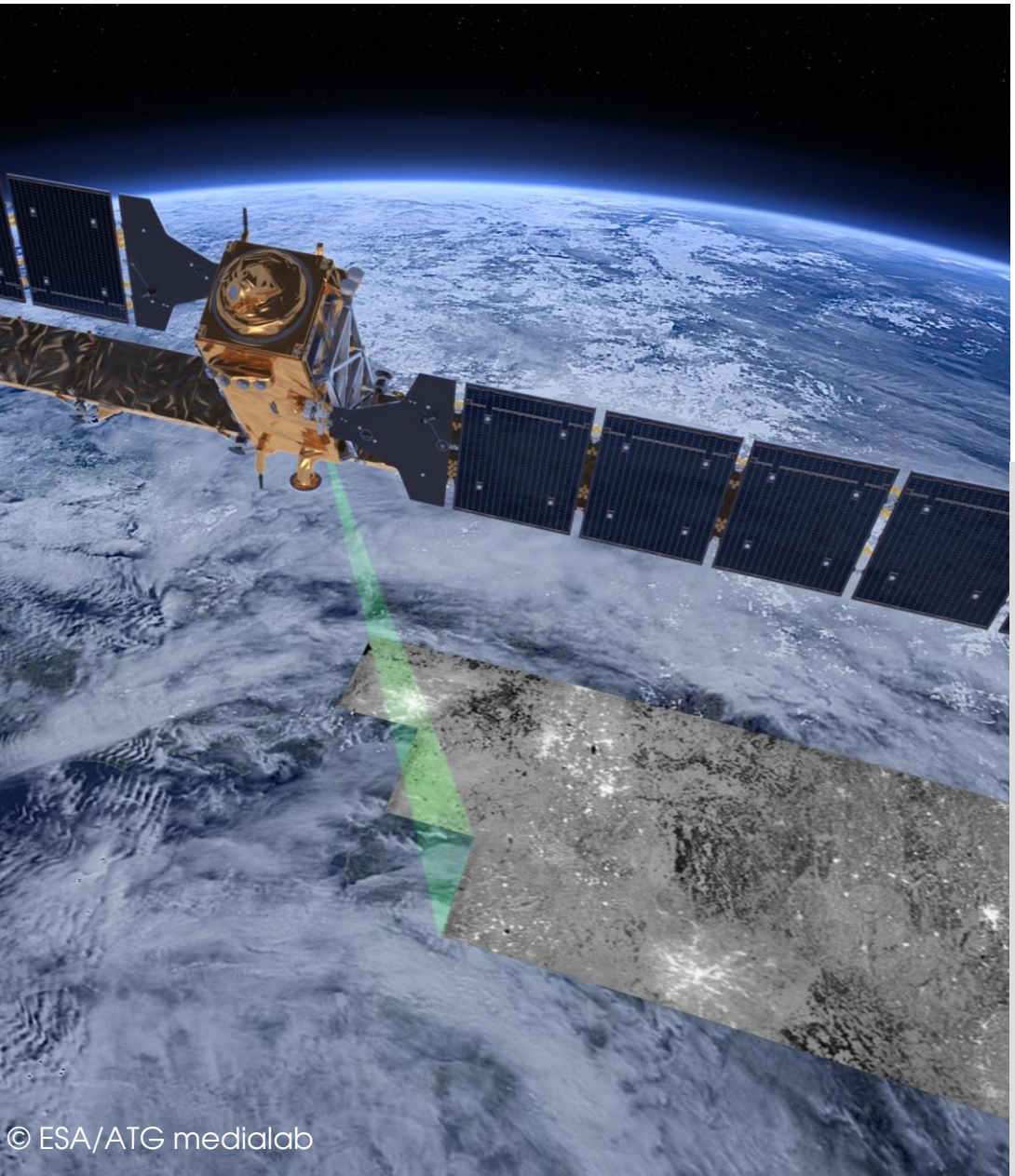
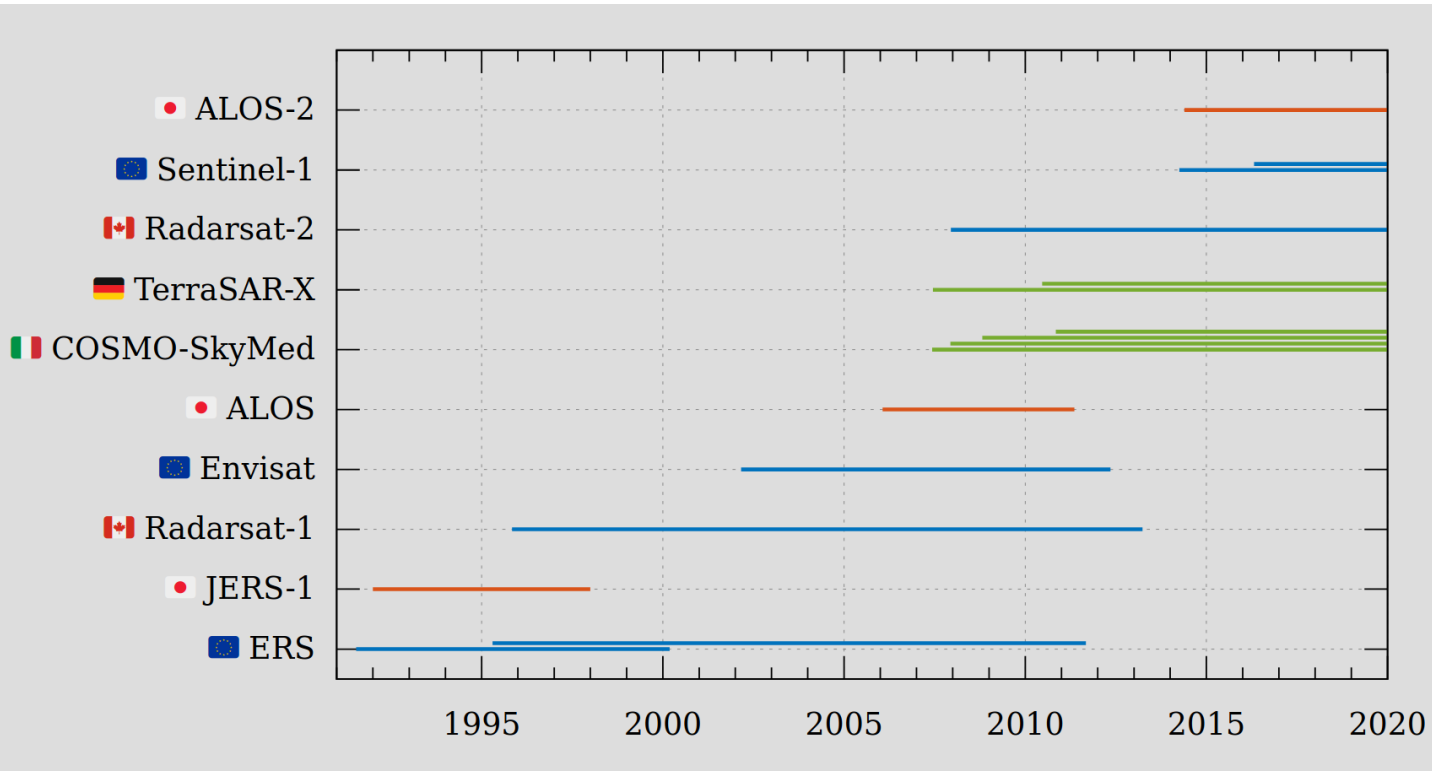
The value of using InSAR for monitoring natural hazards in Iceland

Vincent Drouin

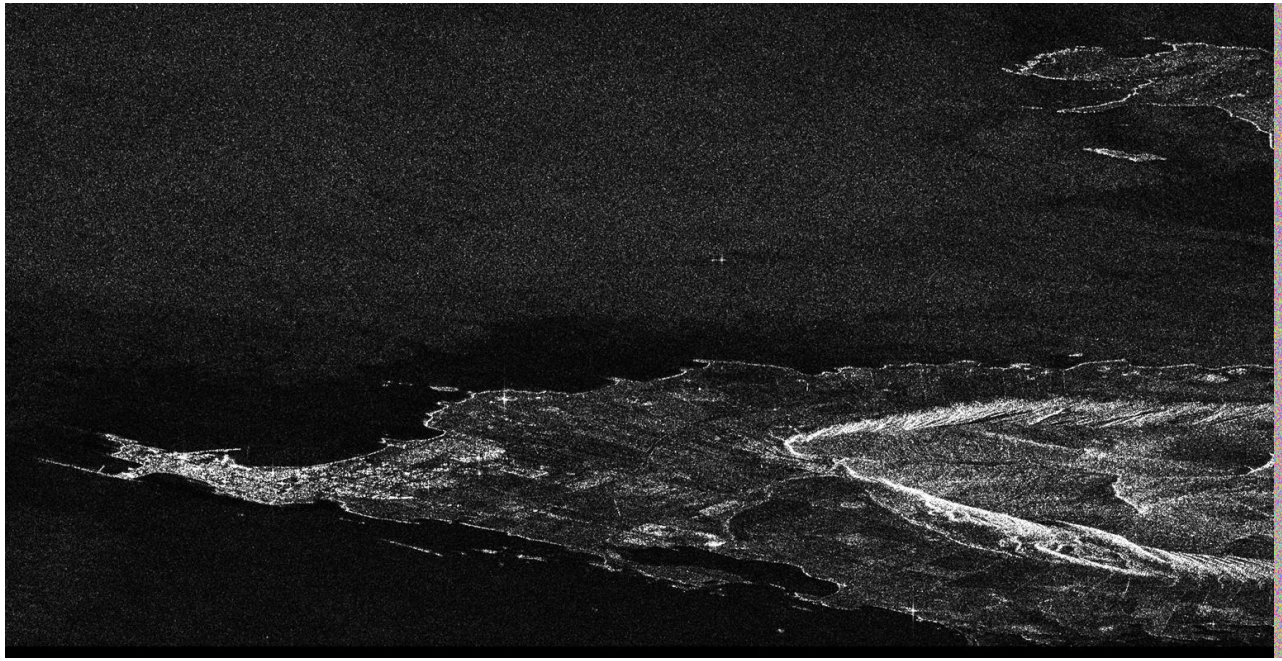
Synthetic-aperture radar

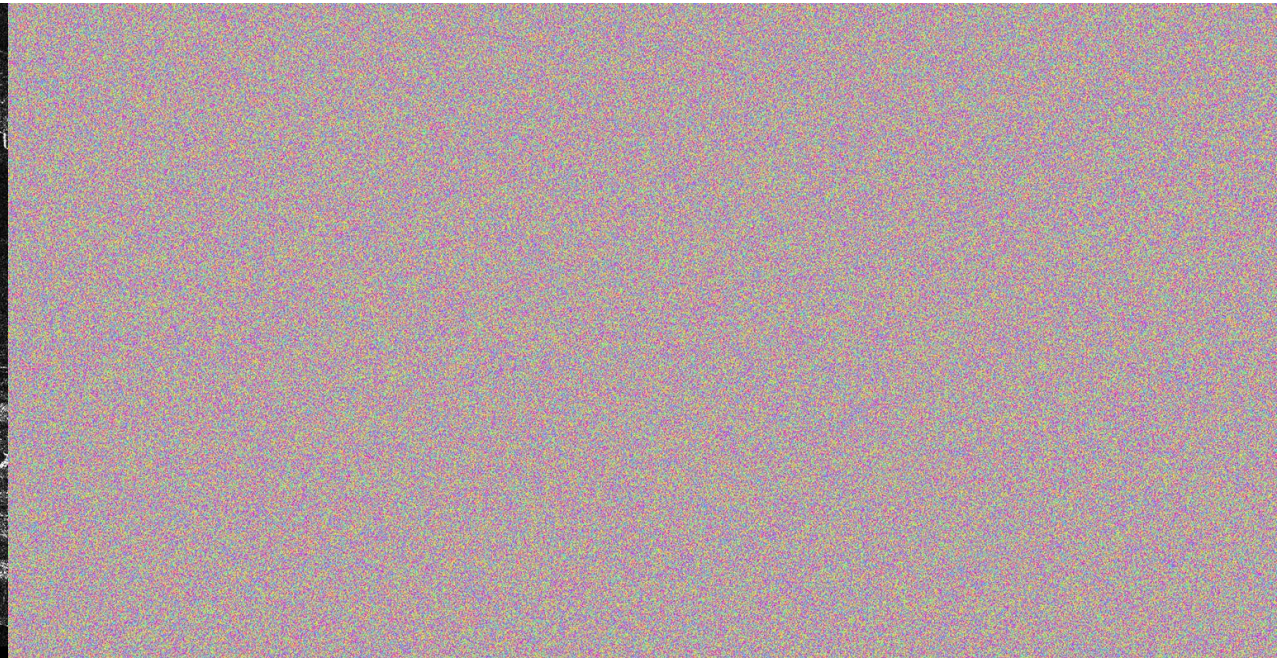


- **Remote-sensing:** No need to go to the place of interest
- **Imaging:** Information over continuous area
- **Microwaves:** Cloup penetrating capabilities
- **Active:** Night time capabilities



Single-look complex





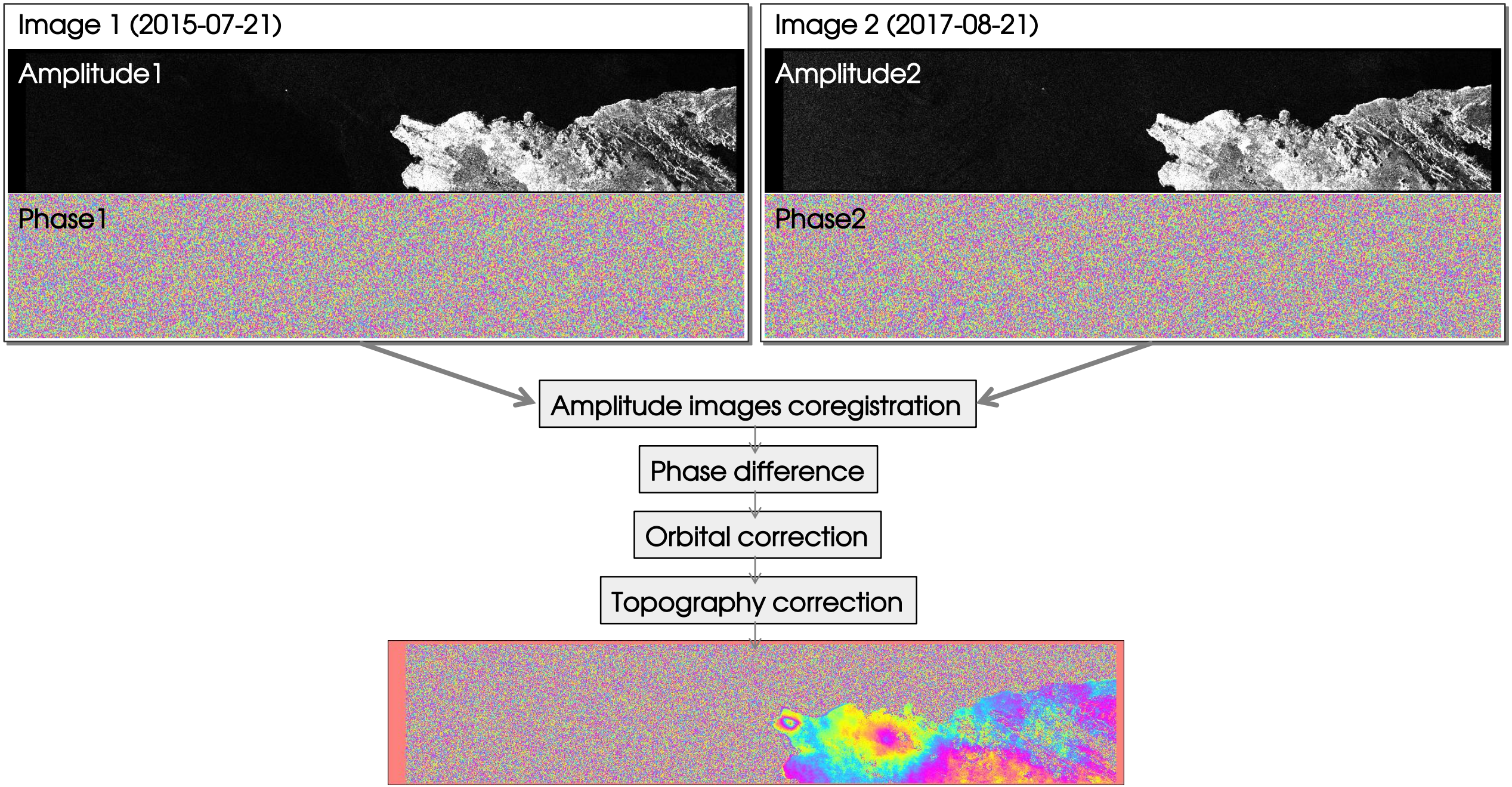
Amplitude

- Depend on the roughness of the terrain
- Buildings, exposed rocks = strong amplitude
- Water, vegetation = low amplitude

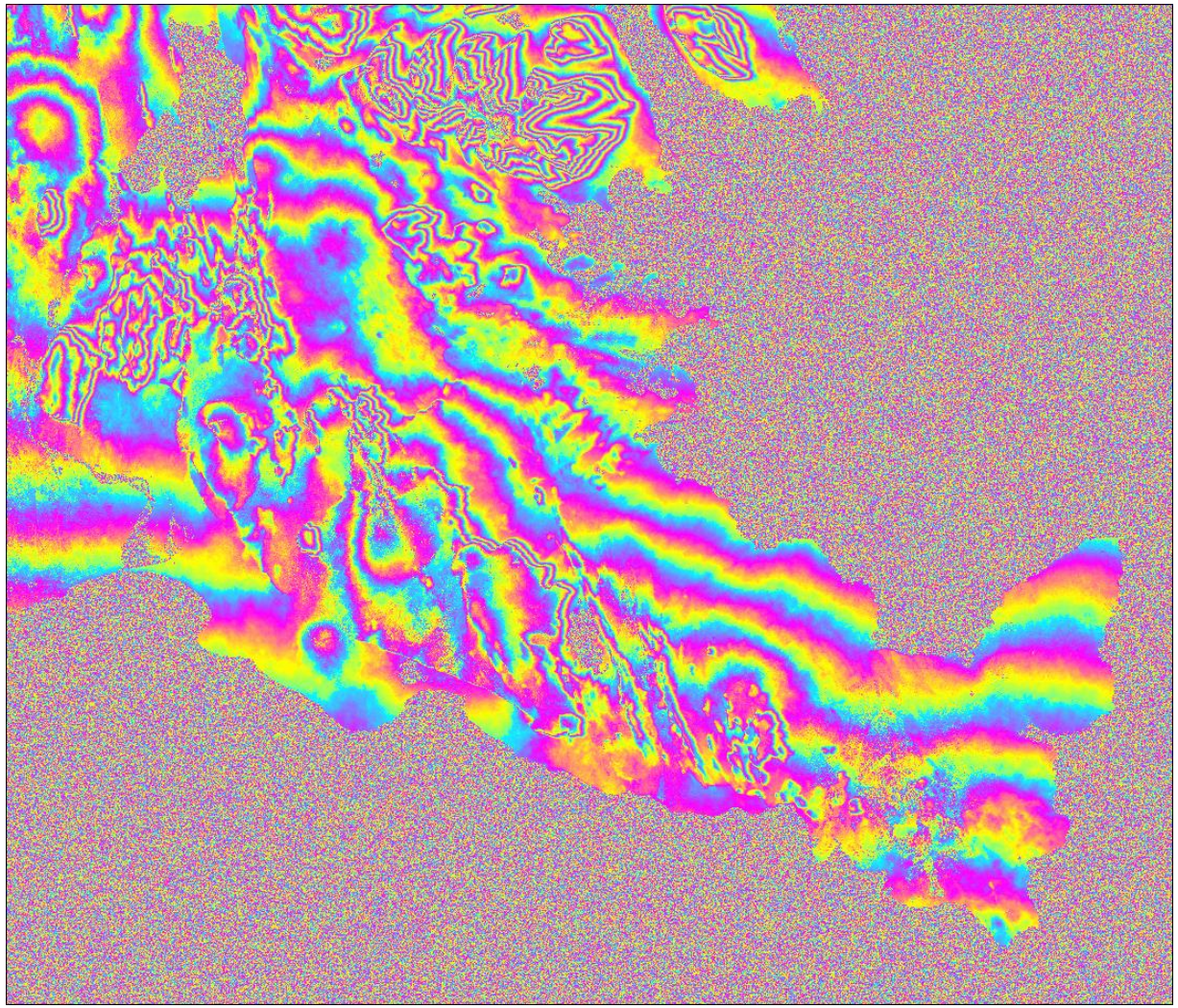
Phase

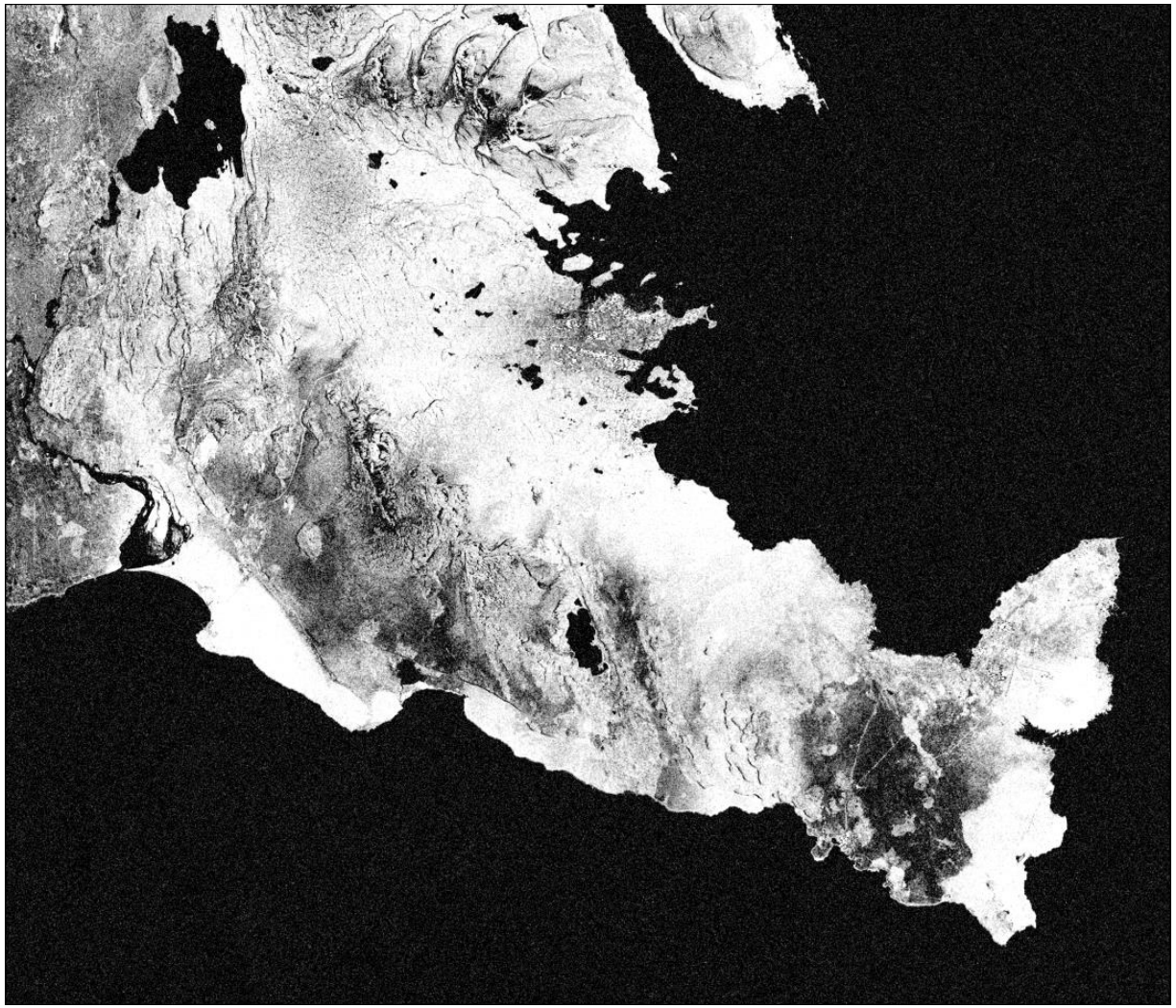
- 2π
- Apparent randomness

Interferogram



Coherence

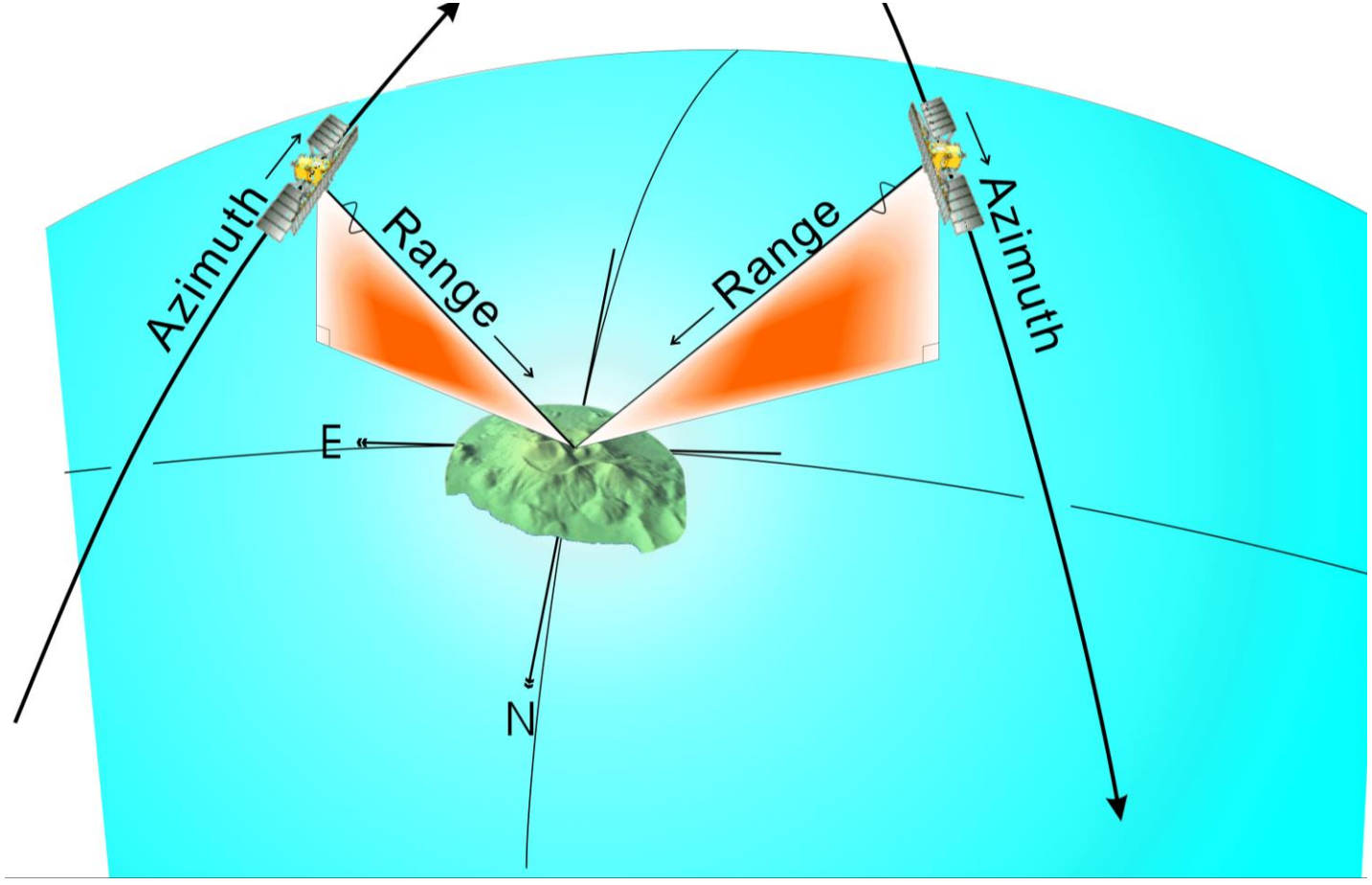


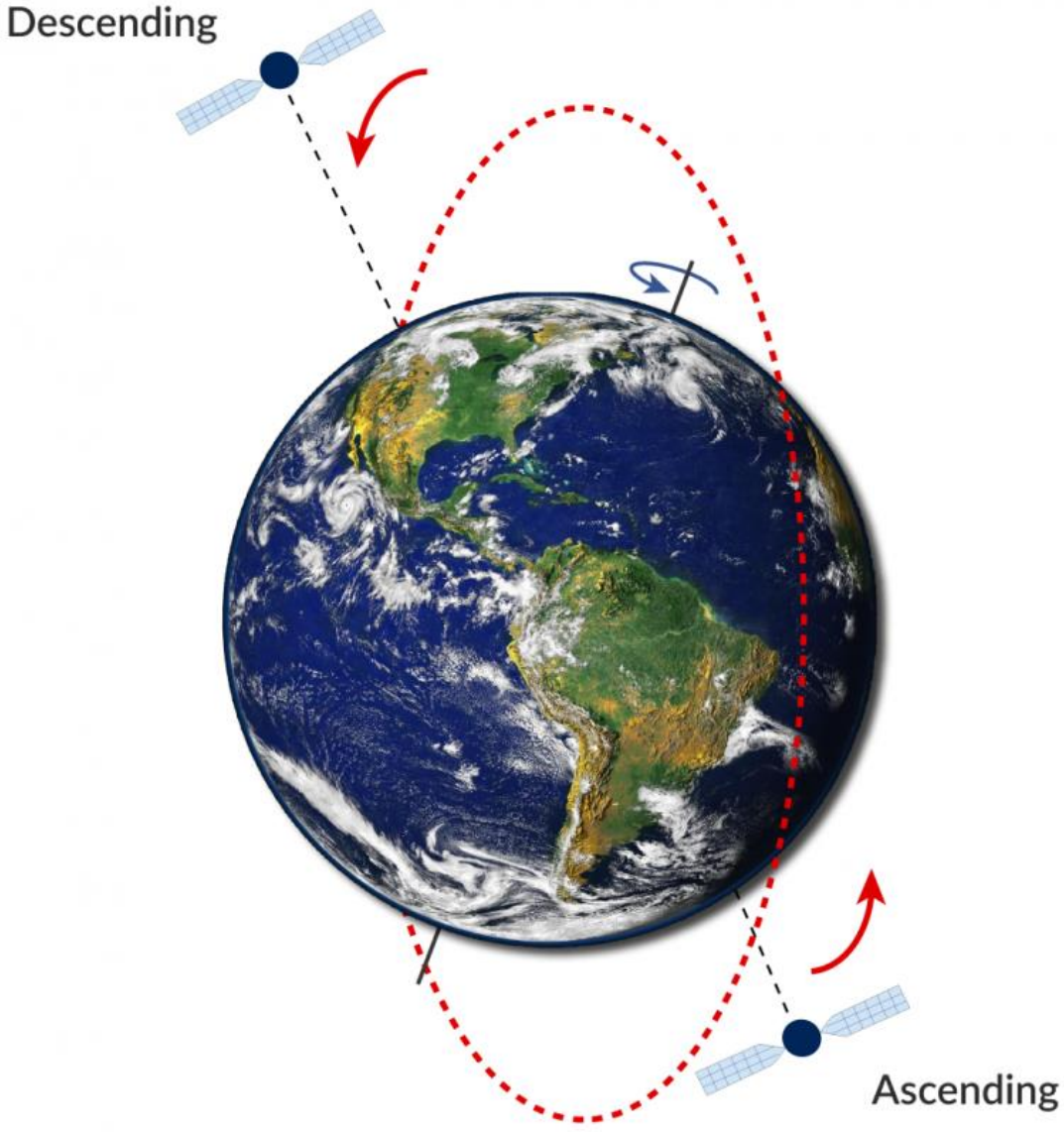


Ascending and descending?

