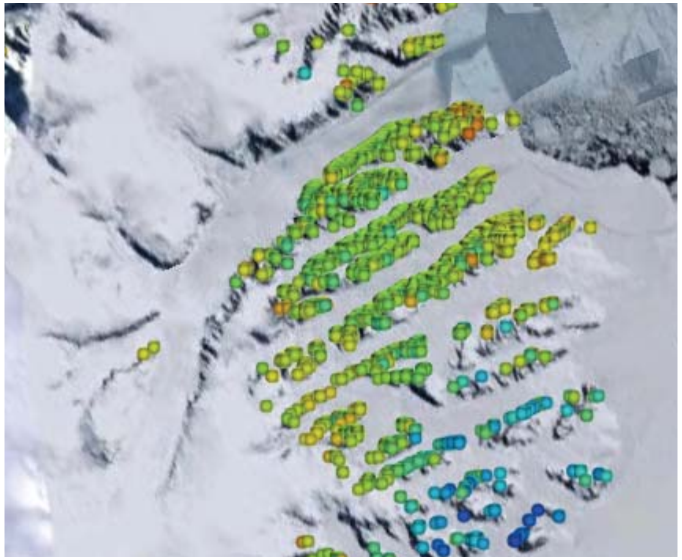
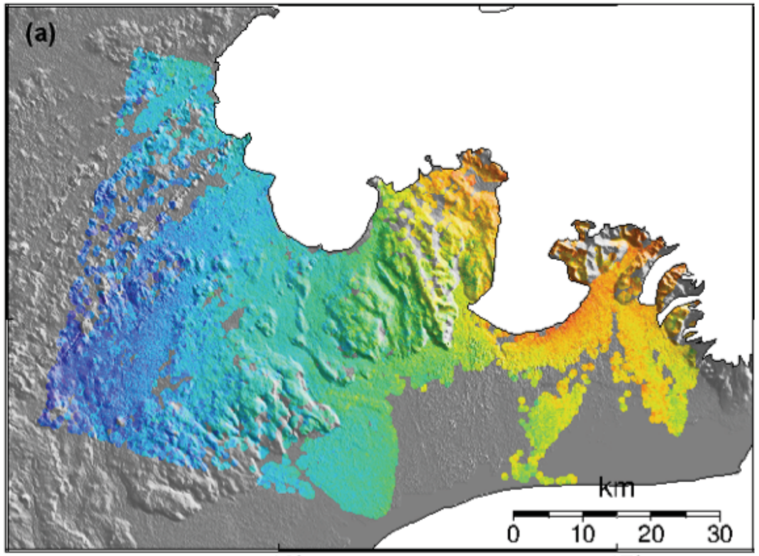
High-resolution constraints on the response to ice load changes in the Antarctic Peninsula and Iceland, using radar interferometry





Andy Hooper[1], Amandine Auriac[2], Anneleen Oyen[3], Karsten Spaans[1], Freysteinn Sigmundsson[2], Peter Schmidt[4], Björn Lund[4], Matt King[5]

[1]University of Leeds
[2]University of Iceland
[3]Delft University of Technology
[4]Uppsala University
[5]University of Tasmania

