EGU2020-4288, updated on 25 Oct 2020
https://doi.org/10.5194/egusphere-egu2020-4288
EGU General Assembly 2020

Effect of Rheology on Afterslip and Viscoelastic Patterns Following the 2010 Mw 8.8 Maule, Chile, Earthquake

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After large earthquakes at subduction zones, the plate interface continues moving due to mostly frictional afterslip processes. Below depths of 60 km, little frictional afterslip is to be expected on the plate interface due to low shear strength, lack of apparent geodetic interseismic locking, and low seismic moment release from aftershocks. However, inversion models that consider an elastic crust above a mantle with viscoelastic rheology result in a significant portion of afterslip at depths > 60 km. In this study, we present a forward 3D geomechanical-numerical model with power-law rheology that simulates dislocation creep processes for the crust and upper mantle in combination with an afterslip inversion. The linear rheology case is also considered for comparison. We estimate the cumulative viscoelastic relaxation and the afterslip distribution for the first six years following the 2010 M_w 8.8 Maule earthquake in Chile. The cumulative afterslip distribution is obtained from the inversion of the residual surface displacements between continuous GPS (cGPS) observations and predicted displacements from viscoelastic forward modelling. We investigate three simulations: two with the same dislocation creep parameters in the slab and upper mantle but different ones in the continental crust, and another with elastic properties in the crust and slab and a linear viscoelastic upper mantle. Our preferred simulation is the one with power-law rheology in the crust and upper mantle with a weak continental crust since the corresponding afterslip distribution shows the best overall fit to the cGPS displacements (cumulative and time series) as well as having a good correlation with aftershock activity. In this simulation, most of the viscoelastic relaxation occurs in the continental lower crust beneath the volcanic arc due to dislocation creep processes. The resulting afterslip pattern from the inversion is reduced at depths > 60 km, which correlates well with the spatial distribution of cumulative seismic moment release from aftershocks. We conclude that by allowing for non-linear stress relaxation in the continental lower crust due to dislocation creep processes, the resulting afterslip distribution is in better agreement with the physical constraints from the shear strength of the plate interface at depth, the predicted locking degree, and the aftershock activity.