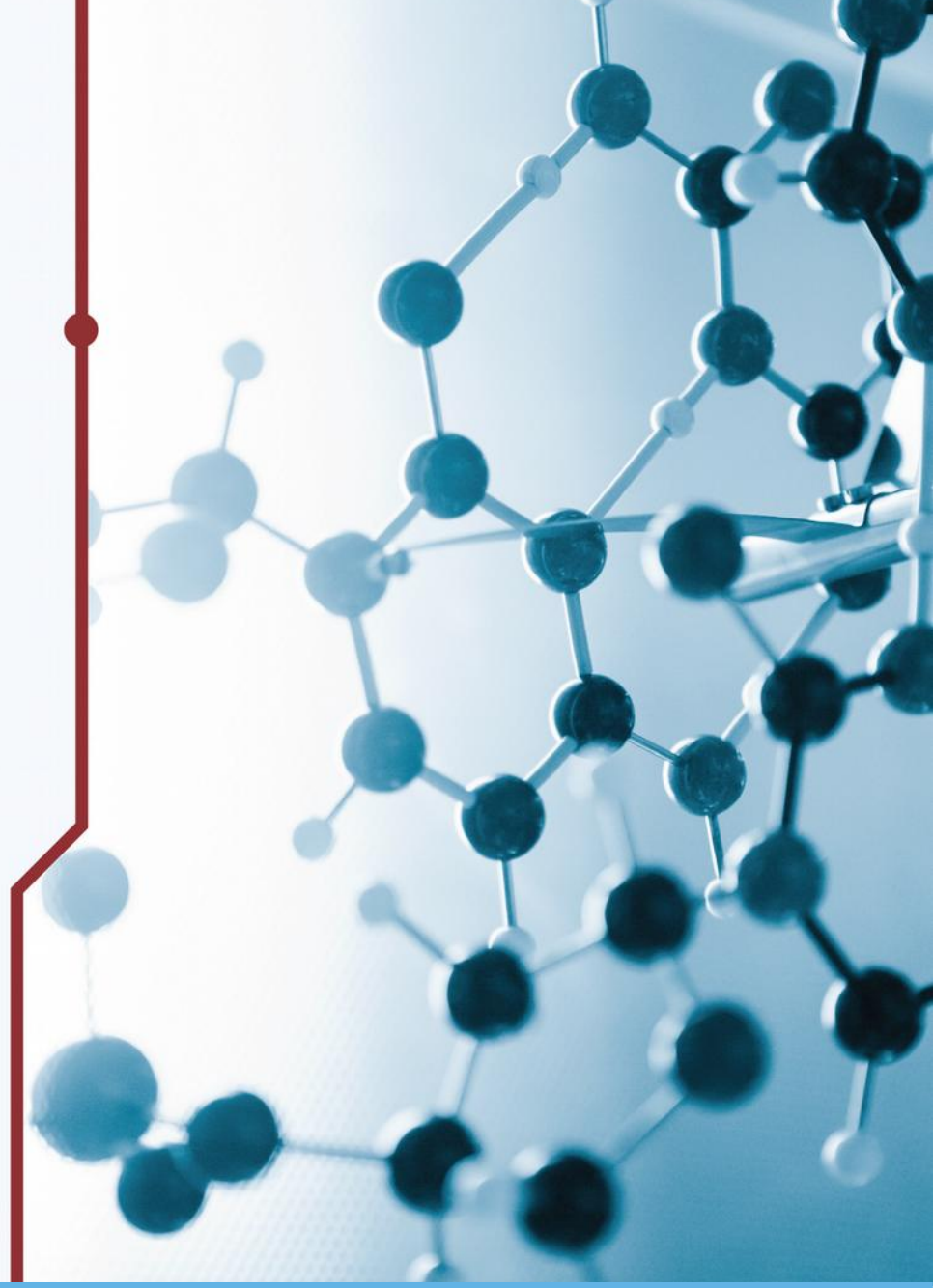
REINFORCE

REsearch INfrastructures FOR Citizens in Europe

COsmic Muons Images for Citizens (COMICs)

WEBINAR

June 1, 2020, 11:00 AM CEST



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2019

OUTLINE

Muography = **μ**-ray imaging technique : absorption / scattering → sensitive to **ϱ** (opacity)

Geosciences

- Volcanology
- Geology
- Hydrology
- Atmosphere physics
- CR physics
- ...

Archaelogy

- Tumulus
- Anthropic structures
- Ruins
- ...

Industrial controls

- Non invasive controls
- Nuclear cycle production
- Civil engineering
- Tunnel boring machines
- Prospection & mining
- ...

Technological transfer

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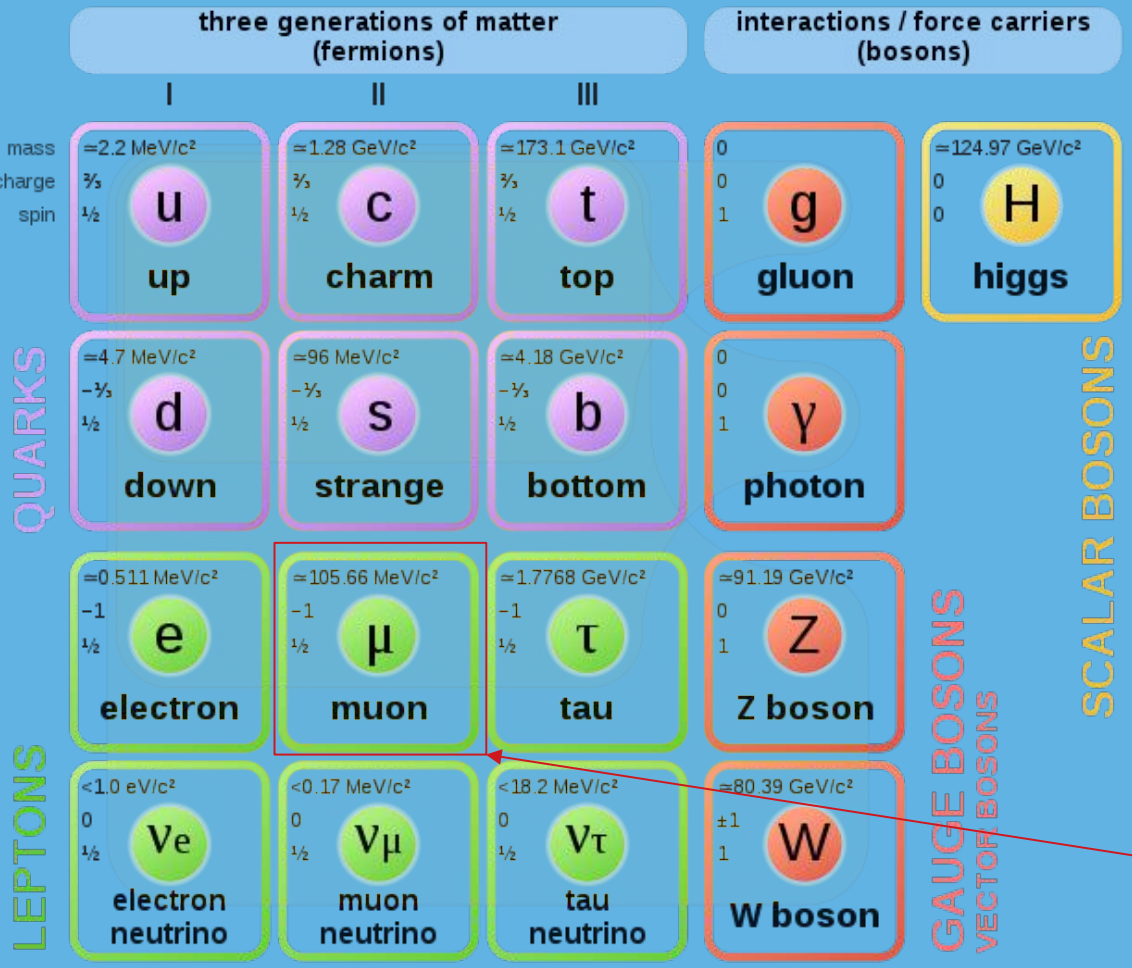
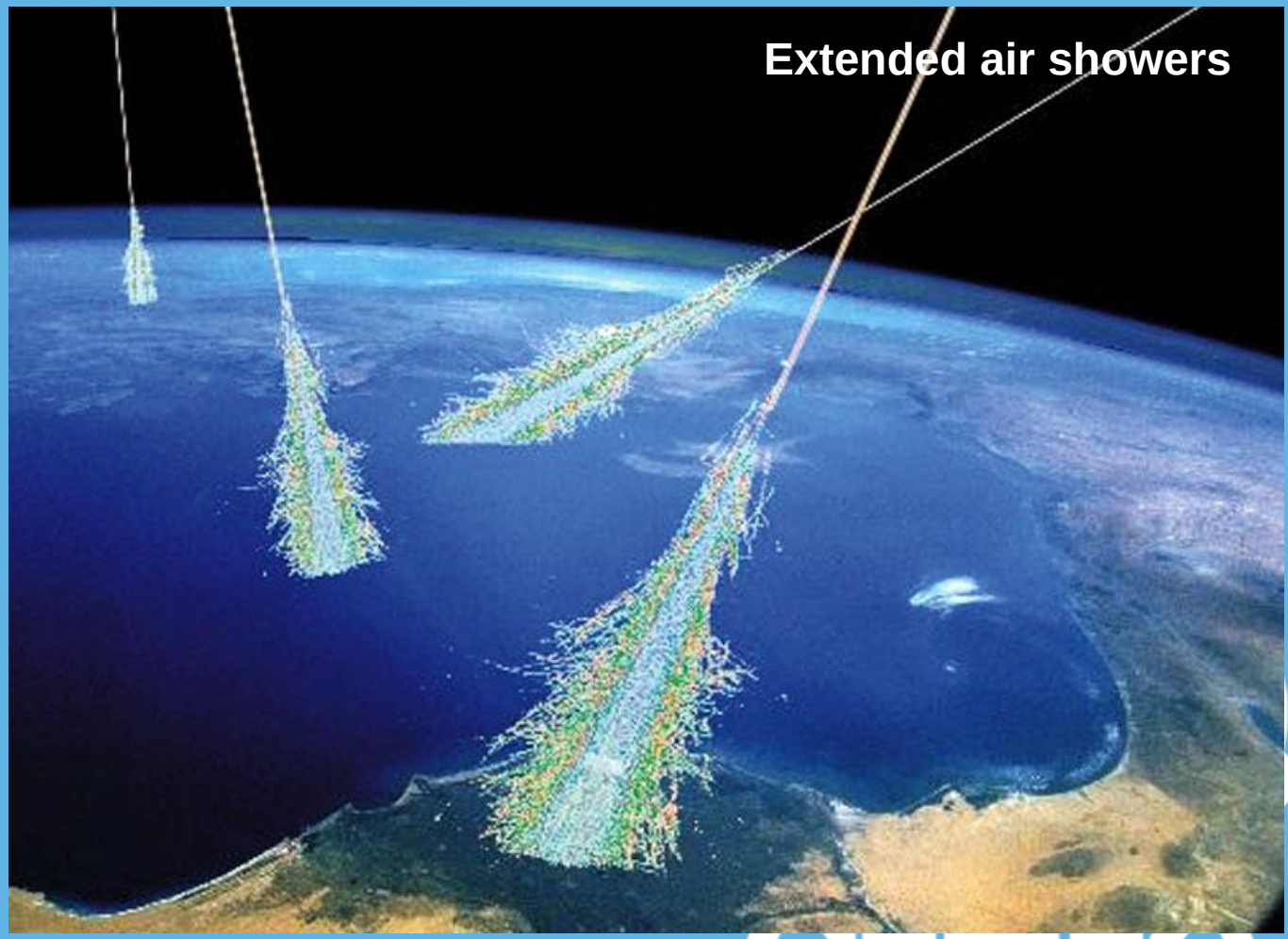
Standard Model of Elementary Particles