Near-polar orbit of satellite missions and Earth's rotation

- **Ascending** passes: from South to North
- **Descending** passes: from North to South





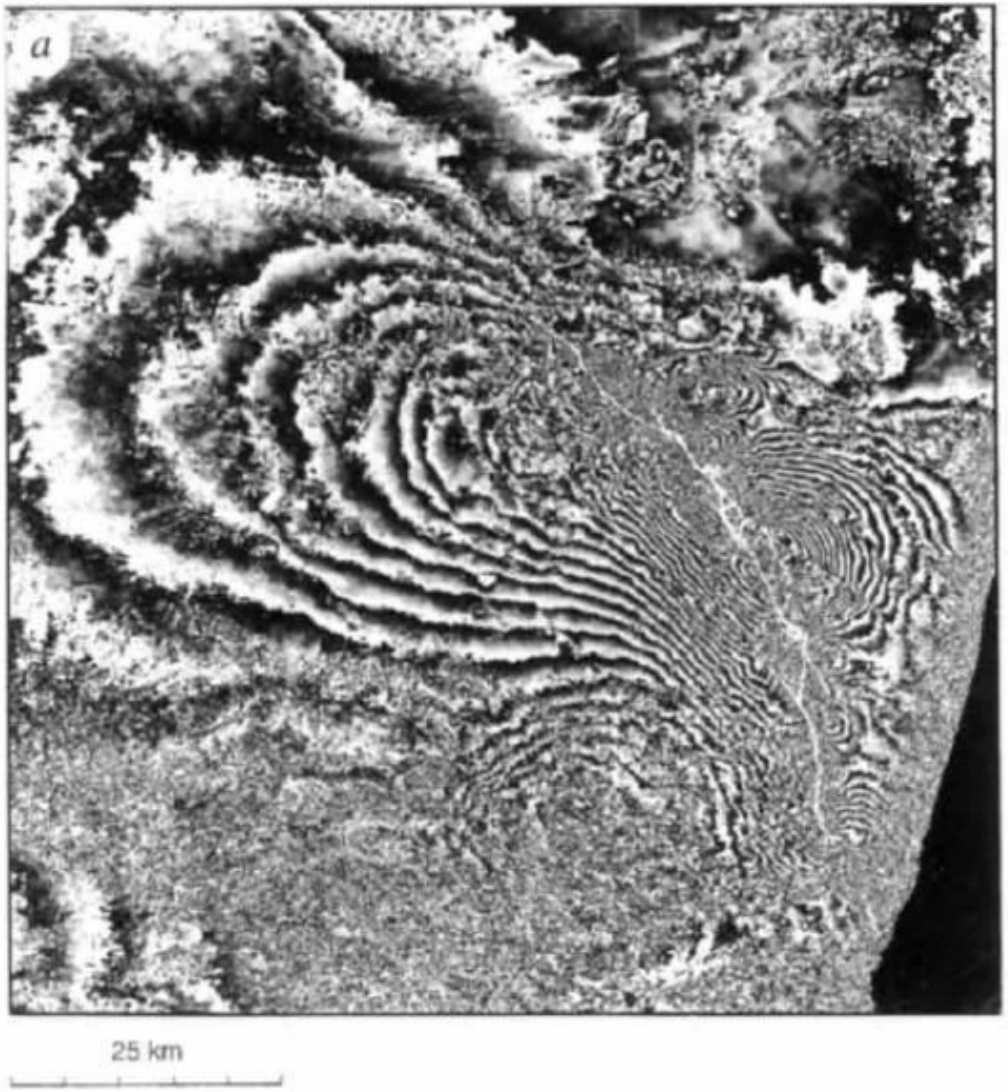
First use of InSAR to look natural hazard

Letter | Published: 08 July 1993

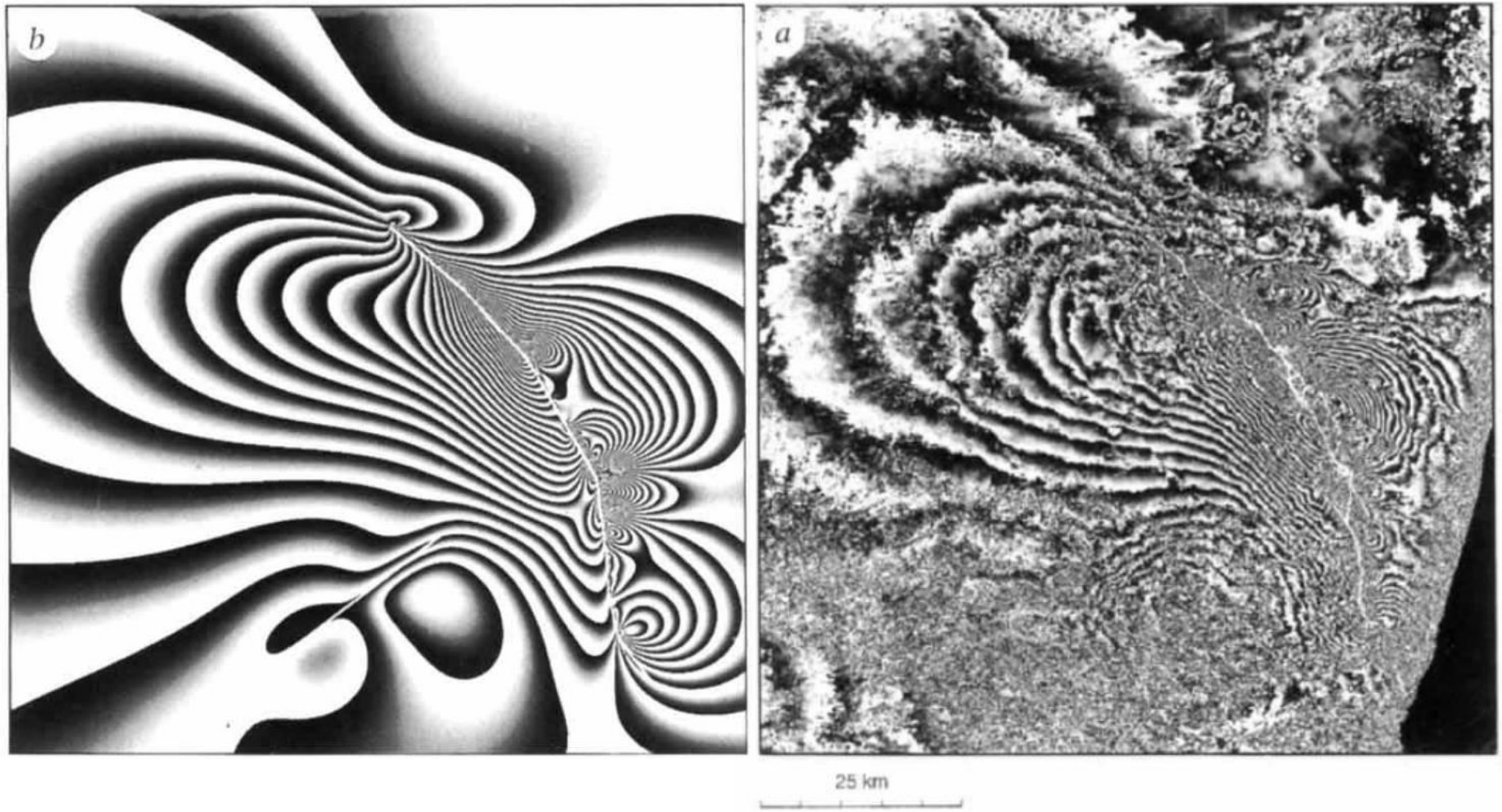
The displacement field of the Landers earthquake mapped by radar interferometry

Didier Massonnet, Marc Rossi, César Carmona, Frédéric Adragna, Gilles Peltzer, Kurt Feigl & Thierry Rabaute

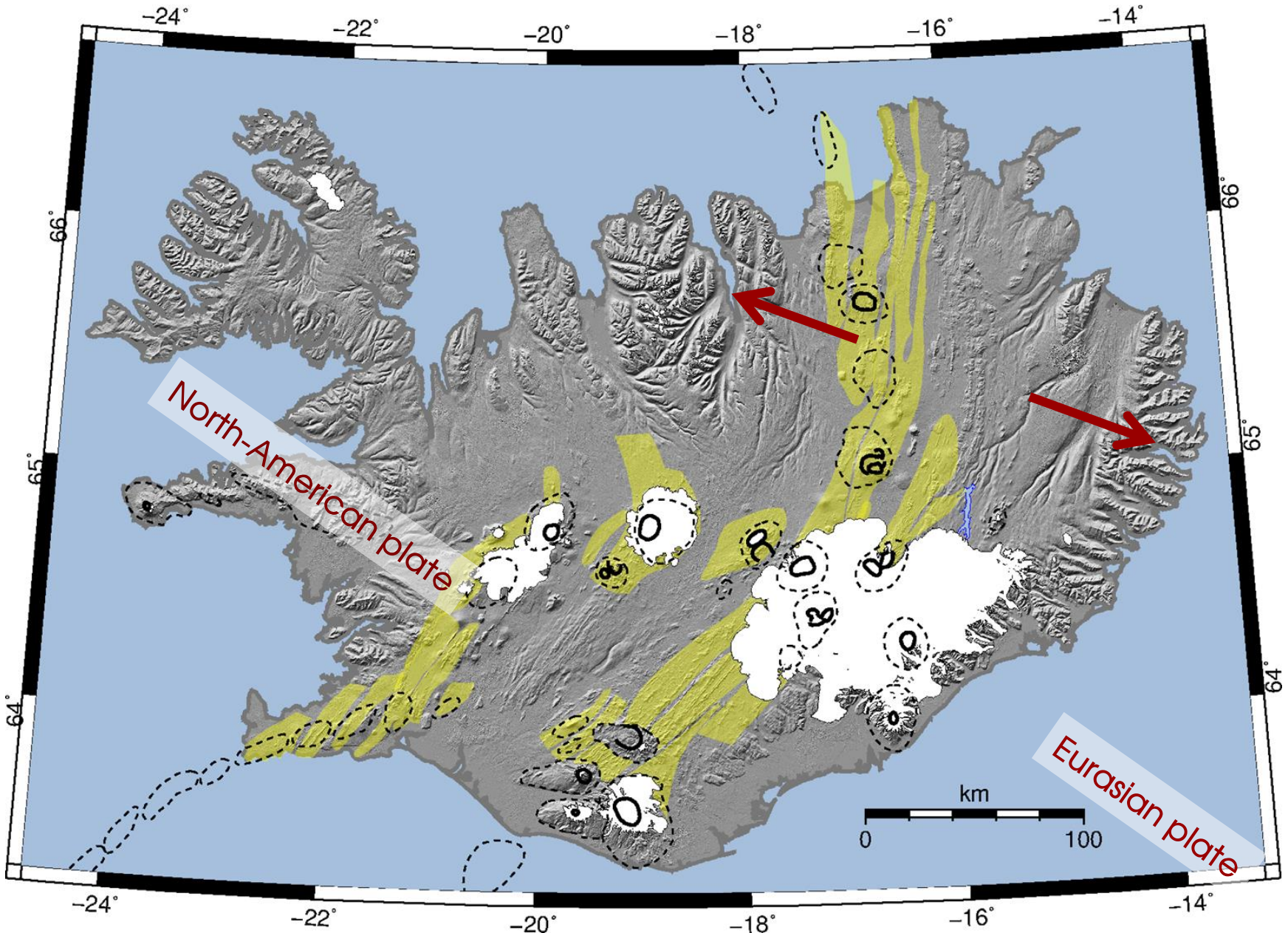
Nature **364**, 138–142(1993) | Cite this article



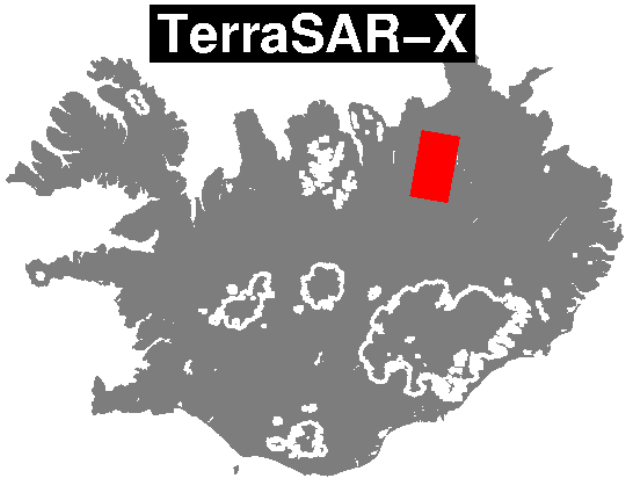
First use of InSAR to look at natural hazard

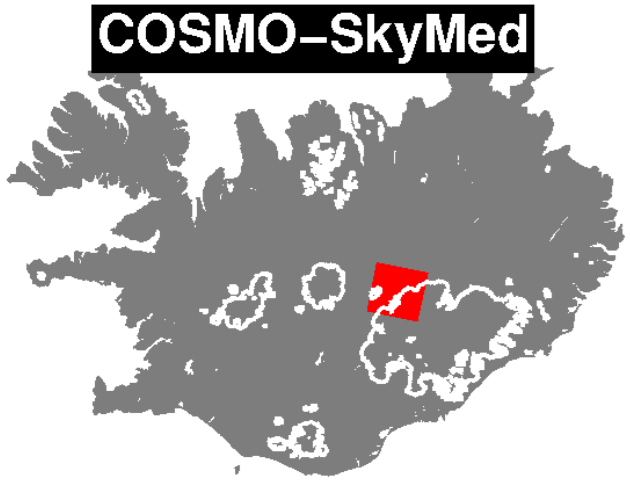


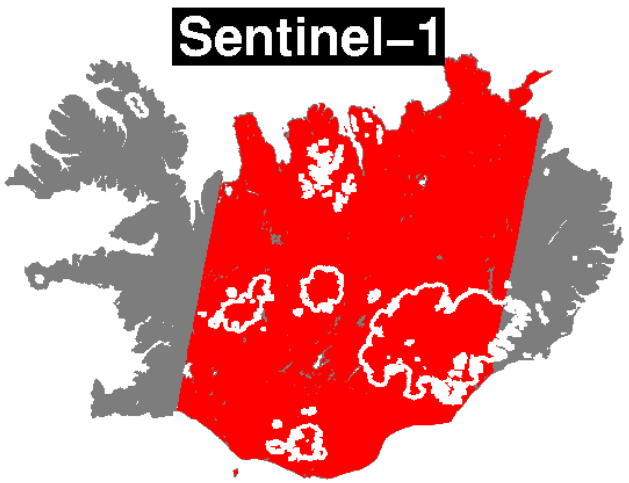
Iceland

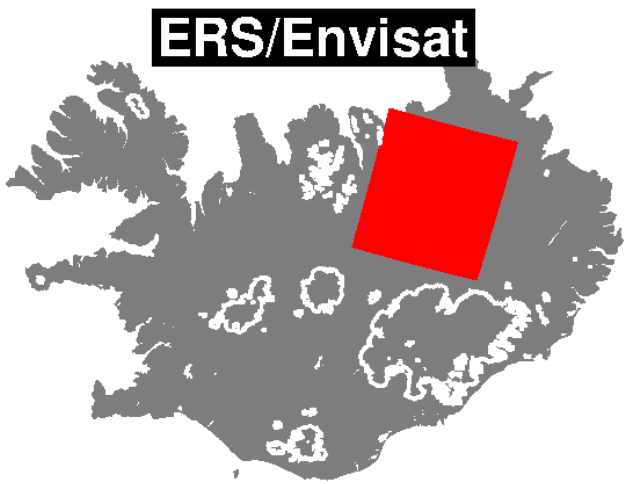

−24°
−22°
−20°
−18°
−16°
−14°
66°
65°
64°
North-American plate
Eurasian plate
km
0
100

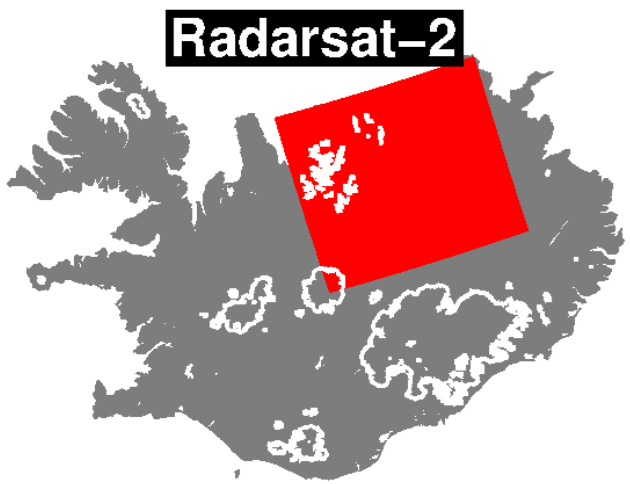
SAR satellites coverage



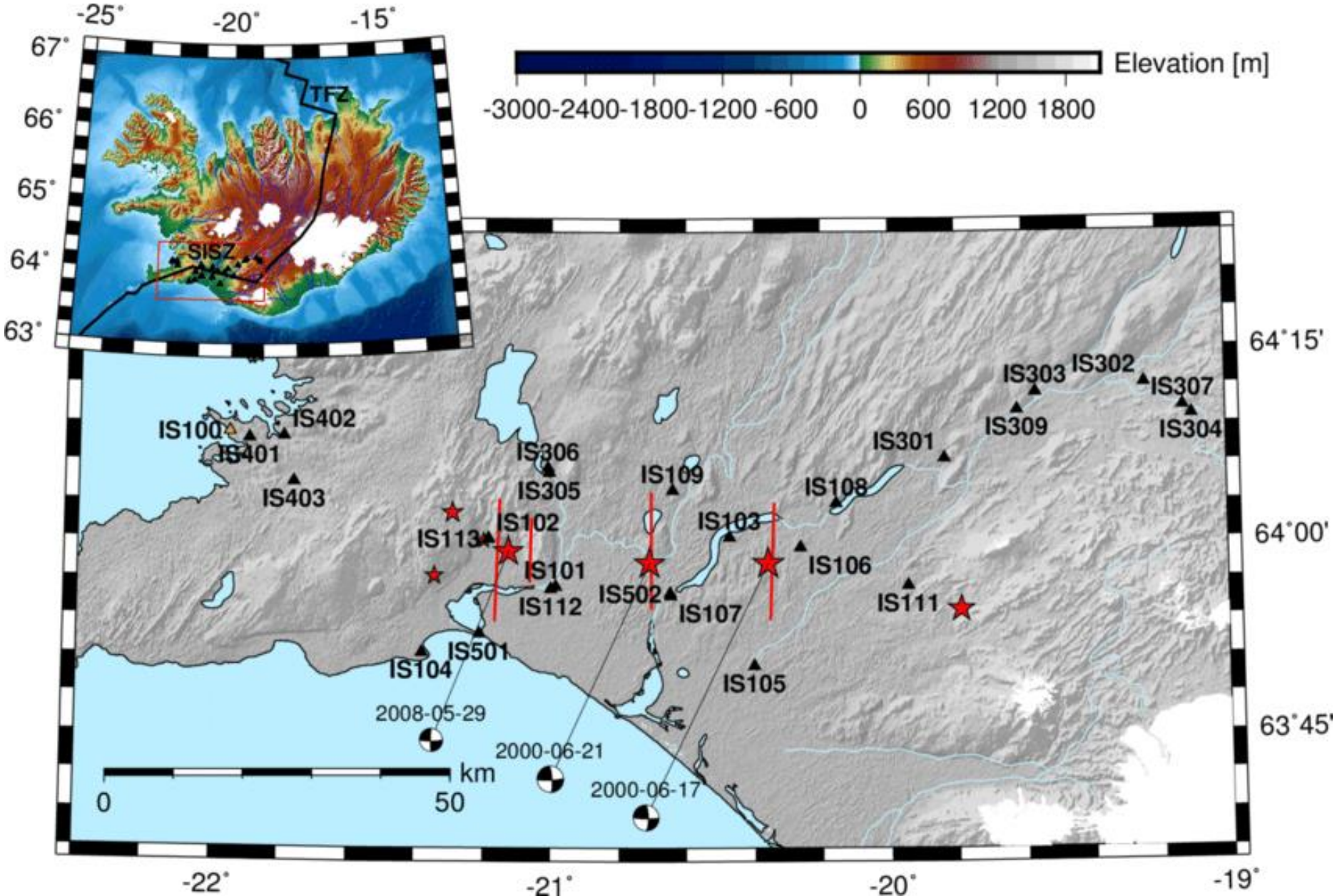








2000 and 2008 South Iceland earthquakes



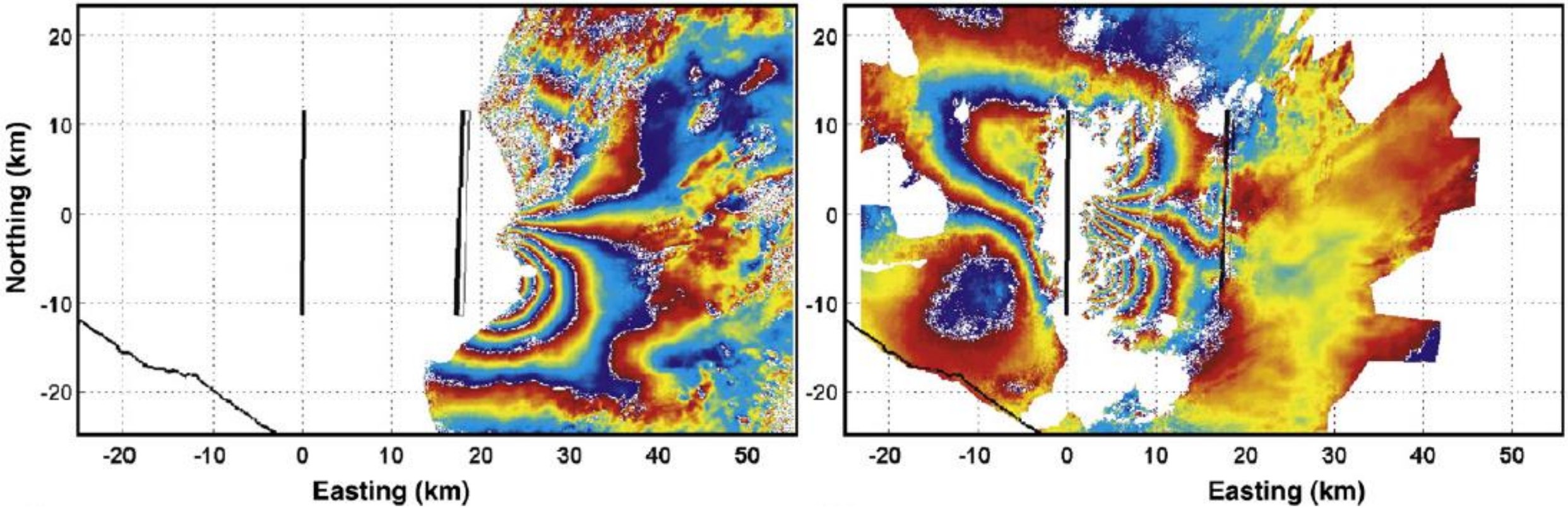
(Sonnemann & Halldorsson, 2019)

2000 South Iceland earthquakes

- June 17: M_w = 6.5
- June 21: M_w = 6.5

ERS T52 16 June – 21 July

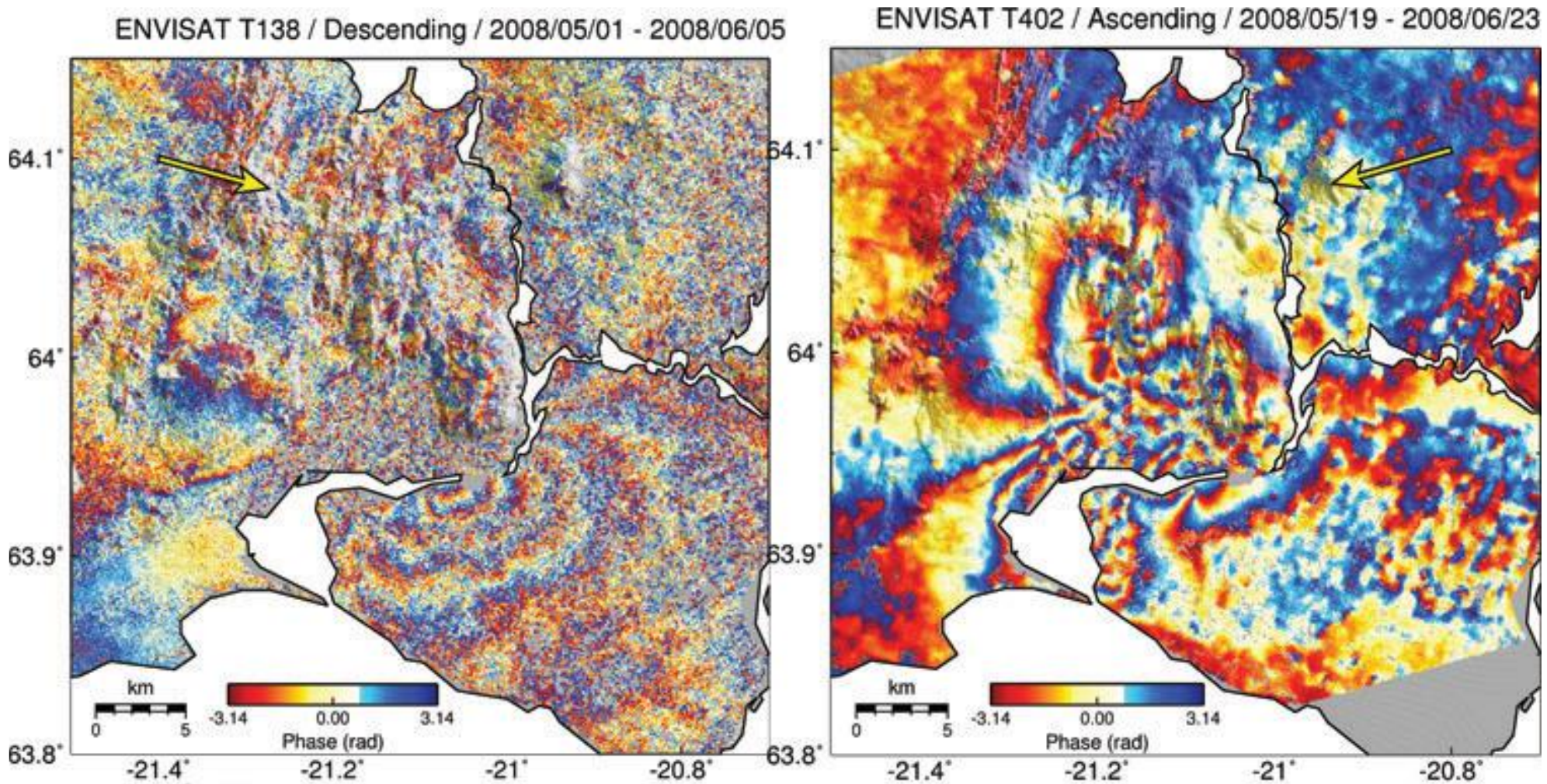
ERS T95 19 June – 24 July



(Dubois et al., 2008)

2008 South Iceland earthquakes

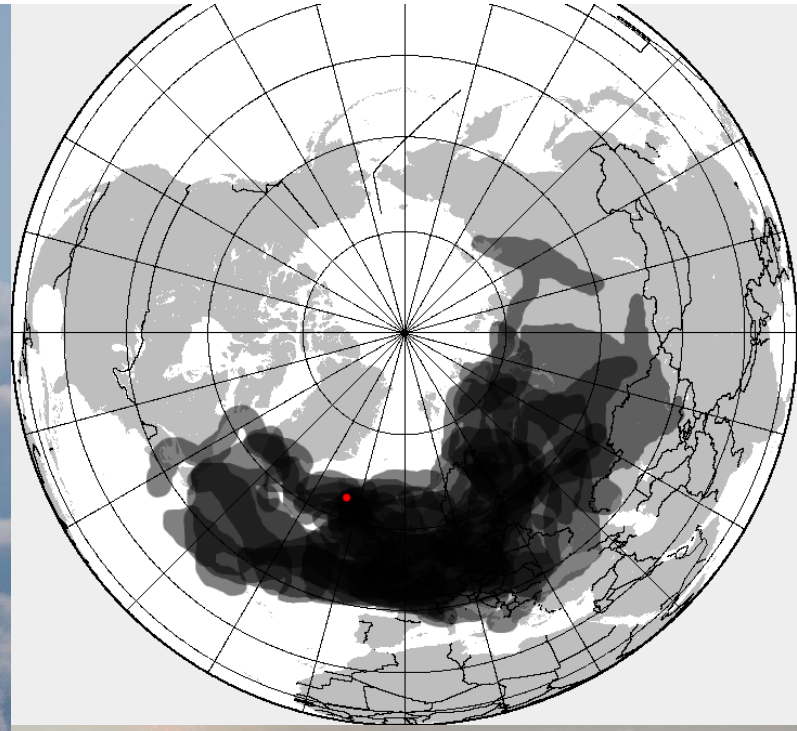
- May 29: M_w = 5.8
- May 29: M_w = 5.9



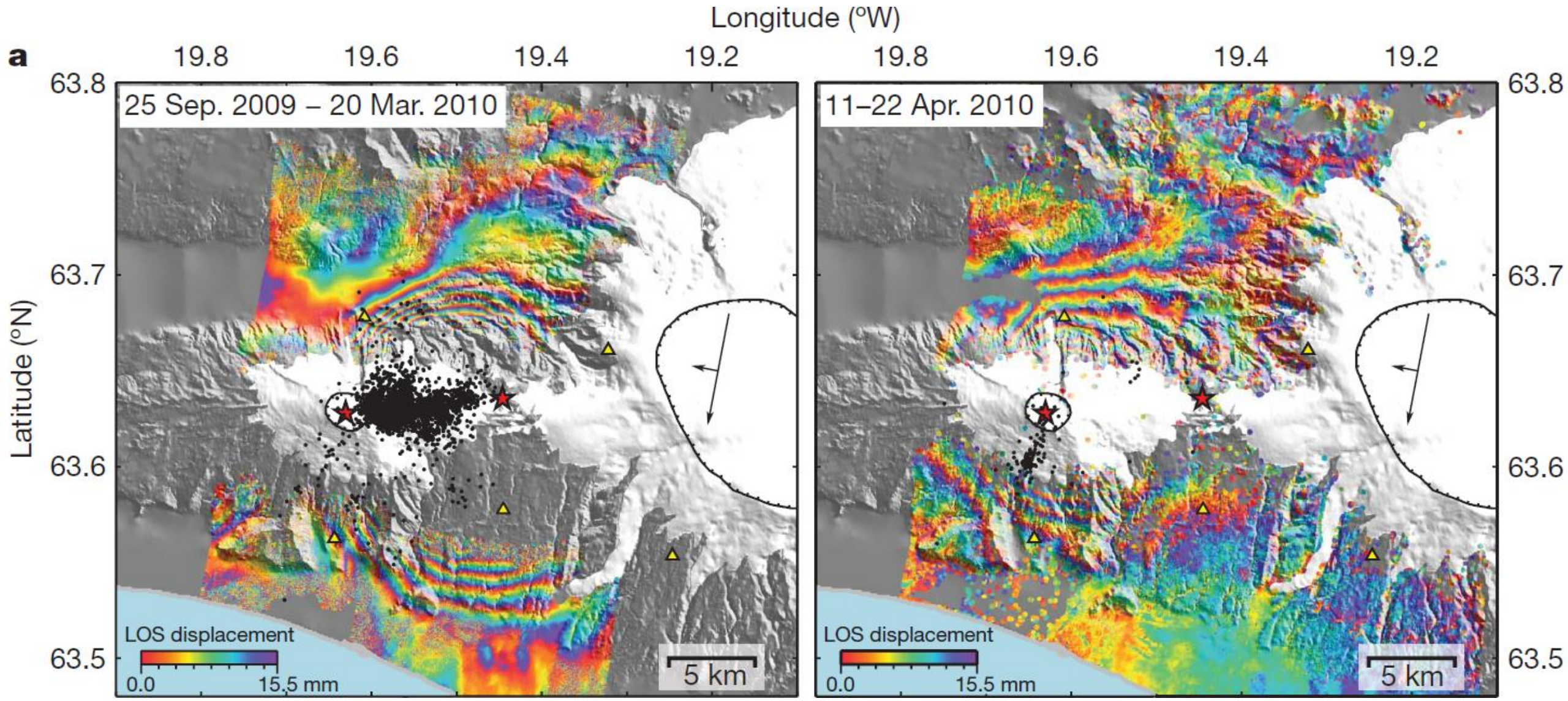
(Decriem et al., 2010)

Eyjafjallajökull 2010

- **Seismicity began in late 2009**
- **Fissure eruption: 10 March 2010**
- **Summit eruption: 14 April 2010**

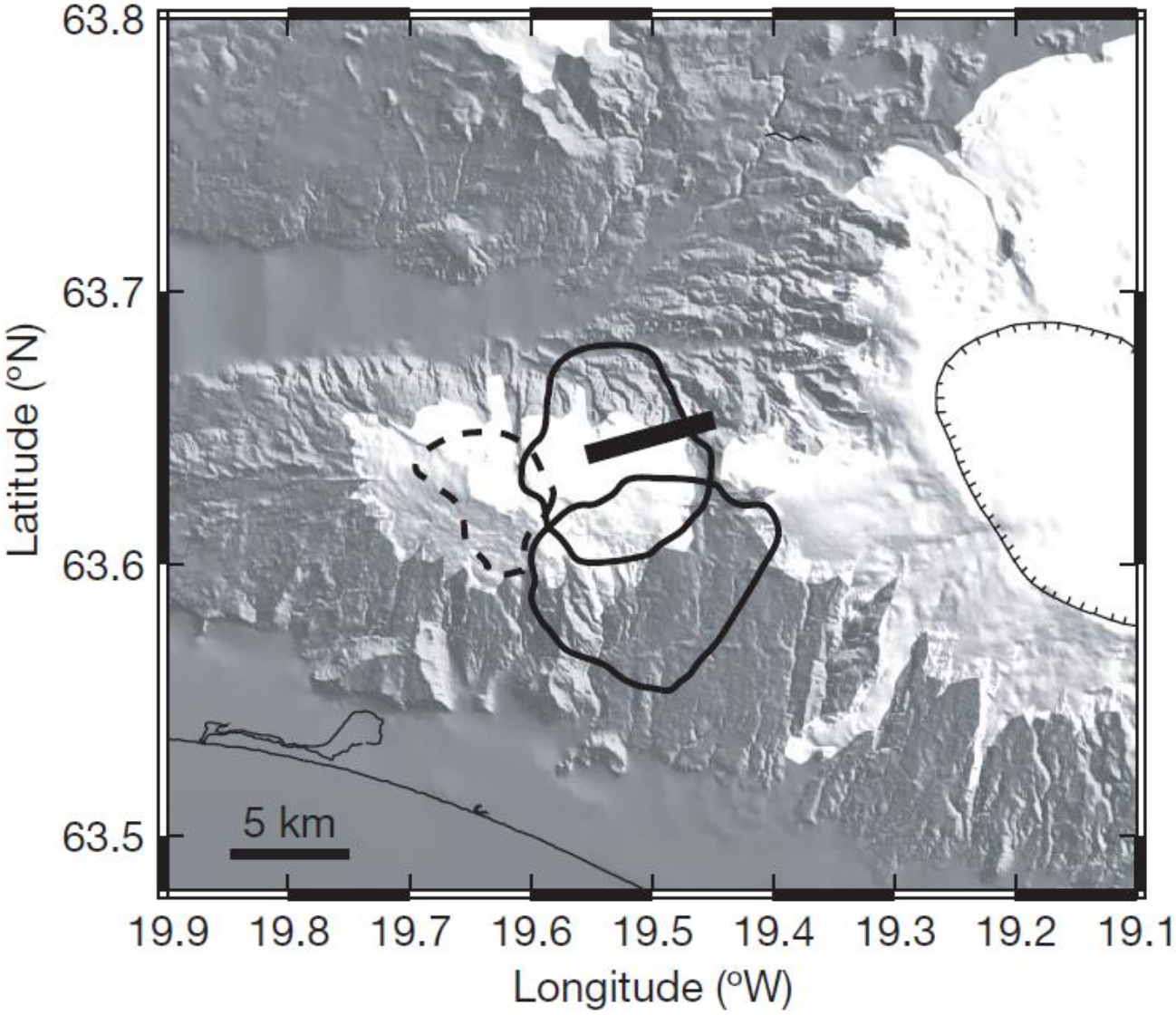


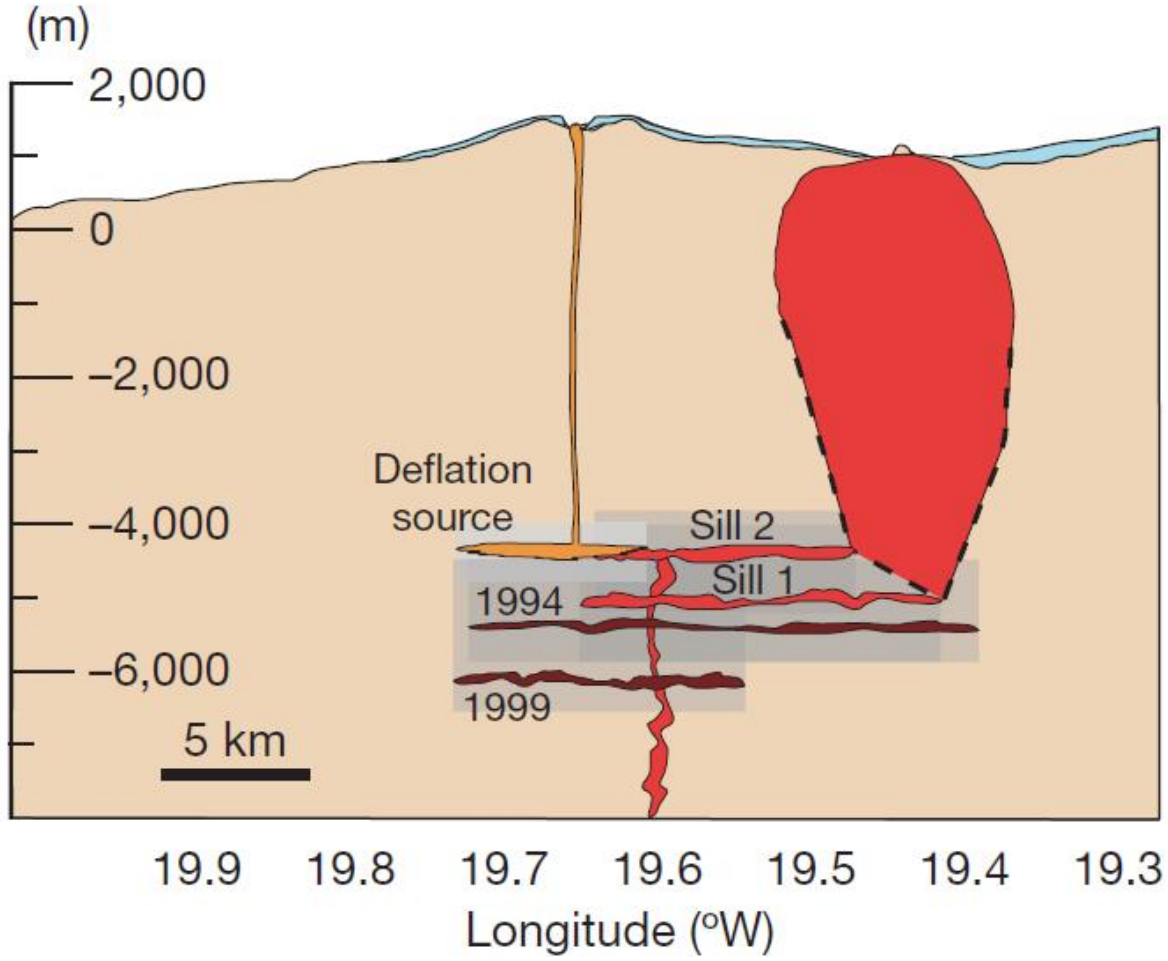
Eyjafjallajökull 2010



(Sigmundsson et al., 2010)

