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Applicability of time-lapse refraction seismic tomography for the detection of ground ice degradation

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The ice content of the subsurface is a major factor controlling the natural hazard potential of permafrost degradation in alpine terrain. Monitoring of changes in ground ice content is therefore similarly important as temperature monitoring in mountain permafrost. Although electrical resistivity tomography monitoring (ERTM) proved to be a valuable tool for the observation of ground ice degradation, results are often ambiguous or contaminated by inversion artefacts.

In theory, the P-wave velocity of seismic waves is similarly sensitive to phase changes between unfrozen water and ice. Provided that the general conditions (lithology, stratigraphy, state of weathering, pore space) remain unchanged over the observation period, temporal changes in the observed travel times of repeated seismic measurements should indicate changes in the ice and water content within the pores and fractures of the subsurface material. The applicability of refraction seismic tomography monitoring (RSTM) as an independent and complementary method to ERTM was analysed for two test sites in the Swiss Alps. The development and validation of an appropriate RSTM approach involved a) the comparison of time-lapse seismograms and analysis of reproducibility of the seismic signal, b) the analysis of time-lapse travel time curves with respect to shifts in travel times and changes in P-wave velocities, and c) the comparison of inverted tomograms including the quantification of velocity changes. Results show a high potential of the RSTM approach concerning the detection of altered subsurface conditions caused by freezing and thawing processes. For velocity changes on the order of 3000 m/s even an unambiguous identification of significant ground ice loss is possible.