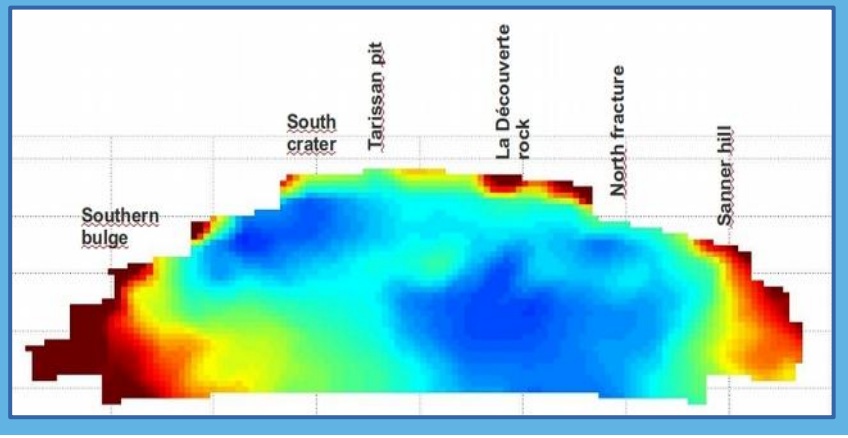
Here are the muons

Absorption Muon Tomography

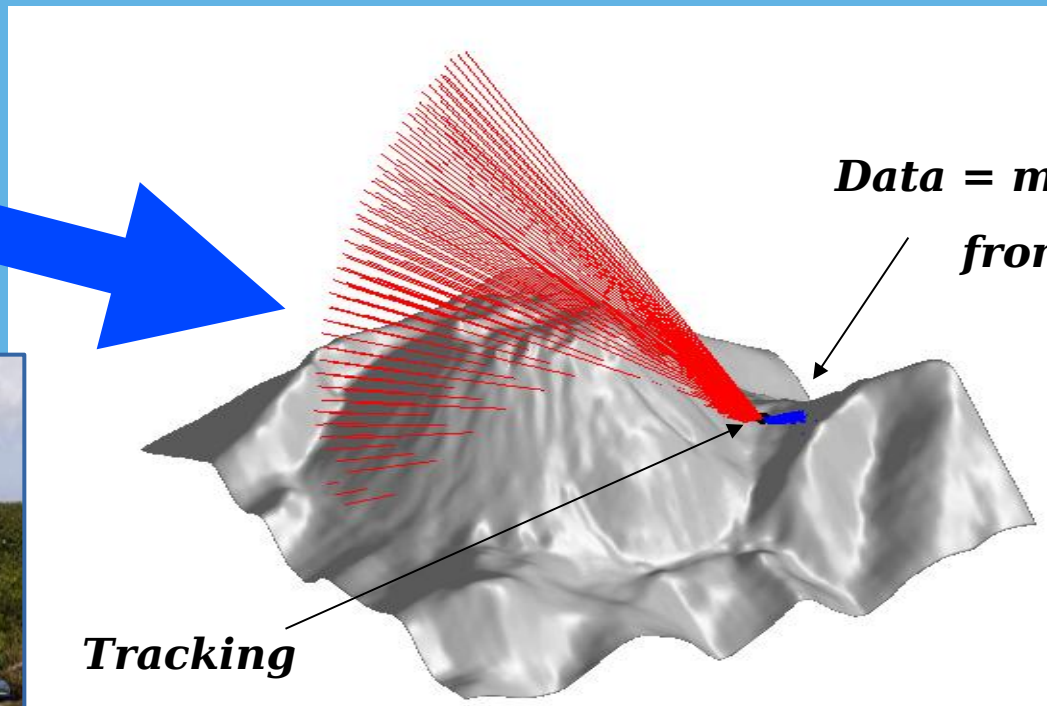
Muon flux emerging from the target ↔ opacity (amount of matter)

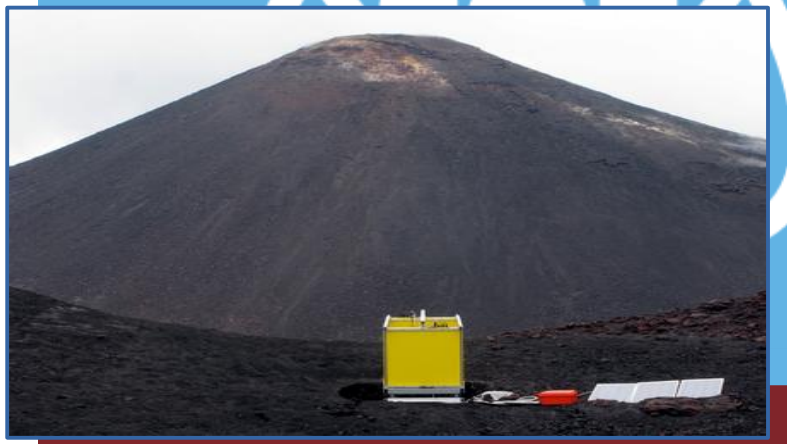
$$\varrho(L) \equiv \int_L \rho(\xi)\mathrm{d}\xi$$

