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Studying the Earth's interior based on correlations of ambient seismic noise

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Extraction of the time-distance information from temporal cross-correlations of the random background oscillations was first applied in helioseismology (e.g., Duvall et al., 1993). In the Earth's seismology, the abundance of natural point-like sources (earthquakes) resulted in numerous powerful methods to sound the Earth interior at different depths and scales based on deterministic analysis of elastic waves emitted by those sources. At the same time, the background seismic oscillations of the Earth excited by non-tectonic sources related to the coupling of the solid Earth with the atmosphere and the oceans were often categorized as noise and were not used in the seismic imaging of the Earth. However, recent findings demonstrated that deterministic information about the Earth's interior can be extracted from correlations of ambient seismic noise.

Seismic surface waves are most easily extracted from correlations of background oscillations mostly excited by superficial sources and recorded by receivers located at the Earth's surface. As a consequence, the noise based surface wave tomography is a rapidly emerging field of seismological research. This method is especially advantageous when applied to records of modern dense networks of broadband seismometers when Rayleigh and Love waves can be extracted for numerous inter-station paths. Resulting waveforms are used to measure surface-wave dispersion curves in a wide range of periods and to obtain high-resolution images of the Earth subsurface down to 100 km or more. We present applications of this method to studies of the crustal and upper mantle structure in United States and Europe. The method also works at smaller scales allowing us, for example, to image the internal structure of volcanic edifices.

Another set of applications arises from a possibility to the repeat the travel-time measurements from the noise cross-correlations for selected pairs of stations. Our results show that inter-stations travel time perturbations can be measured from the noise cross-correlations with uncertainties smaller than a fraction of a percent. In some cases this level of accuracy is sufficient to detect small changes in the underlying media opening an opportunity to develop new methods of passive monitoring of volcanoes and tectonically active faults.