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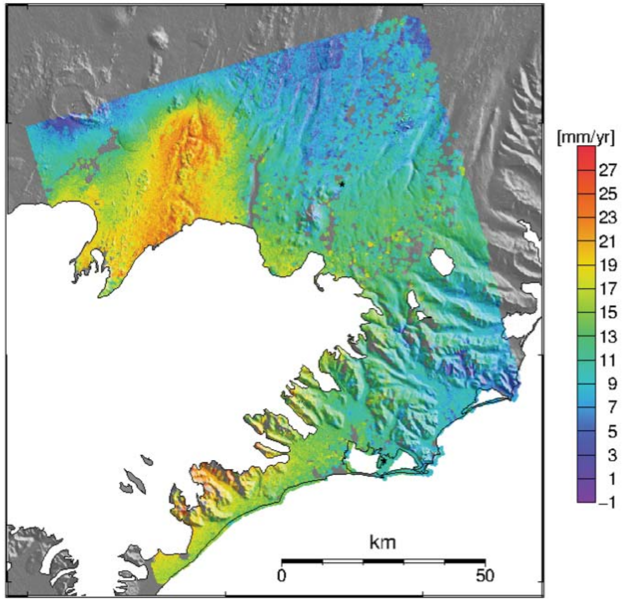
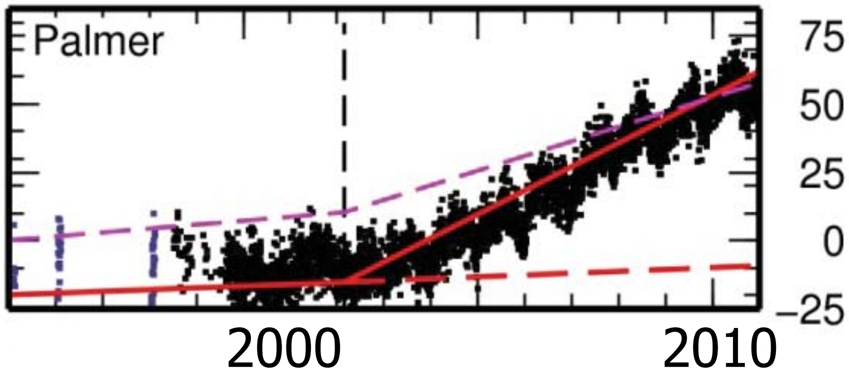
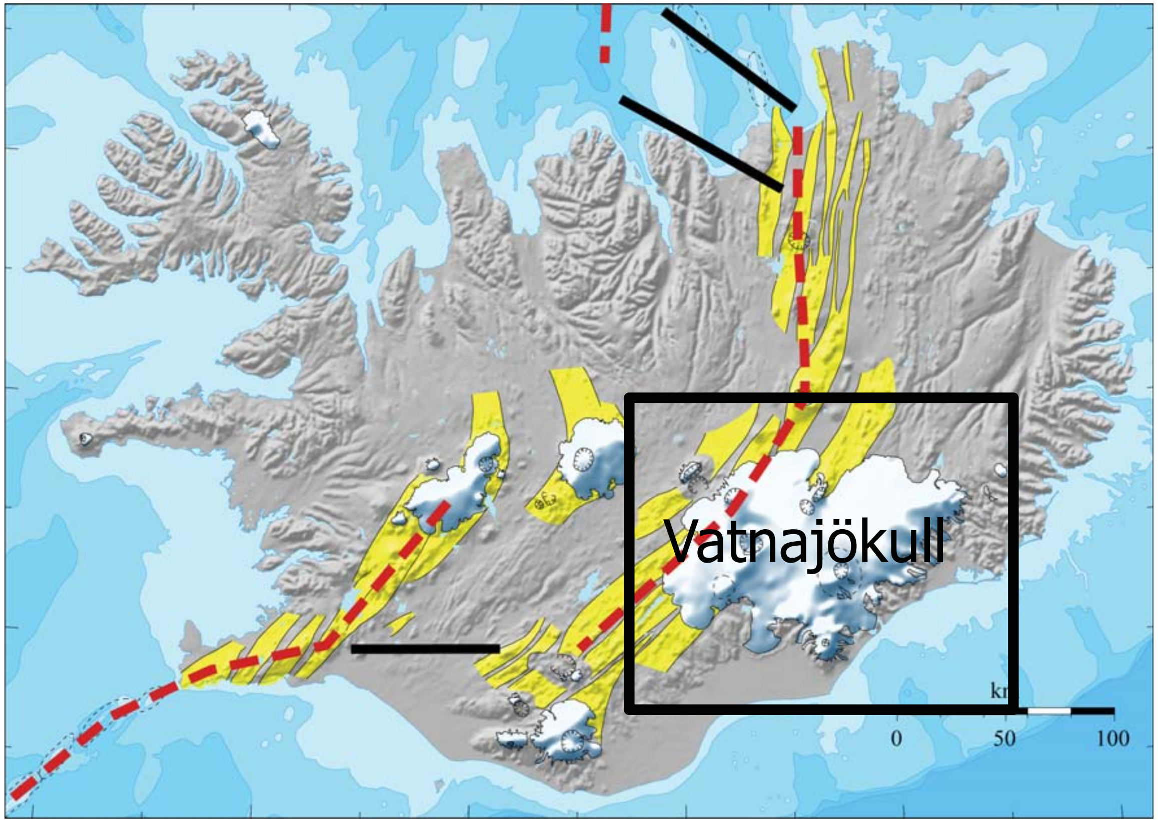
Motivation

- In regions undergoing present-day ice loss deformation is spatially and temporally variable.
- GNSS sampling is good temporally but limited spatially.
- Combination with InSAR has the potential for better spatial constraint



