Environmental and Water Resources Engineering
Department of Civil Engineering
Indian Institute of Technology Madras

Workshop on "Integrating Climate Action in the Development Planning of Puducherry Union Territory"

Multimodal Climate Change Assessment – A case study of Puducherry

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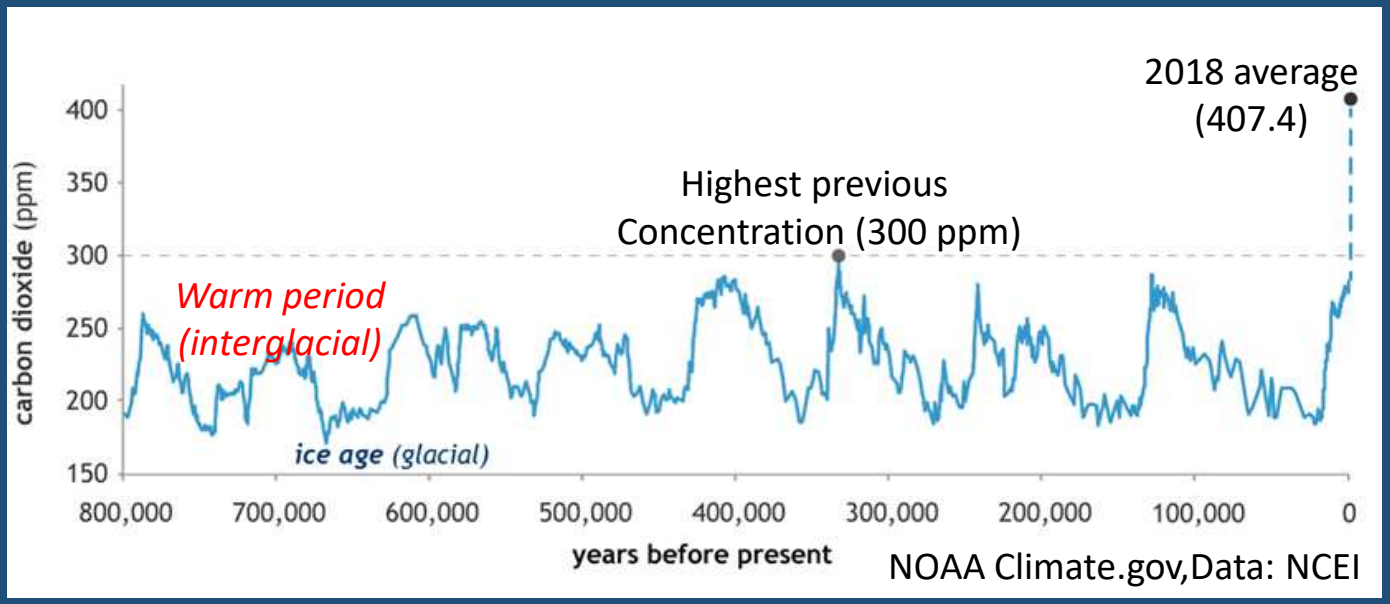
ABOUT CLIMATE CHANGE

