Waveform inversion for 3-D velocity structures and source process analyses using its results -2003 Miyagi-ken Hokubu earthquake-

Kazuhito Hikima[1]; Kazuki Koketsu[2]

[1] Oyo Corp. and ERI; [2] Earthq. Res. Inst., Univ. Tokyo

An accurate velocity model is important to calculate theoretical Green's functions for slip inversion. In this study, we propose an efficient waveform inversion method for 2-D velocity structures and 3-D velocity structures are constructed by interpolating the results of the inversions. These approaches significantly reduce computation time to obtain a realistic 3-D velocity model. We apply these methods to study the source process of the 2003 Miyagi-ken Hokubu earthquake. We will first construct a velocity model, then determine the source processes of this earthquake sequence using the Green's function calculated in the resultant 3-D velocity model.

We formulate the inversion procedure in a 2-D cross-section. In the 2-D problem, the source is a line source. Therefore we introduce approximate transformation from a line source to a point source (Vidale and Helmberger, 1987). We use the 2-D velocity-stress staggered-grid finite difference method for forward modeling, so that the source representation is somewhat different from the original 'source box method'.

We perform 2-D velocity inversions in the 2-D cross-sections which involve a medium-size earthquake and observation points. We assemble the results for many stations and interpolated them to construct the 3-D velocity model. Finally, we calculate waveforms from the target earthquake by the 3-D finite difference method with this velocity model to confirm the validity of the model.

Then, we perform waveform inversions for source processes of the 2003 Miyagi-ken Hokubu earthquake using the resultant 3-D velocity model. We divide the fault plane into northern and southern subplanes, so that the southern subplane includes the hypocenter of the mainshock and the largest foreshock. The strike directions of northern and southern subplanes were N-S and NE-SW, respectively. The Green's functions for the waveform inversions are calculated using the reciprocal theorem. This greatly reduces computational costs for producing a large number of Green's functions. We determine the slip models using the 3-D structure and compare them with the models determined using the 1-D structures. The synthesized waveforms in the 3-D structure better explain the observed waveforms than those in 1-D structures. While the large slip area (asperity) of the mainshock is recovered at the shallowest part of the northern subplane in the 1-D models, the asperity of the 3-D model is located on a relatively deeper part of the northern subplane. The aftershocks occurred around the asperity of the 3-D model. The asperity of the 3-D model is consistent with that of the previous result from geodetic data. In addition, the 3-D model is in good agreement with the estimated strong motions in the source area, such as the seismic intensity map derived from the questionnaires and the PGV map from the investigation on gravestones. Based on these comparisons, we adopted the slip distribution in the 3-D model as the final result.

To examine the reason why the different slip distributions were recovered using the 1-D structures and 3-D structure, we performed synthetic comparisons. The variations of the Green's functions due to the depth change of subfault position were different for the 1-D models and 3-D model. Therefore, the difference of depth dependence is responsible for the difference between the two inversion results. Because the waveform difference is larger mainly in a later part, an inversion of body wave parts alone was not produce such difference..

However, in some situation, we have to use distant stations because of lack of station around the source region, and we cannot extract clear body waves not contaminated by later phases. Therefore, a source process inversion should be performed using accurate Green's functions which include later phases based on well-calibrated velocity models.