EGU 2020 – SHARING GEOSCIENCE ONLINE
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A Monte Carlo Markov Chain Approach to Stress Inversion and Forecasting of Eruptive Vent Locations

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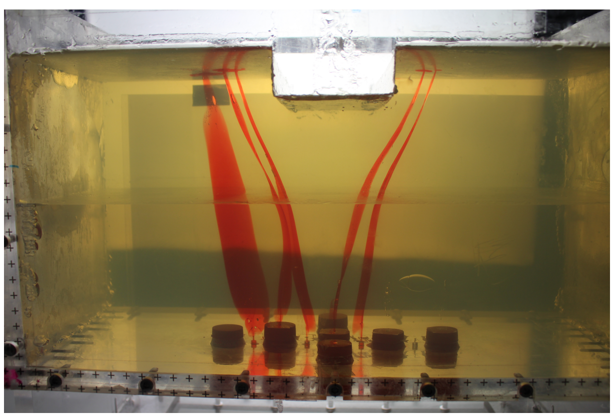

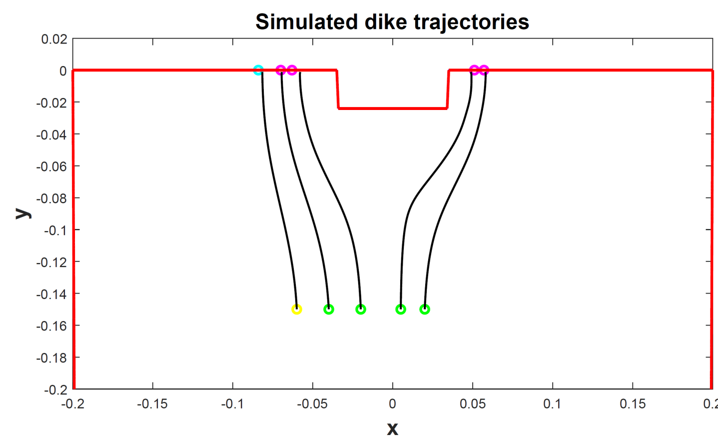

1) Helmholtz Zentrum Potsdam – Deutsche Geoforschungszentrum (GFZ) 2) Universität Potsdam

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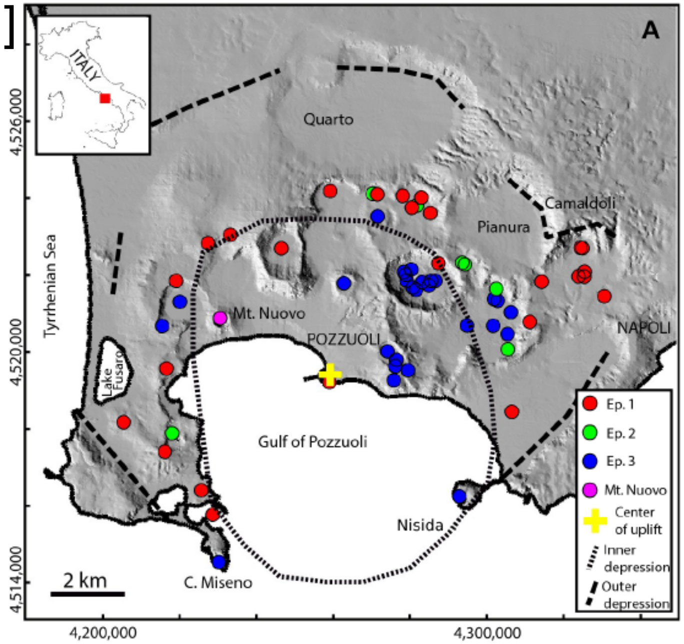
Probabilistic forecasting in distributed volcanic fields: where is the next eruption more likely to take place?

Current approaches focus on the spatial density of past vents and structural features (e.g. faults and fractures)

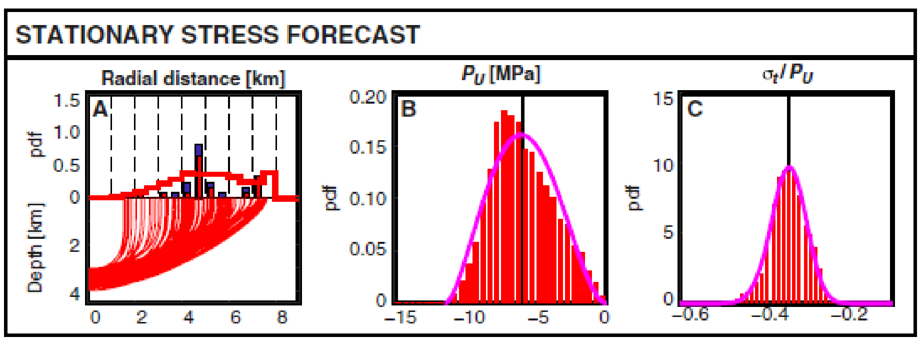
↓

Few and/or scattered vents lead to poorly constrained probability maps

[1]