ϱ = opacity ρ = density



Incident muon flux





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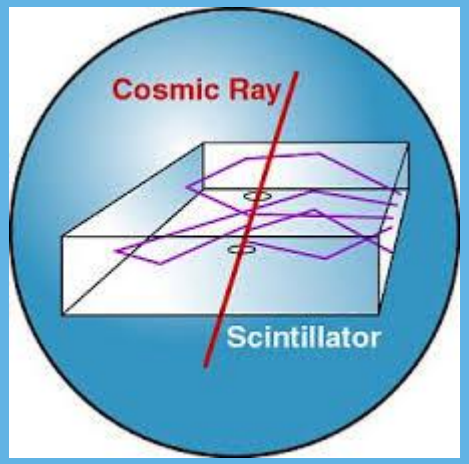
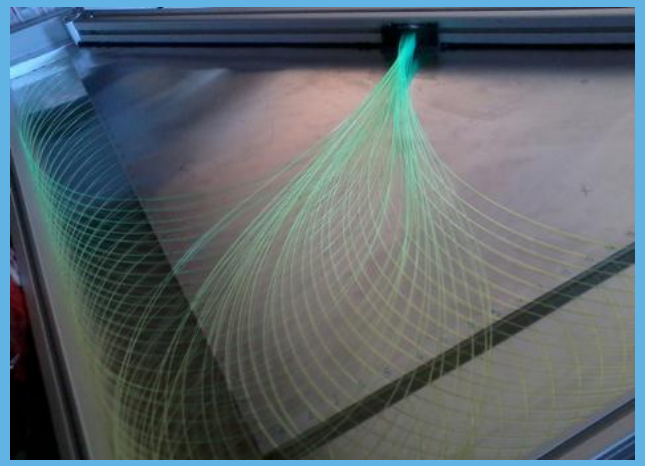
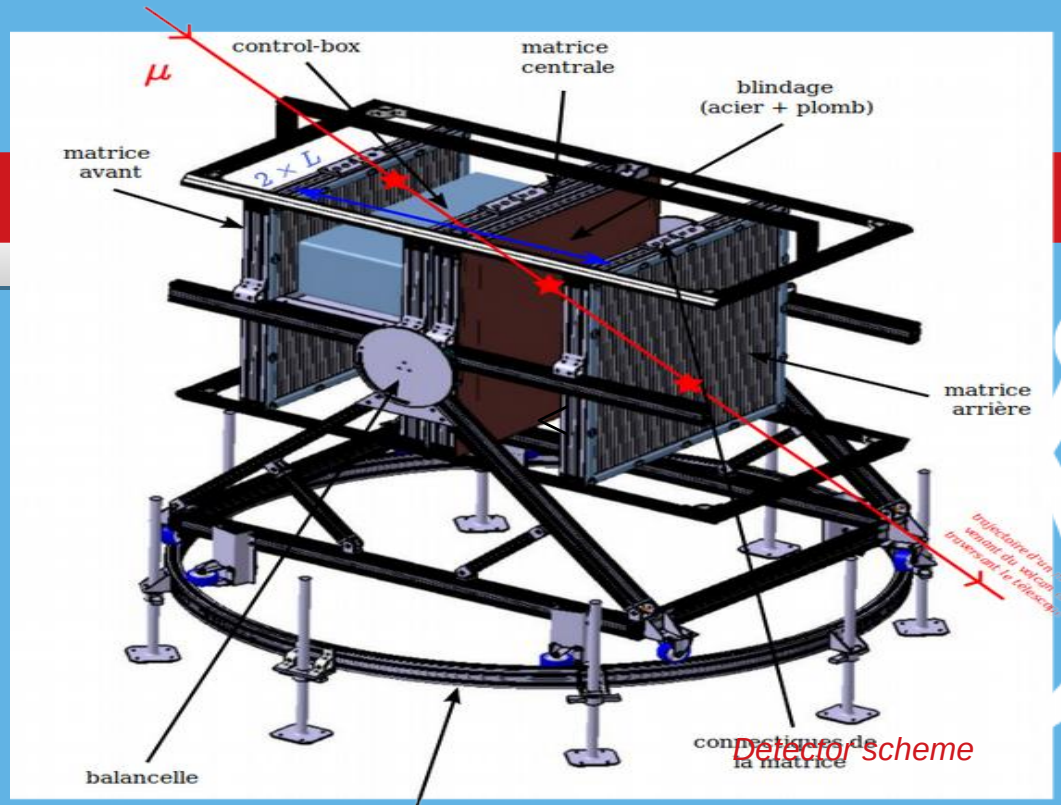




A field detector

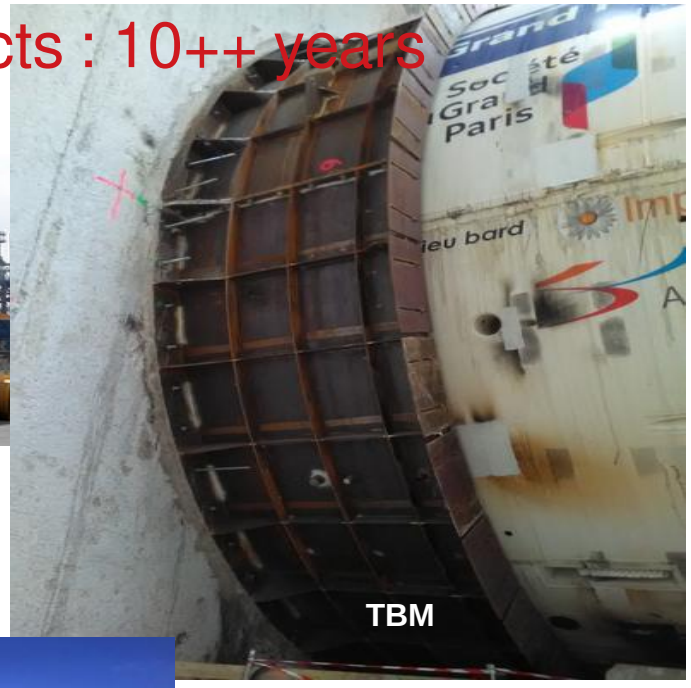
Muon detector @ Soufrière

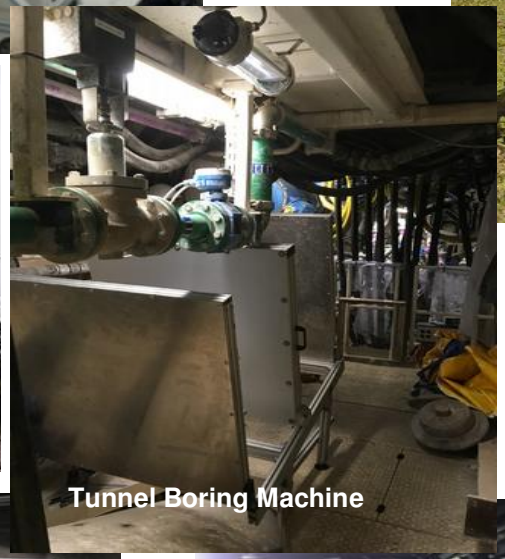


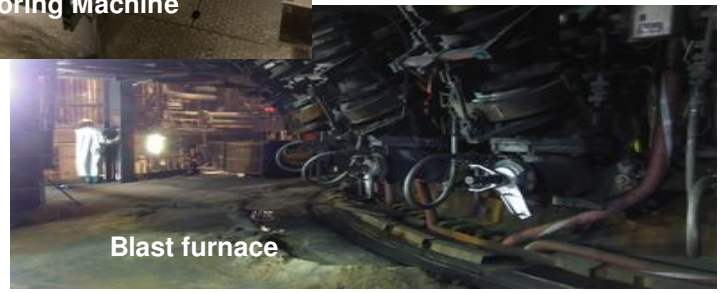
Detector Scheme

A simple **tracking++** device using scintillators, emulsions, micro-megas, RPC's…

