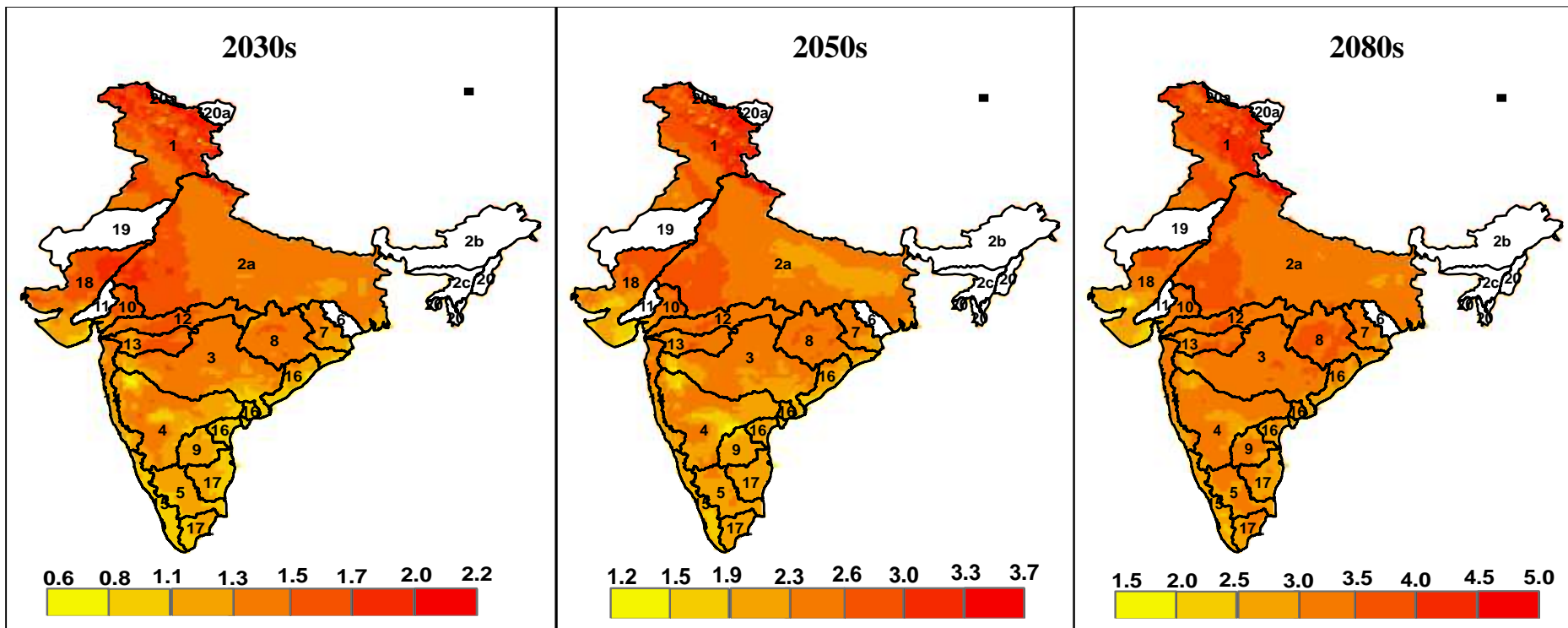
Increase of Maximum Temperature with respect to baseline(1970-2000):

