Suivi des essaims de sismicité volcanique en contexte de réactivation aux Petites Antilles

Seismic swarm monitoring during volcanic unrest in the Lesser Antilles

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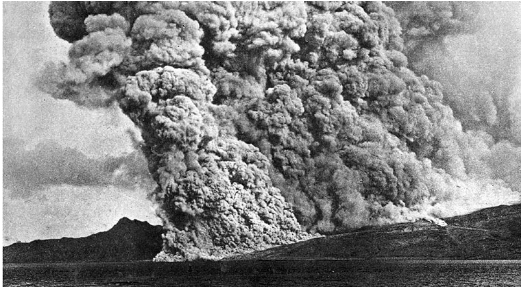
RESIF – November, 15-18, 2021

Last eruptions in Martinique and Guadeloupe

Mount Pelée

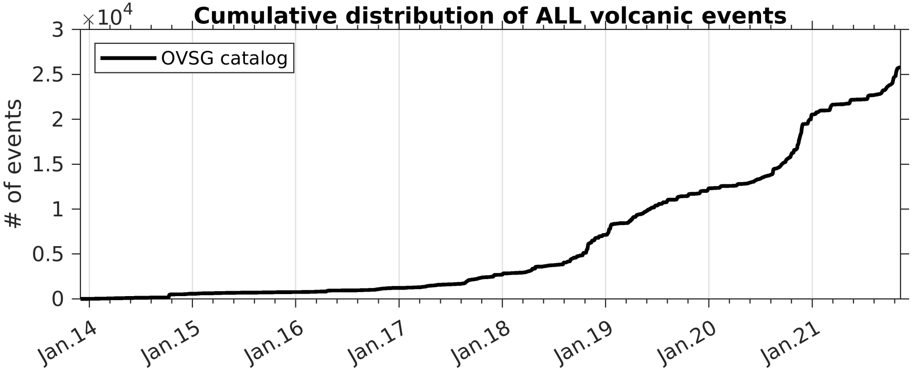


- Magmatic eruption of May 1902, 28 000 deaths
- Last eruption in October 1929
- Recent increase of seismic activity with a large diversity of events (VT, LP, harmonic tremor)

Soufrière de Guadeloupe

- Last phreatic explosion in 1976
- Eviction of about 76 000 peoples during several months
- M_L 4 earthquake in April 2018, largest earthquake recorded since 1976 crisis

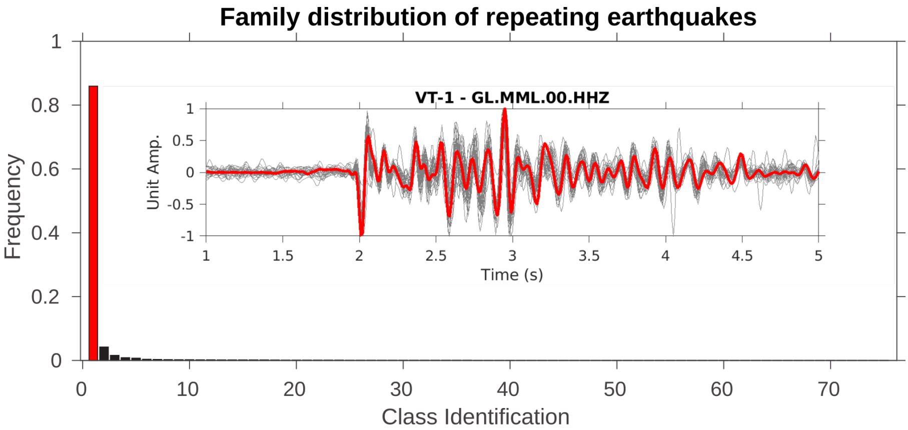
Volcanic unrest at la Soufrière de Guadeloupe



- An increase of VT number is observed since the end of year 2017
- About 95% of the VTs are located in the dome at shallow depths (< 1 km below the summit) with Md < 0.5
- This VT activity is triggered during swarm episodes, up to 3 000 events in November 2020

