Application of Helicopter Electromagnetics as Part of an Integrated Program to Map Permafrost, Fairbanks, Alaska

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Abstract

The goal of this research is to evaluate helicopter frequency domain electromagnetic (HFEM) to map permafrost over large areas. The preliminary results of the HFEM data are compared to borehole and ground geophysical data collected as part of a larger, on-going research program.

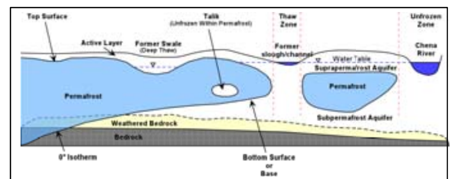
The study area on Fort Wainwright in Fairbanks Alaska, is comprised of alluvial deposits containing discontinuous permafrost up to 45 m thick. Relict river channels, often deeply thawed, are dispersed across the alluvial surface. A south-facing hill slope at the north end of the site is assumed to be permafrost-free. Permafrost has been studied using ground resistivity and ground penetrating radar surveys. Several drill holes provide estimates of the permafrost thickness and lithology. A 3D model of the permafrost configuration was created using over 200 boreholes. The model is currently being further refined by adding geophysical and vegetation data. Over 138 km of ground-penetrating radar (GPR) data were collected to map depth to permafrost and to obtain dielectric permittivity estimates for frozen and thawed soil types. Laterally discrete thawed areas are present in both the GPR and ground resistivity datasets that often coincide with changes in vegetation. Vegetation analysis is an integral part of interpreting extent of permafrost beyond ground geophysical surveys. However, the vertical extent of thaw is generally not represented by vegetation changes and therefore integration of geophysical and borehole data with vegetation type is necessary for 3D representations of permafrost.

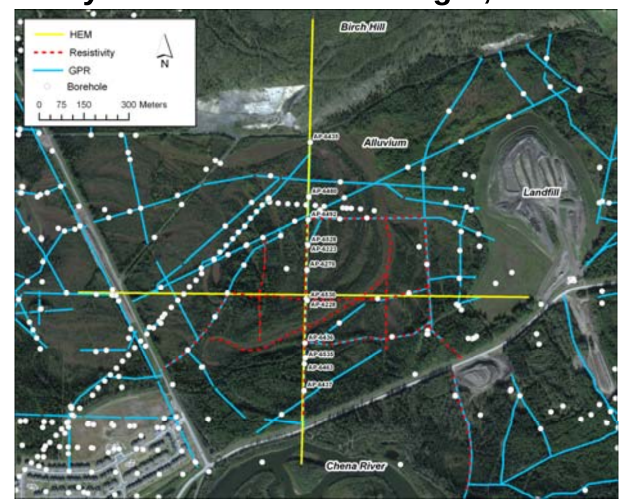
Two one kilometer long lines were flown with a helicopter frequency domain electromagnetic (HFEM) system to evaluate the capabilities of the system to map permafrost geometry (extent and depth) and to estimate electrical resistivity and dielectric constant. The HFEM survey used a horizontal coplanar coil system with transmitted frequencies of approximately 400 Hz, 1800 Hz, 8200 Hz, 40 kHz, and 140 kHz and a vertical coaxial system at 3300 Hz. The north-south and east-west flight lines were flown with system elevations of 30, 40, 45, 50 and 60 meters above ground surface in order to provide redundant data for system calibration computations. Improved system calibrations may allow more accurate estimates to be made of resistivity dispersion and dielectric constant, especially in conductive, layered conditions. In general the simple resistivity depth imaging of the airborne data mapped to greater depth, and appears to map the thickness of the permafrost better than the ground DC lines, but with less detail. HFEM methods offer an approach to gain wider and more complete geophysical coverage in areas difficult to access or having delicate ecosystems. The ground and airborne data coupled with deep borehole data offer a unique opportunity for quantitative comparisons and interpretation.

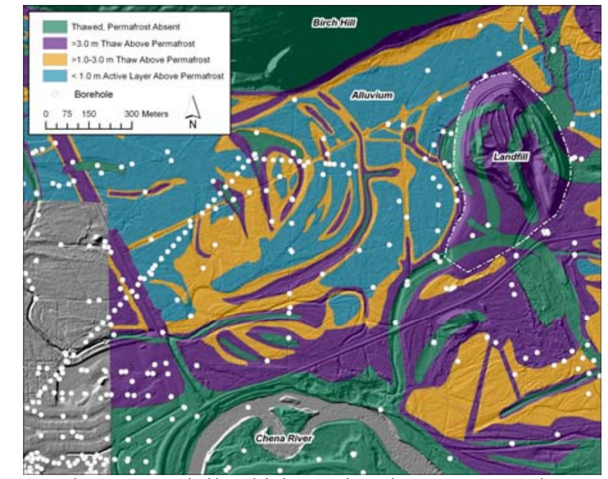
Methods

Resistivity:	Dipole-Dipole and Wenner ground resistivity and capacitively coupled techniques.
GPR:	50- and 100-MHz
Model:	Minimum tension gridding
HFEM :	400 Hz, 1800 Hz, 8200 Hz, 40 kHz, and 140 kHz horizontal co-planar coil, 3300 Hz vertical coaxial
Other:	Boreholes, vegetation, slope and aspect