2030s(2005 – 2035) – 0.3 to 2.2 °C

2050s(2035 – 2065) – 1.0 to 3.7 °C

2080s(2065 – 2095) – 1.8 to 5.2 °C

MINIMUM TEMPERATURE PROJECTIONS FOR INDIA USING RCP 4.5



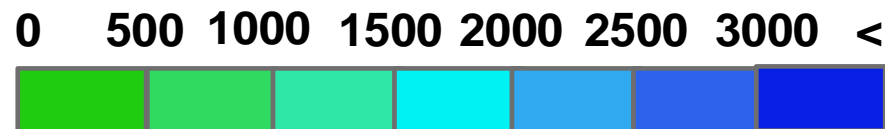
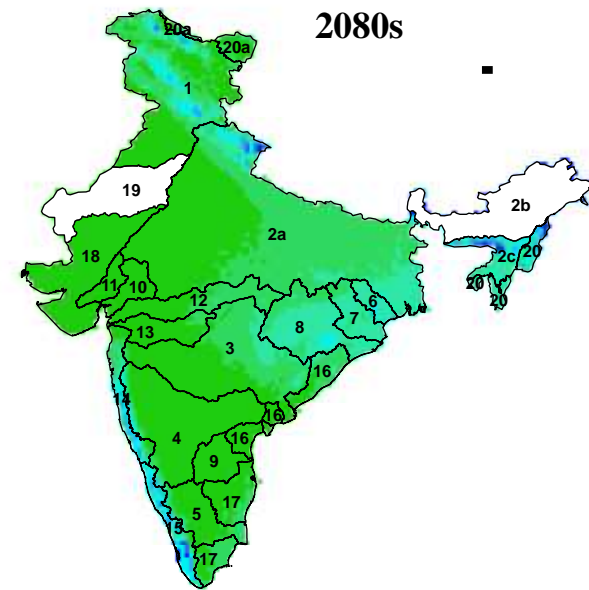
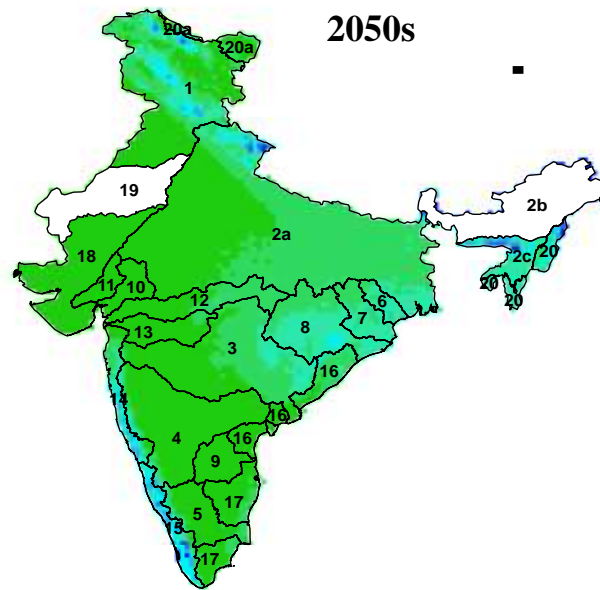
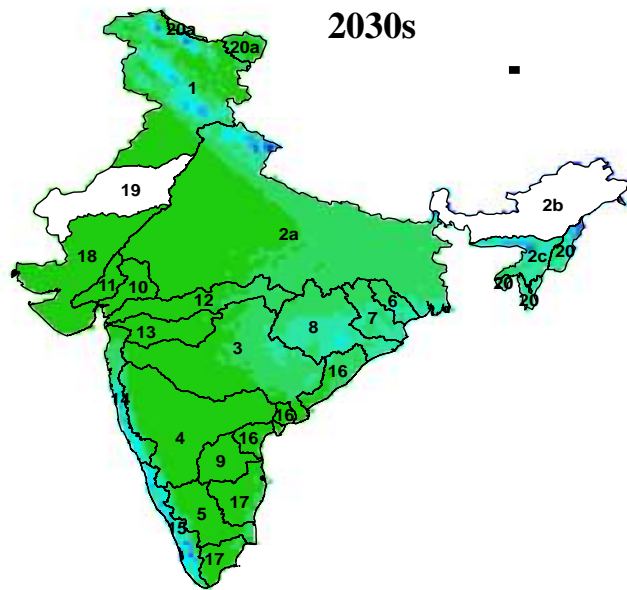
Increase of Minimum Temperature with respect to baseline(1970-2000):