Repeating earthquakes at la Soufrière

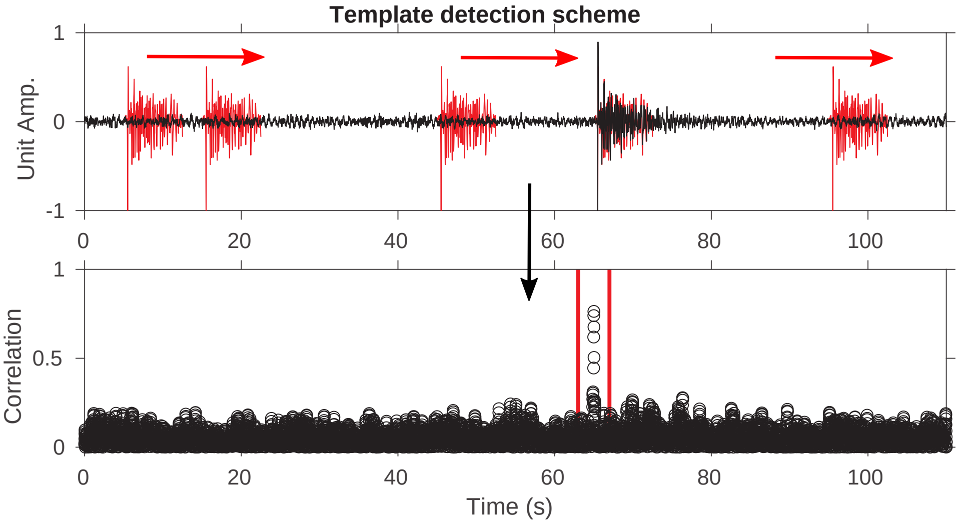
- Identification stage, cross-correlation of waveform and event association



- One repeater contributes for 85% of family association and represents a shallow VT earthquake (almost all the VT catalog)
- Deployment of a template detection to increase the catalog performance

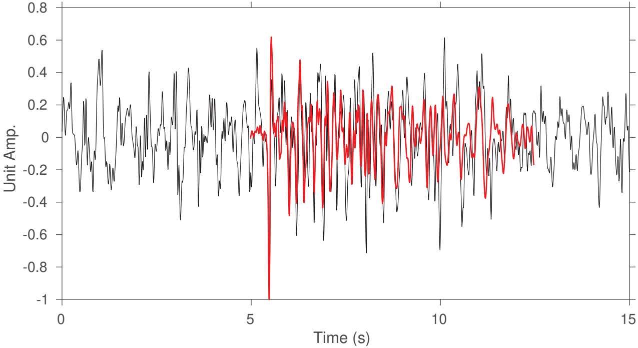
Template detection: principles and interests

- Waveform detector based on correlation estimates



Template detection: principles and interests

- Automated process unbiased by operator evolution
- Detection well beyond the “screen resolution” (visual detection in observatory)
- Still working with low Signal-to-Noise Ratio (SNR)
- Learning process (improve the MASTER waveform, include new waveforms)
- Possibility to go back in the archive of continuous seismic data



