

The 2024-2025 Santorini seismo-volcanic unrest: insights using GNSS and InSAR data

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Τα ίχνη των ρηγμάτων προέρχονται από τα
NOAFAULTs
Η βυθομετρία προέρχεται από την Δρ.
Νομικού, ΕΚΠΑ



Sikinos

Ios

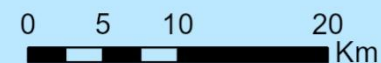
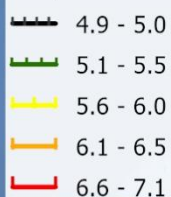
Amorgos

South Aegean

Thira

Anafi

Μέγιστα Αναμενόμενα Μεγέθη



ΕΘΝΙΚΟ ΑΣΤΕΡΟΣΚΟΠΕΙΟ ΑΘΗΝΩΝ
Γεώργιος Γούτσος, Δρ. Βαρβάρα Τσιρώνη, Δρ. Αθανάσιος Γκανάς

Esri, NASA, NGA, USGS; Esri, TomTom, Garmin, Foursquare, FAO, METI/NASA, USGS

The Santorini volcano

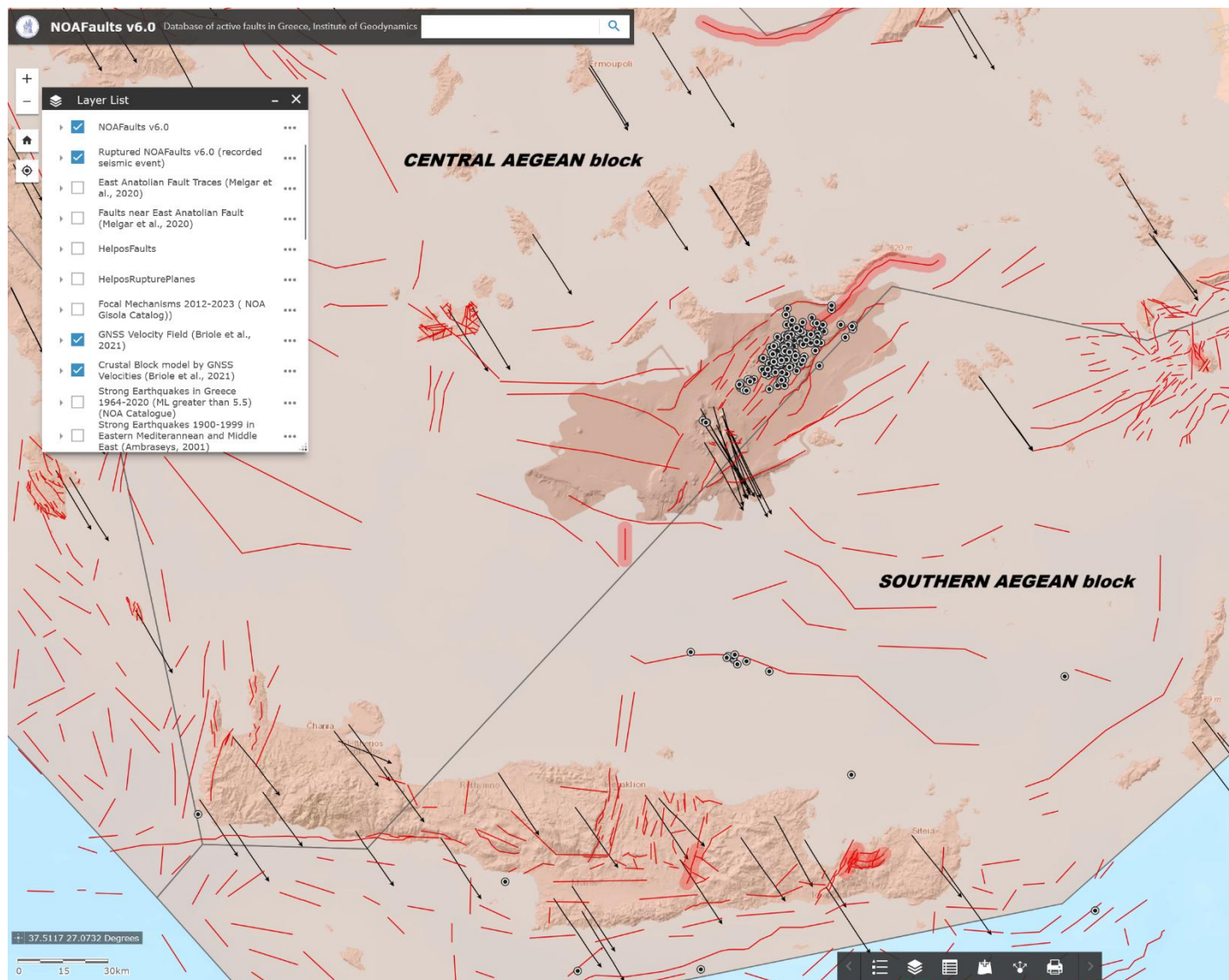
Santorini is an active stratovolcano emplaced within a region of extensional faulting in South Cyclades, Greece.

Santorini erupted in the 19th century, in the 20th century (1928-1950).

The latest episode (earthquake swarm & ground deformation) was in 2011.

In 2025 a two-month-long seismic crisis reaching Amorgos (NE of Santorini), together with GNSS measurements made before and during the crisis, provide insights into the relations between the volcano dynamics and its surroundings.





Based on GNSS data:
There is a dextral transtensional movement of 4.5 mm / yr between the Amorgos and Astypalea islands
3.7 mm/yr RL S.S
2.5 mm/yr Normal

Seismicity at block boundaries

1956 EQ M7.2

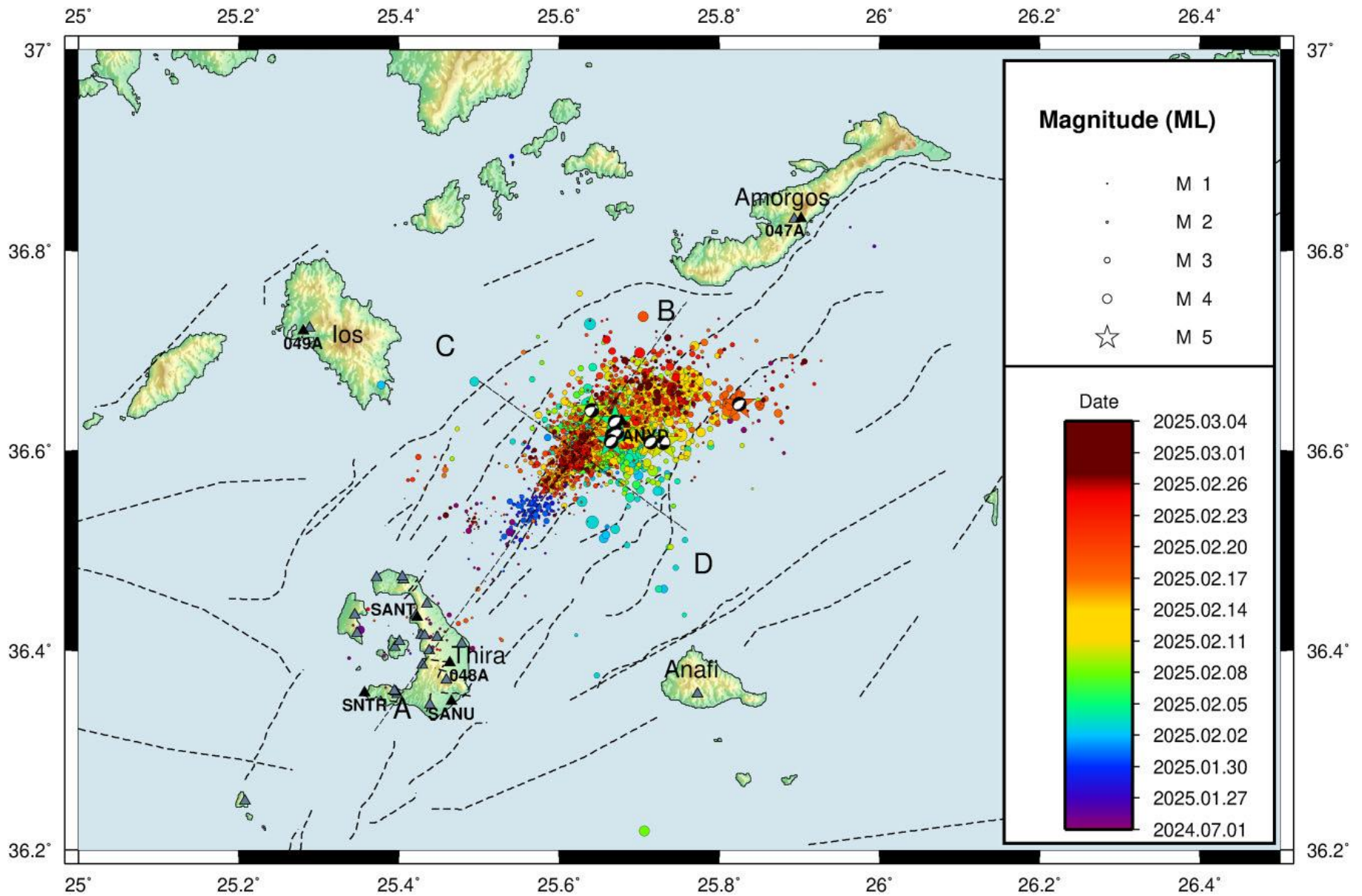
The 2024-2025 crisis

The GNSS / InSAR data show that Santorini inflated since the summer of 2024.

