Precursory ground deformation prior to the 2018 phreatic eruption of Kirishima Iwo-Yama volcano, Japan, revealed by airborne and spaceborne InSAR

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Phreatic eruptions are often attributed to the consequences of the activation of volcanic hydrothermal systems. Preceding the eruptions, precursory ground deformation possibly could appear, reflecting pressure change in the hydrothermal system. In recent years, space geodesy observations such as satellite-borne synthetic aperture radar (SAR) have depicted the precursory ground deformation on many non-eruptive volcanoes. However, few case studies successfully revealed transient pressure change of the hydrothermal system before the eruption. To gain insights on the temporal evolution of the shallow hydrothermal system which is responsible for eruptions, we analyze SAR data acquired at the pre-eruptive period of Kirishima Iwo-Yama volcano where a small phreatic eruption occurred on 19 April 2018.

Analyzed SAR data are space-borne PALSAR-2, observed from two orbits from 2014 to 2018, as well as Pi-SAR-L2, which is an L-band airborne-SAR operated by JAXA, observed from three orbits from 2014 to 2017. As for the Pi-SAR-L2 data, we use interferograms analyzed by Murakami et al. (2019, JpGU). We perform space-air combined three-dimensional analysis for two time periods; 2014-2016 and 2016-2017. The combination of aircraft and satellite SAR enables us to precisely estimate the three-dimensional deformation field even of a small amplitude (~10 cm), which is hardly attainable by only satellite SAR data.

From 2014 to 2016, an axisymmetric pattern of ground inflation with a diameter of ~200 m was dominant. It seemed to be well modeled by a spherical or penny-shaped crack source. The deformed area almost coincided with the fumarolic area at the center of Iwo-Yama volcano. In contrast, the deformation pattern from 2016 to 2017 was obviously different; the location of maximum uplift moved 70 m to the south, which was close (~30 m) to the 2018 eruption vents. This sequence was quite similar to the case of the 2015 Hakone eruption. This suggests the possibility of predicting the location of vents or craters formation of coming eruption by tracking the maximum deformed point.

For 2014-2016, a sill-like opening crack at a depth of 150 m well explained the observed deformation. Although this model also explained the general pattern of the observed deformation during 2016-2017, the localized inflation to the south of the peak during 2014-2016 remained unexplained. This suggests that another pressurized part was formed at near-surface depth, shallower than the opening crack. Using only PALSAR-2 SAR data, we estimated a 2.5-dimensional deformation field from September 2017 to April 10, 2018. The result shows almost the same pattern as in 2016-2017, and the maximum uplift point did not change temporally. To determine the epoch of the peak migration, we focused on time series of the line-of-sight deformation derived from the PALSAR-2 data. The time series shows that the migration occurred at the end of April 2017. This is temporally close to the mud discharge event on 26th April 2017, which occurred only 30 m to the east of the deformation peak. Those could be a result of episodic

fluid injection from a deeper part. We infer that the localized and shallow inflation during 2016-2017 started with the mud discharge and then continued until the eruption onset.

Keywords: ground deformation, phreatic eruption, InSAR, volcanic hydrothermal system, airborne SAR