Monthly Bulletin

Institut de physique du globe de Paris
Observatoire volcanologique du Piton de la Fournaise

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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 southeastern part of La Réunion Island (Indian Ocean).
The volcano 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 eruptions can potentially threaten communities that live in the surrounding areas.
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).

Alert level: Vigilance
(Since August 31, 2023)

(cf. table in the appendix)

A. Piton de la Fournaise activity

Seismicity

In December 2023, the OVPF-IPGP recorded at Piton de La Fournaise:

- 12 shallow volcano-tectonic earthquakes (0 to 2.5 km above sea level) below the summit craters;
- 5 deep earthquakes (below sea level);
- 0 long-period earthquake;
- 203 rockfalls.

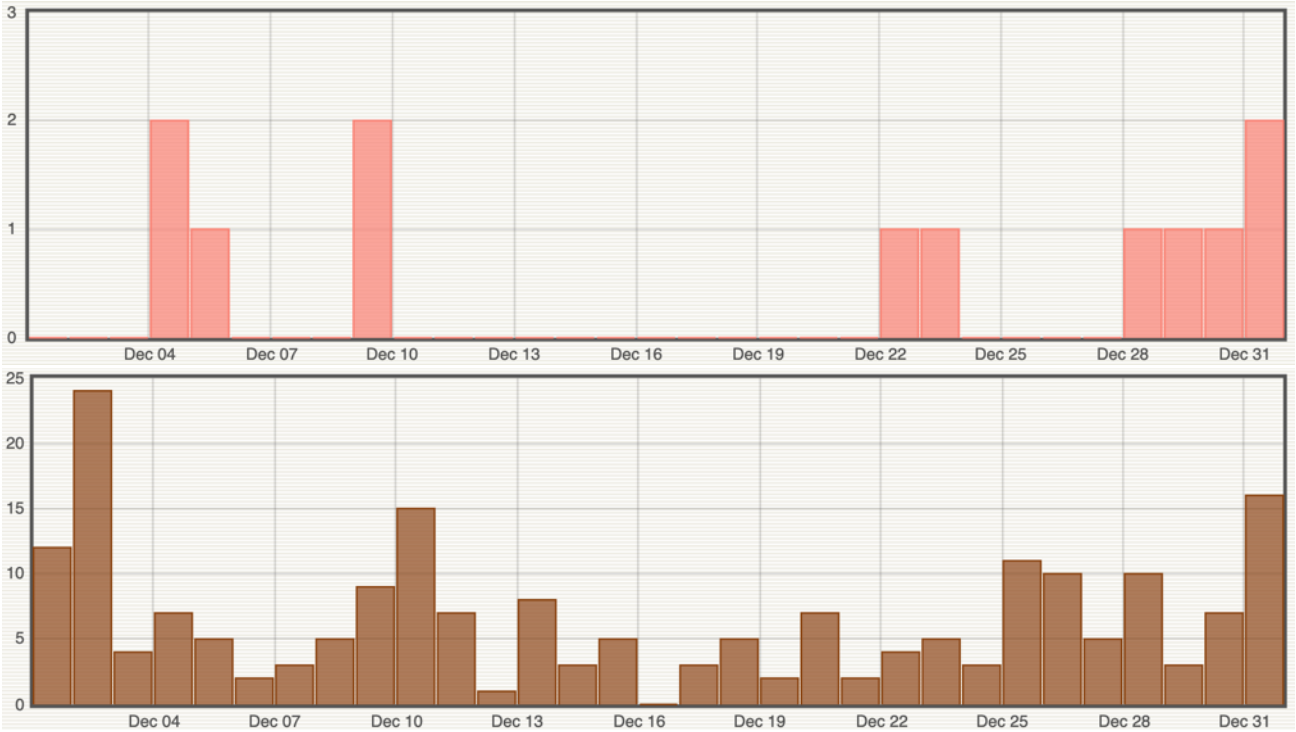

Figure 1: Number of (top) shallow volcano-tectonic earthquakes and (bottom) rockfalls per day recorded in December 2023 (© OVPF-IPGP).

The seismic activity at Piton de la Fournaise in December 2023 was low, with a mean of 0.4 shallow volcano-tectonic earthquake per day (Figure 1). Five deep earthquakes were also recorded.

Only one volcano-tectonic earthquake could be located - below the Dolomieu crater - and four deep earthquakes - below the eastern flank (Figure 2). The other volcano-tectonic earthquakes - of lesser magnitude - could not be located.

