Development and downscaling of High-Resolution (5-km) Climate Data for Bangladesh, Nepal and Pakistan

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Abstract

This study is a part of the APN project titled "Towards Robust Projections of Climate Extremes and Adaptation Plans over South Asia." The aim of the project is to generate local-scale (5-km) reference and future climate data for Bangladesh, Nepal and Pakistan. In the 1st phase of the project, we developed 5-km reference data (Ali et al., 2023) utilizing both station and ERA5 data. ERA5 data were excluded in areas where observation stations were available due to their higher weighting. The temperature adjusted the values based on the average Lapse Rate of Temperature (LRT), using topographical data from the Global 30 Arc-Second Elevation (GTOPO30) dataset provided by the U.S. Geological Survey (USGS). In the 2nd phase, we carried out the validation of 48 CMIP6 models and identified the top 5 models. In the 3rd phase, these selected CMIP6 datasets (2020-2100) were statistical downscaling and bias correction using spatial disaggregation quantile delta mapping (SDQDM).

Data & Methods

Observe daily data (1981-2016) were acquired from the meteorological departments of Bangladesh, Nepal, and Pakistan. The data quality control procedures were employed using both objective and subjective methods. The observe station and ERA5 data were integrated and interpolated using the kriging method. The process of developing reference data is shown in Figure 1. For CMIP6 (https://esgf-node.llnl.gov/search/cmip6/) data validation & downscaling, we acquired temperature and precipitation data for 48 Global Climate Models (GCMs). Three different ranking methods were employed to validate these models. The selected CMIP6 models were then statistical downscaled and bias corrected using the spatial disaggregation quantile delta mapping (SDQDM) technique for the period 2020-2100. This approach effectively addresses the issue of non-stationarity in the data while preserving future climate trend signals.

