Far-Field Viscoelastic Post-Seismic Deformation of the 2011 Mw9 Tohoku Earthquake

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Observed deformation produced by strong subduction zone earthquakes has been widely used to constrain rheological properties of the upper mantle, but mainly for regions not far from the rupture zone. Here we studied far-field post-seismic deformation of the 2011 Mw 9.0 Tohoku earthquake by analyzing time series of more than 30 continuous GPS stations in Korea, China and Russia. For example, post-seismic velocities at stations in NE China, more than 1000 km from the Japan Trench, decayed quickly with time from up to ~1.5 cm/yr in the first year after the earthquake to up to ~0.5 cm/yr in 2017. Building on previous studies, we constructed spherical-Earth viscoelastic finite element models to study how the deformation is controlled by changes in rheological properties of the upper mantle with distance from the subduction zone. Our model includes the elastic continental and oceanic plates, the elastic subducting slab, the viscoelastic continental upper mantle, the oceanic asthenosphere and upper mantle. The viscoelastic relaxation of the upper mantle is represented by the bi-viscous Burgers rheology. The continuous aseismic afterslip of the megathrust is modeled through a thin and weak shear zone over the fault. Our preliminary tests indicate that the steady-state viscosity of the upper mantle in NE China has to be about one order of magnitude higher than that of the mantle wedge in the arc and backarc region. This lateral viscosity change may be outlined by the 400-km and 600-km depth contours of the subducting slab surface. Variations in lithospheric thickness and viscoelastic relaxation in the lower crust in the far field are shown to be second-order effects in controlling the post-seismic deformation.