



Volcanological and Seismological Observatories (VSO) of IPGP

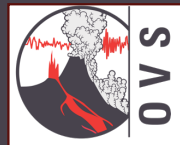


J-C Komorowski, J-M Saurel, P. Sakic, A. Lemarchan, S. Bonaimé (IPGP-Paris),

A. Peltier, P. Kowalski, C. Brunet, F. Lauret (OVPF-IPGP)

J. Vergne, J. Corbeau, A. Andrieu (OVSM-IPGP),

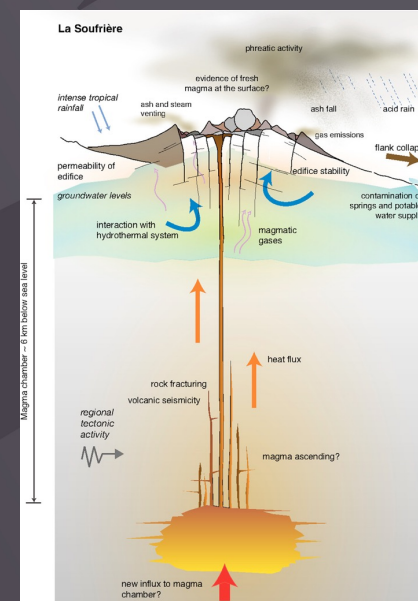
I. Vlastelic, C. Berthod, S. Deroussi (OVSG-IPGP) and collaborators of the VSO



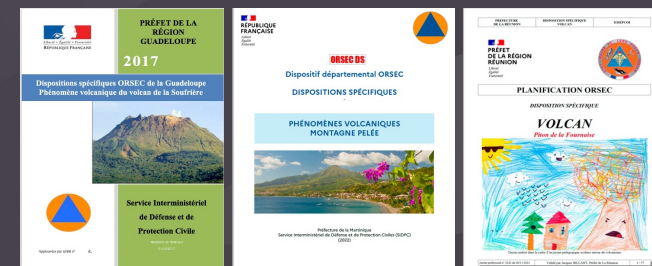


Missions of the Volcanological and sismological observatories (VSO) of IPGP (established in 1973)

1. **Operate observation/monitoring networks** to establish a **baseline** (reference) level of activity for hazardous active volcanoes, based on long **multi-parameter time series**.
2. **Monitor evolution** of the baseline and **detect changes** in behavior, trends
3. **Determine activity levels** and analyze the evolution of phenomena in terms of **system criticality**, ("thresholds", "precursors")
4. **Evaluate conditional probability of occurrence of surface phenomena**, given the signals recorded and their links to the volcano's internal variables
5. **Transmit to the authorities** in charge of civil security, **scientific alerts** on observed phenomena and possible **evolution scenarios**.
6. **Contribute to knowledge leaps** via **fundamental research** on volcanic systems
7. **Disseminate regular information** and knowledge to **all stakeholders** and the **general public**, with the aim of raising **awareness** and **preventing risks**.

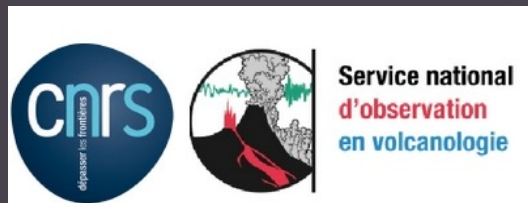


Hincks, Komorowski, Sparks, Aspinall, 2014





Service National d'Observation en volcanologie (SNOV)



To acquire data describing the formation, evolution and variations of astronomical systems and terrestrial environments, INSU of CNRS creates and evaluates national observing services (SNO), which implement observing systems over several years, or even decades and distribute data to the community.

These SNOs provide a service to the community to advance knowledge. The SNOs are grouped into «National Actions for Observation» (ANO) in each of INSU's major fields.

The IPGP Grand Etablissement contributes by mandate to the operational science (observation / monitoring), the human resources and funding of various SNO's, including via its VSOs.

Leader : Jean-Christophe Komorowski (IPGP)
Co-leader : Séverine Moune (OPGC, LMV, UCA)

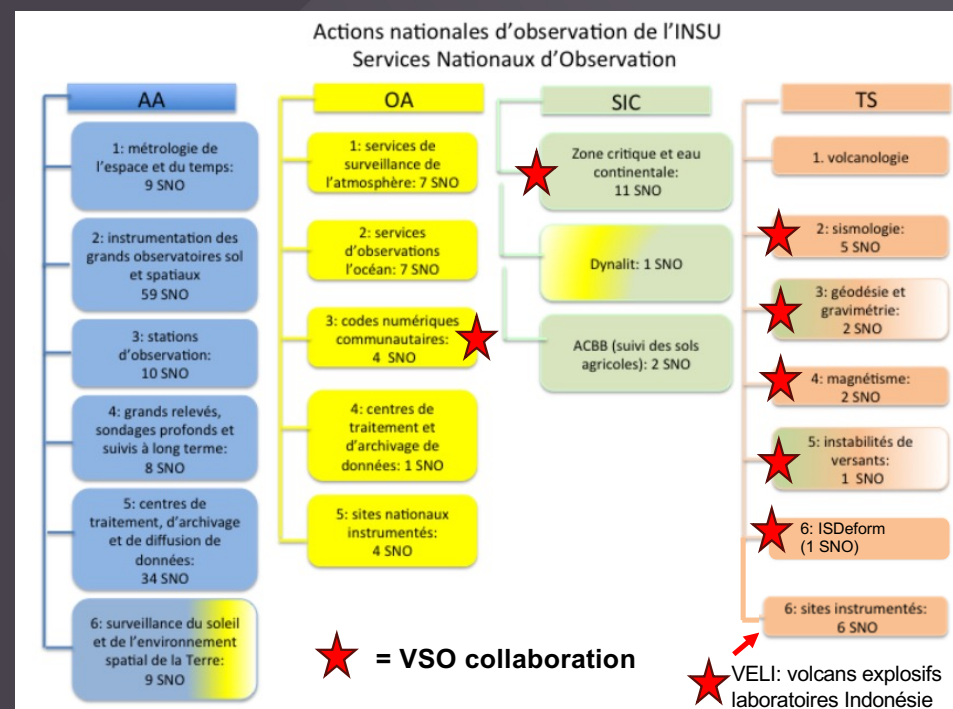
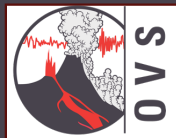


Figure 1 : Organisation actuelle des SNO de l'INSU et des regroupements en ANO. Les couleurs se réfèrent aux thématiques concernées.



Coordinating scientist-in-charge:

J-C Komorowski (PHY, CNAP) since 2016

Operational engineer-in-charge:

J-M Saurel (IR, CNRS) since 31 May 2021

A. Lemarchand (IR, CNRS) 15 years til 30 May 2021

Permanent Paris OVS staff FTE Observation 100%:

A. Lemarchand, IR

P. Sakic, IR

S. Bonaimé, IR

2022	OVS Total (Excluding REVOSIMA)
Maximum number persons	72
Total FTE observation	43,55
% FTE by CDD engineers+technicians	21

2017-2022:
 65 ± 10 [49-73]
 $42,74 \pm 5,78$ [33-44]

Overseas
VSO:
35 FTE
(79%)

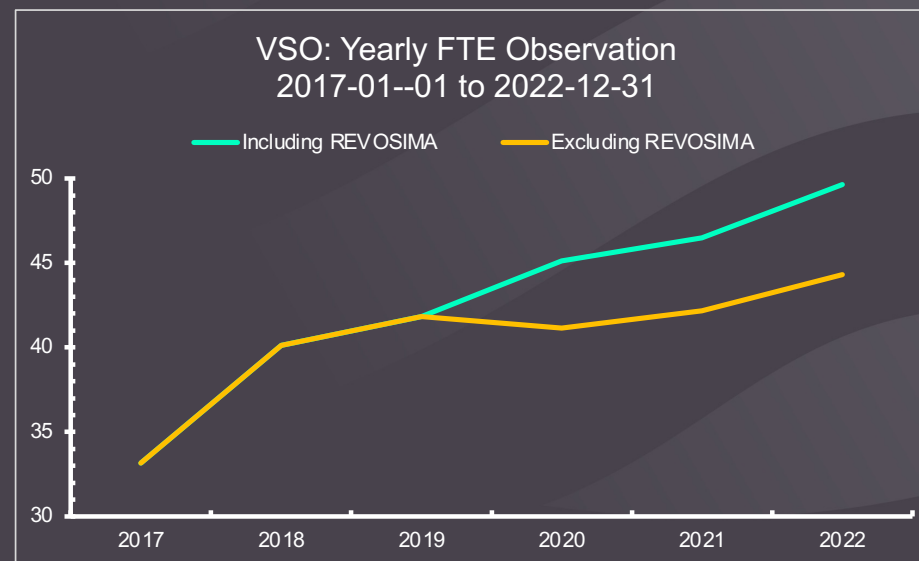
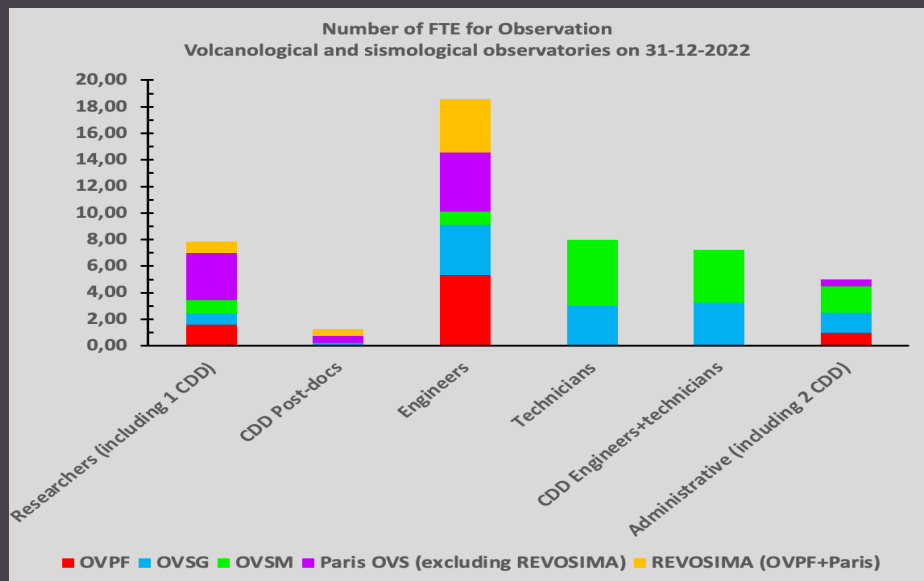
45 staff

IPGP Paris
VSO:
9 FTE (21%)

27 staff from
different
teams

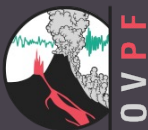
Age pyramid proxy - Permanent staff excluding REVOSIMA: As of 31-12-2022:

- Deceased: 1
- Emeritus: 1
- Will retire before 2027: 4





Observatoire volcanologique du Piton de la Fournaise (OVPF-IPGP)



Director Scientist-in-charge : A. Peltier (PHY, CNAP)

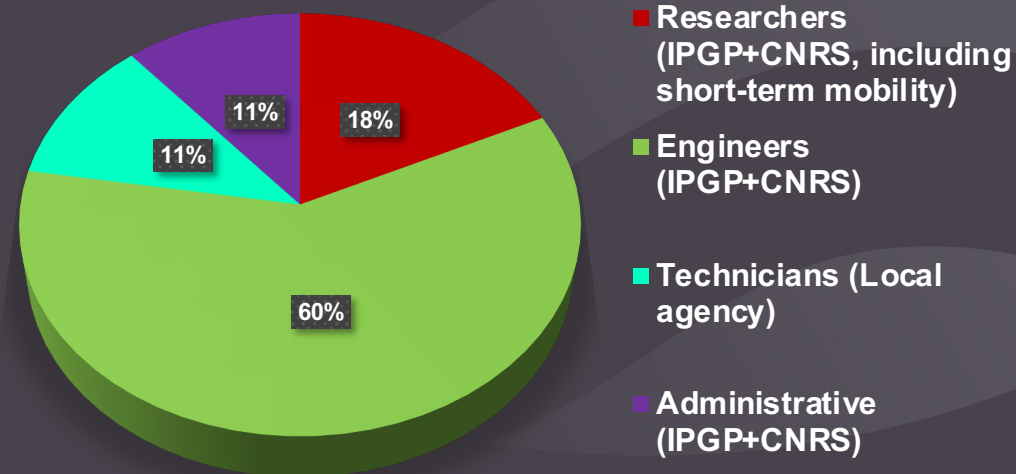
Deputy Director : P. Kowalski (IR)

Technical directors: C. Brunet (IR) and F. Lauret (IE)

2022	OVPF (excluding REVOSIMA)
Maximum number persons	12
Total FTE observation	7,93
% FTE by CDD	0



OVPF





Observatoire volcanologique et sismologique de Martinique (OVSM-IPGP)



Short-term Directors – Scientist-in-charge : A-M Lejeune (2018-2020),

F. R. Fontaine (2020-2022)

Interim Directors – Scientist-in-charge (CNAP), 2022-09 - 2024-07-01 : J-B de Chabaliér, F. Beauducel, G. Carazzo, J-C Komorowski, C. Aubaud, J. Corbeau

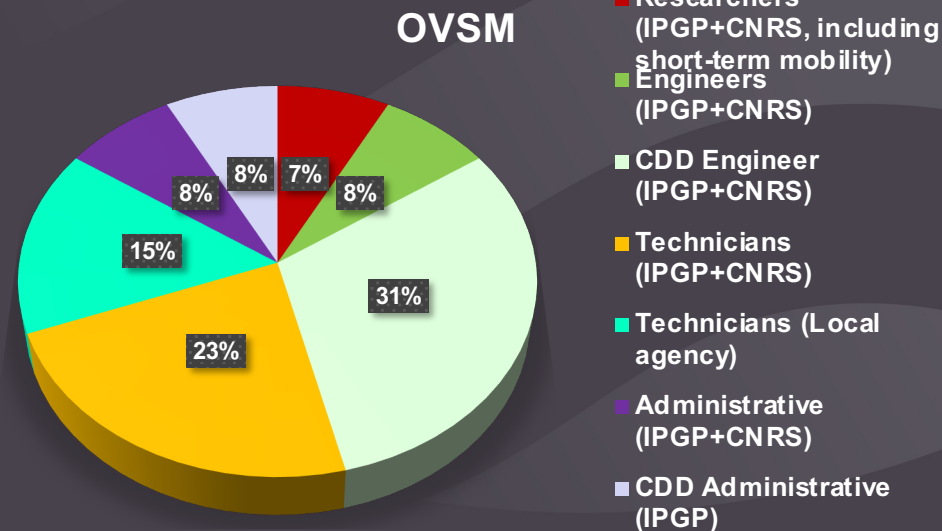
New recruited long-term Director – Scientist-in-charge on 2024-07-01 : **J. Vergne**
(PHY CNAP, moved to IPGP from IPGS Strasbourg)

Deputy Director – Deputy Scientist-in-charge: J. Corbeau (PHAD CNAP)

Technical Director (CDD): A. Andrieu (IE)



2022	OVSM
Maximum number persons	15
Total FTE observation	13,00
% ETPT by CDD	63



Observatoire volcanologique et sismologique de Guadeloupe (OVSG-IPGP)

Director / Scientist-in-charge :

I. Vlastelic (DR CNRS) since 2022-08 – 20-12-2025

C. Berthod (PHAD) starting on 20-12-2025

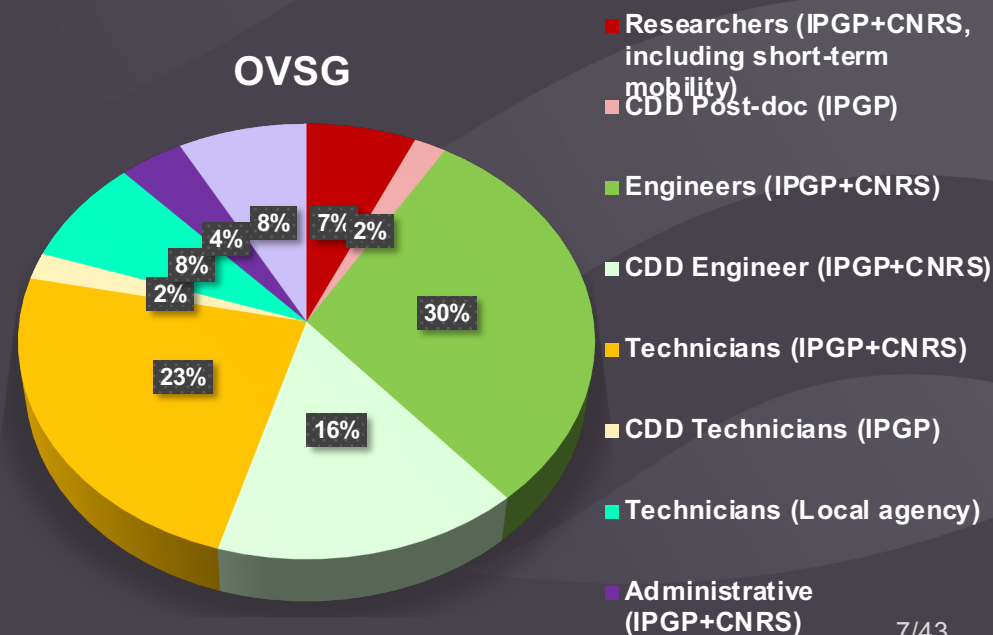
Operational assistant director: S. Deroussi (IE)



