Abnormally large magma flux does not lead to eruption in subduction zone calderas: The 2022-2023 episode of unrest of Aniakchak Crater (Aleutians)

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Abnormally Large Magma Flux Does Not Lead to Eruption in Subduction Zone Calderas: The 2022–2023 Episode of Uplift of Aniakchak Crater (Aleutians)

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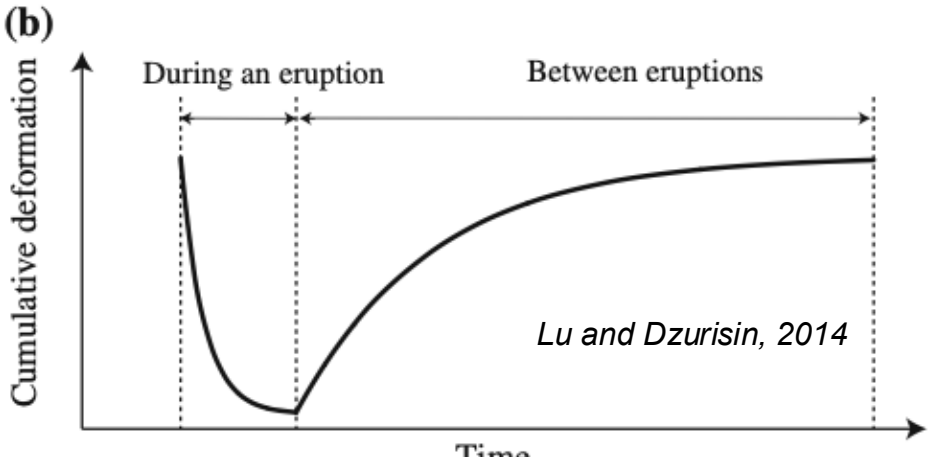
Introduction

- In the era of multiple SAR missions, tens of hundreds of images per year, and AI, can we still do science with a few interferograms and a Mogi model?

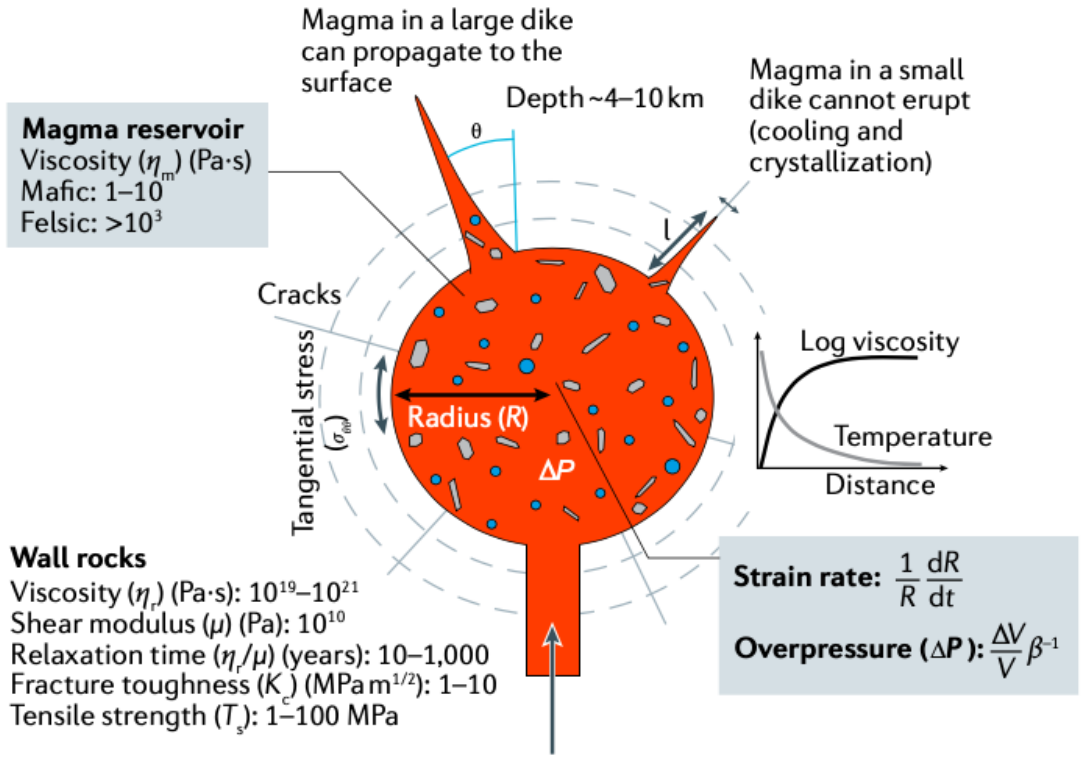
- YES!

- Despite 3 decades of InSAR, many volcanoes located on middle and high latitudes still lack good quality InSAR observations

Can we predict eruptions with these model?



Lu and Dzurisin, 2014



The build-up and triggers of volcanic eruptions

Luca Caricchi[1]✉, Meredith Townsend[2], Eleonora Rivalta[3,4] and Atsuko Namiki[5]

Unexpected large eruptions from buoyant magma bodies within viscoelastic crust

Freysteinn Sigmundsson[1]✉, Virginie Pinel[2], Ronni Grapenthin[3], Andrew Hooper[4],

$$\Delta\rho gh + \Delta P_{\text{magma body,flow}} \geq \sigma_{\text{failure}} + \sigma_{\text{external}}$$

Eruption at basaltic calderas forecast by magma flow rate

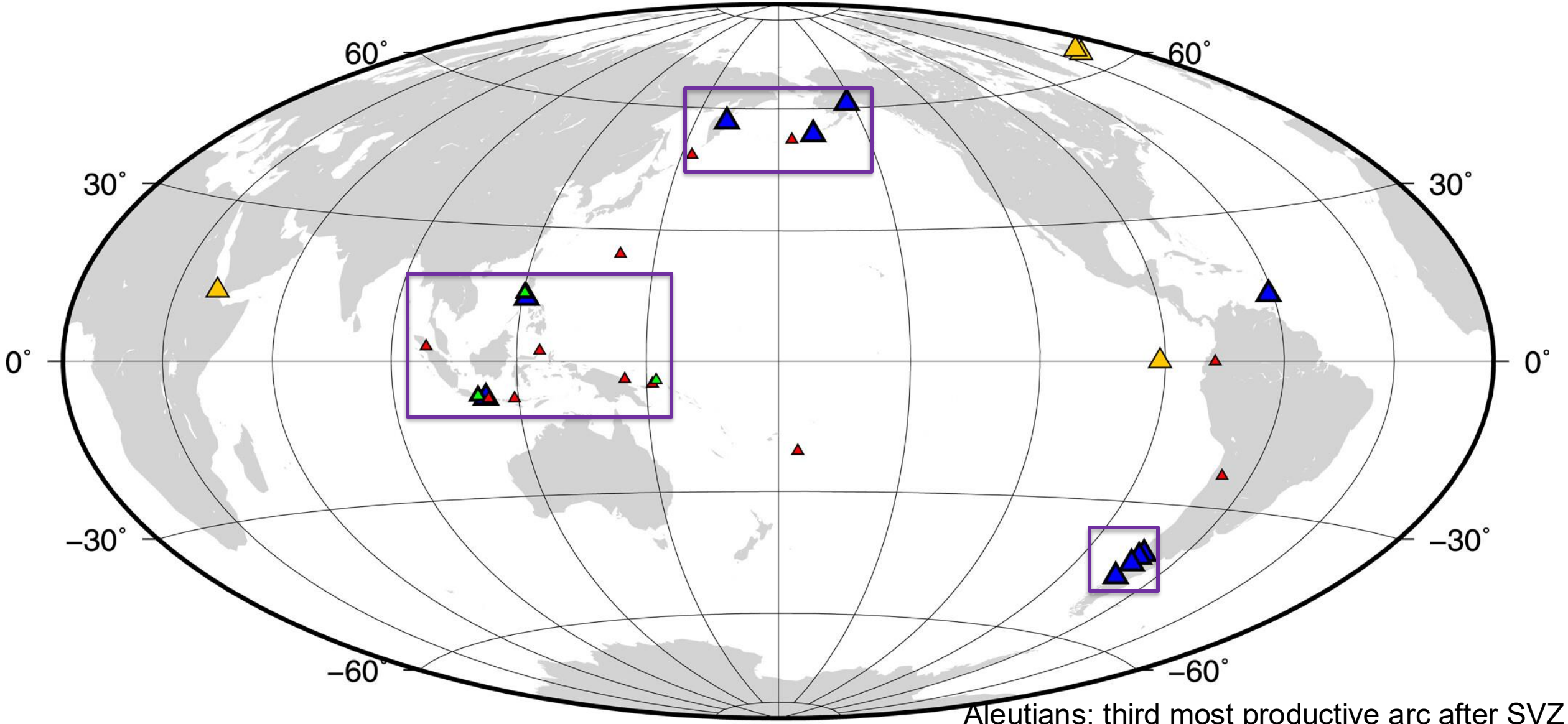
Key points

- The thermal evolution of magmatic systems influences the physical properties of magma and the rocks surrounding the volcanic plumbing system, which, over the long term, favours magma storage over eruption.
- Magma recharge is the primary driver of magma reservoir pressurization and destabilization. Second boiling can trigger reservoir failure, although it is less likely to cause repeated eruptions.

