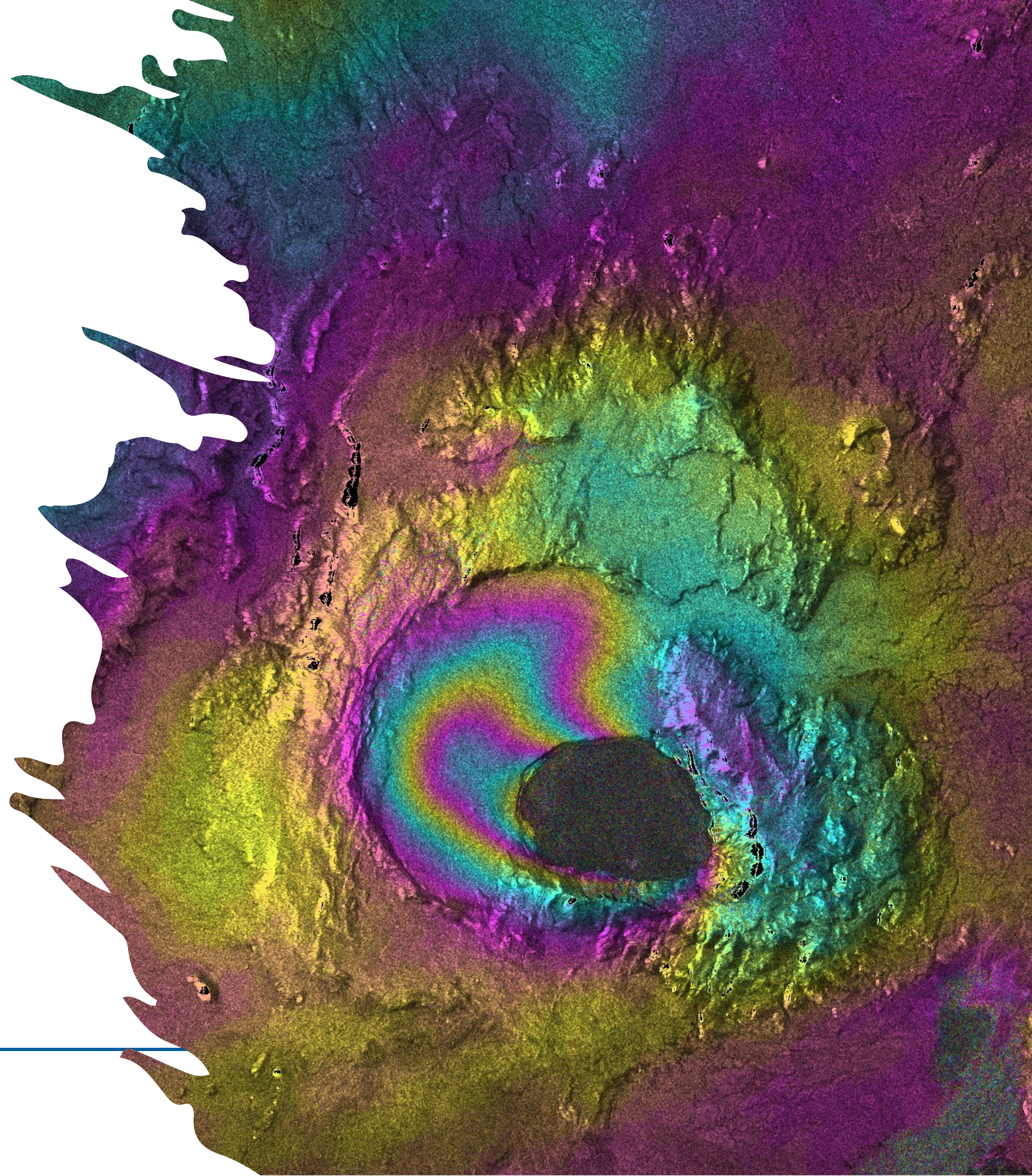
InSAR Reveals Interaction Between an Inflating Magma Chamber and Caldera Ring Faults at Askja Volcano, Iceland



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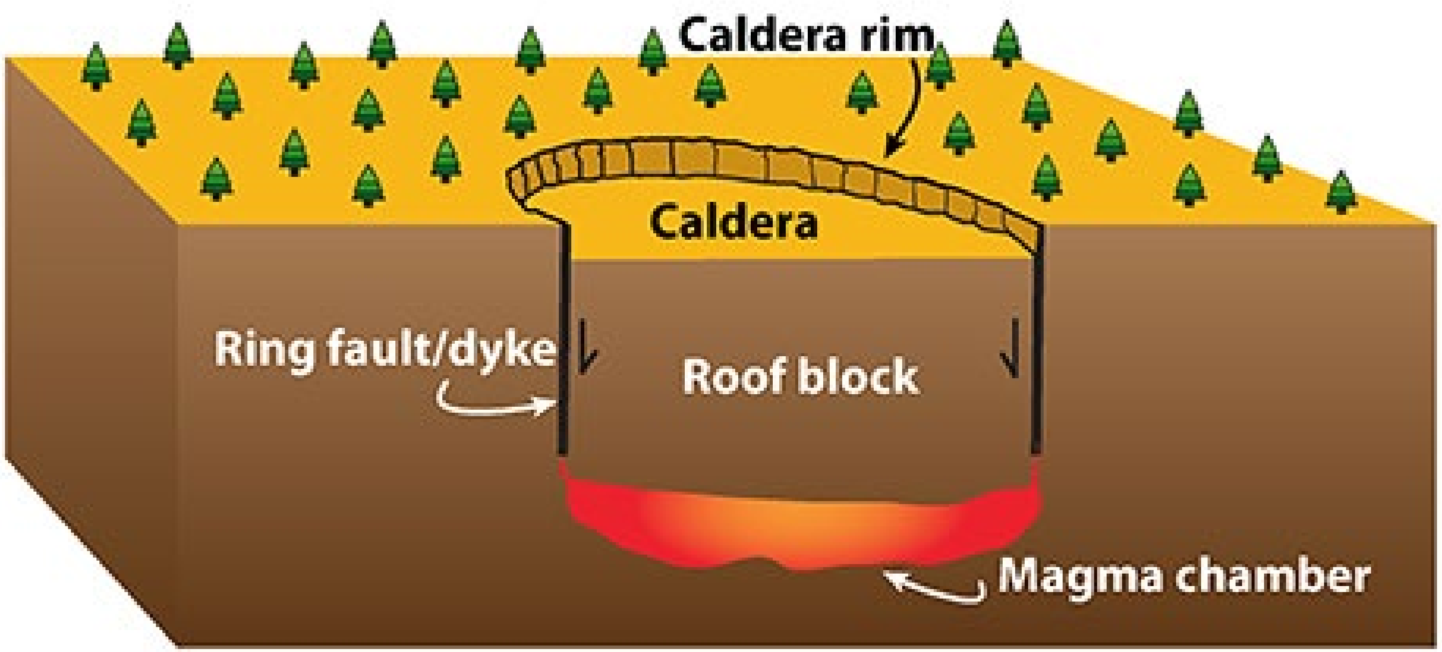
GFZ Helmholtz Centre Potsdam

Fringe 2023 – ID 249 – Sep. 13

Caldera Formation

Ring Fault (RF)

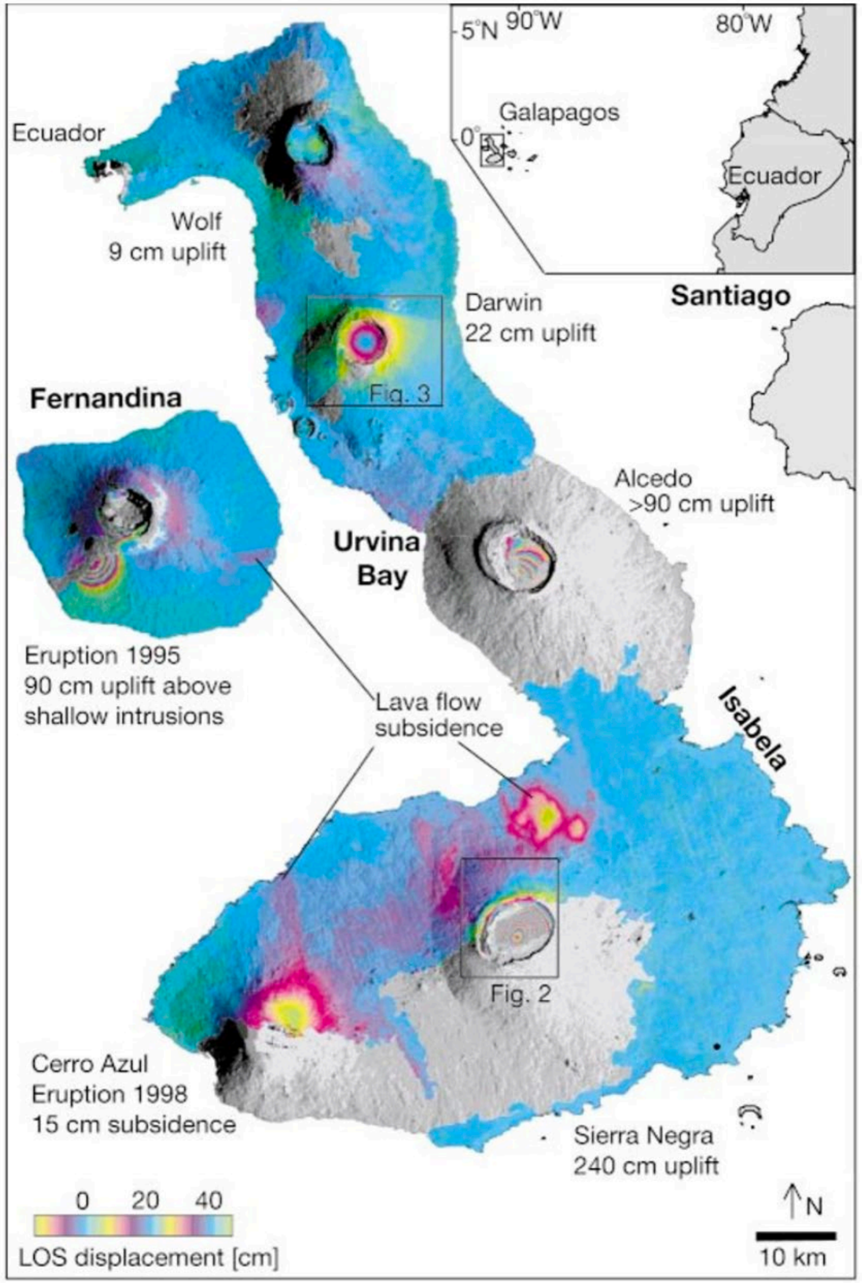


Geyer and Martí, 2014

→ Emptying of the magma chamber (eruption or intrusion)

