Source, path and site effects of the 2016 Kumamoto earthquake, the foreshocks and aftershocks using the spectral inversion method

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We estimate source, path and site effects of the 2016 Kumamoto earthquake, the foreshocks and aftershocks using the spectral inversion method. We use 37 events with M_J larger than 4.0 and the focal depth < 20 km around the 2016 Kumamoto earthquake in 1997 to April 19, 2016.
The spectral inversion method and the data selection criteria are basically same to those by Satoh (2010), but we use JMA-95 type records and KiK-net records at the borehole as well as K-NET and KiK-net records at the surface. The used data are Fourier spectra of S wave parts of horizontal components with PGA < 200 cm/s^2 and the hypocentral distance < 60 km at the strong motion stations in the fore arc. We remove the data with hypocentral distance < 30 km for the main shock because we assume the point source. For the main shock the data around OIT009 which are contaminated by an aftershock just after the main shock are removed by above criteria.
The estimated frequency (f) dependent Q is modeled to $Q=62f^{0.87}$, which agrees with that estimated using the moderate earthquakes around Kumamoto by Satoh (2010). The short period spectral level A is estimated to fit the estimated source spectra to omega squared model in the frequency of 0.2 to 5 Hz. Figure compares the M_0-A relations of three largest strike-slip earthquakes estimated in this study with those of previous crustal earthquakes. M_0 by F-net is used. The A of the main shock is almost the same to the relation for crustal earthquakes by Dan et al.(2001). The A of the largest foreshock (M_J6.5) is a litter larger than the relation by Dan et al.(2001). The A of the two earthquakes are the largest among previous strike-slip earthquakes but smaller than the relation for dip-slip earthquakes by Satoh (2010). The A of the second largest foreshock (M_J6.4) is smaller than the relation by Dan et al.(2001) and almost the same to the relation for strike-slip earthquakes by Satoh(2010). There are no clear differences of M_0-A relations between strike-slip and normal-slip earthquakes among 37 earthquakes.
The observed PGVs of the main shock and the largest foreshock are compared with GMPEs. We assume the fault plane and Mw based on Koketsu et al.(2016). The GMPE by Satoh(2008) is derived from data observed in the fore arc of crustal earthquakes from Niigata prefecture to western Japan by considering the difference between strike-slip and dip-slip earthquakes. The attenuation of Satoh’s GMPE is different near and far from the fault distance of 70km. The attenuation of Satoh’s GMPE almost reproduces the observed PGVs, but the absolute values of observed PGVs of the main shock (Mw7.0) are a little larger and those of the largest foreshock (Mw6.1) are obviously larger than the GMPE within the fault distance of 60 km. This result is consistent with the A estimated in this study.
Although KMMH16(Mashiki), KMM006(Kumamoto) and EEB(JMA Kumamoto) are located within 10km, the seismic intensity is 6.4, 6.0, and 6.0 during the main shock and 6.4, 5.9, and 5.9 during the largest foreshock, respectively. The empirical amplification factors at three stations have the peaks at 4Hz and are almost the same less than 5Hz. The surface-to-borehole spectral ratios and H/V of strong motions at KMMH16 during the main shock and the largest foreshock are obviously different from weak motions. At KMM006 and EEB the differences of H/Vs between strong and weak motions are smaller than those at KMMH16. Therefore causes of the difference of the seismic intensity at three stations are thought to be source effects and the nonlinear site effects depending on nature of soil, but not the 1-D effects due to deep structures.
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