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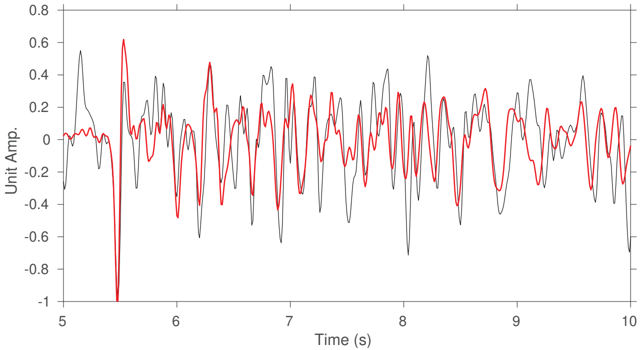
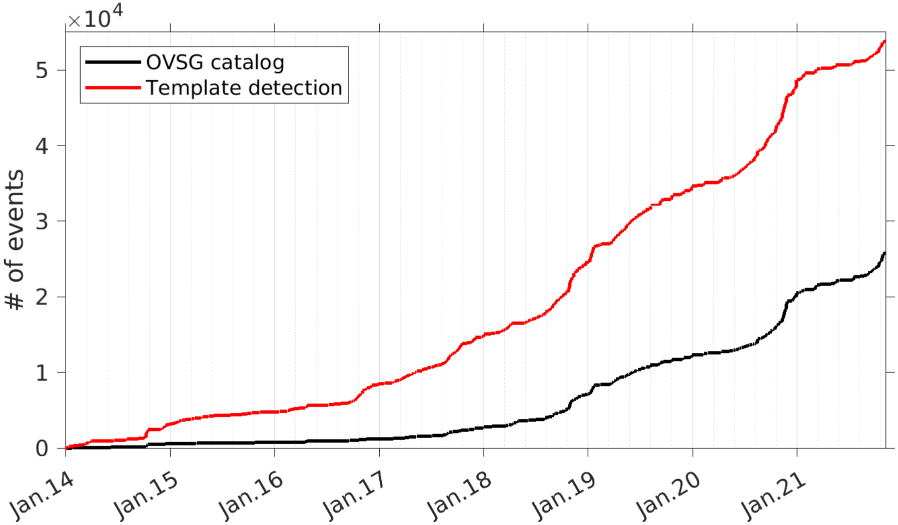


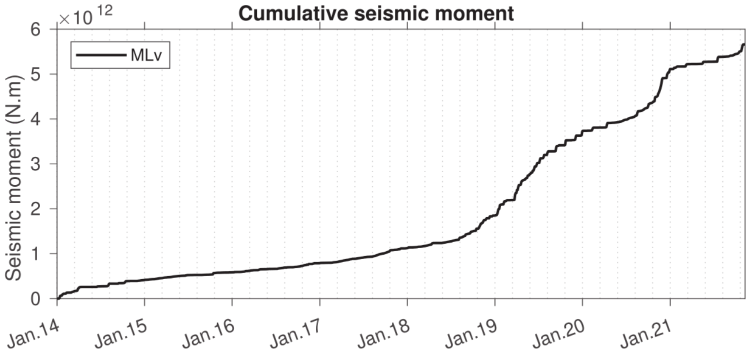
Template detection: result



⇒ Improve the VT detection and opportunity to deploy automated processes

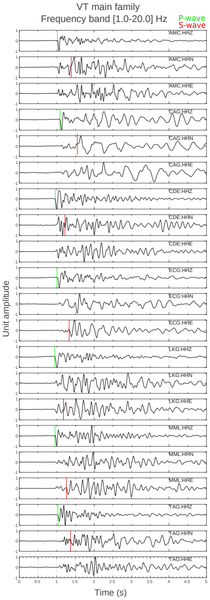
Seismic energy release in the dome

- Event magnitude estimated from signal peak amplitude with a relation scaled with duration (M_{Lv} - $M_d(M_w)$ relation)
- Interest for an automatic estimate when event duration is difficult to extract, when seismic energy and SNR is low

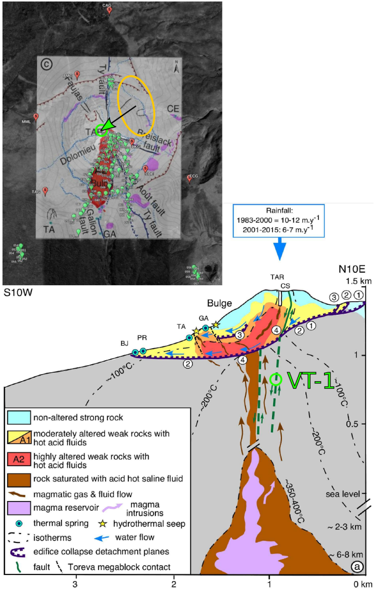


⇒ Increase of seismic moment release at shallow depth after the M_L 4 earthquake (April 2018)

