← Back to Gallery (https://seismosoc.secure-platform.com/a/gallery?roundId=29)

The Effects of Precursory Seismic Velocity Changes on Earthquake Sequence Simulations

Predicting the onset and timing of fault failure is one of the ultimate goals of seismology. However, our current understanding of the earthquake preparation and nucleation process is limited. One direction towards understanding this process is looking at precursory signals preceding large earthquakes. Previous laboratory experiments have studied robust precursory signals, observed as temporal changes in pressure and shear wave velocities during the seismic cycle. The effects of such precursory velocity changes on the seismic cycle are not well understood.

We use numerical models to simulate fully-dynamic earthquake cycles in 2D strike-slip fault systems with antiplane geometry, surrounded by a narrow fault-parallel damage zone. By imposing shear wave velocity changes inside fault damage zones, we investigate the effects of these precursors on multiple stages of the seismic cycle, including nucleation, coseismic, postseismic and interseismic stages. Our modeling results show a wide spectrum of fault-slip behaviors including fast earthquakes, slow-slip events and variable creep. One primary effect of the imposed velocity precursor is the acceleration of an otherwise slow-slip event into a fully dynamic earthquake. Furthermore, the onset time of these precursors have significant effects on the nucleation phase of the earthquakes, and earlier onset of precursors causes the earthquakes to nucleate earlier with a smaller nucleation size. Our results highlight the importance of short and long-term monitoring of fault zone structures for better assessment of regional seismic hazard.

Session: Multi-scale Dynamics of Complex Earthquake Faulting and Seismic Wave Propagation

Type: Oral

Room: Grand C

Date: 4/22/2022

Presentation Time: 02:45 PM Pacific

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