Satellite Monitoring of the 2014 Dyke Intrusion and Eruption within the Bárðarbunga Volcanic System, facilitated by the CEOS Icelandic SUPERSITE

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Photo credit: S Dumont

Overview

- Volcano deformation monitoring in Iceland: FUTUREVOLC and the Icelandic SUPERSITE

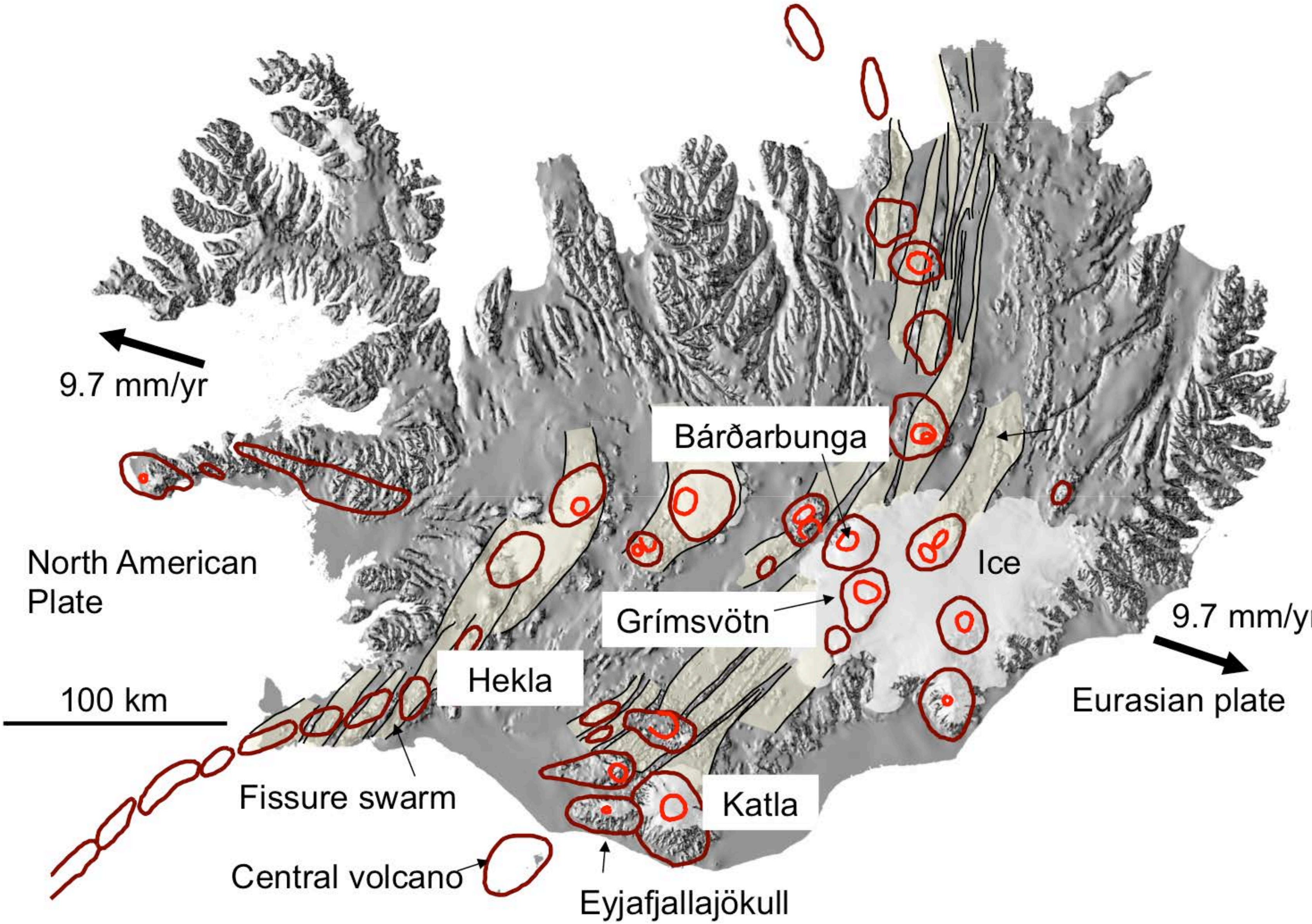
- Monitoring Bárðarbunga unrest and eruption
  - Seismicity, GPS and Satellite images
  - Deformation modelling
  - Stress modelling - how has the eruption influenced neighbouring volcanoes?

- Eruption ended on Feb 2015 - what happens next?
  - Plan for continued deformation monitoring
  - sensitivity of cGPS network and importance of InSAR

FUTUREVOLC – A European volcanological supersite in Iceland: a monitoring system and network for the future

- European collaboration comprising 26 partners aimed at long term volcano monitoring
- Primary objectives:
  - Establish an integrated volcanological monitoring procedure
  - Develop new methods to evaluate volcanic crises
  - Increase scientific understanding of magmatic processes
  - Improve delivery of relevant information to civil protection and authorities