DIAPHANE projects : 10++ years

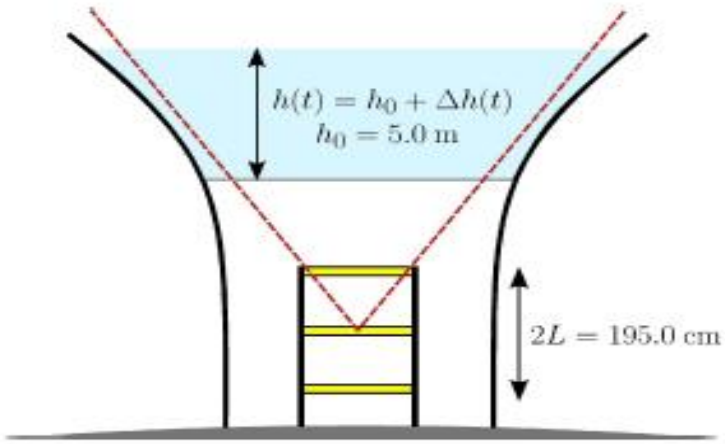


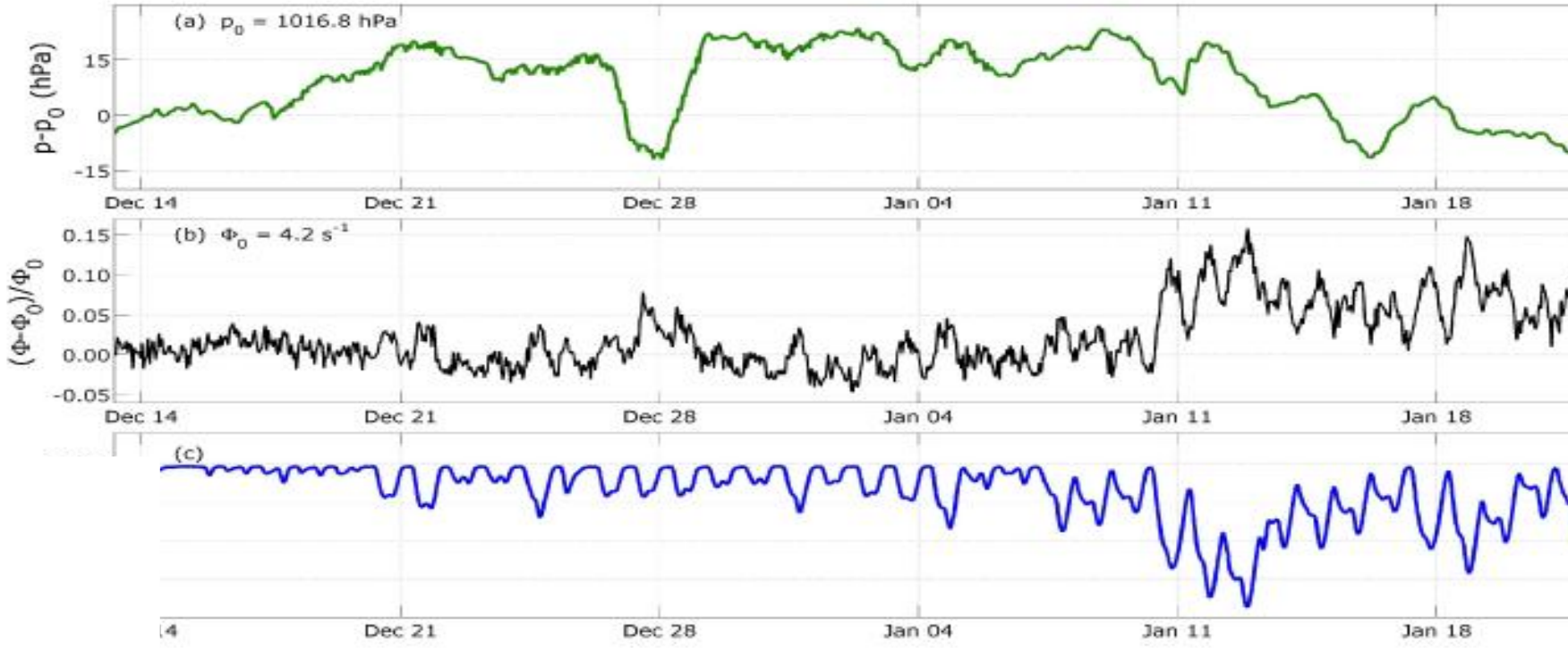




Monitoring capabilities – P & T sensitivity

Water level monitoring of a water tower tank



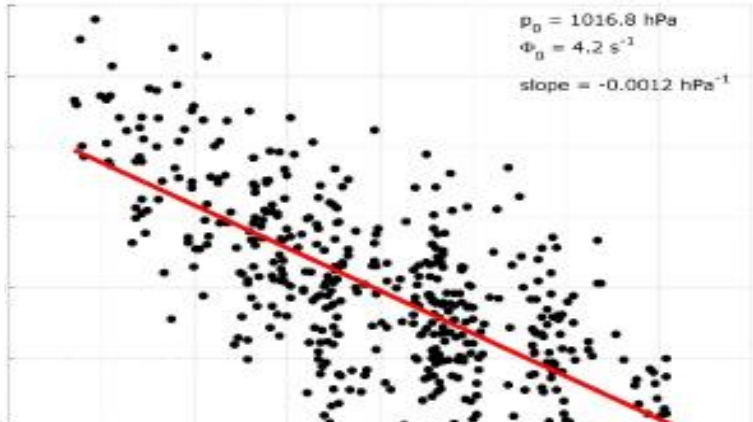


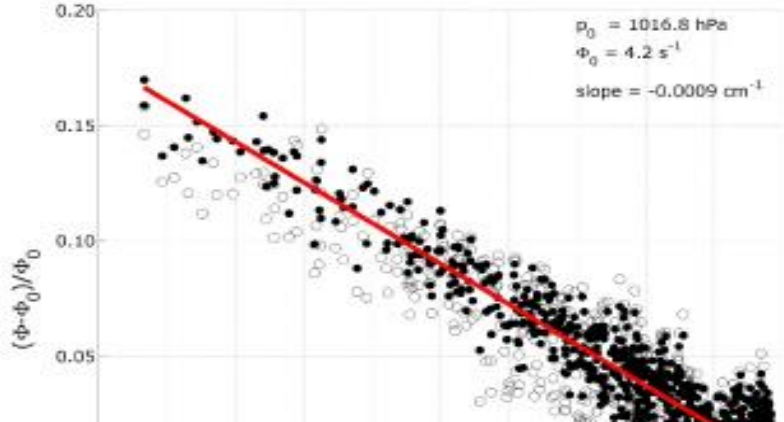
Low energy cut ~1.5 GeV:

- high statistics
- time resolution
- E-dependent barometric effects

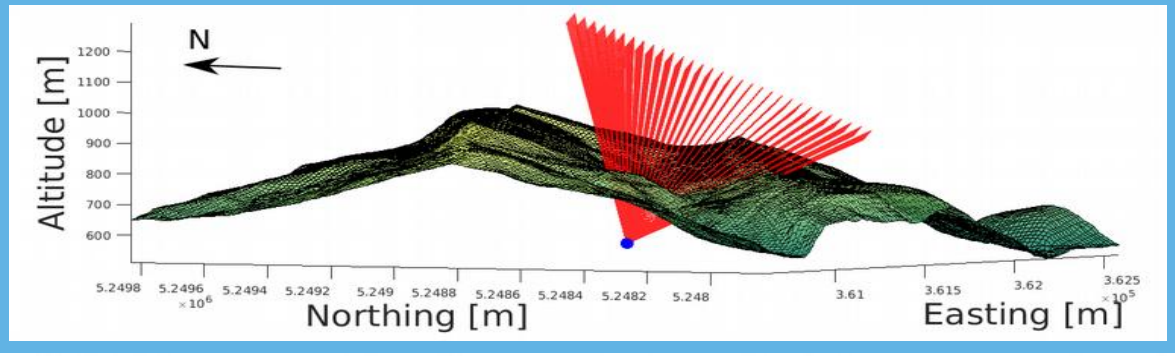
$$\frac{\Delta R}{\langle R \rangle} = \alpha_T \frac{\Delta T_{\text{eff}}}{\langle T_{\text{eff}} \rangle} + \beta_P (p - \langle p \rangle)$$