Numerous rockfalls (203) also occurred inside the *Dolomieu* crater, along the cliffs of the *Rivière de l'Est* and on the recent lava flows (Figure 1).

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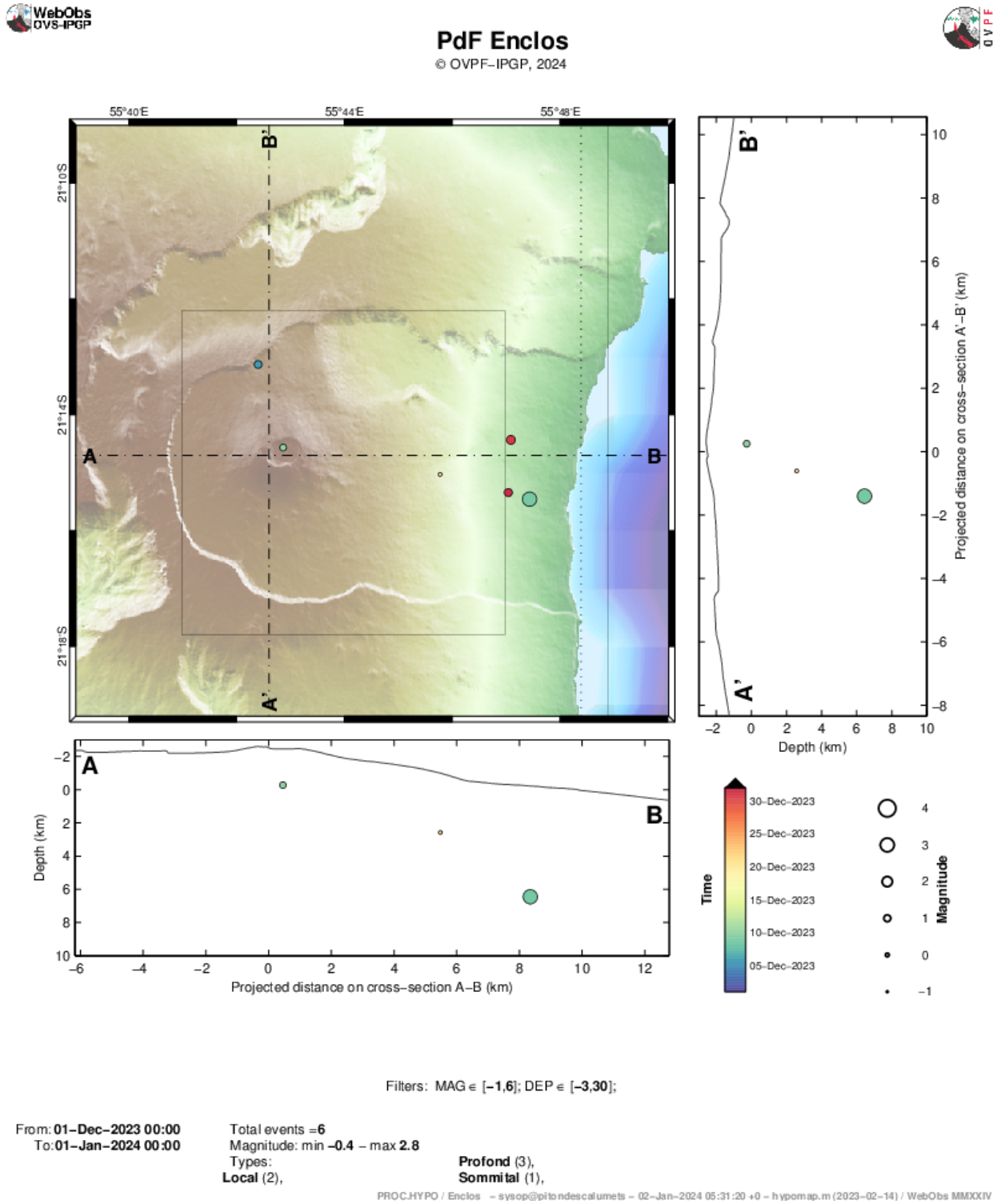

Figure 2: Seismicity below Piton de la Fournaise in December 2023. Location map (epicenters) and north-south and east-west cross-sections (hypocenters) of earthquakes as recorded by OVPF-IPGP. Only manually located earthquakes are shown on the map (© OVPF-IPGP).

Deformation

In November 2023, a resumption of summit inflation was recorded (Figures 3 and 4). This inflation ended at the end of November. Since then, a slight summit deflation is recorded.

