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Geophysical monitoring and joint inversion to improve the quantitative characterisation of mountain permafrost

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Permanently frozen ground is a widespread phenomenon forming a major part of the cryosphere. Characterizing the thermal state of the ground, alpine permafrost is a particularly sensitive climate change indicator. Geophysical methods have the potential to bridge the gap between direct observations and remote sensing techniques, and have been extensively used to image physical properties in the subsurface. Although the ground ice content is a key parameter controlling alpine slope stability, the volumetric ice content is rarely estimated in permafrost studies, as it is particularly difficult to retrieve. Electrical resistivity tomography (ERT) and refraction seismic tomography (RST) methods have been combined due to their complementarity in terms of sensitivity to individual ground properties. Addressing the necessity for improving geophysical processing techniques to quantify the ground ice content, this thesis contributes to the development of a new approach of petrophysical joint inversion to assess the spatial distribution of the volumetric fractions of water, ice, air, and rock.
Within this PhD thesis, a unique permafrost geophysical data set (in terms of spatiotemporal coverage) has been used to qualitatively and quantitatively analyze the freezing and thawing processes as well as estimate the ground ice content with lower uncertainties in comparison to previous approaches. In spite of the wide range of morphological, climatological, and geological differences between the sites, the observed inter-annual resistivity changes and long-term tendencies (i.e. permafrost degradation) are found to be similar for all sites of the ERT monitoring network, suggesting that the climate signal is stronger than site-specific local signals. Furthermore, the more reliable ice content estimated through the petrophysical joint inversion has the potential to improve the parametrization of permafrost thermo-hydro-mechanical process models.

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