Total FTE observation	2022	12,65
% FTE by CDD		51
Total Nb CDD (short-term contracts)		6
Maximum number persons		18



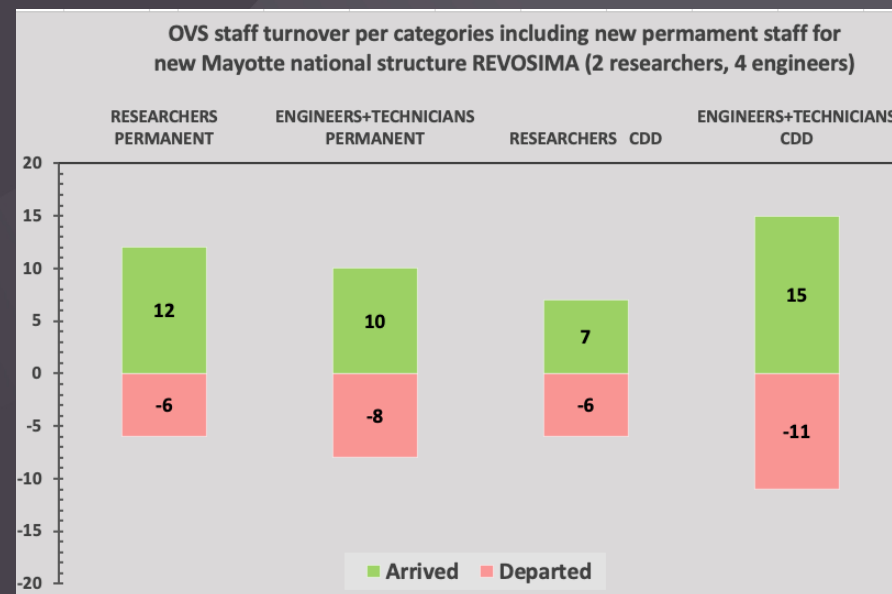
OVSG





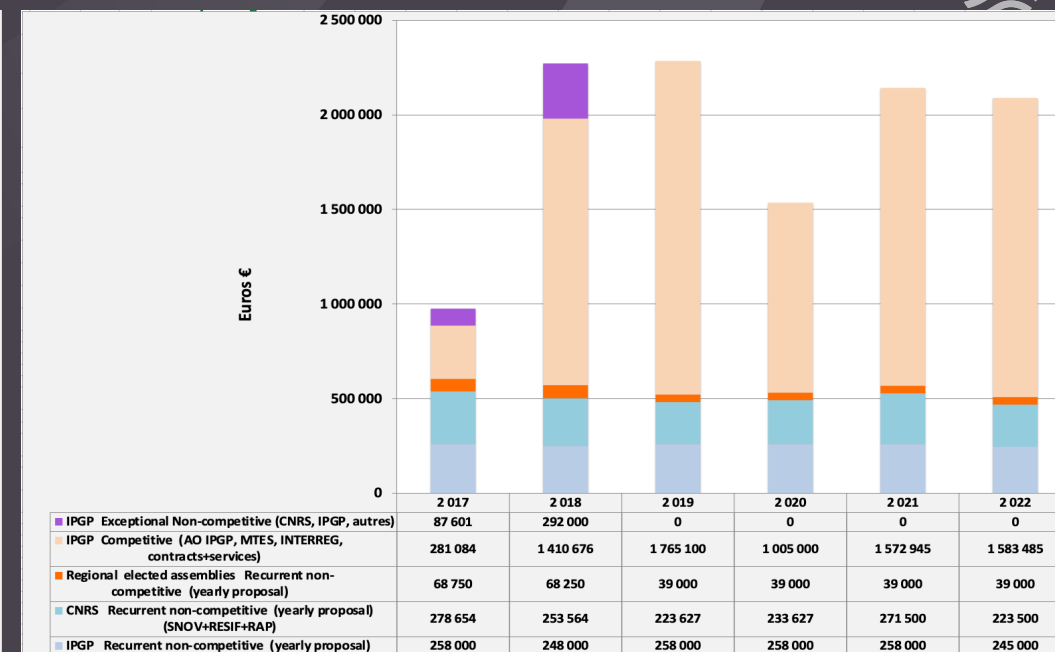
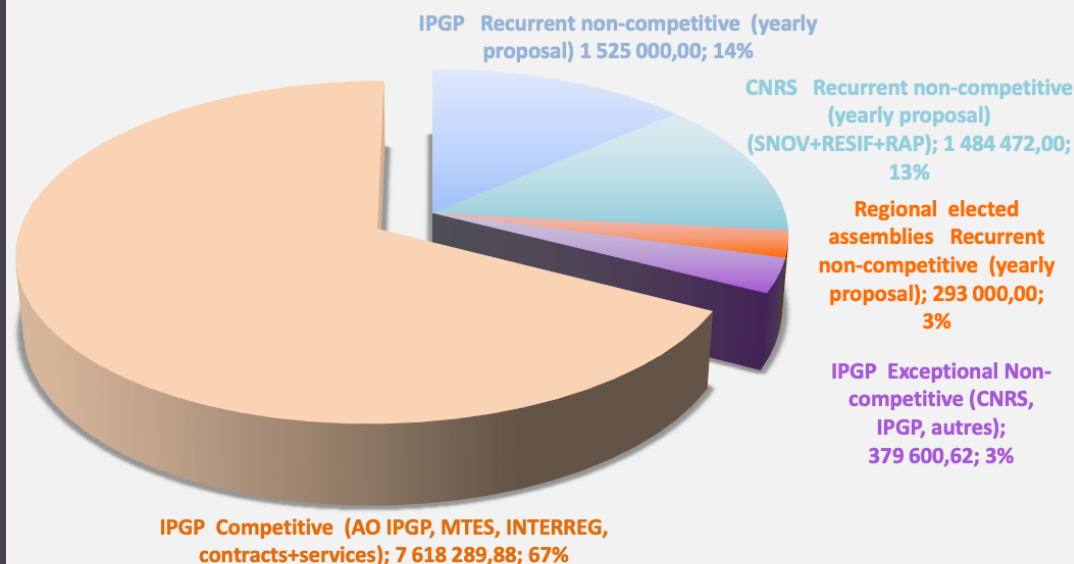
- **Excluding REVOSIMA**, the VSO of IPGP : main contributor (72 staff) to the National service for observation in volcanology of CNRS-INSU (SNOV) (105 staff) with the OPGC of Univ. Clermont Ferrand as the 2nd main contributor
- **72 staff = 60 permanent contracts + 12 short-term contracts (CDD, 17%)**
- 28 permanent researchers include 20 CNAP + 6 CNRS, 1 IRD +1 Univ
- Researchers contribute from 27 to 50% of their full time to observation
- **Strong turnover** especially for coordinating leadership position (Director and Technical directors in Guadeloupe and Martinique; engineers and technicians, the technical director at OVSM and IT computer engineer at OVSG)
- **With intense efforts in 2022 and support from CNRS and MESR, staffing of the VSO is improving significantly in 2023 with:**
 - ✓ New permanent administrative manager (CNRS) at OVSG since June 2023
 - ✓ New permanent IE (CNRS) in geochemistry opened at OVSG in October 2023
 - ✓ New short-term 3 year IE position OVSG (CNRS) tenure-tracked permanent post
 - ✓ New short-term 3 year IE position OVSM (MESR) tenure-tracked permanent post
 - ✓ In 2024, with strong support of MESR, a similar 3 year IE position tenure-tracked to permanent post will open of OVPF (La Réunion)
- Trend of increasing CNRS researchers in overseas VSO (1 OVSG; 2 OVPF)

REVOSIMA (not an IPGP VSO): new national structure in charge of the Mayotte volcanological and sismological monitoring network = an unprecedented effort by MESR to create in 2021 **6 new positions at IPGP** (2 EC, 4 IE/IR) with 1 EC + 3 IE at OVPF and 1 EC and 1 IR in Paris. **REVOSIMA is hosted and operated by IPGP with A. Peltier, Coordinating operational scientist-in-charge in co-leadership with L. Sadeski (BRGM Mayotte) and partnership with BRGM, Ifremer, CNRS and associated universities).** The REVOSIMA staff contributes new expertise, skills and capacities for some of the VSO activities and vice versa.





TOTAL BUDGET OF VOLCANOLOGICAL AND SISMOLOGICAL OBSERVATORIES OF IPGP - 2017-2022 EXCLUDING SALARIES (TOTAL = 11 300 363 €) and EXCLUDING REVOSIMA OPERATIONAL BUDGET



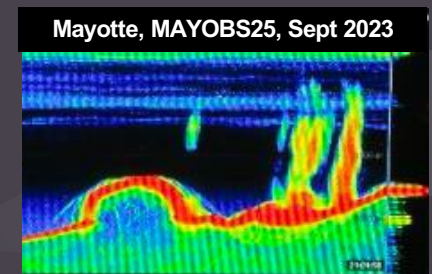
- Excluding salaries, total funding for 3 VSO for 2017-2022 (excluding REVOSIMA) = 11,3 M€ = 1,88 M€ / year for 3 VSO -> ~0,627 M€ / VSO / year with 67% from competitive funding (MTES, INTERREG, EU, ANR, CNRS-INSU)
- Total operational costs 3 VSO (excluding REVOSIMA) = 30,05 M€ 2017-2022 with 63% for human resources, 12% from recurrent funding and 25 % from competitive funding
- Total IPGP contribution = 70% of the total of 30,05 M€
- Average yearly budget of 5 M€ for all 3 VSO (OVSM, OVPF, OVSG) for 2017-2022 period including salaries, excluding REVOSIMA
- Average yearly budget of 1,7 M€ per observatory including salaries
- Comparing the previous HCERES evaluation of 2012-2017 with 2017-2022 period: the total budget increased by 9% (+ 2,49 M€) although there is some uncertainty and 2012-2017 budgets were likely underestimated

Observatory policy

- 2017-2022: VSO faced several unprecedented major challenges for monitoring, understanding and scientific management of volcanic activity in the context of the **COVID pandemic**:
 - ✓ **Prolonged and increasing unrest at La Soufrière of Guadeloupe**, 27 April 2018 M 4.1 Eq (largest since 1976) & aborted phreatic eruption
 - ✓ **New unrest began in 2019 at Montagne Pelée** -> recommendation by IPGP to Préfet to increase the level of volcanic alert to **Vigilance (Yellow)** on 04 December 2020
 - ✓ **Reactivation Mayotte volcanic zone after several milenia of inactivity** -> birth in July 2018 of **new French volcano « Fani Maoré »** at least 820 m tall, 6,55 km³, largest effusive eruption since 1783 Laki and largest effusive submarine eruption ever documented -> creation, structuration, implementation, operation of new monitoring network REVOSIMA national structured hosted at IPGP and operated by IPGP and BRGM with CNRS and Ifremer
 - ✓ **19 eruptions of Piton de la Fournaise**
 - ✓ **Devastating hurricanes** Maria and Irma (Guadeloupe 2017), and Batsirai and Enmati (La Réunion 2022, Chido (Mayotte, 2024), Garance (2025) that impacted the observatories and the network
- VSO role goes well beyond observation since scientific teams provide expertise, give early ascending warning to authorities (**Caribbean Tsunami Warning System, UNESCO**), Préfecture and EMZ, civil aviation (**VAACS, VONA** messages protocole), open information outreach strategy
- **Training periods for 100 bachelor and Masters** (1-6 months in OVS), **Master observatory field course, 5 postdocs supervised in VSO overseas and 6 PhD students**
- Tutoring program of geoscientists in Haïti, Djibouti, and Comoros part of long-term partnerships

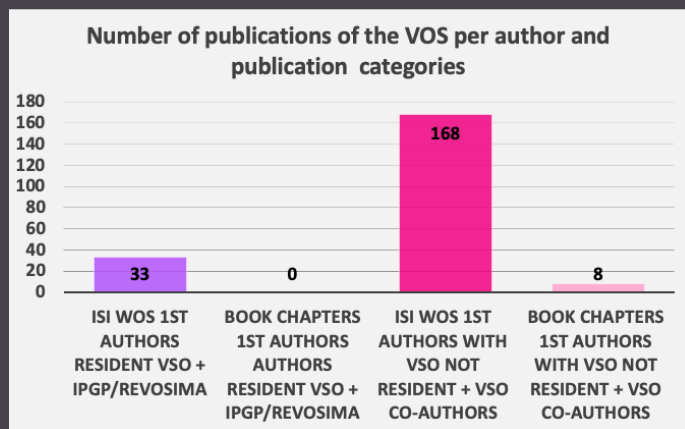


© OVPF/IPGP, 2019-07-29





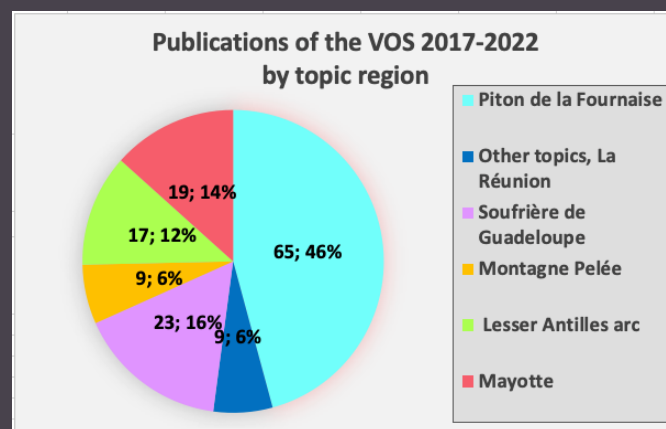
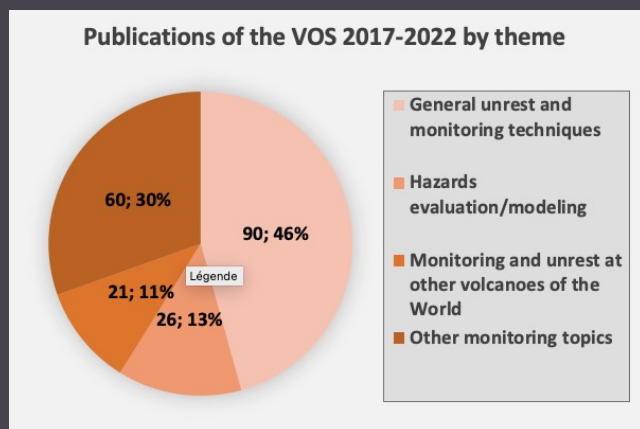
Scientific productivity (2017-2022)



- **6 publications in high-ranking journals** (Nature, Science, Science Advances, PNAS, Geology)
- **6 publications in the full open-access peer-reviewed journal VOLCANICA**
- Among total of 209 publications, 14 where first-authored PhD + MS students mentored by VSO staff

Projects involving VSO researchers:

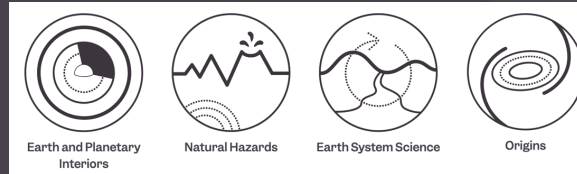
- ✓ ANR RAVEX 2016-2020
- ✓ **ANR SlideVolc 2016-2019 PI**
- ✓ **ANR LAVA 2016-2021 PI. Co-PI**
- ✓ ANR DIAPHANE 2014-2018
- ✓ ANR STRAP 2014-2019
- ✓ ERC SLIDEQUAKES 2014-2018
- ✓ H2020 EU EUROVOLC (2018-2021)
- ✓ ANR MEGAMU 2019-2022
- ✓ ANR MYGALE 2021-2024
- ✓ **INTERREG PREST 2017-2020 PI**
- ✓ **INTERREG HATARI PI**



- Contributed to the revision of the volcan response plans (ORSEC, Préfecture): Guadeloupe 2018; Martinique 2022; Fournaise 2021
- Elaborated volcano eruptive scenarios, contributed and acted in the volcano crisis exercises by the Préfectures: Guadeloupe: 2019, 2021; Martinique: 2022; Fournaise 2021 (ANR LAVA)
- New IPGP volcano expert committee (CEV) met 3x in 2022 to review volcanic activity + advise IPGP Director on scientific response to unrest at overseas volcanoes monitored by IPGP.



