Magma mass transport in the volcanic vent at Asama Volcano in the central Japan revealed by physical corrections of hydrological gravity disturbances

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Continuous gravity observation is one of the most powerful methods to monitor time variations in mass distributions (e.g., Imanishi et al., 2004). Especially at volcanoes, absolute and relative gravimeters have been utilized for detecting magma mass transport associated with volcanic eruptions (e.g., Furuya et al., 2003). However, the gravity signals are often masked by hydrological gravity disturbances at humid climate areas like Japan (e.g., Okubo, 2005). Although the hydrological gravity disturbances have been empirically corrected by estimating response functions of gravity to rainfall, water distribution geometry and nonlinear water flow often make the response functions vary according to place and time (e.g., Kazama et al., 2005). In order to detect the volcanic gravity signals with high accuracy, time variations in three dimensional water distributions should be adequately modeled with nonlinear physical equations.

We were thus motivated to correct hydrological disturbances in observed absolute gravity data at Asama Volcano in the central Japan with physically-based hydrological modeling, in order to detect volcanic mass transport during eruptions in 2004. In an original software G-WATER [3D] (Kazama and Okubo, 2009), nonlinear diffusion equations of water flow in soil were solved for time variations in distributions of soil water and groundwater at Asama Volcano, by using observed precipitation data, digital elevation model and measured soil parameters. Then, the hydrological gravity disturbance was calculated with the spatial integral of the water distributions for each time.

The estimated time variation in soil water at Asama Volcanic Observatory (AVO; 4 km east of Asama summit) agreed with the observed one within the observation error range, since the measured soil parameters and the physical water flow equations were applied to our hydrological model. In addition, the calculated hydrological disturbance was consistent with the observed absolute gravity data at AVO from 2004 to 2009 within 3 micro-gal in root-mean-square. After subtracting the estimated disturbance from the observed gravity (i.e., correcting the hydrological effect in gravity data), 5-micro-gal gravity change was detected in the observed gravity during Asama eruptions in 2004. We concluded that the gravity change was caused by transporting magma in a volcanic vent of Asama Volcano, because the gravity change correlated with the existence of a lava cake at Asama summit in September 2004 and increases in B-type earthquakes and emitted mass of SO_2 and ash.

In principle, this hydrological correction method can be utilized for any gravity data, if required data (such as precipitation and ground elevation) and soil parameters are prepared. In the future, we will apply the real-time disturbance correction to observed gravity data, in order to immediately understand magma transport in active volcanoes such as Sakurajima Volcano in the southern Japan.