# Detection, location and characterization of VLF events during the 2018-2019 seismovolcanic crisis in Mayotte

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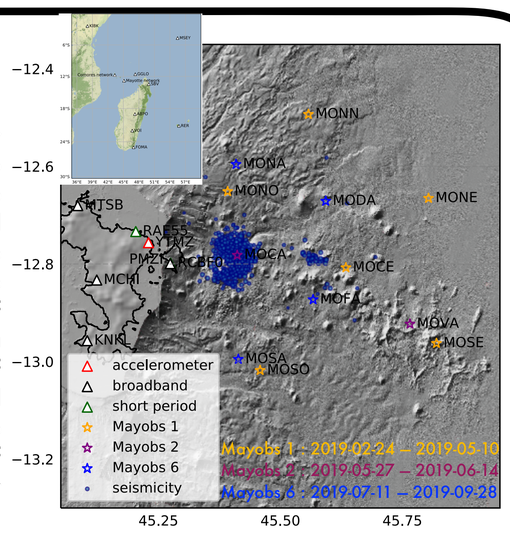
**The seismovolcanic crisis of Mayotte started in May 2018 with a sudden activation of seismicity to the east of the island. Along with thousands of volcano-tectonic earthquakes, an energetic very low frequency signal (VLF, 15 seconds of period) was recorded on November 11, 2018 at seismic stations worldwide. This exceptional monochromatic signal was not an isolated event: in this study we detected and analyze several hundredths of such signals, all along the duration of the Mayotte crisis.**

**We used two different type of detectors: a STA/LTA triggering on band-passed filtered traces and a time-frequency detector based on the signal spectrogram. The data comes from local and regional stations in Mayotte, Comores and Madagascar, and from OBH (Ocean Bottom Hydrophones) installed during marine campaigns aboard the R/V Marion Dufresne II, between May and July 2019 [Feuillet et al, 2019].**

**Event location is performed though spatial 3D back-projection of station-pair cross-correlation functions (Poiata et al., 2016), assuming surface-wave speed. To investigate the possible physical origin of such signals, we discuss different type of resonating sources.**

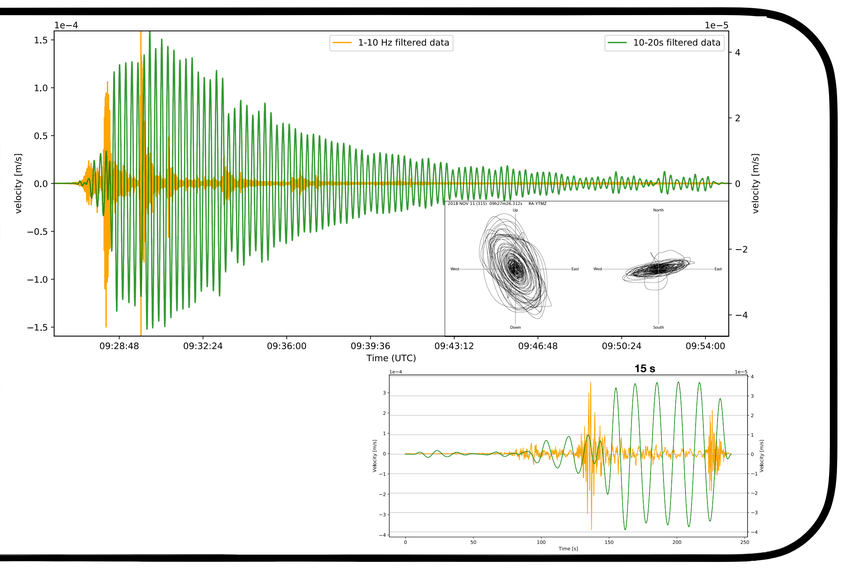
## 1. Context :

Mayotte volcano-seismic crisis started on 10 may 2018, 3 000 events manually localised in two swarms at 10 and 30 km, on sea, on the East side of Mayotte island. OBS with hydrophone channel have been deployed during severals marine campaigns. During Mayobs1, a new submarine volcano is discover around 50 km on East of Mayotte island [Feuillet, et al, 2019]. GNSS data have showed that the island is moving of a dozen of centimetres downward and toward East and vertically. These movements are interpreted as the deflation of a source at 30 km deep on the East of Mayotte. The total estimate volume on November was around 2 km³ [Lemoine et al, 2019].




