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Derivation of coseismic geoid height changes using strain and displacement: Comparison with GRACE observations

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Coseismic gravity/geoid height changes have been calculated directly from fault parameters using, e.g. Sun and Okubo (1998), and observations by superconducting gravimeter were compared with them (Imanishi et al., 2004). On the other hand, we calculate coseismic displacement of GPS stations from fault parameters using Okada's (1992) program. Here we propose a simple method to derive coseismic geoid height changes using surface displacement and subsurface volume strain calculated with Okada (1992). Coseismic uplift and subsidence of the ocean floor and Moho cause mass perturbations due to deformation of layer boundaries with density contrasts. In addition to them, coseismic dilatation and compression of crustal and mantle rocks cause another kind of mass perturbations as the density changes of rocks. These two factors contribute to the coseismic gravity/geoid height changes. The small perturbing masses due to displacement and volume strain can be calculated by assuming densities of ocean, crust and mantle. Assuming spherical Earth, we integrated small additional scalar potentials due to small perturbing masses (= Gdm/r, where dm is the small perturbing mass at distance r from the point on geoid, and G is the universal gravity constant), and geoid height changes by dividing them with surface gravitational acceleration. Okada (1992) assumes an elastic homogeneous half space. However, difference of calculated quantities from a more realistic approach assuming spherical and layered Earth would not exceed 10 percent because mass perturbations mainly occur within 100 km from the fault (Cummins et al., 1998). Han et al. (2006) also calculated gravity changes using Okada (1992). However, they use spatial Fourier transformation for the upward continuation of gravity anomalies, and our approach is much simpler.

GRACE (Gravity Recovery and Climate Experiment) is a satellite system composed of two identical satellites, and precise range measurements between them provide information on time varying gravity field of the earth. GRACE has been used mainly to infer seasonal and secular variations of hydrological masses. Recently, Han et al. (2006) reported detection of the formation of geoid depression associated with the 2004 Sumatra-Andaman earthquake from GRACE, and showed that it was in good agreement with those calculated using Okada (1992).

Here we also try to detect coseismic geoid height changes using GRACE level 2 data from UTCSR. We recovered geoid height using the coefficients with degree/order complete to 80 and isotropic 350km Gaussian filter to reduce short-wavelength noises (Wahr et al., 1998). In addition to secular and seasonal components, we modeled the time series with coseismic offset of geoid height and postseismic change with exponential decay. We found an oval shaped coseismic geoid depression as large as 7 mm covering the Andaman Sea, which was in good agreement with geoid height changes calculated with the method described above. We also detected postseismic geoid height changes, characterized by slow recovery of coseismic geoid depression with a time constant of about 0.6 year. Such a postseismic change cannot be explained with simple afterslip or viscous mantle relaxation, and requires contribution from the upward diffusion of pore fluid at the down-dip end of the fault. Geophysical interpretations of such postseismic changes shall be presented as a separate paper in another session (T234).