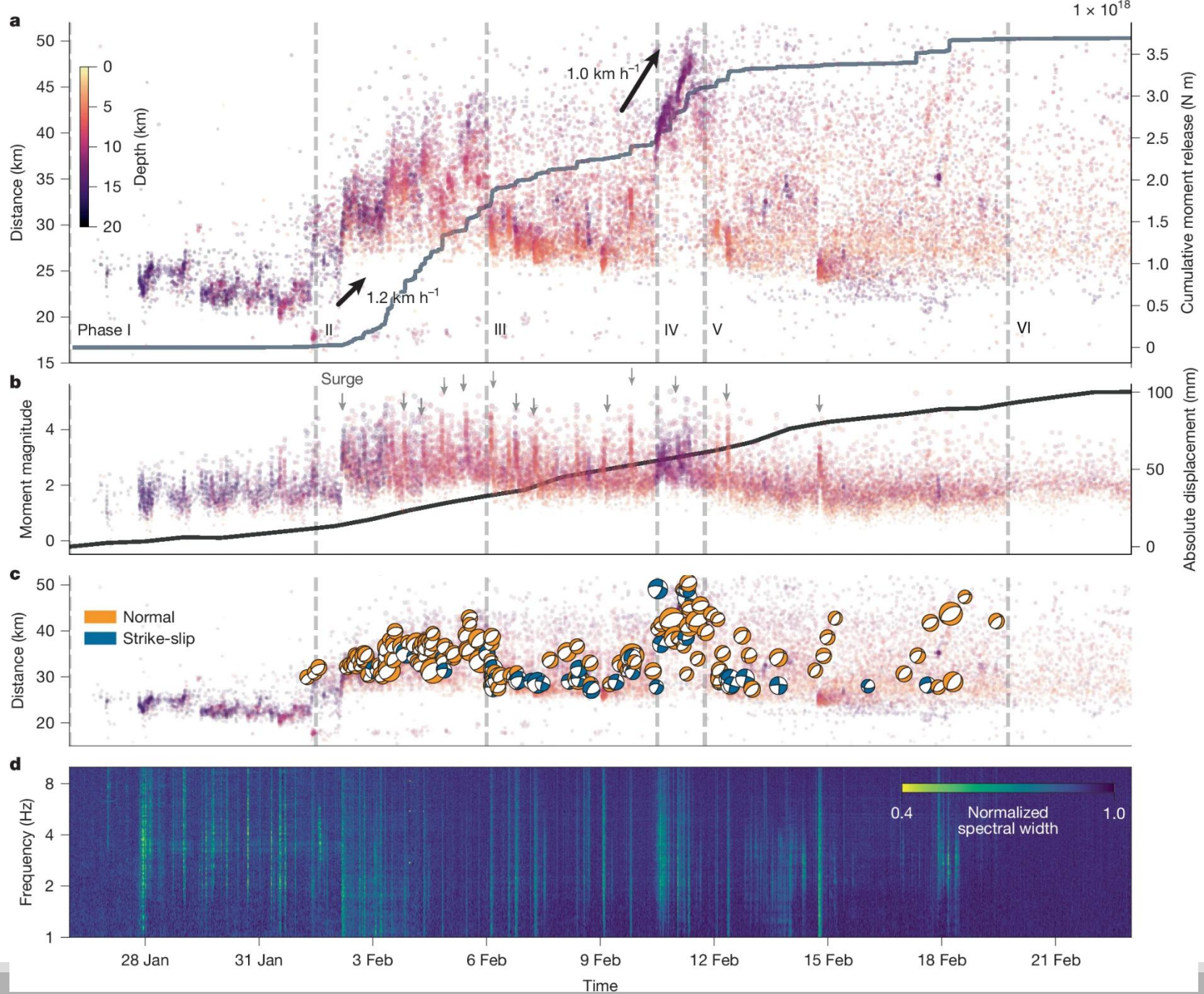
We model this inflation with a magma source of $\sim 7.7 \times 10^6 \text{ m}^3$ located ~ 3.5 km under the north-central floor of the caldera, near the inflation centre of 2011.

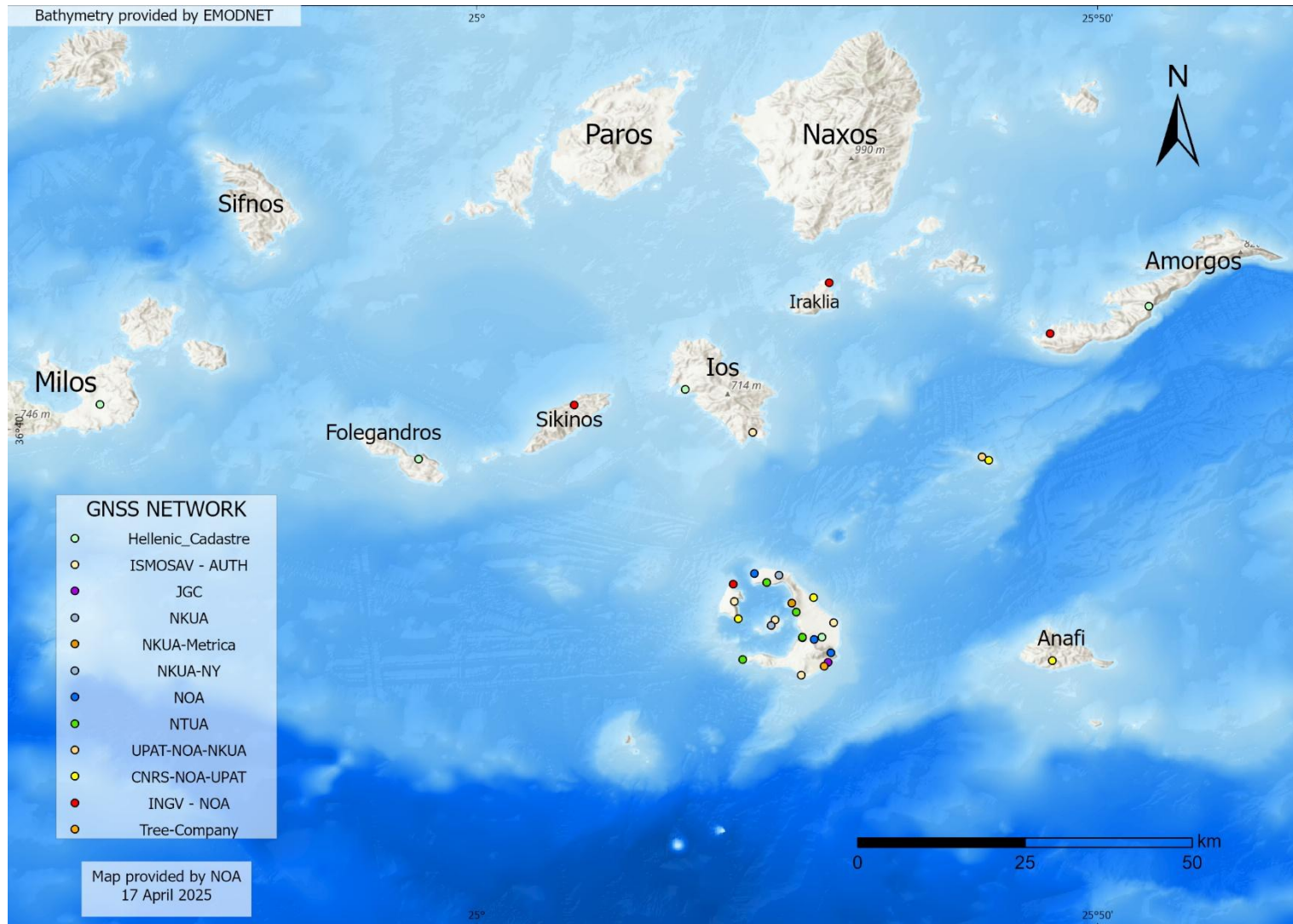
The inflation phase ceased around 27 January 2025.

Contemporaneously, the seismic activity, shifted to the north-east of Santorini near the islet Anydros. This phase lasted about ten days, before leading into a most intense phase that produced ground deformation measurable at large distances over the South Cyclades.



Relocated seismicity from 2024 July 1 to 2025 March 4 and focal mechanisms (from the National Observatory of Athens catalogue of the eight events of $M_w \geq 5$). The colours indicate the dates of the events.



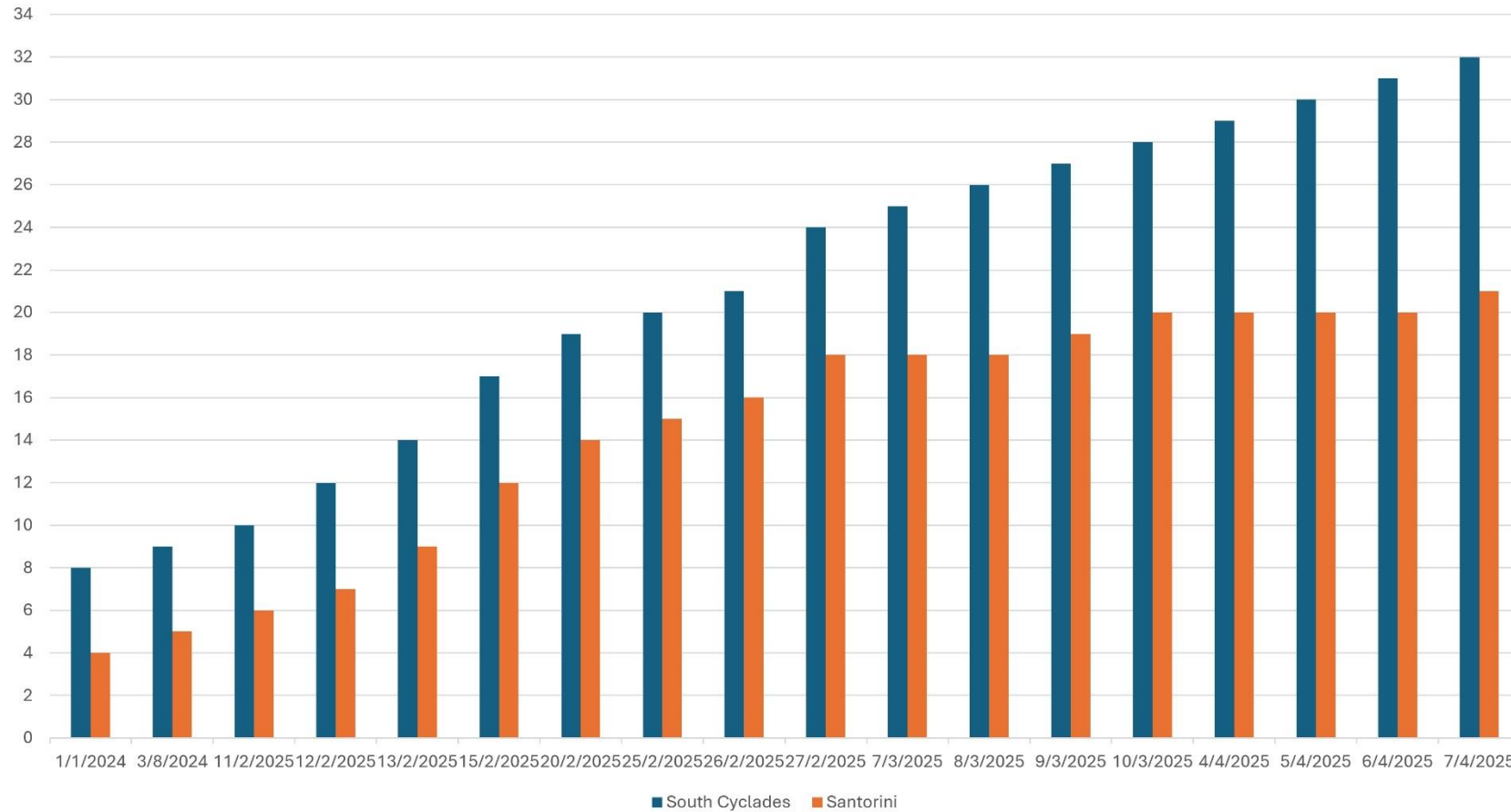


GNSS sites 2024 - 2025

Total:
32 / 21 sites
(installed by
8/4/2025)

