CORDEX Regional Climate Models Performance in Present-day Climate for South Asia

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Introduction

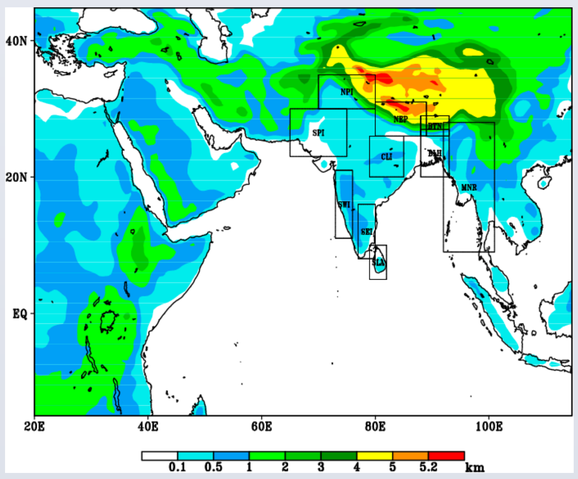
The fidelity of regional climate models (RCMs) in reproducing the observed regional climate is important for providing reliable information of regional climate change. The **CORDEX** (**Co**ordinated **R**egional Climate **D**ownscaling **Ex**periment) initiated by WCRP provides a framework to understand model uncertainties through use of multiple RCMs which are driven by boundary conditions from state-of-the-art coupled atmosphere ocean general circulation models (AOGCMs).

Objective

To evaluate the performances of the RCMs participating in the CORDEX South Asia evaluation & historical experiments in comparison with those of the AOGCMs participating in the fifth phase of the Coupled Models Intercomparison Project (CMIP5) to facilitate multi-model intercomparison over South Asia.

Data and Methods

Fig 1. The topography (km) over the domain used for the CORDEX South Asia RCM simulations with 0.44° horizontal resolution.



The performance of ten CMIP5 AOGCMs & five RCMs are assessed for a common 15-year evaluation period (1990-2004) using the Regional Climate Model Evaluation System (RCMES) tool from NASA JPL, USA, by validating the model simulations with the monthly mean rain gauge-based global land precipitation dataset available at 0.5° spatial resolution from the Climatic Research Unit (CRU) at the University of East Anglia.

For intercomparison, the monthly mean values of each model data are bilinearly interpolated onto the same grid.

Systematic biases in different models are evaluated with regard to simulation of the annual mean climate, as well the seasonal cycle over different sub-regions of South Asia.

Expected Outcome

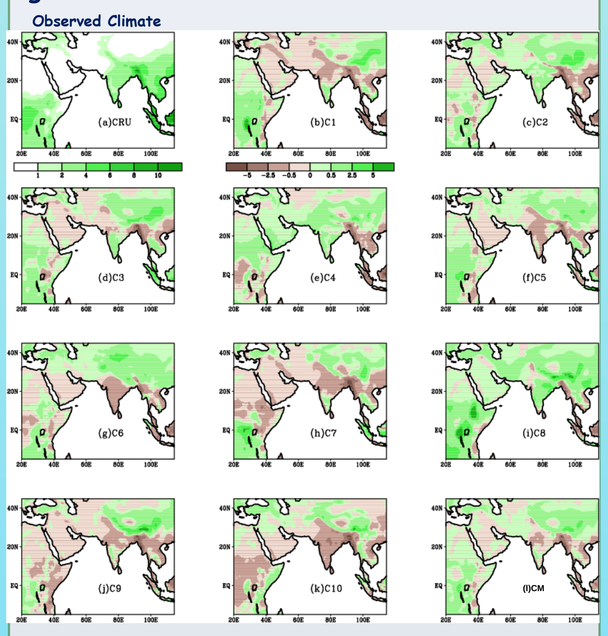
Such evaluation methodologies of the CMIP5 AOGCMs & CORDEX RCMs are aimed towards bringing out additional value of regional climate information required for impact assessments and decision support activities and the value gained via dynamical downscaling.

