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Characterization of Shallow Rupture Kinematics in Strong Ground Motion Simulations of Strike-Slip Earthquakes Constrained by Dynamic Rupture Modeling

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The objective of our study is the improvement of shallow rupture characterization in kinematic rupture models used in strong ground motion simulations. Based on geological investigations, earthquake stress drop, depth-variation of seismicity, as well as recorded near-fault ground motion, there is clear evidence for depth variation of frictional properties of crustal materials. The material ductility in the weak zone (upper 3-5 km of the crust) and the transition from ductile state to brittle state in the upper seismogenic zone, determine how the fracture energy is consumed by the earthquake rupture, and how generated seismic energy is distributed in space and time.

Using plausible stress models for crustal ruptures, we performed dynamic rupture simulations on vertical strike slip faults that break the free surface. We used a 3D staggered-grid finite-difference method (Pitarka and Dalguer, 2009) and regional 1D velocity model. The stress drop as a function of slip was modeled using a linear slip weakening frictional law that reflects the depth and lateral variations of frictional properties of crustal materials. Through dynamic rupture modeling we were able to extract kinematic rupture characteristics, such as changes in the shape of slip rate functions, rupture velocity, and peak slip rate across the weak zone, and in the slip asperity areas. These results were then used to refine our existing rupture generating model (Graves and Pitarka, 2016) for crustal earthquakes. The modifications to the rupture generator code include changes to the shape of slip-rate function at shallow depths, rise time variation with depth and stronger correlation with slip at shallow depths.

The effects of the new characterization of shallow rupture kinematics on simulated ground motion was thoroughly investigated in broad-band (0-10Hz) simulations of the M7.1 2019 Ridgecrest California earthquake. The ground motion time histories were computed using the hybrid method of Graves and Pitarka (2010. In our simulations we considered several slip distributions, including two that were obtained by inverting recorded velocity and displacement ground motion, respectively. Finally, through comparisons with recorded data, we analyzed the sensitivity of computed near-fault broad-band ground motion characteristics, including amplitude of ground motion velocity pulse, peak acceleration, and response spectra, to shallow slip characterization and location of strong motion generation areas for each rupture model. The proposed modifications to kinematic rupture models of crustal earthquakes provide improved simulation of broadband strong ground motion and seismic hazard assessment.

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