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Detection of acoustic signals associated with the eruption of a submarine volcano at "Fukutoku-Oka-No-Ba" in the southern Bonin Arc using cabled ocean bottom seismometers along the Japan Trench

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1. Introduction

"Fukutoku-Oka-No-Ba" is a submarine volcano located in the southern part of the Ogasawara Islands, or the Bonin Arc, about 1,300 km south of Tokyo, the capital of Japan. At around 6:20 JST on August 13, 2021, the meteorological satellite Himawari observed a volcanic plume associated with the eruption. Subsequently, pumice stones have washed ashore and caused damage in various places in Japan. It is reported that acoustic signals associated with the eruption were detected by hydrophones moored at three points in the sea off Wake Island, about 2680 km east-southeast of "Fukutoku-Oka-No-Ba"[1)]. They propagate the deep-sea sound channel (Sound Fixing and Ranging, SOFAR channel). In Japan, on the other hand, partly because there are few observation stations with the hydrophone whose data are open to the public for scientific observation purposes, the detection of the acoustic signals associated with eruptions by the hydrophone is not reported. In fact, the author first investigated the waveform data of the hydrophones installed in the cabled underwater observatory of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) installed off Kushiro and Tokachi in Hokkaido, northern Japan[2)], but could not identify the signal related to the eruption.

Meanwhile, by analyzing the waveform data of the ocean bottom seismometers (OBSs) of the submarine cabled observatory "S-net" along the Japan Trench, offshore east of Japan, author detected the underwater acoustic signals associated with the eruptions at "Fukutoku-Oka-No-Ba". In this paper, the author reports the method and the results obtained.

2. Data and analysis method

S-net is a submarine cabled observatory consisting of 150 observation stations installed by the National Research Institute for Earth Science and Disaster Resilience (NIED) over a vast sea area from the Nemuro Peninsula in Hokkaido to the Boso Peninsula in Chiba Prefecture, central Japan.

In S-net, a velocimeter and an accelerometer are attached to each station in the same way for each of the three components in arbitrary direction. This time, the velocimeter is used. The vertical component is calculated based on the direction of gravity measured by the accelerometer[3)] and used for analysis. The sampling frequency is 100 Hz.

The original waveform data contains ambient noise including ship noise and earthquake signals, mainly aftershocks still continuing after the 2011 Great East Japan Earthquake. For that reason it is difficult to identify eruption-related signals at first glance. The ship noise has a sound source near the stations, and it is considered that there is no correlation between each station over a wide range. In addition, the signals associated with earthquakes are mainly composed of seismic waves such as P waves and S waves. On the other hand, the underwater acoustic signal related to the submarine volcanic eruption propagates through the SOFAR channel at the sound speed and reaches the station, but its propagation velocity is slower than the above-mentioned seismic waves. Therefore, as a means to distinguish the acoustic signal propagating through the SOFAR channel from the seismic waves, firstly the horizontal distance between each volcano and each station is divided by the sound speed (1500 m/s) in order to obtain the propagation time. Secondly, the spectrogram was drawn by shifting the time axis by the propagation time corresponding to each station, and the differences among the stations were compared. Accordingly, the acoustic signal associated with the eruption should be displayed at the same position in the drawn spectrogram regardless of the station. Specifically, the author created moving pictures that sequentially display the spectrograms of each station, and visually checked them.

As a result, acoustic signals associated with the eruption were detected at about 40 stations of the S-net. In **Fig. 1** and **Fig. 2**, the spectrograms of stations S1N08 and S2N04 of S-net are shown respectively. The horizontal axis is the elapsed time (seconds) from the stated time. The filled triangles indicate the events associated with the eruption, and the hollow triangles indicate the earthquake that is not related to the eruption.

Those results, however, are limited to visual identification of acoustic signals associated with the eruption in the spectrogram of observed waveforms, and further waveform analysis is required in order to extract information for understanding the overall eruptive activity, such as changes in eruption events over time.

Looking at these figures, the detection limit of the frequency component of the signal associated with the eruption seems to be about 5 Hz, although it differs depending on the station. Although the noise environment also differs depending on the stations, a band-pass filter that passes the frequency band from 5 Hz to 10 Hz is used in consideration of the situation of the same figure and other stations for the further event analysis on time domain.