## 2. Overview:

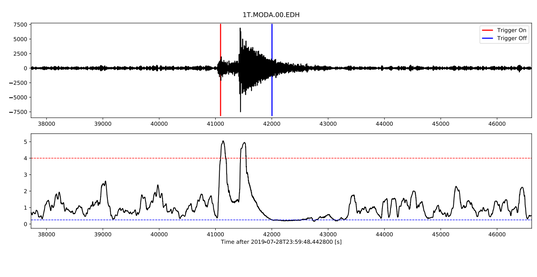
VLF major event is recorded on 2019-11-11, with a duration of 25 minutes, a central period of 15s and Rayleigh waves polarisation. The wave polarisation is retrograde and longitudinal compared to the direction of wave propagation. The hypothesis of [Lemoine et al, 2019] is oscillating fluids into a magmatic reservoir. A similar case is seen at Le Rocard submarine volcano, interpreted by [Talandier et al., 2016] as a migration of resonance fluids in an open superficial and pressurised pipe.

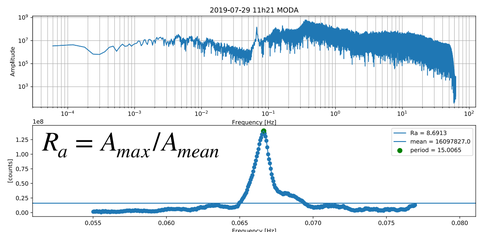



## 3. Methodology :

- **STA/LTA detector :**

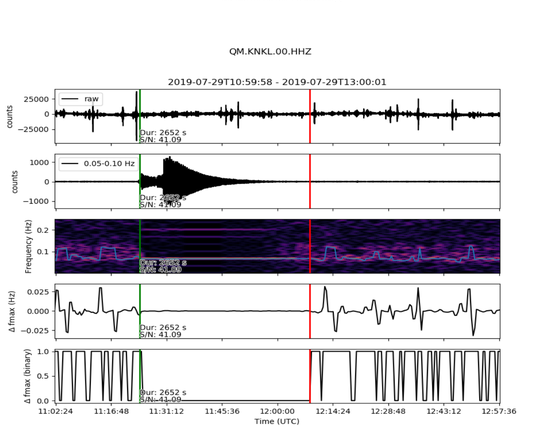
We compute STA/LTA ratio on the filtered (10-20 s) signal and use a triggering threshold of 4 (red dashed line). We only keep detected events with central period between 16 and 14.5 s, and Ra ≥ 3.



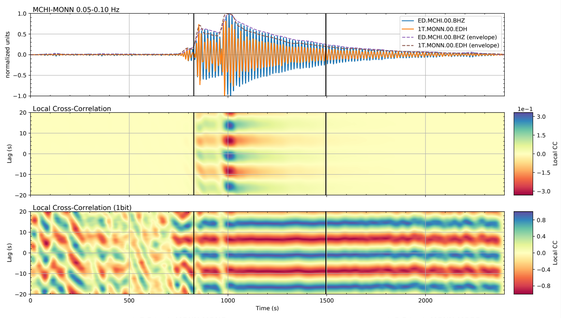

- **Spectrogram detector :**

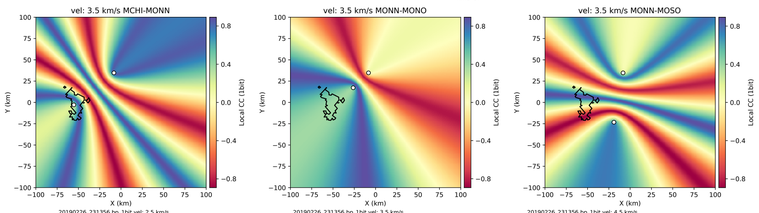
We compute the spectrogram of signals filtered between 10 and 20 s and 1-bit normalised. We then search for monochromatic transients (horizontal lines) on the spectrogram by looking at the derivative of f_max(t).



