Fringe, Leeds, 11-15 Sept. 2023

King Abdullah University of Science and Technology

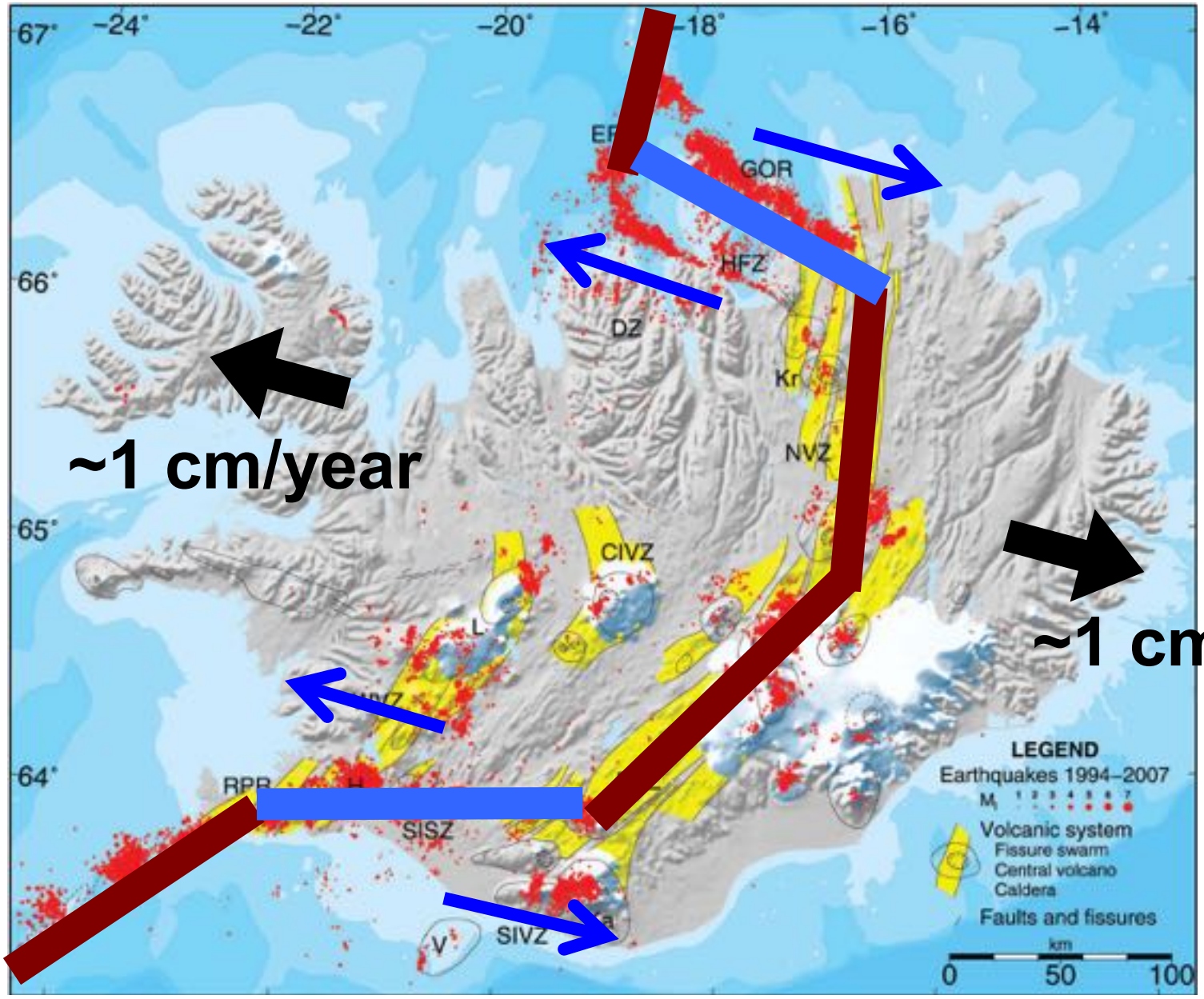
KAUST

All Slopes in Iceland are Moving

Sigurjón Jónsson[1] and Yunmeng Cao[1,2],

[1]King Abdullah University of Science and Technology (KAUST)
[2]Now at GNS, New Zealand

Dynamic Iceland



IMO and Einarsson et al., 2008

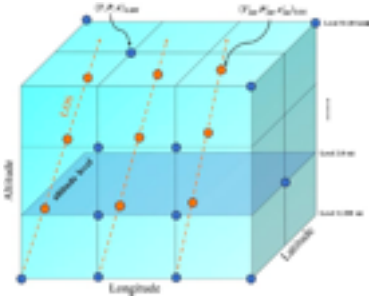
Countrywide deformation mapping by InSAR

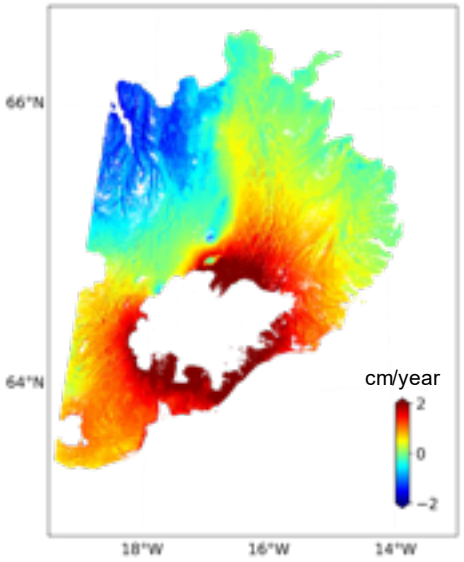
- **Sentinel-1**: 3 ascending tracks + 3 descending tracks
- **Summer season** only (May ~ October)
- **2015 to 2021** (7 years)

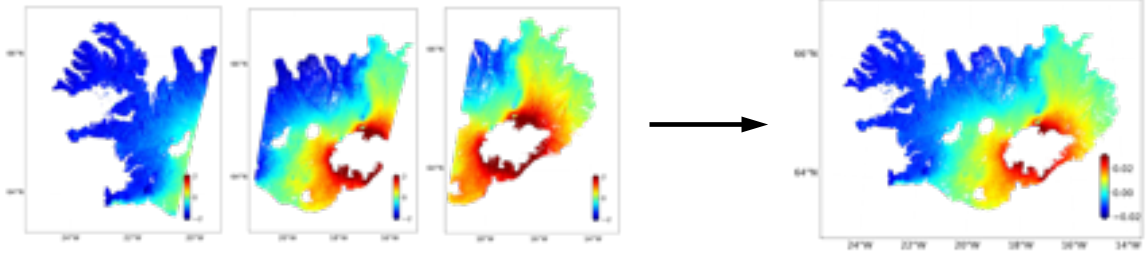
3 images for each track
~ 170 observations in time
~1060 (x3) Sentinel-1 images
~ 8700 Interferograms

Data Processing

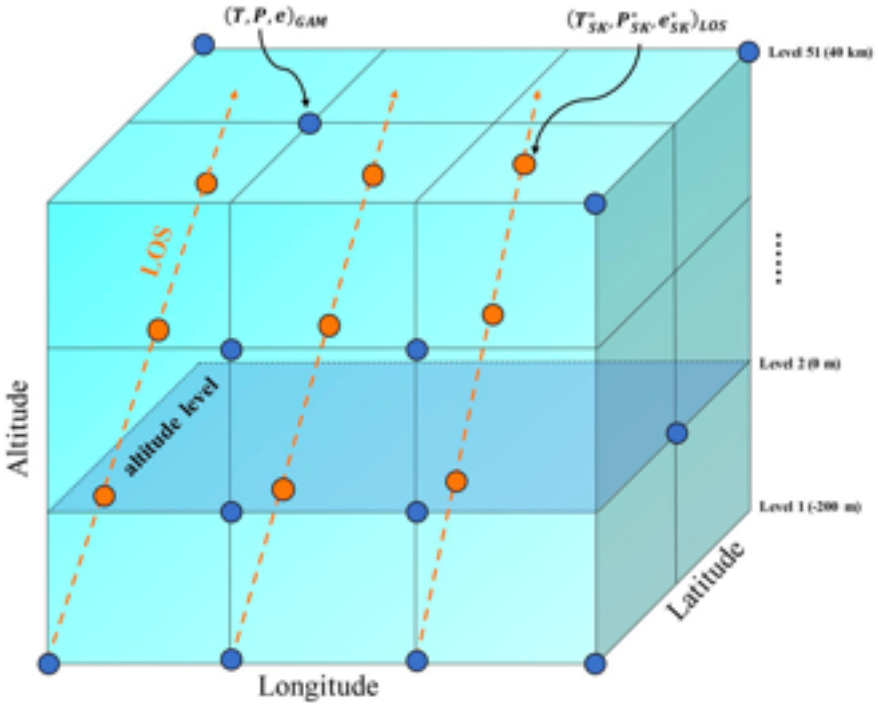
- Step 1: Interferogram generation at 100 m per pixel
- Step 2: Time-series estimation with error corrections (tropospheric corrections from global atmospheric models, DEM and unwrapping corrections)
- Step 3: Tropospheric variance-covariance modeling for each SAR radar image
- Step 4: Estimation of average velocities, seasonal and transient signals from the time-series results
- Step 5: Combination of the different tracks into countrywide ascending and descending velocity maps
- Step 6: Estimation of near-vertical and east velocity







Advanced InSAR Tropospheric Correction



Cao, Jónsson, Li, JGR, 2021

Key points of *ICAMS*

- Based on Global Atmospheric Models (GAMs)
- ECMWF-ERA5 reanalysis
- Stochastic nature of the variability considered in the interpolation (kriging)
- Slanted-path integration, not only zenith delays
- **ICAMS performs better than other GAM-based methods like GACOS, PyAPS, d-LOS**

ICAMS on Github:
https://github.com/ymcmrs

JGR Solid Earth

RESEARCH ARTICLE
10.1029/2020JB020952

Key Points:

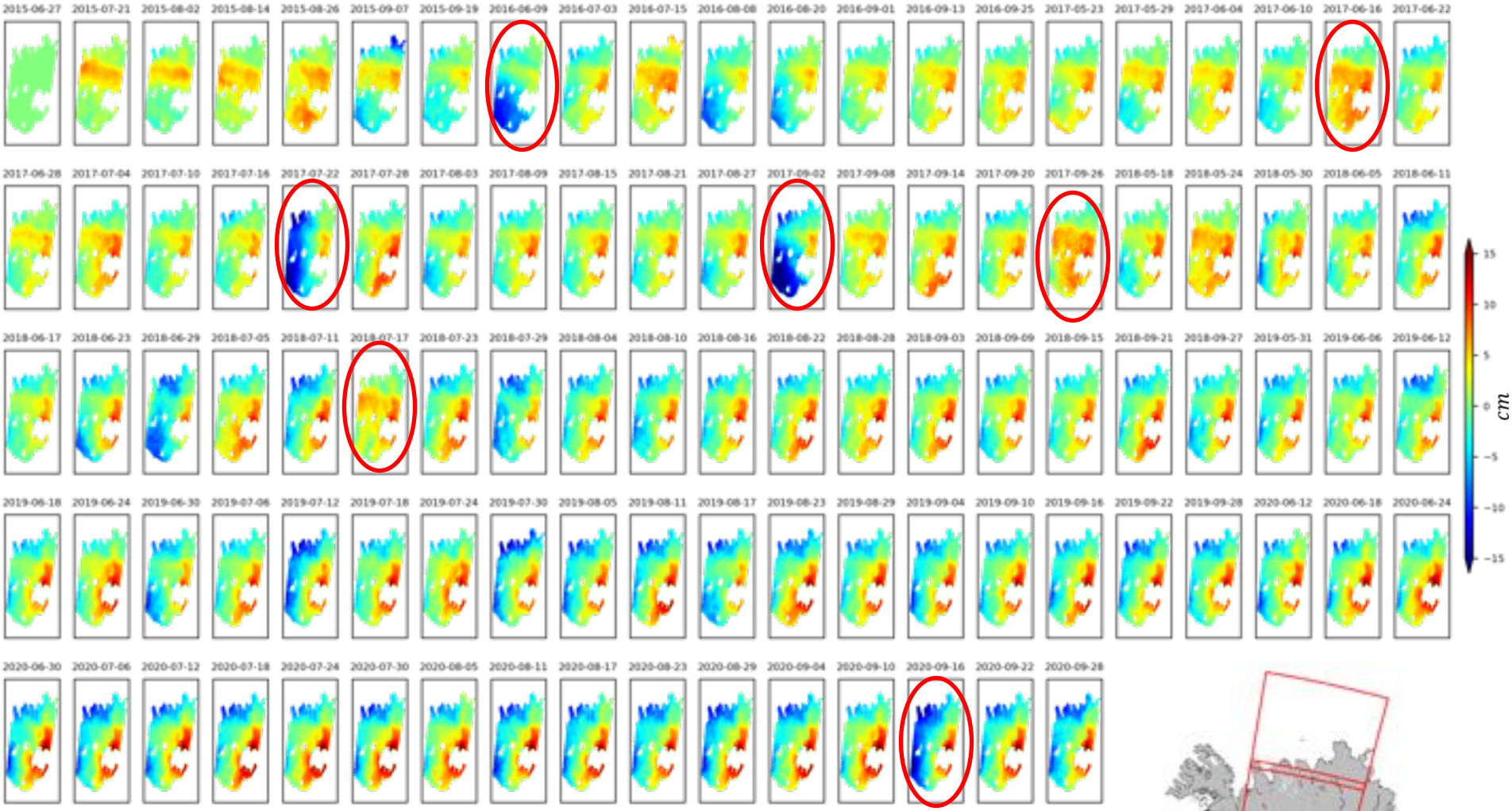
- An improved InSAR troposphere correction method proposed, based on Global Atmospheric Models (GAM), that considers spatial stochastic properties of the troposphere at different altitude

Advanced InSAR Tropospheric Corrections From Global Atmospheric Models that Incorporate Spatial Stochastic Properties of the Troposphere

Yunmeng Cao[1], Sigurjón Jónsson[1], and Zhiwei Li[2]

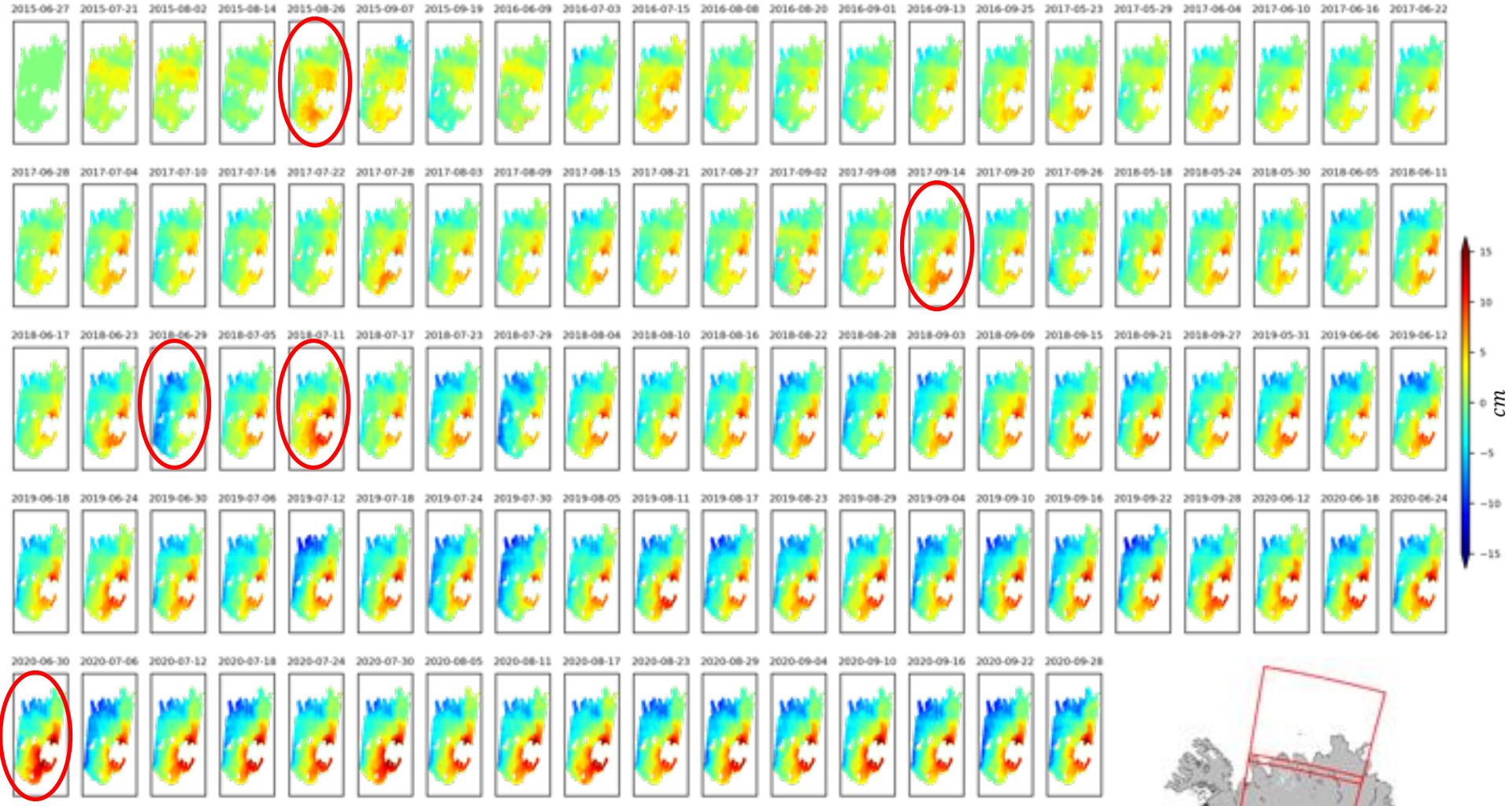
[1]King Abdullah University of Science and Technology (KAUST), Thuwal 23955, Saudi Arabia, [2]School of Geoscience and Info-Physics, Central South University, Changsha, Hunan, China

