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Role of viscoelastic rheologies on heterogeneous stress fields in dynamic rupture models.

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Understanding how past ruptures will affect the propagation of the following ruptures, and how stress heterogeneities develop on faults are fundamental to a better comprehension of earthquake behavior. In that sense, numerical simulations provide a useful tool to study slip dynamics. In this study, we show, using dynamic rupture simulations, the importance of viscoelastic rheologies on the persistence of heterogeneous stress states along a frictional interface.

The modeled set-up is a system used in laboratory friction experiments [Rubinstein et al., 2007; Ben-David et al. 2010]. Using a finite-element code, we model two 2D blocks of viscoelastic material (PMMA), with a slip-weakening friction law at the interface between the two solids. The system is loaded from the side of the upper block, resulting in a sequence of precursory slip events, which initiate at the trailing edge and stop before propagating over the entire interface. Their length increases with increasing loading, and high stress concentrations are generated at the tip of each arrested rupture. We analyze the evolution of these stress concentrations when the following slip events take place.

We show that due to the viscous properties of the bulk material, the stress concentrations created by the arrest of precursory slip are not erased by the propagation of the following rupture, but reappear with the relaxation of the material, with a smaller amplitude. The amplitude of the stress concentrations follows an exponential decrease rate with successive rupture, which is controlled by by the material properties, and in particular by the ratio of the viscous over instantaneous Young's moduli. We extend this analysis by using rheological parameters relevant for rocks.

Our results highlight the importance of viscous relaxation mechanisms in the persistence of heterogeneous stress states along a frictional interface. This study also provides a mechanism to explain how previous slip history will influence the propagation of the next rupture.