However:
Available on 31
January 2025: 9
(5 in Santorini and
4 in Amorgos, Ios,
Folegandros, Milos)

GNSS Data availability time line - all networks

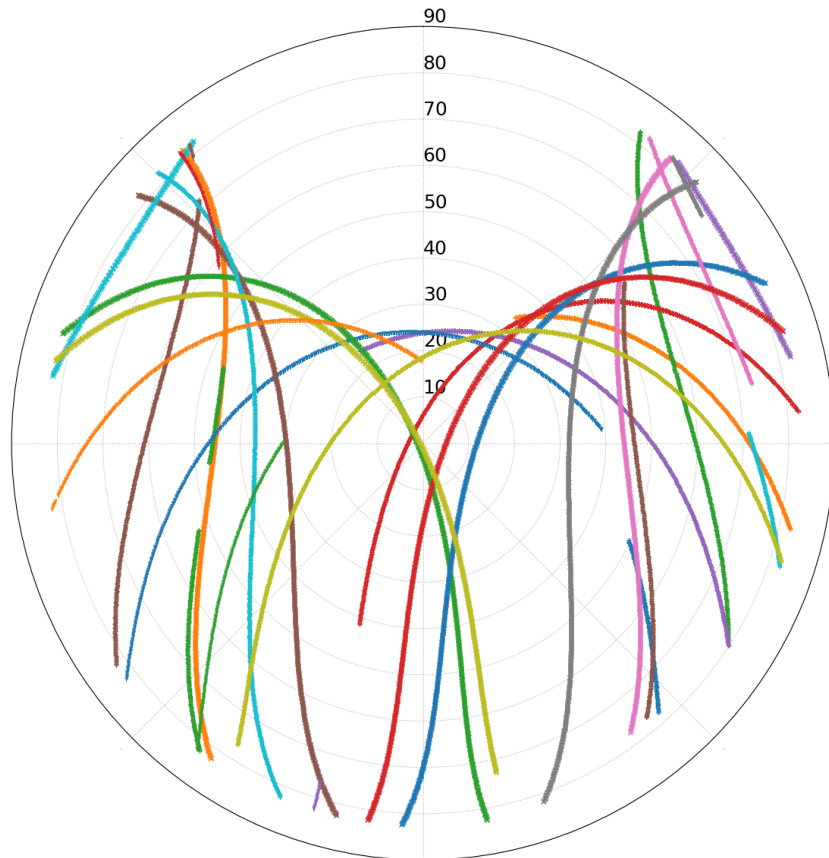


GNSS sites
2024-2025

32 / 21 sites

after 11 February
2025
Installed-opened
19/15
and
Between
3-8/4/2025
4/1)

Distribution spatiale des satellites



• G03	• G08	• G14	• G18	• G23	• G28
• G04	• G09	• G15	• G19	• G24	• G29
• G05	• G11	• G16	• G20	• G25	• G30
• G06	• G12	• G17	• G22	• G26	• G31
• G07	• G13				



12/2/2025: panoramic view of
installation *ANYD* (*Anydros*)

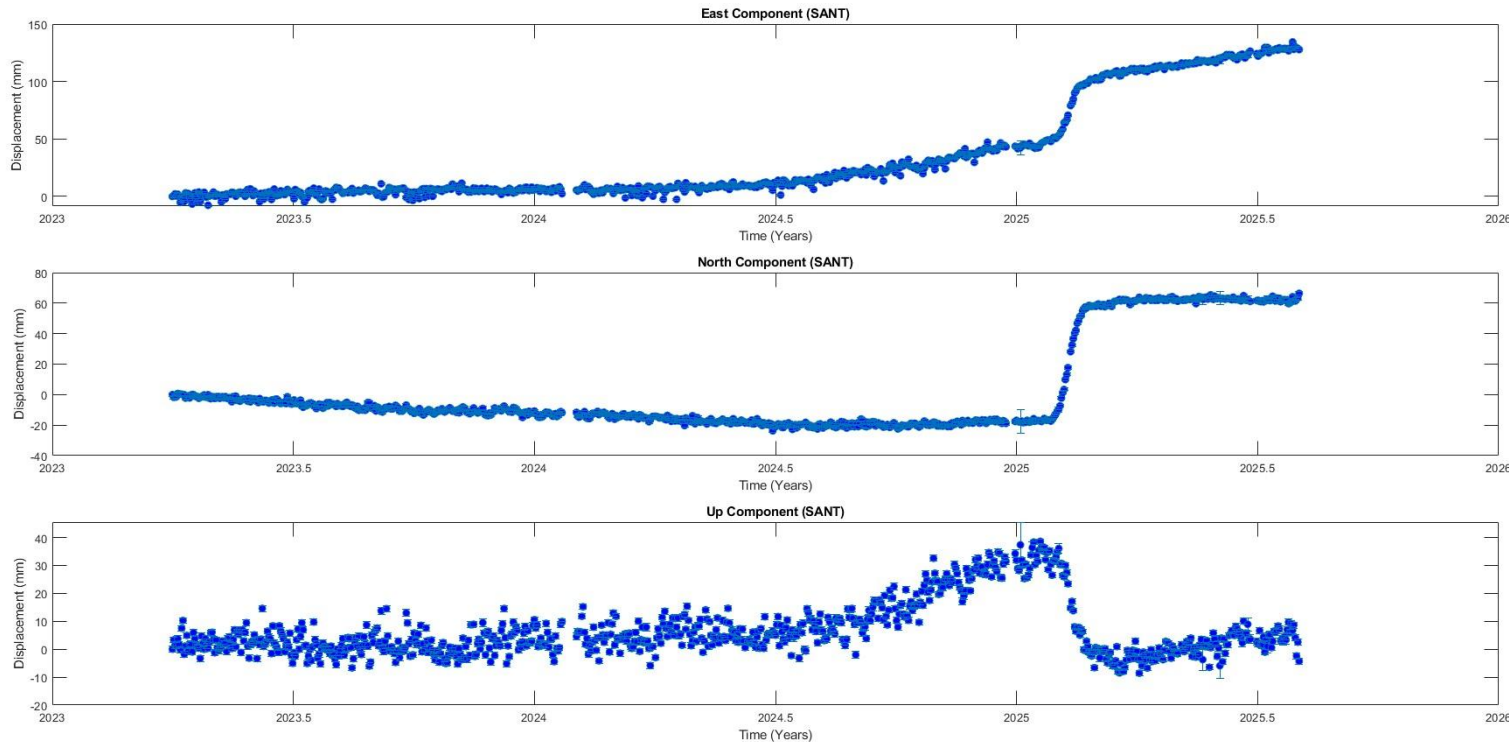
GNSS site
Available via the
NOA GLASS node

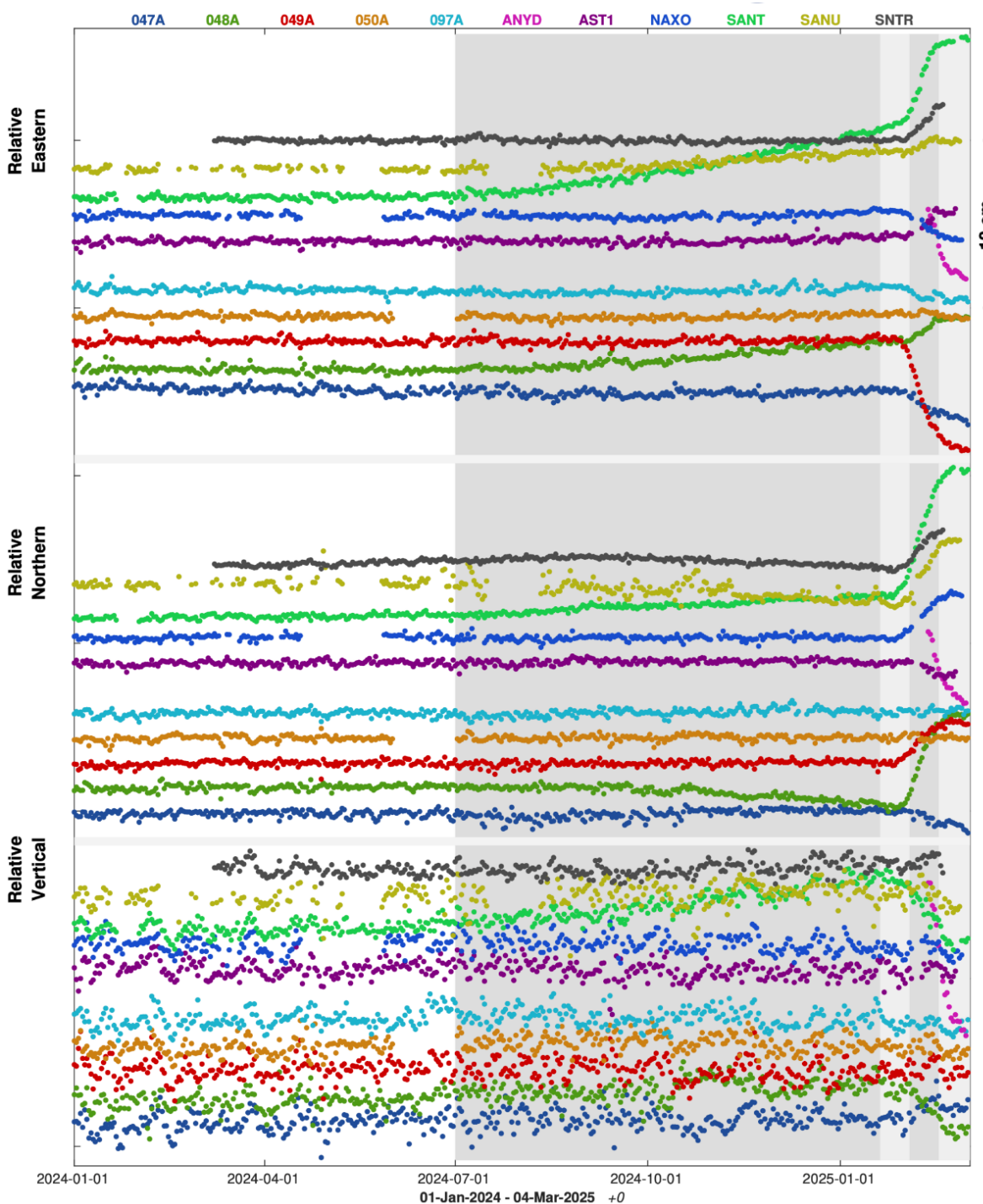
Inflation phase
1 August 2024
20-21 January
2025