Iceland: Volcanic systems and primary target volcanoes for monitoring



Initial activity – following the main fissure eruption on the 31 Aug, 2014

Date – 3 Sep, 2014

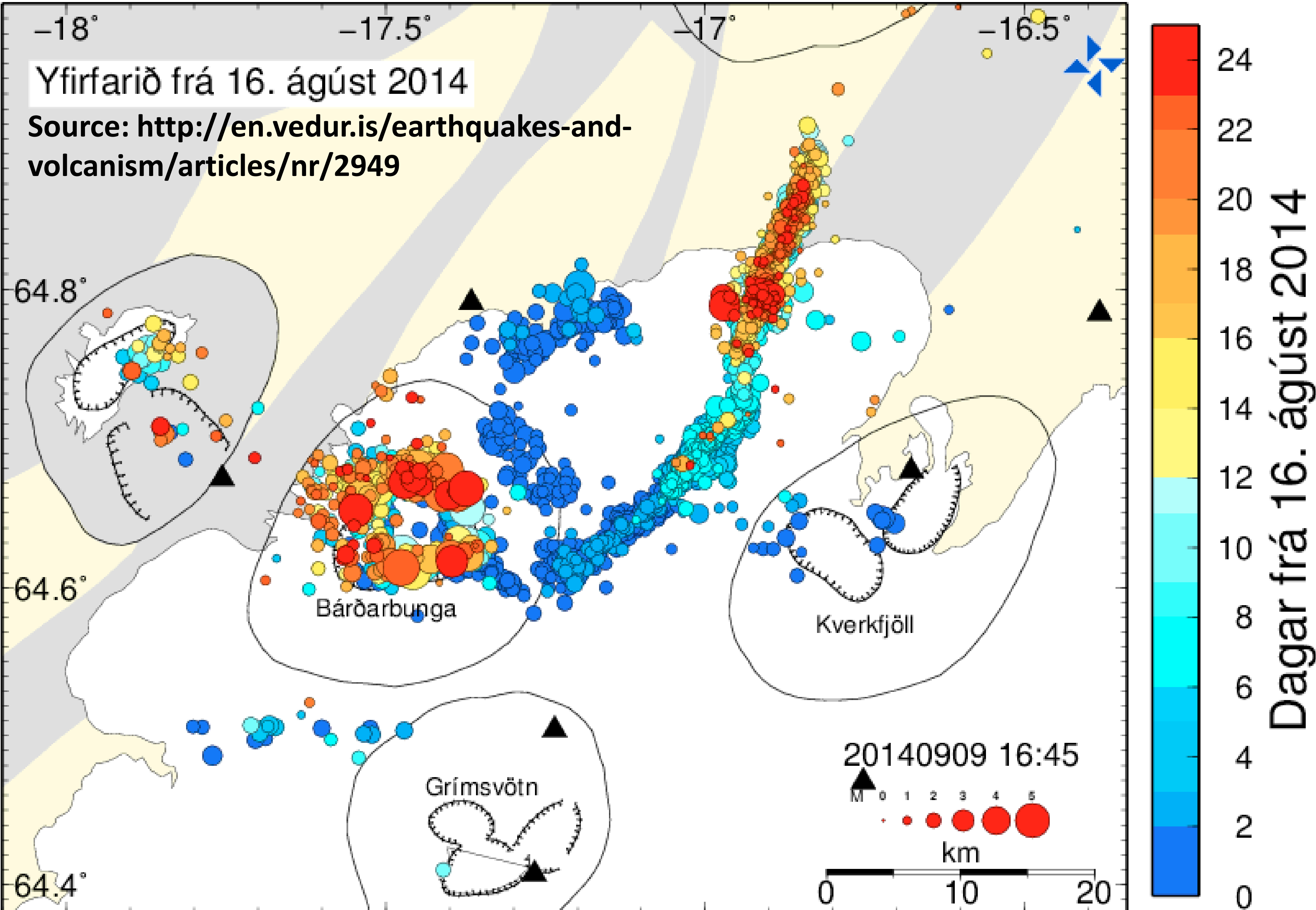
Photo credit: M Parks

Overflight – 4 Nov, 2014

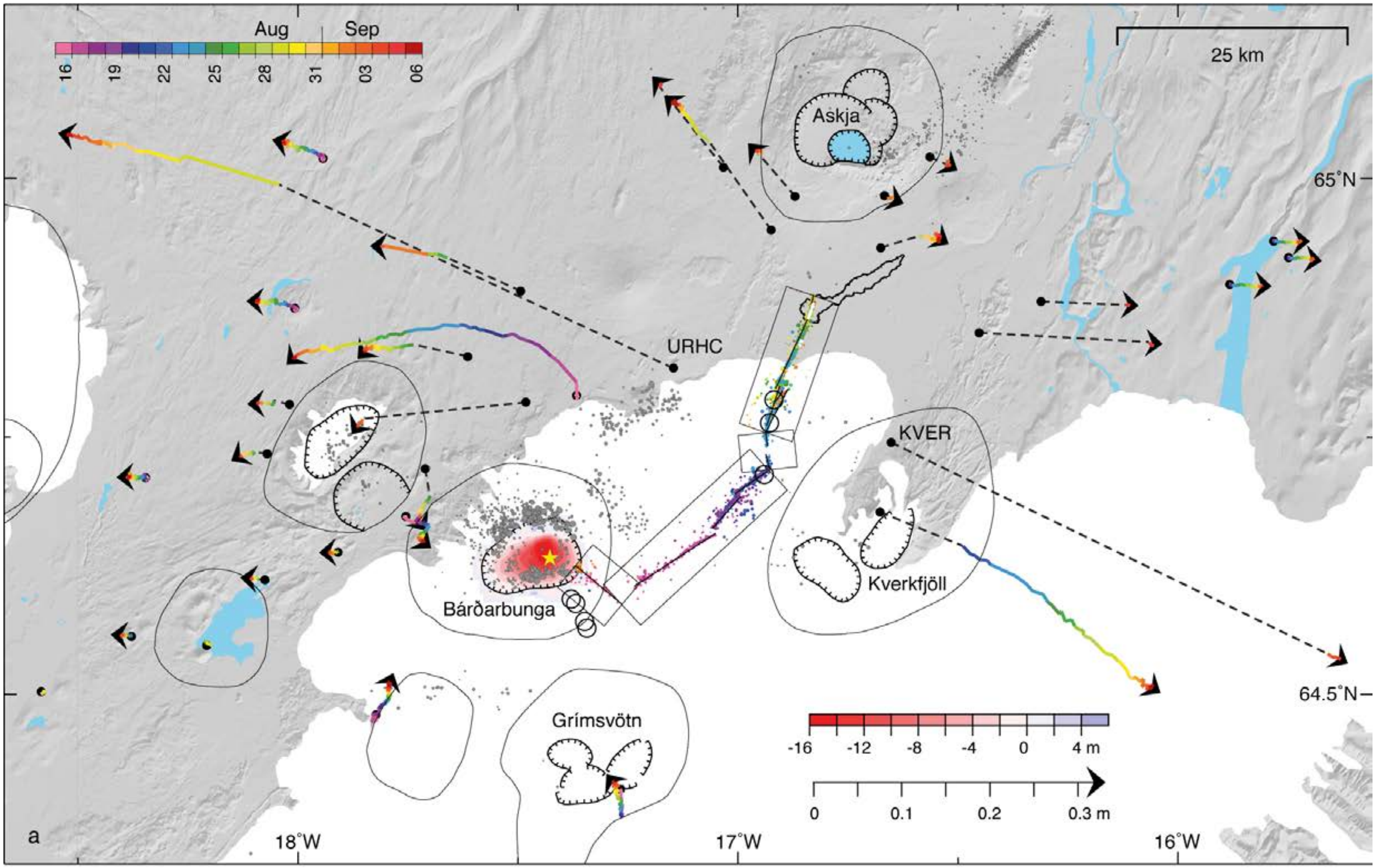
Photo credit: M Parks

The vent, lava pond and part of the lava field at 16:30 21 January 2015

Seismicity since the 16th August. Preliminary data analysed by the SIL seismic monitoring group of the Icelandic Meteorological Office, as of the 9th September, 2014 (IMO, 2014).

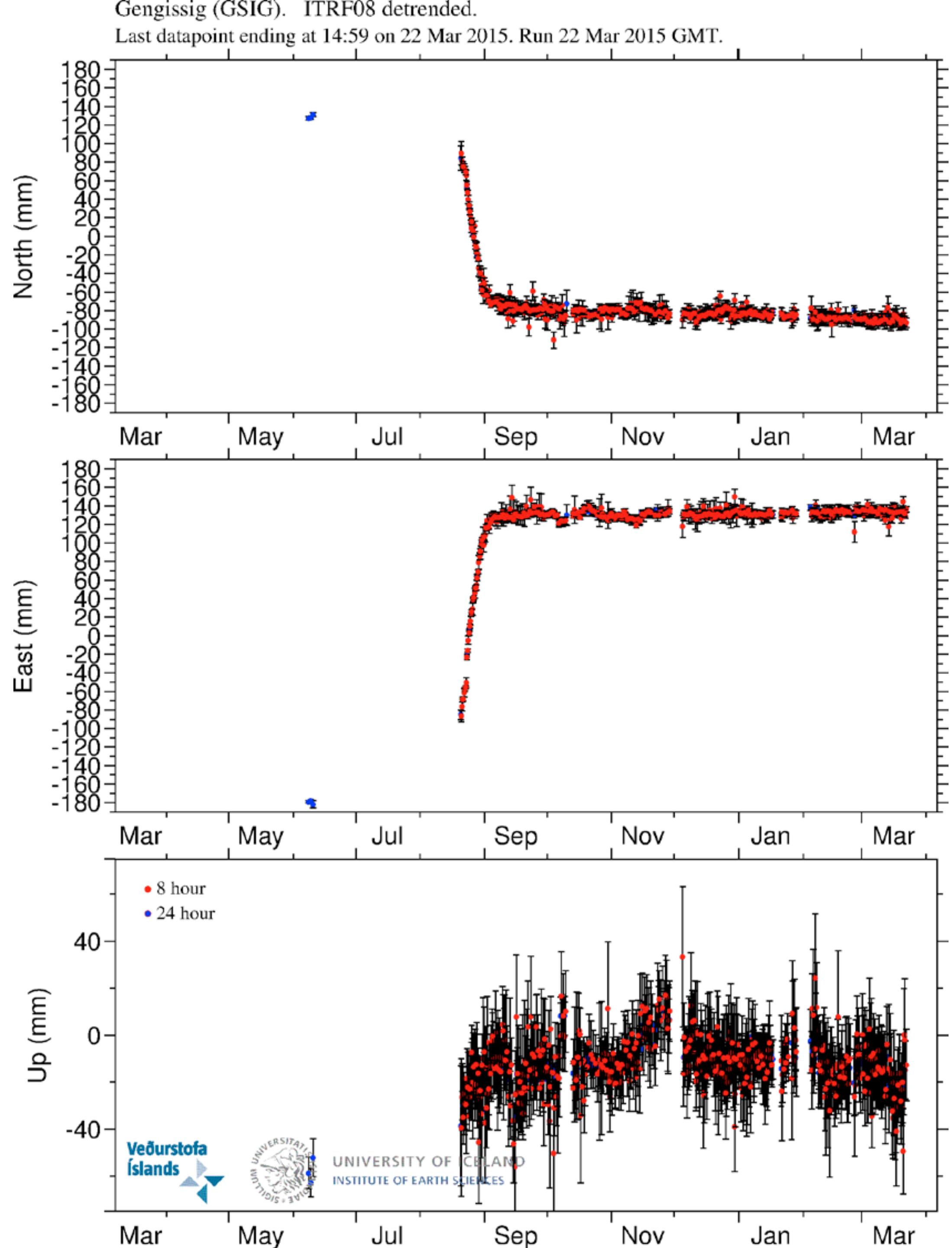


Evolution of seismicity and GPS displacements during the 2014 unrest and start of the eruption

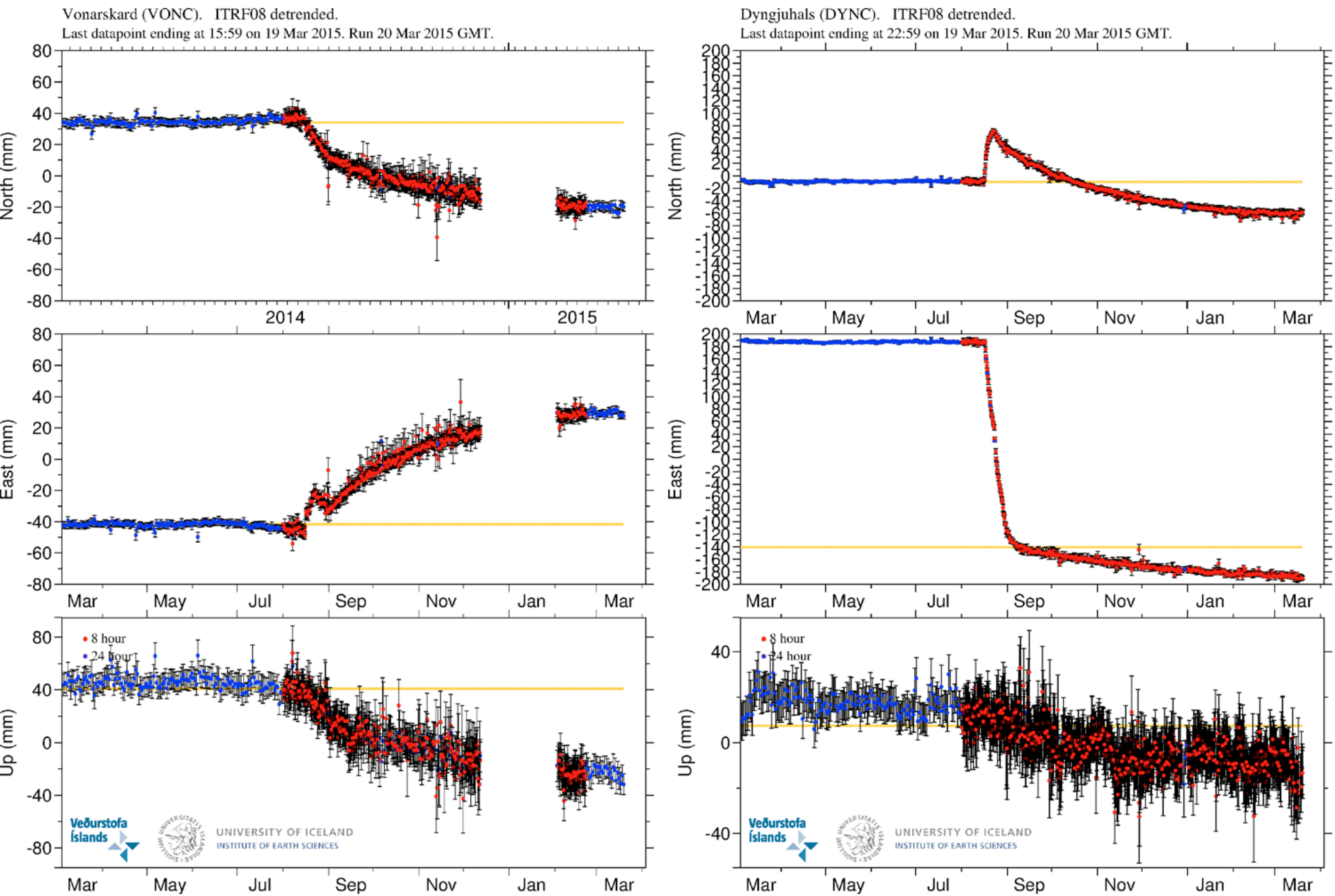


From Sigmundsson et al., 2014. Segmented lateral dyke growth in a rifting event at Bárðarbunga volcanic system, Iceland, *Nature,* doi:10.1038/nature14111

