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Locally-distributed inflational deformation at Midagahara volcano, Japan, detected by InSAR time series analysis

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Preface: Midagahara volcano is an active volcano located in the Toyama Prefecture. Jigoku-dani area is known as an active geothermal area with fumarole and boiling water activity. In these past few years, activity on the ground has become more visibe with burning and flow out of sulfur in 2010 and increased temperatures of fumarole. It is known that phreatic eruptions have occurred historically, and therefor there is a current concern about phreatic eruptions in the near future. Generally, a phreatic eruption is thought to occur by a heat supply to a geothermal system under the ground, probably leading to an inflational crustal deformation due to pressure increase in the crust. Crustal deformation is valuable information to know what proceeds under the ground, and can be an important indicator to assess the degree of activity. However, no significant deformation has been observed in recently-conducted GPS observations which were done in and around the Murododaira area which is about 500 m away from the geothermal area. It suggests that the crustal deformation, if there would be any, occurs in a small area with small magnitude. Thus, InSAR time series analysis may contribute to grasp the whole picture of the crustal deformation with its high measurement accuracy and high spatial resolution.

Data analysis: We used ALOS/PALSAR data observing Midagahara volcano. Only 12 SAR images are available due to the long-term snow cover, acquired from Jul. 2007 to Oct. 2010. We applied a PSI analysis for the observation but made some changes in the processing methodology. The land of the analyzed area is covered by tree/grass, thus it is thought that PS points cannot be extracted well enough to obtain the deformation in detail. Thus we applied the phase linking method in which phases of distributed scatters (DSs) are optimized so that we can handle as a point equivalent to PS point in PSI analysis. To pick up PS candidates, we use the signal-to?clutter ratio (SCR) method in addition to amplitude dispersion (AD), because the AD does not have a good performance for small data set, while SCR can pick up PSCs from a single SLC image. For DSs analysis, we first picked up statistically homogeneous pixels for multilooking by applying the 2-sample KS-test (Ferretti et al., 2011), and then conducted the phase linking. We used the spatio-temporal consistency as a quality indicator (Hanssen et al., 2008) to select final measurement points. Resultantly, the PS of 7094 pixels was obtained in full pixel size of 720000, while we could get the optimized DSs of 82138, leading that the observation density significantly improves.

Results: We detected locally-distributed ground surface displacement in the Jigoku-dani geothermal area, which is close to the satellite, namely, inflational deformation. The deformation speed is estimated to be at about 4cm/yr at maximum. The deformation area is spatially consistent with the area that active fumarole and boiling water are seen on the ground. The time series data of displacement is almost linear, suggesting that there is no significant non-linear deformation. The deformation is locally distributed with the extent of only a few hundreds of meters, strongly suggesting that the deformation source is located at rather shallow. Assuming a sill-shaped source, we constructed the opening crack source model by a simulated annealing method. The estimated optimal depth is 100 m, which supports the above-mentioned idea. To know the more detailed spatial extent, we constructed a distributed opening model that consists of 100 by 100 m rectangular sill-patches. The result shows that the major crack opening concentrates on a local area with the extent of about a hundred meter just below the area centered at Kajiya-jigoku fumarole vent, and the amount of opening is estimated to be about 10 cm/yr at maximum.

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Keywords: Midagahara volcano, InSAR time series analysis, Crustal deformation