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# Understanding large subduction earthquakes from joint analysis of seismology, satellite geodesy and GRACE gravity data

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The high accuracy and resolution of the present-day GRACE monthly models, together with accumulation of more than a decade-long series of these models, enabled us to investigate processes occurring in areas of large (M>8.5) earthquakes not previously studied. Previous researches based on the study of the time variations of the satellite gravity field in regions of the giant earthquakes, such as Sumatra (2004), Chile (2010), and Tohoku (2011), addressed the coseismic gravity variation generally followed a gravity trend. Coseismic and postseismic gravity signals associated with lower-magnitude events are generally smaller compared to noise level. However, we have established a long steady growth of the positive gravity anomaly above the oceanic trench after two events with smaller magnitudes in the Sumatra region (the Nias earthquake of March 2005 and the Bengkulu event of September 2007), after the magnitude 8.5 earthquake in Hokkaido (September 2007), after the doublet Simushir earthquake with the magnitudes 8.3 and 8.1 in the Kuriles (November 2006 and January 2007), and after the M 8.1 Samoa Island event of September 2009.

We present detailed analysis of the growth of the positive gravity anomaly after the Simushir earthquake of November 2006. The growth started a few months after the event synchronously with the seismic activation on the downdip extension of the coseismically ruptured fault plane zone. The data demonstrating the increasing depth of the aftershocks since March 2007 and the approximately simultaneous change in the direction and average velocity of the horizontal surface displacements at the sites of the regional GPS network indicate that this earthquake induced postseismic displacements in a wide area extending to depths below 100 km. The total displacement since the beginning of the growth of the gravity anomaly up to July 2012 is estimated at 3.0 m in the upper part of the plate's contact and 1.5 m in the lower part up to a depth of 100 km. The released total energy would be equivalent to a magnitude 8.5 event earthquake. Comparison of detailed results of numerical modelling of possible post-seismic viscoelastic relaxation suggests that this process unlikely played a major role in the region of Simushir earthquake as compared to afterslip.