Strong-motion data recorded by 1s-sampling GNSS during the 2016 Kumamoto earthquake

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The high-rate GNSS data have a potential to observe dynamic ground motions as well as static permanent displacements during large earthquakes (e.g., Bock et al. 2004). However, few attempts have investigated “strong” ground motions recorded by GNSS. In this study, we investigate GNSS records at near-source stations during the 2016 Kumamoto earthquake.

First, we compare ground motions recorded at GNSS and strong-motion stations, which adjoin each other. For GNSS data, we use 1s-sampling records of GEONET of GSI. The 1s-sampling GNSS data is converted into displacement waveforms using Kinematic PPP as implemented in RTKLIB Ver. 2.4.2 (Takasu 2013). For GNSS precise ephemeris, we use the satellite orbit data (15m sampling) and the clock data (5s sampling) produced by Center for Orbit Determination in Europe (CODE). We also use ground-motion records of K-NET and KiK-net of NIED. From the original acceleration records, displacement waveforms are obtained by numerical double integration in time domain with baseline corrections and are resampled to 1s after the high-pass filtering operation at the period of 2s. We conduct a comparison of displacement waveforms at two station pairs: KiK-net Oguni and GEONET Kumamoto-Oguni, and K-NET Tamana and GEONET Tamana. The maximum amplitudes of horizontal components at these stations range between 10–40 cm, and the maximum amplitudes at vertical components are smaller than 10 cm. The permanent displacements are approximately 10–20 cm at horizontal components. The comparison of displacement waveforms indicates that horizontal displacement waveforms at GNSS stations are similar to those at strong-motion stations. Their displacement spectra are consistent in the period band between 5–20s, although the spectra at periods of less than 5s differs among them. This difference at short period is expected to be caused by the multi-path error of GNSS observation due to the strong shaking. The permanent displacements of the GNSS and seismometer data are close to those estimated from F3 solutions of GEONET. These features are also found at vertical waveforms, although the spectral difference at short period is lager.

We also investigate the effect of GNSS ephemeris on displacement waveforms. When using final or rapid ephemeris of International GNSS Service (IGS), whose sampling rate of clock data (30s or 5m) is lower than that of CODE, obtained horizontal waveforms are consistent with waveforms obtained with CODE ephemeris, although there are cases where permanent displacements cannot be obtained stably. The comparison of displacement amplitude spectra indicates that spectra obtained with IGS final or rapid ephemeris are consistent with those obtained with CODE ephemeris in the period band of 5-20s. Horizontal displacement waveforms obtained with IGS ultra-rapid ephemeris can also reproduce major phases of seismic waves, although they have a lot of short-period noises. The use of only broadcast ephemeris cannot reproduce major phases of seismic waves.

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