Earth System Modelling with Special Focus on South Asian Region

Swapna Panickal
Centre for Climate Change Research
Indian Institute of Tropical Meteorology, Pune
E-mail: swapna@tropmet.res.in

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IITM-ESM for long-term climate change studies
Centre for Climate Change Research

Atmosphere: GFS (Global Forecast System)
- T62; vertical: 64 sigma – pressure hybrid levels
- Resolution ~200 km
- Model top 0.2 mb
- Prescribed MAC-v2 aerosols

Land surface: Noah LSM

Ocean: Modular Ocean Model v4p1 (MOM4p1)
- Tripolar; 360x200; 1 deg poleward; 0.33 deg near equator
- 50 levels; Top grid cell 5m
- Ocean Biogeochemistry: TOPAZ
- Ice Model: Sea Ice Simulator
IITM-ESM Development

ESMv1: Incorporation of new ocean model with interactive ocean GC (MOM4p1). 6 Wm$^{-2}$ energy imbalance

ESMv2: Radiatively balanced framework with improved coupling between component models. Partial grid implementation and incorporation of sea ice model (SIS)

IITM-ESM CMIP6: Long control runs to reach quasi-equilibrium. Incorporated 3-D varying aerosol conc., GHG, ozone, LULC changes

2018
CMIP6 forcing

2019
DECK Simulations

2020
CMIP6 & MIP Simulations

2021
Research Publication and Applications
IOD-Monsoon teleconnection in IITM-ESM

Prajeeesh et al. 2021
## WCRP CMIP6 Experimental Design

**Eyring et al., 2016v**

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**CCCR-IITM Earth System Grid Federation (ESGF) node**
Assessment of Climate Change over the Indian Region, MoES Report
Why need regional climate models?

- The coarse spatial resolution of GCMs have limited capability to resolve the local factors that influence regional climate, such as complex topography, land–sea contrasts, and convective processes.

- Global climate models (GCMs) are essential for investigating climate change, but their coarse scale limits their efficacy for climate adaptation planning at the regional scales.

Regional climate models (RCMs) dynamically downscale GCM outputs to provide higher resolution simulations of the current and future climate that can better inform climate policy and decision making at regional scales.
Projected change in the mean number of days per year with maximum temperature exceeding 35°C from CMIP6 and CORDEX

CMIP6

CORDEX

IPCC AR6
TS24
Performance in reproducing the historical climate

Bias associated with the annual mean precipitation in the 14 CORDEX regions over a 20-year period.

- Bias in precipitation in ISIMIP and CORDEX are small, especially in the Mediterranean, Southeast Asia, and the polar regions.

- The spreads are within the spread of the discrepancy among the observations, which suggests that the model selection works effectively to select models with high ability to reproduce the observed regional mean precipitation.
HighresMIP model resolution

Evolution of model resolution from AR5 to AR6

(a) CMIP5: 37 models
   - Number of models:
     - 1
     - 2
     - 3
     - 4
     - 5
     - 6
   - Atmospheric horizontal resolution (km)
   - Oceanic horizontal resolution (km)

(b) CMIP6
   - HighResMIP: 50 models
   - Number of models:
     - 1
     - 2
     - 3
     - 4
     - 5
     - 6
   - Atmospheric horizontal resolution (km)
   - Oceanic horizontal resolution (km)

(c) Number of vertical atmospheric levels
   - Number of vertical oceanic levels
   - Number of models:
     - 1
     - 2
     - 3

(d) Number of vertical atmospheric levels
   - Number of vertical oceanic levels
   - Number of models:
     - 1
     - 2
     - 3
Higher effective resolution

Higher resolution in tropics

30% less number of grid points (effective resolution): less memory requirement

Can be parallelized more efficiently: Lower computational cost
Vegetation Type (TCO126 ; 24 type)

Courtesy ; Priya, CCCR
Precipitation difference (TCO126 (24 type)-T62 (13 type))
Community Ice Sheet model: CISM is a Dynamic ice sheet model, which computes ice velocities and the resulting evolution of ice sheet geometry and temperature. (Component of CESM2)

A surface mass balance scheme in the Land Model (Noah LSM), which computes accumulation and ablation at the upper surface of ice sheets. Courtesy; Sandeep, CCCR
Polar ice loss and impacts on the tropical precipitation

Deser et al., 2015

Sourav et al., 2021

Sandeep et al., 2023
Future Plans: Modeling changes over the Himalayan Cryosphere

CISM glacier simulations in the Nepal Everest region

Initial surface elevation and glacier outlines

Simulated surface ice speed (m/yr, log scale)
Lessons learned and way forward

- High resolution climate information is essential for various sectorial applications. CORDEX simulations provide valuable insights for decision making at regional levels.

- Our goal is to perform high resolution climate simulations 27Km (AGCM) and 67 Km global coupled simulations for addressing issues related to climate change over South Asian region.
THANK YOU!