- geomagnetic effects
- solar activity effects

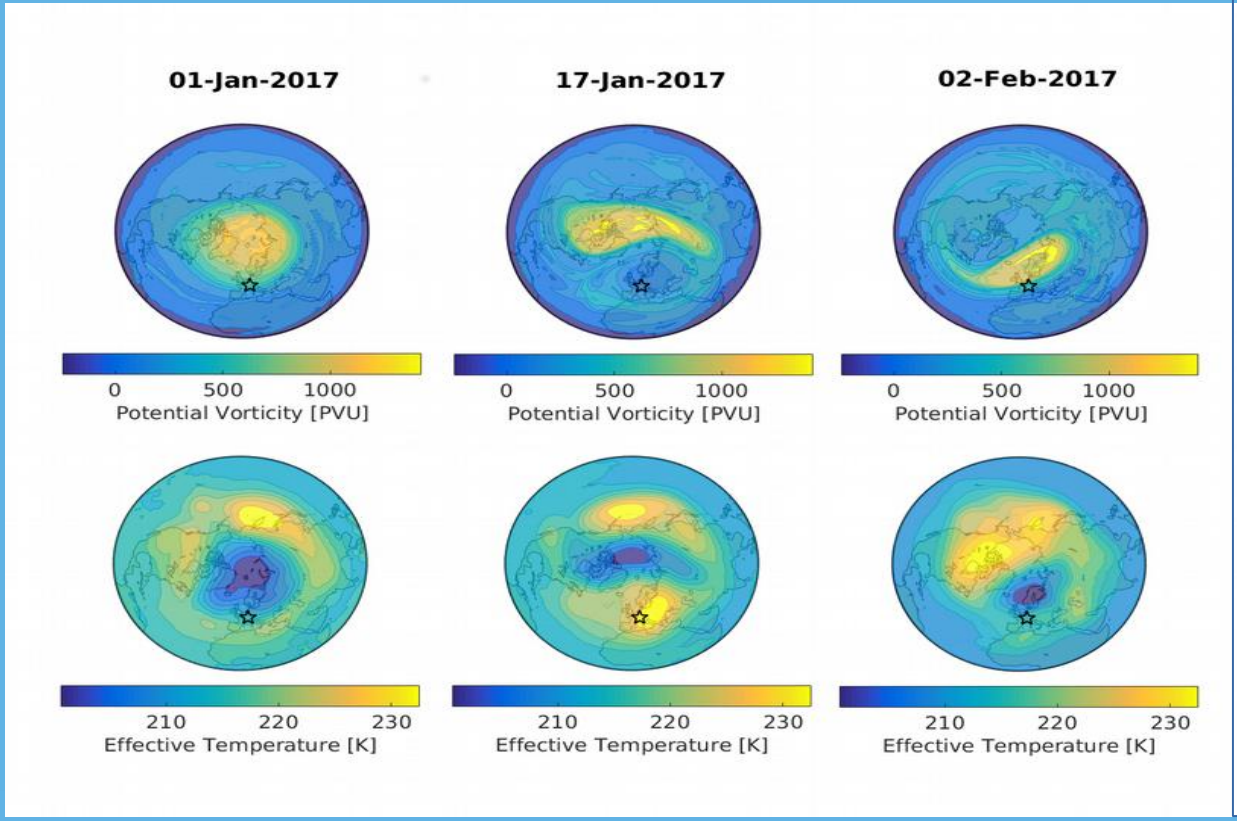


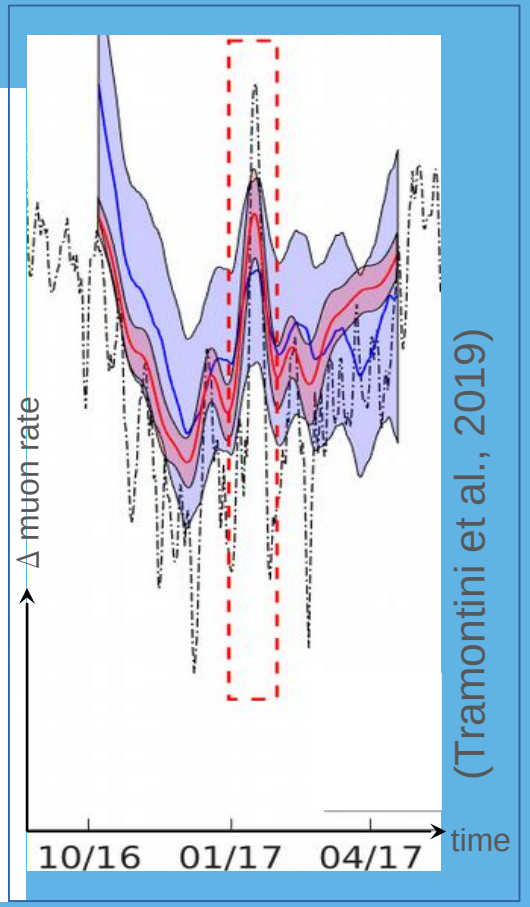


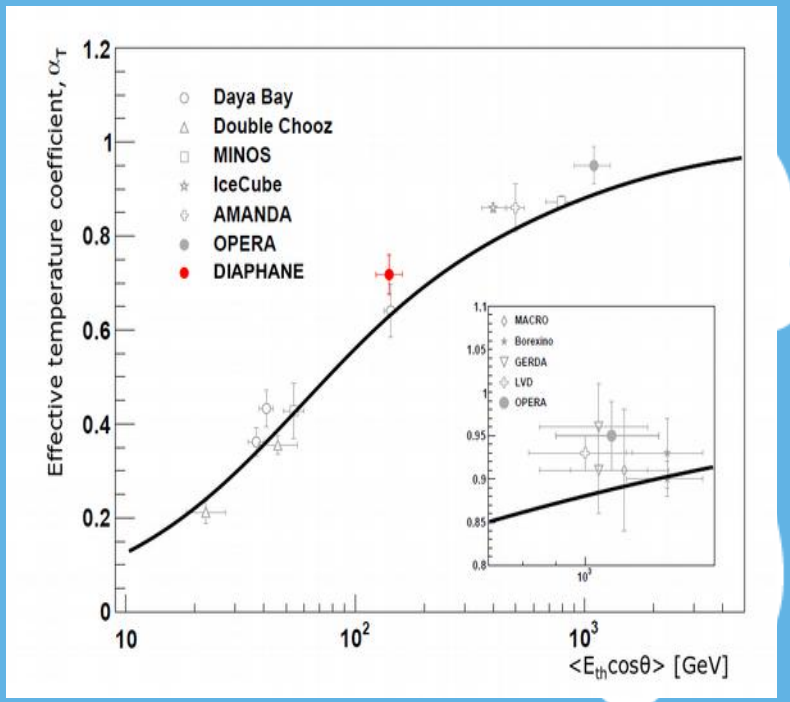
P & T sensitivity



$$\frac{\Delta R}{\langle R \rangle} = \alpha_T \frac{\Delta T_{\text{eff}}}{\langle T_{\text{eff}} \rangle} + \beta_P (p - \langle p \rangle)$$

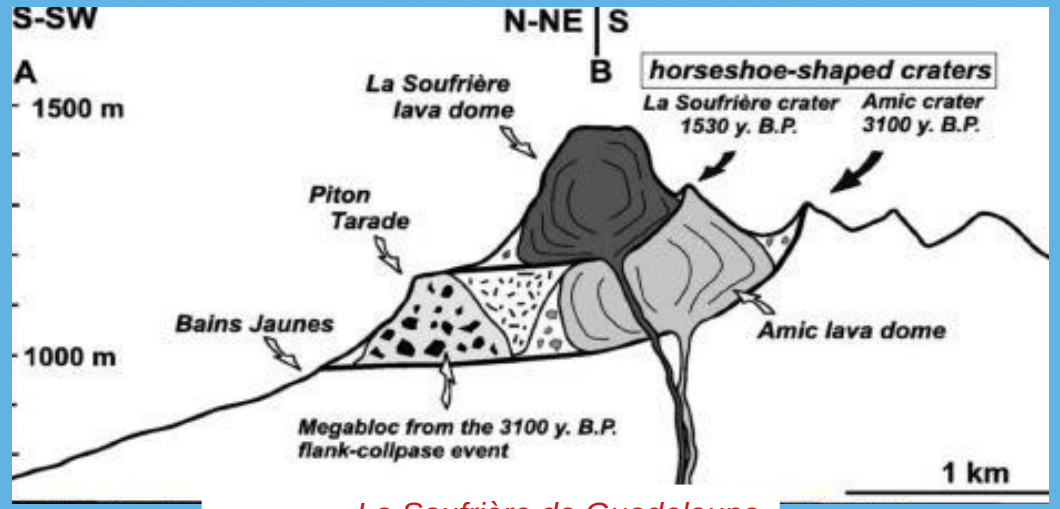






Sudden Stratospheric Warming

Volcanology : Lesser Antilles



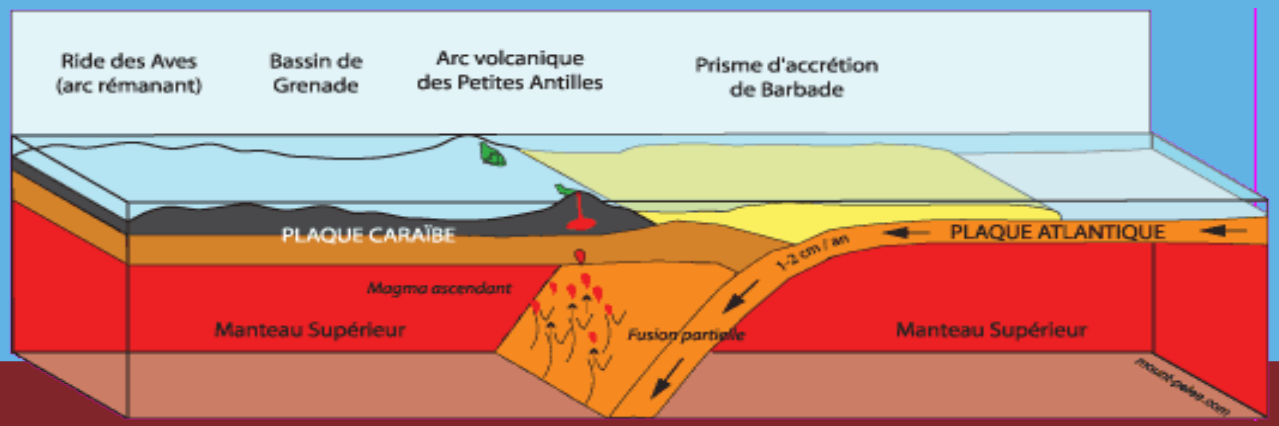
La Soufrière de Guadeloupe

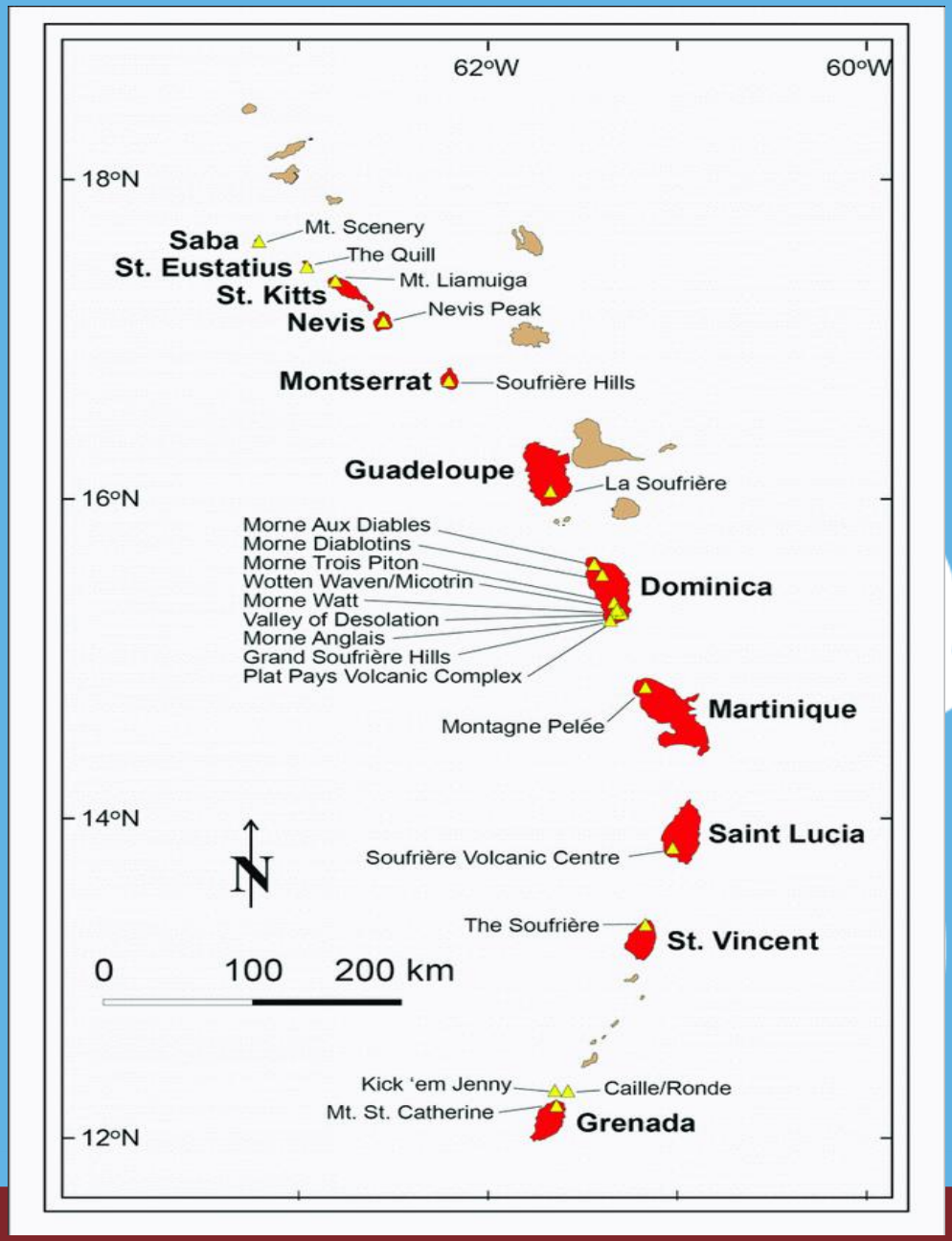
3 active volcanoes (N to S):

The Soufrière Hills, Montserrat : magmatic eruption since 1995, pyroclastic jets, risks of dome collapse, magmatic explosion etc. Activity decrease since a few months.

