# Joint analysis of GNSS and seismic network to track magma transport at Piton de la Fournaise

EGU 2022 Session GMPV9.4 – Volcanic processes: Tectonics, deformation, geodesy, unrest

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This presentation participates in OSPP

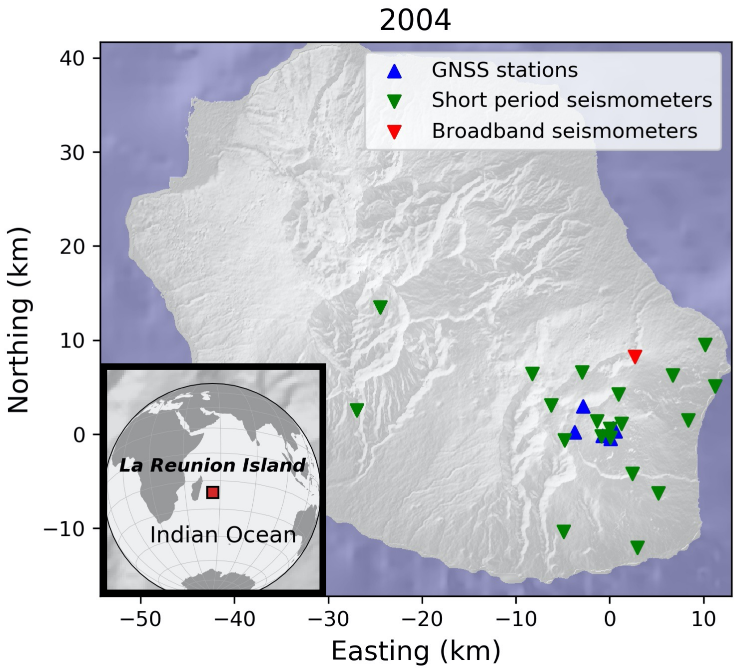
Outstanding Student & PhD candidate Presentation contest

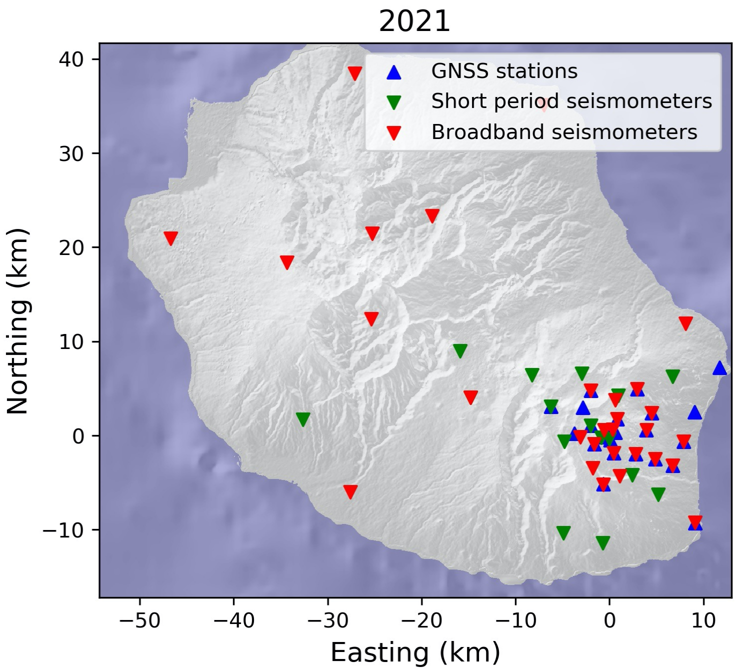
*How to image the internal magmatic system beneath the active Piton de la Fournaise volcano?*

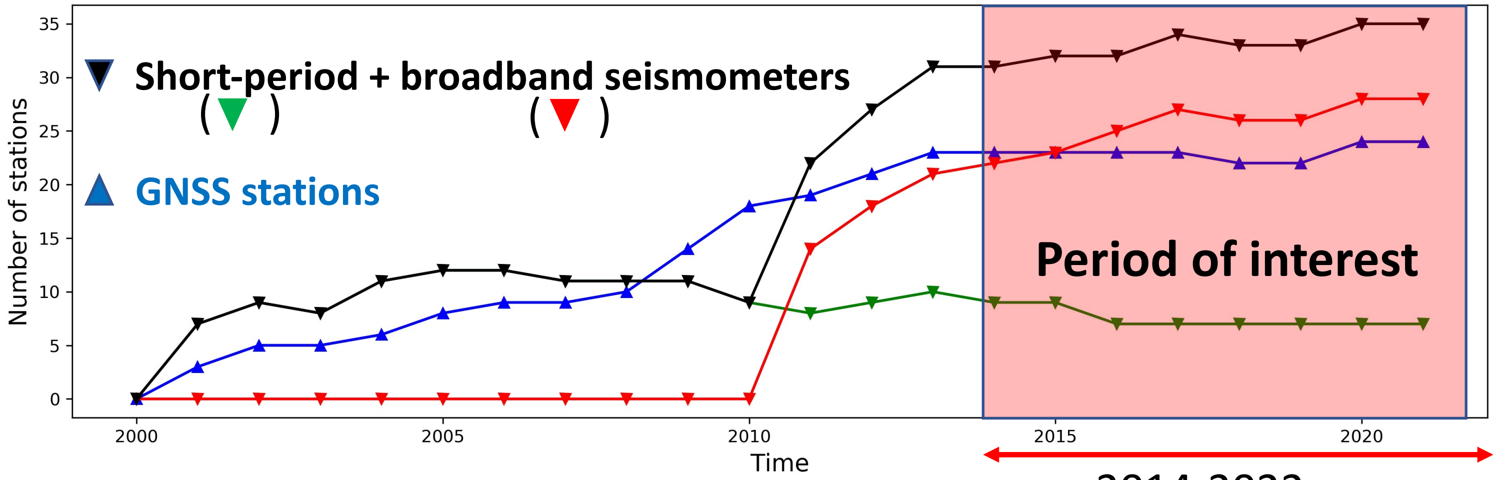
# Piton de la Fournaise: a very active and densely instrumented volcano



