Automated System for Anomalous Volcanic Crustal Deformation Detection and Source Estimation by Using Real Time Observation Data.

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1. Introduction

NIED has conducted continuous observations of volcanic activities at 5 volcanoes (Mt. Fuji, Izu-Oshima, Miyakejima, Mt. Nasu, and Iwojima). The observation data of the networks other than Iwojima are transmitted to NIED in real-time. Recent establishments of observation stations at the volcanoes enable us to know underground magma movements with a high spatio-temporal resolution. Using the real-time data, we developed a system that automatically detects underground magma movements. The automated system can provide practical information for volcanic disaster mitigation to the other researchers or those who is in charge of crisis management.

2. Method

To estimate a magmatic activity from the observation data, we generally carry out three steps as follows, (1) detection of anomalous crustal deformation due to a magma movement, (2) extraction of the crustal deformation, and (3) estimation of an appropriate source model for the deformation. Therefore, we need to automate these steps. For the detection of anomalous crustal deformation, we used 1-hour sampled borehole tiltmeter data with high accuracy and high temporal resolution. Since noise of the tiltmeter data obeys a random walk (e.g., Wyatt et al., 1988, JGR), we define a tilt change that significantly exceeds the random walk noise as an anomalous deformation. The detection level of the anomalous tilt change with duration of 1 day is +-0.2-0.6 micro rad. The model parameters of deformations sources are estimated by using the method of Ueda et al. (2005, GJI accepted), which is based on GA and suits for an automated analysis. The system calculates for several models and selects a best model by using Akaike's information criterion (Akaike, 1974).

3. Test Case

We tested a performance of the system by using a test data set that based on a volcanic process of the 1707 eruption of Mt. Fuji estimated by the Mt. Fuji Working Group of CCPVE (Report of CCPVE, 2003). In the estimated process, a dike ascended from a magma chamber 15 km deep beneath the summit about 2 months before the eruption on Dec. 16, and then the chamber contracted during the eruption of about 0.7km^3 for a half-month. We assumed that the dike has a size of 4 km x 10 km and a thickness of 1 m (0.04km^3). The test data are synthesized by adding a theoretical crustal deformation by the source model to the observation data of 6 tiltmeter stations during 2004. We assumed 4 candidate source models for the source estimation (Model A: one Mogi source, B: two Mogi sources, C: a Dike source, D: Mogi + Dike source).

4. Result

An anomalous tilt change due to the dike intrusion was firstly detected at two weeks before the eruption when the dike ascended at the depth of 5 km. Until one week before the eruption, the model A was incorrectly selected as the best model because the tilt change was still too small. However, the period from one week before the eruption to then, at the beginning of the eruption and during the eruption, the model C, D, and A were selected, respectively. The estimated model parameters are almost the same as the test model. We also used GPS data at three one-frequency receivers for the model estimation, but the clear anomalous crustal deformation is not observed until one day before the eruption.

The result shows that, in such cases like this, the system has a capability to detect automatically a small tilt change before an eruption and estimate a location and amount of intruded magma in real-time. Displaying the result of automated analysis on the Web site of NIED, we expect that the other researchers or those who is in charge of crisis management can know a magmatic activity in real-time and utilize for volcanic disaster mitigation.