Automatic detection and location of hydro-acoustic signals linked to Mayotte submarine eruption

Submarine volcanic eruptions generate numerous seismic and hydro-acoustic signals (West Mata, Axial Seamount). Some hydro-acoustic signals have been associated with explosions due to the contact between hot lava and sea water or lava flow collapse.
The ongoing activity in Mayotte since May 2018 is the largest basaltic eruption for its length and volume since the Laki eruption in Iceland in 1784 (Feuillet et al., 2021). A seismic activity that persists today is happening along with the eruption.

The manual analysis of the continuous signals recorded by ocean bottom seismometers (OBS) have highlighted the recording of hydro-acoustic signals (propagating in the water column). These ocean bottom seismometers are equipped with a geophone and a hydrophone and have recorded multiple hydro-acoustic signals. Hundreds of events have been identified during analyses of deployment data since 2019.

Thanks to the location of some of these events, these signals have been associated with the active lava flows that have been observed through bathymetric studies (Figure 1). Consequently, these signals are indicators of the active lava flows and their evolution.

The analysis of a line of ocean bottom seismometers (micrOBS) deployed during 10 days in October 2020 during the Mayobs15 oceanographic campaign highlighted the time evolution of the location of the sources of hydro-acoustic signals.

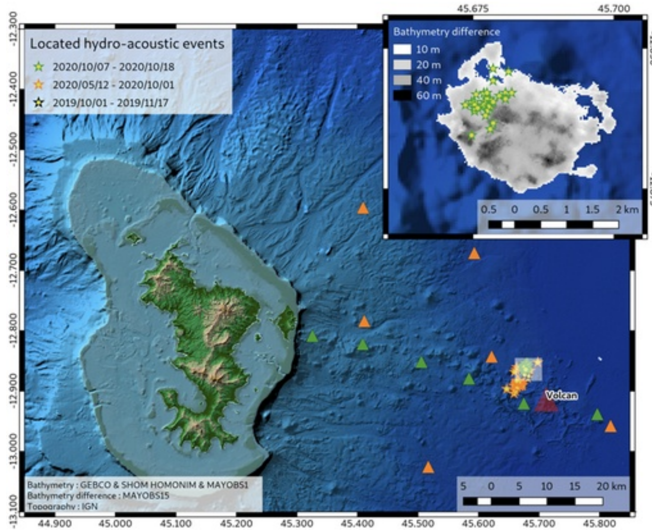

Figure 1: The orange and green triangles represent the OBS locations during two deployments late 2019 and in October 2020 respectively. The stars represent events located during these two deployments. The insert represents a zoom of the last active flow area and the bathymetric differential observed during Mayobs15 (green deployment).

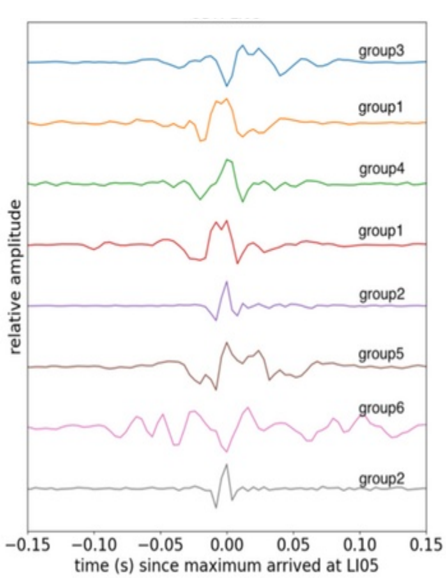

Figure 2: Signal example of 8 events on an hydrophone close to the sources.

The goal of this internship is to automatically detect and locate the hydro-acoustic signals on the OBS continuous recordings since the first deployment in February 2019, until 2021. These events were first handpicked on a small number of deployments starting from the end of 2019, when they were first identified. On each OBS stations, the hydro-acoustic signals are recorded both on the 3 components geophone and on the hydrophone (with usually shows clearer arrivals). Depending on the deployment, the sampling rate of the continuous timeseries varies from 62.5 Hz to 250 Hz with 4 to 16 stations deployed at a time.