Dyke emplacement



Caldera subsidence



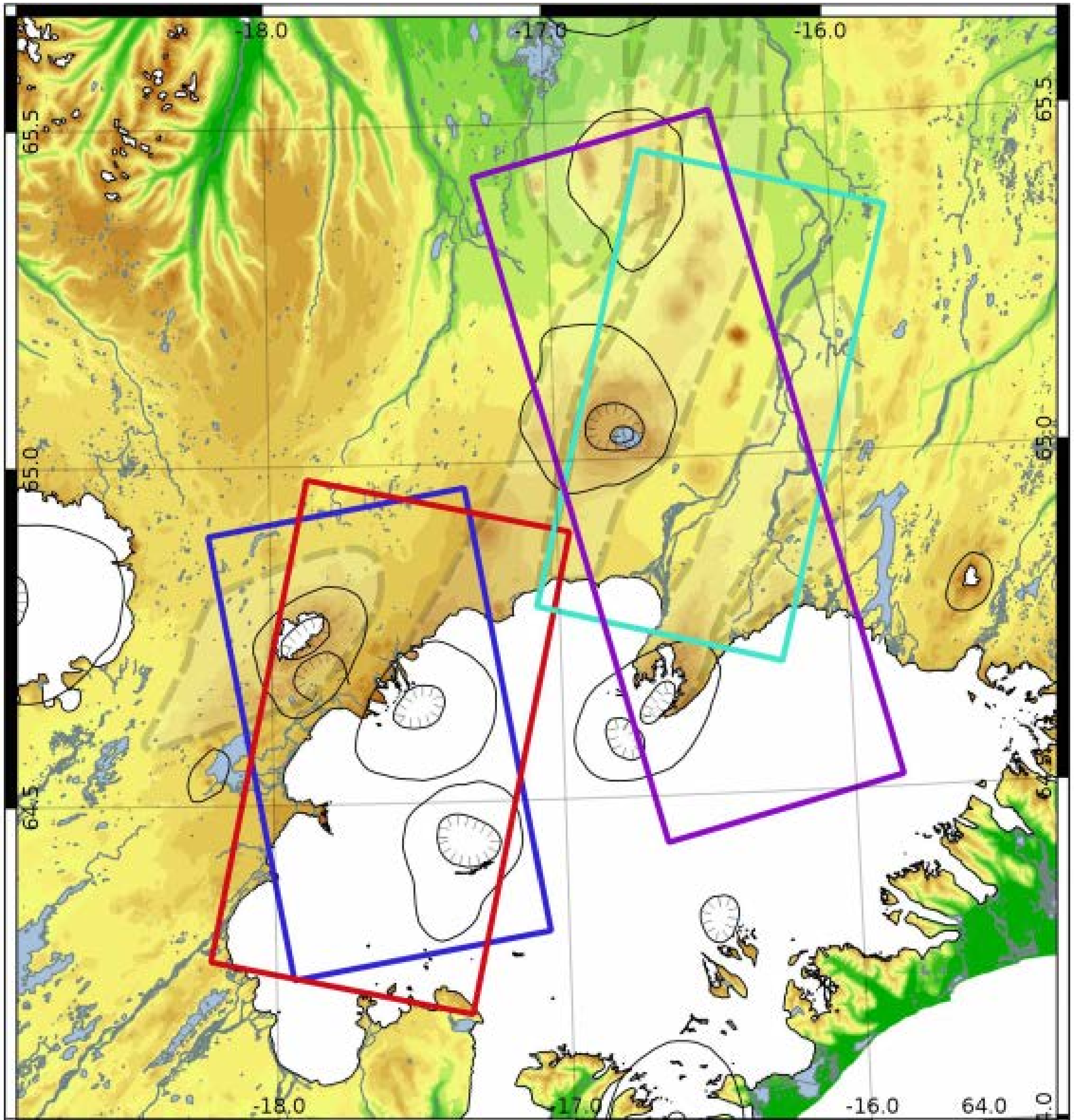
CSK footprints over Holuhraun and Bárðarbunga

CSK 2761

26/07/2014
11/08/2014
27/08/2014
28/08/2014
31/08/2014
04/09/2014
13/09/2014
16/09/2014
02/10/2014
06/10/2014
14/10/2014
15/10/2014
18/10/2014
22/10/2014
31/10/2014
03/11/2014
07/11/2014
16/11/2014
19/11/2014

CSK 2762

25/07/2014
10/08/2014
26/08/2014
30/08/2014
15/09/2014
05/10/2014
13/10/2014
14/10/2014
17/10/2014
21/10/2014
30/10/2014
02/11/2014
06/11/2014
18/11/2014



