Observatoire volcanologique du Piton de la Fournaise
INSTITUT DE PHYSIQUE DU GLOBE DE PARIS

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A - Piton de la Fournaise activity

PITON DE LA FOURNAISE (VNUM #233020)
Latitude: 21.244°S
Longitude: 55.708°E
Summit elevation: 2632 m

Piton de la Fournaise is a basaltic hot spot volcano located in the southeast of La Réunion Island (Indian Ocean).
Piton de la Fournaise first erupted about 500,000 years ago. Its volcanic activity is characterized by frequent effusive eruptions (with emissions of lava fountains and lava flows) that occur on average twice a year since 1998. More rarely, larger explosive eruptions (with blocks covering the summit area and ash emissions that can disperse over long distances) have happened in the past with a centennial recurrence rate.
Most of the current eruptive activity (97% during the last 300 years) occurs from vents inside the Enclos Fouqué caldera. A few eruptions, however, have occurred from vents outside the caldera (most recently in 1977, 1986, and 1998). Such eruption can potentially threaten communities.
Since late 1979, the activity of Piton de la Fournaise is monitored by the Piton de la Fournaise Volcanological Observatory (Observatoire Volcanologique du Piton de la Fournaise - OVPF), which belongs to the Institut de Physique du Globe de Paris (IPGP).

Volcano Alert level: Vigilance
(since April 5, 2019)

(see table in appendix)

Seismicity

In May 2019, the OVPF recorded at Piton de La Fournaise:

- 329 shallow volcano-tectonic earthquakes (0 to 2 km depth) below the summit craters;
- 3 deep earthquakes (>2 km depth);
- 229 rockfalls (inside the Cratère Dolomieu or along the cliff of the Enclos Fouqué caldera).

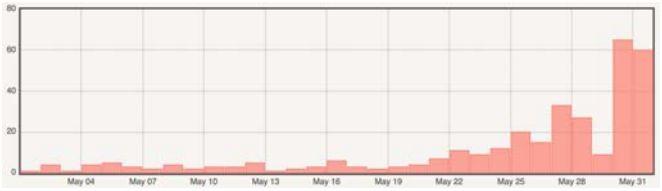

***Figure 1**: Daily number of shallow volcano-tectonic earthquakes recorded in May 2019 (© OVPF-IPGP).*

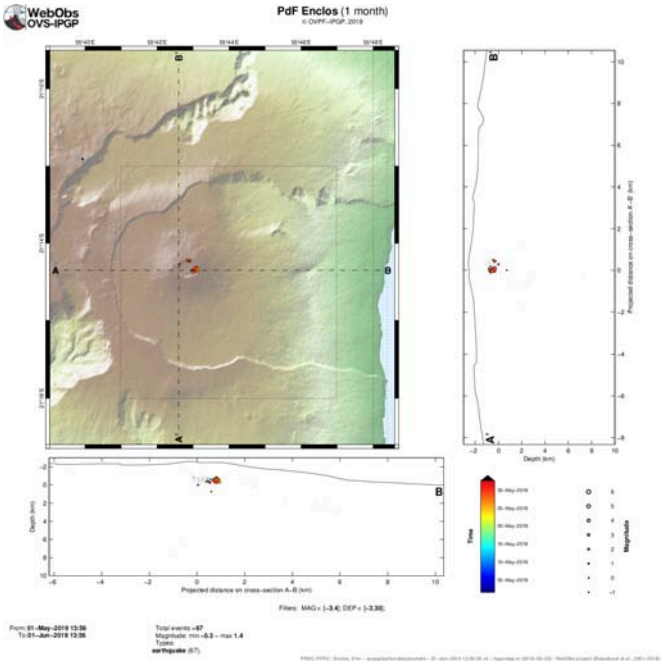

***Figure 2**: Location map (epicentres) and north-south and east-west cross-sections (hypocentres) of earthquakes at Piton de la Fournaise as recorded by OVPF-IPGP in May 2019. Only localizable earthquakes are shown on the map, while the observatory records more seismic events that are not localizable due to their low magnitude (© OVPF-IPGP).*

Since May 21, a gradual increase in the number of shallow volcano-tectonic earthquakes (0 to 2 km depth) below the summit craters (Figures 1 and 2) has been observed.
A strong seismicity was recorded on May 30 and 31 (125 shallow volcano-tectonic earthquakes, 0 to 2 km depth) with notably two small short-lived seismic crises on May 3 between 2:43 am and 3:00 am (local time) and between 04:29 and 04:37 (local time).