Raw time-series solution (track 9)



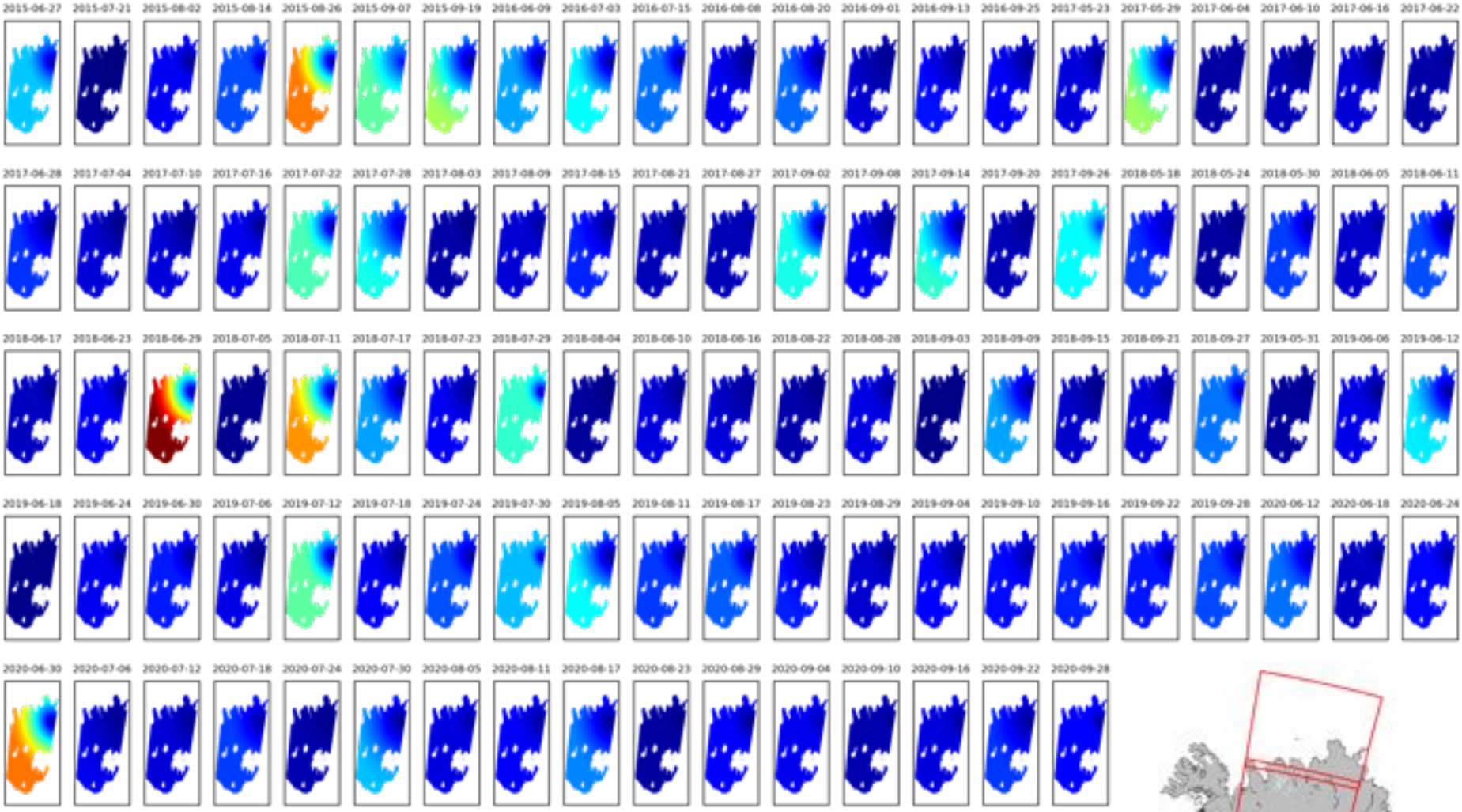
- Strong **tropospheric effects** on some SAR acquisitions

ICAMS corrected time-series solution



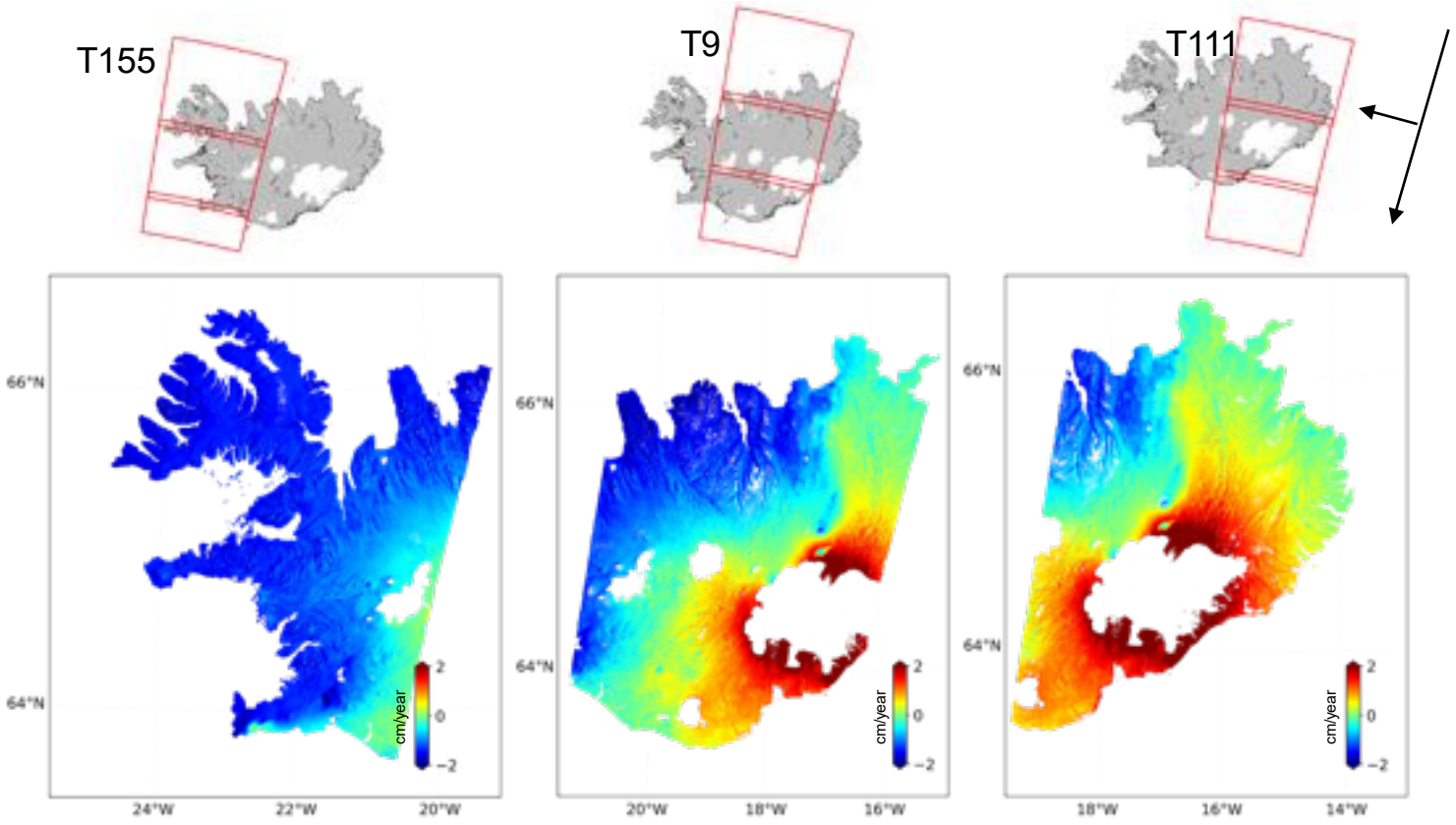
- Most of the troposphere are well corrected
- Residual errors due to **tropospheric turbulence**

Variogram estimation of the SAR images (track 9)



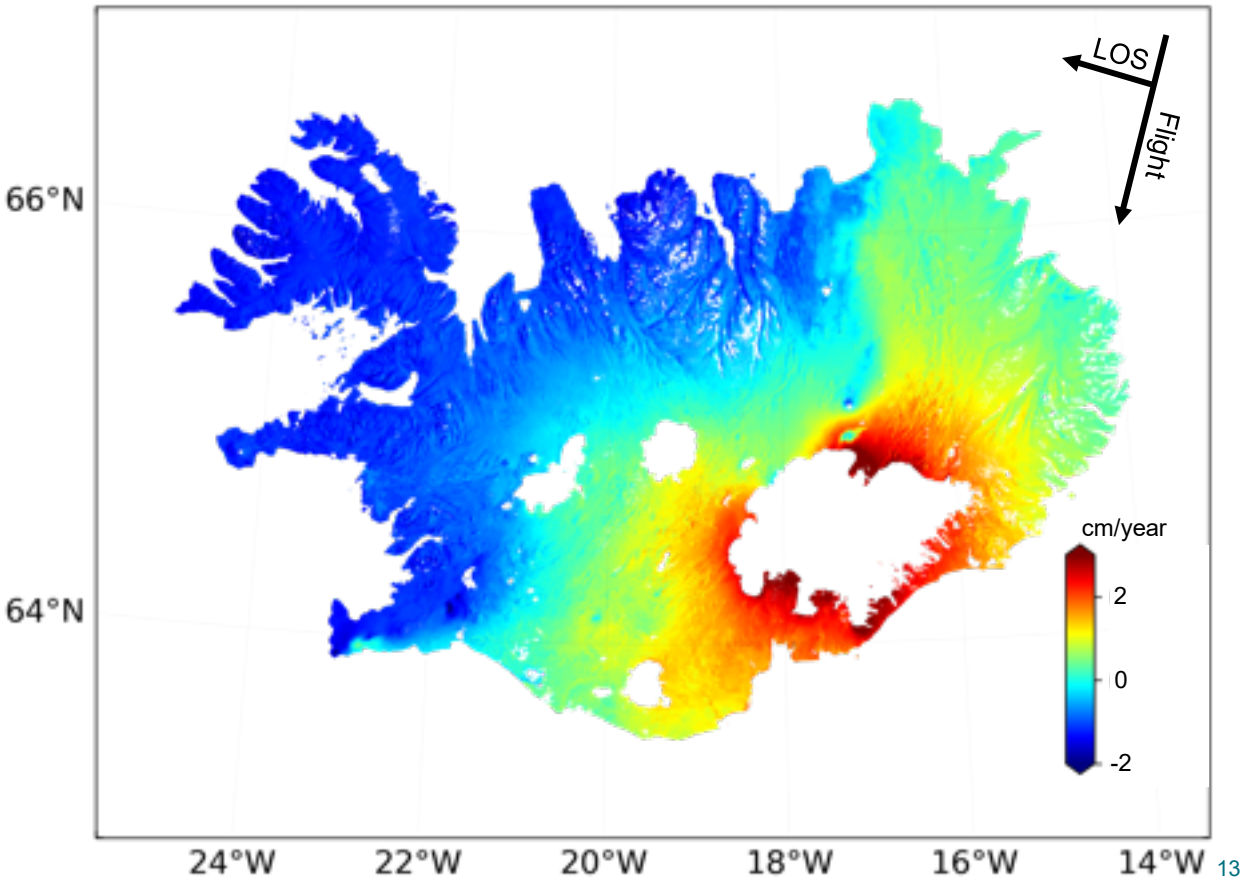
- Quantitative assessment of the turbulent component in SAR images
- **Better estimation of temporal parameters** (e.g., velocity, season-amp.)

