Time-dependent Seismic Tomography

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Variation of seismic wave speeds with time is an expected consequence of many natural and anthropogenic processes, but detecting and mapping such variation is difficult. Three-dimensional structure models derived using seismic tomography are subject to ambiguities caused by incomplete data coverage and by observational errors, which can easily exceed any real changes in the wave speeds. Simply comparing tomographic models derived independently using data from different epochs may thus lead to false detections of change.

These difficulties can be greatly reduced by inverting data from different epochs simultaneously, imposing “regularization” constraints to minimize the differences between derived models. This method suppresses spurious changes that are not required by the data. In the case of two epochs, this approach leads to a system of linearized normal equations whose order is twice as great as for a single epoch, but which can nevertheless be solved efficiently. Tests using synthetic data show that the method is sensitive to small changes in wave speed but suppresses false anomalies, i.e., changes in structure that are not required by the data.

We apply this method to local microearthquake data from the commercially exploited Coso Geothermal area in southeastern California to study possible changes in structure related to electricity generation. Coso is the seventh largest exploited geothermal area in the world. Previous studies using independent inversions of data from different epochs have suggested that the wave speeds in and around the geothermal reservoir vary over time, but the effect was small and uncertain. Joint inversions in our new study, using data from five epochs (2006, 2007, 2008, 2010, and 2012), confirm that changes are real and resolve their spatial distribution on scales of about 3 to 4 km.

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