VT-1 location: constraints from a dense nodal array

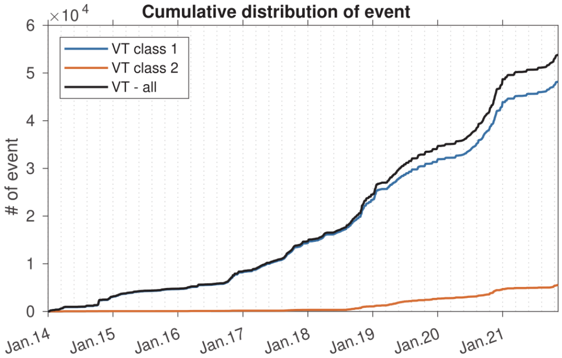


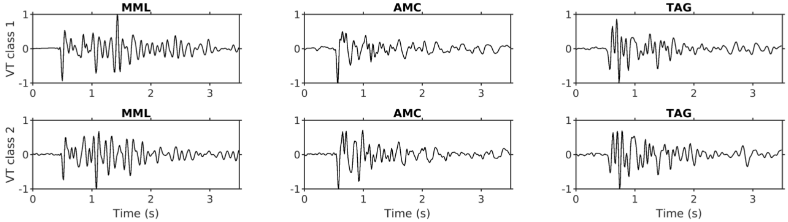
- Stacking waveforms to generate a MASTER VT-1 event with high SNR
- Picking P- and S-waves for almost all sites (76 stations more than 120 picks)
- New hypocentral location inferred from nodes (study of L. Pantobe) – below the Tarissan acid lake
- Coherent with surface activity and the anomaly of high conductivity from Rosas-Carbajal *et al.* (2016)



Evolution of VT-1 – development of VT-2

- The M_L 4 earthquake of April 28th 2018, located 3 km away from the summit, damaged the dome (velocity drop observed with dV/V)
- A new class of VT (VT-2) has developed and shares similarities with VT-1 (almost same source and origin)
- Interaction of VT-1 and VT-2: swarms of VT-1 usually precede VT-2 swarms (time scale of hours)





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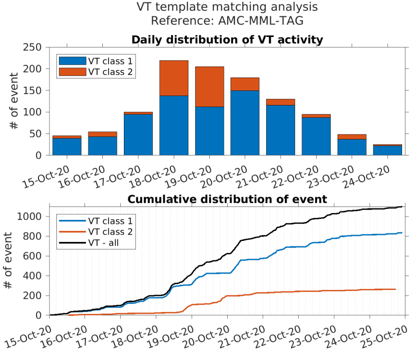
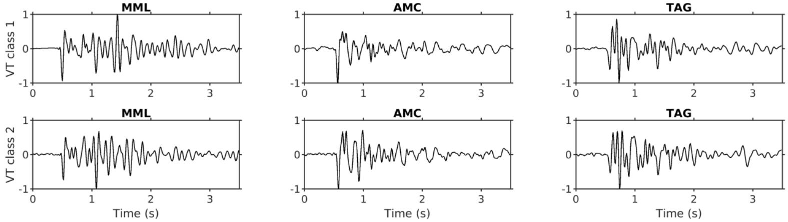
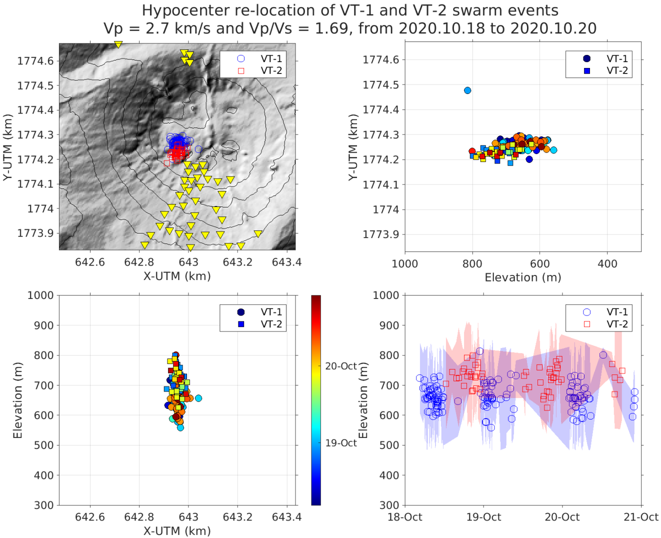