Descending-orbit Line-of-Sight (LOS) velocity



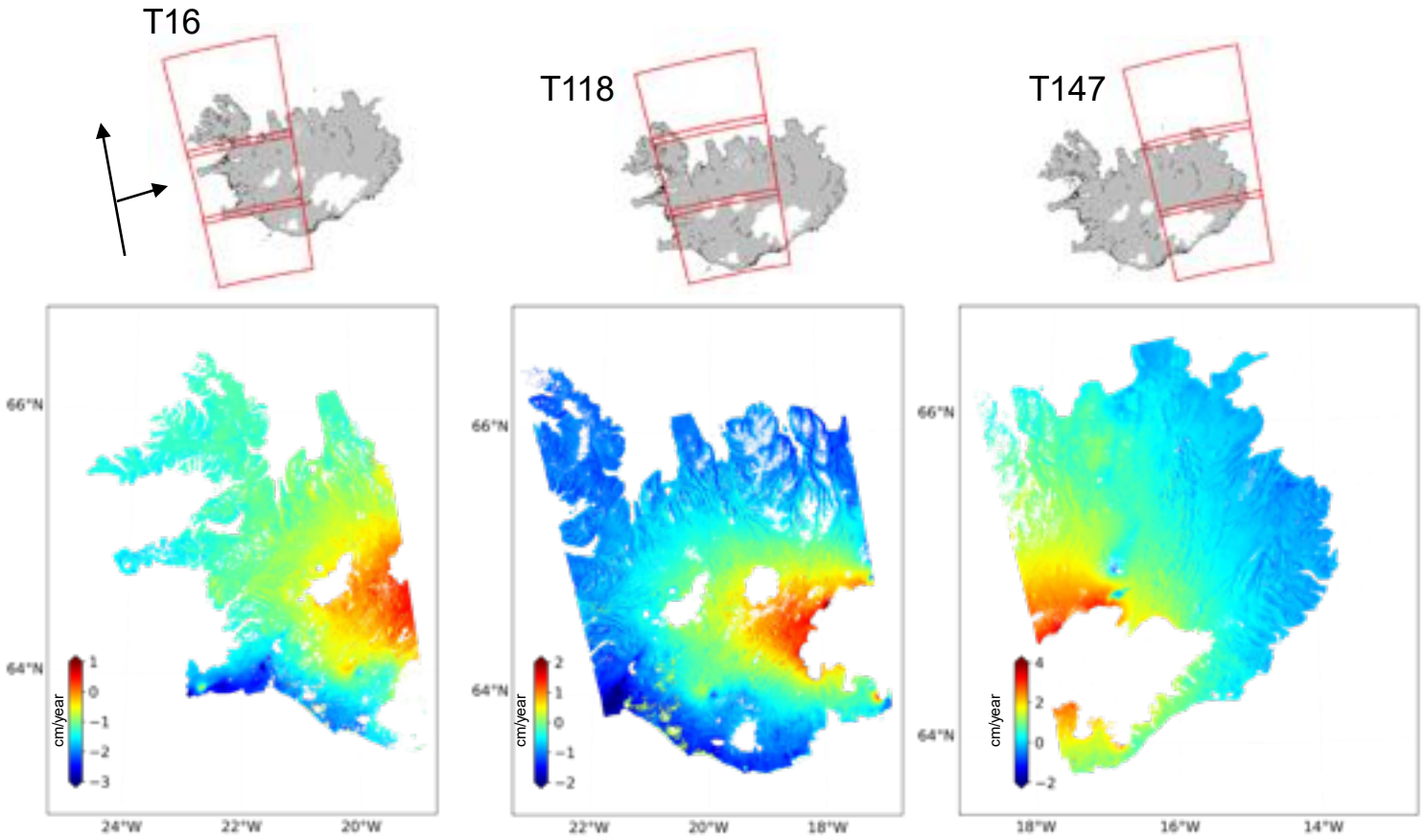
Cao, Jónsson, Hreinsdóttir, JGR, 2023

Descending-orbit Line-of-Sight (LOS) velocity



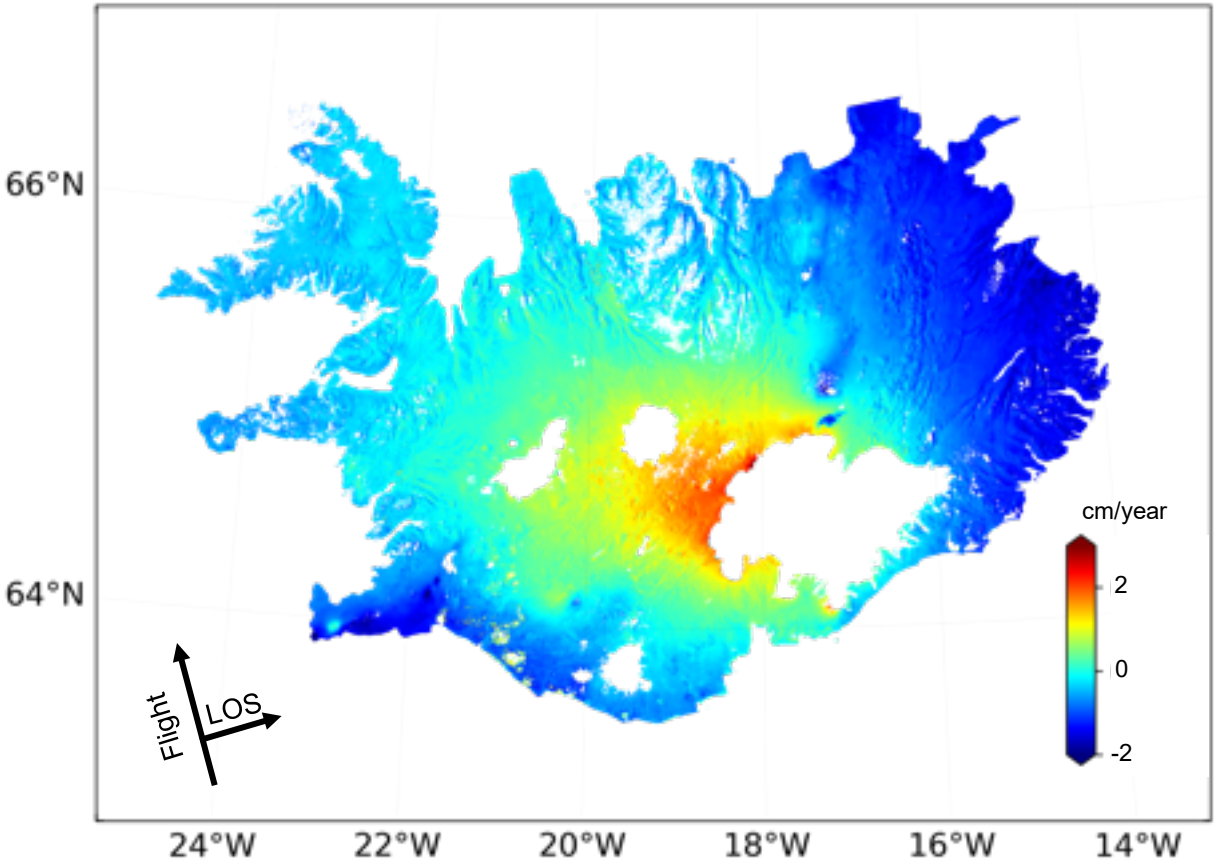
Cao, Jónsson, Hreinsdóttir, JGR, 2023

Ascending-orbit Line-of-Sight (LOS) velocity



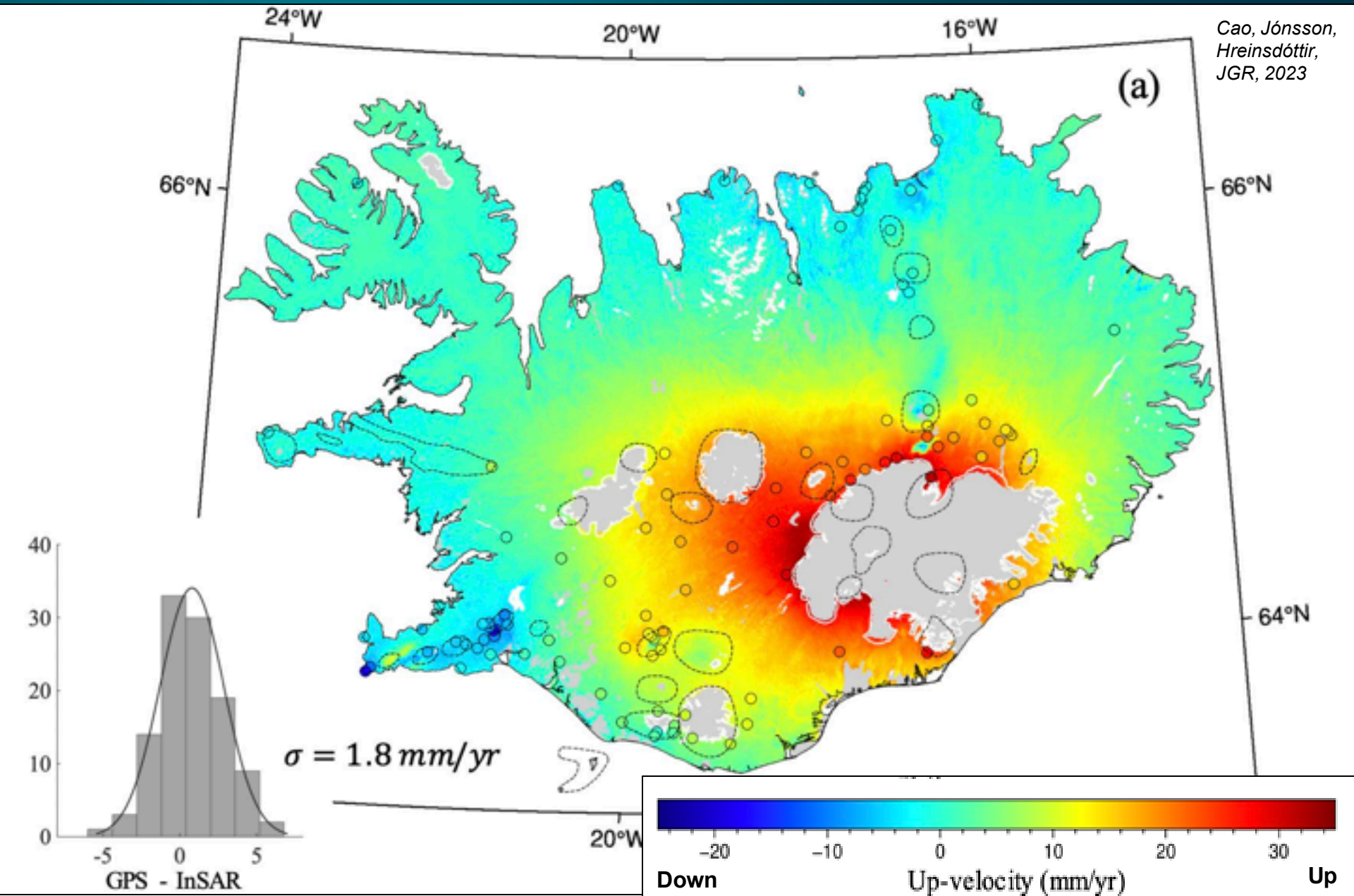
Cao, Jónsson, & Hreinsdóttir, JGR, 2023

Ascending-orbit Line-of-Sight (LOS) velocity



Cao, Jónsson, & Hreinsdóttir, JGR, 2023

Vertical Velocity: Iceland is going up!



Cao, Jónsson, Hreinsdóttir, JGR, 2023

JGR Solid Earth

RESEARCH ARTICLE
10.1029/2022JB025546

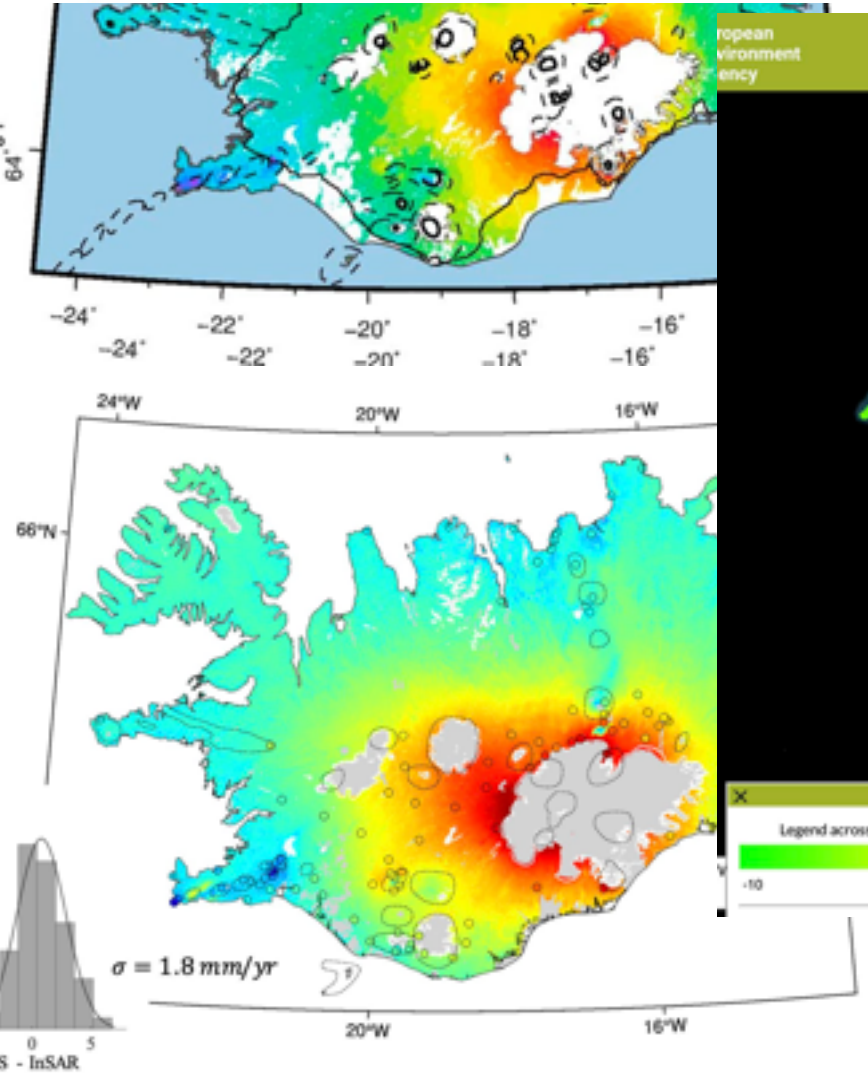
Iceland Kinematics From InSAR

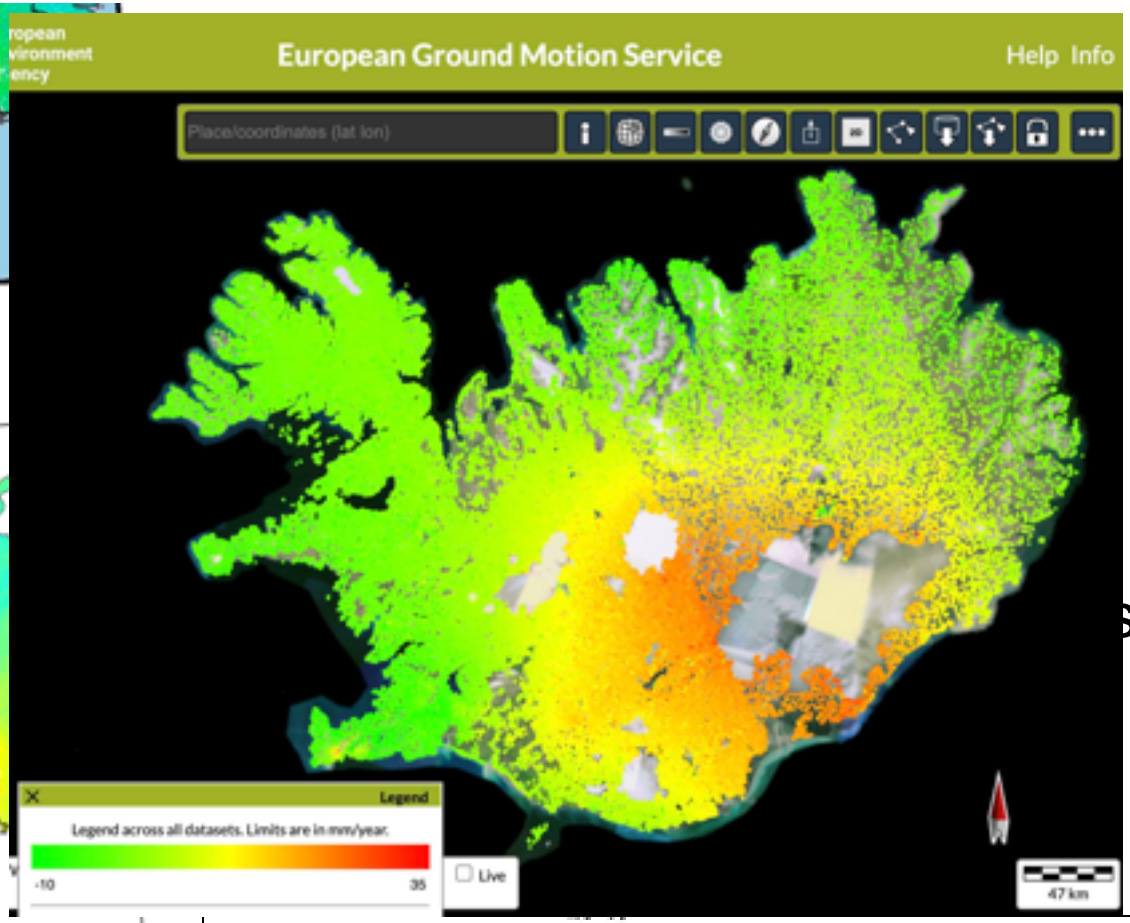
Yunmeng Cao[1,2], Sigurjón Jónsson[1], and Sigrún Hreinsdóttir[2]

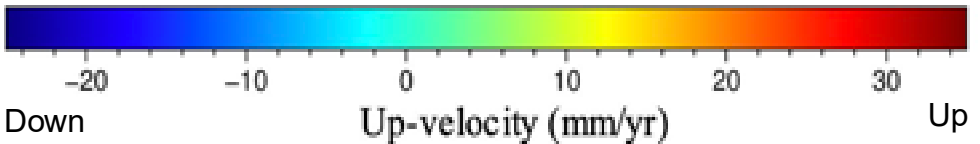
[1]King Abdullah University of Science and Technology (KAUST), Thuwal, Saudi Arabia, [2]Now at GNS Science, Lower Hutt, New Zealand

Key Points:

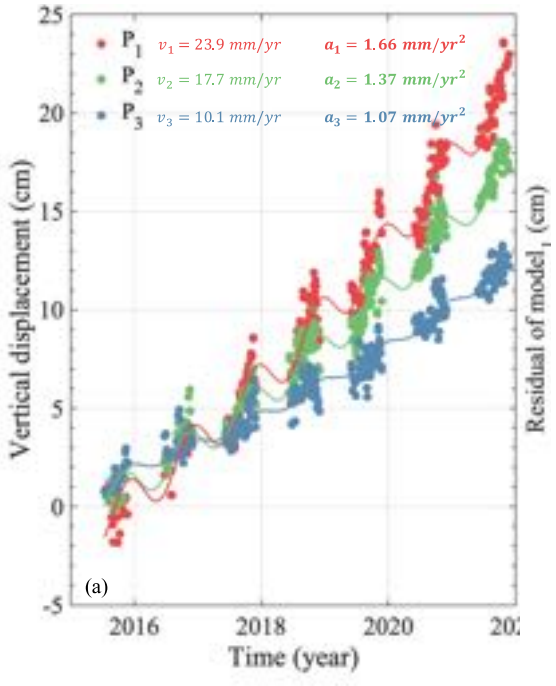
- Time series of countrywide displacements over Iceland from

