Seasonal and annual dynamics of frozen ground in a mountain permafrost site in the Italian Alps detected by Spectral Induced Polarization

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Permafrost regions are currently undergoing considerable changes due to climate change related to warming and thawing events yielding a decrease in the ice content reported for permafrost sites worldwide. Thus, long-term monitoring of the thermal state of permafrost has become an essential task in the European Alps. Geophysical methods are increasingly being used to support and interconnect spatially sparse borehole data and investigate the spatial distribution and temporal evolution of permafrost in a quasi-continuous manner. Electrical resistivity tomography (ERT) is a widely applied technique for the quantification of ice-rich permafrost, commonly associated with a significant increase in the electrical resistivity upon freezing. However, air is also characterized by high electrical resistivity values hindering a direct interpretation of the ERT results. Theoretical and laboratory studies have revealed that ice exhibits a characteristic induced electrical polarization response in the low frequencies (< 1 kHz), with the frequency-dependence of the electrical properties being also related to changes in temperature and ice content. Thus, the application of the spectral induced polarization (SIP) method has been recently proposed as a suitable technique in permafrost studies.

We present here for the first time SIP imaging results collected at a representative permafrost site covering a one-year monitoring period, with measurements in the frequency range between 0.1 and 225 Hz. The selected study area Cervinia Cime Bianche (Italian Alps) is a long-term permafrost-monitoring site situated at an elevation of ~3100m and provides comprehensive geophysical and borehole temperature data for validation. To minimize the contamination of the SIP data with parasitic electromagnetic fields, we took particular care in the installation of coaxial cables and the use of an adequate measuring protocol. SIP data were collected as normal and reciprocal pairs for the quantification of data error and we developed an analysis of data quality taking into account changes in time and in the frequency to remove outliers and erroneous measurements. Our results show clear changes in SIP anomalies for summer and winter months, which can be associated to freeze and thaw processes within the subsurface.

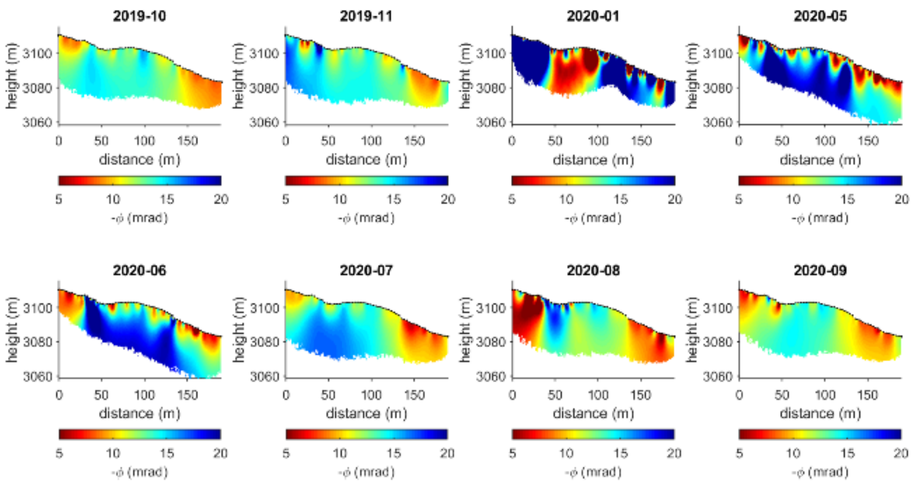

Figure caption: SIP data collected on a monthly basis covering one year of measurements. Here we present the phase of the complex resistivity at 0.5 Hz for 10 time stamps of the year 2019/20.