Relative Stability
End of January

Deflation &
Motion to NE
2-22 February
2025

Motion continues





GNSS site

HEPOS, METRICA, NOA-UPAT,
URANUS, NTUA

Inflation phase

1 August 2024

20-21 January 2025

Relative Stability

End of January 2025

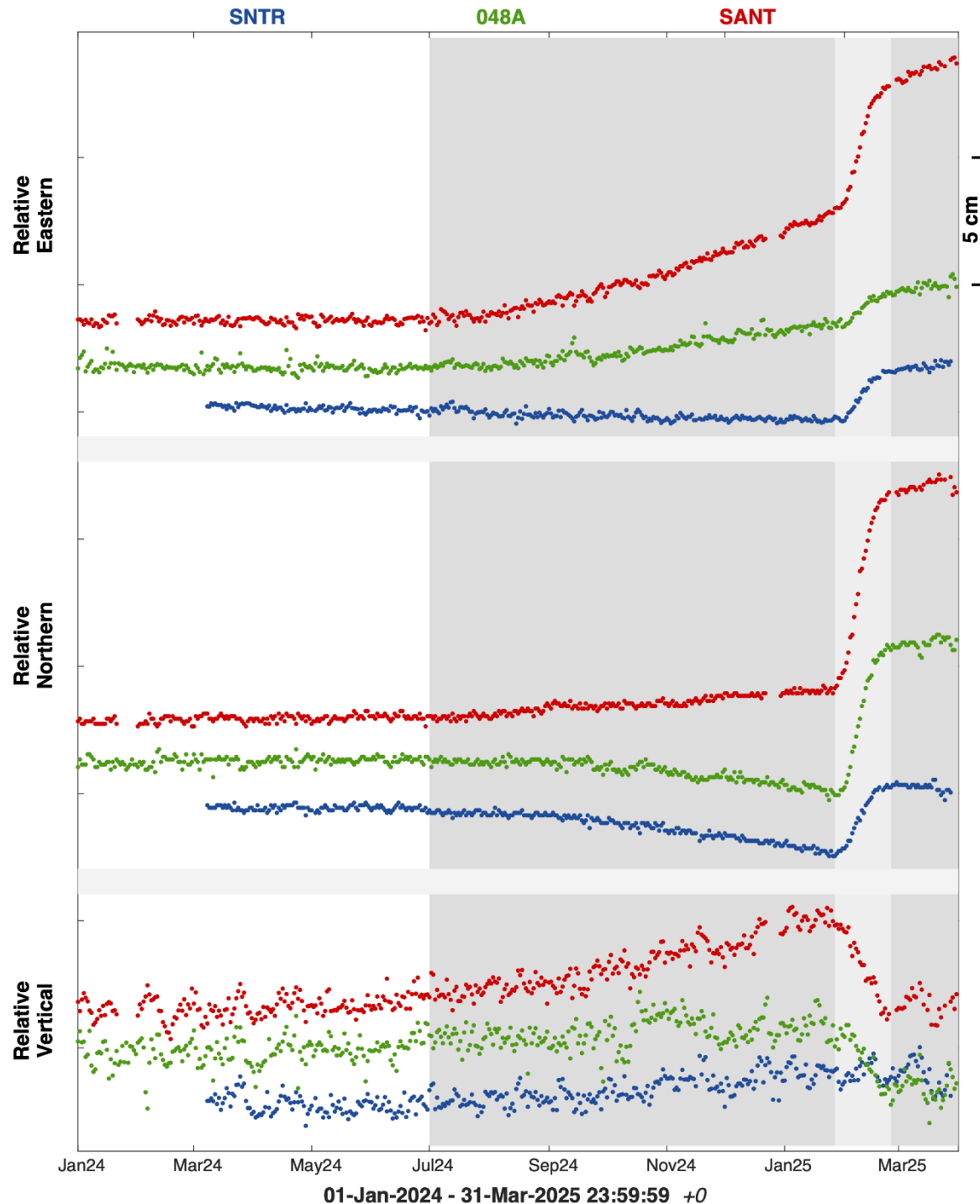
Deflation &

Motion to NE

2-22 February 2025

Brìole, Ganas et al. 2025

<https://doi.org/10.1093/qji/qqaf262>

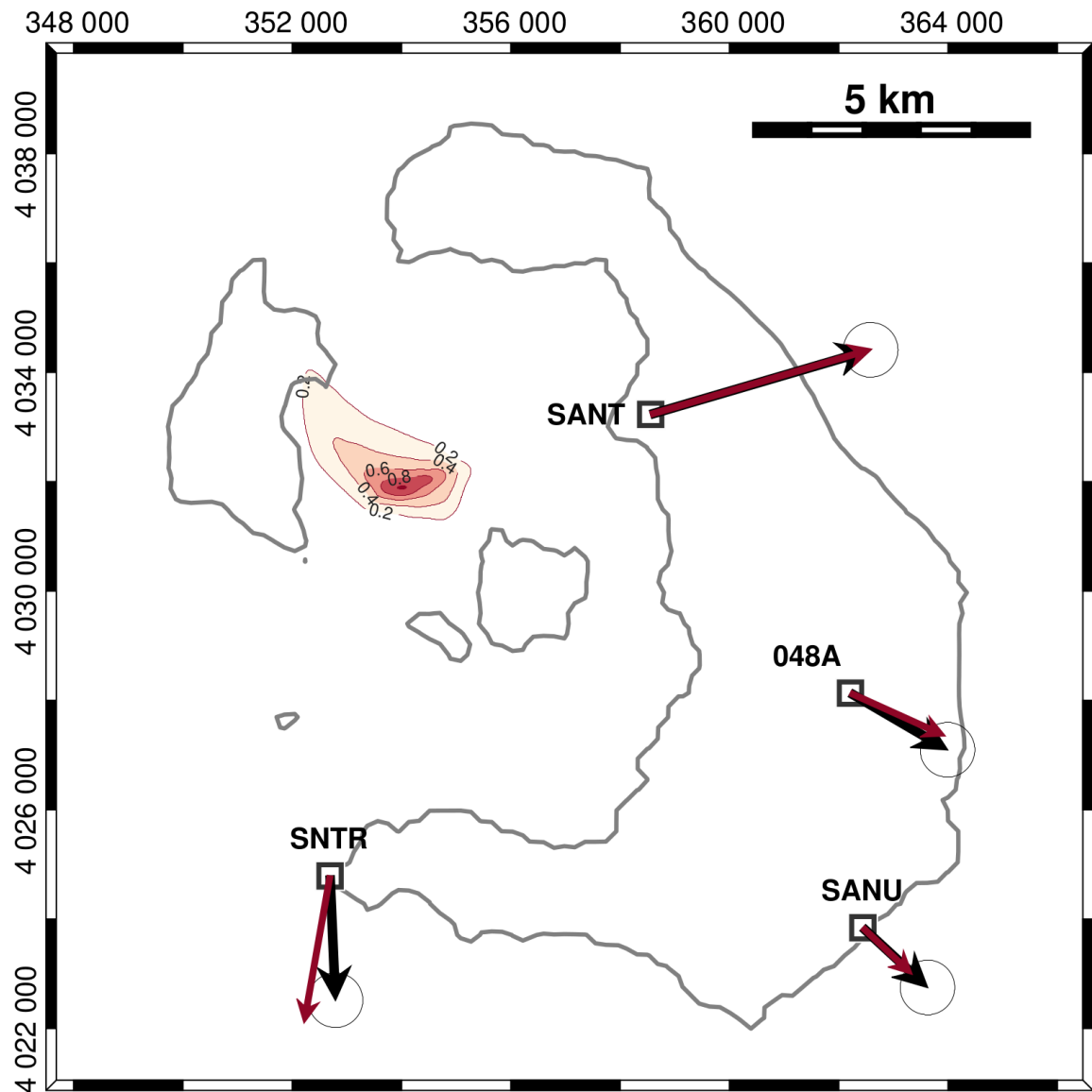


Time-series (East, North, Up) of daily coordinates of the GNSS stations 048A, SANT and SNTR from 2024 January 1 to 2025 May 26 corrected for the tectonic trend (calculated with data before the unrest).

Grey areas indicate phase 1 (dark grey), phase 2 (light grey) and phase 3 (dark grey), respectively.

