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Trans-Himalayan water contributions to river discharge

Christoff Andermann (1), Thomas Stieglitz (2,3), Jan A. Schuessler (4), and Binod Parajouli (5)

(1) German Research Centre for Geosciences GFZ, Geomorphology, Potsdam, Germany (christoff.andermann@gfz-potsdam.de), (2) European Centre For Research And Teaching In Geosciences CEREGE, Aix en Provence - France, (3) Centre for Tropical Water & Aquatic Ecosystem Research TropWATERr, James Cook University, Australia, (4) German Research Centre for Geosciences GFZ, Earth Surface Geochemistry, Potsdam, Germany , (5) Department of Hydrology and Meteorology DHM, Kathmandu, Nepal

Hydrological processes in high mountains are not well understood. Groundwater is commonly considered to be of little importance in the mountain water balance, while direct runoff, snow and ice melt are thought to be the principal hydrological buffer. We present new insights into hydrological fluxes between major reservoirs in a trans-Himalayan catchment. The study area is the Kali Gandaki catchment, rising in the dry Tibetan interior, carving through the high Himalayas and draining the full width of the foothills to the Ganges foreland. The catchment has a well-defined monsoon climate, with pronounced annual wet and dry seasons and a clear separation of wind- and leeward regions. We have sampled the main river and its tributaries as well as several springs during the four hydrological seasons (winter, pre-monsoon, monsoon, post-monsoon). We have measured major element abundances as well as 222Rn in situ, as a tracer for groundwater contribution. These measurements are placed in a context of topographic analyses as well as continuous discharge and precipitation measurements. Furthermore, we have equipped two sites with continuous water samplers, sampling over > 4 monsoon seasons, allowing us to resolve the seasonal hydrological dynamic range on a very high temporal resolution.

Chemical fluxes vary spatially over several orders of magnitude, showing a systematic downstream dilution trend for most major elements during all hydrological seasons. High initial concentrations derive from evaporite deposits in the uppermost part of the catchment, constituting a large scale, natural salt tracer experiment. The well-defined decline of solute concentrations along the main river, paired with constraints on the composition of lateral water inputs downstream allow the calculation of the spatial distribution of additional hydrological fluxes, by applying end member mixing modeling. Continuous river stage and bulk dissolved load (electrical conductivity) monitoring depict well-defined diurnal cycles in water temperature, stage level and water chemistry. These diurnal cycles have a profound impact on the chemical concentrations and need to be corrected for to estimate representative geochemical fluxes for the full river and end member mixing modeling. Radon and trace element data indicate that groundwater contributions are primarily associated with the main tectonic structures of the Himalayan range, but also concentrate on the steep southern mountain front, and that groundwater outflow from the Lesser Himalayas is limited during baseflow season. Over the seasons the chemical dilution signature across the Himalayan range is persistent. However, specific elements have temporally distinct dilution signatures highlighting the alternating contribution of different hydrological compartments over the annual hydrological cycle. Our analysis allows to decipher the hydrological contribution of different water reservoirs to the surface water discharge in rivers, along a major Himalayan stream. Our results highlight the volumetric importance of a high mountain deep-groundwater storage compartment across the Himalayan mountain belt and provides first order quantification of groundwater contribution to stream flow.