[1]



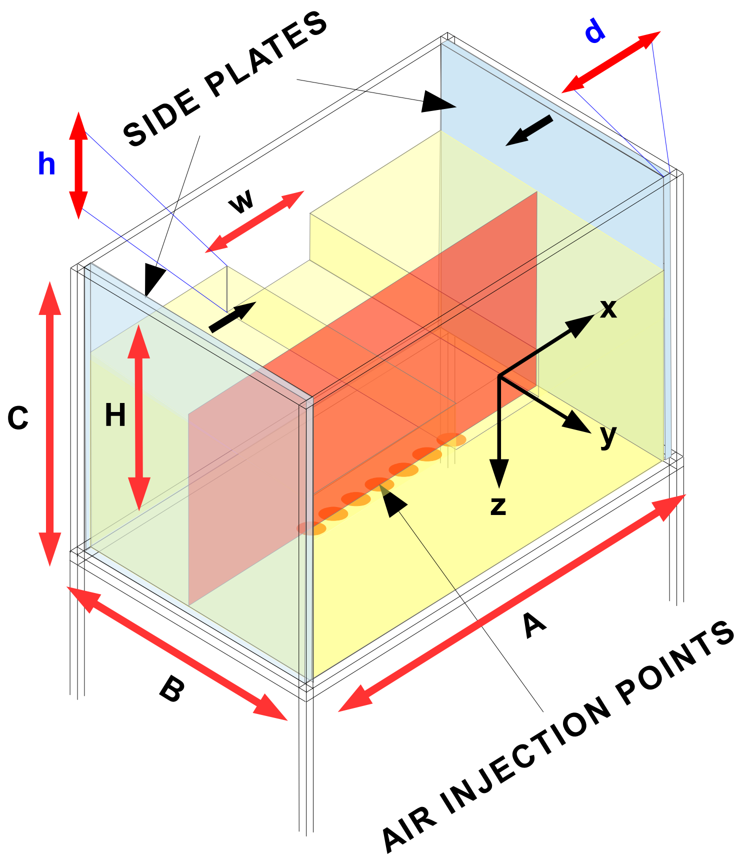
Rivalta et al., 2019 [1] proposed a mechanics-based approach to constrain the state of stress of the volcanic region on the base of past eruptive vent locations. The method was applied to one case only: the Campi Flegrei caldera in Italy.

General assumptions:

- Dykes are driven by stress and not by pre-existing fractures
- More simplifying assumptions case by case

