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Hydroacoustic observatory of Mayotte volcano: preliminary results

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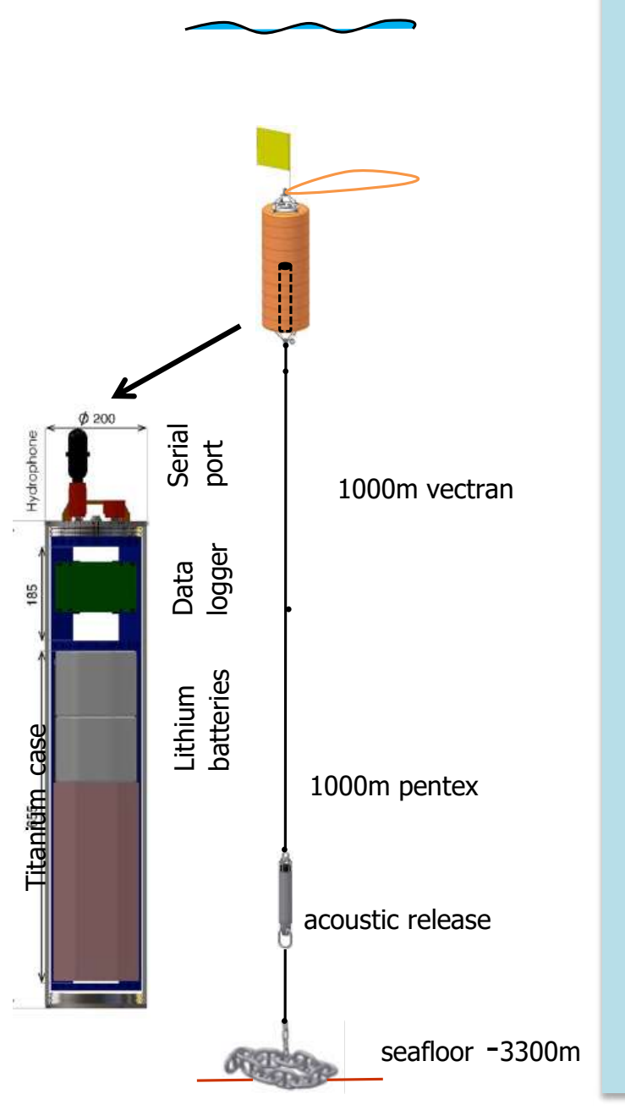
A new underwater volcano was discovered in 2019 by 3500 meter water depth, 50 km east of Mayotte archipelago in the Mozambique Channel. The eruption is still on-going and is monitored by the recently created REVOSIMA observatory. The associated seismicity recorded by ocean bottom seismometers forms two deep clusters located 10 km east of Mayotte and between this first cluster and the new volcano. A deep-tow camera survey evidenced fresh lava flowing NW of the volcano summit. In October 2020, we moored 4 hydrophones in the SOFAR channel surrounding the volcano (50km away) to monitor these volcanic flows and explosions. The first six months of hydroacoustic data recorded many earthquakes, underwater landslides, large marine mammal calls, and anthropogenic noise. Of interest are some impulsive signals that may be generated during lava flows. If confirmed these sounds would be of great help to detect and monitor active underwater eruptions in the absence of seafloor deep-tow or repeated multibeam surveys. Detection of pygmy blue whale calls from October to December 2020 and unattributed large whale calls assess the importance of this area for endangered marine species. The limited size of array may also allow to track some of them.,