Eyjafjallajökull 2010



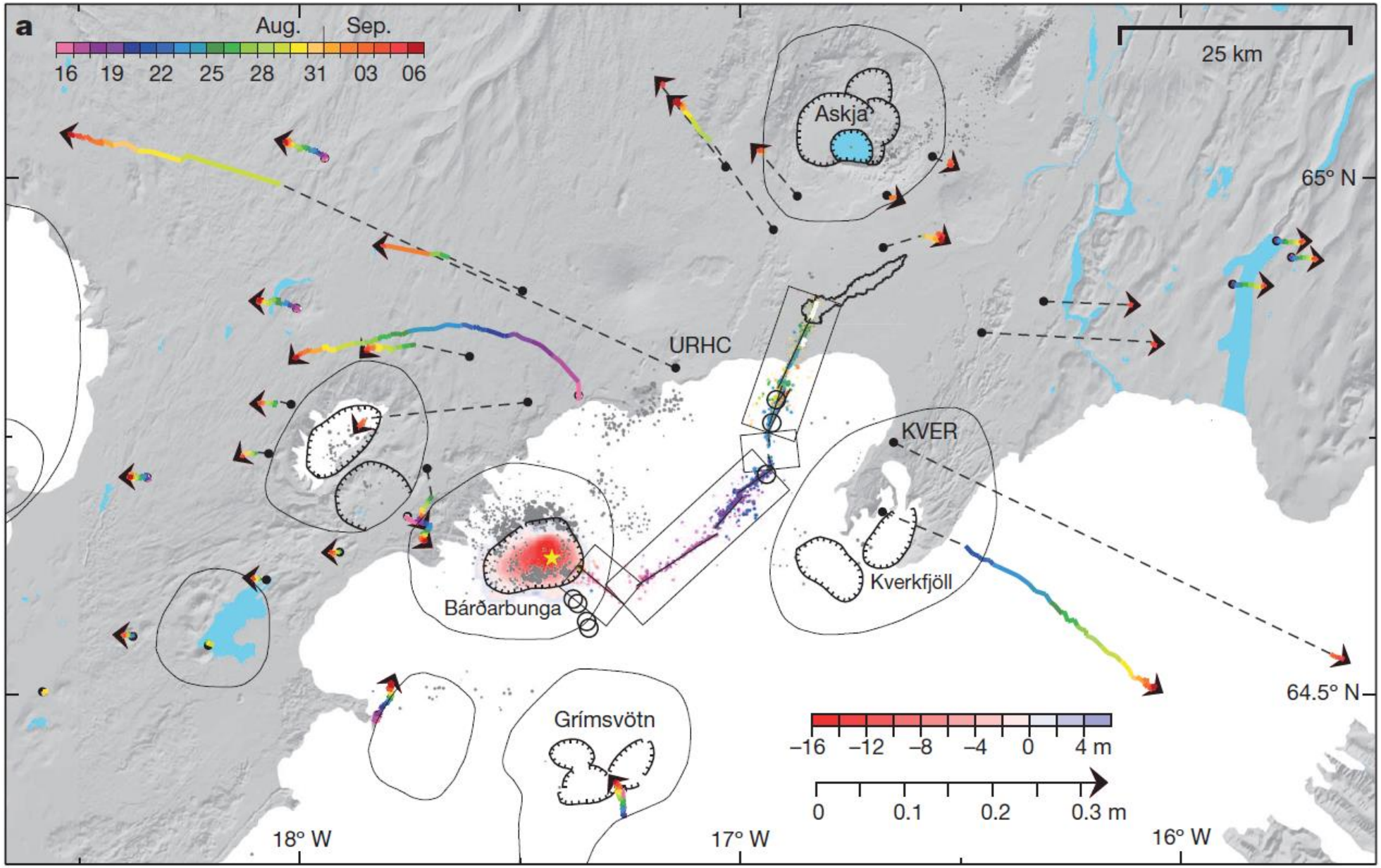


(Sigmundsson et al., 2010)

Bárðarbunga rifting event (Aug. 2014 - Feb. 2015)

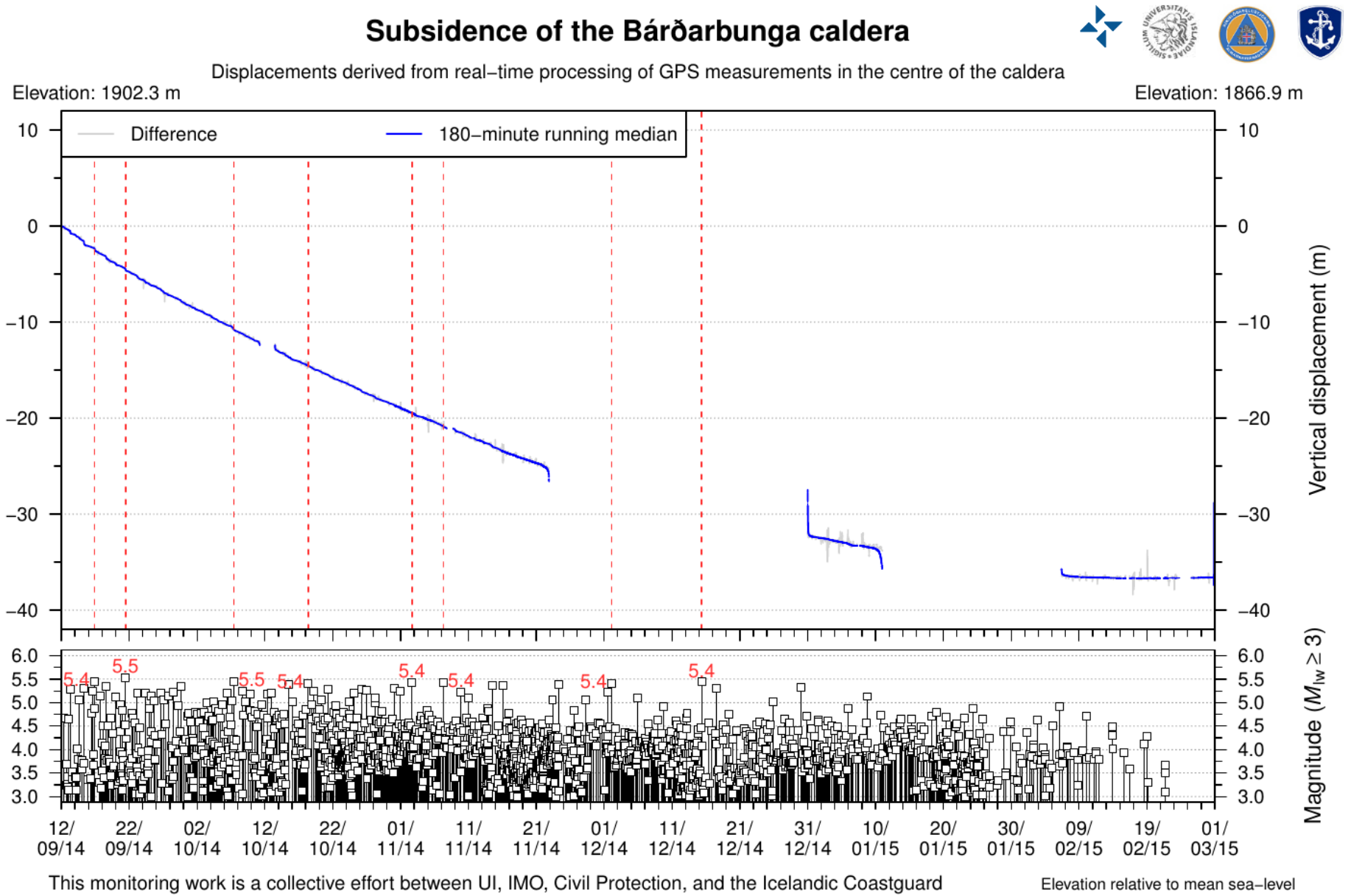
- **Seismicity began on 16 August 2014**
- **Eruption: 29 August 2014 – 27 February 2015**

Bárðarbunga rifting event (Aug. 2014 - Feb. 2015)

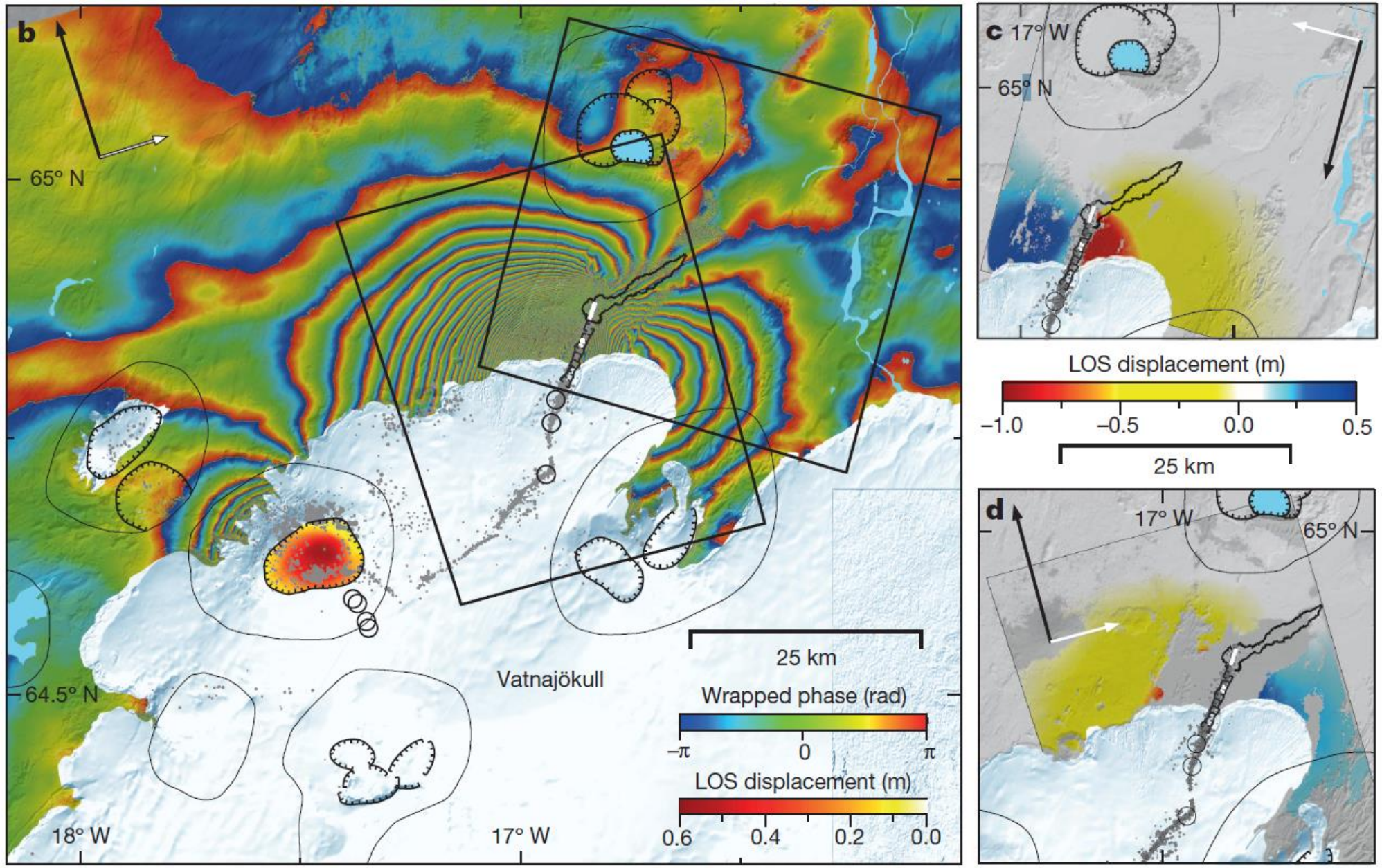


(Sigmundsson et al., 2015)

Bárðarbunga rifting event (Aug. 2014 - Feb. 2015)

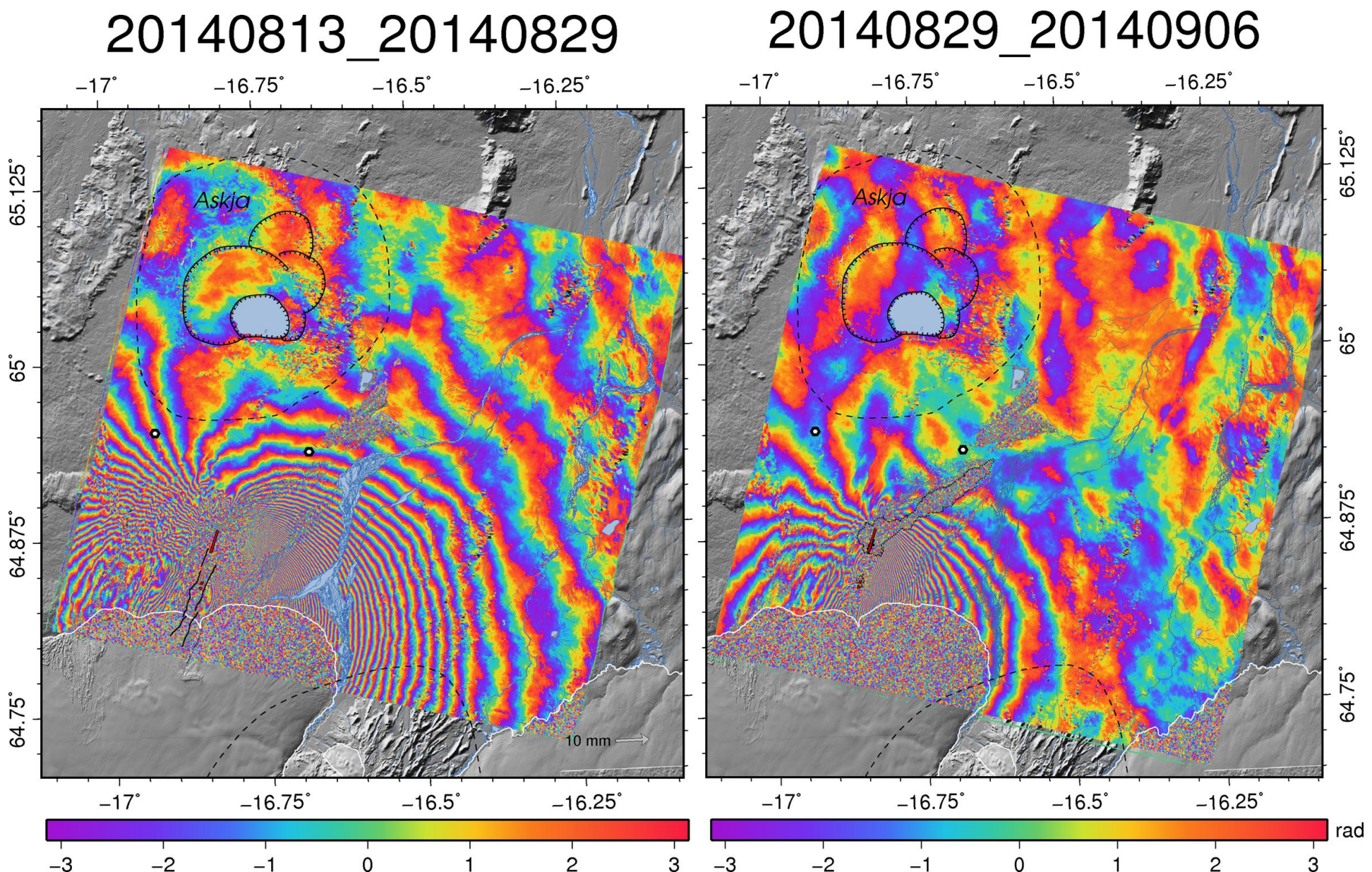


Bárðarbunga rifting event (Aug. 2014 - Feb. 2015)

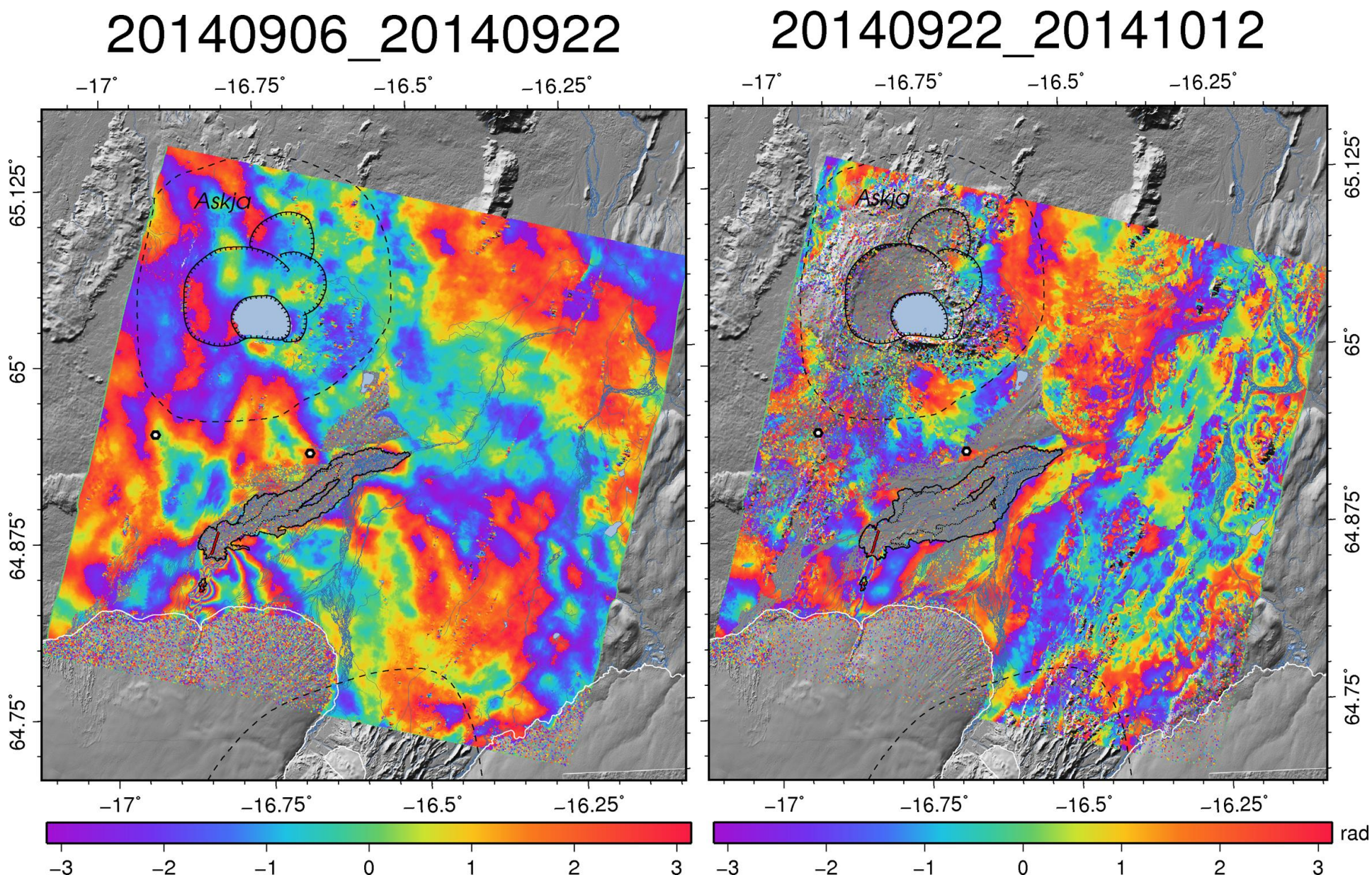


(Sigmundsson et al., 2015)

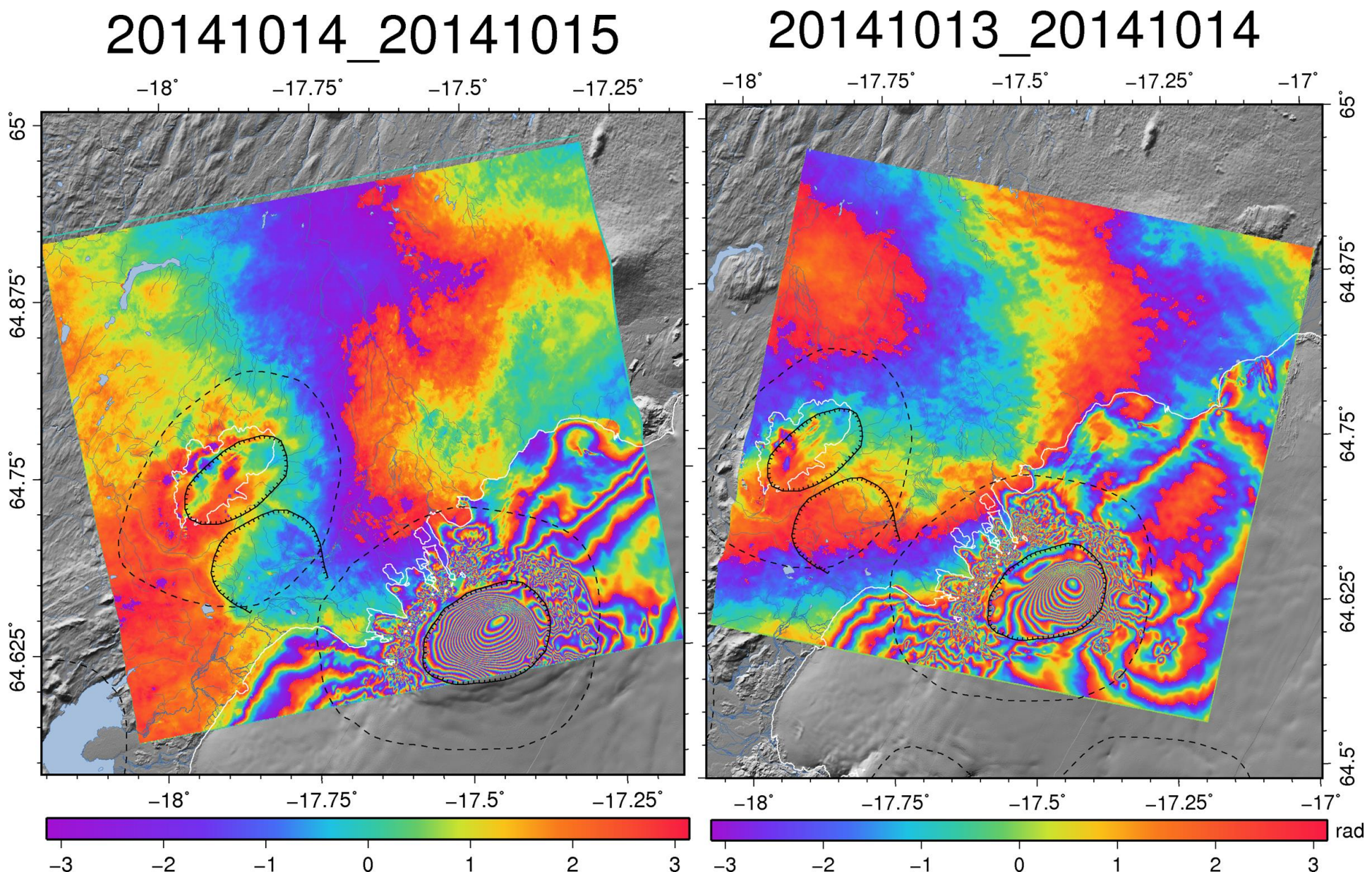
Interferograms over the early phase of the unrest/eruption



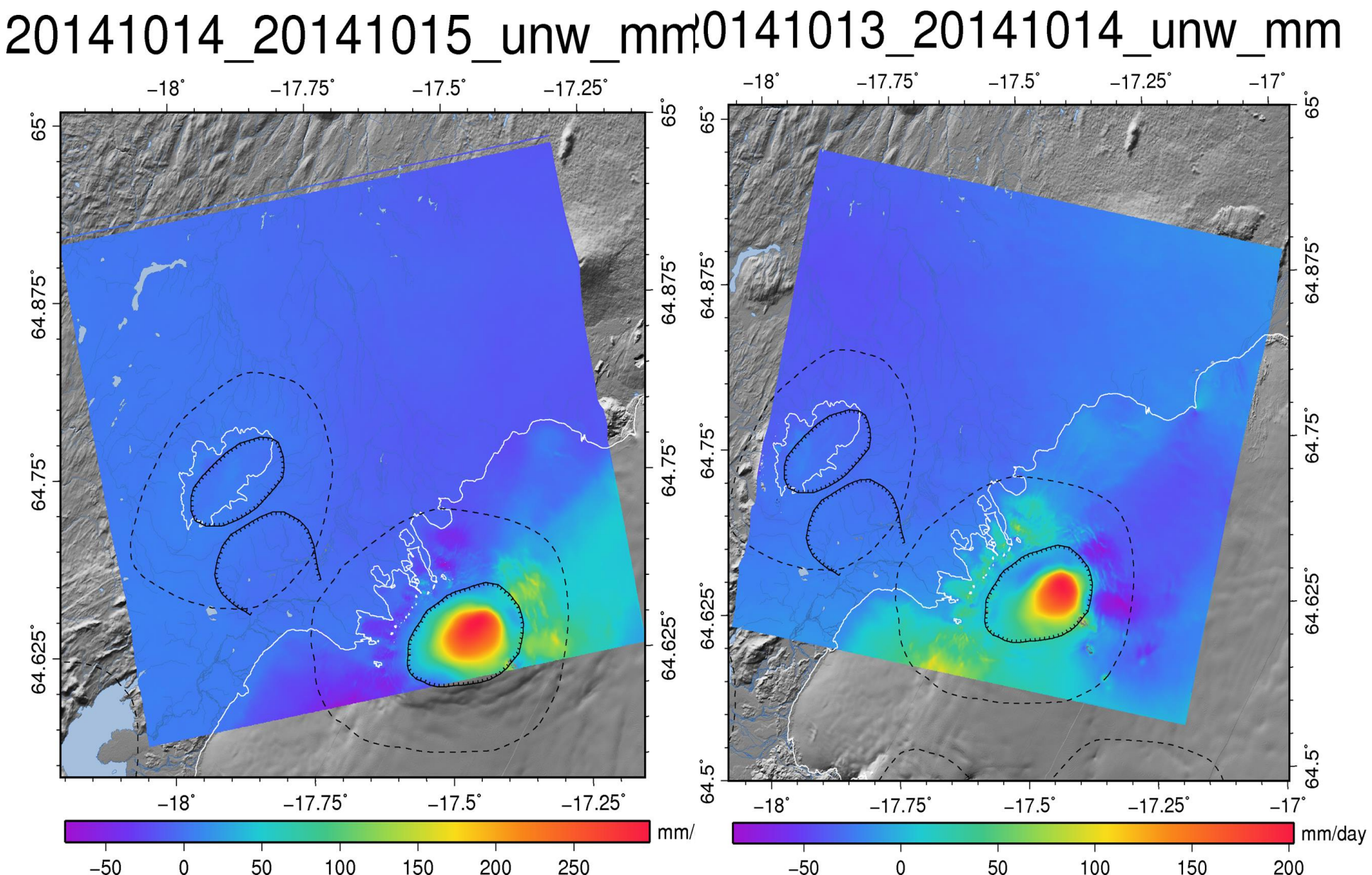
Interferograms over the early phase of the unrest/eruption



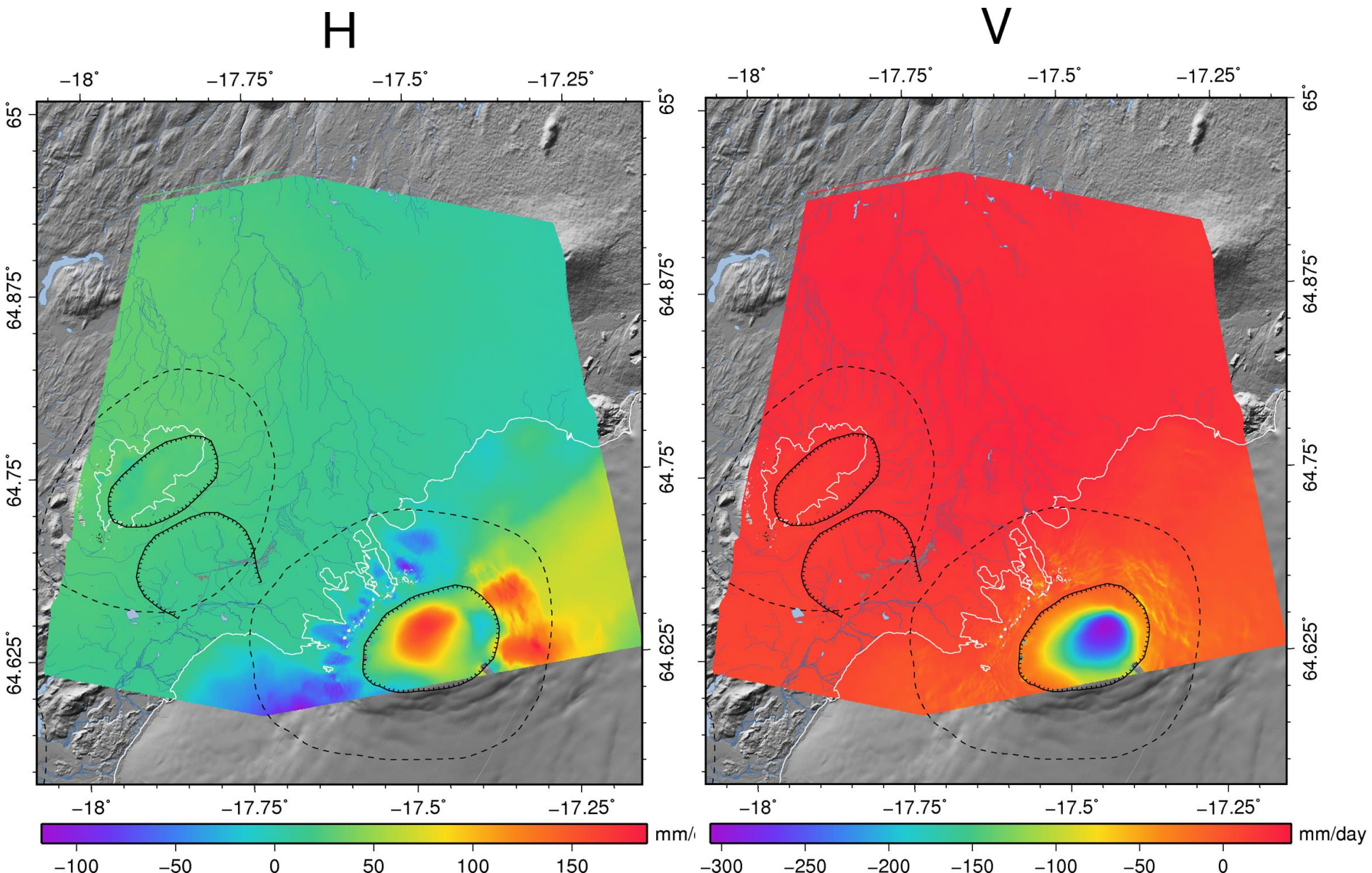
1-day interferogram over the ice-capped caldera