Deformation

In early May 2019, the OVPF deformation measurement networks recorded the renewal of edifice inflation and continued throughout the month (of about 1-1.5 cm max. of distance elongation between two GNSS stations spanning the summit zone; Figures 3 and 4).
This phase of inflation is thought to be linked to the pressurisation of the shallow magma reservoir, located at ~1.5-2 km depth below the summit.

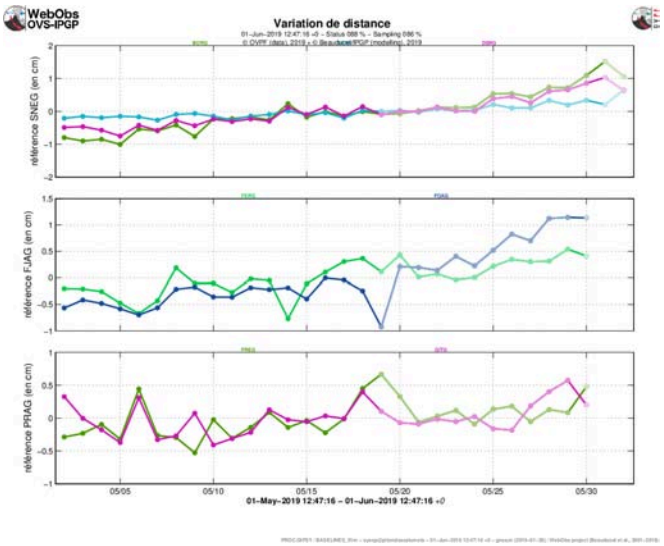

***Figure 3**: Illustration of the ground deformation in May 2019. The time series plots show the distance changes between pairs of GPS stations crossing the Dolomieu crater, the terminal cone and the Enclos Fouqué caldera, from north to south (see location in Figure 5). Increasing distances (or baseline elongation) indicate volcano inflation, while decreasing distances (or baseline contraction) reflect an edifice deflation (© OVPF-IPGP).*

** Glossary: The summit GPS signals indicate the influence of a shallow pressure source below the volcano, while distant GPS signals indicate the influence of a deep pressure source below the volcano. Inflation usually means pressurization; and conversely deflation usually means depressurization.*

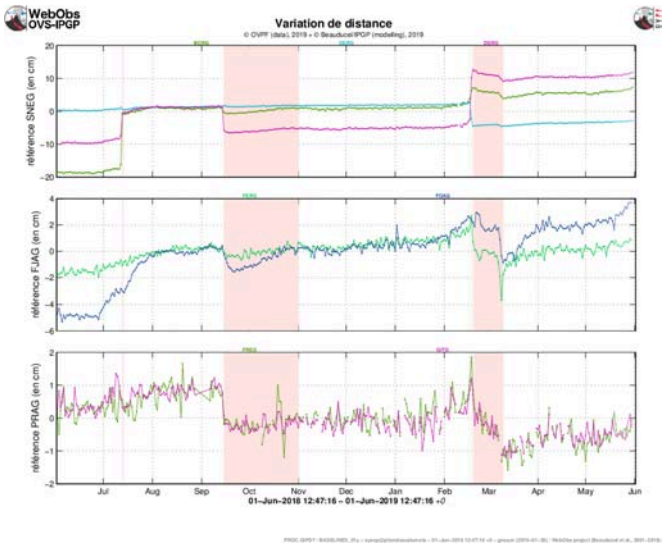

***Figure 4**: Illustration of the ground deformation over the last twelve months (red and green shaded areas represent the eruptive and intrusive periods, respectively). The time series plots show the distance changes between pairs of GPS stations crossing the Dolomieu crater, the terminal cone and the Enclos Fouqué caldera, from north to south (see location in Figure 5). Increasing distances (or baseline elongation) indicate volcano inflation, while decreasing distances (or baseline contraction) reflect an edifice deflation (© OVPF-IPGP).*

