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# IMS hydroacoustic hydrophone station detections associated with volcanic eruptions at Kadovar Island, Papua New Guinea


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[P1.3-291]

POSTER


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## ABSTRACT

The analysis of hydroacoustic signals originating from marine volcanic activity recorded by a remote hydroacoustic (HA) station, HA11 at Wake Island, of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) International Monitoring System (IMS) is presented. The events studied pertain to an eruption series at Kadovar Island, Papua New Guinea during the period January to February 2018. Local visual observations determined that the Kadovar volcano began to erupt at the summit of the island, and then created new vent spots near the coast. The events included the collapse of a lava dome on 9 February 2018. Directions-of-arrivals (DOA) of the hydroacoustic signals detected at HA11 were evaluated using a cross-correlation technique. This allowed discrimination between hydroacoustic signals originating from the Kadovar volcanic activity and other numerous hydroacoustic signals generated by general seismic activity in the Pacific. Discrimination between volcanic activity and seismicity was achieved by examining the time-frequency characteristics of the hydroacoustic signals, i.e. associating short duration broadband bursts with volcanic eruptions, in line with criteria generally applied for such events. Episodes of high volcanic activity with as many as 80 detections per hour (calculation based on 30-s time-window with 25-s over-lap) were identified on two occasions, separated by a one-month period of relative quiet. Some of the hydroacoustic signals were characterized by broadband frequency content and high received levels (i.e. ca. 30 dB higher than the ocean background noise).

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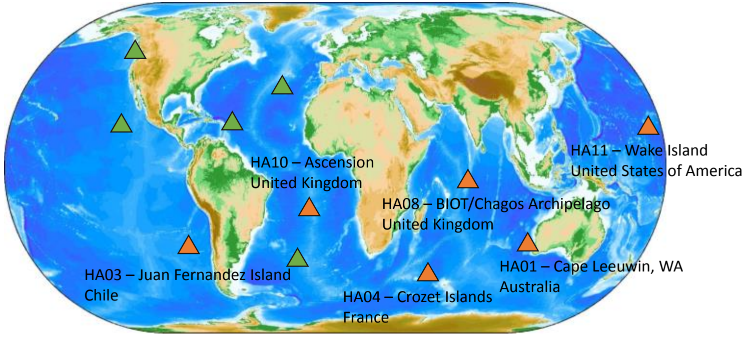
INTRODUCTION

## IMS hydroacoustic network & hydrophone triplet




Underwater hydrophone stations / *T*-phase stations

**Figure 1.** CTBT IMS hydroacoustic network.

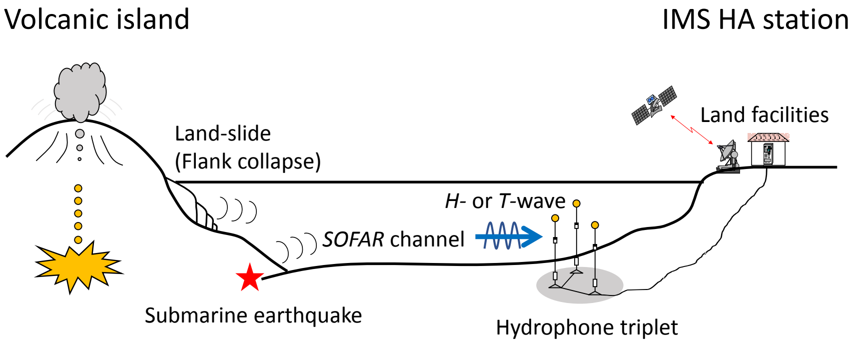



**Figure 2.** Overview of an IMS hydrophone triplet and events which generate underwater sound.

The hydroacoustic network is part of the International Monitoring System (IMS) of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) and has 11 stations. Of the 11 hydroacoustic stations, five (denoted by green triangles) are *T*-phase stations which use seismometers to pick up water-borne signals from acoustic events coupled in the crust of coastal areas. The other six (orange triangles) are cabled stations that utilize underwater hydrophones. All the cabled stations have two triplets of underwater hydrophones suspended in the water column, in a horizontal triangular configuration with a separation of 2 km, except for HA01 at Cape Leeuwin, Australia which has only one triplet.

