Modeling Convective Heat Transfer in the Porous Active Layer of an Alpine Rock Glacier

J. Wicky[1], M. Scherler[1], Ch. Hauck[1]

[1]Alpine Cryosphere and Geomorphology Group, University of Fribourg, Switzerland

Abstract

Permafrost is defined as soil which remains frozen for at least two consecutive years. In the Swiss Alps, it is a widespread phenomenon with a great impact on the landscape particularly regarding natural hazards. The occurrence of permafrost is not only influenced by meteorological parameters and the elevation of the site, but also by landform and subsurface substrate. Especially coarse blocky material with high permeability allows air to circulate. Thus, convective heat transfer takes place and influences ground temperatures. In this study, we present results from numerical experiments on the effect of air circulation within the porous active layer (the uppermost 3-4m of the ground which thaws each summer) of an Alpine rock glacier. We couple the COMSOL Multiphysics® modules Heat Transfer in Porous Media and Darcy's law to solve for buoyant (density hence temperature dependent) air flow and temperature distribution within the ground. The numerical domain consists of a porous medium in the active layer, a phase change material as the rock glacier body and a solid material as underlying bedrock. The upper boundary condition of this transient simulation consists of a ground surface temperature series from monitoring data at Murtèl rock glacier in the Engadin (Eastern Swiss Alps). The model results show that convective heat transfer in the active layer has a significant effect on the thermal regime of a rock glacier. Winter temperatures are highly influenced by convective heat transfer due to the unstable thermal stratification of the air which allows a pronounced convective cooling. In contrast, summer temperatures show almost no sensitivity to convective heat transfer. The prevailing air circulation pattern and the efficiency of cooling strongly depend on the thermal gradient between interior and boundary temperatures and on the material properties, especially on the permeability of the porous active layer. Compared to borehole data, the model performs well but shows some discrepancy at depth which is maybe due to (i) convection at depth which is not represented, (ii) uncertainty in material properties or (iii) convective effects within the borehole, which influence the validation data. In mountain permafrost research, the explicit modeling of convective processes on a 2D domain is a novel approach. Our results highlight that air convection cannot be neglected in porous permafrost substrate and should be considered in future modeling approaches. Under warming climate conditions and increased permafrost thawing a thorough understanding of the ground thermal regime is crucial to modeling reliable future projections.

Figures used in the abstract

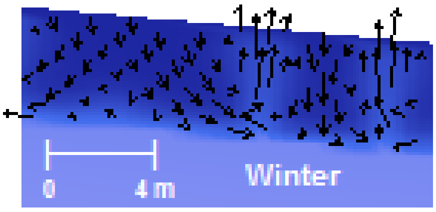

Figure 1: Vector arrows showing the multicellular convection in the active layer of a rock glacier. Convection allows a more efficient ground cooling during winter.