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Simulation for coseismic and postseismic deformation in the Japan region due to the 2011 Tohoku earthquake with finite e

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The 2011 Tohoku earthquake, Japan (M9) remarkably characterizes earthquake generation system in the northeastern Japan arc and greatly affects the plate subduction system in the Japan region. For the rational prediction of earthquake activities and crustal deformations in these situations, we have to quickly construct a realistic model for the physical property structure under the Japan region and simulation model of crustal deformation based on the structure. In this region, two plate subduction system is formed due to the Pacific and Philippine sea plates. Thus, the deformation problem in this region is essentially three-dimensional. To solve a problem of this kind, it is necessary to model with finite element methods with which we can incorporate realistic structures. Currently, it is very important to reveal how the Tohoku earthquake generated the stress field change and how the stress field will change with time. Therefore, for the purpose of realistic prediction of earthquake activity in the Japan region after the Tohoku earthquake, we simulated the coseismic and postseismic deformation of the Tohoku earthquake with a three-dimensional crustal structure using the finite element method.

The most basic structure for simulation of time-dependent deformation in the Japan region is the geometry of the plate boundaries and elastic/viscoelastic material structure. First, we take a modeling space of 4500 km x 4900 km x 600 km. This space corresponds to the region from Kuril islands to Mariana islands and Ryukyu islands. So far, studies on earthquake activity have proposed a plate boundary model under Japan (e.g., Nakajima & Hasegawa, 2006; Nakajima et al., 2009; Kita et al., 2010; Hirose et al., 2008). For the Kuril, Izu-Bonin and Ryukyu arc, Hayes et al. (2012) made Slab1.0 plate boundary model. We constructed geometry of plate boundary structure for the whole region by interpolating these two models. Detailed seismic velocity structure under the Japan region has already been obtained by observation of densely aligned Hi-net seismograph network (Matsubara et al., 2011). At this stage, however, we simply assume uniform thickness of 30 km in the continental side, and 70 km in the oceanic plate and the slabs as the first version structure.

Then, we set boundary conditions. In this type of problem we have to give not only boundary conditions for the outer surface of the model space but also we have to give relative displacement on the two sides of the fault surface (fault slip) of the source region of the Tohoku earthquake. Under these conditions, we ran numerical computation and solve the deformation problem. In this study, we show results for the deformation in the above first-order structure.

From the computational results, we can identify the structural parameters that mainly constrain the behavior of the model, which make us to construct a rational plan for observation of these parameters. Then, we can update the deformation model with the new results and construct more effective observation plans. Establishing such a cycle of observation and modeling is required for studies of prediction of the earthquake activity and crustal deformation.

Keywords: Japan islands, Community model, 2011 Tohoku earthquake, Stress field, Crustal structure, Finite element modeling