→ Collapse of the roof block through the Ring Fault

→ Characteristic caldera depression

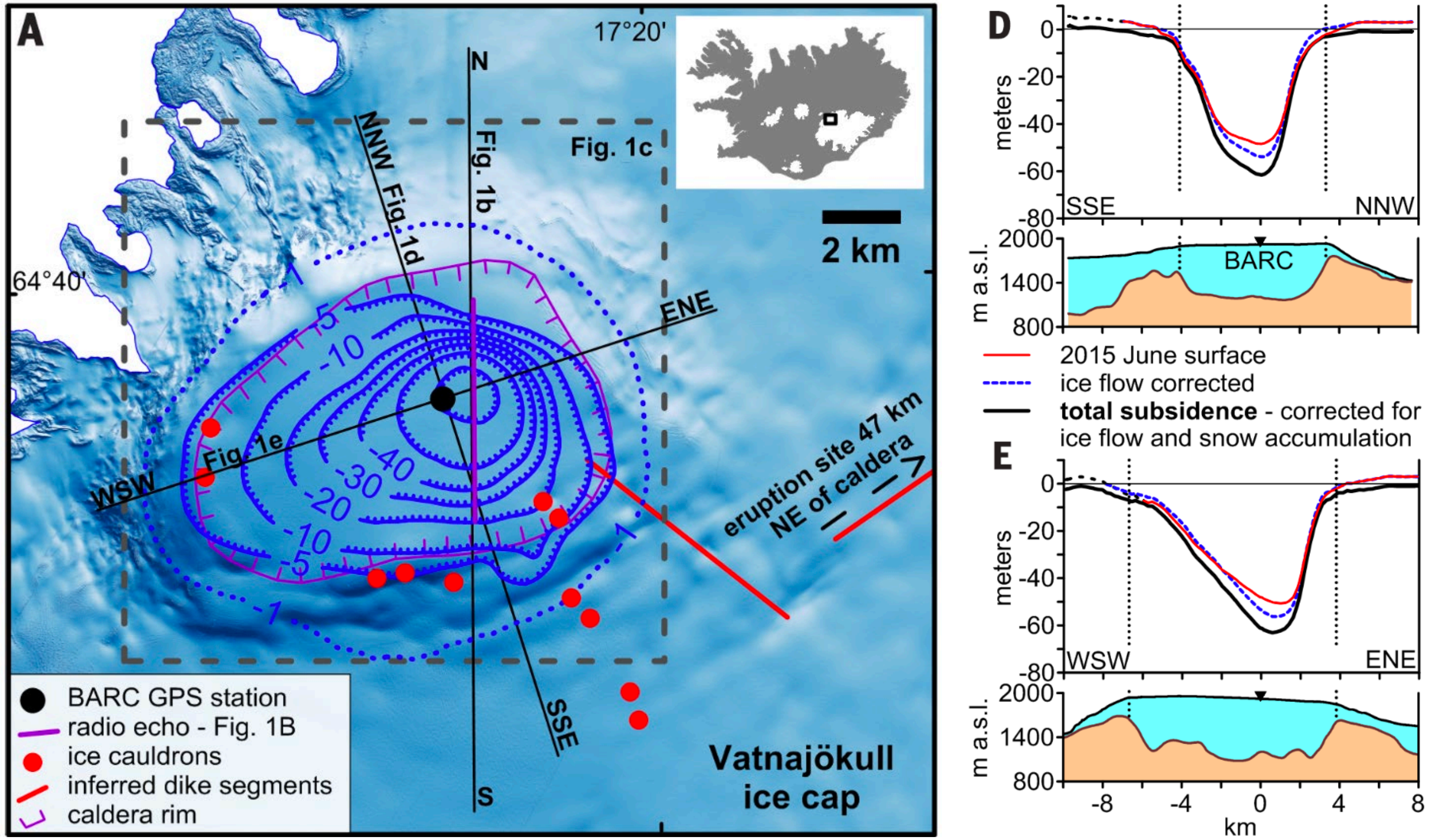


Amelung et al., 2000

Effects of the RF on the Ground Deformations

→ Constrain and enhance the GD inside the caldera rims

→ Produce asymmetries in the deformation pattern



Gudmundsson, 2016

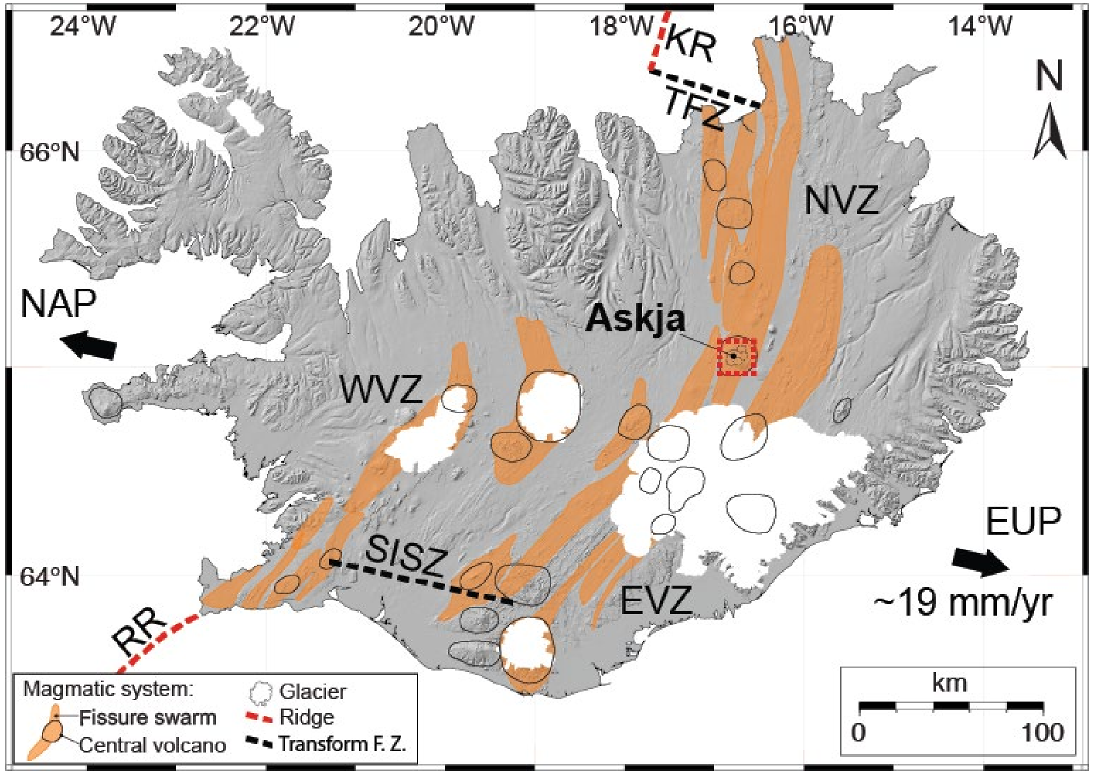
Askja Volcanic System

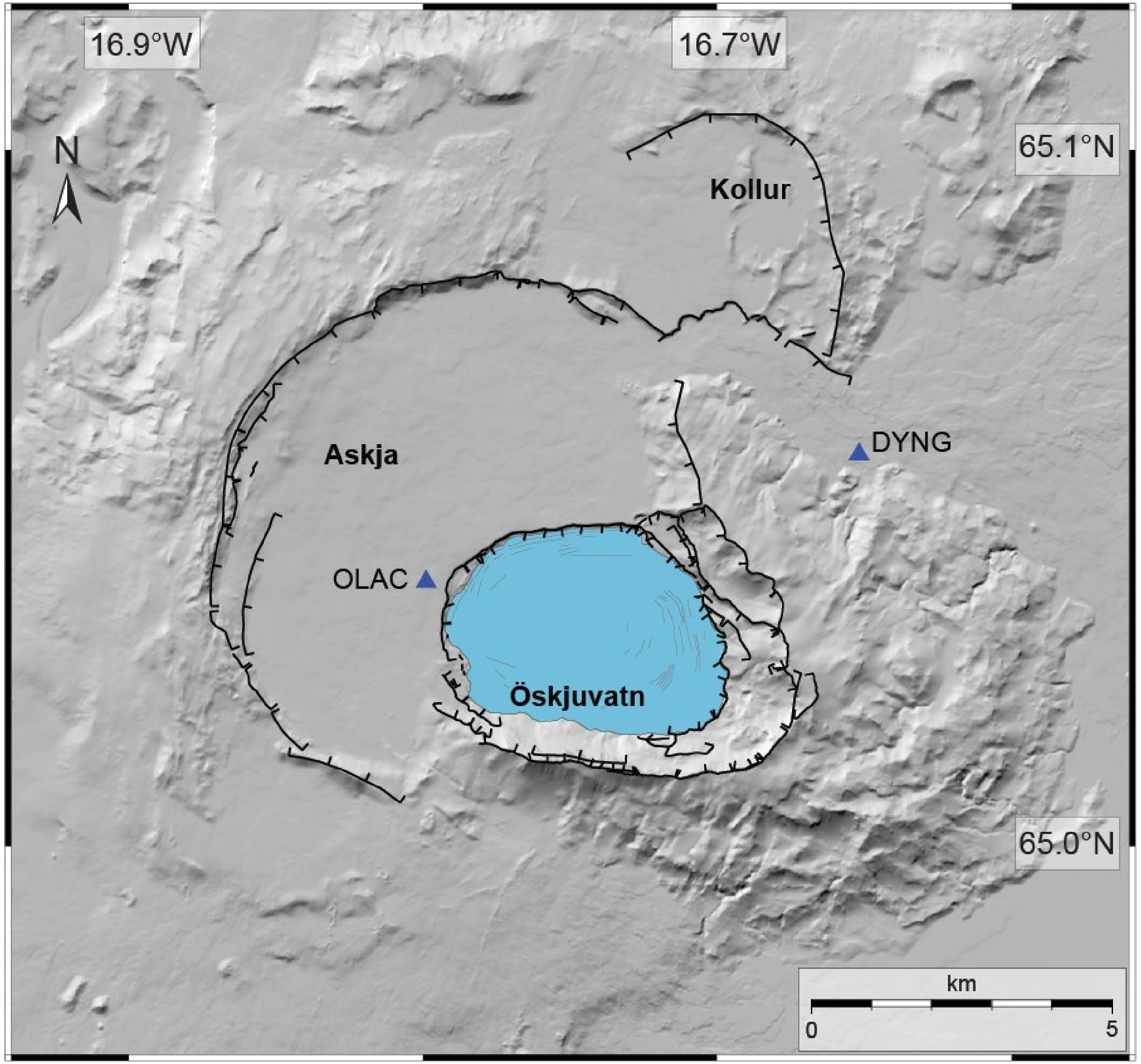
→ Along the NVZ of the Icelandic Rift

→ Central volcano (three nested calderas)

→ Eruptive fissure swarms (N & SW)

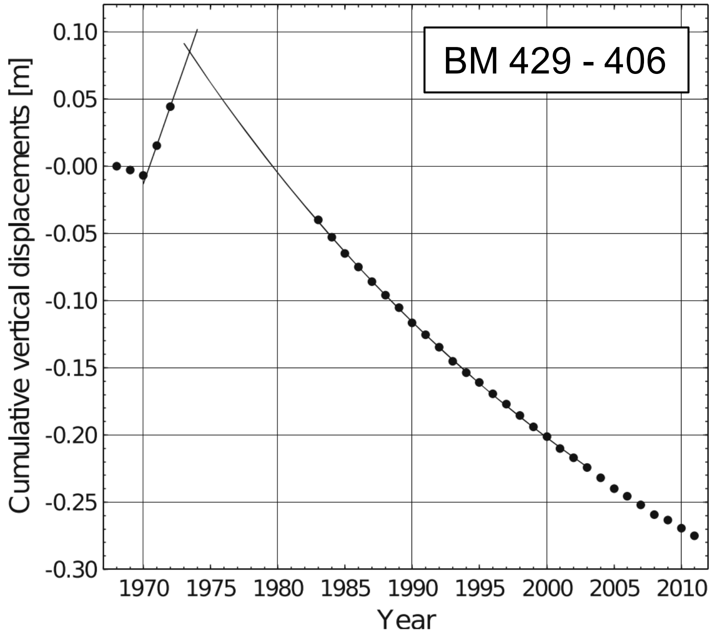
→ Explosive and effusive eruptions



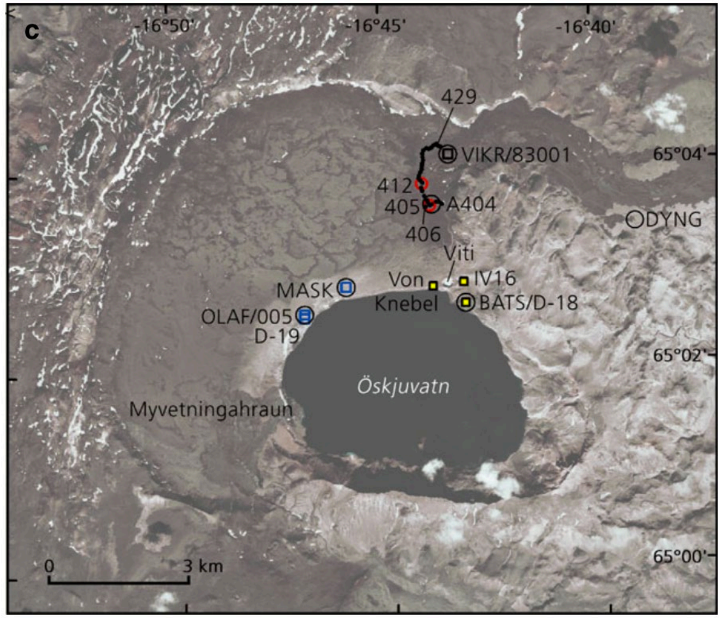


Askja Ground Deformation

1966-2012

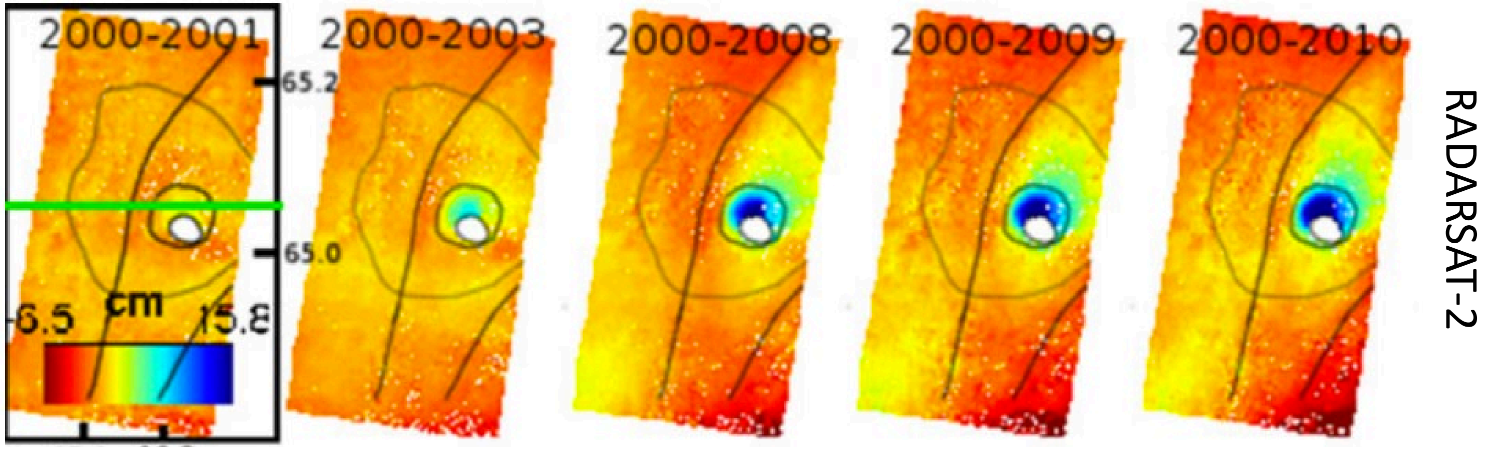


- → Levelling, GPS (campaign and continuous), InSAR
- → Uplift between 1970-1973
- → Continuous slowly decaying subsidence since 1984 (possibly since 1974) until 2012

