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A Comparative Study of Regional Climate Models and Global Coupled Models over Uttarakhand

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***Abstract*—**As a great physiographic divide, the Himalayas affecting a large system of water and air circulation which helps to determine the climatic condition in the Indian subcontinent to the south and mid-Asian highlands to the north. It creates obstacles by defending chill continental air from north side into India in winter and also defends rain-bearing southwesterly monsoon to give up maximum precipitation in that area in monsoon season. Nowadays extreme weather conditions such as heavy precipitation, cloudburst, flash flood, landslide and extreme avalanches are the regular happening incidents in the region of North Western Himalayan (NWH). The present study has been planned to investigate the suitable model(s) to find out the rainfall pattern over that region. For this investigation, selected models from Coordinated Regional Climate Downscaling Experiment (CORDEX) and Coupled Model Intercomparison Project Phase 5 (CMIP5) has been utilized in a consistent framework for the period of 1976 to 2000 (historical). The ability of these driving models from CORDEX domain and CMIP5 has been examined according to their capability of the spatial distribution as well as time series plot of rainfall over NWH in the rainy season and compared with the ground-based Indian Meteorological Department (IMD) gridded rainfall data set. It is noted from the analysis that the models like MIROC5 and MPI-ESM-LR from the both CORDEX and CMIP5 provide the best spatial distribution of rainfall over NWH region. But the driving models from CORDEX underestimates the daily rainfall amount as compared to CMIP5 driving models as it is unable to capture daily rainfall data properly when it has been plotted for time series (TS) individually for the state of Uttarakhand (UK) and Himachal Pradesh (HP). So finally it can be said that the driving models from CMIP5 are better than CORDEX domain models to investigate the rainfall pattern over NWH region.

***Keywords*—**Global warming, rainfall, CMIP5, CORDEX, North Western Himalayan region.

I. Introduction

HIMALAYAS play an important role in air circulation as well as water which has influenced the climatic condition in the Indian subcontinent. By defending rain-bearing south-westerly monsoon it helps to provide maximum precipitation over Indian region in rainy season [1].The extreme weather events like cloud burst, heavy precipitation, flash floods and landslides happen regularly in the western Himalayan region [2]. As there is a considerable variation between the variation and amount of rainfall, the NWH region becomes unpredictable to project future rainfall [3]. Now it has become a topic of scientific debate, the dynamically downscaled CORDEX-SA domain models are able to capture rainfall pattern over NWH region properly compared to the CMIP5 models or not [4]. In that context the present study has been planned to investigate the better performed model(s) which can be further used to predict future rainfall pattern over NWH region.

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II. Study Area

The study area is North-West Himalayan region (Fig. 1). It encompasses three states namely Jammu & Kashmir, HP and UK. The geographical extension of this region is varies in between 28° N to 37° N latitudes and 72° E to 82° E longitudes.

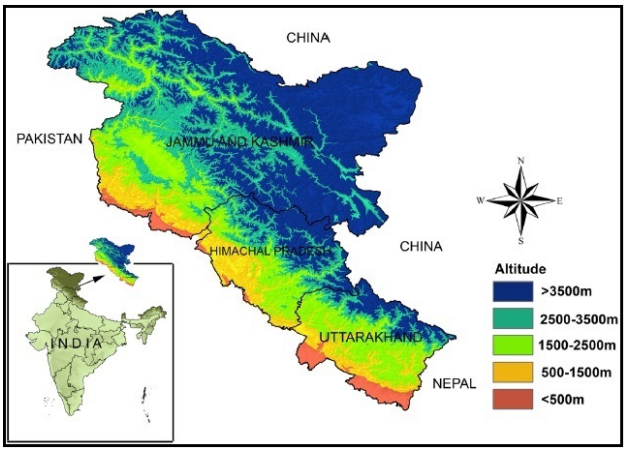

Fig. 1 Study area map of NWH region

III. Datasets and Methodology

The following datasets have been utilized-

- **CMIP5 models:** CMIP5 is a framework and the analogue of the atmospheric model intercomparison project (AMIP) for global coupled ocean-atmosphere general circulation model (GCM). The following models from CMIP5 have been used to do this analysis.

TABLE I
Details of 2 Models Participated in the CMIP5 Project

Models	Contributing Institute	Resolution **(Lon×Lat)**
MIROC5	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology, Japan	1.4˚×1.4˚
MPI-ESM-LR	Max Planck Institute for Meteorology, Germany	1.8˚×1.8˚

- **CORDEX domain models:** CORDEX is a strategic approach to understand the regional climate change and the fidelity of climate model. The model in Table II has been utilized to investigate this study.