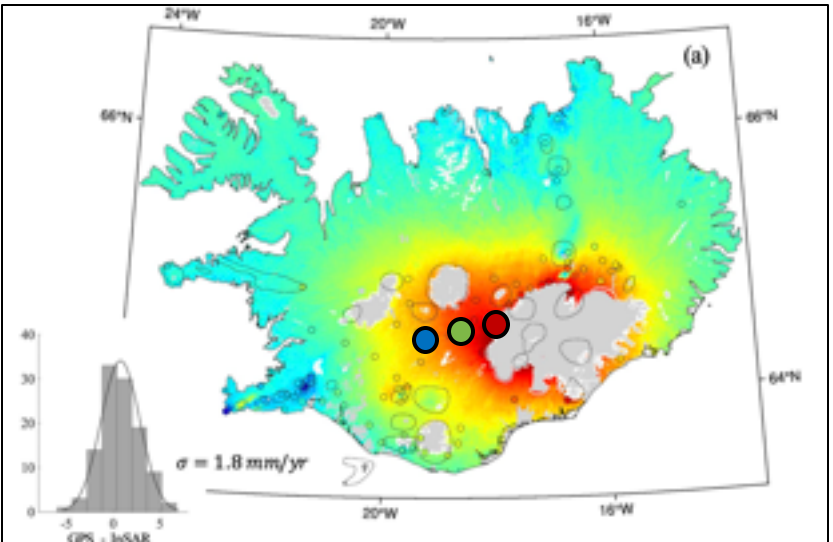


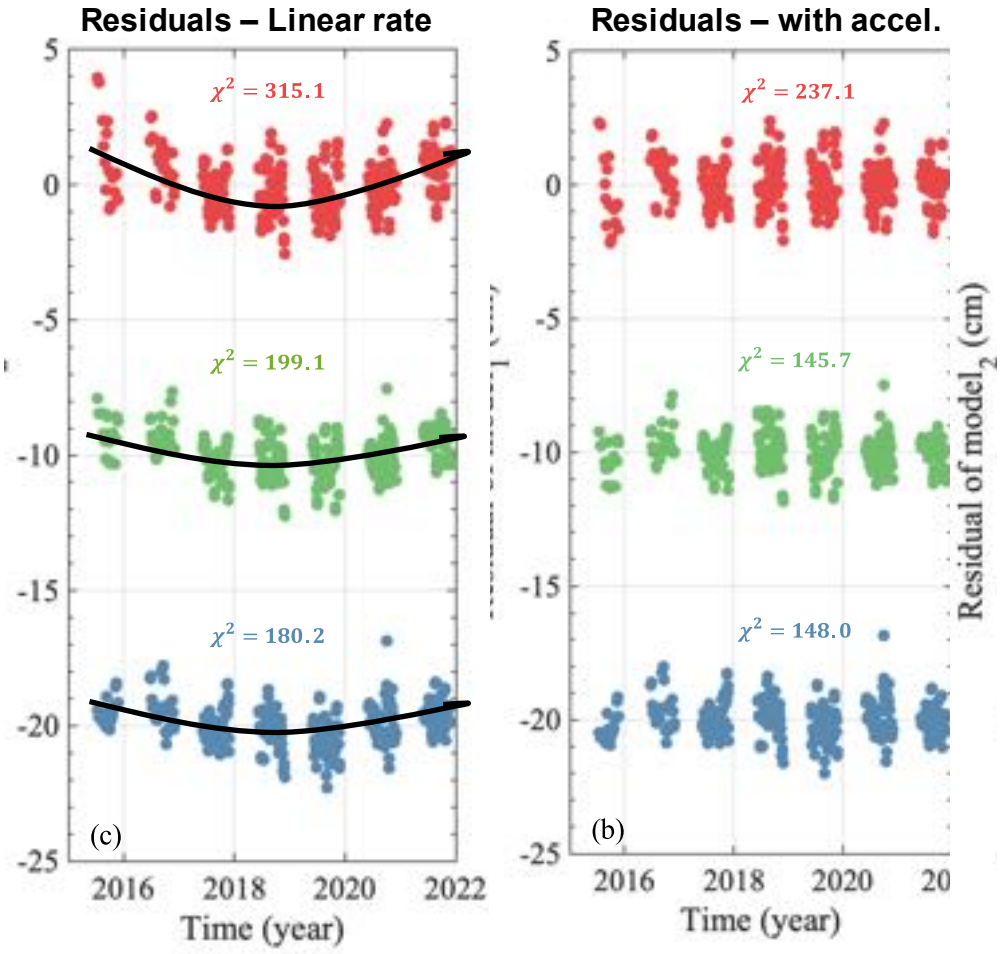




Acceleration of Uplift?



