Postseismic and interseismic deformations associated with megaearthquakes: towards time-dependent lithospheric deformation

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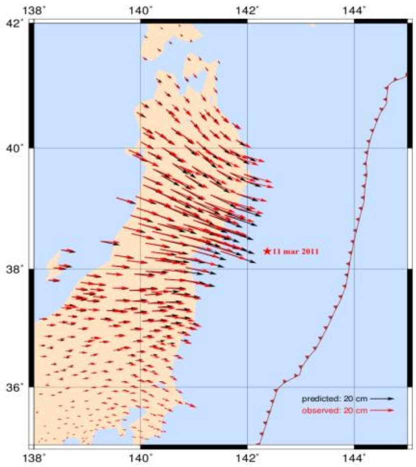
Three megaearthquakes (Sumatra-Aceh(2004), Chili-Maule(2010) and Japan-Tohoku(2011)) struck the Earth during the last ten years. They are the first megaearthquakes since lithospheric deformations can be measured with a high precision (GPS, interferometry). What can we learn from the lithospheric deformations following these earthquakes concerning both the stress accumulation and release on the subduction plate interface, on the short-term mechanical properties of the mantle and on the interpretation of recent (decadal) intraplate deformation?

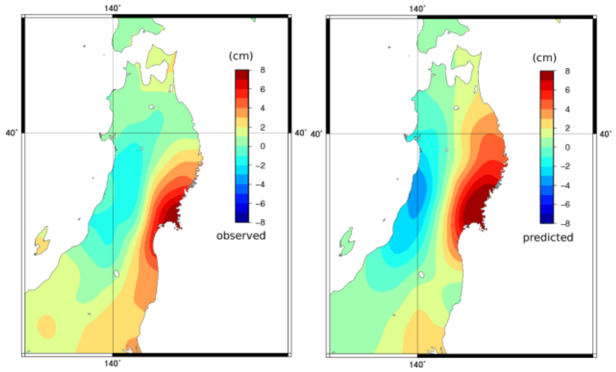
Velocity perturbations are clearly detected up to 2000km away from the epicenters. Subsidence is observed in the far-field while uplift is observed above the volcanic arc. The postseismic deformations are remarkably similar for the three megaearthquakes. They are modeled with the help of a finite element code (Zebulon-Zset), over a 3D mesh representing in a spherical shell a portion of the mantle more than 60° broad.
The coseismic displacements on the interface are inverted from the coseismic motions registered by GPS.
We show that the postseismic deformation can be explained only with the combination of viscoelastic relaxation in an asthenosphere 100 to 200km thick (newtonian viscosity of the order of 3.10^{18}Pas) and in a low viscosity serpentinized channel above the plate interface at depths larger than 45km (viscosity of some 10^{17}Pas). Slip on the plate interface at shallow depths is moreover required in the case of Aceh and Maule.

This mechanical model can be extended to predict deformations over the whole seismic cycle. We show that at distances over 1000km from zones of large earthquakes, the velocities and intraplate deformations vary significantly through the whole seismic cycle.
As a consequence, we suggest that the relative velocities of blocks or subplates measured by GPS during the last ten years near subduction zones (Sunda Block, Amurian plate) are in fact transient velocities. More generally, we question the geological significance of the 'stress-field' measured during the last decades.

Figure 1. Observed and modeled postseismic displacement in Japan

Comparison between observed and predicted velocities (jan to dec 2012)





Horizontal velocities **Vertical velocities**

Fit to far-field stations time series