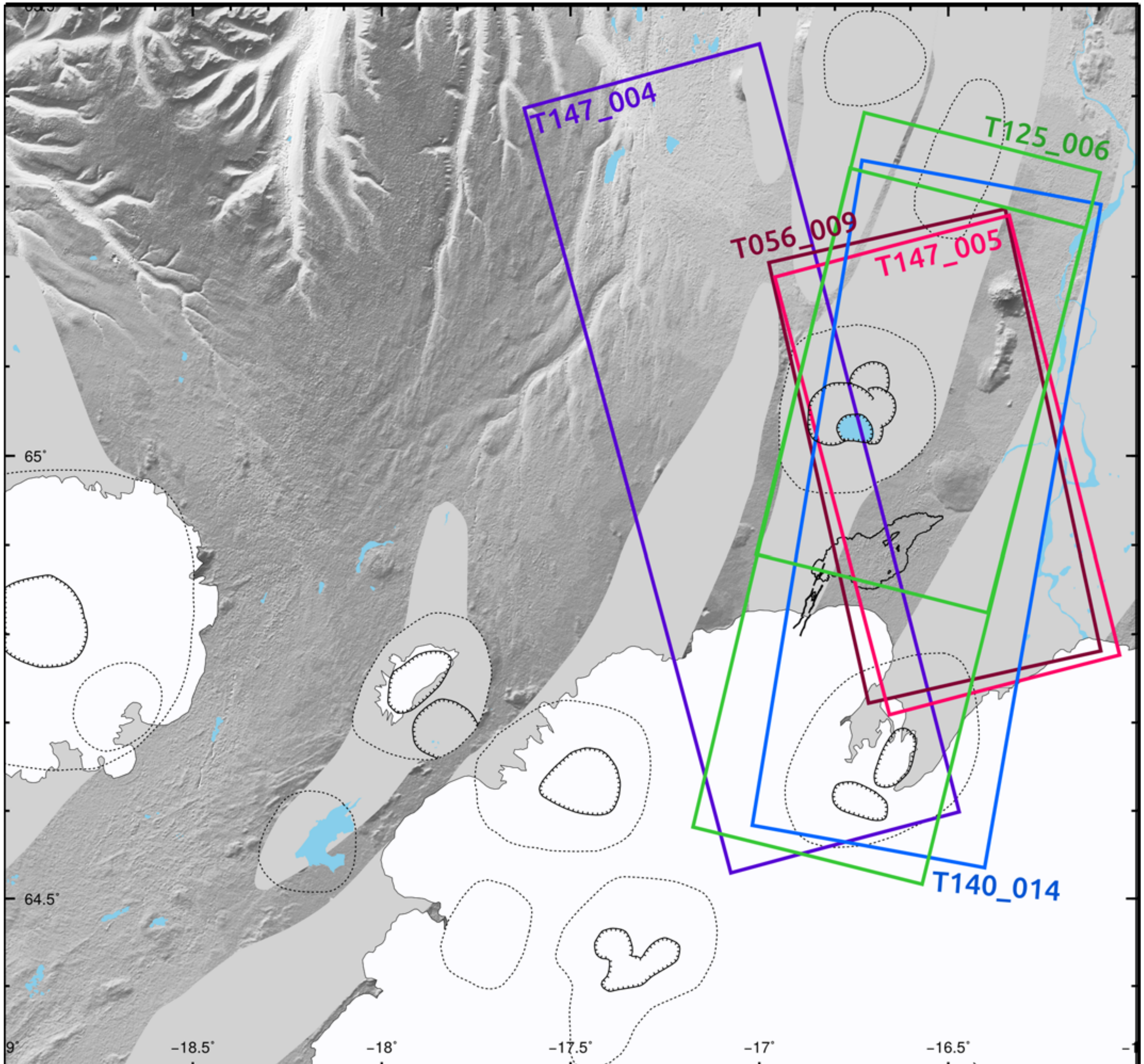
CSK 2631

28/06/2014
30/07/2014
01/09/2014
18/10/2014
19/10/2014
22/10/2014

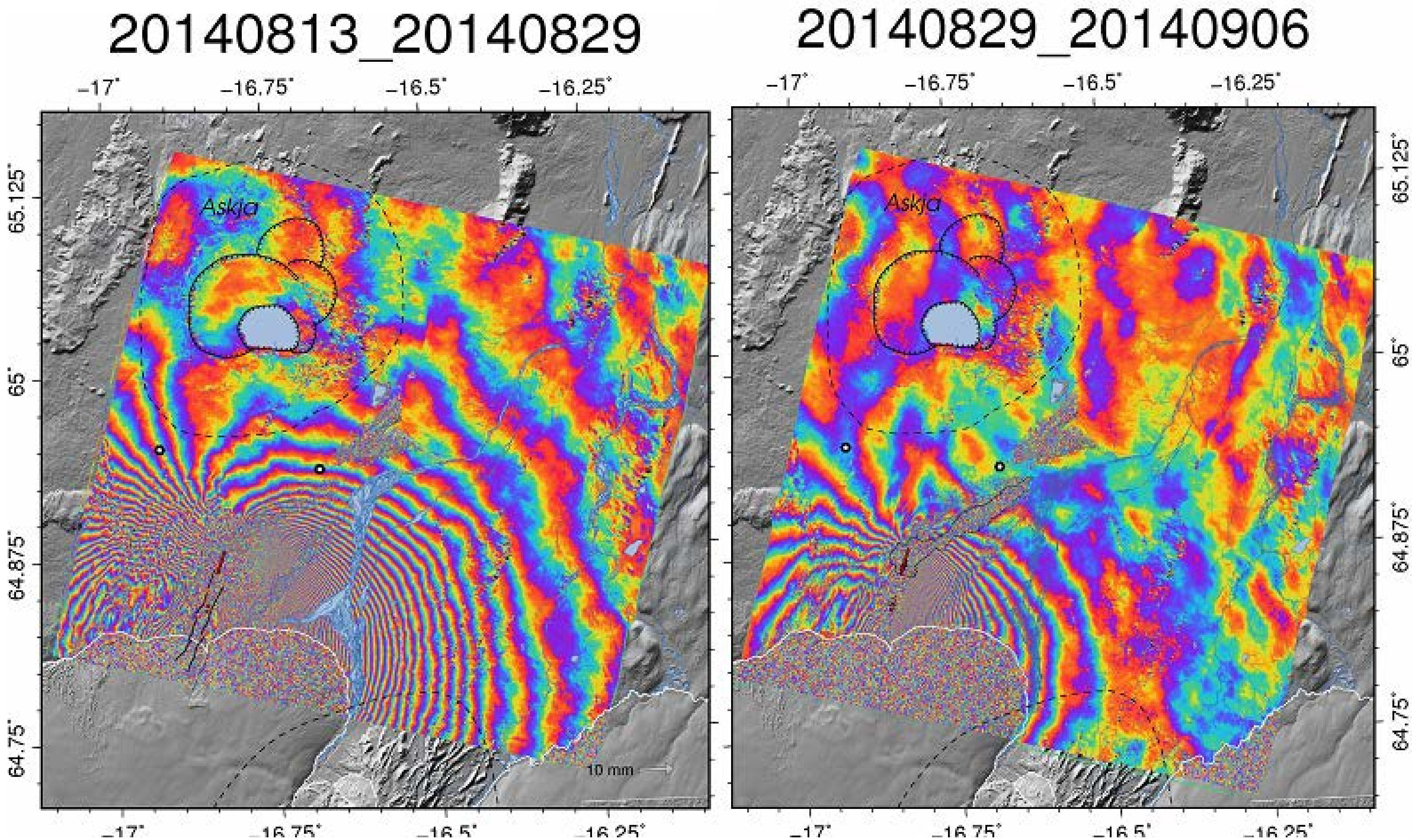
CSK 2631

26/06/2014
28/07/2014
13/08/2014
29/08/2014
06/09/2014
22/09/2014
26/09/2014
30/09/2014
08/10/2014
12/10/2014
24/10/2014
25/10/2014
28/10/2014
01/11/2014
13/11/2014

TSX footprints over Holuhraun and Bárðarbunga



InSAR over Holuhraun eruption site



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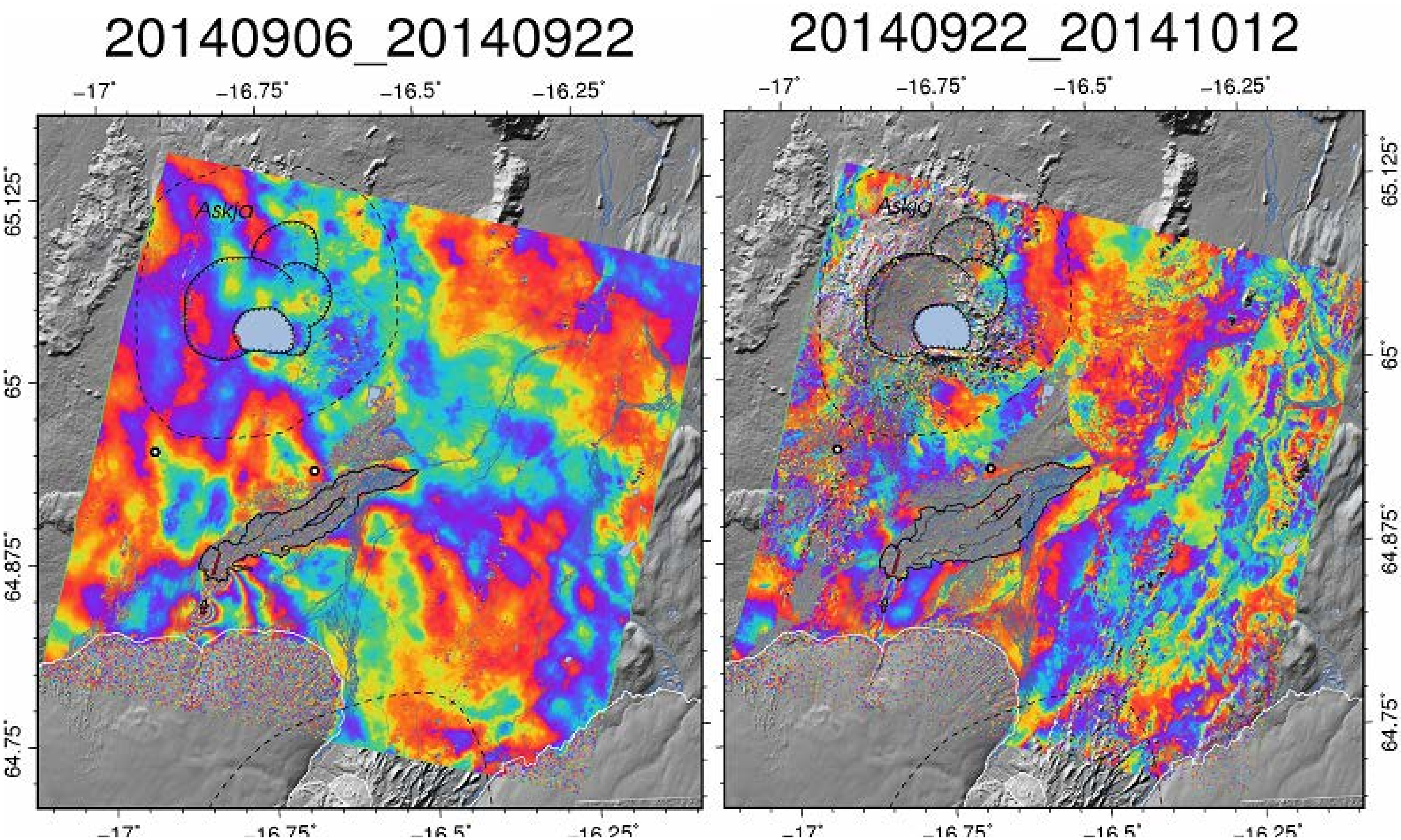
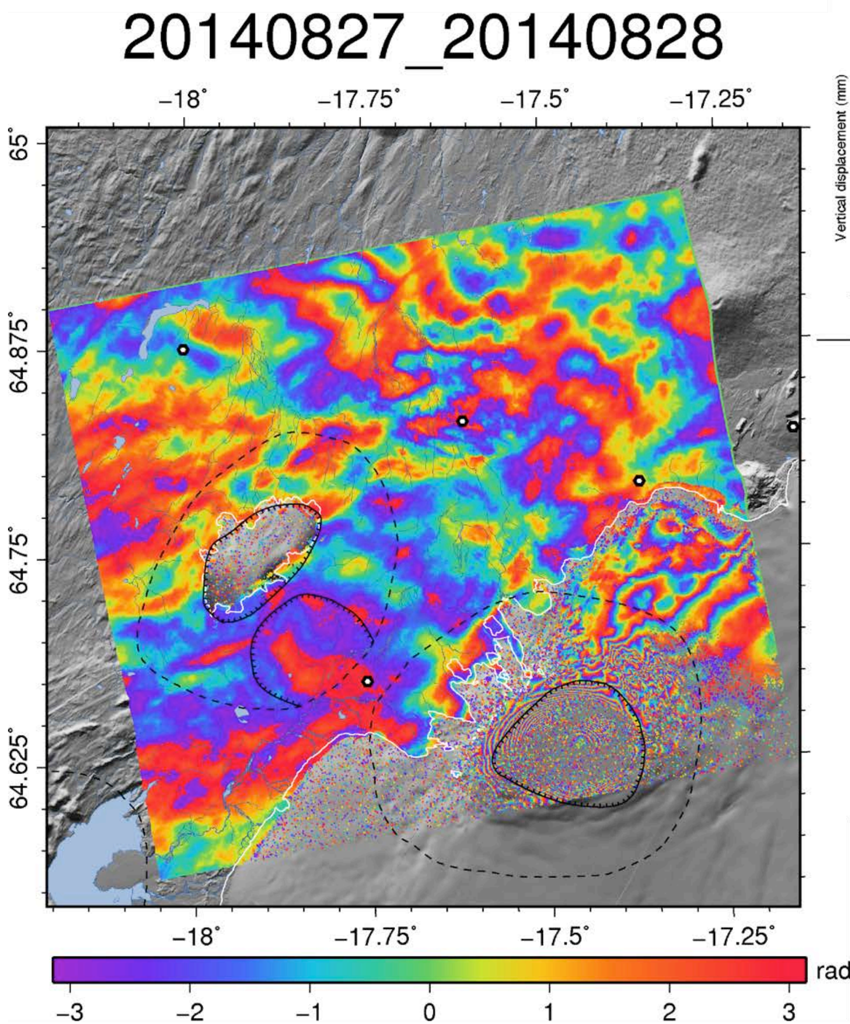
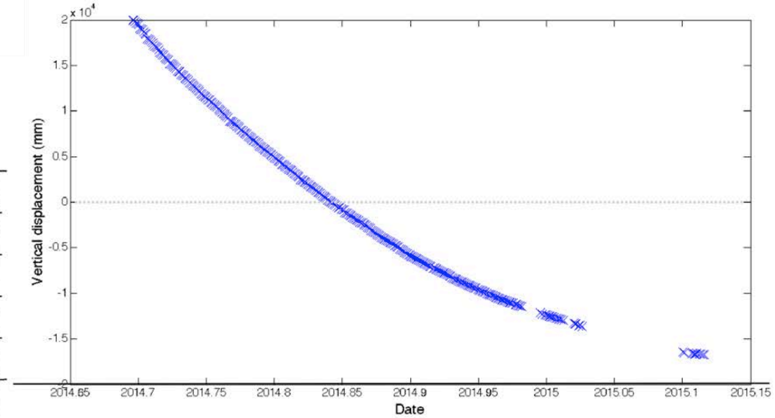
InSAR over Holuhraun eruption site