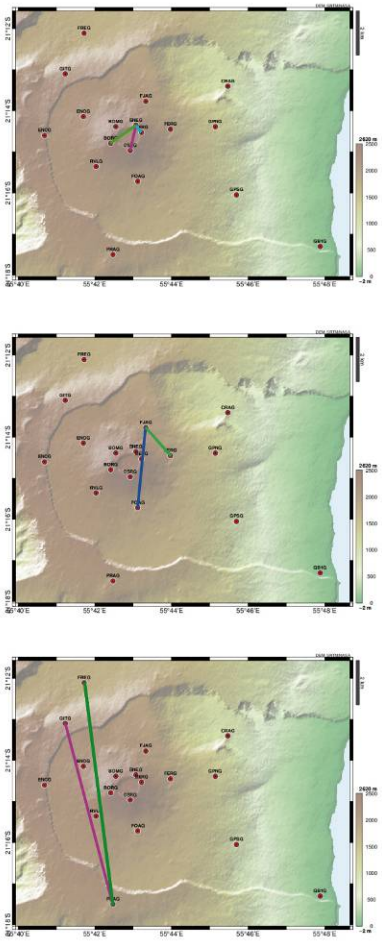

***Figure 5**: Location map of GPS stations and baselines as discussed in the text and shown in Figures 3 and 4 (© OVPF-IPGP).*

Gas geochemistry

CO_2 concentration in the soil

In the far field (Plaine des Cafres and Plaine des Palmistes sectors): A new increase of soil CO_2 flux is recorded since the beginning of April 2019. Soil CO_2 flux still increases since this date, reaching intermediate level. (Figure 6).

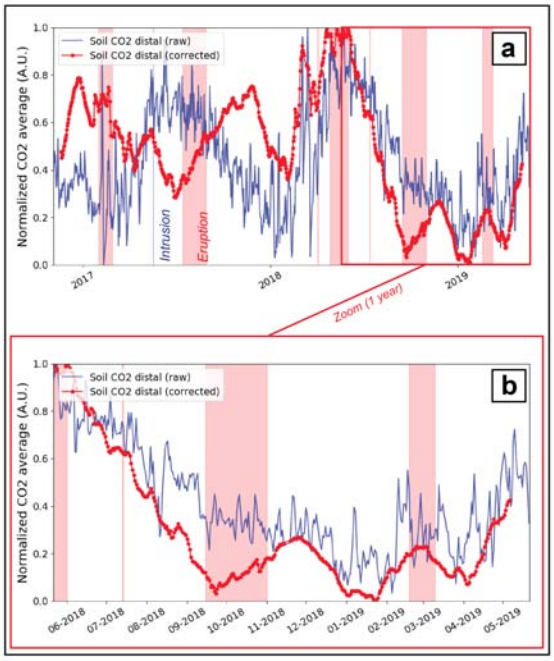

***Figure 6**: Comparison between the normalized average of raw (in blue) and corrected (in red) soil CO_2 flux from distal stations (a) since October 2016 (last station set) and (b) for one year. (© OVPF-IPGP).*

** Glossary: CO_2 is the first gas to be released from deep magma (from the mantle), so its detection in the far field often means a deep rise of magma. Its near-field evolution may be related to magmatic transfer in the shallowest part of the feeding system (< 2-4 km below the surface).*

Summit fumaroles composition by MultiGas method

The MultiGas station has been repaired on May 23.
On May 30, it detected sulfur species in the air (H_2S and to a lesser extent SO_2)

** Glossary: The MultiGaS method allows measuring the concentrations of H_2O, H_2S, SO_2 and CO_2 in the atmosphere at the summit of the Piton de la Fournaise volcano. Magmatic transfer in the Piton de la Fournaise feeding system can result in an increase in SO_2 concentrations and C / S ratio (carbon / sulfur).*

SO_2 flux in the air by DOAS method

SO_2 flux close or below the detection threshold.