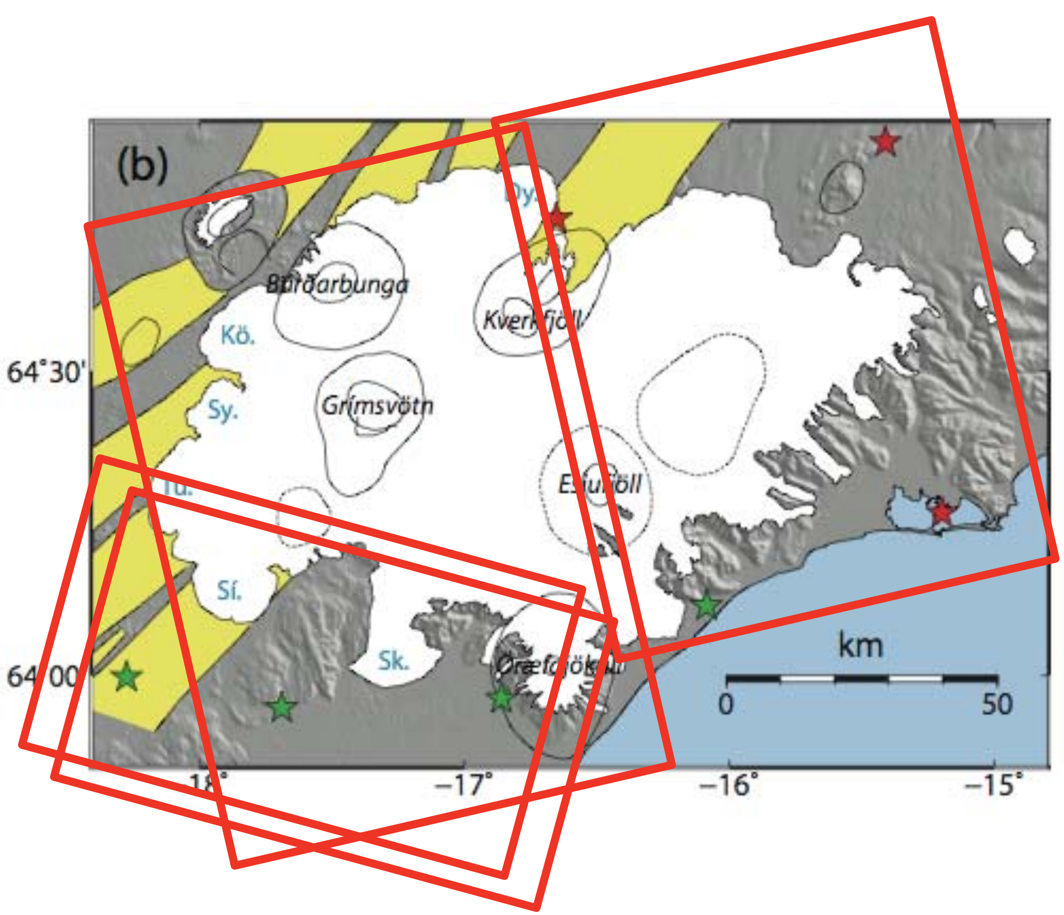


Icelandic ice caps



- GIA from last glaciation is over.
- Thinning rates of up to ~80 cm/yr since ~1890 cause of present-day GIA.

