The 2025-2026 Eruption of Krasheninnikov Volcano, Kamchatka: Constraints from Satellite InSAR, Thermal, and Topography Observations

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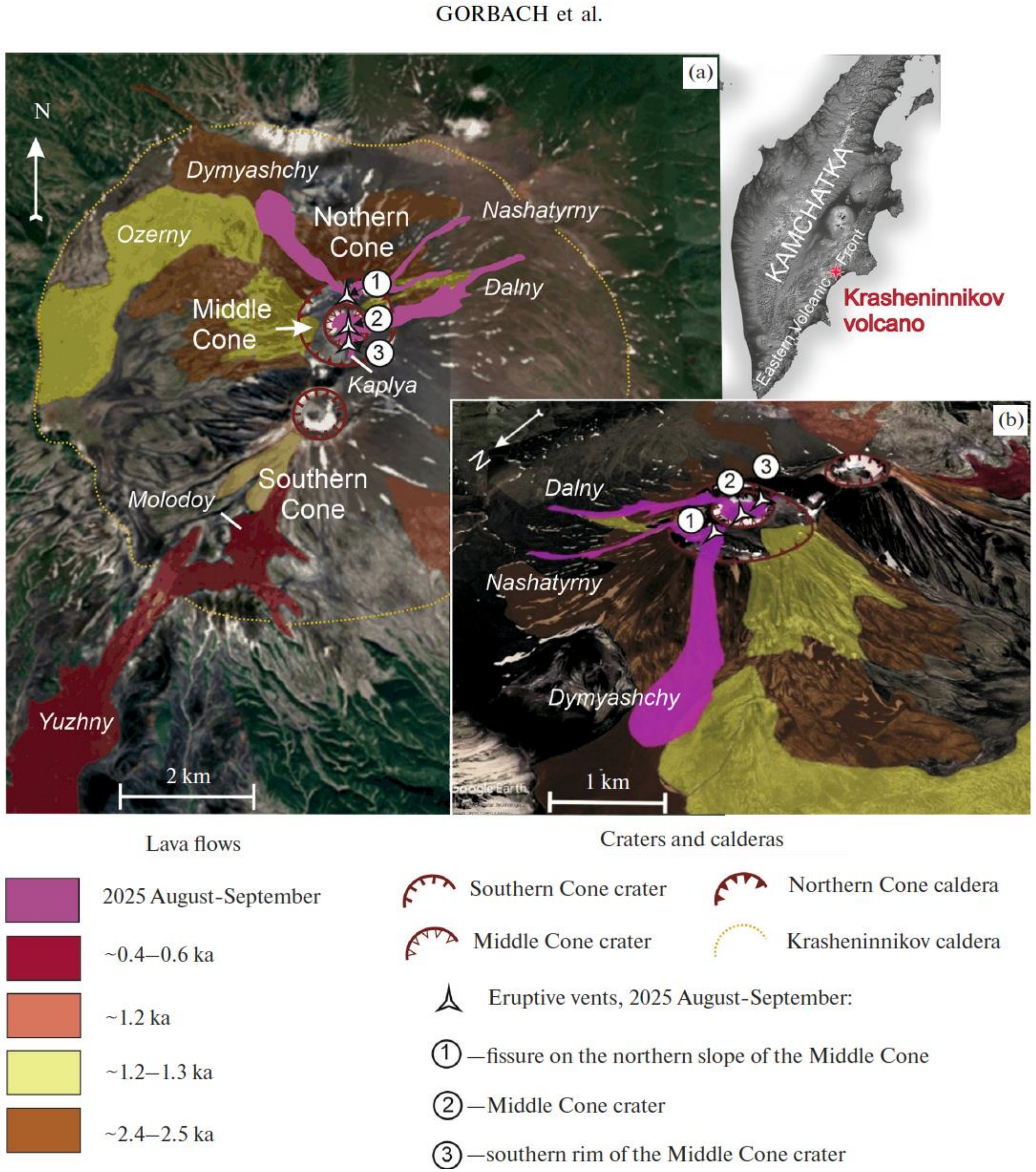
Motivation

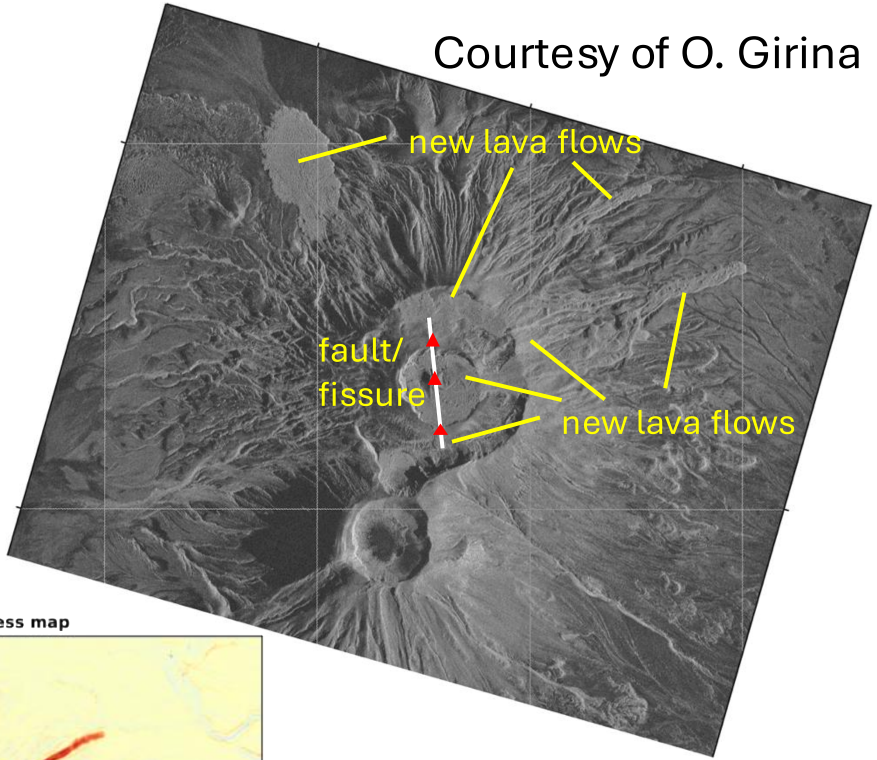
- Krasheninnikov ongoing eruption started ~16:38 UTC (Aug. 2), ~3 ½ days following the 2025, Mw 8.8, Kamchatka earthquake at 23:24 UTC (July 29), after more than 400 years of quiescence. *Was the eruption triggered by the earthquake?*
  - We will show through InSAR and thermal time series there was no precursory (years to decade timescales) signs of impending unrest.
- Kinematic source modeling (dikes) shows a sequence of shallow upper crust-NW flank dike intrusion (arrested) followed by the summit eruption (~1 day later). *Was the dike orientation related to the coseismic stress change? What can the dike orientations and sequence tell us about the diking process?*
  - We will show that the coseismic stress (~0.1 MPa) is likely too small, depending on the competing edifice, reservoir overpressure, and tectonic stresses.
  - The orientation and distribution of opening suggests upward propagation in a closed system.
- No source deflation was detected. What are the source depth and volume change detection limits?
  - We will show that sources deeper than ~4-8 km would be difficult to detect depending on volume change (dV), atmospheric noise, and values of magma compressibility.

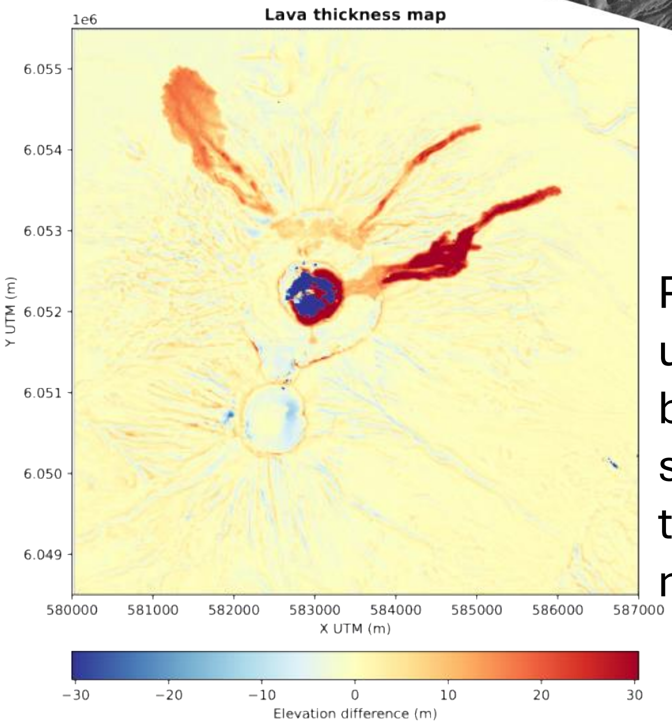
Krasheninnikov eruption (ongoing)



From Gorbach et al., *J. Volcan. Seis.*, 2026

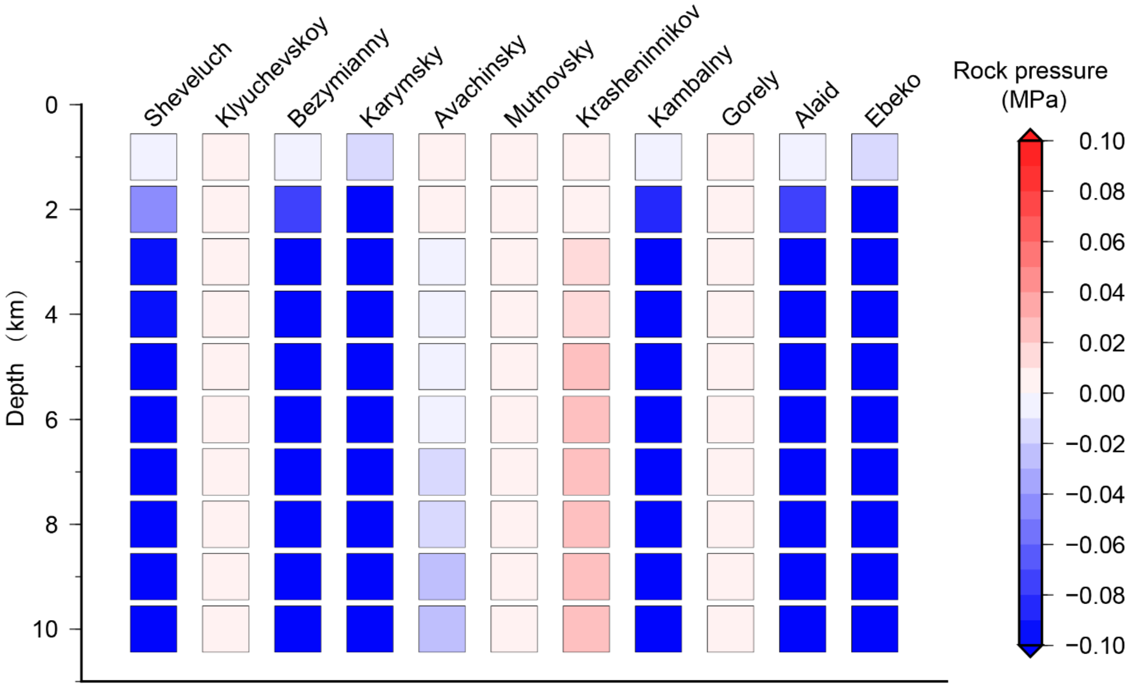
Courtesy of O. Girina

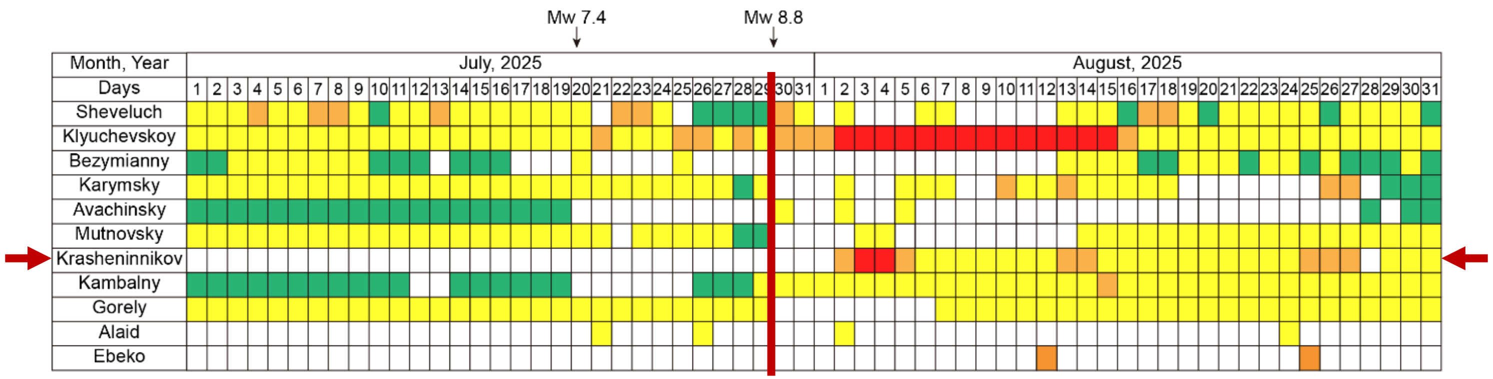




Preliminary DEM differencing using Pleiades optical data by Arthur Hauck (IPGP, Paris) shows the primary flows and the filled Middle crater of the northern cone's summit.

