



Changes in borehole temperatures, ice content and creep velocities – results from 10 years of monitoring mountain permafrost in Switzerland

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The network for permafrost monitoring in Switzerland (PERMOS) has been built up since the early 1990s aiming to document the state and changes of mountain permafrost on a long-term basis. Following a 6 year pilot-phase starting in 2000, the PERMOS network is now funded and integrated into the national and international monitoring structures. The observations are based on three elements: (1) ground temperatures measured in boreholes and at the surface near to the drill site, (2) changes in subsurface ice and water content at the drill sites by geo-electrical surveys, and (3) velocities of permafrost creep determined by geodetic surveys and/or photogrammetry. In addition, standardized documentation of fast mass movements from permafrost areas (e.g., rock fall) is being established. In this contribution, we present measurement results of all observation parameters and their joint interpretation, along with a short overview on PERMOS and its monitoring strategy.

The connection between air temperatures and permafrost temperatures is not straightforward. Effects of winter snow conditions, surface cover (cooling effects by coarse blocks), subsurface ice content (effects of latent heat), and steep topography mask changes in atmospheric conditions when they propagate into the subsurface. The signal is additionally delayed by the high thermal inertia of the system. This can explain why temperature time series from 24 boreholes of up to 20 years length do not (or not yet) reflect a clear warming signal. Seasonal variations in air temperatures and snow conditions, however, are well visible in active layer thicknesses in most boreholes, with the intensity of the signal depending on site characteristics. The information gained from borehole temperatures is complemented by geo-electrical surveys. Results can be linked to changes in frozen and unfrozen water content, indicate substantial degradation of ground ice, and show the potential of a combined approach compared to thermal monitoring alone.

Kinematics results show an increase of creep velocities or even a destabilization of rock glaciers in the past years or decades. In view of the borehole measurements, this acceleration may be related to changes in water content or availability. The inventory of rock falls comprises more than 150 events from permafrost regions, with an increase of events in the past two decades. This is likely a result of a combination of factors: growing human activities in high mountain regions, raised public and scientific awareness to this phenomena, and an increase of such events.