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What can satellite geodesy tell us about fault zone mechanics and seismic hazard in the continents?

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Reliable assessment of hazard from short-term geodetic observations requires physical models that can explain any time-dependent surface deformation. In this lectures, I will review the observations, show models that are consistent with all the data, and discuss the implications for the mechanics of fault zones and the strength of the continental lithosphere.

The last twenty years has seen a dramatic growth in our ability to measure surface deformation in fault zones using satellite geodesy. Collectively, these observations require any successful model to be capable of producing rapid postseismic deformation transients that decay with a 1/t dependency, and steady strain focussed in relatively narrow regions around the fault later in the cycle. I will show that these observations require (i) the lower crust outside of fault zones to have a viscosity greater than $\sim$1020 Pa s, (ii) a region beneath the seismogenic upper crust that can respond rapidly to a stress perturbation.

Rapid postseismic relaxation can occur through afterslip on a downward continuation of the fault, or by viscoelastic relaxation in a weak zone beneath the fault. If the relaxation is occurring viscoelastically, explaining the 1/t dependency requires a non-linear power-law relationship between stress and strain, and/or a viscosity that varies spatially due to temperature. It has been shown that such rheologies concentrate lower-crustal shear into narrow zones, a few kilometres wide. A model with narrow shear in the lower crust beneath major faults is also consistent with geological observations and results from a recent seismic experiment on the North Anatolian Fault conducted by the University of Leeds with Turkish partners at Kandilli Observatory and Sakarya University.

I will conclude by discussing the implications of this synthesis for the use of satellite geodesy for seismic hazard assessment, the mechanics of continental deformation, and the strength of the continental lithosphere, and by speculating on the future of geodetic observations in the coming era of big data.