Annen et al., 2023, JVGR

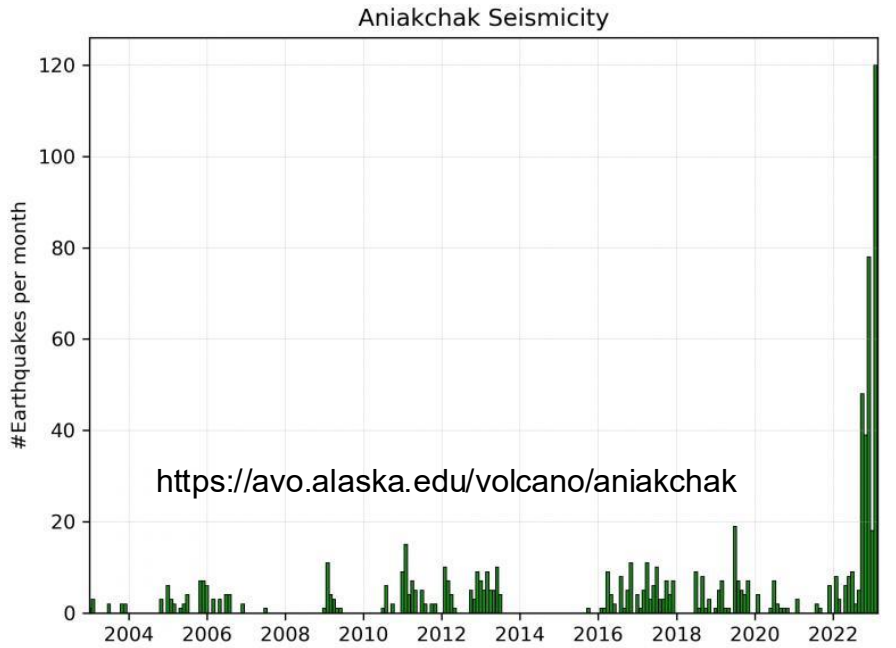
Probably due to the lack of joint inversion of deformation and gravity data recorded in pre-eruptive periods, there is, to our knowledge, no unambiguous observation supporting the case of an eruption triggered by second boiling without magma input. It is noteworthy that eruptions,

Volcanoes withVEI≥4 eruptions and InSAR detected ground deformation

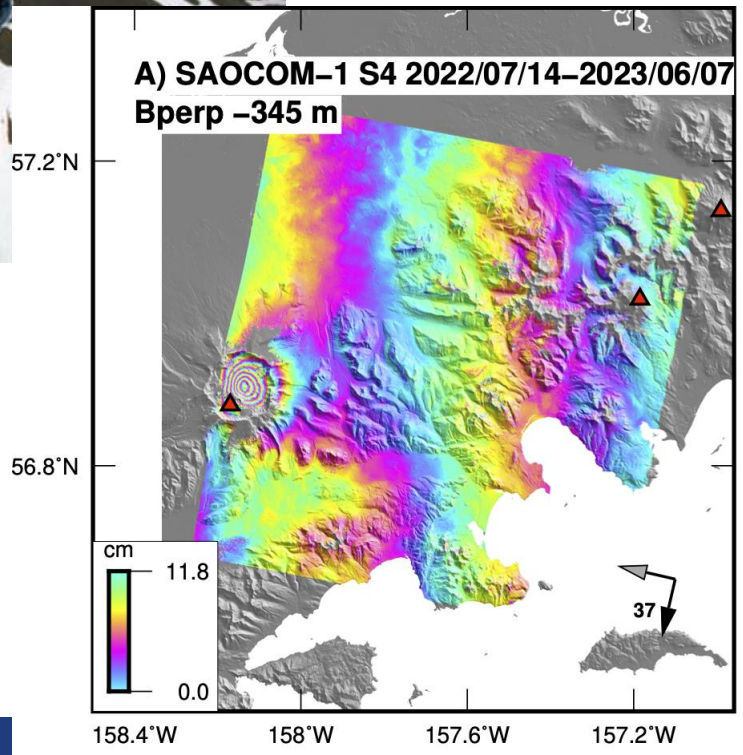


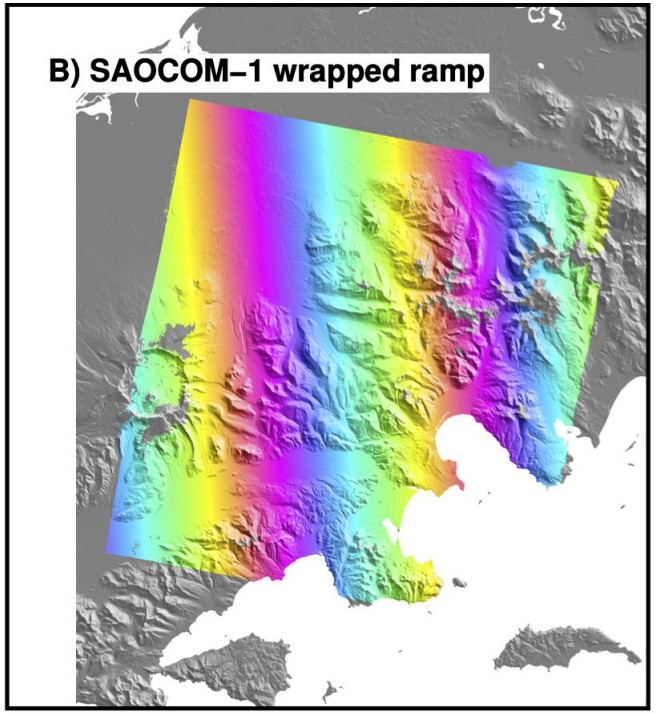
Delgado et al., 2025

Aleutians: third most productive arc after SVZ and Kamchatka since 1980 [*Galetto et al., 2023*]