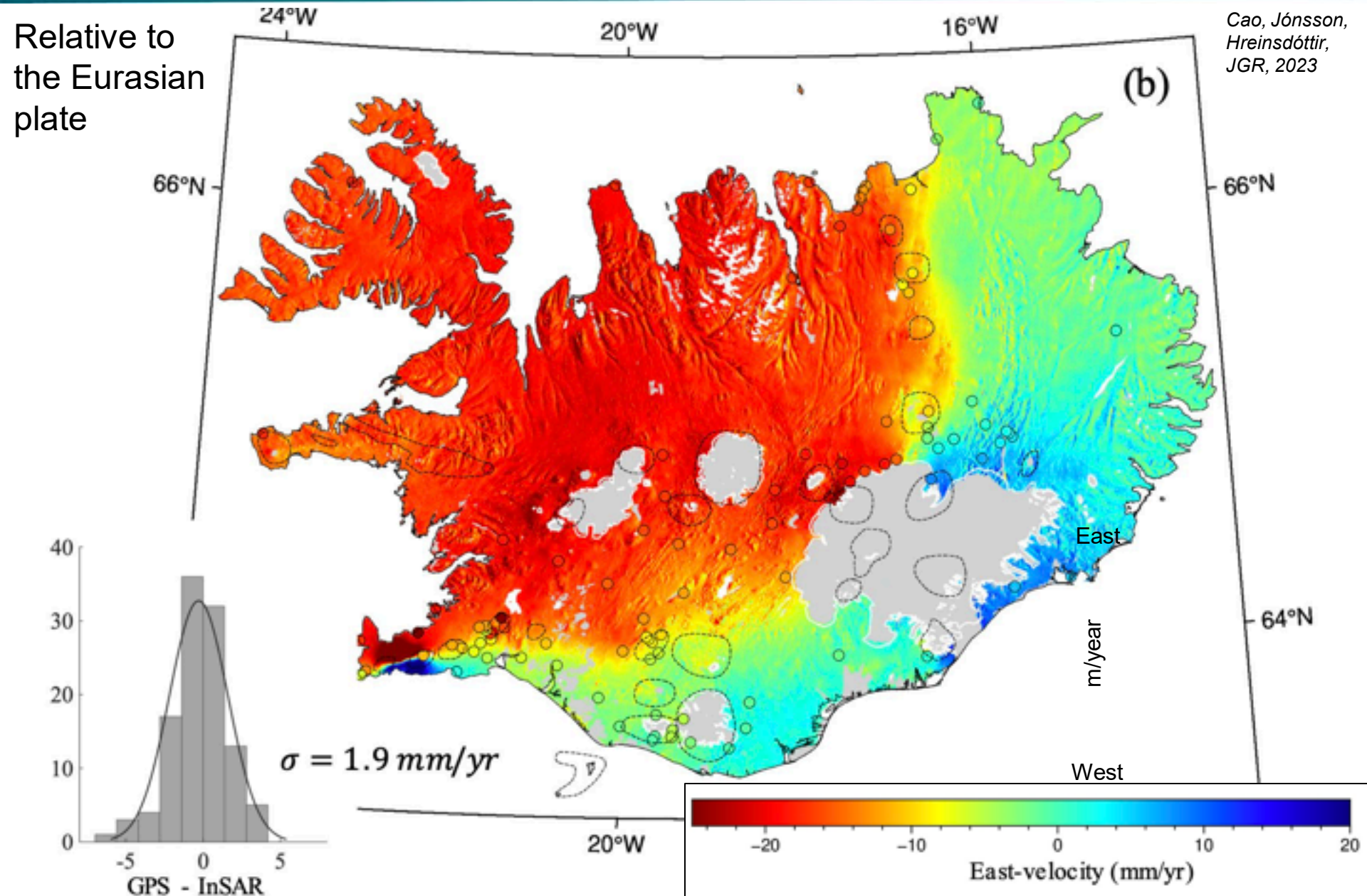




- **Uplift is accelerating by 1-2 mm/year²**

Countrywide (near) East velocity

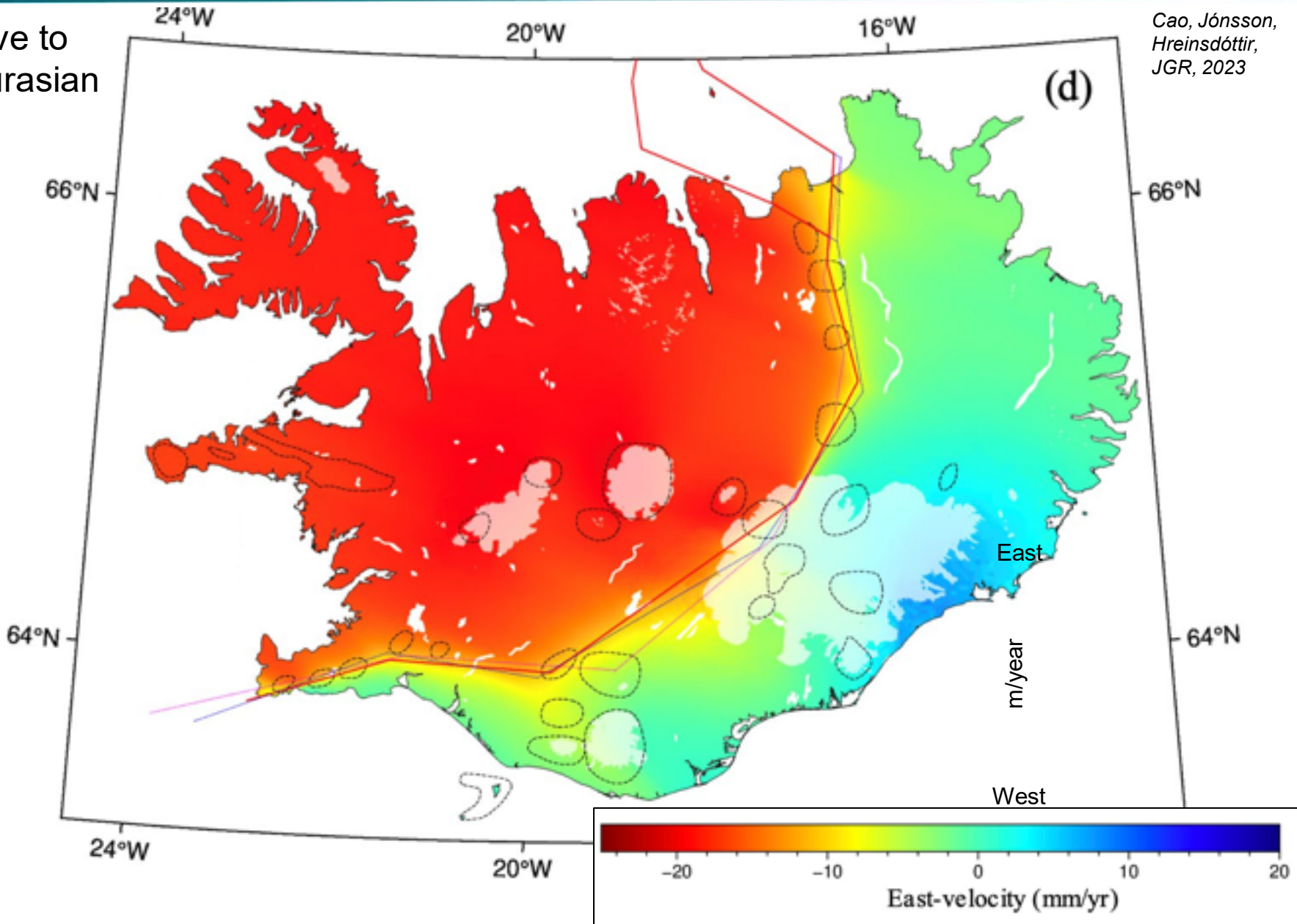
Relative to the Eurasian plate



Cao, Jónsson, Hreinsdóttir, JGR, 2023

Modeling the East velocity

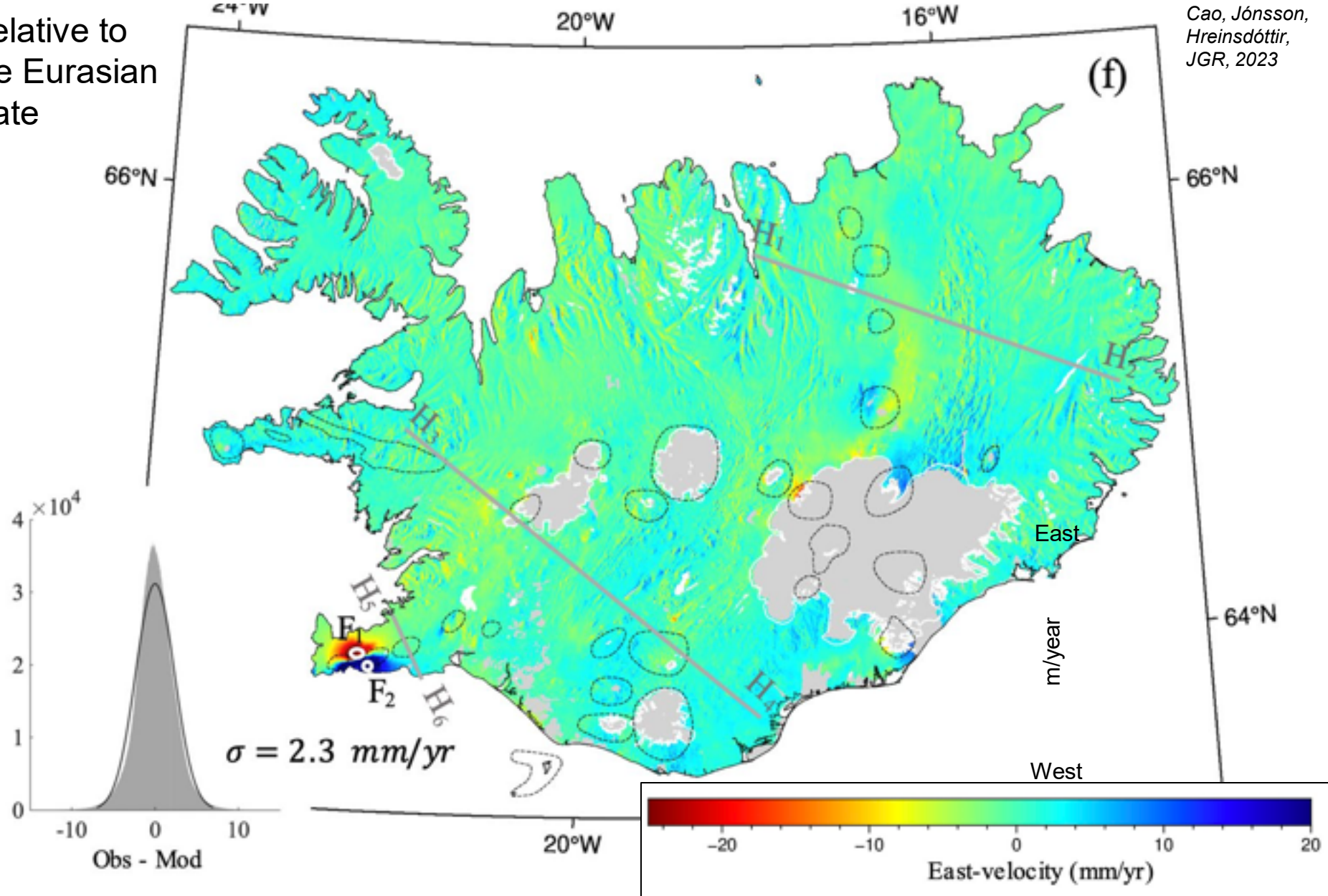
Relative to the Eurasian plate



Cao, Jónsson, Hreinsdóttir, JGR, 2023

Residual East velocity

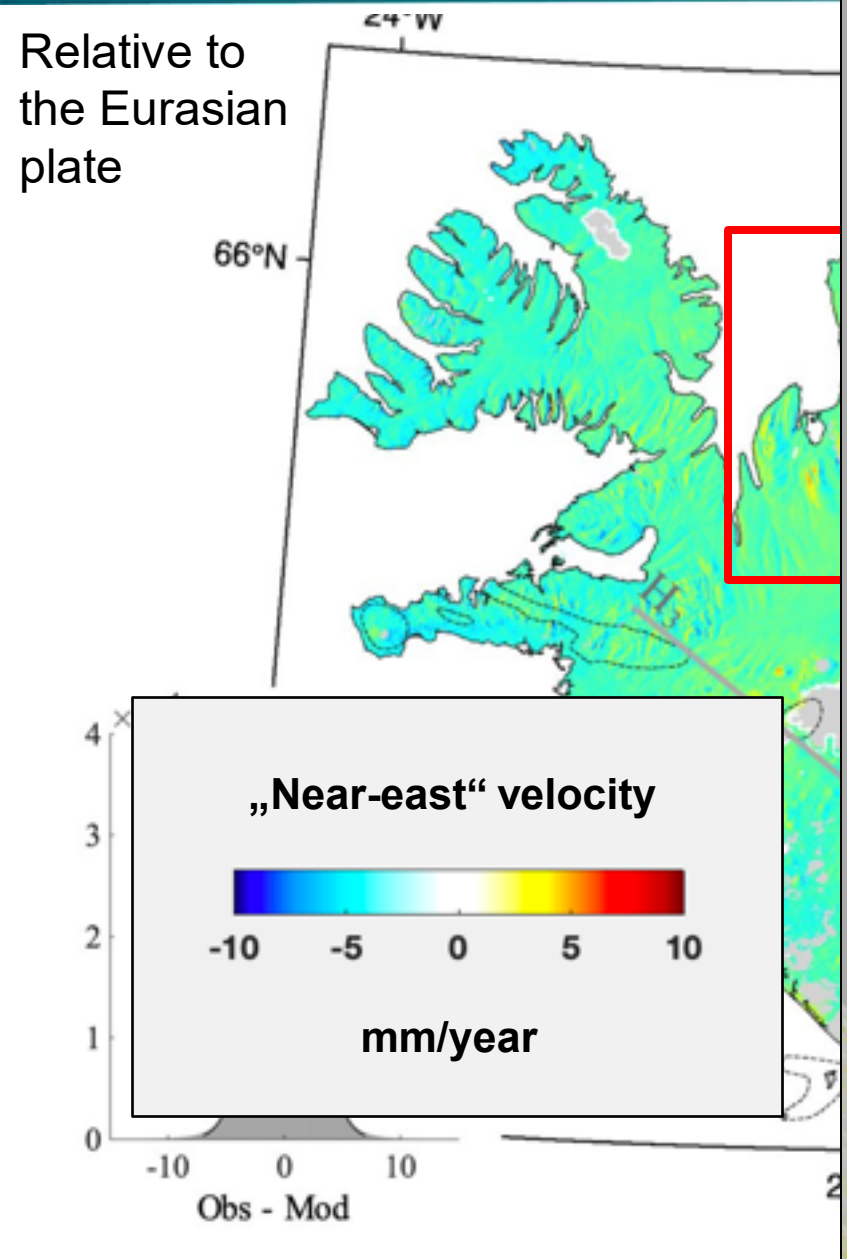
Relative to the Eurasian plate

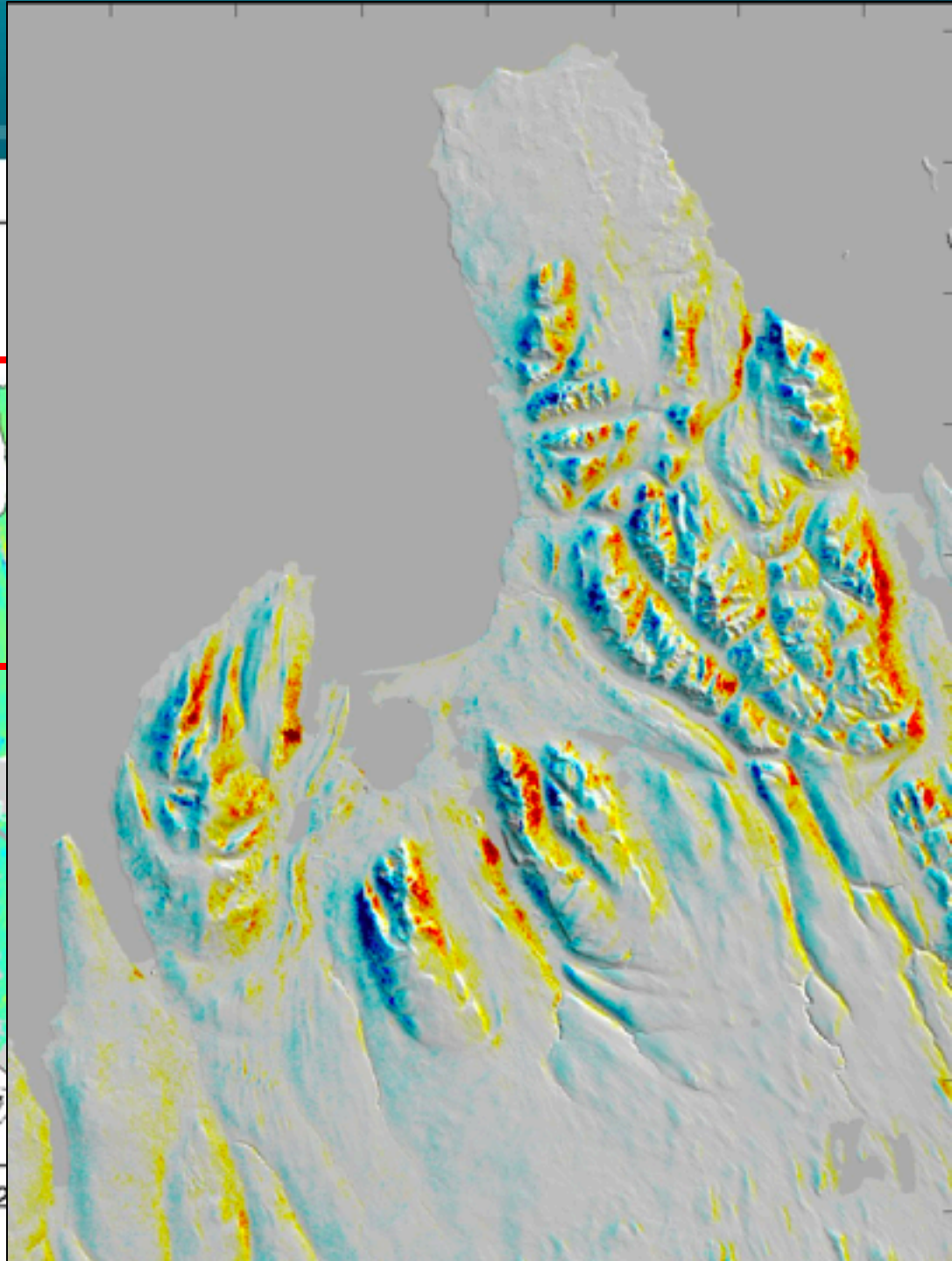


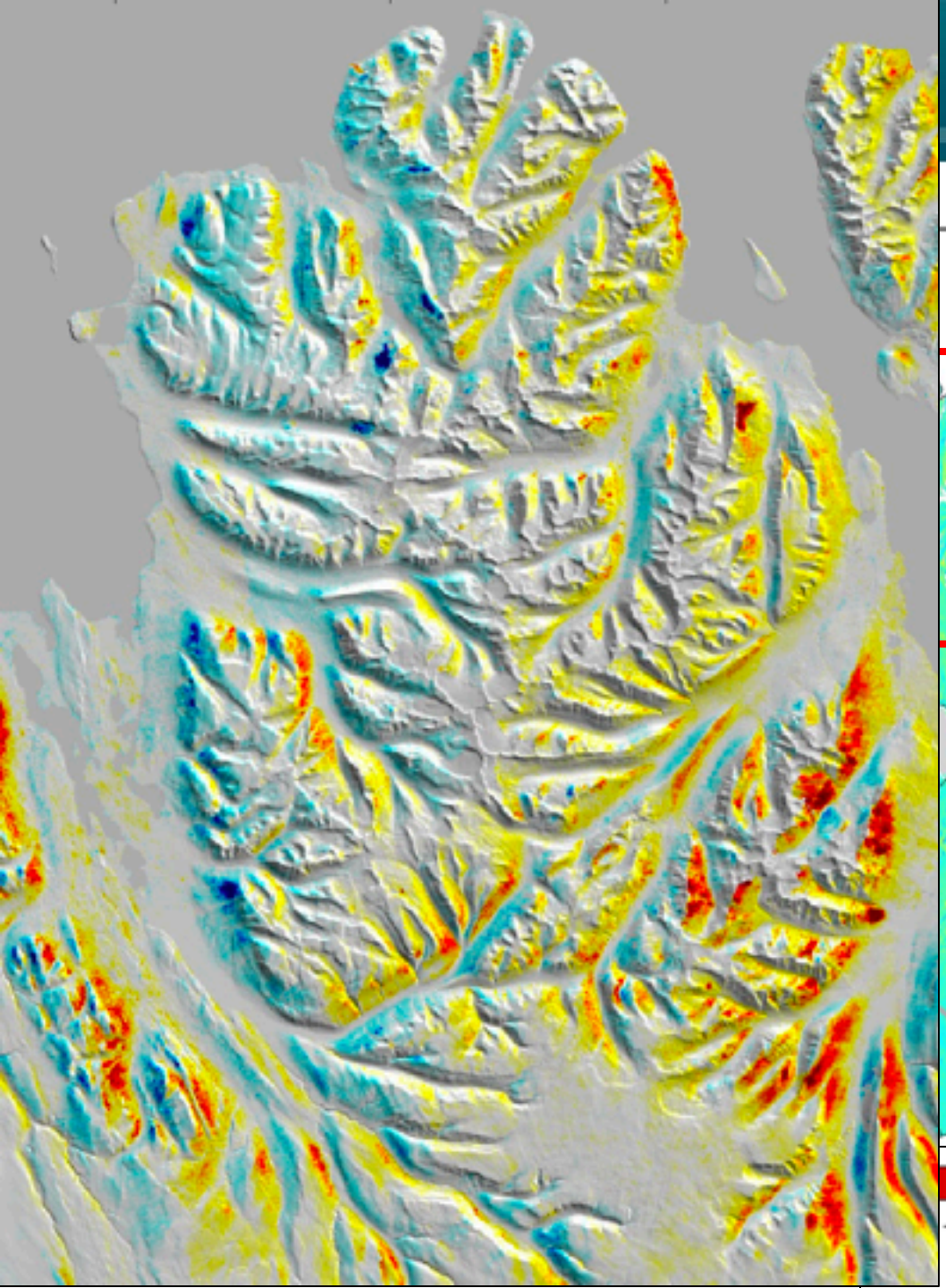
Cao, Jónsson, Hreinsdóttir, JGR, 2023

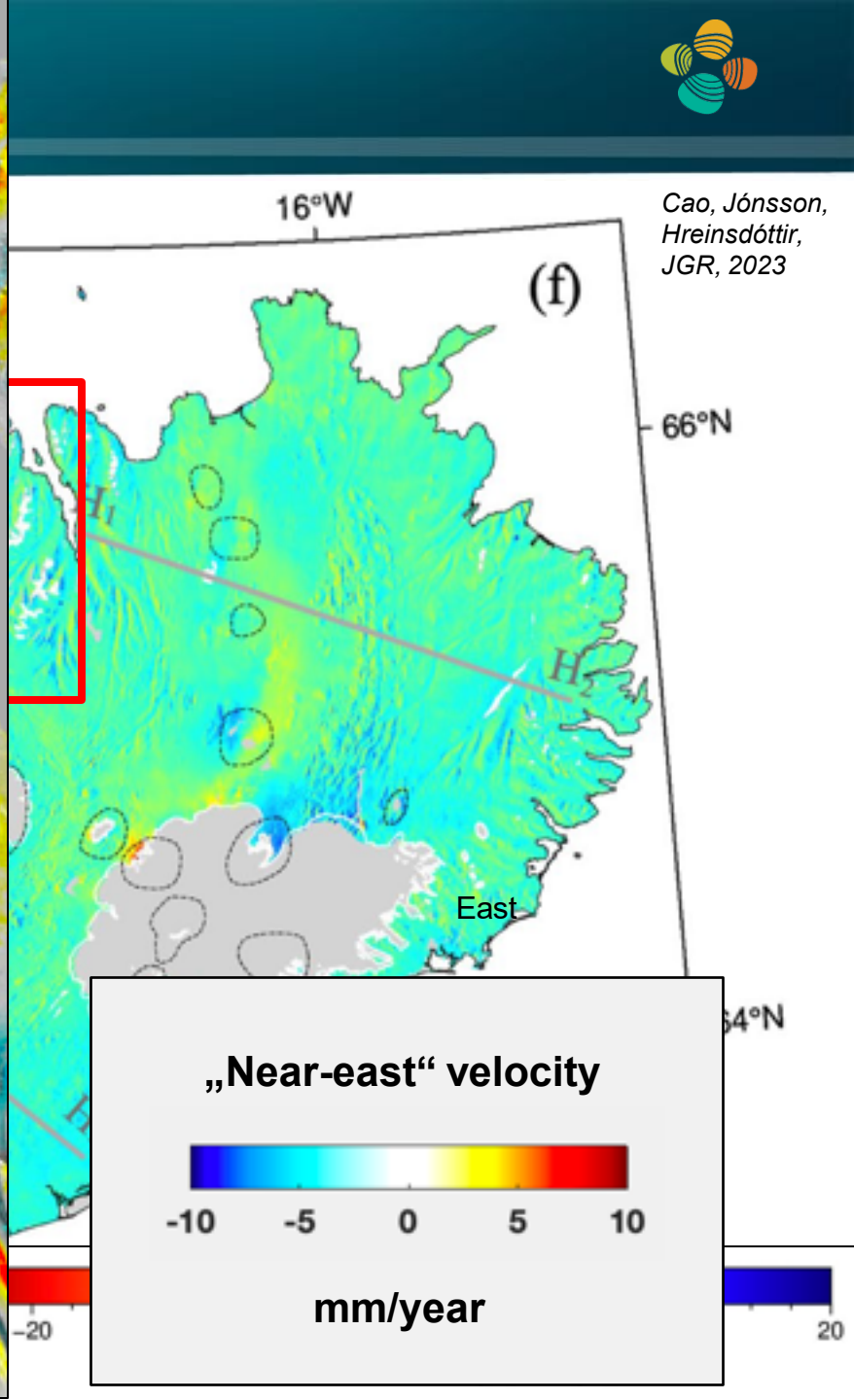
Residual East velocity

Relative to the Eurasian plate









