3D-modelling of transient permafrost temperatures below steep alpine topography

Jeannette Noetzli (1), Stephan Gruber (1) and Thomas Kohl (2)

(1) Glaciology and Geomorphodynamics Group, Department of Geography, University of Zurich, Switzerland
(2) Geowatt AG, Zurich-Oerlikon, Switzerland

Permafrost degradation can be an important factor influencing the stability of steep rock in alpine areas. In addition, mountain permafrost is relevant for a number of reasons such as for construction practices, the stability of hanging glaciers or as a climate archive. As permafrost is defined by temperature it is important to have detailed knowledge about the temperature distribution and evolution in the subsurface in high mountain areas. In this study, our focus is on A) the effect of topography on the subsurface thermal field inside steep high mountain ridges and peaks and B) the depth scales of transient effects that influence today's thermal field inside steep high mountain peaks.

The investigation of ground temperatures beneath such topography needs to account for 2- and 3-dimensional effects, since strong lateral components of heat fluxes exist that are caused by geometry and variable surface temperatures even in equilibrium conditions. This may lead to permafrost occurrence at locations where surface temperatures do not point to. Additionally, the subsurface thermal field is perturbed by transient effects. Due to the time needed for a temperature signal to penetrate to greater depth, permafrost that would not be expected under present climate conditions can remain inside mountains over centuries. Pore ice and latent heat may have an additional retarding influence on the temperature evolution even in low-porosity rock. In contrast, alpine topography plays an accelerating role for a warming signal propagating into the mountain: The signal intrudes from more than one side and affects both the permafrost table and the permafrost base and substantially increases the pace of permafrost degradation. The thermal field below steep topography is therefore less influenced by past cold periods than flat terrain, though more sensitive to current atmospheric warming.

Due to the complex and highly variable conditions in high mountain topography, this study concentrates on numerical experimentation using typical idealised geometries such as ridges, peaks or spurs. A surface energy-balance model is used together with a 3-dimensional ground heat-conduction scheme to calculate subsurface thermal fields. Both models are specially designed for use in complex topography.