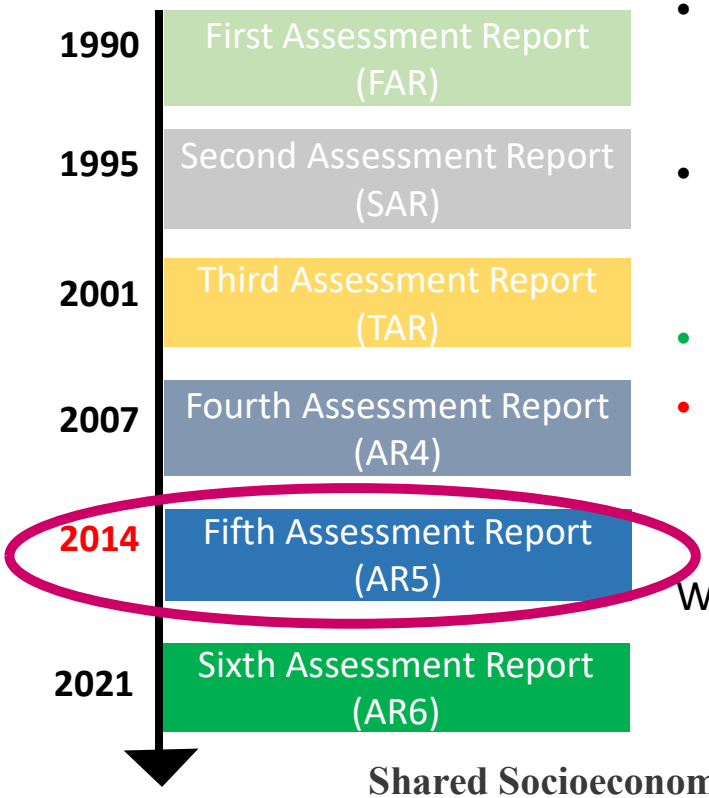
For the first time in last 300,000 years the carbon dioxide level has gone more than 300 ppm

Post industrialization, the CO_2 level has gone to 400 ppm

CO_2 during ice ages and warm periods for the past 800,000 years



Intergovernmental Panel for Climate Change



- Created in **1988** by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP)
- Responsible to provide governments at all levels with scientific information that they can use to develop climate policies
- **AR6** is the latest report
- **AR5** is used in the present work where four possible future scenario based on GHGs emission

RCP 2.6 **RCP 4.5** **RCP 6.0** **RCP 8.5**

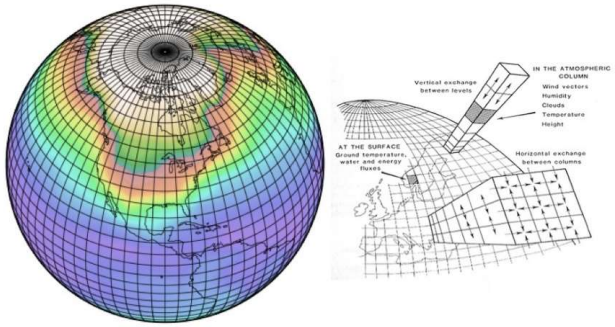
Where, RCP is Representative Concentration Pathways

Shared Socioeconomic Pathway (SSP)

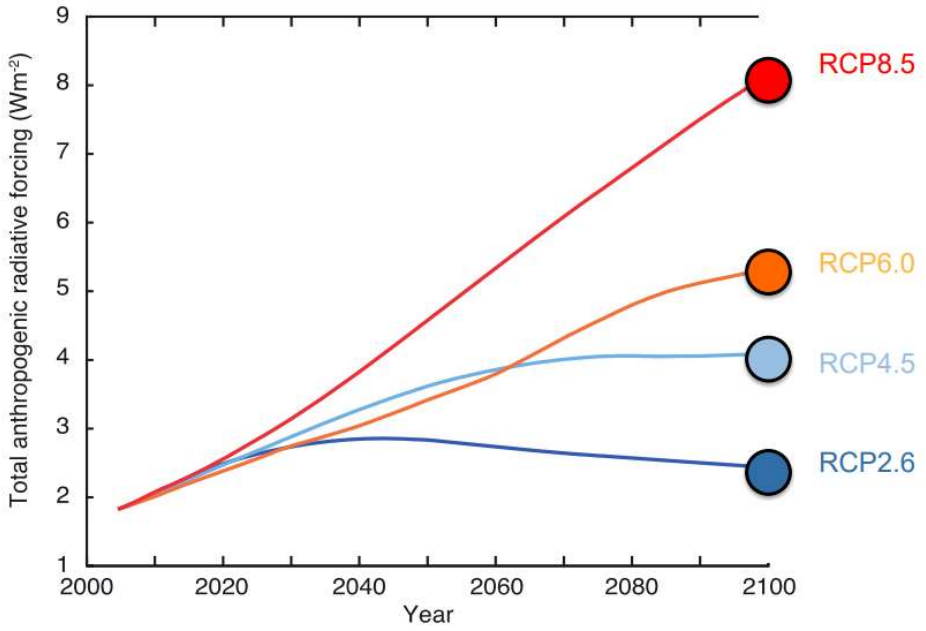
GENERAL CIRCULATION MODELS (GCMs)

