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New insight into the December 2018 Etna eruption through the joint inversion of ground deformation and gravity data

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Key Points:

- An eruption took place on 24 December, 2018 at Mt. Etna (Italy), which was accompanied by a seismic swarm that culminated in the M4.9 earthquake on the 26th having epicenter on the eastern flank of the volcano.
- We inverted the ground deformation and gravity data, which was observed during the eruption of Mt. Etna (Italy) in December, 2018.
- A dike type source (Okada and Okubo formulations) is used for modelling the magmatic source and data is inverted using the pattern search algorithm (PSA) and Markov Chain Monte Carlo (MCMC) method.
- We propose a complex mechanism that leads to the eruption mere a dike intrusion.

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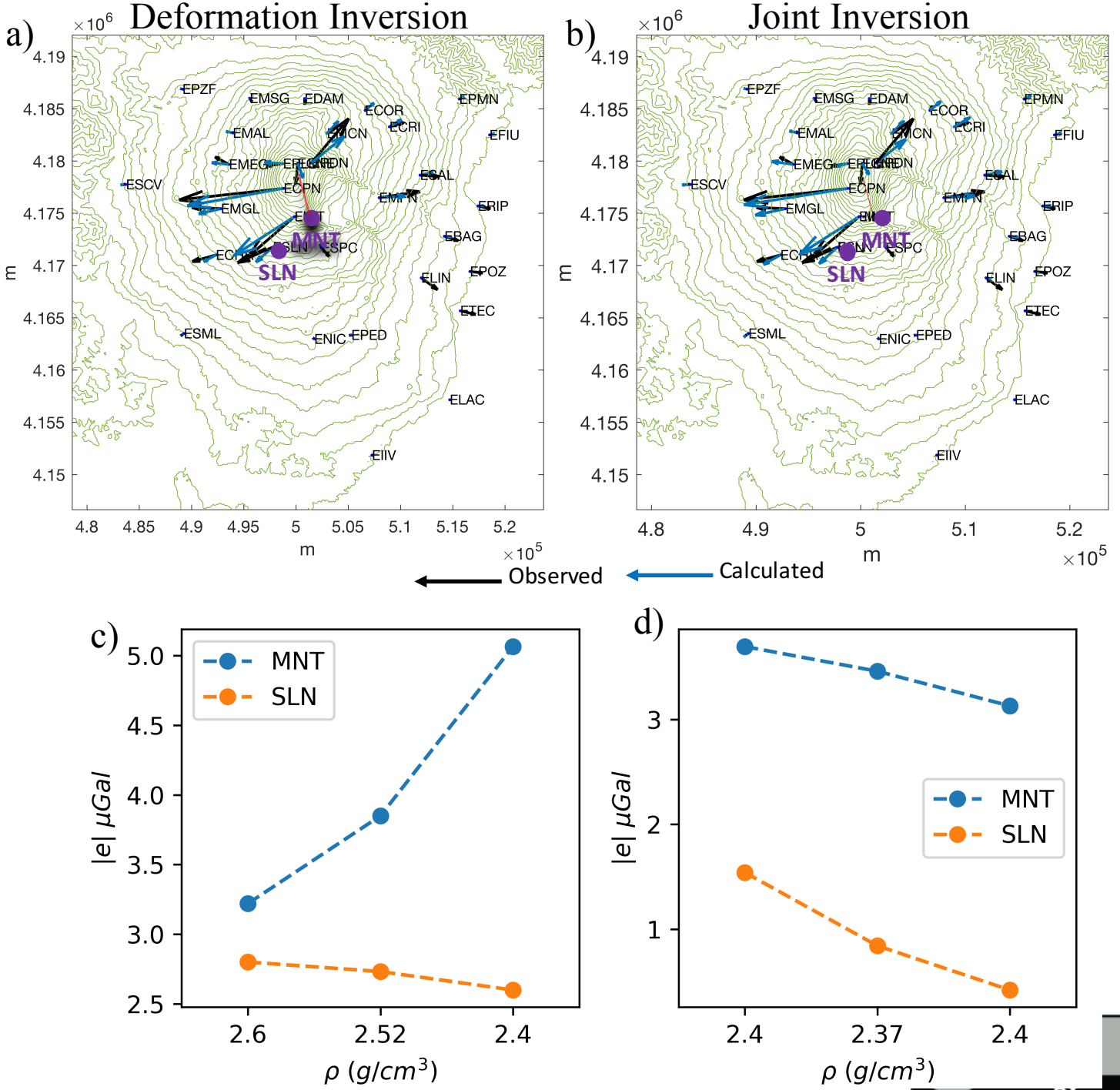
Results

DATA: 30 GPS stations (3-components) and 2 superconducting gravimeters (purple color).