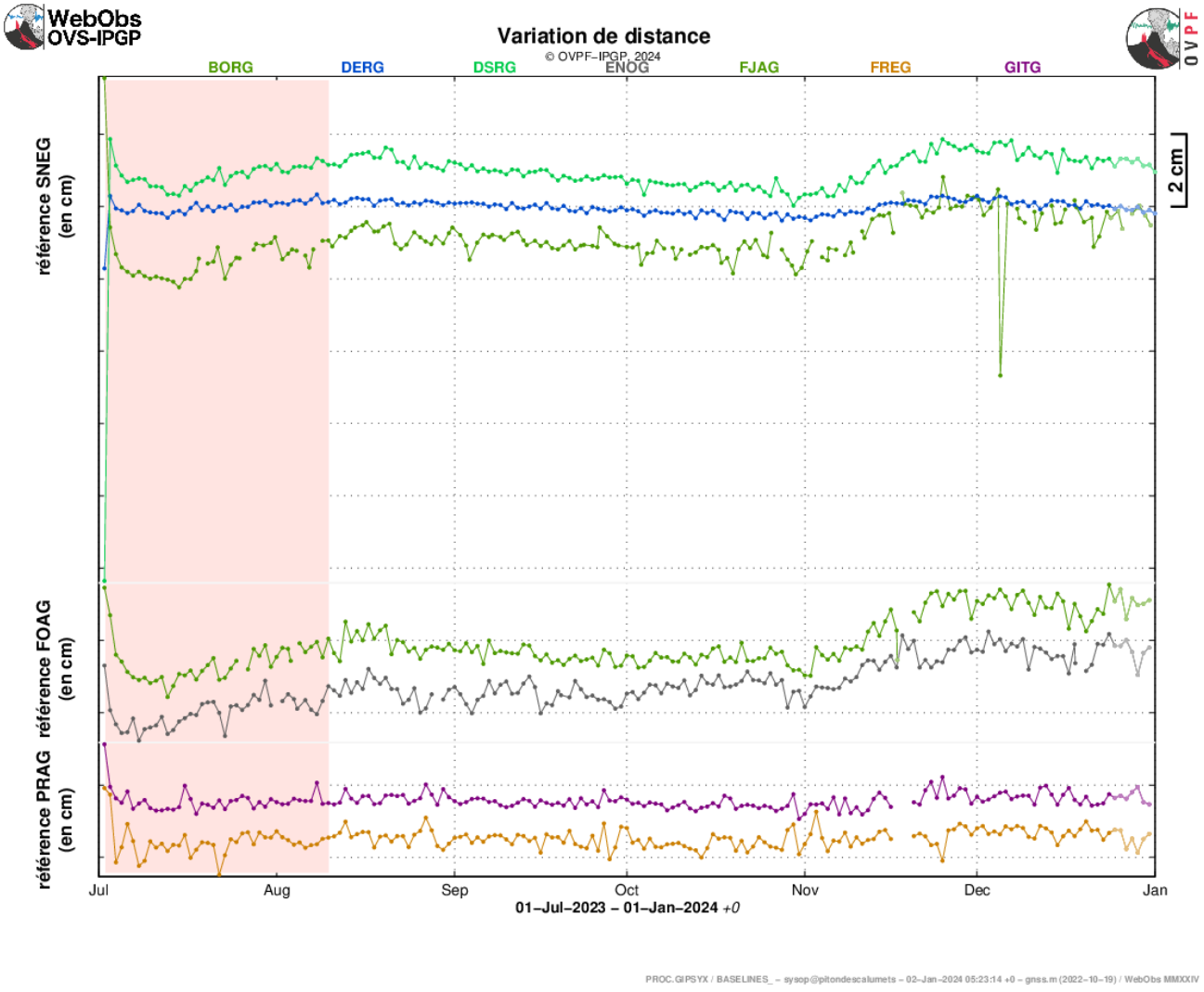

Figure 3: Ground deformation records over the past six months (in case of eruptive or intrusive periods, red and green bars represent eruptions and intrusions, respectively). The time series plots show the changes in distance between pairs of GPS stations located around the Dolomieu summit crater (reference: SNEG; top graph), the terminal cone (reference: FOAG; middle graph) and the Enclos Fouqué caldera (reference: PRAG; bottom graph), from north to south (see location in Figure 5). Increasing distances (or baseline elongation) indicate volcano inflation, while decreasing distances (or baseline contraction) reflect edifice deflation (© OVPF-IPGP).