** Glossary: During rest periods, SO_2 flux at Piton de la Fournaise is below the detection threshold. The SO_2 flux may increase during magma transfer in the shallowest part of the feeding system. During eruptions, it is directly proportional to the amount of lava emitted at the surface.*

Phenomenology

No eruptive activity reported in May 2019.

Summary

The renewal of edifice inflation, as well as seismicity and CO_2 concentration in the soil, show that deep magma recharge and pressurization of the shallow magma reservoir resumed in early May and continued throughout the month.

B–Seismic activity on La Réunion and in the Indian Ocean basin

Seismicity

In May 2019, the OVPF recorded:

- 64 local earthquakes (below the island, mainly in the Piton des Neiges area, Figure 7);
- 8 regional earthquakes (in the Indian Ocean basin).

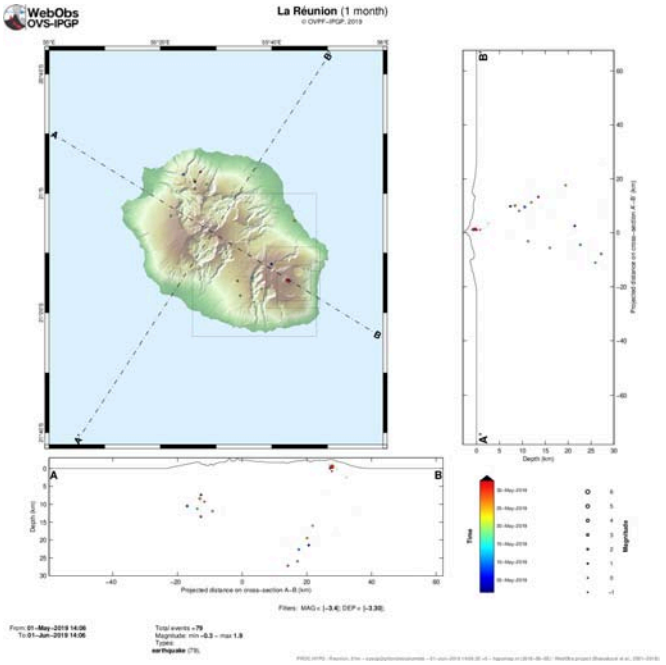

***Figure 7**: Location map (epicentres) and north-south and east-west cross-sections (hypocentres) of earthquakes below La Réunion Island as recorded by OVPF-IPGP in May 2019. Only localizable earthquakes are shown on the map, while the observatory records more seismic events that are not localizable due to their low magnitude (© OVPF-IPGP).*

Seismic crisis in Mayotte

Seismic activity is recorded off shore the island of Mayotte since the beginning of May 2018. These earthquakes form a swarm located 30 to 60 km east of the coast of Mayotte. The majority of these earthquakes are of low magnitude, but several events of moderate magnitude (maximum M5.9) were felt by the population and damaged a few buildings. Since July 2018 the seismic activity is weaker but remains with events felt by the population. Data from the Teria GPS network installed on Mayotte, and distributed by the RGP of the Institut Géographique National (IGN), still indicates since July 2018 a continuous displacement to the east (about 16-19 cm since July 2018) and a subsidence (about 7-14 cm depending of the sites since July 2018; Figures 8 and 9). Automatic and daily calculations have been set up at the OVPF to follow this deformation (via the Gipsy software), as well as the source at its origin. Thus for the last 3 months, the source of "depressurization" at the origin of these displacements could be located about twenty five-thirty km east of Mayotte and about 37 km deep (Figure 10). This suggests that fluid transfers in the crust are still on-going.