**3 eruptions per year in average**

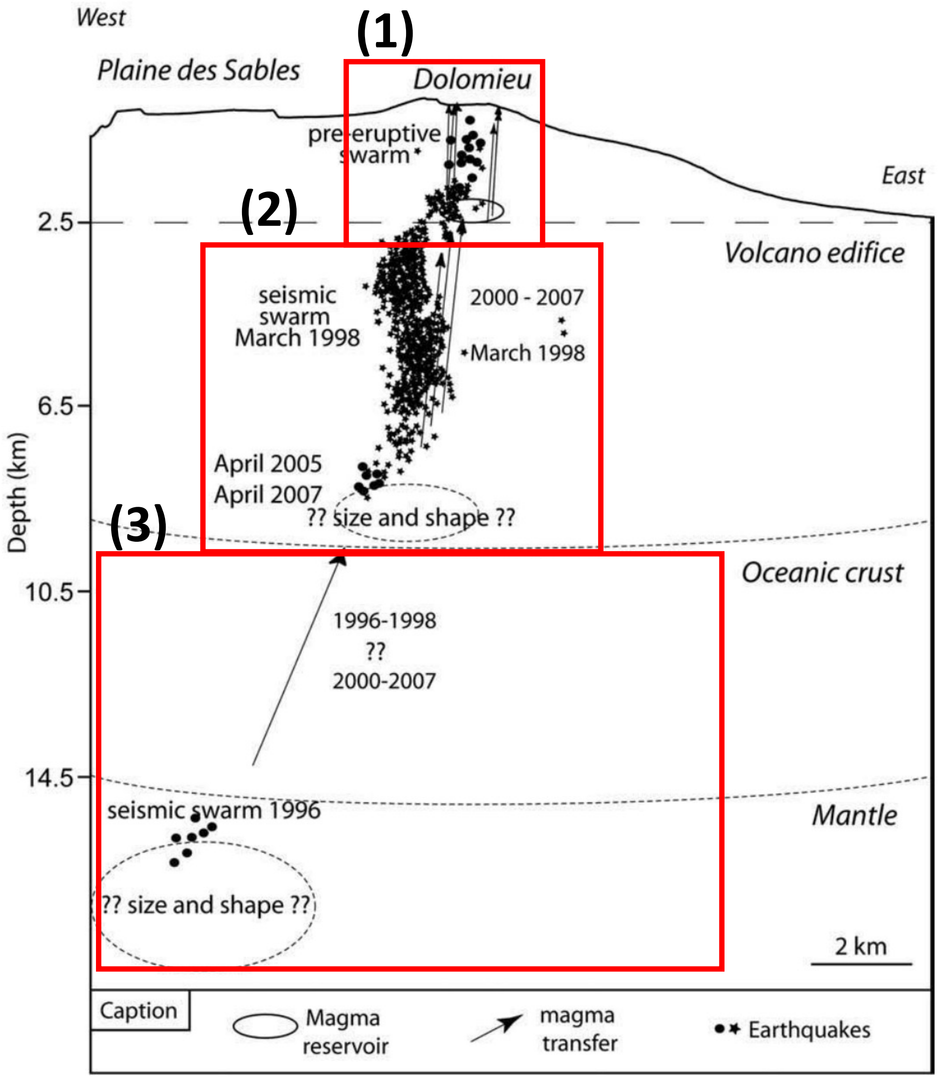


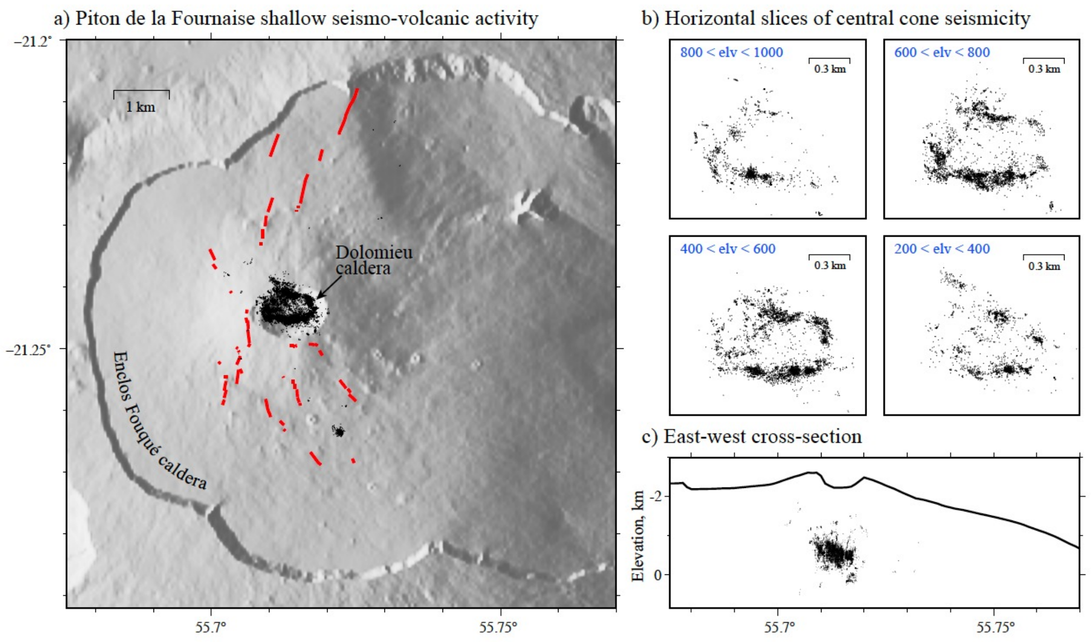




2014-2022
(23 eruptions)

# Insights into Piton de la Fournaise plumbing system from GNSS and seismic data




[Peltier et al 2010]




