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The Competitive Effects of On-fault Normal Stress and Off-fault Seismic Velocity Change on Seismic Cycles

The temporal variation of elastic property of the bulk material surrounding the fault is considered an important contribution to the observed co-seismic velocity reduction and interseismic healing. Paglialunga et al. [2021] found that as fault normal stress increases, co-seismic velocity reduction becomes larger because more cracks reopen with higher stress drops. Larger normal stress can lead to smaller nucleation size and contribute to larger co-seismic slip. By contrast, with larger co-seismic velocity reduction and interseismic healing, more slow slip events can propagate in the seismogenic zone [Thakur and Huang, 2021], because the temporal velocity change related to fault zone damage modulates earthquake nucleation. Hence, fault normal stress and temporal damage zone structure evolution have opposite influences on the spatial distribution and recurrence intervals of earthquakes.

We conducted 2-D anti-plane fully-dynamic seismic cycle simulations and explored the effects of fault normal stress on seismic cycle when there is coseismic damage and interseismic healing in the fault damage zone. The normal stress is in a range of 40-70 MPa and the co-seismic rigidity reduction is in a range of 5-8%. We find larger normal stress results in larger co-seismic slip and fewer slow slip events, while more co-seismic velocity reduction and interseismic healing leads to more partial ruptures as well as slow slip events. With the increase of both normal stress and seismic velocity change, more regular earthquakes occur and slow slip events gradually disappear. For the selected parameter space, the influence of seismic velocity change is not as significant as the effect of normal stress. However, fault zone maturity or the initial rigidity of fault damage zones should also affect the competitive relationship between normal stress and seismic velocity change, and we will characterize earthquakes and slow-slip events in immature and mature fault damage zones when both on-fault normal stress and off-fault seismic velocity vary over earthquake cycles.

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