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Long-duration Signal Generated by Volcanic Activity at Nishinoshima Detected by Dense OBS Array Observation at Hyuga Nada

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Hyuga Nada, a region offshore of Miyazaki Prefecture, is attracting widespread attention from seismologists due to its potential for a megathrust earthquake accompanied by a tsunami, as well as slow earthquake activity near the trench. From March 2018 to September 2018, we conducted a dense Ocean Bottom Seismometer (OBS) array observation in a region where active tectonic tremor activities [Yamashita et al., 2015; 2021] and Very Low Frequency Earthquake activities [Tonegawa et al., 2019] have been observed. The OBS array consisted of 10 OBSs, forming double concentric circles with radii of 1 km and 2 km. The primary objective of the observation was to investigate the seismic structure related to slow earthquake-genesis of this region. Receiver function images constructed based on the array records revealed a possible fluid reservoir on the Kyushu-Palau Ridge [Akuhara et al., 2023]. In addition to investigating the seismic structure, we performed array analysis using data from the dense OBS array. Although our primary target was to detect slow earthquake activity through the array analysis, we also detected a long-duration signals likely to be generated by volcanic activities at Nishinoshima, a volcanic island in the Izu-Mariana-Bonin arc.

Array analysis, specifically array beamforming, is a method used to extract information such as the arrival direction and/or apparent velocity of waves observed by a dense array. It has been widely used in the field of telecommunications, but has also been adopted in seismology. One of the advantages of incorporating beamforming analysis in seismology is its high capability in detecting weak but coherent signals. To detect signals that are stable in space and time, we perform slant-stack beamforming [e.g., Rost and Thomas, 2002] on the OBS array data. First, continuous waveforms of the vertical component are band-pass filtered between 2 Hz and 4 Hz. The analyzed frequency band is selected based on the ambient noise characteristics of the observed data. Then, the waveforms are beamformed every 60 seconds using a half-overlapping moving time window. In the array beamforming process, the waveforms from multiple stations are time-shifted in the frequency domain based on assumed pairs of apparent velocities (1.4 km/s – 40 km/s) and directions (0° - 360°), and then stacked to enhance coherently observed signals.

As a result of the analysis, we detected several substantially long-duration signals that may be related to the eruption of Nishinoshima. Starting on July 12, the array beamforming revealed the arrival of a signal near the noise level from a direction of 105°, with an apparent velocity of 2.2 km/s. This signal remained stable for over 32 hours. The timing of the detection coincides with the eruption of Nishinoshima on July 12 [Marine Volcano Database, Japan Coast Guard], which was confirmed both aerially and by satellite observation of ground surface temperature. Although the island is nearly 950 km away from the array site, the temporal and directional coincidence suggests that the observed signal was possibly produced by the eruption at Nishinoshima. We interpret that the hydroacoustic wave generated during the eruption propagated through the ocean and was converted to a surface wave on the seafloor nearby the OBS array.

The results of array beamforming suggest not only signals from a known volcanic activity but also a possible eruption that has not been documented. The eruptive activity at Nishinoshima was not confirmed by aerial observation after July 30 [Marine Volcano Database, Japan Coast Guard]. However, the array beamforming indicates high-frequency signals arriving from directions of 128˚ and 90˚ for 12 hours on August 10, similar to the event on July 12. The signal arriving from 128˚ had an apparent velocity of 1.5 km/s, and the signal from 90˚ had an apparent velocity of 2.4 km/s. The apparent velocities of these waves suggest that we observed both a hydroacoustic wave traveling through the ocean and a surface wave converted from the hydroacoustic wave. This event suggests a possible short eruption that could not be detected by satellite observation, which has limited capabilities for monitoring during daytime, or possible non-eruptive volcanic activity similar to the one previously documented at Nishinoshima [Baba et al., 2020].