[Duputel et al 2019]

**(1)** Shallow system imaged with seismic and deformation data

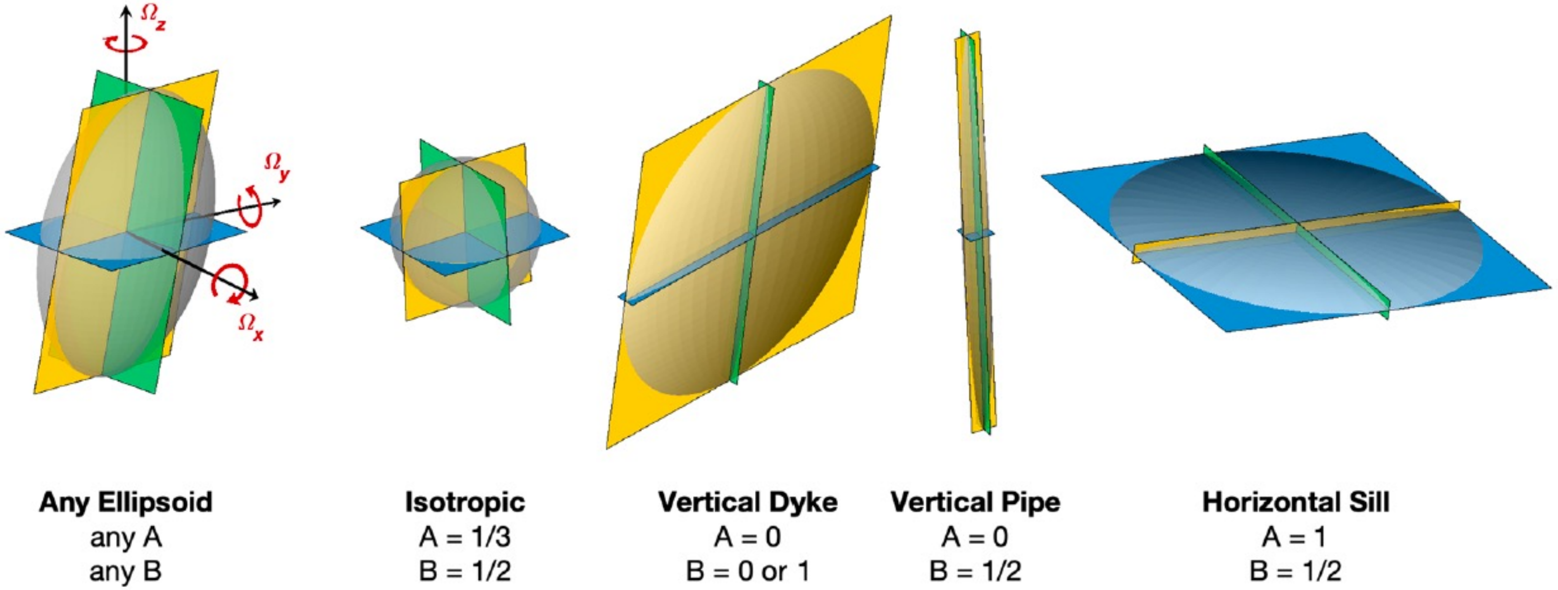
**(2)** Rare occurrence of deep seismic migrations (1998 and 2015)

