A coupled model of stress-driven frictional afterslip and viscoelastic relaxation following the 2011 Tohoku-oki earthquake

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Postseismic deformation following the 2011 Mw9.0 Tohoku-oki earthquake has been captured by both on-land GNSS and seafloor GPS/Acoustic networks. Previous studies have shown that the observed postseismic displacements can be reproduced as a sum of contributions from viscoelastic relaxation of coseismic stress changes in the upper mantle and afterslip on the plate interface surrounding the coseismic rupture. In most previous studies, viscoelastic relaxation and afterslip were modeled separately and afterslip was estimated kinematically. In this study, we develop a three-dimensional coupled model of stress-driven frictional afterslip and viscoelastic stress relaxation in order to investigate the frictional properties on the plate interface, upper mantle rheology, and the relative contributions of the viscoelastic relaxation and afterslip to the overall postseismic deformation following the 2011 Tohoku-oki earthquake.

We assume that afterslip is governed by a rate-strengthening friction law that is characterized with a friction parameter (a-b) σ. Viscoelastic relaxation of the upper mantle is modeled with a biviscous Burgers rheology that is characterized with the steady-state and transient viscosities. We calculate the evolution of afterslip and viscoelastic relaxation using an assumed coseismic slip model as the initial condition.

We examine the effects of the friction parameters, mantle viscosities, elastic thickness of the slab and upper plate, and coseismic slip distribution on the model prediction and explore the range of the parameters that can fit the observed postseismic displacements. We also examine if afterslip overlaps regions that ruptured seismically during M6.3-7.2 earthquakes from 2003 to 2010. We find that significant overlap between afterslip and the historical M6.3-7.2 coseismic rupture areas are required to fit the horizontal displacements.

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