The "conveyor belt" model of plate tectonics, in which steady flow in the Earth's asthenosphere carries plates along through basal tractions, has been shown to be unrealistic. Nevertheless, it remains possible that the lithosphere and asthenosphere are mechanically coupled in some way and that viscous flow in the asthenosphere contributes to lithospheric deformation. Two key questions are 1) whether this coupling exists and 2) if so, whether the asthenosphere flows quickly enough to play a role in the loading of earthquake faults in the interseismic period, affecting seismic hazard.

One way to answer these questions is to study the quasisteady evolution of surface deformation following large earthquakes. The stress changes imparted by a large earthquake to the surrounding medium trigger a number of postseismic processes that may include viscous flow in the lower crust and upper mantle, afterslip on the deep extension of the coseismic rupture, and poroelastic rebound in the crust. Each process produces deformation at the surface, and so one can study the evolution of surface deformation following an earthquake in hopes of determining which processes caused the deformation, thereby gaining insight into the nature of deformation at depth.

Due to the paucity of information about the depth of the asthenosphere, previous studies of postseismic deformation have generally been unable to determine whether surface deformation specifically required viscous flow in the asthenosphere (as opposed to, for example, in the mantle lithosphere). The depth to the lithosphere-asthenosphere boundary in southern California has recently been constrained using receiver functions and has been observed to be uncommonly shallow (<50 km) in the Salton Trough region due to the onset of continental rifting there. The 2010 M=7.2 El Mayor-Cucapah earthquake, the largest event in the Salton Trough in over a century, occurred directly above this shallow asthenosphere. If the lithosphere and asthenosphere are coupled and the asthenosphere can flow quickly enough to affect interseismic deformation, the postseismic deformation here should be entirely explainable by shallower mechanisms.

Using the Fallo et al. (2010) slip model for the mainshock and the deformation modeling software RELAX, we calculate the expected postseismic surface deformation resulting from coupled afterslip and viscous flow in a variety of hypothetical geometries, then compare these forward models to continuous GPS data. Preliminary findings suggest that viscous flow in the shallow Salton Trough asthenosphere is required to explain a pattern of systematic uplift observed at GPS stations in the Imperial Valley in the first year after the earthquake.

**Ingredients**

- RELAX deformation modeling software
  - Plug in coseismic slip model, calculate elastic stress changes in generalized viscoelastic halfspace
  - Simulate postseismic deformation mechanisms (afterslip, viscoelastic relaxation, poroelastic rebound) triggered by the instantaneous state of stress at each timestep
  - All mechanisms are represented as equivalent body forces and surface tractions -> they also feed back on the instantaneous state of stress
    - can simulate full dynamic coupling between mechanisms

**Coseismic slip model** (Fallo et al. 2010)

Inverted from GPS, InSAR, optical displacements

M=7.2, L = 115 km, max. slip = 1.7 m

**Afterslip at 14-18 km depth**

Triggered by coseismic shear stress changes

Constitutive law: rate-strengthening sliding

**Viscoelastic zone (elastic stress change -> diffusion creep) in lowermost 5 km of crust**

**Viscoelastic zone (coupled diffusion creep and dislocation creep) in shallow asthenosphere**

**Deformation during the mainshock**

- GPS offsets + full dislocation model
  - Cross sections of offsets in dislocation model
  - Just NE of rupture
  - Just SW of rupture

**Deformation patterns of individual postseismic mechanisms**

- Afterslip: stations in Imperial Vly. move due south (SSE in data) and subside (uplifted in data)
- Viscous flow in lower crust: Imperial Vly. stations move SSE but subside
- Viscous flow in asthenosphere: Only mechanism that produces uplift in Imperial Vly.