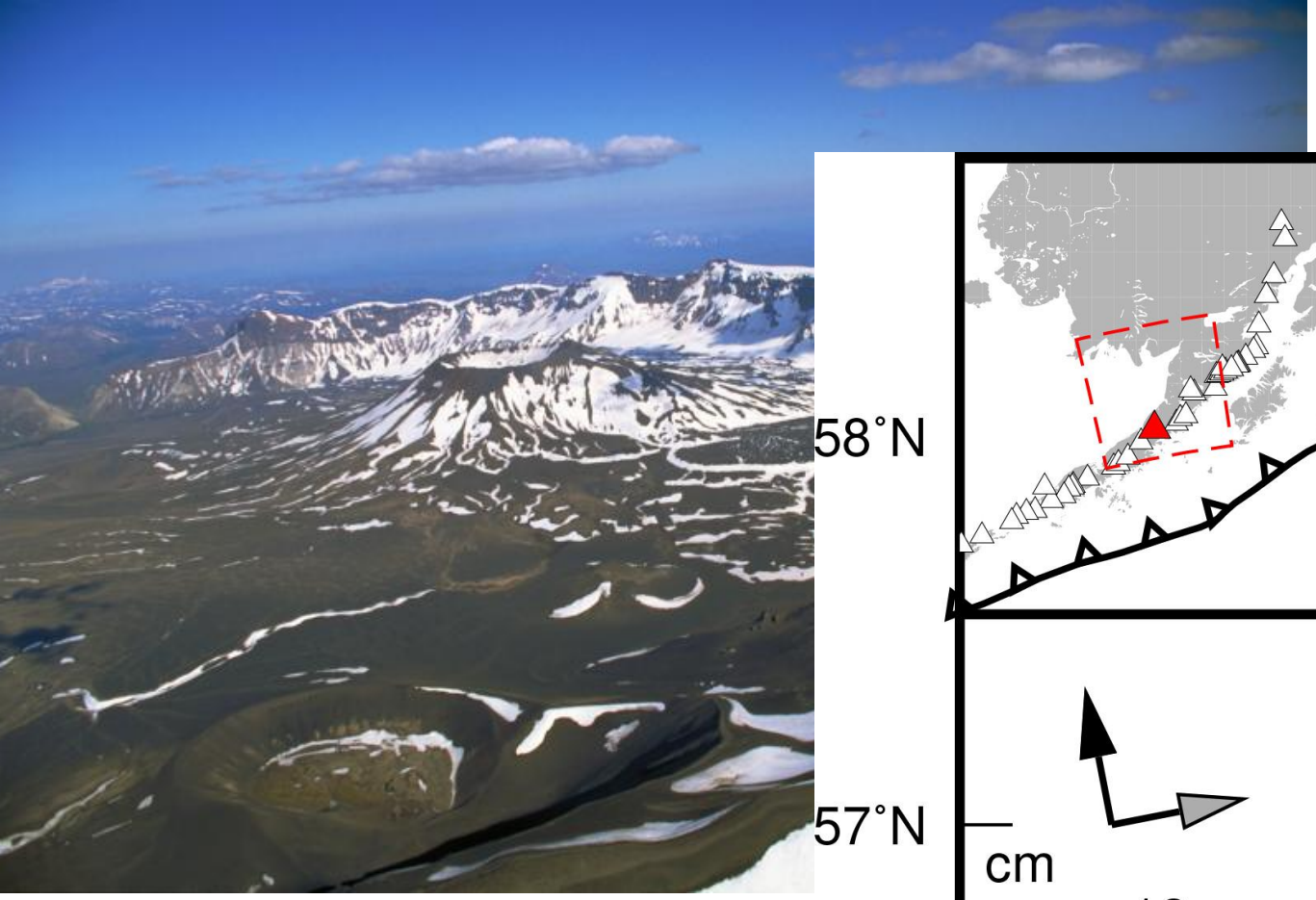


Large Scale InSAR Surveys





Delgado et al., IEEE TGRS, 2024



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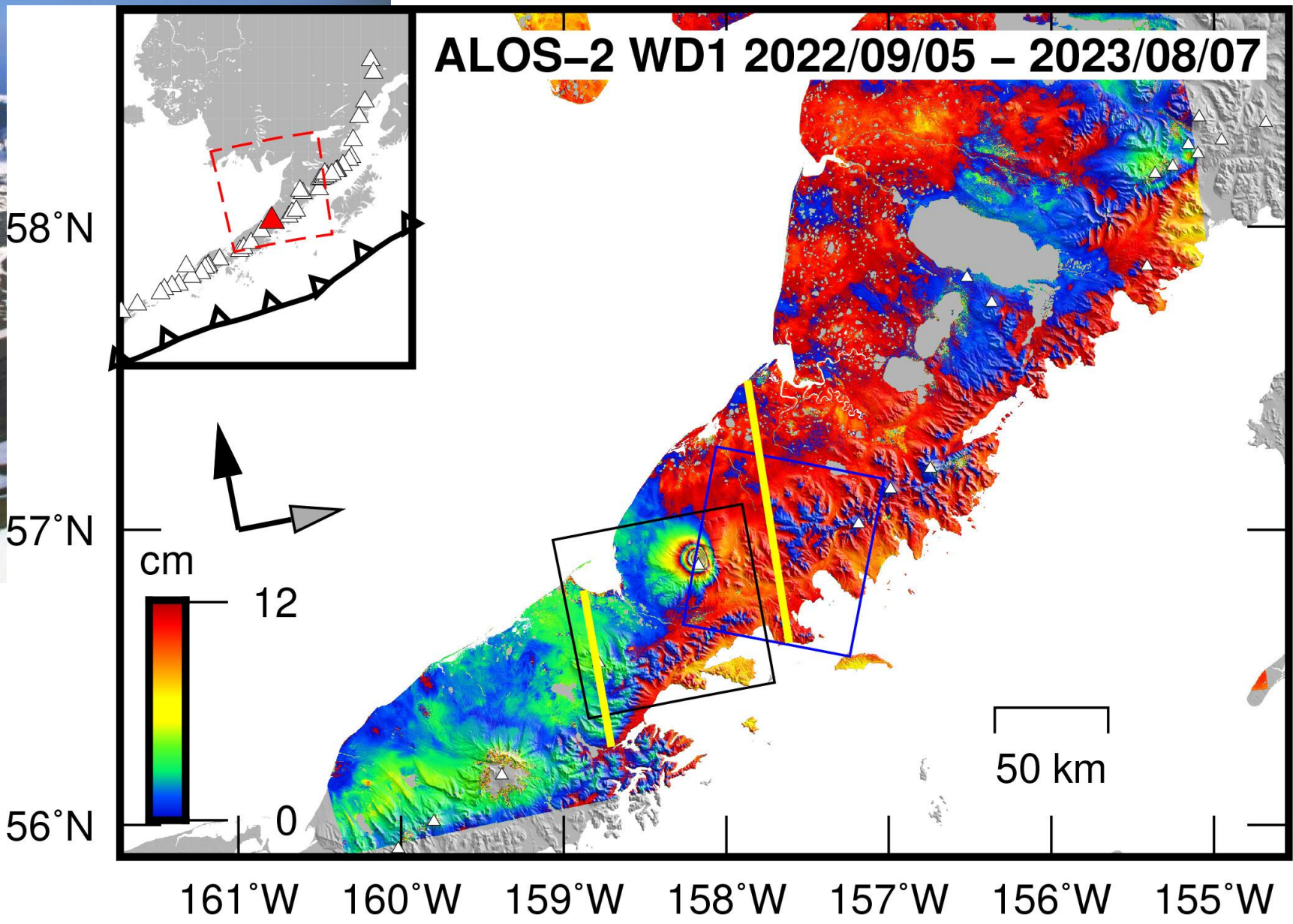
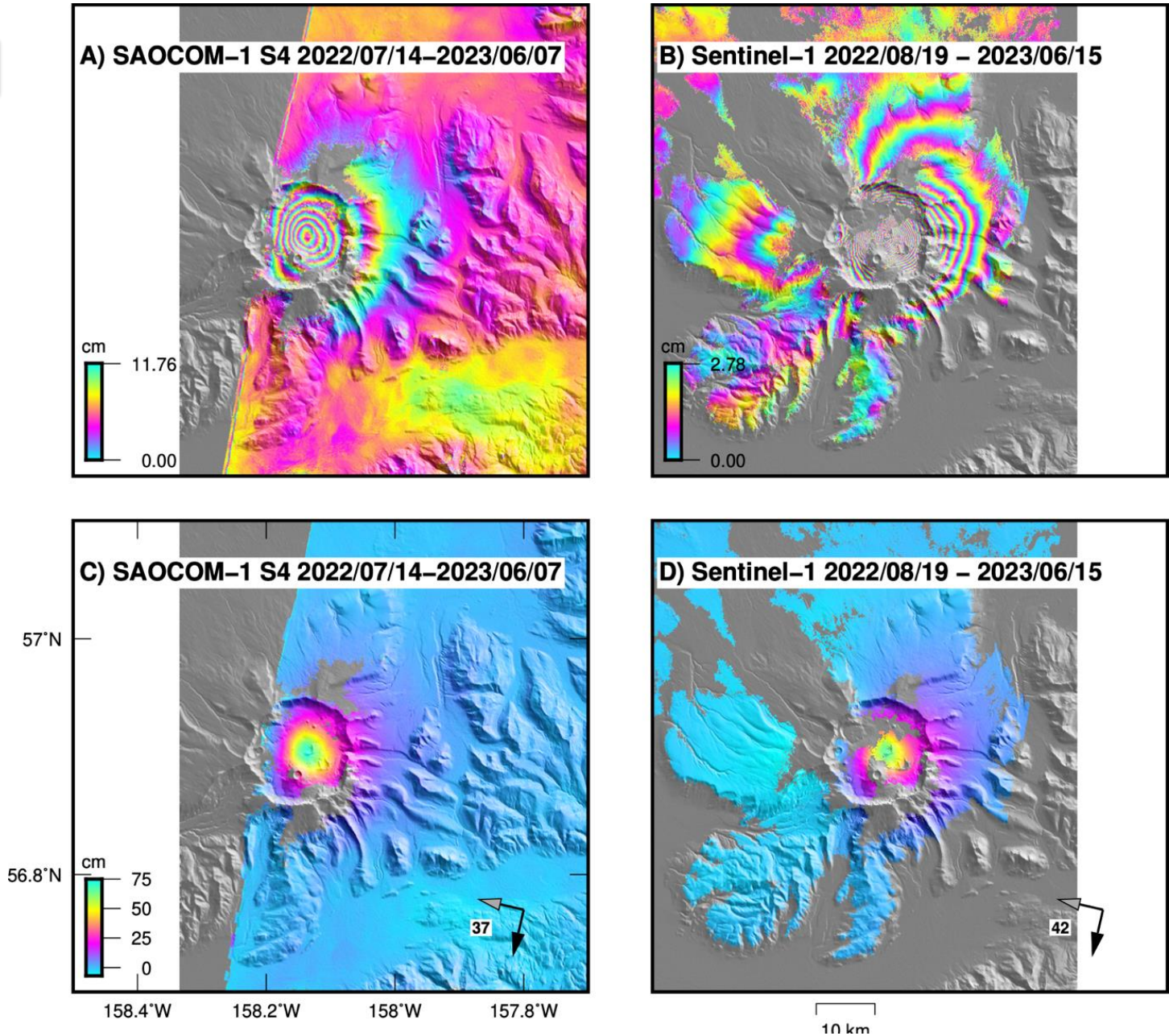


