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A vertical hydroclimatology of the Upper Indus Basin and initial insights to potential hydrological change in the region

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The water resources of the Upper Indus Basin (UIB) are of the utmost importance to the economic wellbeing of Pakistan. The irrigated agriculture made possible by Indus river runoff underpins the food security for Pakistan's nearly 200 million people. Contributions from hydropower account for more than one fifth of peak installed electrical generating capacity in a country where widespread, prolonged load-shedding handicaps business activity and industrial development. Pakistan's further socio-economic development thus depends largely on optimisation of its precious water resources. Confident, accurate projections of future water resource availability and variability are urgent insights needed by development planners and infrastructure managers at all levels.

Correctly projecting future hydrological conditions depends first and foremost on a thorough understanding of the underlying mechanisms and processes of present hydroclimatology. The vertical and horizontal spatial variations in key climate parameters (temperature, precipitation) govern the contributions of the various elevation zones and subcatchments comprising the UIB. Trends in this complex mountainous region are highly varied by season and parameter. Observed changes here often do not match general global trends or even necessarily those found in neighbouring regions.

This study considers data from a variety sources in order to compose the most complete picture possible of the vertical hydroclimatology of the UIB. The study presents the observed climatology and trends for precipitation and temperature from local observations at long-record meteorological stations (Pakistan Meteorological Department). These data are compared to characterisations of additional water cycle parameters (humidity, cloud, snow cover and snow-water-equivalent) derived from local short-record automatic weather stations, the ECMWF 'ERA' reanalysis projects and satellite based observations (AVHRR, MODIS, etc). The potential implications of the vertical (hypsometric) distribution of these parameters are considered. Interlinkages between observed changes in these parameters and the evolution of large-scale circulation indices (ENSO, NAO, local vorticity) are also investigated.

In parallel to these climatological considerations, the study presents the typology of the observed UIB hydrological regimes – glacial, nival and pluvial – including interannual variability as quantified from the available river gauging record. In order to begin to assess potential implications of future climate change on UIB hydrology, key modes of variability in the climate parameters are identified. The study then analyses in detail the corresponding observed anomalies in UIB discharge for years exemplifying these modes. In conclusion, this work postulates potential impacts of changes in the hydrological variability stemming from continuation of estimated present local climatic trends.