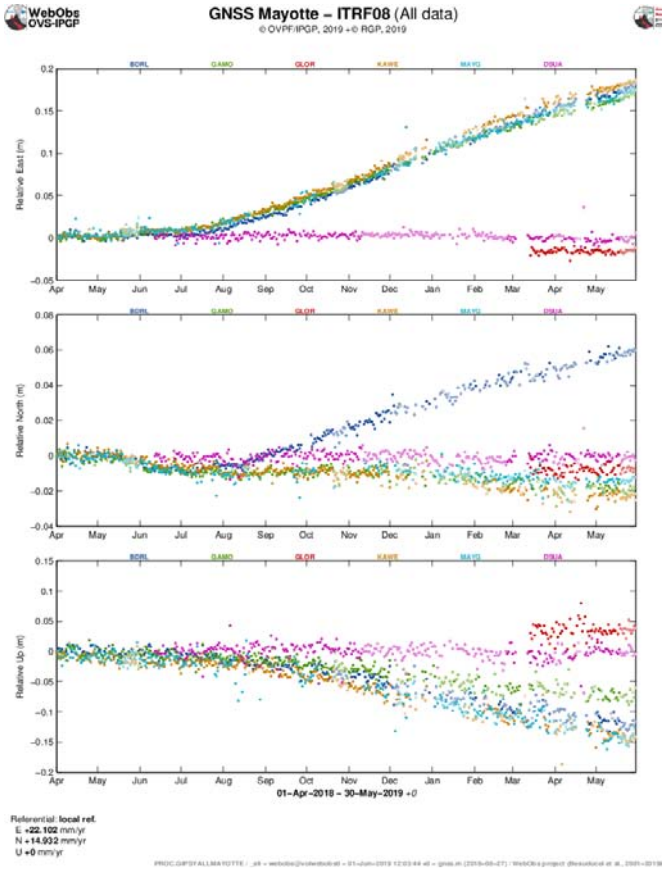

***Figure 8**: Displacements (in m) recorded on 4 GPS stations located in Mayotte (BDRL, GAMO, KAWE, MAYG), on station in Grand Glorieuse (GLOR) and one station north of Madagascar to Diego Suarez (DSUA), on the east (top), north (middle) and vertical (bottom) components, between April 2018 and May 2019. The data from the 4 Mayotte stations come from the Teria network and are distributed by the RGP of the Institut Géographique National (IGN), and data from the Diego Suarez station in Madagascar were obtained by LACy (Université de la Réunion) under the INTERREG-5 Indian Ocean 2014-2020 project "ReNovRisk Cyclones and Climate Change", funded by Europe, the Region of La Réunion and the State. Post-processing of this data by OVPF-IPGP (© OVPF-IPGP).*