Delgado, GRL, 2026

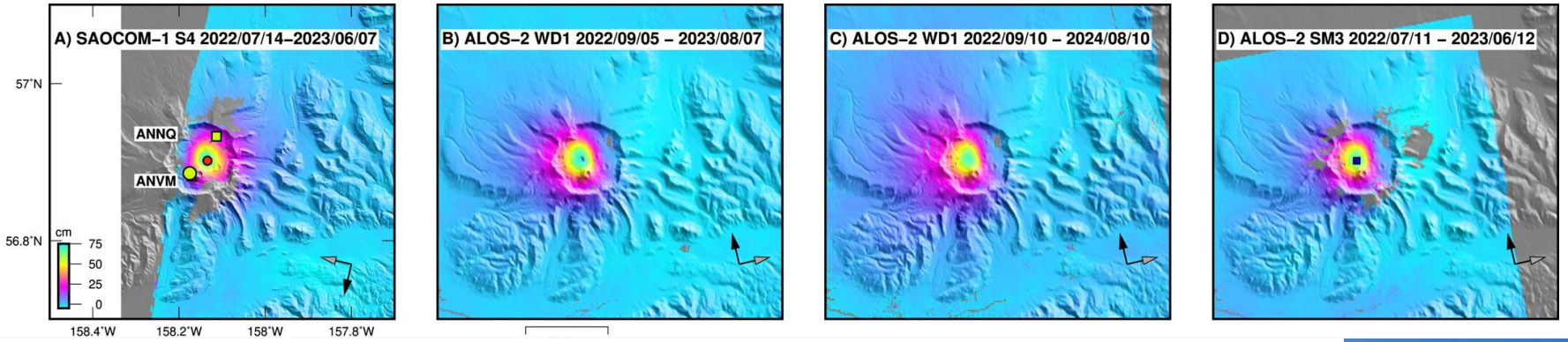
SAOCOM-1 vs Sentinel-1

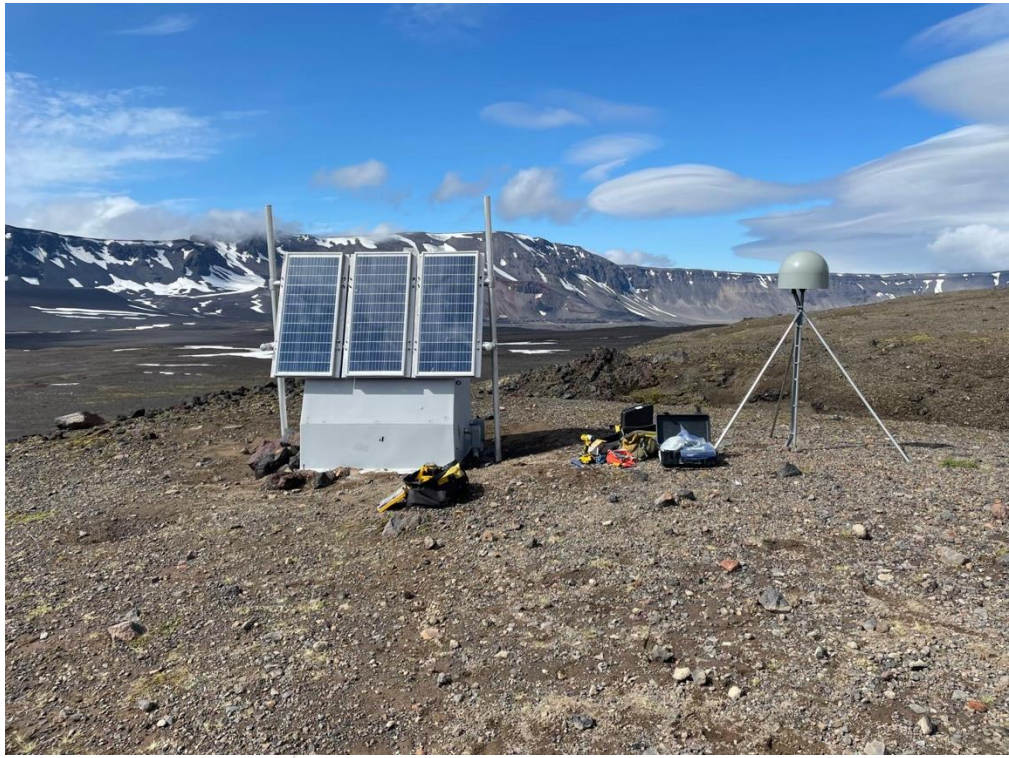
- Sentinel-1 only acquired descending data with no systematic 12 day acquisitions: data gaps
- L-band missions acquired data of much better quality than Sentinel-1: less phase aliasing, higher coherence.