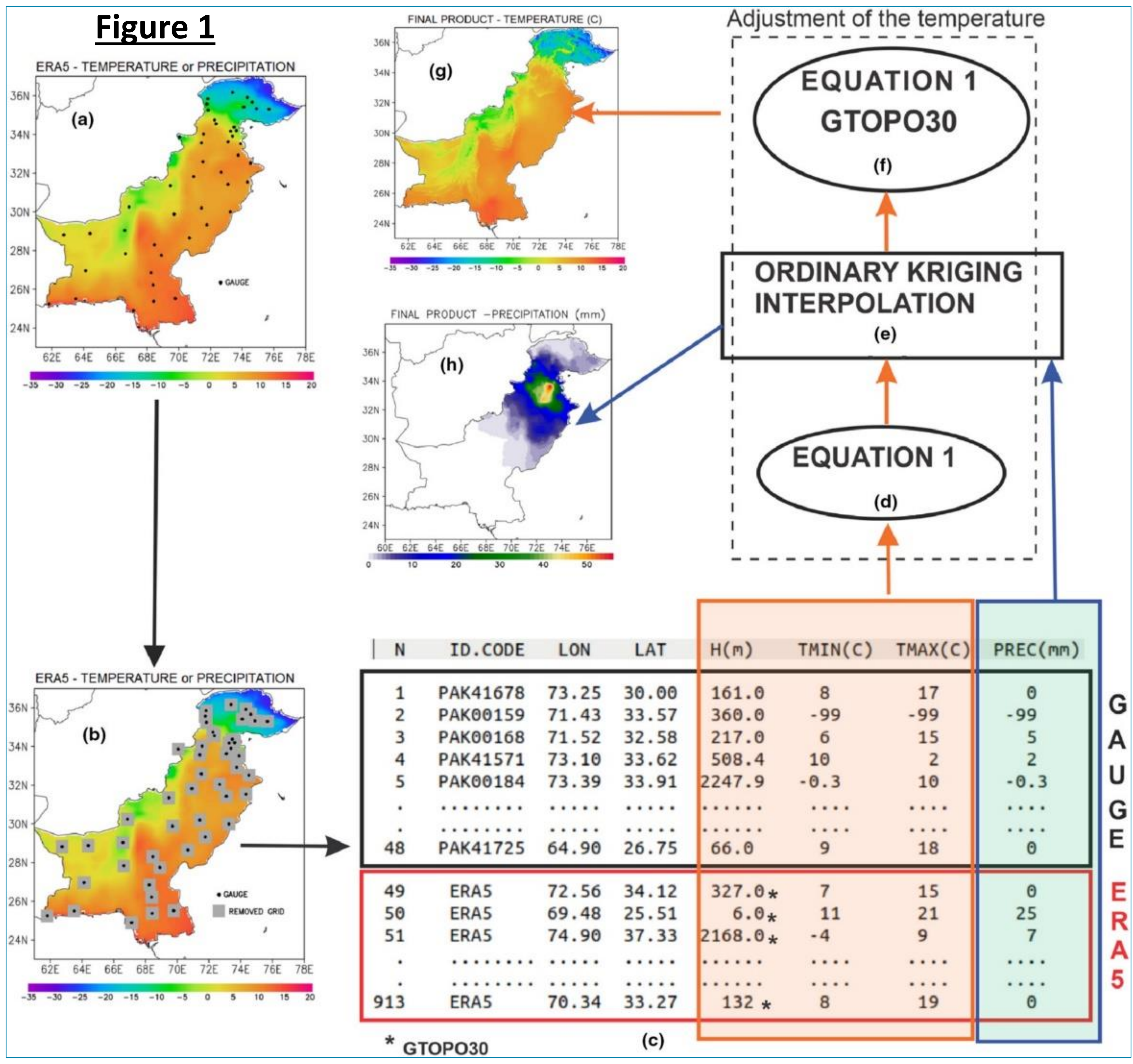

Figure 1: Schematic illustration of the steps to obtain the 5-km grid dataset product.

Results

Observe data quality test shows that Pakistan has the highest percentage of valid data (96%) followed by Bangladesh (93%) and Nepal (less than 90%). For mean temperature, all regions show a positive increase during 1981-2016. Considering the annual time series, the increase is 0.74°, 0.76°, and 1.4°C in Bangladesh, Pakistan and Nepal respectively. The annual trends have more contribution of MAM since it is 1.05°, 1.74° and 2.07°C in Bangladesh, Nepal and Pakistan respectively. But, in JJA Pakistan has a negative trend of -0.53°C while the others have a positive trend.

The best models for the overall region (Pakistan, Nepal and Bangladesh) and variables (precipitation and air temperature) combined are IITM-ESM, EC-Earth3-AerChem, EC-Earth3-Veg shown in Figure 2.

Figure 3 shows a comparison of trend preserving capacity of QM, DQM and QDM for future projection of extremes are presented along with the model trend. It can be noted that the performance of QDM dominates other methods in performance and can be considered as a reliable method of bias correction for future projection studies as other two methods (QM and DQM) encounter the problem of stationarity. The future projection of temperature and precipitation for 2020-2100 were analyzed for Pakistan, Nepal and Bangladesh, the results for Nepal for June-July-August (2080-2100) are shown in Figure 4 which show 30 to 40% increase in monsoon precipitation.

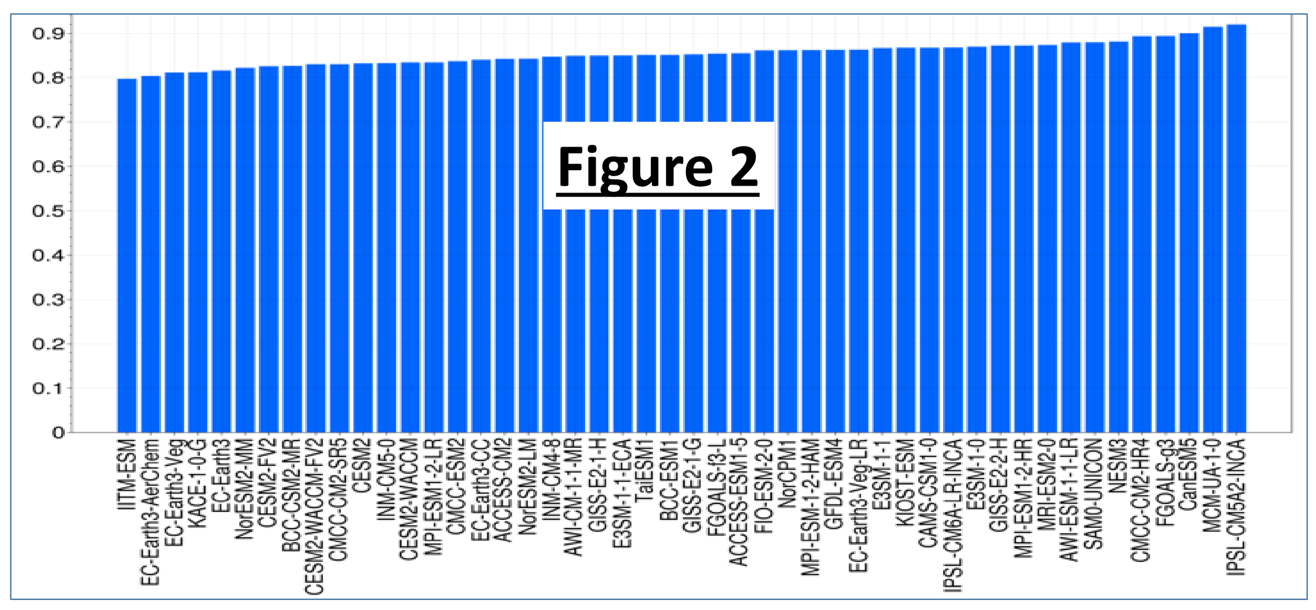

Figure 2: Overall CMIP6 GCM performance considering the three countries for precipitation and air temperature.

