Time-dependent stress change in the Kanto region due to 2011 Tohoku earthquake, Japan, considering viscoelastic relaxation in the asthenosphere and afterslip

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The 2011 M9 Tohoku earthquake, Japan, was the fourth largest earthquake among ever observed, which caused broad deformation and abrupt change in seismicity in the surrounding regions. The Kanto region is located in vicinity to the southern end of the source area of the M9 earthquake, and possible triggering of rupture of blind thrusts and volcanic activity is concerned. In order to understand the postseismic crustal activity, it is important to investigate regional stress state. Mechanisms of postseismic crustal activity are considered to be afterslip which occurs around the mainshock slip area and viscoelastic relaxation in the asthenosphere. We construct a finite element model which accounts for both mechanisms to calculate stress. Model region is defined by a cuboid of 3400 km x 4600 km x 700 km, which includes the Kuril, Mariana, and Ryukyu arcs. We made the plate boundaries by interpolating the plate boundary models from previous studies. The model region is divided by 1000,000 linear tetrahedral elements of the size of 5-100 km. Slip region is divided into 480 subfaults (28 km x 28 km in average) and displacement response for each subfault is calculated. Coseismic slip and afterslip is obtained by the following procedure with inversion of GPS and sea floor deformation data. First, we obtain coseismic slip by inversion of the coseismic displacement data. The coseismic slip distribution is put into the FEM to calculate postseismic displacements. Comparing calculated and observed postseismic displacements, we obtained a viscosity structure explaining the observation in a trial and error way. We assume that residual displacements are caused by afterslip, which is obtained by inversion of the residual. Then, the coseismic slip and afterslip are put in the FEM again to calculate the Coulomb stress on the blind thrusts in the Kanto region. Calculated Coulomb stress is 0.3-0.4 MPa in 10 years, which is a significant value for affecting the seismicity. Most of the stress change is caused by the viscous relaxation in the asthenosphere, indicating its importance. On the other hand, stress change due to the afterslip is ~0.1 MPa.

Keywords: 2011 Tohoku earthquake, Crustal deformation, Finite element modeling, Viscoelasticity, Afterslip, Northeast Japan arc

