# The removal of noise to detect volcanic earthquakes which occurred under Hakone volcano

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There are many kinds of volcanic earthquakes. However, the methods, criteria, and thresholds for their classification are not unified and strongly depend on a researcher and a volcano (Nishimura &Iguchi, 2006). Such dependence in the classification is confusing, and a unified classification framework is desired. Establishment of the framework should be based on enough examples of volcanic earthquakes extracted from continuously recorded seismic data. To that end, at first, to extract volcanic earthquakes from seismic records is required.

However, seismometers installed near a volcano frequently record human-driven noise as well as volcanic earthquakes. Therefore, we should discriminate volcanic earthquakes from other events. For the discrimination, we should investigate a continuous seismic record including signals of many volcanic events and human-driven noise simultaneously. In addition, we should also investigate an inactive term of the volcano because human-driven noise will dominate and be extracted easily from a record at that term; it allows us to understand the intensity and dominant frequencies of the human-driven noise. The understanding may contribute to extracting human-driven noise from seismic records obtained in an active term of the volcano.

From the point mentioned above, we investigate Hakone volcano, which was active from April to September in 2015. We used a continuous seismic record of the Ninotaira observation station published by Japan Meteorological Agency. The continuous record observed at the Ninotaira observation station has been repeatedly contaminated by characteristic waveforms due to every passage of trains near the observation station. Acausality between the waveforms and trains is obvious because the appearance of the waveforms and scheduled arrival and departure of trains described in a timetable of the train are simultaneous.

Using the record, we develop a method to detect noises due to the train passage regarding some of them as templates. First, we divide 20 waveforms of the train noise extracted between 5AM-9PM of March 29, 2015, the day when the volcano is not active, into 54 packets. We regard these 54 packets as templates after calculating their envelopes and smoothing them with a moving average. Next, we apply the aforementioned procedure to the whole part of the continuous record and calculated correlation function of the processed record and the templates.

After evaluation of a threshold to detect the train noises from the correlation function, we can detect 112 out of 116 train passages on March 29, 2015. On the other hand, extra 300 seconds within 24 hours are judged as train noises although no train passed in the terms. This noise detection method may enable us to detect volcanic events in an active term of the volcano. Actually, by applying the method to a record of June 29, 2015, the day of the eruption, some of the train noises dominated by significant seismic signals are not detected. Hence, our development succeeded in view of our purpose, detection of signals due to the volcanic event.

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