VSO collaborations



- SNOV:

OPGC-UCA, ISTerre-
OSUG, IPGS, GET-OMP,
Géoazur-OCA, OSUC

- All SNO's of Solid Earth (INSU-CNRS) see previous slide 7
- ESEO
- IRD

- Volcanic Systems
- Seismology
- Dynamics of geological fluids
- Geodesy
- Marine geosciences
- Tectonics and mechanics of the lithosphere
- Geochemistry of stable isotopes
- Geochemistry of external enveloppes
- Geomagnetism
- Planetology and space science
- Cosmochemistry, astrophysics and experimental geophysics

- BRGM
- EOS (Singapore)
- INGV
- USGS HVO, CVO
- CVGHM - BBPTK Indonesia
- Montserrat Volcano Observatory (SRC)
- Seismic Research Center (Univ West Indies, Trinidad)
- KNMI : The Royal Netherlands Meteorological Institute (KNMI)
- Karthala Volcano Observatory (CNDRS, Comoros Republic)
- Observatoire d'Arta (Djibouti)
- Earthquake Research Institute, Tokyo
- CENAI, Cuba
- Funvisis, Venezuela
- Université d'Etat, Haïti
- Bureau des Mines, Haïti



Organization and life of the observatory

- **Activity spread on 4 locations (3 time zones)**
 - Paris (IPGP, REVOSIMA coordinating unit)
 - La Réunion island (OVPF, REVOSIMA operational unit)
 - Martinique island (OVSM)
 - Guadeloupe island (OVSG)
- **Similar organization in each observatory**
 - Scientific staff
 - Engineering staff
 - IT staff
 - Administrative staff
- Yearly on-site meetings between IPGP and local observatory staff and local stakeholders





- **Collaboration and coordination**

- ✓ Dedicated online tools : RESANA, CITADEL, mail lists
- ✓ Weekly video-conference
- ✓ Frequent field missions between different sites
- ✓ Directors are members of the COPIL of SNOV
- ✓ Directors and Engineer in charge are members of the Volcanology Expert Committee (CEV) of IPGP (2-3 meetings/year)
- ✓ WOVO IAVCEI best practices

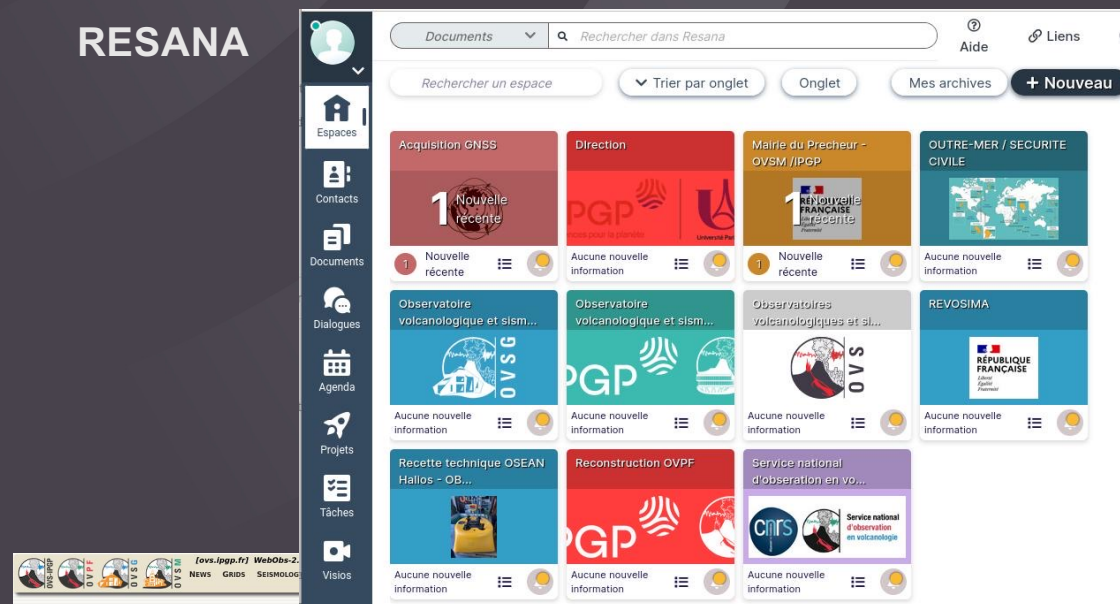
- **Budget tracking**

- ✓ Collaborative spreadsheets
- ✓ Mutualized access to budget lines

- **24/7 duty**

- ✓ Cellphone alarms based on automatic parameter threshold detection algorithms
- ✓ Remote access to WebObs and monitoring tools
- ✓ Re-inforced permanent duty during eruptions
- ✓ Standard operating procedures (SOP) and crisis protocols
- ✓ Yearly crisis exercises with the Préfecture and EMZ

RESANA



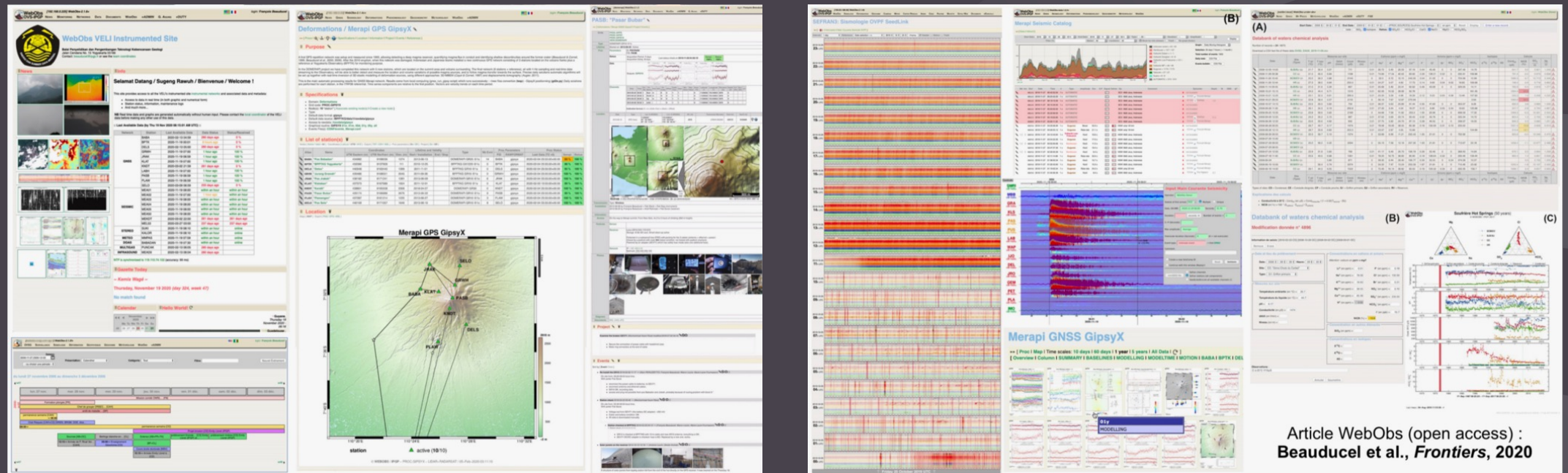
WebObs



WebObs : 20 years of development at the center of the volcano observatories

2022 : MESR open science prize

2023 : CNRS-INSU solid earth science community code label



Article WebObs (open access) :
Beauducel et al., *Frontiers*, 2020

Beauducel et al, Frontiers, 2020



Observations

Main results and output (2017-2022)

- **Piton de la Fournaise**
 - ✓ 18 eruptions
 - ✓ 8 magmatic intrusions
- **Soufrière de Guadeloupe**
 - ✓ Failed phreatic eruption
 - ✓ 2 weak ash projections / emissions
 - ✓ Permanent multiparameter unrest
- **Montagne Pelée**
 - ✓ Non eruptive multiparameter unrest
- **Mayotte**
 - ✓ Fani Maoré submarine basaltic eruption
 - ✓ Non eruptive multiparameter submarine unrest near Mayotte
- Seismic and GNSS networks upgrade in Guadeloupe and Martinique
- Sensor development (geochemical, borehole, optic-based)
- Operational data processing and modelling
- Development of new methodologies for volcanic systems imaging



Monitoring networks : permanent stations = 276

- **Seismology and deformation : 81%**

- ✓ ~140 seismic stations
- ✓ ~90 deformation stations

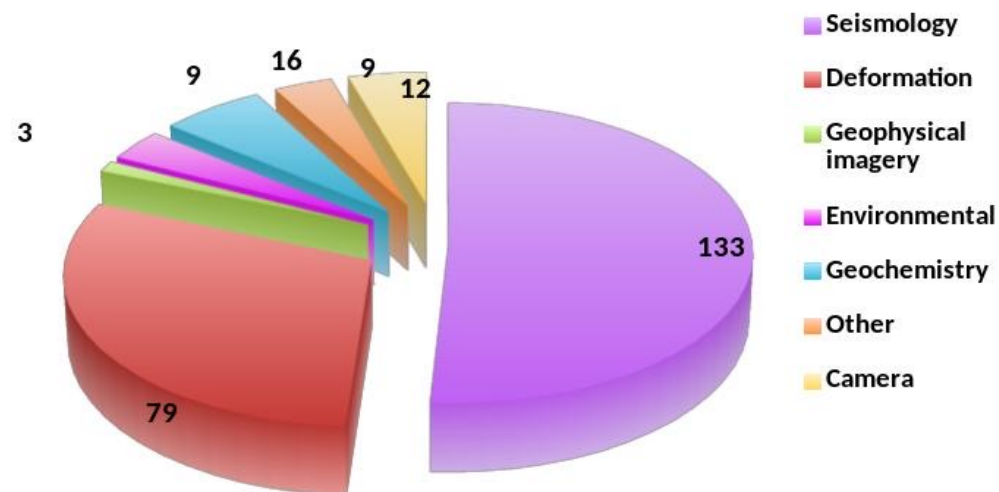
- **Geochemistry : 7% (~16 stations)**

- ✓ Passive soil degassing
- ✓ Fumaroles
- ✓ Hydrothermal waters

- **Other : 13% (~30 stations)**

- ✓ Cameras
- ✓ Weather
- ✓ Phenomenology

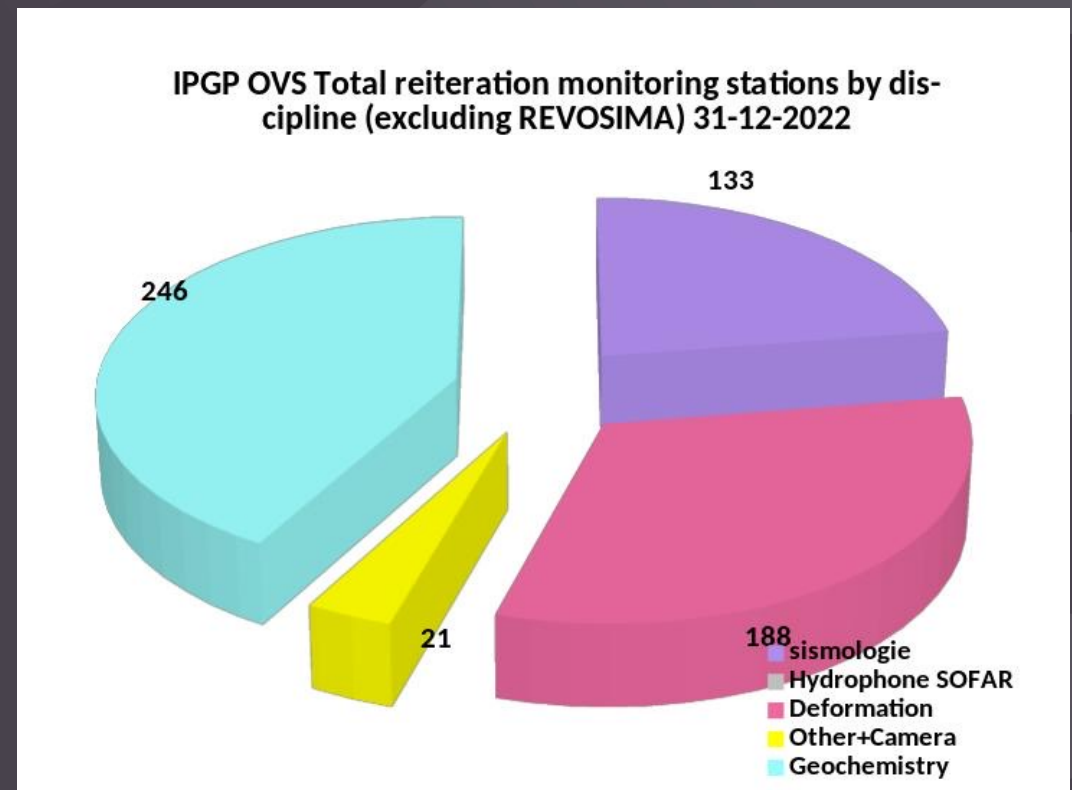
IPGP OVS Total telemetered monitoring stations by discipline (Excluding REVOSIMA) 31-12-2022





Monitoring networks : reiteration stations / measurement sites = 580

- **Geochemistry : 57% (~250 sites)**
 - ✓ Manual sampling
- **Deformation : 42% (~200 sites)**
 - ✓ Yearly measurements in the Antilles
 - ✓ After each eruption in La Réunion
- **Seismology : 31% (~130 sites)**
 - ✓ Includes nodes temporary experiments





Quantitative data: -> voir présentation REF2025 de J-M Saurel on 2025-11-21

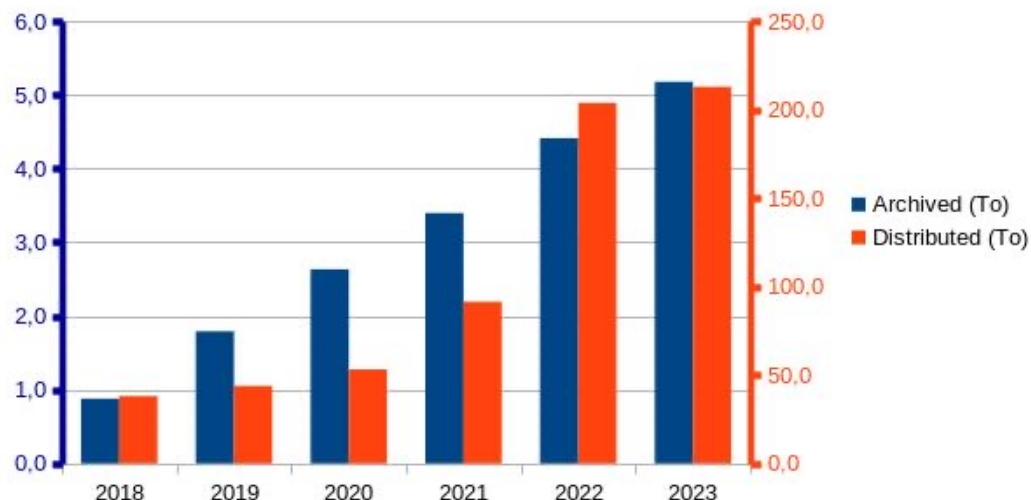
Data available from :

- IPGP datacenter
- Epos-France datacenter
- EPOS data portal

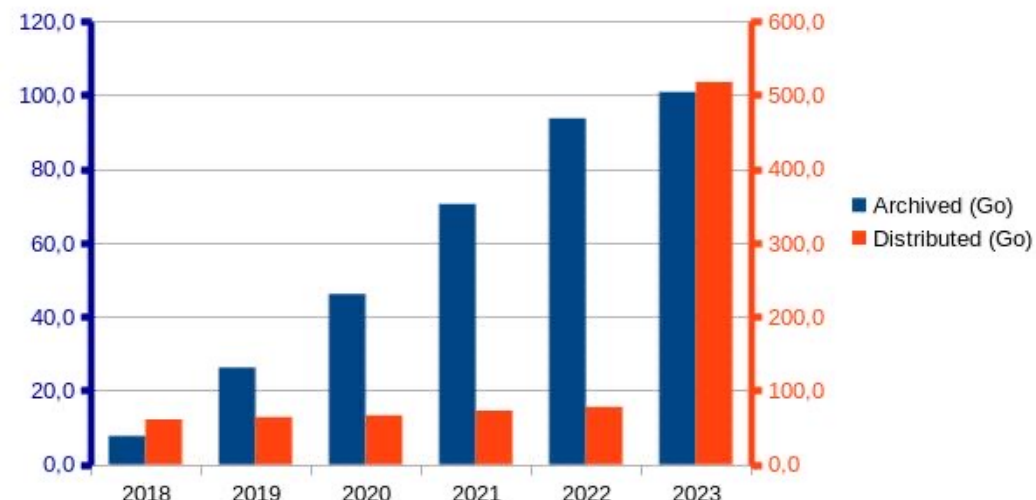
Data available from :

