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Time-Dependent Tomography Using TOMO4D: Theoretical Advances and Early Applications

Najwa Mhana, Ceri Nunn, Bruce R. Julian, Gillian R. Foulger & Andrew Sabin

TOMO4D is a seismic tomography program that inverts multiple earthquake arrival-time data sets simultaneously, imposing constraints to minimize the structural differences calculated for different epochs. This approach is similar to that of seeking models that resemble an *a priori* assumption, and it can be solved using a regularization method similar to damped least squares. During 2015 we applied TOMO4D extensively to real data for the first time. In the light of this experience, programming developments were made that include model-steepness and roughness optimization and the use of regional-earthquake data.

Mt. Etna, a persistently active volcano in Sicily poses a significant volcanic hazard, and any methods that might provide early warning of activity are potentially important. In volcanic systems, the distribution of fluids, cracks and pressurized gases can cause rapid changes in the elasticity of the host rocks that are potentially detectable using time-dependent tomography. We selected and relocated about 400 local earthquakes having at least 5 *P* and 5 *S* observations, provided by **, and compared epochs that correspond to pre-eruptive, co-eruptive and post-eruptive periods between 2000 and 2006. Current results suggest that, while epoch results obtained independently using the inversion program SIMUL2000A show changes in structure, TOMO4D reveals that these changes are probably not required by the observations.

Long Valley caldera in eastern California has been the site of ongoing seismic activity since 1978. In particular, a region to the south of the resurgent dome (the “south moat”) has been the site of multiple swarms involving hundreds of thousands of earthquakes. We applied TOMO4D to sets of data from 1997 and 2009/10. Differencing independently determined inversions obtained using SIMUL2000A again shows changes in structure. These changes are also detected by TOMO4D, but with lower amplitudes. These results suggest that the amplitudes of structural changes determined by differencing independent inversions using SIMUL2000A may be exaggerated in their magnitude.

The commercially exploited Coso geothermal area in southern California is highly seismogenic, with thousands of earthquakes occurring each year and monitored by the Geothermal Program Office of the US Navy. We studied each of the years 1996 - 2008, plus 2010 and 2012. As for Mt. Etna and Long Valley, we determined changes in structure from year to year by comparing independent inversions obtained using SIMUL2000A. Our preliminary results show that inversions conducted using TOMO4D also show changes but again, they are weaker than those obtained using simul2000A.