Spatiotemporal gravity variations from the 1990s in Sakurajima Volcano, revealed by repeated relative gravity measurements

*Ryo Oyanagi[1], Takahito Kazama[1], Keigo Yamamoto[2], Hiromitsu Oshima[3], Kazumi Okada[3], Tadaomi Sonoda[2], Masato Iguchi[2]

1. Graduate School of Science, Kyoto University, 2. DPRI, Kyoto University, 3. ISV, Hokkaido University

Gravity observation is one of the most effective methods to detect spatiotemporal mass variations in volcanoes. In and around Sakurajima Volcano, relative gravity measurements were first started in 1975 and have been repeated 20 times until 2018. The long-term gravity variations from 1975 to 1992 was modeled by Kazama et al. (2018), to understand volcanic mass variations associated with active eruptions at the Minami-dake summit during the same period. They showed that the relative gravity increase in Sakurajima cannot be fully explained by two spherical deflation sources, which were expected from the leveling data. Instead, they found that the gravity increase can be modeled by an additional point mass of 6.0 E+10 kg/yr at 5 km depth under the Kita-dake summit. However, Kazama et al. (2018) modeled the volcanic mass distributions only from 1975 to 1992, and mass distributions during the subsequent period from the late 1990s to the 2010s should be modeled as well to understand present mass accumulating processes and forecast future volcanic activities of Sakurajima Volcano.
We therefore analyzed the GPS and relative gravity data obtained from the late 1990s to the 2010s, to model the long-term pressure and mass sources under Sakurajima Volcano as follows. We first subtracted the effect of tectonic crustal deformation in the southern Kyushu Island from the horizontal displacement data of the GEONET F3 solution, using the method of Takayama and Yoshida (2007). We also reproduced the residual horizontal displacement data by a spherical pressure source of Mogi (1958), assuming the inflation of a magma reservoir located under Aira Caldera; in this calculation, several parameters about the location and volume change of the pressure source were determined by the grid search method so as to most reproduce the horizontal displacement data. The inflation source was calculated to be located at 9 km depth under the center of Aira caldera with the inflation rate of 5.5 E+6 m3/yr. However, this inflation source never agrees with the gravity increase observed in Sakurajima volcano after the late 1990s, because the source inflation and consequent ground uplift leads to the gravity decrease (Hagiwara, 1977).
After correcting the effect of the inflating pressure source, the observed gravity values were found to increase at rates of +7.49 and +1.61 microGal/yr at S110 (located at the summit of Sakurajima) and S16 (located at the western foot of Sakurajima), respectively. We thus calculated theoretical gravity variations in Sakurajima Volcano by assuming a point mass under the center of the volcano, so as to explain the observed gravity increase; in this calculation, the parameters about the depth and mass increase were determined with the trial-and-error method. The point mass was estimated to be located at 3.3 km depth below sea level with a mass increasing rate of 2.3 E+10 kg/yr. This result implies that the mass accumulation continues under Sakurajima Volcano even now, although the present accumulating rate reduced by less than half compared with that from the 1970s to the former 1990s. We will sophisticate the pressure/mass source models in the future, to reveal the mass redistribution processes associated with volcanic activities of Sakurajima Volcano.

Keywords: Sakurajima Volcano, relative gravity, crustal deformation, mass variation, magma, hydrology