- IPGP GLASS node
- Epos-France GLASS portal
- EPOS data portal

Seismic and geophysical data



Geodetic data

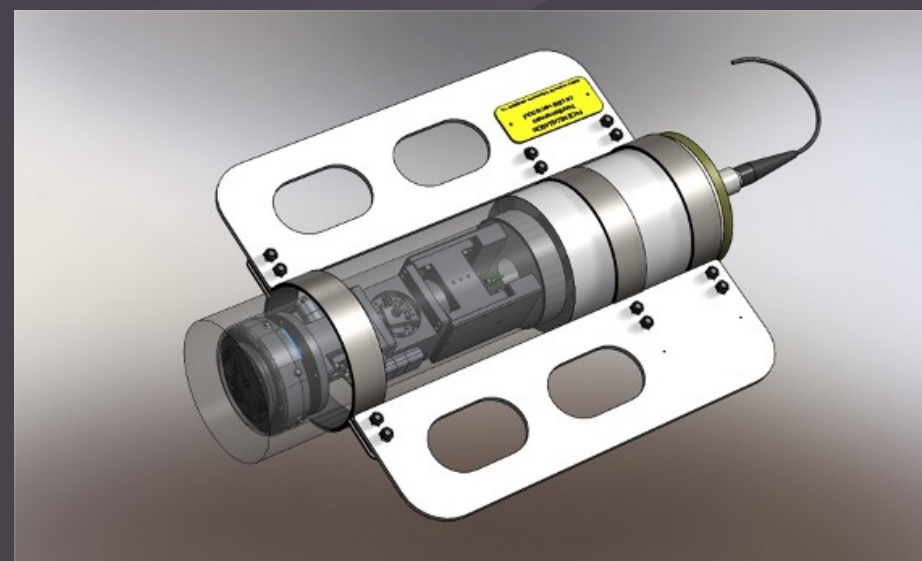




Innovative instrumentation

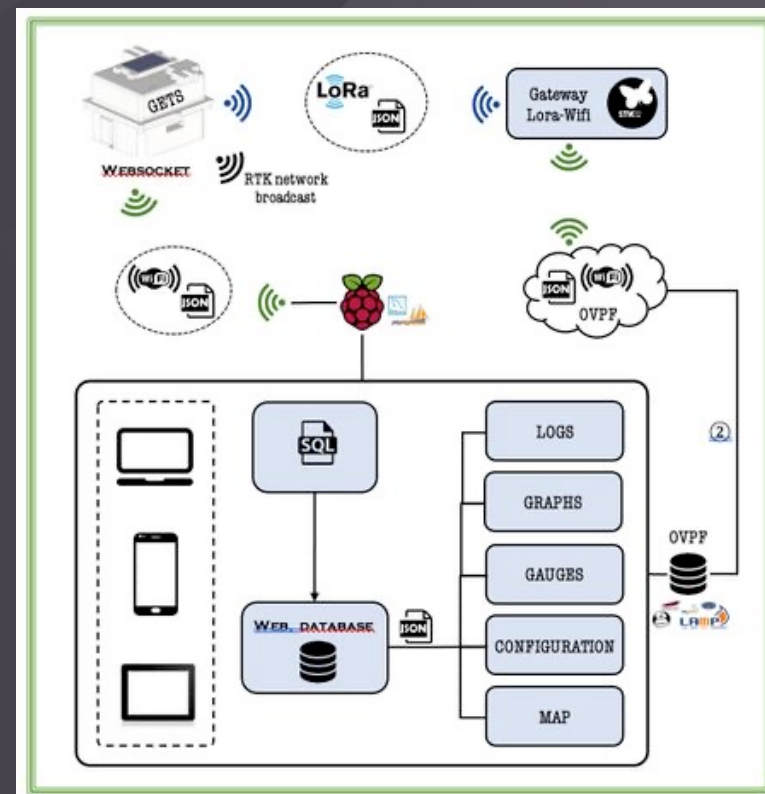
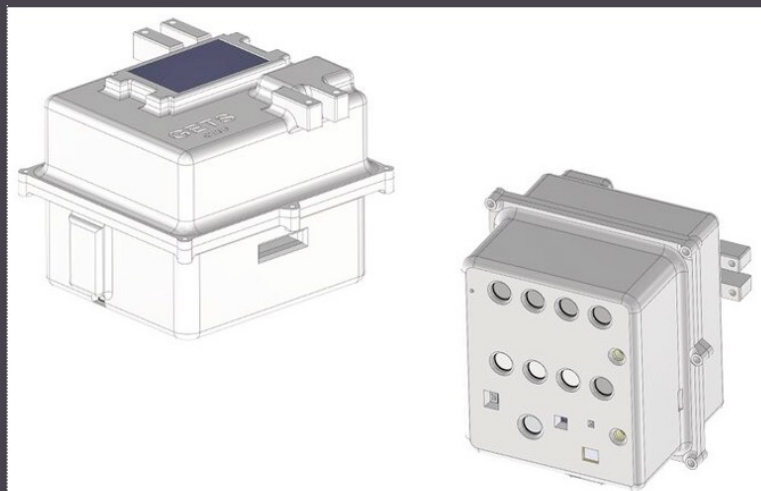
- Optical seismometer for harsh conditions
 - Soufrière fumaroles
 - Les Saintes sea-bottom
 - Development in collaboration with Seismology team
- Tiltmeter calibration bench
 - Calibration of low-cost sensors
- Portable multigas sensors
 - Fumarole flux estimations
- UAV adapted sensors and instrumentation

(Pôle Drone, IPGP, leader S. Bonaimé)



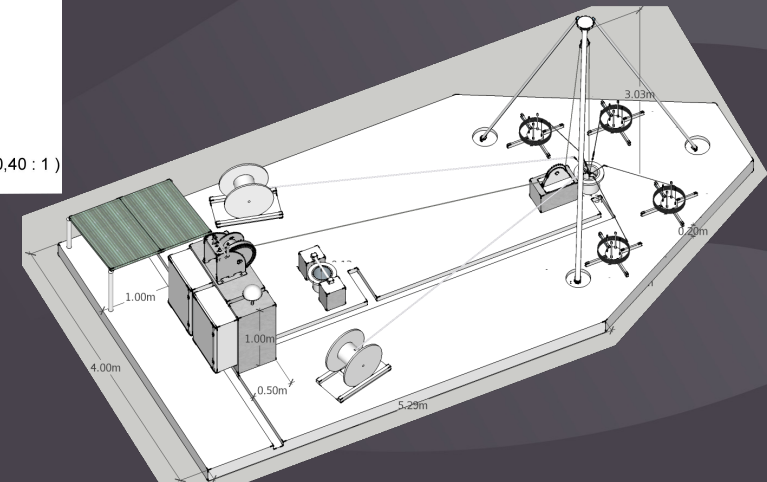
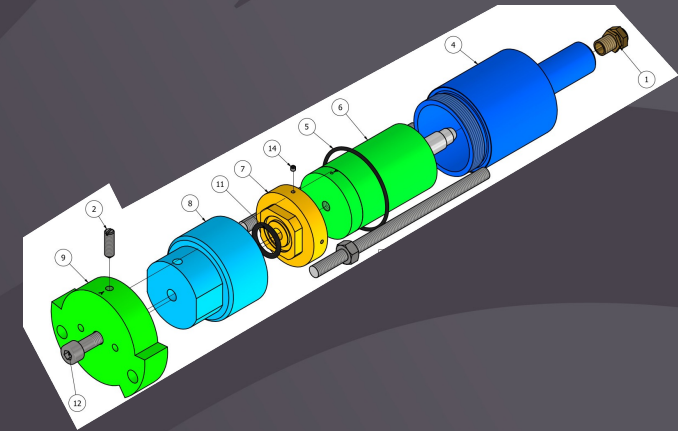
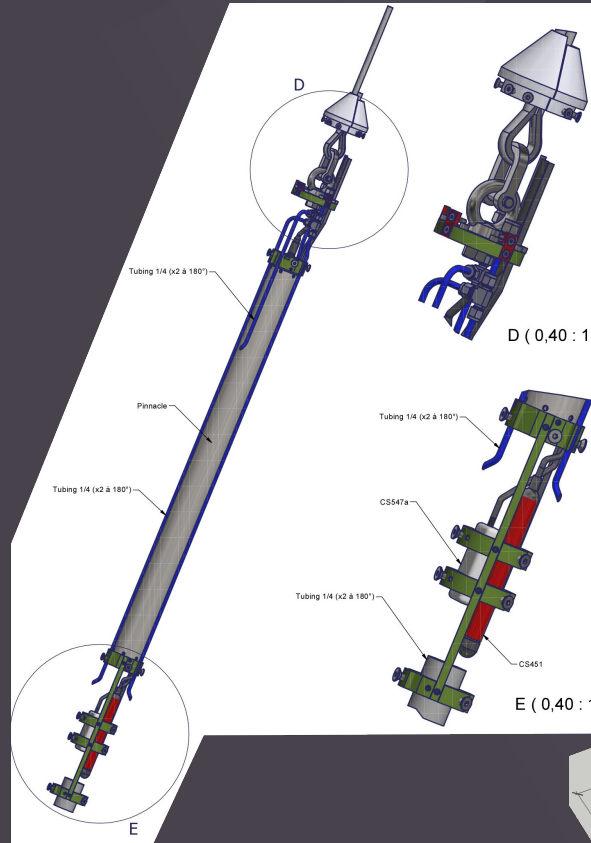


- GETS : light-weight geochemical analyzer
 - 9 chemical species
 - Particle monitor
 - UAV ready





- Borehole instrumentation package
 - High resolution tiltmeter (nanoradian)
 - Low-drift tiltmeter (microradian)
 - Pore-pressure sensor
 - Conductivity
 - Thermal flux sensor
 - Ready for Fiber-Optic based measurements
- Reduced environmental influence
- Increased signal to noise ration for detecting early precursory signals
- Reduced surface installation
- Increased robustness





National structure hosted at IPGP and operated by OVPF-IPGP and BRGM-Mayotte with partnership with IFREMER and CNRS.

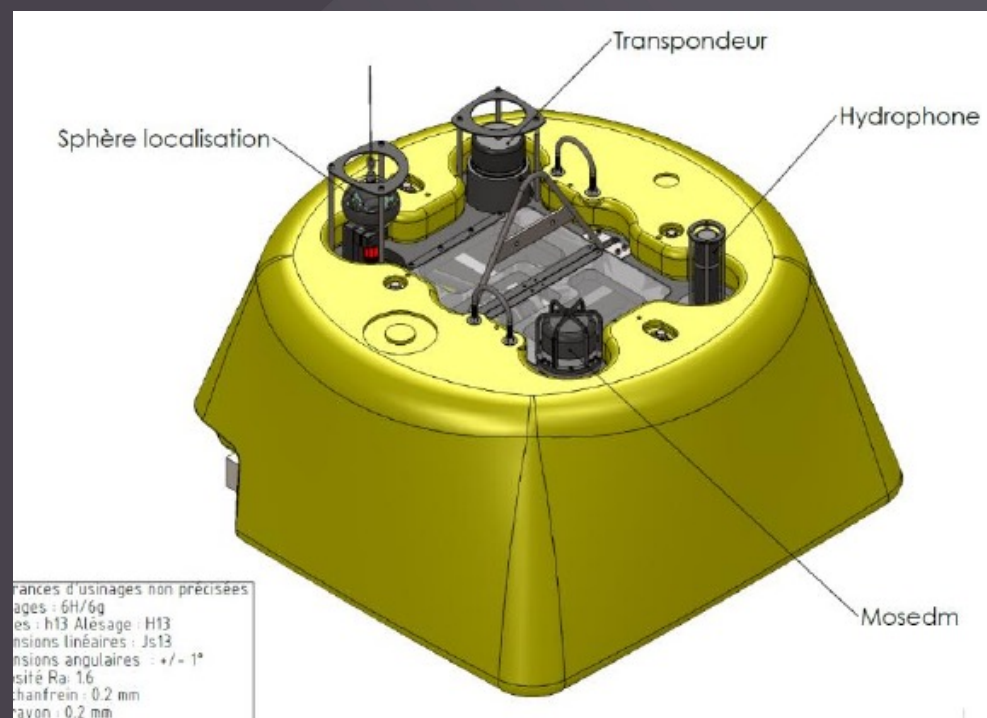
- HALIOS Ocean Bottom Seismometer (@OSEAN)

- Chip-scale atomic clock
- Acoustic modem
- Broadband seismometer
- Absolute pressure gauge

- Enhanced monitoring capabilities

- Events data collection through acoustic communication every 2 weeks
- 6 months no-drift clock

- Ready for cabled real-time operation



REVOSIMA



Development of operational tools



- More and more data available in observatories
- Continuous 24/7 instrumental monitoring
- Automatic and rapid monitoring tools are needed to detect unrest and eruptive precursors and help scientists to trigger ascending alerts

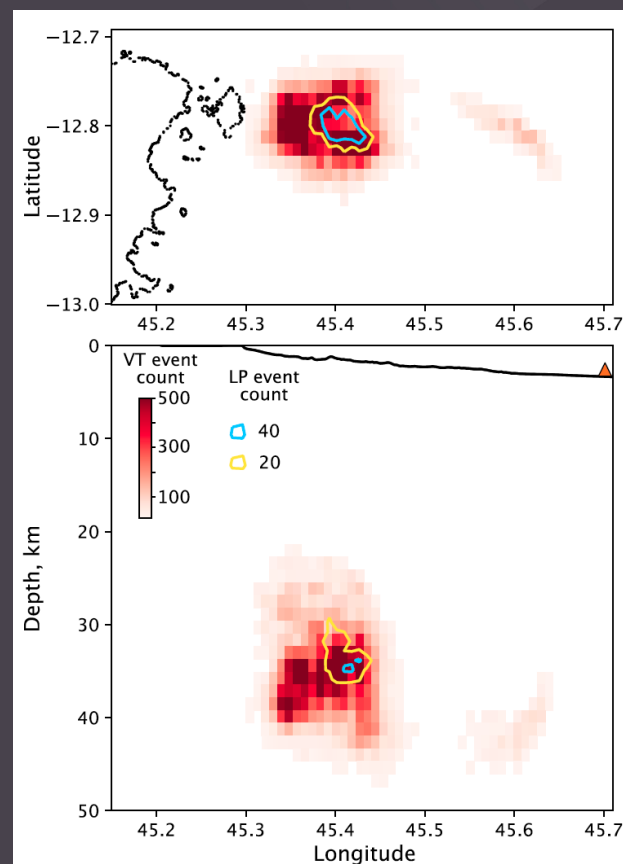
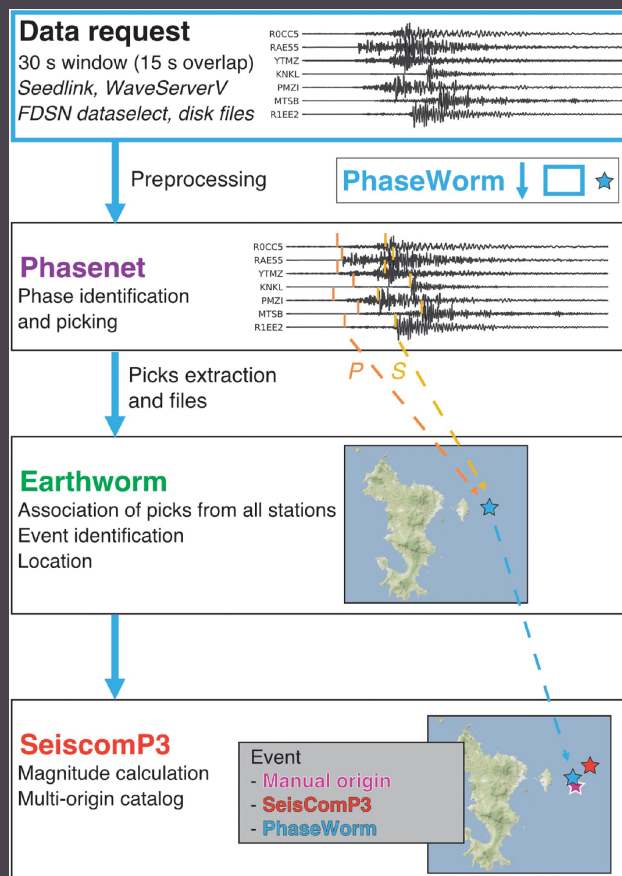


