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Multiannual year-round mountain permafrost monitoring using electrical resistivity- and seismic refraction tomography

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During recent years, electrical resistivity tomography (ERT) has been established as a state of the art method for monitoring the seasonal and long-term permafrost evolution. However, for permafrost related problems various authors recommend the joint application of at least two methods to avoid ambiguities and misinterpretations of inversion artefacts using solely ERT. Up to now, the only approach using seismic refraction tomography (SRT) for monitoring the permafrost evolution during the summer half-year has been presented by Hilbich (2010).

Presented are results from year-around ERT monitoring at three talus slopes with permafrost below the timberline in the Swiss Alps (Upper Engadin; Appenzell) over a period of up to four years. To support ERTM-data, a SRT monitoring array was installed at one test site; measurements were conducted during the winter half-year of 2010/11. Up to now this is the first SRT-monitoring to record the permafrost evolution during winter below a consistent snow cover. While for most parts of the year ERT and SRT-data lead to coinciding conclusions, results diverge for the period of permafrost degradation during summer, as well as for the period of snowmelt in spring. Repeatability tests, as well as forward and inverse modelling were conducted for validation and to achieve a more sophisticated interpretability of ERTM-data. Interpretation of geophysical data is supported by numerous temperature measurements, and also snow cover-data.

A distinct seasonal variability of geophysical properties within the permafrost bodies that exceeds the intra-annual variations has been detected by ERTM and SRTM. During summer, ERTM-data indicate a low variability of permafrost properties, while velocity values constantly decrease between spring and autumn. A massive increase of resistivity and velocity values within the subsurface during winter is followed by a rapid decrease with incipient snowmelt. While winter temperatures as well as snow thicknesses were highly variable during the monitoring period, variability of geophysical properties for measurements in high-winter is low. With onset of snowmelt, and onset of the zero-curtain period in spring, resistivity- as well as velocity values within the active layer rapidly decrease. Geophysical properties within the permafrost body during this period are characterized by an increase of resistivity values, but a decrease of velocity values between the measurement in high-winter (February) and March. Based on synthetic data modelling, it must be assumed that the increase of resistivity values is rather an inversion artefact caused by the increased gradient of resistivity values between active layer and permafrost body during the zero-curtain period.

The generally good consistency of results from ERT and SRT mirror their suitability for monitoring the evolution of mountain permafrost. However, divergences of results underline the importance of a combination of methods to avoid ambiguities and misinterpretations. Additional SRT measurement are very work-intensive – especially during winter –, but deliver valuable information on subsurface properties.