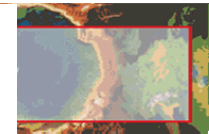
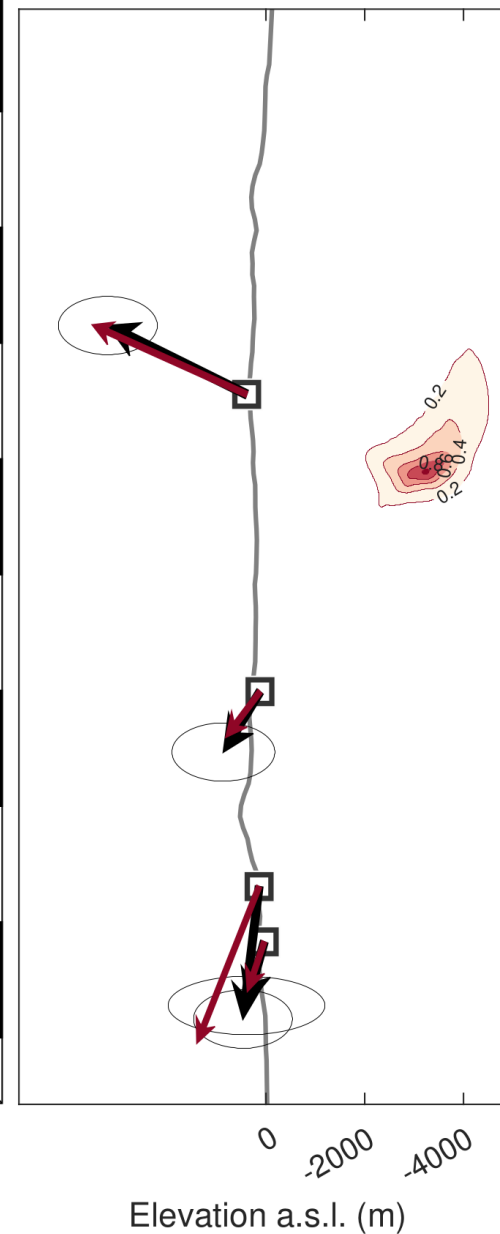
Brìole, Ganas et al. 2025

