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Modeling surface deformation in the New Madrid seismic zone

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We model the surface deformation and strain rate signal associated with steady-state creep on deeply buried faults beneath the Mississippi embayment and post-earthquake viscoelastic relaxation from the 1811-1812 New Madrid earthquakes and compare these results with geodetic observations. This comparison has not previously been done primarily because of expectations of low signal-to-noise ratio for the geodetic data in this stable intraplate region of the North American plate. Improvements in the precision of geodetic measurements indicate very low rates of surface deformation, which appear to be inconsistent with the return periods of large earthquakes in the New Madrid seismic zone. We build upon previous studies and seek to answer the following questions: How much signal is in our data and what variance reduction can we expect to achieve? How do subsurface faulting and steady-state creep, if present, translate into surface deformation? What are the far- and near-field drivers of stress, and how do they affect surface deformation? The answers to these questions will help us to constrain and address questions significant for earthquake hazard assessments.

We present estimates of constant and time-variable surface deformation. The former results are derived from models in which steady-state creep occurs on lower crustal faults within the New Madrid seismic zone. The latter, time-variable surface deformation estimates, result from modeling the viscoelastic relaxation in the lower crust and upper mantle associated with earthquakes on faults within the New Madrid seismic zone. Our model that best fits the geodetic data involves 1.5 mm/yr of slip imposed across a discontinuity along the downdip extension of the reverse-slip Reelfoot fault and can explain 43% of the variance in the geodetic observations. In an alternative model, 20% of the variance can be explained by 3.5 mm/yr of slip across the downdip extension of the right-lateral strike-slip Cottonwood Grove fault. If modeled together, 1.5 mm/yr on downdip extensions of both faults best explains the data with 46% variance reduction. For models involving viscoelastic relaxation, our best fitting model has 1 m of slip on both the Reelfoot and Cottonwood Grove faults during the 1811-1812 earthquakes and can explain 18% of the variance in the geodetic observations. We continue this investigation by studying the effect of a finite lower crustal dislocation in the presence of regional and far field drivers rather than imposing slip across the dislocation locally. We also assess the uncertainty in the geodetic observations resulting from white, flicker and random walk noise to better appreciate the amount of signal in the data and whether we can expect to achieve 15 - 45% variance reduction.