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Non-stationary Creep Modeling on the Northern California Fault Systems

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Fault creep along Northern California strike-slip faults is widespread but strongly variable in space and time. This heterogeneity complicates seismic-hazard models that assume steady interseismic coupling derived from kinematically smoothed slip inversions. Commonly used steady-state, stress-controlled creep formulations (e.g., Johnson et al., 2022) assume stressing rate is either zero or positive and tend to favor gradual spatial creep rate variations and therefore do not easily represent abrupt locking-creep transitions. This is a problem for capturing abrupt changes in creep rate due to creep fronts intruding into the locked zone, generating locally negative stress-rate changes. Independent observations and physical arguments suggest that transitions from locked to creeping behavior can be sharp, for example, through progressive asperity erosion. Here, we apply the asperity-erosion, non-stationary asperity inversion framework of Johnson and Sherrill (2026) to jointly estimate interseismic creep rates and distributions of locked asperities on the central San Andreas, Hayward, and Maacama faults. We integrate GNSS velocities and surface creep rates from InSAR, creepmeter records, and alignment array measurements, following the observational dataset used by Johnson et al. (2022). Fault geometry is represented with triangulated dislocation surfaces in an elastic half-space and evaluated using a backslip formulation. Physics-regularized constraints on locking-stress evolution allow for creep fronts to erode locked regions through time. The models reproduce the observed along-strike variability in surface creep rates and fit the GNSS-derived velocities with residuals generally below 3 mm/yr. Compared with steady-state approaches, the non-stationary inversion resolves larger locked areas and quantifies their uncertainties, consistent with recent applications of similar physics-regularized frameworks in subduction and continental collision environments (Acharya et al., 2026, in prep.; Johnson & Sherrill, 2026, in prep.). Interseismic creep varies widely with depth along strike, reaching more than 30 mm/yr on actively creeping sections of the Central San Andreas faults. At the same time, we resolve discrete embedded eroding asperities that persist at depths of roughly 10-20 km on the Hayward and Central San Andreas faults. These asperities show high locking probabilities (>0.8) and host localized slip-deficit accumulation that is low across most creeping reaches but increases to about 20-30 mm/yr within locked patches and near segment transitions. On the Hayward Fault, our results indicate a persistent central low-slip patch accompanied by enhanced shallow creep to the north, consistent with mixed locked-creeping behavior. By explicitly mapping where and how slip deficit concentrates within dominantly creeping fault systems, this approach refines moment-deficit estimates relative to steady-state creep models.