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Two-dimensional investigation of ground temperatures in steep rock slopes

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A temperature-dependent reduction in rock-wall stability of alpine permafrost areas, that is likely induced by climate change, has recently been demonstrated both in theory and laboratory experiments. The delineation of typical locations of sensitive zones that are prone to critical temperature changes and are subjected to thaw requires knowledge of the temperature distribution at and below the surface of rock walls. In high mountain areas the effect of complex topography leads to a strong lateral component of heat fluxes. Therefore, ground temperatures and permafrost degradation beneath variable topography such as ridges or spurs can only be investigated where 2- and 3-dimensional effects (geometry and variable surface temperatures) are accounted for. The Matterhorn rock fall on July 15, 2003 is an example of such a situation. The corresponding knowledge, however, still remains limited.

In order to investigate 2- and 3-dimensional thermal responses of rock walls to climate change, numerical modelling is carried out in a recently started study. To better understand natural complex situations, model simulations of typical idealized test cases are performed. In a first step, cross sections of various 3-dimensional geometries are explored to describe the distribution of ground temperatures under influence of high-mountain topography. The thermal regime of the subsurface is modelled in 2-dimensional cross sections of ridges, peaks or spurs with varying topographical factors such as slope, aspect or elevation, aiming at identifying typical zones of warm permafrost with critical temperature ranges (entering a range of ca. -1.5 to 0 °C). Finite-element meshes of typical topographies are generated and forced with different surface boundary conditions. The experimentation is conducted by applying a surface energy-balance model (TEBAL) to determine surface temperatures, together with a 3-dimensional ground heat-conduction scheme (FRACTure), both especially designed

for use in complex topography.

Together with knowledge on the position and depth of the degrading permafrost boundaries, that will be analysed in a following step, the results may contribute to identify areas that are especially sensitive for permafrost degradation on maps and serve as a basis for hazard assessment of permafrost related slope instabilities.