Hydrothermal fluid circulation from soil CO_2 degassing, thermal flux, and self-potential

Amelie Klein[1], David E. Jessop[1, 2], Franck Donnadieu[1], Joanny Pierre[3], Ivan Vlastelic [2, 3], Roberto Moretti[4]

[1]Laboratoire Magmas et Volcans, OPGC, Université Clermont Auvergne, Clermont-Ferrand, France
[2]Institut de Physique du Globe de Paris, Université Paris Cité, France
[3]Observatoire Volcanologique et Sismologique de la Guadeloupe, Gourbeyre, France
[4]Department of Engineering, University of Campania Luigi Vanvitelli, Italy

amelie.klein@uca.fr

La Soufrière de Guadeloupe

- Andesitic dome with extensive hydrothermal system, fueled by magma reservoir 6-7 km below the summit [1] and tropical rainfall
- Growing unrest with peak in activity in 2018 [2]
- Host rock alteration and sealing by acid hydrothermal fluids:
  - affects dome permeability
  - promotes pore fluid pressurisation
  - increases likelihood of flank collapses and explosive activity [3].

Dome permeability reflects in ground heat and gas fluxes. Thus our **objectives** were to:

- constrain the spatial distribution of hydrothermal activity on the summit
- quantify ground heating and, for the first time, ground CO_2 flux.

Results provide important clues for interpreting the development of volcanic unrest and assessing hazards linked to fluid pressurisation.

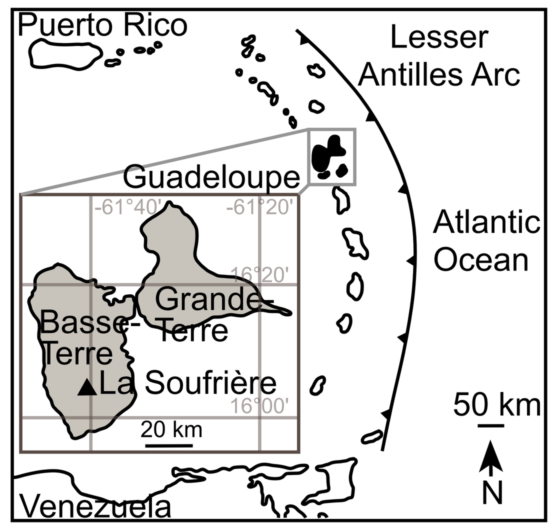
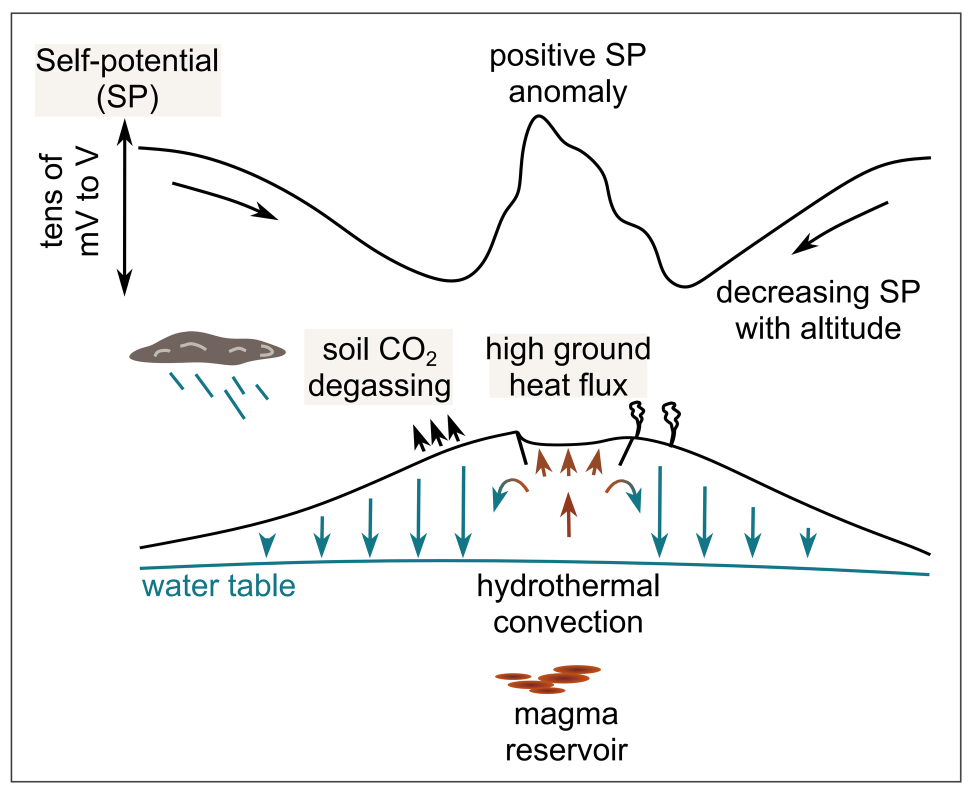