2030s(2005 – 2035) – 0.6 to 2.2 °C

2050s(2035 – 2065) – 1.2 to 3.7 °C

2080s(2065 – 2095) – 1.5 to 5.0 °C

ANNUAL RAINFALL PROJECTIONS FOR INDIA USING RCP 4.5



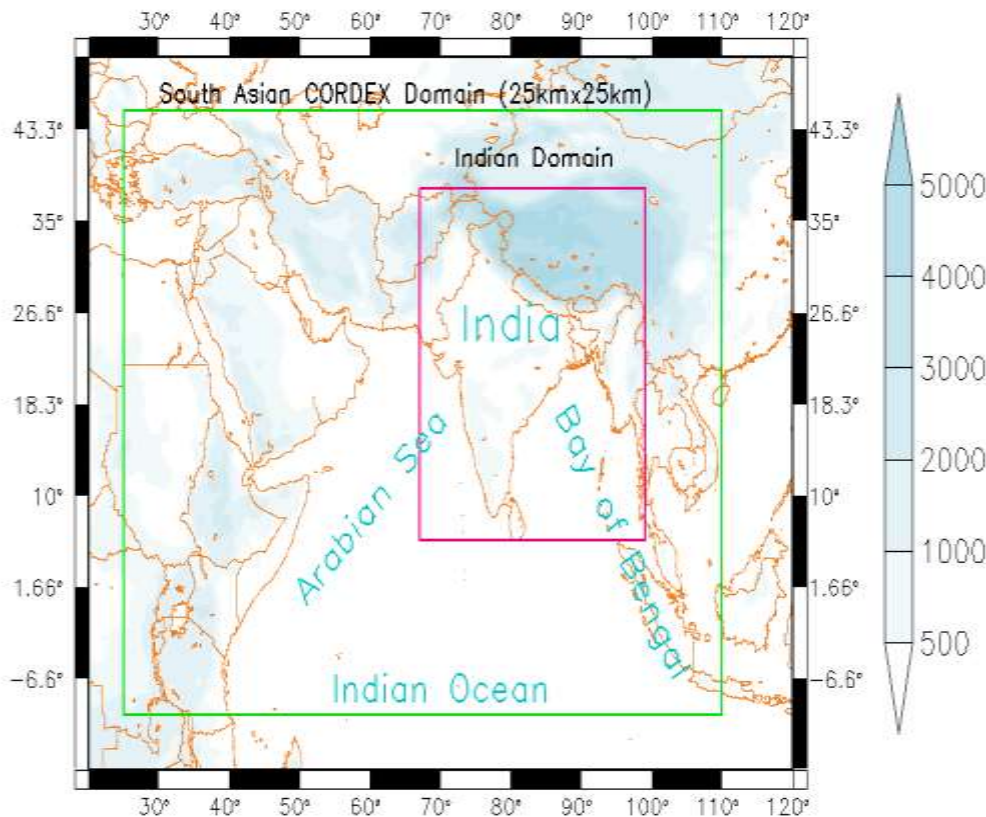
BHU

DST Mahamana Centre of Excellence
for Climate Change Research
Banaras Hindu University

Model domain for the simulations

RCM:

- Regional Climate Model: RegCM version 4.6
- Resolution: 25 x 25 km



Work in progress:

Sensitivity study on different land surface parameterizations scheme.

Downscaling of GCM model data output for future projection of climate.

Analysis of different hydrological events.

Experiment Design

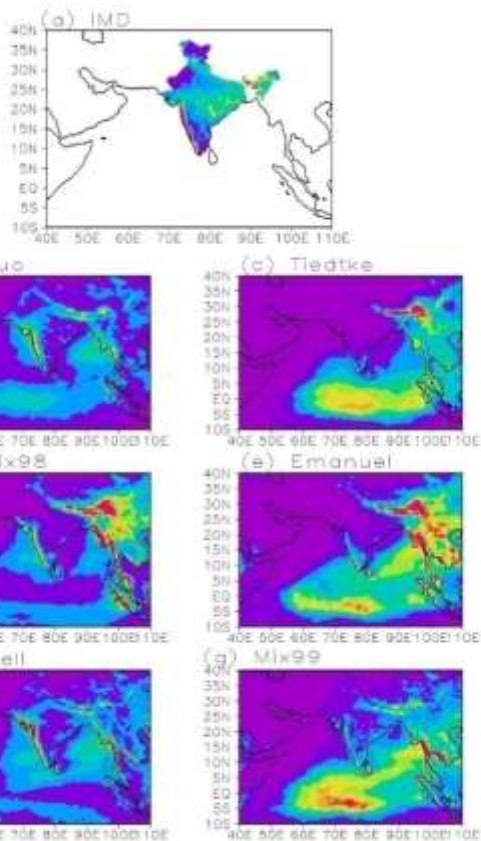
- RegCM-4.6 model (Giorgi et al., 2012) was run over India domain for the period of 2013, 2014 and 2015.
- ICBC is taken from ERA-Interim reanalysis at $1.5^{\circ} \times 1.5^{\circ}$ resolution.
- SST for the model initial condition is taken from NOAA optimum interpolation (OI) global data at $1^{\circ} \times 1^{\circ}$ resolution
- Historical run is 1950 - 2005
- Will be validated based on available observation and reanalysis datasets from various organizations viz., NCEP, EIN, IMD, TRMM, APHRODITE. GPCP, GPCC, CRU etc.
- AOGCMs :MPI-ESM-LR and NorESM1-M
- For the Future scenario is 2019-2100 (RCP scenarios 4.5 and 8.5)

