What is the contribution of snow and glacier to discharge in Swiss alpine headwater catchments under climate change?

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Switzerland is often referred to as Europe's Water Tower. During the melt season, water stored in the Alps as snow and ice feeds large European rivers such as the Rivers Rhine and Rhone. Under climate change conditions, snow and glacier melt contributions to discharge are expected to change dramatically. These changes might be very important during dry periods, when snow and glacier melt are the main sources of water. Assessing water availability in the future is essential for sustainable management of our water resources. Understanding how much melt water contributes to the discharge at different locations along the rivers is therefore necessary.

In this study, we used a customized version of the bucket-type hydrological model HBV-light, specially developed to assess the daily contribution of snow and glacier melt to discharge in a transient way. We assess the discharge components for 195 glacierized headwater catchments covering the entire Swiss Alps from 1973 to 2099. Hydrological processes in the Alps are spatially and temporally highly variable. Snow and glacier melt modelling are also challenged by data scarcity. Heterogeneously distributed meteorological measurement stations in high elevated and remote regions further complicate the representativity of the data. We show the advantages and challenges of using datasets from various sources as meteorological input data and for model calibration and validation of discharge, snow and glacier cover. In a second step, we applied a regionalization approach to defining model parameters for the ungauged catchments. A multi-criteria calibration was used to ensure that all hydrological processes are correctly represented within the model.

For future climate projections, we used the newly generated precipitation and temperature gridded products from MeteoSwiss for 45 climate models and for three emissions scenarios (RCP 2.6, RCP 4.5 and RCP 8.5). The results show that glacier peak water is already reached by most of the catchments and will be reached by all catchments during the first half of the Century for all three emissions scenarios. Under RCP 8.5, total glacier contribution summarized over all headwater catchments is 8% of total discharge under current climate and less than 2% at the end of the century. Snow melt will still be an important contribution to discharge during the first half of the century. In the second half of the century, however, snow melt contribution will significantly decrease from 34% (current climate) to 25% +/- 10% (2070-2099) of the total discharge. In contrary,
rainfall contribution will increase from 58% to 72% +/- 15% of total discharge. Overall, the total annual discharge is expected to decrease slightly. The intensity of these changes in discharge contributions depends on the catchment elevation and large regional differences can be observed. The effects are much smaller under emission scenario RCP 2.6.