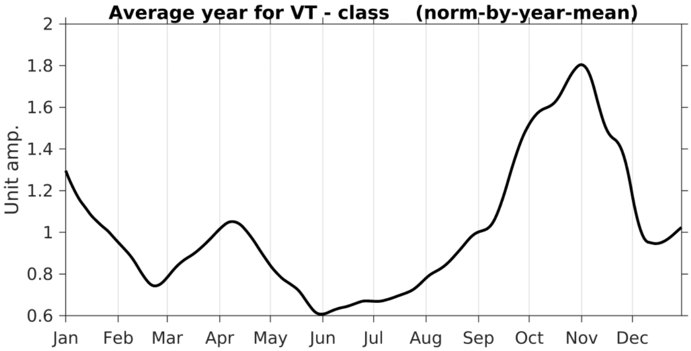
Relative location of shallow VT



- Relative location using a MASTER event procedure
- Each class has a reference location (nodal array constraints)
- Automatic P- and S-phase picking using a cross-correlation approach with respect to the MASTER P- and S-wave
- Hypocenters are aligned along a sub-vertical conduit below the Tarissan acid lake
- VT-2 above VT-1, illustrating their interactions ?

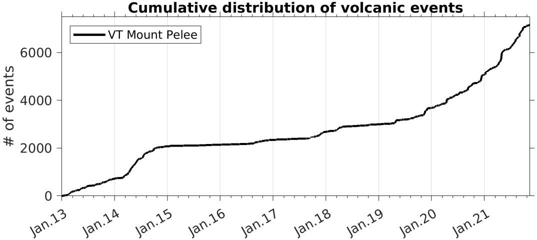
Temporal feature of shallow VT

Event rate activity during a year scale (average over 8 years):

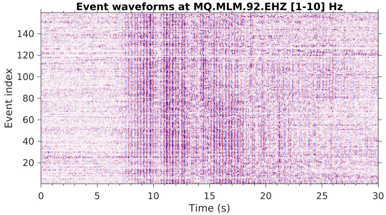


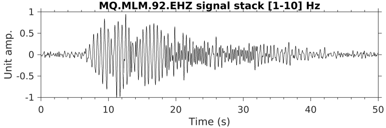
- Peak of activity from September to November during the cyclonic season (rainfall peak)
- Low activity in February and June, rebound in April
- Origin of this VT time distribution and other periods?

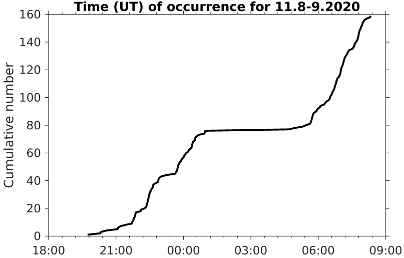
Volcanic unrest at Mount Pelée



- Signs of volcanic unrest since April 2019
- Increase number of VT with a large diversity of seismic signals (ex. harmonic tremor)
- Degassing on ground and in the sea

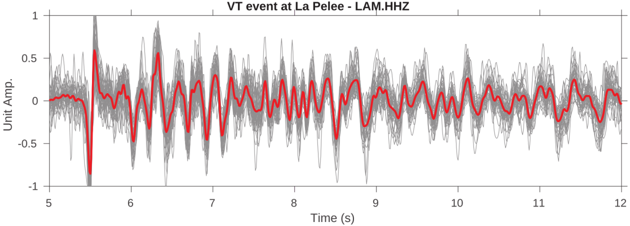






Shallow VT at Mount Pelée

- Similarities with la Soufrière de Guadeloupe with the occurrence of a repeater



- VT-1 observed for nearly 40 years (Hirn *et al.*, 1987)
- Template detection approach is possible
- Equivalent processing to characterize the spatio-temporal evolution of VT-1