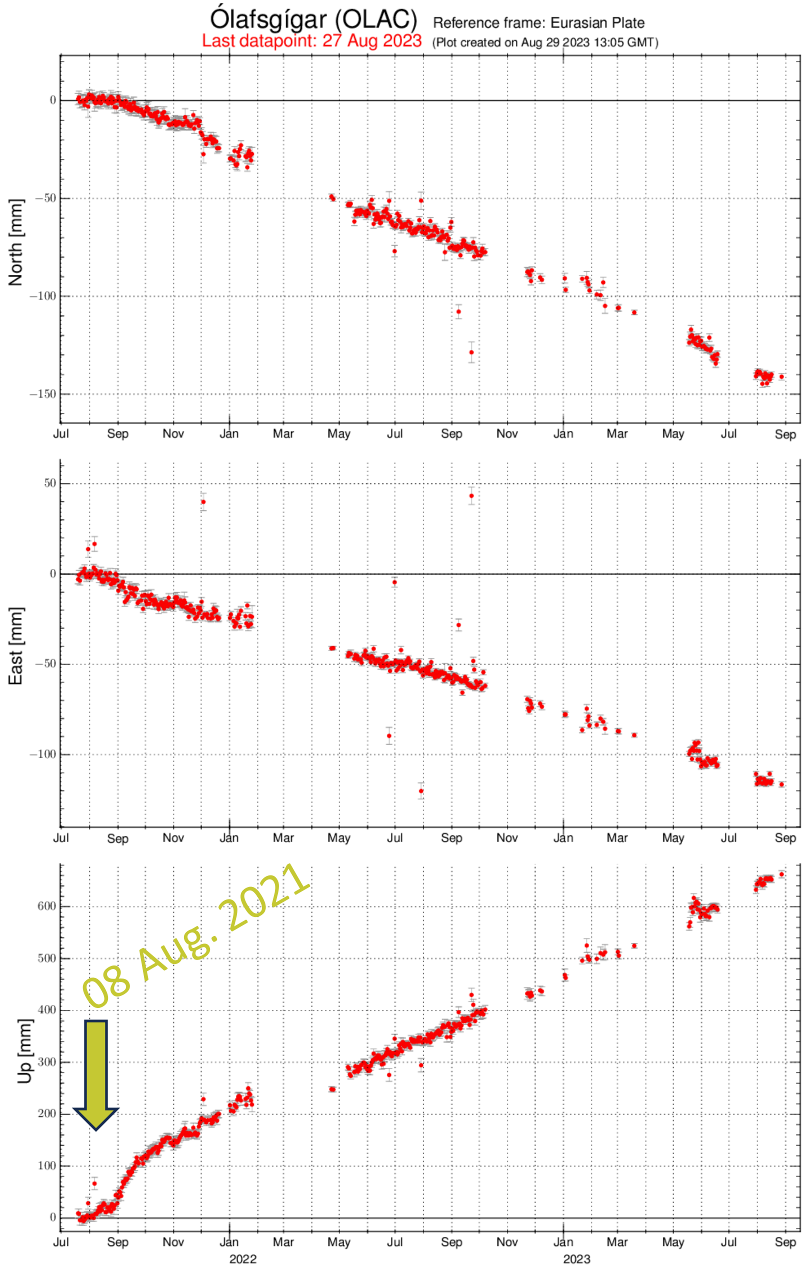


de Zeeuw-van Dalfsen et al., 2013

Source models suggest:
Shallow (~3 km deep) **contracting magma chamber**
at a divergent plate boundary



Icelandic Met Office



Current Volcanic Unrest

August 2021

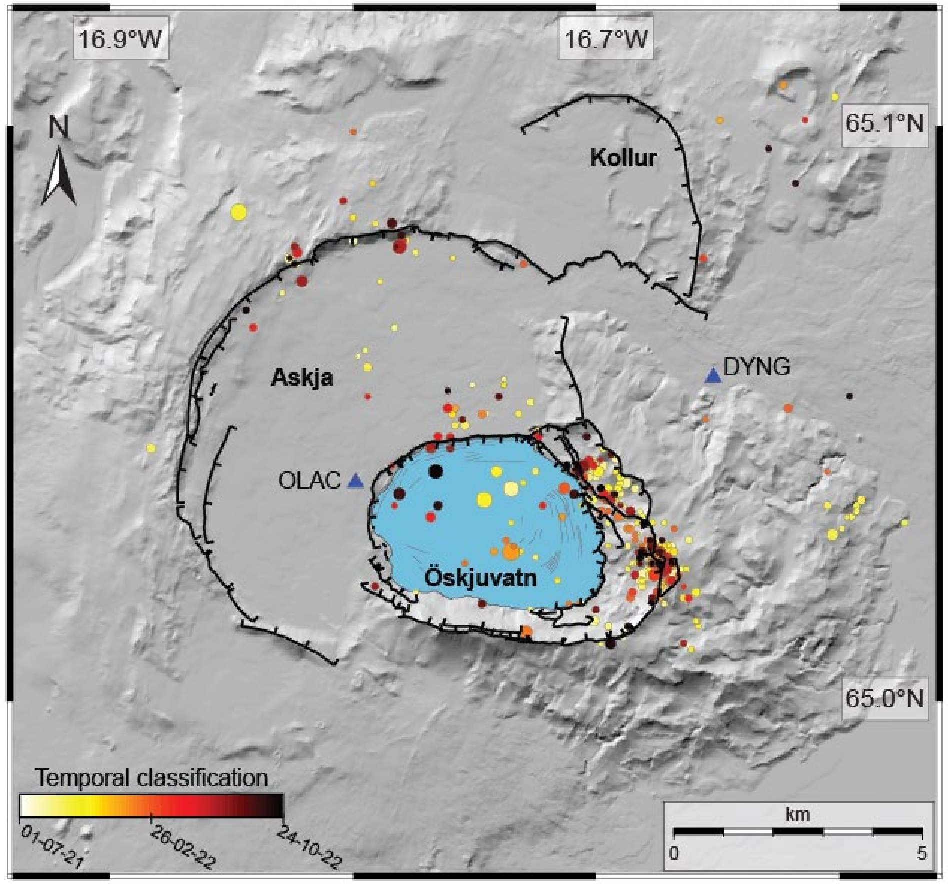
→ Change in the def. trend - **Uplift**

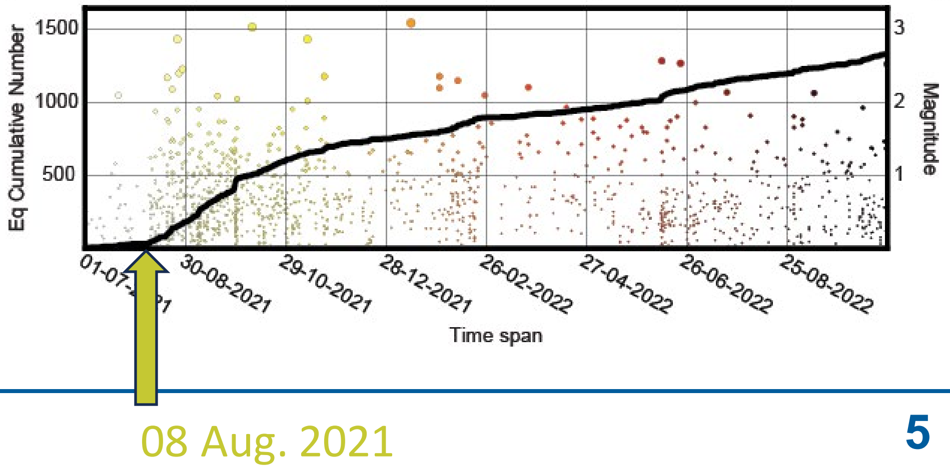
- >60 cm/yr Aug - Nov
- ~30 cm/yr – constant

→ Increase of the **seismicity**

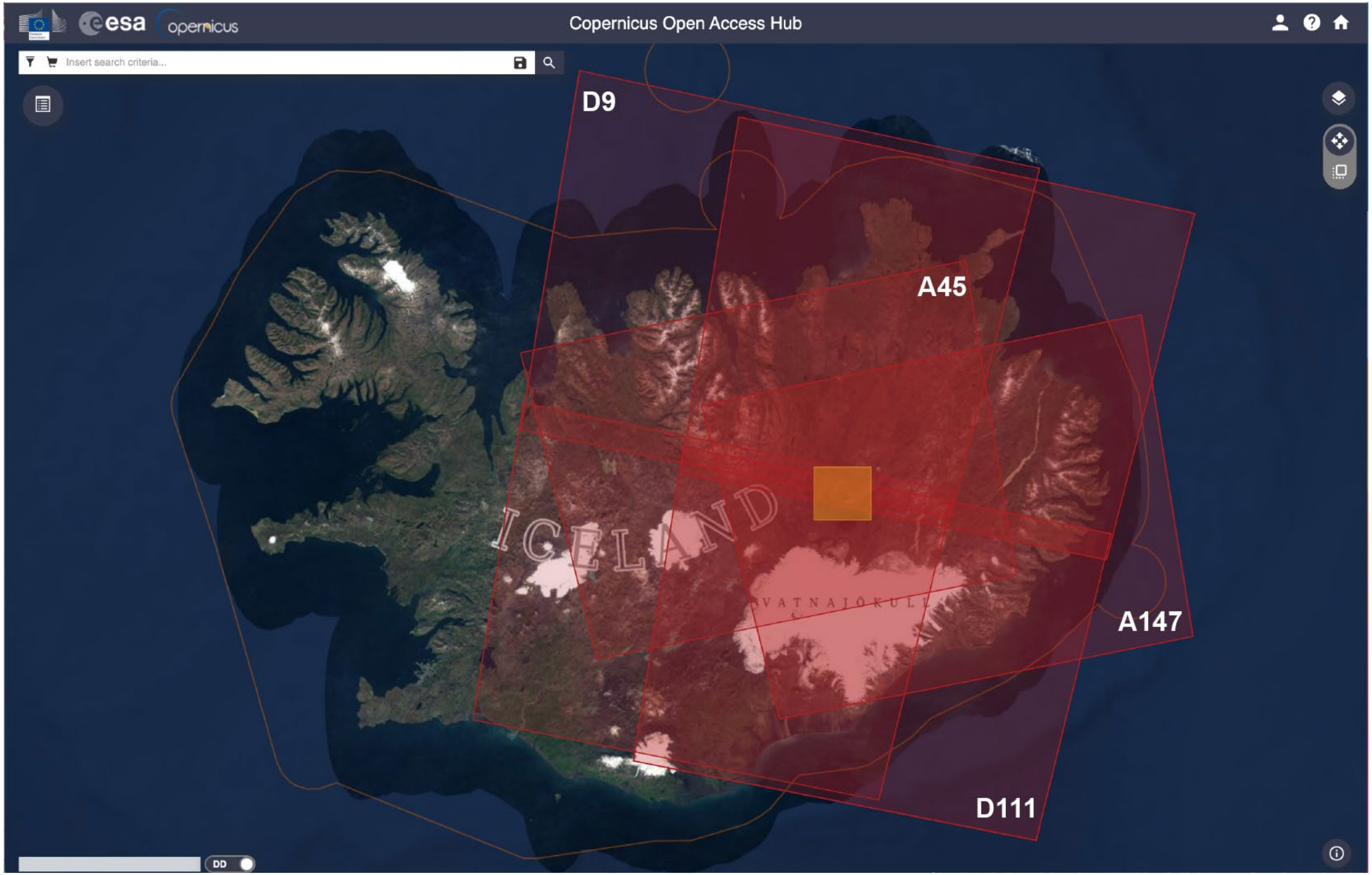
- Background level from Nov
- A few bursts of seismicity later