Fig.1: Location of La Soufrière de Guadeloupe and photo of the dome

Quantifying hydrothermal fluxes

Multi-parameter mapping to identify upwelling and recharge zones + estimate ground heat and CO_2 fluxes



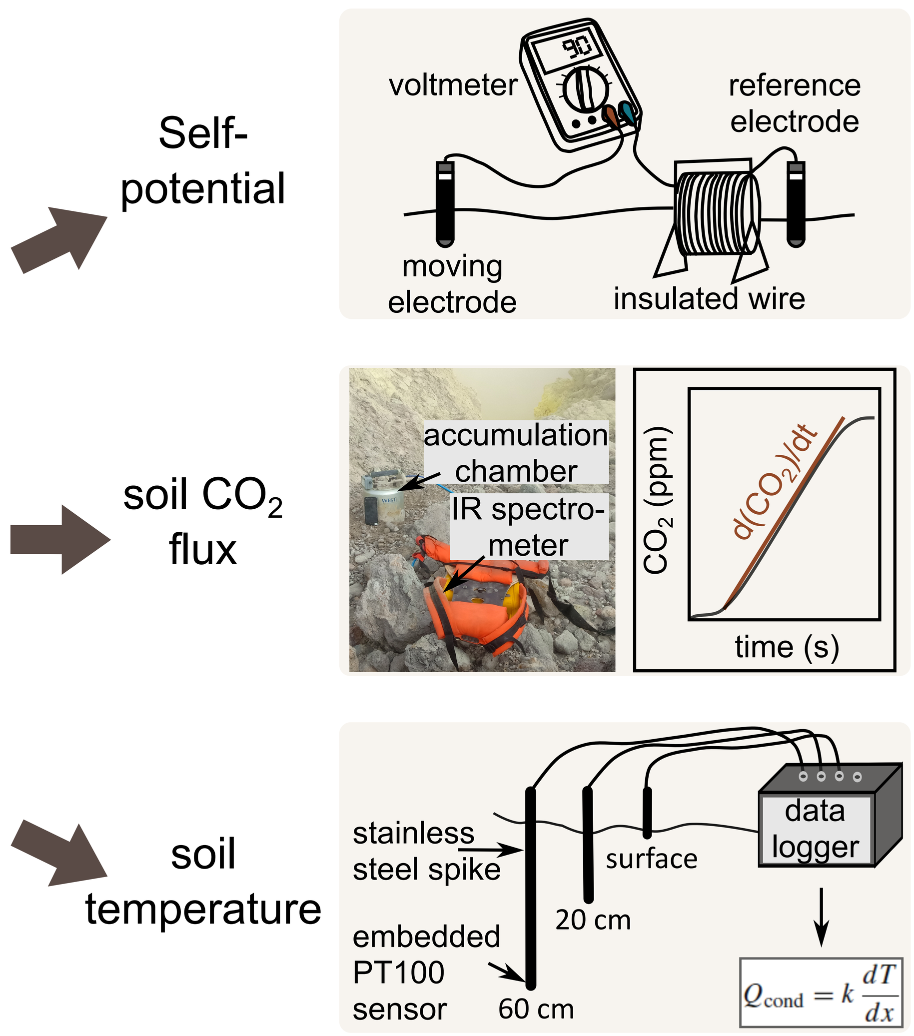


Fig. 2: Surface expressions of hydrothermal circulation and methods applied to localise and quantify subsurface fluid flow