Resources

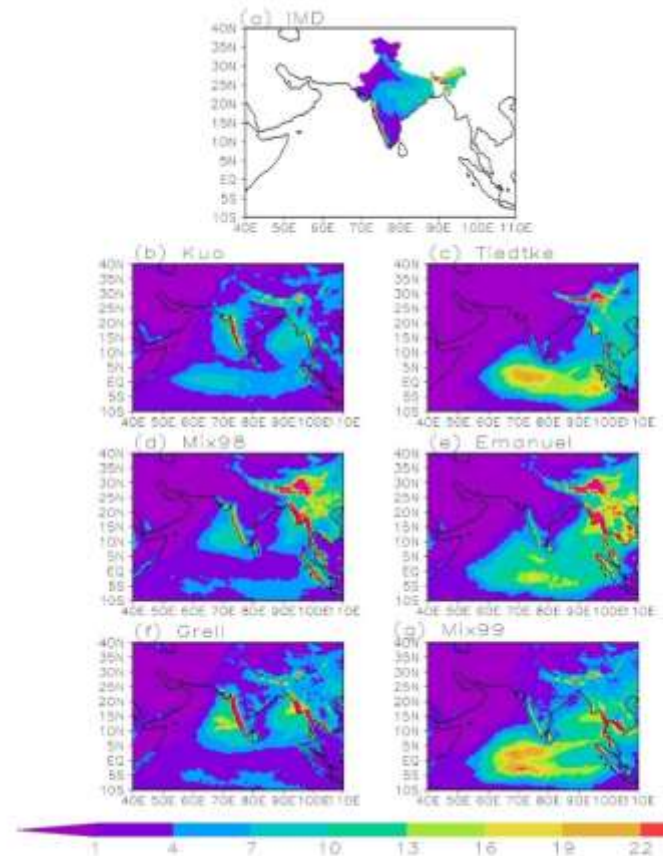
- Access to server of IESD, BHU.
- Orders have been placed for 44 TF clock speed with 170 TB storage server. 18 cores Intel Xeon Gold Processor 2.3 GHz with 192 GB RAM (1 master node, 16 compute node and 1 storage node).
- One Research Scholar and one Research Associate have started working on this project

Preliminary results of Sensitivity study

Flood Events



Drought Events



Sensitivity analysis showing the composite monsoon rainfall pattern over Indian subcontinent during flood and drought events simulated by different cumulus parameterized schemes of RegCM4 (1981-2012).

Calibration and validation of RegCM

Statistical error of seasonal Maximum Temperature

The Root Mean Square Error for a series of N forecasts is given by:

$$RMSE = \left[\frac{1}{N} \sum_{i=1}^N [(F_i - O_i)^2]^{\frac{1}{2}} \right]$$

$$\text{Index of Agreement} = 1 - \left[\frac{\sum_1^n (O - M)^2}{\sum_1^n (|M - \bar{O}| + |O - \bar{O}|)^2} \right]$$

$$\text{Mean Bias} = \frac{1}{n} \sum_1^n (M - O)$$

$$\text{Mean Error} = \frac{1}{n} \sum_1^n |M - O|$$

City	MAE	MBE	RMSE	IA
Allahabad	2.48	-2.10	2.97	0.93
Kolkata	3.88	-3.82	4.46	0.81
Jharsuguda	1.99	-1.62	2.47	0.88
Hyderabad	2.32	-1.75	2.62	0.81
Bhubaneswar	6.78	-6.76	7.04	0.64
Delhi	2.11	-1.40	2.60	0.96

Thanks