The present study is concerned with the IMS hydroacoustic (HA) hydrophone stations, which have been installed since the early 2000's. The hydrophone stations are based on islands and connected by electro/fiber-optic cables to the hydrophone triplets. The triplets are deployed up to 200 km from the island. All hydrophone sensors are located in the SOund Fixing And Ranging (SOFAR) channel axis at a depth of 600 m to 1200 m, suspended by subsurface floats. Hydrophones record the pressure change in the water caused by passing hydroacoustic waves, such as *H*-waves and *T*-waves.

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INTRODUCTION

## Kadovar volcanic Island

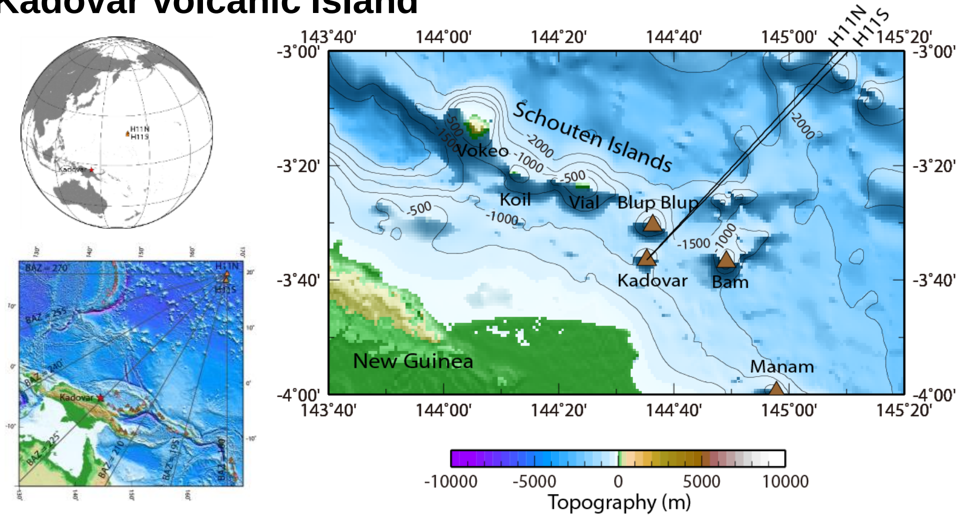
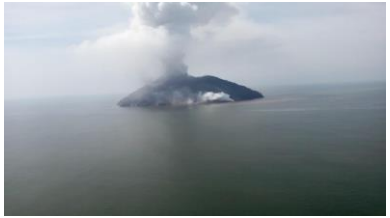



**Figure 3.** The Asia-Pacific area and detailed map covered by the present study.

Flyover photo on 05 January 2018

*Data Source*: Bulletin Reports of the Smithsonian Institution

Flyover photo on 11 January 2018



Report by Sharoi Romkentuo

The location of Kadovar Island volcano is denoted by a red star, and the IMS HA11 hydroacoustic station triplets at Wake Island are denoted by orange triangles in the left panels. HA11 comprises two triplets of hydrophones, referred to as H11N and H11S (see Figure 4). The distance between Kadovar and HA11 is about 3,500 km. Dark and bright red triangles locate above-surface and submarine volcanoes, respectively, as registered by the Smithsonian Institute.  Radial marks are back-azimuths (BAZ) from the North triplet H11N. The central panel shows a local map off New Guinea Island. Two local flyover photos are present in the right panels; an eruption began at the summit of Kadovar Island on 05 January 2018, and then a new vent spot was created on 11 January 2018 .