Soil CO_2 emissions

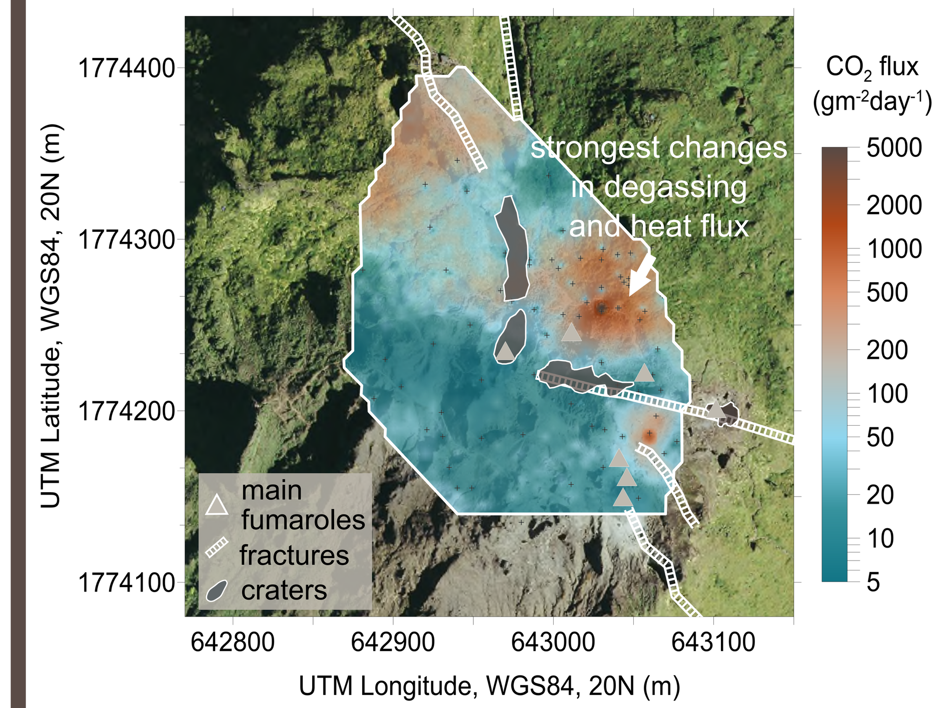


Fig. 3: Interpolated soil CO_2 flux on La Soufrière summit from May 2023. Background image IGN, BD ORTHO 2017

- 4.2 t m^{-2} d^{-1} soil CO_2
  → roughly half the flux from summit fumaroles [4, 5]
- highest CO_2 flux, ground heat flux and SP in NE sector of summit plateau
  → strong hydrothermal fluid circulation
- activity shifted to NE summit sector [1, 4, 6]