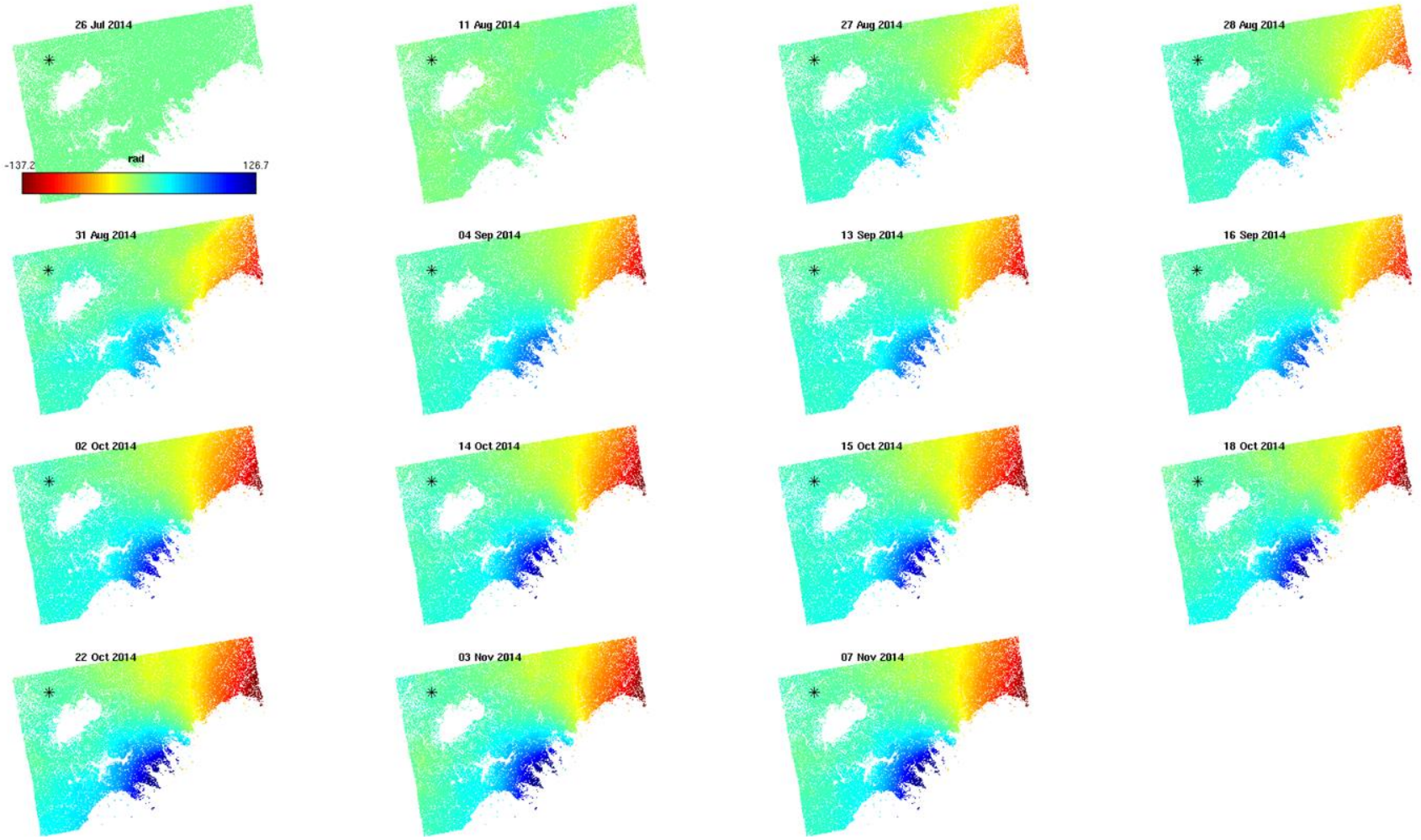
1-day interferogram over the ice-capped caldera



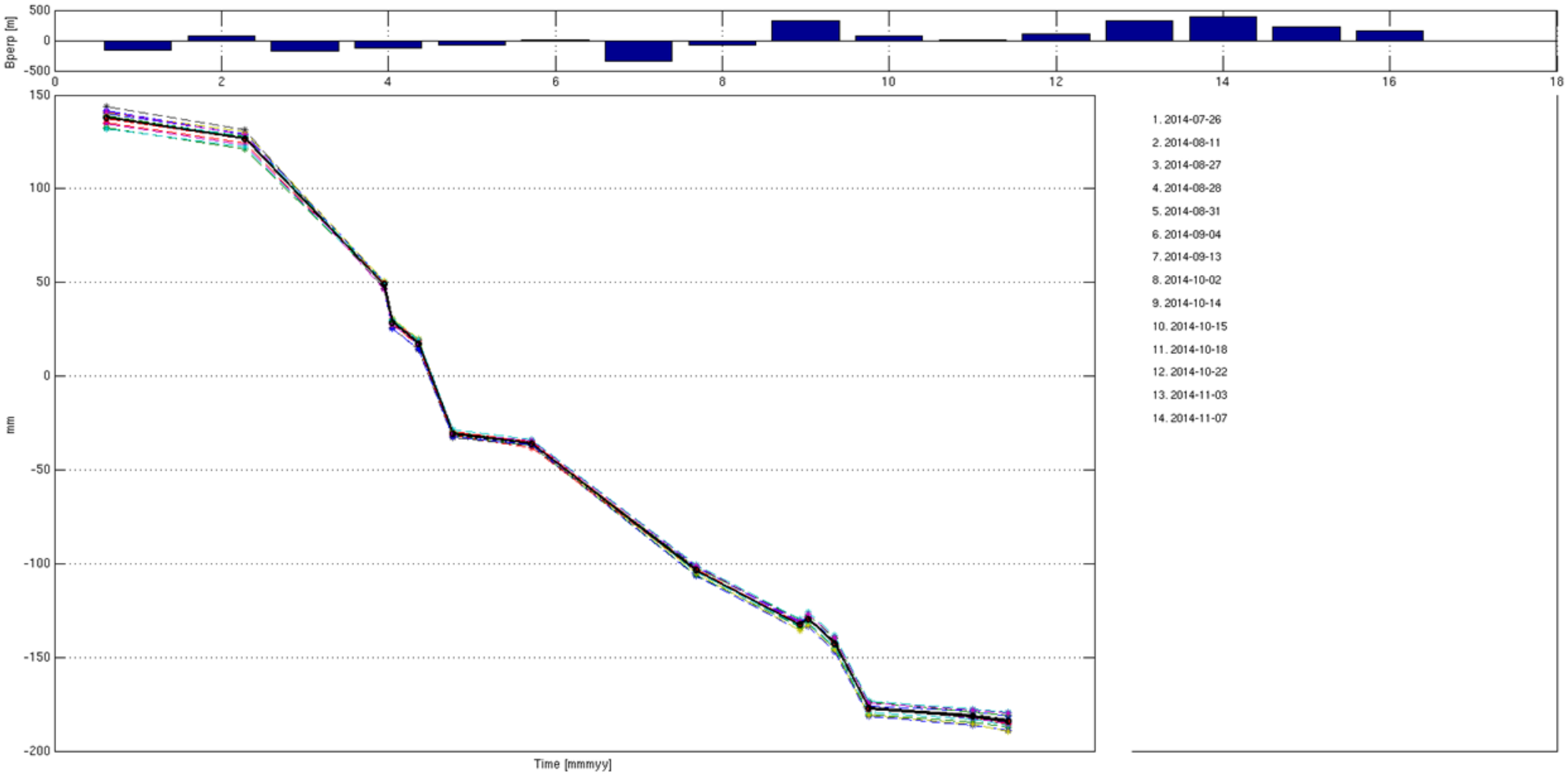
1-day interferogram over the ice-capped caldera

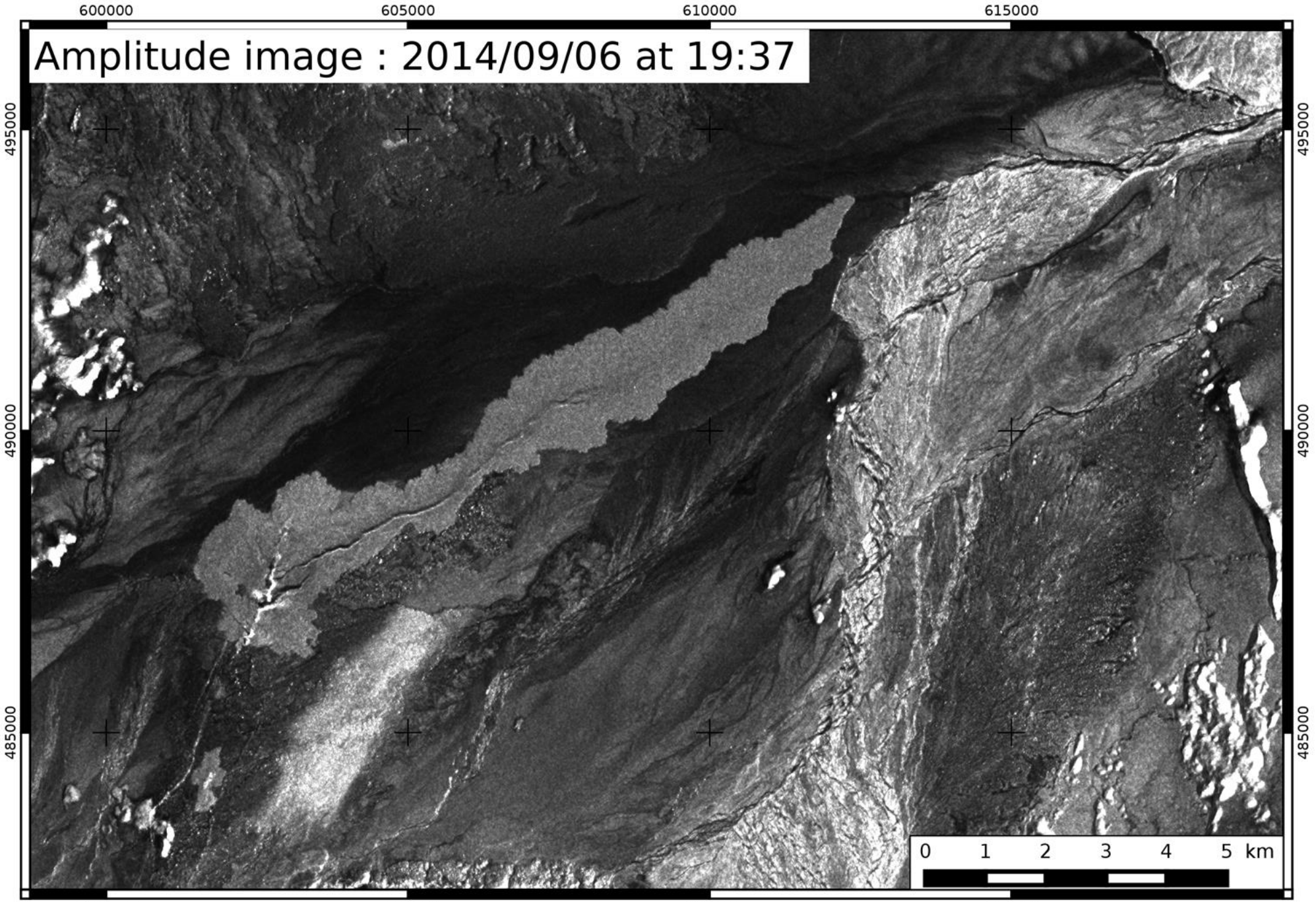


PS-InSAR time-series

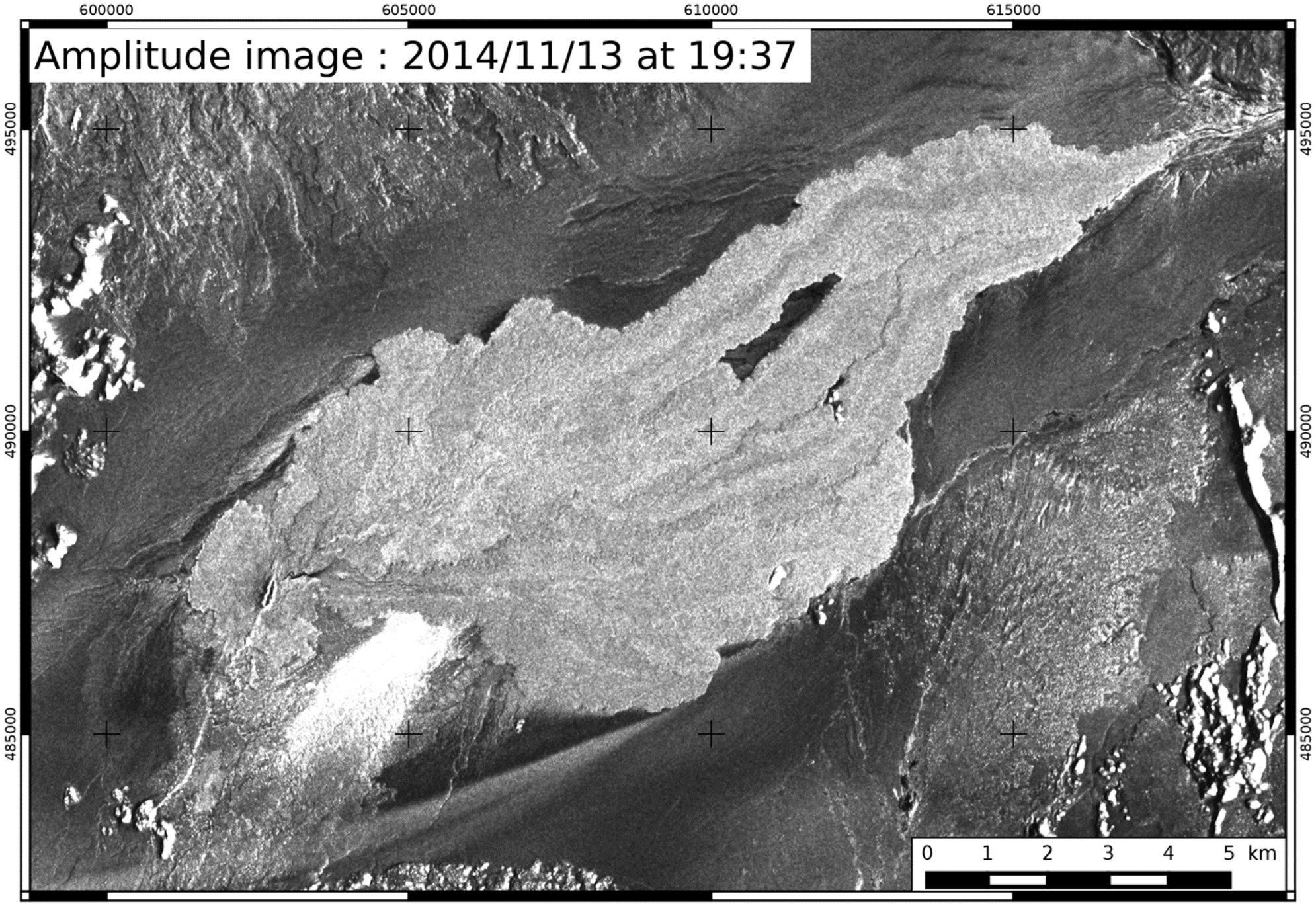


Cumulative displacement

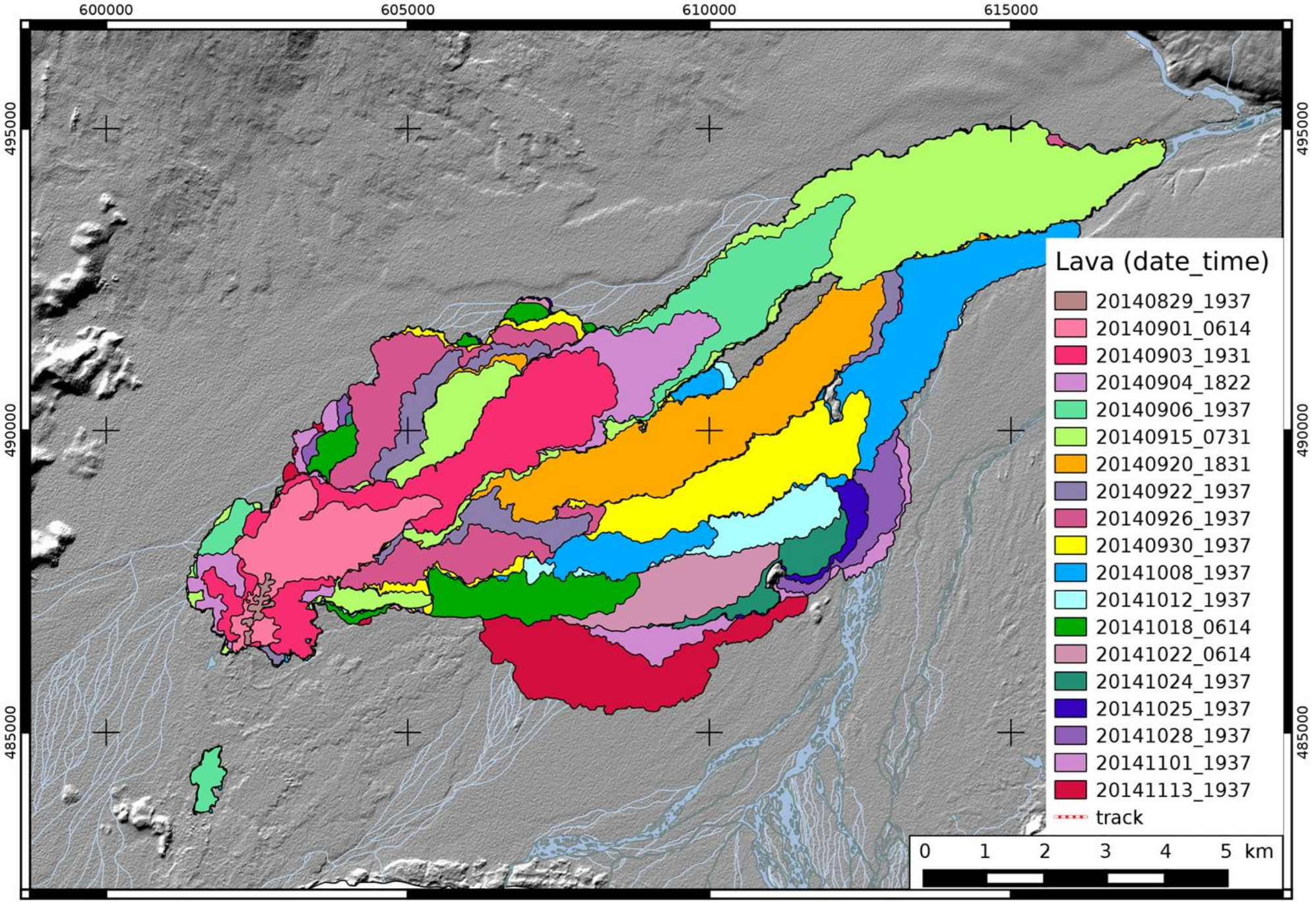




Coordinate system : ISN93 - Vincent Drouin - Institute of Earth Sciences - University of Iceland - 2014/11/21

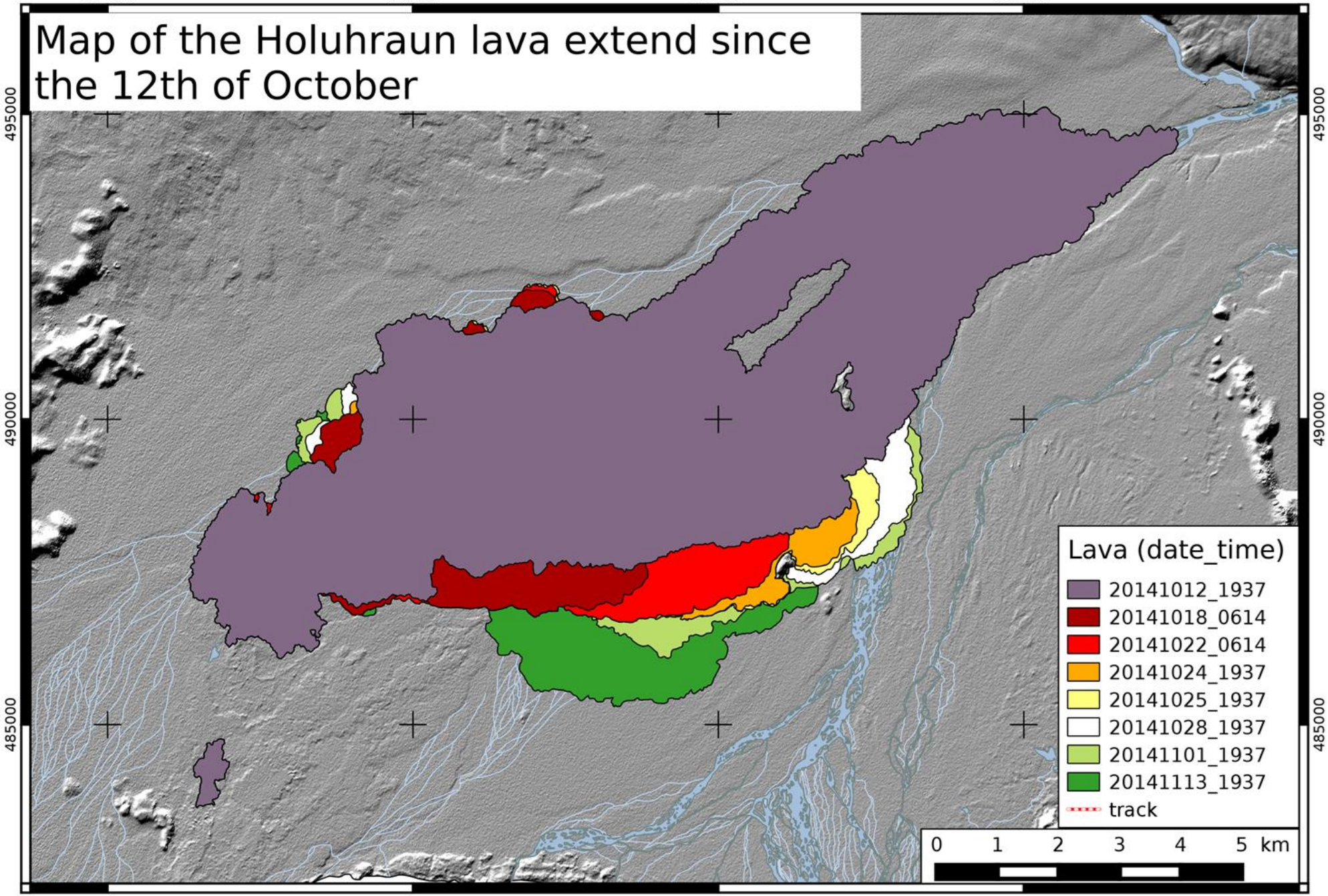


Coordinate system : ISN93 - Vincent Drouin - Institute of Earth Sciences - University of Iceland - 2014/11/21



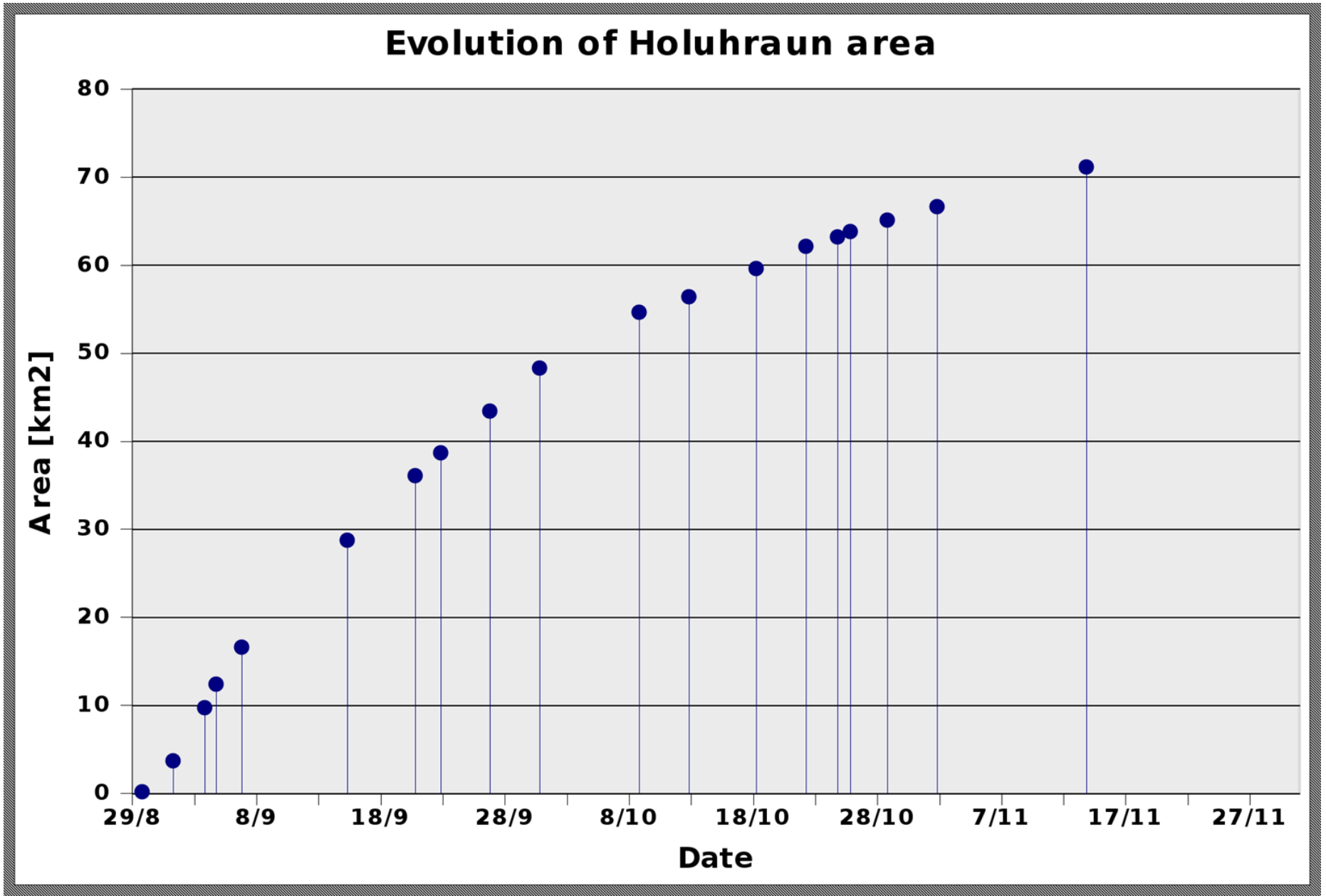
Coordinate system : ISN93 - Vincent Drouin - Institute of Earth Sciences - University of Iceland - 2014/11/17

Map of the Holuhraun lava extend since the 12th of October

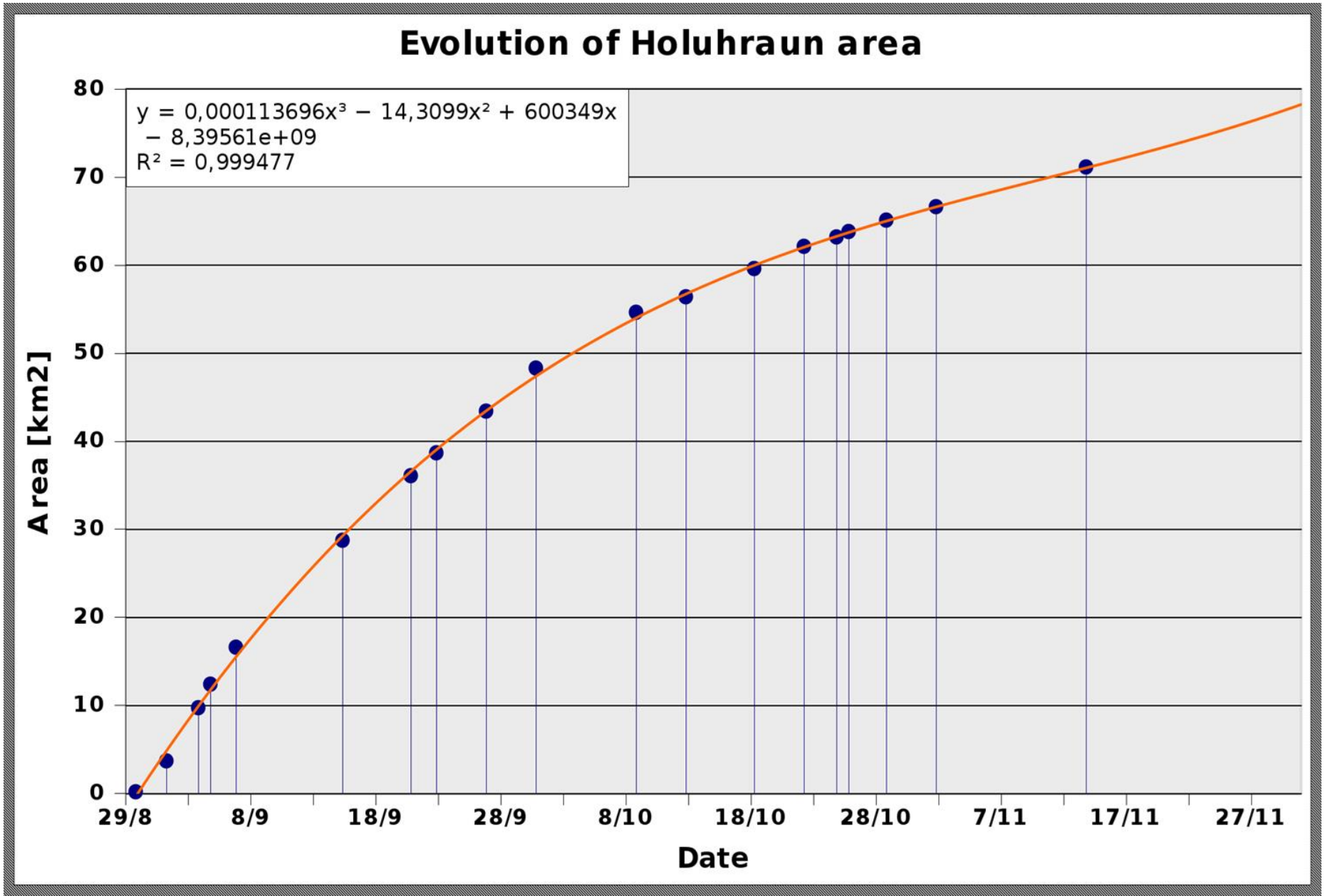


Coordinate system : ISN93 - Vincent Drouin - Institute of Earth Sciences - University of Iceland - 2014/11/17

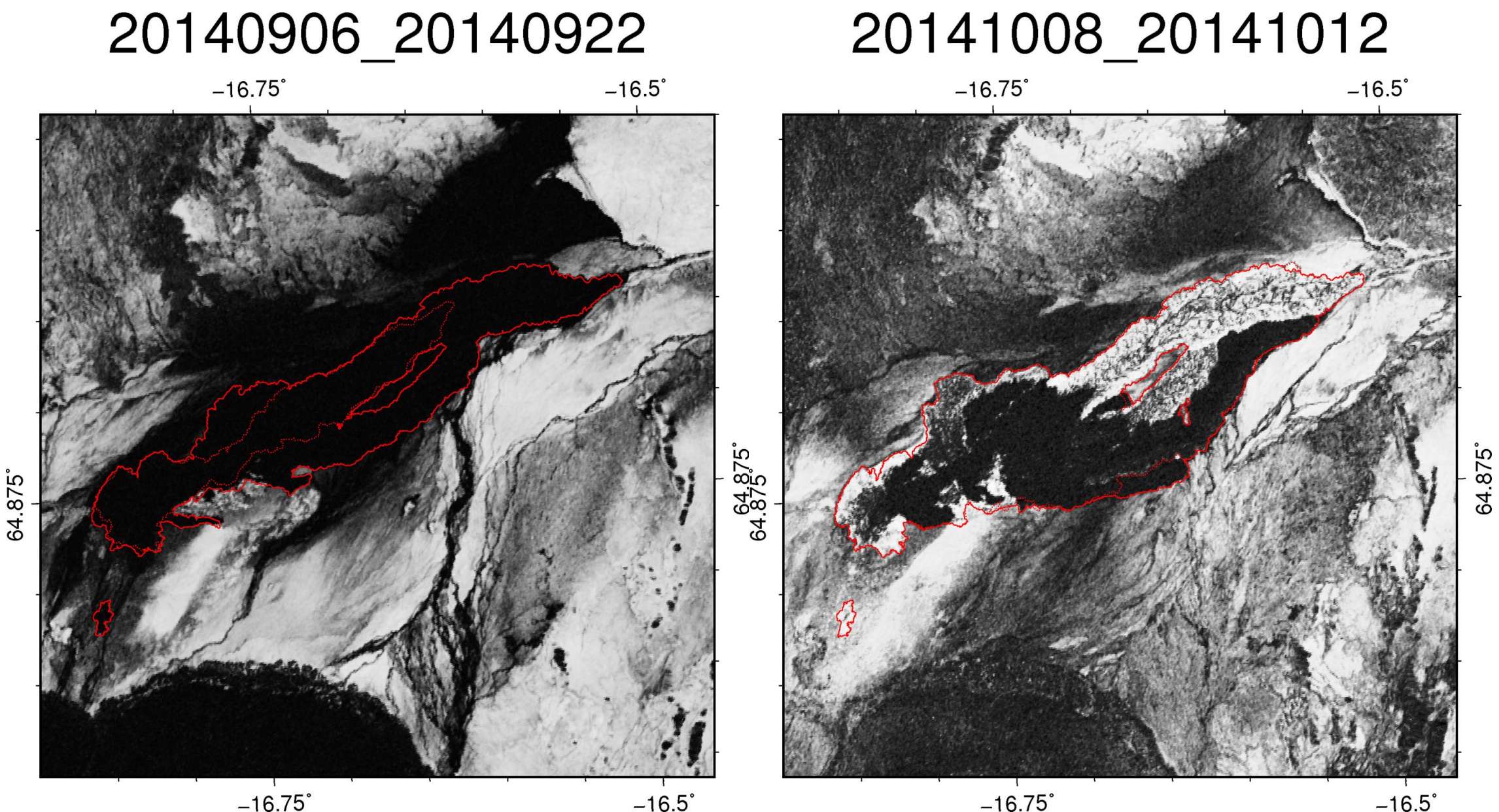
Area covered by lava



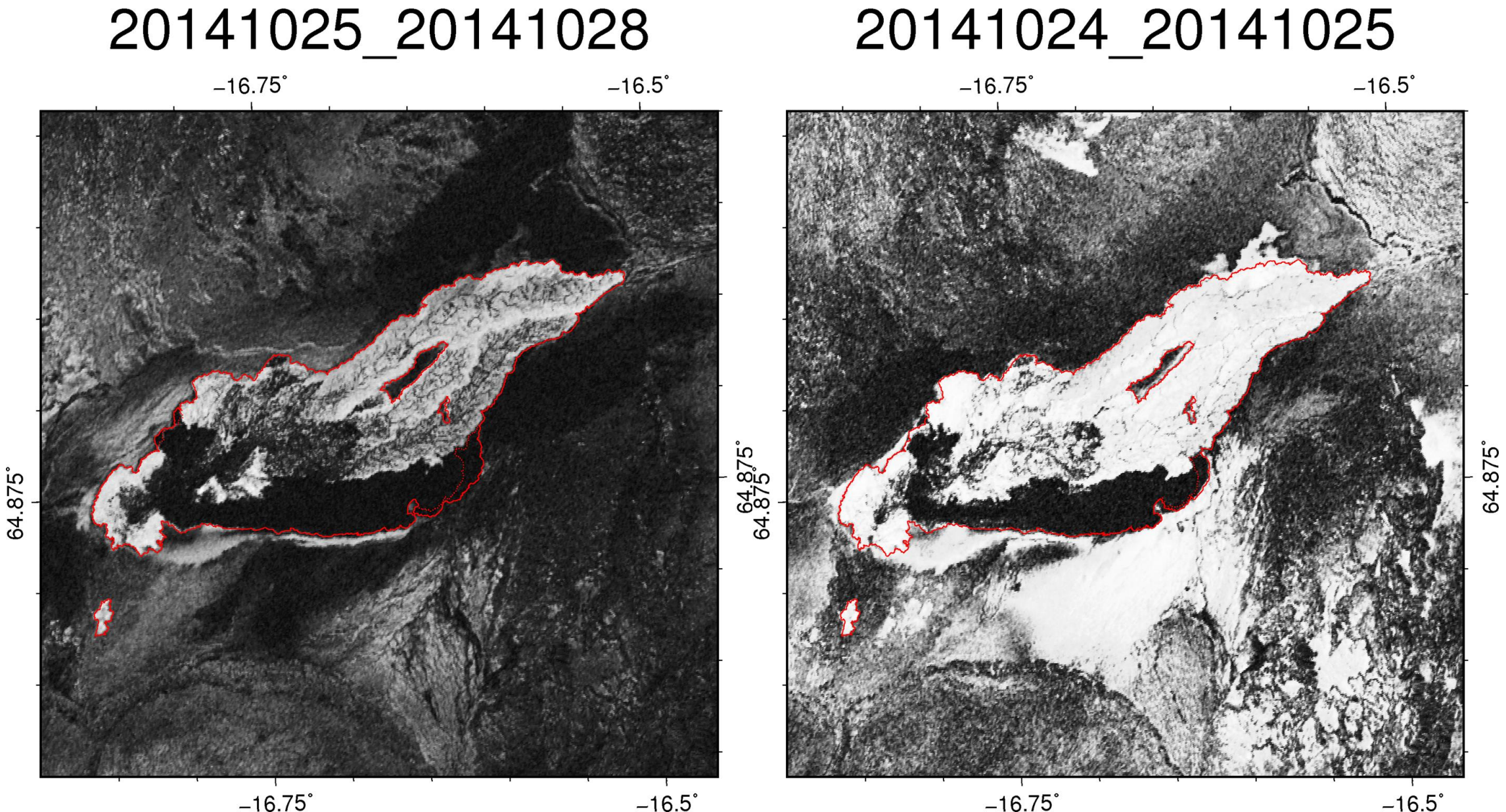
Area covered by lava



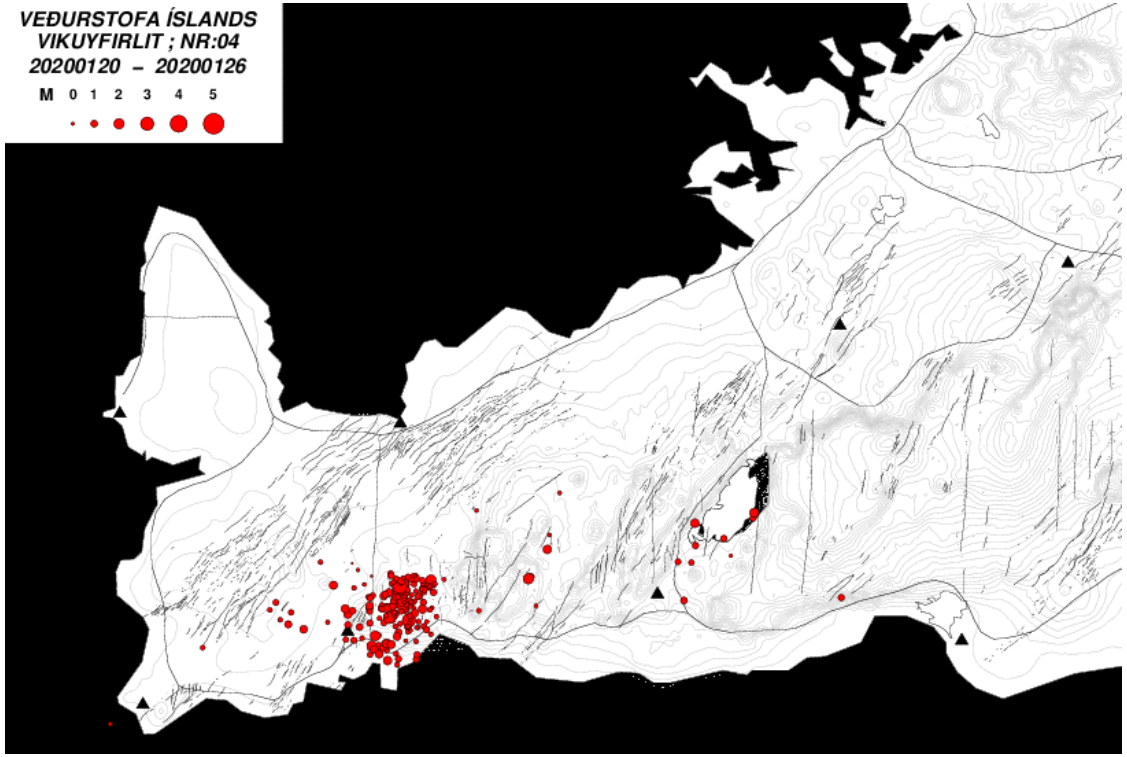
Coherence showing active parts of the lava flow