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RESULTS

## IMS HA11 Wake Island & identification of volcanic eruptions

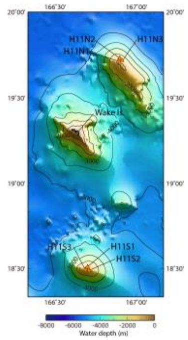


**Figure 4.** Locations of hydrophones on sea-mounts off HA11 Wake Island.

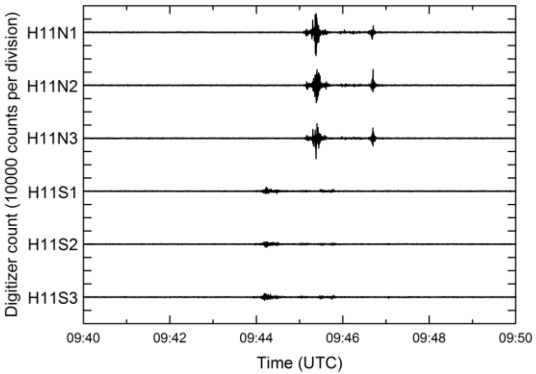


**Figure 5.** An example of HA11 typical recordings associated with the Kadovar volcano eruptions on 11 January 2018 (10-min waveforms centered at 09:45:00 UTC). A band-pass filter with 10 – 60 Hz is applied.

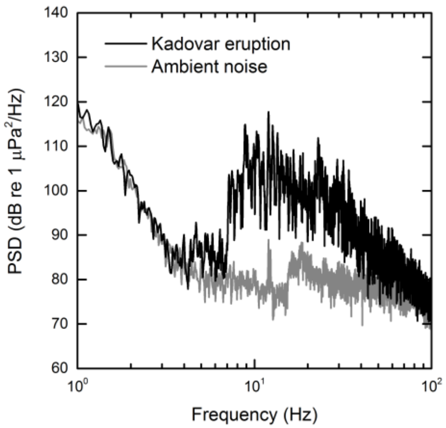


**Figure 6.** Comparison of Power Spectral Densities (PSDs) of ambient noise and a typical signal from a Kadovar volcano eruption.

The hydroacoustic signals associated with the Kadovar volcano eruption are identified at both the North and the South triplets between 09:44 UTC and 09:47 UTC, respectively (Figure 5). The Power Spectral Densities (PSDs) are calculated for these signals. Figure 6 compares PSDs between the ambient noise and the hydroacoustic signals of the Kadovar volcano eruptions. Amplitude is corrected by the Frequency-Amplitude-Phase (FAP) response of the hydrophones. The hydroacoustic signals associated with the volcanic eruptions are characterized by broad-band energy.

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RESULTS

## Direction-of-arrivals (DOA) of hydroacoustic signals

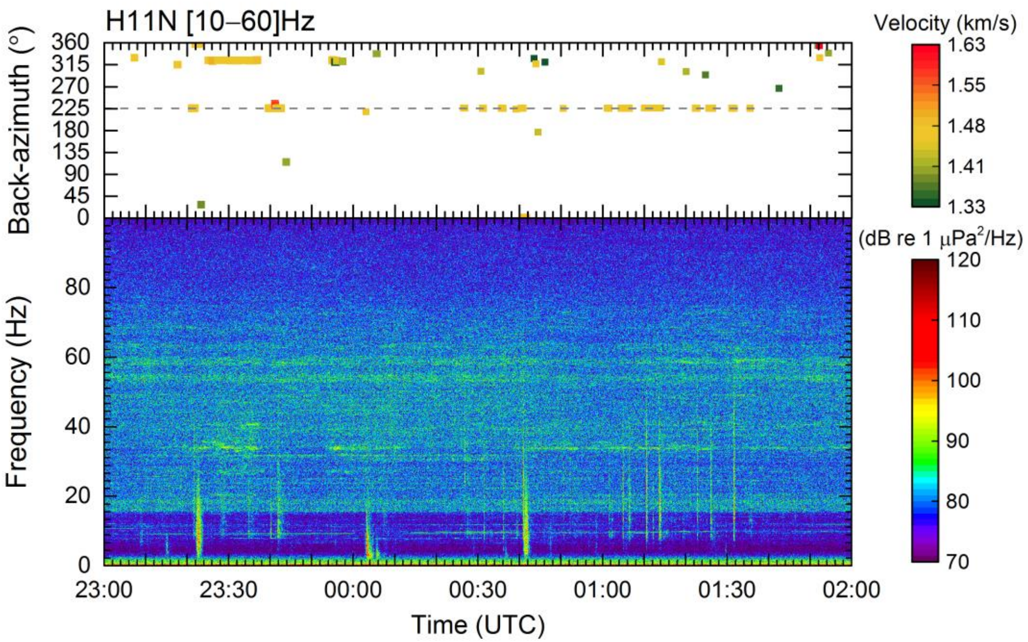


**Figure 7.** Back-azimuth evaluated by the cross-correlation analysis of H11N and the corresponding spectrogram on 09 February 2018.