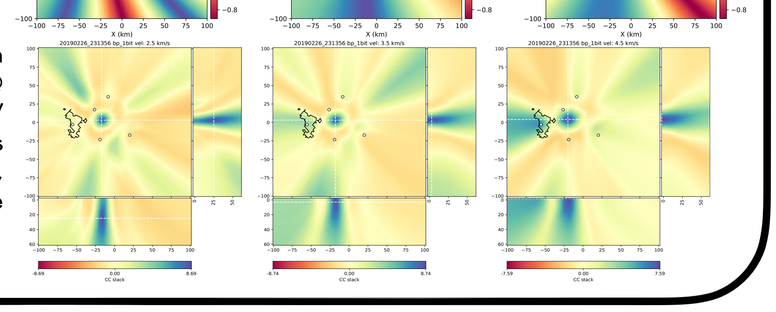

- **Back-projection localisation :**

We cross-correlate for each pair of stations (broadband and hydrophones) VLF signals filtered between 10 and 20 s and 1-bit normalised. Station-pair cross-correlations are then mapped in 3D space using a constant velocity. Cross-correlation maps are finally stacked to find the maximum likelihood source location.



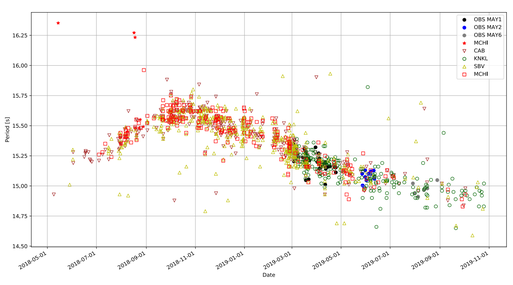

Event depth (Z) depends on chosen velocity: Z>20 km @ 2.5 km/s; Z<5 km @ 4.5 km/s. A velocity of 3.5 km/s gives depths between 5 and 20 km, in better accordance with the chosen velocity value.




## 4. Results :

- **VLFs catalog :**

All along the seismic crisis of Mayotte, we detect more than 300 events. We observe that the central period is increasing until almost 16s (oct 2018) and since is in constant decay. This change of central period of VLFs might be interpreted like the source degradation.




- **Classification :**

We performed an amplitude ratio between three band of frequencies :

Hight Frequencies (HF) : 10 - 20 Hz

Med Frequencies (MF) : 1 - 5 Hz

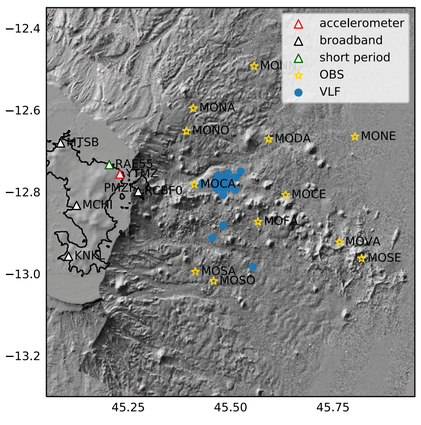
Low Frequencies (LF) : 0.05 - 0.1 Hz → 10 - 20 s

The high frequency band highlights the volcano-tectonic earthquake (VT) occurring all along the Mayotte crisis. The medium frequency band enhance the long period earthquake (LP) and the low frequency band reclaim the very low frequency signals (VLF). The aim of this classification is to determine the possible link between VT, LP and VLF, all three present in the volcanic crisis of Mayotte. Vt or LP events that occur before a VLF can be thought as precursors or triggers, in this case they can inform us about the current phenomenon.

We show three cases : VLF in the coda of a VT event (A), LP at the beginning of a VLF (B) and a VLF that seems to be “alone” (C).

