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Dynamic rupture and seismic radiation in a damage-breakage rheology model

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We present simulations of dynamic ruptures in a continuum damage-breakage rheological model and waves radiated by the ruptures observed in the far field. The model combines aspects of a continuum viscoelastic damage framework for brittle solids with a continuum breakage mechanics for granular flow. The brittle instability is associated with a phase transition between a damaged solid with distributed cracks and a granular medium within the generated rupture zone. The formulation significantly extends the ability to model brittle processes in structures with complex volumetric geometries and evolving elastic properties, compared to the traditional models of pre-existing frictional surface(s) in a solid with fixed properties. A set of numerical simulations examines the sensitivity of dynamic ruptures, seismic source properties and radiated waves to material properties controlling the coupled damage-breakage evolution, the thickness and geometry of the damage zone, and fluidity of the granular material. The simulations are performed in two stages. First, details of the rupture process are simulated using adaptive fine grid model. The results of these simulations include source parameters such as rupture velocity, potency, stress and strain drop, heat generation, and others. In the second stage, the obtained velocity source function is used for simulating radiated seismic waves and synthetic seismograms sampled by stations around the rupture zone and in the far field.

Detailed comparisons between the simulated source properties and those obtained by analyzing the synthetic seismograms demonstrate the relations between different source processes and inferred seismic parameters (potency, strain drop, directivity, rupture velocity, corner frequency, and others). One main effect shown in these simulations emphasizes the important role of rock damage and granulation process generating dynamic expansion-compaction around the process-zone. This expansion-compaction process leads to isotropic source term, while shear motion that accumulates behind the propagating front produces deviatoric deformation and shear heating behind the rupture front. Changing through our simulations, source geometries, and fault zone properties, we demonstrate that the process-zone dissipation due to the damage-breakage mechanism, and the isotropic source component, significantly affect the radiation pattern, rupture directivity, S/P energy partitioning, seismic potency and moment, and more. The results are significant for understanding better the proper usage and limitations of methods applied within the observational framework of earthquake seismology.