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In-situ hydro-meteorological records in conjunction with stable isotope systematics to understand the hydrological processes in Glaciers of Garhwal Himalaya, India

Amit Kumar, Akshaya Verma, Sameer K Tiwari, and Santosh K Rai
Wadia Institute of Himalayan Geology, Dehradun, India (amithydrocoin@gmail.com)

Glaciers in the Indian Himalayan Region (IHR) are sensitive to climatic changes. Rivers originating from Himalaya have higher water yields in the ablation season due to large inputs from the melting of snow and glaciers, which is critical for sustaining downstream ecosystem, agricultural practices, hydroelectric power generation, and urban water supplies. Integrated investigations are frequently unavailable at a regional scale over a longer period, which is hampered due to the non-availability of data caused by harsh weather conditions, difficult terrain, as well as difficulty in maintaining the instruments at such high altitudes (> 3000 m asl). The hydrological understanding of melting processes from glacierized basins requires a network of reliable meteorological and hydrological observations. In absence of such reliable meteorological data, most of the hydrological simulation studies are forced to extrapolate air temperature from nearby basins, lower elevations, or consider satellite-based observations, which often deviate or differ from the actual ground conditions and lead to large uncertainty in model outputs. Therefore, an integrated approach for collecting hydrological and meteorological data along with other data like snow-cover, suspended sediment transfer and stable isotopic signatures of different components of the hydrograph were conceptualized for glacierized river basins in Garhwal Himalaya (Bhagirathi and Alaknanda). Our results suggest that the annual distribution of temperature lapse rates (TLR) established exhibits a bimodal pattern and the TLR's are significantly lower than the adiabatic lapse rate. The major components of the streamflow are derived from snow and glacier melt, while rainfall contributes little during the Indian Summer Monsoon (ISM). Westerlies significantly feed the glacier with snow, while rainfall is dominant during the Indian Summer Monsoon (ISM). Precipitation and temperature are the dominant meteorological factors controlling melting processes and sediment delivery. Climate and topography control the distribution of seasonal snow cover/ snowline in the region. Extreme events like heavy rainfall, flash floods, glacial lake outbursts floods, etc. can be traced using hydrometeorological and isotopic data at high altitude stations. Therefore, in light of the challenges and potential research gaps, the study produces actionable knowledge in the Garhwal Himalaya for better understanding and modeling of glacio-hydrological processes by incorporating ground-based observations.