Mw 8.8 earthquake slip model by Liu et al., Science, 2026.





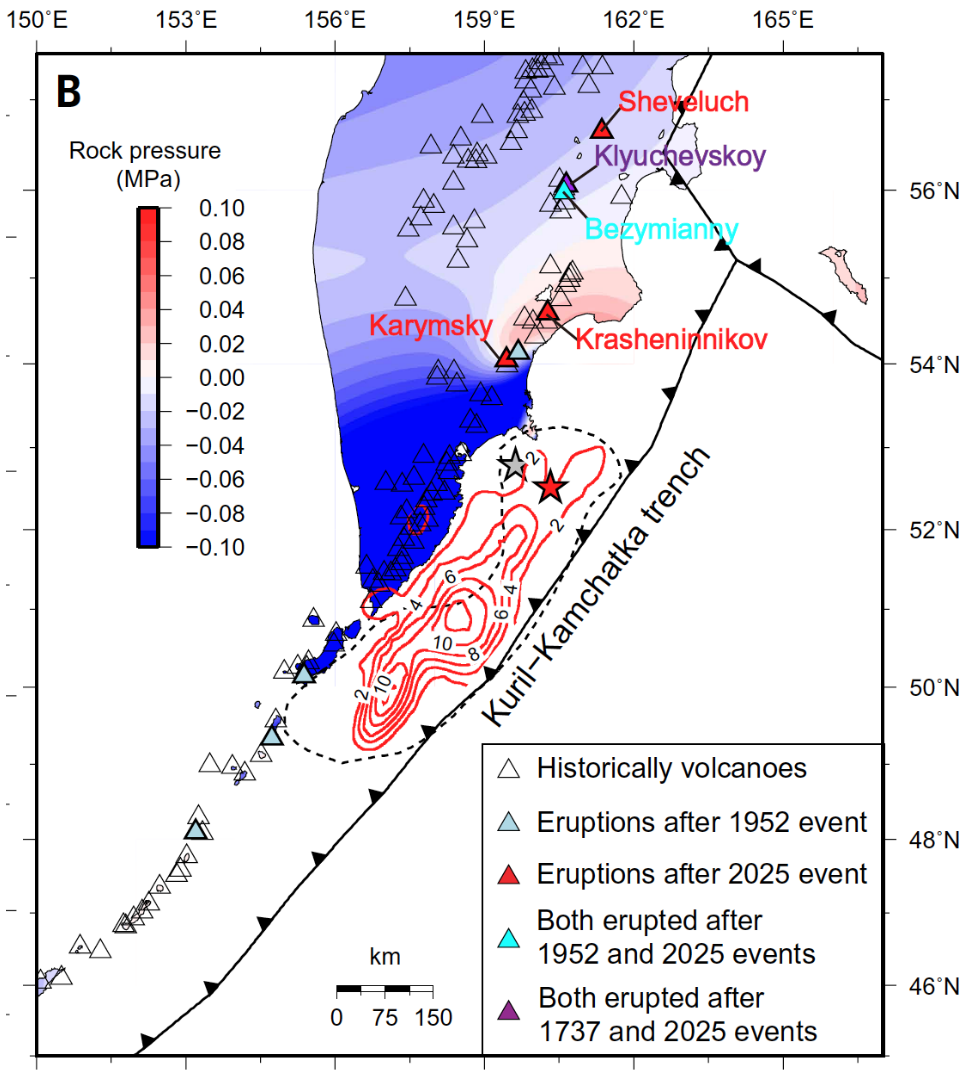
Information from Monitoring of volcanic activity Factual database (https://www.emsd.ru/~ssl/monitoring/main.htm)

Green - Volcano in calm state. Seismicity - not higher than background, volcano - calm or fumarole activity, thermal anomalies - none.

Yellow - Weak local earthquakes, increased level of volcanic gas emissions. Seismicity is higher than background, the presence of ash in emissions, the presence of thermal anomalies.

Orange - Large the number of local earthquakes, lava flows, the height of ash emissions up to 8 km above sea level.

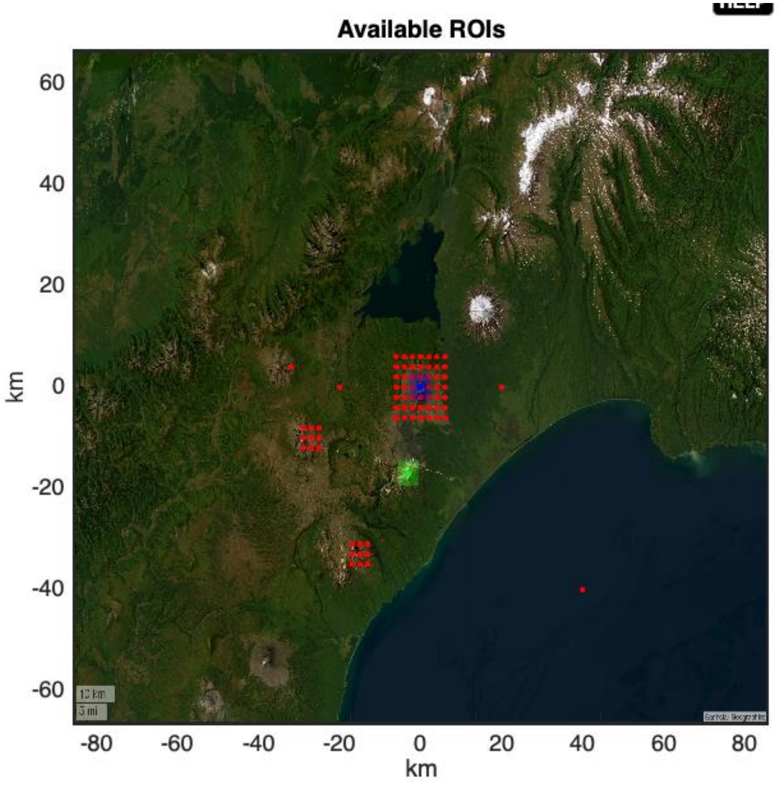
Red - Strong earthquakes are recorded at remote stations, the height of ash emissions is more than 8 km above sea level.

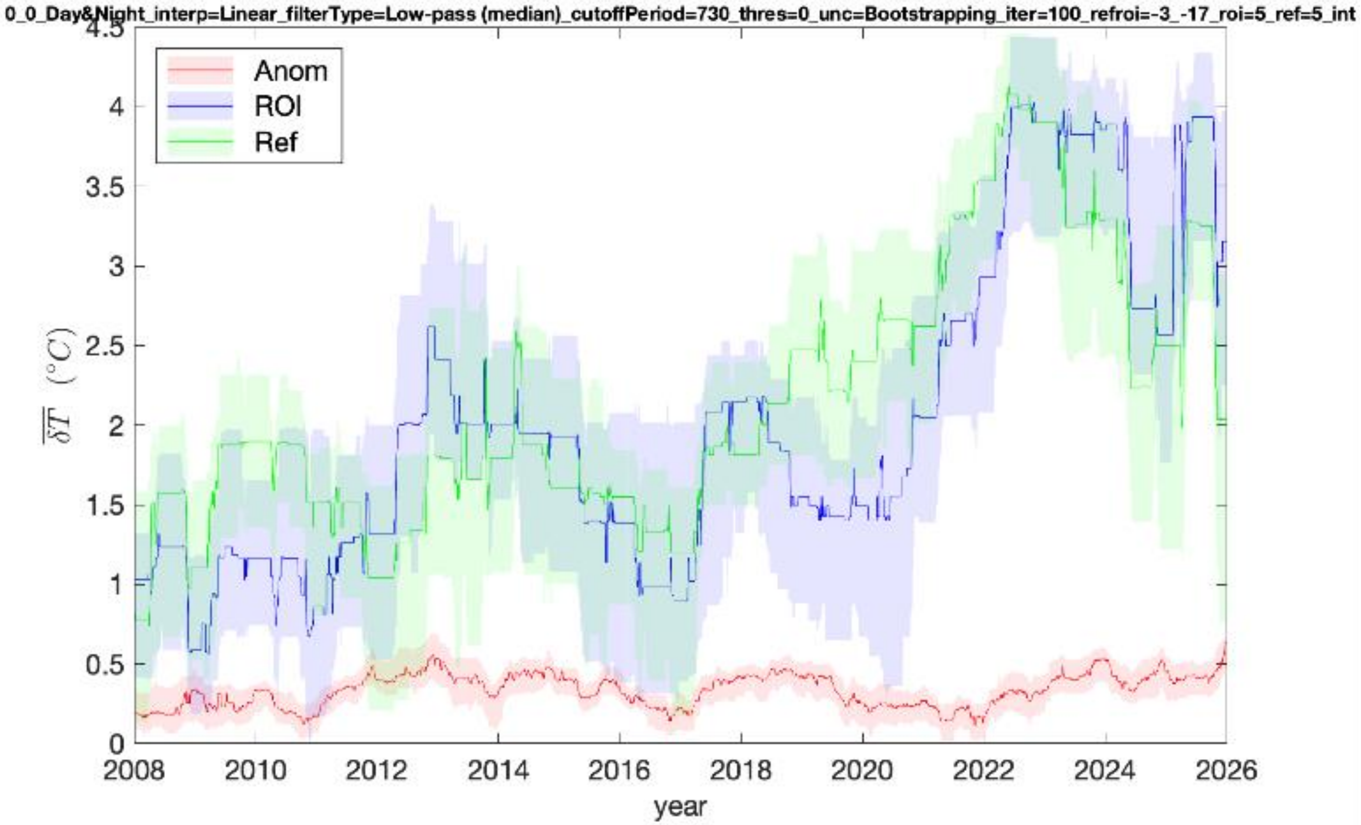


From Liu et al., *Science*, 2026

Was the eruption triggered by the earthquake?