Delgado et al., 2024; *Delgado, GRL, 2026*

An abnormal case study: Aniakchak Crater, Alaska





Delgado et al., IEEE TGRS, 2024
Delgado, GRL, 2026

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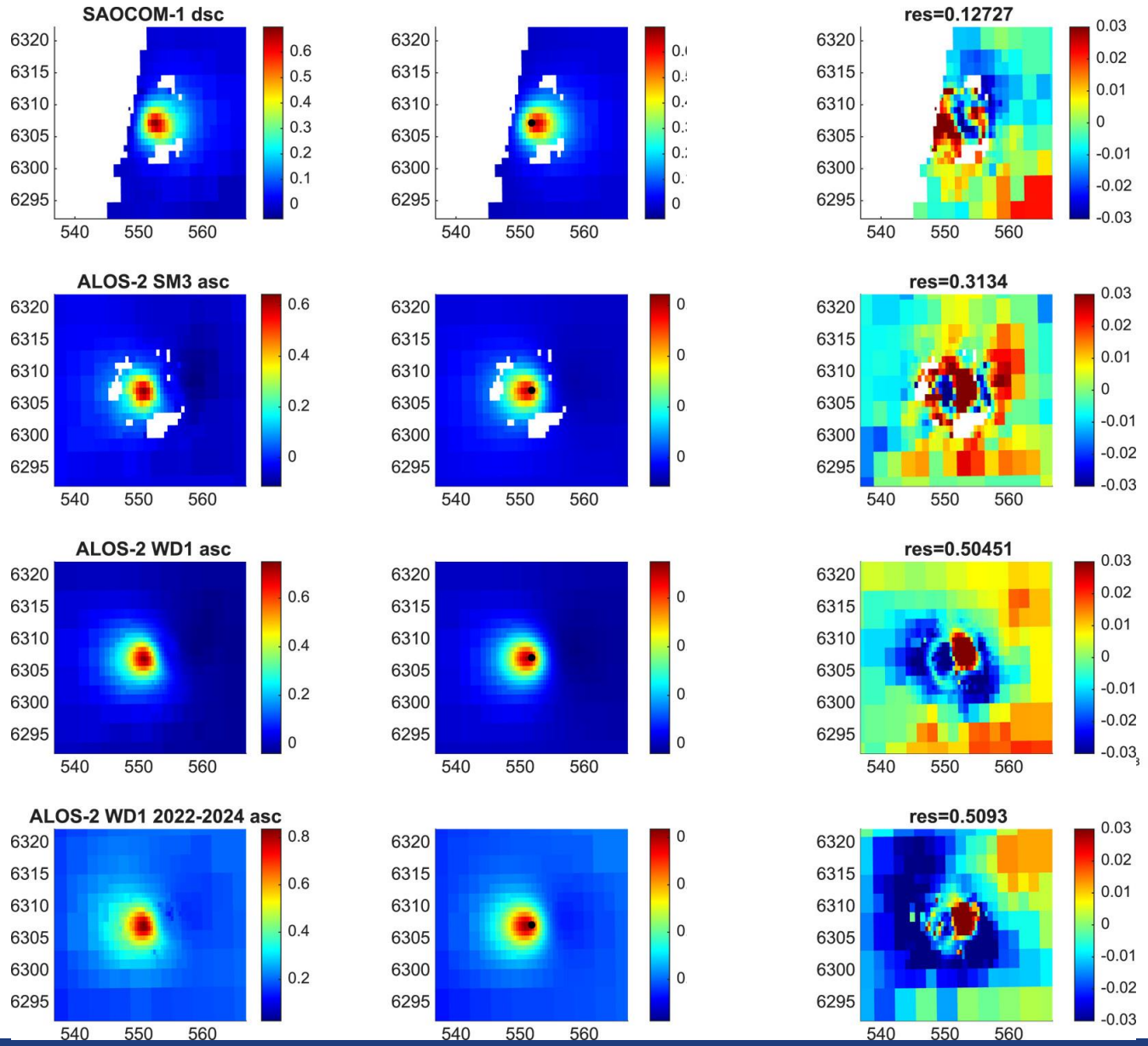
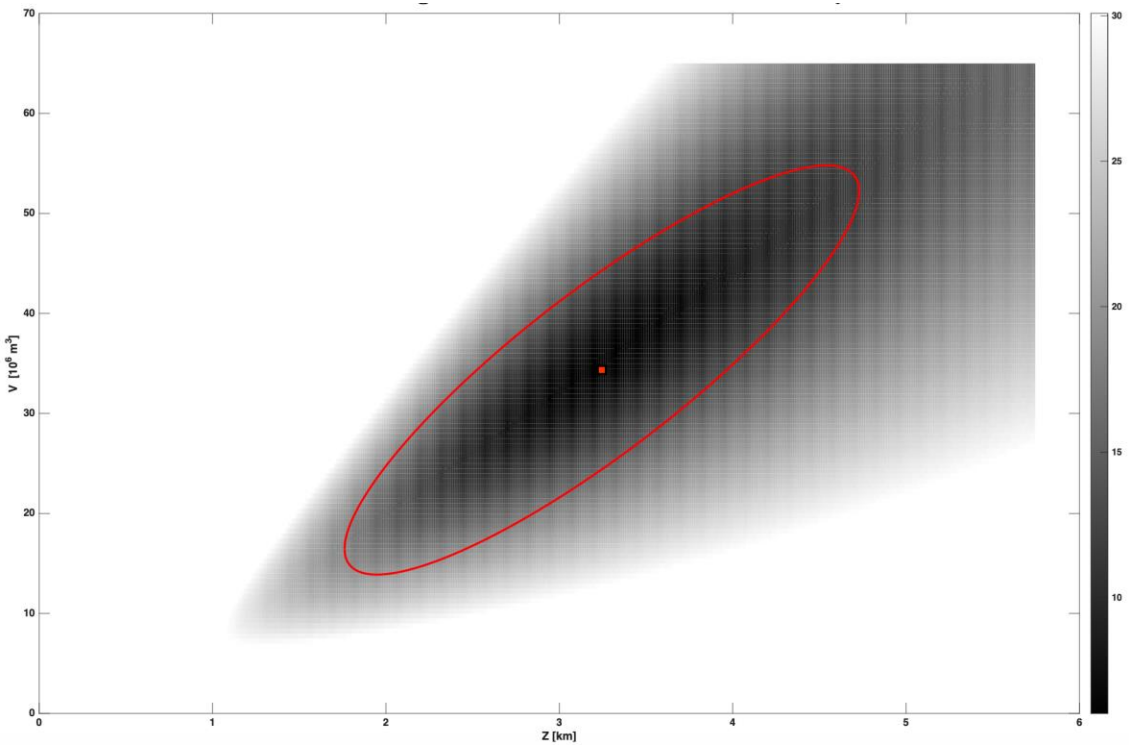


