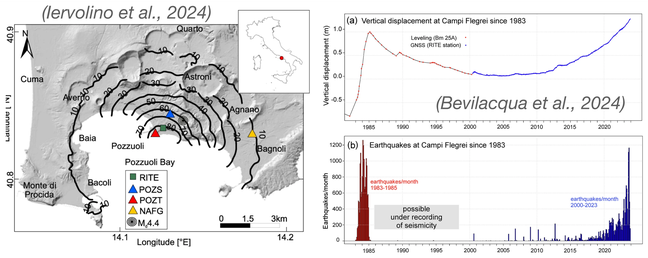
Source model of surface deformation and seismicity at the Campi Flegrei

Jinhui Cheng[1], Mateo Acosta[2], Zhen Li[1], Jean-Philippe Avouac[1]
1. Division of Geological and Planetary Sciences, California Institute of Technology
2. Department of Geosciences, Virginia Tech

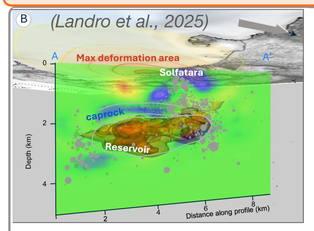
Background

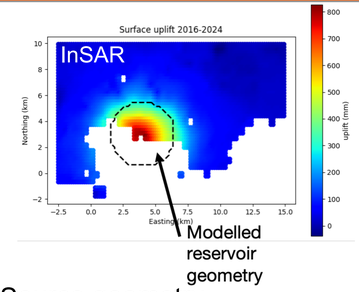


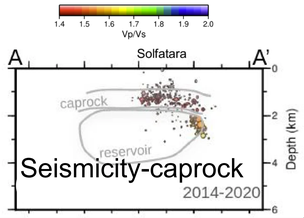
- **Campi Flegrei caldera:** Bradyseism since 1950s, cumulative uplift >3 m.
- Episodes linked to earthquakes, fumaroles, and hydrothermal activity → increase eruption risk.
- Surface deformation reflects reservoir pressurization, rock compaction, and fluid migration.
- Link between **deformation, Coulomb stress changes, and Seismicity** remains unclear.

Can a unified model of shallow reservoir inflation explain both deformation and seismicity?

Method



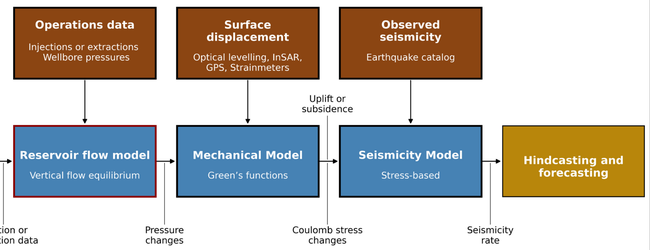




Source geometry constrained by seismic tomography and reflections

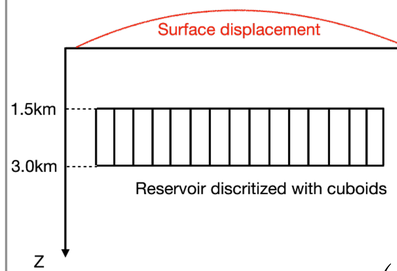
low Vp/Vs isosurface — gas reservoir.

Flow2Quake (Acosta et al., 2023, 2025)



Geodetic observation

Geo-mechanical model prediction on surface deformation



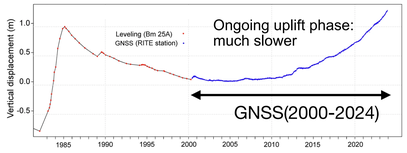
$$d = Gm$$

$$\varepsilon_z = \frac{\Delta h}{h} = C_m \Delta P$$

m: reservoir inflation

$$\begin{pmatrix} \overrightarrow{W} & \overrightarrow{1} \end{pmatrix} \begin{pmatrix} \mathbf{G} \\ \gamma^2 \mathbf{R} \nabla^2 \end{pmatrix} \overrightarrow{m} = \begin{pmatrix} \mathbf{W} & \overrightarrow{1} \end{pmatrix} \begin{pmatrix} \overrightarrow{d} \\ \overrightarrow{0} \end{pmatrix}$$

- Greens function (Geertsma,1973; Kuvshinov,2008) Strain volume formulation
- Linear poroelastic reservoir embedded in a homogeneous elastic half-space.
- Stress tensor and displacement

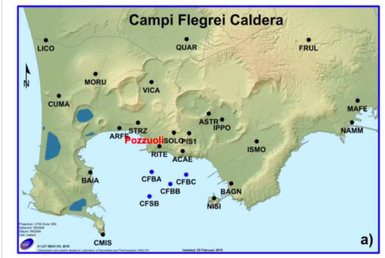


Sentinel-1(2016-2024)