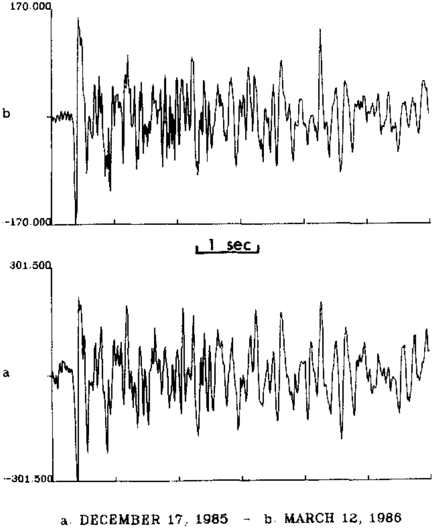


Fig. 3. Records of two Pelée events at the LAM station. The amplitudes are in arbitrary units. 170 corresponds to 3.40 microns per second

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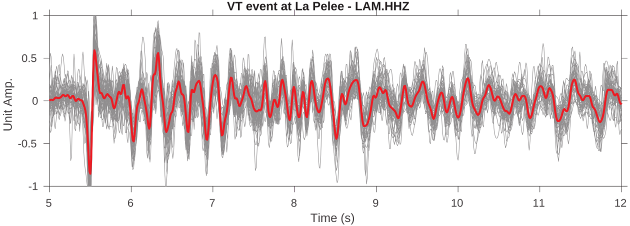

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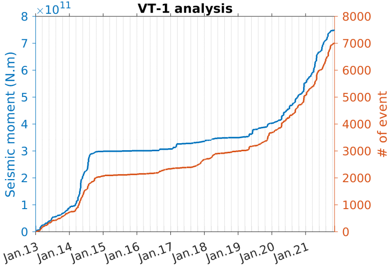

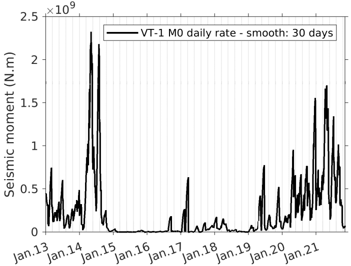

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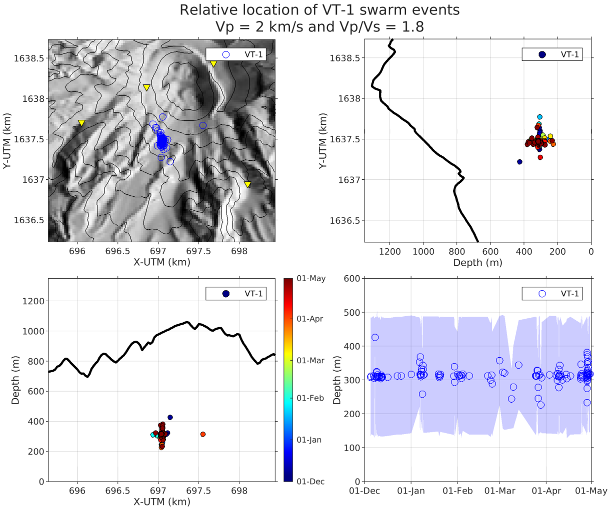
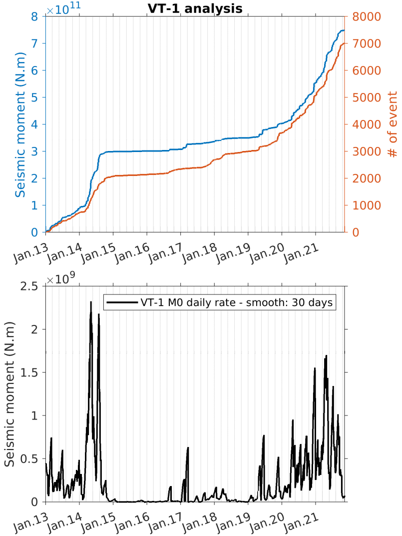
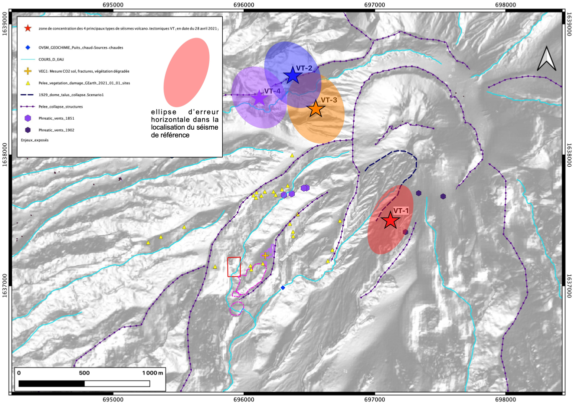
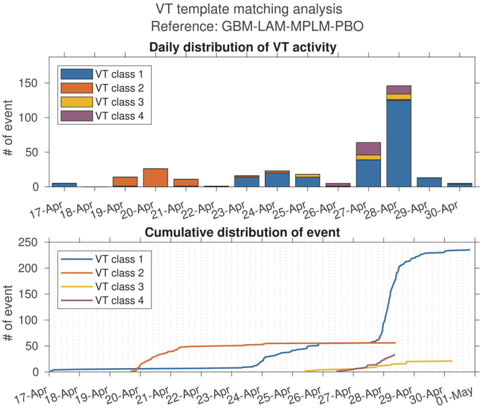




