EGU2020-20081
https://doi.org/10.5194/egusphere-egu2020-20081
EGU General Assembly 2020

Improved thermal characterization of alpine permafrost sites by broadband SIP measurements

Jonas K. Limbrock, Maximilian Weigand, and Andreas Kemna
Universtiy of Bonn, Institute of Geosciences, Geophysics Section, Germany (limbrock@geo.uni-bonn.de)

Geoelectrical methods are increasingly used for non-invasive characterization and monitoring of permafrost sites, since the electrical properties of the subsoil are sensitive to the phase change of liquid to frozen water. In this context, electrical subsurface parameters act as proxies for temperature and ice content. However, it is still challenging to distinguish between air and ice in the pore space of the rock based on the resistivity method alone due to their similarly low electrical conductivity. This ambiguity in the subsurface conduction properties can be reduced by considering the spectral electrical polarization signature of ice using the Spectral Induced Polarization (SIP) method, in which the complex, frequency-dependent impedance is measured. These measurements are hypothesized to allowing for the quantification of ice content (and thus differentiation of ice and air), and for the improved thermal characterization of alpine permafrost sites.

In the present study, vertical SIP sounding measurements have been made at different alpine permafrost sites in a frequency range from 100 mHz to 45 kHz. From borehole temperature measurements, we know the thermal state of these sites during our SIP soundings, i.e., an active layer thickness of about 4 m at the Schilthorn field site. In order to understand and to calibrate ice and temperature relationships, the electrical impedance was likewise measured on water-saturated soil and rock samples from these field sites in a frequency range from 10 mHz to 45 kHz during controlled freeze-thaw cycles (+20°C to -40°C) in the laboratory.

For field and laboratory measurements, the resistance (impedance magnitude) shows a similar temperature dependence, with increasing resistance for decreasing temperatures. For each sample, the impedance phase spectra exhibit the well-known temperature-dependent relaxation behavior of ice at higher frequencies (1 kHz - 45 kHz), with an increasing polarization magnitude for lower temperatures or larger depths of investigation, respectively. At lower frequencies (1 Hz - 1 kHz), a polarization with a low frequency dependence is observed in the unfrozen state of the samples. We interpret this response as membrane polarization, considering that it decreases in magnitude with decreasing temperature (i.e., with ongoing freezing).

Using the independently measured borehole temperature data, a systematic comparison of the SIP laboratory and field measurements indicates the possibility of a thermal characterization of an alpine permafrost site using SIP.