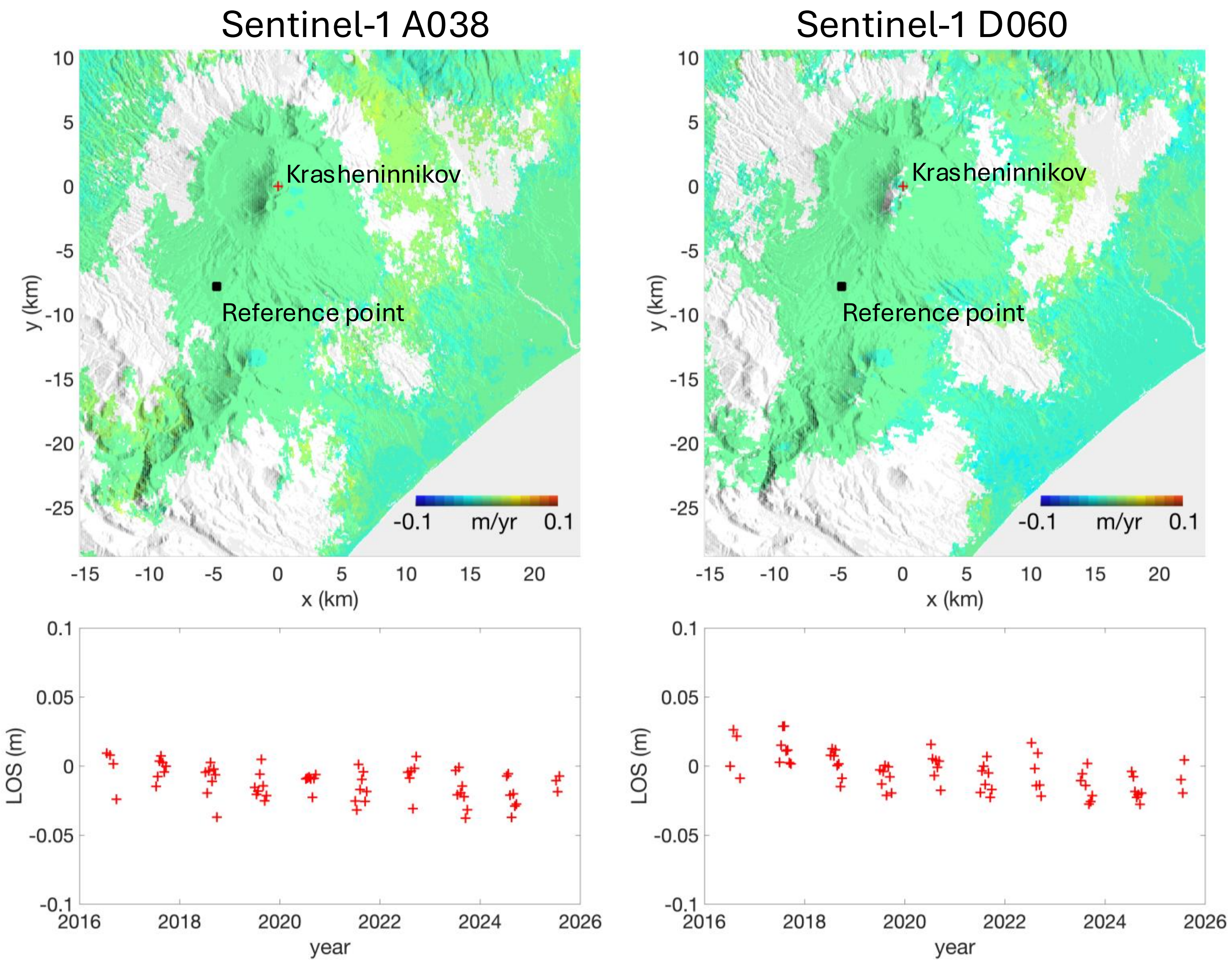
Thermal anomaly time series using the SSTAR software (Girona et al., 2021; Girona and Brenot, *in review*) applied to NASA MODIS observations show no thermal anomaly at Krasheninnikov volcano (blue) vs nearby volcanoes of similar height (Kikhpinych, green)





Was the eruption triggered by the earthquake?

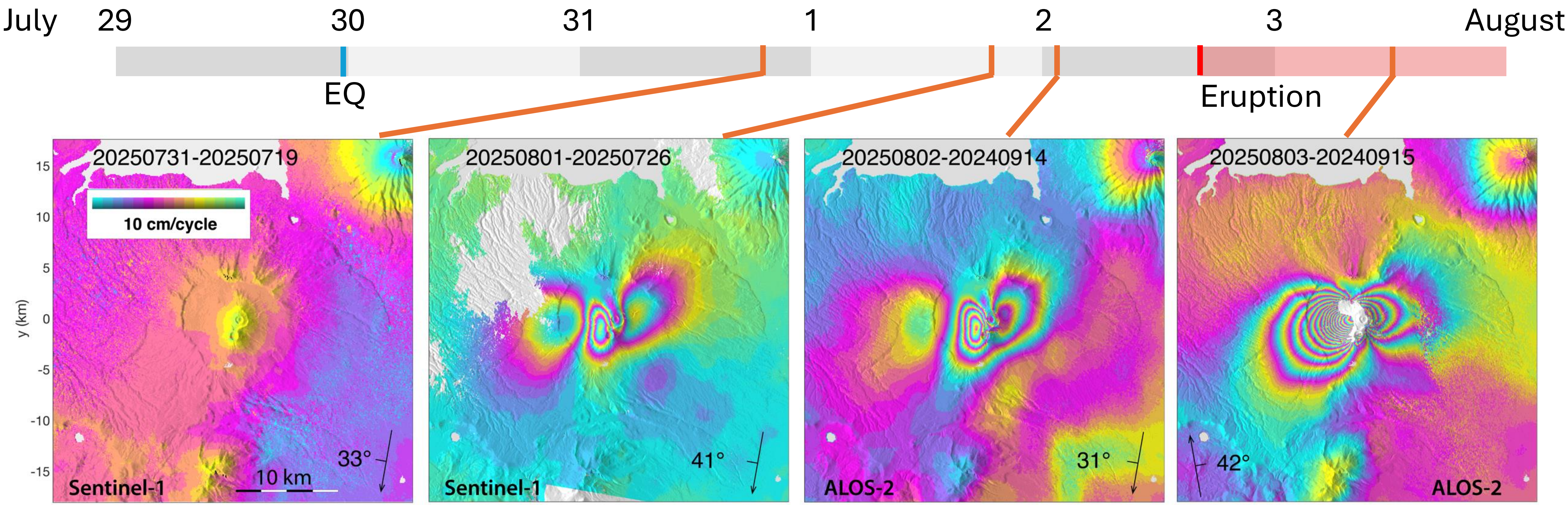
InSAR time series (2016-2026) show no significant deformation prior to eruption



What can the orientation and sequence tell us about the dike process?

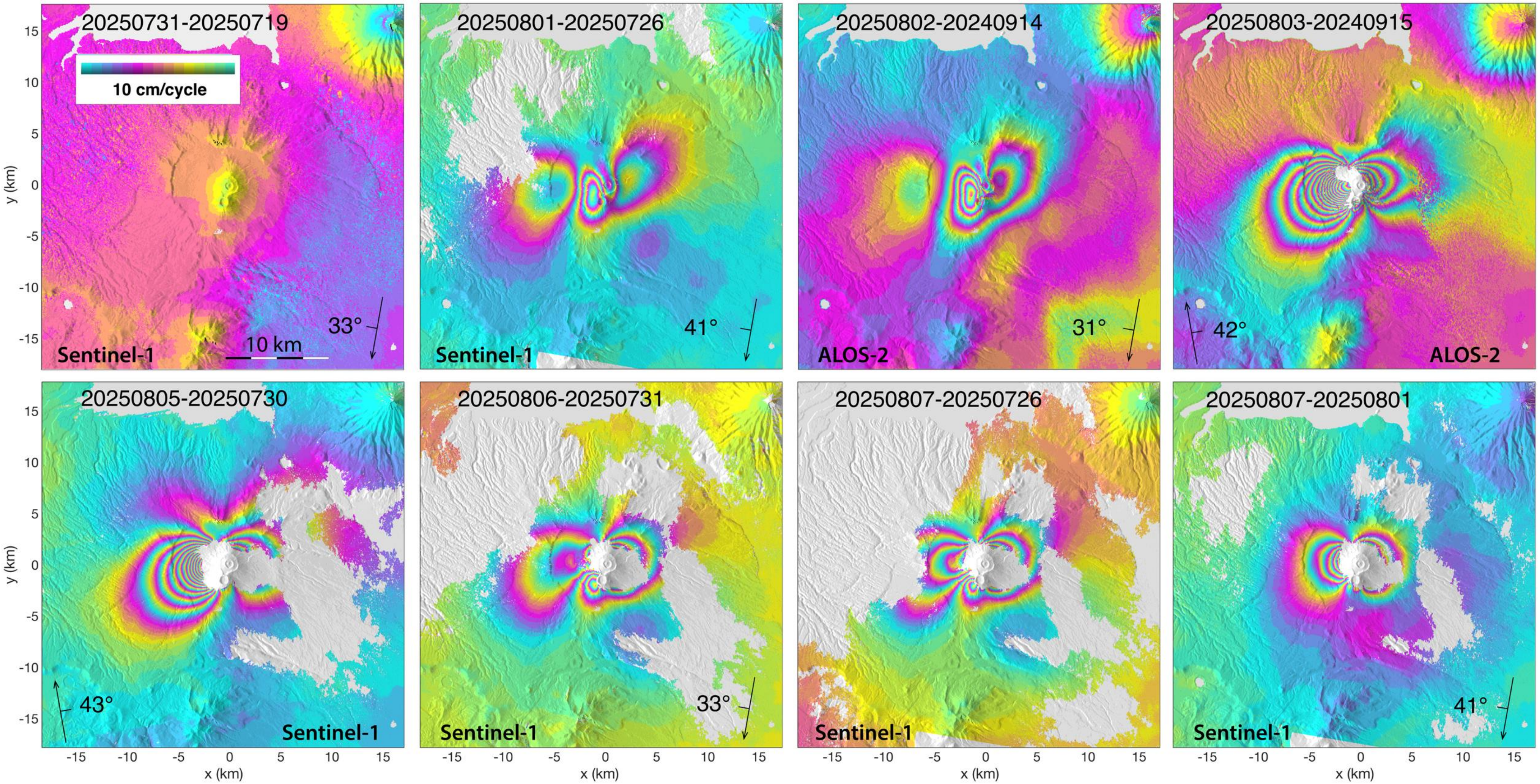
InSAR observations

SAR interferograms (July 30, 31) show no detectable deformation until Aug. 1 (19:32), < 2 days following the earthquake.



What can the orientation and sequence tell us about the dike process?