- **Global Climate Models (GCMs)** are the primary tool for understanding how the global climate may change in the future.
- **Numerical model** - represent physical processes in the atmosphere, oceans, cryosphere and land surface. They depict climate using a three-dimensional grid.

Three-dimensional models which simulate the atmosphere, Atmospheric General Circulation Models (AGCMs) and a model to simulate the ocean, Ocean General Circulation Models (OGCMs)is coupled to form an atmosphere-ocean coupled general circulation model



Fifth Assessment Report (AR5)



- Consist of an **even number** of scenarios, in order to avoid a clear middle scenario
- **Year 2100** is selected as the base year to stabilizing the radiative forces
- **"Concentration"** is used instead of "emissions (as used in AR4 and earlier report) "

To emphasize that **concentrations are used as the primary product** of the RCPs, designed as input to climate models

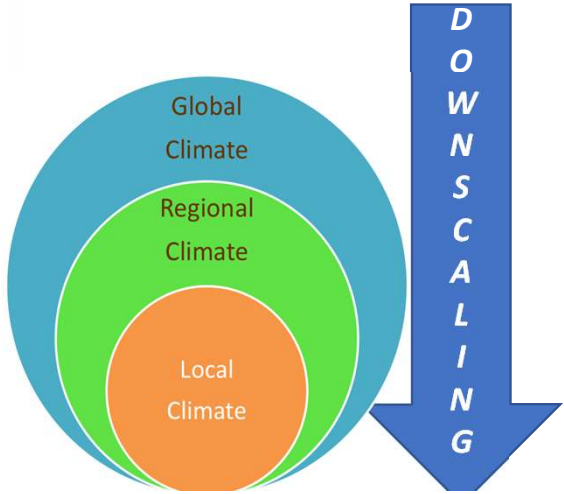
Representative Concentration Pathways (RCPs)

KEY CHALLENGES

- **GCMs accuracy** decreases from free tropospheric variables to surface variables

  Atmospheric Variable, Land Surface variable, Oceanic variable

- Downscaling – Statistical and Dynamic
- Spatial mismatch
  - Scale ranges from 100-150 km
- Model **uncertainty**
  - **Temporal reliability – Monthly, Daily, Hourly**
  - **Model reliability**



Envelop of Uncertainty

Some of the models shows a consistent bias under different scenarios in different regions.

The uncertainty among various models are also quite high

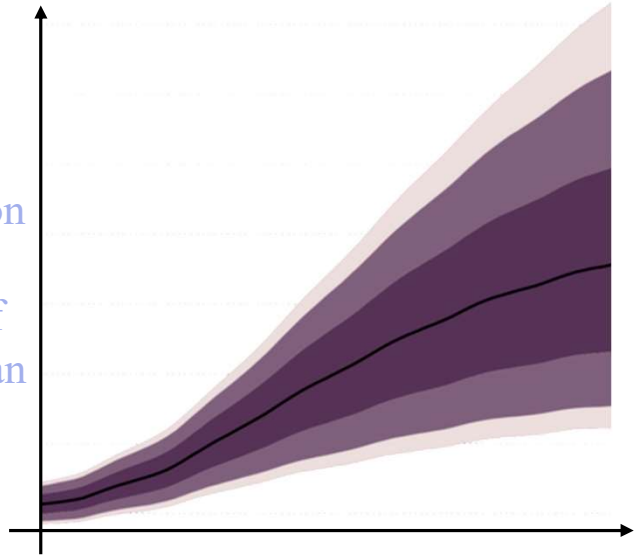
i.e. some models predicts (+) change in precipitation while some predicts (-) change

Multimodal Climate Change Prediction

A single model analysis may not be sufficient to establish a possible climate change projection.

