Monitoring physical processes in degraded permafrost using ambient seismic noise and novel multidisciplinary observations

Understanding the impact of permafrost thaw and thermokarst formation on the global carbon budget remains incomplete due to the complex relationships between above and below ground processes, dramatic seasonal changes, and limitations in subsurface measurement capabilities. To address some of these uncertainties and better understand the subsurface physical controls on carbon fluxes, we are conducting a multidisciplinary field experiment using novel combinations of geophysical and biogeochemical methods. In April 2018, instrumentation was installed in a transect between forested permafrost and two collapse scar bogs within the Bonanza Creek Experimental Forest, ~30 km SW of Fairbanks, AK. An array of nine seismic stations will continuously monitor velocity variations (δv/v) related to subsurface freeze/thaw and water saturation changes along the thermokarst gradient. Periodic borehole nuclear magnetic resonance (NMR) profiles will provide direct measurements of unfrozen water content. These geophysical recordings will be collocated with *in situ* measurements of subsurface gas concentrations, soil moisture, and temperature. Other key variables such as organic layer thickness, surface gas fluxes, and active layer thickness will also be measured at select locations. Initial work has also begun using SUTRA-ICE to generate 1-D numerical simulations of water and energy transport for representative vertical profiles along the experiment transect. Physical properties from the SUTRA-ICE simulations are combined with forward modeling of seismic velocity variations from synthetic ambient noise to quantify the sensitivity of the seismic velocity variations to subtle changes in ice and water saturation. We will present an overview of the experiment design and preliminary geophysical and modeling results. This multifaceted, interdisciplinary approach will serve as a proof-of-concept for the integration of geophysical and biogeochemical measurements for better understanding the impacts of thermokarst development on ecosystem-scale carbon fluxes in a lowland boreal forest.

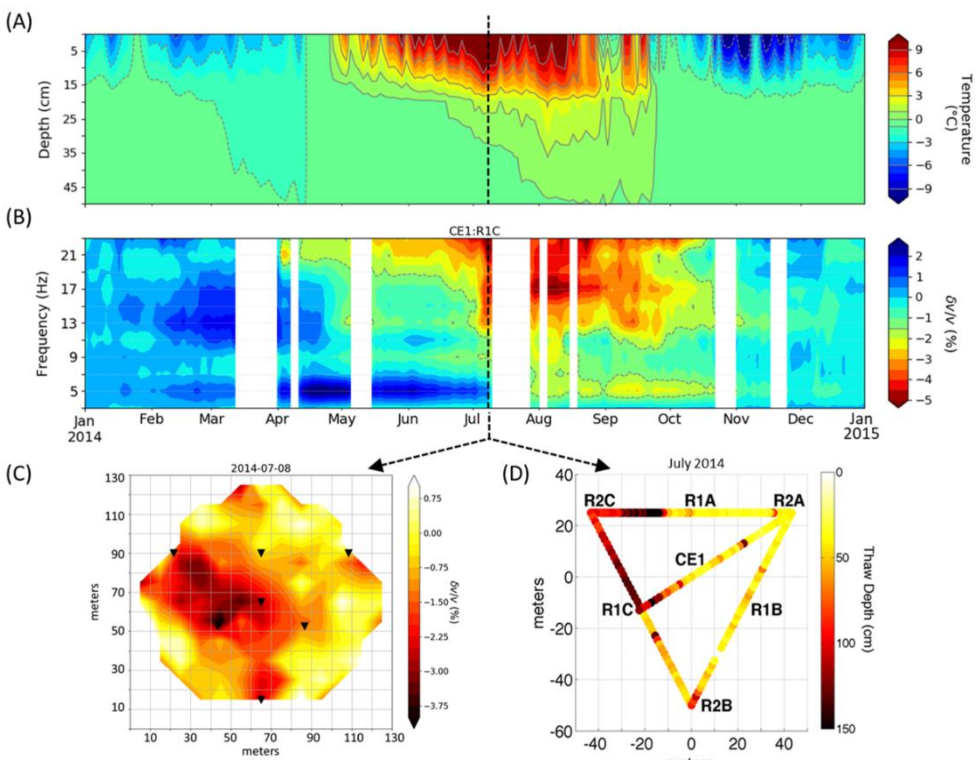

Figure 1. Relative velocity variations (δv/v) from ambient seismic noise are able to capture important permafrost dynamics. Contoured soil temperature profiles (A) correspond well with δv/v results (station pair CE1:R1C) as a function of frequency (B), in which the seasonal active layer freeze and thaw process is observed. 2D Bayesian tomography using results from all station pairs (C) produces a map of spatial variability in velocity change and illustrates the local variability in thaw depth, as supported by probe survey data for the same point in time (D).