Physical modeling of postseismic deformation following the 2008 Iwate-Miyagi Nairiku Earthquake

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The Iwate-Miyagi Nairiku Earthquake (hereafter IMNE) occurred on June 14, 2008 (Mw 6.8). Fault models of the mainshock have been proposed from GNSS survey (Ohta et al., 2008; Iinuma et al., 2009), InSAR analysis (Takada et al., 2009; Abe et al., 2011), and seismographs (Suzuki et al., 2010). The fault models proposed from GNSS and seismographs consist of west-dipping reverse faults with maximum slip exceeding 6 meters. On the other hand, InSAR and offset measurement of SAR intensity images clearly indicate the existence of east-dipping fault along the western side of the hypocentral area.

Large postseismic deformation following the mainshock also have been detected by GNSS and InSAR (e.g., Iinuma et al., 2009; Ohzono et al., 2011; Takada et al., 2011). The interferograms taken from descending orbit (2008/7/16 - 2010/7/22) indicate the LOS displacements ~10 cm away from the satellite at hanging-wall side of the west-dipping faults, and ~15 cm toward the satellite around the northern part of Mt. Kurikoma.

Two physical models of the postseismic deformation of IMNE have been proposed previously. Iinuma et al. (2009) estimated the after-slip distribution from GNSS data near the fault traces for a month after the mainshock. They found cumulative afterslip on the coseismic faults as well as nearby active fault named the Dedana Fault (DF). The viscoelastic relaxation of this earthquake was calculated by Ohzono et al. (2011). They modeled crust-mantle system as an elastic layer overlying a viscoelastic substratum, and successfully explained the far-field displacements. In these studies, (1) only GNSS data were used, and (2) mutual interaction between the afterslip and viscoelastic relaxation has not been considered.

In this study, we construct a physical model of the postseismic deformation following IMNE on the basis of half analytic solution, named Unicycle (Barbot et al., 2017; Moore et al., 2017). With Unicycle, we consider (1) mutual interaction between the afterslip and the viscoelastic relaxation, (2) afterslip following the rate-and-state friction law (e.g., Dieterich, 1979; Ruina, 1983), and (3) horizontal heterogeneity of rock rheology with nonlinear power-law creep predicted from room experiments (e.g., Kirby, 1983). We started from simple model with the rheological structure proposed by Ohzono et al. (2011) and the coseismic slip distribution proposed by Iinuma et al. (2009).

In our calculation, large afterslip on DF is not triggered unlike Iinuma et al. (2009). The calculated postseismic displacement field well explains far-field GNSS data, which is consistent with Ohzono et al. (2011). In addition, our calculation explains the near-field GNSS data in the eastern side of the faults. Large discrepancies between the calculated and the observed displacements along the western side of hypocentral area are, possibly due to lack of the east-dipping fault in the current coseismic slip model. Thus, we have to consider the conjugate fault system proposed by Takada et al. (2009) and Abe et al. (2013) to explain both GNSS and InSAR data.

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