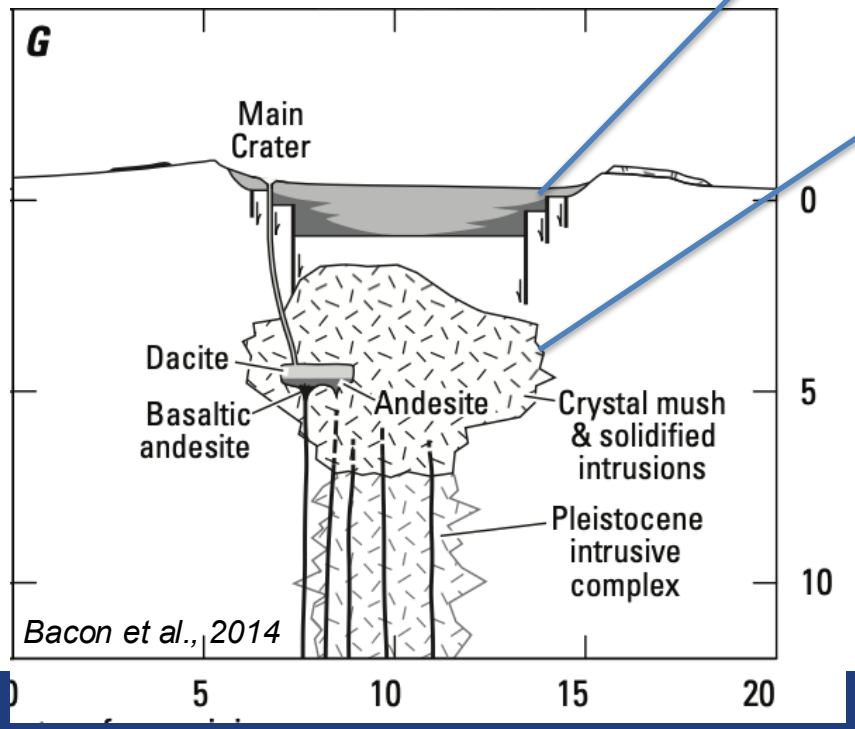


$\Delta V = 0.035\ km^3$

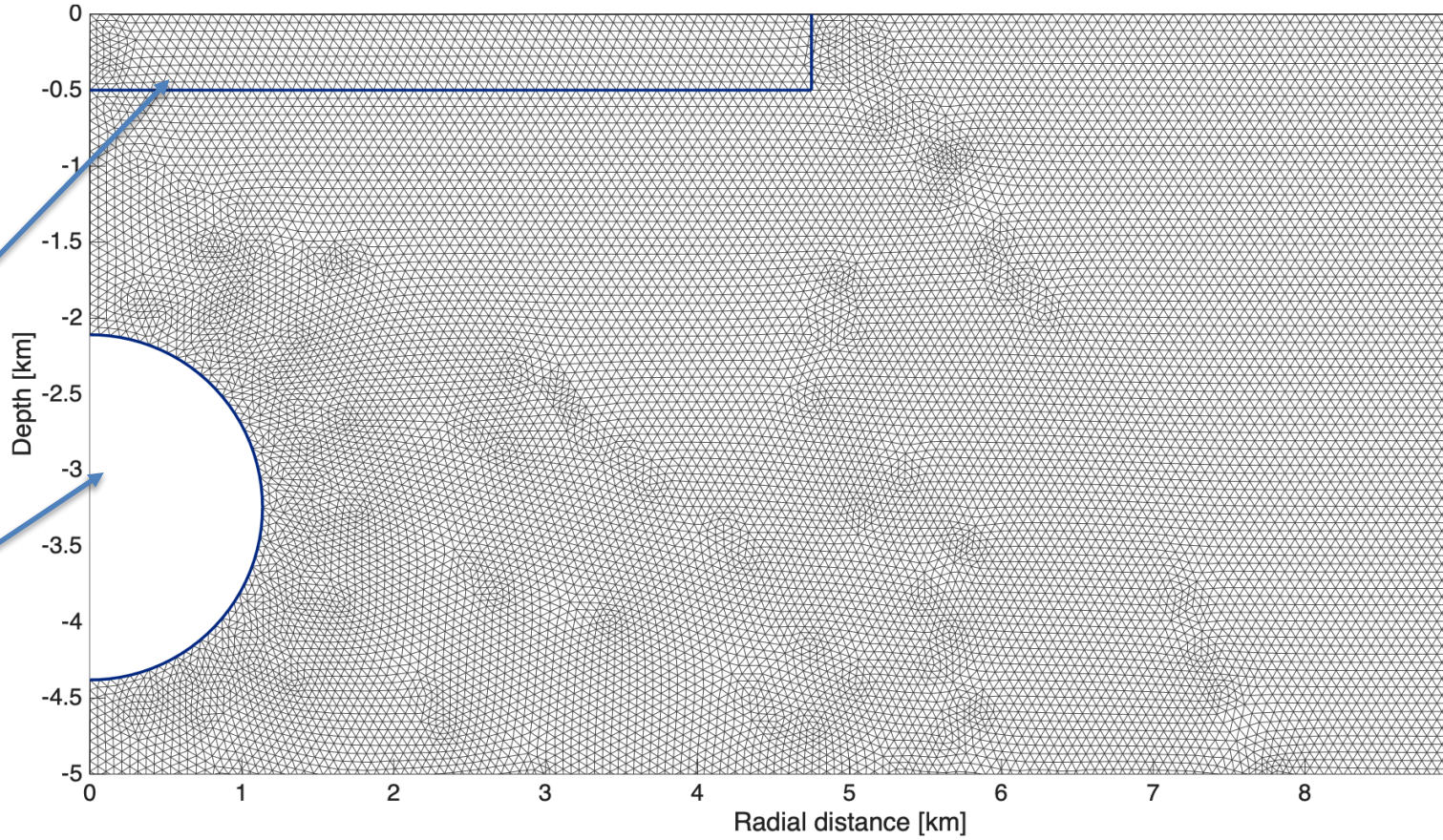
$Q = 1.7\ m^3/s$

Delgado, GRL, 2026

Caldera infill in volcano ground deformation



Bacon et al., 2014



Delgado, GRL, 2026

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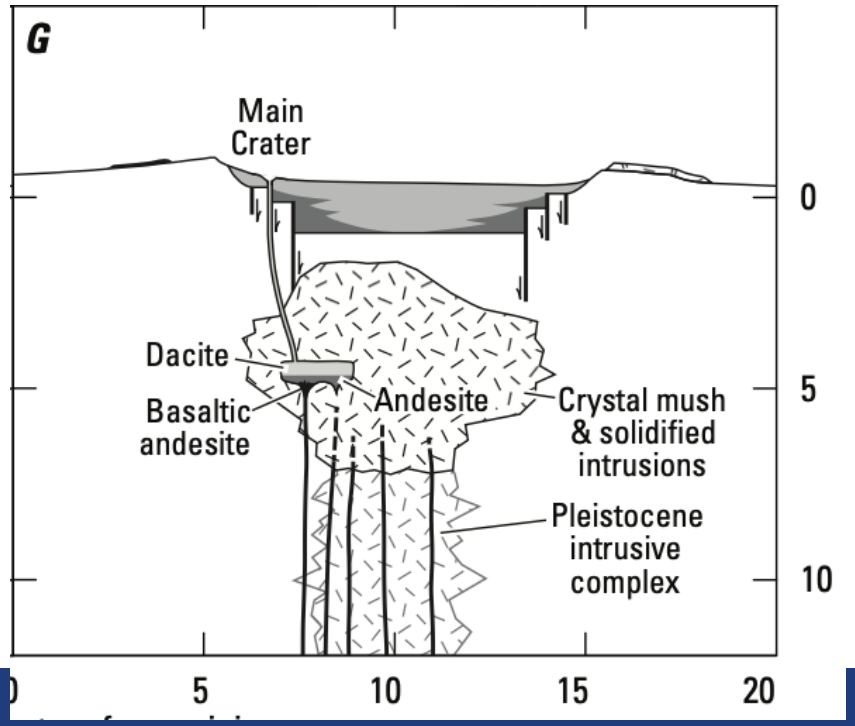

