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Contrasting response of glacierized catchments in the Central Himalaya and the Central Andes to climate change

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The Andes of South America and the Himalaya in high-mountain Asia are two regions where advanced simulation models are of vital importance to anticipate the impacts of climate change on water resources. The two mountain systems hold the largest ice masses outside the polar regions. Major rivers originate here and downstream regions are densely populated. In the long run, glacier recession generates concerns about the sustainability of summer runoff.

This study benefits from recent efforts of carefully planned short-term field experiments in two headwater catchments in the Central Andes of Chile and in the Central Himalaya in Nepal. The two study catchments contrast in terms of their climate and in the characteristics of their glaciers. A systematic approach is developed, built upon the available local data, to reduce the predictive uncertainty of a state-of-the-art glacio-hydrological model used for the projection of 21st century glacier changes and catchment runoff. The in-situ data are used for model development and step-wise, multivariate parameter calibration. Catchment runoff and remotely sensed MODIS and Landsat snow cover are used for model validation. The glacio-hydrological model simulates the water cycle with a high temporal (hourly time steps) and spatial (100 m grid cells) resolution and accounts for processes typical of both regions like glacier melt under debris cover or mass redistribution through avalanching. Future projections are based on the outputs of twelve stochastically downscaled global climate models for two emission scenarios (RCP 4.5 and RCP 8.5). This is one of the first truly intercomparative modeling studies at the catchment scale across mountain regions of the world to assess and compare future changes in glaciers and snow cover and associated impacts on streamflow production.

Both catchments will experience significant glacier mass loss throughout the twenty-first century. However, the trajectories of simulated future runoff and total melt from glaciers differ fundamentally. In the Langtang region in the Central Himalaya, the model results indicate increasing catchment runoff until mid-century and then either slowly declining or constant runoff depending on the climate scenario. In the Juncal region in the Central Andes catchment runoff starts to decline sharply after 2031-2040, so that annual river runoff may decrease by up to 60% until the end of the century. While in the Juncal region the seasonality of runoff may change dramatically, due to less snow- and glacier melt during the summer, the seasonality of runoff in the Central Himalaya will be essentially unaffected by climate change. Differences in catchment response are explained by differences in climate change projections (as precipitation is projected to increase in the Central Himalaya but to decrease in the Central Andes), but also by the differences in glacier characteristics and glacier evolution. Meltwater production of glaciers in Juncal is already on a decline under the present climate. In Langtang, in contrast, the rate of glacier area decrease at lower elevations is exceeded by the rate of additional glacier area at high elevations contributing to melt in a warming climate. As a consequence of this, annual icemelt in the Central Himalaya will reach its peak not before mid-century.