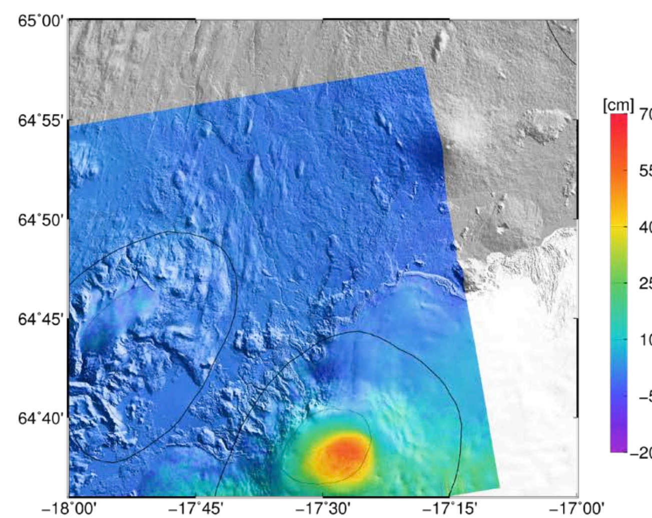


Examples of Bárðarbunga 1-day interferograms





27-28 August unwrapped interferogram



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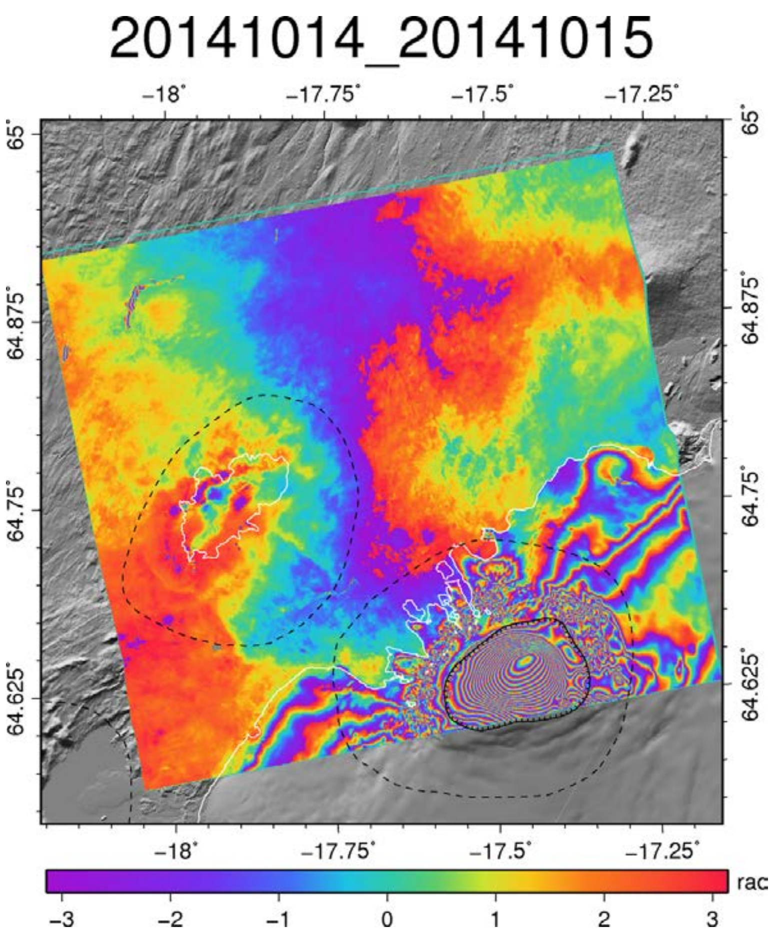
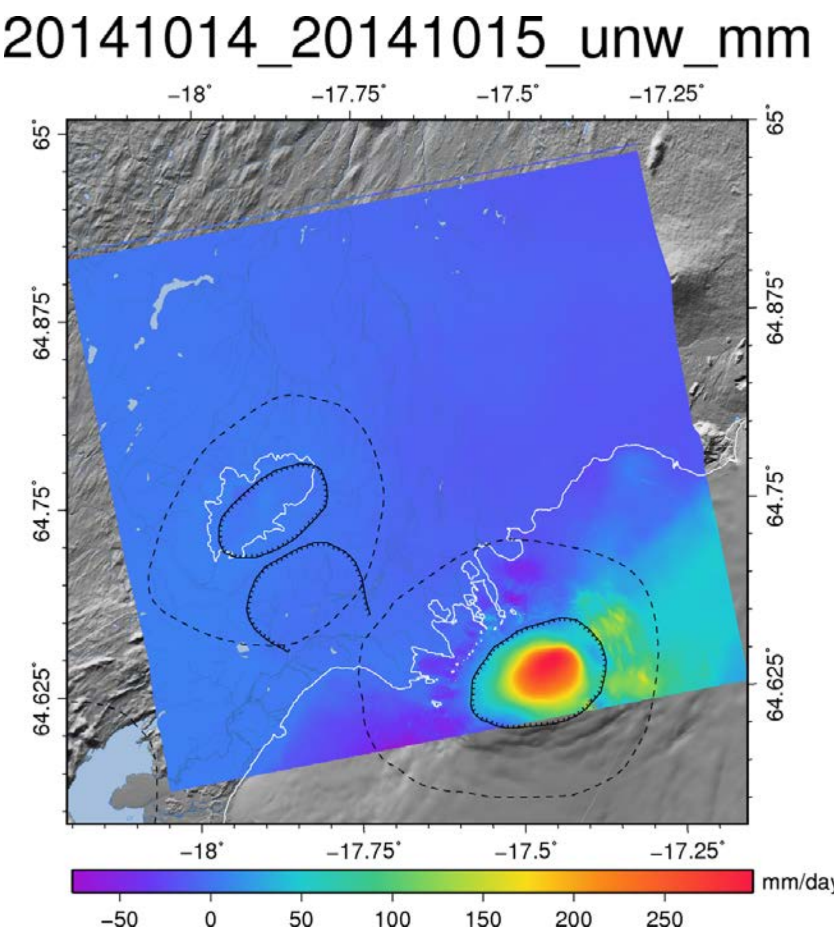
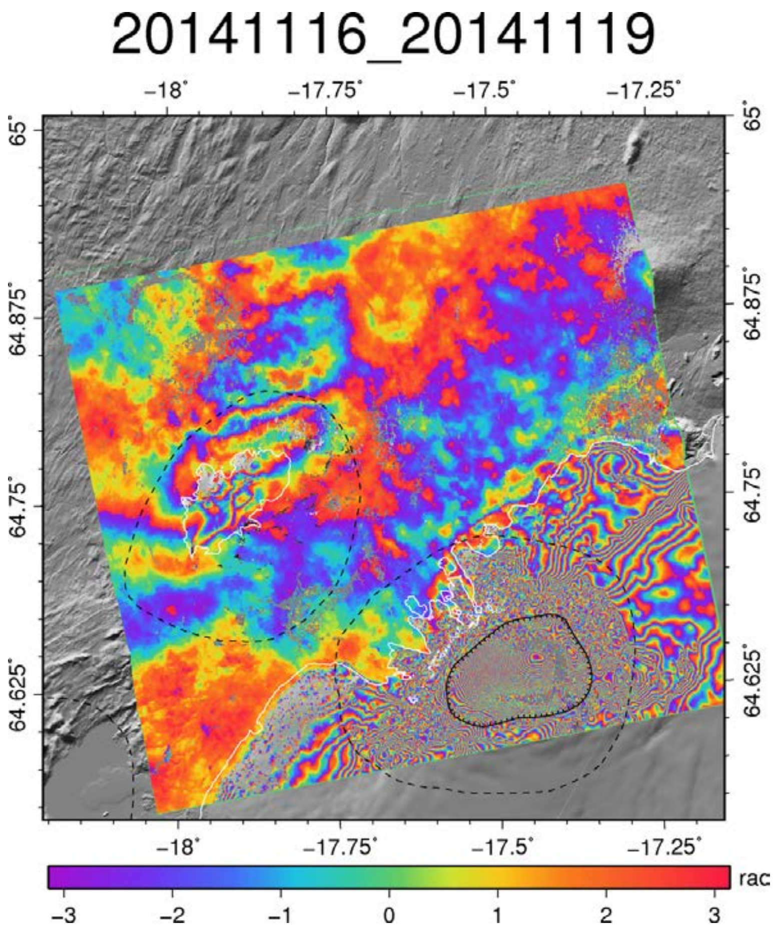
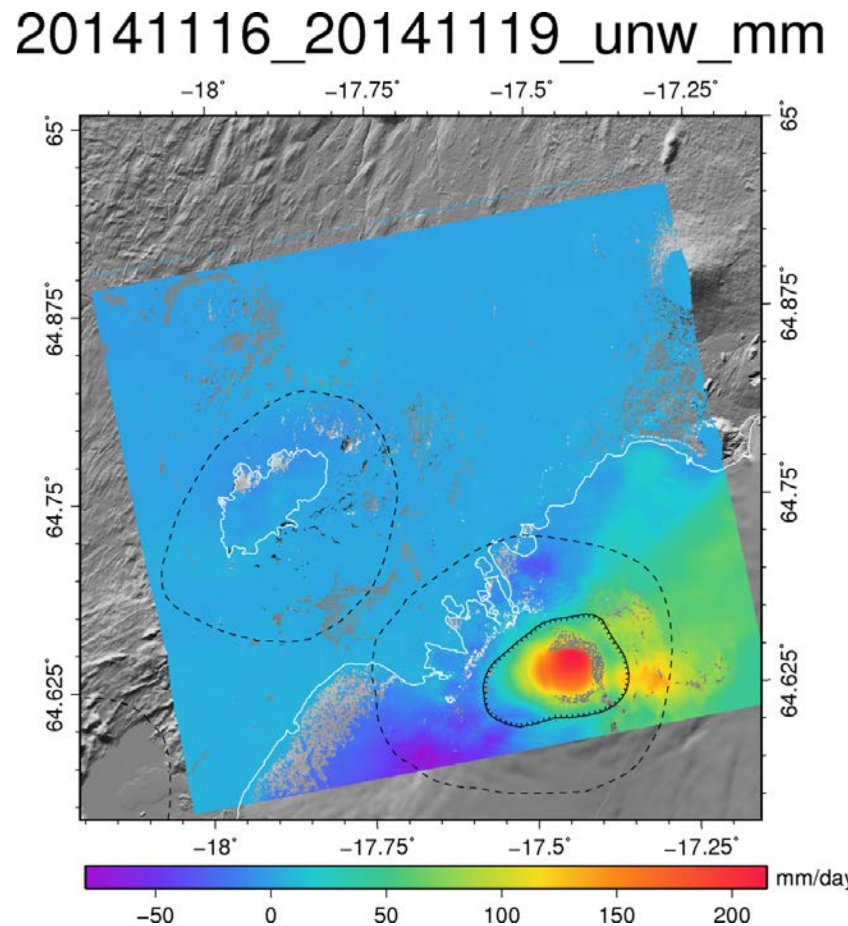
Examples of Bárðarbunga 1-day interferograms