Cao, Jónsson, Hreinsdóttir, JGR, 2023

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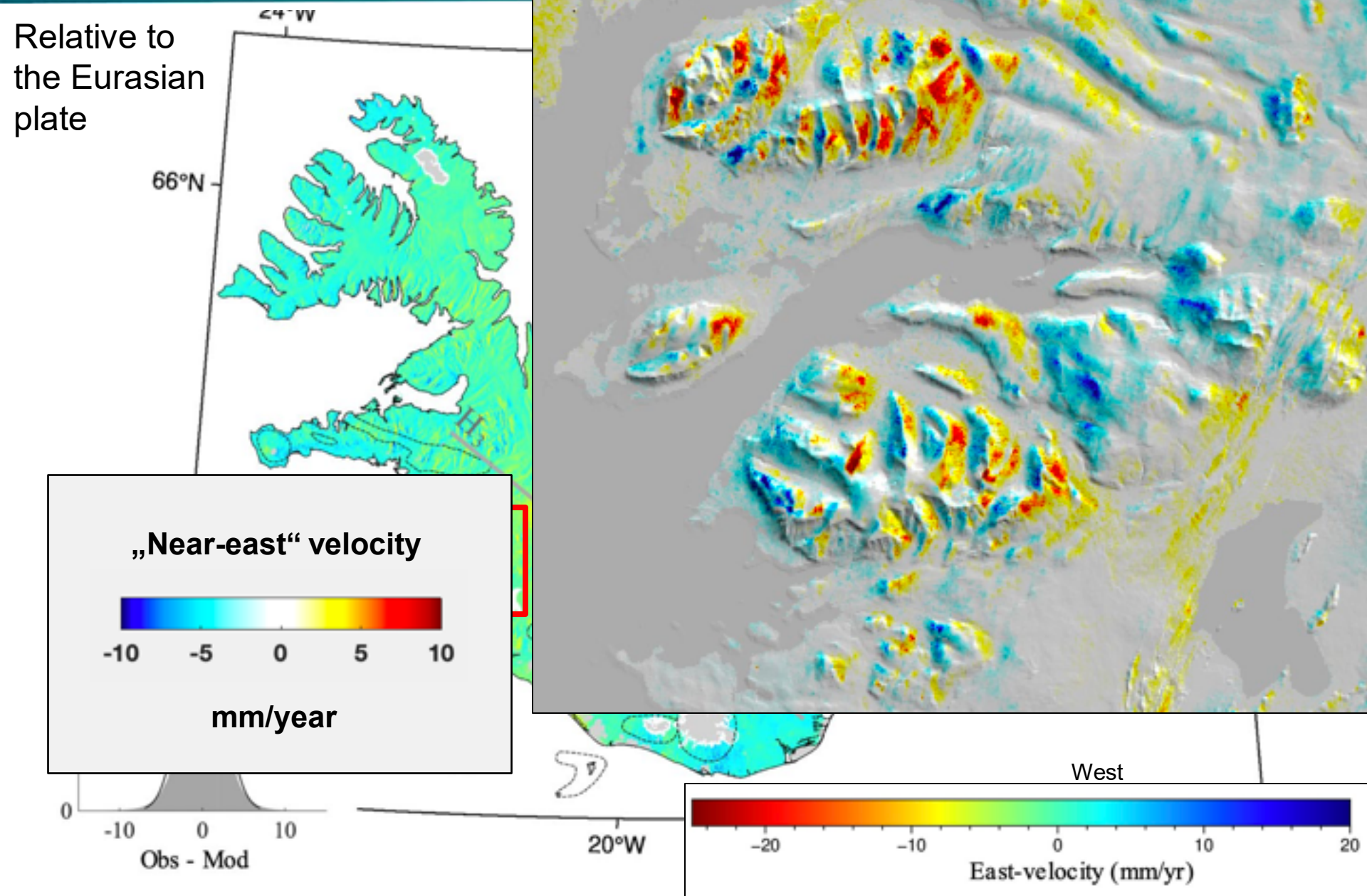
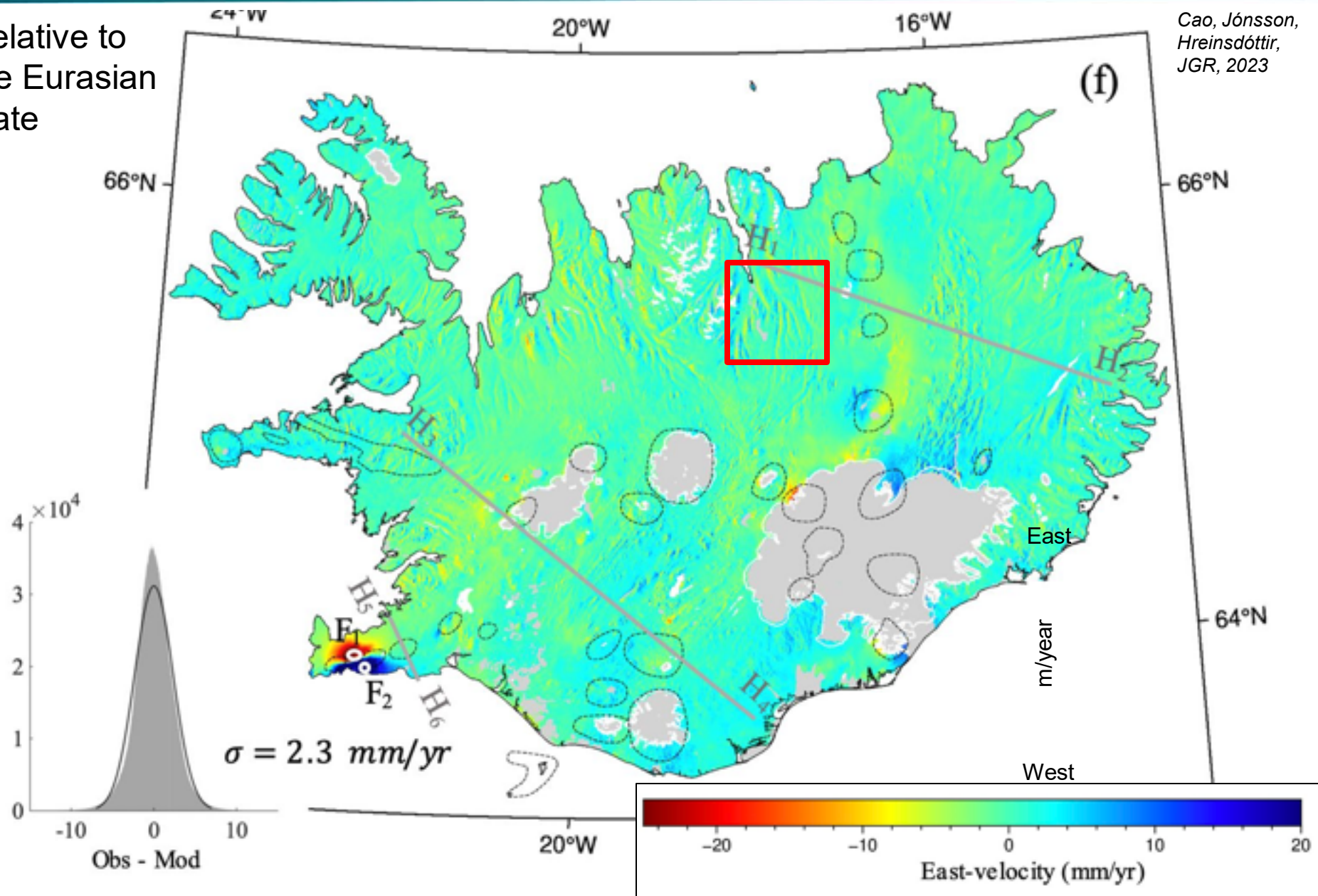
Relative to the Eurasian plate

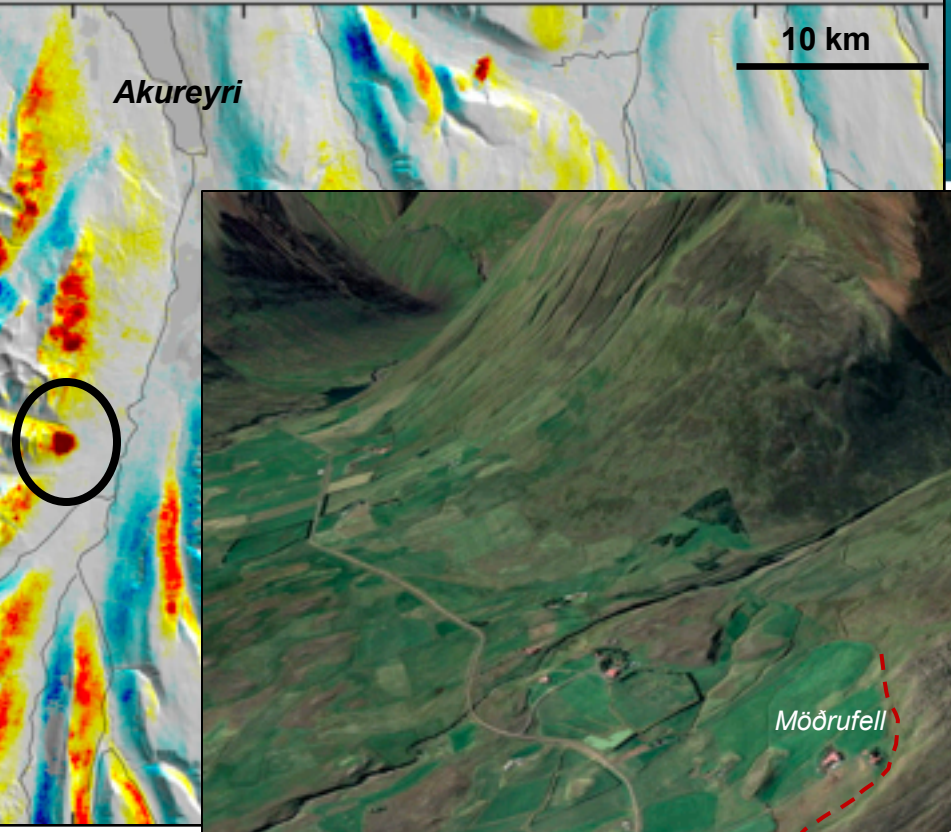


Residual East velocity

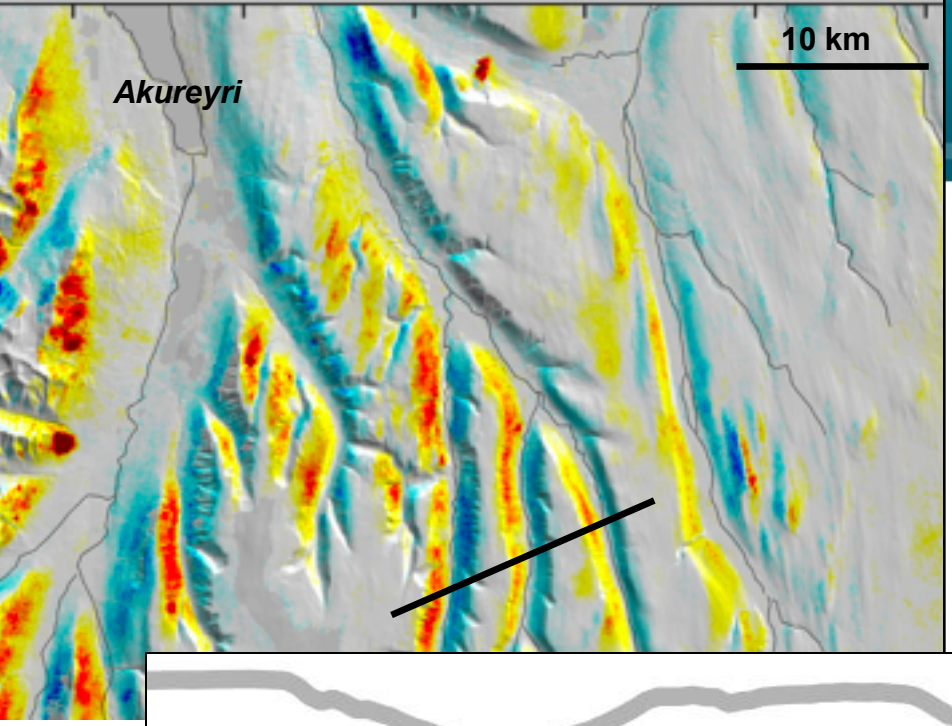
Relative to the Eurasian plate



„Near-east“ velocity



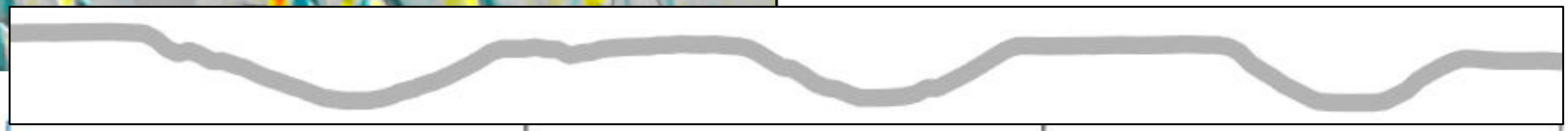
Google Earth

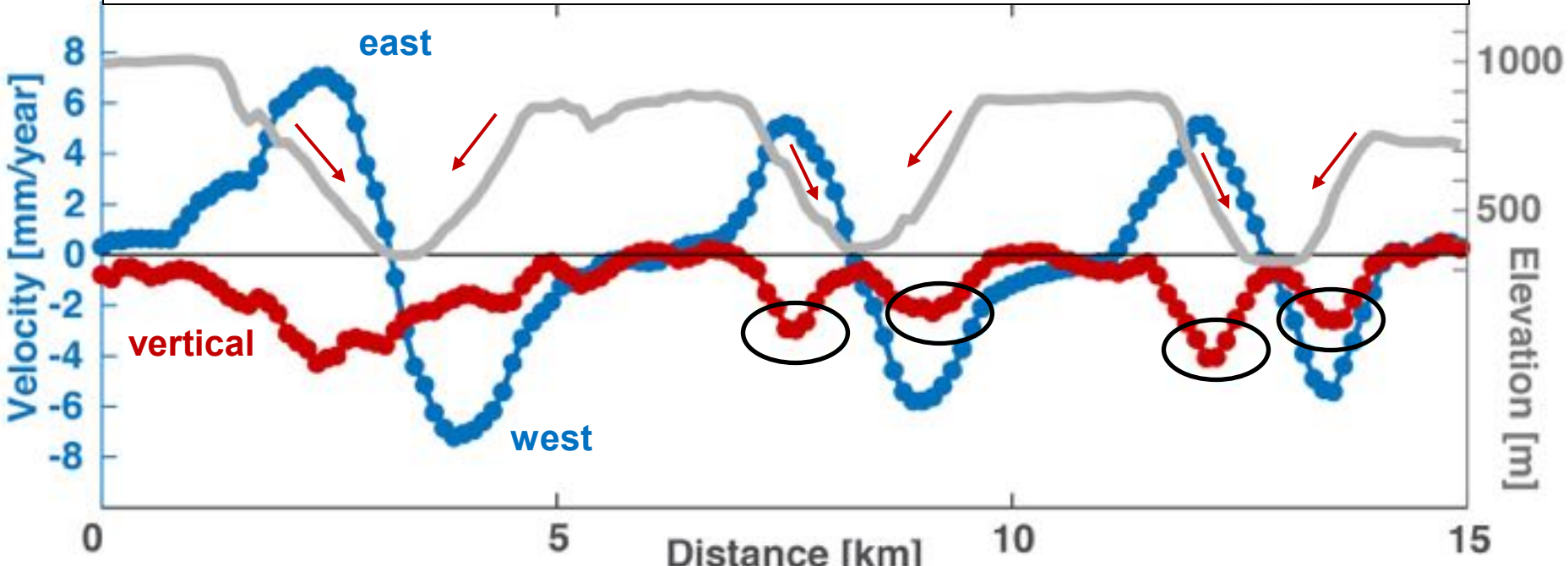


„Near-east“ velocity

-10 -5 0 5 10

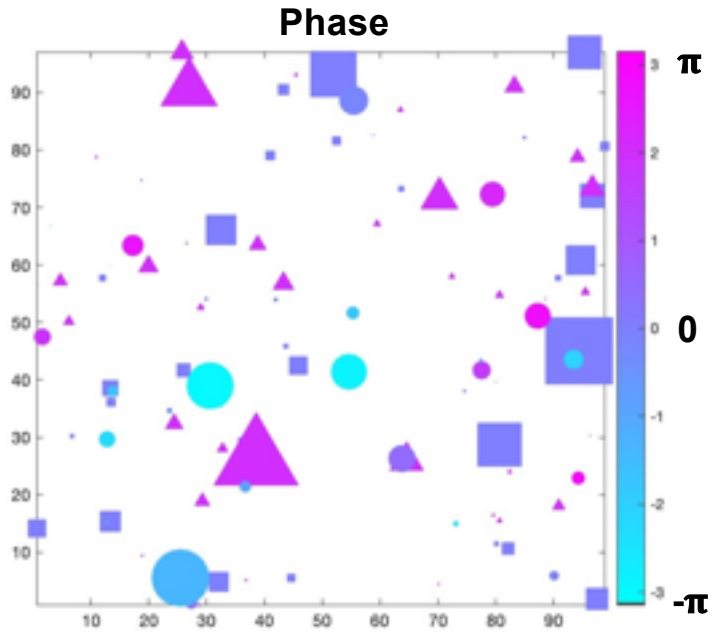
mm/year

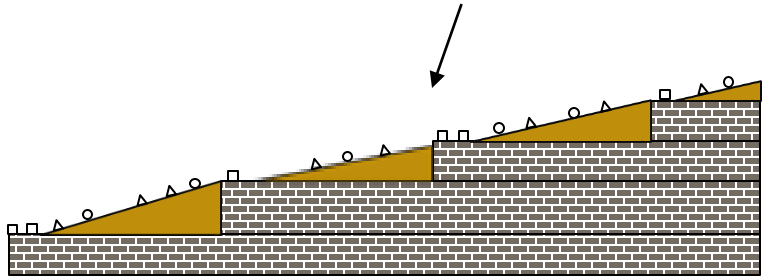




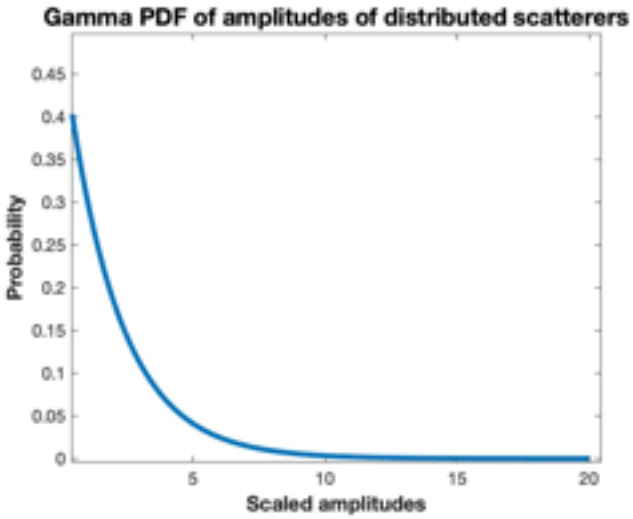

27/08/2020

How come the bedrock is seen moving?





