Electrical modelling for an improved understanding of GPR signatures in alpine permafrost using results obtained from different geophysical surveys

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As a consequence of climate change, current environmental research focuses on understanding the effect of extreme atmospheric events, for instances, in the degradation of alpine permafrost. To this end, here we present the modelling of Ground Penetrating Radar (GPR) monitoring signatures collected at the summit of Hoher Sonnblick in frame of the ATMOperm project. The Hoher Sonnblick is located in the Austrian Central Alps, 3106 m above sea level, where a permanently installed monitoring array permits the collection of Electrical Resistivity Tomography (ERT), which provides information about changes in the electrical resistivity in an imaging framework. To improve the interpretation of the observed changes in the electrical properties, and to extend the investigation to areas away of the ERT monitoring, we performed GPR monitoring measurements in a series of profiles spread across the entire summit area. GPR is a well-stablished method in permafrost investigations used to gain structural information about lithological changes and to evaluate variations in the active layer, taking into account the contrasting electrical properties of frozen and unfrozen materials. Nevertheless, in comparison with previous studies at the Hoher Sonnblick, GPR investigations in our study aimed not only at the identification of possible interfaces, but to develop a methodology for the modelling of subsurface electrical properties for an improved understanding and interpretation of GPR and ERT imaging results. To achieve this, we investigated the synthetic response for subsurface models taking into account the resistivity distribution in the subsurface as derived from ERT monitoring data and literature. Further analyses were performed on several synthetic and field data sets, varying the properties of the electrical structures, for instance, geometry and electrical contrasts. Comparison of synthetic and measured radargrams permitted us to evaluate the proposed model. This interactive process was repeated for each profile and for data collected along the monitoring dataset. Finally, we quantified the temporal variations in the electrical properties to assess seasonal changes in the active layer. Modelling results demonstrate the applicability of the proposed methodology considering signal reflection and attenuation to validate the interpreted lithologic and thermal units within permafrost environments.