Analysis:

- We used two approaches: (1) inverting only deformation field in order to retrieve the geometry of the dike then fixing the geometry and inverted the gravity data for density; (2) then performing the joint inversion of deformation and gravity data.
- Figure (a & b) shows the fitting between observed and calculated deformation field, inverted using both the approaches by Pattern Search Algorithm. *Please note that in both the cases, the misfit is similar.*
- However, when we try to improve the fitting of gravity data at both the stations using the first approach, the misfit slightly improve for the SLN station while at MNT it worsen (Figure c) and density decreases. Which means the geometry of the dike needs to be inverted.
- In the second (joint inversion) approach, the misfit improve for both the stations with a density value of ~ 2.4 g/cm^3 (Figure d).



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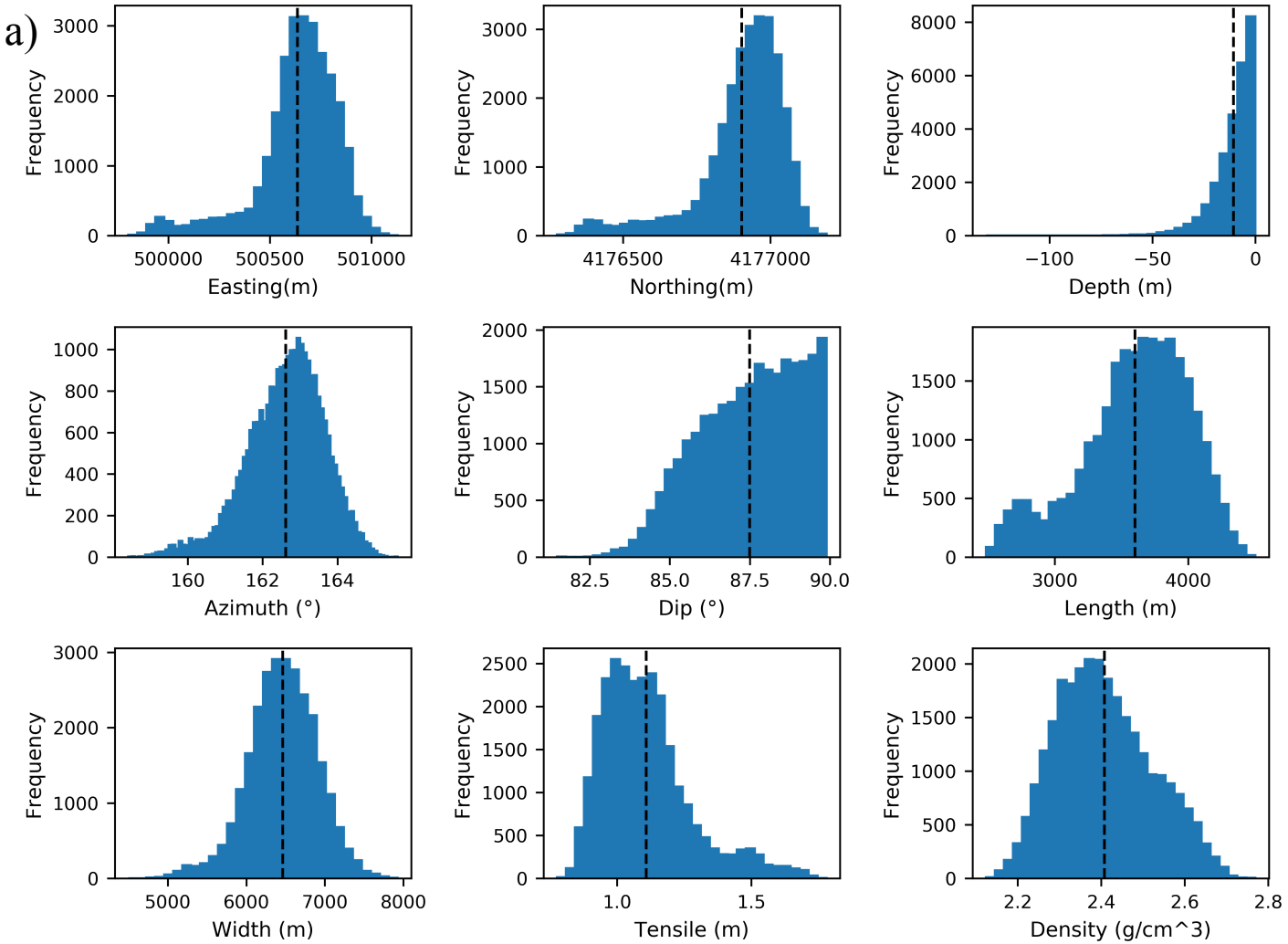

