Monitoring Active Layer Freeze/Thaw Using Seismic Noise

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In permafrost settings, the seasonal freeze and thaw cycle of the active layer results in large variations in seismic velocity. We used ambient seismic noise to monitor these variations at the Poker Flat Research Range, 30 miles north of Fairbanks, Alaska. We computed daily cross-correlations using nearly two years of data from an array of 7 broadband seismometers. The Python package MSNoise was used to employ the moving window cross-spectral analysis (MWCS) technique to measure relative changes in seismic velocity. The large shifts in velocity between frozen and thawed soil is suspected to have caused prevalent cycle-skipping when comparing cross-correlations to a stationary reference. To improve the results, we modified the approach to measure the day-to-day changes in velocity and then cumulated the daily changes to recover the full velocity change relative to a desired starting point. A positive drift needed to be removed through a linear correction. The resulting velocity variations show a seasonal trend that is consistent with the expected timing of active layer freeze and thaw in this region. A decrease in relative velocity begins in the late spring and continues through the summer, and relative velocity increases through the fall and winter months. Periods of increased snow depth and low temperatures correspond with periods of increased relative velocity. Increased temperatures in mid-April and subsequent snow melt is followed by a decrease in relative velocity. The spring/summer velocity decrease does not begin until after snow cover is gone, likely due to an insulating effect of the snow that keeps the soil frozen. From this we conclude that seismic interferometry is a promising new approach for monitoring the dynamics of active layer freeze and thaw and has the possibility to provide insights into the physical processes involved.

A comparison of relative seismic velocity variations (c) with snow depth records (a) from the CRREL and LTER2 sites located in the region of study as well as ground temperature records (b) from the ground surface, 20 cm below ground surface (bgs), and 40 cm bgs. Temperature data comes from a borehole near Fox, AK above the CRREL permafrost tunnel.

Data sources:
Hourly Soil temperature data, Fox, Alaska, Permafrost Laboratory, Geophysical Institute, University of Alaska Fairbanks. http://permafrost.qi.alaska.edu/site/fx1.

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