Tomography of the sub-Mojave lithospheric viscosity from space geodetic data of the Landers and Hector Mine earthquakes postseismic relaxation

Sylvain Barbot

I investigate the transient deformation following the 1992 Mw 7.3 Landers and the 1999 Mw 7.1 Hector Mine earthquakes (Mojave desert, Southern California) using a combination of GPS and synthetic-aperture radar interferometry (InSAR) for an interval spanning 1992 to 2010. I test the possible mechanisms of postseismic relaxation using physically based time-dependent models of deformation driven by coseismic stress changes. Considered mechanisms include viscoelastic flow in the lower crust and upper mantle, afterslip governed by a rate-dependent friction, and poroelastic rebound.

I find that both afterslip and viscoelastic relaxation models can explain the horizontal post-Landers GPS data equally well. Afterslip however gives rise to vertical displacements of opposite polarity to the ones measured by GPS. A viscoelastic model marked by a strong (high viscosity) lower crust and weak (low viscosity) upper mantle transitioning at a depth of 40 km - the so-called "Crême brûlée" model - gives rise to large wavelength line-of-sight (LOS) deformation in the near field which is not observed in the InSAR data. Poroelasticity models are consistent with wavelength of InSAR LOS displacements and campaign GPS vertical data, but cannot explain the azimuth and amplitude of horizontal displacements. None of these simple models can explain all the available geodetic measurements simultaneously and a more complex explanation is required, involving either multiple mechanisms or more spatial variations in material properties.

Assuming that forward models of deformation are self similar I devise a linear inversion to infer the amplitude and location of source mechanisms required by all the geodetic data. For the post-Landers data a model combining viscoelastic relaxation in the lower crust and the upper mantle and poroelastic rebound best reduces the data but the fit is only marginally improved by the poroelastic contribution. Afterslip on the down-dip extension of the rupture is not required. Simultaneous inversion of the post-Landers and post-Hector Mine data warrants a viscoelastic relaxation in the lower crust and upper mantle as the single mechanism of transient deformation. Resolution of available data does not allow discrimination between a gradient of viscosity between the lower crust and upper mantle and two viscous layers separated by a competent strata, but a viscous layer in the lower crust, between 25 and 30km depth, is required as well as a deep viscous substrate in the upper mantle below 50km. Lateral variations in viscosity are mild but a low-viscosity zone in the lower crust may be present in the South West towards the San Bernardino Mountains.