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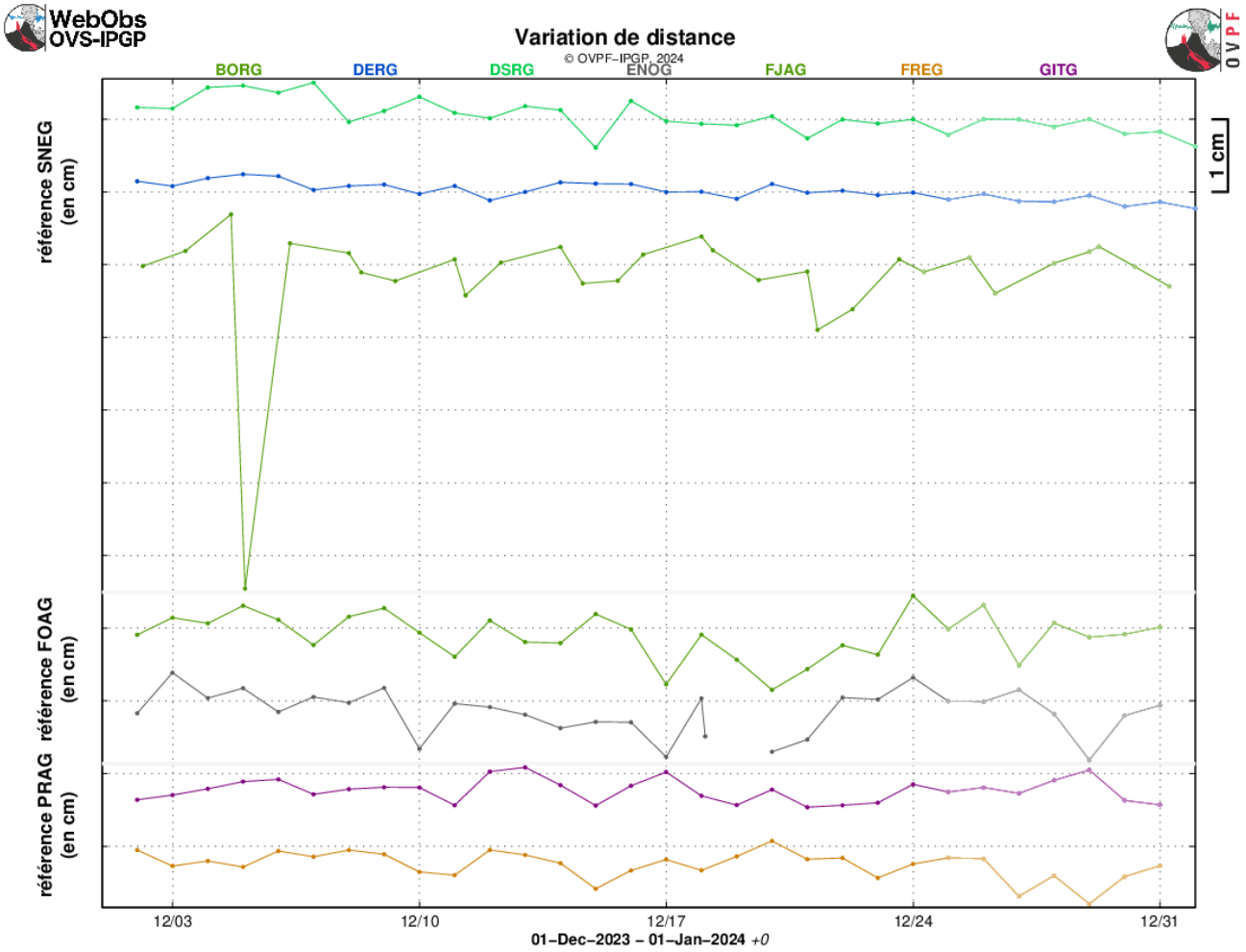

Figure 4: Ground deformation records over the course of December 2023 (in case of eruptive or intrusive periods, red and green bars represent eruptions and intrusions, respectively). The time series plots show the changes in distance between pairs of GPS stations located around the Dolomieu summit crater (reference: SNEG; top graph), the terminal cone (reference: FOAG; middle graph) and the Enclos Fouqué caldera (reference: PRAG; bottom graph), from north to south (see location in Figure 5). Increasing distances (or baseline elongation) indicate volcano inflation, while decreasing distances (or baseline contraction) reflect edifice deflation (© OVPF-IPGP).

