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Regional Precipitation Projections for the 21st century across the Indus River Basin of Pakistan using Statistical Downscaling

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Two contrasting synoptic scale processes primarily govern the precipitation distribution across trans-Himalayan Indus River basin of Pakistan: Indian Summer Monsoon and Western Disturbances. Besides, snow and glacier melt within Upper Indus Basin (UIB) primarily control the hydrological regime of Indus flows. A Generalized Linear Model framework with Gamma and Tweedie models was used to develop robust, physically consistent and skillful statistical models for different regions of the basin, using ERA-Interim reanalysis as predictors. These models simulated observed precipitation distributions during winter, pre-monsoon and monsoon seasons in the period 1979-2015. More focus was given on UIB compared to the remaining parts of the Indus Basin due to its strategic significance for basin runoff.

The entire CMIP5-Generalised Circulation Model (GCM) suite was explored to identify the relevant GCMs offering required predictors and complete spatial coverage across the study domain. Taylor diagrams were used for comparative model evaluation during historical period for relevant GCMs, due to their effectiveness for pattern matching through easy visualization. Initially, separate Taylor diagrams were constructed to identify best matching pairs of each reanalysis PC and individual GCM simulated PCs of corresponding variables. Subsequently, the Taylor diagrams were again developed by lumping all matched PCs of a set of predictors used in the final regression models. Thus, each diagram was representing one precipitation model in terms of best-matched predictor patterns. Final GCM selection was made by maximizing an indicator score computed using regression coefficients as weights with Taylor diagram computations. This process led to identify better GCM for each seasonal region as well as across the basin for all seasons, by giving more importance to major centers of variations. However, considering orographic implications and mostly inadequate representation of study regions by GCMs, it was decided to use all 8-member relevant GCM ensemble for projections. This ensemble approach helps to quantify the scale of future precipitation uncertainty and to support sensible adaptation planning process across the basin.

Historical precipitation for each ensemble member was computed by projecting relevant GCM fields into loading patterns of corresponding reanalysis PCs and subsequently forcing through the final regression models. These downscaled historic precipitation rates were used as a benchmark for tracking future climate change signal. The GCM-ensemble precipitation projections for short (20s), medium (50s) and long term (70s) projections were computed under RCP4.5 and RCP8.5 scenario assumptions for different regions and seasons across the study basin. Widespread and quite contradicting projections across ensemble members, particularly within UIB were evident for all seasons and justified the need for ensemble simulations. Mean precipitation change signals were derived and interpretation was made by considering signal to noise ratio for each seasonal region