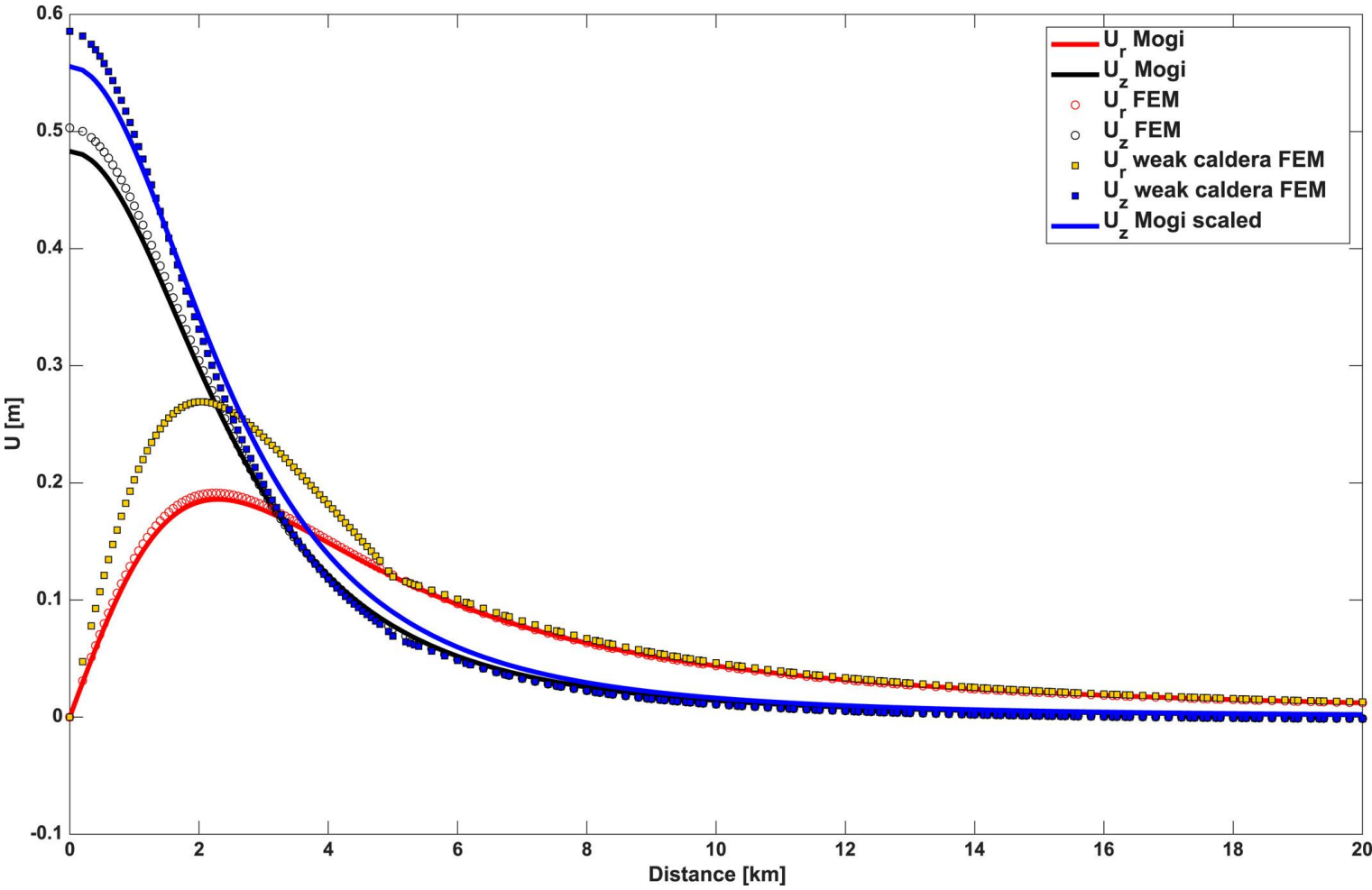

Delgado, GRL, 2026

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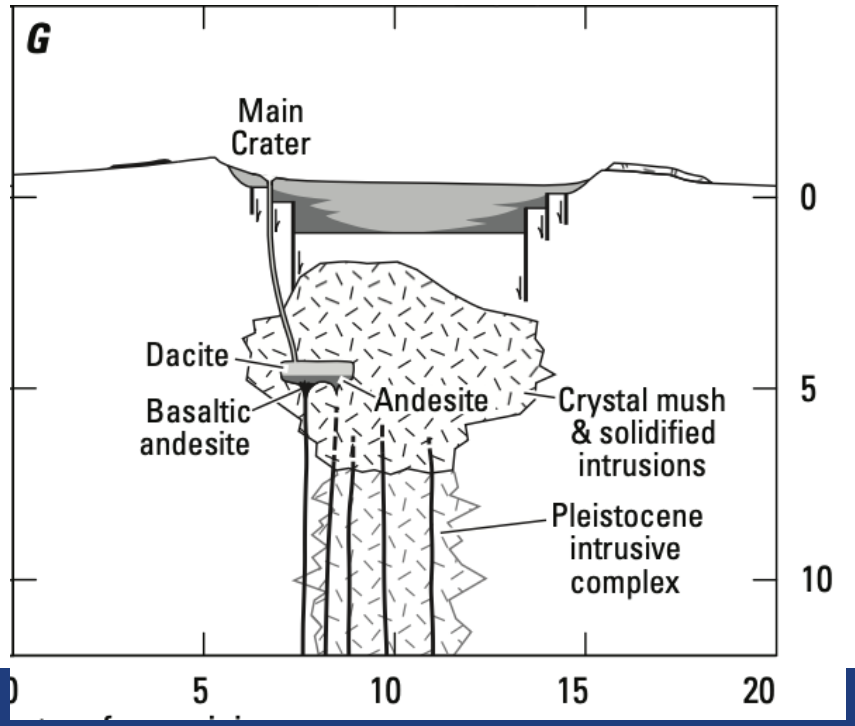
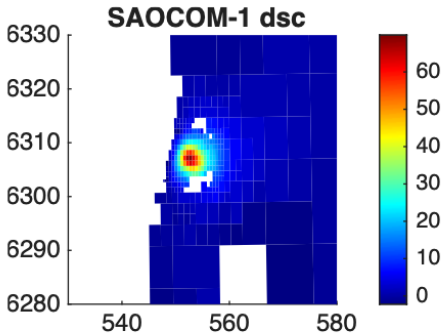
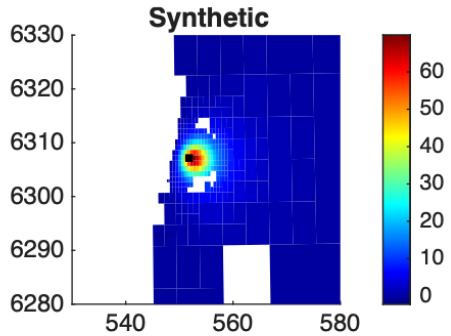
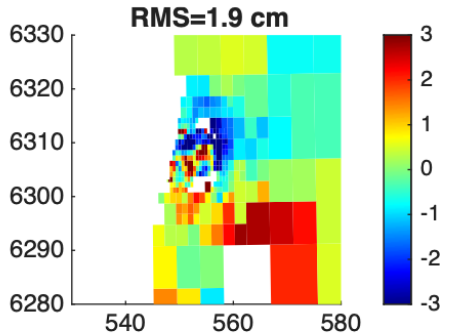
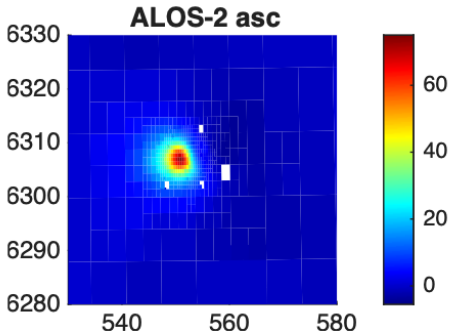
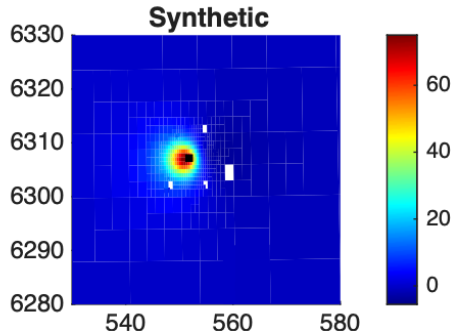