Researchers have advocated use of **multimodal climate analysis.**

However, a **simple averaging** of multimodal prediction **may give an unrealistic results** if one single model is an outlier



Reliability Ensemble Averaging

Reliability of a model depends on

ability of a GCM to reproduce different aspects of present-day climate – **"model performance"**

convergence of simulations by different models for a given forcing scenario – **"model convergence"**

(greater convergence implying higher reliability of robust signals)

$$R_i = \left[\frac{\epsilon_T}{abs(B_{T,i})}\right]\left[\frac{\epsilon_T}{abs(D_{T,i})}\right]$$

ϵ_T is the measure of natural variability in 30-yr average regional precipitation

Model Bias

Absolute difference between simulated and observed mean precipitation for the present-day period of 1971–2000

Model Convergence

Distance of the change calculated by a given model from the REA average change

Reliable Ensemble Average Change

and uncertainty range

$$\widetilde{\Delta P} = \frac{\sum_i R_i \Delta P_i}{\sum_i R_i} \qquad \widetilde{\delta_{\Delta P}} = \left[\frac{\sum_i R_i \left(\Delta P_i - \widetilde{\Delta P}\right)^2}{\sum_i R_i}\right]^{1/2}$$

A Multimodal Precipitation Change - A Case Study of Puducherry

- Based on **AR 5** of IPCC
- Grid size is around 100 km ×100 km
- 7 GCM models are used
- Seasonal variability of precipitation is assessed
- Two hydrological cycle years have been selected for future prediction: **2021–2050 (Near future)** and **2051–2080 (Far future)**

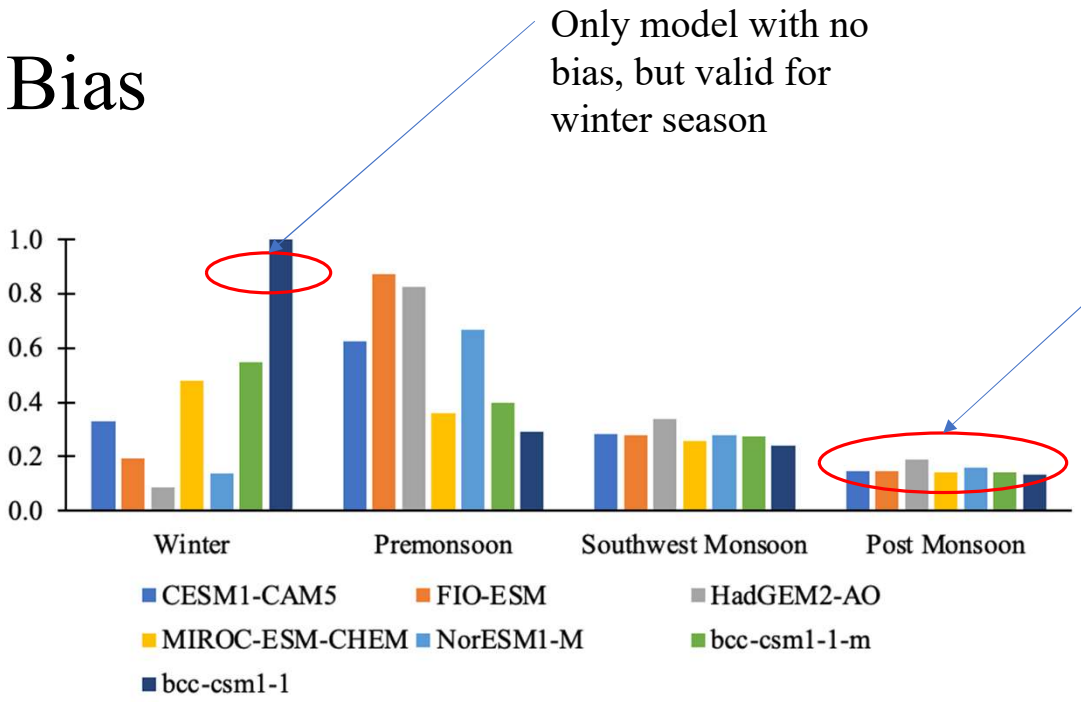
Mean seasonal rainfall

	Winter	Pre-monsoon	Southwest Monsoon	Post Monsoon
Mean rainfall (mm)	42.12	118.1	382.6	637.3

