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Strong ground motions of the 2009 L'Aquila earthquake: modeling and scenario simulations

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On April 6, 2009 a Mw 6.3 earthquake struck the L'Aquila city, one of the largest urban centers in the Abruzzo region (Central Italy), causing a large number of casualties and damage in the town and surrounding villages. The earthquake has been recorded by several digital stations of the Italian Strong-Motion Network. The collected records represent a unique dataset in Italy in terms of number and quality of records, azimuthal coverage and presence of near-fault recordings. Soon after the earthquake the damage in the epicentral area was also assessed providing macroseismic intensity estimates, in MCS scale, for 314 localities (I $\geq$5). Despite the moderate magnitude of the L'Aquila earthquake, the strong-motion and macroseismic data in the vicinity of the fault depict a large variability of the observed shaking and damage.

In this study we present broadband (0.1 – 10 Hz) ground motion simulations of the 2009 L'Aquila earthquake to be used for engineering purposes in the region. We utilize Hybrid Integral-Composite (HIC, Gallovič and Brokešová, 2007) approach based on a k-square kinematic rupture model, combining low-frequency coherent and high-frequency incoherent source radiation and providing omega-squared source spectral decay. We first model the recorded seismograms in order to calibrate source parameters and to assess the capabilities of the broadband simulation model. To this end, position and slip amount of the two main asperities, the largest asperity time delay and the rupture velocity distribution on the fault is constrained, based on the low-frequency slip inversion result. Synthetic Green's functions are calculated in a 1D-layered crustal model including 1D soil profiles to account for site-specific response (where available). The goodness-of-fit is evaluated in time (peak values and duration) and frequency domains (elastic and inelastic response spectra) and shows a remarkable agreement between observed and simulated data at most of the stations. The results show that not only the local site effects improve the modeling results, but also that the spatial broadband ground-motion variability is to large extent controlled by the rupture kinematics revealed by the low-frequency inversion.

We simulate the ground motion at a grid of sites and compared the observed macroseismic intensity distribution with that obtained applying ground-motion to intensity conversion equations to the synthetic data. We find that the spectral ordinates at periods larger than 2s are well correlated with the macroseismic intensity pattern observed in the epicentral area. Finally, we compare the synthetic ground-motion parameters with estimates from several empirical ground motion prediction equations (GMPEs). The comparison highlights potential drawbacks in using GMPEs to validate simulated motions and/or when used for engineering purposes.