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High uncertainty in 21st century runoff projections from glacierized catchments

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Climate change is expected to significantly alter the hydrological regime of glacierized drainage basins. Quantifying the impacts of changing climatic conditions on snow and ice melt runoff is highly important for future water resource management, for example in the context of hydropower production and water supply at the local to continental scale. However, many insufficiently understood processes in the impact modelling, as well as the spread in climatic change scenarios given by different Regional Climate Model (RCM) results leads to considerable uncertainties in projections of future runoff from glacierized basins.

This study aims at providing an integrative quantification of the uncertainties in modelled glacier runoff over the 21st century. A valley glacier in the Swiss Alps, Findelengletscher (13.4 km^2), for which a variety of field data on snow accumulation, surface mass balance, ice volume change and runoff is available, serves as an example. We present time series of glacier area change and runoff until 2100 based on temperature and precipitation provided by 10 RCMs from the ENSEMBLES project, and various parameterizations of important processes influencing simulated glacier response to climate change.

Runoff from the highly glacierized catchment of Findelengletscher is simulated using the glacio-hydrological model GERM that includes modules for snow accumulation distribution, snow and ice melt, 3D glacier geometry change, evapotranspiration and runoff routing. The model is carefully calibrated and validated using various types of field data. Differences in projected runoff are analyzed relative to (1) the RCM input, (2) the melt model applied (degree-day / energy balance model), (3) the availability field data used for model calibration, (4) possible changes in ice surface albedo, (5) the method for calculating glacier geometry change, (6) the initial ice volume obtained from ground penetrating radar surveys or best estimates based on indirect methods, (7) the protecting effect of supra-glacial debris, and (8) uncertainties in snow accumulation distribution.

We find that the uncertainties in modelled glacier area loss, changes in runoff volumes and the hydrological regime are considerable. Simulated glacier area change 2010-2075 lies within a range (90% confidence interval of individual model runs) of –35% and –95% compared to today; modelled changes in August runoff range between +25% and –50%. Nevertheless, a trend towards a shift in the hydrological regime is revealed by all model realisations. The choice of the RCM input is particularly important for determining future runoff; the spread of RCM results forced with the same emission scenario determines roughly half of the total uncertainty in future glacier runoff. Among other factors a better description of the initial ice volume and winter accumulation data are highly critical for reducing the uncertainties in the impact modelling.