Seismic data from IMO catalog





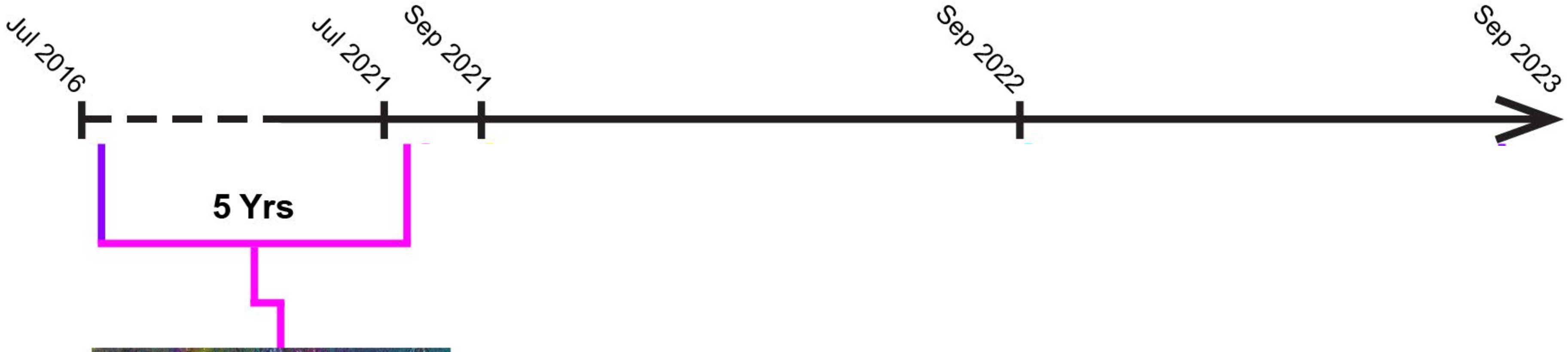
Askja – Sentinel-1 Dataset



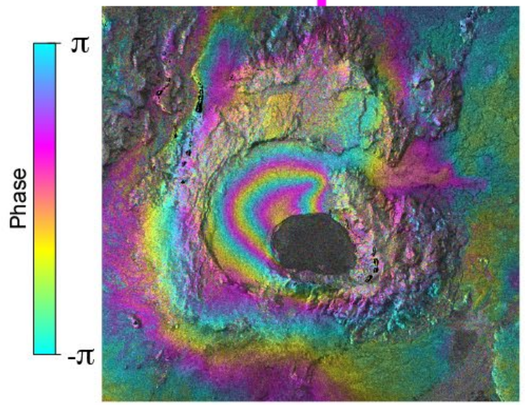
Askja – Sentinel-1 Dataset

Sentinel-2 – Sentinel Playground

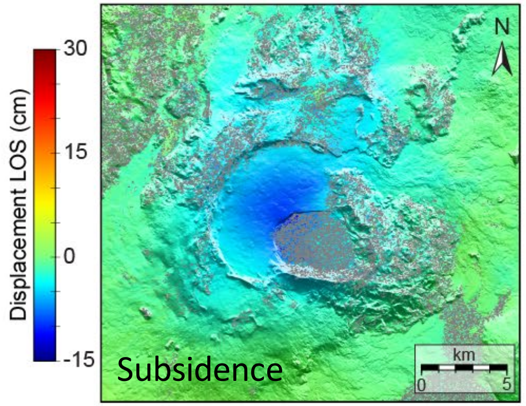
A147 - Interferograms



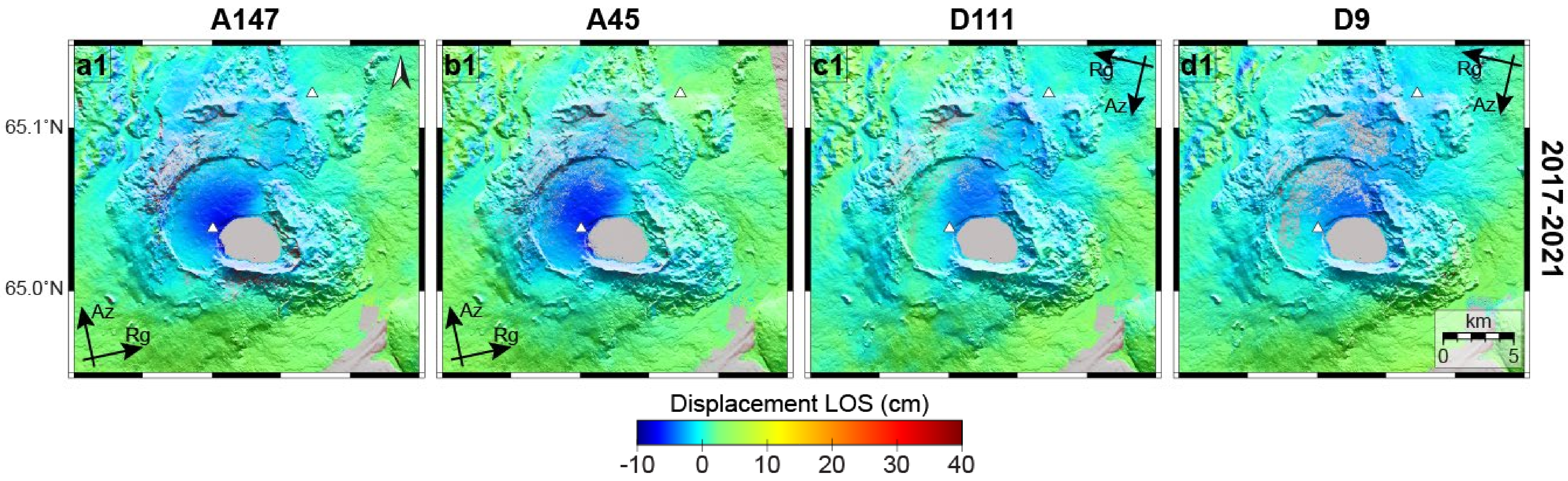
Filtered IFG



Def. Map



InSAR – Deformation Maps

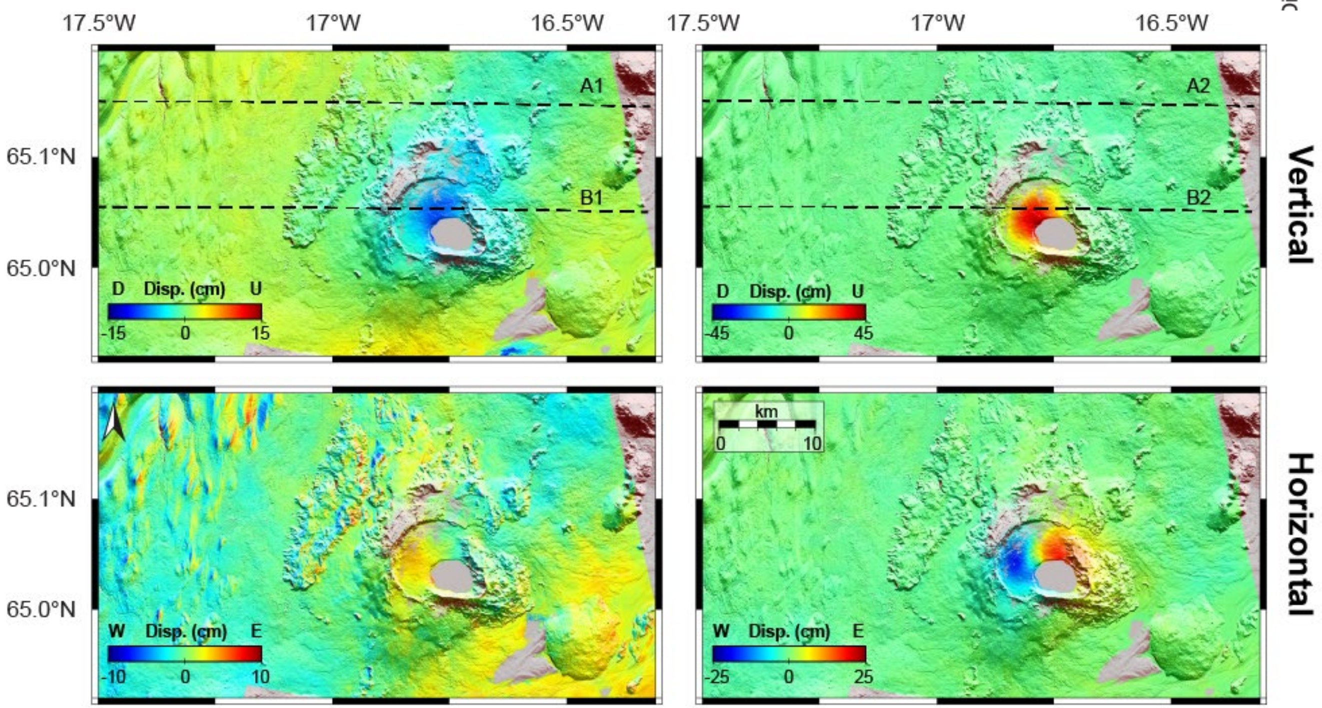


InSAR – V and EW Components

→ A147 + D111

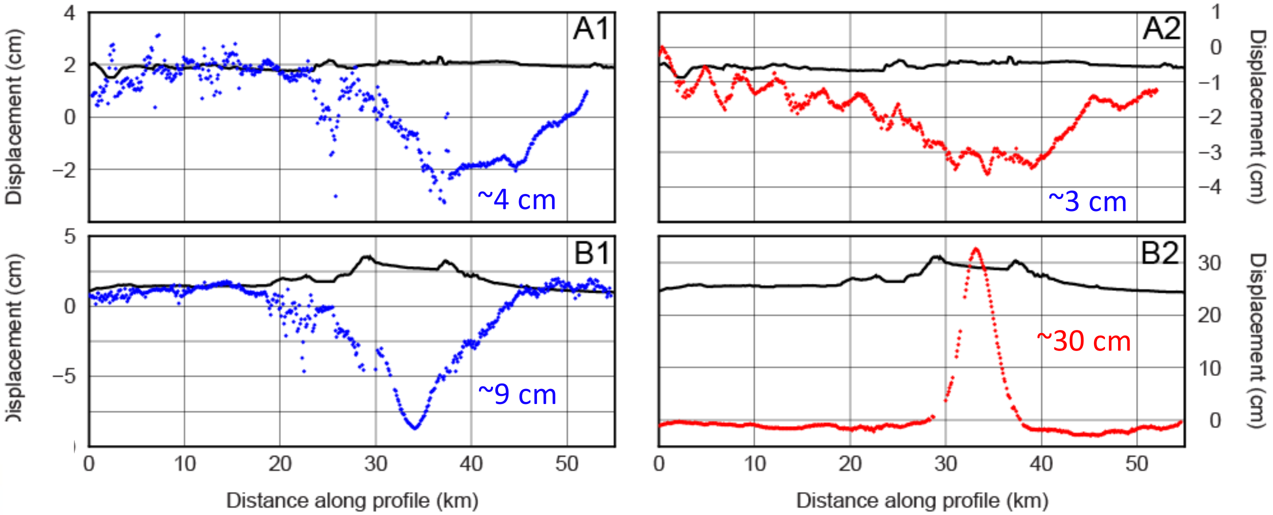
→ 2017-2021 & 2021-2022 Def. Maps

→ Large horizontal component



2017-2021 2021-2022

2017-2021 2021-2022

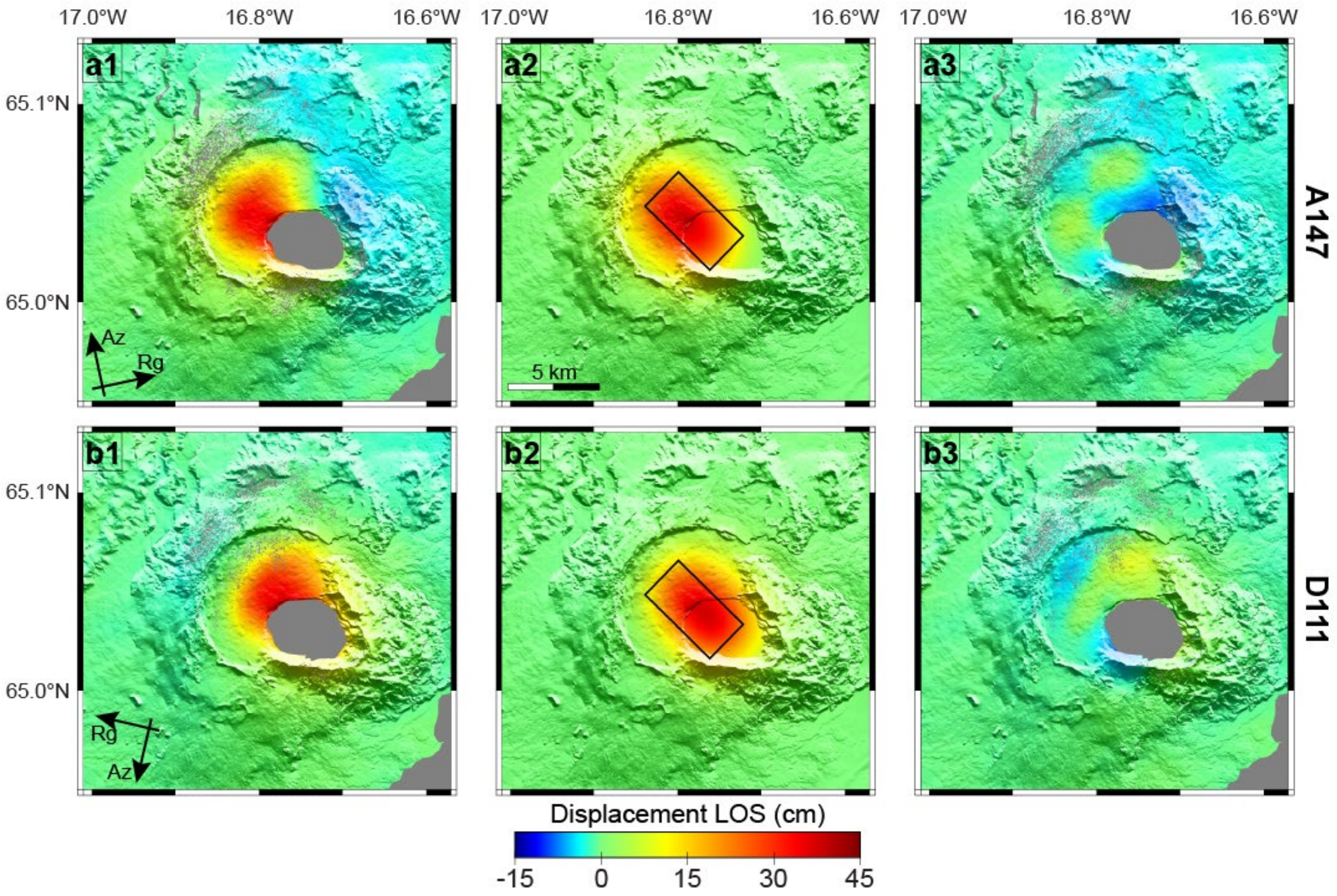


→ Subsidence north of the central volcano

→ Faster during the unrest episode

Possible interaction between the Askja magma plumbing system and rift opening

InSAR – Deformation Source
2021-2022



→ Analytical model - Joint inversion of the 4 orbits

→ Geodetic Bayesian Inversion Software - GBIS

→ Elastic half-space – μ = 0.25

Explained deformation:
A147: ~61% ♦ **A45**~56% ♦ **D111**: ~71% ♦ **D9**: ~55%

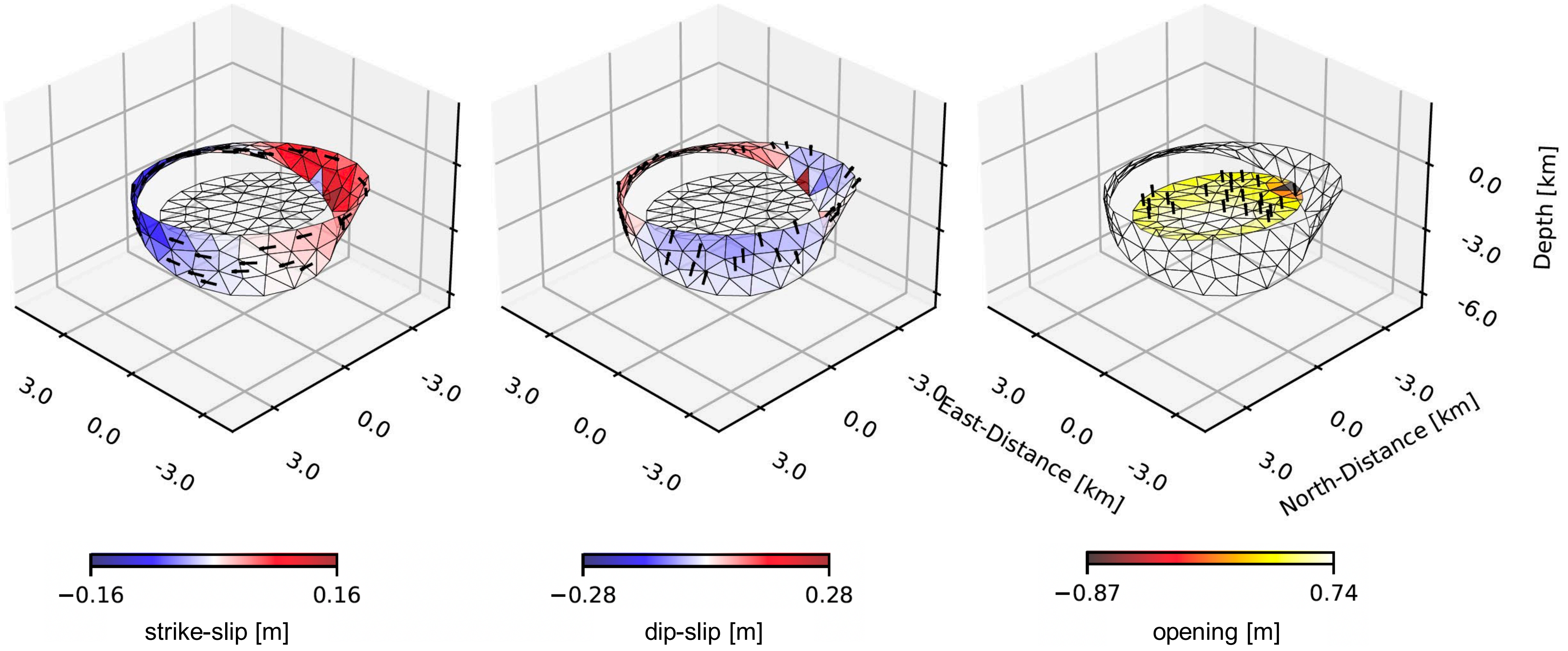