**(3)** Deep system: few earthquakes beneath Piton de la Fournaise

**What contribution from dense GNSS network for imaging the deep system?**

# Methodology（1/2）: Modelling GNSS data using a point Compound Dislocation Model（pCDM）

**[Nikkhoo et al 2016]**: The Compound Dislocation Model (CDM) and point Compound Dislocation Model at far-field observation considering point source approximation




**[Figure from Beauducel et al. 2020]**

$$A = \frac{dV_Z}{\Delta V},$$

$$B = \frac{dV_Y}{dV_X + dV_Y},$$

$$\Delta V = dV_X + dV_Y + dV_Z$$

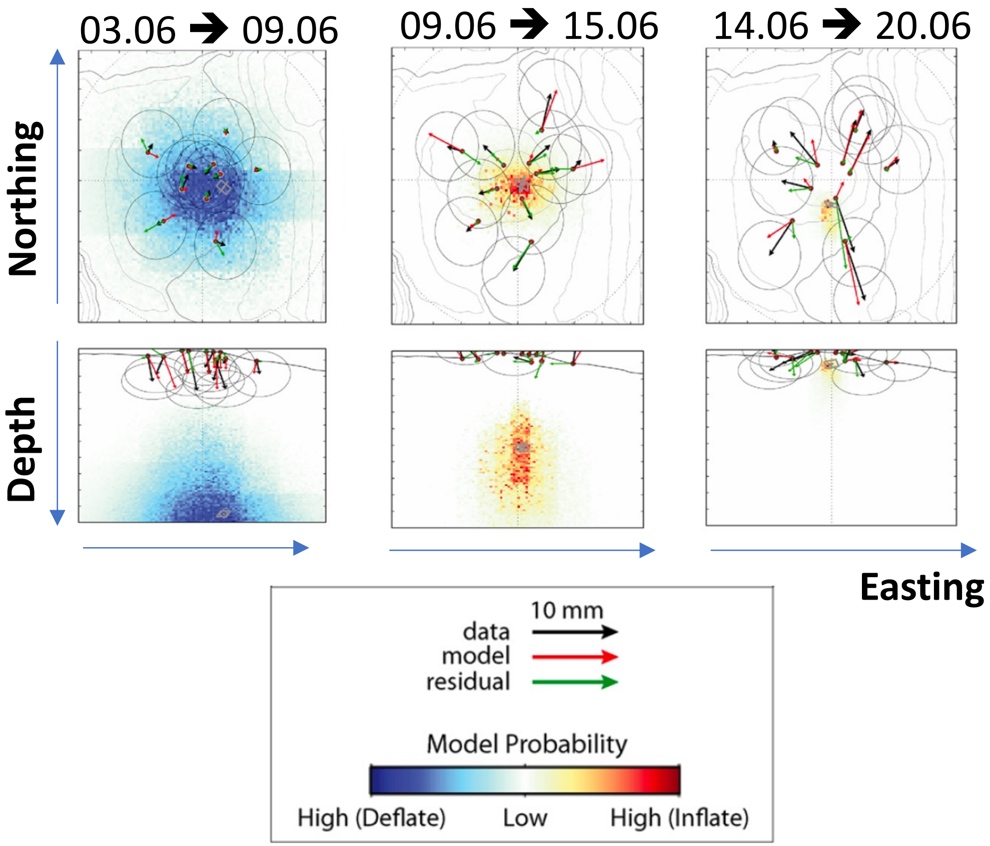
*Geometrical shape of pCDM is determined by these ratio potencies*

pCDM: 3 orthogonal tensile point dislocations in elastic homogeneous half-space
9 model parameters: hypocenter location (*X,Y,Z*), volume variation ($dV_X, dV_Y, dV_Z$) for each plane perpendicular to axis and rotation angles ($\Omega_X, \Omega_Y, \Omega_Z$)