Pre- and co-eruptive interferograms

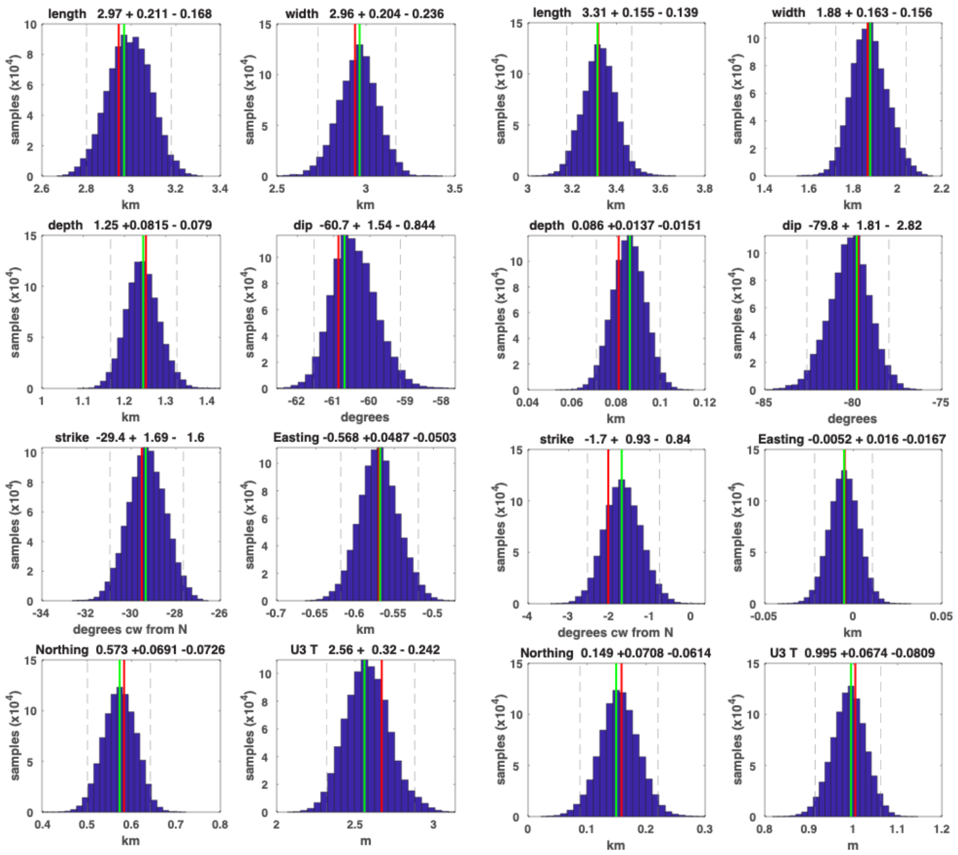


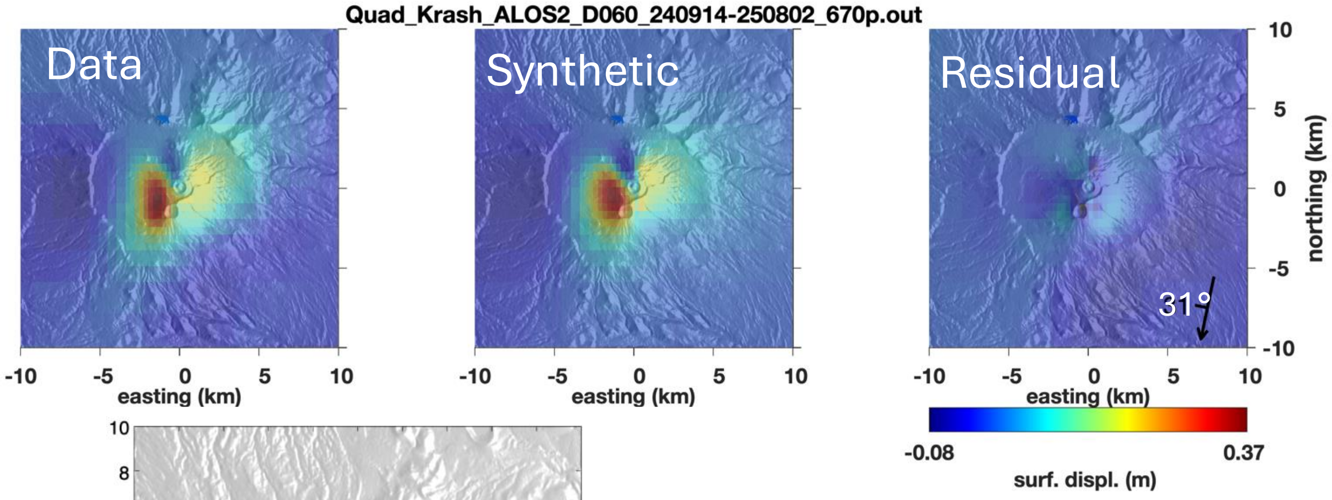
What can the orientation and sequence tell us about the dike process?

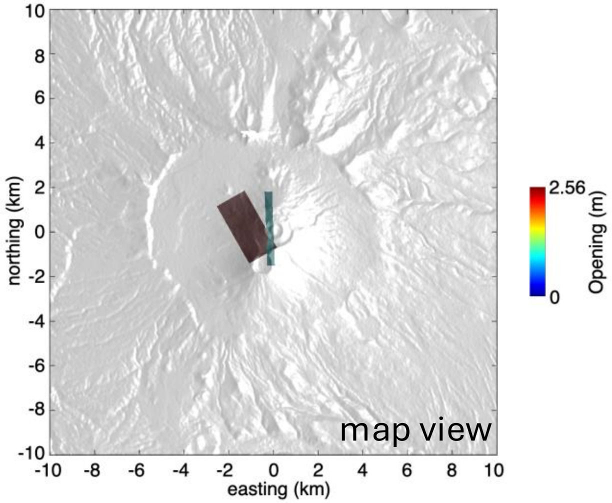
Source Modeling

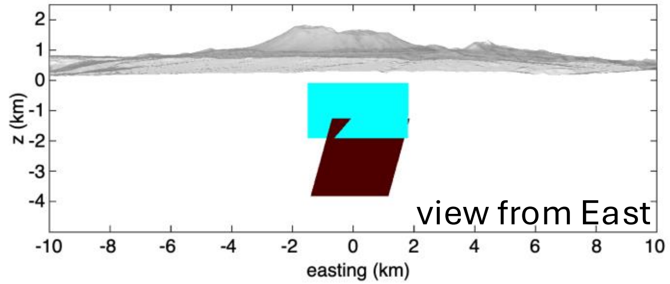
Bayesian inference tensile dislocation 2-source model Aug 2, ALOS-2 D010 path

Dike 1 (NW flank) Dike 2 (summit craters)



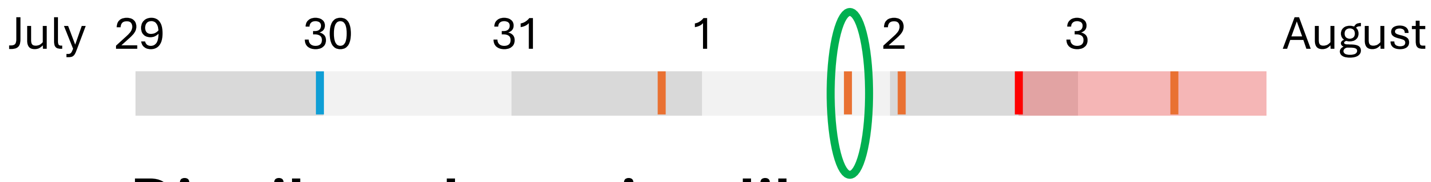




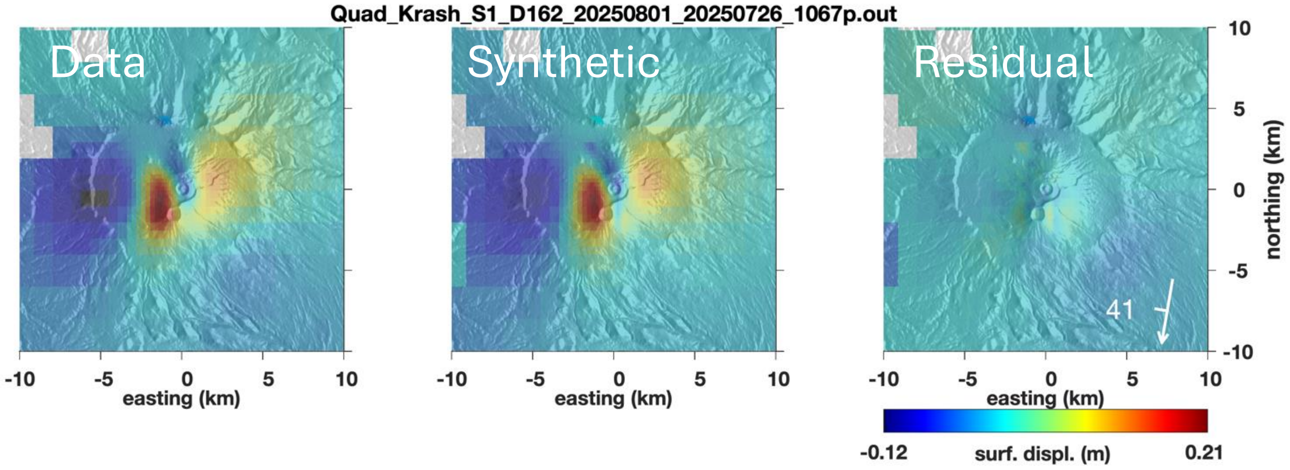


The geometry of these two dikes used for the finite dike models for all dates.

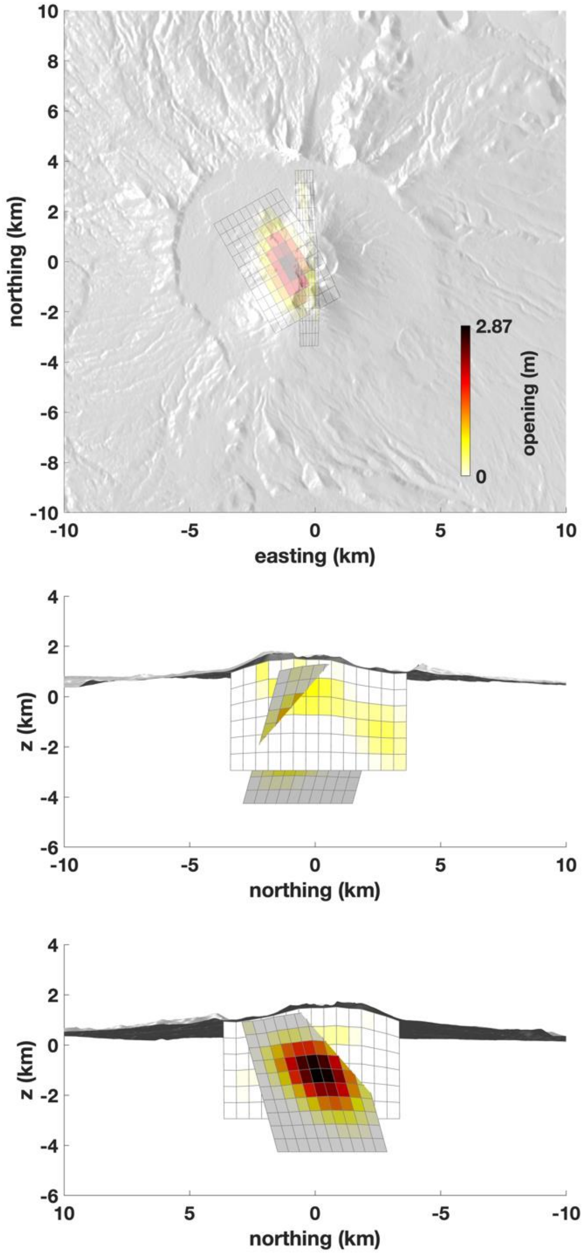
What can the orientation and sequence tell us about the dike process?



Distributed opening dike model: August 1, 2025

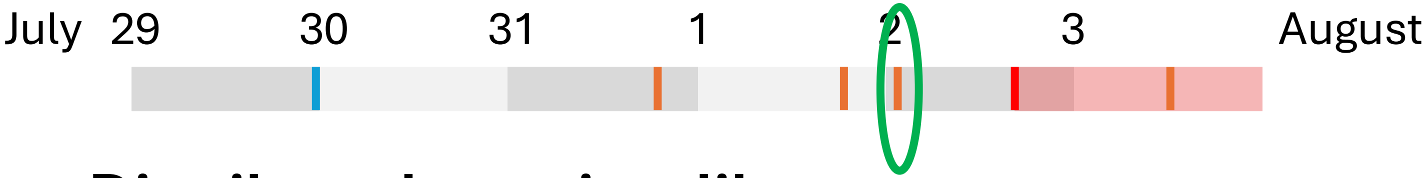


Data acquired ~19:32 UTC
Eruption started ~16:38 UTC (Aug. 2)