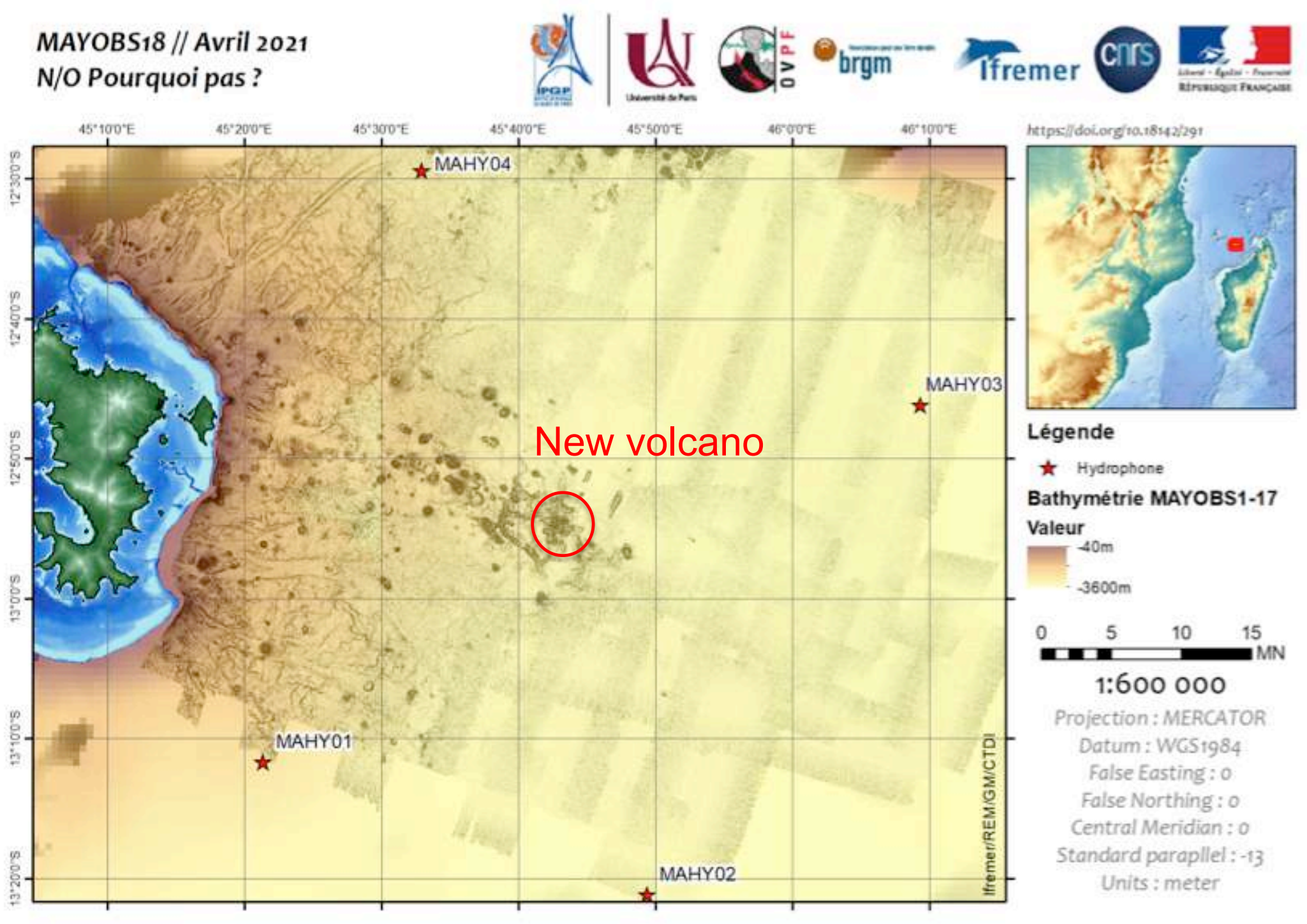
Acoustics for studying marine geophysics

Mooring networks of autonomous hydrophones (AUHs) is an effective way to monitor the oceanic sound sources. For more than 10 years, the LGO at IUEM has been maintaining in the open ocean hydroacoustic networks, composed of a few AUHs moored in the Sound Fixing and Ranging (SOFAR) channel, which acts as an acoustic waveguide, carrying sounds over thousands of kilometers (Fox et al., 2000). Those arrays have been deployed along mid-ocean ridges in the North Atlantic and the Indian Ocean (Royer et al., 2015). A recent analysis of hydroacoustic clusters along the South West Indian Ridge has been able to quantify the relative contribution of tectonic and volcanic activities, in order to better understand the accretionary processes at mid-ocean ridges (Ingale et al., 2021, and poster). Chadwick et al. (2008) reported the first co-registered hydroacoustic and video recordings of an actively erupting submarine volcano in the Mariana Arc. Since this first observation, the use of hydroacoustic arrays to monitor underwater volcanoes has developed and triggered a new research field. For example, Axial Seamount, which is the most active submarine volcano in the NE Pacific, has become the best monitored submarine volcano in the world. Amongst the monitoring tools that can be deployed on underwater volcanoes, hydroacoustics provides an exceptional window into eruption dynamics.