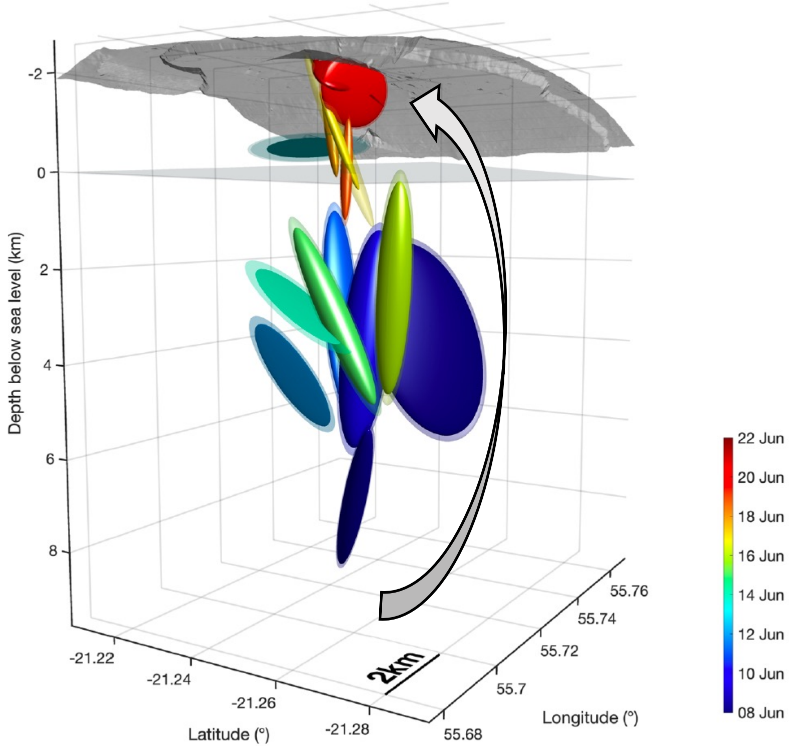
# Methodology (2/2): An unsupervised Bayesian inversion procedure

**Inverse problem**:
Monte Carlo Bayesian parallel algorithm with five iterations of 500,000 forward problems using pCDM equations
Misfits computation L1 norm between observed and modeled data
A posteriori uncertainties: interval of variation keeping 68% of highest model probabilities for all iterations

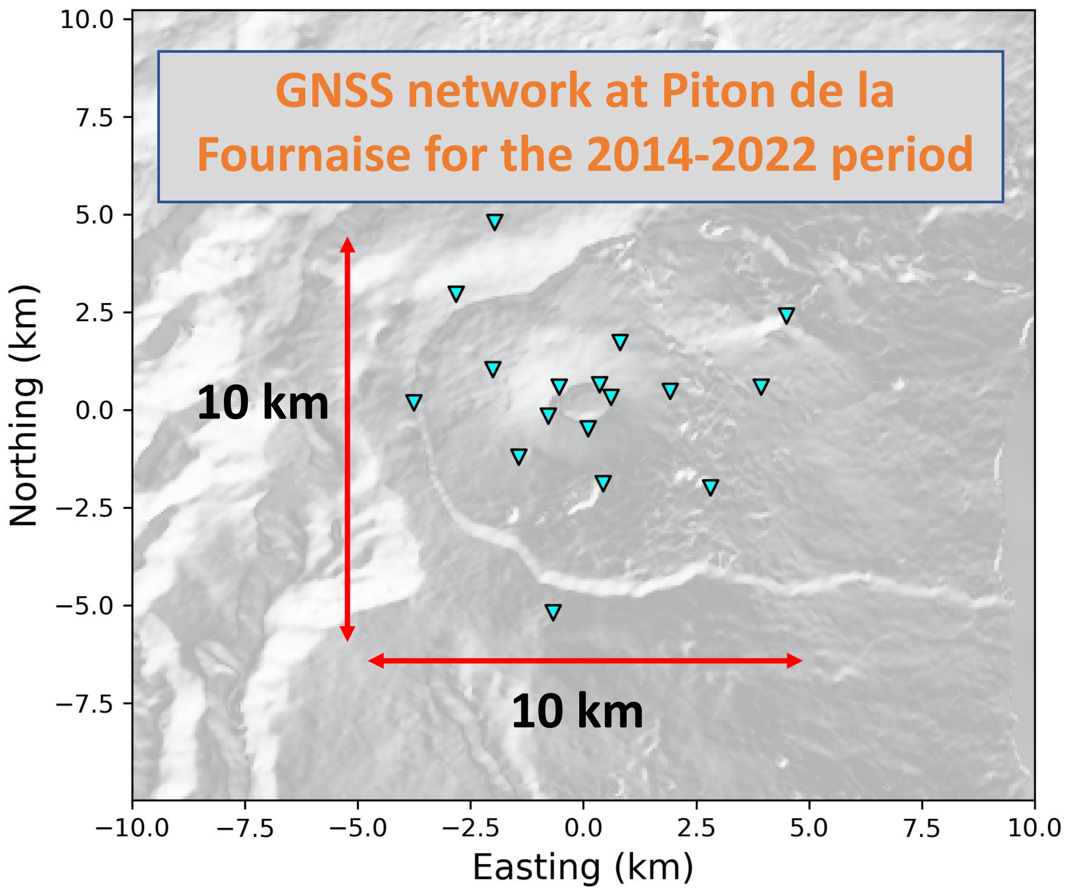
**An example from Piton de la Fournaise June 2014 pre-eruptive deformation**