La Soufrière, Guadeloupe :
active, young dome (~500y), phreatic eruption risks, flank destabilization

Montagne Pelée, Martinique :
no sign of activity at the moment, the most important natural catastrophe in France (1910)





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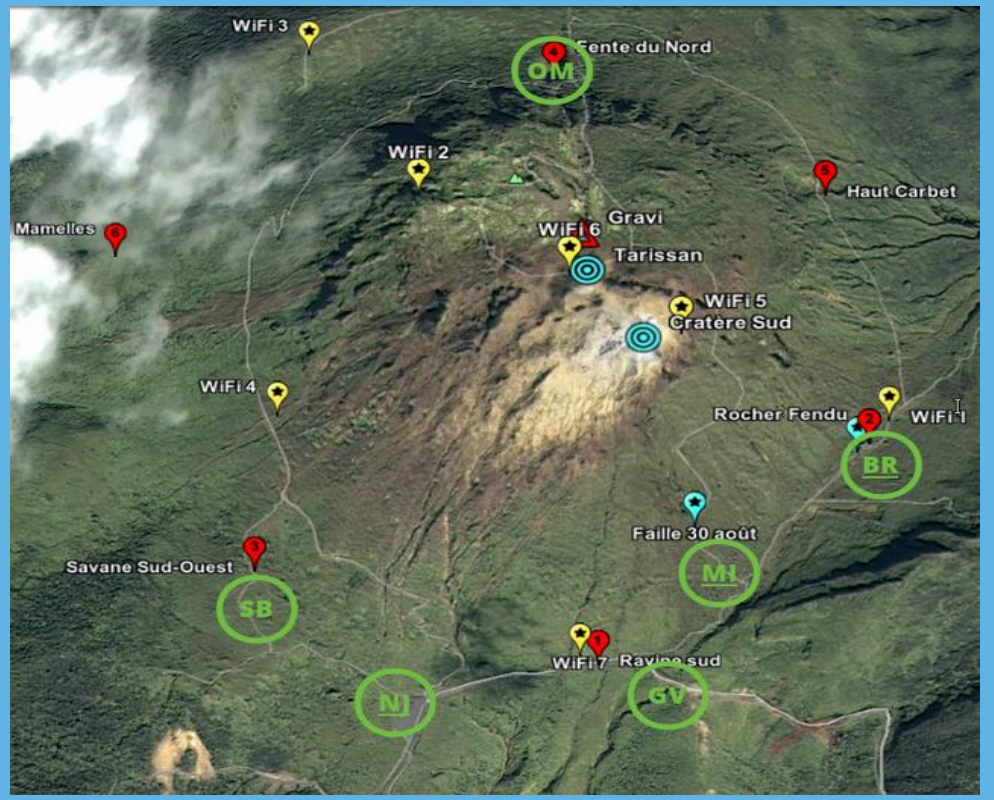
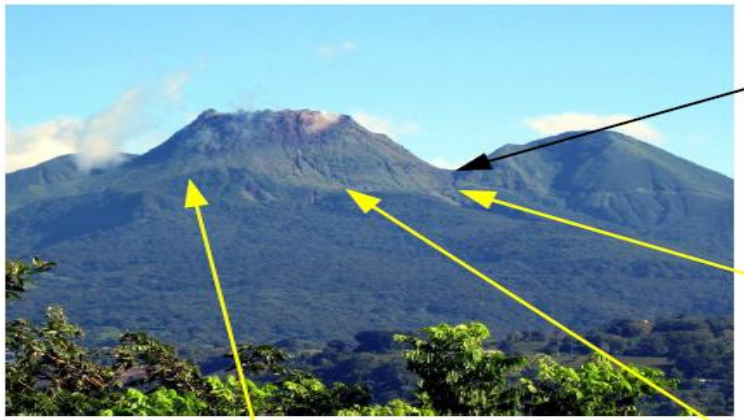
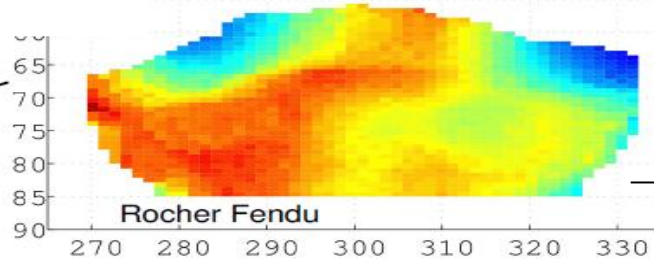
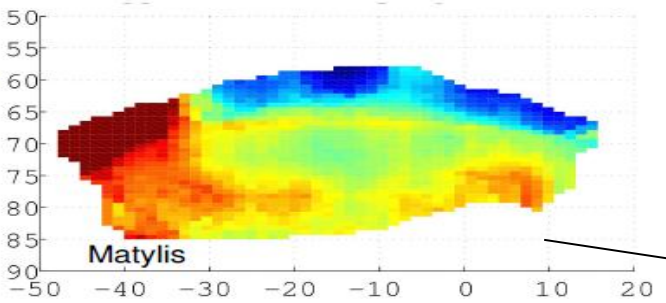
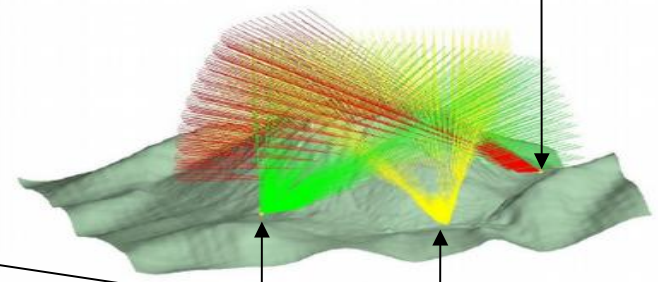