Experiment	Centre	Location
BCC CSM 1.1 M	Beijing Climate Centre	China
BCC CSM 1.1	Beijing Climate Centre	
FIO ESM	The First Institute of Oceanography	China
MIROC ESM CHEM	Atmosphere and Ocean Research Institute, National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Tech.	Japan
NCAR CESM 1 (CAM5)	National Center for Atmospheric Research	USA
NCC NOR ESM1 -M	Bjerknes Centre for Climate Research, Norwegian Meteorological Institute	Norway
NIMR KMO KadGEM2 A0	National Institute of Meteorological Research, Korea Meteorological Administration	South Korea

https://www.ipcc-data.org/sim/gcm_monthly/AR5/Reference-Archive.html

Model Bias



Model bias depends mainly on the difference between the observed data and historical simulated data, irrespective of any scenario

The model bias is very consistent in the post monsoon season

A typical value of 1 indicates that the model does not have any systematic bias.

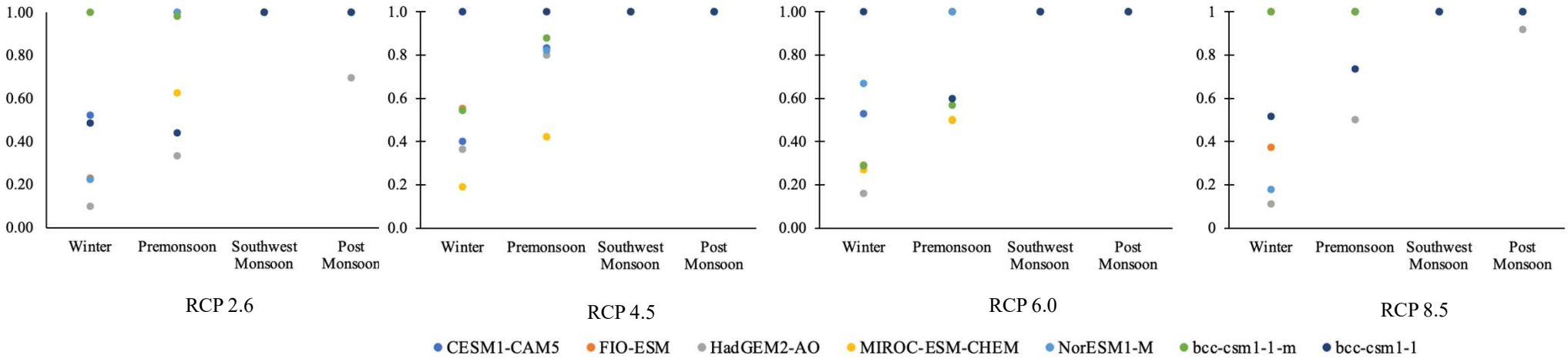
Lower the value, higher the bias

Model Convergence

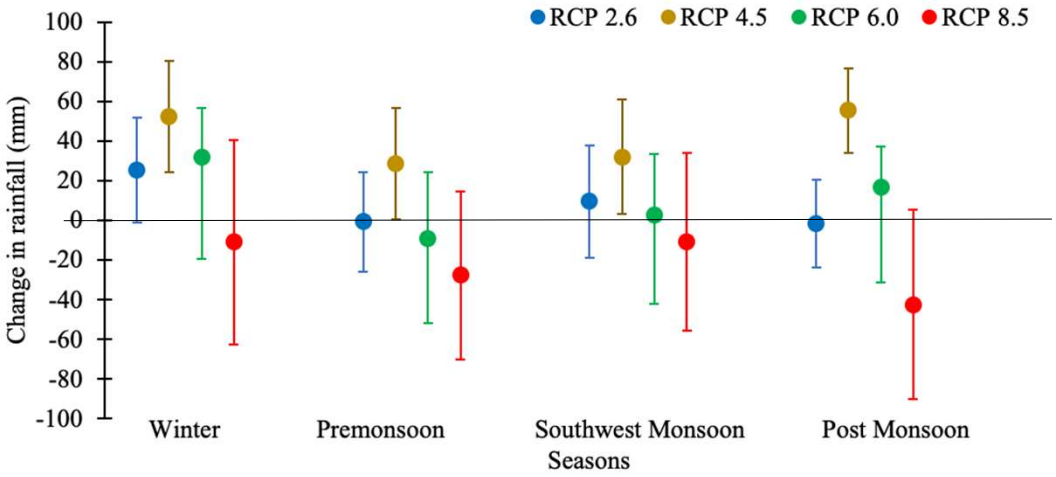
Most of the models have model convergence 1. Hence, the variability in the projection of climate among various models is very less