**Results and figures from [Beauducel et al, 2020]**



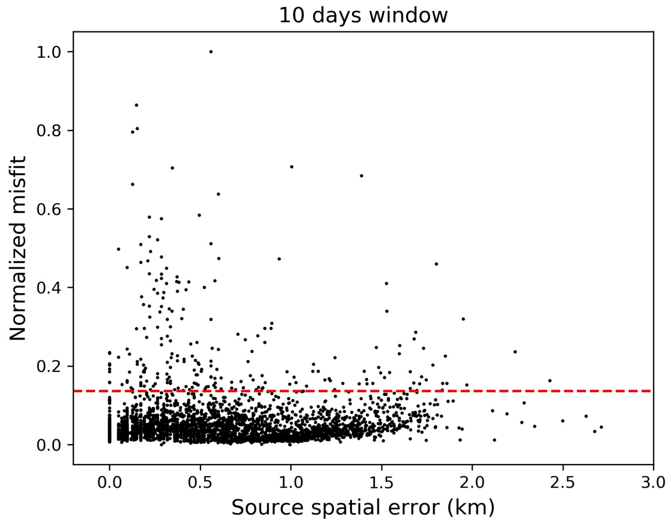
# Methodology application and parameters setting

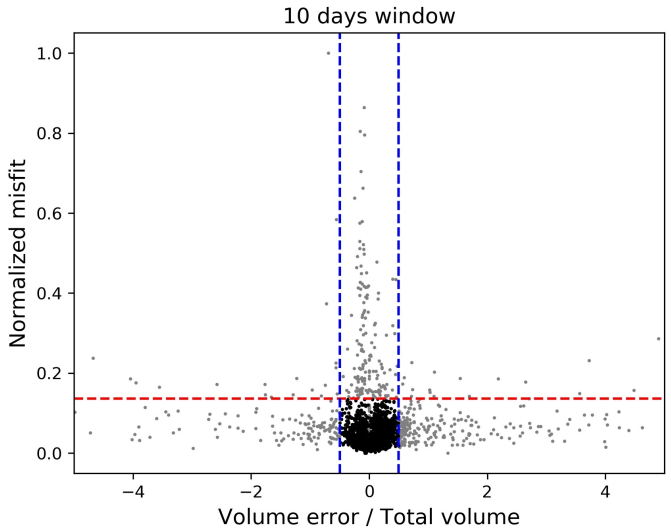



# 17 GNSS stations: daily solution from 2014 to 2022

# GNSS network aperture ~ 10 km

# Compute and invert displacement trends over a 10 day moving-window




# Assumptions: point-source approximation, elastic and homogeneous medium

# Misfit and Posteriori uncertainties used as criteria for keeping robust sources (75.3%, 2224 over the total 2954 ones)

# Results（1/2）: Imaging Piton de la Fournaise magmatic system

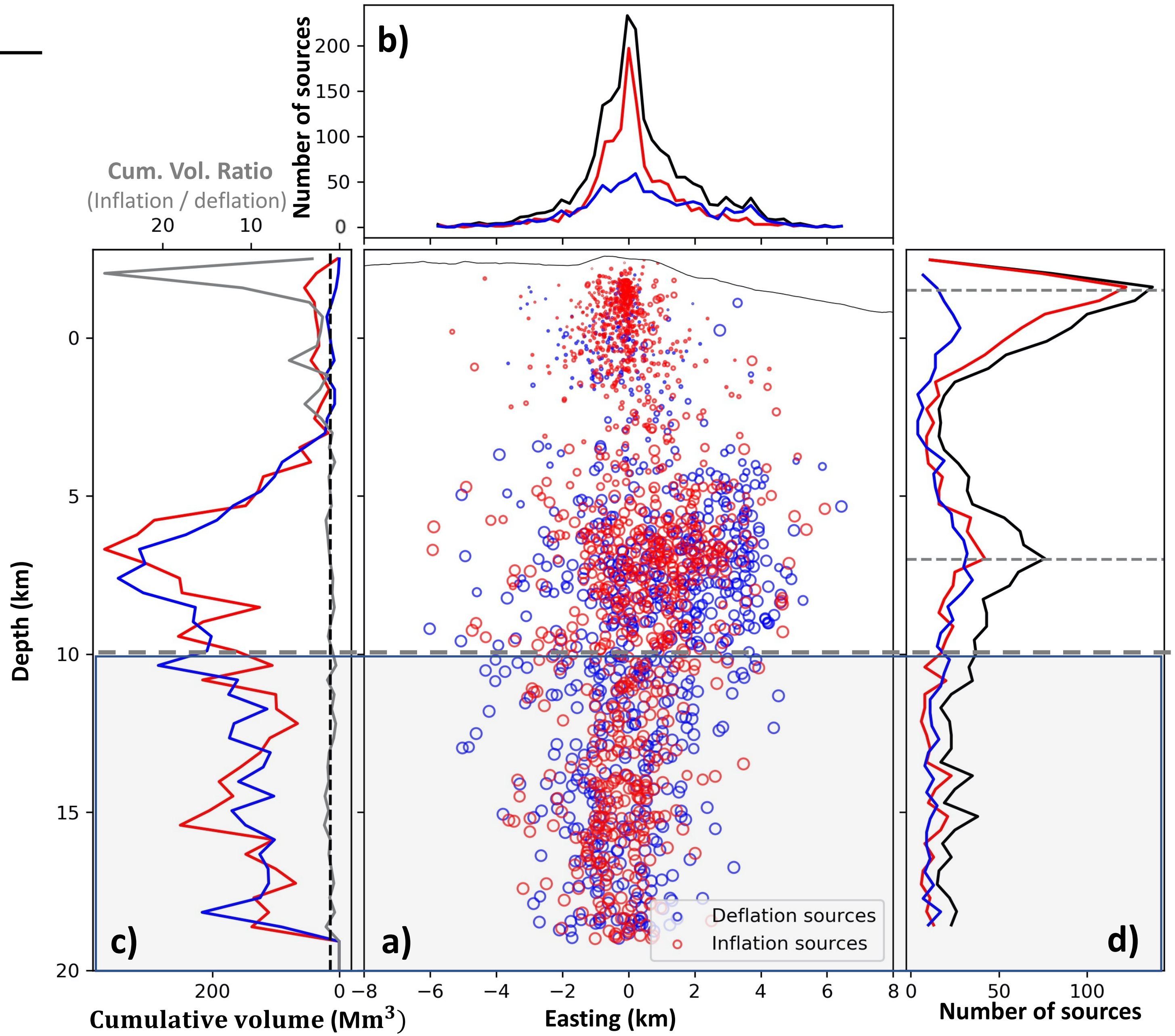
| $\Delta V = \mathrm{d}V_X + \mathrm{d}V_Y + \mathrm{d}V_Z$ | $\pm 0.1$ | $\pm 10$ $(\mathrm{Mm}^3)$ |
|---|---|---|
| Inflation sources | • | ○ |
| Deflation sources | • | ○ |

