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The surface in the subsurface? – Towards small-scale permafrost distribution and quasi-3D resistivity imaging

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The study presented focuses on the small-scale variability of surface substratum and the potential incoming solar radiation (PISR). Both effect snow cover evolution and duration, ground surface temperature regimes and, hence, permafrost distribution in the subsurface.
These surface characteristics act as a buffer-system in the energy balance between atmosphere and lithosphere and, along with climate conditions and elevation determine the patchy occurrence of mountain permafrost.
The permafrost distribution will be mapped by using quasi-3D images as a new approach in periglacial environments.

The study site, a glacier forefield, ranging from 2650 to 2900 m a.s.l., is located in the Muragl Valley, in the Upper Engadine/Swiss Alps. The forefield is characterized by a complex glacier-permafrost interaction (e.g. thrust-moraine, glacial flutes) due to the polythermal regime of the former Muragl glacier.

ERT (electrical resistivity tomography) soundings were performed in summer 2008 at two sites in the glacier forefield, to establish two quasi-3D resistivity images of the subsurface to map the permafrost distribution. The two sites differ mainly in their surface material: The lower site is characterized by coarse blocky, but although fine grained material, whereas the upper site consists of a much finer grained substrate. In addition, the upper site is located in the shadow of an adjacent mountain ridge, while the lower site is more exposed to incoming solar radiation. The first image in the lower part consists of 22 merged ERT soundings (5m electrode spacing, Wenner array, 792 electrode positions, 4356 data points), covering an area of 175 x 175 m. The second image, covering an area of 72 x 72 m, consists of 17 combined ERT surveys (2m electrode spacing, Wenner Schlumberger array, 612 electrode positions, 4896 data points). The large amount of data points results in two high resolution images of the subsurface structure.
To record surface substratum geomorphological mapping of the glacier forefield was carried out in summer 2008. Furthermore, to get a higher resolution in these parts of the forefield, surface material was mapped inside the two ERT-grids at each electrode position. Ground surface temperature was measured using 15 miniature temperature loggers (MTDs), which were placed throughout the glacier forefield. In order to log ground temperatures, two boreholes (8m depth, 8 sensors) were drilled at the two ERT-grid sites in 2006. Additionally, BTS measurements (bottom temperatures of snow cover) were realized in March 2007 and 2008. PISR was calculated by using the solar analyst, integrated in the ESRI ArcGIS software package. Simple statistical procedures were performed to analyze the correlation between BTS and surface substratum plus BTS and PISR.

Surface substratum show a high variability in grain-size distribution within short distances. The MTDs as well as the borehole measurements illustrated the different temperature regimes of different substrate classes. Mean annual ground temperature at the lower site was slightly colder than at the upper site. Nevertheless, borehole temperature logging proved the occurrence of permafrost at both sites. Modeled PISR clearly shows the mountain shade effect. The ERT-grid in the lower part of the forefield was more exposed to solar radiation compared to the ERT-grid in the upper part.
Results of the quasi-3D images enable linking the subsurface structure with the surface maps. The images point out, that the permafrost distribution is very heterogeneous in between small distances. Warm permafrost/lower ice content coexists next to slightly colder permafrost/higher ice content in between small distances due to the complex surface characteristics.

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