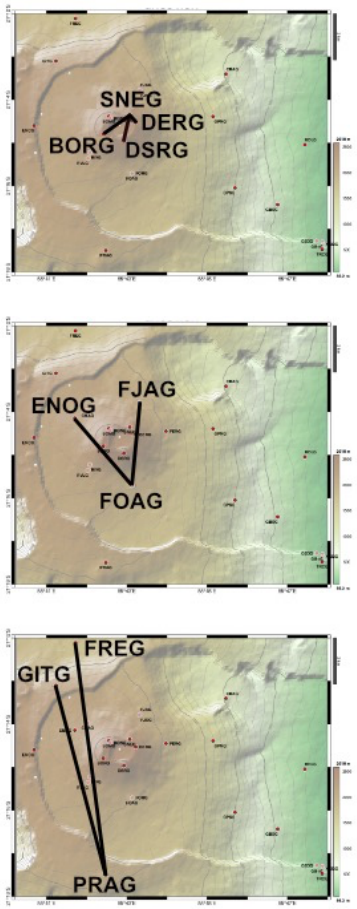

Figure 5: Location map of GPS stations and baselines as discussed in the text and shown in Figures 3 and 4 (© OVPF-IPGP).

** 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.*

Gas geochemistry

CO_2 concentration in the soil

In the proximal *Gîte du volcan* site, a sudden drop to very low CO_2 fluxes was detected after January 3, 2022. Since the end of the December 22 - January 17 eruption a new phase of increase was recorded, but with a lower rate.
The significant fluctuations observed during February 2022 are likely related to the environmental influence of two cyclonic events (Figure 6).

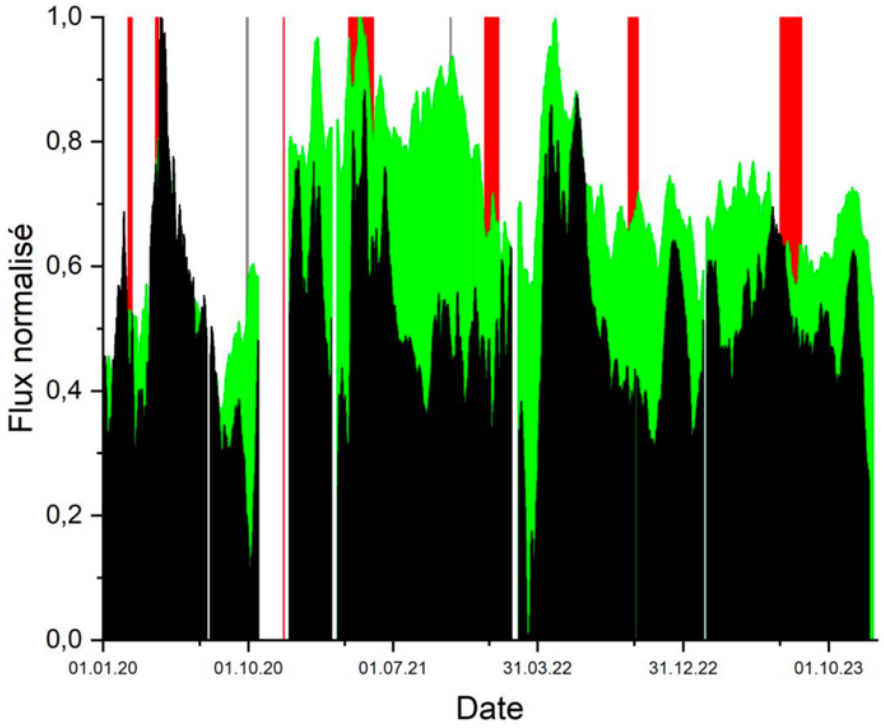

Figure 6: Comparison between the normalized average of corrected for short (OVPF-model; 15 days moving average; in green) and long-term influence of environmental parameters (INGV MALFIT model; in black) soil CO_2 flux from all distal stations since October 2016 (last station set). Red bars: eruptions; Gray bars: intrusions (© OVPF-IPGP).

A new increase in soil CO_2 emissions was recorded in both distal (*Plaine des Cafres, Plaine des Palmistes*) and proximal (*Gîte du volcan*) stations at the end of February 2022 (Figure 6), with a strong acceleration from March 15. The new phase of increase in CO_2 soil emissions has lasted till May 05 in the distal area and till May 19, 2022 in the proximal area.

