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Source Rupture Process of the 2014 Northern Nagano Earthquake Estimated by Strong Motion Data

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A large inland crustal earthquake occurred in the northern Nagano prefecture, central Japan, on November 22, 2014 (M_{JMA} 6.7). According to the moment tensor solutions by Global CMT Project and F-net (NIED), this earthquake was a reverse-slip type event. This event has been reported to be related to an active fault, the Kamishiro fault of the Itoigawa-Shizuoka Tectonic Line (e.g., HERP, 2014). The surface rupture is observed along the Kamishiro fault. We estimated the source rupture process of this earthquake by the kinematic waveform inversion analysis using strong motion data.

We used strong motion data from 12 strong motion stations of K-NET, KiK-net, JMA, and Nagano prefecture. The S-wave portion of the velocity waveform in 0.05-1 Hz are used in the inversion analysis. Since the underground velocity structure in this region seems complex, it is not good strategy for calculating Green's functions that single one-dimensional velocity structure is applied to all stations. We assumed individual one-dimensional velocity structure model for each station, which is extracted from the nation-wide three-dimensional velocity structure model, Japan Integrated Velocity Structure Model Version 1 (JIVSM, Koketsu *et al.*, 2012). The Green's function was calculated by the discrete wavenumber method (Bouchon, 1981) and the reflection and transmission matrix method (Kennett and Kerry, 1979).

The fault model consists of two fault planes, which have different dip angle between the north and south plane based on the aftershock distribution by NIED (2014) and the surface fault information. The south fault plane has relatively steep dip angle compared to the north fault plane. The top of the south fault plane corresponds to the Kamishiro fault. The total length and width of the fault plane is 22 km and 14 km, relatively. The fault plane is divided into subfaults of 2 km $\times$ 2 km. The moment function of each subfault is represented by a series of six smoothed ramp function.

The kinematic waveform inversion method is based on the multiple time-window linear waveform inversion method by Hartzell and Heaton (1983). The relative strength of the smoothing constraint (Sekiguchi *et al.*, 2000) and the first time-window front triggering velocity were determined to minimize Akaike's Baysian Information Criteria.

The estimated source model has a large slip area in a slightly deep portion approximately 5 km north to the rupture starting point. Its largest slip is 1.8 m. It is consistent with the centroid location of the CMT solutions by GCMT and JMA. The aftershock activity in this large slip area is relatively low compared to the other area on the fault. The slip amount of the shallowest subfaults are approximately 0.3-0.5 m, and this slip would be related to the surface rupture observed after this earthquake. The total seismic moment is 3.85×10^{18} Nm (MW 6.3), and the average slip is approximately 0.4 m. Comparing these source parameters with previous inland crustal earthquakes in Japan, this earthquake is not an unusual earthquake.

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Keywords: the 2014 northern Nagano earthquake, source process, strong motion data