A previous work on a 10-days deployment has shown that several types of waveforms are recorded related to these signals (Figure 2), although all of them have a duration of less than 0.1s. Because of the high level of seismicity in Mayotte and because of instrumental noise and glitches, it's challenging to identify these small signals and discriminate them from other sources in the OBS continuous recordings. Another challenge is the amount and variety of data and instruments to be processed with sometimes more than two years of data recorded on a few stations with broadband hydrophones and shorter deployments with more than ten stations equipped with short-period hydrophones.

Template matching techniques are a solution to detect low signal to noise ratio signals such as these hydro-acoustic records. The first step of this internship will result in a long-term catalog of hydro-acoustic events since 2019. It will give insight on the activity level of the lava flows through time. This will dramatically improve the resolution of the lava flow timeline estimates that are currently only constrained by the bathymetry surveys which only occur a few times a year.

Hydro-acoustics waves propagates through the water column. From the source location to the instruments, waves can be reflected several times between the sea-surface and the sea-floor. The second goal of this work is to locate the events detected. During the different marine surveys, several water column sounding have been done and give information on the sound velocity profiles in the area. Together with hydro-acoustic waves propagation modeling, travel-time tables will be elaborated and used with a location algorithm. The challenge in this task will be to correctly estimate how the different uncertainties involved in the wave propagation modeling impact the final location accuracy. The resulting map of locations will be compared with the active lava flows maps recovered from bathymetric surveys.

This work will improve our knowledge of the lava flow history for this exceptional eruption in Mayotte, which is today sparsely understood. Indeed, the timeline of the different lava flow structures and morphologies creation is still largely unknown and under-constrained by the sparse bathymetry surveys. Within 4 years, the MARMOR project will install 3 permanent ocean-bottom stations with real-time data transfer which will allow continuous monitoring of Mayotte current and future submarine eruptions. The results of this internship will pave the way for operational algorithms that could be used on the real-time data of this future permanent sea-floor cabled observatory in Mayotte.

Location : Institut de physique du globe de Paris (Paris)

Supervisors: Jean-Marie Saurel (IPGP) saurel@ipgp.fr, Lise Retailleau (IPGP/OVPF) retailleau@ipgp.fr, Valérie Ferrazzini (IPGP/OVPF), Clément Hibert (ITES), Themis Palpanas (LIPADE).

References

J. Caplan-Auerbach, R. P. Dziak, J. Haxel, D. R. Bohnenstiehl, and C. Garcia. 2016. Explosive processes during the 2015 eruption of Axial Seamount, as recorded by seafloor hydrophones ; Geochemistry, Geophysics, Geosystems ; doi :10.1002/2016GC006734 .

Nathalie Feuillet, Stephan Jorry, Wayne C. Crawford, Christine Deplus, Isabelle Thinon, Eric Jacques, Jean Marie Saurel, Anne Lemoine, Fabien Paquet, Claudio Satriano, Chastity Aiken, Océane Foix, Philippe Kowalski, Angèle Laurent, Emmanuel Rinnert, Cécile Cathalot, Jean-Pierre Donval, Vivien Guyader, Arnaud Gaillot, Carla Scalabrin, Manuel Moreira, Aline Peltier, François Beauducel, Raphaël Grandin, Valérie Ballu, Romuald Daniel, Pascal Pelleau, Jérémy Gomez, Simon Besançon, Louis Geli, Pascal Bernard, Patrick Bachelery, Yves Fouquet, Didier Bertil, Arnaud Lemarchand and Jérome Van der Woerd. 2021. Birth of a large volcanic edifice offshore Mayotte via lithosphere-scale dyke intrusion ; Nature Geoscience ; doi :10.1038/s41561-021-00809-x .

M. Le Saout, D. R. Bohnenstiehl, J. B. Paduan, and D. A. Clague. 2020. Quantification of Eruption Dynamics on the North Rift at Axial Seamount, Juan de Fuca Ridge ; Geochemistry, Geophysics, Geosystems ; doi :10.1029/2020GC009136 .

William S. D. Wilcock, Maya Tolstoy, Felix Waldhauser, Charles Garcia, Yen Joe Tan, DelWayne R. Bohnenstiehl, Jacqueline Caplan-Auerbach, Robert P. Dziak, Adrien F. Arnulf, M. Everett Mann. 2016. Seismic constraints on caldera dynamics from the 2015 Axial Seamount eruption ; Science ; doi :10.1126/science.aah5563 .