Since mid-May 2022, a trend of decrease in CO_2 gas fluxes is recorded in both proximal and distal sites. The September 19, 2022 eruption occurred after a significant decrease in CO_2 fluxes, likely recording the progressive transfer of magma to shallow crustal levels. Since the end of the September 19 – October 5, 2022 eruption CO_2 fluxes have remained on a stable level.

Interestingly, isotopic analysis of gas sampled at both distal (PNRN, BLEN, PCNR) and proximal (P0; GITN) sites shows a marked increase in the magmatic contribution in the March-April 2022 period (Figure 7). The magmatic contribution has then decreased in the second half of 2022.

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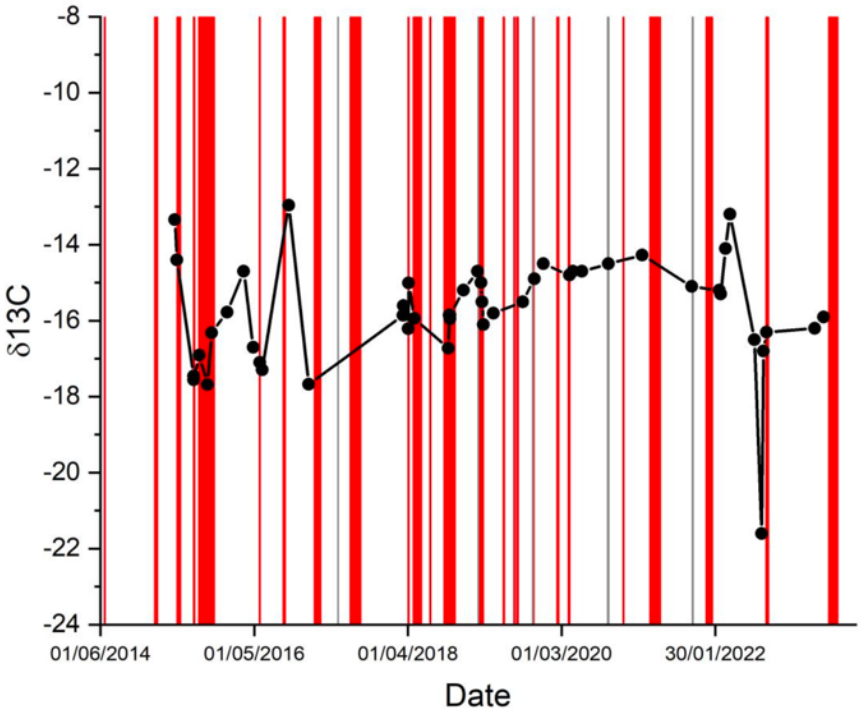

Figure 7: Carbon isotope (δ13C) variations in CO_2 from soil gas emitted from the control point with the highest flux in the proximal area (control point: GIT0).

A continuous decrease in the CO_2 emission rate in both the distal and the proximal stations was measured from mid-June 2023, possibly heralding a progressive transfer of magma to shallow depth. CO_2 fluxes, stable at the end of the July – August, 2023 eruption, decreased continuously till October.

Starting from mid-October, a new trend of increase was measured in both distal and proximal stations. This pulse stopped in mid-November and a continuous decrease is measured since then.

** Glossary: CO_2 is the first gas to be released from deep magma (rising 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 obtained by the MultiGas method

- Awaiting replacement of the current station by a new one.

** 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 in the C/S ratio (carbon/sulfur).*

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SO_2 flux in the air obtained by DOAS method

The SO_2 fluxes in the air were low; 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 December 2023.

Summary

A magma migration from deep level to the shallow magma reservoir, located at about 2-2.5 km depth, has been evidenced in November 2023 from ground deformation and soil CO_2 flux. But since December 2023, magma recharge and pressurization of the shallow magma reservoir stopped.
At the same time, seismicity remained low with a mean of 0.4 volcano-tectonic earthquake per day recorded below the summit craters in December 2023.

Note that since 2016, magma recharge of the shallow magma reservoir below Piton de la Fournaise is discontinuous and occurs in pulses. For example, several periods ranging from 15 to ~80 days that were characterized by no deformation and low seismic activity have been observed several times between 2016 and 2023.

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

Local and regional seismicity

In December 2023, the OVPF-IPGP recorded:

- 81 local earthquakes (below the island, within a radius of 200 km around the island, Figures 8 and 9);
- 5 regional earthquakes (in the Indian Ocean basin).

In December 2023, the OVPF-IPGP recorded 81 local earthquakes below the La Réunion island, and mainly near *Roche Ecrite* (Figure 9).

