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Automated time-lapse electrical resistivity tomography (ERT) for improved process analysis and long-term monitoring of frozen ground

Christian Hauck (1,5), Christin Hilbich (2,3), and Christian Fuss (4)

(1) University of Fribourg, Department of Geosciences, Fribourg, Switzerland (christian.hauck@unifr.ch), (2) Geographical Institute, University of Zurich, Switzerland, (3) Geographical Institute, University of Jena, Germany, (4) Geolog, Starnberg, Germany, (5) Institute for Meteorology and Climate Research, Karlsruhe Institute of Technology (KIT), Germany

Determining the subsurface ice and unfrozen water content in cold regions are important tasks in all kind of cryospheric studies, but especially on perennial (permafrost) or seasonal frozen ground, where little insights can be gained from direct observations at the surface. In the absence of boreholes, geophysical methods are often the only possibility for visualising and quantifying the subsurface characteristics. Their successful applications in recent years lead to more and more sophisticated approaches including 2- and 3-dimensional monitoring and even quantifying the ice and unfrozen water content evolution within the subsurface.

Due to the strong sensitivity of electrical resistivity to the phase change between unfrozen water and ice, the application of electrical and electromagnetic techniques has been especially successful. Within these methods, Electrical Resistivity Tomography (ERT) is often favoured due to its comparatively easy and fast data processing, its robustness against ambient noise and its good performance even in harsh, cold and heterogeneous environments. Numerous recent studies have shown that ERT is principally suitable to spatially delineate ground ice, differentiate between ice-poor and ice-rich occurrences, monitor freezing, thawing and infiltration processes. However, resistivity surveys have still to be made manually, which poses large constraints concerning the comparability of measurements at specific time instances, e.g. the choice of the date for end-of-summer measurements, and/or the possibility for measurements during winter, when many locations are inaccessible. Furthermore, many climate studies require the analysis of statistically meaningful properties, such as maximum/minimum values and monthly or annual mean values, which cannot be determined using temporally sparse and irregularly spaced measurements.

As a new system for future automated measurements with regular time interval (e.g. 1 measurement per day), an automated ERT monitoring system for the use in cryospheric environments was recently developed in co-operation with the geophysical company Geolog (Starnberg, Germany). The system is based on an existing multi-electrode resistivity instrument (Geotom) with up to 100 electrodes, a solar panel driven battery and wireless data transfer to a base station.

In a prototype version the system has been installed at two high-altitude permafrost sites within the Swiss permafrost monitoring network PERMOS, i.e. at Schilthorn (2970 m) and Stockhorn (3410 m), located in the Northern and Central Swiss Alps, respectively. Both systems are currently running in a test phase, but first results show reproducible 2-dimensional resistivity tomograms with small temporal changes during periods with snow cover, medium changes in summer and largest changes during snow melt in early summer and freezing in autumn.