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Effect of Brittle off-fault Damage on Earthquake Rupture Dynamics

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In the shallow brittle crust, following earthquake ruptures, geophysical observations show a dramatic drop of seismic wave speeds in the shallow off-fault medium. Seismic ruptures generate, or reactivate, damage around faults that alter the constitutive response of the surrounding medium, which in turn modifies the earthquake itself, the seismic radiation and the near-fault ground motion. This numerical study aims to assess the interplay between earthquake ruptures and dynamically evolving off-fault medium and to underline the damage-related features pertinent to interpret geophysical observations. We present a micro-mechanics based constitutive model that account for dynamic evolution of elastic moduli at high-strain rates. We consider 2-D inplane models, with a 1-D right lateral fault featuring slip-weakening friction law. We demonstrate that the response of the damaged elastic solid is different in the compressional and tensional quadrant. We observe that dynamic damage induces a reduction in elastic moduli and produces slip rate oscillations which result in high frequency content in the radiated ground motion, consistent with strong motion records. We underline the importance of incorporating off-fault medium history in earthquake rupture processes. We find that dynamic damage generation is sensitive to material contrast and that it introduces an additional asymmetry beyond that of a bimaterial fault, in agreement with experimental studies.