Several state-of-the-art analysis tools were developed in the IPGP VSO

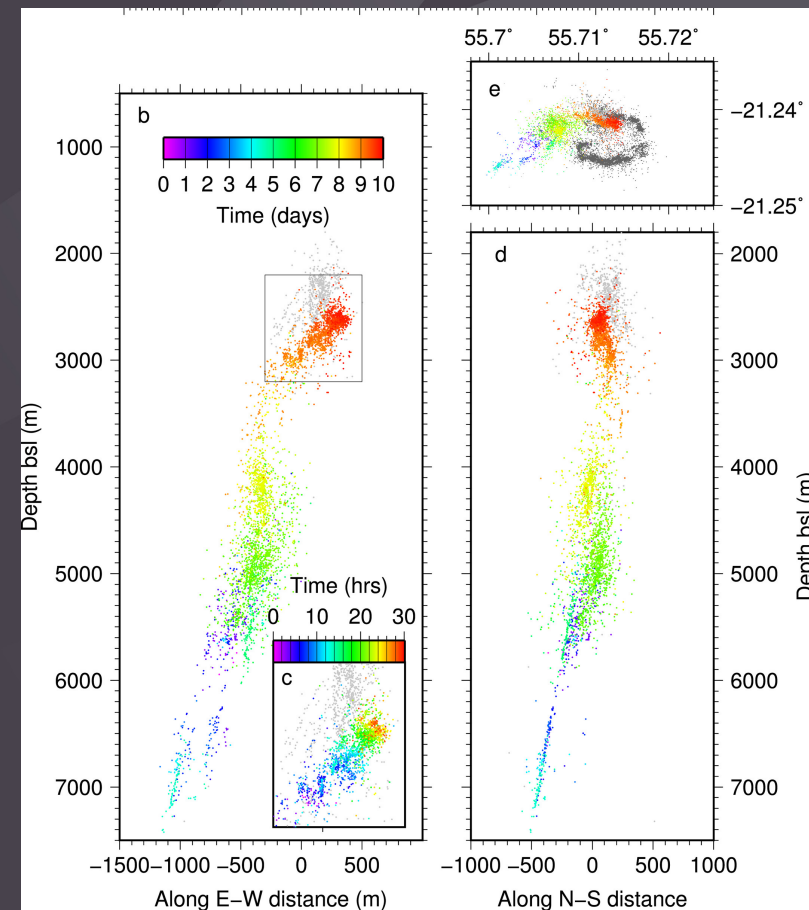
- For seismology

REVOSIMA: Mayotte

Piton de la Fournaise



Retailleau et al., 2022b

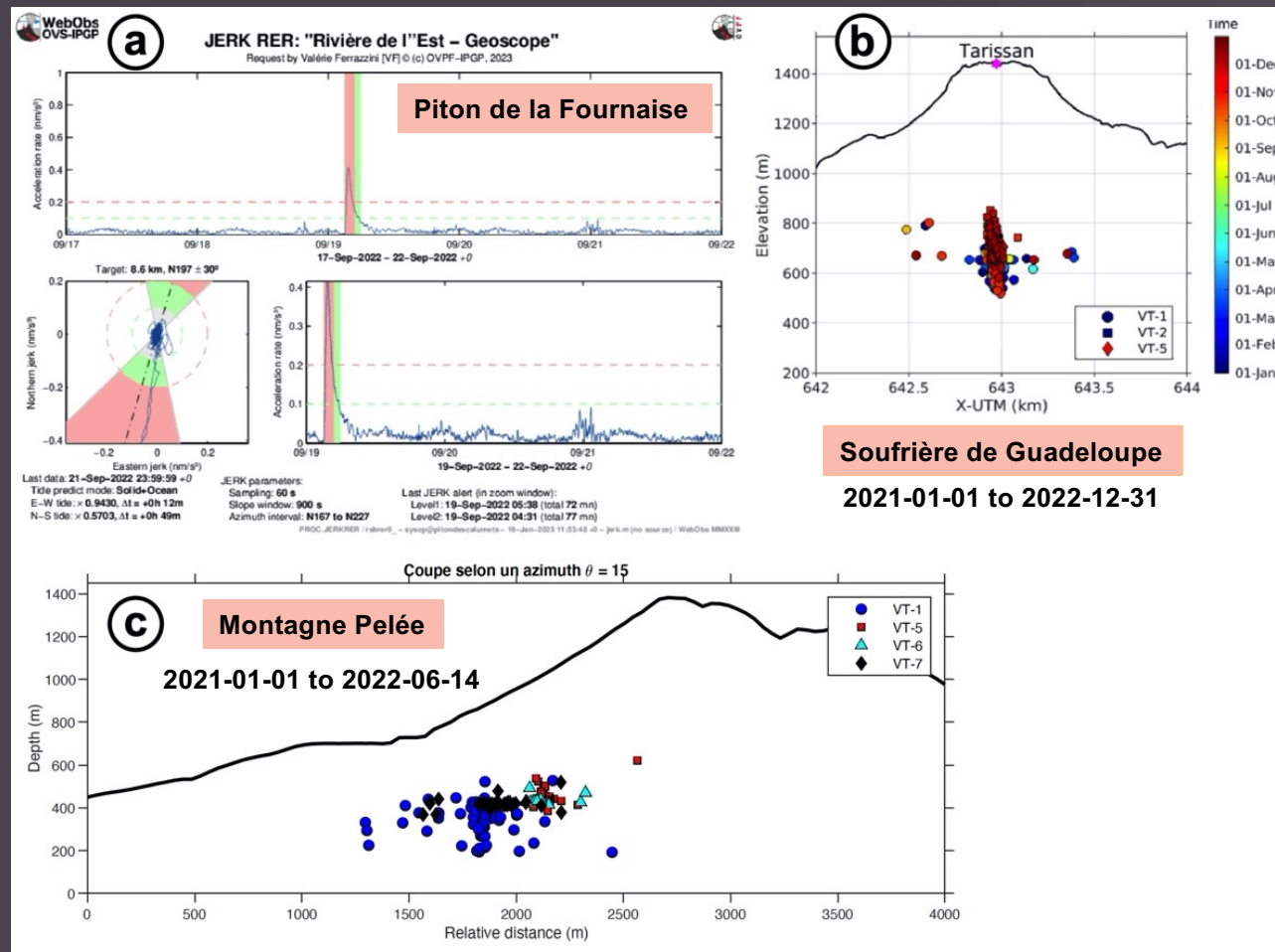


Template matching detection
(Lengliné et al., 2016)

Artificial Intelligence based phase detection
and recognition (e.g. Retailleau et al., 2022a)



Several state-of-the-art analysis tools were developped in the IPGP VSO



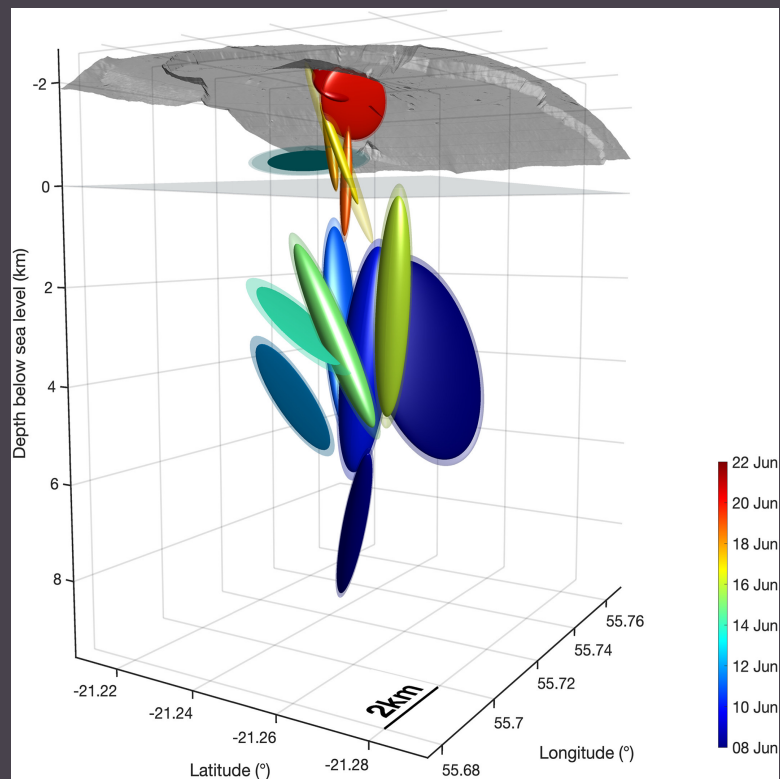
a) Jerk signal detecting transitory low frequency ground movements associated with dyke propagation at shallow depth before the 19 Sept 2022 eruption, **Piton de la Fournaise** (precursor, ~100% eruptions preceded by JERK signal few tens of minutes before an eruption) (Beauducel et al., in prep);

b) Relocalized hypocenters of main classes of volcano-tectonic earthquake repeaters below **La Soufrière de Guadeloupe**, initially detected by template matching (Pantobe et al., 2021);

c) Relocalized hypocenters of main classes of volcano-tectonic earthquake repeaters below **Montagne Pelée (Martinique)** initially detected by template matching (Burtin et al., in prep).



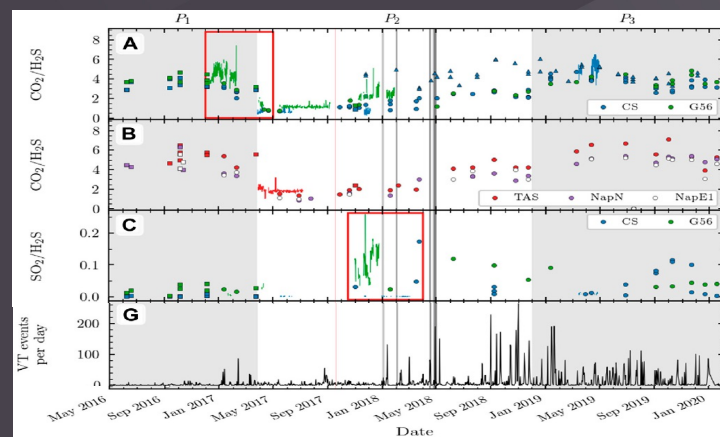
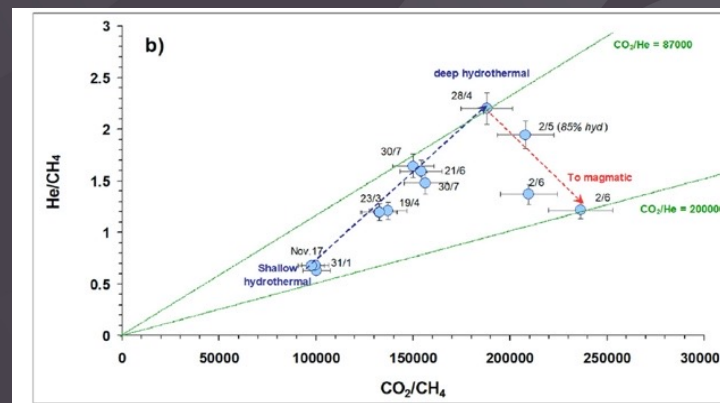
- For geodesy Piton de la Fournaise



Automatic unsupervised pCDM deformation source modelling (Beauducel et al., 2020)

- For geochemistry Soufrière de Guadeloupe

All analyses performed at the OVSG



Origin and process from fumarole gas ratios (top: Moretti et al., 2022; bottom: Moune et al., 2022)



2 examples of OVS research results with implication for crisis response

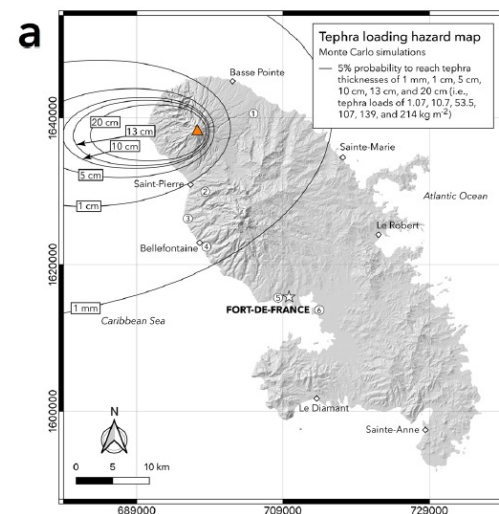
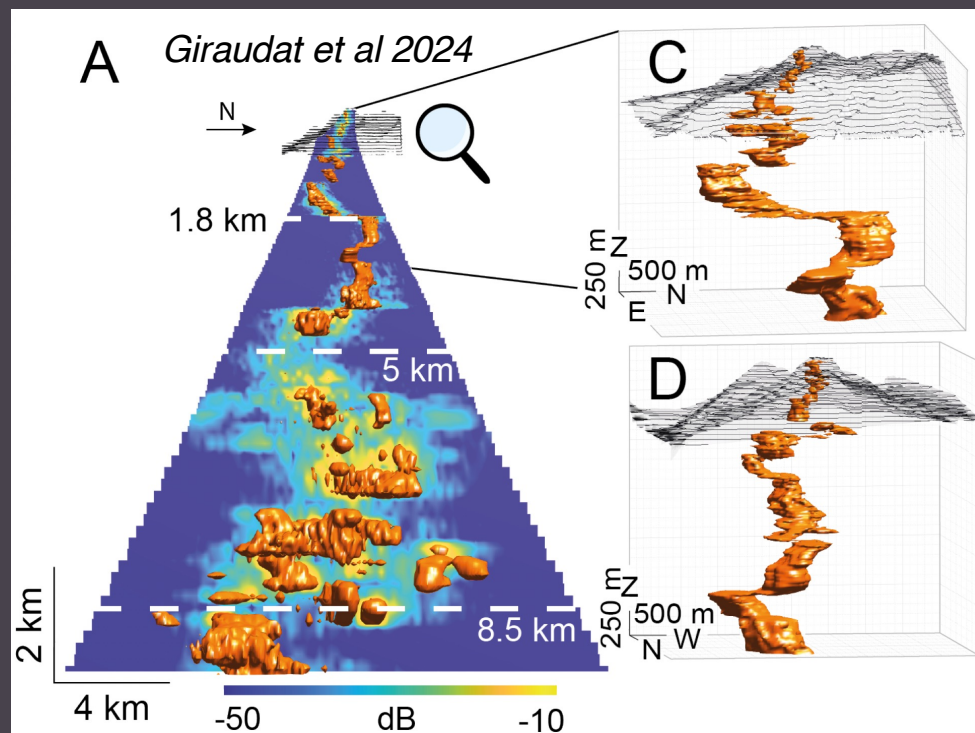
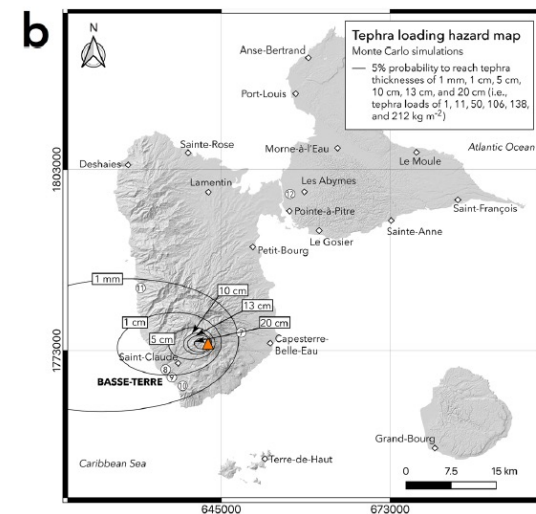


Fig. 6 5% probability contours of reaching the different tephra load thresholds detailed in Table 2, for **a** Montagne Pelée and **b** La Soufrière, using the Monte Carlo procedure, the complete 43-year wind ERA5 database, and three different TGSD (565,416 simulations for each island). The locations of all key infrastructures discussed in Table 4 are also reported, for Martinique (1, Capot pumping station; 2, Volcano Observatory OVSM; 3, North Caribbean hospital;



4, Bellefontaine gas-fired power plant; 5, Prefecture of Martinique; 6, Aimé Césaire international airport) and for Guadeloupe (7, Carbet pumping station; 8, Main hospital of Basse-Terre; 9, Prefecture of Guadeloupe; 10, Volcano Observatory OVS; 11, Bouillante geothermal power plant; 12, Pointe-à-Pître Le Raizet international airport)

communications earth & environment

Article


<https://doi.org/10.1038/s43247-024-01659-2>

Matrix imaging as a tool for high-resolution monitoring of deep volcanic plumbing systems with seismic noise

Check for updates

Elsa Giraudat¹, Arnaud Burtin², Arthur Le Ber³, Mathias Fink⁴, Jean-Christophe Komorowski² & Alexandre Aubry¹✉

Bulletin of Volcanology (2025) 87:11
<https://doi.org/10.1007/s00445-025-01795-3>

RESEARCH ARTICLE

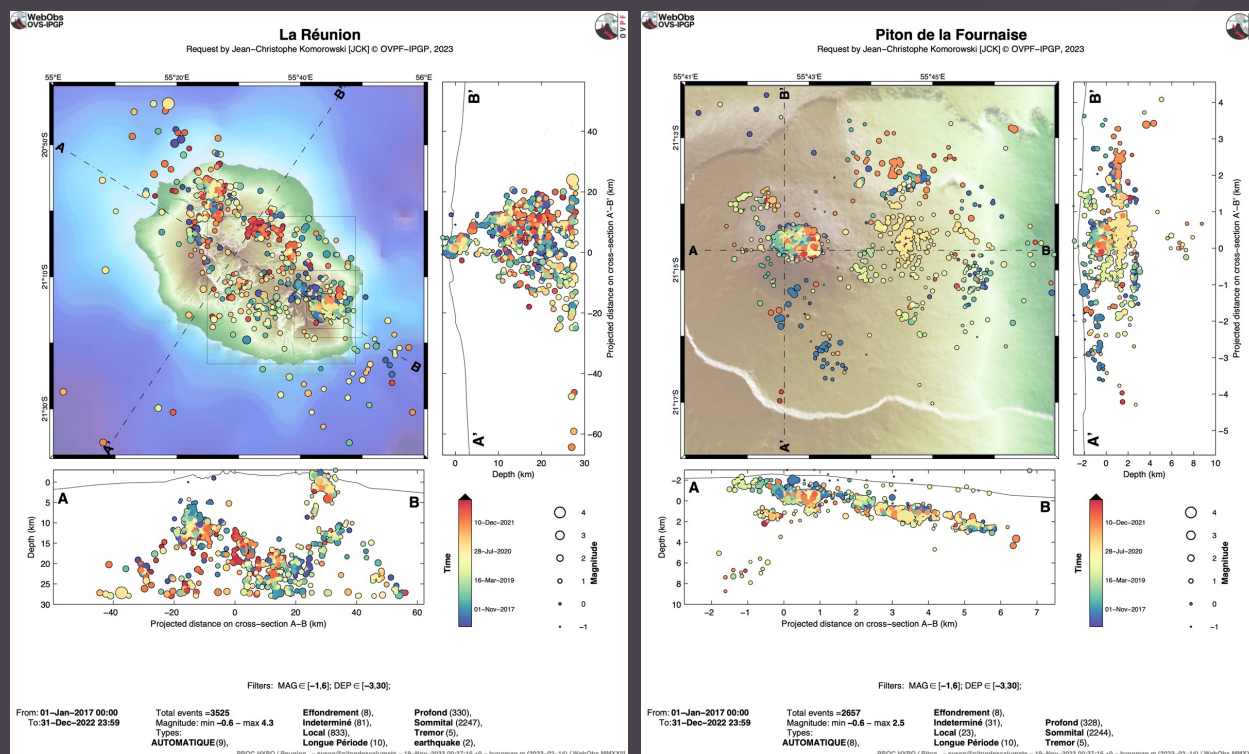
Tephra fallout and dispersal modeling of phreatic eruptions: implications for volcanic hazard assessment in Martinique and Guadeloupe (Lesser Antilles)

A. Michaud-Dubuy^{1,2}✉ · J.-C. Komorowski² · G. Carazzo²

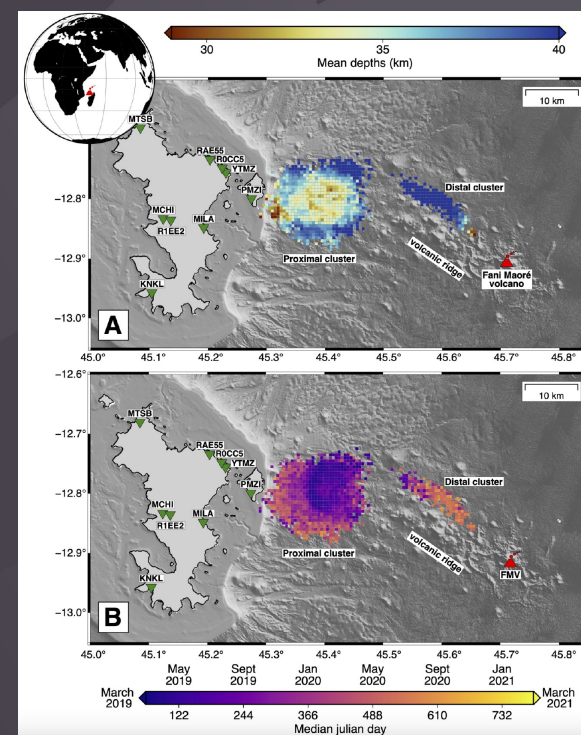


Regional seismicity in La Réunion recorded by the VSO and for Mayotte, recorded by REVOSIMA

(national structure hosted at IPGP, operated by OVPF-IPGP and BRGM-Mayotte in partnership with IFREMER and CNRS)



Real-time locations of earthquakes – OVPF-IPGP
<https://renass.unistra.fr/fr/zones/la-reunion/>



Lavayssière and Retailleau, 2023

Real-time locations of earthquakes REVOSIMA
<https://renass.unistra.fr/fr/zones/mayotte/>



Regional seismicity in Lesser Antilles arc recorded by the network of the Volcanological and seismological observatories (VSO)

FAIR DATA ACCESS: Multi-origin merged validated seismic catalog based on catalog from IPGP observatories in Martinique (OVSM) and Guadeloupe (OVSG).