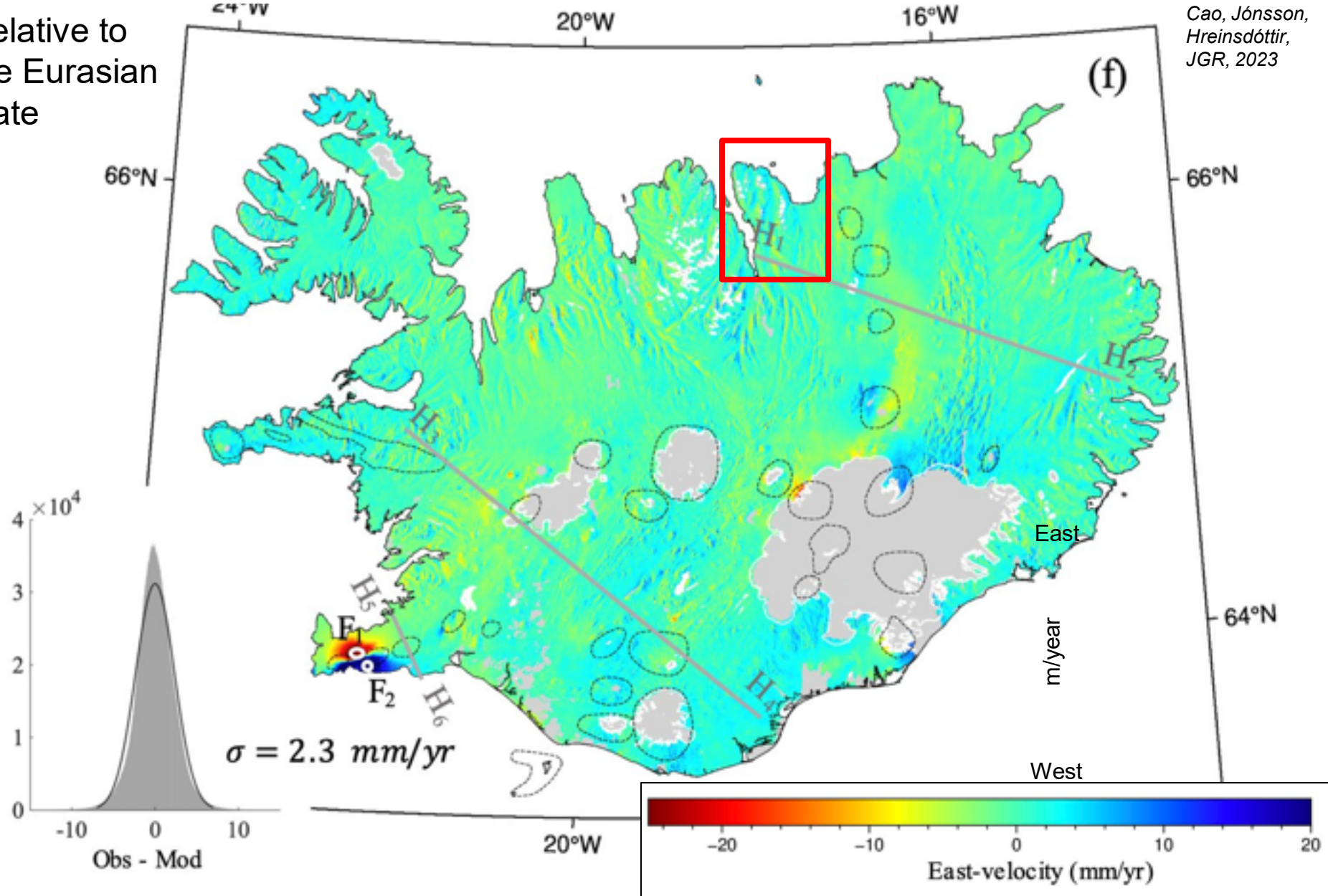
- *Stable - not moving*
- *Stable – creeping*
- *Unstable*



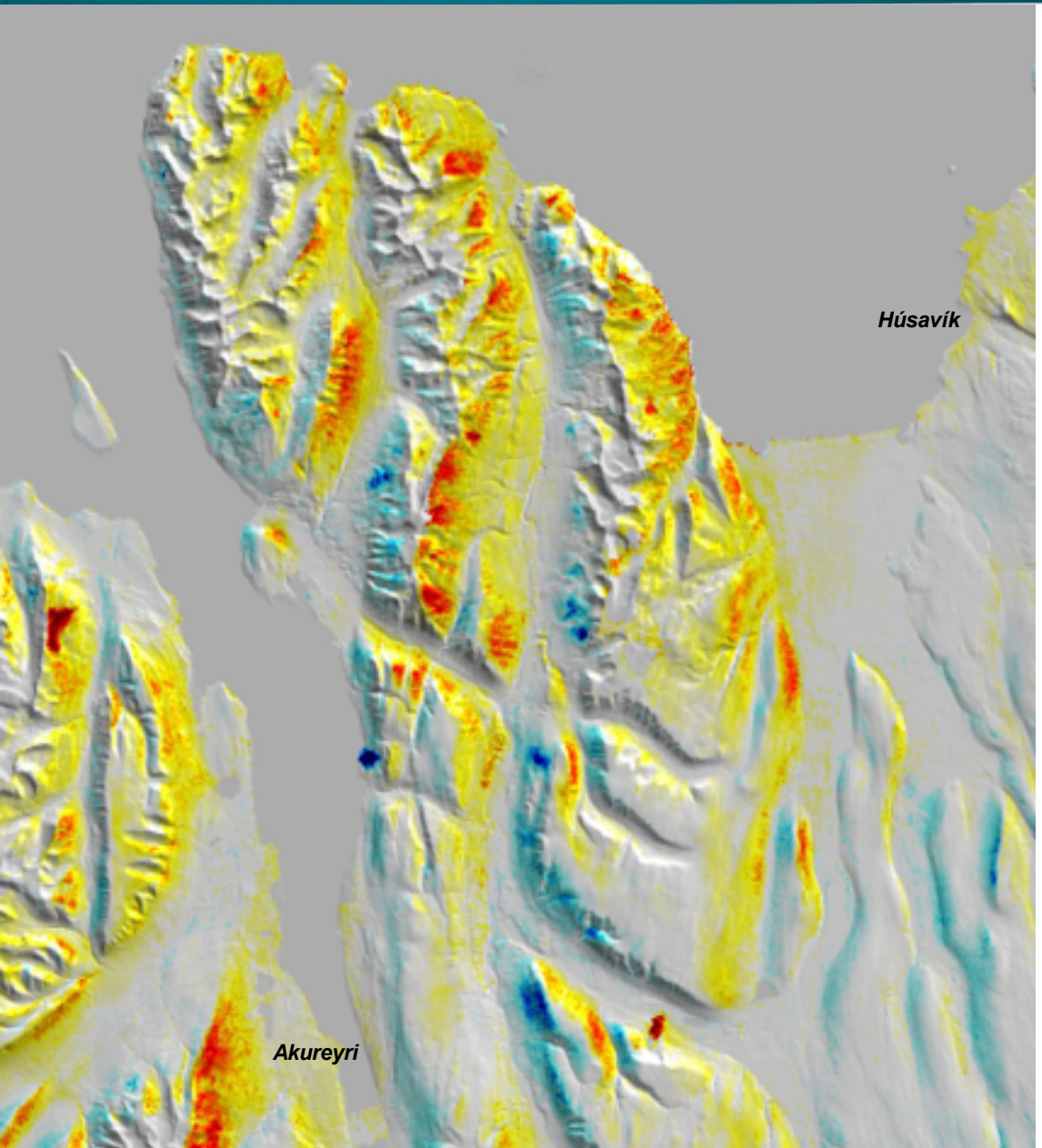
- Bedrock layers with soil wedges
- Assume Gamma distribution of natural scatterers, many weak, a few strong
- Sum of stable, creeping, and unstable reflectors shows coherent but reduced creep motion

Residual East velocity

Relative to the Eurasian plate

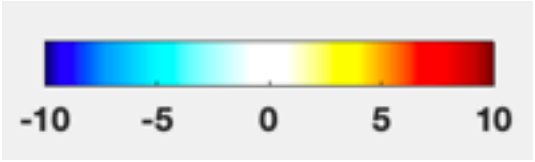


Slope motion in Flateyjarskagi Peninsula



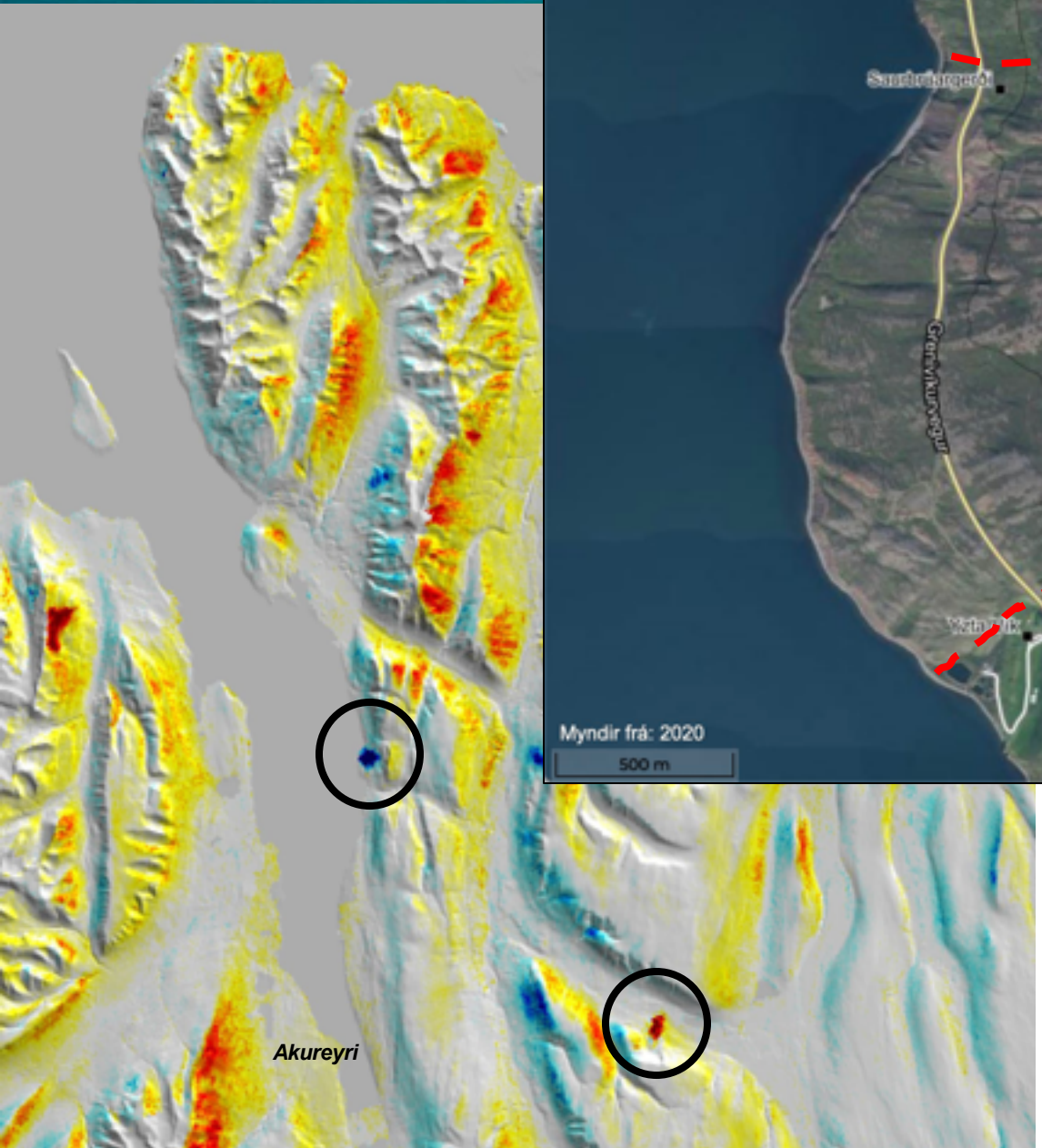
- Almost all east-facing slopes are moving east
- West-facing slopes are moving to the west
- Several hot spots

„Near-east“ velocity



mm/year

Slope motion i



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-10 -5 0 5 10

mm/year

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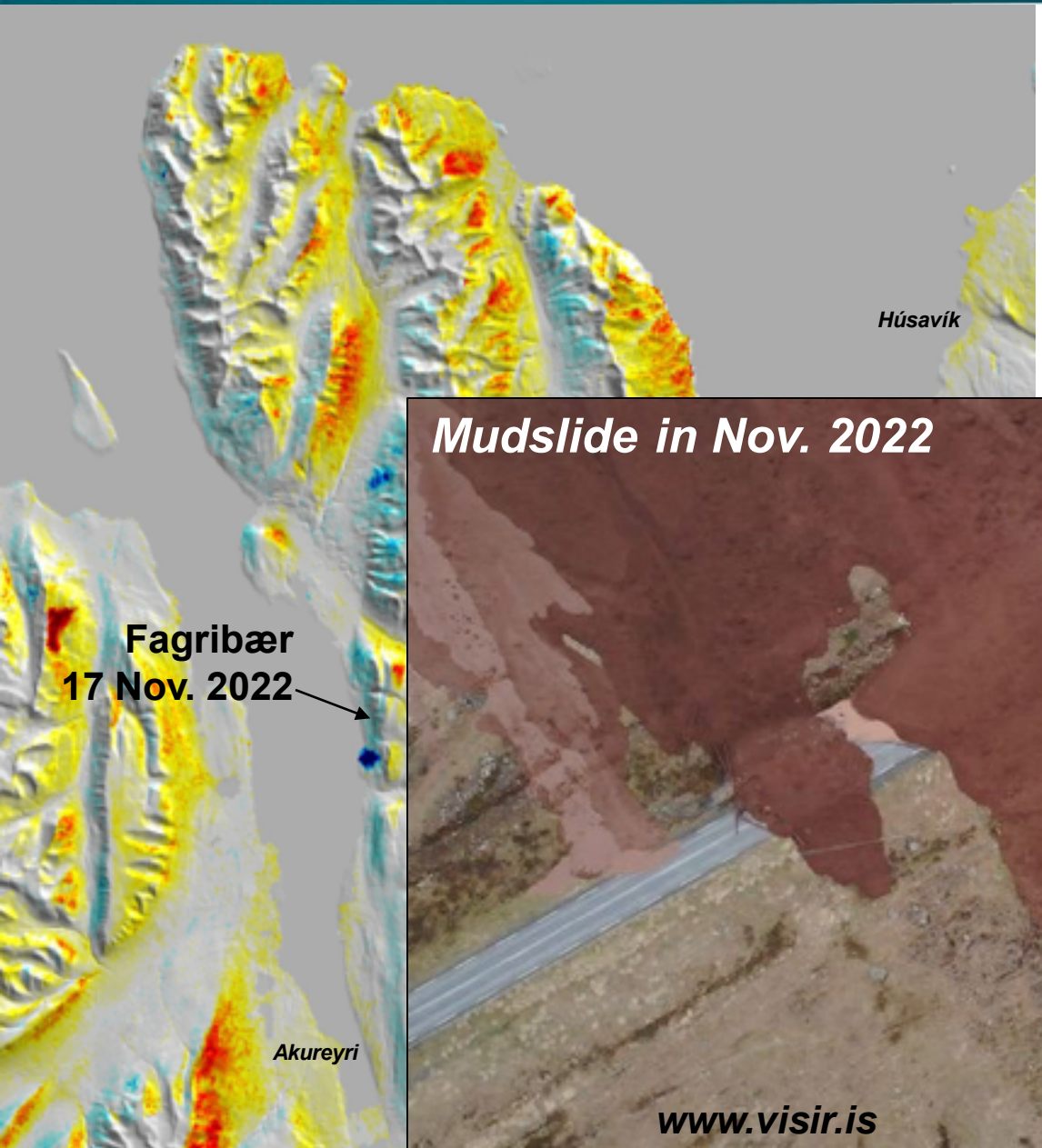