The back-azimuth of the signals detected by H11N, together with the corresponding spectrogram, are shown in Figure 7. Before the cross-correlation analysis, a digitial filter with pass-band 10 – 60 Hz is applied. Each of the plotted dots is calculated with a 30-s time window and a 25-s over-lap. The dashed line represents the true back-azimuth to Kadovar. The cross-correlation analysis suggests that the Kadovar volcano erupted very frequently from 00:20 UTC to 01:40 UTC. Long-duration signals with a frequency content below 30 Hz in the spectrogram can be associated with seismicity in the Pacific; the 23:23 UTC, 00:04 UTC and 00:42 UTC signals correspond to earthquakes off Kamchatka (M3.5), Papua New Guinea (M4.7) and a previously unknown signal from a north-north-western direction, respectively.

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RESULTS

## Hydroacoustic signals associated with the Kadvar volcanic activity

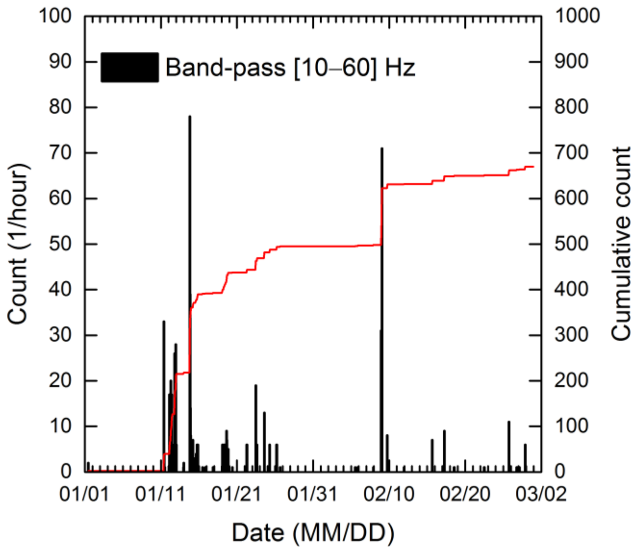


**Figure 8.** Histograms of cross-correlation analysis for January and February 2018. Note that the dataset is not available for the entire period, because of a temporary outage between 05 and 10 January 2018.

Each bin in Figure 8 shows counts of hourly detections of H11N hydroacoustic signals with a DOA consistent with sources at Kadovar. The red curve shows the cumulative detections of H11N hydroacoustic signals. A 30-s time-window with 25-s over-lap is used for cross-correlation analysis to associate the signals with volcanic activity over time. The time window overlap may lead to a slight over-estimation of the counts, similarly to what was found in previous work (Martsumoto *et al.*, 2019, *Sci. Rep.*). Arrivals between 5 and 10 January could not be identified because of a brief temporary outage of HA11, therefore the absence of arrivals during this period cannot be associated with a reduction of volcanic activity during those 5 days. With this caveat in mind, our results suggest that the Kadovar volcanic activity can be divided into two stages separated by a one-moth relatively quiet period; the first burst of activity was identified between 11 and 13 January 2018, and the second one was identified around 09 February 2018. These identifications correspond well with the available documentation and reports of flyover observations pertaining to the Kadovar volcano eruptive activity during this period.

# Hydroacoustic observations using Distributed Acoustic Sensing technology on a fiber-optic submarine cable

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## CONCLUSIONS

1. The hydroacoustic detections at HA11 from the Kadovar volcanic eruptions for January and February 2018 were supported by flyover observations and documentation.

2. Estimation of the direction-of-arrival (DOA) of the signals recorded at HA11 by cross-correlation analysis made it possible to identify hydroacoustic arrivals from the volcanic activity at Kadovar.

3. Using the time-frequency characteristics of the arrivals, the present study made it possible to discriminate between volcanic eruptions and seismicity.

**Acknowledgements**
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