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Permafrost dynamics within the Muragl glacier forefield (Swiss Alps) – Characterization by a geophysical and photogrammetrical approach

Julie Kaestl and Christof Kneisel
Departement of Physical Geography, University of Wuerzburg, Germany (julie.kaestl@uni-wuerzburg.de)

Permafrost as a hidden part of the alpine cryosphere is as sensitive to the predicted climate change as glaciers. In contrast to glaciers, reactions of permafrost are not visible; therefore it's necessary to use geophysical and photogrammetrical methods to infer subsurface permafrost dynamics. The study site is located in a glacier forefield in the upper parts of the Muragl Valley (Upper Engadin, Switzerland), that has been object of several investigations (geomorphological mapping, 1D, 2D geoelectrical surveying, surface and subsurface temperature logging etc.) during the last decades.
Due to the small scale surface and subsurface heterogeneity, it is necessary to use investigation methods that are capable of detecting small variations in large-areas. To illustrate this, 2D electrical resistivity tomography (ERT), seismic refraction tomography (SRT) and remote sensing (horizontal surface displacements) have been used. By collating several parallel and perpendicular two dimensional ERT-profiles a quasi-3D image of the subsurface has been generated. The in-line spacing of the survey is 3 m, the grid is collated out of 16 2D-ERT, showing the variability of resistivity values within short distances.

Results of the quasi-3D imaging compared to the surface characteristics (fine-grained to coarse grained glacial till) indicate the important influence of surface substratum on subsurface frozen ground conditions.
To assess the spatio-temporal permafrost variability, three 2D ERT monitoring sites have been installed. Those sites represent the forefield as they have different substrates, altitudes, aspect and geomorphologic activity. During summer the monitoring has been measured, a time-lapse of the electrical resistivity has been created. The combination of monitoring 2D ERT and 2D SRT allows a characterization of permafrost conditions (ice content, content of unfrozen water, air and rock/soil) in comparison to surface substrate.
Creeping rates of 0.5 m per year have been detected by Kääb and Kneisel (2006) for the investigated area of the glacier forefield. Actual remote sensing data is currently compared for horizontal surface displacements of those, of the years 1981 and 1994.

Geophysical measurements for the part with the high creeping rate show low resistivity values (9-30 k ohm) and moderate seismic velocities (3000 m/s). Only a fine-grained border area shows high resistivity (120 k ohm) and higher velocities (4000 m/s). During summer, the extent of the permafrost body shrinks and a variation of the active layer depth (2 - 4 m) was detected.

References:
Kääb, A. & C. Kneisel (2006): Permafrost Creep within a Recently Deglaciated Glacier Forefield: Muragl, Swiss Alps; Permafrost and Periglacial Processes 17: 79–85.