Other VT events

- End of April 2021: a peak of VT activity was observed and 3 deeper clusters of VT were detected
- Depths of $\sim$ 1.5 km (below sea-level) and many $M_d > 0$ (max. 0.9)

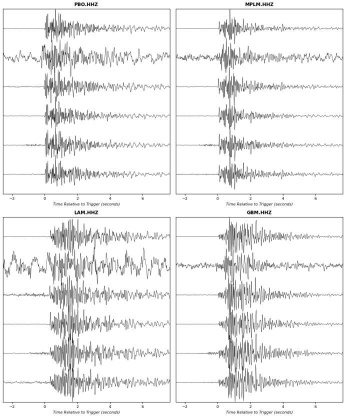


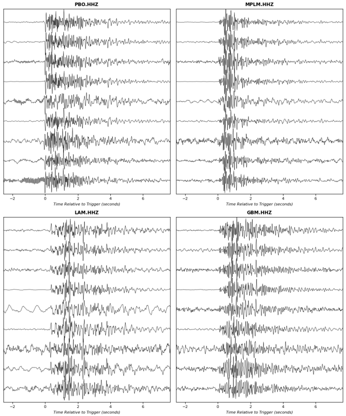


Other VT events

- Since May 2021: occurrences of high-frequency VT located in the shallow VT-1 zone ($\sim$ 0.3 km above sea-level), activation of new fractures, VT migrations?
- At least 4 repeaters are frequently observed with $M_d > 0$ (max. 1.1)
- Meanwhile VT-1 occurrences are less detected and less energetic

$\Rightarrow$ Towards an evolution of VT-1, up to the destruction?





Conclusions

Only for repeating. . .

- Occurrences of repeaters at la Soufrière de Guadeloupe and Mount Pelée in Martinique
- Swarms of shallow VT up to thousands of events (Nov. 2020 - OVSG)
- Development of procedures allowing volcanic observatory to quickly process VT events during a crisis
- Help to target new VT signals linked to an evolution of the volcanic activity (focus on waveforms which are unknown)
  - Soufrière de Guadeloupe: a strategy in practice since a new episode of intermediate depth seismicity is recently observed (new feature since April 2018)
  - Mount Pelée: following the evolution of VT activity at shallow depth (dynamics of VT-1)
- Applying these procedures on “old dataset” to better characterize the recent state of activity
  - Soufrière de Guadeloupe: what was the influence of the M_w 6.3 Les Saintes earthquake (Nov. 2004)
  - Mount Pelée: what about the previous VT activity of 2014, 2006-2007