Geological context

Mayotte is a volcanic island which is part of the Comoros archipelago, and located in the northern part of Mozambique Channel between Africa and Madagascar. The archipelago was formed by intraplate volcanism in oceanic context. Since May 10 2018, Mayotte Island has experienced intense seismicity (Lemoine et al., 2020). The first scientific cruise, MAYOBS1, took place only in May 2019 and revealed that this seismic event gave birth to a 820m tall volcanic edifice, whose summit reaches 1900 m depth (Feuillet et al., 2021). The volume of erupted material during the 2014-2019 period is at least 5.0 ± 0.3 km3. 21 scientific cruises have been planned in order to monitor the volcano activity since the onset of the seismic crisis. Successive ship-borne multibeam surveys have revealed changes in the bathymetry, indicating new lava deposits. After 2019, the main volcano edifice stopped growing and only lateral flows were observed.

In October 2020, onboard the MAYOBS15 cruise, we moored four AUHs in the SOFAR channel at 1300 mbsl (meters below sea level). They were located 50km around the new volcano (see map). The MAHY instruments were maintained during the MAYOBS18 cruise in April 2021 and during the MAYOBS21 cruise in October 2021.



Instruments and data processing

The instruments deployed for the investigation were initially designed by NOAA's Pacific Marine Environmental Laboratory (PMEL, Fox et al., 2001) and later modified by the LGO at IUEM. They continuously record low-frequency sounds (0-120Hz) at 250 Hz. A high-precision TCXO clock is synchronized with a GPS clock prior to deployment and after recovery. The instrument clock drift is usually on the order of 1-2s over 1-year deployments. We use a software developed by PMEL, called Seasick, for visualization and picking of the time arrivals. Using at least three arrival times, the software determines the origin time and localization of the source. Because of the long duration of the recordings, only a subset of the annual dataset has been handpicked so far.

Recordings during the first year deployment

The four AUHs recorded 100% of data during the first 6 months of deployment (Figure 1). Three AUHs recorded 100%, 86% and 77% of data during the second 6 months of deployment (Figure 2). The fourth instrument still needs to be recovered.

