2008年Wenchuan地震における拡張特性化震源モデルによる近地地震動シミュレーション

Extended characterized source model for simulating near-fault motions during the 2008 Wenchuan earthqake

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Introduction
Many studies have been done of the source model of this earthquake using different datasets (ex. Geodetic data, GPS, InSAR, teleseismic data and strong-motion data. Kurahashi and Irikura (2010) constructed the characterized source model using a hybrid method of the empirical Green’s function (EGF) method at high frequencies more than 1 Hz and the theoretical method at low frequencies less than 1 Hz. The synthetic motions obtained by the hybrid method agree well with the observed motions, however, long-period velocity pulse and permanent displacement at the Qingping station (MZQ) were not reproduced by this source model. Dalguer et al. (2019) proposed a combined model of the strong motion generation areas (SMGA) and long-period motion generation area (LMGA) in a weak shallow layer zone defined as part of the crust between the top of the seismogeneic zone and the free surface for the 2010 Darfield earthquake. Then, we examine the characterized source model by adding the LMGAs in the weak shallow layer zone above the seismogenic zone to reproduce the long-period motions with permanent displacements at the Wenchuan earthquake using the discrete wavenumber method (Bouchon, 1981) excluding near-surface areas and the wavenumber integration method (Hisada and Bielak, 2003) in the near-surface ones.
Fault model and Source model
The fault model was defined a two-segment source fault consisting of the Beichuan farult and the Pengguan fault in southern part of the Wenchuan earthquake, according to surface rupture investigations. The dip angle was determined from the aftershock distribution by Chen et al. (2009). The dip angle of the Beichuan segment is 62.4 deg. The dip angle of the Pengguan fault which set two fault planes are 62.4 deg at part of shallow plane and 26.6 deg at part of deep plane.
Irikura et al. (2019) proposed an extension of the characterized source model by adding LMGAs in the SL zone over the seismogenic zone from the reproduction of the observed long-period velocity pulses and permanent displacement waveforms at stations close to surface earthquake faults during the 2016 Kimamoto earthquake.
We thus construct the extended characterized source model in the following procedures.
1) To estimate the SMGA source model which targeted broadband ground motions in intermediate-distance stations using the numerical simulation method with the discrete wavenumber method (Bouchon, 1982).
2) To estimate the LMGA source model which targeted long-period ground motions in near-distance stations using the wavenumber integral method.
3) To complete the broadband source model including spatial permanent displacements compared with InSAR data

First, we constructed the SMGAs, in which slip velocity time function is assumed to be a Kostrov-type function, comparing the observed and simulated velocity-pulse waveforms at stations except very-fault stations based on the slip distribution by Ramire-Guman and Hartzell (2020). The Green's functions are calculated for each subfault divided the fault plane into 2 km square. The velocity structure models are given by Hartzell et al. (2013). The best-fit SMGA model is obtained from comparison between the synthetic and observed ground motions, which consists of three SMGAs.
Second, the LMGAs, in which slip velocity time function is assumed to be a smoothed ramp function, were estimated fromthe comparison between the observed and simulated displacement waveformsat very-near-fault stations. The best-fit LMGA model consists of two LMGAs. Ground motions generated from the LMGAs have weak amplitudes at short periods but rich amplitudes at long periods, including permanent displacements, being consistent with the observed motions at MZQ and SFB near the fault.
Third, we revised the best-model so that the two distinct LMGAs can reproduce the distribution of surface displacements derived from InSAR data estimated by Feng (2012).
Finally, we discussed validation for slip time velocity function and setting of the LMGAs. The observed waveforms were well fitted to the calculated waveforms using smoothed ramp function better than the Kostrov-type one. This is consistent with the result of dynamic simulation during the 2016 Kumamoto earthquake by Kaneko and Goto (2021). If long-period ground motions are estimated for the background area, where seismic moment release was small, substitute for LMGAs, the pulse shapes of the calculated waveforms were similar to the observed records, but their amplitudes were underestimated.

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