**GNSS-derived Piton de la Fournaise system characteristics:**

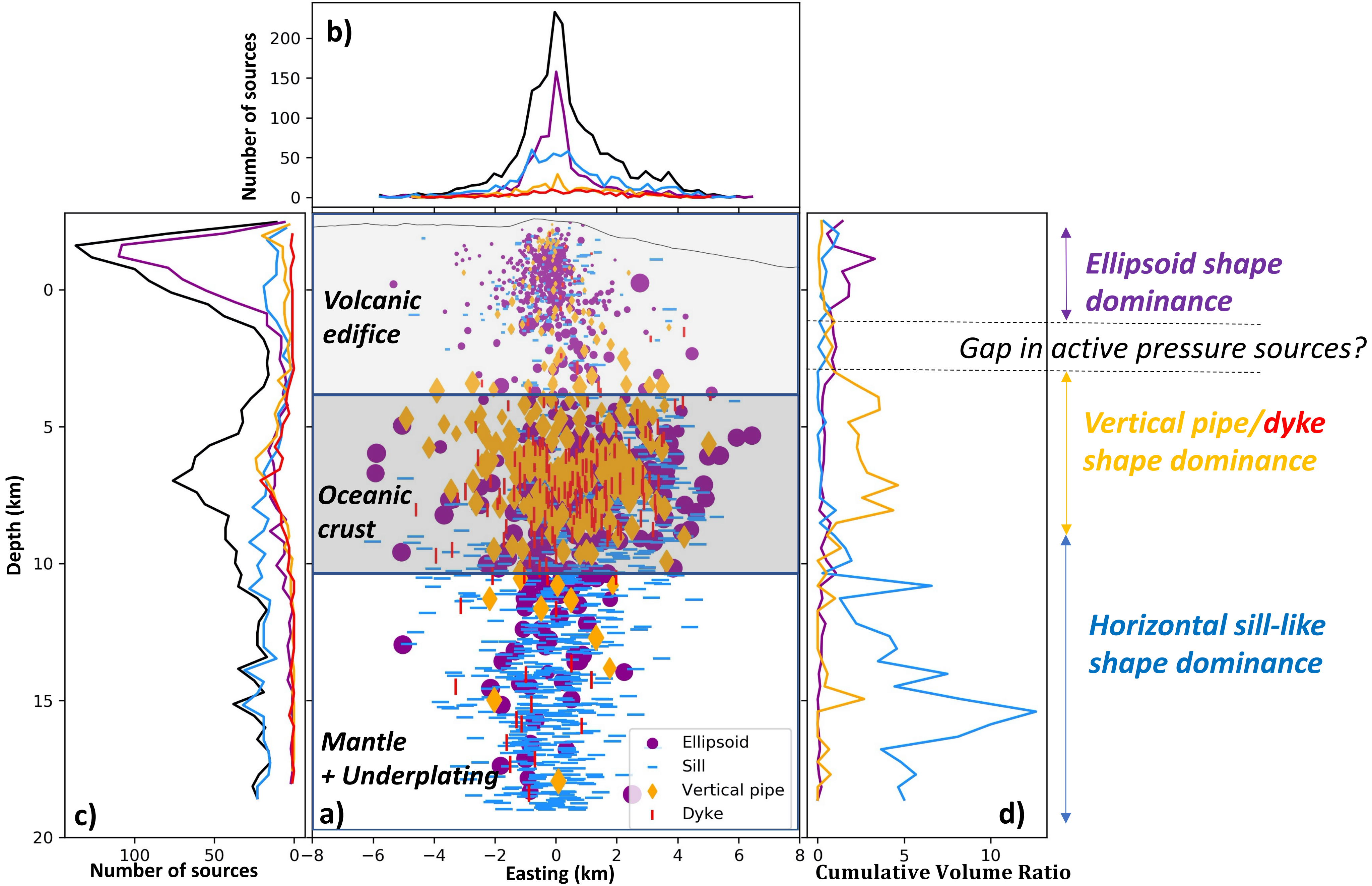
# Maximum density of pressure sources in the shallow system dominated by inflation sources

