Workshop on Arctic Permafrost Dynamics: Reconciling Subterranean Biogeochemistry and Space-Based Characterization Techniques

Recent trends in atmospheric warming have led to an unprecedented rate of permafrost thaw that is difficult to predict over a range of spatiotemporal scales. Satellite optical characterization is a promising technique for high-resolution monitoring of permafrost change; however, reliable interpretation is often limited by the availability of correlative surface conditions and an incomplete understanding of how surface and subsurface soil biogeochemical conditions drive hyperspectral imagery. The purpose of this workshop is to define scientific research objectives, challenges, knowledge gaps, promising technical approaches, and implementation strategies for characterizing how chemical, biological, and physical mechanisms drive reflectance spectra characteristics that will ultimately lead to improved space-based optical characterization of permafrost dynamics.

Scientific Background:

Achieving high-fidelity optical permafrost characterization requires a detailed understanding of the soil dielectric constants of permafrost environments, which depend on the underlying biological, chemical, and thermal conditions of the permafrost itself. The amalgamation of soil, pore water, and the chemical and biological constituents of the subterranean environment create a poorly defined heterogeneous media with hitherto unknown dielectric properties. In the last decade, there have been significant advancements in our understanding of the mobilization of previously frozen soil pore water in permafrost environments and the quality and availability of on-orbit optical imagery, motivating further investigation into the potential for dramatically improving optical characterization. Specific questions include:

- What advancements are necessary to enable direct calculations of the dielectric spectrum of soil considering the highly heterogeneous media with intermixed liquid and solid components?
- How do individual (chemical and microbial) and collective components of soil pore water alter its dielectric properties? What is the interplay between surface structure and the subsurface state?
- How do ice and snow cover, vegetation, and atmospheric components affect the ability to characterize permafrost optically? Can they also provide information on the subsurface state?
- How do limitations on spatial, temporal, and spectral availability and resolution affect the ability to characterize permafrost optically?
- How can other remote sensing techniques complement optical measurements to enhance the interpretation of the reflectance spectrum, and characterization of the subsurface properties more broadly?

These critical knowledge gaps are heightened because ground-based measurements and low-altitude aerial observations are often difficult or impossible to obtain in Arctic environments. An extensive understanding of the biogeochemical drivers of soil dielectric constants, when combined with satellite imagery and other remote sensing techniques, may allow for enhanced characterization and prediction of groundcover in Arctic and other polar regions for the Department of Defense, and ultimately lead to accurate understanding and better predictive capability of permafrost dynamics.

Desired Outcome:

Define the scientific objectives, challenges, and novel research initiatives focused on space-based characterization of permafrost at the nexus of environmental chemistry, microbiology, materials science, and physics along with possible collaborations for future data collection activities.