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Modelling of the postseismic deformation of the 2011 Tohoku Earthquake based on land and seafloor geodetic observations

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On 11 March 2011, the 2011 off the Pacific coast of Tohoku Earthquake (M 9.0, hereafter Tohoku Earthquake) occurred on the plate boundary between the subducting Pacific and overriding continental plates. Terrestrial and seafloor geodetic observations on and around the Japanese Islands has been clearly detecting postseismic deformation associated with the Tohoku Earthquake, although three years have passed since the main shock. Iinuma et al. (2013, IAG Scientific Assembly) reported that just considering elastic response to the interplate coupling and postseismic slip on the plate boundary is insufficient to investigate the mechanical process of the postseismic deformation. We must take the inelastic deformation such as viscoelastic relaxation into account.

To tackle this problem, we estimated the displacement due to the viscoelastic relaxation by using a FEM model that includes subducting oceanic slab, difference of the viscosity between the continental and oceanic mantle, and high viscosity at the mantle wedge. The coseismic slip model based on the terrestrial and seafloor geodetic data (Iinuma et al., 2012) is used to initialize the viscoelastic relaxation process. After subtracting displacements due to the large aftershocks and viscoelastic relaxation from the original displacement time series data that are measured not only with the terrestrial GPS but also GPS/Acoustic ranging and vertical displacements observed by using Ocean bottom pressure gauges, we estimated the spatial and temporal evolution of the postseismic slip distribution on the plate interface by applying a time-dependent inversion method devised by Yagi and Kikuchi (2003).

The result of FEM calculation shows that westward displacements at seafloor sites are accounted for by viscoelastic relaxation process. However, eastward movements larger than the observed displacements at the most terrestrial GPS stations are predicted by means of the FEM model. Therefore, postseismic slip (or recovery of the interplate coupling) needs account for onshore westward displacement.

One of two areas where normal-fault-type slip distributes is estimated by applying the time dependent inversion analysis to the displacement time series as well as the result of the inversion when we assume a spherical layered structure to calculate the displacements due to the viscoelastic relaxation. But, the locations of the normal-faulting areas are different. When we use the layered structure, the area is mapped inside the main rupture area of the M9 main shock. On the other hand, normal-fault-type slip at a portion of the plate boundary deeper than the coseismic main rupture area is estimated when we calculate displacements due to the viscoelastic relaxation by means of our FEM model. Since such normal faulting areas can be regarded as the patches on the plate boundary where interplate coupling occur, it is essential to estimate the locations and rates of the slip accurately to consider the frictional character on the plate interface. Therefore we need reduce and exclude the dependency of the postseismic slip distribution with respect to the estimation of crustal deformation due to the viscoelastic relaxation. We will examine and improve rheological structure that is included in the FEM model, and will present results of further investigation at the meeting.

Keywords: The 2011 off the Pacific coast of Tohoku Earthquake, Postseismic deformation, Viscoelastic relaxation, Postseismic slip, GPS, Seafloor crustal deformation