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A physics-based approach to investigating temporal evolution of deep interseismic slip

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While substantial progress has been made in understanding how and where interseismic strain accumulates on faults, enabling the identification of fault segments that are more likely to host earthquakes, the mechanical behavior of the deep locked-to-creeping transition remains unclear. Estimates of slip deficit in such transitional regions are particularly complicated. Since earthquakes result from the sudden release of elastic strain along a fault interface, reasonable estimates for slip deficit, and consequent strain accumulation, are critical for earthquake hazard assessment.

In this work, we combine physics-based models of the locked-to-creeping transition region with geodetic inversions of surface deformation rates to evaluate the slip and stress behavior of the deep edge of the locked region. Most of my work focuses on the Cascadia subduction zone, a region known to host Mw 9 megathrust events which presents one of the greatest earthquake hazards in the US. In northern Cascadia, interpretations of interseismic slip deficit on the megathrust are complicated by an unresolved "gap" between the down-dip limit of the locked region, inferred from kinematic inversions of deformation rates, and the top of the ETS (Episodic Tremor and Slip) zone. we first present evidence that negative shear stress rates in this transitional region are required to fit the surface velocities, producing unexpected large interseismic slip rates. We then develop a new method that allows slip to penetrate up dip into the locked region. Up dip propagation of deep interseismic slip indeed provides a physical explanation for the steep slip rate profile and the negative shear stress rates inferred in northern Cascadia without requiring temporal changes of the fault strength. We finally extend this approach to strike-slip fault environments, and include coupling of creep to viscoelastic flow in the lower crust and upper mantle. Using this updated approach, we develop a physics-based solution for deep interseismic creep which accounts for possible slow vertical propagation, and investigate how it improves the fit of the horizontal interseismic deformation rates along the Carrizo Plain section of the San Andreas fault.