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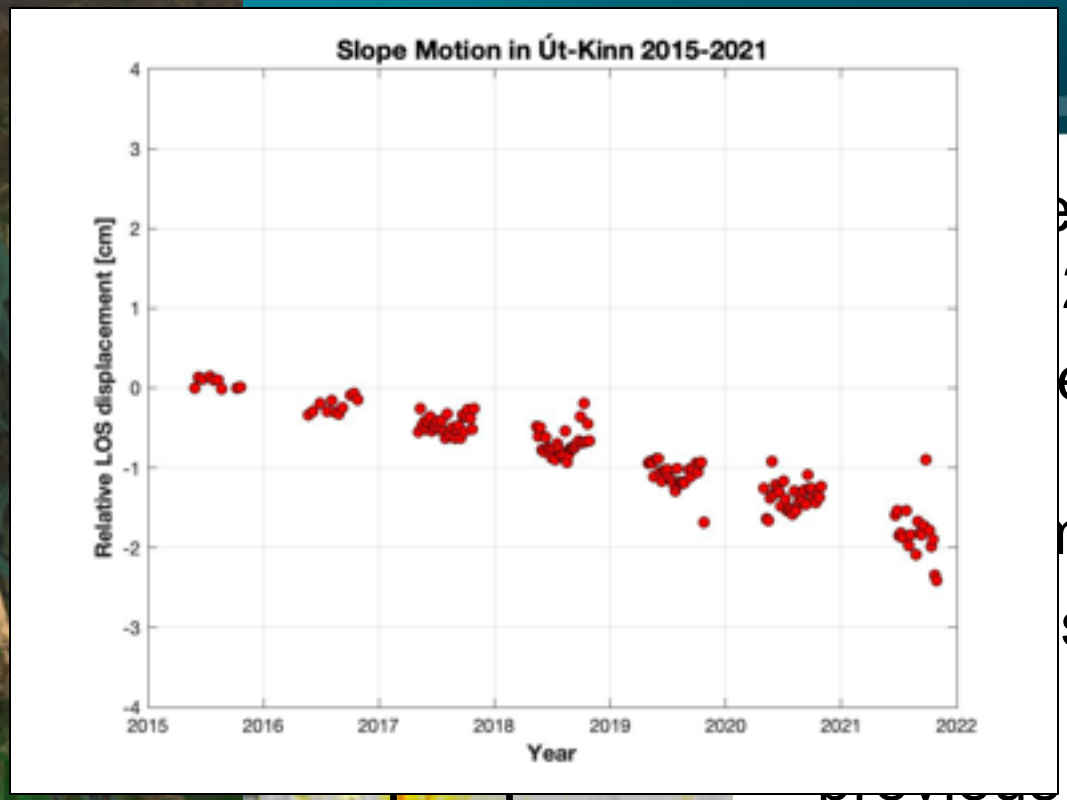
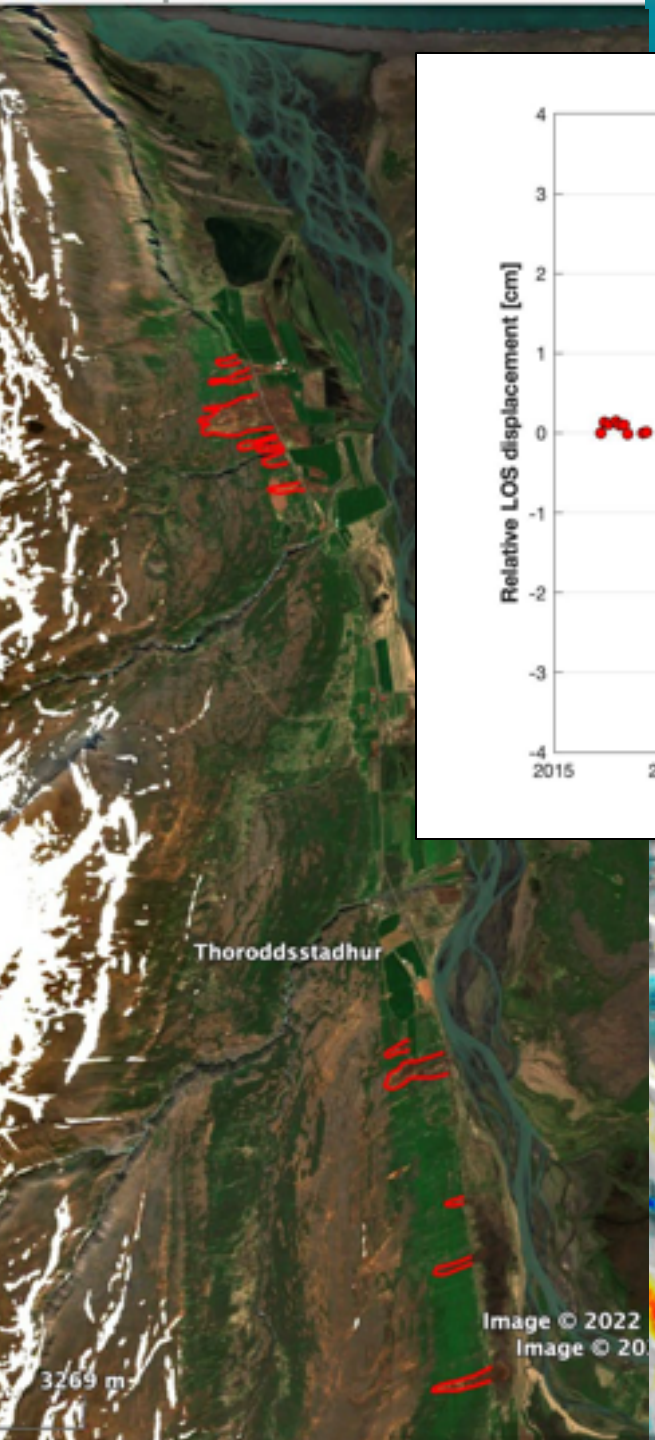
Mudslides in Út-Kinn in Oct. 2021

http://640.is – Hafþór Hreiðarsson



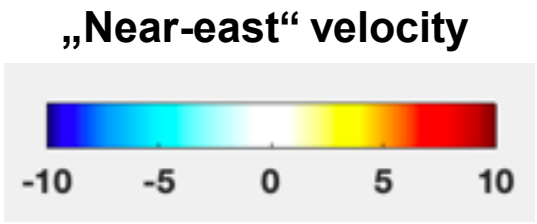


es in Út-Kinn in
2021

es roughly
in Sentinel-2
nages

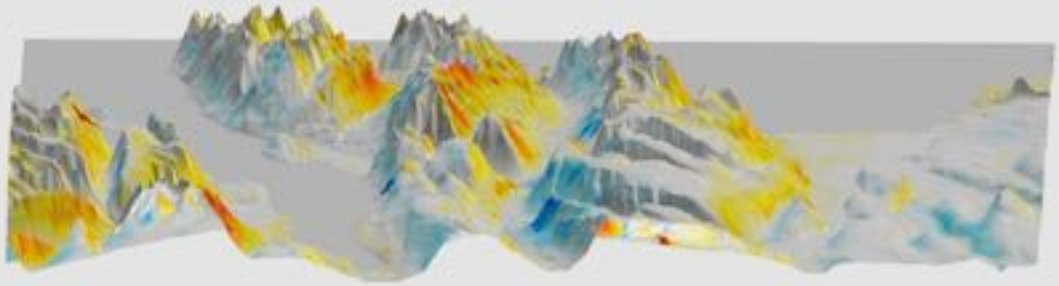
s correspond
moving in
years

- Any acceleration?



Conclusions

- Countrywide InSAR deformation mapping provides new details at volcanoes, geothermal fields, plate boundaries, GIA, etc.
- Widespread slope movement - almost all slopes are moving!
- Faster motion (>10 mm/year) usually on known landslides, but practically all unconsolidated slopes are creeping downslope
- Even slopes with exposed lava bedrock layers found moving due to coherent creep of soil wedges between bedrock layers
- Slopes moving before the Oct. 2021 and Nov. 2022 mudslide failures (Út-Kinn/Fagribær), but no clear speed-up detected



Fringe, Leeds, 11-15 Sept. 2023

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KAUST

Thanks!

Sigurjón Jónsson[1] and Yunmeng Cao[1,2],

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[2]Now at GNS, New Zealand

JGR Solid Earth

RESEARCH ARTICLE
10.1029/2022JB025546

Key Points:

- Time series of countrywide displacements over Iceland from

Iceland Kinematics From InSAR

Yunmeng Cao[1,2], Sigurjón Jónsson[1], and Sigrún Hreinsdóttir[2]

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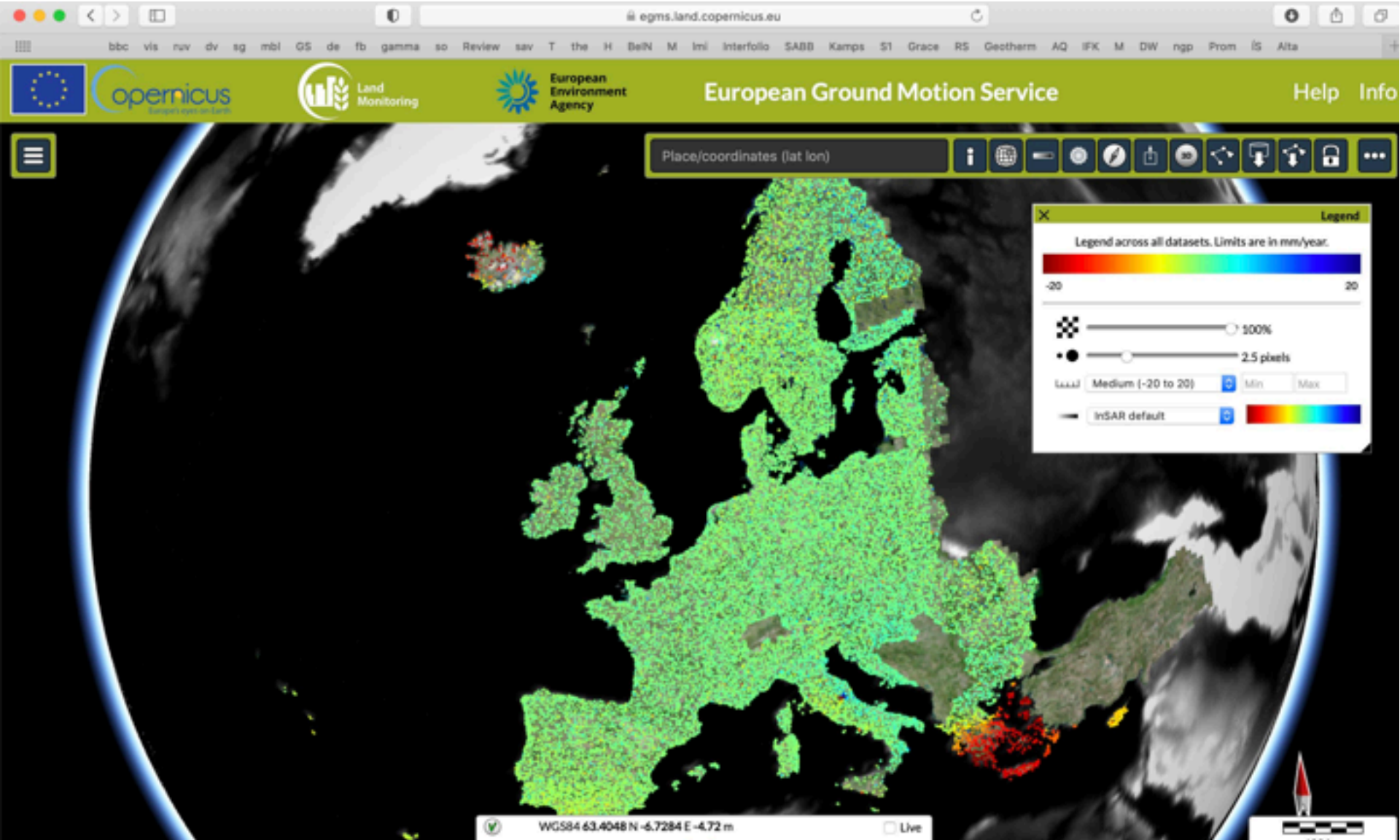
European Ground Motion Service 2015-2020

https://egms.land.copernicus.eu



European Ground Motion Service 2015-2020

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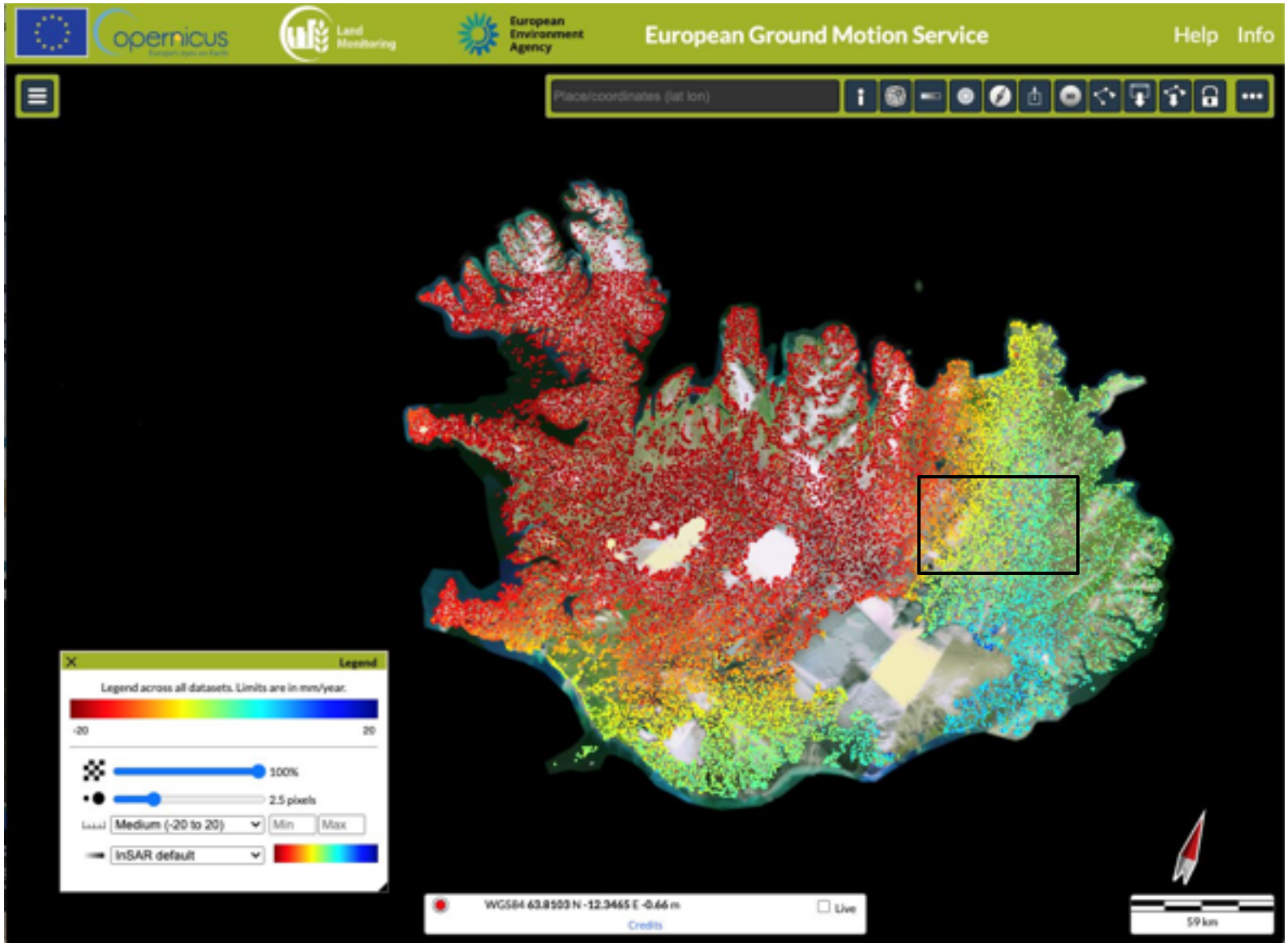

European Ground Motion Service 2015-2020