

Source location determination based on seismic cross-correlations: application to simulated tremor using volcano-tectonic earthquakes

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Source location determination of volcanic tremors is important to clarify the source mechanism and understand the volcanic process. Onset time of P- and S-wave phases in tremors is unclear so that the hypocenter determination methods based on phase-picking are difficult to implement. The CCF-based SSA method, in which the source-scanning algorithm (SSA) is applied using cross-correlation functions (CCFs) of seismic waves recorded for pairs of stations, was recently presented for hypocenter determination of tremor by Droznin et al. (2015). It assumes a near-surface source and estimates travel time curves using the CCFs obtained from tremor signals. The method was applied to the data from regional networks with large interstation distances up to 90 km. However, to understand the mechanism of tremor and magma or hot water activity at volcanoes, more accurate estimation is necessary. In the present study, we modify CCF-based SSA method presented by Droznin et al. (2015) to be used for a seismic network deployed around an active volcano with interstation distances ranges from a few to 10 km. We apply our method to locate volcano-tectonic (VT) earthquakes with known hypocenter locations to quantitatively examine the estimation errors. We further simulate tremor signals by using VTs and assess the accuracy and the reliability of the method.

We incorporate a seismic velocity model into the CCF-based SSA to compute the predicted travel times and avoid the inaccuracy of travel time estimation in the original method and to determine the source depth. We analyze VT earthquakes occurring at Izu-Oshima volcano. The hypocenters are first determined by a phase-picking method. The CCF-based SSA is applied at the dominant frequencies of the observed waveforms at 4 to 16 Hz. We first determine 273 VTs individually and compare their source locations to the hypocenters obtained by the phase-picking method. The location errors are estimated to be less than 1.8 km in both horizontal and vertical direction. Next, we apply our method to simulated tremor. Volcanic tremor is often thought to be a superposition of successive seismic events such as long-period signals. Izu-Oshima did not show low-frequency events or tremors during our observation period. Therefore, we simulate tremors signals by using the waveforms of VTs that occurred within a defined circle. We stack CCFs of the VTs and determine the source locations from the stacked CCF. The error is measured as the distance of the source location obtained using the stacked CCF to the centroid of the stacked VTs. We create a total of 806 tremors by setting circles over the study area with 500 m interval. The results show that the location error becomes smaller as increasing number of the stacked VTs and smaller region where the VTs are located. When the VTs are distributed within a radius of 1 km and more than 50 VTs are used, the location error is less than 1 km. These estimation errors may not be as good as errors by the phase-picking method, but our CCF-based SSA may give us more accurate source locations of tremor and low-frequency events where the estimation errors have not been well determined.

Keywords: source location, volcano-tectonic earthquake, volcanic tremor, cross-correlation, Izu-Oshima