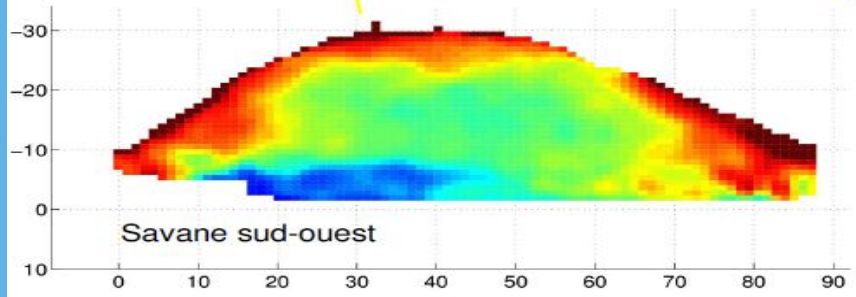
Imaging & monitoring

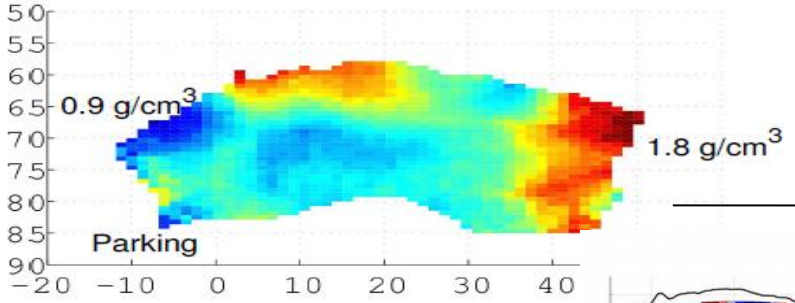


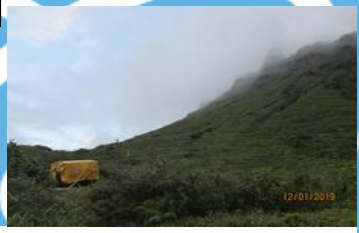


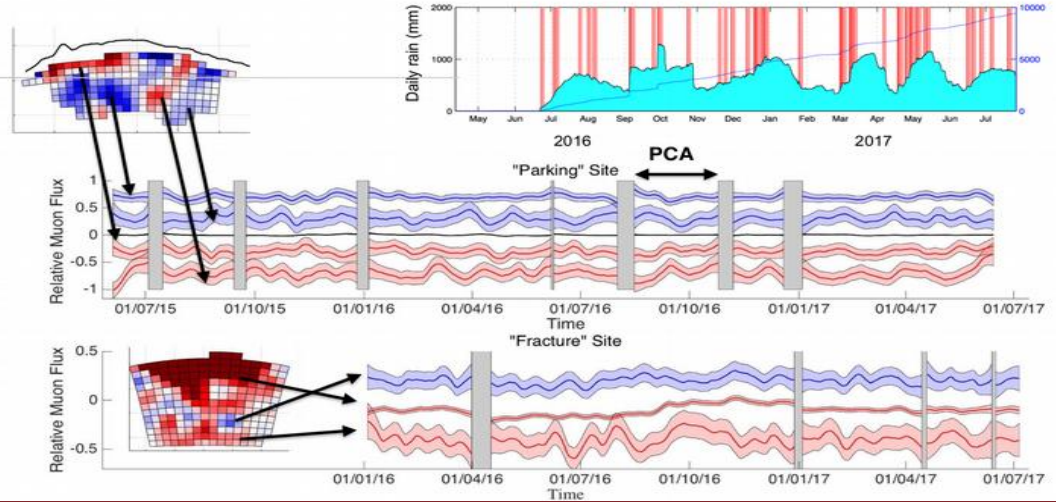












World's largest muon station

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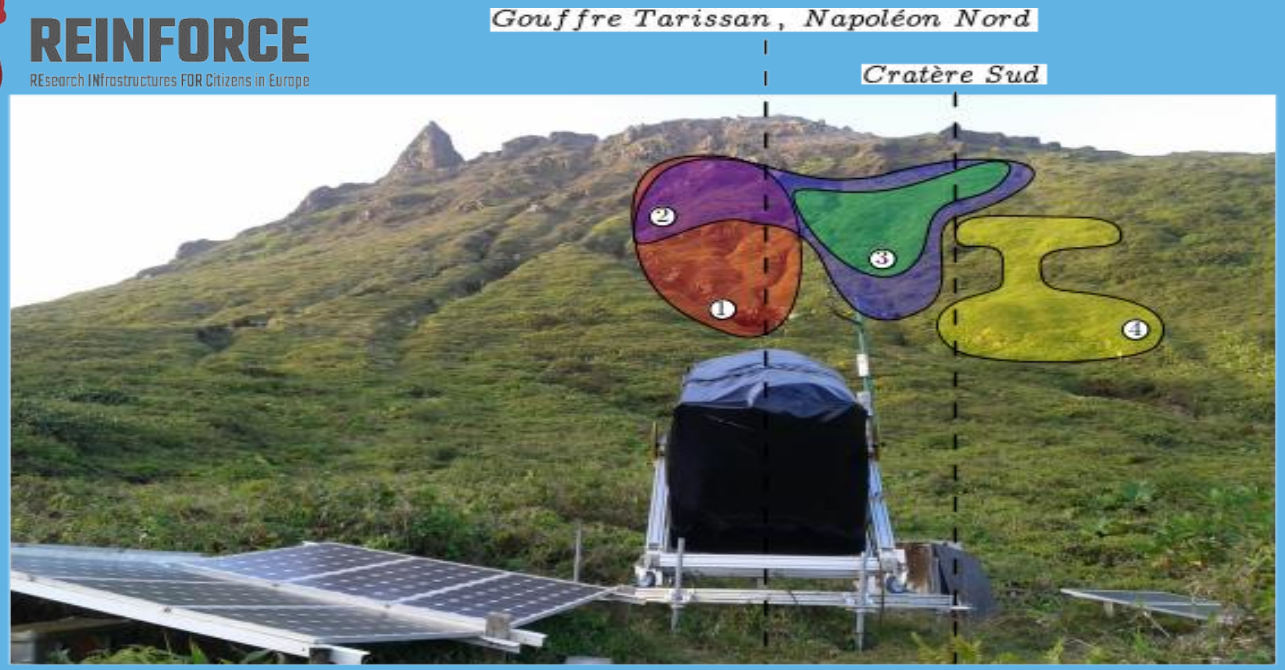
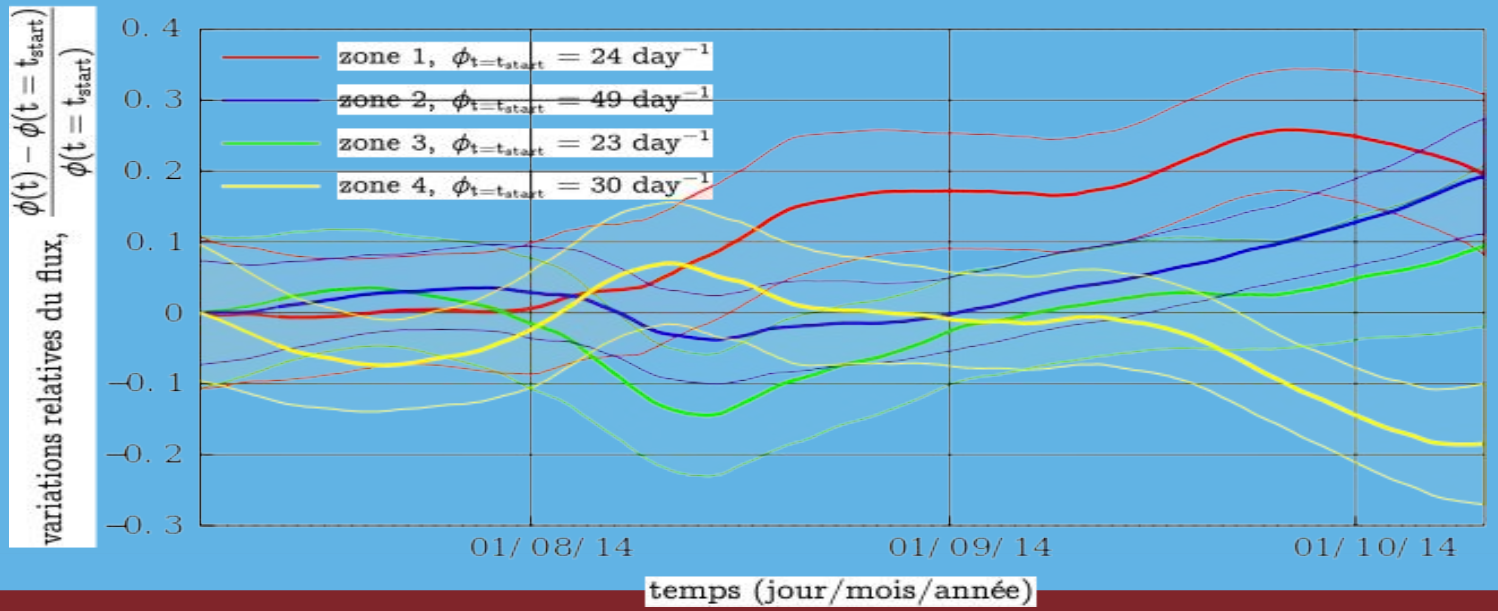




The volcano is under cautious surveillance as a **regain of activity** has been noticed in the fumes (Allard et al. 2014) and in the sources (Villemant et al. 2014).

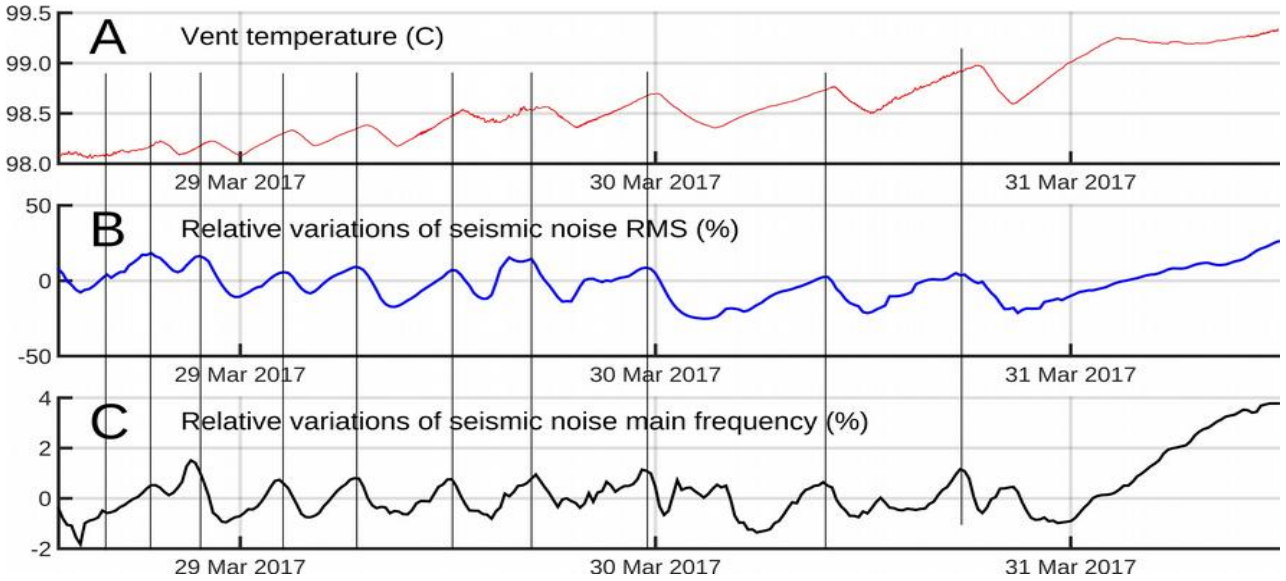
Principal component analysis allows to isolate regions in the volcano with similar time behaviors.

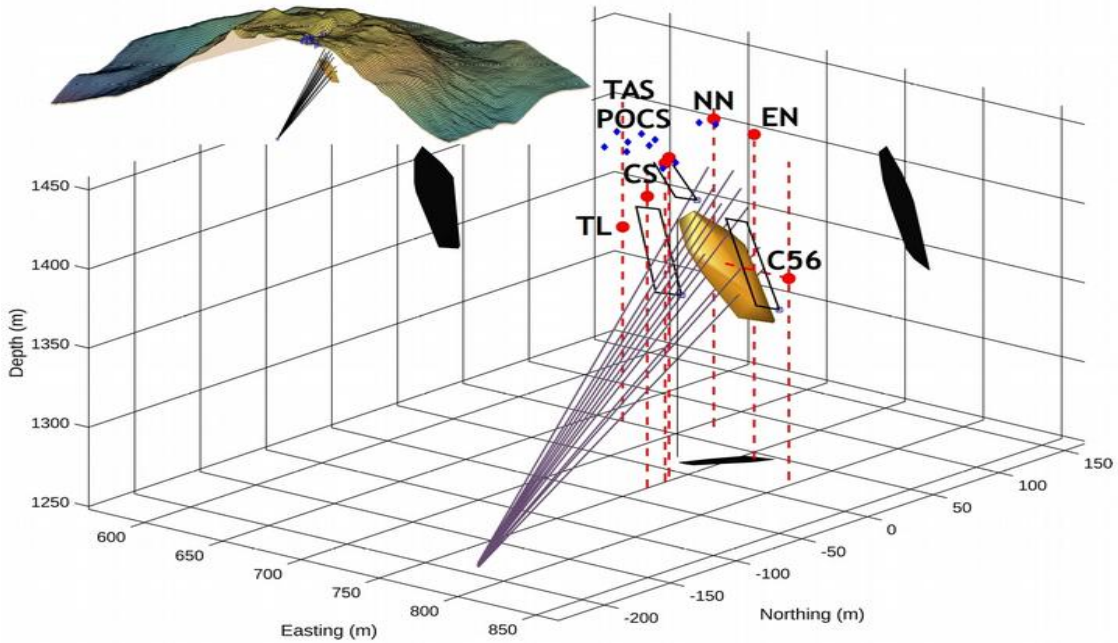
The various active zones are clearly correlated with the observations on the surface. They are correlated in time with the appearance of the new vent at the summit.