Fig. 3 and **Fig. 4** show examples of the results of shifting the time axis of the waveform after applying the filter by the propagation time for each station and arranging them in order of propagation distance. The horizontal axis corresponds to the emission time at the sound source of the signal detected at each station. The vertical axis is the propagation distance (km). Only the 44 stations that detected the signal associated with the eruption were selected. Similar to the spectrograms in Figs. 1 and 2, the acoustic signals propagating through the SOFAR channel at the speed of sound appear at the same position on the horizontal axis, making it possible to identify and extract them as eruption events. Fig. 2 is the record for one hour from 05:00 JST on August 13, 2021. There is a pulse-shaped waveform at around 05:57 indicated by the downward pointing triangle. The event occurrence from around 05:55 can be confirmed prior to that. In Fig. 4, multiple pulse-shaped eruption events can be confirmed in the 1-hour record from 09:00 JST on the same day. The event around 09:44 is a T wave associated with an earthquake off the east coast of the Ogasawara Islands, which is different from the eruption site.

3. Concluding remarks

By analyzing the waveform data in noisy environment of OBSs along the Japan Trench, the acoustic signals associated with the submarine volcanic eruptions at "Fukutoku-Oka-No-Ba" are detected.

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References

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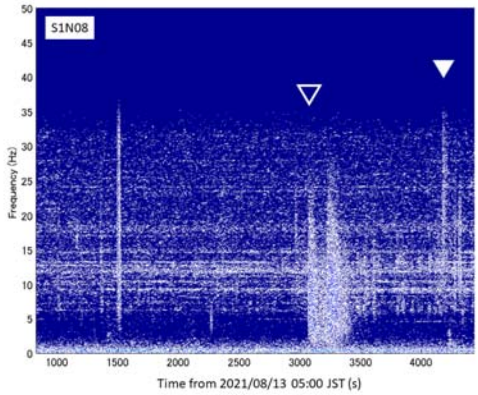

Fig. 1 One-hour spectrogram at S1N08.

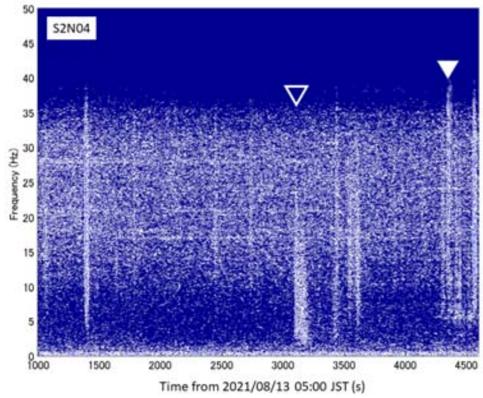

Fig. 2 One-hour spectrogram at S2N04.

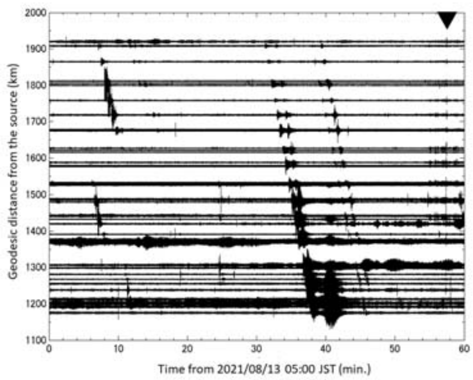

Fig. 3 Profiles of band-pass-filtered waveform of S-net stations. Horizontal axis is elapsed time from 05:00 JST on Aug. 13th 2021, projected in the source time.

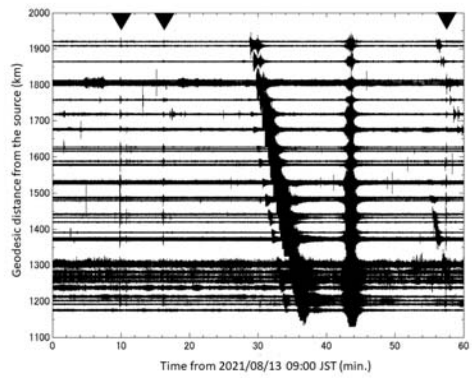

Fig. 4 Profiles of band-pass-filtered waveform from 09:00 JST on Aug. 13th 2021.