# Second local maximum of source density revealing a probable deeper magma reservoir around 7 km depth below sea level

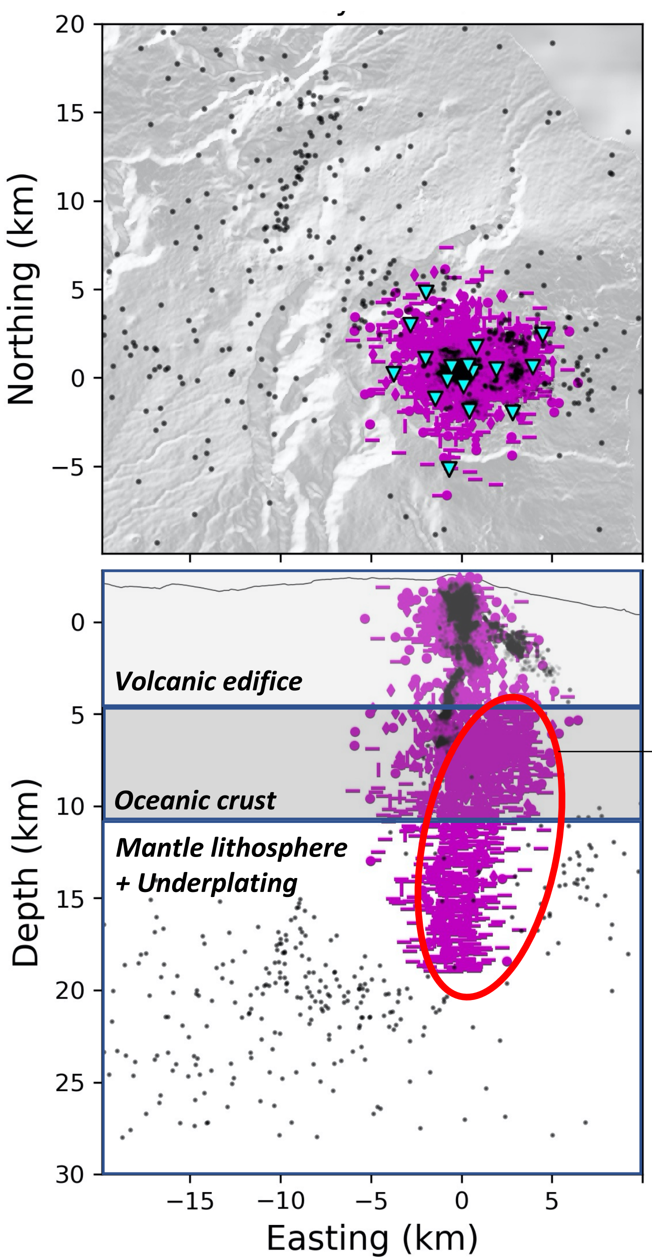
# Sources imaged below 10 km depth should be interpreted with caution (limit of our GNSS network aperture)



# Results (2/2): Imaging Piton de la Fournaise magmatic system



Black Seismicity
Purple pressure sources




# Conclusion

# Despite assumptions and simple models, the unsupervised dense GNSS network data inversion using a point Compound Dislocation Model reveals powerful for a mechanical imaging of the magmatic system active structures

# More insights should be gained in the future exploring in more details spatio-temporal patterns of the activated pressure source in the system as well as comparing systematically these outputs with the Piton de la Fournaise Volcanic Observatory seismicity catalogs

Most of deep active pressure sources inferred from our GNSS inversion lies in an aseismic zone

**Limits:**
**Bad resolution for depth > 10 km?**
**Visco-elastic behavior in the mantle?**
**Heterogeneous layers between 0-20 km**

***Thanks for your attention – cyril.journeau@univ-grenoble-alpes.fr***