<https://doi.org/10.1093/qji/qgaf262>

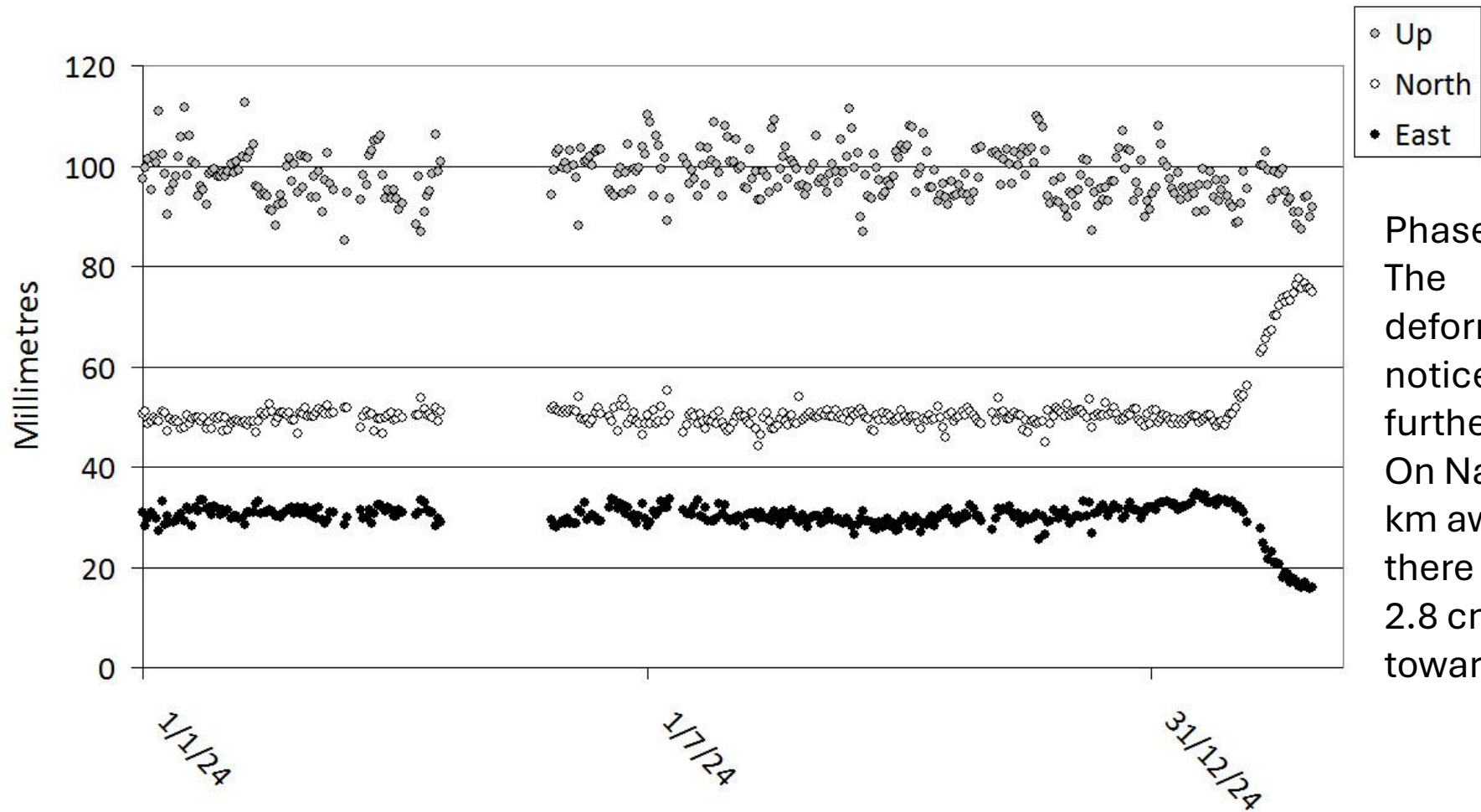


data \longrightarrow 20 mm

best model \longrightarrow

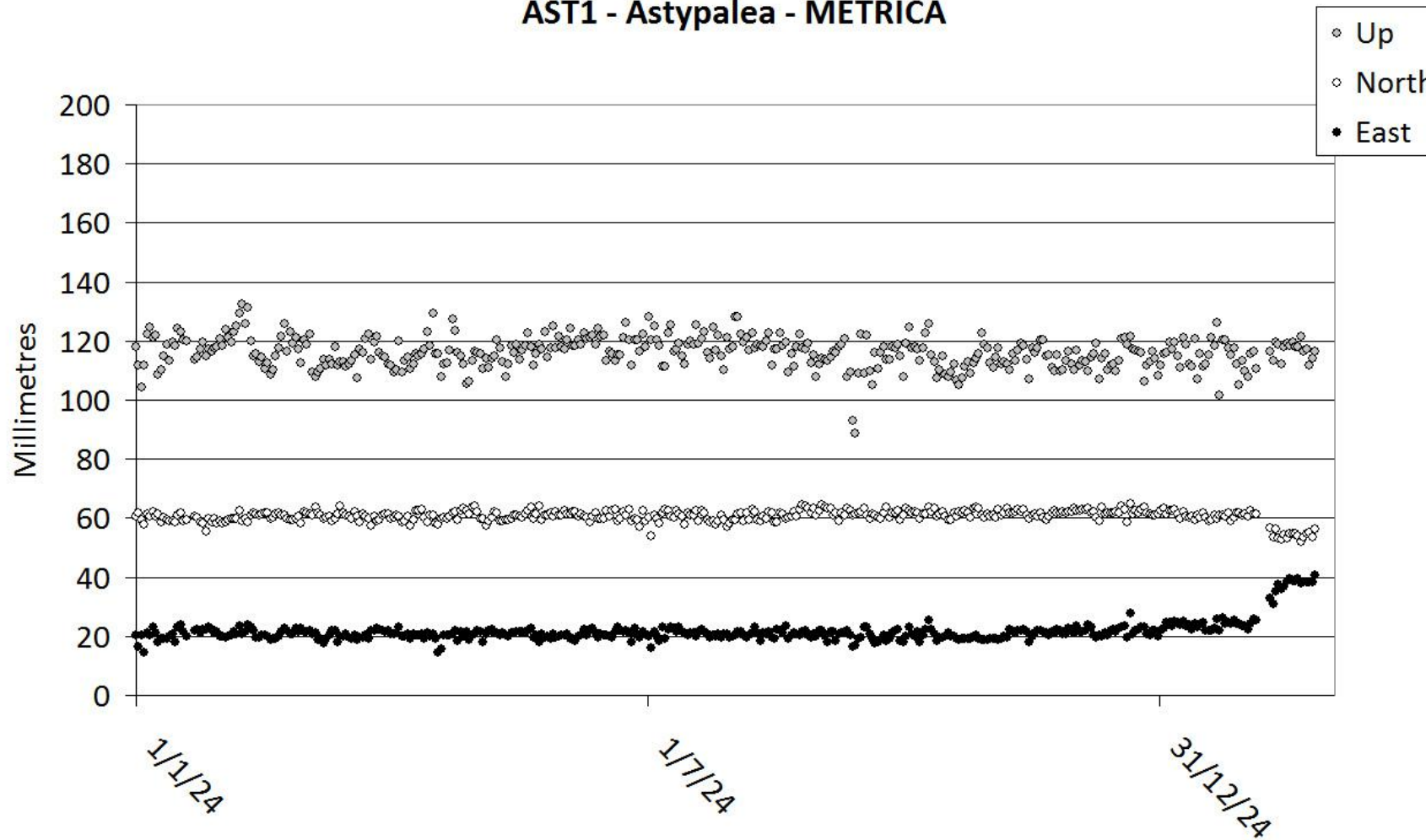


METRICA NAXO Naxos

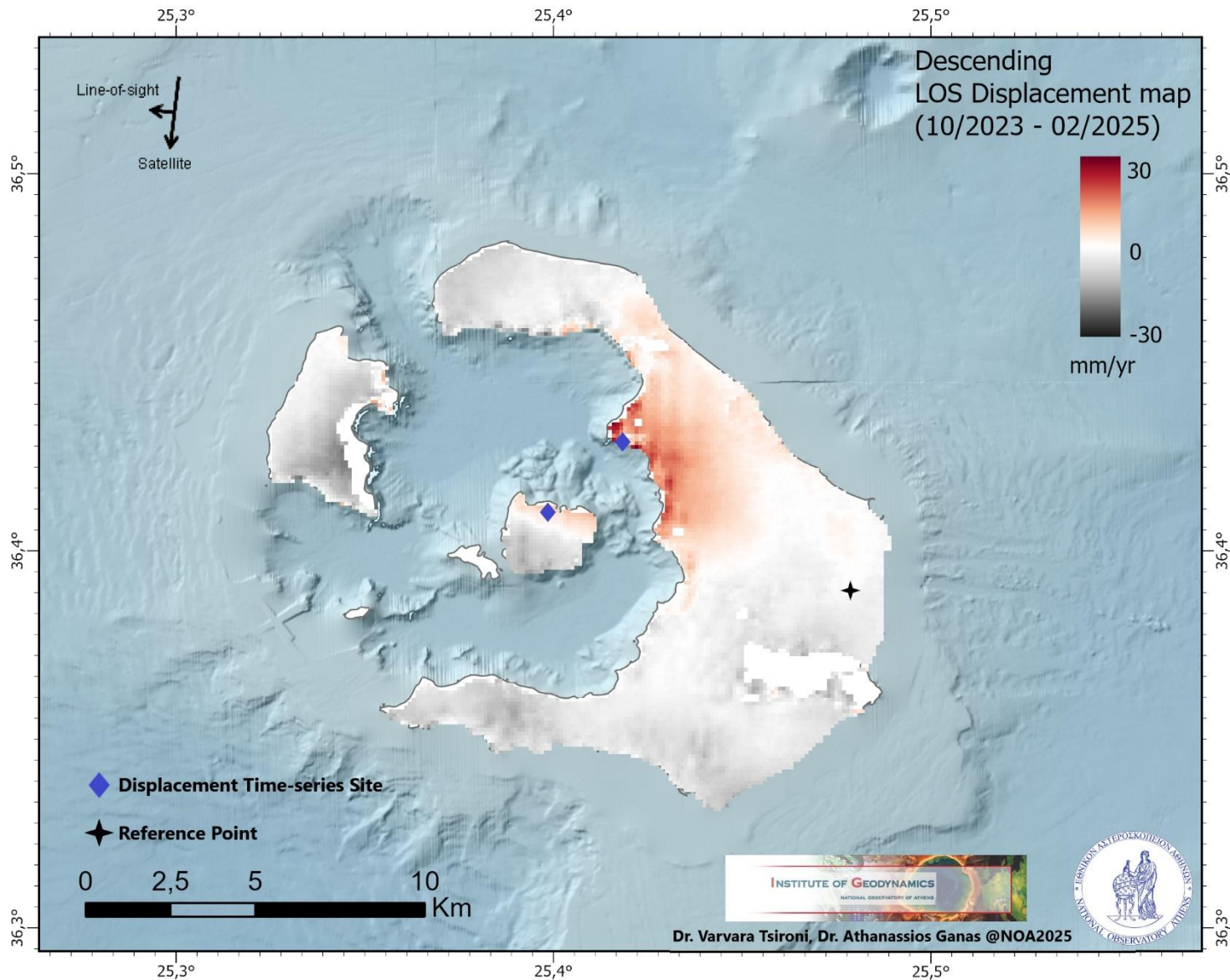


Phase 2
The deformation is noticeable further North. On Naxos (70-km away), there is still 2.8 cm towards NNW.

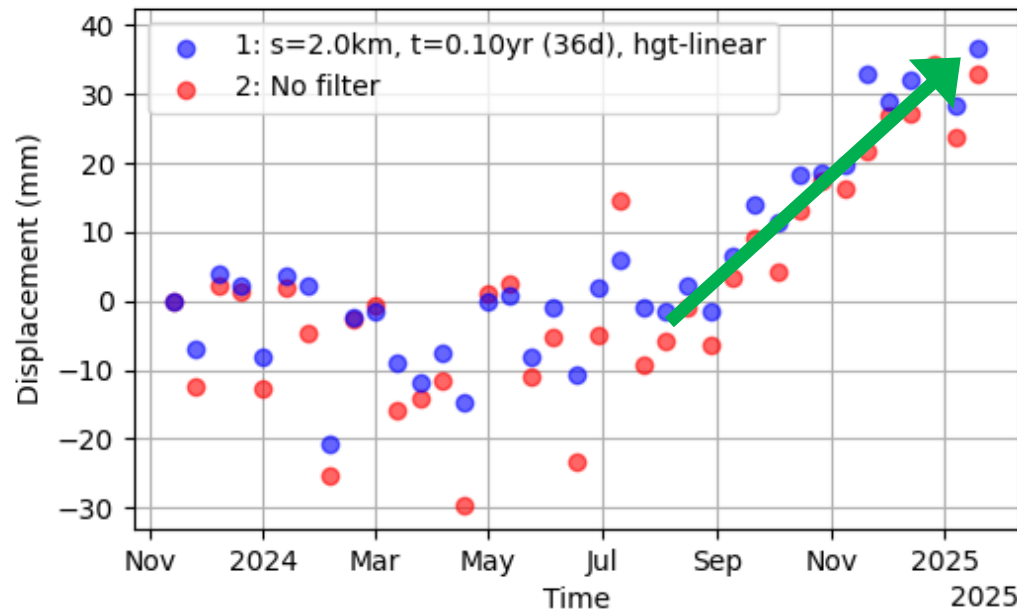
AST1 - Astypalea - METRICA



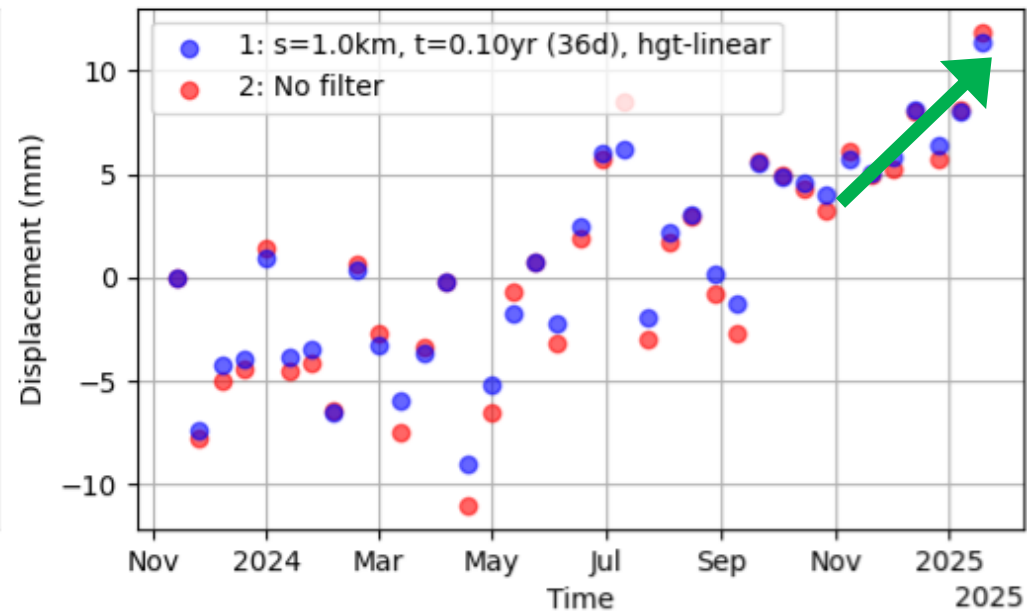
Astypalaia 80
km away
Motion to SE
~2 cm
2-22 February
2025

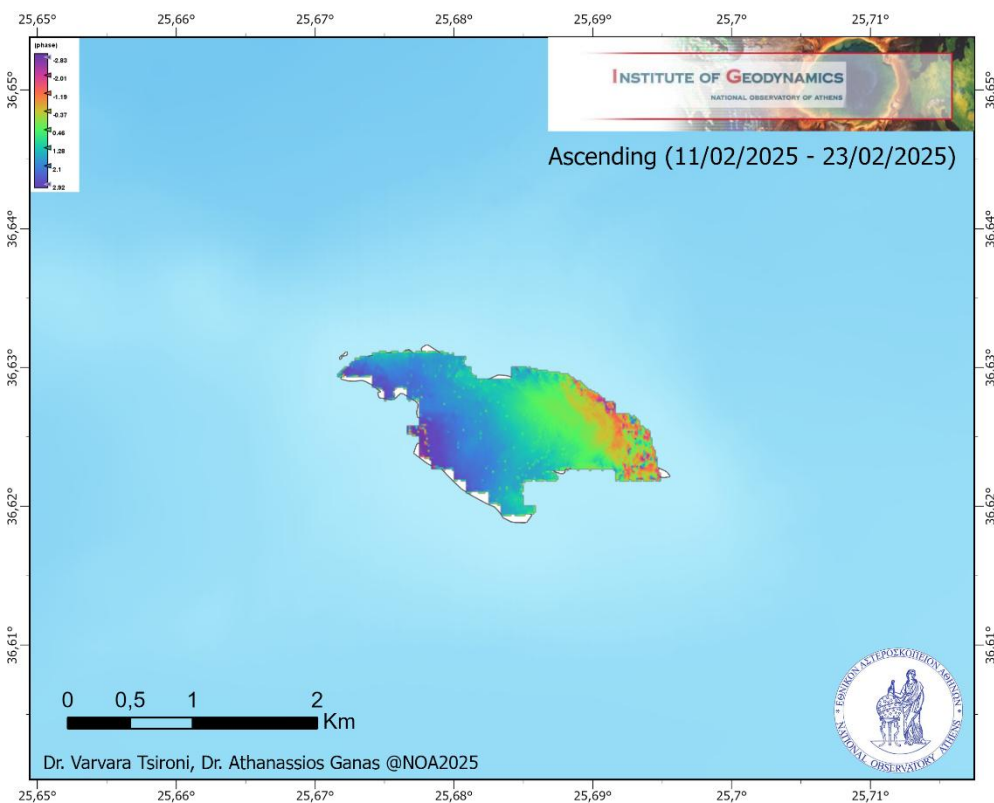
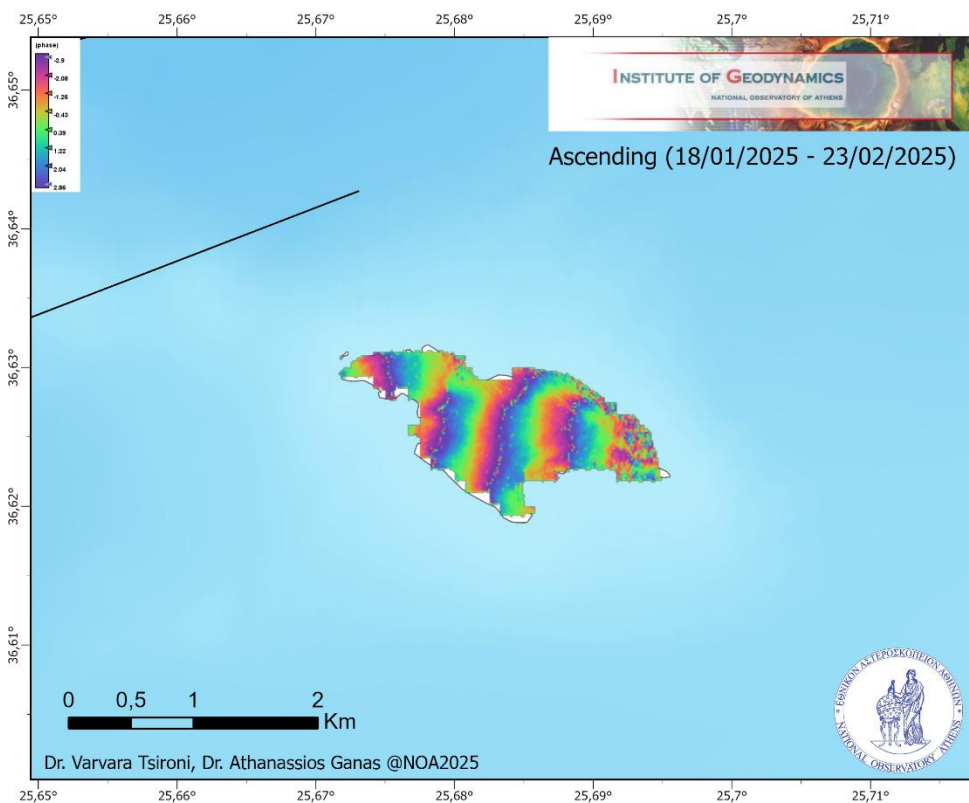


vel(1) = 32.4 mm/yr, vel(2) = 31.2 mm/yr @(204, 117)



