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The use of electromagnetic induction methods for establishing quantitative permafrost models in West Greenland

Thomas Ingeman-Nielsen (1) and Inooraq Brandt (2)

(1) The Arctic Technology Centre, Department of Civil Engineering, Technical University of Denmark, Kgs. Lyngby, Denmark, tin@byg.dtu.dk, (2) The Arctic Technology Centre, Department of Civil Engineering, Technical University of Denmark, Kgs. Lyngby, Denmark, inbra@byg.dtu.dk

The sedimentary settings at West Greenlandic town and infrastructural development sites are dominated by fine-grained marine deposits of late to post glacial origin. Prior to permafrost formation, these materials were leached by percolating precipitation, resulting in depletion of salts. Present day permafrost in these deposits is therefore very ice-rich with ice contents approaching 50-70% vol. in some areas. Such formations are of great concern in building and construction projects in Greenland, as they loose strength and bearing capacity upon thaw. It is therefore of both technical and economical interest to develop methods to precisely investigate and determine parameters such as ice-content and depth to bedrock in these areas.

In terms of geophysical methods for near surface investigations, traditional methods such as Electrical Resistivity Tomography (ERT) and Refraction Seismics (RS) have generally been applied with success. The Georadar method usually fails due to very limited penetration depth in the fine-grained materials, and Electromagnetic Induction (EMI) methods are seldom applicable for quantitative interpretation due to the very high resistivities causing low induced currents and thus small secondary fields.

Nevertheless, in some areas of Greenland the marine sequence was exposed relatively late, and as a result the sediments may not be completely leached of salts. In such cases, layers with pore water salinity approaching that of sea water, may be present below an upper layer of very ice rich permafrost. The saline pore water causes a freezing-point depression which results in technically unfrozen sediments at permafrost temperatures around -3 °C.

Traditional ERT and VES measurements are severely affected by equivalency problems in these settings, practically prohibiting reasonable quantitative interpretation without constraining information. Such prior information may be obtained of course from boreholes, but equipment capable of drilling permafrozen sediments is generally not available in Greenland, and mobilization costs are therefore considerable thus limiting the use of geotechnical borings to larger infrastructure and construction projects.

To overcome these problems, we have tested the use of shallow Transient ElectroMagnetic (TEM) measurements, to provide constraints in terms of depth to and resistivity of the conductive saline layer.
We have tested such a setup at two field sites in the Ilulissat area (mid-west Greenland), one with available borehole information (site A), the second without (site C). VES and TEM soundings were collected at each site and the respective data sets subsequently inverted using a mutually constrained inversion scheme.

At site A, the TEM measurements (20x20m square loop, in-loop configuration) show substantial and repeatable negative amplitude segments, and therefore it has not presently been possible to provide a quantitative interpretation for this location. Negative segments are typically a sign of Induced Polarization or cultural effects. Forward modeling based on inversion of the VES data constrained with borehole information has indicated that IP effects could indeed be the cause of the observed anomaly, although such effects are not normally expected in permafrost or saline deposits.

Data from site C has shown that jointly inverting the TEM and VES measurements does provide well de-

termined estimates for all layer parameters except the thickness of the active layer and resistivity of the bedrock. The active layer thickness may be easily probed to provide prior information on this parameter, and the bedrock resistivity is of limited interest in technical applications. Although no confirming borehole information is available at this site, these results indicate that joint or mutually constrained inversion of TEM and VES data is feasible and that this setup may provide a fast and cost effective method for establishing quantitative interpretations of permafrost structure in partly saline conditions.