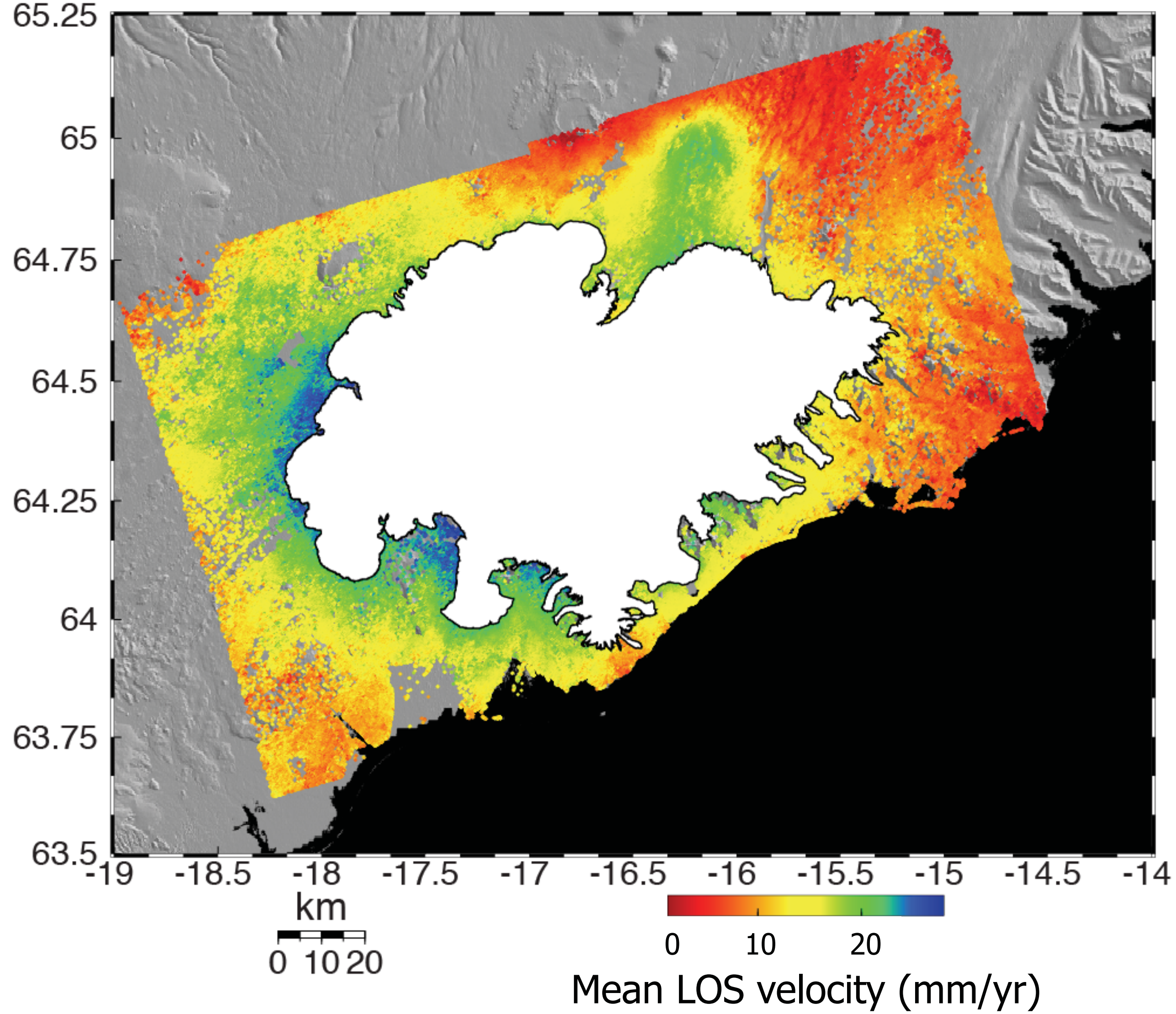
Data



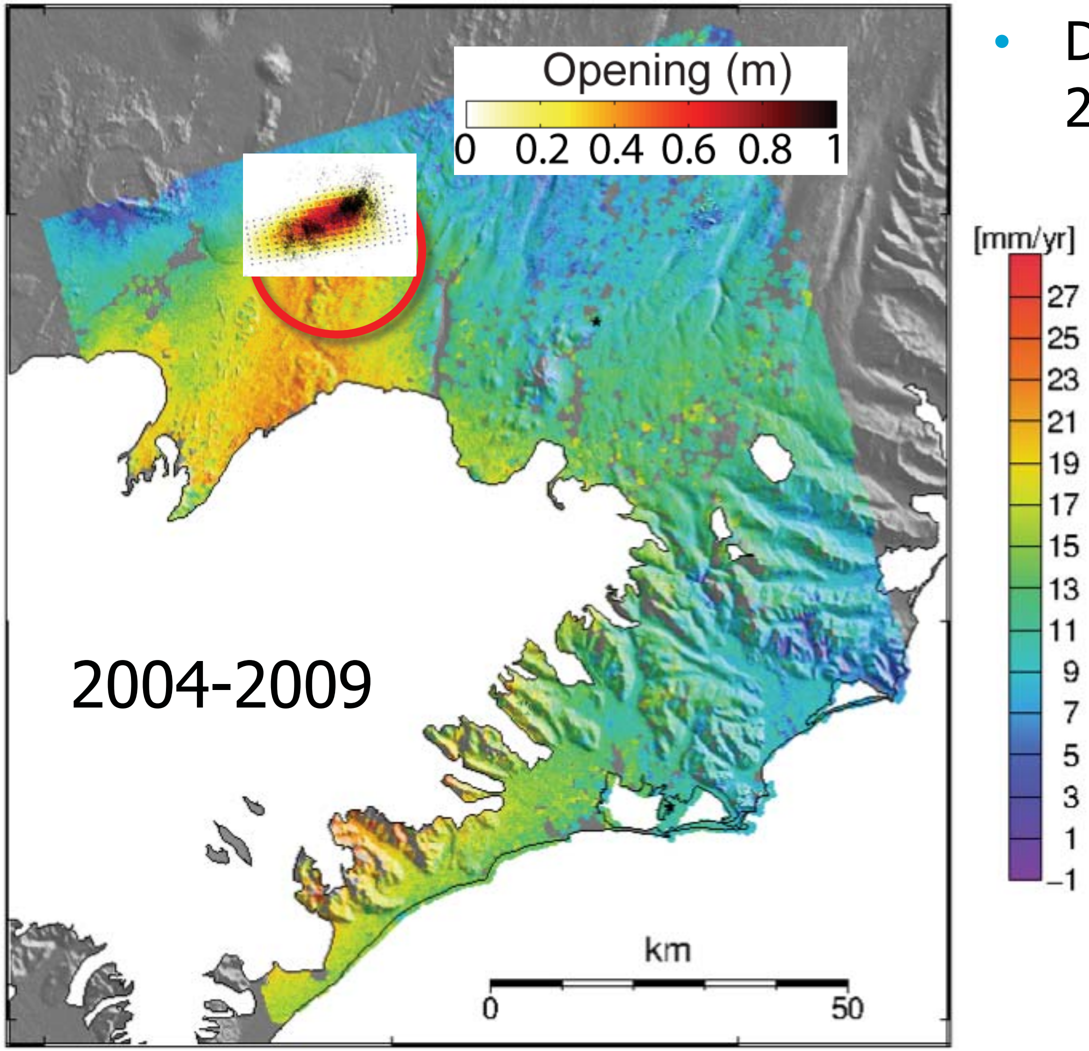
Stars mark continuous GPS stations

InSAR Frames

Time series InSAR results (2 tracks)