One Source – **Sill-like**

- **Depth: 2.6 km**
- Length: 5.1 km
- Width: 2.7 km
- **Opening: 0.9 m**
- ΔV: 12.4e-6 km^3
- **Strike: N33°W**

InSAR – Deformation Source

2021-2022

Preliminary results



→ Boundary element models

→ Elastic half-space – μ = 0.25

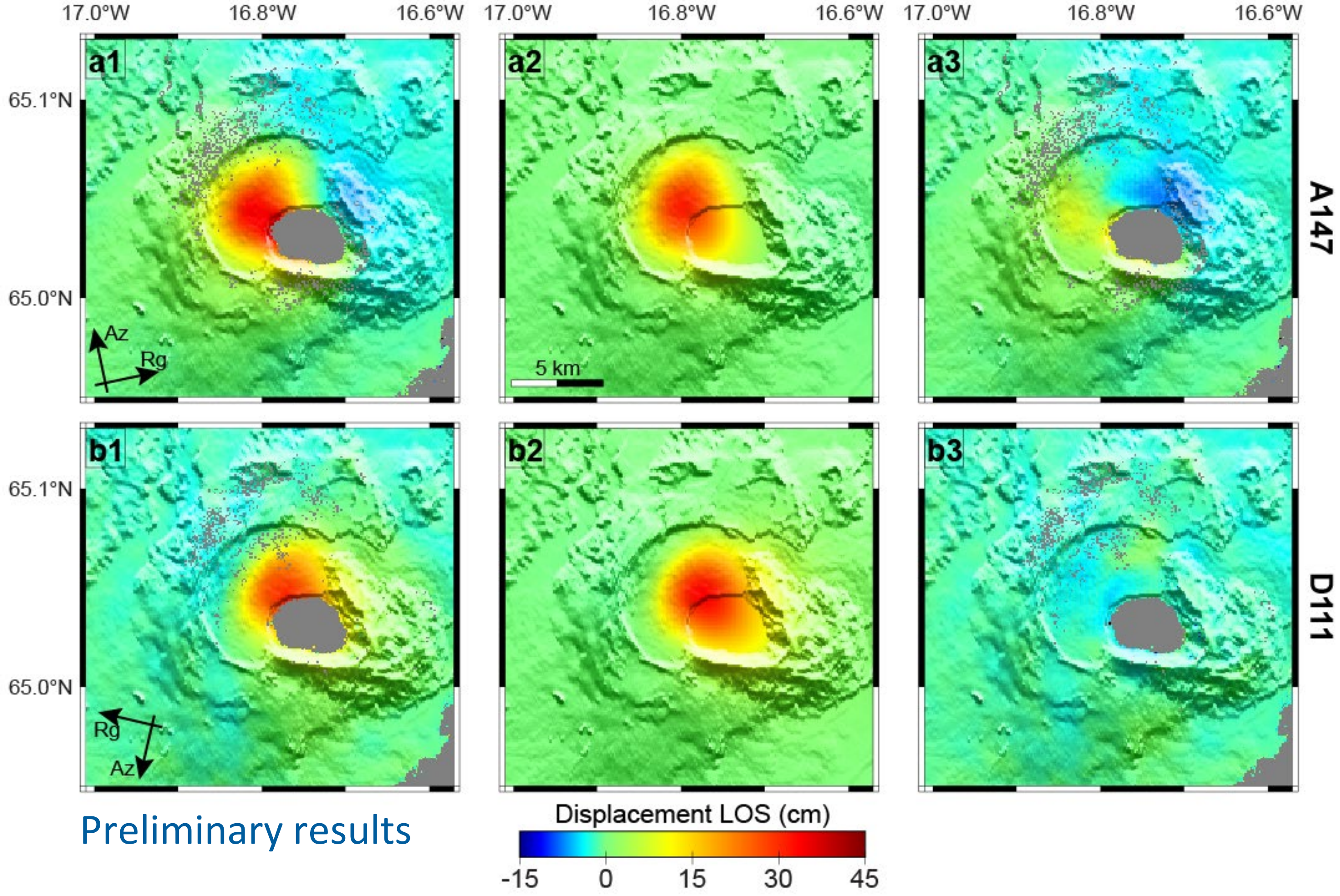
→ Bayesian Inference (MAP)

Sill + Ring Faults

The slip on the RF nodes is produced by the opening of the sill

BEAT
BAYESIAN EARTHQUAKE ANALYSIS TOOL

InSAR – Deformation Source
2021-2022



Preliminary results

→ Asymmetry In the displacement pattern

→ Descending residuals: no evident pattern

→ Ascending residuals: on the east can be related to low seis. Vel. zone

Variance reduction:

A147: ~70% ♦ **A45**~64% ♦ **D111**: ~90% ♦ **D9**: ~83%

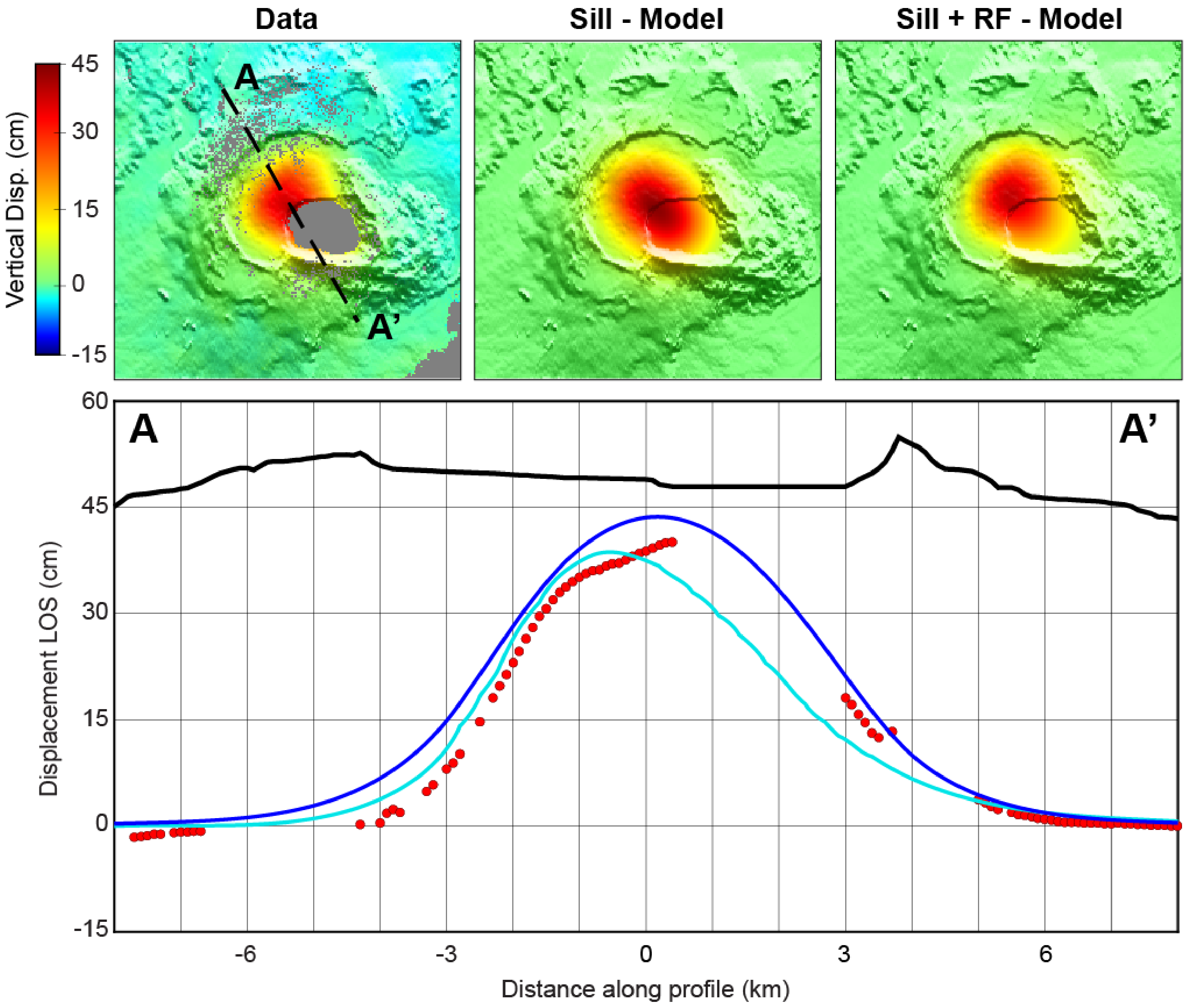
→ Sill

- Depth: 3.2 km
- Opening: 0.5 – 1.1 m
- Strike: N30°W

→ RF

- Depth: 0.8 – 3.1 km
- Strike: N35°E
- Dip: ~40° inward

Sill vs Sill + RF
Vertical component



→ **Sill**

- Overestimate the displacement
- Is symmetric with respect to the center of the sill