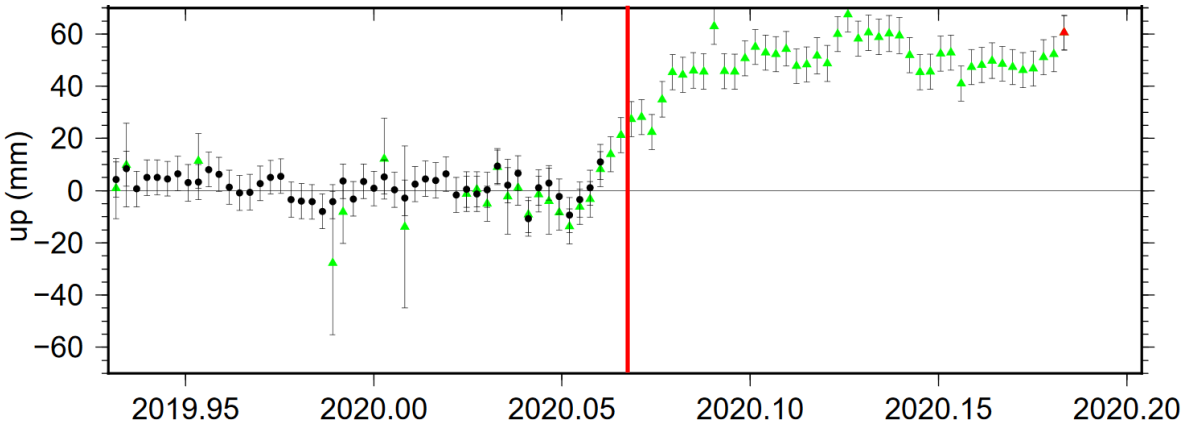


Coherence showing active parts of the lava flow



Uplift near Grindavík in January 2020





Uplift near Grindavík in January 2020

http://icelandsupersite.hi.is/s1/monitoring.html

Sentinel-1 monitoring

Date:

01 / 19 / 2020

Time: 0:00

Location:

- Iceland
- Reykjanes
- SISZ
- Hekla
- KatlaEyja
- Bárðarbunga
- Oraefajökull
- Svinafellsjökull
- Askja
- Krafla

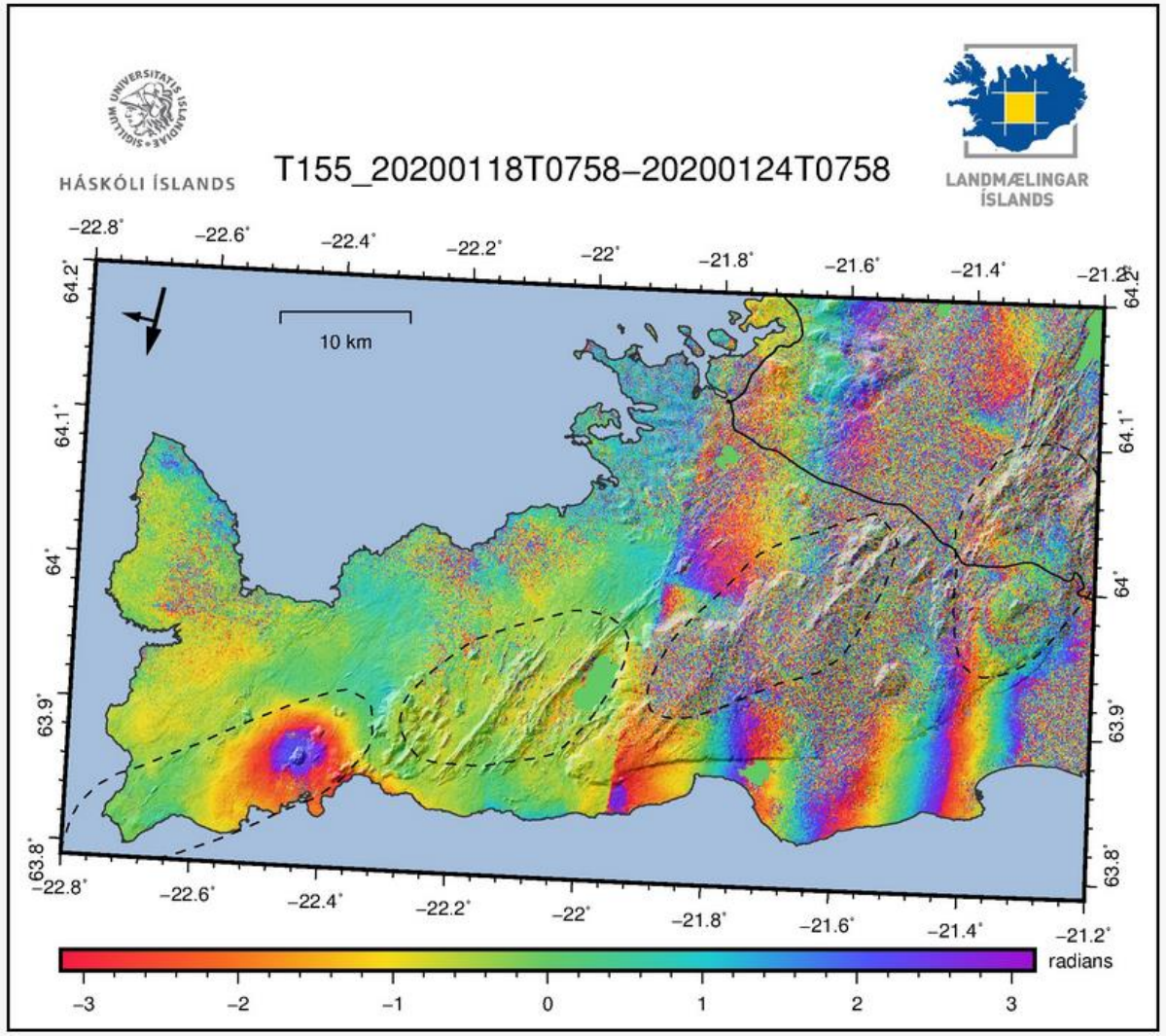
Appearance:

- Unwrapped
- Wrapped

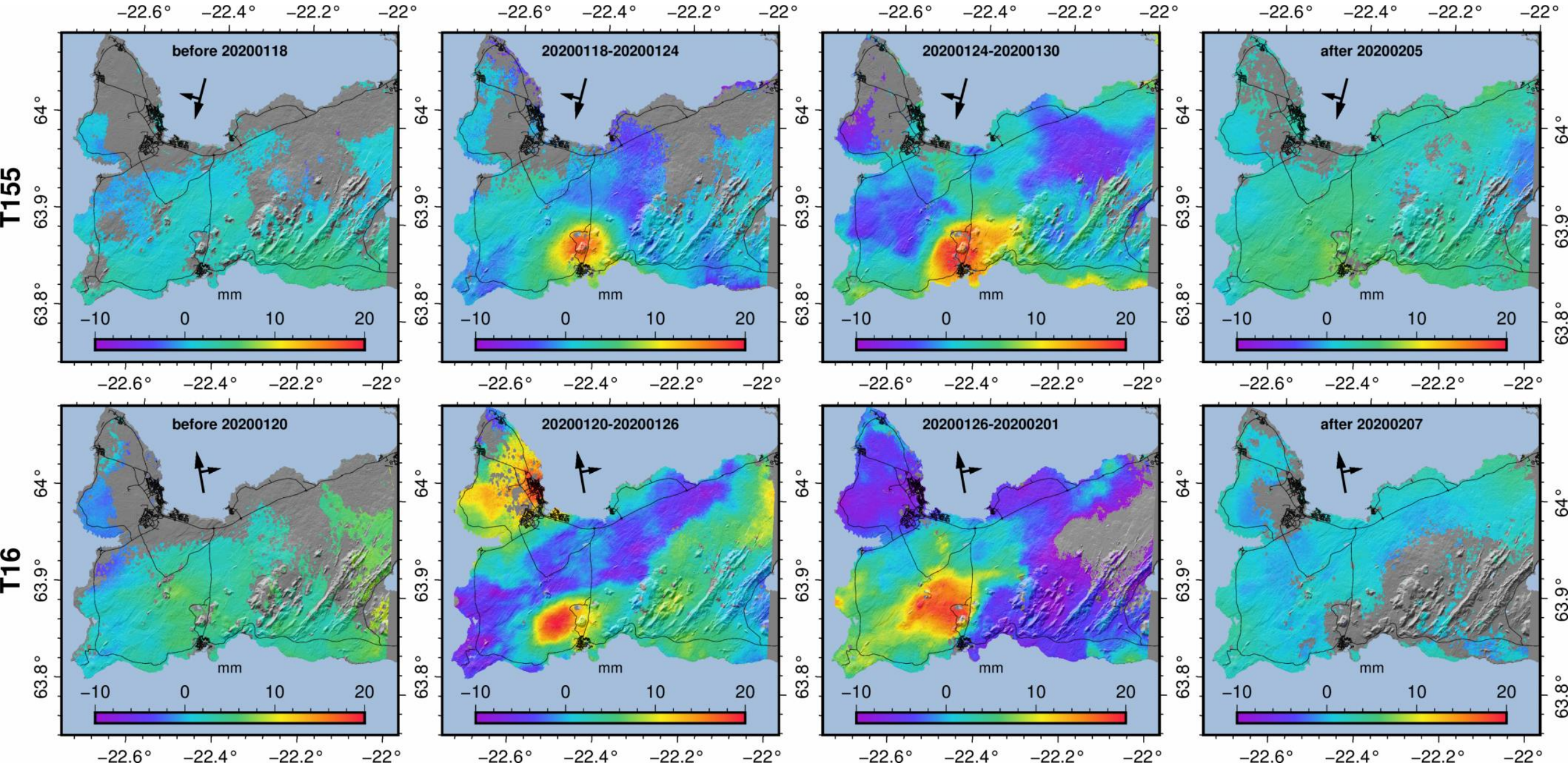
Acquisitions:

Track	Last	Next
T111	Fri Feb 14 2020 07:33	Thu Feb 20 2020 07:33
T118	Fri Feb 14 2020 18:51	Thu Feb 20 2020 18:51
T147	Sun Feb 16 2020 18:34	Sat Feb 22 2020 18:34
T155	Mon Feb 17 2020 07:58	Sun Feb 23 2020 07:58
T16	Wed Feb 19 2020	Tue Feb 25 2020

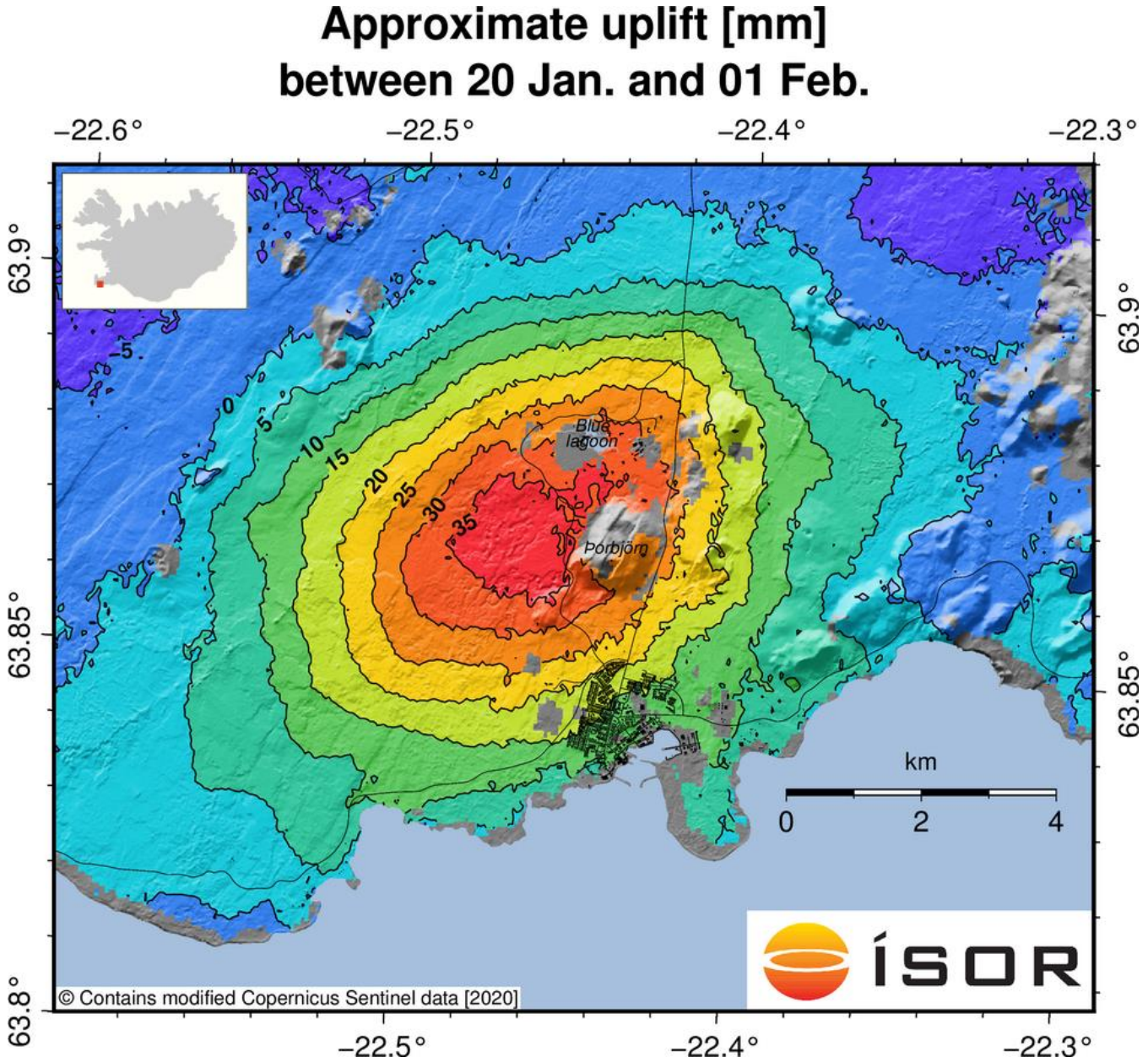
Reykjanes 2020-01-19



Uplift near Grindavik in January 2020 - LOS



Uplift near Grindavik in January 2020 - Vertical



Looking at all Iceland

Geophysical Research Letters

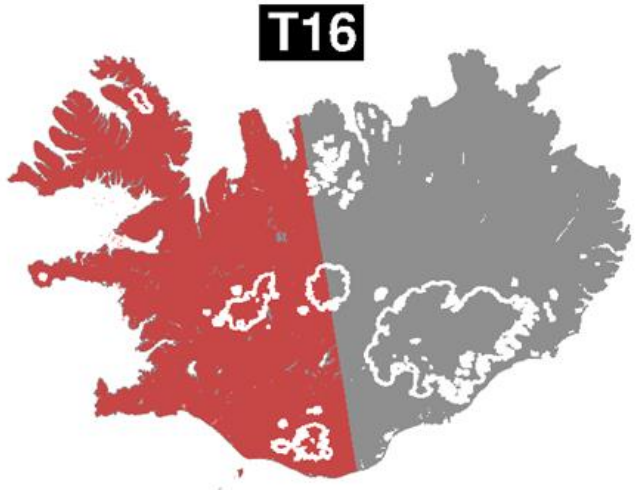
Research Letter | Full Access

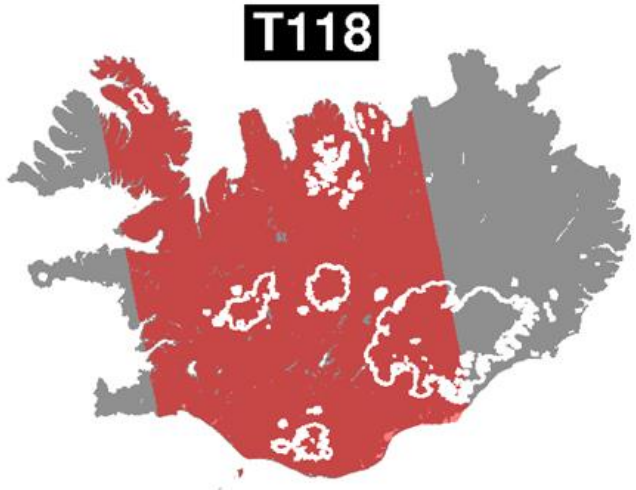
Countrywide Observations of Plate Spreading and Glacial Isostatic Adjustment in Iceland Inferred by Sentinel-1 Radar Interferometry, 2015–2018

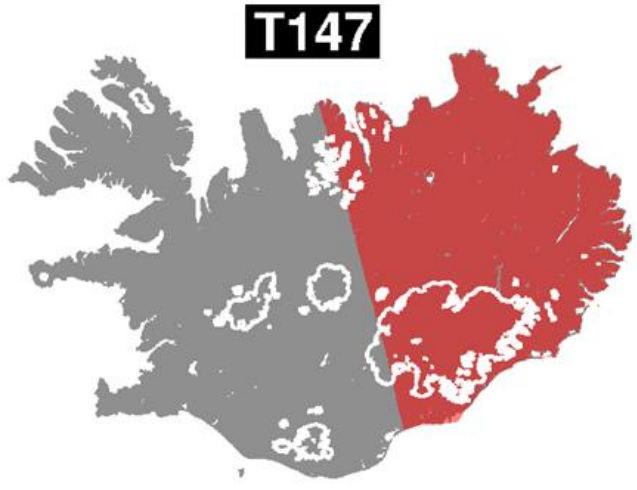
Vincent Drouin, Freysteinn Sigmundsson

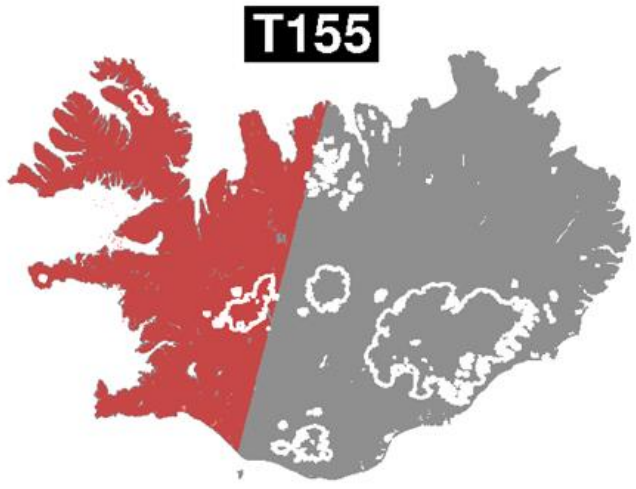
First published: 15 July 2019 | https://doi.org/10.1029/2019GL082629

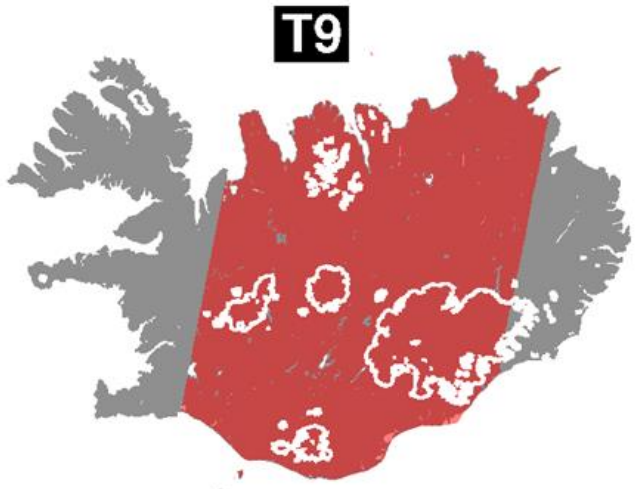
Sentinel-1 IW tracks

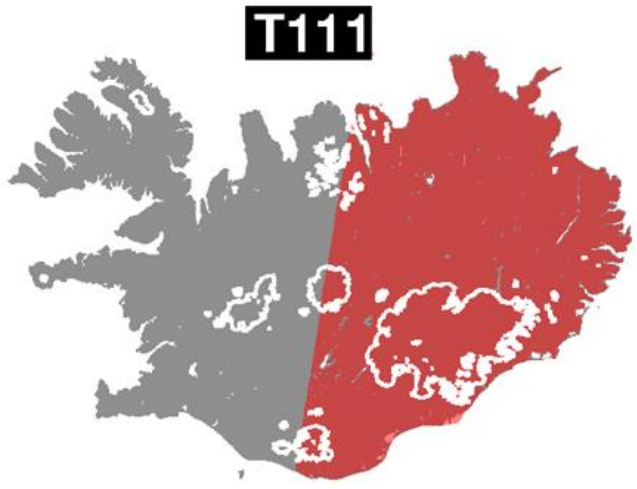




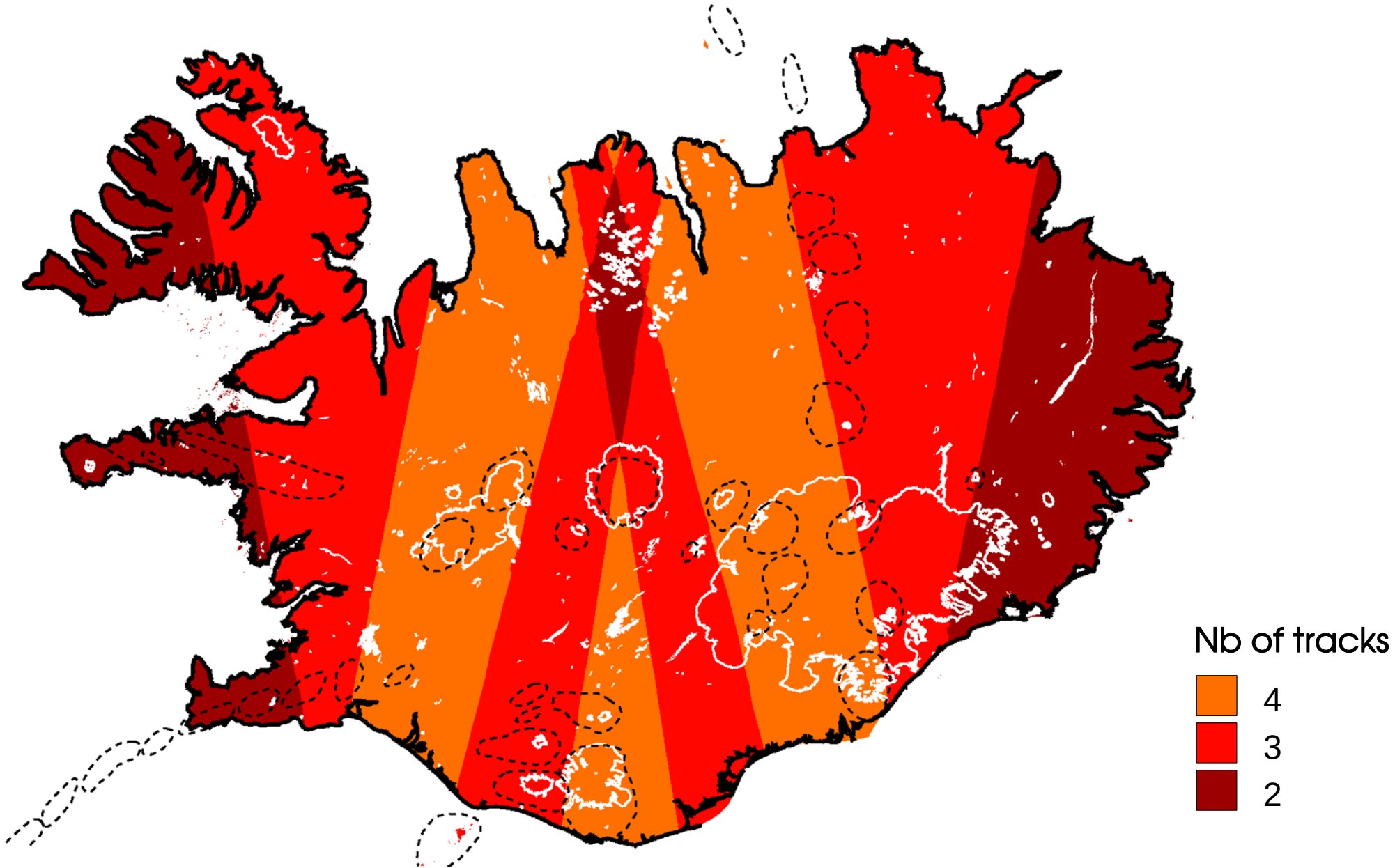








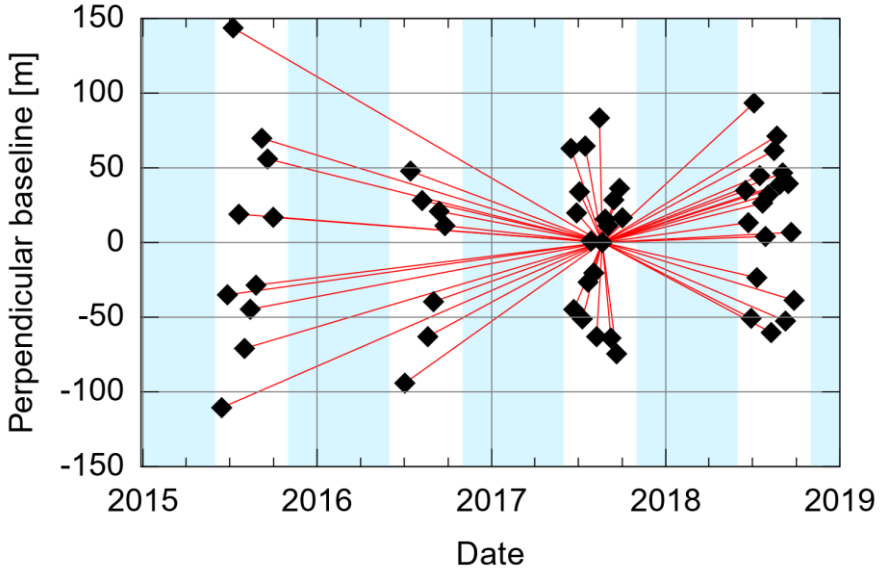
Sentinel-1 IW tracks - overlap



2015-2018 velocities estimation procedure

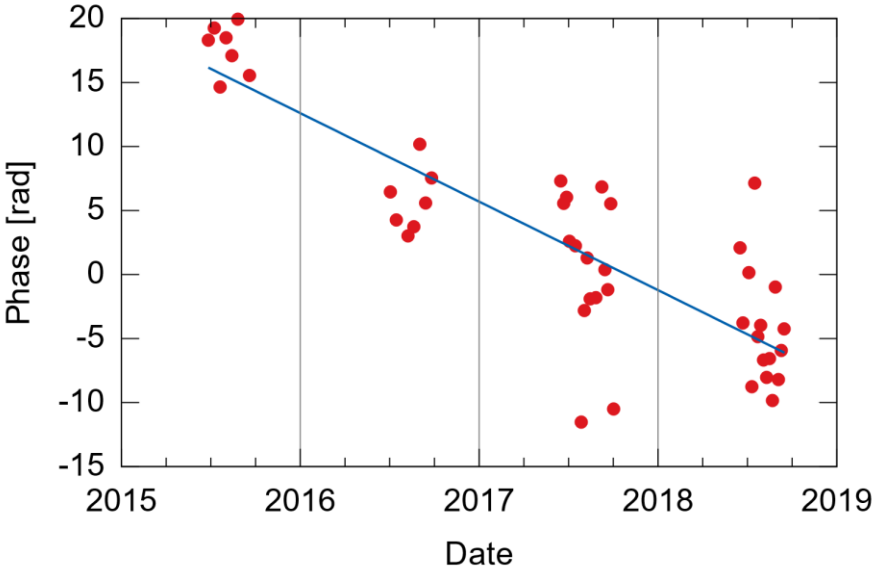
1) Forming the interferograms

- Data: Images from summer 2015, summer 2016, summer 2017, and summer 2018
- Software: InSAR Scientific Computing Environment (ISCE) version 2.2.0
- Method: single-master interferometry
- DEM: Preliminary TanDEM-X DEM with gaps filled with ASTER DEM

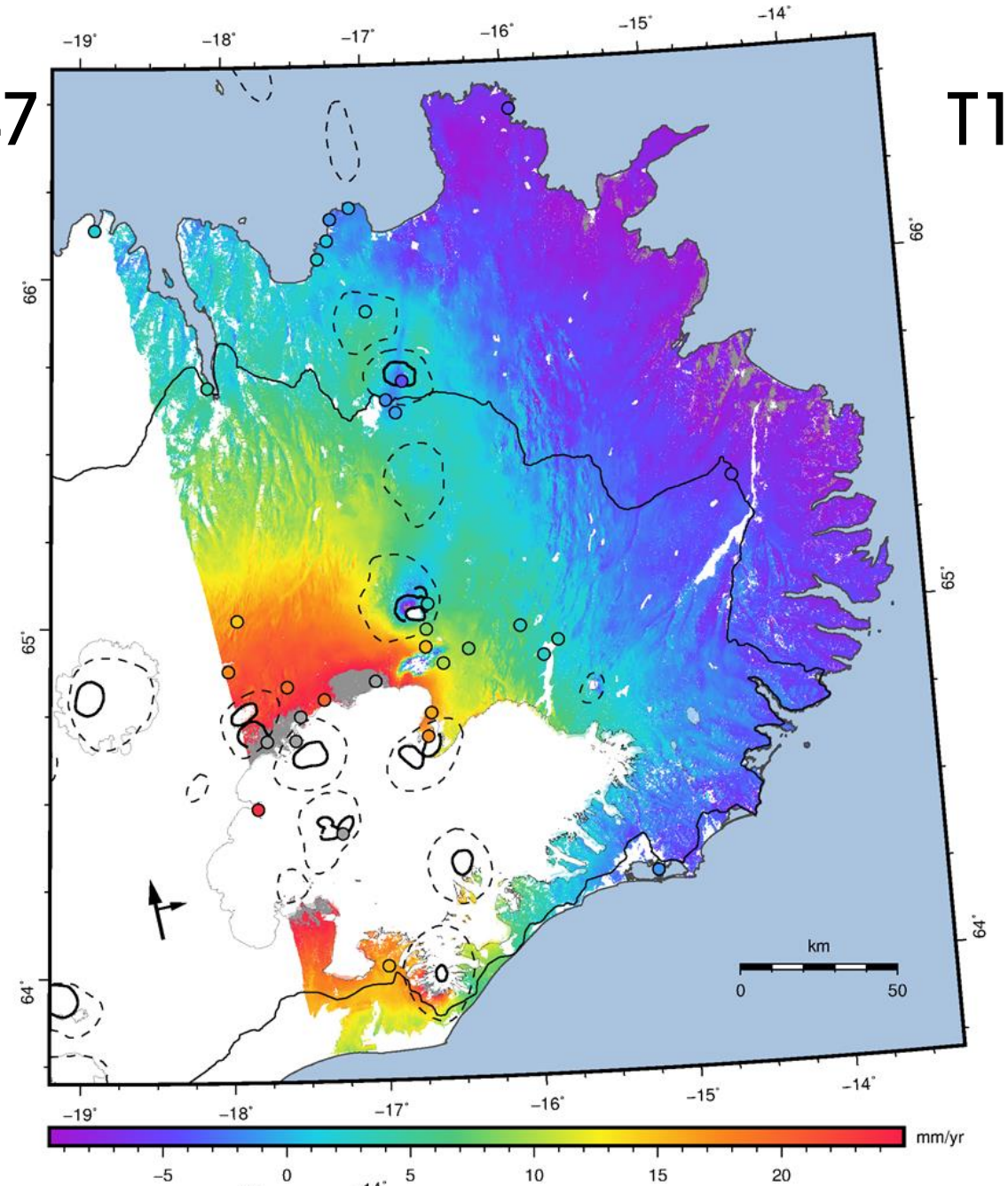


2) Estimating the 2015-2017 velocities

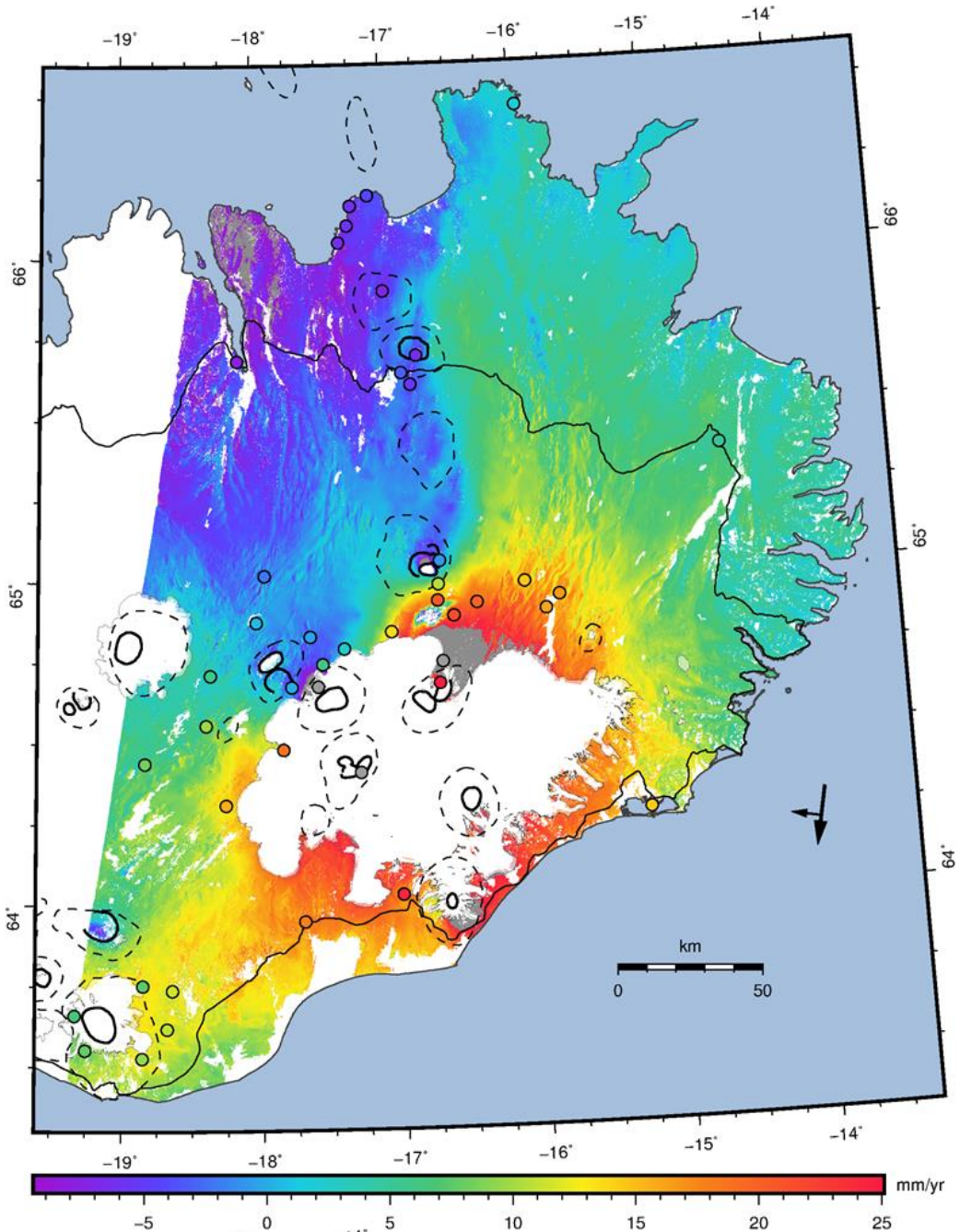
1. Reference all interferograms to the same area to have a stack.
2. Remove the bad interferograms
3. For each pixel, extract the displacement value from each image of the stack to generate a time-series. Then use this time-series to estimate the velocity of the pixel.



