Julian, B.R. and G.R. Foulger, Time-Dependent Seismic Tomography of Geothermal Systems, Thirty-Fourth Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, February 9-11, 2009.

Time-Dependent Seismic Tomography of Geothermal Systems

Bruce R. Julian, U. S. Geological Survey, Menlo Park, CA 94025 USA, julian@usgs.gov
Gillian R. Foulger, Dept. Earth Sciences, Durham University, Durham DH1 3LE, UK, g.r.foulger@durham.ac.uk

Temporal changes in seismic wave speeds in the Earth's crust have been measured at several geothermal areas, notably The Geysers in California, in studies that used three-dimensional seismic tomography. These studies used conventional tomography methods to invert seismic-wave arrival time data sets for different epochs independently and assumed that any differences in the derived structures reflect real temporal variations. Such an assumption is dangerous because the results of repeated tomography experiments differ even if the structure does not change, simply because of variation in the seismic ray distribution caused by the natural variation in earthquake locations. This problem can be severe when changes in the seismicity distribution are systematic, as, for example, when many data come from earthquake swarms. The sudden change in the ray distribution can produce artifacts that mimic changes in the seismic wave speeds at the time of a swarm. Even if the source locations did not change (if only explosion data were used, for example), derived structures would inevitably differ because of observational errors.

In order to determine what apparent changes are real structural changes and what are artifacts, a better approach to determining what changes are truly required by the data is needed. We have developed a new tomography program that inverts multiple data sets simultaneously, imposing constraints to minimize the differences between the models for different epochs. This problem is comparable with that of seeking models similar to some a priori initial assumption, and a method similar to "damped least squares" can solve it. We present an program for performing this computation efficiently. Using our program, inverting multiple epochs simultaneously is comparable in difficulty to inverting them independently. We further illustrate the program's performance using synthetic arrival times and observed data from the Coso and Long Valley caldera areas in California.