

The Interaction of Earthquake Characteristics and Fault Mechanics at Various Scales from Observation-Driven Simulations

Rapid improvement in seismic data acquisition and computational modeling capability provides an unprecedented opportunity to gain new insights into earthquake physics. More realistic simulations driven by high-resolution geophysical observations show that earthquakes interact with fault mechanics at a wide range of spatial and temporal scales. I will present a variety of observation-driven simulations that investigate the physical processes responsible for the rupture nucleation, propagation and arrest of both small and large earthquakes. Based on the shear stress rate inverted from GPS data, our dynamic rupture simulations of Cascadia megathrust earthquakes show persistent penetration of earthquake rupture into the episodic tremor and slip region. The along-strike variation of fault zone damage observed by dense seismic arrays provides a natural explanation for seismic gaps along major strike-slip faults. The highly-damaged fault segments can control the rupture termination of small to moderate earthquakes and occasionally allow a larger earthquake that penetrates into intact rocks. Damaged fault zones also give rise to heterogeneous fault stresses along depth and host the majority of small to moderate earthquakes during earthquake cycles. By simulating both seismic and aseismic slip on a fault that experiences fluid-induced shear stresses, we find large stress perturbations can always advance the next earthquake by either instantaneously triggering seismic events or inducing aseismic transients, whereas small stress perturbations introduced at a very early or late stage of the earthquake cycle may delay subsequent earthquakes. In each case, the observation-driven simulations enable us to identify the fundamental processes, reduce the non-uniqueness of the interpretation, and make physical predictions that can be tested in future geophysical observations.

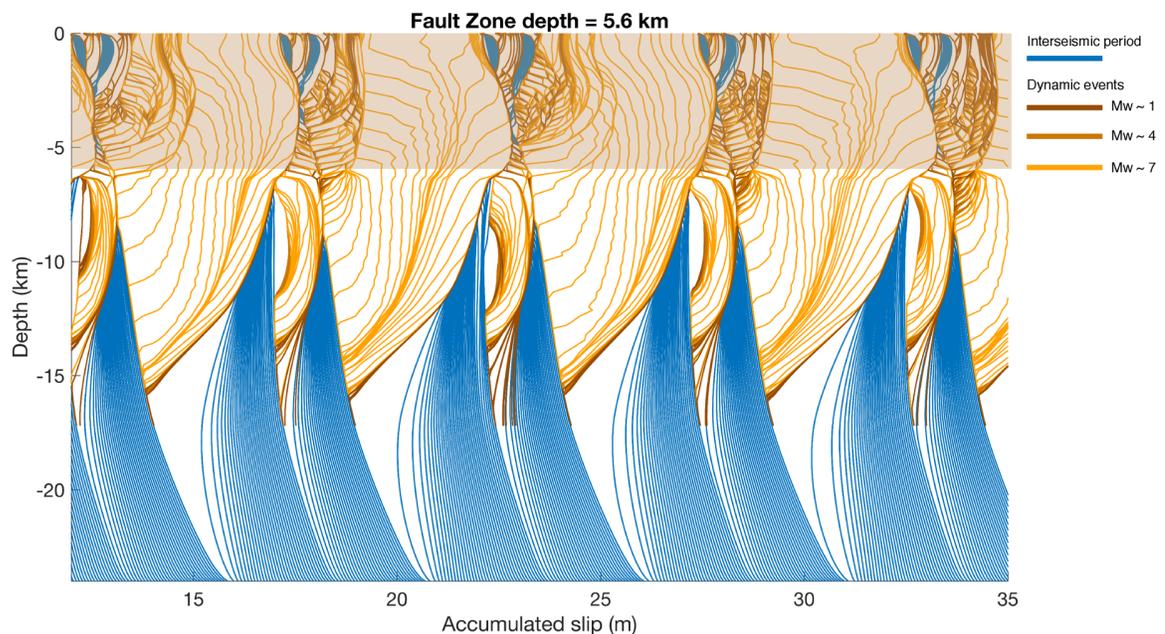


Figure: Slip accumulation during interseismic period (blue) and seismic events (orange to red) over multiple earthquake cycles when a damaged fault zone ends at 5.6 km (light gray). The colors of dynamic events correspond to earthquake magnitudes.