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Mechanisms of postseismic relaxation after a great subduction earthquake constrained by cross-scale thermomechanical model and geodetic observations

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According to conventional view, postseismic relaxation process after a great megathrust earthquake is dominated by fault-controlled afterslip during first few months to year, and later by visco-elastic relaxation in mantle wedge. We test this idea by cross-scale thermomechanical models of seismic cycle that employs elasticity, mineral-physics constrained non-linear transient viscous rheology and rate-and-state friction plasticity. As initial conditions for the models we use thermomechanical models of subduction zones at geological time-scale including a narrow subduction channel with low static friction for two settings, similar to the Southern Chile in the region of the great Chile Earthquake of 1960 and Japan in the region of Tohoku Earthquake of 2011. We next introduce in the same models classic rate-and state friction law in subduction channels, leading to stick-slip instability. The models start to generate spontaneous earthquake sequences and model parameters are set to closely replicate co-seismic deformations of Chile and Japan earthquakes. In order to follow in details deformation process during the entire seismic cycle and multiple seismic cycles we use adaptive time-step algorithm changing integration step from 40 sec during the earthquake to minute-5 year during postseismic and interseismic processes.

We show that for the case of the Chile earthquake visco-elastic relaxation in the mantle wedge becomes dominant relaxation process already since 1 hour after the earthquake, while for the smaller Tohoku earthquake this happens some days after the earthquake. We also show that our model for Tohoku earthquake is consistent with the geodetic observations for the day-to-4year time range. We will demonstrate and discuss modeled deformation patterns during seismic cycles and identify the regions where the effects of afterslip and visco-elastic relaxation can be best distinguished.