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Overall energy budget of earthquake rupture with dynamically generated off-fault crack network

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The overall energy budget of earthquake ruptures is described as the balance between change of stored strain energy, radiated energy and dissipated energy as fracture energy and heat. Numerous studies have suggested that the dissipated energy plays an important role in the overall energy budget. In addition to the dissipated energy on the main fault network, a part of the stored strain energy is also dissipated by nucleating/activating secondary off-fault crack network dynamically induced by earthquake rupture propagating on main fault network. We therefore investigate the implications of the dynamically activated off-fault crack network for the overall energy budget. The combined finite-discrete element method (FDEM), which accounts for the main rupture propagation and nucleation/propagation of secondary cracks, was used to quantify the evolution of the fracture networks and evaluate the energy components associated with the overall energy budget. We modelled an earthquake rupture on a planar strike-slip fault surrounded by a brittle medium where the secondary crack network can be nucleated/activated by the earthquake rupture. We then conducted case study in depth with various sets of initial stress state and friction properties to mimic depth effect. We investigated the evolution of damage zone in depth and the effect of depth on the overall energy budget. The energy components associated with the overall energy budget were computed in time and space during an earthquake rupture event. The simulations were performed with the FDEM-based software tool, Hybrid Optimization Software Suite (HOSSedu) developed by Los Alamos National Laboratory. We firstly obtained the overall energy budget and quantified the contribution of dissipated energy by nucleating/activating the off-fault crack network to the energy balance. We then investigated the effect of the off-fault crack network on the source time function. The rate of increase of seismic moment rate significantly decreases due to the decrease of rupture velocity and slip velocity on the main fault. The case study in depth shows the damage zone in which the off-fault crack network can be activated becomes narrower in depth, which is generally called flower structure. The contribution of the secondary crack network to the overall energy budget and the source time function, however, is nearly independent of depth. Therefore, we conclude that the effect of secondarily activated off-fault crack network on the overall energy budget is non-negligible regardless of the damage zone width in depth.