Role of lower crust in the post-seismic deformation of the 2010 Maule earthquake: Insights from a model with non-linear viscosity

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Abstract

The surface deformation associated with the 2010 Mw 8.8 Maule earthquake in Chile was recorded in great detail before, during and after the event. The high data quality of the continuous GPS (cGPS) observations have triggered a number of studies that model the postseismic deformation signal with a combination of relocking, afterslip and viscoelastic relaxation using linear Maxwell rheology for the upper mantle. Here we investigate with a 2-D geomechanical-numerical model the impact of using linear or non-linear Maxwell model rheology to better understand the relative impact of the processes that control the horizontal and vertical postseismic deformation signal. Our model results indicate that the contribution of relocking to the cumulative postseismic deformation signal is small compared to the impact of afterslip and viscoelastic relaxation. Furthermore, we find that the cumulative horizontal postseismic signal cannot discriminate the relative impact of the various processes in the postseismic phase or if linear or non-linear rheology is controlling the viscoelastic relaxation. However, we confirm recent studies that in particular the vertical postseismic deformation signal is the key to better assess the relative importance of the involved processes. Our model results reveal that the cumulative vertical postseismic signal in particular in the near-field at distance $<$ 300 km from the trench has large differences in the model response when changing the location of the maximum afterslip and between linear and non-linear Maxwell rheology. The model with non-linear rheology achieves a qualitatively good fit when the afterslip maximum is located at 20-35 km depth rather than at depth $>$ 45 km in the down dip end of the rupture zone as suggested in previous studies. The explanation for this difference in the response to afterslip location (and amplitude) is that in the model with non-linear rheology the relaxation of coseismically imposed tensional stresses occurs mainly in the deeper part of the lower crust. However, even though the model with non-linear Maxwell rheology has more potential to fit better in particular the vertical cumulative displacement in the near-field between 150-250 km distance from the trench and the shape of the cGPS time series (horizontal and vertical), the uncertainty of the applied temperature field are substantial and need further investigations and improvements.

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