Results & Discussion

Table 1. Selected 10 CMIP5 AOGCM Historical Simulations (1890-2005)

Model Label	AOGCM Name	Resolution (Latitude° X Longitude°)
C1	CanEsm2	2.8° X 2.7°
C2	GFDL-CM3	2.5° X 2.0°
C3	GFDL-ESM2M	2.5° X 2.0°
C4	EC-EARTH	1.125° X 1.125°
C5	HadCM3	3.75° X 2.5°
C6	HadGEM2-ES	1.875°X 1.25°
C7	IPSL-CM5A-LR	1.875°X 3.75°
C8	MIROC5	1.4°X 1.38°
C9	MPI-ESM-LR	1.875° X 1.865°
C10	MRI-CGCM3	1.125°X 1.121°

Fig 2. The biases in CMIP5 simulated annual-mean precipitation (mm d^{-1}) for 1990-2004 against the CRU data

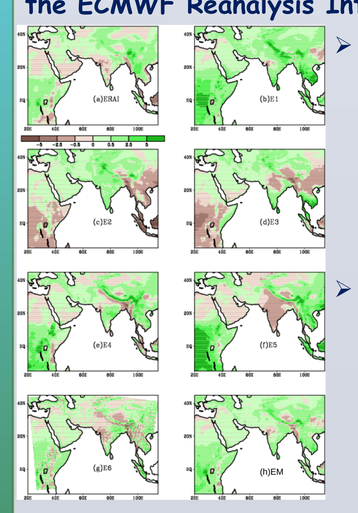


- The simple statistical (zeroth order) downscaling of the coarse resolution CMIP5 AOGCMs indicate dry bias over central & northern parts of India in most models.
- Three models C2, C4 & C8 tend to show wet bias over this region.
- The overall spatial distribution of the annual mean precipitation climatology is depicted relatively better in the ensemble mean (CM).

Table 2. Selected 6 CORDEX South Asia RCM Evaluation Experiments (1989-2007)

Model Label	Contributing Institute	Model Name & Version	Cumulus scheme
E1	IITM	ICTP-RegCMv3	Emanuel
E2	IITM	ICTP-RegCMv3	Grell
E3	IITM	ICTP-RegCMv4.1	Grell (land) & Emanuel(ocean)
E4	IITM	NCAR-ARWv3.1	Betts-Miller-Janjic
E5	IITM	NCAR-ARWv3.1	Kain-Fritsch
E6	SMHI	SMHI-RCAv4	Kain-Fritsch

Fig 3. The biases in simulated annual-mean precipitation (mm d^{-1}) for 1990-2004 against the CRU data for the CORDEX South Asia RCM evaluation experiments driven with the ECMWF Reanalysis Interim (ERAI).

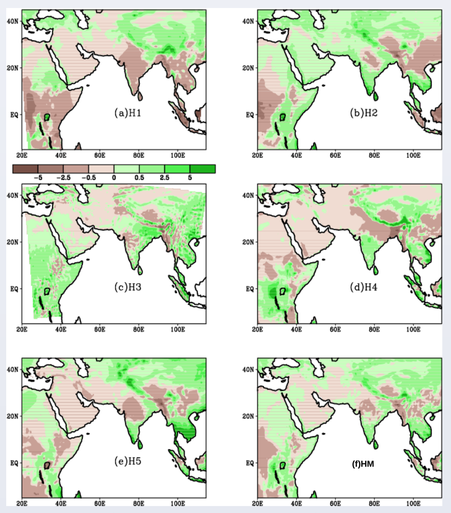


- ERAI indicates slightly larger dry bias over the peninsular & western parts of India (Fig. 3a) than the CMIP5 ensemble mean (Fig. 2l).
- The 3 versions of the ICTP-RegCM RCM (E1, E2 & E3), mainly differing in the choice of the parameterization of deep cumulus convection, shows that the model bias changes from wet to dry over central India.
- Two different cumulus schemes in the NCAR ARW RCM (E4 & E5) also brings out the large sensitivity of the physics to the simulated annual precipitation.
- However the ensemble mean (EM) of these 6 RCMs show relatively lesser dry bias over Indian region (Fig. 3h) than the CMIP5 ensemble mean (Fig. 2l).

