Continuously recording, dense seismic arrays could help us better understand earthquake and landslide hazards, permafrost thaw, our hydrological cycle, and near surface changes at energy production sites. But such arrays have typically been expensive to maintain long-term and are logistically difficult to install in populated areas. We combine two methods to make continuous subsurface monitoring significantly cheaper: estimating wave equation Green's functions from random vibration recordings in the area of interest, and measuring vibrations as meter-scale strain rate profiles along fiber optic cables. In addition, the continuously recorded data from fiber optics can be used to analyze ground motion during earthquakes.

These methods can make continuous high-resolution subsurface imaging a possibility where it was previously impossible, but there are several challenges I will address: (i) algorithms must be modified for real-time analysis of streaming data from many sensors, (ii) the theory for Green's function estimation must be altered to account for new sensors measuring tensor strain rates as opposed to particle velocity vectors or pressure scalars, and (iii) existing Green's function estimation theory assumes independent, uncorrelated vibration sources (which is far from the reality of urban and infrastructure noise sources). These issues will be shown in the context of two data sets: a buried fiber array near a road in Alaska for monitoring permafrost thaw, and a fiber network in existing telecom conduits under the Stanford campus for earthquake hazard analysis. The fundamental issues behind working with noisy, streaming data for weak signal detection, imaging and inverse problems are common to a wide range of Earth science problems.

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