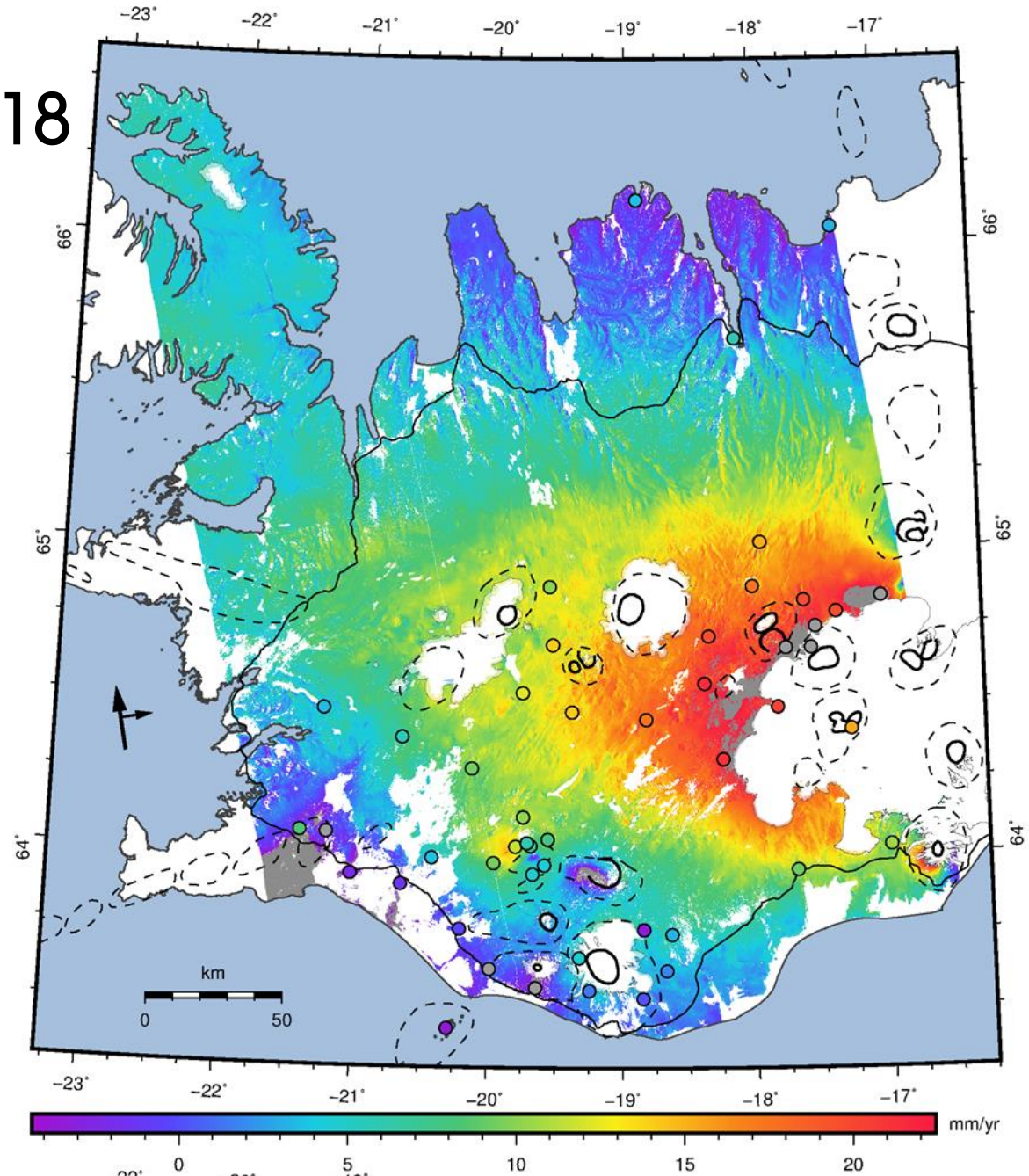
T147


−19°
−18°
−17°
−16°
−15°
−14°
66°
65°
64°
km
0
50
mm/yr
−5
0
5
10
15
20

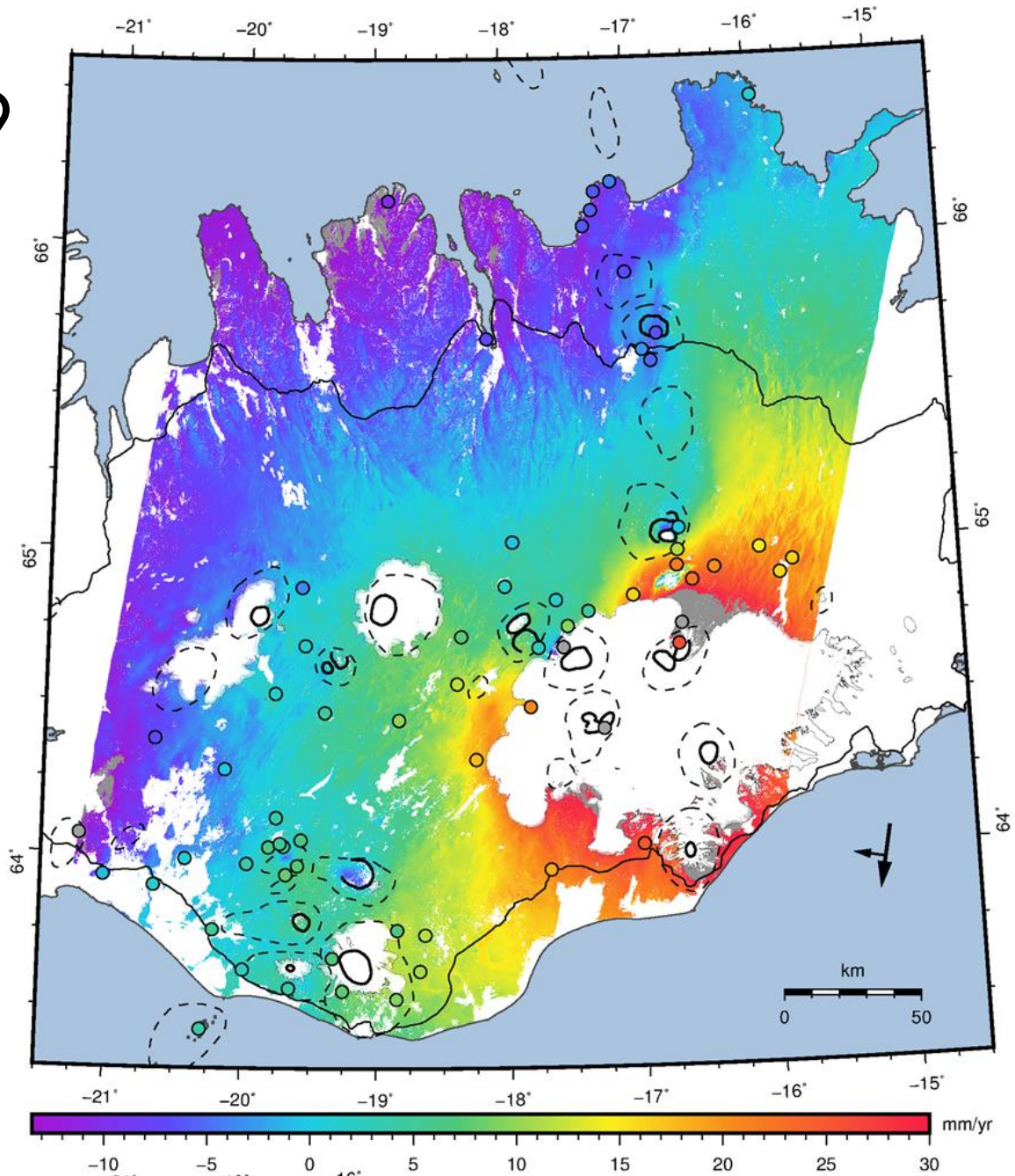
T111


−19°
−18°
−17°
−16°
−15°
−14°
66°
65°
64°
km
0
50
mm/yr
−5
0
5
10
15
20
25

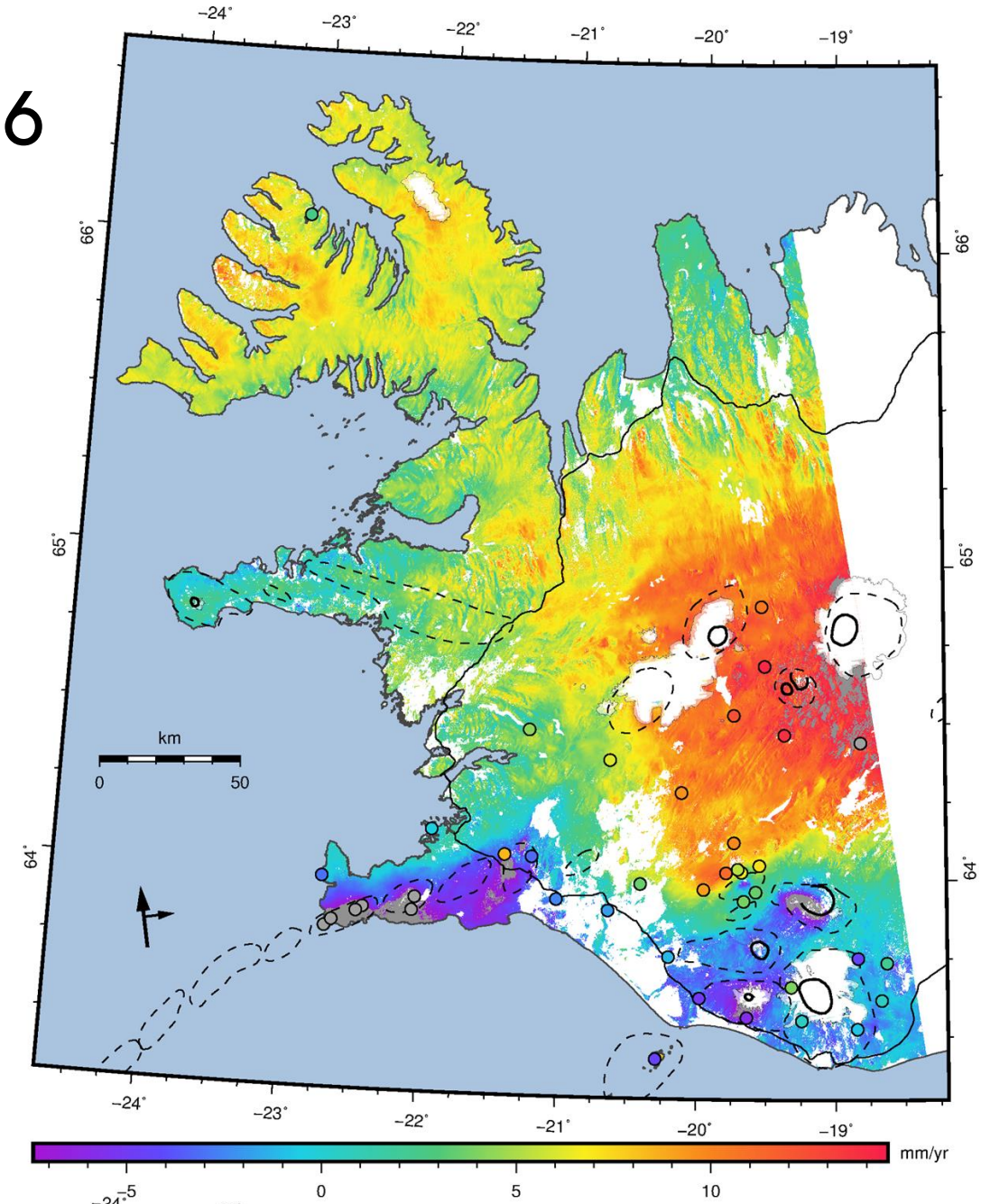
T118


−23°
−22°
−21°
−20°
−19°
−18°
−17°
66°
65°
64°
km
0
50
mm/yr
0
5
10
15
20

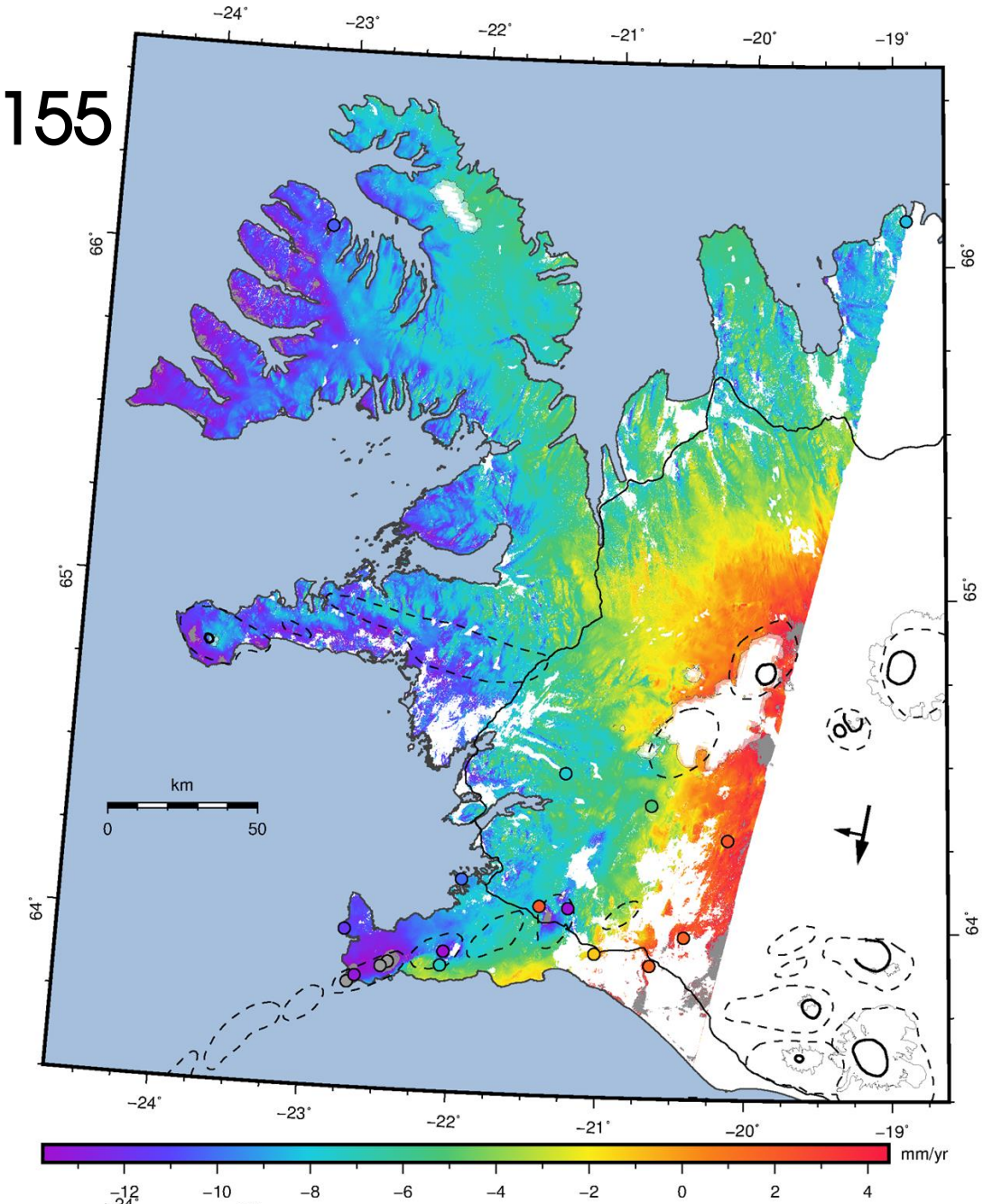
T9


−21°
−20°
−19°
−18°
−17°
−16°
−15°
66°
65°
64°
km
0
50
mm/yr
−10
−5
0
5
10
15
20
25
30

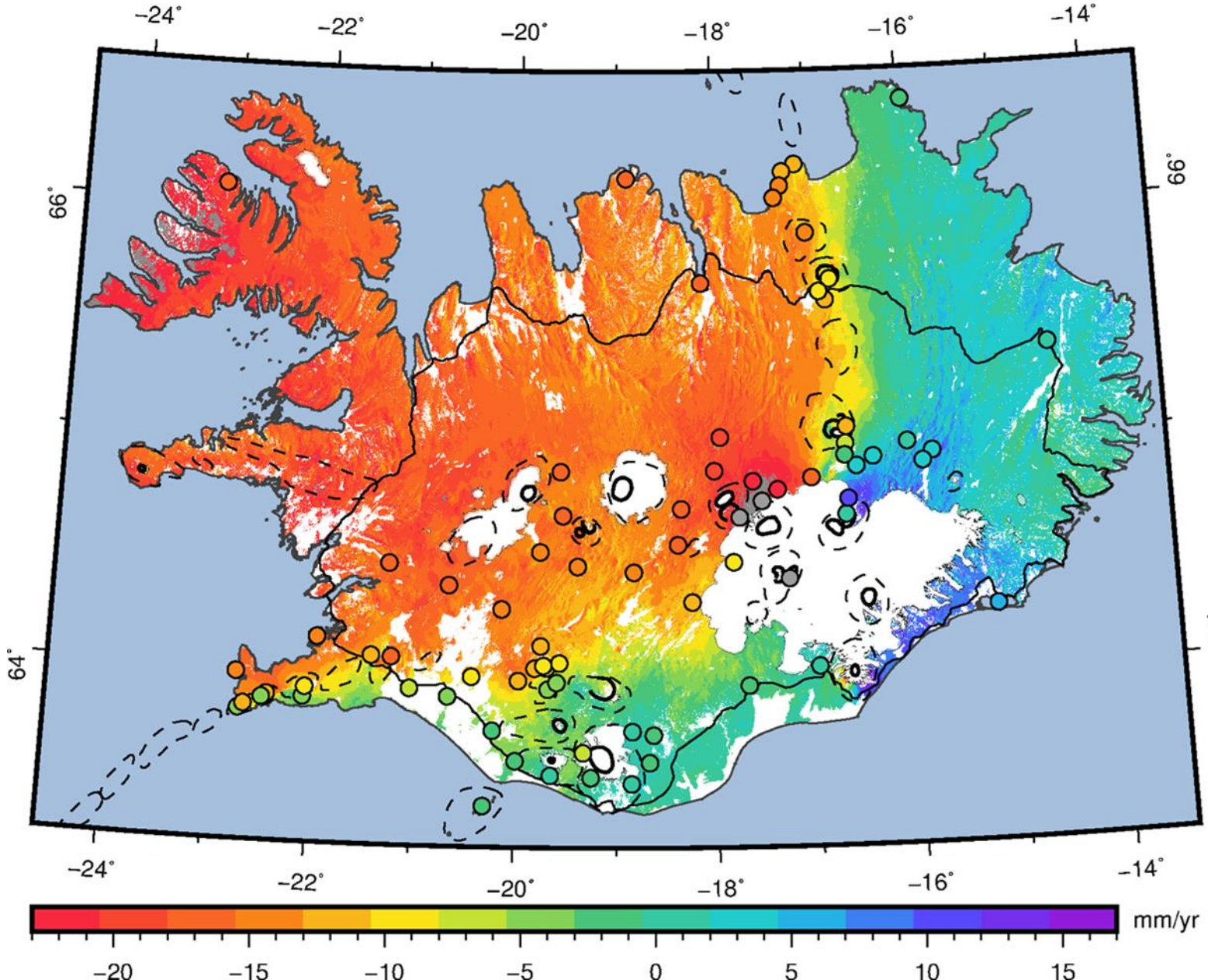
T16

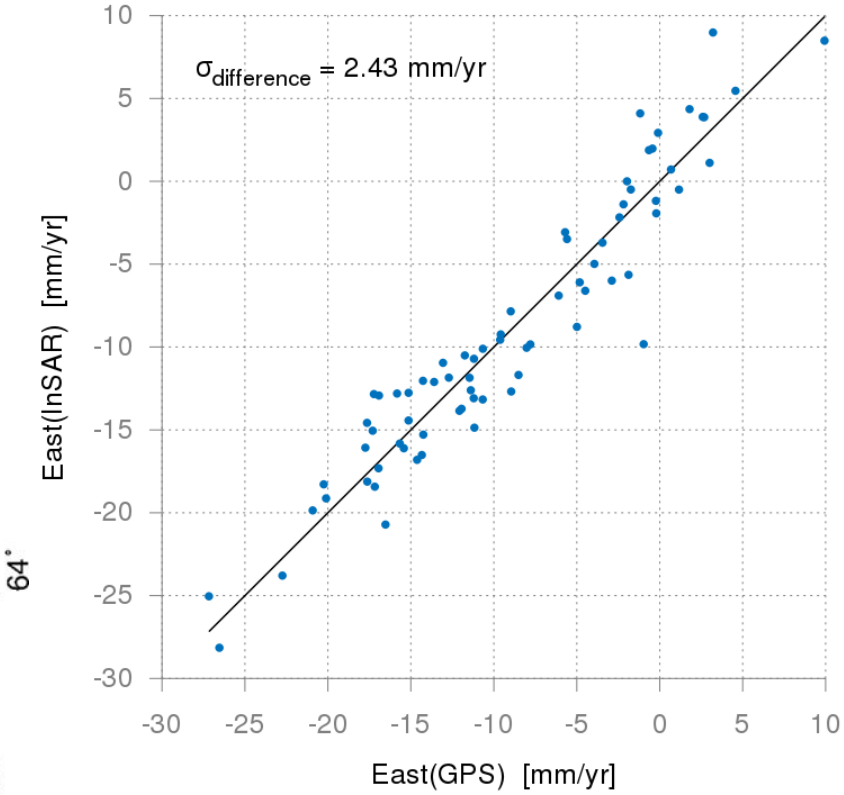

−24°
−23°
−22°
−21°
−20°
−19°
66°
65°
64°
km
0
50
−5
0
5
10
mm/yr

T155

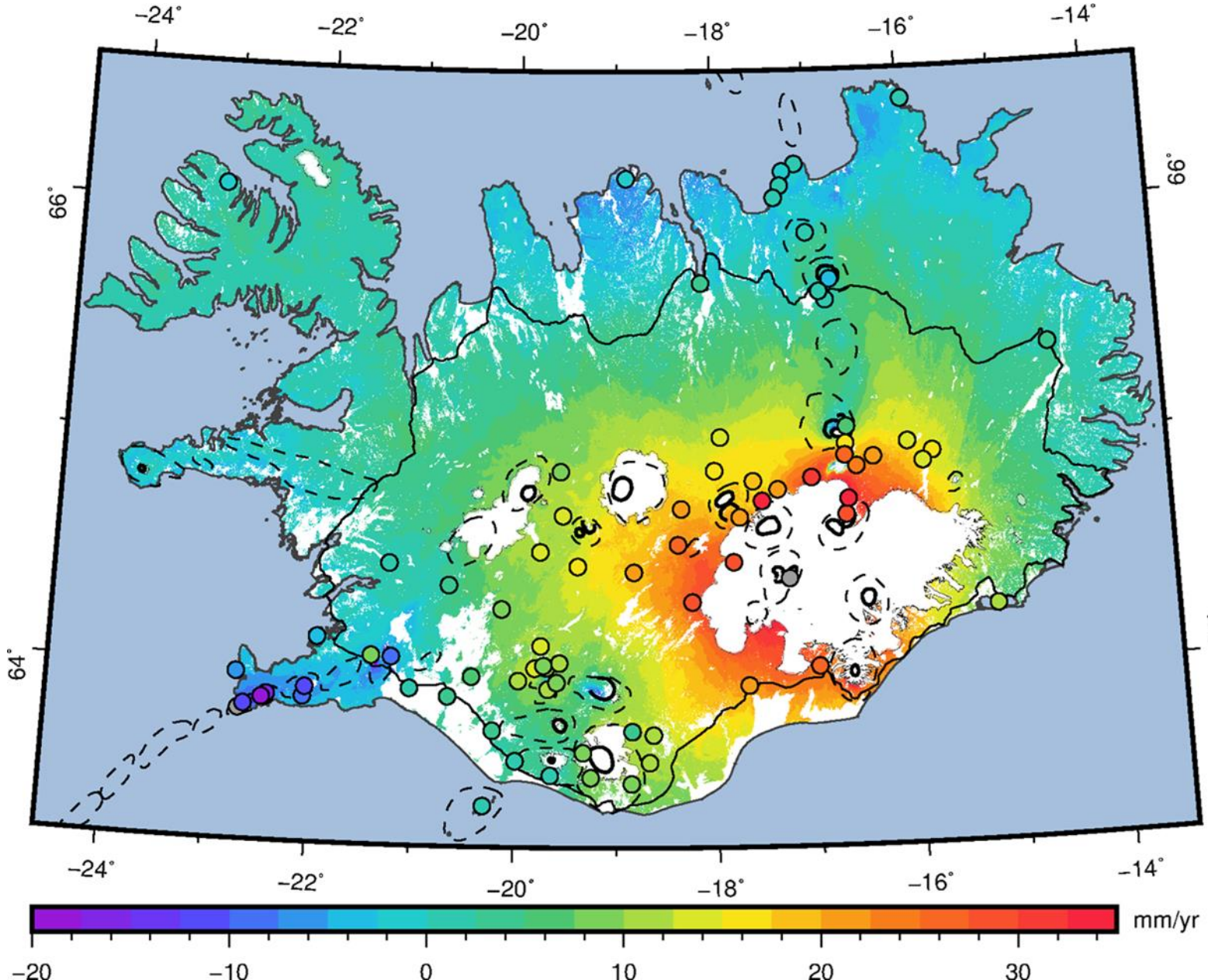

−24°
−23°
−22°
−21°
−20°
−19°
66°
65°
64°
km
0
50
−12
−10
−8
−6
−4
−2
0
2
4
mm/yr

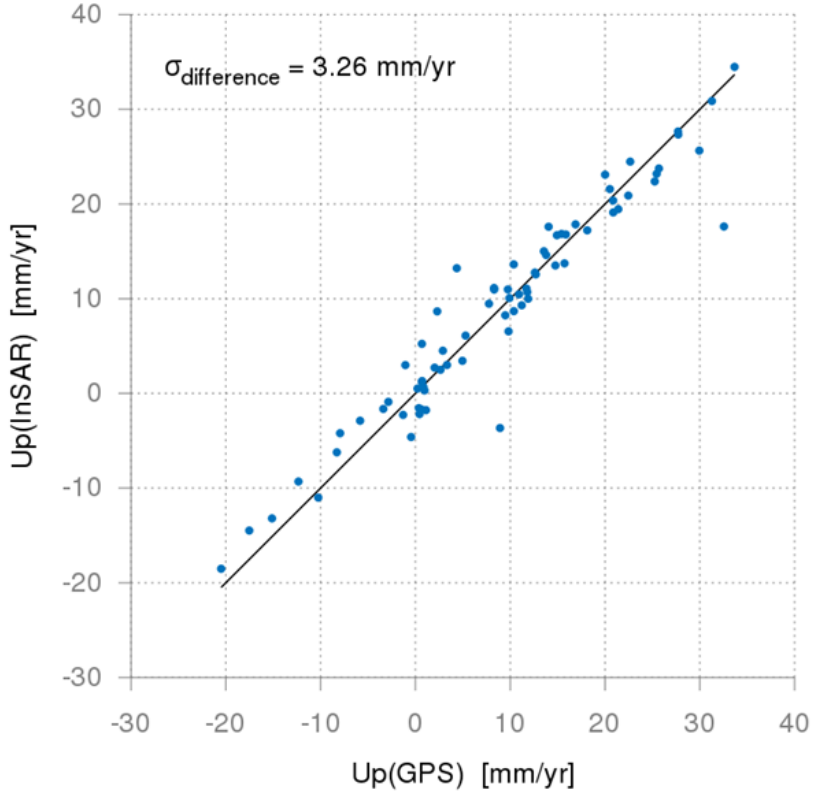
Near-East velocities compared to continuous GPS



