Revisiting the Coseismic Slip Distribution of the 2011 Tohoku-oki Earthquake Considering Early Postseismic Deformation, Non-linear Viscoelasticity, and Heterogeneous Structure

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The 2011 Tohoku-oki earthquake produced large coseismic displacements that were detected by terrestrial and seafloor geodetic observations, namely, global navigation satellite systems (GNSS), GNSS-Acoustic (GNSS-A), and ocean bottom pressure (OBP) measurements. Previous studies constructed coseismic slip distribution models of the Tohoku-oki earthquake using the daily GNSS site coordinate time series, seafloor GNSS-A, and/or OBP data to estimate the coseismic displacements [e.g., Ito et al., 2011; Koketsu et al., 2011; Ozawa et al., 2011; Iinuma et al., 2012]. However, studies for these several years suggested that the coseismic displacements must include early postseismic deformation due to a low-viscosity zone beneath the Pacific plate that is necessary to explain terrestrial and seafloor postseismic crustal deformations [Sun et al., 2014; Freed et al., 2017; Suito, 2017]. This low-viscosity zone may not be persistent but could result in huge changes in stress resulting from the coseismic slip with reflecting non-linear rheology [Muto et al., 2018; Agata et al., 2019]. The effect of non-linear rheology is great immediately after a main shock. Therefore, coseismic displacements based on the daily site coordinate time series and GNSS-A measurements inevitably must include early postseismic deformation.

Thus, we derived "pure" coseismic displacements based on 1-Hz site coordinate time series at GNSS sites of the Geospatial Information Authority of Japan estimated by utilizing kinematic PPP (precise point positioning) analysis and based on 1-min average seafloor level time series at OBP sites. The residual displacements were obtained by subtracting the pure coseismic displacement from that based on the daily site coordinate time series. The data showed subsidence and trenchward motions in the entire Tohoku district. These broad deformations could not be explained solely by aftershocks nor by afterslip on the plate interface. Viscoelastic deformation that occurs immediately after the main shock is required to explain the displacement field. We present the results of our investigations into coseismic slip distribution and early postseismic deformation by applying Green's function, which is calculated by considering the shapes of surface terrain and subducting slabs as well as heterogeneous thermal structures and power-law rheology.

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