Imaging active layer and permafrost variability in the Arctic using electromagnetic induction data

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Characterizing the spatial variability of active layer and permafrost properties is critical for gaining an understanding of Arctic ecosystem functioning and for parameterizing process-rich models that simulate feedbacks to a changing climate. Due to the sensitivity of electrical conductivity measurements to moisture content, salinity and freeze state in the active layer and permafrost and the ease of collecting electromagnetic induction (EMI) data with portable tools over large regions, EMI holds great potential for characterization of permafrost systems. However, inversion of such EMI data to estimate the subsurface electrical conductivity distribution is challenging. The challenges are due to the insufficient amount of information (even when using multiple configurations that vary coil spacing, orientation and elevation and signal frequency) needed to find a unique solution. The non-uniqueness problem is typically approached by invoking prior information, such as inversion constraints and initial models. Unfortunately, such prior information can significantly influence the obtained inversion result.

We describe the development and implementation of a new grid search based method for estimating electrical conductivity from EMI data that evaluates the influence of priors and the information contained in such data. The new method can be applied to investigate two or three layer 1-D models reproducing the recorded data within a specified range of uncertainty at each measurement location over a large surveyed site. Importantly, the method can quickly evaluate multiple priors and data from numerous measurement locations, since the time-consuming simulation of the EMI signals from the multi-dimension search grid needs to be performed only once.

We applied the developed approach to EMI data acquired in Barrow, AK at the Next-Generation Ecosystem Experiments (NGEE Arctic) study site on the Barrow Environmental Observatory. Our specific focus was on a 475-meter linear transect that spanned a range of low- to high-centered polygons. Comparison with collocated point measurements (including deep core), electrical resistivity tomography data, and information from ground penetrating radar data demonstrates that the inverted EMI data permits reliable estimation of electrical conductivity variations in the active layer and permafrost. In particular, we find that electrical conductivity in the active layer correlate to variations in moisture content, whereas deeper imaging responds to the distribution of ice wedges, massive ice and regions of higher salinity. The developed approach represents a significant advance in parameter

estimation methods to explore electrical conductivity models that reproduce EMI data and to evaluate the need for and influence of priors.