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Attribution of observed hydrological changes and impacts of future climate change in glacierized mountain catchments in Central Asia

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High elevation areas in Central Asia currently undergo considerable changes. Trend analyses show that discharge in two headwater catchments of the Tarim River, Northwest China, increased by more than 30% over the past decades. While many studies focus on trend detection, understanding the causes of these changes, i.e. trend attribution, may be even more important. In this study, we first demonstrate the use of a simulation-based approach for attributing the observed streamflow increase to its possible causes. In a second step, we analyze the impact of future climate scenarios for these catchments.

Particular attention was given to multiobjective and multivariable calibration, including daily streamflow variability, long-term streamflow changes, annual variability of glacier and regional glacier mass changes. The hydrological model thus allows us to evaluate whether the causes for the observed changes in discharge are also consistent with these data. The hydrological model considers transient reductions in glacier area and lowering of the glacier surface elevation resulting from sustained negative glacier mass balances.

For trend attribution, we compare simulations with original and detrended temperature and precipitation series. In the catchment with a lower glacierization, temperature and precipitation increases were both important for the discharge increase. In the catchment with a higher glacier cover, discharge increases are predominantly attributed to temperature increases and related increases of glacier melt, indicating that the increased discharge originates to a considerable extent from loss of glacier storage. A major advantage of the simulation-based attribution approach is seen in the fact that it relies on process-based relationships.

The climate impact analysis is based on hundreds of simulations runs that consider different GCMs, emission scenarios and hydrological model parameters. By 2100, projections show a reduction in glacier area by 28 to 89% and 47 to 94% for the two catchments (uncertainties of the 5–95 percentile range of the ensemble). Over the course of the 21st century, glacier melt first increases, but then decreases due to smaller glacier areas. For overall discharge, the projections show a tendency toward increased interannual variability. Uncertainties are dominated by differences between the GCMs, while differences in emission scenarios become more important from the mid of the 21st century and uncertainties in hydrological parameters play a minor role. The projections have important implications for the water management of the Tarim River basin. Increases in irrigated area impair ecological conditions and livelihoods in downstream areas already under today's conditions. Decreasing streamflow from the headwaters would be an enormous challenge for the region.