Source rupture process and strong motion generation area assuming the curved fault model for the 2003 northern Miyagi prefecture earthquake

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At 07:13 on 26 July 2003 (JST), a shallow inland crustal earthquake (M_{JMA}6.4) with reverse faulting occurred in the northern Miyagi prefecture, north-east Japan. From the strong ground motion records in 0.05-0.5 Hz, the kinematic source rupture processes assuming a two-segment fault model have been estimated by waveform inversion method (e.g., Hikima and Koketsu, 2004). They showed large slips around 1.0 m occurred in a shallow part of the northern segment. However, surface breaks caused by this earthquake were not found along the source area by field surveys (e.g., Imaizumi et al., 2003). Since the shallow large slip area was identified between the north and the south segment, it is reasonable in estimating robust slip distribution to consider the more realistic fault plane with bending zone rather than a simple two-segment fault plane. Actually, the precisely relocated hypocenters of aftershocks were located along a curved plane dipping westward to north-westward (Okada et al., 2003). In this study, we investigate the source rupture process assuming the curved source fault, and estimate the strong motion generation areas (SMGAs; Miyake et al., 2003), in order to discuss the broadband ground motion generation processes during this event.

First, we employed the multi-time window linear waveform inversion method by using the strong motion waveforms (0.1-1.0Hz) recorded by K-NET, KiK-net, and JMA stations around the source area. From the observational information of relocated aftershock distribution and geological structure, the assumed curved fault model was composed of two planar segments (north and south segments) set by Hikima and Koketsu (2004) with transitional part that smoothly connect the north with south segment. The length, width, and shallowest top depth of fault model were 20 km, 11 km, and 0.59 km, respectively. This curved fault model was divided into 220 subfaults of 1.0 ×1.0 km. The temporal moment release history from each subfault was expressed by a series of 6 smoothed ramp functions with a rise time of 1.0 sec separated by 0.5 sec. The first-time window triggering velocity (FTWTV) was 2.8 km/s given by the smallest misfit solution. The theoretical Green’s function was calculated by using the discrete wavenumber integration method (Bouchon, 1981) with the reflection and transmission matrix (Kennett and Kerry, 1979) assuming a 1D velocity structure model. The velocity structure model of each station was given by referring the Somei et al. (2018) or Petukhin and Miyakoshi (2006).

Second, the SMGAs were constructed based on the forward simulations using the empirical Green’s function method (Irikura.1986) in the frequency range 0.3-10 Hz. The locations of rupture starting points and rupture times for two SMGAs were fixed by using the onset times of first and second S-wave packets in observations. Scaling parameters *N* and *C* were obtained based on the source spectral ratio analysis. The best set of parameters for SMGAs, such as the size, rupture velocity, rise time, and rupture starting point inside the SMGA, were determined by a grid searching to minimize the residual function of waveform fitting between observations and synthetics.

The principal findings from the source inversion and SMGA modeling are following. 1) The large slip area whose maximum slip of 0.93 m was concentrated in the transitional segment, where is north of the hypocenter. The top depth of characterized asperity area (Somerville et al., 1999) was 3.07 km, which is deeper than that of Hikima and Koketsu (2004) model. The size of asperity area was 35 km^2, which is comparable to that expected by empirical scaling relationship (Somerville et al., 1999). 2) High peak moment ate areas (HRA; Yoshida and Miyakoshi, 2013), which implied the large slip velocity, were characterized with a size of 29 km^2 near the edge of the asperity area. 3) Synthetic ground motions generated from two SMGAs with a size of 24 km^2 identified close to the HRAs explained well the observations in a broadband frequency range. 4) The stress drops of two SMGAs were 13.7 MPa, which are comparable to those estimated for past large inland crustal earthquakes in Japan.

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