Modelling of Ground Penetrating Radar in alpine Permafrost at Hoher Sonnblick Summit

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Abstract

In frame of the ATMOperm project, we conducted a series of Ground Penetrating Radar (GPR) surveys at Hoher Sonnblick Summit. The objective was to determine the internal structures and distribution of mountain permafrost and associated changes due to seasonal variations in temperature. To achieve this, 3D GPR surveys were repeated between 2015 and 2017 at different times. Besides the processing of the raw data, modelling of electrical properties for the computation of synthetic radargrams was carried out to permit a better interpretation of the observed changes in GPR results.

Keywords: Ground Penetrating Radar, synthetic modelling, monitoring

Introduction

Current permafrost research focuses on understanding the effect of atmospheric events, such as climate change in the degradation of alpine permafrost.

To better understand subsurface processes, here we present geophysical imaging results for data collected at the Hoher Sonnblick Summit. This is located in the Austrian Central Alps, 3106 m above sea level, where a permanently installed monitoring array (Fig. 1) permits the collection of electrical resistivity tomography (ERT) being a standard method in permafrost investigations (Krautblatter et al., 2008). However, ERT measurements might be limited in winter due to the low current injections taking place in surfaces covered by snow and ice. To overcome such limitation, we performed monitoring measurements with GPR, a contactless method based on the propagation of electromagnetic waves, which has been successfully applied in previous studies in permafrost environments (Hauck & Kneisel, 2008; Moorman *et al*, 2007).

The final objective of our investigations is to obtain a 3D subsurface model of the electrical properties at the Hoher Sonnblick Summit for an improved characterization of the active layer and lithological contacts and discontinuities (e.g., fractures). Aiming at improving the quantitative interpretation, the synthetic response was numerically modelled taking into account the resistivity distribution in the subsurface as derived from ERT monitoring data and information from supplementary geophysical surveys.

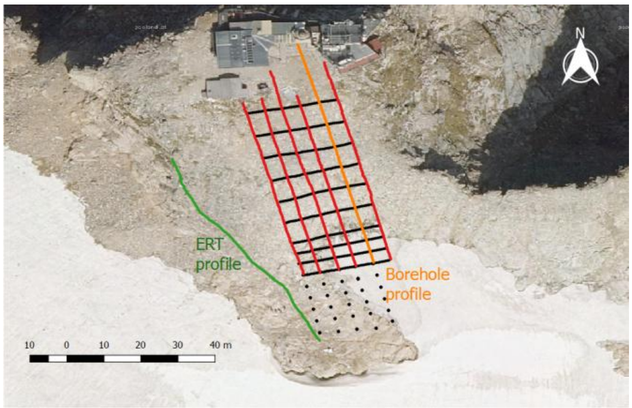

Figure 1: Orientation of the GPR profiles defined by six long profiles (red), 13 transverse profiles (black) and ERT monitoring profile (green).

Field Work

A total of eight GPR campaigns were organized between August 2015 and September 2017. In those campaigns GPR datasets were collected using a SIR 3000 unit in a common offset configuration, mainly with 200 and 400 MHz antennas. Results presented here refer to a campaign in winter 2017 collected along 6 long profiles and 13 perpendicular shorter profiles (Fig. 1) covering an area of ca. 25 x 100 m using a 200 MHz antenna.

Results

GPR raw data were analyzed using REFLEXW software, based on the application of standard filter routines and topographic correction. Results obtained for an exemplary dataset clearly reveal interfaces between materials with different electrical properties (Fig. 2). The first interpretation of the radargrams took into account amplitude information and the propagation velocity of the radar waves derived by hyperbola analysis. To validate such interpretation, we perform numerical modelling after assigning electrical values to the different materials based on GPR- and ERT-measurements and those reported in literature (Hauck & Kneisel, 2008; Moorman *et al*, 2007).

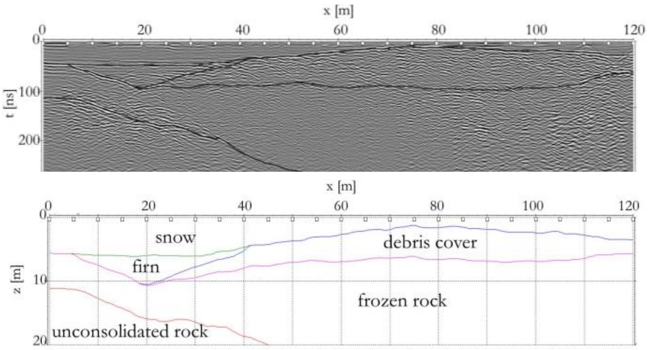

Figure 2: Radargram of borehole profile using a 200 MHz antenna (top) and corresponding interpreted model (bottom).

Since the reflection of GPR signals is related to variations in both the electrical permittivity (ε) and conductivity (σ) of the medium, our modelling included variations in the contrasts between those parameters and the geometry of the interfaces. Hence, the analysis of different numerical models permits us to adjust the synthetic radargram to approximate the actual measured data (Fig. 3). Fractures were added representing the debris cover to reconstruct the patterns observed in the measured data. Moreover, further structural information in the models has been obtained through results from seismic P-wave velocity information and transient electromagnetic soundings.

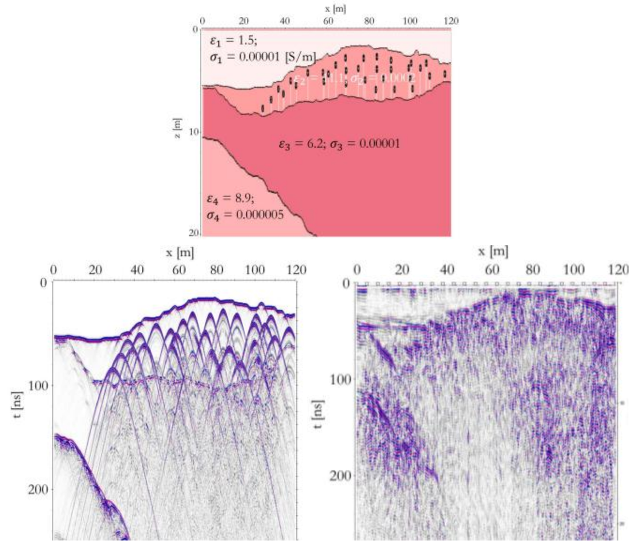

Figure 3. Comparison of synthetic (left) and measured (right) radargram representing the heterogeneous debris-covered mountain environment at the Hoher Sonnblick.

As expected due to the complexity of alpine permafrost soils, the models need to take into account the large number of discontinuities observed in the GPR data. Thus, careful data processing is required to permit the identification of the active layer and improve the quantitative meaning of the deviated electrical models. Future research will focus on the integration of borehole temperature data for the improved modelling of GPR.

Acknowledgments

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