These earthquakes were located between 10 km and 25 km depth in oceanic lithosphere on which was built the volcanic edifice at the origin of La Réunion island.

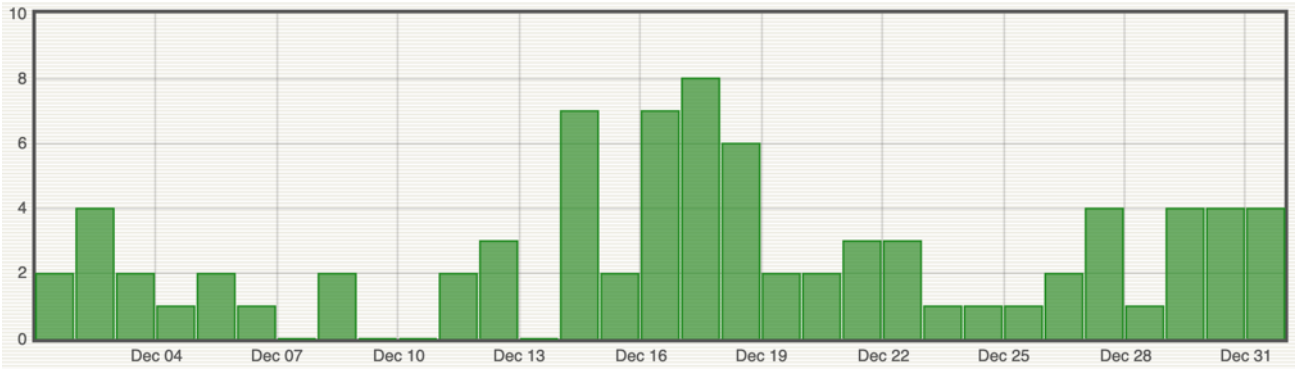

Figure *8: Number of local earthquakes (La Réunion island) per day recorded in December 2023 (© OVPF-IPGP).*

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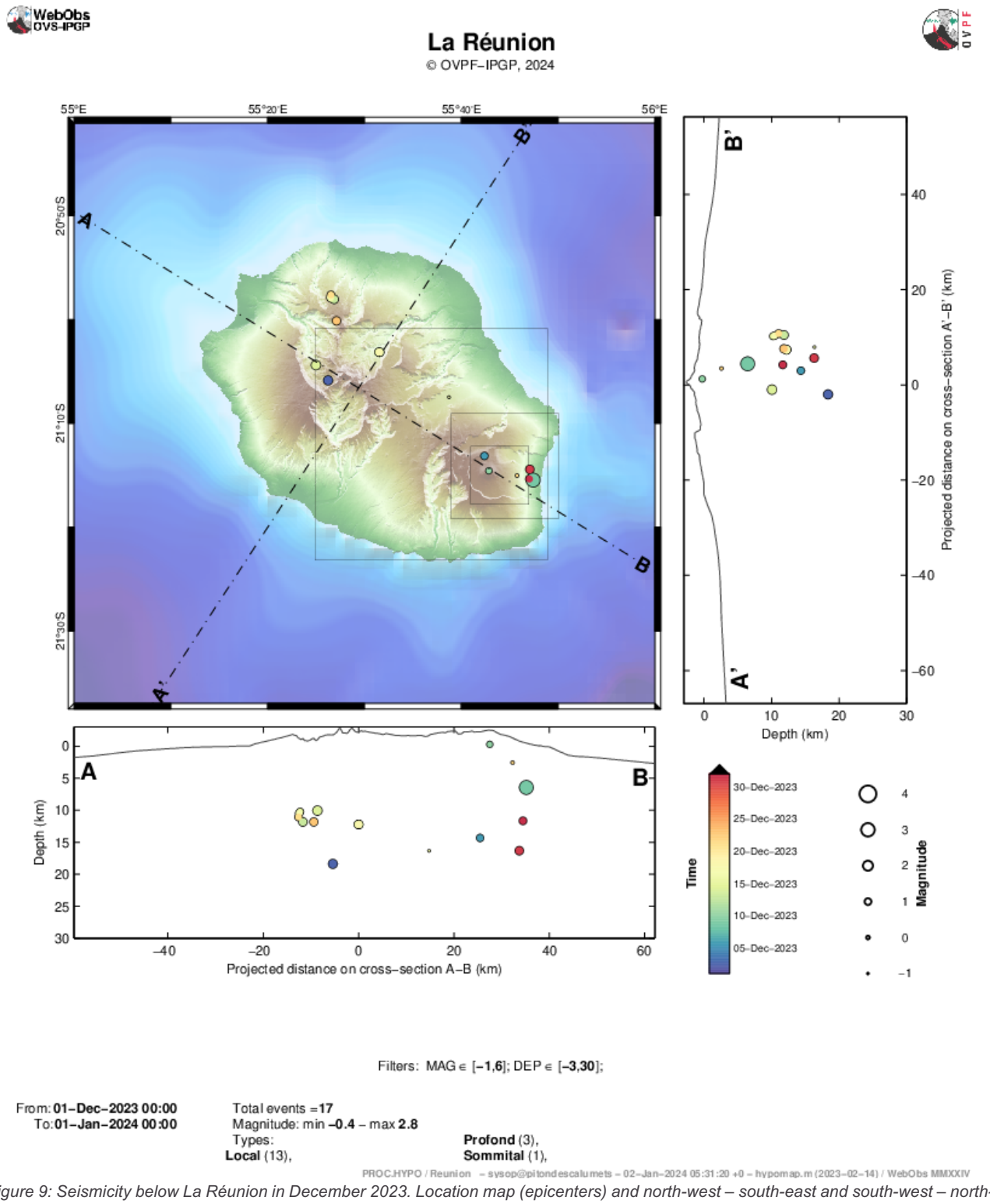

