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A geophysical monitoring network to quantify permafrost degradation in the Swiss Alps

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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 permafrost. In the context of an increased frequency of extreme weather periods, such as the hot summer 2003 or the warm autumn 2006 in the European Alps, and associated slope instabilities, a monitoring of mountain permafrost degradation becomes more and more important. Common observation techniques are based on thermal aspects of permafrost evolution, as in existing European (Permafrost and Climate in the 21st Century, PACE21) and Swiss (PERMOS) borehole temperature monitoring networks. However, concerning slope instabilities as well as for permafrost distribution and evolution models, not only temperature but especially the ice content of the subsurface plays an important role for permafrost observation purposes. In order to successfully predict the evolution of ground temperatures in a changing climate as well as to analyse the potential impact, surface and subsurface monitoring techniques have to be extended from temperature monitoring at point locations (boreholes) to cost-effective, 3-dimensional geophysical monitoring of freeze and thaw processes in the ground. In this regard, electrical resistivity tomography (ERT) provides a valuable potential, since the measured electrical resistivity is directly linked to the content of frozen and unfrozen water in the subsurface.

In summer 2006 the installation of a semi-automatic ERT monitoring system has been finished at 5 permafrost sites in the Swiss Alps (in close co-operation with the Swiss permafrost monitoring network PERMOS). This geophysical monitoring network serves to investigate the sensitivity of characteristic morphological sites to extreme atmospheric forcing in order to estimate the long-term evolution due to climate induced warming. Monitoring profiles are located at rockglaciers (Murtél and Muragl, Upper Engadine), steep slopes (Schilthorn, Bernese Alps), talus slopes (Lapires, Valais) and frozen bedrock (Stockhorn plateau, Valais), comprising both ice-rich and ice-poor sites. The geophysical monitoring strategy includes repeated ERT measurements with a monthly to seasonal resolution over several years, as well as annual refraction seismic measurements at all sites. Whereas the relative resistivity changes with time can be attributed to freeze and thaw processes, combined ERT and refraction seismic tomography will serve to determine the total fractions of ice, unfrozen water and air within the pore space of the respective subsurface sections.

First results of the newly installed ERT monitoring network reveal varying seasonal permafrost dynamics at the different sites, suggesting a differentiated response of mountain permafrost bodies to atmospheric forcing. Similar trends of quasi-decadal active layer depth evolution are assumed for almost all sites based on a comparison with previously obtained ERT data (except for Stockhorn) in 1998 and 2000, respectively. The extraordinary hot summer of 2003 was strongly affecting the Schilthorn and Lapires sites, which is clearly confirmed by associated borehole temperature records.