From 2014/01/01 to 2019/12/31:

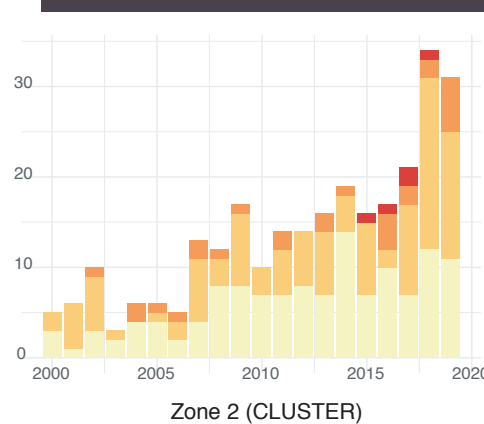
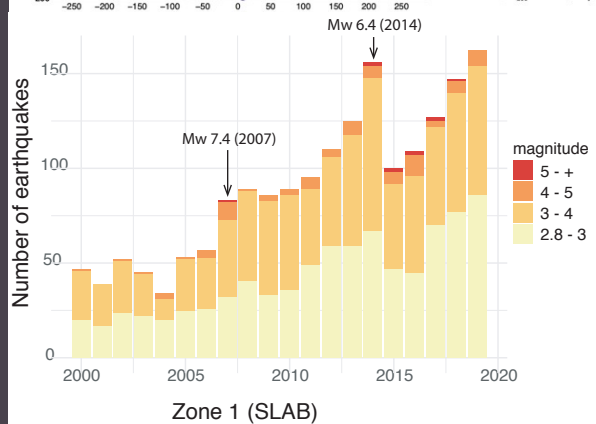
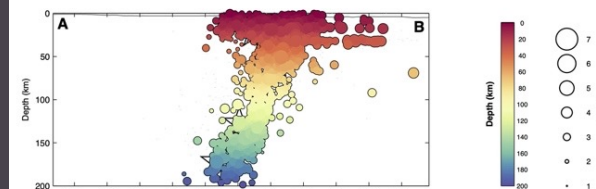
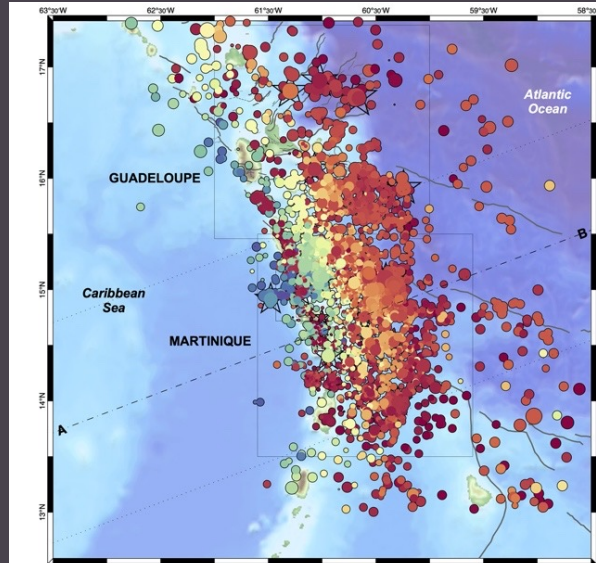
<https://dataverse.ipgp.fr/dataverse/OVSM>

<https://dataverse.ipgp.fr/dataverse/OVSG>

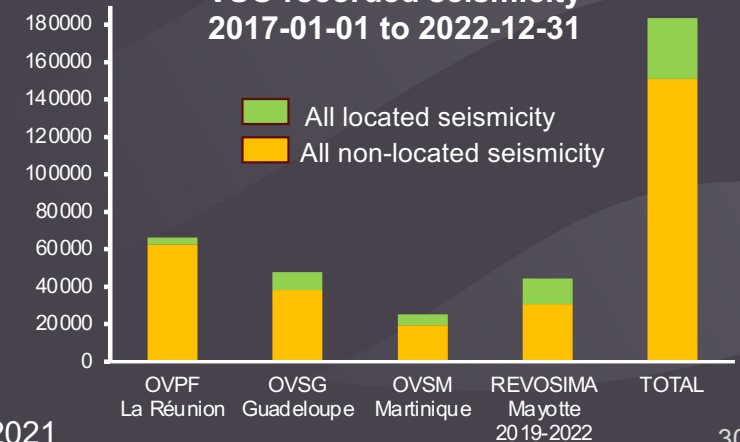
VSO of IPGP produce a very large set of localized seismicity :

- Public catalogs of seismicity via volobsis webservice <http://volobsis.ipgp.fr>
- Real-time locations of earthquakes <https://renass.unistra.fr/fr/zones/les-antilles>
<https://renass.unistra.fr/fr/zones/la-reunion>
<https://renass.unistra.fr/fr/zones/mayotte>

01-01-2017 to 12-31-2022



VSO recorded seismicity 2017-01-01 to 2022-12-31



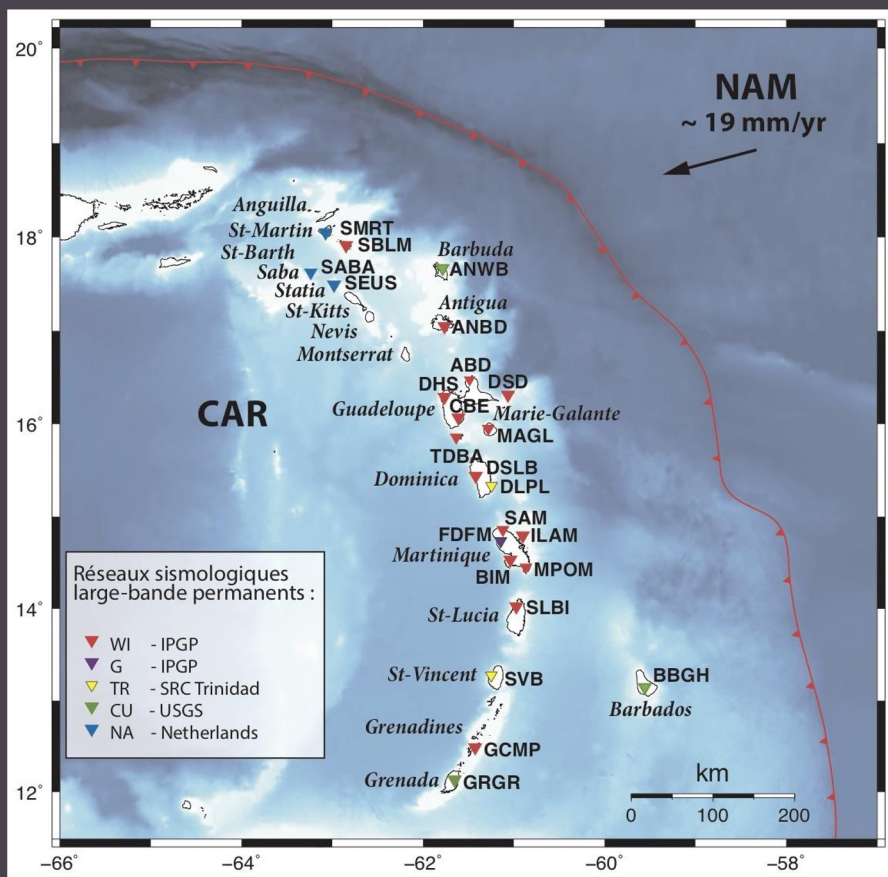
Corbeau et al., 2021



Contribution to the UNESCO Caribbean tsunami early-warning system (GIC-SATCAR)

OVSG and OVSM contribute to the ascending scientific alert for Caribbean tsunamis via :

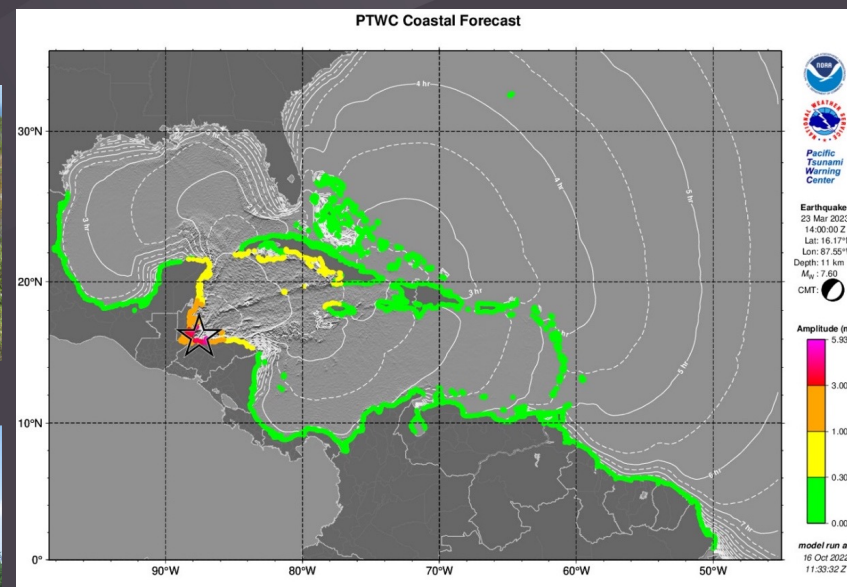
- seismic network with satellite transmission
- tide gauges (SHOM and CTM collaboration)



DSD, La Désirade



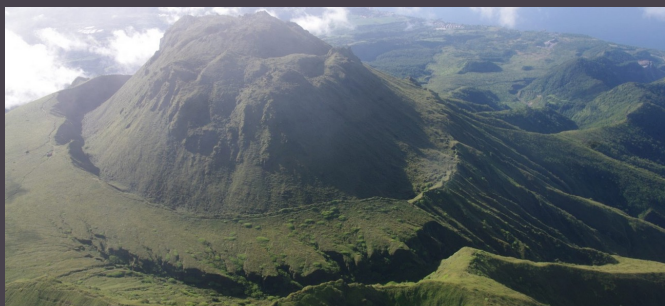
ILAM, Caravelle





Level of volcanic activity (2017 – 2022)

Montagne Pelée, Martinique
Subduction stratovolcano
closed conduit



La Soufrière, Guadeloupe
Subduction stratovolcano closed conduit
highly active hydrothermal system



Since
12 - 2020

Since 1999

Volcanic Alert Level

Level	Activity
Reference	Base level
Vigilance	Increasing
Pre-Alert Soufrière Pelée Alert 1 Fournaise	Potential eruption precursors
Alert 2-1 (Fournaise) 2-2 (Fournaise)	Eruption Inside Enclos, no risks Inside Enclos, risks
Alert 2-3 (Fournaise)	Eruption outside caldera
Safeguard (Only Fournaise)	Eruption ended, buffer safety period

Mayotte volcanic zone, subaerial and
submarine oblique plate boundary
explosive and effusive volcanism

**Volcano alert level system in
preparation (REVOSIMA)**

Piton de la Fournaise, La Réunion
Regularly active hotspot volcano



87
changes



Volcano Observatory Notice for Aviation – VONA

Official legal agreement between VSO and MTE (Arrêté JORF n°0079 du 3 avril 2014 page 6413 texte n° 52, Arrêté du 27 mars 2014 portant règlement pour l'assistance météorologique à la navigation aérienne)

Antilles: Washington DC, USA VAAC

La Réunion & Mayotte: Météo France
Toulouse VAAC

OVPF: 61 VONA messages

OVSG, OVSM: NO VONA

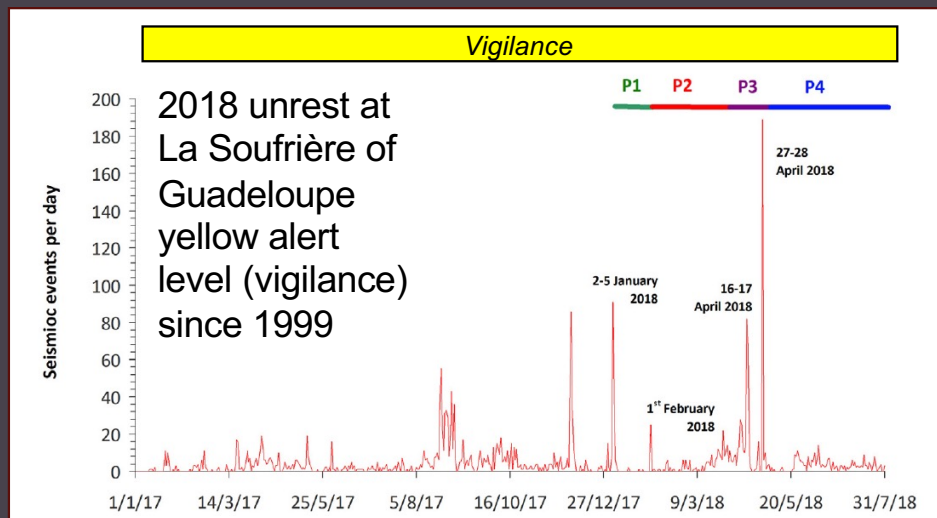
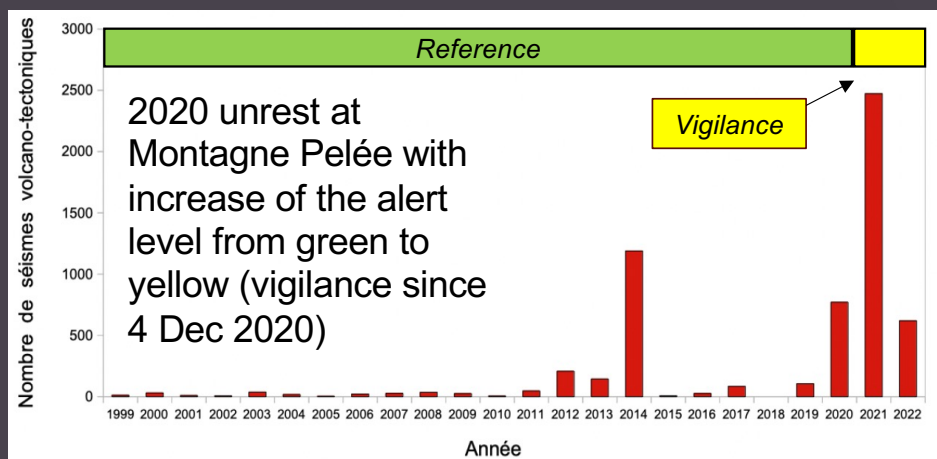
Color codes, which are in accordance with recommended International Civil Aviation Organization (ICAO) procedures, are intended to inform the aviation sector about a volcano's status and are issued in conjunction with an Alert Level. Notifications are issued for both increasing and decreasing volcanic activity and are accompanied by text with details (as known) about the nature of the unrest or eruption, especially in regard to ash-plume information and likely outcomes.

Color	Description
GREEN	Volcano is in typical background, noneruptive state <i>or, after a change from a higher level,</i> volcanic activity has ceased and volcano has returned to noneruptive background state.
YELLOW	Volcano is exhibiting signs of elevated unrest above known background level <i>or, after a change from a higher level,</i> volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase.
ORANGE	Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe uncertain, OR eruption is underway with no or minor volcanic-ash emissions [ash-plume height specified, if possible].
RED	Eruption is imminent with significant emission of volcanic ash into the atmosphere likely OR eruption is underway or suspected with significant emission of volcanic ash into the atmosphere [ash-plume height specified, if possible].