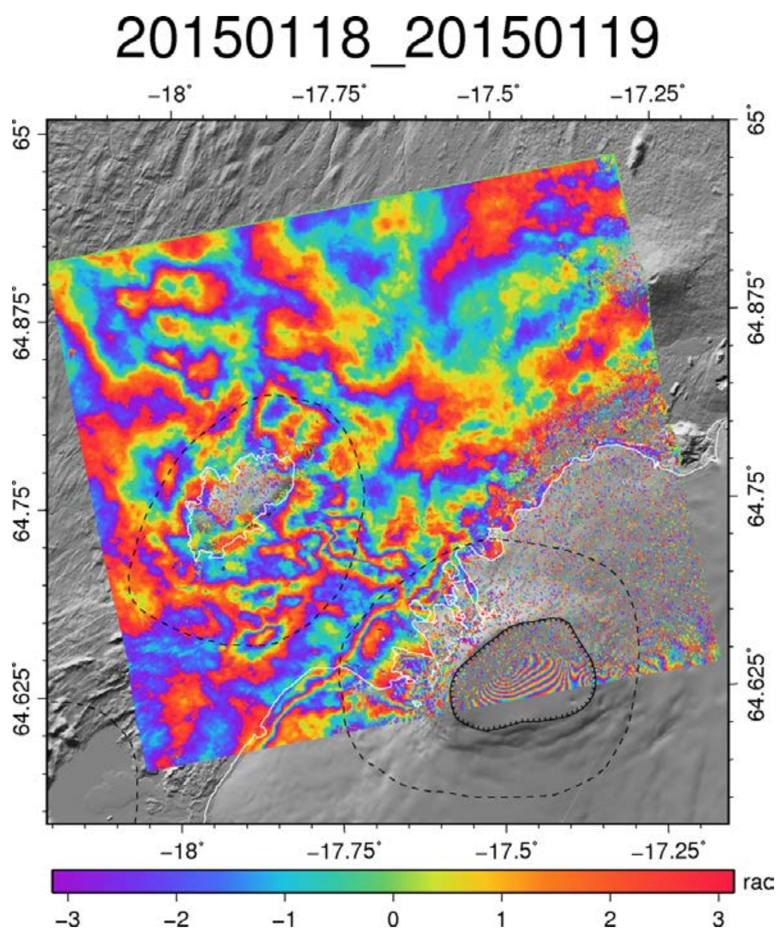


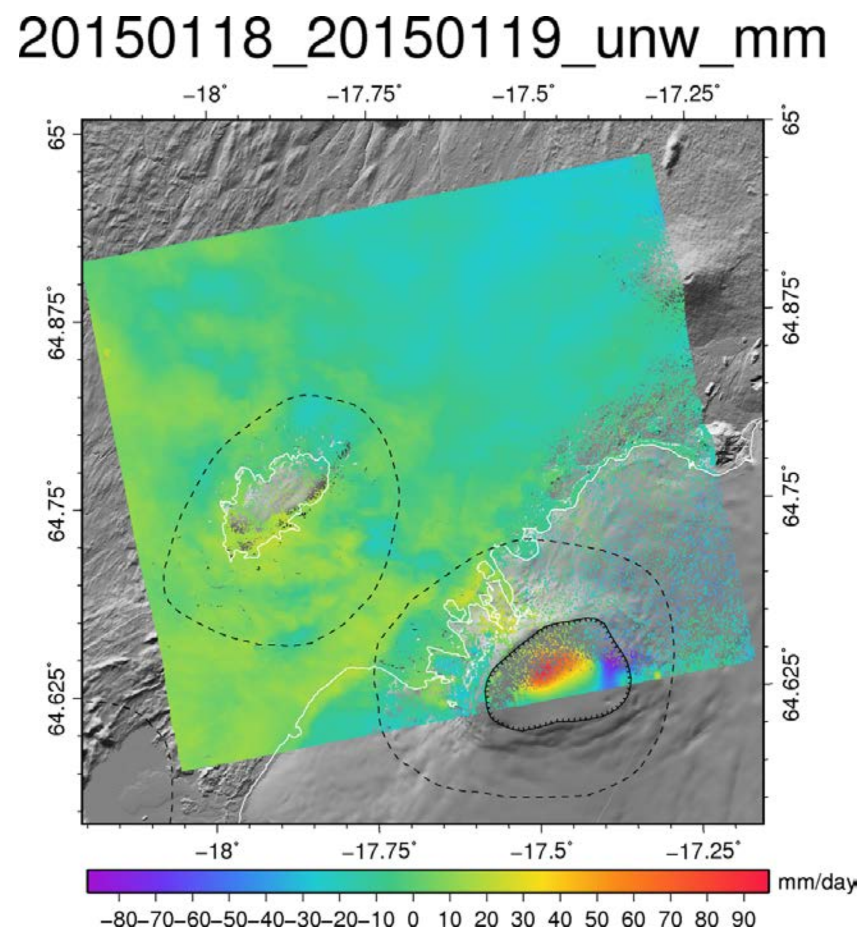
Examples of Bárðarbunga 1-day interferograms





Examples of Bárðarbunga 1-day interferograms





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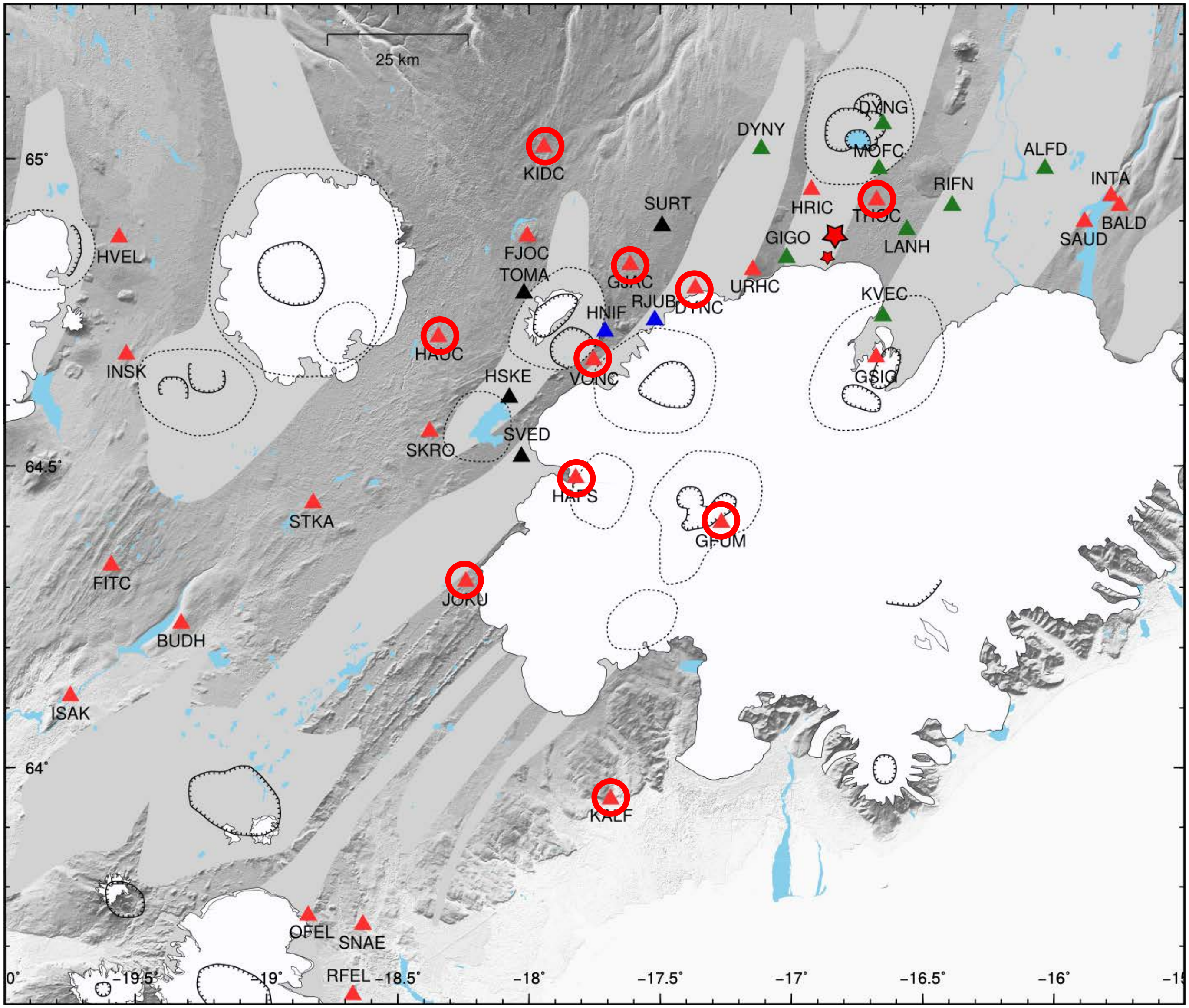
Modelling deep source of subsidence at Bárðarbunga caldera

