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Far away motions associated with giant subduction earthquakes and the mechanical properties of the lithosphere-asthenosphere system

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The giant subduction earthquakes such as Aceh, Maule or Tohoku are associated with conspicuous far-field post-seismic horizontal motions and subsidence. This subsidence can only be explained by relaxation in the asthenosphere. The deformations observed by GPS during the seismic cycle are then an ideal dataset to study the mechanical response of the lithosphere-asthenosphere system to small stress perturbations over relatively short time scales (0.1 to 100 years).

The post-seismic displacements, normalized by the coseismic displacements are unexpectedly similar for the three giant earthquakes. This suggests that, at least for the low far-field stress perturbations involved in the seismic cycle, the creep law is linear and that the other mechanical parameters are relatively similar in the regions of the three giant earthquakes.

Using a 3D finite element model, we show that the post-seismic data of Aceh earthquake are well fitted by models with an elastic lithosphere 80km thick and a low viscosity asthenosphere 120km thick with a burger viscoelastic rheology. The transient burger viscosity is of the order of 3.5 10^{18}Pas and $\mu_{transient} = \mu_{elastic}/2.8$. A low viscosity wedge is necessary to explain the GPS data in the middle field (South coast of Sumatra).

We tried to find the range of parameters which are compatible with the postseismic data. Large values of the elastic lithosphere (larger than 120km) or of the asthenosphere (more than 200km) do not provide good fits to the observed postseismic subsidence. The minimum acceptable values for the asthenosphere or the lithosphere thicknesses are more difficult to pinpoint but values around 60km are still acceptable.

Our study points towards 'short-term' mechanical thicknesses of the lithosphere compatible with both the thermal and the seismological thicknesses (60 to 90 km). The short-term viscosity of the asthenosphere below this elastic lithosphere is lower than the long term viscosity by about one order of magnitude if one evaluates this long-term viscosity from convective models with temperature dependent viscosity. The existence of such a low short term viscosity is indeed expected for a heterogeneous medium like the asthenosphere.