→ **Sill + RF**

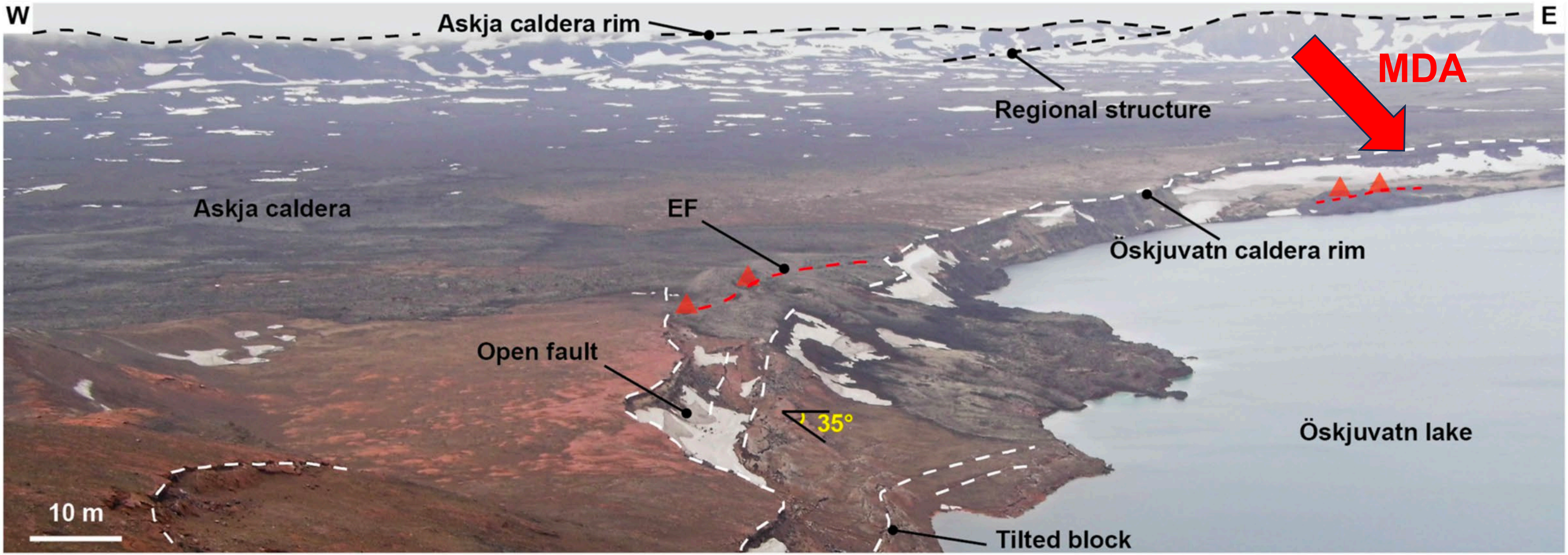
- It fits better the deformation
- Asymmetry

→ Anomaly on the shore's lake

→ The area is characterized by Öskjuvatn RF

Maximum Vertical Displacement Area

Trippanera et al., 2018



- In the middle of Askja Caldera
- Western shore of the Lake
- Close to Öskjuvatn caldera rim
- Eruptive fissures

Discussions

→ **InSAR at Askja volcanic system**:

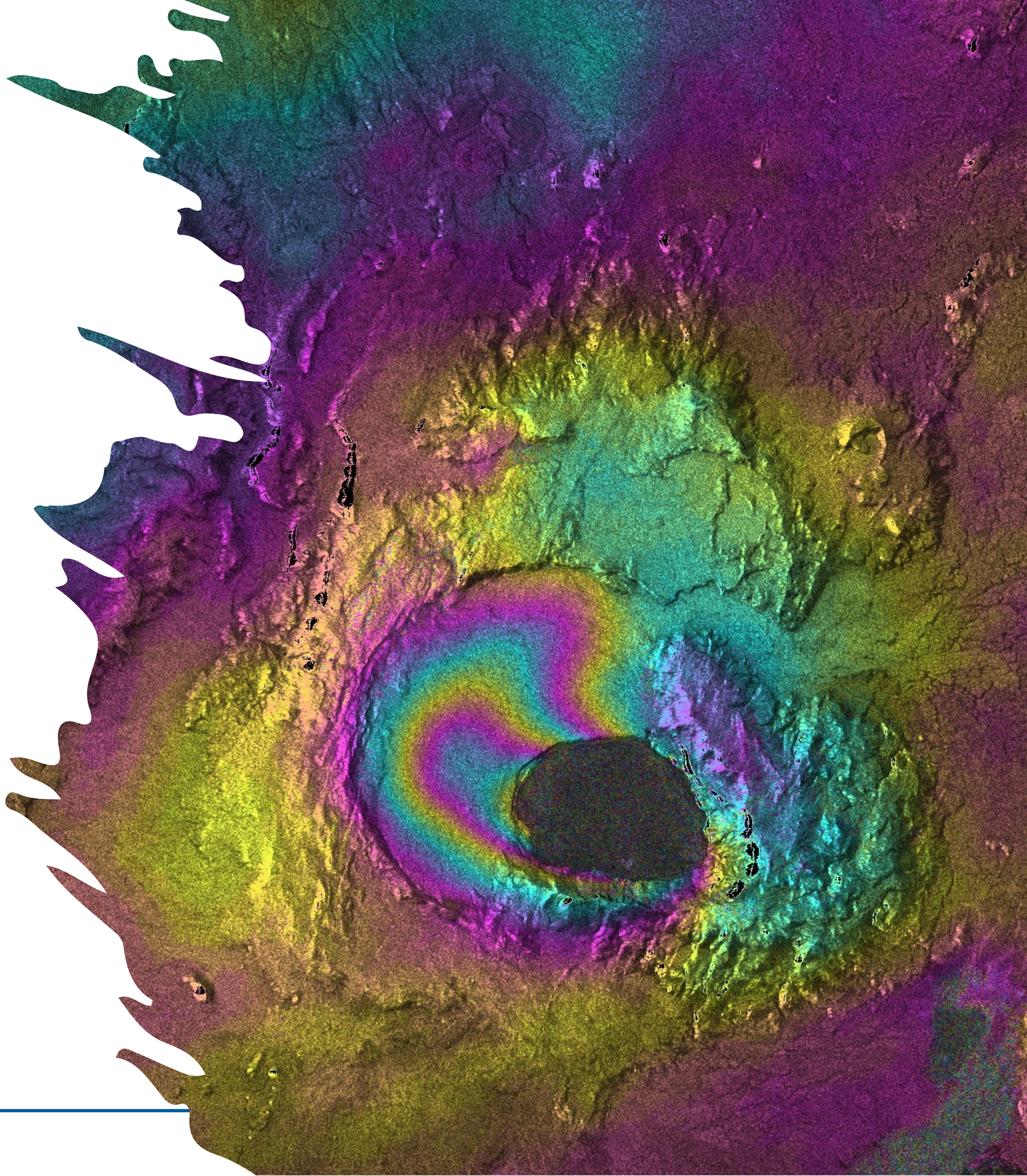
- 2016 – 2021 subsidence inside Askja Caldera
- 2021 – 2022 fast uplift inside Askja Caldera (ongoing)
- Possibly the same deformation source
- Rift extension and Askja magmatic system interaction

→ **Modelling**:

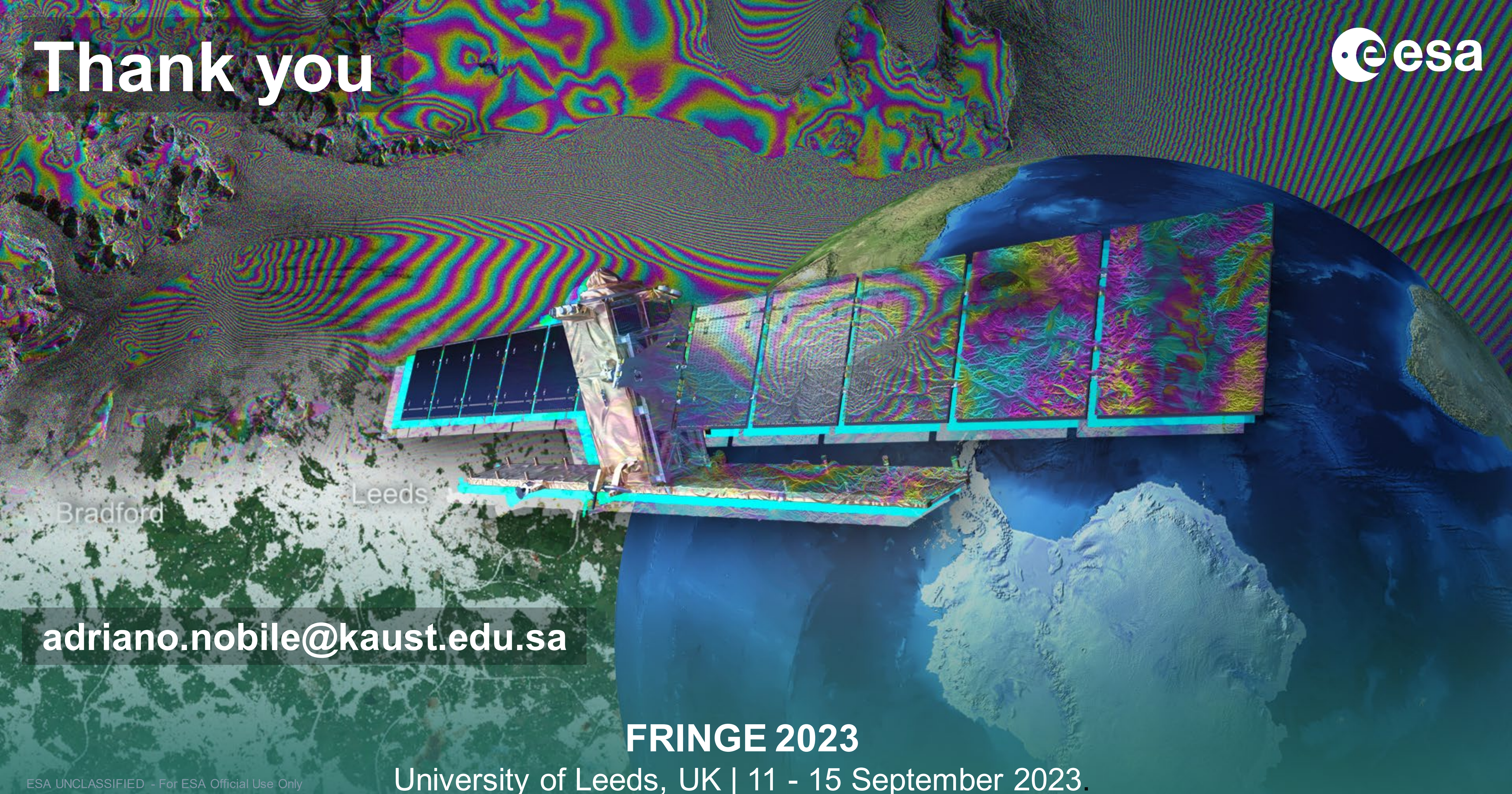
- One source cannot explain the observed deformation
- The interaction between the magma chamber and ring faults increases the fit with the data
- Other complexities (rift opening, spatial heterogeneities) cannot be modeled

→ **Monitoring**:

- Microseismicity
- Lake temperature



Thank you



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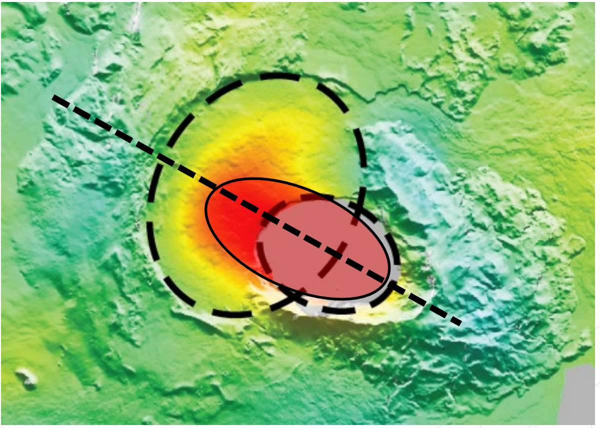
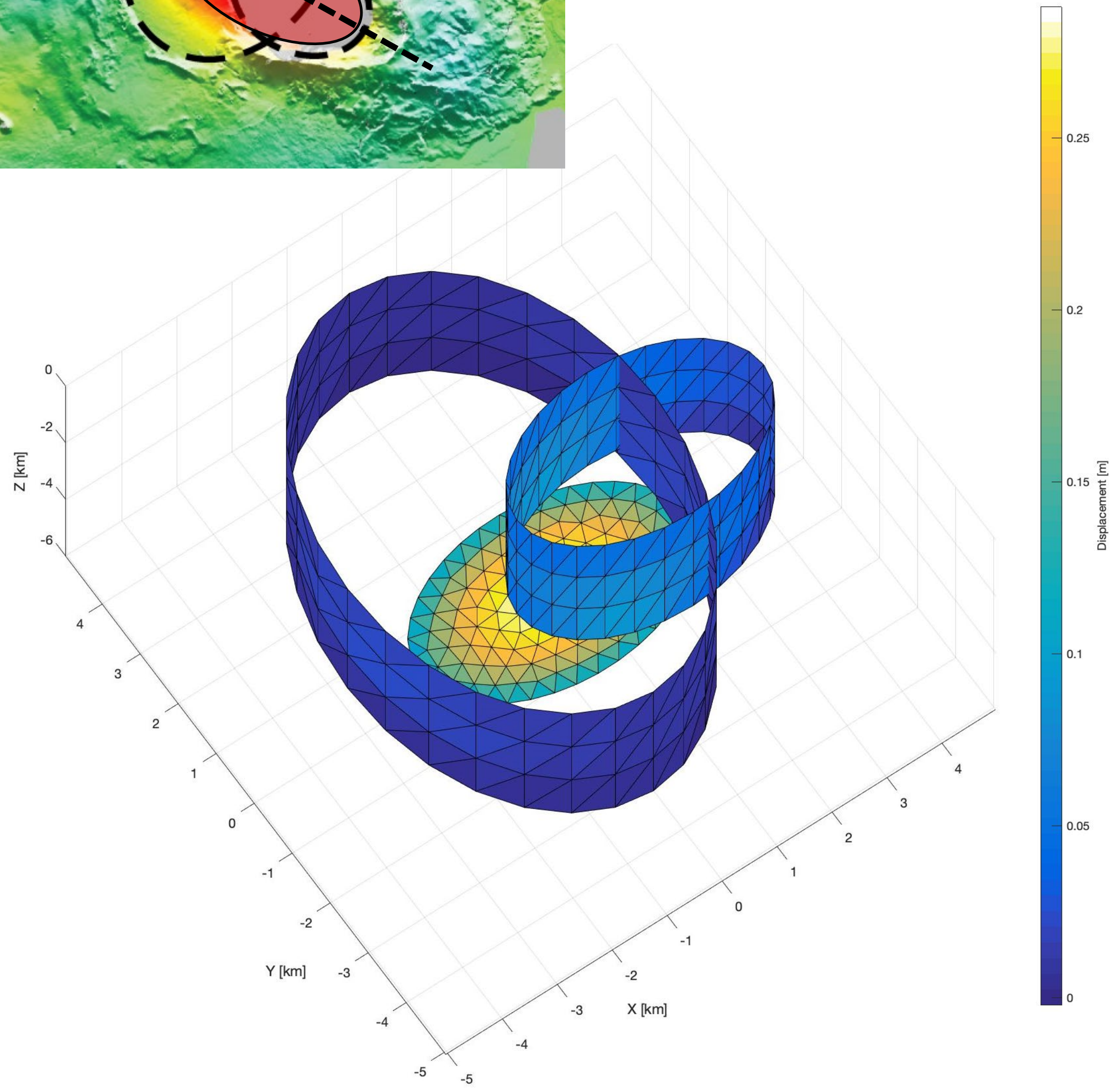
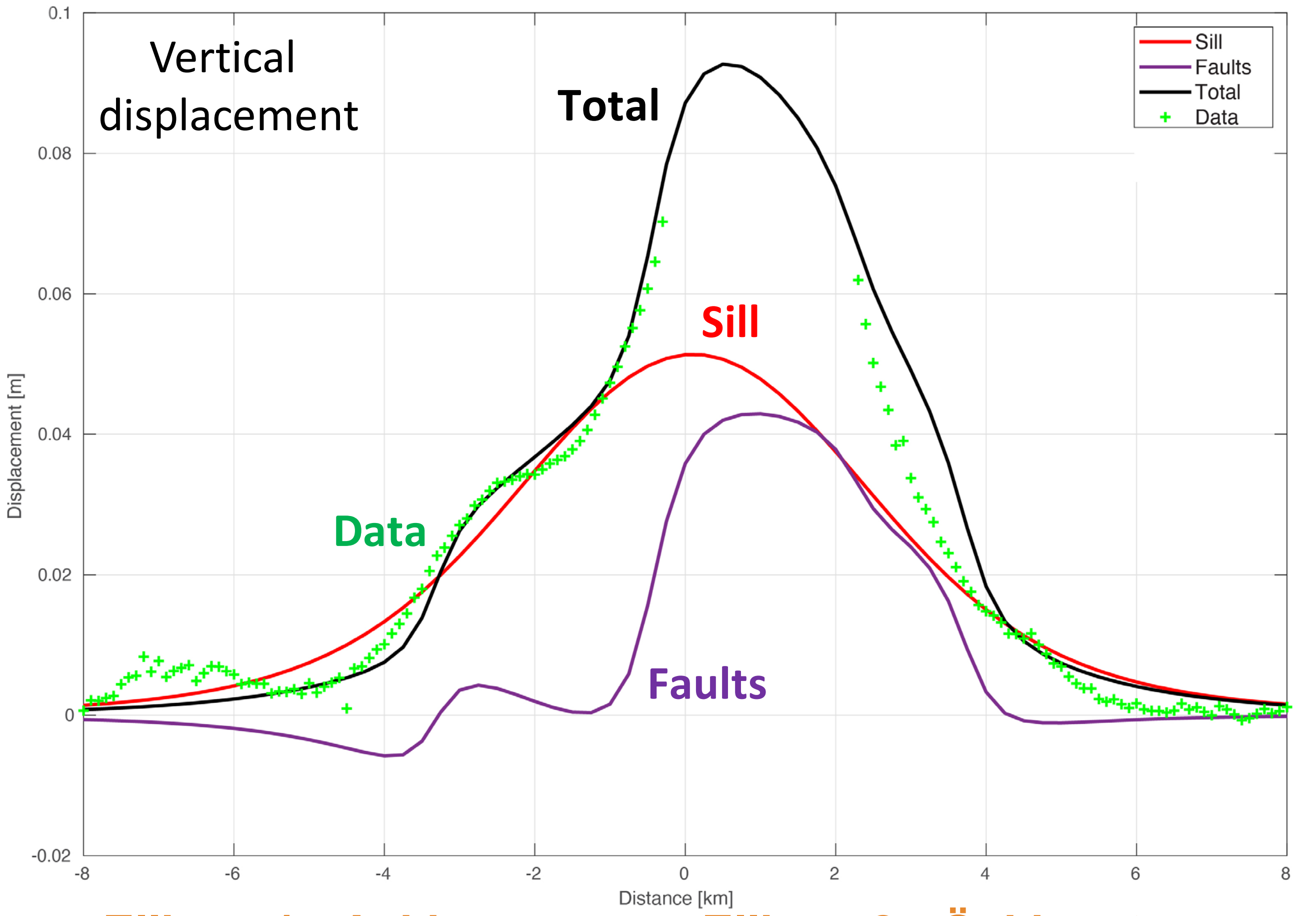
University of Leeds, UK | 11 - 15 September 2023.

Two ring faults







Ellipse 1 - Askja

- Semiaxis: 2.8 & 4.0 km
- Top: 0.5 km
- Width: 3.5

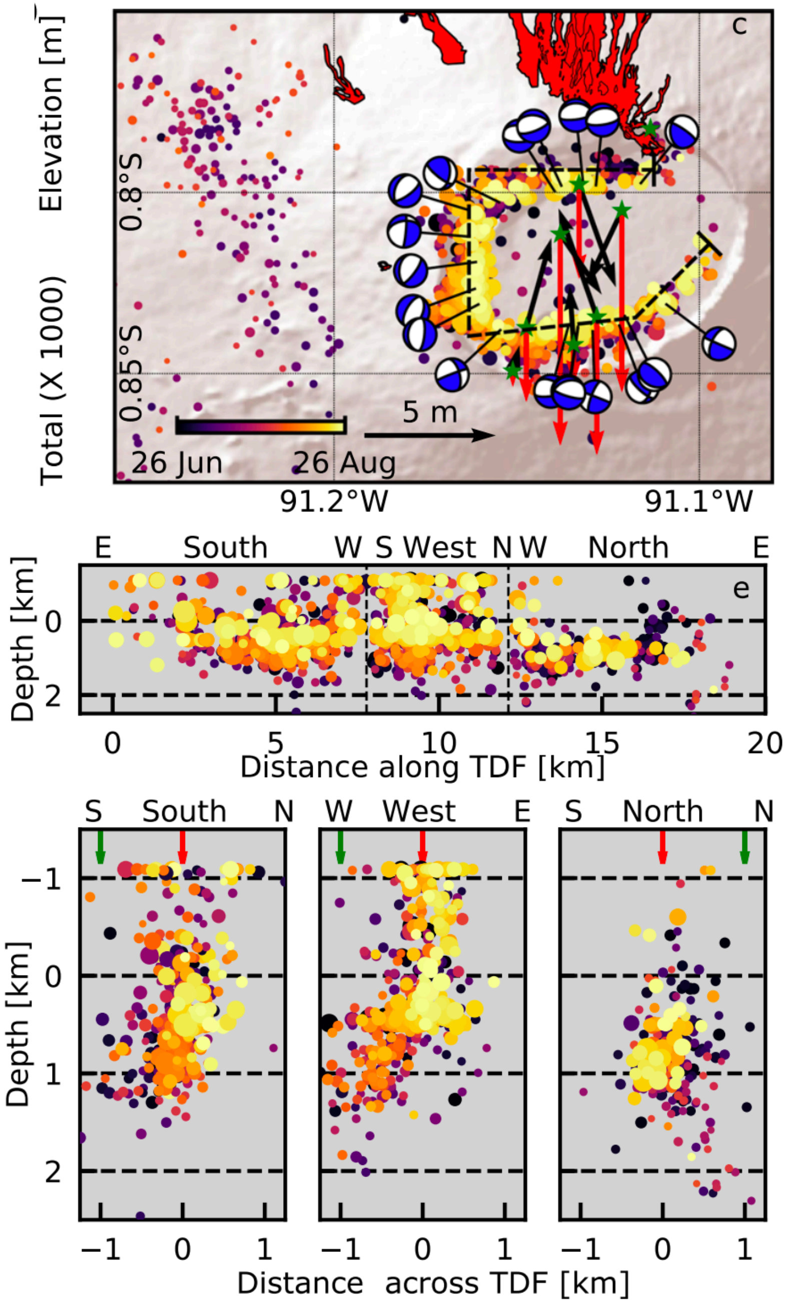
Ellipse 2 - Öskjuvatn

- Semiaxis: 2.25 & 1.5 km
- Top: 0.5 km
- Width: 3.3

Sill

- Semiaxis: 2.4 & 1.5 km
- Depth: 4.1 km

RF- Seismicity



Bell et al., 2021

Sierra Negra

Galapagos

→ 2018 eruption

→ Caldera collapse (~8.5 m)