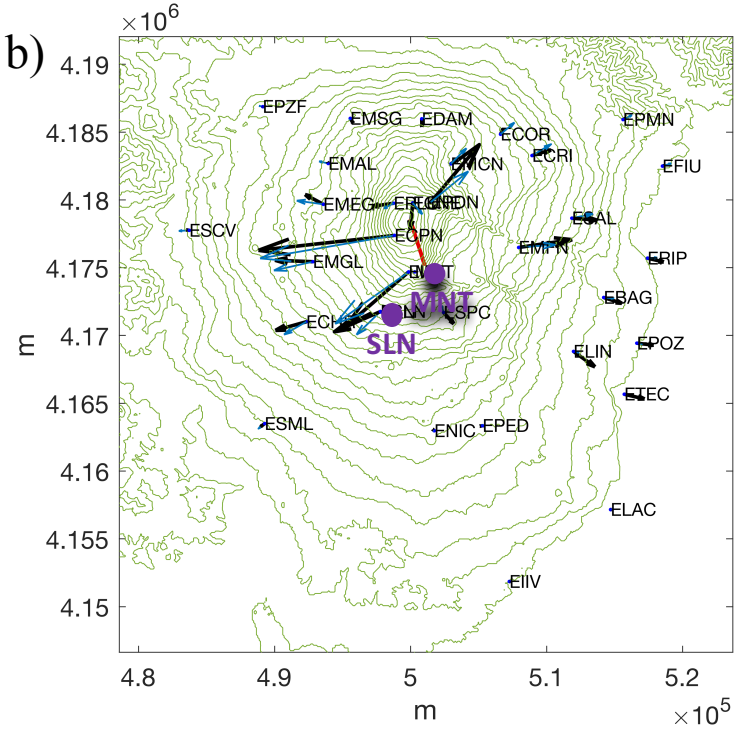

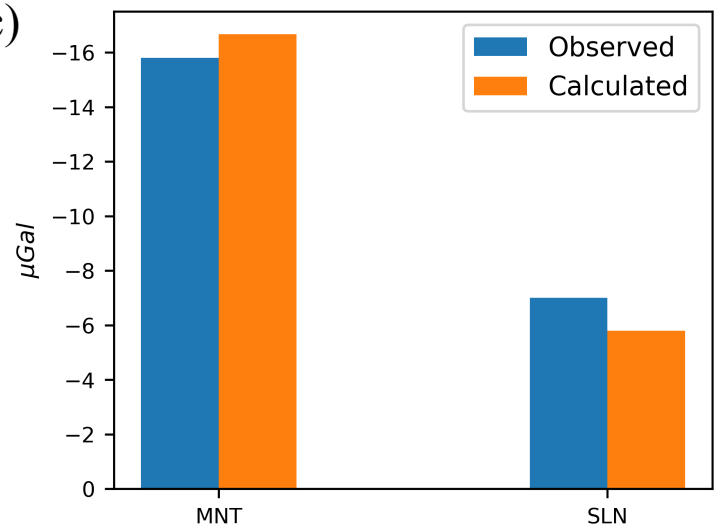

- Since PSA gives only a best-fit model, we decided to use MCMC using Metropolis-Hasting sampler for the joint inversion in order to retrieve the posterior density function (PDFs) of the model parameters of the dike. The PDFs (Figure a) added more information about the well constrained parameters given the data. Figure (b & c) shows the misfit of deformation and gravity calculated using the mean values of the PDFs (black dotted line in Figure a).

- Interestingly the density once again is lower than the bubble free magma density: almost 85% density values are less than 2.5.

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Conclusions

- A high quality data of superconducting gravimeters is used for constraining the magmatic source model in order to estimate the geometry as well the density of the dike intrusion.
- Results show that using the dike type source (Okada model), a good misfit of the deformation field is obtained irrespective of the approaches. However in order to explain the gravity change a lower values of density (compare to the magma density) is estimated. Although ~3 microGal of gravity at SLN station is not explained by the estimated model.
- To explain a gravity decrease observed at SLN, the source must be rooted in the deeper depth in to the feeding system of the Etna and the shallow position of the dike which is aligned with the top of the assumed elastic half space, can not explain the whole gravity change and a thoughtful insight is need to explain the mechanism that leads to the eruption.
- If the predicted uplift by Okada model is neglected in the Okubo formulation, a very low density is needed to fit the observed gravity change, which implies the possibility of the new void space, which are created in the shallower level of feeding system.
- Regardless of the limitations, a joint inversion approach obtained a unique insight in the volcanic processes even if the gravity data from two stations is available.