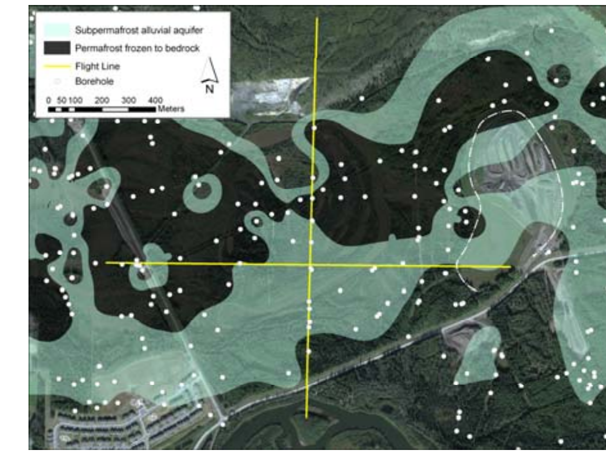
Study Area on Fort Wainwright, Alaska


Generalized cross section of study area



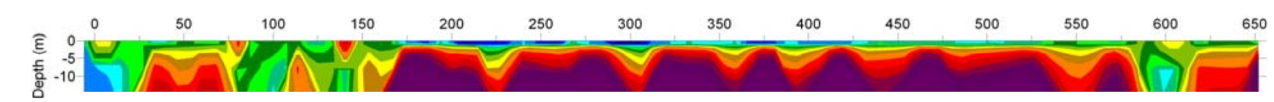


Vegetation was mapped with aerial photographs and transects. Assumptions were made about the depth to top of permafrost based on the vegetation type.
Source: Lawson et al. 1998. Geological and Geophysical Investigations of the Hydrogeology of Fort Wainwright, Alaska Part II: North Central Cantonment Area, CRREL Report 98-6.

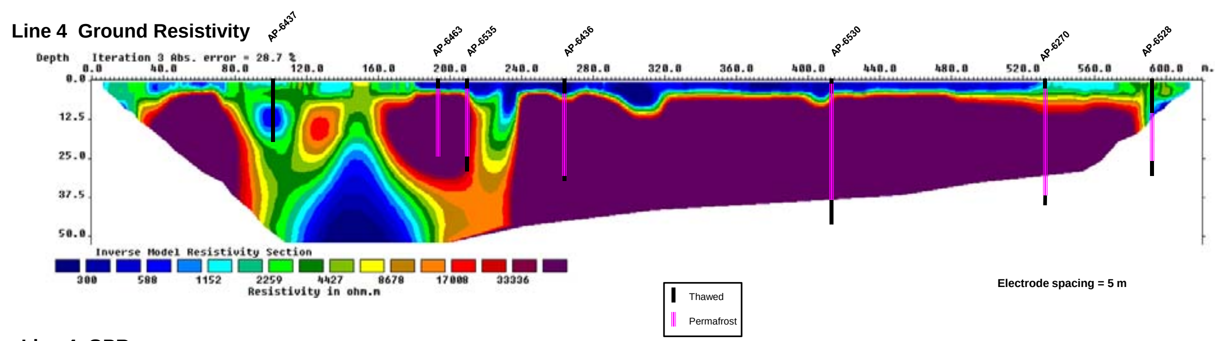


The bedrock surface was modeled using borehole data. The subpermafrost aquifer is present where a thawed zone exists below the permafrost and above bedrock. Groundwater flow is impeded by permafrost therefore mapping the permafrost configuration is integral to hydrologic investigations.

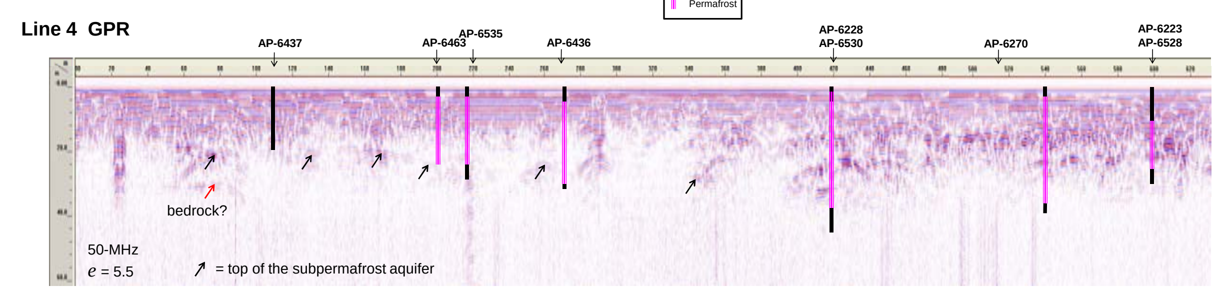
Line 4 Capacity Coupled Resistivity (Ohm-Mapper 5 m dipole)

