Quantifying the Distribution of Soil and Permafrost Properties and Their Linkage with Landscape Properties in Arctic Tundra Ecosystem

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Improving understanding of arctic ecosystem functioning and parameterization of process-rich models that simulate feedbacks to a changing climate require advances in estimating the spatial and temporal variations in land surface, active layer, ice-wedge and permafrost properties. In the context of the Next-Generation Ecosystem Experiments (NGEE-Arctic), we are developing advanced geophysical strategies to improve characterization and monitoring of Arctic ecosystems. An overarching objective is to develop methods that can bridge the wide gaps between the native scales where processes occur (typically <1m) and the scales needed to inform and validate models (typically >10s of kms). To meet this objective, we have performed laboratory and field geophysical efforts and have developed new geophysical acquisition, inversion and interpretation approaches. We are using a variety of acquisition strategies, including point measurements, ground-based measurements, and aerial platforms – some collected autonomously. Field investigations have been performed at the NGEE site, located in the Barrow Environmental Observatory (BEO) near Barrow (AK), which is dominated by different types of ice wedge polygons. Preliminary investigations are underway at two sites near Nome (AK), a warmer region compared to Barrow, with more topography and less continuous permafrost.

We describe the use of multi-dimensional relationships between physical and biogeochemical properties, developed at the lab scale and translated to the field scale. Examples include the estimation and mapping of soil organic matter density, ice-content and salinity informed by X-ray computed tomography and electrical resistivity tomography (ERT) data. In addition, Ground Penetrating Radar (GPR) and ERT methods have been successfully used for imaging thaw layer properties during the growing season and for estimating active layer thickness during the frozen season as well for delineating the geometry of permafrost features such as ice-wedges in Barrow. We are also developing two new research paradigms for characterization and monitoring associated with suites of properties or compartments important for system functioning. One is the development of new above-and-below ground geophysical monitoring approaches to illuminate the co-dynamics of ecosystems and critical bedrock-through-canopy interactions. The other is the development of a Bayesian approach for identifying functional zones in the landscape, which have unique distributions of property suites that are important for ecosystem functioning relative to neighboring regions. Together, the geophysics-based acquisition and inversion approaches are providing unique high-resolution information and new insights about the Arctic ecosystem functioning as well as providing information to models – at scales and resolutions useful for predicting terrestrial ecosystem feedbacks to the climate.