Ambient Noise Surface-Wave Tomography of the San Francisco Bay Area, California

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Simulations of earthquake ground motions relevant to frequencies of engineering interest offer an alternative to poorly constrained empirical relations for seismic hazard assessment. The characterization of 3D seismic wave propagation in realistic velocity models and the effects it has on strong ground motions from earthquakes is important for accurate estimates of seismic hazard. The success of these simulations critically depends on the accuracy of the velocity model being used. The San Francisco Bay area in California, USA is a highly urbanized, densely populated and economically important region. It is also an active tectonic region facing high seismic hazard and crisscrossed by numerous faults including the San Andreas Fault, the Hayward Fault and Rodgers Creek Fault. The complex geology of the region is reflected in the latest version of US Geological Survey 3D velocity model (version 8.3.0, year ~2010) that incorporates low velocities in the bays and basins, high velocities in the Franciscan complex and volcanic rocks, and velocity contrasts across major faults. Our study aims to assess the accuracy of this velocity model and suggest improvements if possible using ambient noise derived surface-wave tomography.

We use continuous waveform data recorded by permanent and temporary stations in specific epochs between 1995 and 2020. We perform multi-component ambient noise cross-correlations using data from various kind of sensors –broadband, short period, borehole sensors and accelerometers, totaling around ~400 stations. Till date, only a small fraction of available data has been utilized in published studies. For three-component stations, the Green’ s tensors are rotated to the tangential-radial-vertical reference frame that allows extraction of both fundamental mode Rayleigh waves and Love waves. We also explore for higher mode Rayleigh waves in basins using polarization analysis. We measure surface-wave dispersion at periods ~4 s -16 s using automated frequency-time analysis. The dispersion measurements are inverted for 2D phase velocity maps at grid spacing of 20 km using the fast-marching surface-wave tomography method. We invert the phase velocity maps for a 3D shear-wave model extending to a depth of ~20 km from the surface using surface-wave sensitivity kernels and compare the features in the model with those in existing models. The estimated empirical Green’ s functions can also be used directly in waveform tomography studies in the future.

Keywords: seismic wave propagation, surface waves, ambient noise cross correlations, crustal structure, San Francisco Bay Area, seismic tomography

