Heterogeneous source modelling by the fully dynamic simulations of earthquake cycles on a strike-slip fault and scaling relations.

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Numerical modeling is a necessary tool for the assessment of variability strong ground motions in potential devastating large earthquakes. In a simulation-based seismic hazard analysis, it is critical to be able to generate a large number of physically self-consistent source models whose rupture process captures the main physics of earthquake rupture and is consistent with the spatio-temporal heterogeneity of past earthquakes. An inherent difficulty in such efforts is that, from a mechanical point of view, stress and strength heterogeneities cannot be prescribed arbitrarily as was done in earlier work. Their interdependence must be consistent with a mechanical model of deformation and stress evolution over the longer time scale of the earthquake cycle.

In this work, a set of spontaneous source models have been generated in a wide magnitude range (*Mw* 5.5-7.5) by using multicycle simulations under the rate-and-state friction law with the goal of studying the characteristics of source scaling relations and strong ground motions. To get realistic irregular seismic sequence, several realizations of 2D correlated heterogeneous random distributions of characteristic weakening distance “*Dc*” in rate and state friction are tested. A mesh grid size of 125 meters has been used to resolve properly the nucleation and cohesive zone of the seismic events. The fault is 128 km in length and 30km in width, the seismogenic width is 18km. The quasi-dynamic solver QDYN (Luo, et al., 2017) has been used to nucleate the seismic events and SPECFEM3D (Galvez et al, 2014; 2016) to resolve the rupture process. Other important parameters are the normal stress, which controls the stress drop and rupture velocity during an earthquake, and the maximum value of *Dc* distribution, that controls rupture velocity but not stress drop. Following these ideas, we perform dynamic rupture modeling to take into account the free surface effects and perform a parametrization study; parameters of our final friction model are shown in Fig.1.

In order to validate source models we compare the source scaling relations vs. seismic moment *Mo* for the modeled rupture area *S*(*Mo*), average slip of the ruptures *Dave*(*Mo*) and the slip asperity area *Sa*(*Mo*), with similar scaling relations from the source inversions. Fig. 2 shows result for *S*(*Mo*). The seismogenic zone width plays a fundamental role in the *S* vs *Mo* scaling. In fact, Luo et al. (2017) reported that events which break the whole seismogenic width and reach the free surface are exposed to an attraction effect from the free surface. This attraction effect may explain the transition regime from Stage 1 (self-similar rupture, *Mw* < 6.5) to Stage 2 (6.5 < *Mw* < 7.4). Ground motions have been also computed from our models. Their peak ground velocities (*PGV*) agree well with the GMPE values.

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Keywords: earthquake rupture dynamics, earthquake cycles, rate-and-state friction, source scaling

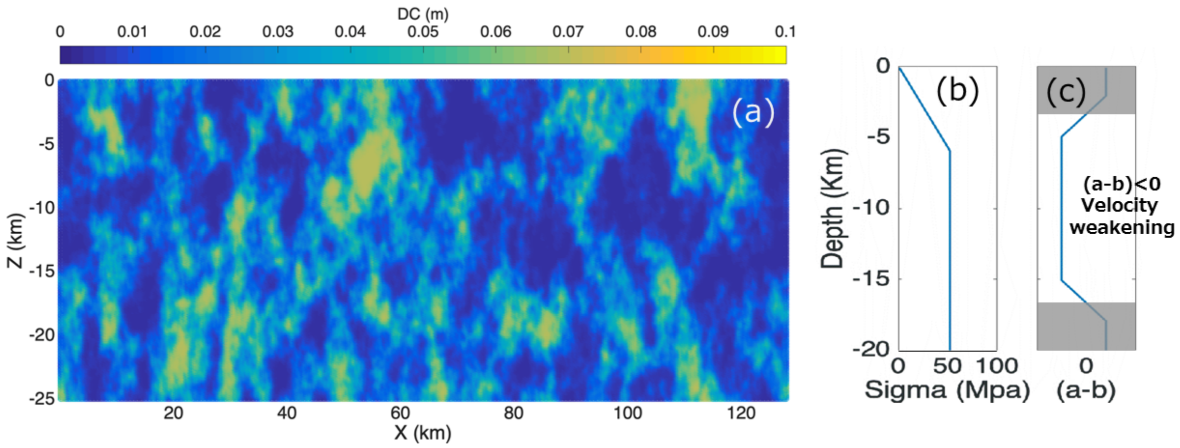

Fig 1. Friction settings: (a) heterogeneous *Dc*, (b) normal stress, and (c) *a-b* friction parameters.

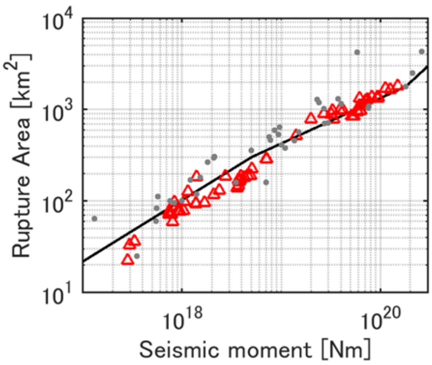

Fig 2. Comparison of *S*-values of modeled events vs. *Mo* (triangles) and observed (dots).
Line is 3-stage scaling assumed for strong-motion simulations.