Double-difference tomography with discontinuities (tomo-D3)

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Waldhauser and Ellsworth (2000) proposed a double-difference (DD) earthquake location technique for determining hypocenter parameters accurately. Zhang and Thurber (2003) extended the algorithm of Waldhauser and Ellsworth (2000) to conduct a joint inversion for both hypocenter locations and 3-D seismic velocity structure, and showed that the DD tomography can better resolve the structure in the high-seismicity areas. Zhang and Thurber (2003) adopted the grid parameterization and ray tracing schemes the same as those in Thurber (1983), and used the LSQR algorithm for the inversion of the observation equations, similar to Zhao et al. (1992).

The tomographic method of Zhao et al. (1992) has the following advantages. (1) It can be applied to local to regional-scale studies because a spherical coordinate is adopted. (2) Velocity discontinuities (such as the Conrad, Moho, and the slab boundary) and their depth variations can be taken into account. (3) Reflected and converted waves from the discontinuities can be used in the tomographic inversion, in addition to the first P and S wave data. In contrast, the tomographic methods of Thurber (1983) and Zhang and Thurber (2003) do not have such favorable features.

In this study we have modified the computer program (Tomog3d) of Zhao et al. (1992) and made it also applicable to the DD travel time data. The new version of the code (tomo-D3) keeps all the three favorable features of Tomog3d as mentioned above. The code (tomo-D3) can use (1) only the arrival time data, (2) only the DD data, or (3) both the DD and arrival time data, thus comparisons can be made for the three images resulting from the three different data sets. We applied tomo-D3 to the data sets in Northeast Japan and the 1995 Kobe earthquake region. Our detailed resolution analyses and inversion results show that the overall pattern of tomographic images keeps the same when the different data sets are used, though DD data can provide more constraints on the hypocenter locations and some structure details in the high-seismicity area. One potential problem is that the generation of the DD data from the original arrival time data is somehow optional. The number of DD data can be tens of times more than that of the original arrival time data, which would cause problems in the CPU time and the memory storage of the computer used.