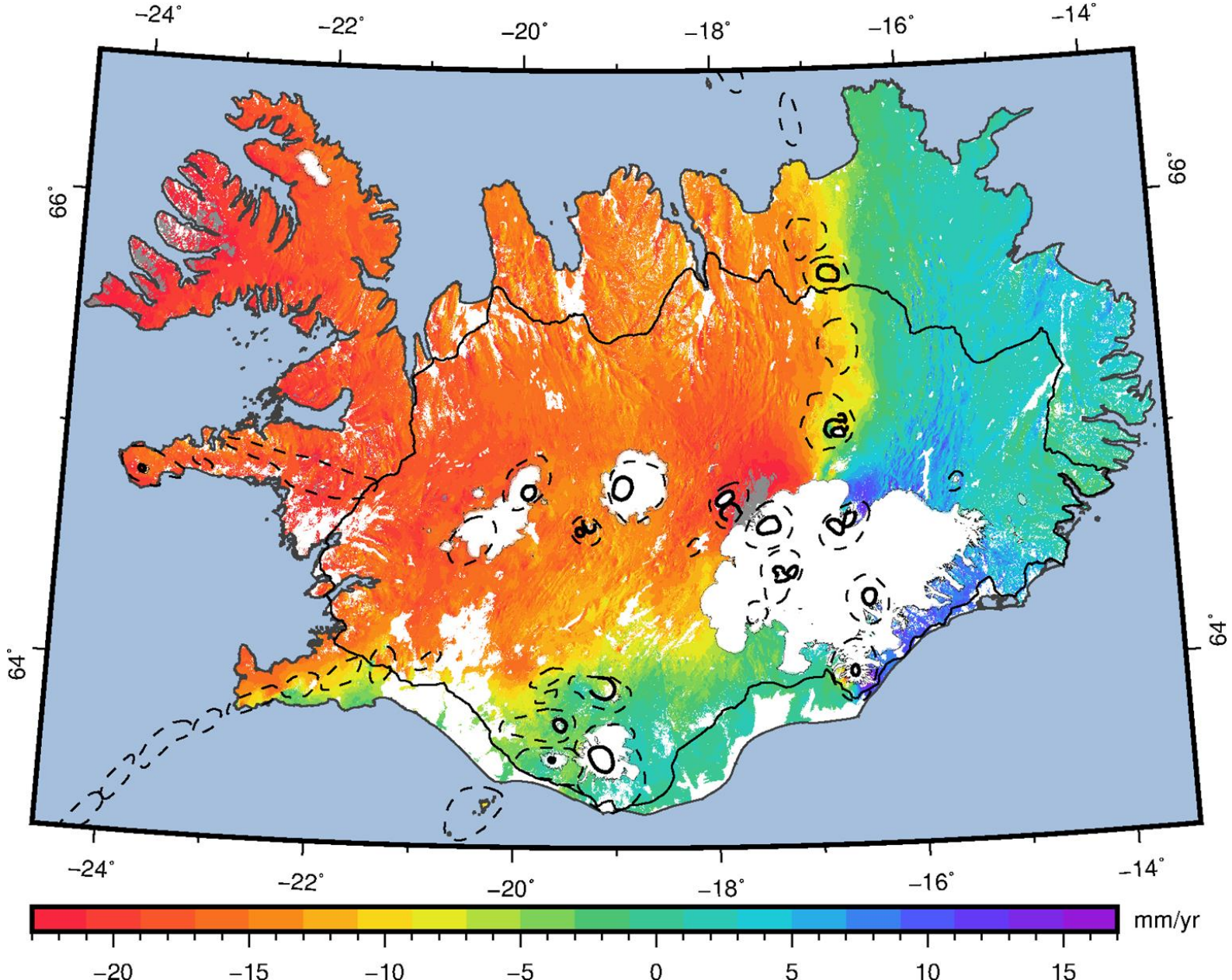


Near-Up velocities compared to continuous GPS





Near-East velocities



Near-East velocities w/o plate spreading w/o GIA

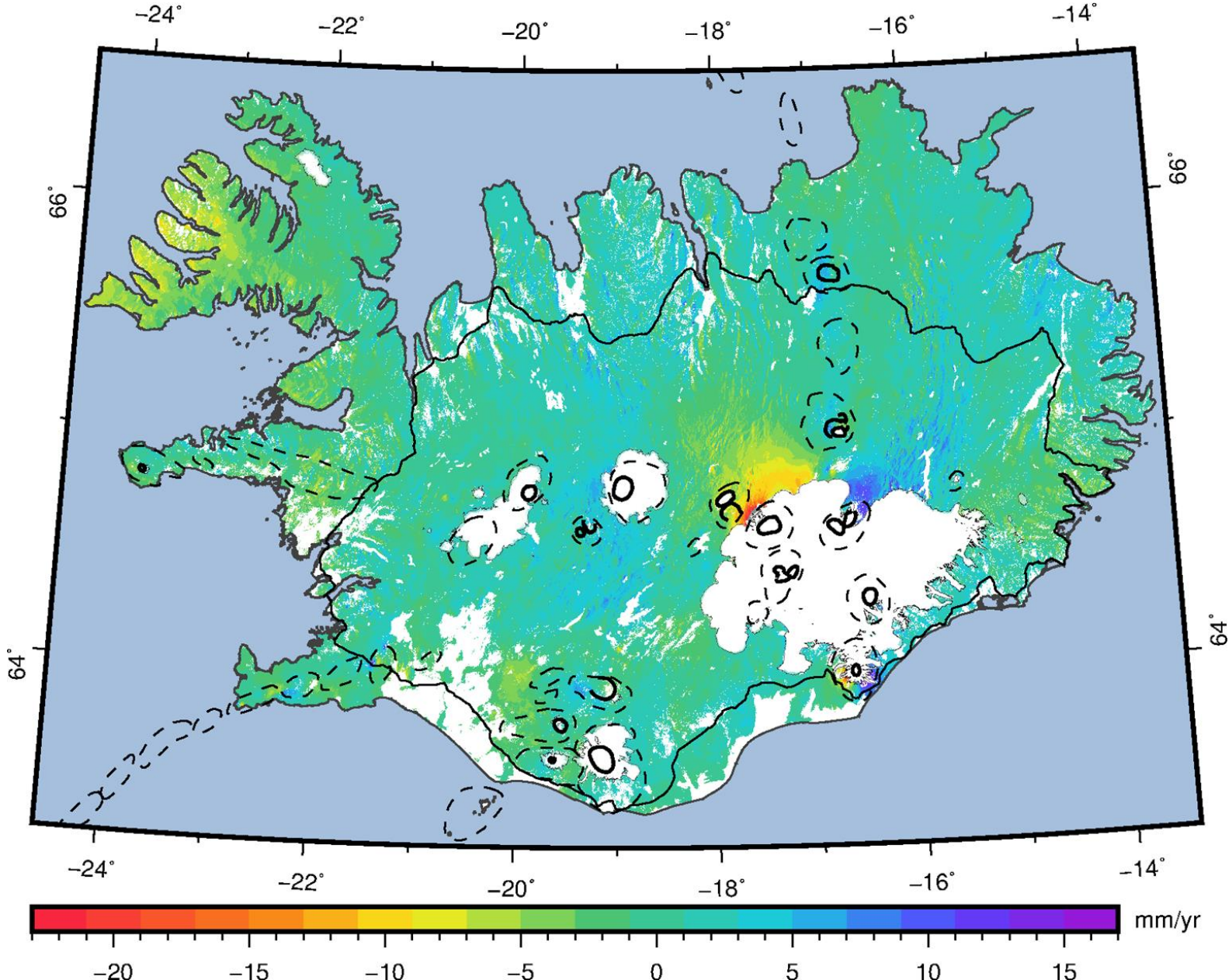
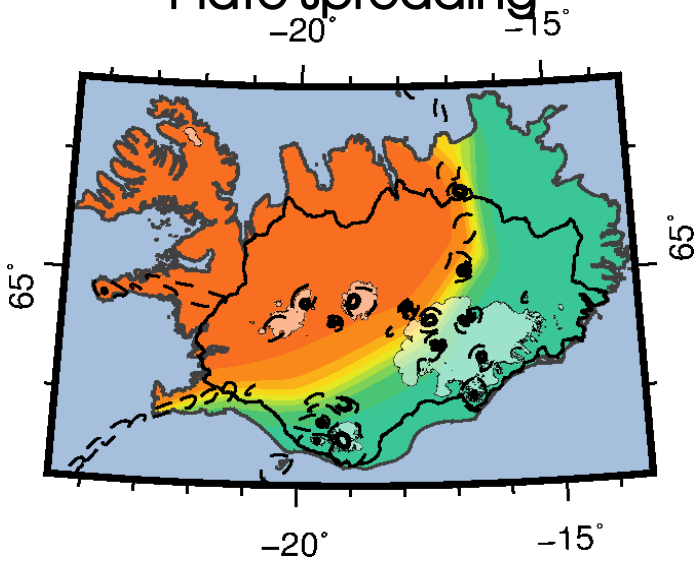
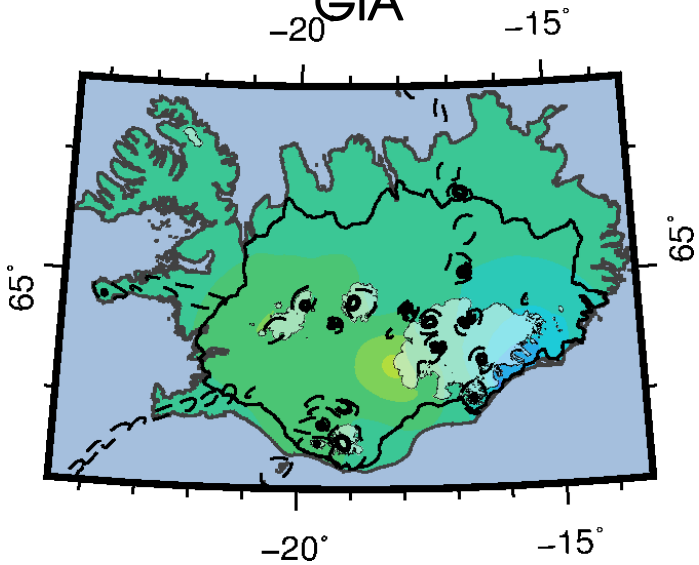


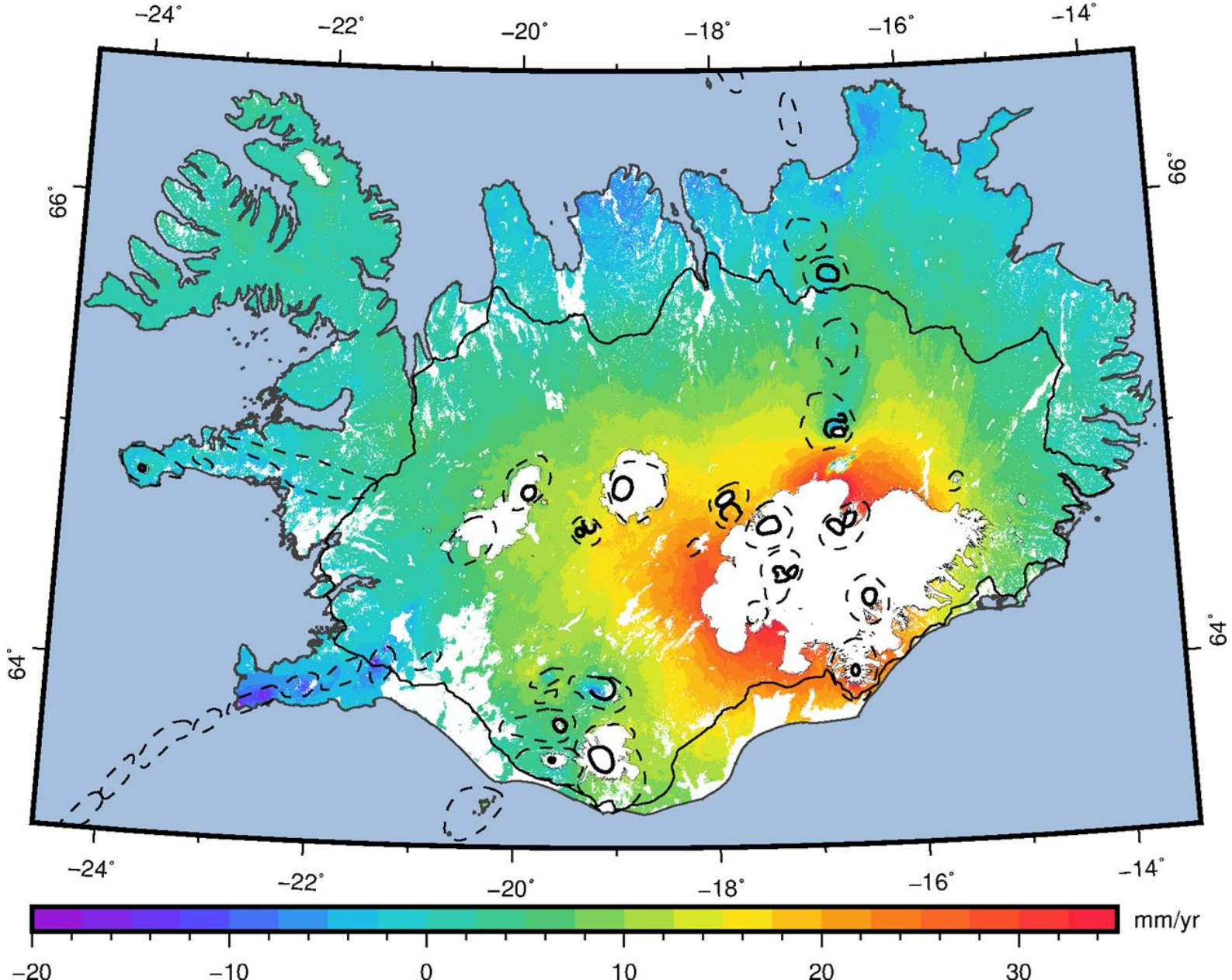
Plate spreading



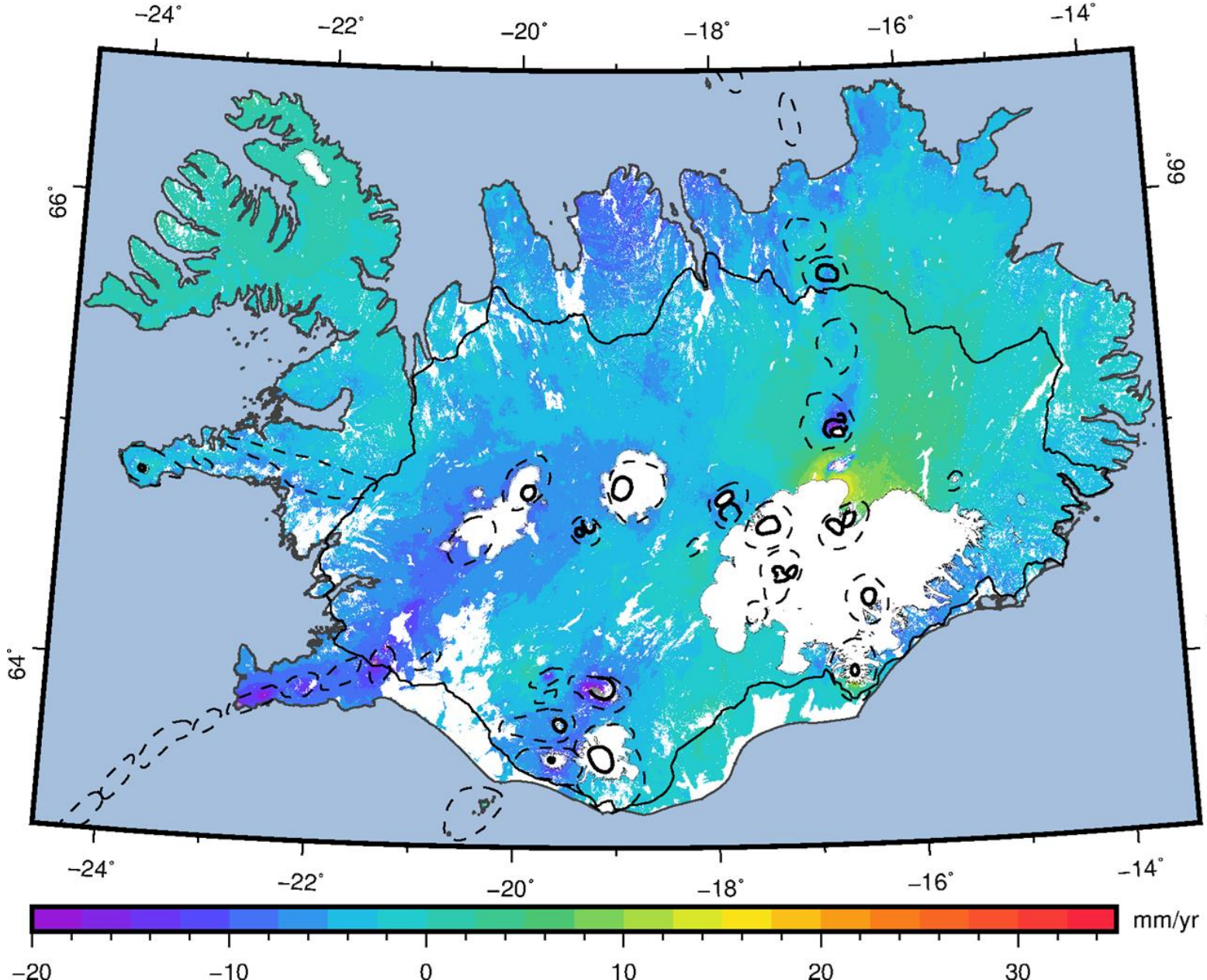
GIA



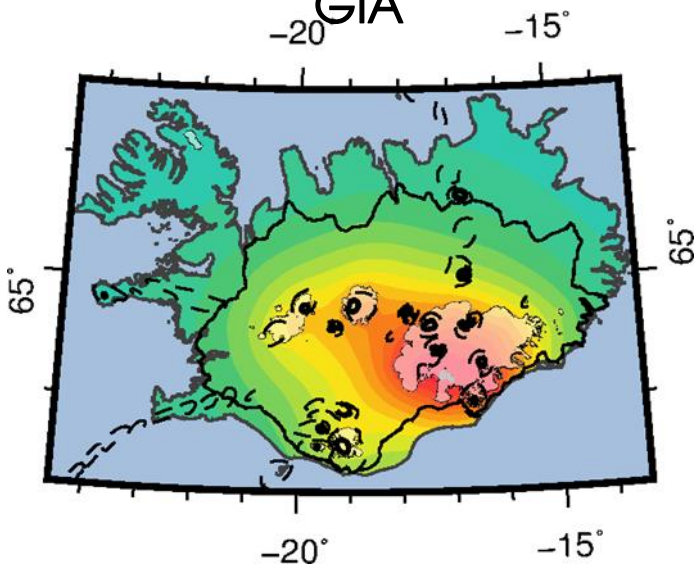
Near-Up velocities



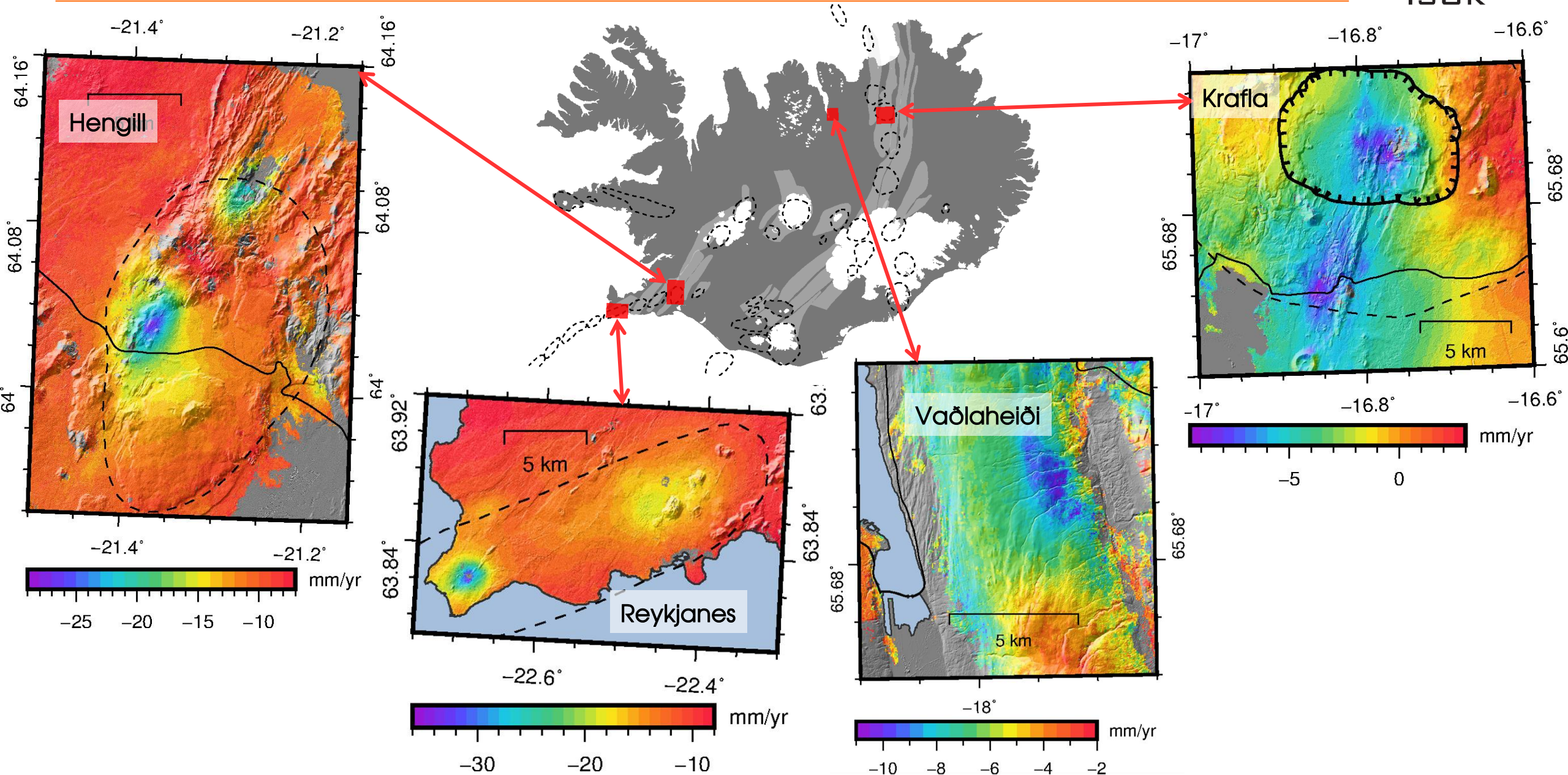
Near-Up velocities w/o GIA



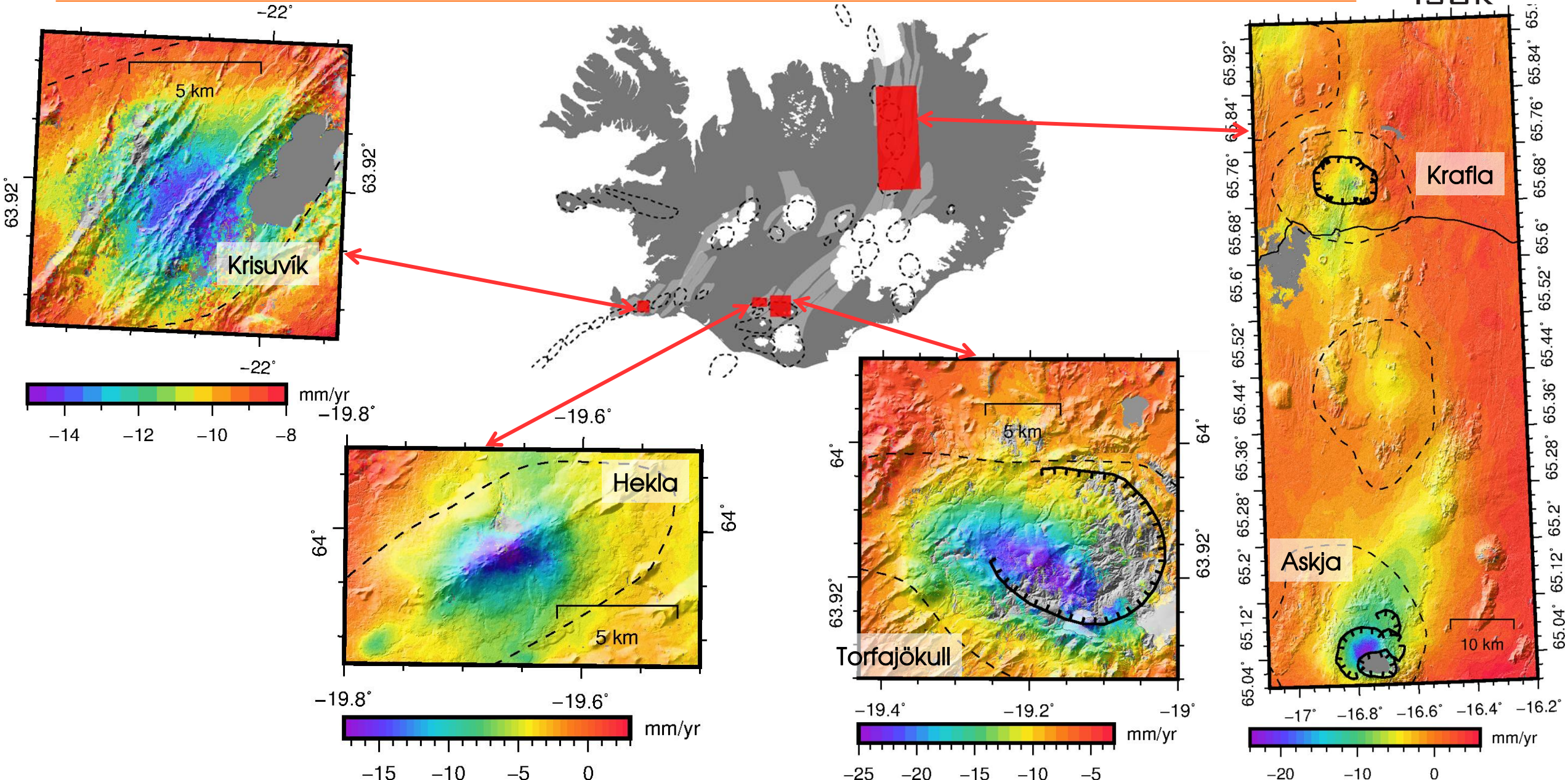
GIA



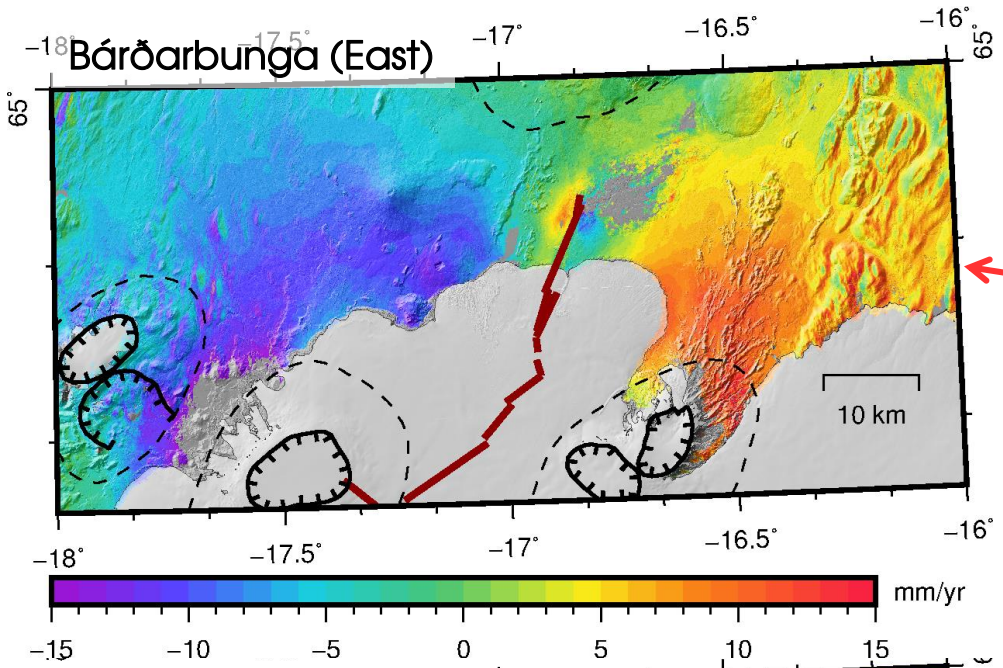
Geothermal utilization / Antropogenic subsidence

