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Fault opening on thrust faults due to free surface interaction and its near-field deformation features

Carlos Villafuerte[1], Harsha S. Bhat[1], Kurama Okubo[2], Esteban Rougier[3], and Pierpaolo Dubernet[1]
[1]Laboratoire de Géologie, École Normale Supérieure, Paris, France (villafuerte.cd@gmail.com)
[2]National Research Institute for Earth Science and Disaster Resilience, Tsukuba, Japan
[3]Earth and Environmental Sciences Division, Los Alamos National Laboratory, Los Alamos, NM, USA

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 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, to carry out dynamic rupture simulations on thrust faults to characterize this opening effect and investigate the physical mechanism responsible for it. Through a systematic analysis of case studies, we explore the effect of fault geometry and friction properties on rupture behavior and its associated deformation pattern. We observe that fault opening occurs in all our simulations and increases significantly as the rupture reaches the free surface and for low dip-angle faults.We document the evolution of different metrics such as slip, slip rate, fault-normal displacement and velocities, as well as the displacements and velocities on the free surface to identify near-field deformation features that will serve as synthetic data when comparing with recorded surface deformation from real-case earthquakes.