- 2 distinct deformation processes (elastic and inelastic)
  - Magma withdrawal from deeper chamber
  - Piston collapse

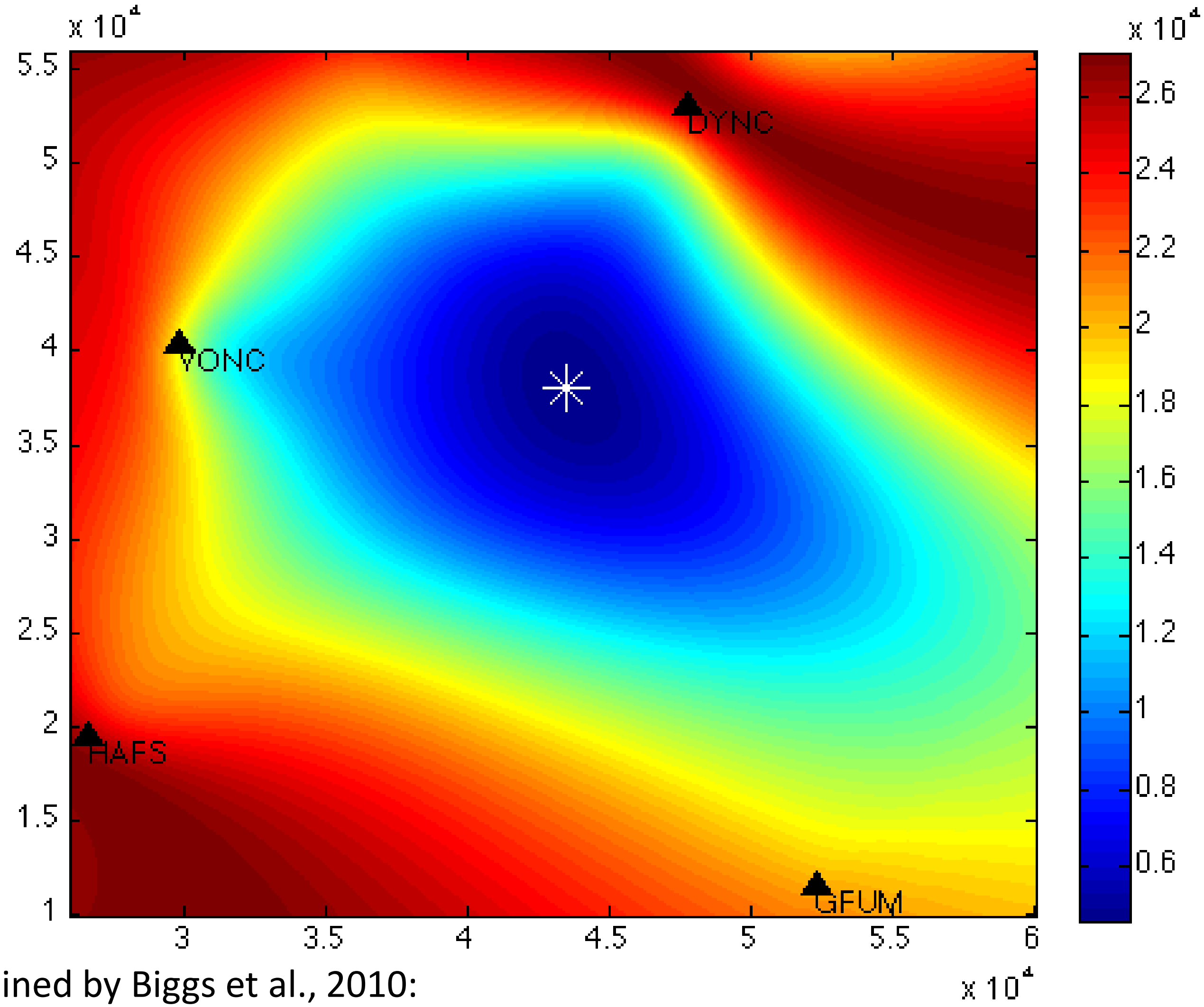
- Multiple models and codes were tested
  - Mogi, Penny shaped crack, Yang spheroid
  - Mogi point source is most stable

10 cGPS sites included in the modelling

- DYNC
- GFUM
- GJAC
- HAFS
- HAUC
- JOKU
- KALF
- KIDC
- THOC
- VONC

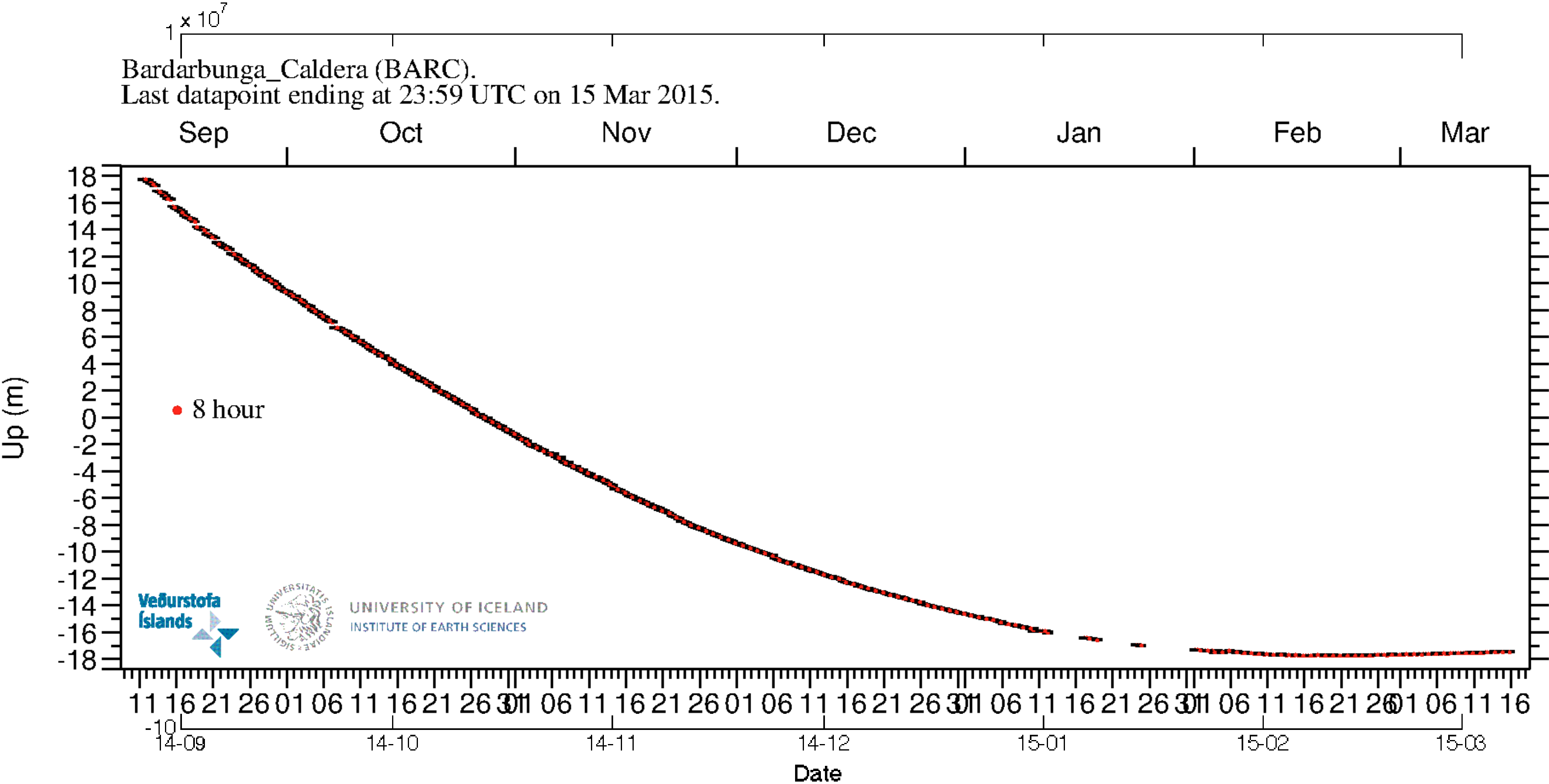


Inversion for the temporal evolution of source parameters: Projected XY source location



Using code outlined by Biggs et al., 2010:
Biggs, et al. 2010, Magma flux at Okmok Volcano, Alaska, from a joint inversion of continuous GPS, campaign GPS, and interferometric synthetic aperture radar. *Journal of Geophysical Research: Solid Earth (1978–2012)* 115.B12.

