THE ROLE OF OFF-FAULT PERMANENT DEFORMATION ON EARTHQUAKE CYCLES

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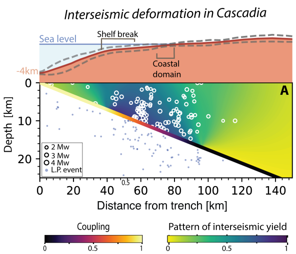
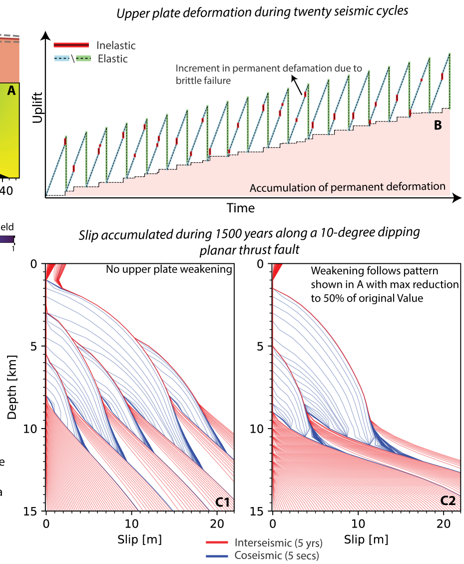
One of the most commonly held assumptions in earthquake hazard assessment is that the off-fault deformation associated with the earthquake cycle is purely elastic. In subduction settings, this suggests that all off-fault strain associated with the slow interseismic loading period is released during large megathrust earthquakes, amounting to effectively zero deformation and surface displacement over numerous cycles. However, recent evidence (Oryan et al., 2024) suggests that interseismic stresses can induce increments of irreversible brittle failure across the overriding plate, creating a spatially variable field of permanent deformation and long-term surface displacement. This indicates that a significant portion of interseismic elastic energy dissipates through yielding and is not available to drive earthquakes.

The impact of this behavior on the coseismic period and earthquake rupture processes remains elusive. To investigate the potential imbalance in co-, post-, and interseismic strain of earthquake cycles, we use Tandem (Uphoff et al., 2022), an open-source discontinuous Galerkin volumetric solver for quasi-dynamic sequences of earthquakes and aseismic slip (SEAS). We simulate SEAS along a 10-degree dipping planar thrust fault with gradually varying off-fault material properties. We incorporate a region with reduced off-fault Lamé parameters to represent a weakened area above the transition in fault-coupling where interseismic stresses and permanent deformation are expected to be most pronounced. Our preliminary findings may hint at a trend towards fewer but larger earthquakes with significant weakening of the wedge, highlighting the importance of off-fault permanent deformation for the long-term behavior of earthquakes.

Note: Figure is on the next page.





Temporal and spatial patterns of upper plate brittle failure, illustrated alongside our initial model results. A displays the modeled pattern of brittle failure in the upper plate of Cascadia, with colors indicating the failure regions and circles marking recorded seismic events. The colors along the megathrust represent the coupling distribution (Oryan et al., 2024). B shows elastic and inelastic deformation at a point in the upper plate over twenty seismic cycles. C shows slip accumulated over 1500 years along a 10-degree dipping planar thrust fault: 1) Reference model without upper plate weakening; 2) Model with Lame parameters weakening following the spatial pattern in Cascadia (A), achieving a maximum reduction to 50% of the original value.