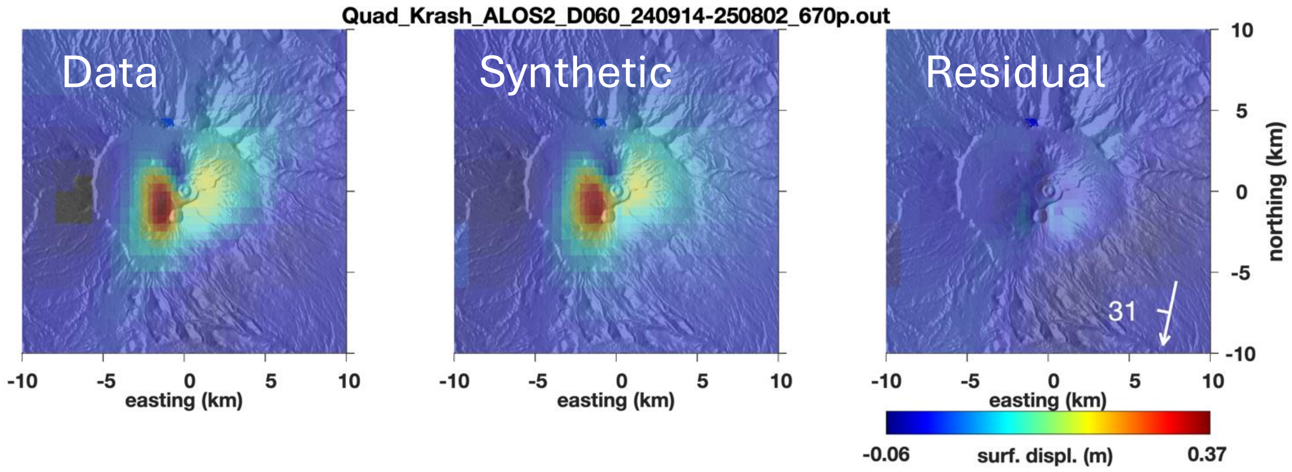


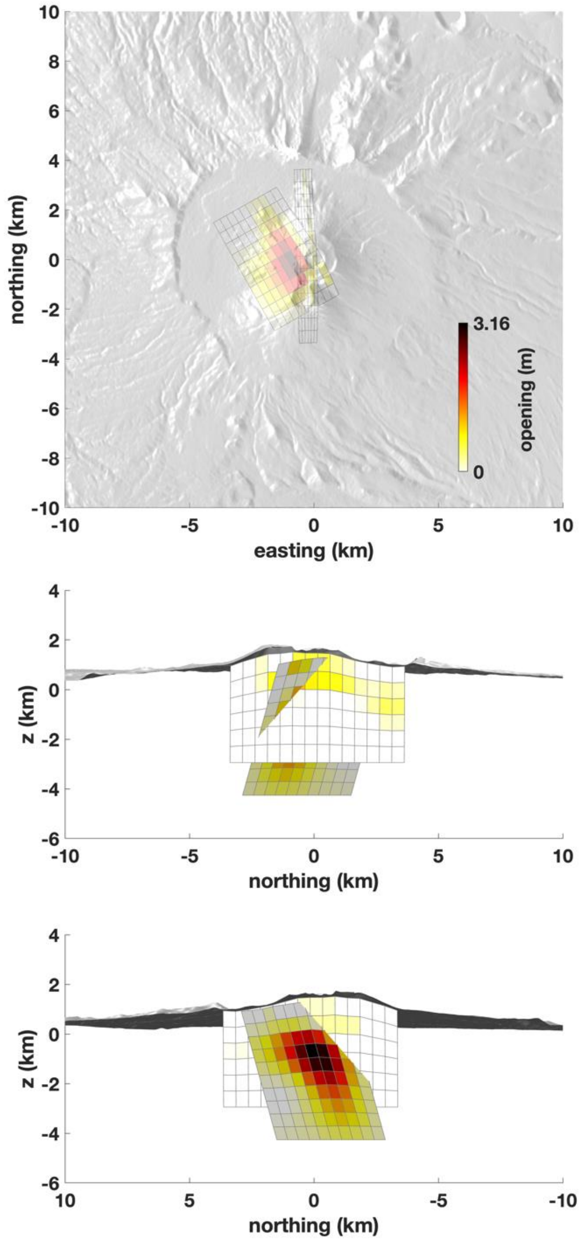
Using Poly3d BEM code (Thomas, 1993)

What can the orientation and sequence tell us about the dike process?



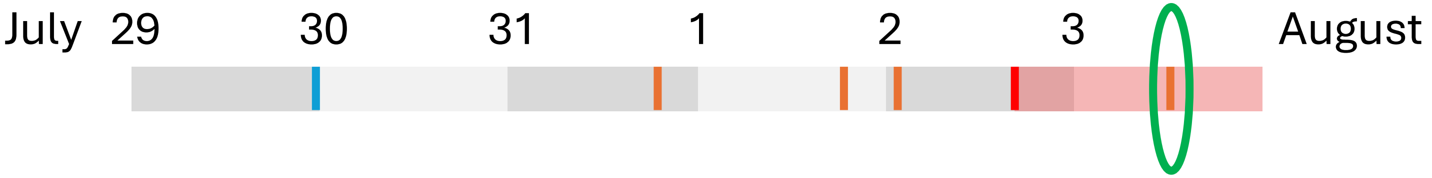
Distributed opening dike model: August 2, 2025



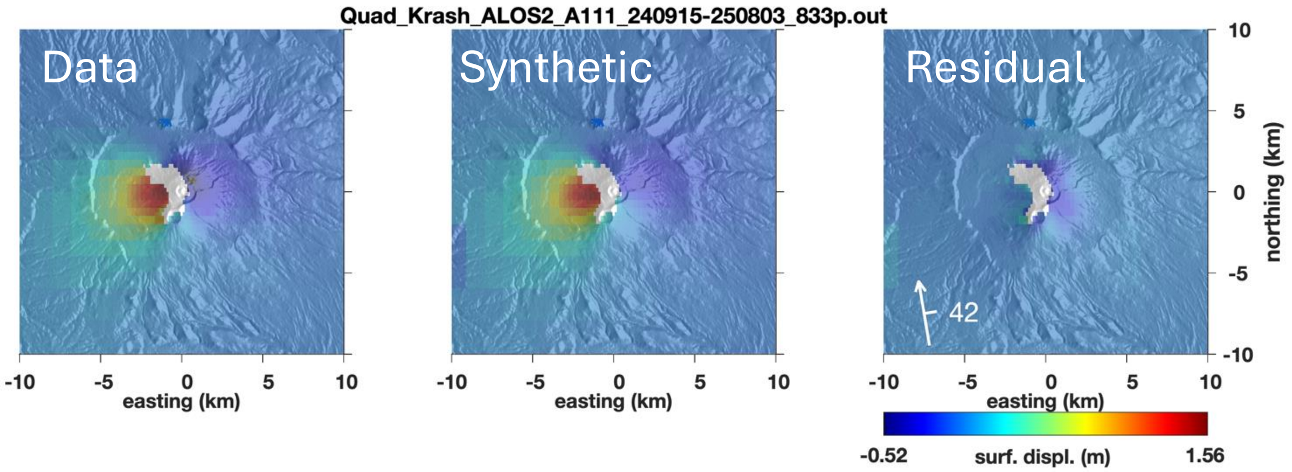


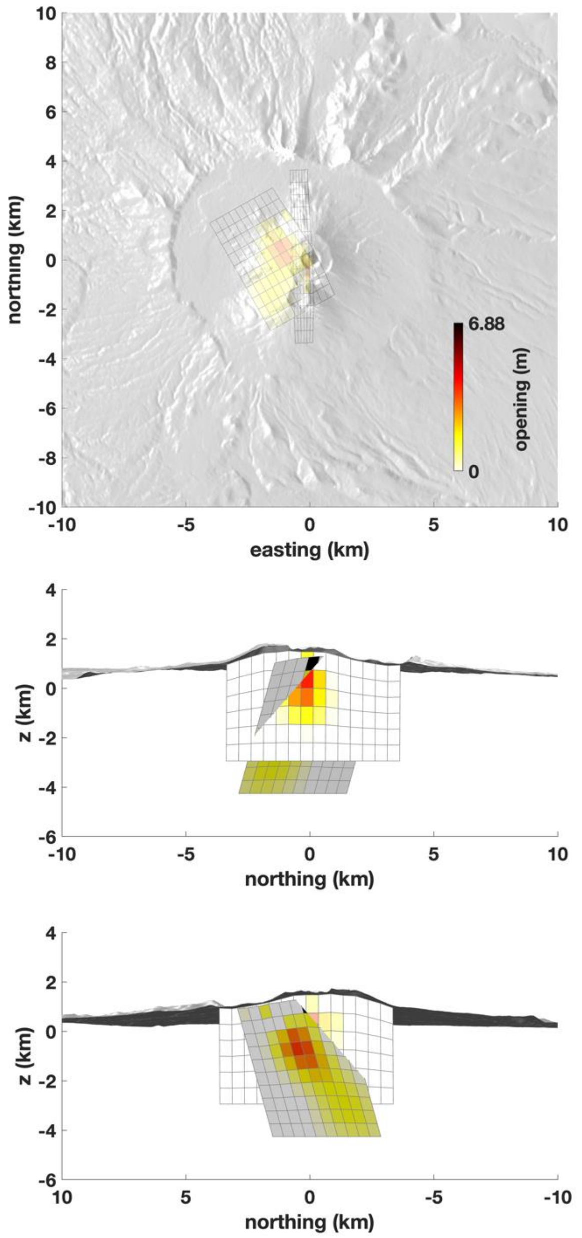
Data acquired ~01:30 UTC
Eruption started ~16:38 UTC (Aug. 2)

What can the orientation and sequence tell us about the dike process?



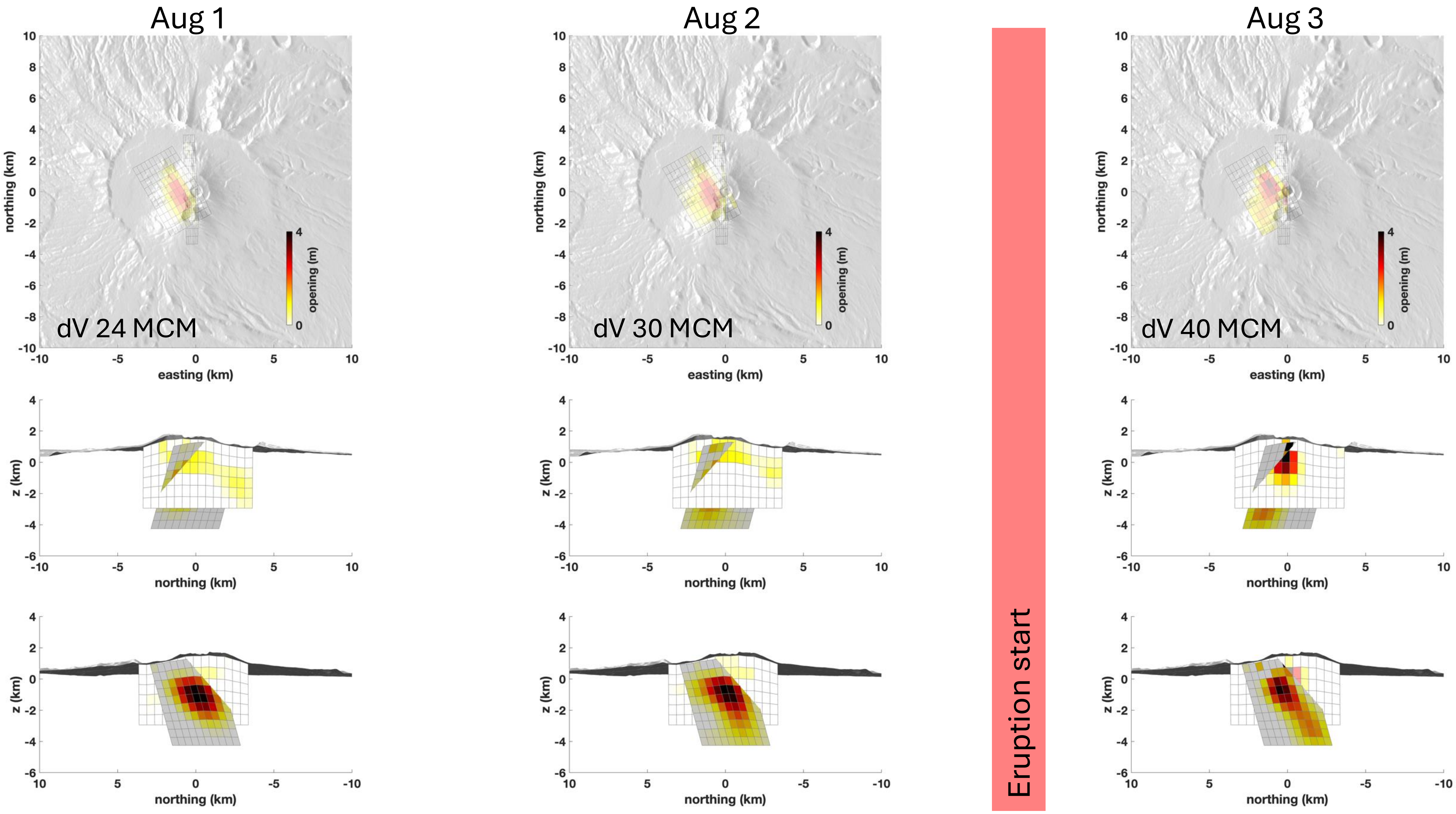
Distributed opening dike model: August 3, 2025





