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Permafrost in vegetated scree slopes below the timberline - characterization of thermal properties and permafrost conditions by temperature measurements and geoelectrical monitoring

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Discontinuous alpine permafrost is expected to exist at altitudes above 2400m a.s.l. at mean annual air temperatures (MAAT) of less than -1°C. Below timberline only a few sites are known, where sporadic permafrost exists in vegetated talus slopes with positive MAAT. Aim of the study is to characterize permafrost-humus interaction, the thermal regime and its influence on temporal and spatial permafrost variability.

Results of geophysical and thermal measurements from three talus slopes, located in the Swiss Alps (Engadin, Appenzell) at elevations between 1200 and 1800m a.s.l. with MAAT between 2.8°C and 5.5°C are presented. Parent rock-material of the slopes are granite (Bever Valley, Engadin) and dolomite (Susauna Valley, Engadin; Brüeltobel, Appenzell). Joint application of electrical resistivity tomography (ERT) and refraction seismic tomography (RST) is used to detect and characterize permafrost. To observe temporal and spatial variability in ice content and characteristics year-around geoelectrical monitoring and quasi-3D ERT are used. A forward modeling approach has been applied to validate the results of geoelectrical monitoring. A number of temperature data loggers were installed in different depth of the humus layer and in different positions of the slope to monitor the ground thermal regime.

Isolated permafrost has been detected by the combination of ERT and RST in the lower parts of the investigated talus slopes. Results from geophysical measurements and monitoring indicate a high spatial and temporal variability in ice content and ice characteristics (temperature, density, content of unfrozen water) for all sites. A distinct rise of resistivities between November and December indicates a decrease of unfrozen water content, caused by a pronounced cooling in the lower parts of the slope. Decreasing ice content and extent of the permafrost lenses can be observed in decreasing seismic velocities from 2600m/sec in spring to only 1500m/sec in October.
Ice characteristics, ice content and extent of permafrost lenses depend on the thermal regime, induced by characteristics of surface (humus, vegetation) and subsurface (parental rock material) material as well as thermal effects, with an inversive air flow inside the talus slope of cold air inflow in winter in the lower parts and cold air outflow in summer through the same vents (chimney effect), a theory that has been proven by temperature measurements in the Brüeltobel and the Susauna Valley. While the dolomitic talus slopes are relatively homogenous concerning surface and subsurface material, showing a consistent thick humus cover, the granitic site shows a small-scale heterogeneity of different humus forms and thicknesses as well as size of granitic boulders, influencing the thermal regime. Temperatures in the humus profile are very constant for the dolomitic sites, reflecting the insulation capability of the humus cover, with temperatures in August around 3°C at 30cm depth (mean air temperature in August 12°C). Humus temperatures (30cm depth) in the Bever Valley vary strongly between areas with consistent humus cover (1-2°C in August) and areas with coarse, uncovered boulders, where temperatures show a stronger coupling to air temperatures. While the chimney effect has strong influence on the ground thermal regime of the dolomitic sites, for some parts of the granitic slope in the Bever Valley the theory has to be expanded towards a continuous air exchange with the atmosphere, for areas where the insulation capability of the humus cover is highly disturbed along large parts of the talus slope.