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Waveform inversion for 2-D boundary shape and construction of the 3-D velocity structures

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Accurate velocity models are required for strong motion prediction and source process inversion. In particular, velocity models for source process inversion should be so accurate that the amplitude and phase of ground motion from a medium-size earthquake in the source areaare reproduced. Since it is difficult to reproduce them with a velocity model based on only results of explorations, we have to carry out waveform tuning of the 3-D velocity model. However, it takes very hard labor and a long computation time to perform this tuning in a trial-and-error fashion. To overcome these problems, we propose the waveform inversion method for 2-D velocity structures and give a procedure of interpolation for modeling 3-D velocity structures.

1. Waveform inversion for 2-D velocity structures

We formulate the inversion procedure in a 2-D cross-section which includes the source and stations. If we calculate waveforms in the 2-D medium, the source is forced to be a line source. So we introduced approximate transformation from a line source to a point source (Vidale and Helmberger, 1987). We used the 2-D velocity-stress staggered grid finite difference method for forward modeling. The source is expressed by a body force at a velocity grid point (Graves, 1996). Because this source representation is different from the original 'source box method', we applied additional corrections to the resultant waveforms.

The boundary shapes of the layers are expressed by connected nodes. We invert the observed waveforms for layer thicknesses at the nodes. We calculate partial derivatives by taking a two-point difference between synthetics for the initial and slightly perturbed models. We used the iterative damped least-square method to perform this non-linear inversion.

2. The construction of the 3-D velocity structure

The 3-D velocity structure is constructed by interpolating the results of 2-D velocity inversion. We applied these methods to the 3-D velocity model around the source region of the 2003 Miyagi-ken Hokubu earthquake. We first made the initial 2-D velocity models based on the results of geophysical surveys and geological data. We also used the results of the 1-D velocity inversion analysis (Hikima and Koketsu, 2004). Then, we performed 2-D velocity inversions in the 2-D cross-sections which involve a medium-size earthquake and observation points. During these inversions, we assumed the hypocenter and focal mechanism to the solutions by F-net and others. We assembled these results and interpolated them to construct the 3-D velocity model. Finally, we synthesized waveforms from the target earthquake by 3-D finite difference method with this velocity model to confirm the validity ofthe model.

3. Summary

The 2-D velocity inversion may fail if the underground structure is too complex. Since the structure in the source area of the 2004 Chuetsu earthquake seems to be very complex, we will apply the proposed procedure to this area and examine the applicability of our methods. We will also construct the detailed 3-D velocity structure there.