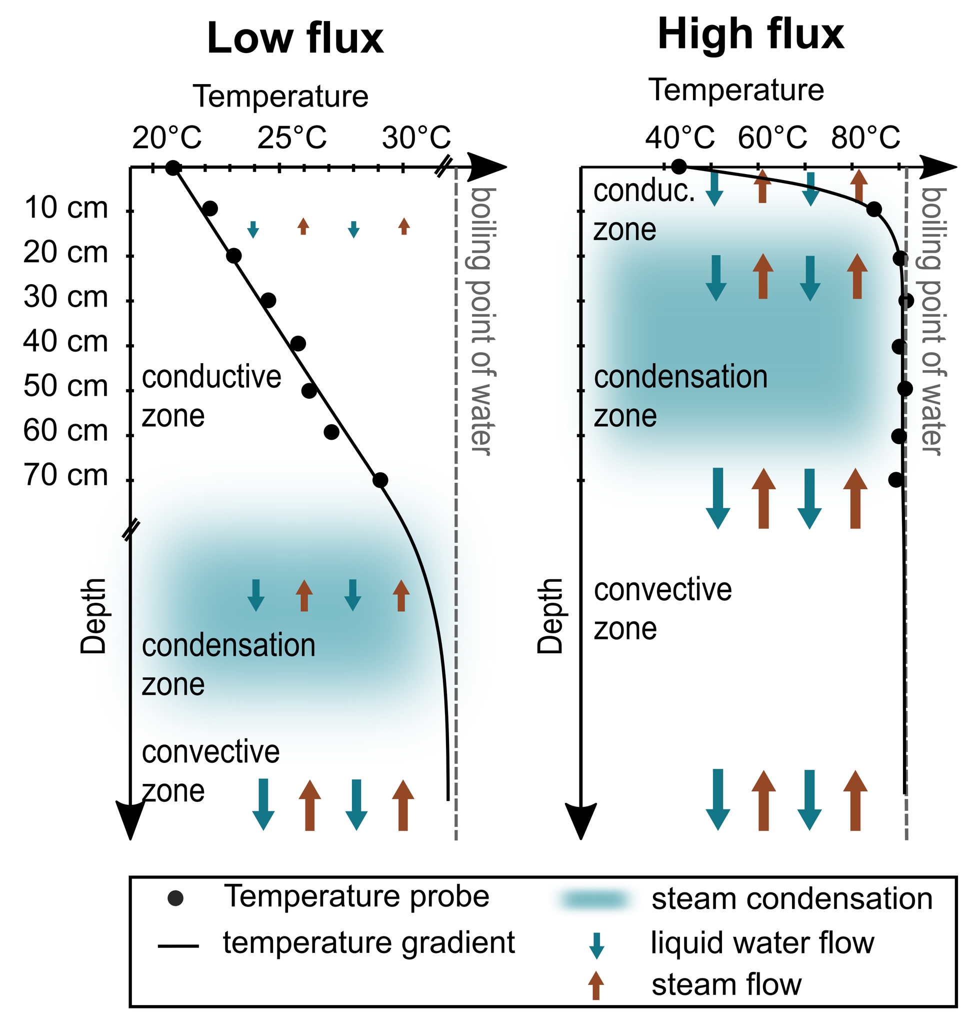
Permeability as controlling factor ...

Estimated condensation depth of rising fluids from measured ground temperature profiles

Shallow condensation level in NE summit sector (few tens of cm)

↓

Increased ground permeability may explain high ground CO_2 and heat flux in NE sector of summit



High ground permeability:

→ fluids rise more easily to surface

→ shallow condensation

→ high soil CO_2 and heat flux

→ latent heat of condens-ation causes extensive ground heating

Fig. 4: Temperature profiles in diffuse degassing zones on La Soufrière summit (figure adapted from Gaudin et al., 2017)

... for changing patterns of unrest

- Area of ground heating has likely expanded since 2019 [4, 6]
- Increase in shallow hydrothermal circulation in NE dome sector [4, 6, 7]

Key factors:

→ changing ground permeability

→ opening of W–E summit fractures and sliding of SW flank [2]

→ contribution of lower water level in hydrothermal aquifer ?

