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Mountain permafrost detection inferred by a combined remote sensing, geomorphological and geophysical approach

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The detection of permafrost in high altitude regions of the Alps is an important aim of alpine studies. Geophysical research in this field is important for alpine risk, infrastructure and climate change studies. Because of the complexity of detecting ground ice, the database of permafrost maps is currently not very well evaluated for wide areas of the Alps.

The research for this study was conducted at Rofenberg (Ötztal, Austria), a typical high alpine environment in mid-latitudes, which ranges between 2800 and 3229 m a.s.l.. Areas that were not covered by Little Ice Age (LIA) glaciers have been exposed to permafrost friendly conditions. These areas are well suited for investigations aiming at the detection of permafrost evidence with a combination of methods. Geomorphological observations, geophysical measurements, like ground penetrating radar (GPR), geoelectrical soundings and refraction seismic, and airborne lasercanning (ALS) based measurements of surface changes on the study site were used to obtain an integrative analysis of possible permafrost distribution.

At several small areas near the mountain ridge of the “Rofenbergköpfe” south of the glacier tongue of Hintereisferner, a small but continuous lowering of the surface was detected throughout the whole data series of 20 ALS flights. The surface changes are assumed to originate from the melting of permafrost or small dead-ice bodies. To verify this assumption, several measurements have been conducted.

As electrical resistivity tomography, GPR and refraction seismic are considered as important multifunctional geophysical methods for research in periglacial and permafrost related environments, these methods were applied to detect permafrost in the areas with significant surface changes. Therefore two geophysical measurement campaigns were carried out at the “Rofenbergköpfe”. The parallel application enables a comparison and cross-validation of the results gained by the three techniques. After the analyses of the single datasets, a tomography including all results was created. For a further investigation of the occurrence and distribution of permafrost, 15 temperature-loggers were installed, which measured the base temperature of the snowpack (BTS) during the whole winter and so recorded potential freezing and thawing of the ground. This offered a further possibility for validation of the geophysical measurements. Additionally, the BTS was measured two times in the area close to the end of the winter snow accumulation period, to get a general idea of the possible distribution of permafrost or ice in the underground.

The results of the measurements at Rofenberg show good correlation. In the areas detected within the multitemporal ALS dataset permafrost is assumed at a depth between 2 meters and 8 meters and similar ground structures can be spotted for every geophysical method. The combined approach of geophysical methods, remote sensing and field investigations allowed a profound cross-validation of the different methods.