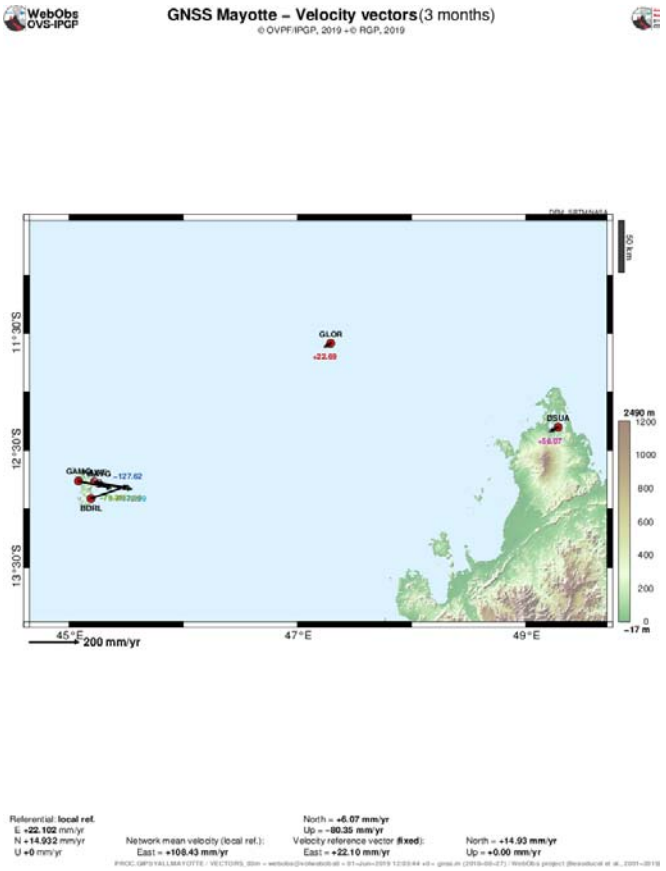

Figure 9: *Ground displacements recorded around the seismic swarm on the GPS stations of Mayotte, Grande Glorieuse and Madagascar during the last 3 months.The data from the 4 Mayotte stations come from the Teria network and are distributed by the RGP of the Institut Géographique National (IGN), and data from the Diego Suarez station in Madagascar were obtained by LACy (Université de la Réunion) under the INTERREG-5 Indian Ocean 2014-2020 project "ReNovRisk Cyclones and Climate Change", funded by Europe, the Region of La Réunion and the State. Post-processing of this data by OVPF-IPGP (© OVPF-IPGP).*

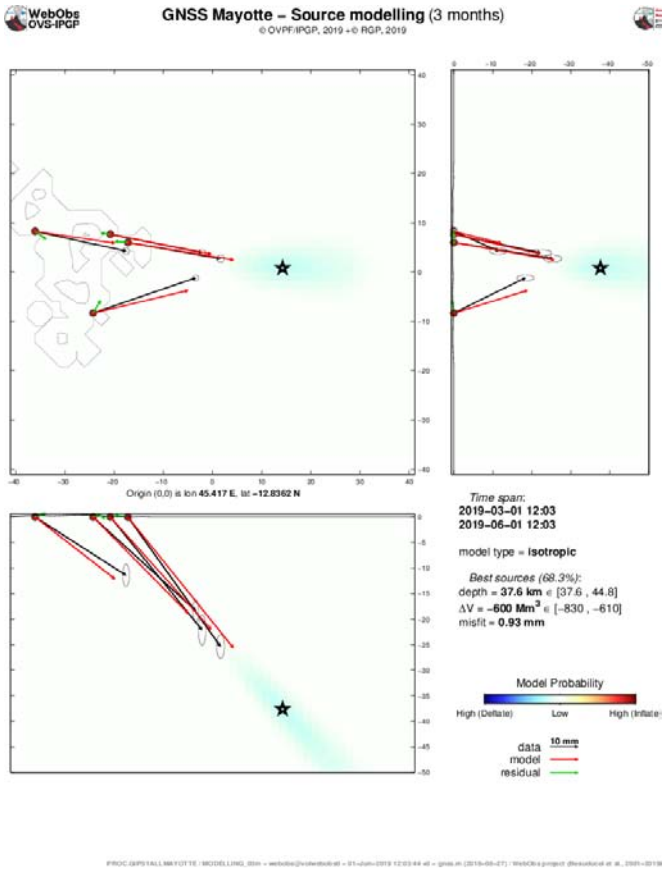

Figure 10*: Location of the source (best model resulting from a "Mogi" source) at the origin of the displacements recorded during the last 3 months on the GPS stations of Mayotte (© F. Beauducel (IPGP/IRD) and OVPF-IPGP).*

For a better follow-up of this crisis the CNRS launches a campaign of observation in Mayotte, in which the Institut de Physique du Globe de Paris and in particular the Observatoire Volcanologique du Piton de la Fournaise are involved. More information on this link:
http://www.cnrs.fr/fr/le-cnrs-lance-une-campagne-dobservation-de-lactivite-sismique-mayotte

From May 2 to 18, 2019, an oceanographic campaign aboard Marion Dufresne led to a major discovery with the birth of a new submarine volcano, east of Mayotte.