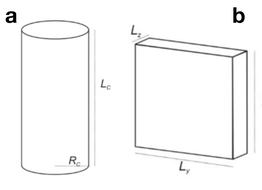
- **Localisation :**

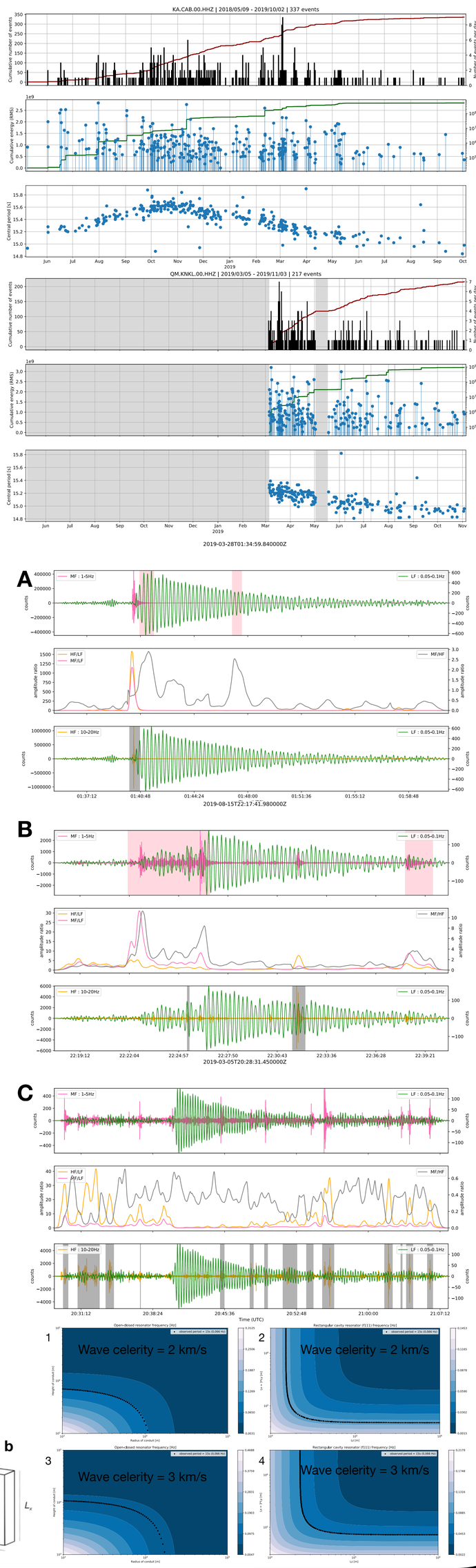
The retrieved epicentral locations are 20 km east of Petite Terre. VLFs are closer to the seismic swarm than to the volcano.




- **Resonator models :**

Fazio et al, 2018 proposed severals Tornillos sources models from laboratory experiences, we choose an open-closed pipe (a) and a rectangular cavity (b) to modelled our resonating source. It helps us to better constrain the physical dimensions of our system. According to the central period of 15s, the source of the VLFs may have a dimension of several kilometers.




## 5. Perspectives :

- ☞ Confirmation of the VLFs localisation by amplitude ratios at station pairs.
- ☞ A automatic classification of VLFs waveforms with or without VT or LP “precursors”. Analyse the frequency content and the localisation of the VT and LP signals before a VLF.
- ☞ To better understand the source phenomenon we should use a numerical modelling of the VLF waveform signal as a dumping oscillator through a medium (soil and/or water).

**Fazio, M.**, Alparone, S., Benson, P. M., Cannata, A., & Vinciguerra, S. (2019). Genesis and mechanisms controlling tornillo seismo-volcanic events in volcanic area. *Sci Rep 9, 7338. https://doi:10.1038/s41598-019-43842-y*

**Feuillet, N., et al** (in prep). Birth of a large volcanic edifice offshore Mayotte through lithosphere-scale rifting.

**Lemoine, A.**, Bertil, D., Roullé, A., & Briole, P. (2019, February 28). The volcano-tectonic crisis of 2018 east of Mayotte, Comoros islands. **https://doi.org/10.31223/osf.io/d46xj**

**Poiata, N.**, C. Satriano, J.-P. Vilotte, P. Bernard, & K. Obara. (2016). Multiband array detection and location of seismic sources recorded by dense seismic networks, *Geophys J Int, 205(3), 1548–1573, doi:10.1093/gji/ggw071*

**Talandier, J.**, Hyvernaud, O., & Maury, R. C. (May 2016).Unusual seismic activity in 2011 and 2013 at the submarine volcano rocard, society hot spot (french polynesia). *Geophysical Research Letters, 43(9) :4247–4254.https://doi.org/10.1002/ 2016gl068342.*