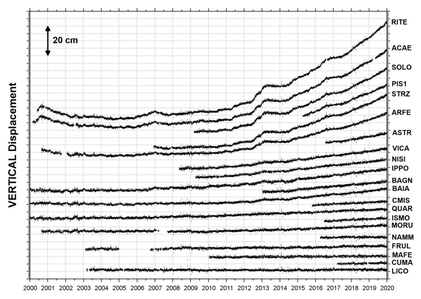
COSMO-SkyMed(2021-2023)

GNSS High temporal resolution

(DeMartino et al., 2021)

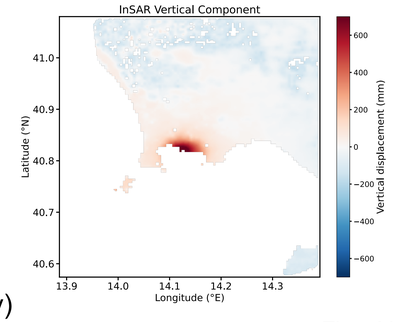


Station: NeVoCGPS (21 onshore, daily) + MEDUSA (4 marine, weekly).

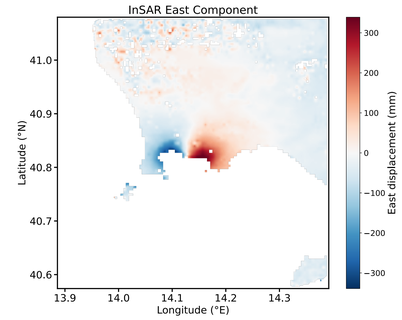


InSAR High spatial resolution

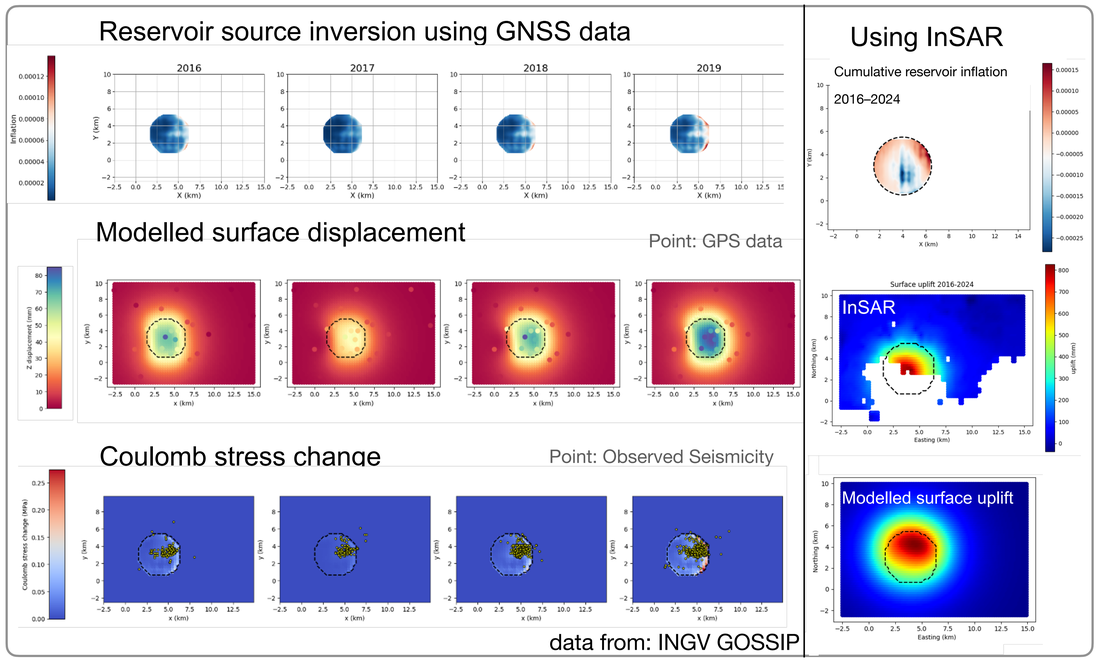
2016-2024 3D decomposition



Zhen Li



Source inversion from geodetic data



Summary

- Hydrothermal activity, ground uplift, and seismicity are closely linked at Campi Flegrei.
- This is the first application of Flow2Quake in a volcanic area.
- GNSS and InSAR show reservoir inflation, strongest at the east edge.
- High Coulomb stress matches the observed earthquakes.
- Future work: joint inversion and test alternative source models.

Reference

- Li, Yuexin, et al. "Geodetic monitoring of elastic and inelastic deformation in compacting reservoirs due to subsurface operations." *Journal of Geophysical Research: Solid Earth* 130.3 (2025): e2024JB030794.
- Smith, Jonathan D., et al. "Reconciling the long-term relationship between reservoir pore pressure depletion and compaction in the Groningen region." *Journal of Geophysical Research: Solid Earth* 124.6 (2019): 6165-6178.