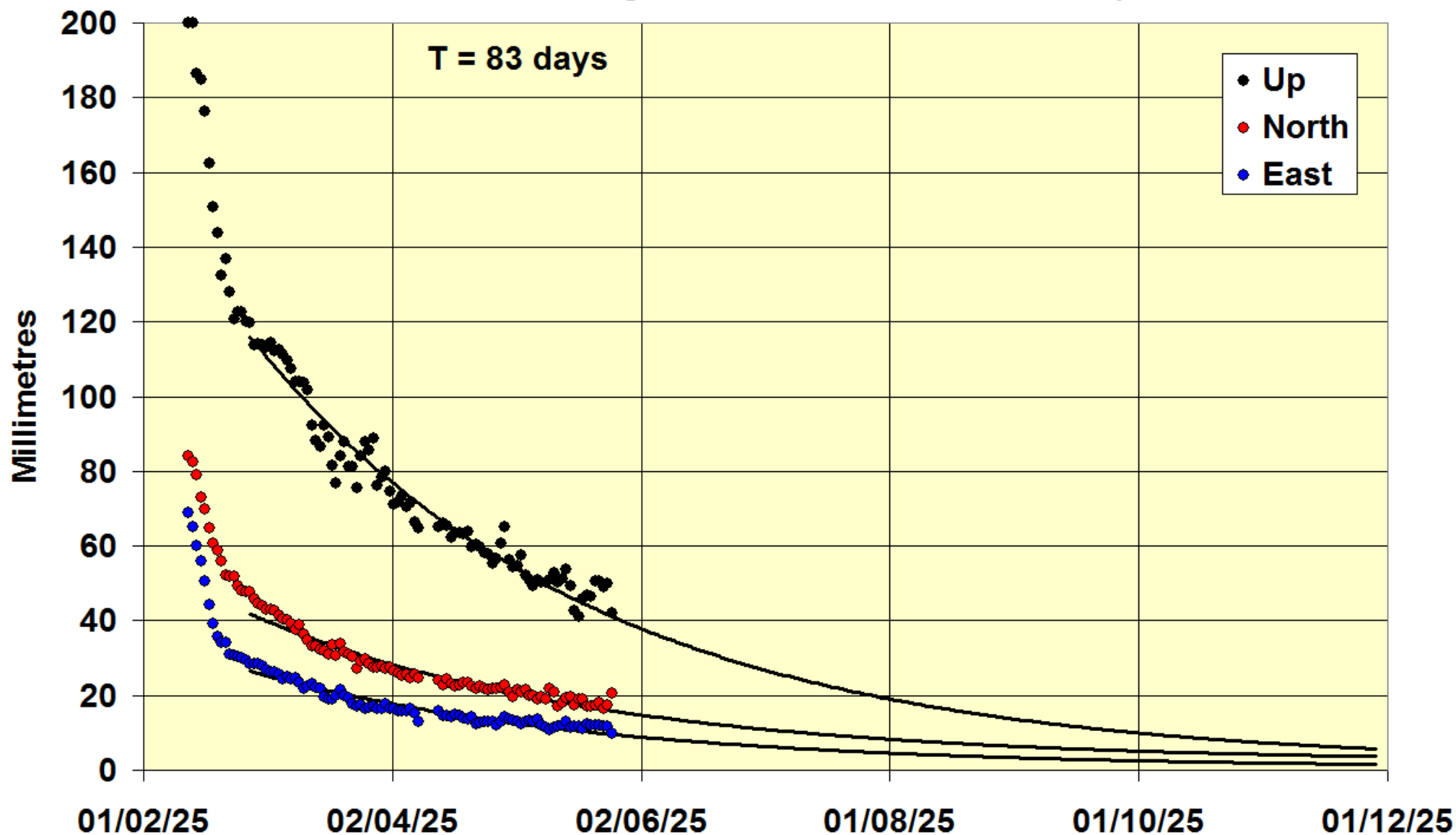
vel(1) = 11.3 mm/yr, vel(2) = 11.4 mm/yr @(31, 16)

