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Precipitation and temperature projections for the Indus River basin of Pakistan during 21st century using statistical downscaling

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The Indus River system originates within high mountain ranges of Hindukush, Karakoram and Himalayans (HKH) and contains the largest cryosphere outside the Polar Regions. It assures livelihood of millions of people, before descending into the Arabian Sea. Different processes, which involve complex interplays of contrasting synoptic-scale circulations and regional topography, largely govern precipitation, which varies significantly with space-time and altitudes in upper Indus basin (UIB). In contrast, the Lower Indus (LI) has arid to semi-arid climate and depends heavily on melt-dominated water supply from the UIB. Considering climate hotspot nature of this basin, a pragmatic assessment of future precipitation and temperature changes at basin-scale are fundamental to provide effective policy advice.

However, long-term, reliable and consistent data to effectively simulate orographic climatology within UIB that largely governs the basin hydrology is scarce. Consequently, even the mean direction of regional climate is highly controversial and ranging from rapidly retreating glaciers to the so-called “Karakoram anomaly”. While the provision of additional useful data is still an ongoing process, improvements in simulation methodologies using the available observational network, can still offer some opportunities to reduce uncertainties. One way is to make use of large-scale atmospheric circulations, which are modeled more reliably than precipitation itself. Moreover, the circulation-precipitation relationships can additionally explain governing mechanisms to improve confidence in resulting simulations.

In our study, we modeled observed precipitation and temperature (Tmax and Tmin) dynamics of the entire basin. A seasonally and spatially differentiated analysis was done using improved UIB monitoring, which provide enhanced spatio-altitudinal information. By taking advantage of the recent high-altitudes (HA) installations within UIB, we argue that precipitation at relatively low-altitudes only quantitatively differ from HA rates, but share a significant joint variability at sub-regional scales. Therefore, the low-altitude stations (historic) can provide reasonable inferences about more uncertain orographic structure of UIB. We adapted generalized linear models (GLMs) with Tweedie and Gamma distributions to model precipitation and multiple linear regressions (MLRs) for temperature simulations using time-series of carefully selected regionally representatives, as predictand and principal component scores of different larger-scale dynamical and thermodynamic variables from ERA-Interim reanalysis, as predictors. The final regression

models, which were identified through a cross validation framework, showed significant statistical skills and physical consistency to simulate observed seasonal precipitation and temperature variability over larger spatio-altitudinal scales.

We further used the predictors to identify better performing regional and seasonal CIMP5- GCMs by comparing predictors through Taylor diagrams in the historical period. ERA-Interim predictors served as a basis for evaluation. Reanalysis uncertainties were assessed by using also NCEP-NCAR-II and ERA5 reanalysis. We considered two radiative forcings (RCP4.5 and RCP8.5) to analyze median change signals of precipitation (temperature) during mid (2041-2070) and end of 21st century (2071-2100). The signal to noise ratio was computed to evaluate future changes compared to observed natural variability.