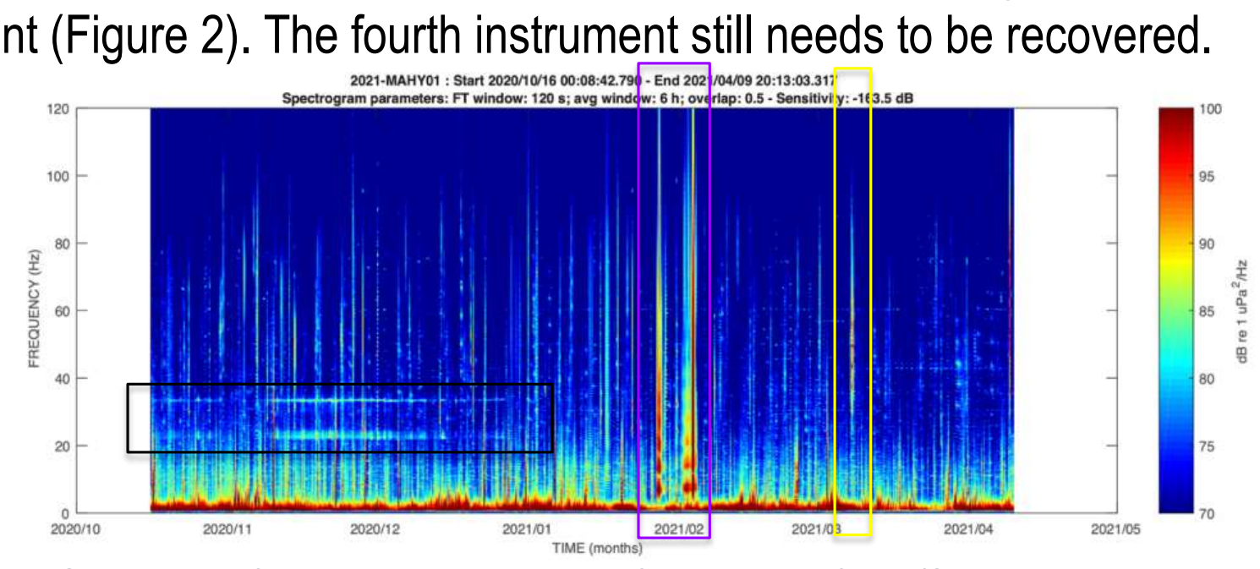


Figure 1: Spectrogram of instrument MAHY3 over the first 6 months of data (Octobre 2020 to April 2021).

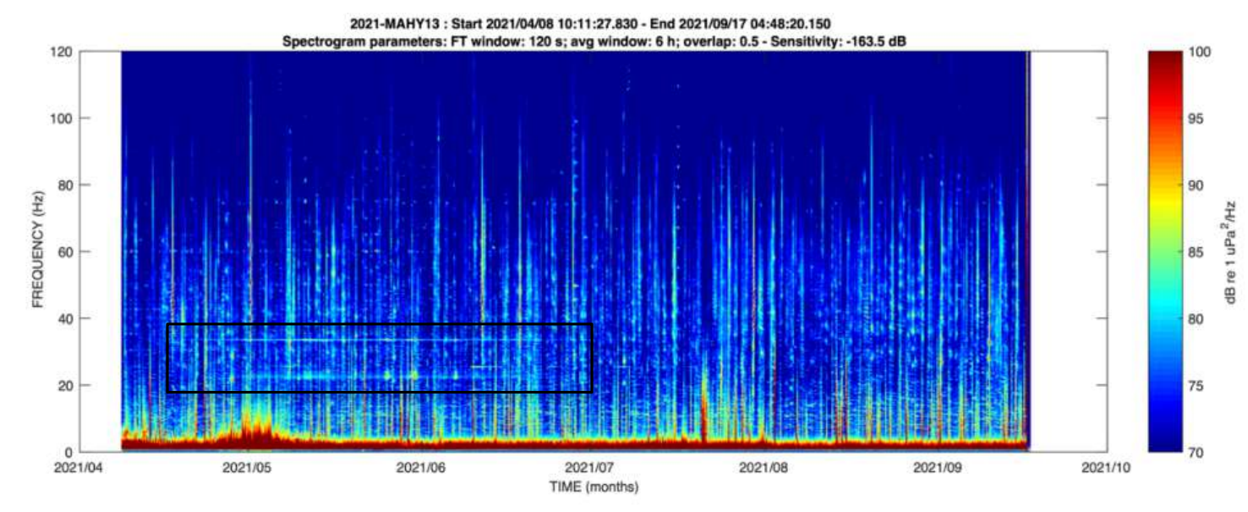


Figure 2: Spectrogram of instrument MAHY3 over the sedond 5.5 months of data (April 2021 to October 2021).

Amongst the different types of sources:

- Ship noise and 3 seismic surveys (SISMAORE 1&2, CARAPASS, in purple) are clearly visible on the spectrograms. Those time periods are too noisy for any detection of other types of sources.
- **Blue whale** songs are recorded during two different seasons (October-December & May-June, in black). Other species are also detected and, thanks to the array dimension, we were able to localize the origin of a few songs.
- **Local and regional seismicity** is recorded thanks to the T-waves (red in Figure 1 and Figure 3) generated by the conversion of seismic energy into hydroacoustic energy, at the seafloor. Unfortunately the localization of the T-waves are not at the epicenters (because of the earthquakes depths, 25 to 50km) and are therefore not of any use.
- **Impulsive events** which are energetic and of short duration (<10 sec) compared with the T-phase generated by earthquakes (see also Ingale et al. poster). Their short durations indicate that they are H-waves, meaning that the energy is released directly in the water and does not travel in the solid crust. We propose that they are generated by thermal explosions when hot lava is in contact with water. They are therefore indicative of new lava flows.