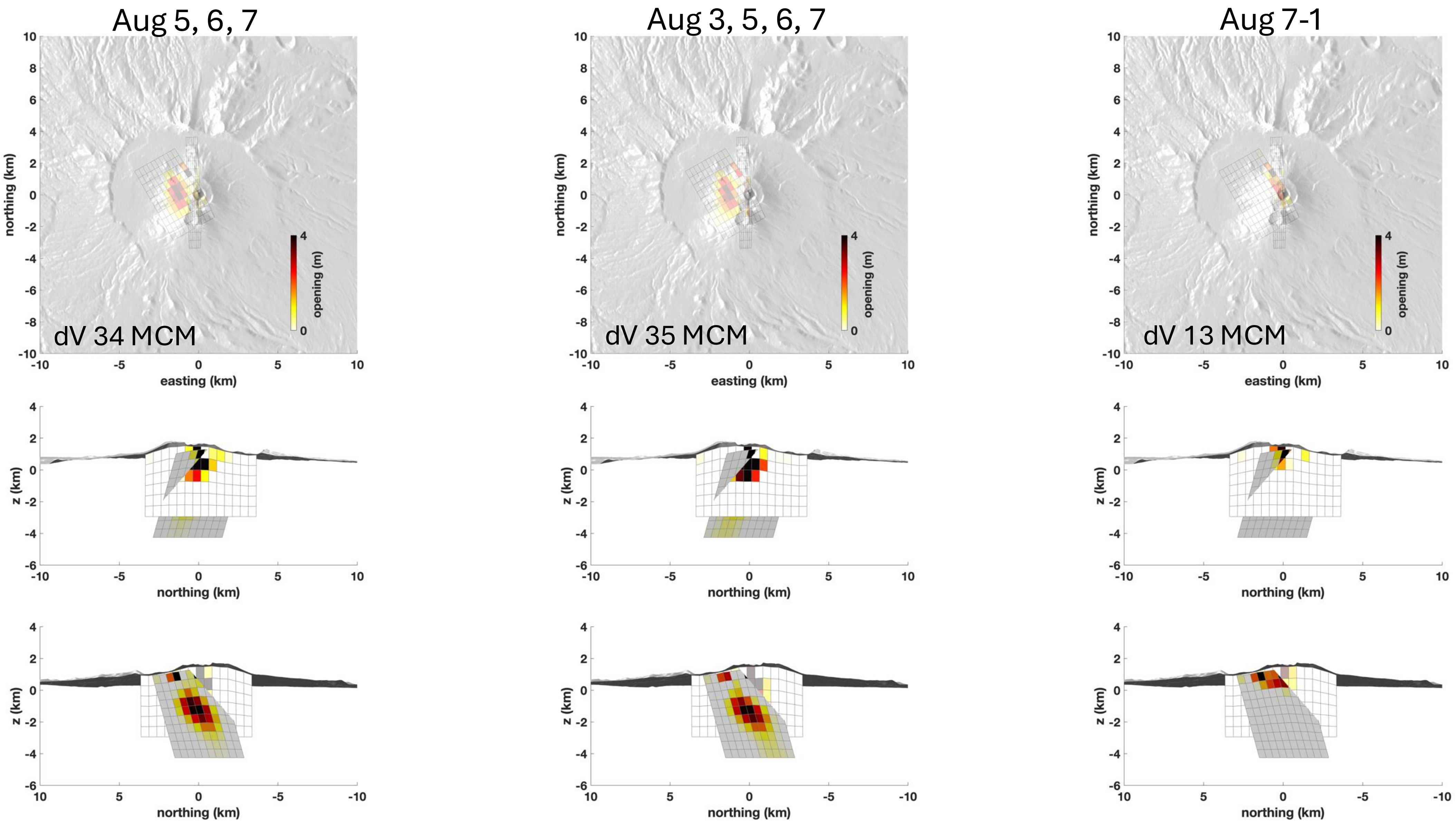
Data acquired 13:00 UTC
Eruption started ~16:38 UTC (Aug. 2)

What can the orientation and sequence tell us about the dike process?



Note: color scale capped at 4 m

What can the orientation and sequence tell us about the dike process?



Note: color scale capped at 4 m

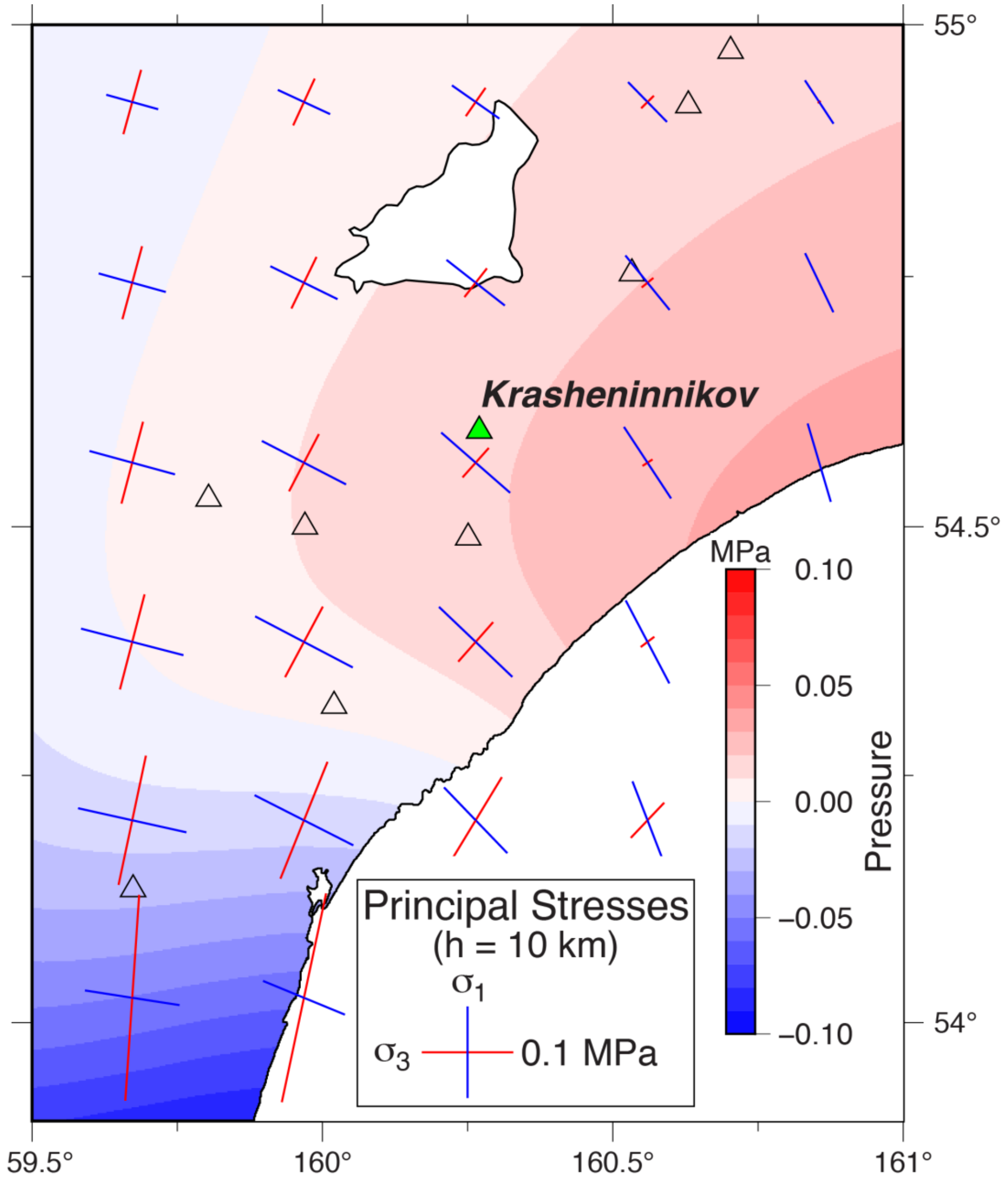
What can the orientation and sequence tell us about the dike process?

M8.8 earthquake stress change

Using the slip model of Liu et al. (2026) we applied the CutAndDisplace BEM code (Davis, 2017) to compute hydrostatic pressure change (similar to Liu et al., 2026) and also the principal stresses.

In this case the most compressive stress (σ_3) points horizontally to the NW at 10 km depth.

Which prompted the question: *Was the dike orientation related to coseismic stress change?*



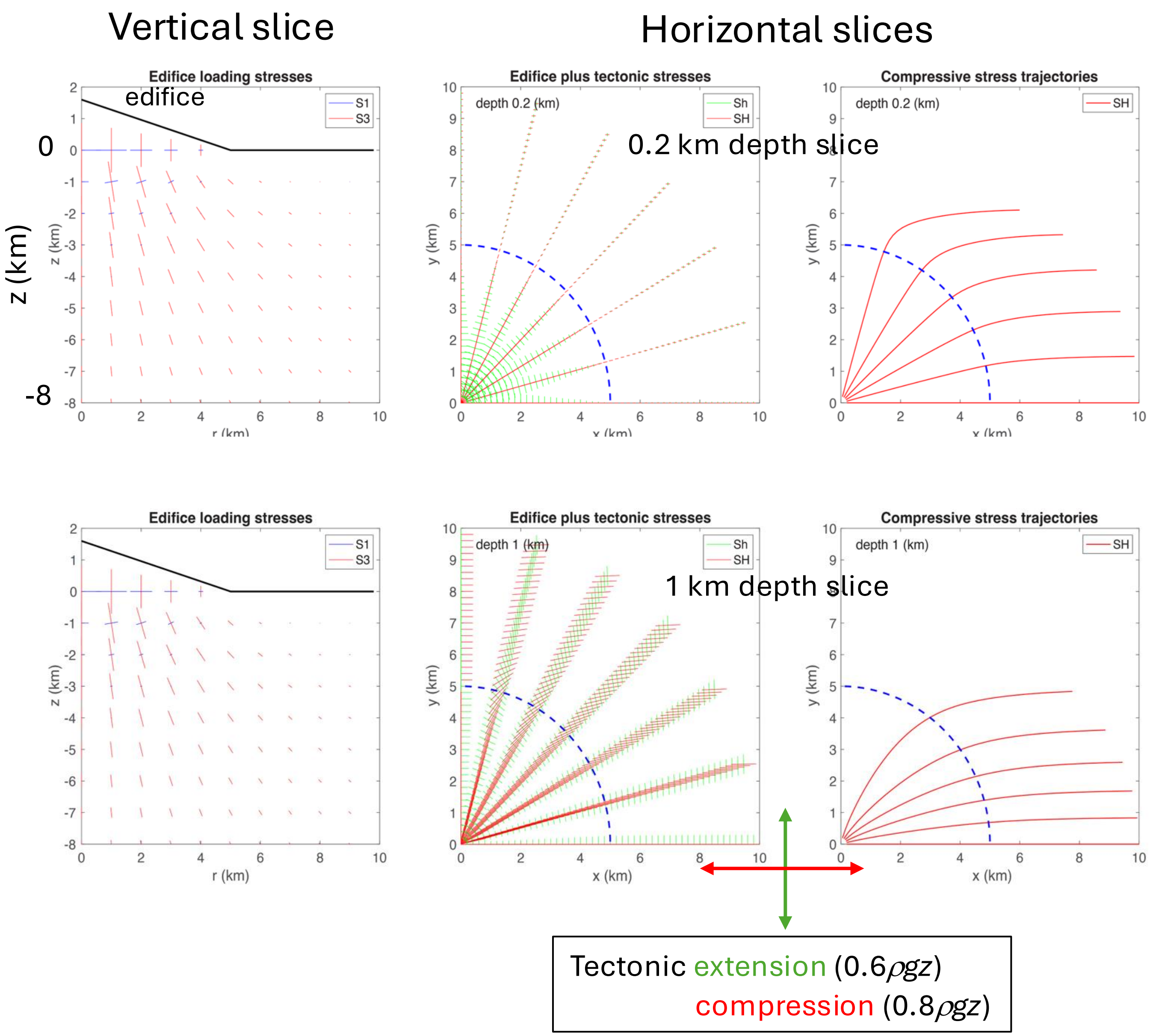
What can the orientation and sequence tell us about the dike process?

