Relative Hypocenter Determination of Volcanic earthquakes at Mt. Azuma using DAS System

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Introduction

Volcanic earthquakes are thought to be generated by fault movements or volcanic fluid motions within volcanic edifice. Since these volcanic earthquakes often show unclear onsets of P and S-waves, we are not able to use the commonly used hypocenter determination using the arrival times of P and S-waves. Recently, ultra-dense observation data using DAS are used for hypocenter determination of volcanic earthquakes [e.g., Nishimura et al. (2021)]. To improve the accuracy of the hypocenter locations, we apply a relative hypocenter determination method that analyzes the arrival time difference and amplitude ratio of seismic waves of volcanic earthquakes that occurred at Mt. Azuma.

Data

We use the data recorded by a DAS system and fiber-optic cable that is deployed along the Bandai-Azuma Skyline for 14 km. Observation period was approximately three weeks from July 4 to July 25, 2019. The data were recorded with a sampling frequency of 1000 Hz, a spatial interval of 10.2 m, and a gauge length of 40.8 m. The earthquake that occurred on July 4 is used as a reference event, and we analyze six events whose hypocenter were determined by Nishimura et al. (2021), which are referred as analysis events in the followings.

Method

We use the arrival time differences between two measurement points along the fiber cable for the reference and six events. The time differences between two points with the separation distance of 30.6, 40.8, 51.0, 61.2, 71.4 m are measured by applying the cross-spectrum method to the observed waveforms. Then, we further calculate the difference of the time difference of each measurement pair between the reference and each analysis event. The time difference is expressed by a linear function of the relative location with respect to the reference source location. The relative hypocenter determination using amplitude ratios [Ogiso and Yomogida (2021)] uses the logarithm of the observed maximum amplitude ratio between the reference event to an analysis event which can be expressed by a linear function of the source amplitude ratio of the reference event to an analysis event and the relative location with respect to the reference source location. We combine these two quantities with a hyperparameter and solve the joint inverse problem by using the least-square method. Changing the hyperparameter, we find the optimal solution with the smallest residuals.

Result

The reference event is located at a depth of about -0.8 km beneath the Oana crater. The seismic wave velocity is assumed to be 3 km/s. All the six analysis events are located within a distance of less than about 0.5 km in horizontal direction and 0.5 km in vertical directions from the location of reference event. The hypocenters are well matched with the results of JMA, which shows the locations of volcanic earthquakes that occurred at Mt. Azuma are distributed within about 1 km in horizontal directions and at a depth of -2 to 1 km beneath the Oana crater (Volcanic Activity Report). The hypocenter determination using the arrival time difference between measurement point pairs and amplitude distribution locate the hypocenters elongating the NNW-SSE directions, which is due to the fiber-optic cable configuration that laid in a north-south direction from the Jododaira to the foot of the mountain. Our results suggest that even when the fiber-optic cable does not surround the earthquakes, we are able to well determine hypocenters with a sufficient accuracy.

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Keywords: Distributed Acoustic Sensing, Relative hypocenter determination, Volcanic earthquake

