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Climate change effects on snow melt and discharge of a partly glacierized watershed in Central Switzerland

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In the Alps, streamflow regimes and water resource availability critically depend on snow and glacier melt. While the capabilities of numerical models have made significant progress in recent years, it remains challenging to accurately quantify the hydrological response of mountain watersheds to climate warming. Apart from uncertainties that relate to atmospheric forcing data for predictive model runs, dealing with snow and glacier melt, steep terrain, complex micro climatic effects, and unknown groundwater processes poses substantial difficulties to numerically reproduce the hydrological behavior of alpine watersheds.

Here we present results of a comprehensive hydrological study in the drainage area of a hydropower reservoir in central Switzerland (lake Goescheneralpsee in canton Uri). The catchment is partly glacierized (20%) and spans over 92 km2 of alpine topography covering elevations between 1800 and 3600 m asl. As is often the case, long-term hydrometeorological data is largely unavailable for the area, apart from reservoir water level measurements. Various measuring devices were installed at the beginning of this study in 2007 and provided valuable evaluation data for both meteorological input and model results. The infrastructure includes three automatic meteorological stations, continuous discharge measurements at three sites, and two remote camera systems for snow-covered area.

Discharge measurements in feeding streams display strong diurnal fluctuations due to snowmelt in spring and glacier melt later in summer. Two models were tested to reproduce the measured discharge dynamics: 1) a detailed energy-balance model (ALPINE3D) primarily designed for snow simulations; 2) a conceptual runoff model system (PREVAH) including a distributed temperature-index ice-melt model. Considerable effort was put into distributing available meteorological station data to the model grids as forcing data. In particular, the energy-balance model was sensitive to the spatial distribution of snowfall. An algorithm accounting for terrain curvature and slope provided the best results, which were assessed against snow covered area data from automatic cameras. As both models do not simulate glacier flow, attention was also given to regularly update glacial areas based on externally provided glacier cover scenarios.

The recent EU regional climate modeling initiative ENSEMBLES provided up-to-date climate predictions for two 30-year periods in mid and late 21st century. These were used to estimate evolutions in the water supply of the hydropower reservoir in response to expected climate changes. Our simulations suggest a shift of spring peak-flow by up to two months for the end of the century. Warmer winter temperatures will cause higher winter base-flow whereas peak snowmelt in spring will decrease. Due to glacier retreat, late-summer flow will significantly decrease by the end of the century.