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Topographic corrections for crustal deformations associated with earthquakes and volcanic activities

Hitoshi Goshima[1*], Shin'ichi Miyazaki[1], Takahito Kazama[1], Masayuki Kano[1]

[1]Kyoto University

Crustal deformations due to earthquakes and volcanic activities have been estimated, assuming a half-space elastic topography (Mogi, 1958; Okada, 1992). However, the half-space topography cannot reproduce the fault slips to the free surface at oceanic trenches such as the 2011 Tohoku earthquake.

We thus calculated topographic effects on the crustal deformations due to earthquakes and volcanic activities, according to Williams and Wadge (2000). We first considered boundary conditions of stress for undulating topography, and then solved them for the 0-th and the 1-st order terms of the crustal deformations (i.e., the half-space solution and the topographic correcting term, respectively). This method can reproduce both true fault depth and fault slips to the free-surface, as well as true elevation of observation stations. Moreover, this model can estimate realistic crustal deformations more easily than Finite Element Method (FEM).

We applied this method to the crustal deformation at Sakurajima Volcano (Takayama and Yoshida, 2007) with a spherical inflating source (Mogi, 1958), and found that the amplitude of the topographic correction term reached about 12 and 24 % (for vertical and horizontal displacements, respectively) of the half-space solution at most. We also applied the method to the crustal deformation due to the 2011 Tohoku earthquake (Geospatial Information Authority of Japan, 2011) using Okada (1992), and found that the amplitude of the topographic correction term reached about 10 and 9 % (for vertical and horizontal displacements, respectively) of the half-space solution at most, especially above the slipped faults.

In the future, we will solve inverse problems for the spatial distribution of the fault slip, using the observed GPS data at the 2011 Tohoku earthquake. Then, the topography-corrected solutions will be compared with the free-surface solutions and the FEM solutions, in order to evaluate the precision of the topography-corrected solutions.

Keywords: crustal deformation, topography, earthquake, volcanic activity, the 2011 Tohoku earthquake, Sakurajima Volcano