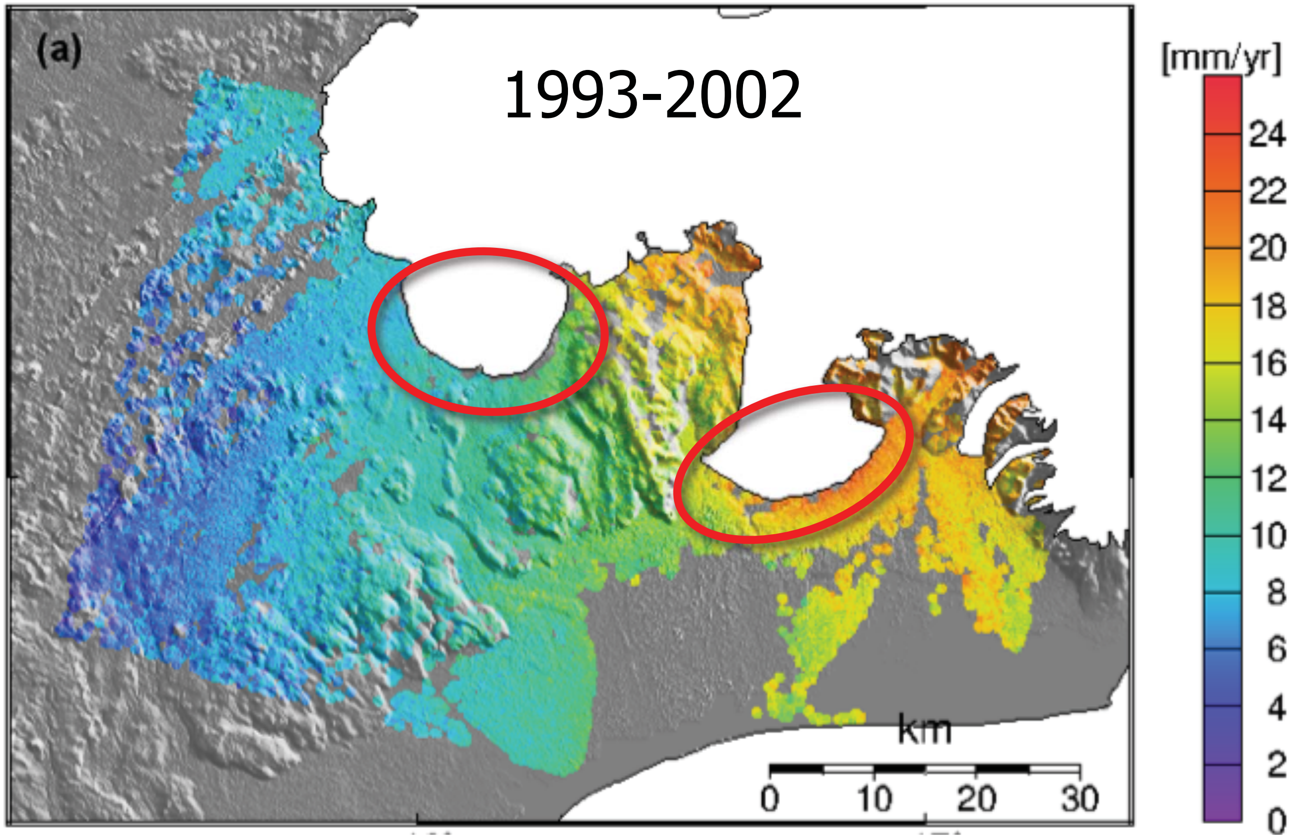


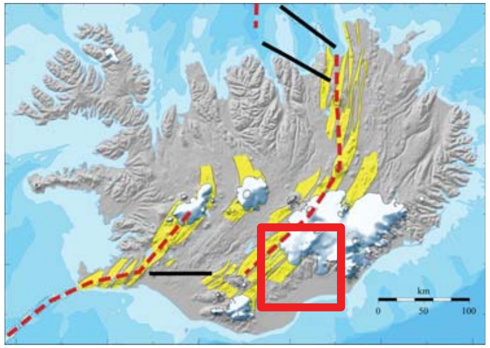
Time series InSAR (east)



- Dike opening 2007-2008 (Hooper et al., Nat. Geosci., 2011)

Time series InSAR (west)

