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Future water yield from melting mountain permafrost: A fully distributed modelling approach

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With climate change the question about water supply security in dry alpine regions arises. Currently, melting glaciers release important volumes of water counteracting droughts in regions with high water stress in the summer months. Significant water reservoirs in frozen ground could potentially moderate low-flow conditions in alpine rivers when the glaciers have completely disappeared. The modelling of the future water yield from permafrost involves a variety of complex problems: (1) soil properties, such as porosity and ice content, must be estimated in a spatially distributed way, and (2) the transient simulation of permafrost melting in a hydrological catchment requires a model including all processes of ground mass and heat transfer.

We present first results of studying the future permafrost evolution in the Murtèl-Corvatsch region, South-eastern Swiss Alps, and the concurrent changes in catchment hydrology. The drainage basin analyzed has a size of 5 km^2, and covers different exposures and surface types. The framework of the novel permafrost model presented here is the glacio-hydrological model GERM that has been developed for calculating future runoff from glacierized basins. The model simulates all cryospheric and hydrological variables (snow accumulation distribution, snow and ice melt, 3D glacier geometry change, evaporation, runoff routing) on a 25m-grid in daily resolution. Ground temperature profiles at all grid cells are simulated using a minimum of readily available meteorological input. The model is thus relatively fast and operationally applicable. Ground ice content and subsurface properties are derived from in-situ measurements using different geophysical methods, or are estimated from surface characteristics if no field data are available. Ground temperature modelling is based on heat conduction and includes processes of thawing and refreezing, as well as heat transfer by infiltrating water, and thus allows calculating water yields due to changes in ice stored in frozen soils.

Results of the distributed permafrost model are compared to the more complex COUP model at one location and are validated against long-term ground temperature measurements available in the Murtèl-Corvatsch region. The future water yield from mountain permafrost simulated using realistic climate scenarios is expected to be relatively small, but could nevertheless moderate extreme low-flow conditions in late summer. According to first model results, permafrost contribution can account for up to 5% of August runoff in dry years. However, uncertainties in this estimate are still considerable.