Modeling ambient noise distributions for surface wave imaging based on full waveform inversion

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Abundant noise sources in urban area has been widely utilized for subsurface investigations based on the seismic interferometry. Reliable dispersion extraction between two seismic stations is an essential basis of surface wave imaging. Noise source directivity has become an inescapable obstacle and a main concern for passive seismic surveys: it basically breaks the physics of Green's function retrieval in travel-time tomography; Moreover, the azimuthal effect of ambient noise sources would inherently cause different levels of early arrival on cross-correlation functions, so that the apparent velocity of surface wave could be overestimated in multichannel slant stackings.

Instead of the conventional frequency-time analysis, which aims to extract the apparent dispersions of phase/group velocity between seismic stations, we proposed a method to jointly invert noise source distributions and the corresponding unbiased surface wave velocities based on the theoretical framework of full waveform ambient noise inversion. Waveform itself could intrinsically contains the features of travel-time, energy and asymmetry of ambient noise cross correlation functions (NCF). And they could in return map the resulted NCF into the noise source distributions and velocity structures. The L2 norm of cross-correlating waveform misfits was taken as the objective function to conduct gradient based inversion (i.e. the L-BFGS algorithm). We parametrized the noise source distributions as a temporally ensemble averaged model, which was discretized as a spatially plane grid of normalized source strength. The surface wave velocity model was approximated as the straight-ray interstation velocity. The two kinds of variants were decoupled in waveform misfit function by their corresponding partial derivatives to iteratively update the model space.

The effectiveness of source-velocity joint imaging using above full waveform inversion work flow was qualified by both the synthetic test and the applied research in Hangzhou urban area. The inverted noise source model was comparable with the urban traffic- and construction- noise distributions. And the truthful surface wave velocities were achieved considering the constraint of noise source distributions, they were also prior constrained and later verified by local borehole
datasets.