[extract of the interministerial press release - May 16, 2019]
http://www.ipgp.fr/fr/decouverte-de-naissance-dun-nouveau-volcan-marin-a-lest-de-mayotte

The mission conducted by Centre national de la recherche scientifique (CNRS), with Bureau de recherches géologiques et minières (BRGM), Institut de physique du globe de Paris (IPGP), Institut français de recherche pour l'exploitation de la mer (IFREMER), université de la Réunion, Institut de physique du globe de Strasbourg (IPGS), Institut national de l'information géographique et forestière (IGN), École normale supérieure (ENS), Centre nationale d'études spatiales (CNES) and Service hydrographique et océanographique de la marine (SHOM), which adds terrestrial observations to the Marion Dufresne oceanographic campaign, has highlighted a new submarine volcano, 50 km away from Petite-Terre.

The discovery of this volcano makes it possible to better understand the earthquakes felt on the island since one year.

The new volcano is located 3,500 meters deep. Its current size is estimated at 800 m in height with a base of 4 to 5 km in diameter. The plume of volcanic fluids, 2 km in height, does not reach the surface of the ocean. The emanations of gas observed on the littoral of Petite-Terre by the population are, according to the mission, a common sign for this type of volcanic activity and will be the object of specific studies.

The deployed marine instrumentation will help to better locate the seismic swarm felt since 2018.
Scientists are mobilized to process, analyze and interpret the wealth of data acquired during the last months. This operation will require extensive work to assess the potential risks for Mayotte related to the seismic and volcanic activity, and possible generation of tsunami.
The study program will then be updated and strengthened in the light of new knowledge provided by these in-depth analyzes.

More information:

- Dedicated webpage on the IPGP website:

http://www.ipgp.fr/fr/essaim-simique-a-lest-de-mayotte-mai-juin-2018

http://www.ipgp.fr/fr/essaim-simique-a-lest-de-mayotte-mai-juin-2018

- BRGM website:

www.ipgp.fr/fr/essaim-simique-a-lest-de-mayotte-mai-juin-2018

http://www.brgm.fr/content/essaim-seismes-mayotte-faq-scientifique?pk_campaign=twitter&pk_kwd=2018-06_seismes-mayotte-faq

- ENS website:

http://volcano.iterre.fr/mayotte-seismo-volcanic-crisis

- BCSF website:

http://www.franceseisme.fr/

- *"Préfecture de Mayotte" website:*

http://www.mayotte.pref.gouv.fr/

- *GEOSCOPE website:*

http://geoscope.ipgp.fr/index.php/fr/actualites/actualite-des-seismes

- *NEIC / USGS website:*

https://earthquake.usgs.gov/earthquakes

June, 1 2019
OVPF-IPGP Director

C - Appendix

Definition of Volcanic Alert Levels for Piton de la Fournaise

from : *dispositif ORSEC974 – D.S « Volcan du Piton de la Fournaise »*

Emergency plan set up by the department responsible for the protection of the population in the event of unrest or activity of the Piton de la Fournaise

•**"Vigilance"**: possible eruption in medium term (a few days or weeks) **or** presence of risks on the sector (rockfalls, increase of gas emissions, still hot lava flows…).

Access to the Enclos Fouqué caldera and to the summit volcano are allowed with restrictions.

• **"Alert 1"**: probable or imminent.

Access to the Enclos Fouqué caldera and to the summit are closed and prohibited.

• **"Alert 2"**: ongoing eruption.
Alert 2-1: ongoing eruption in the Dolomieu crater.
Alert 2-2: ongoing eruption inside the Enclos Fouqué caldera.
Alert 2-3: ongoing eruption outside the Enclos Fouqué caldera.

Access to the Enclos Fouqué caldera and to the summit are closed and prohibited.

•**"Sauvegarde"**: end of eruption or eruption stabilized.

Evaluation of a partial reopening of the Enclos Fouqué caldera access.

Thank you to organizations, communities and associations for publicly posting this report for the widest dissemination.

All informationon the Piton de la Fournaise activity can be found on the OVPF-IPGP media:
- website (http://www.ipgp.fr/fr/ovpf/actualites-ovpf)
- Twitter (https://twitter.com/obsfournaise?lang=fr)
- Facebook (https://www.facebook.com/ObsVolcanoPitonFournaise/)