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Fault opening related to free surface interaction on reverse faults: insights from numerical modeling

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Thrust faults are commonly known to produce significant amounts of slip, damage and ground acceleration, especially close to the free surface. The effect of the free surface on faulting has always been a standing issue in theoretical mechanics. While static solutions exist, they still cannot explain the large amounts of slip, damage and ground acceleration observed on low dipping faults. Dynamics effects raised by the presence of a free surface were first evaluated by Brune [1996] using analog experiments, which hinted at a torque mechanism induced in the hanging wall leading to a natural reduction in elastic compressive normal stress as the rupture approaches the surface. This solution was recently supported by preliminary work from Gabuchian et al. [2017], which, combining numerical and experimental simulations, also showed that the earthquake rupture, propagating up dip, induces rotation of the hanging wall, and might promote fault opening.

In this work, we take advantage of new numerical algorithms for dynamic modeling of earthquake rupture to confirm and document this opening effect. We use enhanced numerical solutions for earthquake rupture, based on the Combined Finite-Discrete Element Methodology (FDEM), which were recently developed by the Los Alamos National Laboratory. Through a systematic analysis of case studies, we investigate the effect of fault geometry, friction parameters and rupture behavior on the deformation pattern. Fault opening is observed in all simulations, growing dramatically as the rupture reaches the surface. Evolution of slip, fault-normal displacement and velocities, and of the predicted surface displacements and velocities are documented for each simulation. These predictions will serve as synthetic data when comparing with recorded surface deformation from real-case earthquakes.