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Depth scales of transient effects and their influence on current permafrost temperatures in alpine topography

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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 alpine topography, the subsurface thermal field is mainly controlled by 3-dimensional geometry and aspect-related variable surface temperatures. This leads to complex 3-dimensional patterns of temperature distribution and heat flow density even for equilibrium conditions: isotherms are steeply inclined and strong lateral heat fluxes exist. However, 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. For the understanding and quantification of present-day or future thermal conditions in high mountain topography it is therefore necessary to go back in time for model spin up.

In this study, we investigate the depth scales of transient effects that influence today's thermal field inside steep high mountain peaks: How big is the influence of past cold periods on the current permafrost occurrence inside high mountains (e.g. the Matterhorn)? What time periods have to be considered for the initialisation for thermal modelling of massive mountains or smaller ridges or spurs? Special emphasis is given on the influence of 3D-situations such as ridges or peaks because alpine topography plays a decisive 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, which substantially increases the pace of permafrost degradation. Sensitivity analysis of the main factors influencing the transient thermal field will also be presented. Numerical experiments are performed using artificial DEMs of simplified topography as well as such of real topography (e.g. the Matterhorn). 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.