TABLE II
DETAILS OF 4 MODELS PARTICIPATED IN THE CORDEX-SA PROJECT

Driving models	Contributing Institute	Resolution **(Lon×Lat)**
GFDL-ESM2M	CCCR, IITM, Pune, India	0.54˚×0.46˚
IPSL-CM5A	CCCR, IITM, Pune, India	0.54˚×0.46˚
MIROC5	Rossby Centre, Swedish Meteorological and Hydrological Institute (SMHI), Sweden	0.50˚×0.47˚
MPI-ESM-LR	Rossby Centre, Swedish Meteorological and Hydrological Institute (SMHI), Sweden	0.50˚×0.47˚

- **IMD Gridded data:** National Climate Centre (NCC), India Meteorological Department, Pune provides CD ROMs which contain high resolution daily gridded rainfall and temperature datasets for the Indian region. The 0.5˚×0.5˚ IMD gridded rainfall data have been used for the validation purpose.

IV. RESULTS AND DISCUSSIONS

To investigate the suitable model(s) we have prepared the spatial as well as TS map by using models from both CMIP5 and CORDEX-SA domain for the historical time period (1976-2000). After that those outcomes are compared with the IMD gridded rainfall data for the validation purpose.

❖ *Spatial Plots*

At first, spatial map (Fig. 4) has been generated by using the models both from CMIP5 and CORDEX-SA domain. And spatial map (Fig. 3) for rainfall data also has been generated by using IMD gridded rainfall data in the parallel way over NWH region.

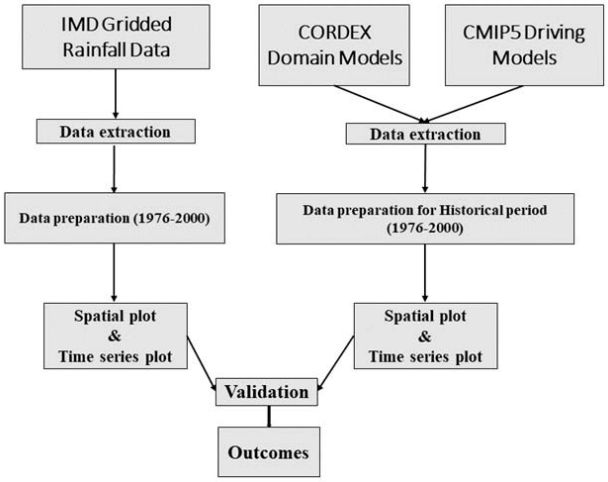

Fig. 2 Methodology

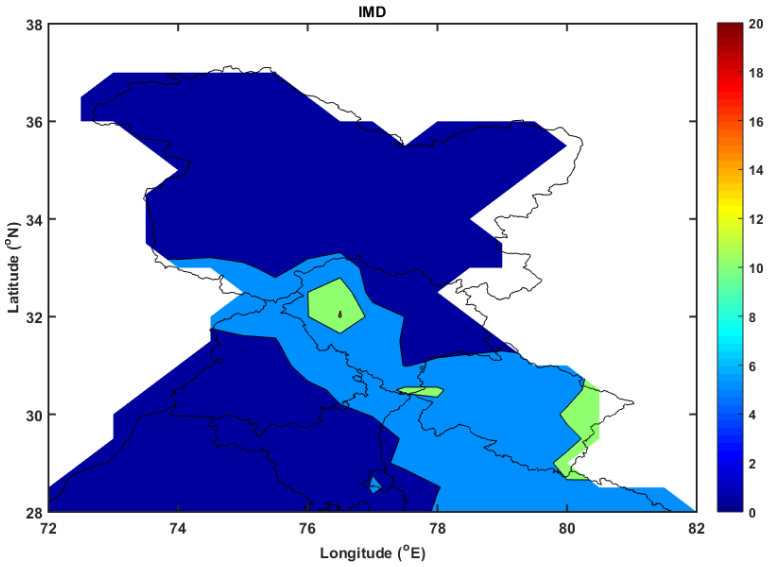

Fig. 3 Spatial map of IMD gridded rainfall data for the historical period (1976-2000)

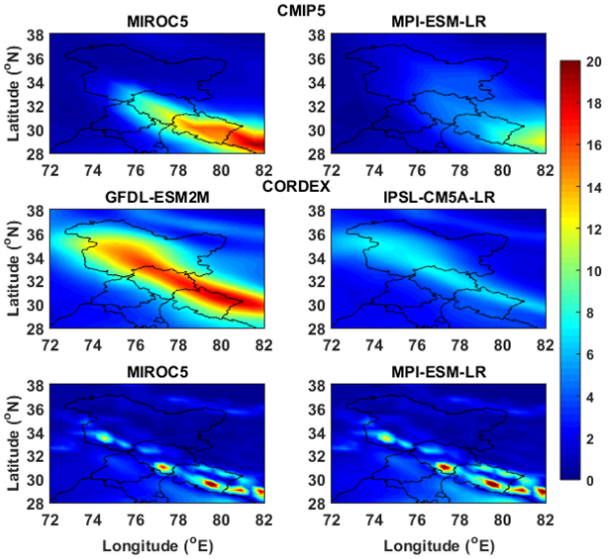

Fig. 4 Spatial map for the comparison study between CMIP5 models and CORDEX-SA domain models for the historical period (1976-2000)