Effects of edifice loading and tectonic extension (after Roman and Jaupart, 2014)

With increasing depth beneath the edifice, edifice loading stresses diminish with respect to horizontal extensional stresses, σ_H and σ_h (that scale as a fraction of the lithostatic stress, $\rho g z$, which increases at nearly 10 MPa/km)

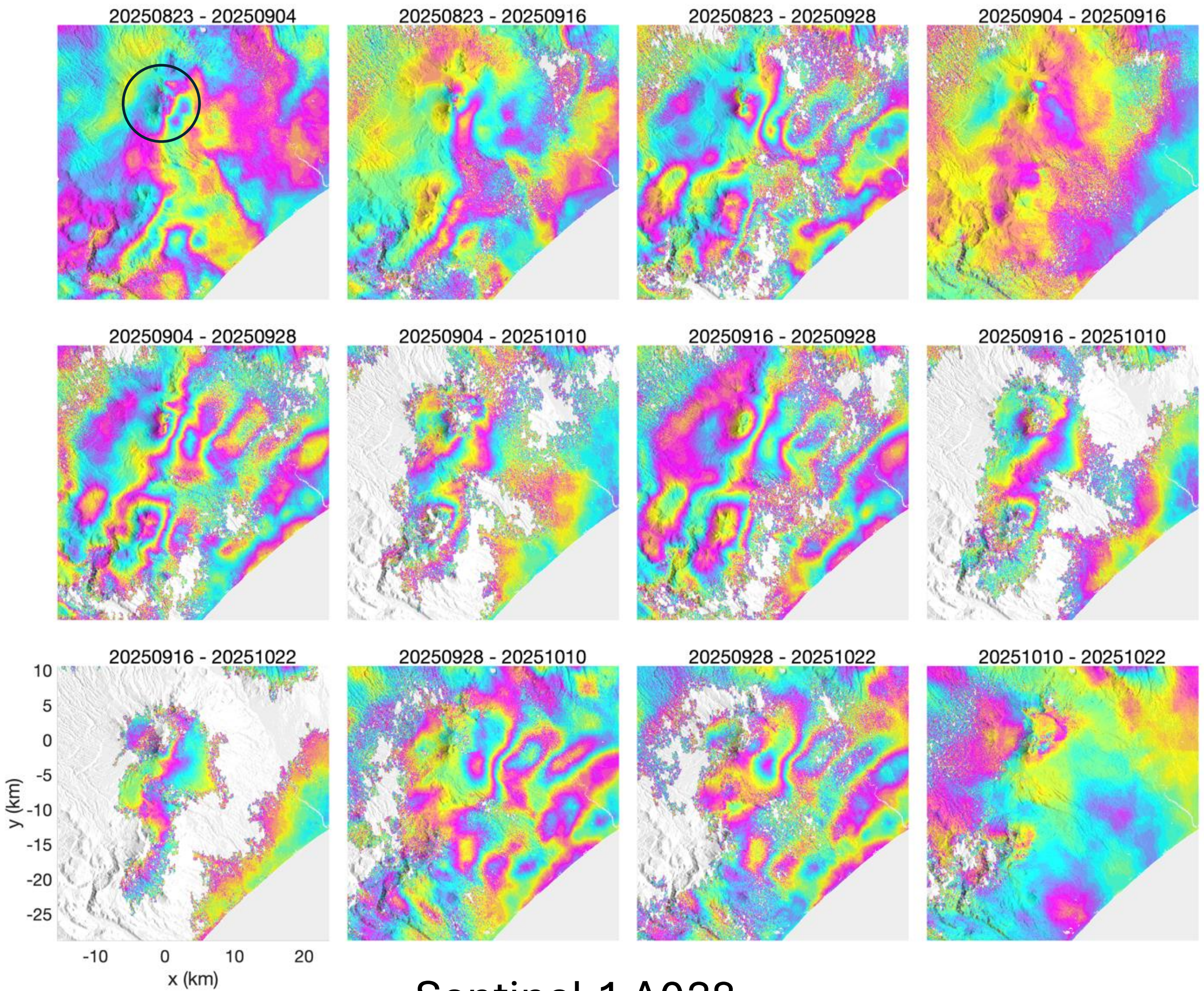
*The co-seismic stress change would be **unlikely** to affect dike azimuthal orientation at magma reservoir depths.*

Special thanks to Damian Walwer (JPL) for providing the edifice loading code (after Roman and Jaupart, 2014)

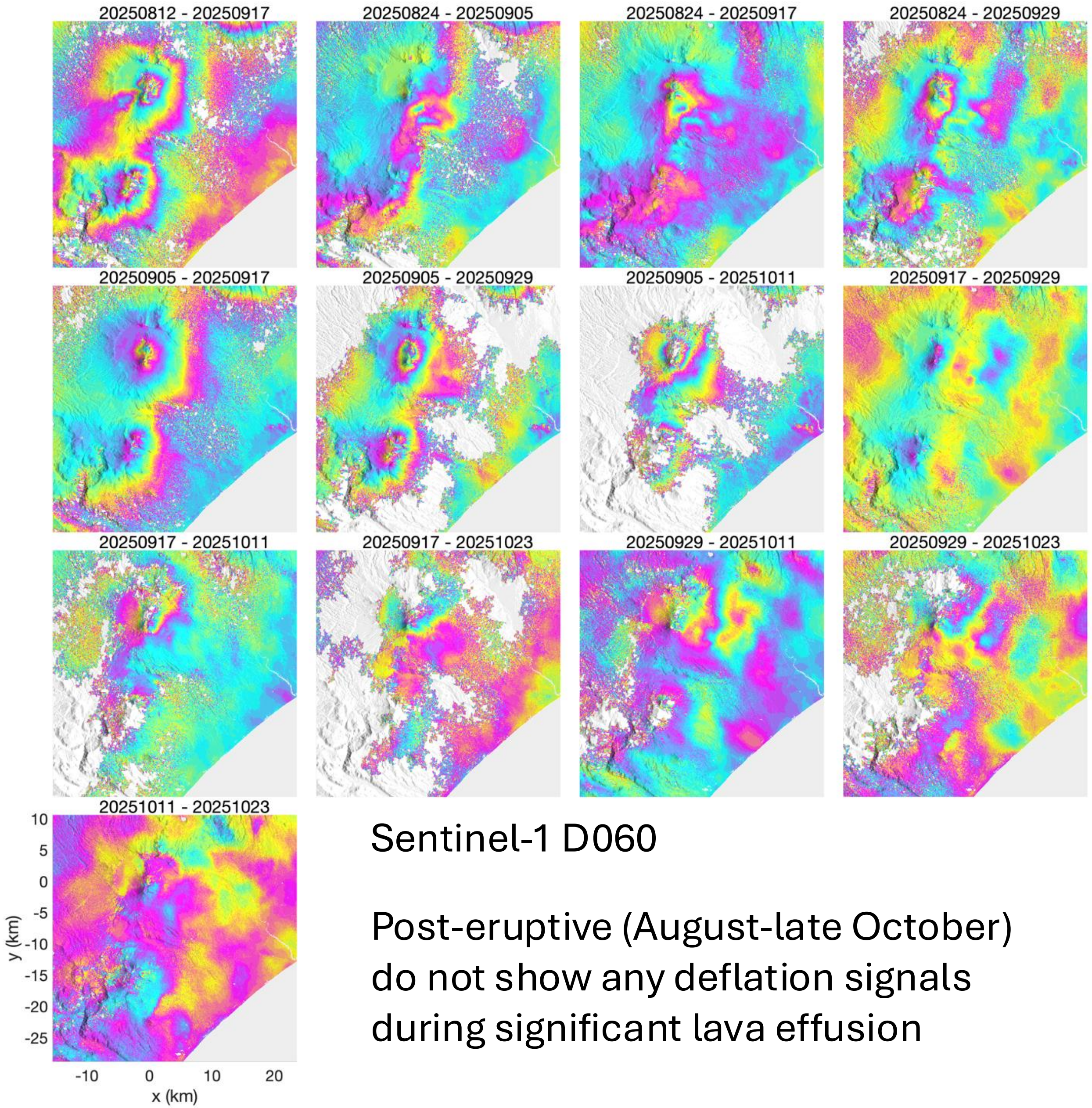


What are the source depth and volume change detection limits?

Where is the source?



Sentinel-1 A038



Sentinel-1 D060

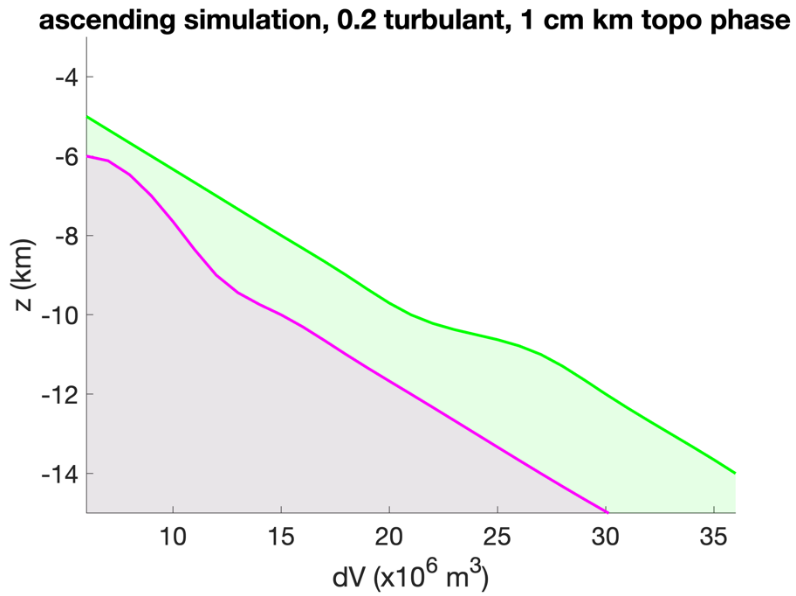
Post-eruptive (August-late October) do not show any deflation signals during significant lava effusion

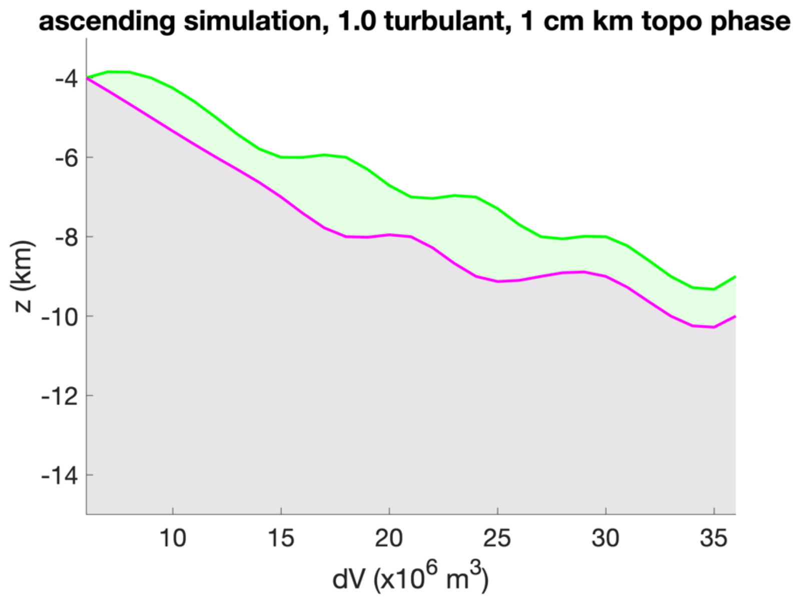
What are the source depth and volume change detection limits?

Source detectability as a function of depth and volume change for ranges of atmospheric noise

A magma source approximately **deeper than 4-8 km** (dV -6 to -30 MCM) would be **difficult to detect**.

The source volume change (dV) could be in the lower magnitude range depending on magma compressibility and the amount of stored (dikes) and erupted volumes.

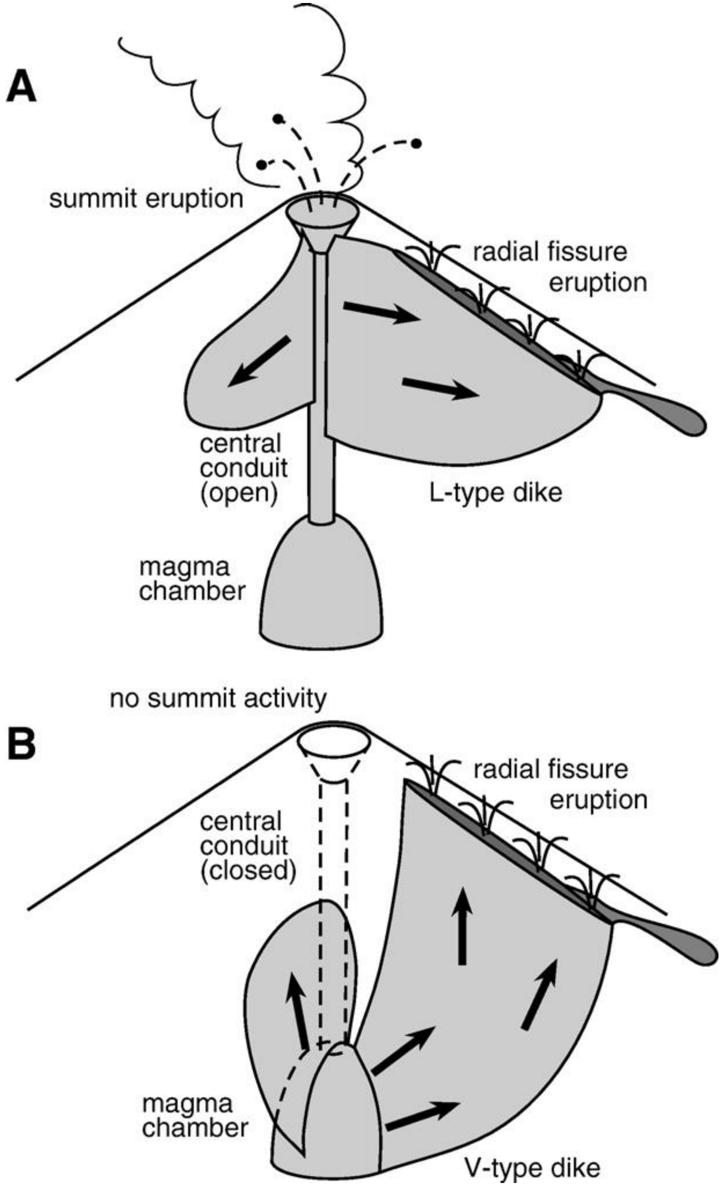




Conceptual model

Our arrested radial, dipping dike is similar to a dike propagating upward from depth where with a closed central conduit (B) on the right (Porreca et al., 2006; Geshi, 2008).

