Distributed fault slip model for the 2011 Tohoku-Oki earthquake from GNSS and GRACE/GOCE satellite gravimetry

Abstract:

The Gravity Recovery and Climate Experiment (GRACE) mission (launched 2002) and the Gravity Field and Steady-State Ocean Circulation Explorer (GOCE) mission (March 2009 to November 2013) collected spaceborne gravity data for the preseismic and postseismic periods of the 2011 Tohoku-Oki earthquake. In addition, the dense Japan GeoNet Global Navigation Satellite Systems (GNSS) network measured with approximately 1050 stations the coseismic and postseismic surface displacements. We use a novel combination of GNSS, GRACE, and GOCE observations for a distributed fault slip model addressing the issues with gravimetric and geometric change over consistent time windows. Our model integrates the coseismic and postseismic effects as we include GOCE observations averaged over a 2 year interval, but their inclusion reveals the gravity change with unprecedented spatial accuracy. The gravity gradient grid, evaluated at GOCE orbit height of 265 km, has an estimated formal error of 0.20 mE which provides sensitivity to the mainly coseismic and integrated postseismic-induced gravity gradient signal of −1.03 mE. We show that an increased resolution of the gravity change provides valuable information, with GOCE
gravity gradient observations sensitive to a more focused slip distribution in contrast to the filtered 
GRACE equivalent. The 2 year averaging window of the observations makes it important to 
incorporate estimates of the variance/covariance of unmodeled processes in the inversion. The “GNSS and GRACE/GOCE combined model shows a slip pattern with 20 m peak slip at the trench. 
The total gravity change (≈200 μGal) and the spatial mapping accuracy would have been 
considerably lower by omitting the GOCE-derived fine-scale gravity field information.

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