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Future high-mountain hydrology: a new parameterization of glacier retreat

Matthias Huss (1,2), Guillaume Jouvet (3), and Daniel Farinotti (2)

(1) University of Fribourg, Department of Geosciences, Switzerland (matthias.huss@unifr.ch), (2) Laboratory of Hydraulics, Hydrology and Glaciology (VAW), ETH Zurich, 8092 Zurich, Switzerland, (3) Institute of Analysis and Scientific Computing, EPF Lausanne, 1015 Lausanne, Switzerland

Climate warming is expected to significantly affect the runoff regime of mountainous catchments. Simple methods for calculating future glacier change in hydrological models are required in order to efficiently project economic impacts of changes in the water cycle in alpine regions over the next decades. Models for temporal and spatial glacier evolution need to describe the climate forcing acting on the glacier and ice flow dynamics. Flow models, however, demand considerable computation power and field data input. Moreover, they are not applicable on the regional scale.

We propose a simple parameterization – termed Δh-parameterization – for calculating the change in glacier surface elevation and area. The parameterization is mass conserving and thus suited for long-term hydrological modelling. The Δh-parameterization is an empirical glacier-specific function that is derived from observations in the past. It can easily be applied to large samples of glaciers and therefore be used for regional scale hydrological projections for alpine catchments over the 21st century.

We compare the results of the Δh-parameterization against a 3D finite-element ice flow model. In case studies the evolution of two Alpine glaciers of different size over the period 2008-2100 is investigated using different regional climate scenarios. The parameterization closely reproduces the distributed ice thickness change, as well as glacier area and length predicted by the ice flow model. This indicates that for the purpose of transient runoff forecasts, future glacier geometry change can be approximated using this simple parameterization instead of complex ice flow modelling.

According to our model the two analyzed glaciers show dramatic retreat over the 21st century in response to climate warming. Silvrettagletscher, a small mountain glacier, is expected to disappear around 2070. Rhonegletscher, a medium-sized valley glacier, might still be present by 2100, however, strongly reduced in size. We analyse the consequent shifts in the runoff regime of the highly glacierized catchment of Rhonegletscher using the proposed methods. Fast release of water from long-term glacial storage leads to a significant increase in runoff over the next decades. For 2040 calculated annual runoff is between 23% and 36% higher than in 1961-1990, depending on the scenario. We find strong changes in the hydrological regime; after an initial surge from intense ice melt, low-flow conditions will prevail in the summer months over the second half of the 21st century. Peak runoff will be shifted and is expected to occur two months earlier in the season.