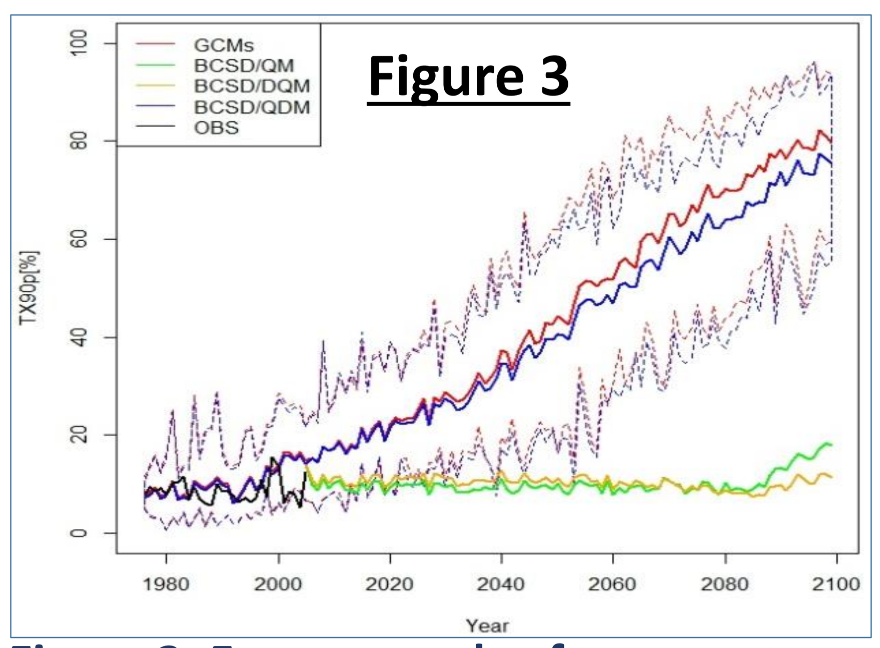

Figure 3: Future trends of temperature downscaled by three statistically downscaling methods of QM, DQM and QDM for RCP8. 5 over Pakistan.

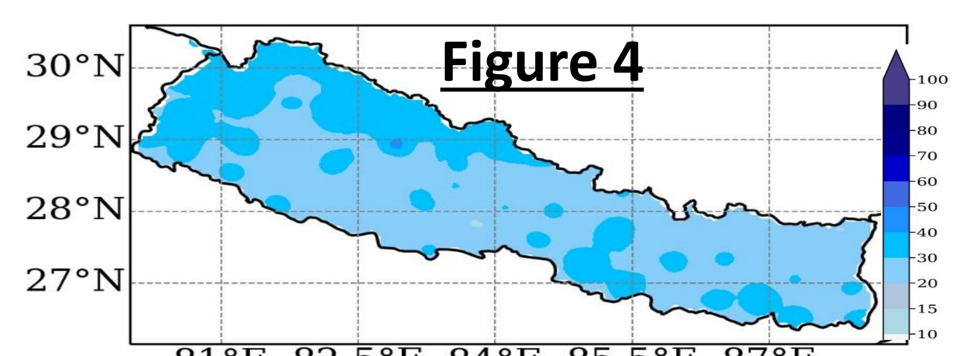

Figure 4: Future projection of precipitation (Jun-Aug) for 2020-2100 over Nepal.

Conclusion

The high-resolution (5-km) daily data product (observation 1981-2016 & CMIP6-Future 2020-2100) can be useful for impact studies such as extreme events, water resources, agriculture, health, energy, etc. Moreover, this fine-resolution data (1981-2016) will be utilized by the downscaling research community and CMIP6 (2020-2100) model data can be used for future climate change assessments and its impacts in the region at a higher resolution which will assist in local policy decisions.

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Reference: Ali, S., Bhutta, Z. A., Reboita, M. S., Goheer, A. M., et al., (2023). A 5-km gridded product development of daily temperature and precipitation for Bangladesh, Nepal, and Pakistan from 1981 to 2016. Geoscience Data Journal.

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