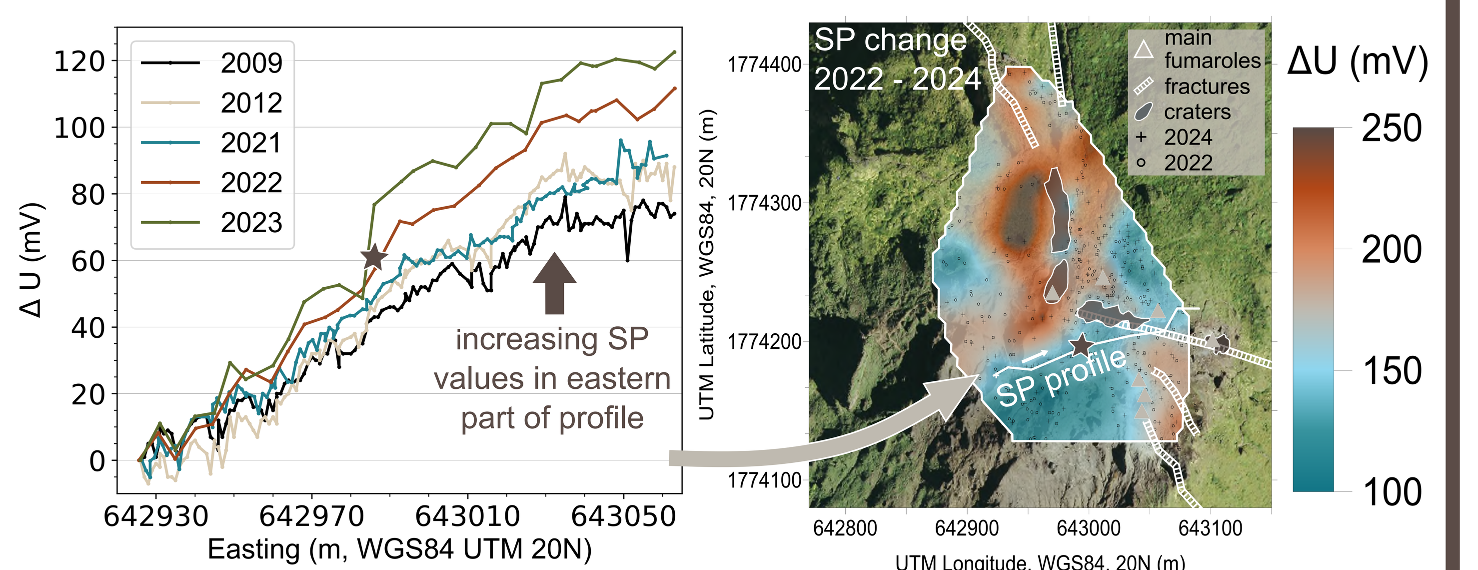


Fig. 5: Repeated self-potential (SP) measurements along W-E profile and difference in SP between January 2024 and May 2022 (interpolated). Background image IGN, BD ORTHO 2017

Outlook

How do fluid flux patterns vary and change over time?

- SP signals correlate with rainfall and seismicity
- Effect of aquifer water level?
- Periodicity/response times?
- Repeated mapping to track evolution of hydrothermal unrest

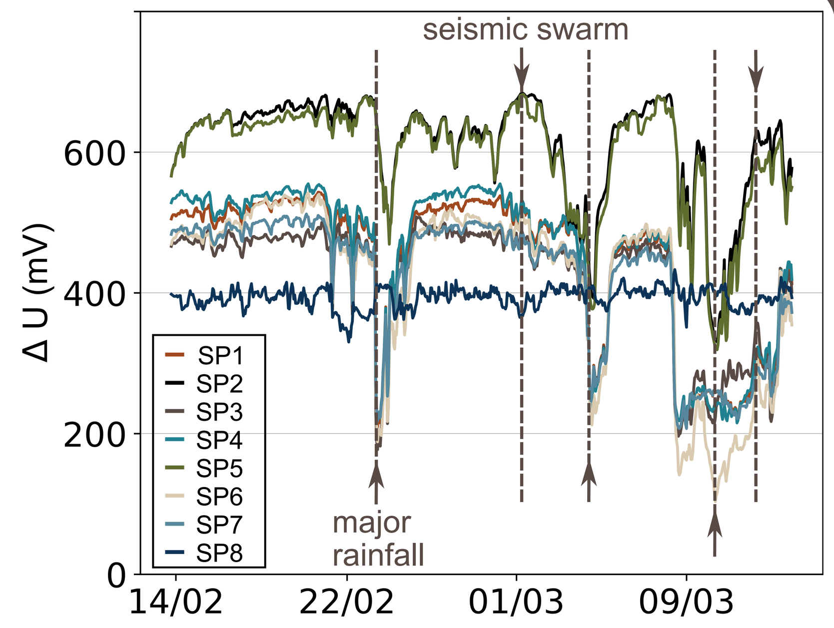


Fig. 6: SP timeseries extract of eight permanently installed electrodes on La Soufrière's summit

References

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