New idea: validate the strategy thorugh analog models

THE ANALOG MODEL

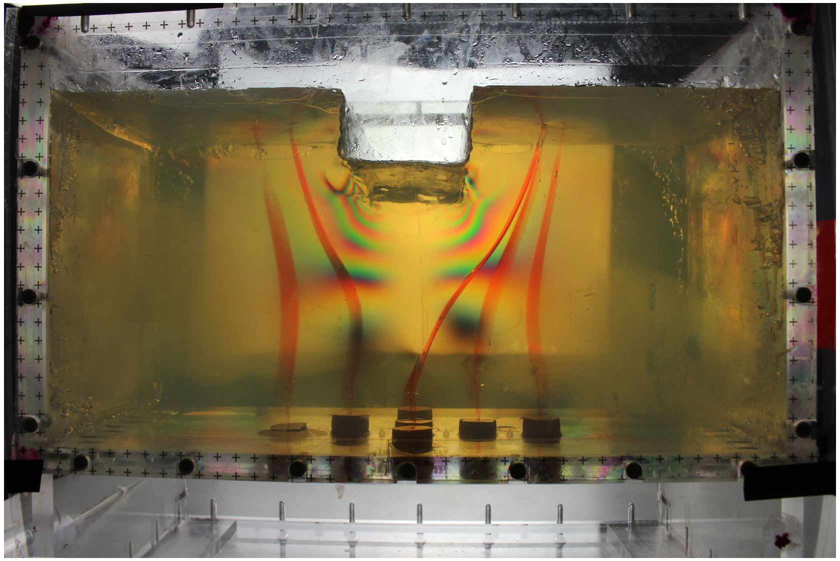


Perspex box filled with homogeneous or layered gelatin

Surface can be modelled to reproduce topographic loading/unloading

Plates at the sides can induce compression / extension

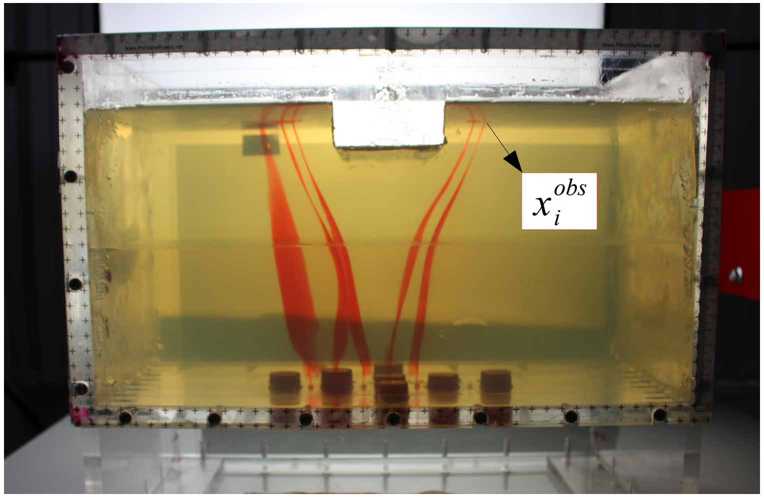
Air is injected through holes in the bottom → air-filled cracks propagate upward



6 experiments performed:

- Extension (1) & Compression (2) + unload
- Extension + unload + layered medium (3, 4)
- Extension (5) & Compression (6) + partially refilled unload

THE NUMERICAL MODEL

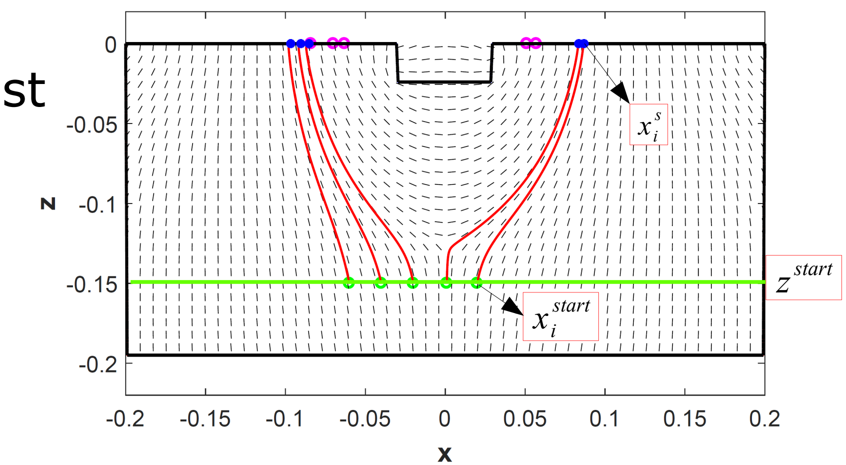


Crack trajectories are simulated through a Boundary-Element code:

- Based on Tim Davis' Cut&Displace MatLab tool [2]
- Inputs: gelatin parameters and geometry, side displacement, starting points of cracks (x_i^{start}, z_i^{start})
- BEs on the gelatin surface → stress BC (gravitational load/unload)
- Outputs: coordinates of the arrival points of cracks (x_i^{s})

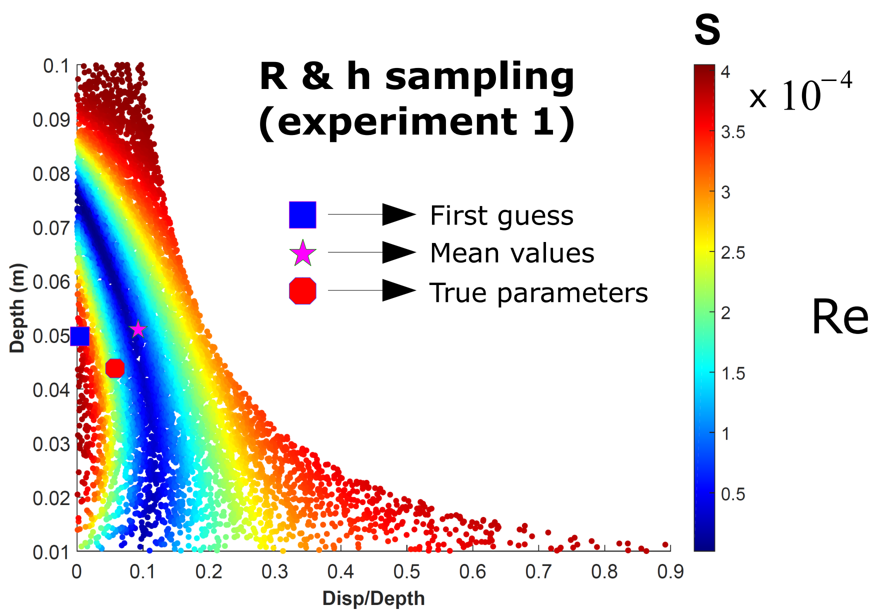
Assumptions:

- Cracks propagate along the direction of the most compressive principal stress axis
- State of stress is modeled through two parameters:
  - Vertical dimension of the surface unload → ***h***
  - Fixed side displacement → ***d***



MCMC & FORECAST STRATEGY

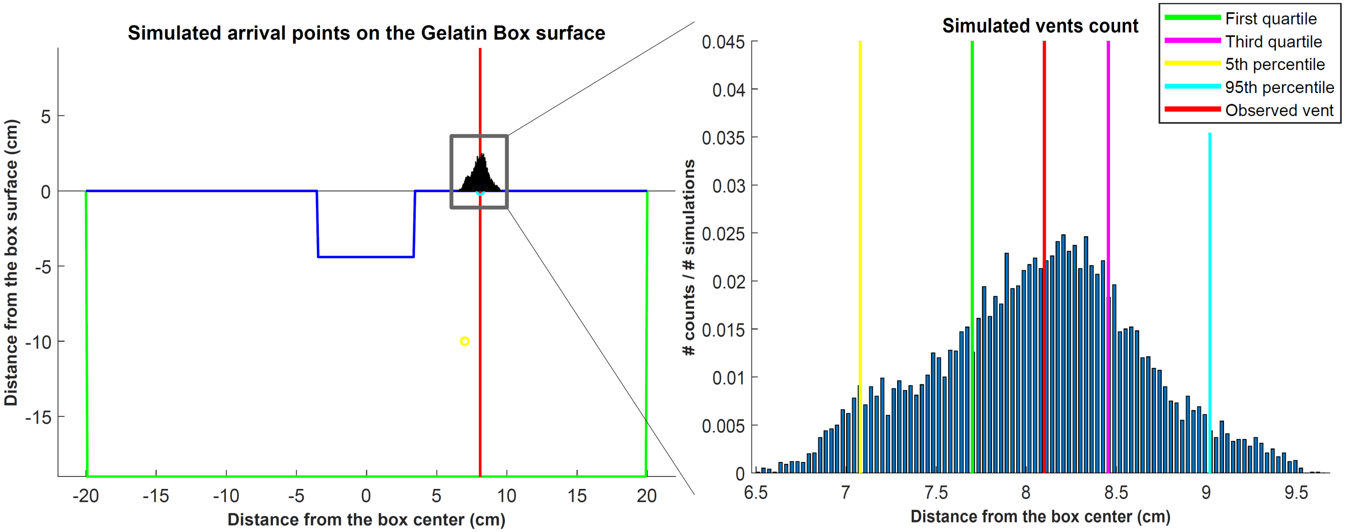
- Data → x_i^{obs}
- Two parameters to invert for **($R = d/h$, h)**



Idea: simulate the same amount of cracks with different parameters → x_i^s

$$S = \sum \left(x_i^{obs} - x_i^s \right)^2$$

Residual sum of squares → MCMC objective function



Forecasting:

- Divide the dataset into 2 subsets and run the inversion with the bigger one
- Run 10^4 simulations from a realization of the retrieved PDFs

FURTHER STEPS & REMARKS

- Controlling the volume of injected air and the orientation of the injecting needle can be difficult
- Properties and rheology of gelatin depend on the history of cooling process -> hard to control
- Cracks velocity and interaction with layering, free surface and previous cracks are neglected...

These are however advantages in this particular application, as the approach is able to map these variabilities into very few parameters and their distributions

2D modeling, 3D effects neglected → need for a more realistic 3D model

Models work in gelatin → need for more applications to nature

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References:

[1] Rivalta, E., Corbi, F., Passarelli, L., Acocella, V., Davis, T., & Di Vito, M. A. (2019). *Stress inversions to forecast magma pathways and eruptive vent location*. Science advances, 5(7), eaau9784.

[2] Davis, T. (2017). *A new open source boundary element code and its application to geological deformation: Exploring stress concentrations around voids and the effects of 3D frictional distributions on fault surfaces* (M.Sc thesis). Aberdeen University; GitHub repository: https://github.com/Timmmdavis/CutAndDisplace.

THANK YOU!

Comments & suggestions are welcome

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