Using distributed acoustic sensing (DAS) to track a changing permafrost landscape (Jonathan Ajo-Franklin)

Recent Arctic temperature increases are driving rapid transformations in the structure and depth of permafrost, particularly in regions where shallow permafrost is poised near zero degrees. Transportation infrastructure components (e.g. roads, runways, and rail corridors) are particularly vulnerable to permafrost failure in regions where they are constructed on ice-rich materials. Geophysical measurements provide a route to observing early signatures of permafrost erosion before the mechanical properties of near-surface sediments degrade to the point of failure; soil seismic and electrical properties both show changes well before thaw occurs. Unfortunately, the combination of long lateral distances and required spatial and temporal resolution make traditional campaign-based geophysical monitoring challenging. Distributed fiber optic monitoring of temperature (DTS), strain (DSS), and seismic wavefields (DAS) offer one approach to tracking permafrost state with a low linear cost over long distances.

We present results from a recent project which combines these methods, focusing on the utilization of ambient seismic noise from infrastructure, recorded by distributed acoustic sensing (DAS), to monitor permafrost state over time. Given the novelty of the approach, two scoping studies were conducted to evaluate (a) the sensing properties of DAS to seismic wavefields and (b) the repeatability of ambient-noise surface wave property estimates using infrastructure wavefields. A challenge for testing such an approach is installing the appropriate array in a location that will experience thaw over the course of a field trial. One solution to this dilemma is to induce rapid thaw in a prescribed location. We demonstrate such a test using results from a large scale active thaw experiment conducted during the summer of 2016 in Fairbanks, AK, utilizing 120 downhole heaters to thermally erode ~1 m of permafrost over a 10x 15 m area. The thaw zone was monitored using a combined 2D DTS/DAS/DSS array complemented by subsurface thermistor and thermocouple arrays, timelapse total station surveys, LIDAR, secondary seismic measurements (geophone and broadband recordings), timelapse ERT, borehole NMR, soil moisture measurements, hydrologic measurements, and multi-angle photogrammetry. This dense combination of measurement techniques provides an excellent opportunity to characterize the geophysical signatures of permafrost thaw in a controlled environment.

Bio : Jonathan Ajo-Franklin is a staff scientist in the Energy Geoscience Division at Lawrence Berkeley National Laboratory (LBNL). He received his BA in Computer Science and History at Rice University (1998) followed by an MS (2003) and PhD (2005) in Geophysics at Stanford University. His graduate work focused on high-resolution crosswell geophysics applied to environmental site characterization. From 2005 to 2007 he was a postdoctoral fellow at the Earth Resources Laboratory at MIT. Since 2007, he has led a group at LBNL, first as a researcher (2007-2013) and since 2013 as a staff scientist. He leads the Environmental and Applied Geophysics Lab (EAGLe) and the Reservoir Processes group in the Center for Nanoscale Control of Geologic Carbon (NCGC).

Jonathan's research focuses broadly on using geophysical techniques to understand dynamic alterations in subsurface properties of relevance to the environmental and energy sectors. His technological focus in the field is on novel acquisition approaches including semi-permanent seismic sources and fiber-optic distributed acoustic sensing (DAS). He is active in several research efforts applying timelapse borehole seismology to geologic carbon sequestration (GCS), geothermal energy production, and hydraulic fracturing. He also leads projects exploring the use of large fiber optic arrays and DAS for geotechnical monitoring (in permafrost environments) and hydrogeologic monitoring at the basin scale. At a smaller length scale, he has a research program examining the rock physics of GCS, thermo-mechanical fracturing, and permafrost processes at the pore to core scale using dynamic (4D) synchrotron micro-tomography.