The vertical fingerprint of earthquake cycle loading in Southern California

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The San Andreas Fault System (SAFS), one of the best-studied transform plate boundaries on Earth, is well known for its complex network of locked faults that slowly deform the regional crust in response to large-scale plate motion. Horizontal interseismic motions of the SAFS are largely predictable, but vertical motions arising from tectonic sources remain enigmatic along this plate boundary. Dense Global Positioning System (GPS) vertical velocity data in southern California should theoretically observe vertical velocity fluctuations from earthquake cycle loading. However, this signal is often masked by velocity variations across small distances (<10s km) in both magnitude and direction induced by non-tectonic signals. We show that when carefully treated for spatial consistency, GPS-derived vertical velocities expose a small amplitude (-3.9/+1.5 mm/yr), but spatially considerable (200 km), coherent pattern of uplift and subsidence straddling the SAFS in southern California. We employ model selection, a statistical technique that provides an objective and robust estimate of the velocity field that best describes the regional signal without overfitting the highly variable short-wavelength noise. This vertical velocity field shows remarkable agreement with the sense and relative magnitude of vertical motions predicted by 3D viscoelastic earthquake cycle deformation loading models of the SAFS spanning the last few centuries. Moreover, these results suggest that vertical GPS velocities can be used as additional physical model constraints, leading to a better understanding of faulting parameters that are critical to seismic hazard analyses.

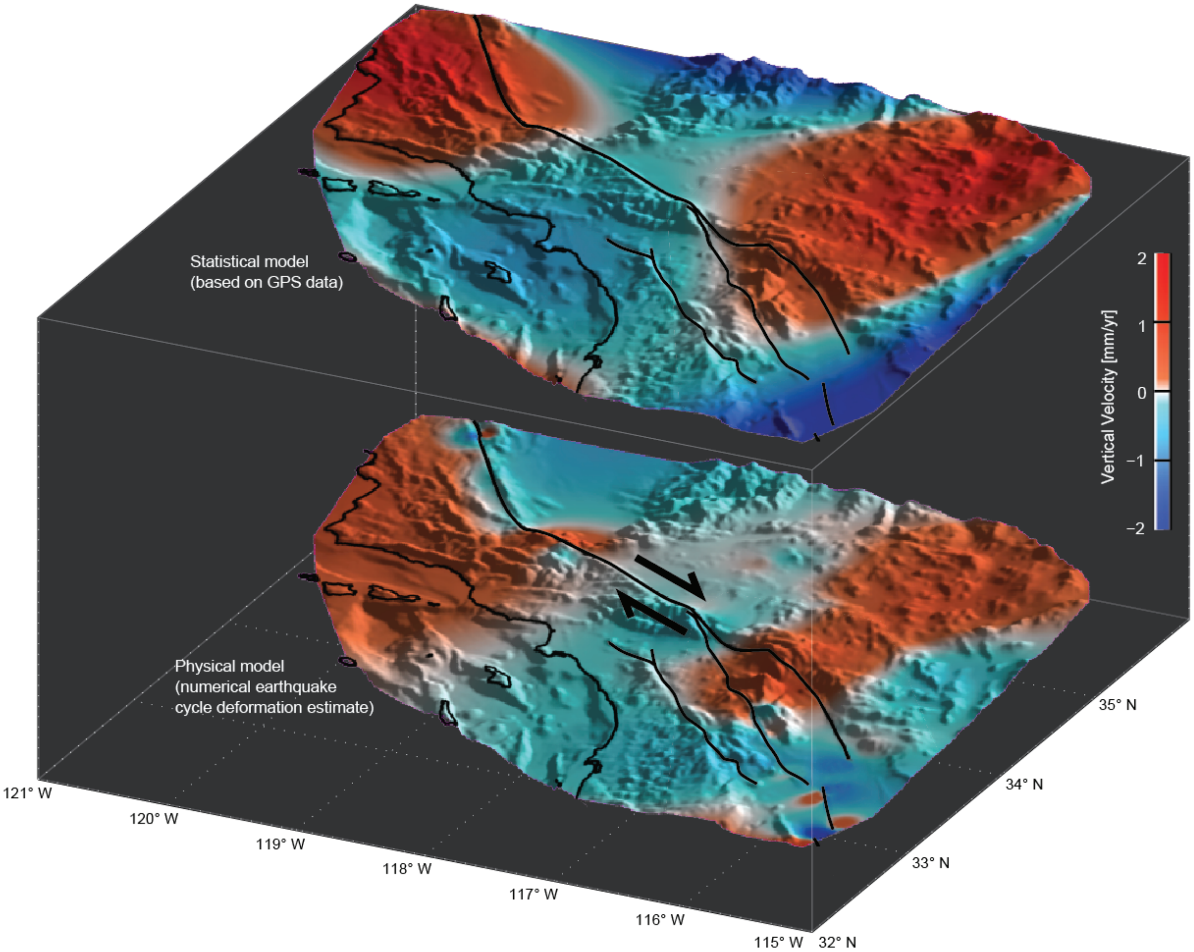

Figure: GPS and physical model comparison. Vertical velocity fields predicted by model selection using GPS data and the best-fitting physical model simulating the vertical crustal response of earthquake cycle loading at depth throughout the last 300+ years.