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Source model of the 2007 Chuetsu-oki earthquake based on precise aftershock distribution and 3-D velocity structure

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In general it is necessary for a source inversion analysis to previously determine a fault plane model based on the focal mechanism and aftershock distribution. However, in case of the 2007 Niigata-ken Chuetsu-oki earthquake, the resolution of the aftershock distribution was rather low because of the source region lying offshore and the complex subsurface structure, hence the geometry of the main shock was difficult to determine. Precise aftershock distribution was eventually obtained using the records of the ocean bottom seismometers temporally installed on and around the source region after the main-shock occurrence, and it revealed a fault plane of the main shock dipping to the southeast (Shinohara et al., 2008). Moreover the detailed aftershock distribution shows a slight change in the alignment angle along the dip direction of the main shock, which suggests a distorted fault plane for the main shock. In this study we assume such a bending fault plane as an initial model for the source inversion analysis, and reconstruct the characterized source model for the broadband strong-motion simulation based on the inversion result.

The fault plane of the main shock is divided into three parts, which are the north, center, and south fault areas. The north and south faults are planar and only the central fault area implies a distorted plane. The dip angles for the north and south fault plane are assumed to be 40 and 30 degrees, respectively. The strike angle is 39 degrees throughout the whole fault. All the fault areas lie within the assumed seismogenic zone, the upper and lower limits of which are respectively 6 and 17 km. The length of the whole fault is assumed to be 28 km, being composed of 7 km for the north, 10 km for the center, and 11 km for the south fault area. The inversion analysis was carried out using the search method combining the empirical Green's function method and the simulated annealing, developed by Shiba and Irikura (2005). The estimated source model showed a similar slip distribution to the model obtained by Shiba (2008) assuming the totally planar fault plane, except for the location of the asperity close to the hypocenter, which slightly moves to the northwest. We further constructed the characterized source model that reproduces the strong-motion records observed at the base mats of the reactor buildings within the Kashiwazaki Kariwa nuclear power station (KK NPS). The optimal source model estimated by the forward modeling approach shows the 20% smaller in area and 10% lower in the stress drop for the asperity closest to the hypocenter, comparing with the previous model by Shiba (2008).

Furthermore, we attempt to simulate the distinct pulse waves observed at the KK NPS, showing obviously different amplitudes among the stations distributed within about 2 km. When the waveform-records of the aftershock occurring near the hypocenter of the main shock were used as the empirical Green's function, such variations of the pulse shapes among the observation stations could not be distinguished, probably due to inconsistent wave-propagating path with that from the southwestern asperity. In this study we employ the synthetic waveforms calculated by the finite difference method with the three-dimensional velocity model including fold structure beneath the KK NPS site (Hayakawa et al., 2011) and the observed records of the small aftershock of Mw 3.5, as the theoretical and empirical Green's functions. As a result the large pulse waveforms observed in the EW component at the KK NPS stations are successfully reproduced through the hybrid simulation.

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Keywords: the 2007 Niigata-ken Chuetu-oki earthquake, source model, aftershock distribution, 3-D velocity structure model, source inversion analysis, hybrid simulation