Characterized source model for estimating strong ground motions during one of the largest foreshocks (Mw 6.0) of the 2016 Kumamoto Earthquake

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1. Introduction
One of the largest foreshocks (Mw 6.0) of the 2016 Kumamoto earthquake occurred along the Hinagu fault zone in Kyushu, Japan, on April 15, 2016. The maximum seismic intensity with 6 lower was observed at KMMH16 (Mashiki, epicentral distance: 11km) and KMMH14 (Toyono, epicentral distance: 8km) station. PGA of 557.9 gal is observed at the KMMH14. We estimated the characterized source model based on the slip distribution results of the waveform inversion using the strong motion data and the empirical Green's function method.
2. Source model inferred from the waveform inversion results
We analyzed the slip distribution during this earthquake using the multi-time window linear waveform inversion method (Sekiguchi et al., 2000). The data sets used for the inversion analysis were velocity waveforms of S-waves parts in the frequency range 0.1-1.0Hz at 11 stations (KiK-net, K-NET). The Green's functions were calculated using the one-dimensional velocity structure models by the discrete wavenumber method (Bouchon, 1981) with the reflection and transmission matrix method (Kennett and Kerry, 1979) at the stations. A fault plane was assumed referring to the aftershock distribution and the moment tensor solution determined by F-net.
The fault plane is divided into 81 subfaults of 1.5km×1.5km. The temporal moment release history from each subfault is modeled by a series of 4 smoothed-ramp-functions with a rise time of 0.8 second each separated by 0.4 second.
Large slip area is constructed in the proximity of the hypocenter.Seismic moment and rupture velocity are estimated 1.6×1018Nm, 2.7km/s, respectively. The synthetic waveforms at KMMH14 station fit the observed ones reasonably.

3. Characterized source model inferred from the waveform inversion results
The characterized source model is constructed based on the slip distribution from the waveform inversion. We extracted asperity from the slip distribution and high rate area (HRA) from the moment rate distribution by the criterion of Somerville et al. (1999). The area and location of the asperity and the HRA are estimated to be almost the same.
4. Estimation of strong motion generation area (SMGA) using empirical Green's function method
We analyzed the SMGA model using the empirical Green's function method. In particular, we attempted to simulate the strong ground motions at KMMH14 located near the source fault. As a result, the location of the SMGA is nearly the same as the estimated large slip area from the waveform inversion results. We obtained one of the best-fitting SMGA models choosing the starting point, rupture velocity, and rise time by comparing simulated and observed ground motions including the ground motions at KMMH14. The SMGA area and stress parameter are calculated about 33 km^2 and 7.5 MPa, respectively. The scaling relationship SMGA area versus seismic moment is consistent with on the scaling law of combined of asperities versus seismic moment by the previous study (Irikura and Miyake, 2001).
5. Conclusion
We estimated the characterized source model of the Mw 6.0 forshock of the 2016 Kumamoto earthquake

based on the slip distribution results of the waveform inversion using the strong motion data and the empirical Green' s function method. The asperity, the HRA and the SMGA of this earthquake are collocated with nearly the same area.

Acknowledgements. Seismic waveform data of the K-NET and KiK-net were used. This study was based on the 2016 research project 'Improvement for uncertainty of strong ground motion prediction' by NRA (Nuclear Regulation Authority).

Keywords: Foreshock of the 2016 Kumamoto earthquake, strong ground motion, characterized source model