The observed fluctuations in zone 1 correspond to vaporization of 40 mwe in only 3 months.

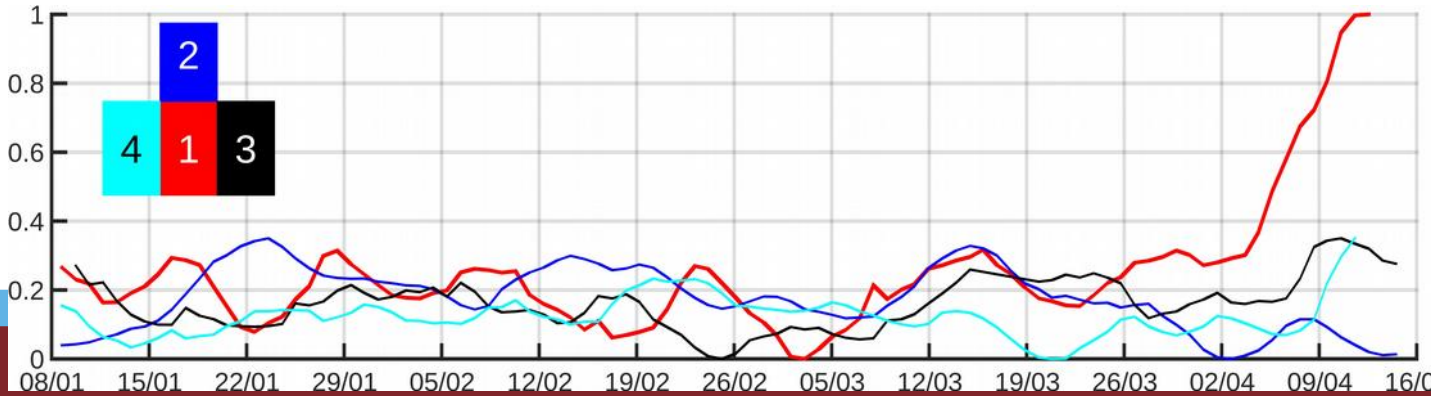
Joined monitoring : muon flux variations in region determined by seismic noise

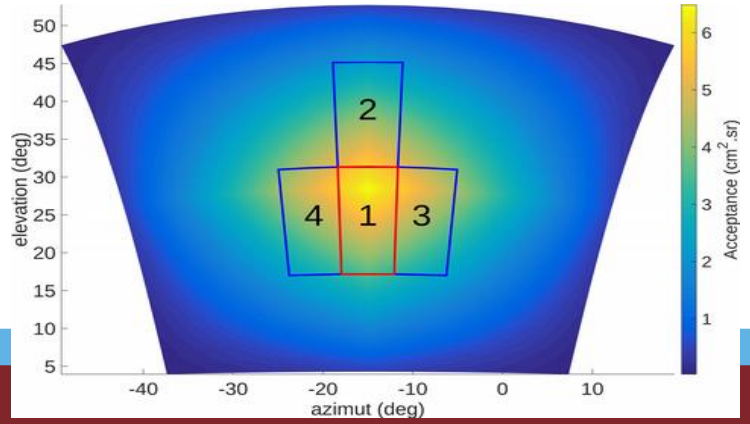
Density changes are expected as a result of fluid content variations
These variations are related to meteoric and magmatic mass input, and/or phase transitions





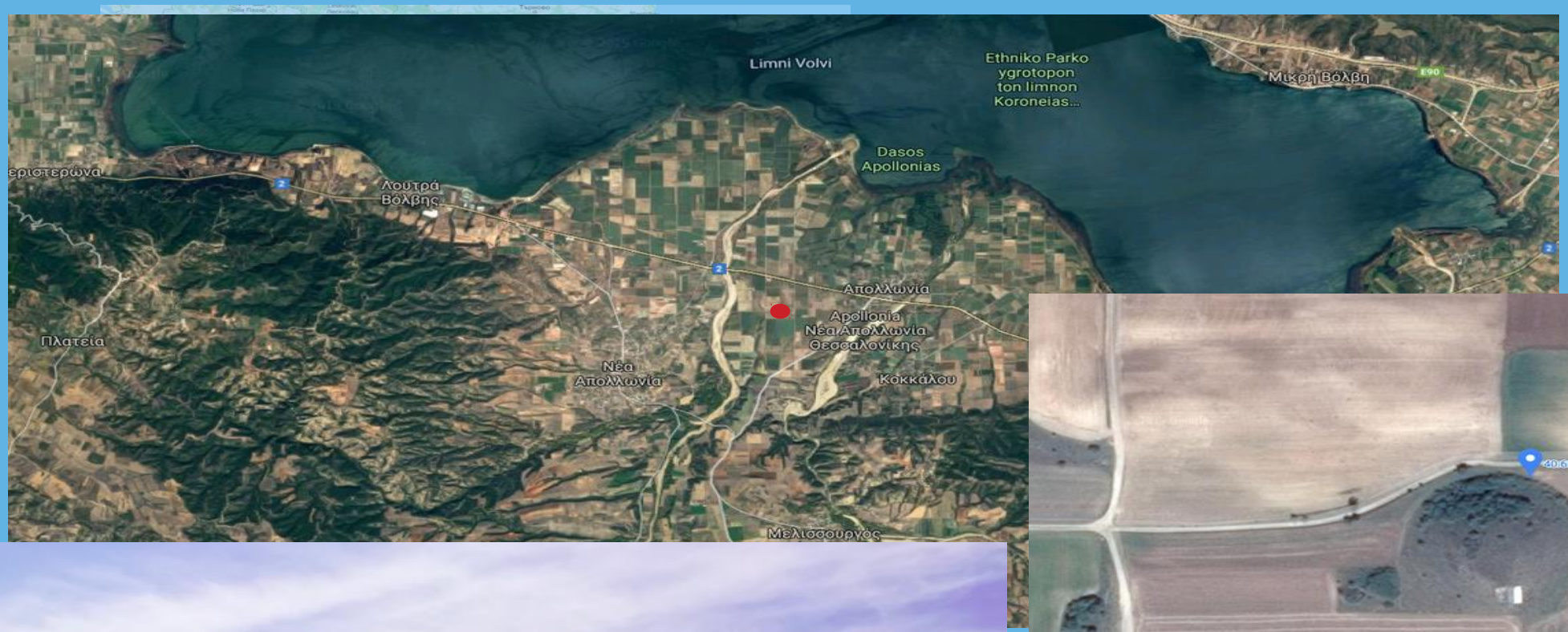
Relative muon flux variations





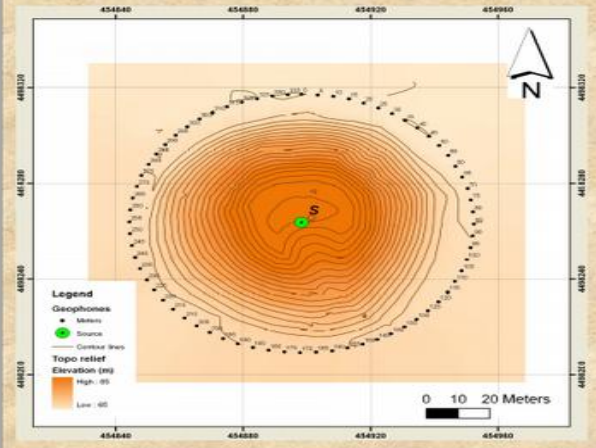
(Le Gonidec et al., 2019)

Archaelogy : Apollonia tumulus (IP2I, APC, LAPP, labex UnivEarth, AUTh)



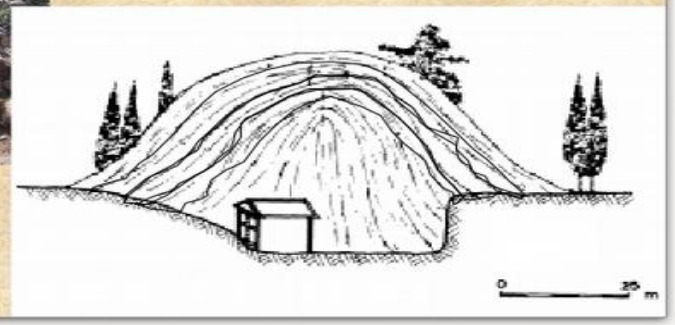
A massive “Macedonian-type” tumulus

Tumulus in Apollonia North Greece
Diameter 100 m; Height 24 m. The biggest in Greece?



CHALLENGES OF THE GEOPHYSICAL SURVEYS ON TUMULI

The material of the tumulus might be highly inhomogeneous (a fact that renders difficult the data interpretation). In some cases, stratification of the tumulus infill material has been observed.



G. Tsokas et al. (2015)

What kind of information can the Muon tomography provide to non-destructive tumulus survey ?

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WELCOME TO THE MUONS HUNTING
HELP US GETTING BETTER IMAGES