(1) VOLCANO OBSERVATORY NOTICE FOR AVIATION - VONA	
(2) Issued:	20230702/0430Z
(3) Volcano:	Piton De La Fournaise, 233020
(4) Current Color Code:	ORANGE
(5) Previous Color Code:	YELLOW
(6) Source:	OVPF (IPGP)
(7) Notice Number:	2022-5
(8) Volcano Location:	S 21°15'18 E 055°42'16
(9) Area:	Indian Ocean (Western)
(10) Summit Elevation:	8633 FT (2632 M)
(11) Volcanic Activity Summary:	Volcanic eruption is underway with no or minor ash emission
(12) Volcanic cloud height:	
(13) Other volcanic cloud information:	
(14) Remarks:	
(15) Contacts:	Aline Peltier (+262 692 62 14 49) Philippe Kowalski (+262 692 87 73 05)
(16) Next Notice:	A new VONA will be issued if conditions change significantly or the colour code is changed. http://www.ipgp.fr/fr/ovpf/actualites-ovpf



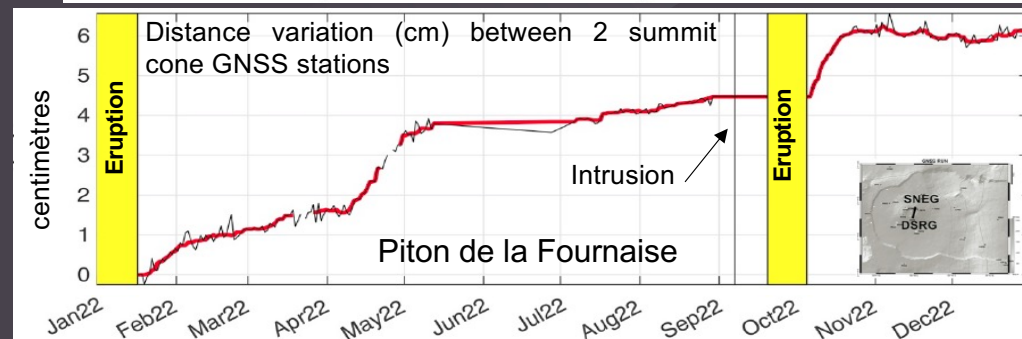
2017 – 2022 volcanic activity highlights



Piton de la Fournaise

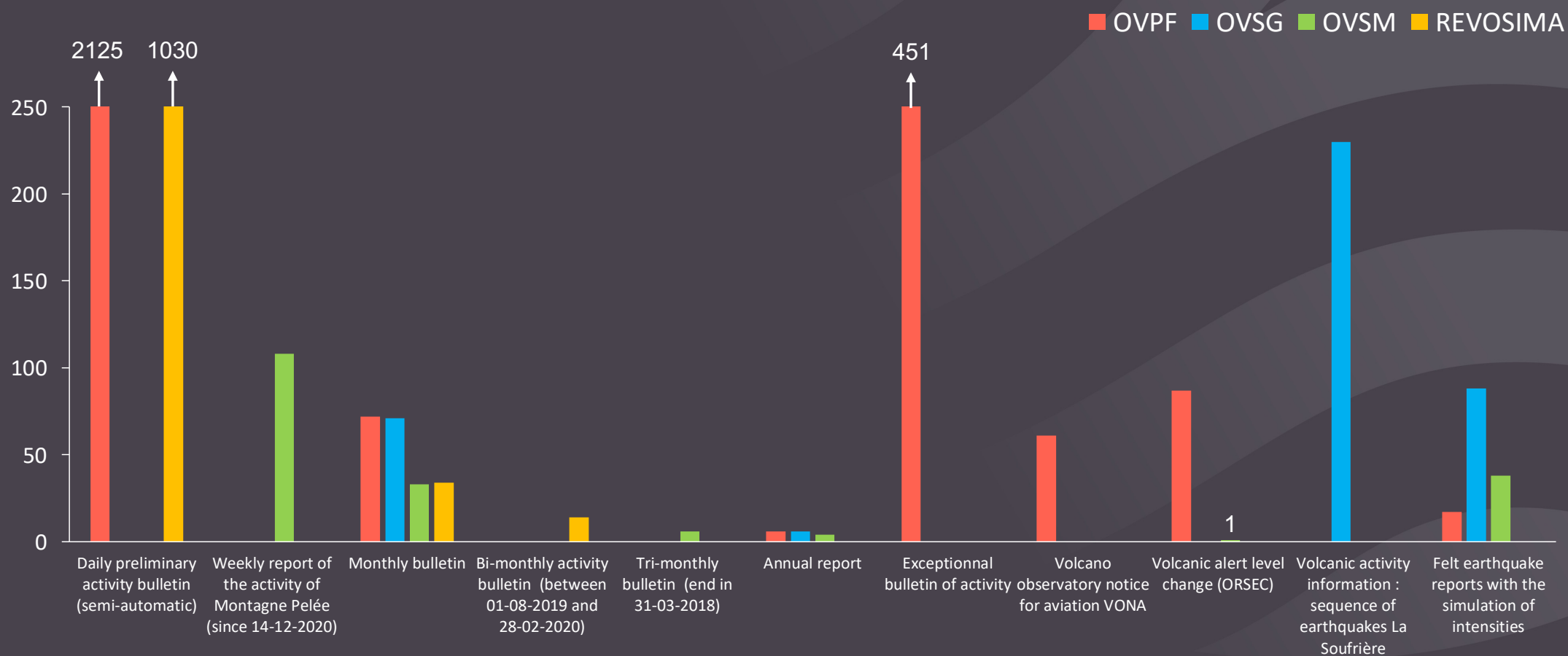
Nominal status: vigilance level since 2016

- 19 eruptions between 2017 and 2022
- increasing intrusive activity with 6 intrusions not immediately before eruption for 2017-2022 compared to 1 intrusion for 2012-2017





Activity reports, bulletins, information releases





Information releases

- web page :

www.ipgp.fr/ovpf

www.ipgp.fr/ovsg

www.ipgp.fr/ovsm

www.ipgp.fr/revosima

- facebook:

ObsVolcanoPitonFournaise

ObsVolcanoSismoGuadeloupe

ObservatoireVolcanoSismoMartinique

ReseauVolcanoSismoMayotte

- twitter :

@ObsFournaise

@ObsGuadeloupe

@ObsMartinique

@Revosima_

The volcano reports are also a product of the Volcano-TCS of EPOS-ERIC distributed by EPOS, to be integrated in Epos-France, and by the Data Center of IPGP via the volobsis (<http://volobsis.ipgp.fr/>) webservice as : <http://ws.ipgp.fr/volcano-reports>

Bulletin mensuel
Institut de physique du globe de Paris
Observatoire volcanologique et sismologique de Martinique
ISSN 2105 – 2301
Octobre 2023

A) Activité volcanique de la Montagne Pelée

La Montagne Pelée est un volcan actif de type explosif ayant connu de nombreuses éruptions magmatiques et phréatiques par le passé. Depuis la fin de la dernière éruption magmatique en 1932, qui a été associée à la mise en place d'un dôme de lave, son activité a décliné de manière significative jusqu'à l'arrêt de l'activité fumerolienne depuis 1970 et une activité sismique globalement très faible.

Depuis décembre 2018, l'activité sismique est passée au-dessus de son niveau de base établi à partir des observations instrumentales continues des années précédentes. Cette nouvelle activité se caractérise à la fois par de nombreux séismes superficiels de faible énergie, par quelques rares séismes profonds (localisés à environ 10-20 km de profondeur sous l'édifice volcanique) et par l'apparition de mouvements de fluides en surface.

La dégradation de la source superficielle de gaz à faible température située au sein du réseau de capteurs GIPG, en partenariat avec le Parc Naturel Marin, l'OVSM et l'évolution de ce phénomène en relation avec l'édifice mesurés par le réseau de capteurs GIPG, interprété par une source superficielle de gaz à faible température, pourrait être engendrée par des éruptions magmatiques (gaz, eaux hydrothermales) dans la zone du dôme.

L'ensemble de ces observations reflète une réaction de l'édifice à la baisse de son niveau de base. Cependant, l'activité sismique reste au-dessus de son niveau de base. Cependant, l'activité sismique reste au-dessus de son niveau de base. Cependant, l'activité sismique reste au-dessus de son niveau de base.

Au mois d'octobre 2023, l'activité sismique d'origine volcanique est faible et aucun séisme d'origine volcanique n'a été enregistré. Les sources thermiques de l'édifice ne montrent aucune variation et semblent stables sur le court terme. Les sources thermiques de l'édifice ne montrent aucune variation et semblent stables sur le court terme.

La probabilité d'une activité éruptive à court terme est faible. Les observations collectées depuis fin 2018 et de la base des observations résumées dans ce bulletin, et en accord avec les dispositions prévues par les autorités, le niveau d'alerte volcanique (tableau en annexe) reste :

JAUNE = Vigilance

Vous pouvez suivre les bilans hebdomadaires de l'activité volcanique de la Montagne Pelée (<https://www.ipgp.fr/fr/ovsm/bilans>).

Bulletin mensuel
Institut de physique du globe de Paris
Observatoire volcanologique et sismologique de Guadeloupe
ISSN 1622 – 4523
Octobre 2023

Résumé

Volcan de la Soufrière

- L'activité sismique s'est manifestée par 734 séismes dont un **petit essaim de 110 séismes** entre le 25 et 26 octobre. Tous les séismes ont une magnitude négative et sont localisés à moins de 1 km sous le dôme de La Soufrière. L'énergie libérée (**1.25 MJ**) est en légère hausse par rapport au mois précédent.
- Les températures des fumerolles sont en légère baisse (95.3°C à Napoléon Nord et 140.8°C à Cratère Sud Nord). Cette baisse peut être mise en relation avec l'importante pluviométrie au cours du mois (**608 mm à Piton Sanner**) en grande partie due au passage des **tempêtes Philippe (2-3 Octobre) et Tammy (22 Octobre)**.
- La déformation centrifuge du dôme est stationnaire.

Sur la base des observations résumées dans ce bulletin, et en accord avec les dispositions prévues par les autorités, le niveau d'alerte volcanique (tableau en annexe) reste :

Vigilance : Jaune

Activité tellurique régionale

- Une activité sismique régulière mais généralement de faible énergie (**158 séismes** de magnitude inférieure à 3.2) s'est manifestée sur l'ensemble du réseau de failles régionales.
- Un séisme a été faiblement ressenti le dimanche 22 octobre 2023 à 03:59 (heure locale). Cette secousse faible (magnitude 2.4 ± 0.3) a été localisée à 9 km au nord-nord-est de Deshaies, à 9 km de profondeur.

Bulletin mensuel
Institut de physique du globe de Paris
Observatoire volcanologique du Piton de la Fournaise
ISSN 2610 – 5101

Piton de la Fournaise (VNUM #233020)
S
8°E
2632 m

Le Piton de la Fournaise est un volcan basaltique de point chaud situé au sud-est de l'île de la Réunion (océan Indien). Son histoire éruptive a débuté il y a environ 500 000 ans. Il produit des laves fluides à l'origine d'éruptions généralement effusives (avec émissions de fontaines de lave et de coulées de lave) dont la moyenne de deux par an depuis 1998. Plus rarement, des éruptions explosives (avec recouvrement de la zone sommitale et émissions de cendres pouvant se disperser sur de grandes distances) ont eu lieu par le passé avec une récurrence centennale.

Les éruptions récentes sont limitées à la caldeira de l'Enclos Fouqué, à l'exception de quelques « coups » qui ne représentent que 3% des éruptions totales sur les 300 dernières années (1977, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023). Ce type d'éruptions « hors Enclos » peut potentiellement représenter une éruption explosive.

L'activité du Piton de la Fournaise est surveillée et suivie par l'Observatoire Volcanologique du Piton de la Fournaise (OVPF), une station de l'Institut de Physique du Globe de Paris (IPGP).

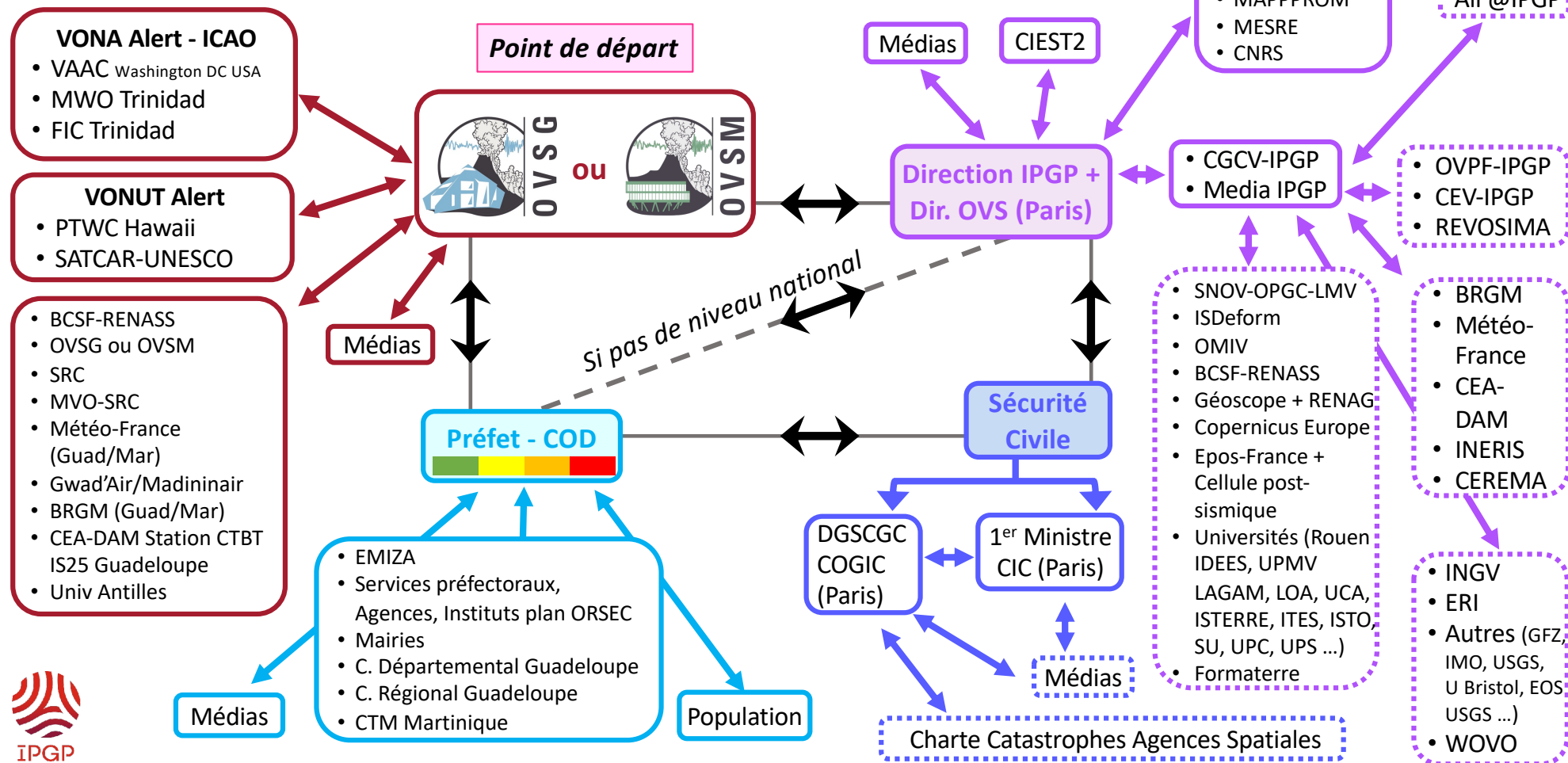
Niveau d'alerte : Vigilance
(depuis le 31 août 2023)

2 juillet 2023 (8h50) au 10 août 2023 (10h30) : Alerte 2-1
10 août 2023 (10h30) au 31 août 2023 (8h00) : Sauvegarde (Voir tableau en annexe)



Gestion opérationnelle scientifique d'une crise volcanique en Guadeloupe ou en Martinique, ou de volcans voisins : niveau institutionnel