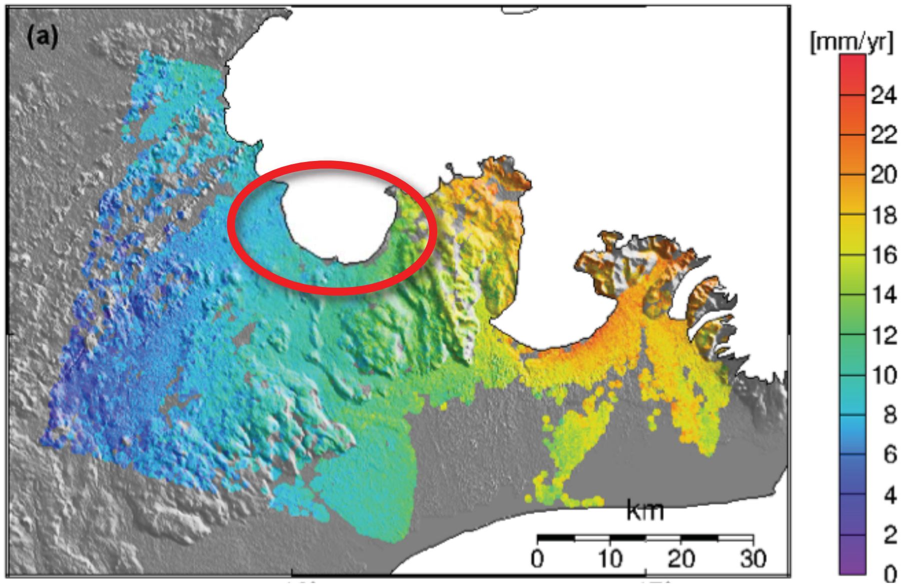




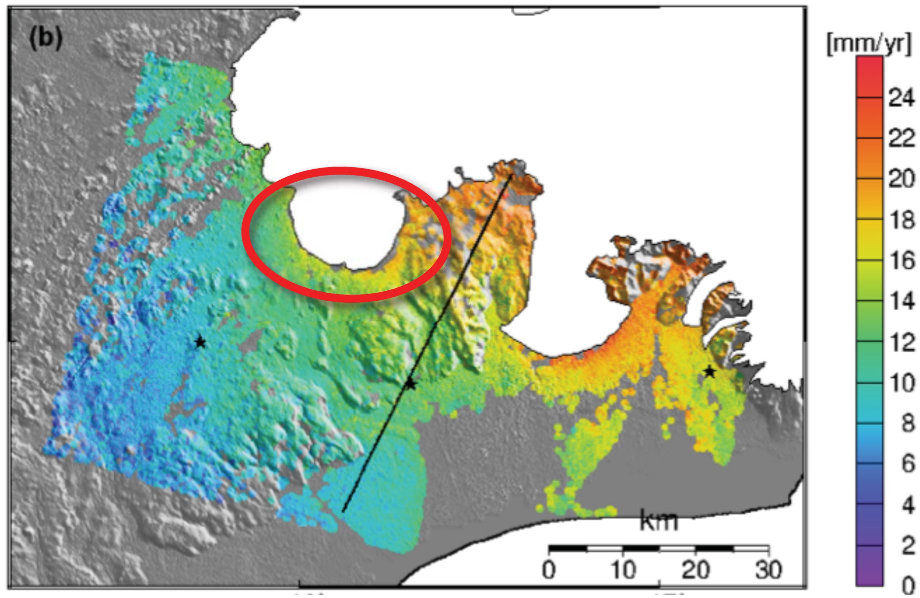
Data: ERS1/2
Auriac et al, JGR, 2013

Change of uplift rate

1993-2002

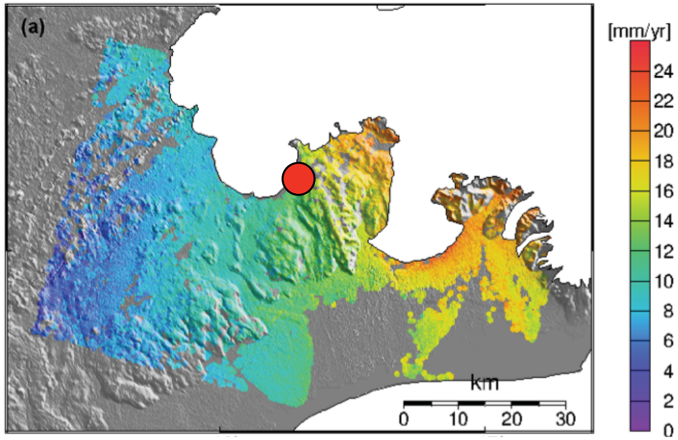