Figure 9: Seismicity below La Réunion in December 2023. Location map (epicenters) and north-west – south-east and south-west – north-east cross-sections (hypocenters) of earthquakes as recorded by OVPF-IPGP. Only localizable earthquakes are shown on the map (© OVPF-IPGP).

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Seismic-volcano activity in Mayotte

The « REseau de surveillance VOlcanologique et SIsmologique de MAyotte (REVOSIMA) » is the structure in charge of the volcano and seismic monitoring of Mayotte. IPGP operates this network through the Piton de la Fournaise Volcanological Observatory in La Réunion with the support of the BRGM regional office in Mayotte. REVOSIMA is supported by a scientific and technical partnership. The REVOSIMA consortium: IPGP and Université Paris Cité, BRGM, IFREMER, CNRS, BCSF-RéNaSS, ITES and Université de Strasbourg, IGN, ENS, SHOM, TAAF, Météo France, CNES, Université Grenoble Alpes and ISTerre, Université Clermont Auvergne, LMV and OPGC, Université de La Réunion, Université Paul Sabatier, Toulouse and GET-OMP, Université de la Rochelle, Université de Bretagne Occidentale, IRD and collaborators.

All information on the REVOSIMA and the activity in Mayotte can be found on the dedicated webpages:
•https://www.ipgp.fr/observation/infrastructures-nationales-hebergees/revosima/
•https://www.ipgp.fr/actualites-du-revosima/
•https://www.facebook.com/ReseauVolcanoSismoMayotte/

January, 2 2024
OVPF-IPGP Director

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C. Appendix

Definition of Volcanic Alert Levels for Piton de la Fournaise

from *disposition spécifique « Volcan Piton de la Fournaise » - arrêté n°2242-* 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 inside the Enclos Fouqué caldera without threat to the safety of people, property or the environment

Alert 2-2: ongoing eruption inside the Enclos Fouqué caldera with direct or indirectthreat to the safety of people, property or the environment.

Access to the Enclos Fouqué caldera and to the summit are closed and prohibited. For Alert 2-2, evacuation of the people and vehicles depending on the issues.

• **"Alert 2-3"**: ongoing eruption outside the Enclos Fouqué caldera with threat to the safety of people, property or the environment.

Access to the Enclos Fouqué caldera and to the summit are closed and prohibited. Evacuation of the people and vehicles depending on the issues.

• **"Sauvegarde"**: end of eruption.

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

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

Information
All information on the Piton de la Fournaise activity can be found on the OVPF-IPGP media:
- Internet website : ipgp.fr/fr/ovpf/actualites-ovpf
- Twitter : twitter.com/obsfournaise
- Facebook : facebook.com/ObsVolcanoPitonFournaise

A preliminary automatic daily bulletin of the OVPF-IPGP, relating to the activities of the day before, validated by an analyst, is published daily. It can be accessed directly at this link:
http://volcano.ipgp.fr/reunion/Bulletin_quotidien/bulletin.html

The seismicity validated in continuous by OVPF-IPGP can also be followed on the RENASS portal: https://renass.unistra.fr/fr/zones/la-reunion

The information in this document may not be used without explicit reference.

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