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Ground thermal conditions and active layer processes within two glacier forefields with heterogeneous permafrost occurrence

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The patchy occurrence of frozen ground in the alpine discontinuous permafrost zone is well known and often restricted to block fields and areas with coarse surface substrate. External factors that account for this heterogeneous distribution on a local scale are snow depth, snow cover evolution, local topography, nature of substrate and glacial history.

We present temperature and geoelectrical monitoring data from two glacier forefields in the Swiss Alps, both deglaciated since the Little Ice Age. Two boreholes were drilled in 2006 at Val Murgal (8 m) and another two in 2008 within glacier forefield Vadret dal Murtèl (10 m) each equipped with temperature sensors in variable depths. Additionally, temperature data loggers were placed at both sites. Boreholes and miniloggers were installed at locations with different substrate to cover the range in grain sizes from sand to boulders that dominate in this kind of alpine environment.
Geoelectrical measurements were conducted across the boreholes to correlate thermal conditions with physical properties of the near surface layer. Whereas in Val Muragl measurements were repeated several times a year since 2005, an automatic monitoring was installed in March 2011 in glacier forefield Murtèl. With the monitoring system changes in subsurface electrical resistivity can be resolved on a diurnal scale. Together with borehole temperatures these data enhance the understanding of processes during snow melt in spring and freeze-back in autumn within the active layer.

Temperature data show a constant depth of the active layer for the 6-year record of Val Muragl. While the blocky debris thaws down to 2 m during summer, the active layer is 5 m at the site with finer till. A contrary trend is visible at the lowermost sensor in 8 m depth that indicates a slight warming at the coarse site. Within the fine debris temperatures dropped from -0.3 °C to -0.7 °C since 2009 and at the same time the annual signal diminished. The 3-year record from Murtèl site shows a constant temperature slightly below the freezing point at the 10 m sensor without any trend at the blocky site. The second borehole in morainic till has seasonal frost conditions. Data from miniloggers document a strong heterogeneity in the thermal regime at the ground surface on a local scale. Mean annual ground surface temperatures differ by more than 3 °C within short distances and show a correlation with grain size. However, outliers with cold MAGST indicate that permafrost may exist even at sites with finer debris.
Results from geoelectrical measurements indicate a fast reduction in ground resistivity within the active layer that occurs immediately when the snow cover gets isothermal and snow melt sets in. Resistivity values decreased by more than 60 per cent during a 6 day period in May 2011.