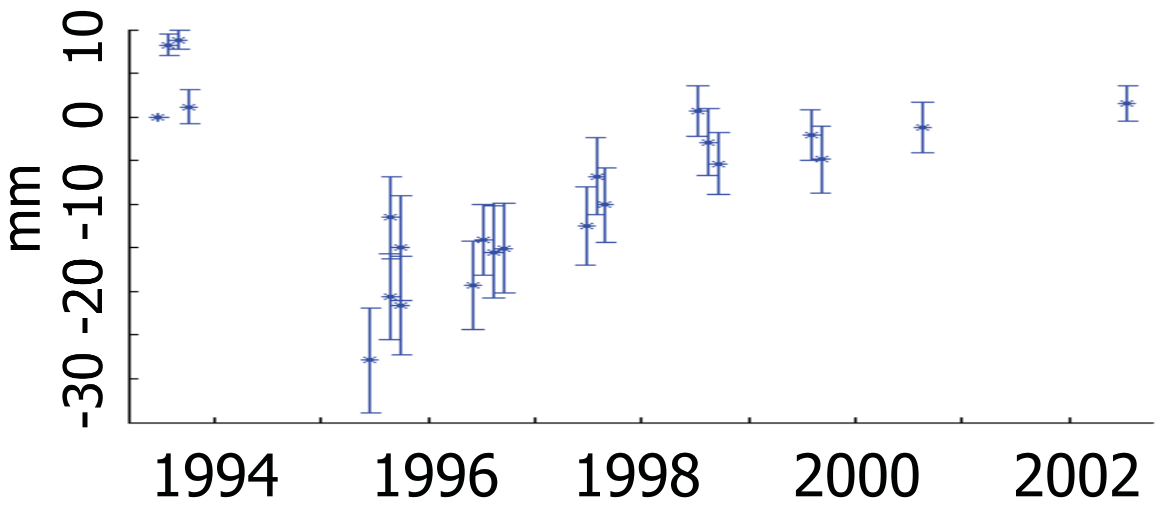
1995-2002



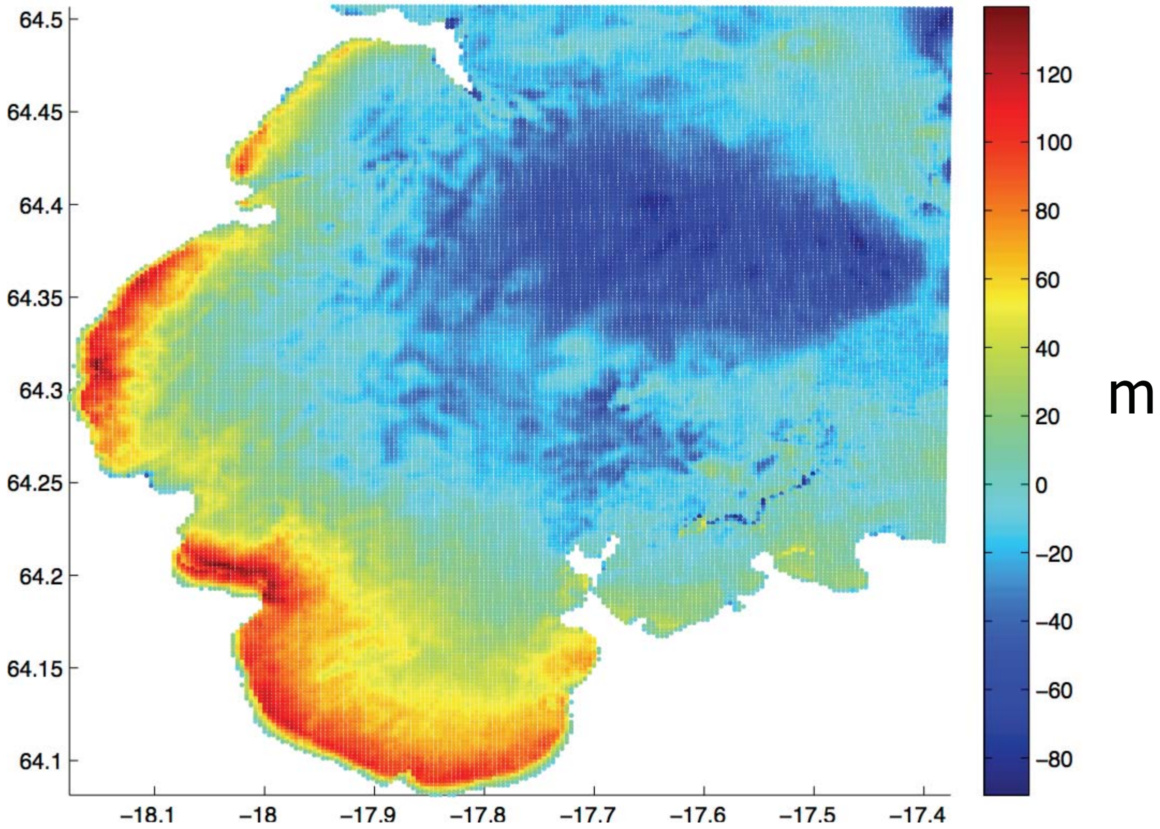
- Surge of Síðujökull in 1994 led to subsidence which biases mean uplift rate

