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Dynamic earthquake ruptures with coseismic off-fault damage on finite faults and fault kinks

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Secondary fractures can be coseismically activated in the off-fault medium by dynamic earthquake ruptures on a pre-existing fault system. The feedback of coseismic off-fault damage has a significant effect on rupture dynamics, radiation and overall energy budget. The first-order geometrical complexities, such as finite faults and fault kinks, can increase the activation of coseismic off-fault damage due to the stress concentration at the tips of fault and the fault kink. However, most of previous studies have modelled the coseismic off-fault damage on an infinite planar fault. Thus the activation of the coseismic off-fault damage around the tips and the fault kinks and its role on the rupture dynamics are not fully understood. Therefore, we conducted the dynamic earthquake rupture modelling with coseismic off-fault damage on a planar finite fault and a fault kink to evaluate the effect of fault geometries on the rupture dynamics. We used the combined finite-discrete element method (FDEM), which accounts for the dynamic earthquake rupture propagation on the pre-existing fault and the dynamically activated off-fault fracture network. The 2-D spontaneous earthquake rupture modelling was performed with the FDEM-based software tool, Hybrid Optimization Software Suite (HOSSedu), developed by Los Alamos National Laboratory. We first show the dynamic earthquake rupture modelling on a planar finite fault. In addition to the coseismic off-fault damage during rupture propagation on the pre-existing fault, a number of off-fault fractures are activated around the tips of fault due to the stress concentration caused by the abrupt arrest of the dynamic rupture. The off-fault damage around fault tips effects the additional radiation. The rate of increase and decrease in source time function is also modified by the coseismic off-fault damage. We also address the comparison of overall energy budget with infinite fault model to the finite fault model in order to investigate the effect of arresting phase. We then conducted simulations with the fault kink, which bends on either compressional or extensional side of the fault. For the case with the fault kink bent on the extensional side, the rupture propagates on the pre-existing fault even with the coseismic off-fault damage. In this case, the off-fault fractures are barely activated at the kink. However, for the case bent on the compressional side, instead of propagating on the pre-existing fault, a major fault blanch is activated in the direction of conjugate shear failure planes associated with the orientation of maximum principal stress. Since natural fault networks can be decomposed into the first-order geometrical complexities, this study helps better understand the rupture dynamics on the natural earthquakes.