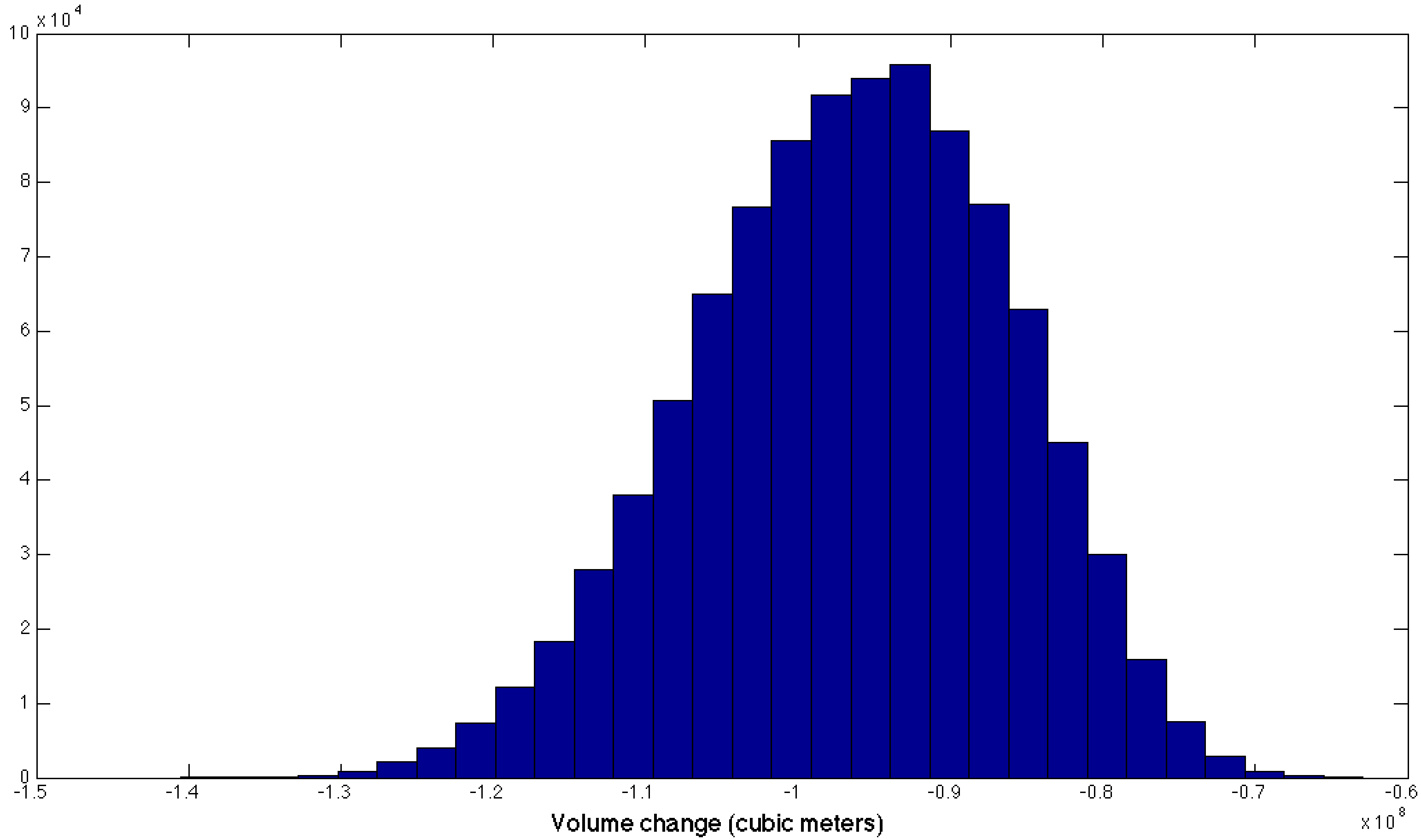
Inversion for the temporal evolution of source parameters: Cumulative volume change

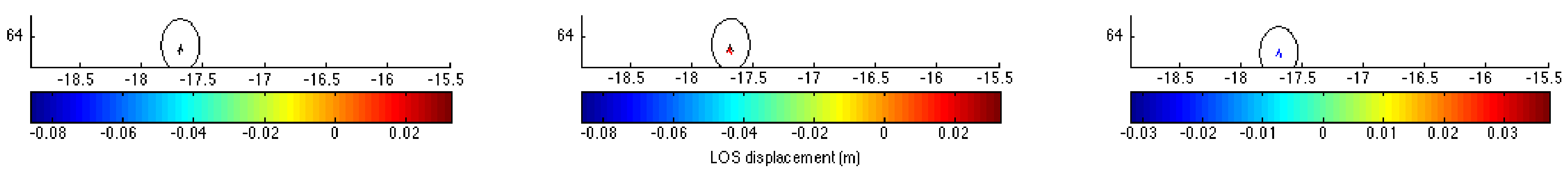


Time period: 21 Sep-26 Feb, source depth: 8.5 km

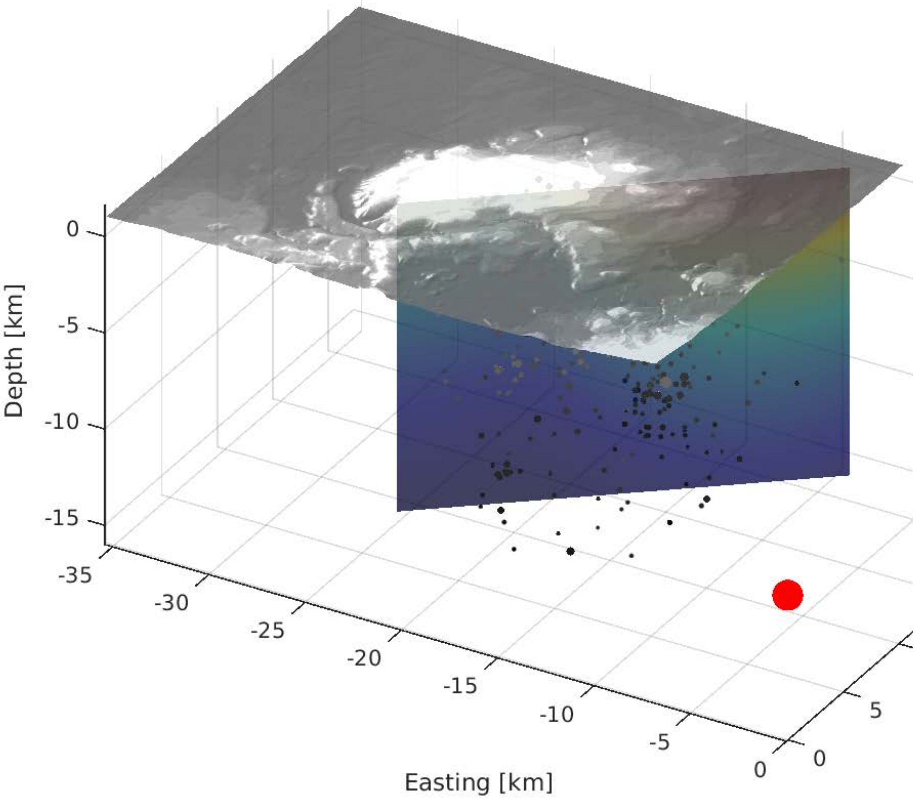
References: Biggs et al., 2010. JGR, DOI: 10.1029/2010JB007577.
Parks et al., 2015. JGR, DOI: 10.1002/2014JB011540.

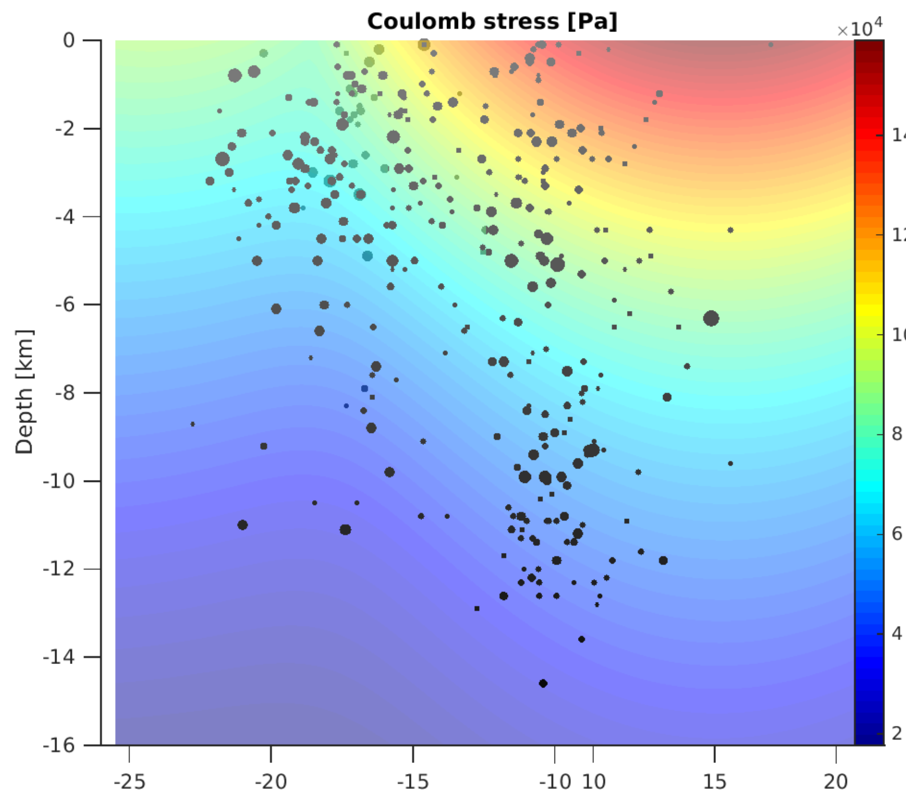
Bayesian inversion of GPS and InSAR





Stress modelling – seismic triggering at neighbouring Tungnafellsjökull





End of the eruption – Feb 2015

- Lava drained from the main crater on the 26th/27th Feb 2015
- Field teams visited the area on the 1st March

Photo credit: Á Höskuldsson

What happens next

- Nothing – Bárðarbunga returns to a state of quiescence

- New influx of magma:
  - Second dyke intrusion and fissure eruption (possibly beneath the glacier) e.g. 1862-1864 eruption on both the Veiðivötn and the Dyngjuháls swarm to the NE (0.3 km^3) or Gjálp 1996 (0.45 km^3 tephra, 3.5 km^3 jökulhlaup – max. discharge rate ~45,000 m^3/s

  - Explosive summit eruption e.g. 1910

  - Explosive phreatomagmatic eruption on fissure swarm e.g. Vatnaöldur ~870 and Veiðivötn ~1477 (~5 and ~10 km^3 respectively).

Continued deformation monitoring is crucial to detect potential signs of renewed activity!

Icelandic weather stops for no one

- Very difficult to deploy and maintain field equipment during the winter

- Problems with icing on GPS antennas
- SAR data in invaluable for continued deformation monitoring!

Thank you to:

- CEOS and GSNL
- FUTUREVOLC partners and collaborators
- ASI, DLR, ESA and CSA
- Funding from EC FP7 Framework programme is gratefully acknowledged

Takk Fyrir!

Photo credit: M Parks

Mapping the extent of the 2014 Holuhraun lava flows and changes in the Bárðarbunga ice-cap