Strong Motion Simulation of 2016 Kumamoto Earthquake Mainshock Using Dynamic Rupture Modeling

*JIKAI SUN[1], HIROSHI KAWASE[1], ARBEN PITARKA[2], FUMIAKI NAGASHIMA[1], ERI ITO[1]

1. Disaster Prevention Research Institute, Kyoto University, 2. Lawrence Livermore National Laboratory

Mainshock of the 2016 Kumamoto earthquake (M_w 7.0) occurred on April 16, 2016 at 01:25 (JST) in the Kyushu Island (Yoshida et al., 2017), on the Futagawa and Hinagu fault system. The kinematic rupture modeling of the Kumamoto earthquake was applied in several studies (Yoshida et al., 2017; Asano and Iwata, 2021) to investigate the rupture process and simulate the strong ground motion for the mainshock. Near-fault ground motions generated by the earthquake were recorded with high accuracy by the NIED strong-motion network (K-NET and Kik-net), the Japan Meteorological Agency (JMA), and the local-government seismic-intensity network.
In this study, the dynamic rupture modeling (Pitarka et al., 2021) was applied to investigate the earthquake rupture process and to simulate the recorded near-fault ground motions. The dynamic rupture is modeled using a split-node method of Dalguer and Day (2007), implemented in the 3D staggered-grid finite-difference method of Pitarka (1999) and a linear slip-weaking friction law (e.g., Andrews, 1976). Following the research results of Yoshida et al. (2017) and Asano and Iwata (2021), we generated 500 and 1020 rupture models including three strong motion generation areas (SMGAs) with elevated stress drops, located on the Futagawa and Hinagu fault zones.
Locations of three SMGAs were randomly generated in the large slip distribution areas specified based on the kinematic inversion results by either Yoshida et al. (2017) or Asano and Iwata (2021). The 3D Japan integrated velocity structure model (JIVSM) (Koketsu et al., 2012) was used in modeling the elastic wave propagation. A simple linear regression method was applied to the eight end points of four fault segments, to define the location of a single, 45 km long rupture plane in this model. The top-left and bottom-right boundaries were determined by 13 km offset from the rupture plane, the bottom-left and top-right boundaries were offset 10 and 5 km from the outmost-edge foot points on the linear regression line.
26 strong-motion stations are located in the target area which observed the mainshock, 2 Kik-net sites, 4 K-net sites, 3 JMA sites, and 17 Kumamoto-ken local shindokei sites. Two kinds of goodness of fit (GOF) function were used to find the optimal simulation within 1520 scenarios; the authors’ original GOF and the MO-GOF (Olsen and Mayhew, 2010) from Anderson’s GOF (Anderson, 2004). After several preliminary investigations in comparing the estimation and observations, the authors’ original GOF considers the misfit ratio of the peak ground velocity (PGV) and cross-correlation coefficient (CCC), while the MO-GOF was consist of ten factors of seismic wave and spectral characteristics. Moreover, the authors’ defined GOF and GOF of PGV and acceleration response spectrum (SA) in MO-GOF were found to be efficient to search for the optimal simulation. We found that three SMGAs of the optimal simulation were located relatively close to the hypocenter and a large shallow SMGA was located on the Futagawa fault. Comparing the observed and estimated strong motions in 0.1-1.0 Hz, 16 of 26 sites displayed good wave fits, while the other 10 sites displayed not so good fits, which were mostly located in the distant area from the edge of the fault. The optimal scenario shows that a large peak slip rate appears in the deeper area (-15 km), which is as large as 7 m/s. However, the large slips are located at -8 km, in the shallow and large SMGA, which is as large as 4 m (Fig. 1). Analysis of the rake angle for the mainshock was found to be in 20-30 degrees, which was confirmed in the previous kinematic inversion reports.

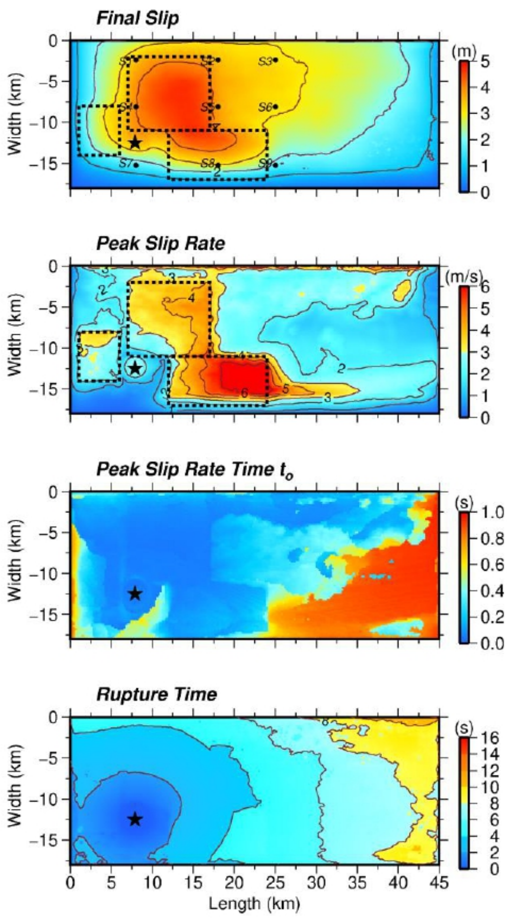

Fig. 1. Simulation of final slip, peak slip rate, peak slip rate time, and rupture time on the fault plane during the mainshock.