Geophysical Research Abstracts
Vol. 21, EGU2019-14546, 2019
EGU General Assembly 2019

Towards dynamic rupture models compatible with ground motion prediction equations

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Strong motion seismology aims to develop correct physical description of earthquake source, path and site effects to improve seismic hazard assessment. In particular, physics-based (dynamic) source models are characterized by spatially varying stress and frictional parameters that control the rupture process. Dynamic source inversions of individual earthquakes provide constraints on such parameters, which are, however, inherent to the studied event. General characteristics of the dynamic rupture parameters are basically unknown. Here we propose to constrain the dynamic rupture parameters by modeling events with waveforms compatible with ground motion prediction equations (GMPEs) using Bayesian inference.

We assume a vertical strike-slip fault governed by the slip-weakening friction law with heterogeneous distribution of dynamic parameters (initial stress, friction drop and critical slip-weakening distance). To increase the efficiency of the forward solver, we have separated the dynamic simulation and the calculation of seismograms. For the dynamic rupture propagation, we utilize finite-difference code FD3D by Madariaga et al. (1998) that solves 3D elastodynamic equation with the given friction law prescribed as a boundary condition in the thin fault approximation. The dynamic simulation results in slip histories along the fault which are convolved with precalculated Green's functions following the seismological representation theorem. Moreover, the code has been ported to GPU allowing the simulations to run within minutes. Synthetic waveforms are calculated for a regular grid of phantom stations considering a 1D velocity model. The misfit is evaluated in terms of spectral accelerations at various periods against GMPEs by Zhao et al (2006).

We sample the probability density function defining the GMPEs using parallel tempering Monte-Carlo algorithm (Sambridge, 2013). In our previous work, we have applied our code to the synthetic dynamic source inversion of SIV benchmark (Mai et al, 2016) as well as real case of Amatrice 2016 earthquake. As a result we obtain a large ensemble of dynamic rupture models with various dynamic parameter settings that statistically fit the observed GMPEs. The synthetic events exhibit various magnitudes and complexities (e.g., one or more asperities). We analyze scaling relations of the rupture parameters to infer general characteristics of dynamic rupture models compatible with the GMPEs.