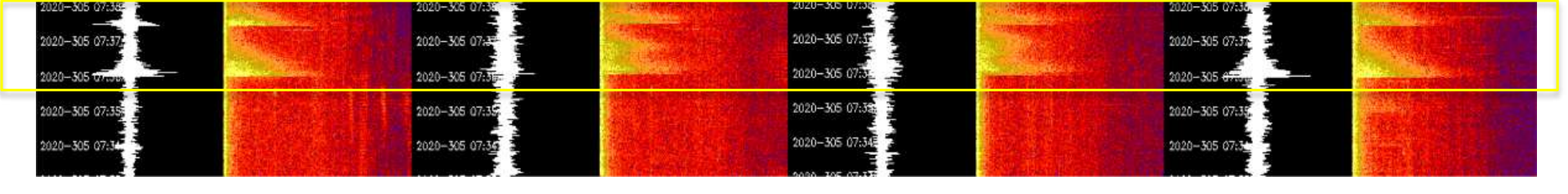


Figure 3: Seasick visualization of the raw signal (in white) and the spectrum (in colors) between 1 and 120 Hz for the 4 AUHs. Each time increment corresponds to 1 min. Notice the difference in signatures between the T phase earthquakes (2 events, in yellow) and an impulsive (in red).

Preliminary detection results

The impulsive events are not visible of the yearly spectrograms, they need to be detected visually. Because of the long duration of the recordings, only a subset of the annual dataset has been handpicked so far. Our strategy was to pick and locate all the impulsive events observed during days of strong activity. Figure 4 shows the localisation of impulsive events localized on 11/15/2020. Most of the impulsive events occurred within a new lava flow located ~5km NW of the new volcano edifice. Successive ship-borne multibeam paths can be compared in order to detect new lava deposits and calculate their surface and volumes.

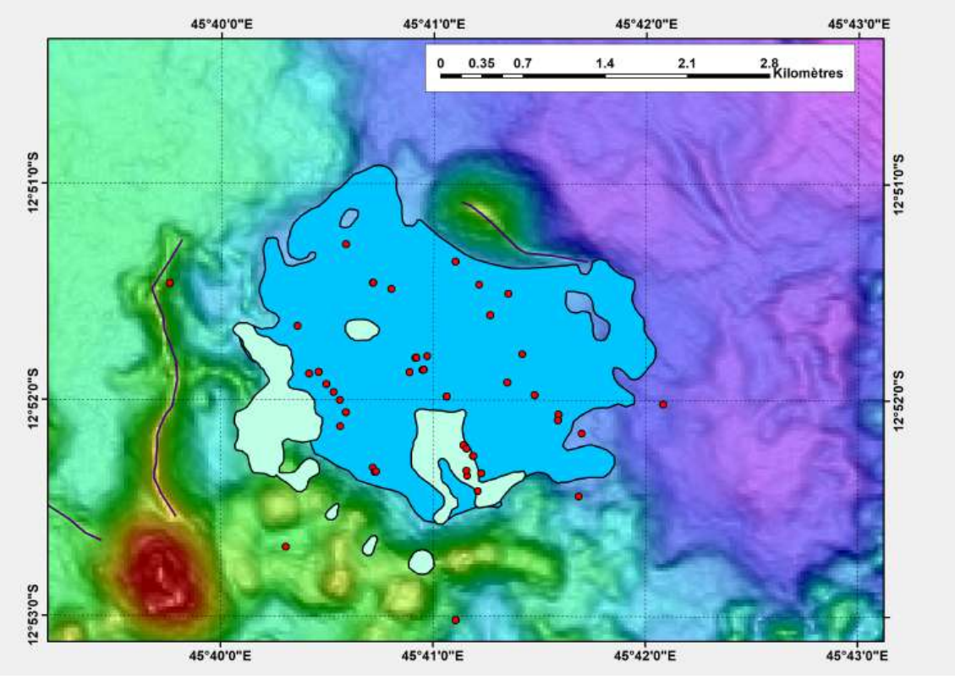


Figure 4 : Bathymetry and contours of two new lava flows (blue contours) detected by successive multibeam paths a few days before 11/15/2021. The impulsive events (red dots) occured in these fresh flows. Their linear alignments may indicate eruptive fissures, not detectable by ship-borne multibeam.