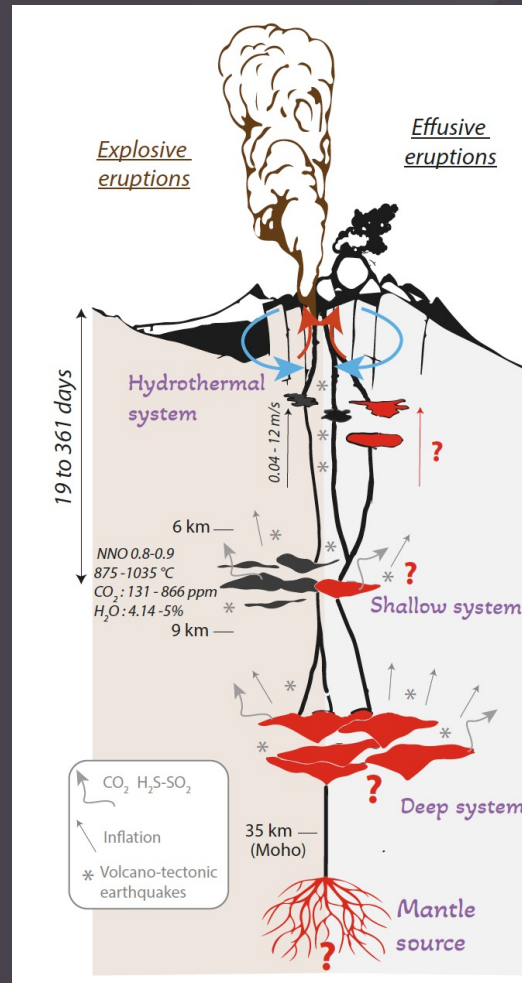
JCK, JMS: - IPGP, V3 maj: 19-11-2025





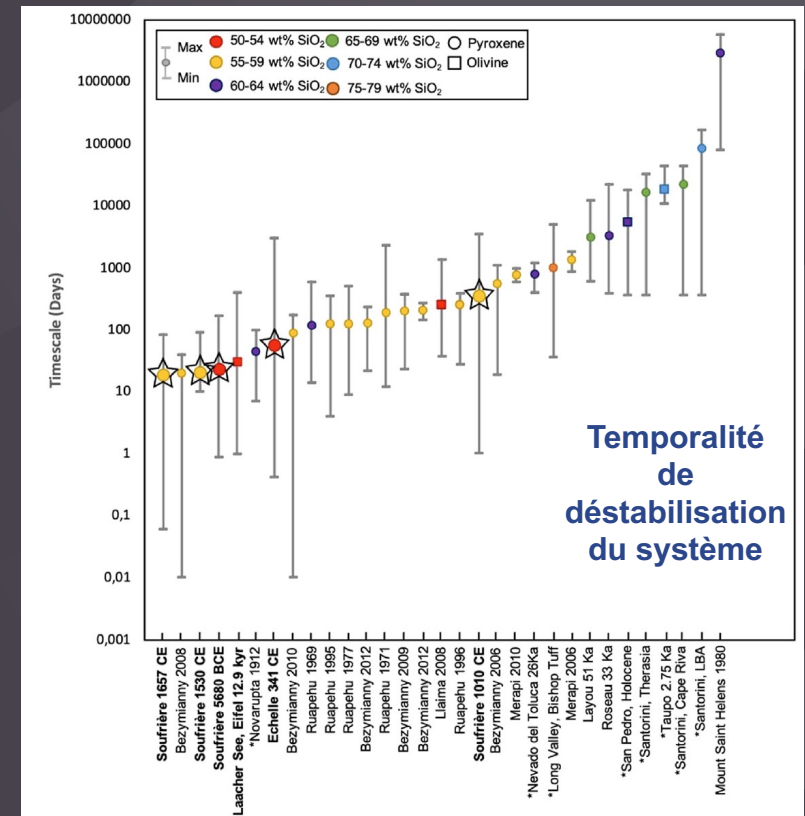
- **Génèse et maturation** des zones de stockage des magma, des systèmes trans-crustaux ≤ 20 km – milliers à centaines de milliers d'années
- **Déstabilisation** rapide des magmas dans les zones de stockage (mush) (**jours à mois**): par ex. 1-2 mois Mayotte (Berthod et al; 2021), 24-36 mois Pelée (Boudon et al., in prep), **Soufrière de Guadeloupe** ~ 12 jours à 6 mois, Metcalfe et al., 2021; 2022.
- **Remontée rapide** profonde magmas fluides (vitesse d'ascension: 0,01 to 10 m.s⁻¹ -> **heures à dizaines de minutes** pour les derniers 20 km voire 6-9 km) [**Soufrière de Guadeloupe** ~ 7 jours à 10 minutes, Metcalfe et al., 2022; Fani Maoré, Mayotte, 17 minutes (Verdurme et al., accepted); Fournaise minutes à dizaines de minutes]
- 1902 Montagne Pelée: ~14-8 **jours** remonté magma le plus riche en gaz (explosion latérale dirigée du **dôme le 8 mai 1902** et à plusieurs reprises jusqu'au 30 août 1902 et ~30 **jours** pour le magma le plus lent (Boudon et al., 2015); pour les **5 dernières éruptions Pliniennes** (Boudon et al., 2018) les temporalités entre le réajustement du magma en profondeur suite à une injection profonde et l'éruption en surface sont de l'ordre de **1-2 ans** mais dans de rares cas débutent **quelques décennies** avant mais de manière plus limitée voire sans signaux détectables en surface (Boudon and Balcone-Boissard, 2021)

Temporalités emboîtées des phénomènes magmatiques et cinétique des éruptions : contraintes des scénarios éruptifs futurs crédibles



Berthod, C. et al., 2023, unpublished

Soufrière de Guadeloupe



Costa et al., 2020; Metcalfe, Moune, Komorowski et al., 2021; Metcalfe, Thèse 21-01-2022

Contribution to eruption, earthquake, and tsunami crisis exercises, Préfecture, EMIZA, EMZPCOI, UNESCO (CaribbeWave), Plan Séisme Antilles, « Journées Japonaises » pour la prévention des risques telluriques en Guadeloupe, ...

Exercice Volcan Montagne Pelée 2022-12-07
Plan Orsec DS Phénomènes volcaniques Montagne Pelée
Préfecture de la Martinique
Observatoire Volcanologique et Sismologique de Martinique IPGP

Exercice = sur table, limité, en interne -> OVSM-IPGP, IPGP, SNOV
 = terrain mais limité -> préfecture, mairies, collectivités

Date / heure	Phénomènes	Actions
2022-11-14 10h00 loc	- Augmentation importante sismicité -> 20 km prof, VT, LP, trémor Eq ressenti M2,5 - GNSS: déformation - inflation X5 taux base - CO2 diffus sol augmente	- SCENEX info au CEV* IPGP - Renforcement surveillance - Rapport OVSM-IPGP Préfet - OVSM Recommande ORSEC -> orange - Préfet accepte, ORSEC pré-alerte, orange - B3 + VONA vert -> orange
2022-12-05 10h00 loc	- Sismicité augmentée - GNSS: 15x taux base	- Rapport OVSM-IPGP Préfet - SCENEX maj infos au CEV IPGP
2022-12-07 07h30 loc	- Sismicité aug. 2 Eq ress. M3,5+4,1 LP essais trémor prof Eq <1 km - Alerte GNSS pression - InSAR vecteur horiz > 1m 45-50°C flanc sud-ouest	- Rapport OVSM-IPGP Préfet - Simulation probabiliste cendres Préfet - OVSM Recommande ORSEC -> rouge - Préfet accepte, ORSEC alerte rouge - OVSM-IPGP alerte CEV CNRS SNOV 4MI - B3+ Préfet + pré-envoi bilan Préfet - B3+ VONA rouge éruption imminente
2022-12-07 08h00 loc	- Augm niv aquifère BRGM - Essais LP + trémor	- Préfet COD - ORSEC Alerte -rouge - Début évacuation zone « rouge » carte ->
2022-12-07 09h00 loc 09h30 loc	- Explosion phréatique - Emission cendres 1h - Retombée cendres 2h - Lahars - Petits glissements ? - Séisme ressenti M4,3	- Rapport OVSM-IPGP Préfet - VONA rouge éruption en cours - Simulation temps réel cendres Préfet - OVSM-IPGP alerte CEV CNRS SNOV 4MI - B3+ Préfet + pré-envoi bilan Préfet - OVSM Bilan public médias Twitter FB

EXERCISE - EXERCISE - EXERCISE
 This is an official exercise
 VOLCAN OBSERVATORY NOTICE FOR AVIATION - VONA
 Hazard: Unusual (2) data and info (VYVIMMCDHIMHIZ)
 202203070902
 Volcano Name and number (per Smithsonian database at Smithsonian volcano database)
 Current Aviation Color Code: RED
 Previous Aviation Color Code: RED
 Volcano Location: 14.85N 61.15W
 Volcano Activity Summary: Moderate level
 Volcano Cloud Height: 1500 m
 Other Volcano Cloud Information: Monitoring in progress
 Remarks: Dr. Jean-Benoît de CHABALIER (Observatoire volcanologique et sismologique de la Martinique)
 Contacts: Dr. Jean-Benoît de CHABALIER (Observatoire volcanologique et sismologique de la Martinique)
 Fac: 0596 9388 9388

VONA: Protocole alerte OACI (UN) + DGAC
OVSM-IPGP -> VAAC Washington DC, USA
+ Meteorological Watch Office Trinidad + Air traffic Control/Flight Information Center (Trinidad)
Préfecture + EMIZA + Météo France + IPGP ...

Plan Orsec, Préfecture:
 Ase router évacuation
 Ase router secours
 Communes à évacuer

Simulation déterministe
 Scénario phréatique
 - Hauteur: 8 km
 - Masse: 3 x 10¹⁰ kg
 - Vent du 28 novembre 2022 (Intensité ERA5)

Isopneusol simulé (cm)
 1000
 2000
 3000
 4000
 5000
 6000
 7000
 8000
 9000
 10000
 11000
 12000
 13000
 14000
 15000
 16000
 17000
 18000
 19000
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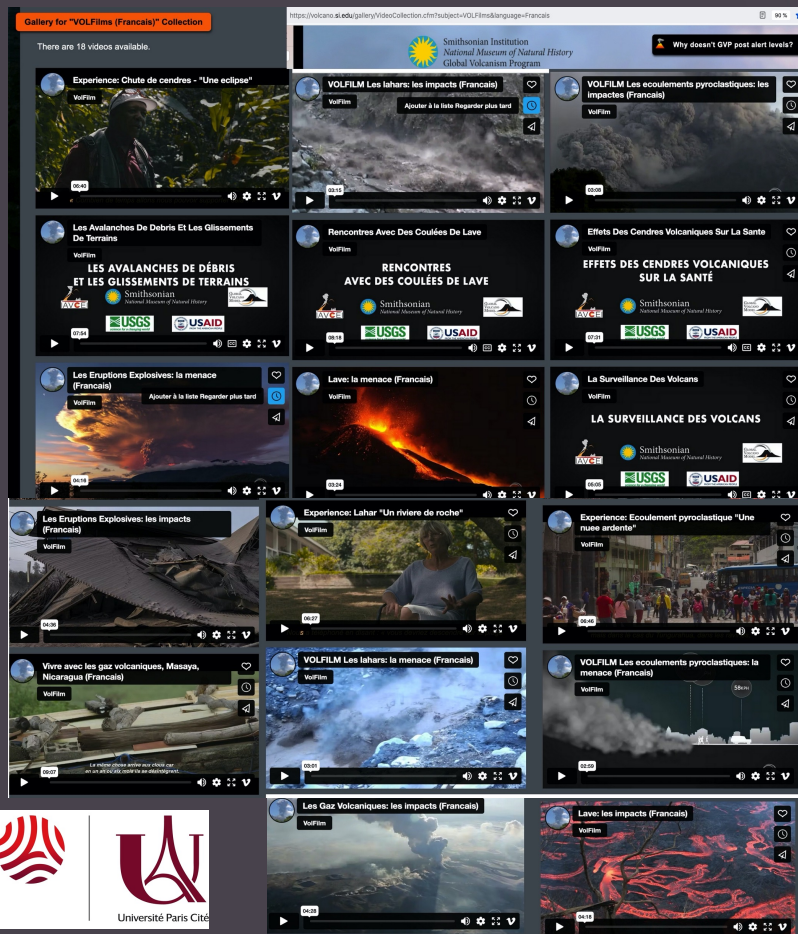
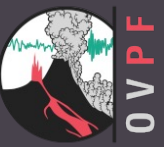
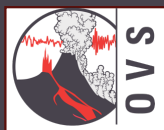
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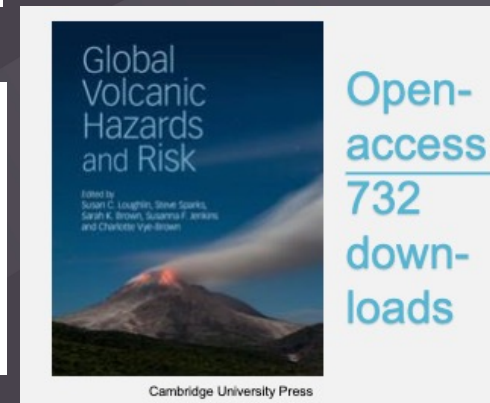
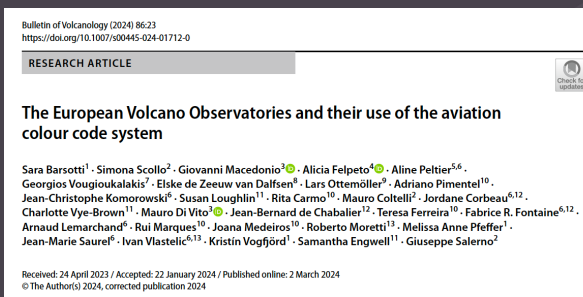
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Collaborative volcanology for building a global understanding of volcanic hazards and risk



World Bank - Global Volcano Model - IAVCEI - Volfilms:
<https://volcano.si.edu/gallery/VideoCollection.cfm?subject=VOLFilms&language=Francais>





Strengths

- Unprecedented activity of 4 French volcanic zones in all major tectonic settings -> high scientific challenges + societal impact
- Large proportion of IPGP research teams work on volcanoes
- VSO are attractive to researchers, PhD, national + international collaborations, innovative methodologies + instrumental development (muon tomography, machine learning, optical fiber)
- VSO scientific + technological breakthroughs have regional, national, and international impact + disseminate know-how
- OVSM 2nd oldest World VSO built in 1902 after tragic Mount Pelée eruption, and now the most recent VSO with new vanguard stunning facility built by CTM territorial council.
- IPGP VSO well respected + appraised in community of World Volcano Observatories (WOVO) of IAVCEI.
- 209 publications VSO staff, 30 first-author overseas VSO staff

Opportunities

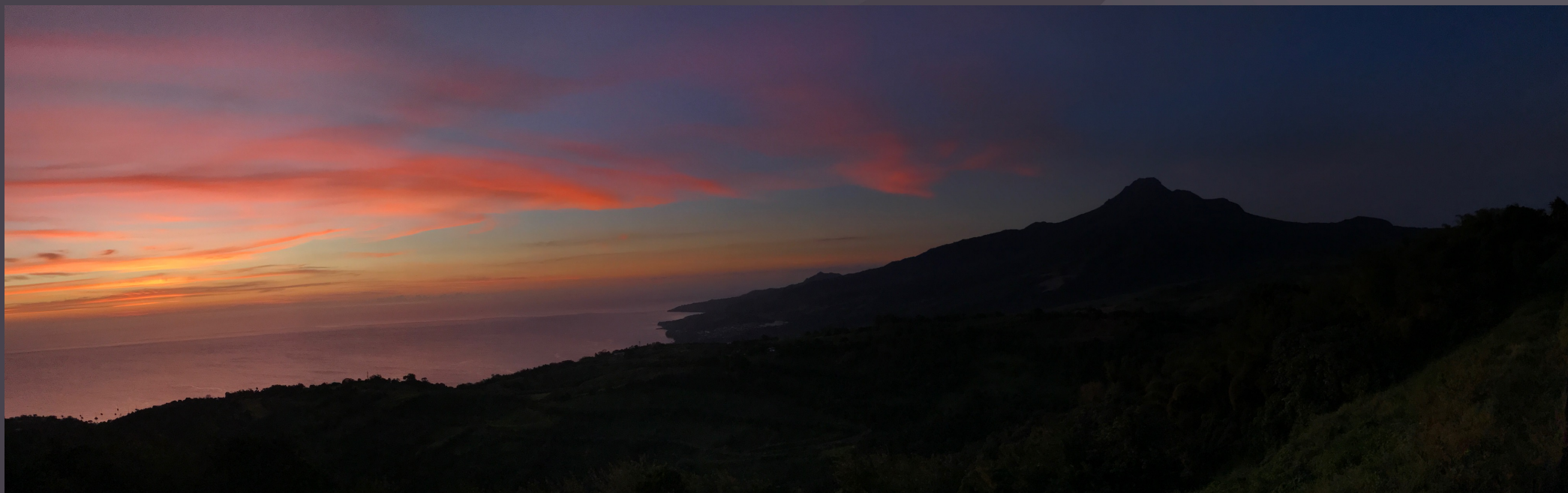
- 2026: Integration process SNOV + REVOSIMA into Epos-France
- 2017-2022: VSO successful at securing partially recurrent funding 1,9 M€ + 0,4 M€ IPGP co-funding from MTES
- Local authorities trust VSO + their scientific expertise in crises
- VSO play central role in transdisciplinary research (volcanoes and health, energy, mineral resources, global change)
- New CNRS + MESR 3 year-long contracts tenure-tracked
- Strong support of authorities + regional councils for ambitious VSO projects (INTERREG PREST, HATARI), MARMOR, IRIMA

Weaknesses

- Remoteness VSO to IPGP, vulnerability to multiple forcing agents (insular setting, natural disasters, limited critical mass of collaborating local scientists and engineers, limited and high cost analytical facilities, administrative difficulties, lack of cutting-edge fiber-optic internet connection)
- Too many short-term contracts (CDDs) causing very high turnover + cost of job search, recruitment, management
- Director, resident scientists assigned to overseas VSO not functional positions, turnover is elevated in the Antilles.
- No strong group geosciences/telluric hazards at the University of Antilles in contrast to University of La Réunion

Threats

- MESR and CNRS + MTES bear most operational costs of VSO's missions of crisis response, risk prevention with minor support of civil protection (DGSCGC) Interior Ministry.
- No governmental secured recurrent multi-year program of funding of the VSO forcing the IPGP to constantly leverage 67% of the VSO costs in competitive funding. So far unsuccessful to obtain multi-year funding strategy from ministries and other stakeholders (natural disasters reinsurers) for a nationally approved road-map for VSO.
- Retirement of 4 key VSO personnel in next 6 years.



Thank You !