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Quantitative assessment of permafrost degradation in steep topography using geophysical monitoring systems - the project GO4ICE

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A climate induced warming of the atmospheric surface layer and a corresponding increase of ground temperatures will lead to substantial changes in the water and energy balance of regions underlain by perennial frozen ground (permafrost). Due to the strong heterogeneity of the subsurface in Alpine terrain, changes in air temperature can not simply be related to changes in ground temperature or melting rates. One of the main problems in the assessment and modelling of the future permafrost evolution is the lack of 3-dimensional information of the subsurface. In addition, the potential instability of a slope depends strongly on the characteristics of the subsurface material like ice content, porosity or crack size/orientation, unfrozen water content and hydraulic properties. As in existing European (Permafrost and Climate in the 21st Century, PACE21) and Swiss (PERMOS) permafrost monitoring networks, subsurface temperature data can be obtained through a network of shallow and deep (down to 100m) boreholes, but due to the heterogeneity of Alpine surface and subsurface characteristics, the temperature data can not easily be generalised for larger areas.

Geophysical methods (including Electrical Resistivity Tomography, Refraction Seismic Tomography and Ground Penetrating Radar) represent a cost-effective alternative for determining 3-dimensional fields of subsurface properties. Due to the indirect nature of the measurements the structure and processes within the subsurface remain unchanged, which makes geophysical methods very suitable for monitoring purposes. Evaluation studies using semi-automatic electric and seismic techniques indicate that subsurface freezing and thawing processes can be detected on time scales of years and even of days and hours (Hauck 2002, Schudel 2003).

In the project GO4ICE (Geophysical Observation and 4-Phase Modelling of Ice Content Evolution) geophysical approaches to quantify and monitor freezing and thawing processes in Alpine regions are developed. The project is connected to the Permafrost Monitoring of Switzerland program (PERMOS), which includes ground and rock temperature monitoring at 14 permafrost sites in the Swiss Alps (Vonder Mühll et al. 2003). GO4ICE will install geophysical monitoring systems at several of these sites and will develop new model techniques to determine the subsurface ice content based on the 4-phase model introduced by Hauck et al. (2005).

First results using the 6-year geophysical data set from Schilthorn, Swiss Alps, suggest that geophysical monitoring systems combining different methods may indeed be used in future to quantify the amount of permafrost degradation as well as its spatial and temporal variability.

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