Test of the checkerboard resolution test

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Generally, we apply LSQR method to resolve matrix equation of travel time tomography, because a huge data is used. Resolution is not evaluated with this method. We usually use checkerboard resolution test to infer the resolution. In this study, we test the checkerboard resolution test by comparing the restoration ratio of the checkerboard pattern of the checkerboard resolution test and the evaluated resolution with the singular value decomposition method applied to smaller dataset.

We assume the cubic region of 288km in each length simulating two dimensional subduction region like a Tohoki area of Japan. The region is divided into 24km blocks in which the velocity is interpolated by the linear function. 54 seismic observed stations distribute near the trench with 32km horizontal interval. 432 events are distributed on three planes with 24km horizontal interval. One plane is at the depth of 14km and the others are in the subducting plate. Synthetic observation data amounts to 23,328 (=54x432) at most. The number seems small, but it was large enough about 10 years ago.

We make two simple models. One is of homogeneous velocity (10km/sec) without the discontinuity. The other model has two discontinuities at the Moho and at the upper plane of the subducting plate. The velocities in each layer are homogeneous. Checkerboard pattern is made by giving +-10% velocity deviations at each grid point.

We calculate the ray traces by the Pseudo-Bending Method. The matrix equation is solved by the singular value decomposition method. Actually we use SGELSS subroutine of LAPACK library. Besides media parameters, station corrections, event origin times and event locations also are solved as unknown parameters.

As a result, we find the good correlation between the restoration ratio and the resolution in the homogeneous model case. At the beginning of the iteration process, the restoration ratio is smaller than the resolution. Iterating the inversion process, the restoration ratio grows large and at about 10 iterations, it nearly equals to the resolution in average. It continues to be larger up to 20 iterations when we terminate our calculation, although the increment of the value in each iteration is smaller. In the discontinuity model, the restoration ratio distribution scatters, but as a whole the same trend is confirmed in our result. The tomography tends to diverge before 10 iterations, so that the trend after 10 iterations can not be traced.

The checkerboard resolution test gives us a good inference about the resolution.

The checkerboard resolution test, however, does not give us any information about the off-diagonal elements of the resolution matrix, which should be evaluated by the other method as the singular value decomposition method. If the restoration ratio is 100% at some point, the off-diagonal element is nearly 0. But, if the ratio is 50%, it is difficult to estimate the off-diagonal element. In practice, we introduce a damping parameter into the inverse calculation, all the restoration ratios will be smaller than 100%.

We investigate the off-diagonal elements in the above simple models. The somewhat large off-diagonal elements are found in the wedge mantle below the basin not well covered with the observation stations. Many neighboring points along vertical direction and some points parallel to the subdcuting plate are correlated, respectively.