Table 3. CORDEX South Asia RCM Historical Simulations (1950-2005)

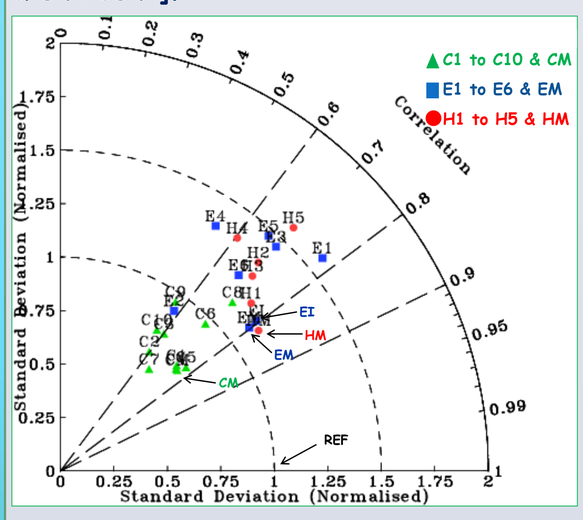
Model Label	Contributing Institute	Model Name & Version	Driving CMIP5 AOGCM
H1	IAES	COSMO CLM	C9
H2	IITM	ICTP RegCMv4.1	C3
H3	SMHI	SMHI RCAv4	C4
H4	IITM	IPSL LMDZv4	C7
H5	IITM	H2	H4

Fig 4. The biases in simulated annual mean precipitation (mm d^{-1}) for 1990-2004 against the CRU data for CORDEX South Asia RCM historical simulations driven with CMIP5 AOGCMs.



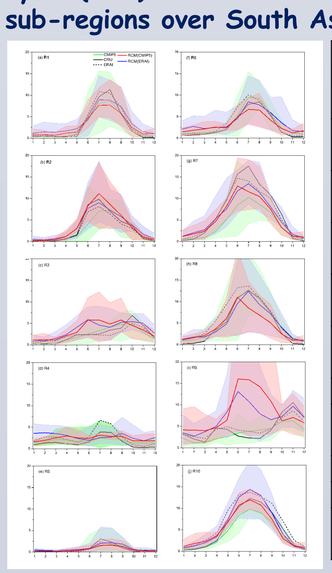
- The individual RCM bias vary from dry to wet over central India in the historical simulations: H1 (Fig. 4a) to H4 (Fig. 4d)
- The spatial distribution of the bias is similar for the two simulations H2 (Fig. 4b) & H5 (Fig. 4e) with the ICTP RegCM RCM driven with different global models (C3 & H4)

Fig 5. Taylor diagram showing the spatial correlation & standardized deviations in the simulated annual-mean precipitation for all models with reference to CRU data (REF) over the South Asian land area [60°E–100°E & 5°N–35°N].



- The AOGCMs (green triangles) & RCMs (blue rectangles & red circles) show similar skill in simulating the spatial patterns of the observed (CRU) annual precipitation climatology over South Asia.
- However the AOGCMs (RCMs) underestimate (overestimate) the observed spatial variability.

Fig 6. The simulated precipitation annual cycle (PAC) for 1990-2004 in 10 selected sub-regions over South Asia



Label	Sub-regions shown as boxes in Fig. 1
R1	Central India (CLI)
R2	South West India (SWI)
R3	South East India (SEI)
R4	North Pakistan & India (NPI)
R5	South Pakistan & India (SPI)
R6	Nepal (NEP)
R7	Bangladesh (BLH)
R8	Bhutan (BTN)
R9	Srilanka (SLA)
R10	Myanmar (MNR)

In Fig. 6 the ensemble mean (thick lines) & the range (shading) for AOGCMs (green), RCMs driven with ERAI (blue) & RCMs driven with AOGCMs (red) are shown. The CRU observations (black line) & ERAI (black dashed line) are also plotted.