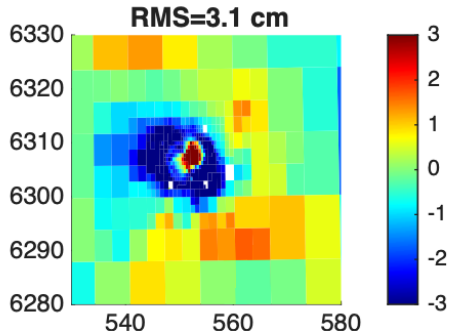






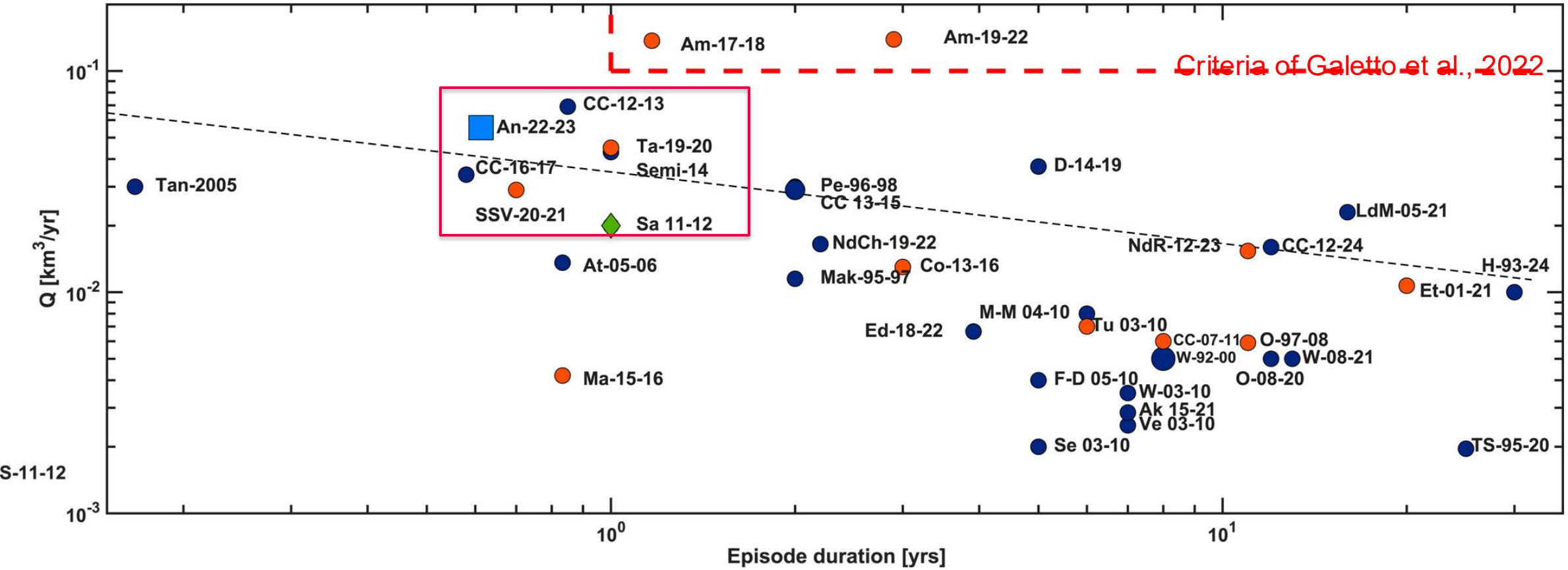






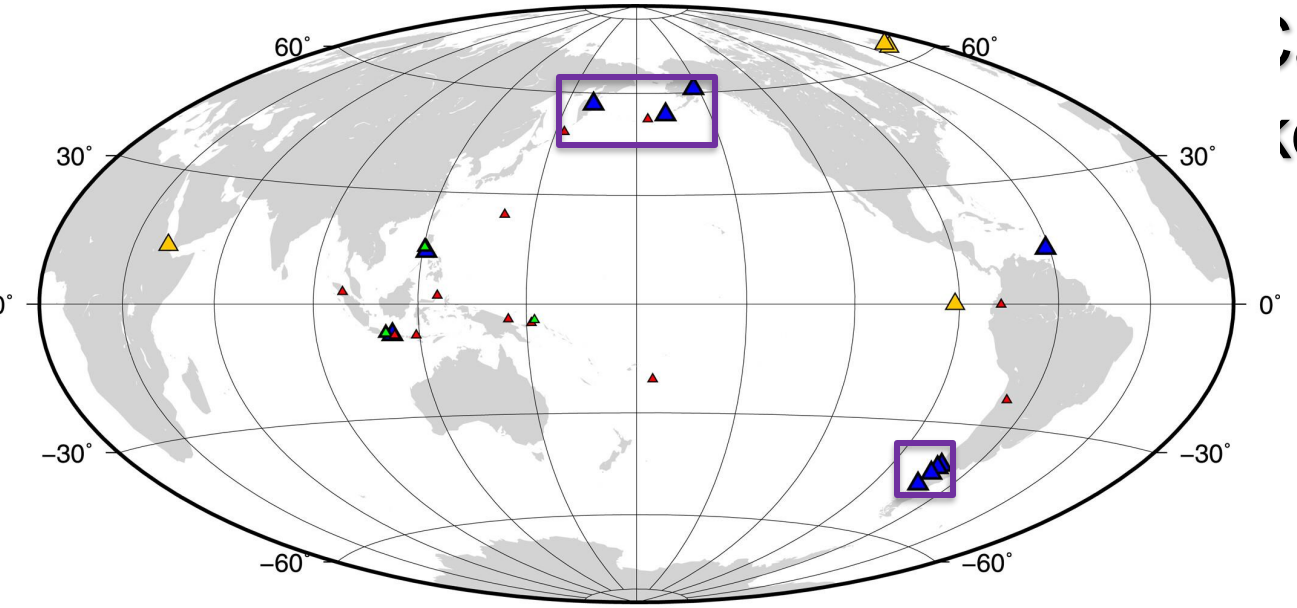
Delgado, GRL, 2026

Global comparison of magma flux in pressure sources subduction zones



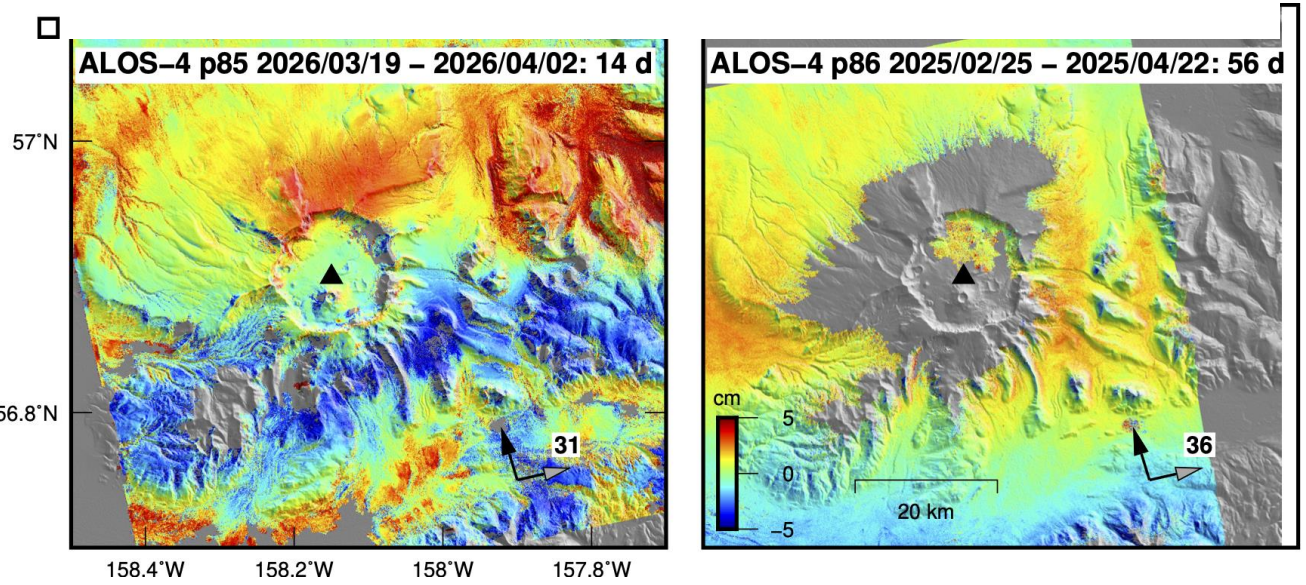
Delgado, GRL, 2026

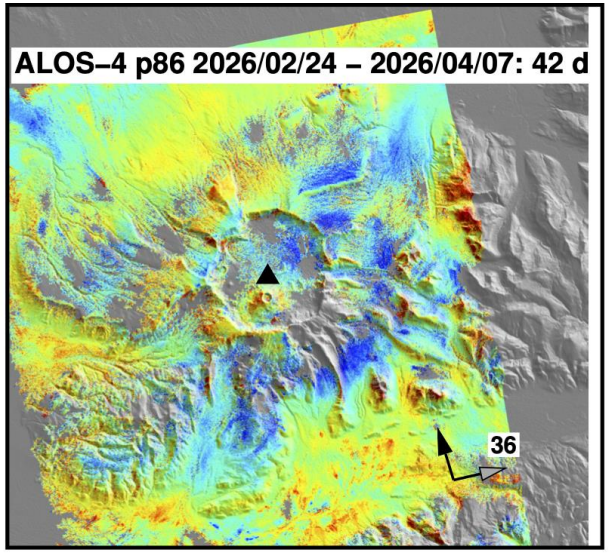
- Magma is assumed to be an incompressible fluid
- Inverse relation
- High magma flux is short lived in subduction volcanoes. Aniakchak-like deformation is quite rare on a global scale.
- Many non-eruptive cases: inflation is by itself non-indicative of eruptions
- Pressure build-up must be episodic and last for decades to trigger an eruption

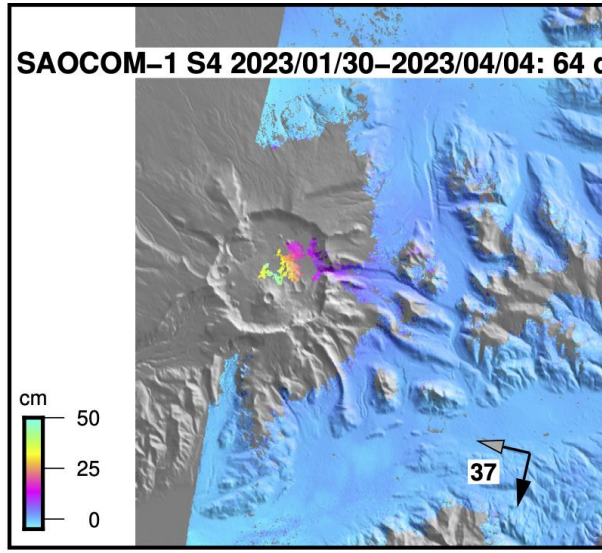


Can we systematically track episodes like this on high latitudes all year long?

- ALOS-4 has acquired at most 7 SLCs per track in one year.
- L-band can sometimes sustain coherence during the winter
- Not suitable for time series

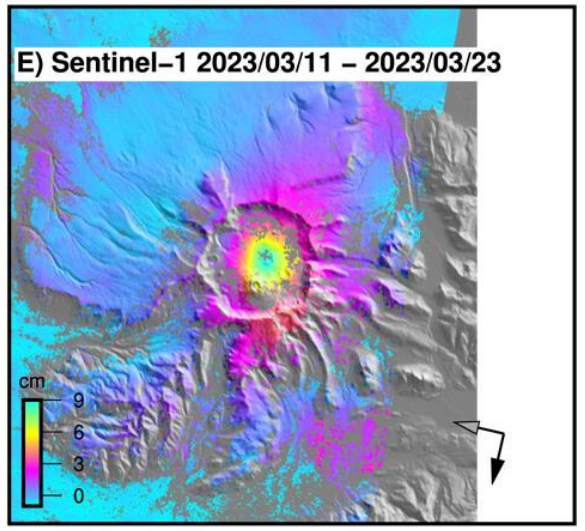


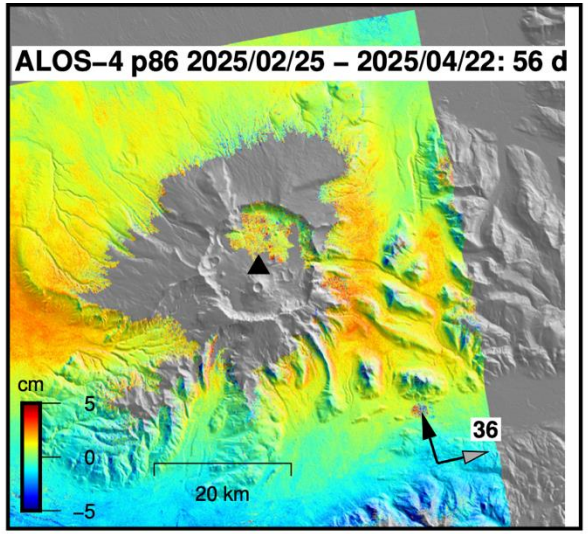




Can we systematically track episodes like this on high latitudes all year long?

- Sentinel-1: no, except exceptionally individual interferograms
- NISAR: six 12 day-long interferograms available during Nov25-Jan26. Too few data to draw a conclusion
- ALOS-2: no data acquired during the boreal winter
- ALOS-4: some interferograms good, some low quality. Too few data to draw a strong conclusion
- SAOCOM-1: some interferograms decent, most of them low quality
- LuTan-1: ?
- BIOMASS (P-band): no data acquired over North America
- Short answer: we do not know yet, but NISAR should provide the answer





Conclusions

- Episodes of volcano uplift like that of Aniakchak 2022-2023 are rare on a global scale.
- **High magma flux in suduction zones** is episodic and short-lived. It rarely lasts long enough to trigger an eruption
- Comparable cases
  - Ambrym 2020-2022 *[Shreve et al., 2023]*
    - Nearly continuous magma flux
  - Cordon Caulle 2012-2013 *[Delgado et al., 2016]*
    - Uplift decreased by pressure gradient
  - Laguna del Maule 2007-2025 *[Navarrete et al., GRL, 2026]*
    - Nearly continuous magma flux. V_Z ~50 cm/yr during second half of 2025
- We need more L-band data acquired with a much higher temporal frequency than what we do today to track episodes like this
- It seems to be more an issue of coordination, not a technical problem

- ANID FONDECYT Regular 1251171

- Tara Shreve and Ronni Grapenthin (Geophysical Institute, University of Alaska Fairbanks)