The model **Had GEM2-A0** performs poorly in all the scenarios with least convergence

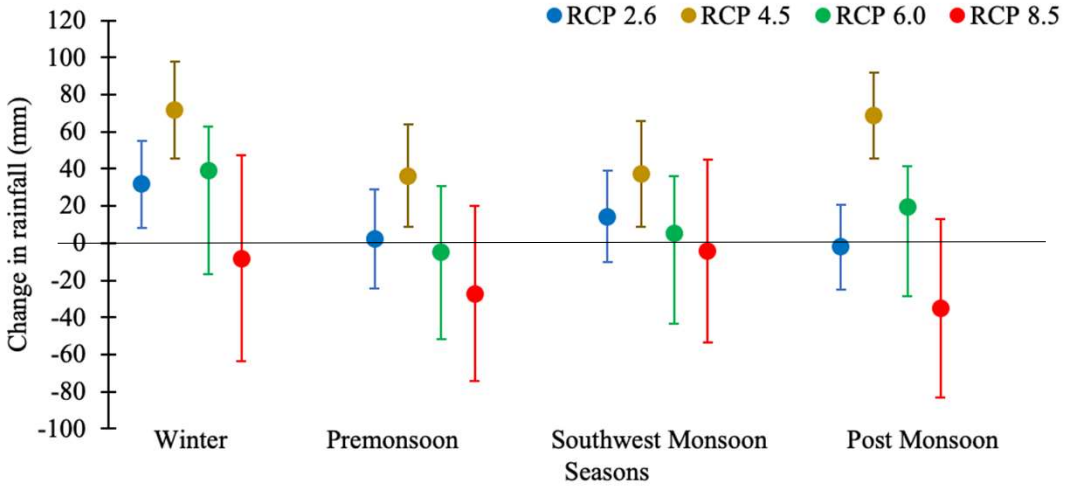
All the models consistent in predicting southwest monsoon and post-monsoon period, with maximum variation in winter season



Near end Prediction



Far end Prediction



The mean seasonal change in both the period (near end and far end) are comparatively similar

Under RCP 2.6 the mean seasonal change in minimal.

All the models indicates that increase in precipitation in maximum in RCP 4.5

Under RCP 8.5, the models shows a continuous decline in mean seasonal rainfall

It should also be noted that the amount of change in **mean precipitation** is in the range of -50 to 50 mm

RCP 4.5 shows overall increase in the mean seasonal rainfall of all the season.

The winter precipitation shows an increase in rainfall for RCP 2.6, RCP 4.5 and RCP 6.0

Summary

- The uncertainty in the climate model need to be assessed with the confidence interval, and is important for decision making
- Proper choice of Climate model, **downscaling technique** can minimize the uncertainty in the modelling
- **Ensemble of set of realization** can give a better result for forecasting climate change projection