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**ABSTRACT TITLE:** Advanced Characterization of Active Layer and Permafrost Variability using Geophysical Approaches

**ABSTRACT:** The arctic tundra ecosystem is recognized as a large source of uncertainty in quantifying feedbacks to global climate warming. Improving understanding of arctic ecosystem functioning and parameterizing process-rich models that simulate feedbacks to a changing climate require advances in estimating the spatial and temporal variations in active layer, ice-wedge and permafrost soil properties. In the context of the Next-Generation Ecosystem Experiments (NGEE-Arctic), we worked on the development of advanced geophysical strategies to improve arctic subsurface imaging and monitoring, as well as understanding interactions between soil properties and arctic ecosystem processes and dynamics. Some specific objectives involved improving (i) geophysical capability in characterizing different subsurface features, including active layer, ice-wedges, ground-ice, saline layers, and permafrost with variable ice-content, (ii) quantifying relations between soil-geochemical properties, geophysical, and geomorphological properties, (iii) integration of multi-scale and -resolution geophysical and point measurements, (iv) strategies to monitor freeze-thaw and water dynamics, and (v) estimates of properties (such as thaw depth, soil moisture, snow depth and water equivalent, ice content and geochemical parameters) and their uncertainty over scales that are relevant for modeling. These objectives were pursued through various numerical developments, laboratory experiments, and field investigations. Field investigations have been performed at the NGEE site located in the Barrow Environmental Observatory (BEO) near the coastal village of Barrow (AK), which is dominated by different types of ice wedge polygons. Acquired geophysical measurements include complex resistivity or electrical resistivity tomography (ERT), electromagnetic induction (EMI) data using portable tools, multichannel analysis of surface waves (MASW) seismic data, ground-penetrating-radar (GPR) data, and time-domain reflectometer (TDR) data. Petrophysical, geochemical, snow point measurements, as well as airborne LiDAR data were used to constrain the interpretation of the geophysical data.

Our major recent advances include (i) a novel parameter-estimation approach adapted to explore the solution non-uniqueness inherent to EMI data and importantly to estimate quickly both electrical conductivity variations in the active layer and trends in permafrost distribution over large areas as enabled by the extensive spatial coverage of EMI data, (ii) an unconventional full-waveform method for MASW data that is especially suitable for resolving low seismic-velocity features that may be associated with permafrost soils with abundant unfrozen water, (iii) high-resolution imaging of ice-wedges, permafrost and active layer using multi 2D ERT at a high-spatial resolution that enables identification of properties that vary substantially over length scales of less than a few meters, (iv) understanding the complex resistivity electrical signature of the freeze thaw states and transitions of arctic soils trough column experiments that will serve for setting field monitoring, (v) an advanced hierarchical Bayesian model for integrating multiscale, multi-type point/geophysical/remote-sensing datasets that provide estimates of subsurface properties and their associated uncertainty, and (vi) identification of relations between subsurface properties and surface properties that can serve for zonation at larger scales and/or parameterization of mechanistic models. The above developments will facilitate the identification and modeling of critical terrestrial ecosystem characteristics and behaviors.