The rapid switch from the failed NW striking dike to the NS summit dike and eruptive fissures may indicate a transition from (B) to (A) type behavior.



From Geshi, *J. Vol. Geotherm. Res.*, 2008

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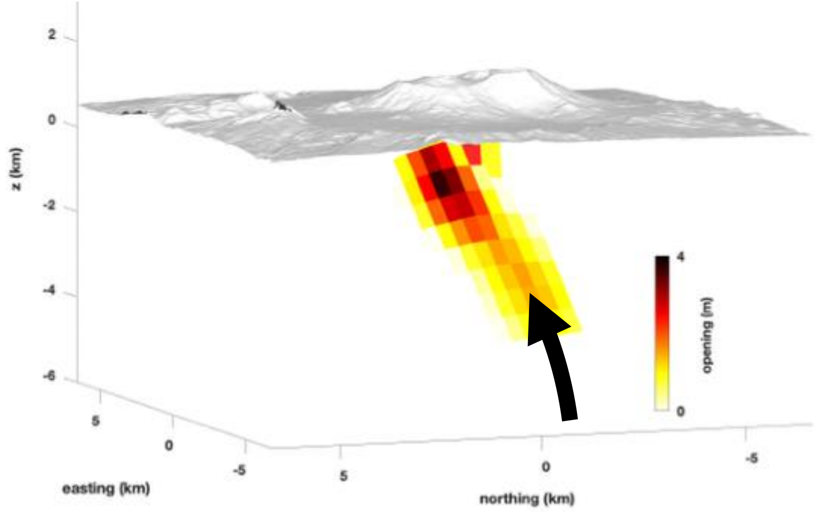
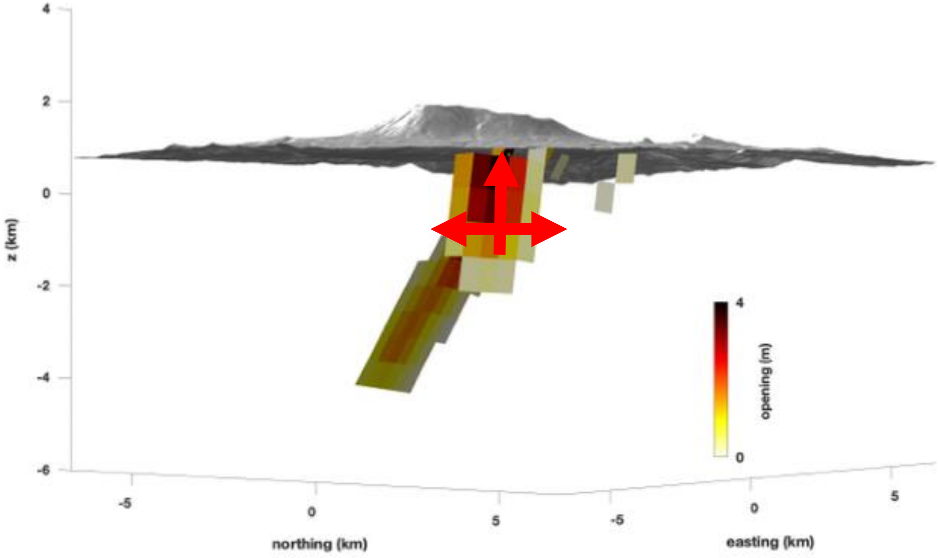




Summary

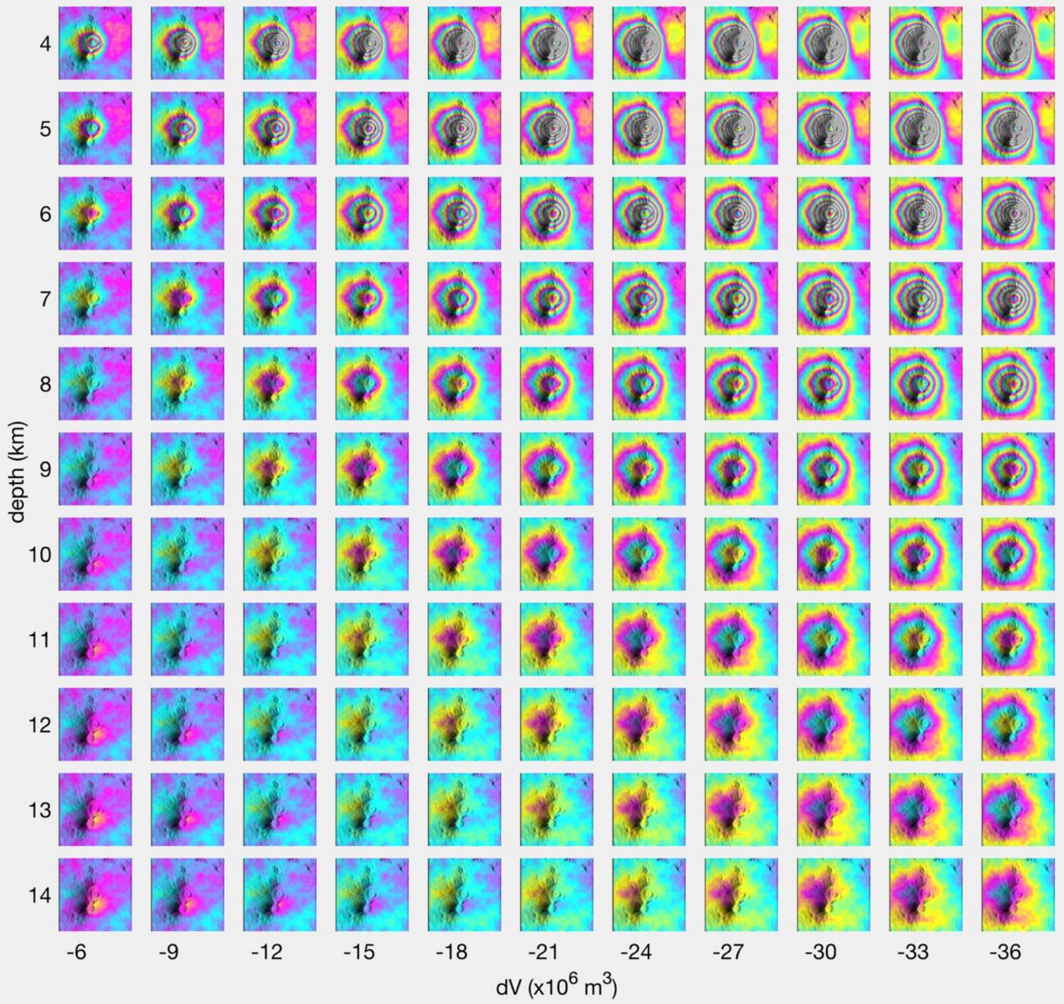
- No precursory decadal-scale thermal or InSAR time series signals detected, suggesting the earthquake triggered the eruption. However, the long duration of the eruption (ongoing) suggest that the system was already primed before the earthquake.
- Dike-feeding sources deeper than ~4-8 km would be difficult to detect depending on volume change (dV) and atmospheric noise.
- The M8.8 earthquake coseismic stress (~0.1 MPa) is likely too small to orient the stalled dike to the NW. Eruption triggering likely due to a combination of dynamic and static stress changes.
- The stalling of the NW directed dike in the shallow crust and the switch to the NS summit dike suggest a dike propagating up from the reservoir before transitioning to the summit eruption.

Backup slides

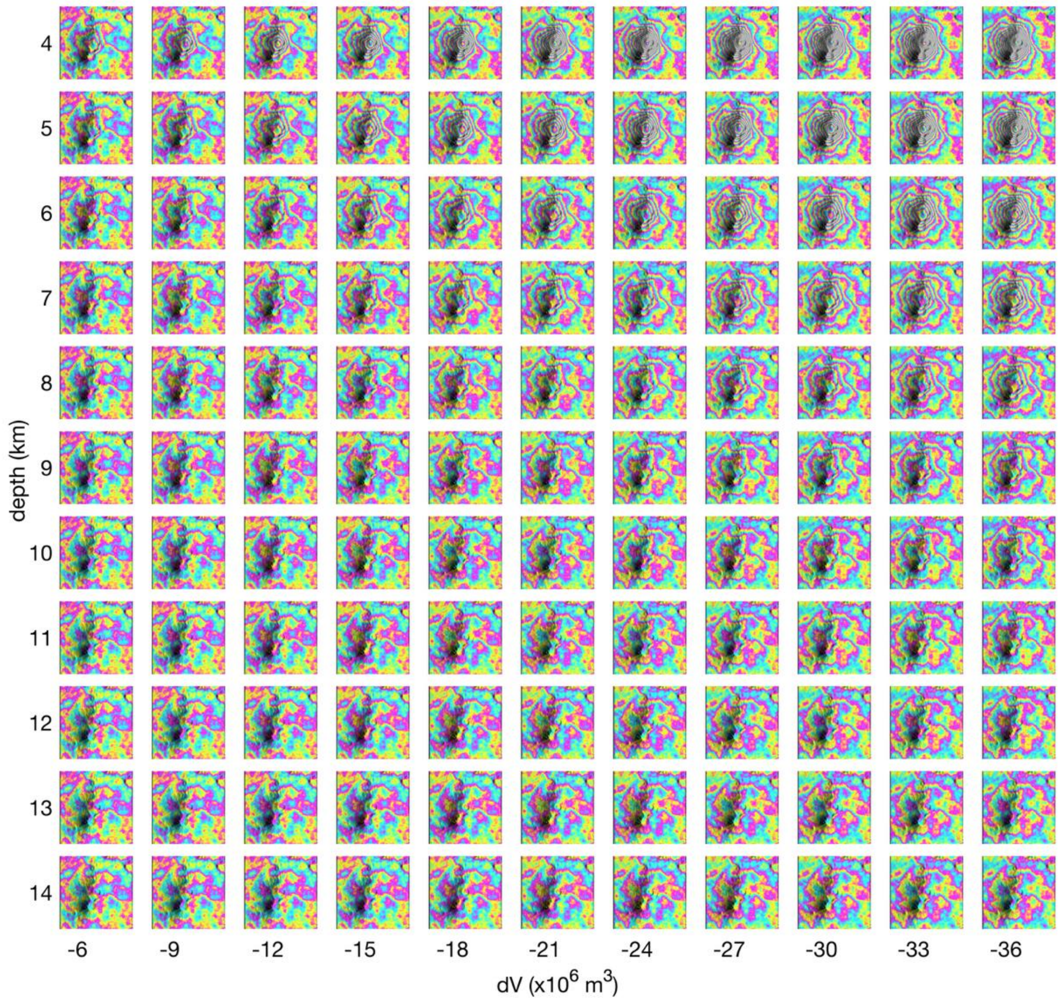
What are the source depth and volume change detection limits?

Sensitivity analysis for a layered and a fractal-based turbulent atmospheric model

Layered troposphere 1 cm/km, fractal amp 0.2, sign -1



Layered troposphere 1 cm/km fractal amp 1.0, sign 1



Sentinel-1 A038

August 5, 6, 7: Sentinel-1