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Validation of a modeled 3D temperature field below the Schilthorn Crest, Switzerland, using borehole measurements and time-lapse electrical resistivity data

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The Schilthorn Crest, Switzerland, is today one of the most prominent permafrost research sites in the Alps. Between 1998 and 2001, three boreholes were drilled in the north-facing slope, which provide the basis for the monitoring and quantification of changes in the permafrost regime. Even though measured temperature profiles in boreholes enable an initial assessment of topography-related and transient effects, in complex mountain terrain they are only representative for isolated local spots. A 3-dimensional description of the thermal conditions of the subsurface can be achieved by numerical modeling. In this study, we combine measurements of borehole temperatures and electric resistivity tomopgraphy (ERT) to validate a modeled temperature field below the Schilthorn crest.

To model a transient 3D temperature field of the subsurface we used a numerical 3D heat conduction scheme and impose interpolated near-surface temperatures as the upper boundary condition. We considered the subsurface to be isotropic and homogenous and took into account the effects of latent heat. To describe the evolution of the upper boundary during the transient model run we used mean annual air temperatures from a meteo station nearby. The measurements in the boreholes are complemented by a number of near-surface temperature loggers distributed on both sides of the crest in summer 2005. In summer 2005, an ERT monitoring was installed across

the crest, and in 2006 a quasi-3D ERT survey was conducted along four transects. Post-processing of ERT data involved time-lapse inversion of repeated measurements to delineate changes in ice and water content and to determine temperature-resistivity relationships. The modeled temperature field agrees well with ERT results and borehole data. The simulated thermal regime below the Schilthorn is characterized by generally warm permafrost, with the coldest zone below the upper part of the northern slope, and permafrost little below the surface on the southern slope.

Based on the modeled temperature field scenarios of a possible future subsurface temperature field can be simulated. The combination of both datasets bears potential to improve modeling and validation strategies. These may include (1) comparing numerical results and measured data to estimate model performance, (2) extending single point temperature data to larger scales using 2D or 3D resistivity values, and (3) improving the representation of the subsurface physical properties in the model by incorporating subsurface information detected by geophysical surveys.