Source Processes of three large events of the 2016 Kumamoto Earthquakes Inferred from Waveform Inversion with Strong-Motion Records

*Kunikazu Yoshida[1], Ken Miyakoshi[1], Kazuhiro Somei[1]

1.Geo-Research Institute

We have investigated the source processes of three earthquakes in the 2016 Kumamoto earthquake sequence by the multi-time-window linear waveform inversion method using the strong-ground motion data. We analyzed the three largest earthquakes of Mj6.5 (21:26 on 14 Apr., JST), Mj6.4 (00:03 on 15 Apr., JST) and Mj7.3 (01:25 on 16 Apr., JST) in the sequence.
We used the strong-motion data obtained from K-NET and KiK-net. The data were windowed for 10-25 s, starting at P-wave arrival time, and band-pass-filtered between 0.05 to 0.8 Hz (period of 1.25-20 s) for waveform inversion. The accelerograms were integrated into ground velocities. Theoretical Green's functions are calculated using the discrete wavenumber method (Bouchon, 1981) and the Reflection/Transmission coefficient matrix method (Kennett and Kerry, 1979) using a stratified medium. We assumed individual one-dimensional velocity structure model for each station, which is made from PS-logging, J-SHIS, and the seismic refraction models. We use multi-time-window linear waveform inversion procedure (e.g., Hartzell and Heaton, 1983) in which the moment-release distribution is discretized in both space and time. The relative strength of the smoothing constraint and the first time-window front triggering velocity (V_{FT}) were determined to minimize Akaike’s Baysian Information Criteria.
For Mj6.5 (Apr. 14) earthquake, a fault model along the Hinagu fault striking N211°E and dipping 88° is assumed. The total length and width of the fault plane is 14 km and 14 km. The fault plane is divided into subfaults of 2 km ×2 km. The moment function of each subfault is represented by a series of three smoothed ramp functions. The estimated source model has two asperities; one is located near the rupture starting point and another at the northern margin of the fault. Its largest slip is 0.8 m. The total seismic moment is 1.6×10^{18} Nm (Mw 6.1).
For Mj6.4 (Apr. 15) earthquake, a fault model along the Hinagu fault striking N211°E and dipping 86° is assumed. The total length and width of the fault plane is 12 km and 9.6 km. The fault plane is divided into subfaults of 1.2 km ×1.2 km. The moment function of each subfault is represented by a series of three smoothed ramp functions. The estimated source model has one asperity located near the rupture starting point. Its largest slip is 0.9 m. The total seismic moment is 1.0×10^{18} Nm (Mw 5.9).
For Mj7.3 (Apr. 16) earthquake, a fault model along the Futagawa fault striking N236°E and dipping 86° is assumed. The total length and width of the fault plane is 34 km and 18 km. The fault plane is divided into subfaults of 2 km ×2 km. The moment function of each subfault is represented by a series of six smoothed ramp functions. The estimated source model has one asperity located on approximately 10 km east to the rupture starting point. Its largest slip is 4.5 m. The total seismic moment is 3.6×10^{19} Nm (Mw 7.0). The average slip is 1.8 m.
Relationships of the estimated three earthquakes between average slip and seismic moment corresponds to the scaling law determined from previous earthquakes (Somerville et al., 1999). For Mj6.5 and Mj6.4 earthquakes, relation between the combined area of asperities and seismic moment corresponds to the scaling by Somerville et al. (1999), although the area of the asperity for the Mj7.3 earthquake is relatively small to the seismic moment.
Acknowledgements: We use the hypocentral information catalog of JMA, the moment tensor catalog by F-net, and the strong motion data from K-NET and KiK-net provided by NIED. This study was based on the 2016 research project ‘Examination for uncertainty of strong ground motion prediction’ by the

Nuclear Regulation Authority (NRA), Japan.

Keywords: 2016 Kumamoto earthquake, source process, asperity