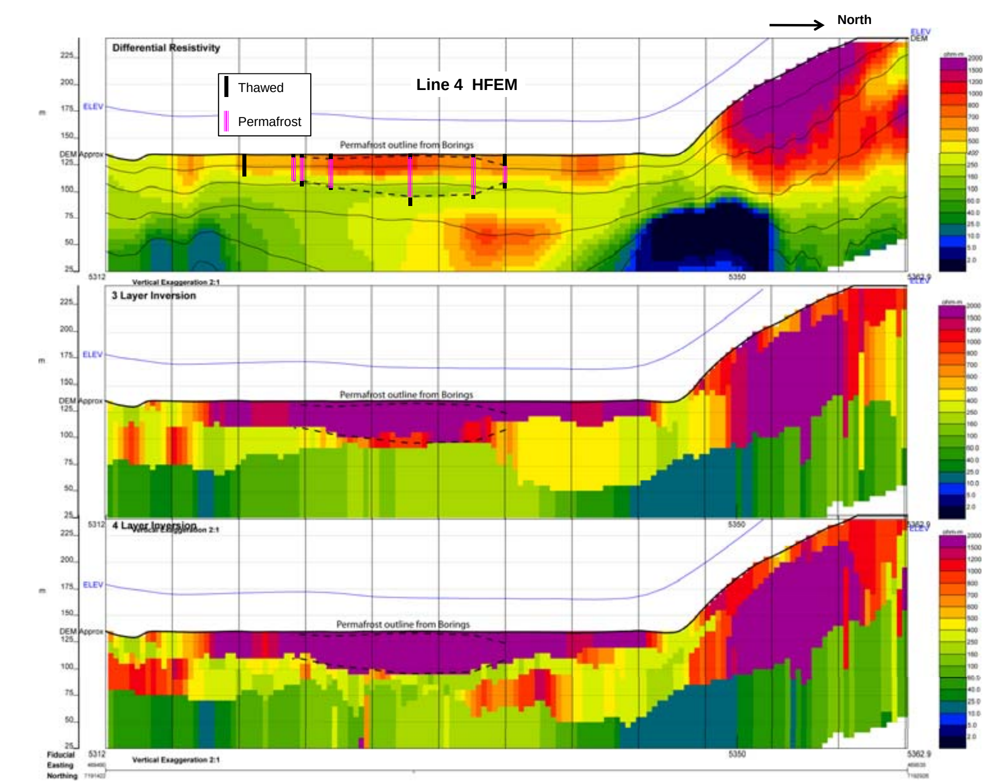


Line 4 Ground Resistivity



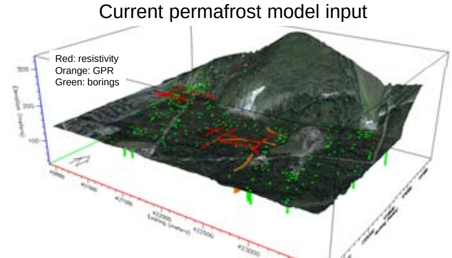
Line 4 GPR



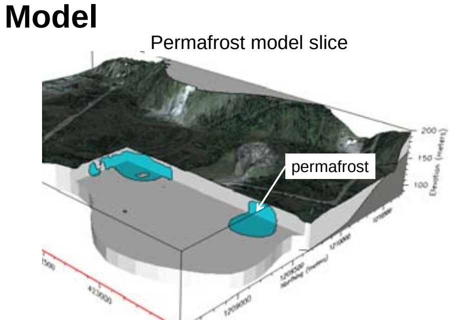


Permafrost Model

Current permafrost model input



Permafrost model slice



Conclusions

- DC resistivity inversions are most useful for delineating lateral and vertical permafrost to thaw transitions. Qualitative assessments of the permafrost, such as where permafrost is degrading, are possible.
- GPR is useful for delineating saturated permafrost aquifers, both shallow (suprapermafrost) and deep (subpermafrost) where signal attenuation is low. Winter GPR data collection is necessary to decrease attenuation in deep surveys.
- The HFEM technique has the greatest depth of penetration and is well suited for estimating permafrost extent in two and three dimensions across large areas. Large thawed zones (>30 m wide) can be resolved. This technique is preferable for mapping permafrost where dense vegetation is present and in remote areas where ground access is difficult.

Acknowledgements

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