The AOGCMs & RCMs skill in simulating the amplitude & phase of PAC with respect to the CRU data is summarized for all sub-regions using portrait diagrams of

- Root mean square error normalized by CRU annual-mean ($RMSE_{norm}$)
- Correlation Coefficients (CC)

Fig 7a. $RMSE_{norm}$ for CMIP5 Historical simulations

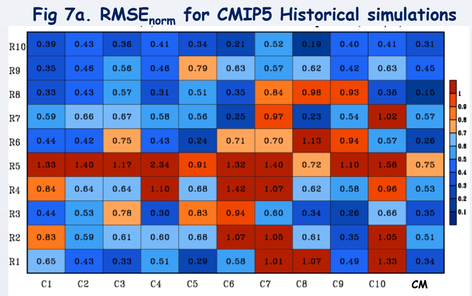
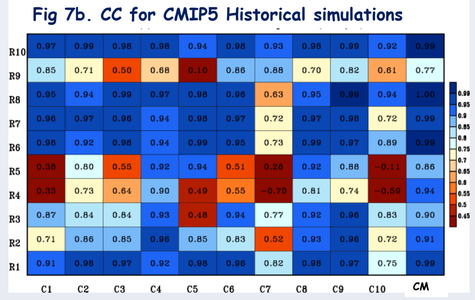


Fig 7b. CC for CMIP5 Historical simulations



- AOGCMs skill in simulating the PAC amplitude (Fig. 7a) & phase (Fig. 7b) varies for each sub-region.

Fig 8a. $RMSE_{norm}$ for RCM Evaluation experiments

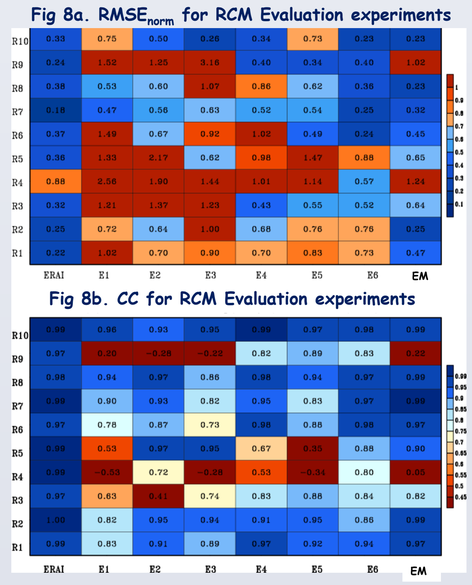


Fig 8b. CC for RCM Evaluation experiments

- SMHI RCA4 RCM driven with ERAI (E6) outperforms the simulation of PAC amplitude (Fig.8a) & phase (Fig.8b) over 4 to 5 sub-regions.

Fig 9a. $RMSE_{norm}$ for RCM Historical simulations

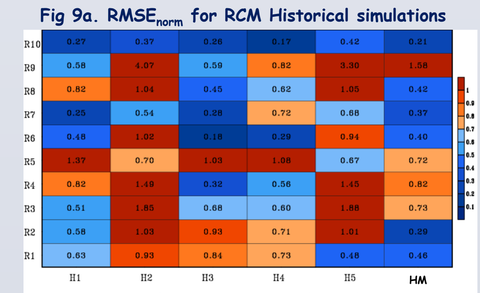
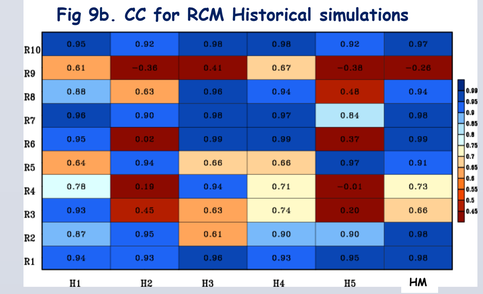


Fig 9b. CC for RCM Historical simulations



- 3 RCMs: H1 (CLM), H3 (RCA4) & H4 (LMDZ) indicate improved skill in simulating the PAC amplitude (Fig. 9a) & phase (Fig. 9b) over R6 (NEP), R7 (BLH), R8 (BTN) & R10 (MNR) relative to their driving AOGCMs: C9, C4 & C7 (see Fig. 7a & 7b).

Conclusions

In summary, the following are the major outcomes of the present study

- Most AOGCMs & RCMs show significant biases in simulating the main features of the annual precipitation climatology over the South Asia
- However dynamical downscaling of AOGCM outputs using RCMs to the scale more suited to end-users appears to be more useful for understanding local monthly precipitation climate in regions that have complex topography such as Nepal, Bangladesh, Bhutan & Myanmar.

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