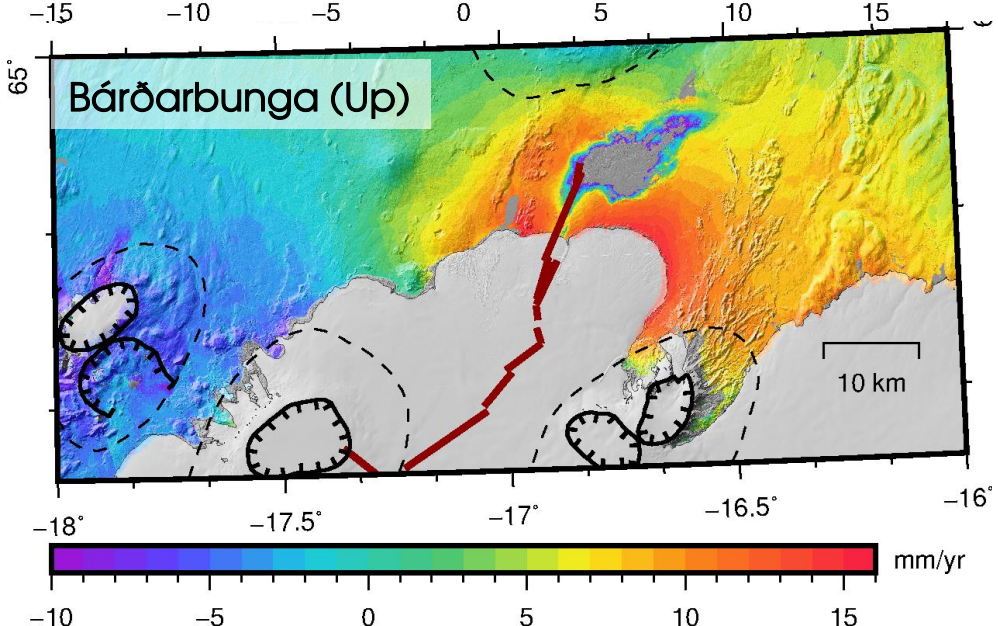


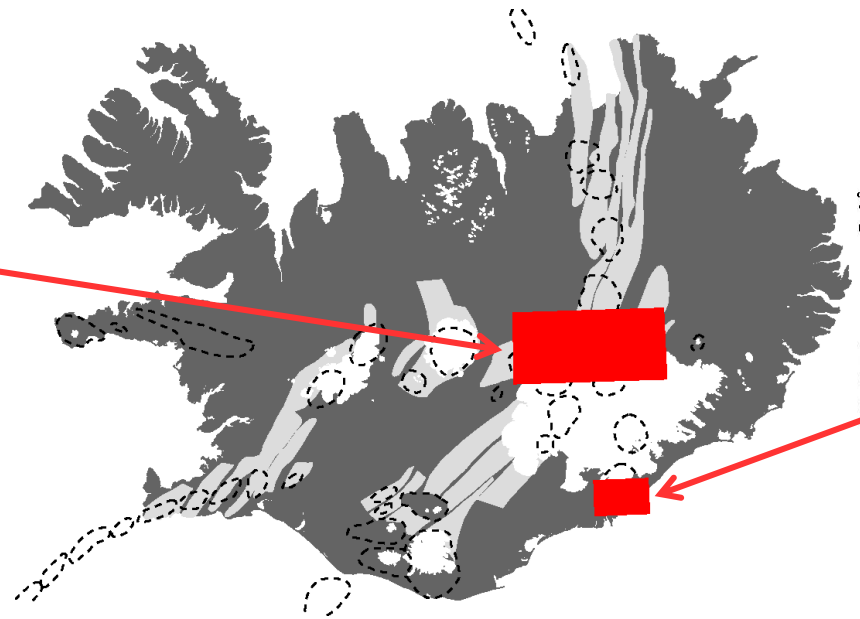
Volcano subsidence

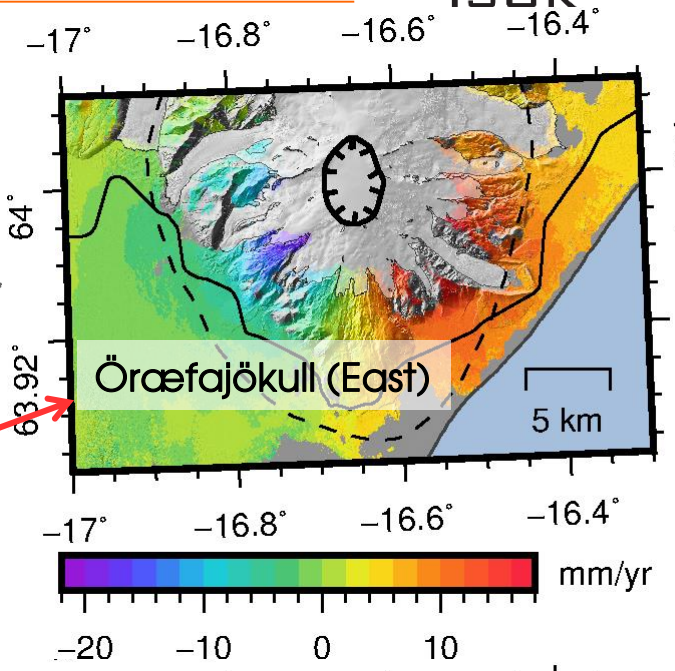


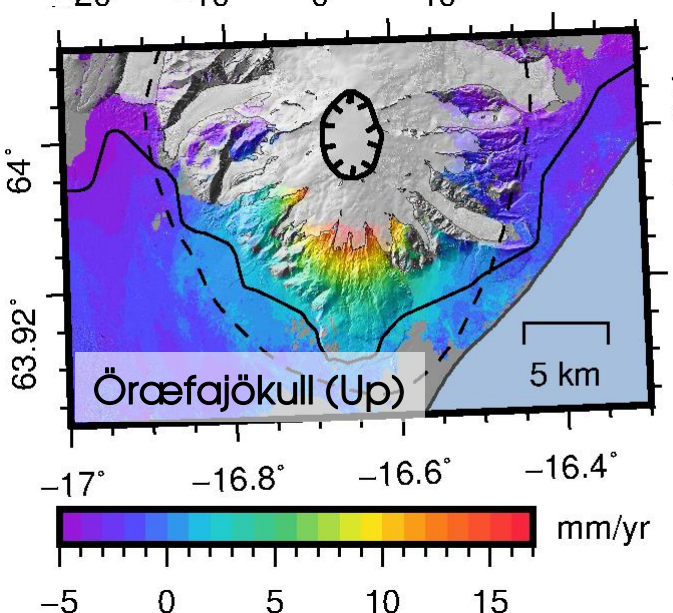
Other volcanic deformations



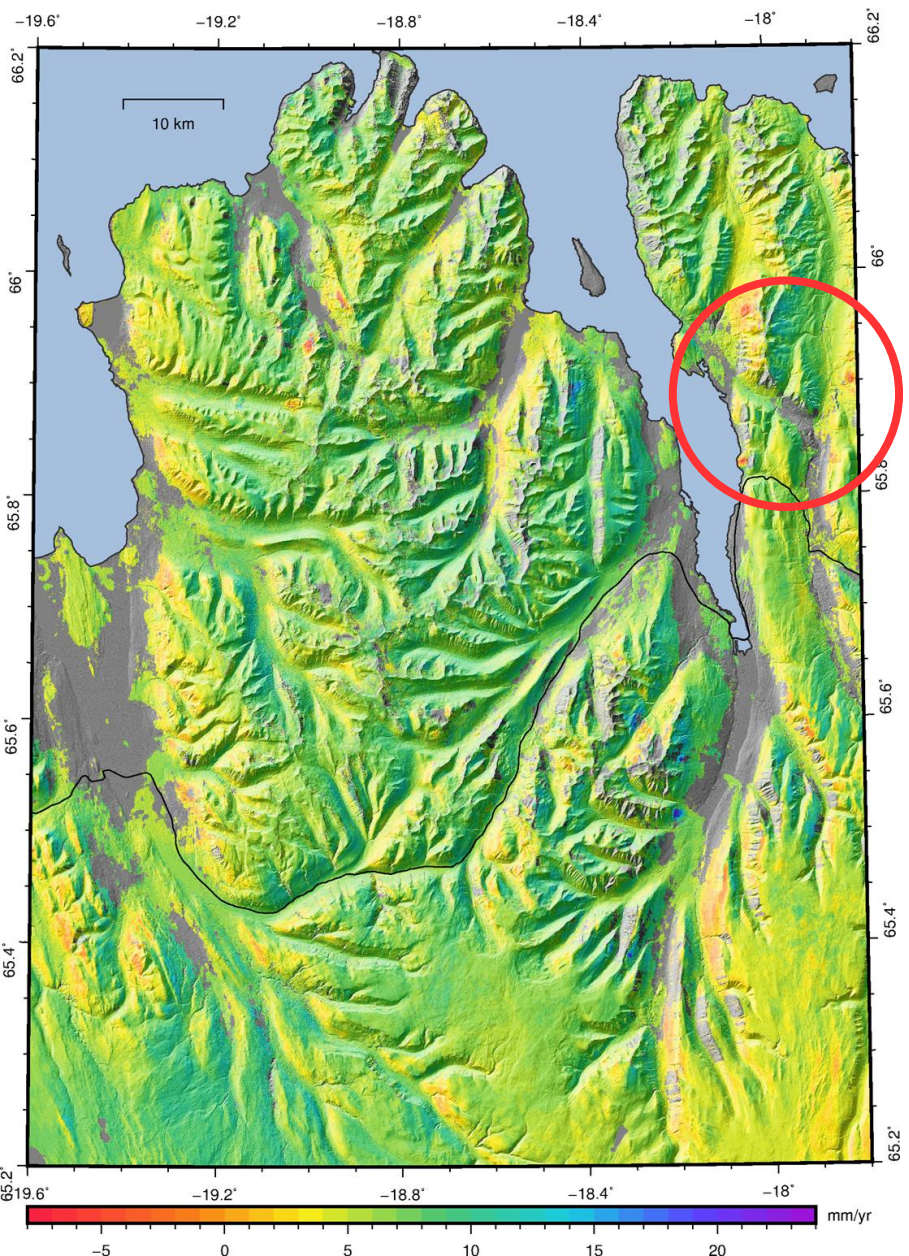


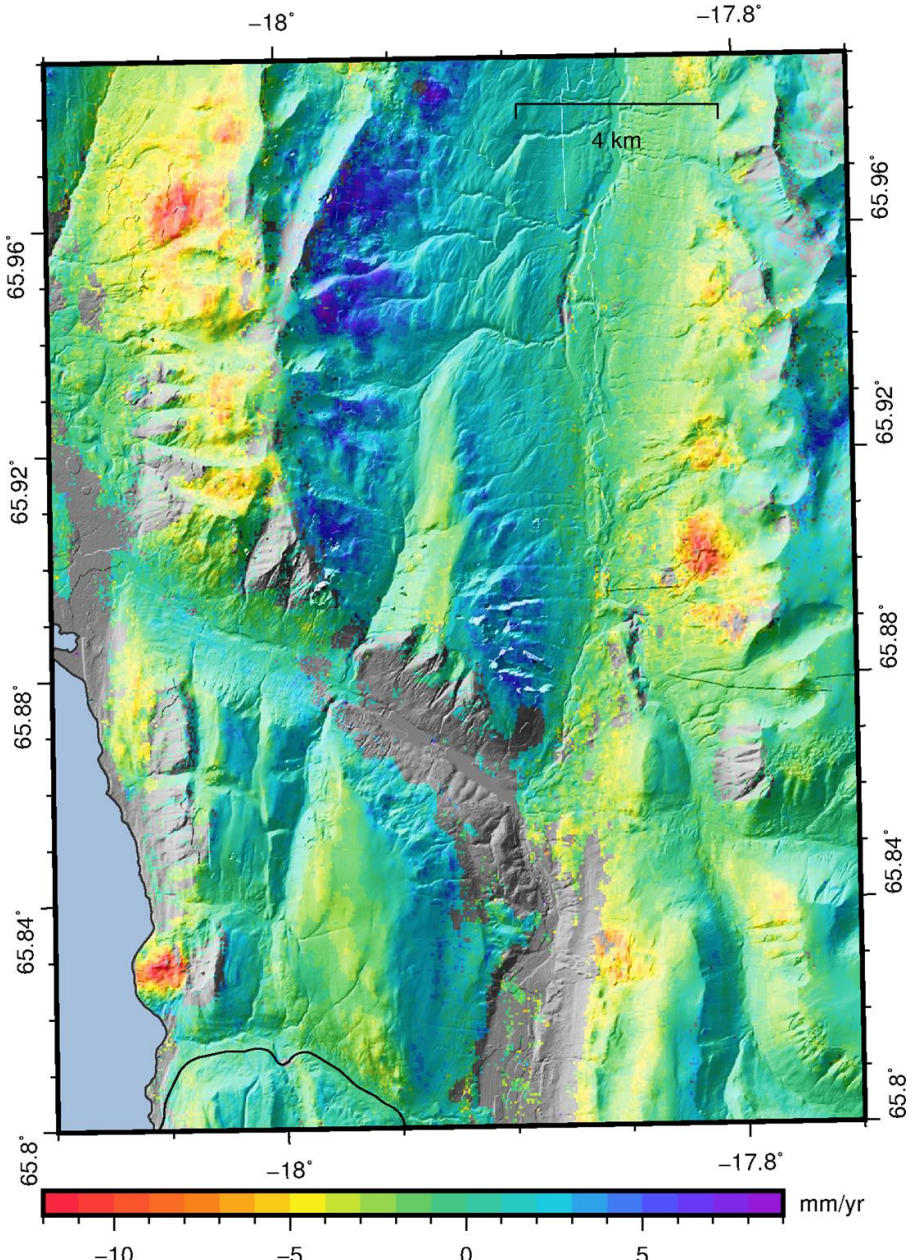


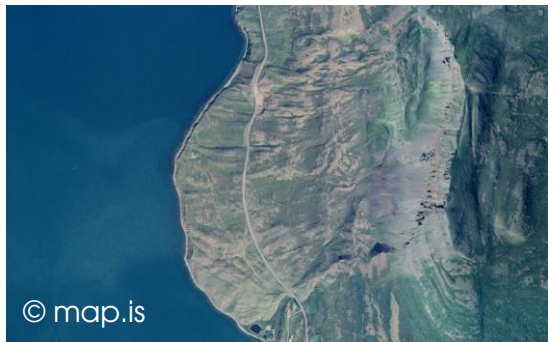




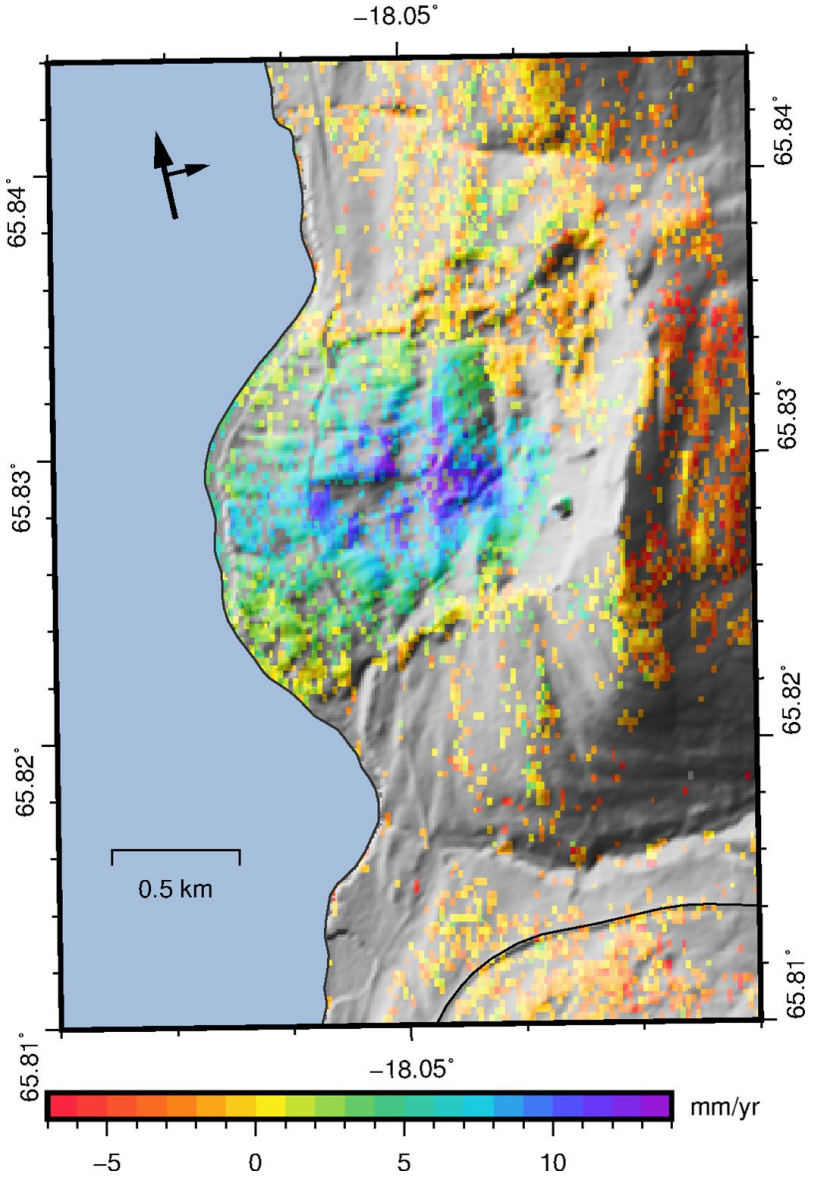
Slope instabilities



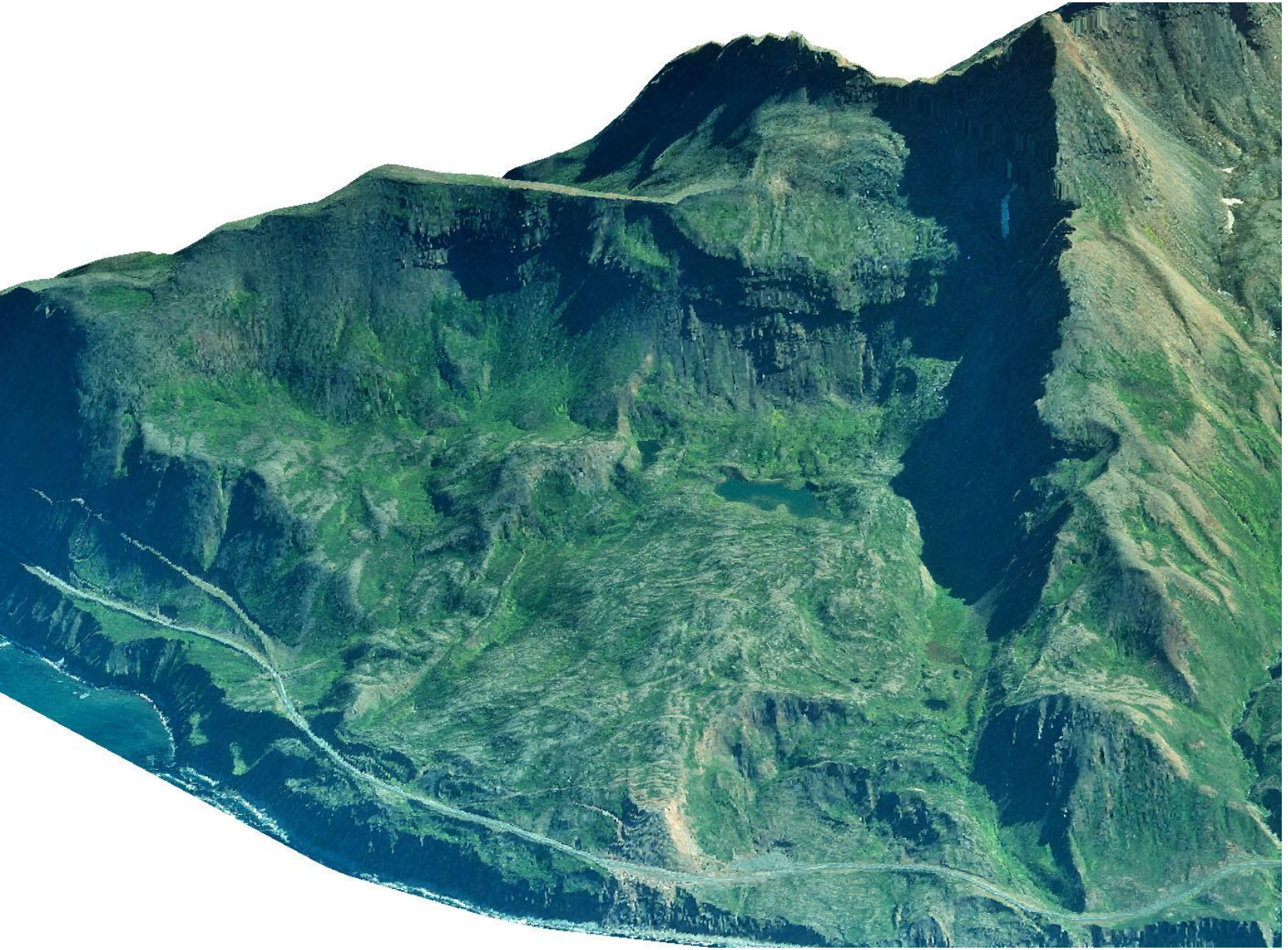


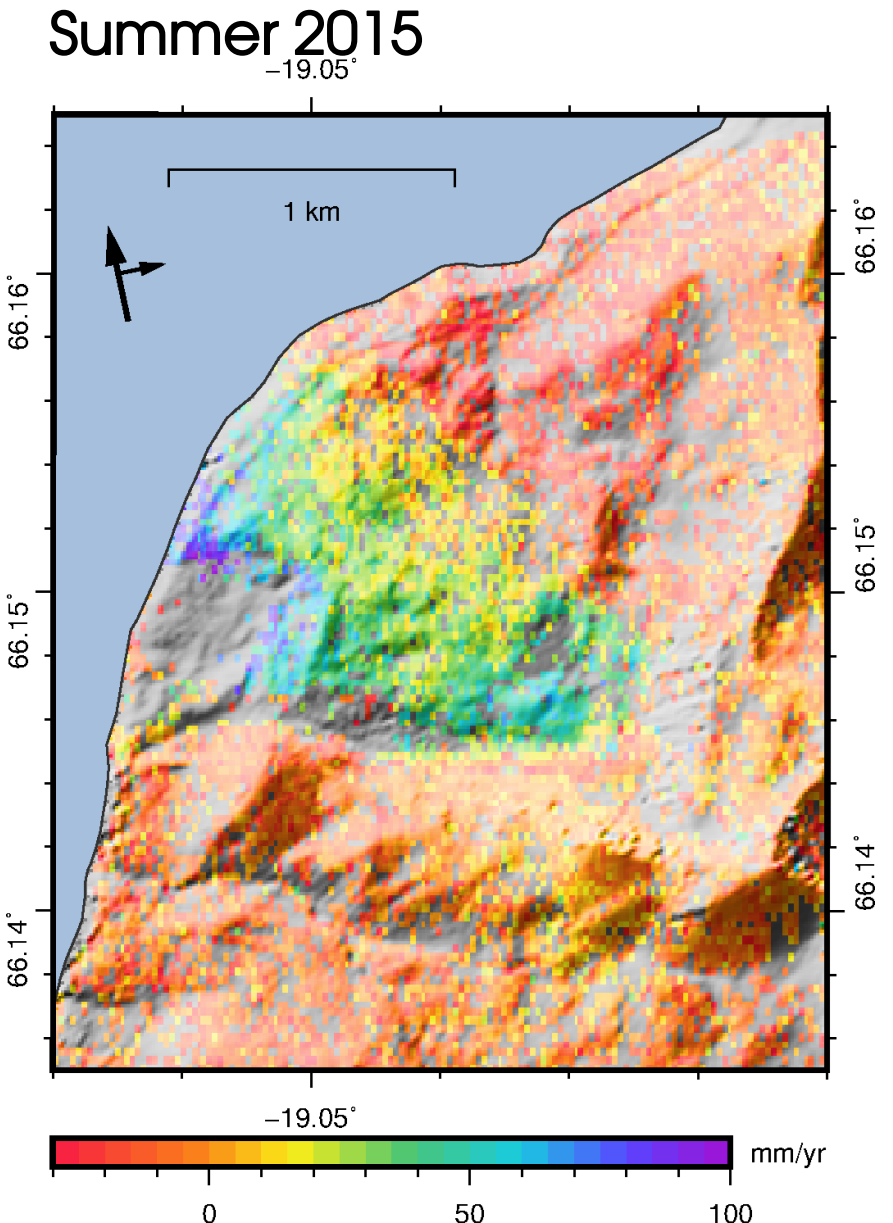


Víkurhólar

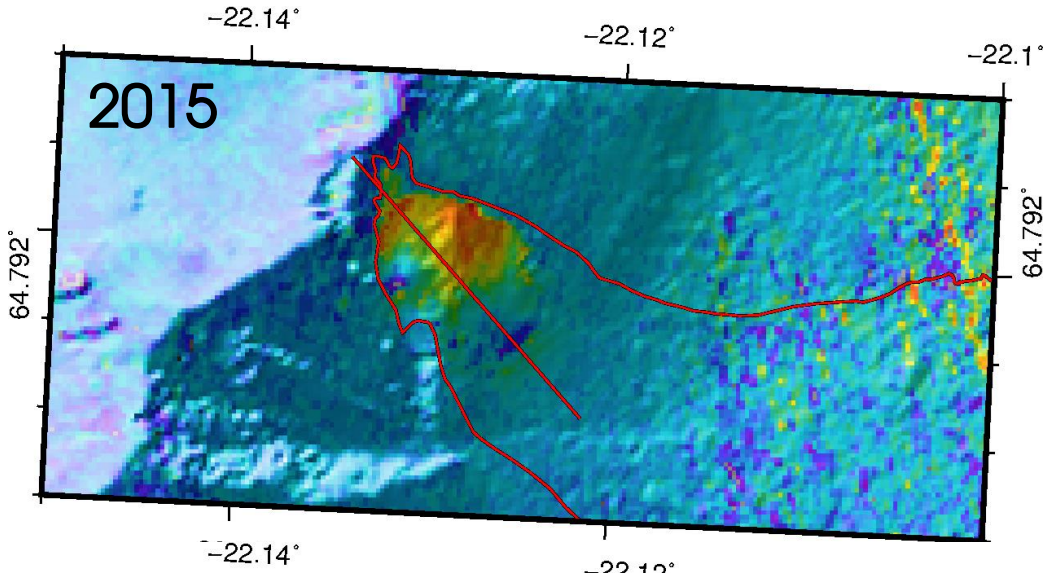


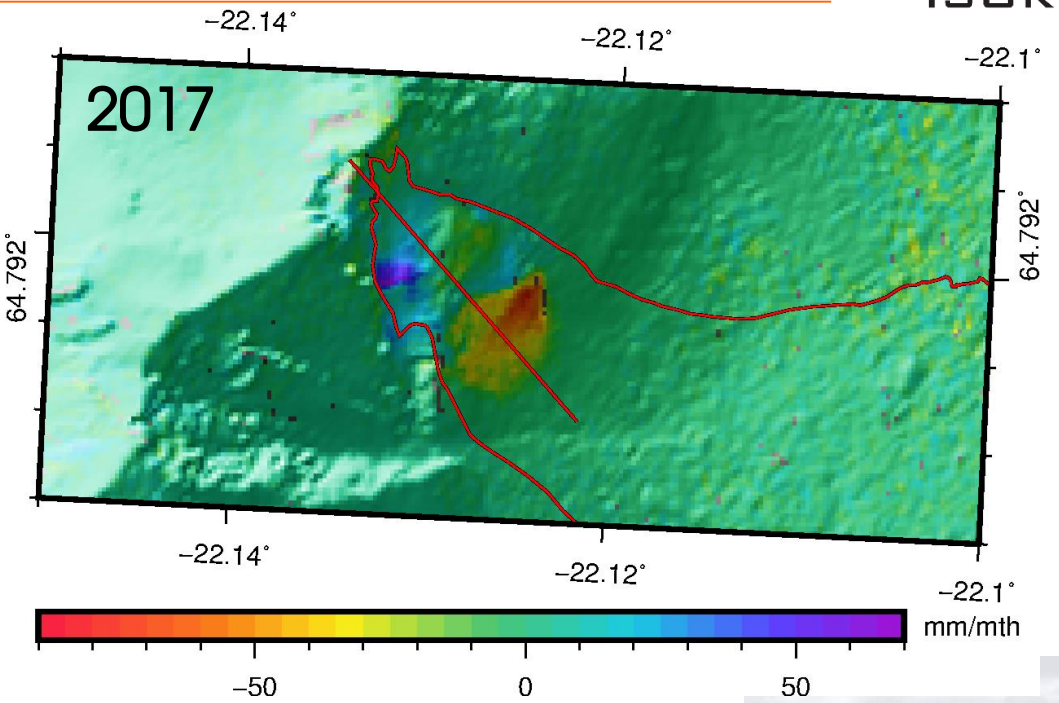
Almeningar

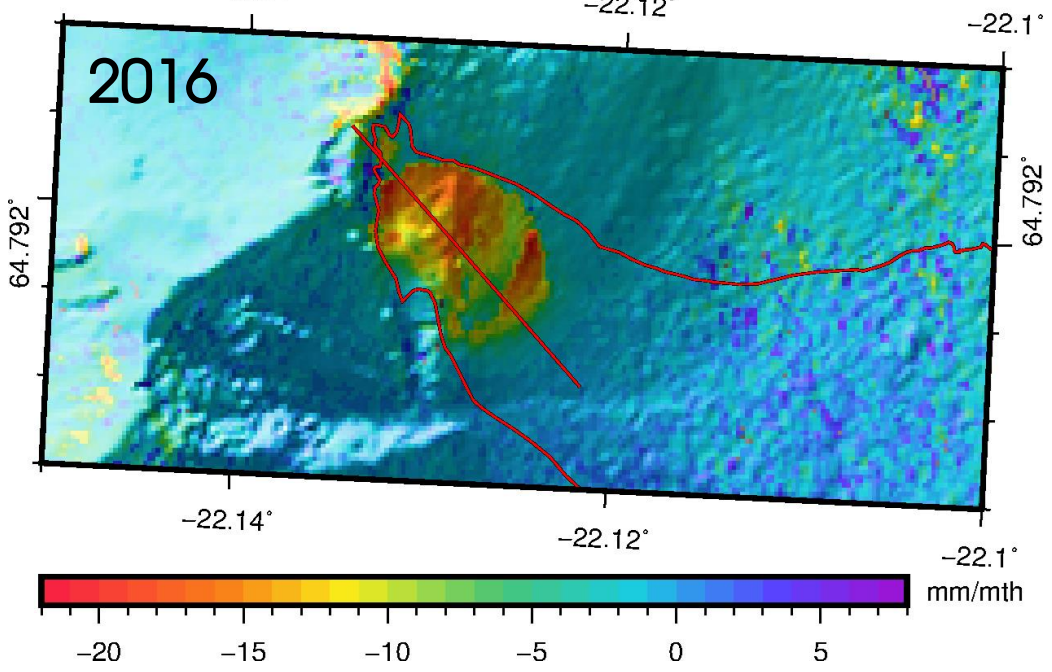


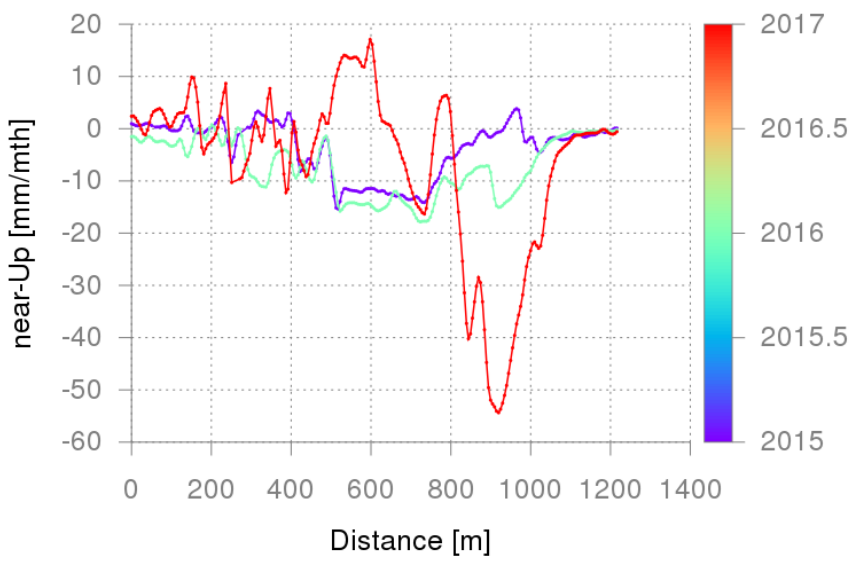

Summer 2015
−19.05˚
1 km
66.16˚
66.15˚
66.14˚
66.16˚
66.15˚
66.14˚
−19.05˚
mm/yr
0
50
100

Hítardalur – Average summer velocities

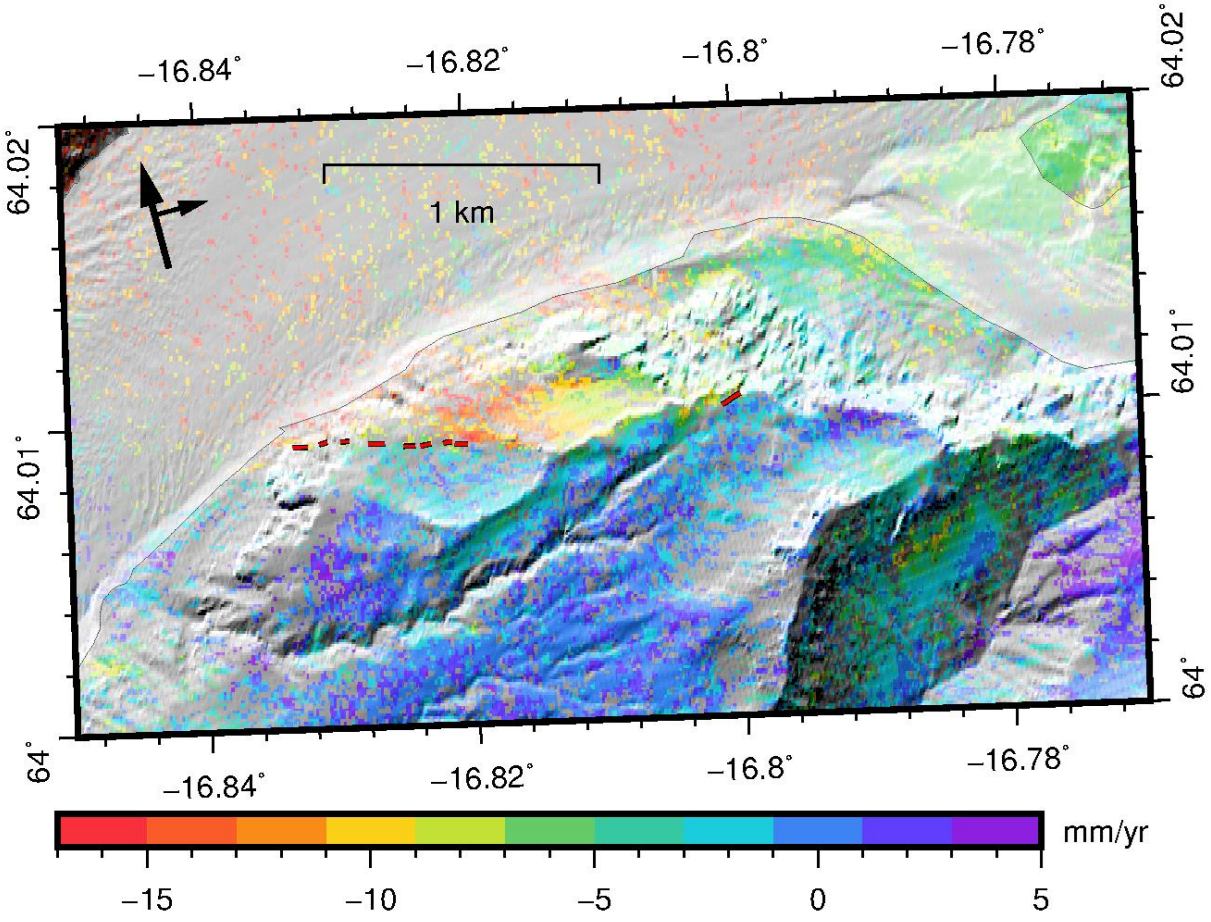






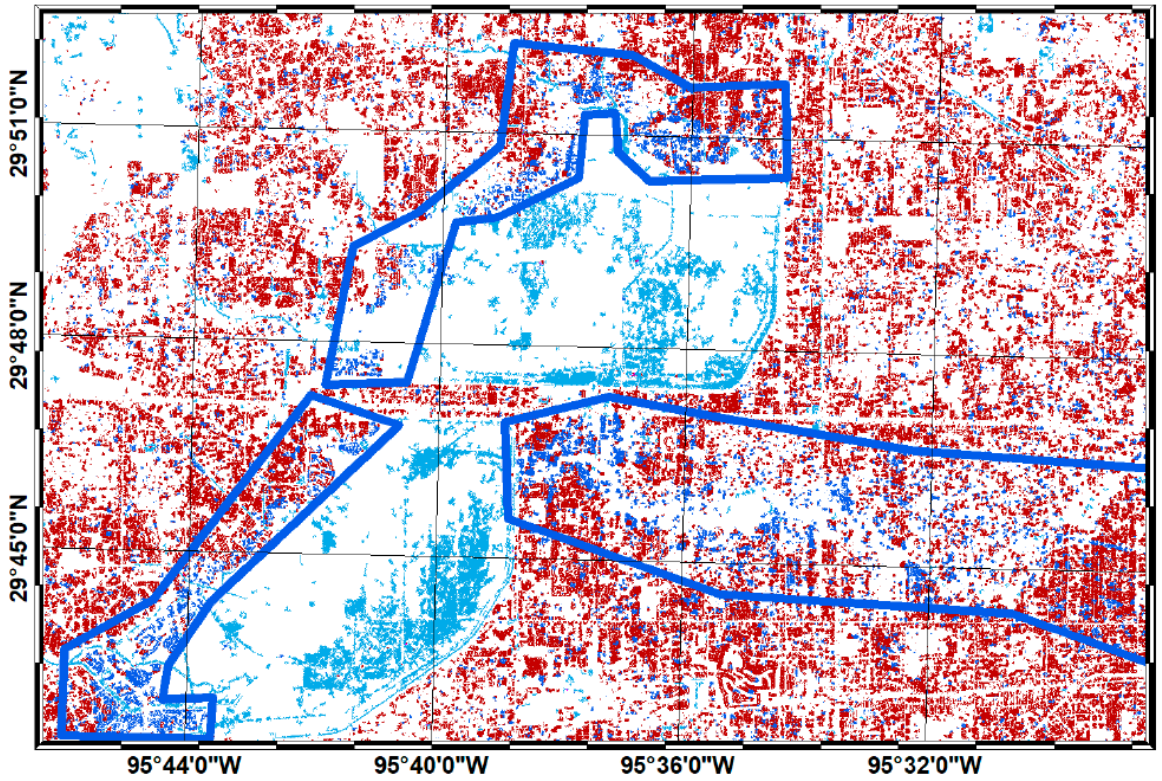


Svinafellsheiði



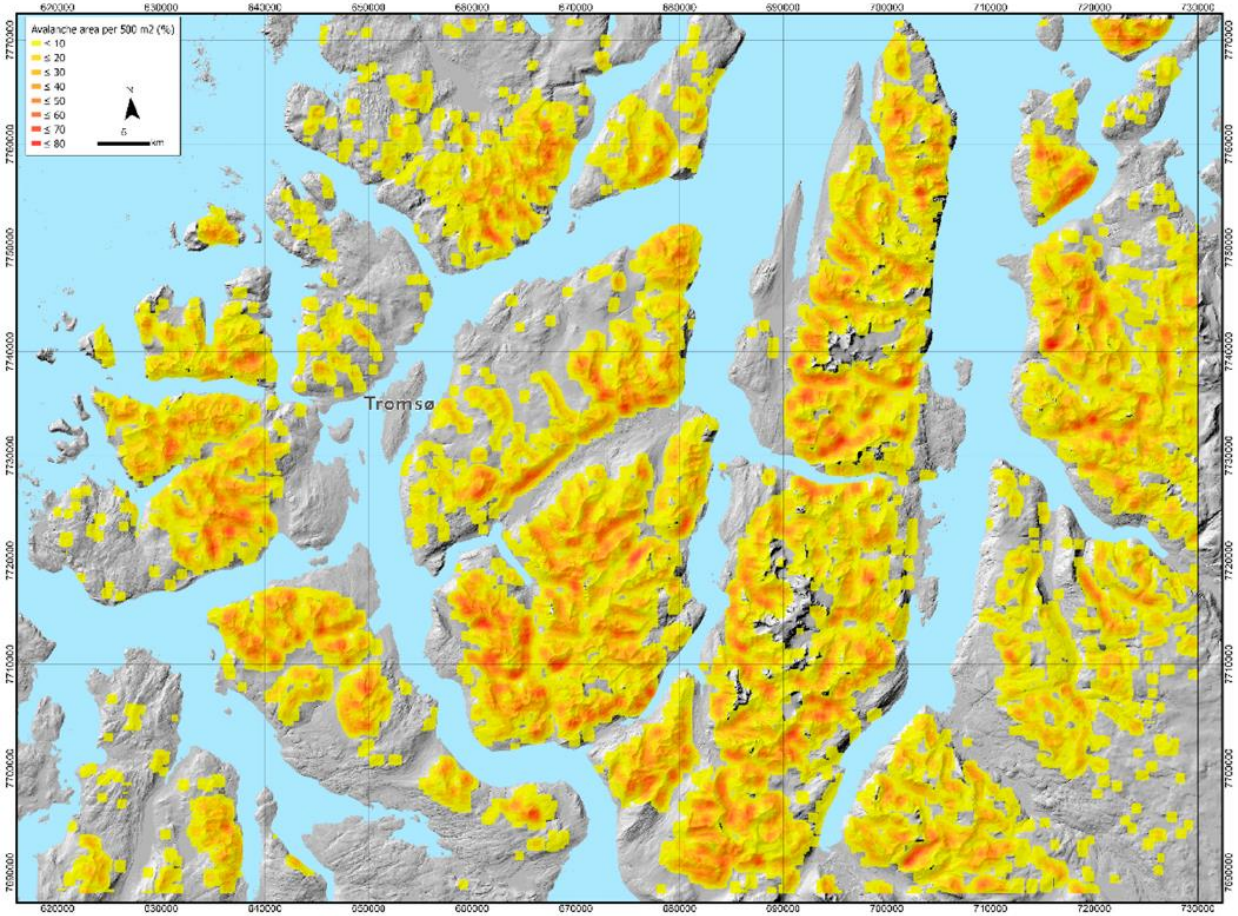
Other hazards

Flood



(Chini et al., 2019)

Avalanches



(Eckerstorfer et al., 2019)


Thank you