From the above comparison maps (Figs. 3 and 4), it can be said that the participated CORDEX-SA domain models are able to capture mean annual rainy season rainfall as compared to IMD gridded rainfall data rather than CMIP5 models. The participated CORDEX-SA models like MIROC5 and MPI-ESM-LR simulate the monsoon rainfall very closely to the IMD gridded data. The CORDEX-SA domain models GFDL-ESM2M and IPSL-CM5A-LR capture comparatively very high in the Kashmir region as well as the norther part of UK and HP. But GFDL-ESM2M indicate an overestimation when the other one underestimates the data. On the other hand, the participated CMIP5 model MIROC5 has better simulation capacity rather than MPI-ESM-LR. But MIROC5 overestimates the mean annual rainfall for rainy season in the western part of UK and underestimates in the western part of HP where MPI-ESM-LR underestimates the rainfall data throughout the region except eastern part of UK.

❖ *TS Plots*

For further analysis we have also generate TS plot (Figs. 5 and 6) for one state of that region namely UK to investigate the simulation capacity on the basis of daily rainfall data.

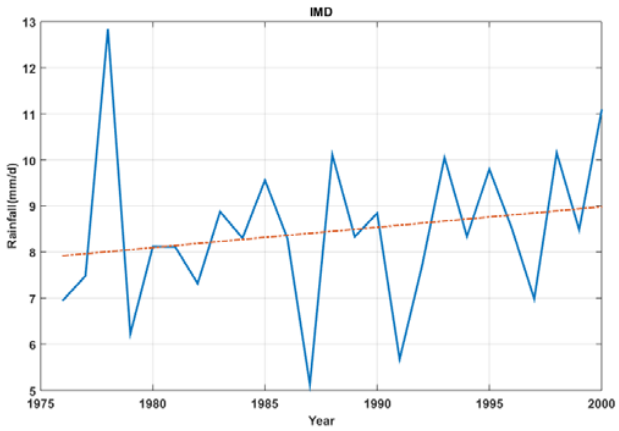

Fig. 5 TS plot for IMD gridded rainfall data over UK for the historical period (1976-2000)

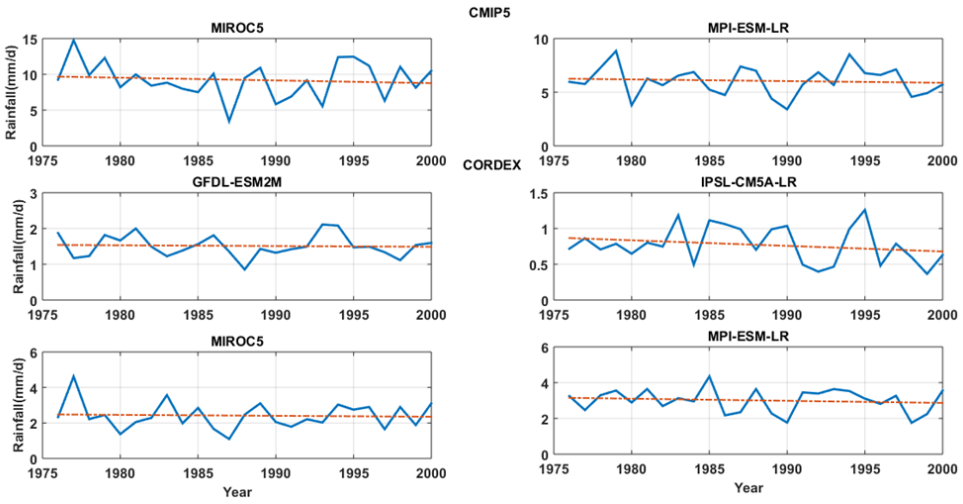

Fig. 6 TS plot for the comparison study between CORDEX-SA domain and CMIP5 models for the historical period (1976-2000) over UK

In case of TS, it shows totally different outputs as per the analysis. The CORDEX-SA domain models are unable to simulate daily intensity of rainfall than CMIP5 models when those are compared to the TS plot of IMD gridded rainfall data. The CMIP5 models namely MIROC5 and MPI-ESM-LR simulate the rainfall data very closely to the IMD data but

IMD data show an increasing trend where both the models from CMIP5 indicate a decreasing trend of rainfall.

V. Conclusions

The future projection of rainfall in the Himalayan region is very difficult as it is fully dependent on complex orographic climatic regime [5]. From the above discussion it can be said that the CORDEX-SA domain models especially MIROC5 and MPI-ESM-LR are able to capture rather than CMIP5 models spatially [6]. But CORDEX-SA domain models underestimate the rainfall data when we analysis the TS as it poorly captures the rainfall data in daily basis. Finally it can be concluded that the CMIP5 models will be better to project future rainfall over that region.

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