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New insights into the ground thermal regime of talus slopes with permafrost below the timberline

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In the central Alps permafrost can be expected above 2400 m a.s.l., at altitudes where mean annual air temperatures are below -1° C. However, isolated permafrost occurrences are present in north-exposed talus slopes, far below the timberline, where mean annual air temperatures are positive. Driving factors are assumed to be a low income of solar radiation, a thick organic layer with high insulation capacities as well as the thermally induced chimney effect (Wakonigg, 1996).

Investigated are three talus slopes with permafrost in the Swiss Alps that differ with regard to elevation level, talus material, humus characteristics and vegetation composition as well as the mean annual air temperatures.
Aim is to achieve a deeper understanding of the factors determining the site-specific thermal regime, as well as the spatially limited and temporally highly variable permafrost occurrences in vegetated talus slopes. Focus is not solely on the question of why permafrost exists at these sites, but also why permafrost does not exist in the immediate surroundings.

To detect the temporal variability and spatial heterogeneity of the permafrost occurrences, electrical resistivity tomography monitoring, seismic refraction tomography monitoring, and quasi-3D ERT were applied. To determine the ground thermal regime, air-, ground surface-, and humus temperatures, as well as temperatures within vents of the chimneys were recorded. Furthermore, humus characteristics (thickness, -temperature and -moisture) were mapped in permafrost-affected slope areas and in the immediate surroundings. To test the correlation between solar radiation, permafrost distribution, and humus/vegetation composition, digital elevation models were used to calculate the income of solar radiation.

The areal extent of the permafrost bodies coincide precisely with slope sections where the organic layer is thickest, a consistent moss cover is present, and where temperatures at the transition between humus layer and talus material are lowest.
The interaction of factors driving the ground thermal regime turned out to be more complex than assumed with differences between the investigated sites. Besides convective heat transport of the chimney effect, conductive heat flow within the humus layer strongly influences the ground thermal regime. Supercooling of the talus material in winter and autumn is aggravated by a high thermal conductivity of the organic material under frozen and wet conditions. The preservation of permafrost is favoured by the high insulation capacity of dry organic material in summer and by a prolonged zero-curtain period of up to 3 months – driven by high water-storage capacity of the organic material – that buffers the propagation of warm temperatures into the subsurface in spring.
The income of solar radiation at the foot of the slope does not state a major driving factor for the occurrence of permafrost. Variability is low between areas with and without permafrost. In fact, differences were detected upslope, below the rock-walls, with summer-values being lowest in areas above the permafrost occurrences. It must be assumed that this affects the thermal circulation of the chimney effect during summer and favours the persistence of frozen ground in spatially limited slope areas.