Abstract

A fundamental objective of seismology is to produce detailed tomographic images of Earth's interior by fitting simulated seismograms to recorded seismograms. The quality of the image depends on the quality of the observations and on the accuracy of the modeling tool. We present a seismic tomography approach that employs accurate numerical methods of seismic wave propagation. Our approach follows successive steps of a minimization problem. First, specify an initial tomographic model in terms of shear wave speed, compressional wave speed, and density. Next, collect a dataset of well-recorded earthquakes. Specify a misfit function that quantifies the difference between sets of recorded and simulated seismograms. For each earthquake, evaluate both the misfit function and the gradient of the misfit function. Adjoint methods are used to compute the gradient via the interaction of a "forward wavefield," propagating from source to stations, with an "adjoint wavefield," propagating from stations to source. Using the gradient for each earthquake, we then compute an update to the initial model. This procedure is then iterated to obtain a better model of Earth's interior structure.

We iteratively improve a three-dimensional (3D) seismological model of the southern California crust. The resulting model is constructed from 16 tomographic iterations, which required 6800 wavefield simulations and a total of 0.8 million CPU hours. The new crustal model reveals strong heterogeneity, including local changes of $\pm 30\%$ with respect to the initial 3D model provided by the Southern California Earthquake Center. The improved crustal model illuminates features at the surface that agree with geology, such as the southern San Joaquin basin. It also reveals crustal features at depth that aid in the tectonic reconstruction of southern California, such as possible Farallon oceanic crustal fragments beneath the western Transverse Ranges. The new model enables more accurate assessments of seismic hazard for scenario earthquakes.