The same dataset was processed with an automatic detection tool of songs of pygmy blue whales from Madagascar (Figure 5, Torterotot , 2020). Unexpectively they were present in the area from October to December (see also Samaran et al. poster).

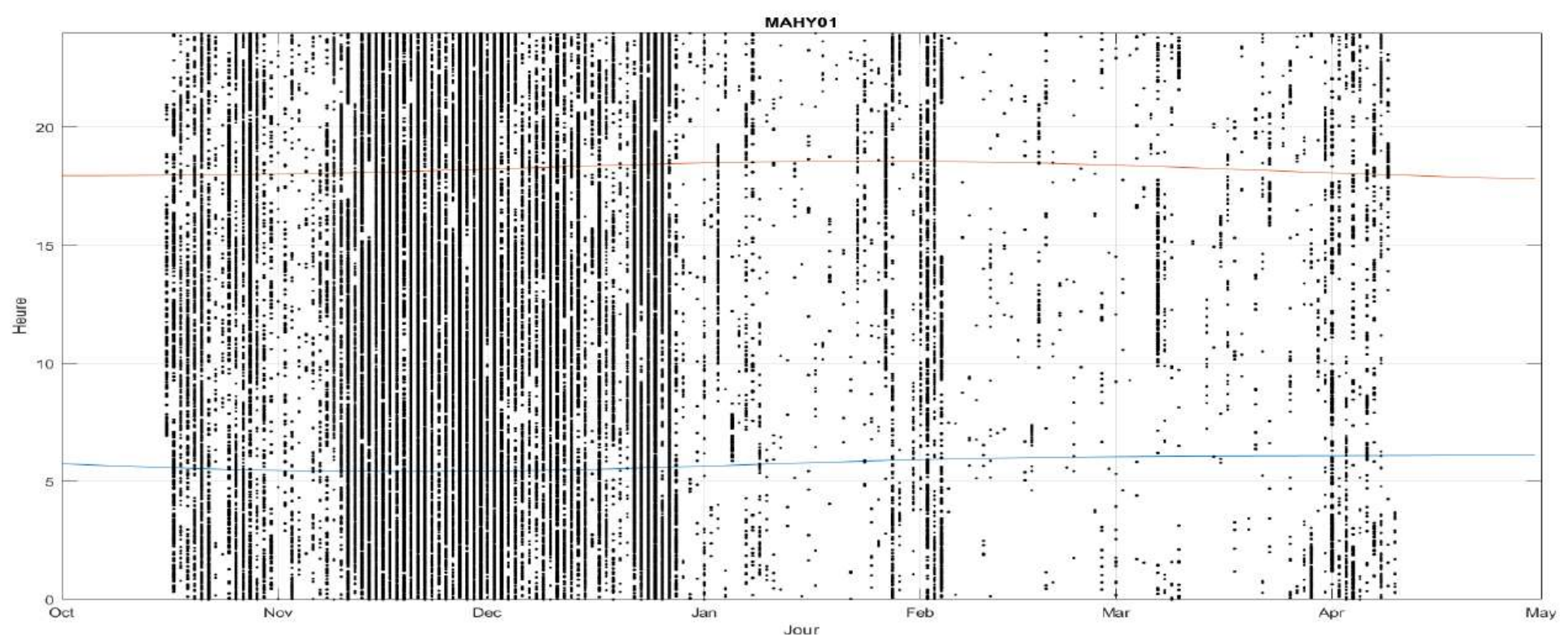


Figure 5 : Automatic detections of vocalizations of pygmy blue whales from Madagascar according to the day at the MAHY01 site (first 6 months of data). The blue line is sunrise time and the red line is sunset. Local time is UTC +3.

Conclusions

Impulsive event catalogs can characterize the Mayotte volcano activity and will help quantify the risk for the Mayotte population and for the local ship activity.
Bioacoustic catalogs will be used to establish statistics on the presence of marine mammals and its evolution over the years, a key to developing conservation measures for biodiversity.
This new monitoring network shows the high potential of collaborations from multiple disciplines for the analysis of common hydroacoustic data. Automatic detection tools are under development.

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Acknowledgments

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