→ Trapdoor faults

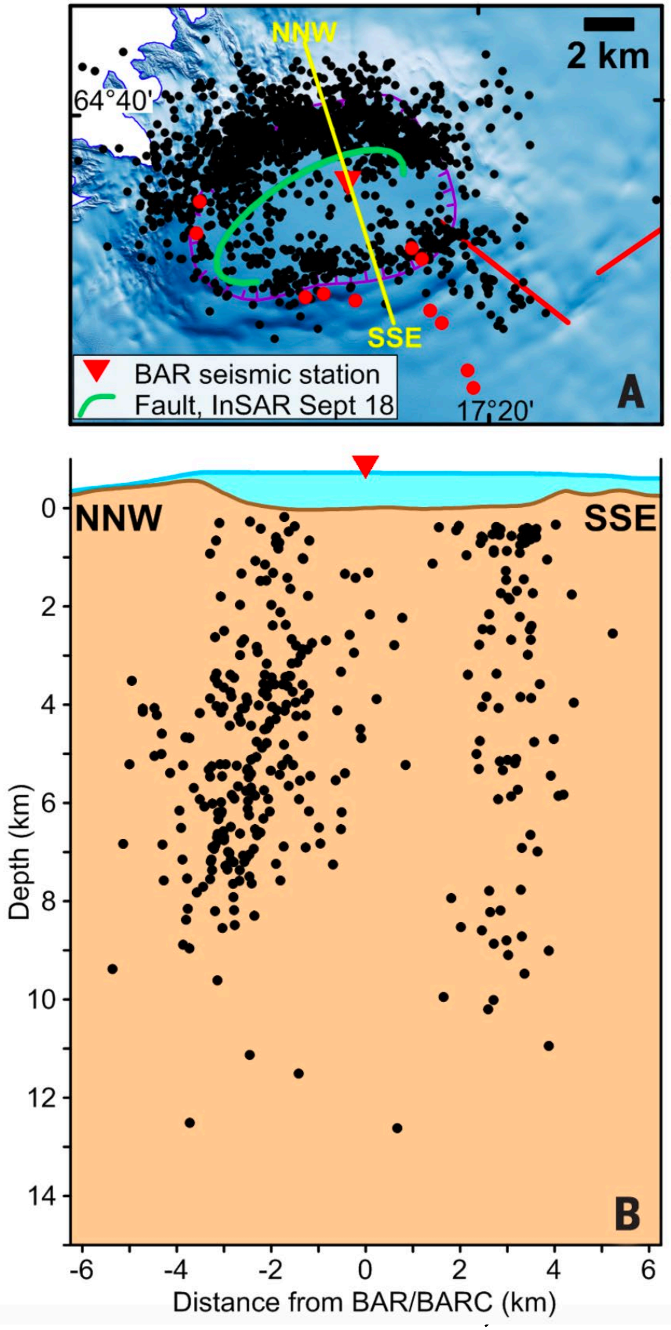
Bárðarbunga

Iceland

→ 2014 – 2015 eruption

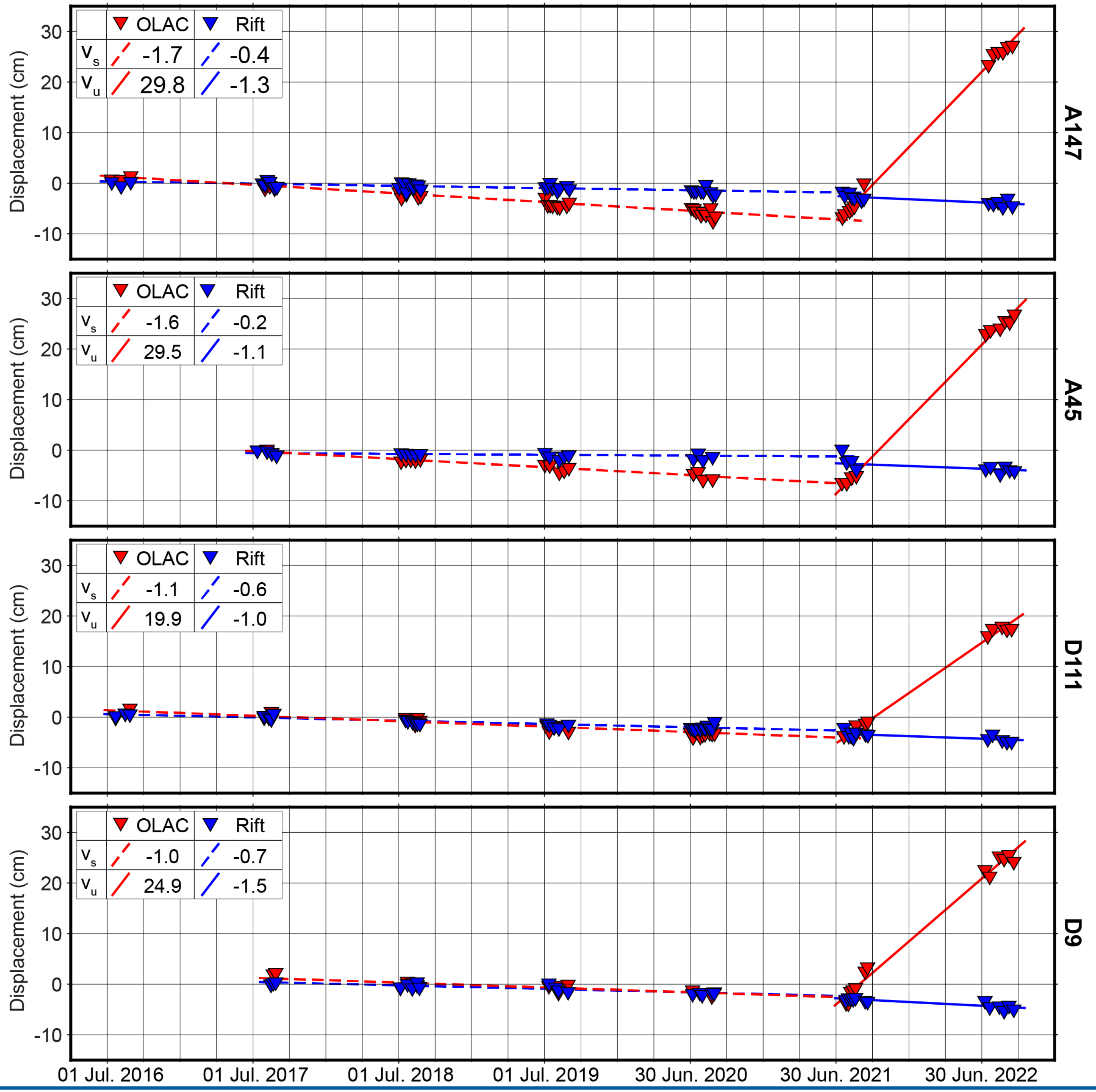
→ Caldera collapse (~65 m)

→ Eqs (Aug. 1 – Oct. 17



Gudmundsson et al., 2016

InSAR – Displacement Time Series
2016-2022



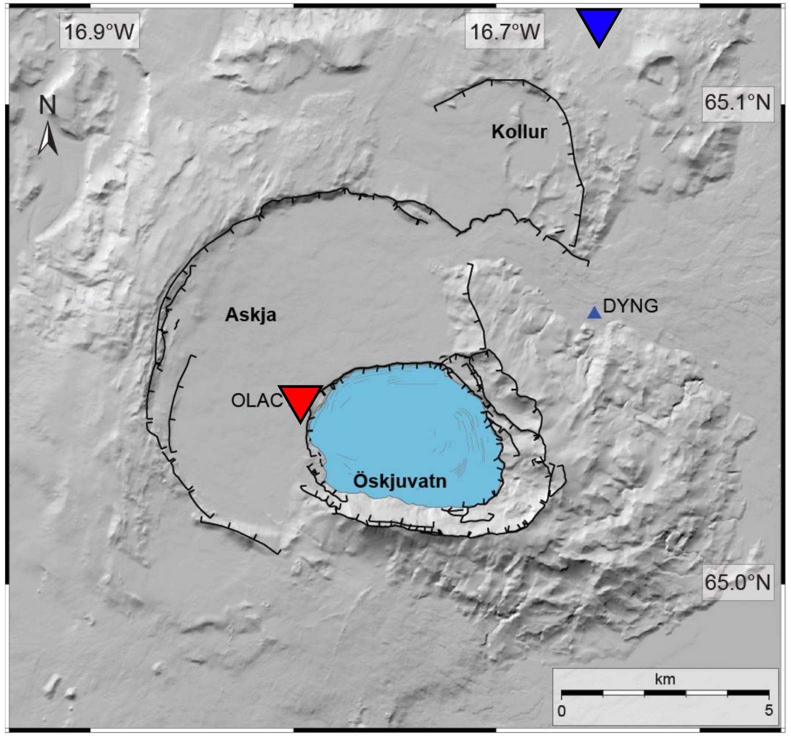
2016-2021

→ Subsidence Inside Askja Caldera and in the rift

2021-2022

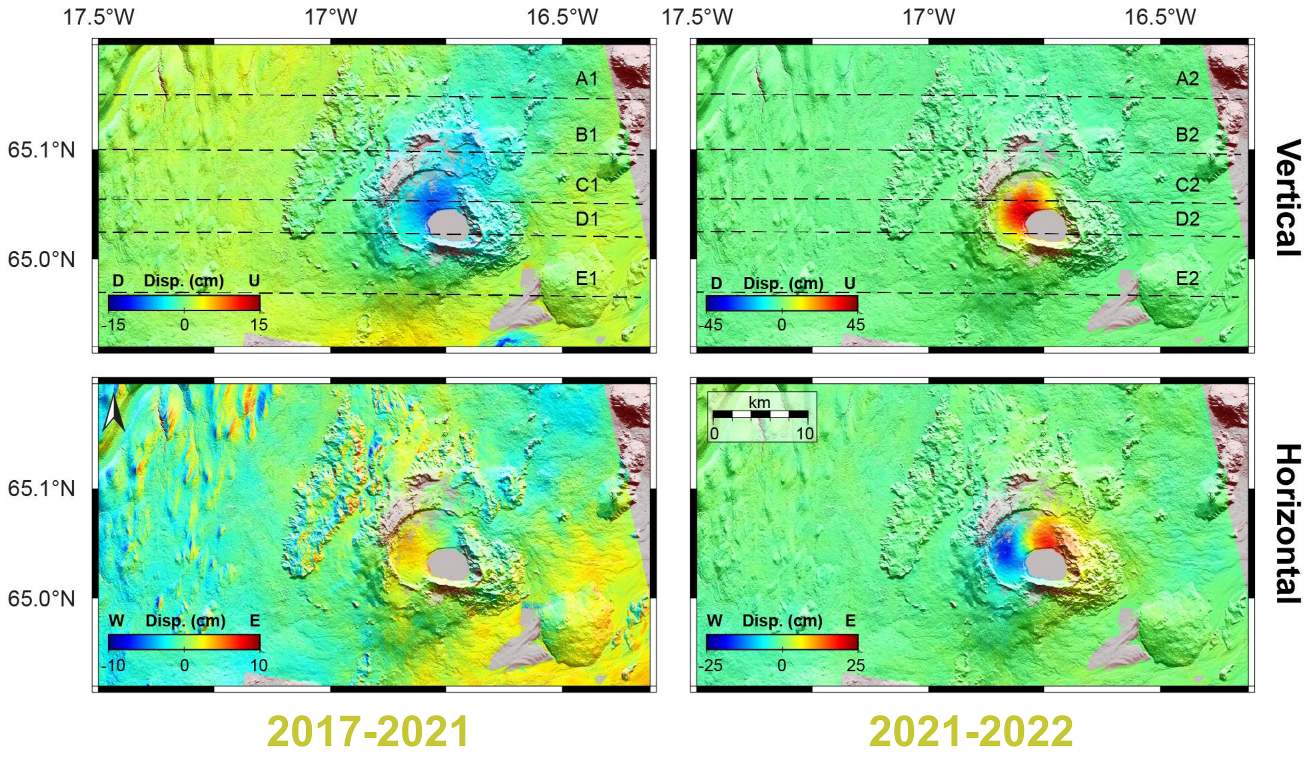
→Subsidence inside the rift (higher rate)

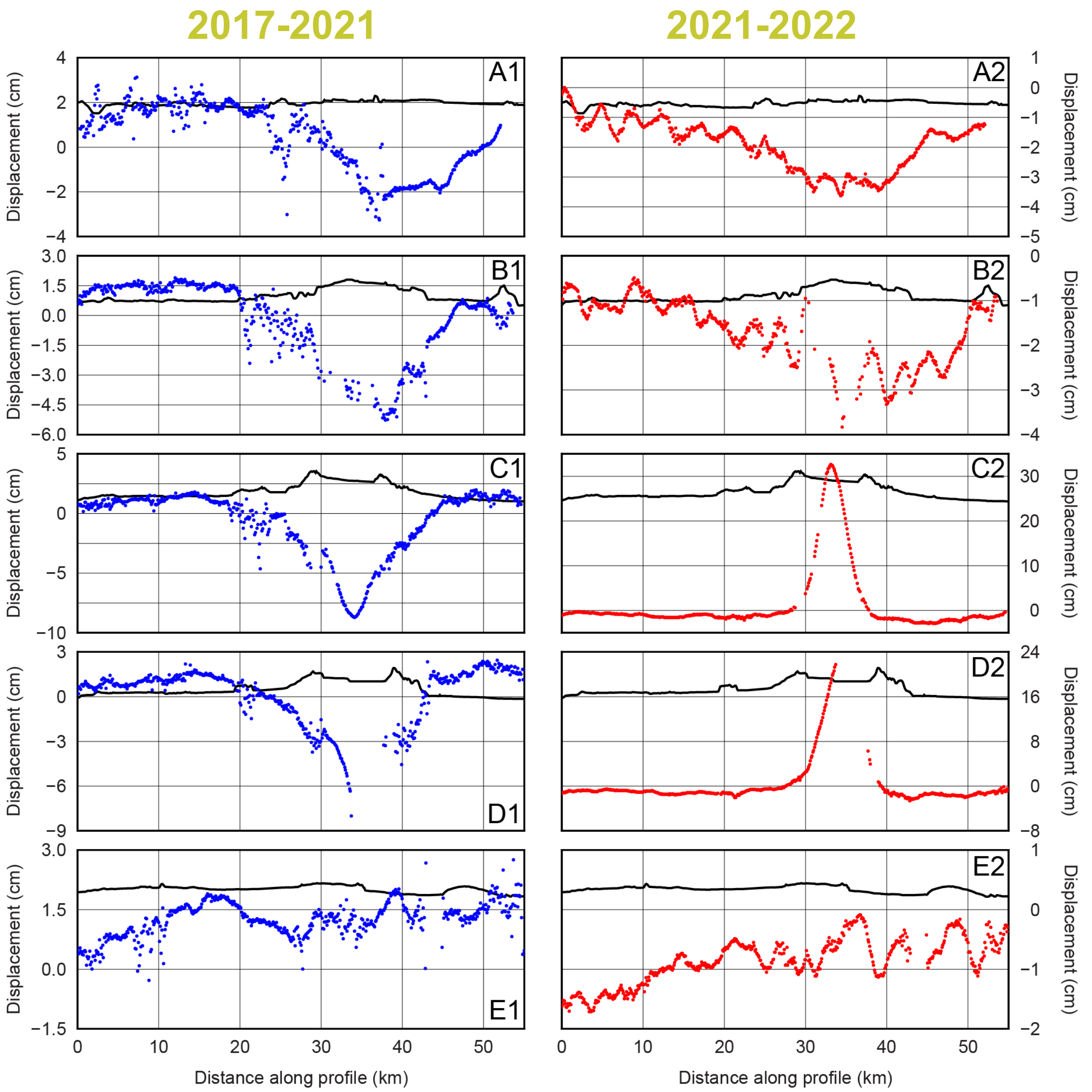
→ Uplift inside the caldera



InSAR – V and EW Components

- → A147 + D111
- → 2017-2021 & 2021-2022
- → Large horizontal component
- → Subsidence in the rift North of Askja





InSAR – Deformation Maps