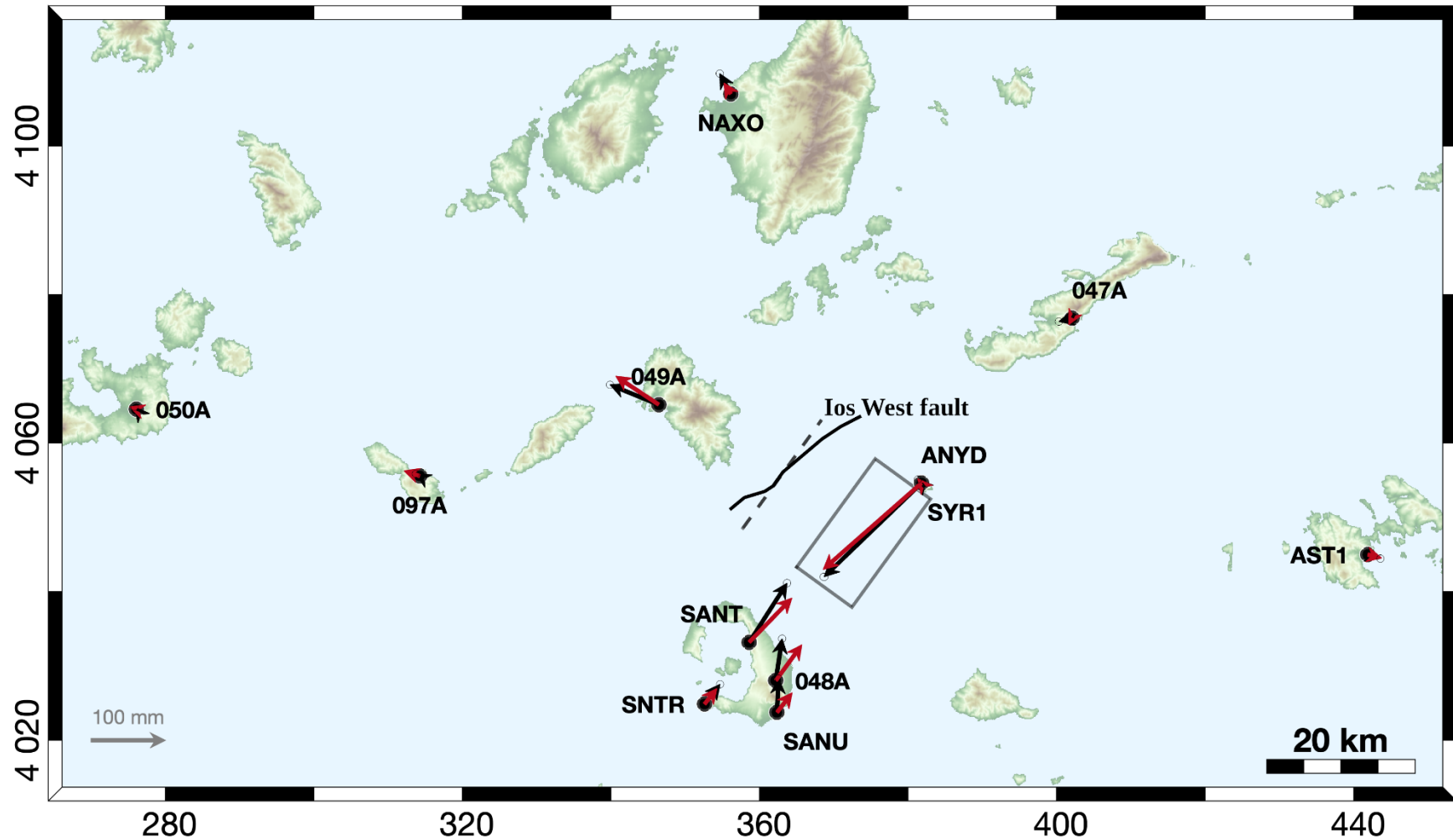




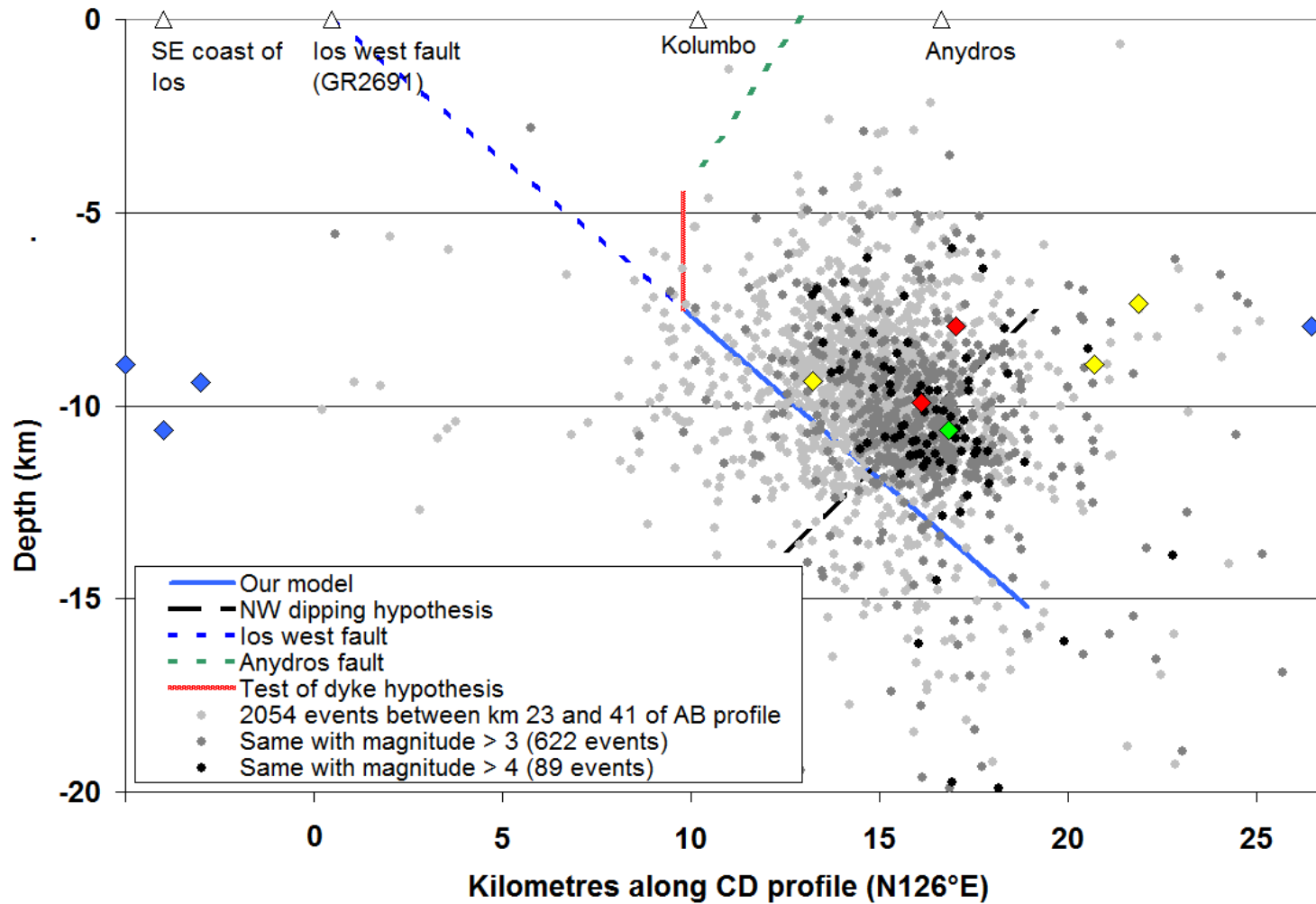
Sentinel-1A InSAR results for Anydros islet
Most of deformation occurred during late January to mid- February 2025

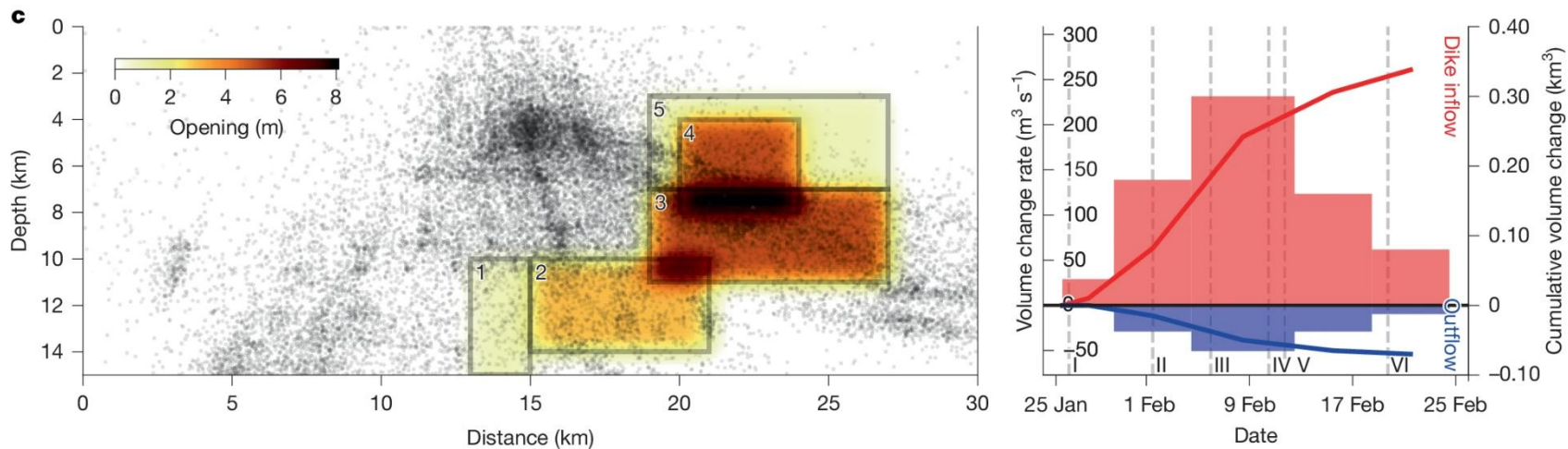
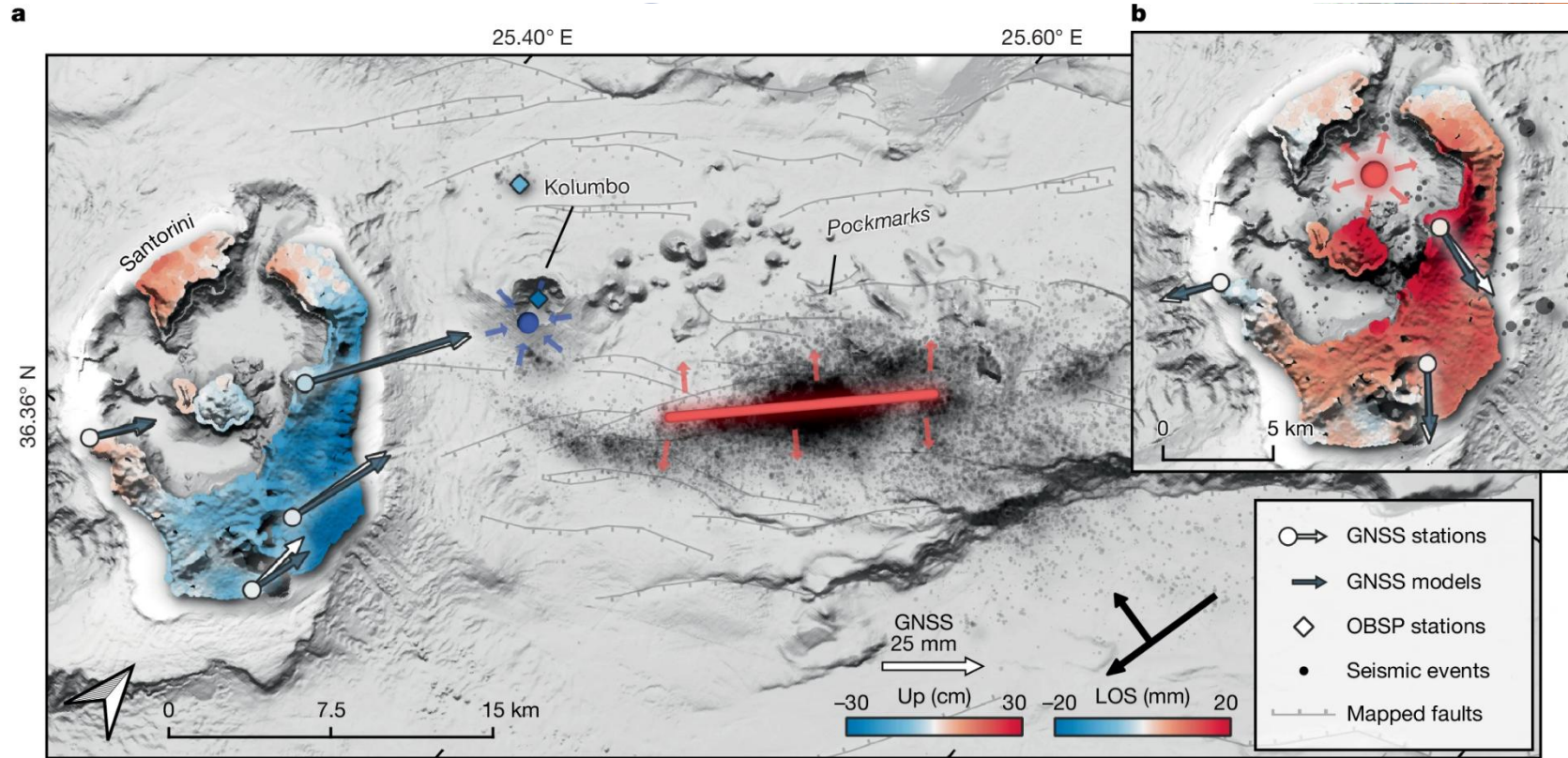
ANYD data : modelling of the relaxation time and amplitude





Aseismic Slip on a SE-dipping normal fault explains the geodetic data





Conclusions

The GNSS data show an inflation of the volcano since August 2024. We model it with a magma source located 3.1 km near the inflation centre of 2011-2012.

After 24 January 2025, the seismic activity, shifted to the north-east of Santorini and increased with eight $M_w \geq 5$ events and ground motion exceeding 3 cm at Naxos

The GNSS data is well fit with a model of dislocation of a south-east dipping fault located between the Kolumbo submarine volcano and the Anydros islet, 18 km long, 12 km wide, with a tip at 7.5 km depth and ~ 3 m of normal **slow-slip**.

The model is consistent with the seismological and tectonic data.

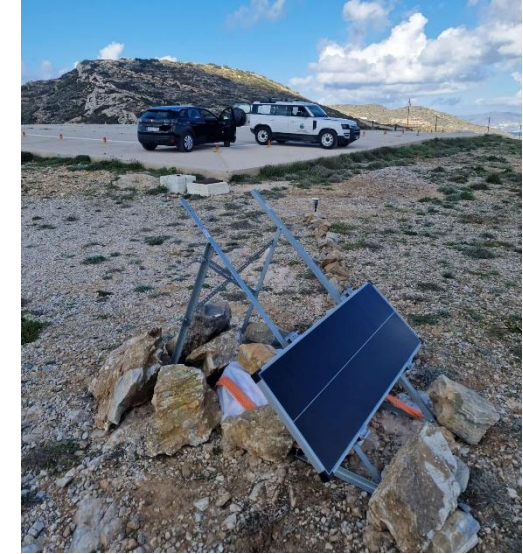
The crisis might have been triggered by a small dyke injected laterally from the source inferred beneath Santorini, however the geodetic data does not support the hypothesis of a magmatic source being the primary responsible of the recorded deformation.



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Thanks, Merci, Ευχαριστώ!