Time history of uplift

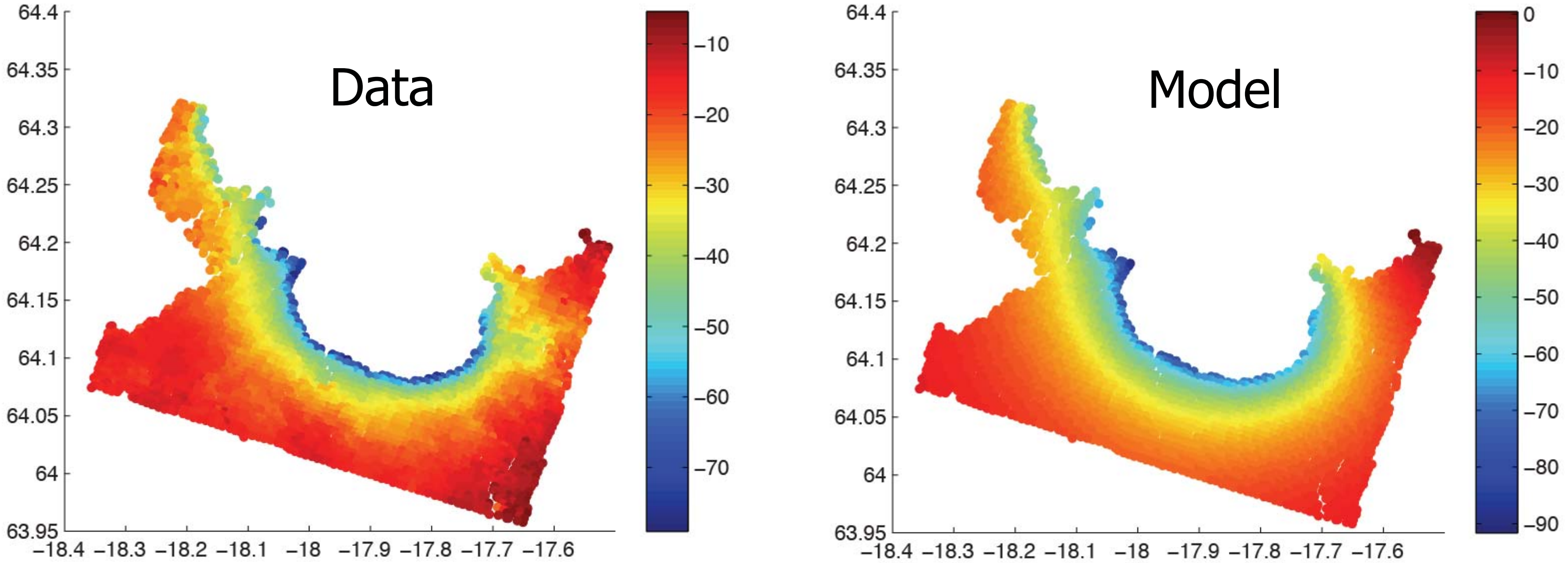




Ice model for surge

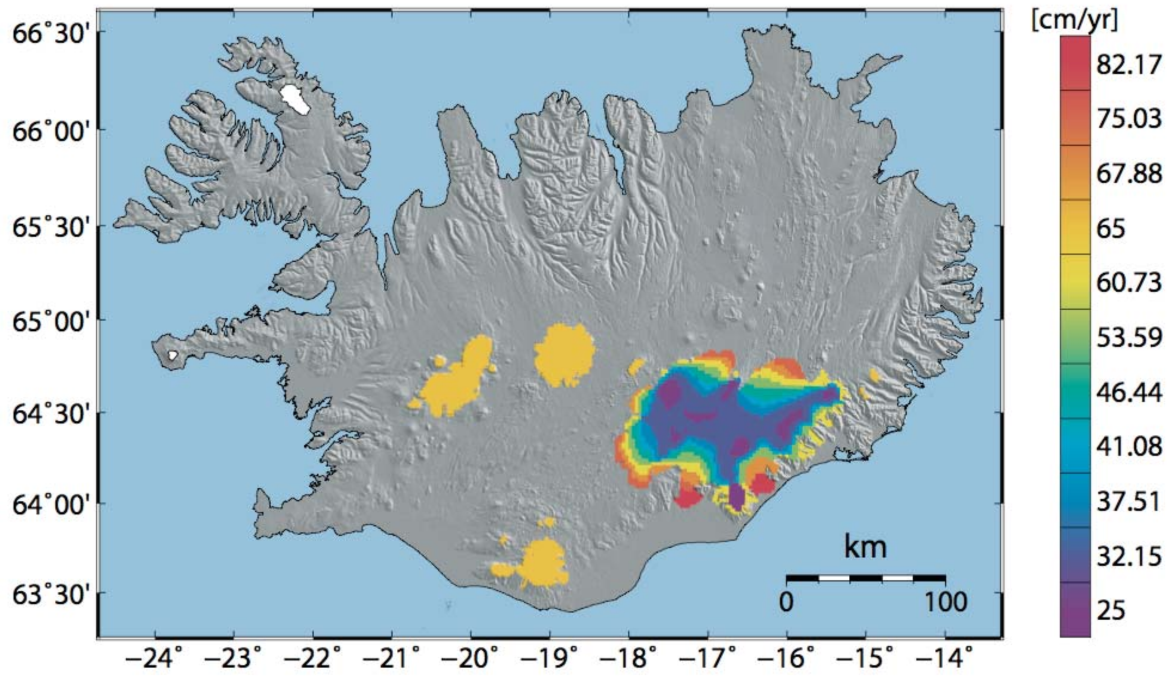


Elastic 2-layer model of surge



- 1 km layer with Youngs modulus 20-25 GPa overlying 57-59 GPa halfspace

GIA Modelling

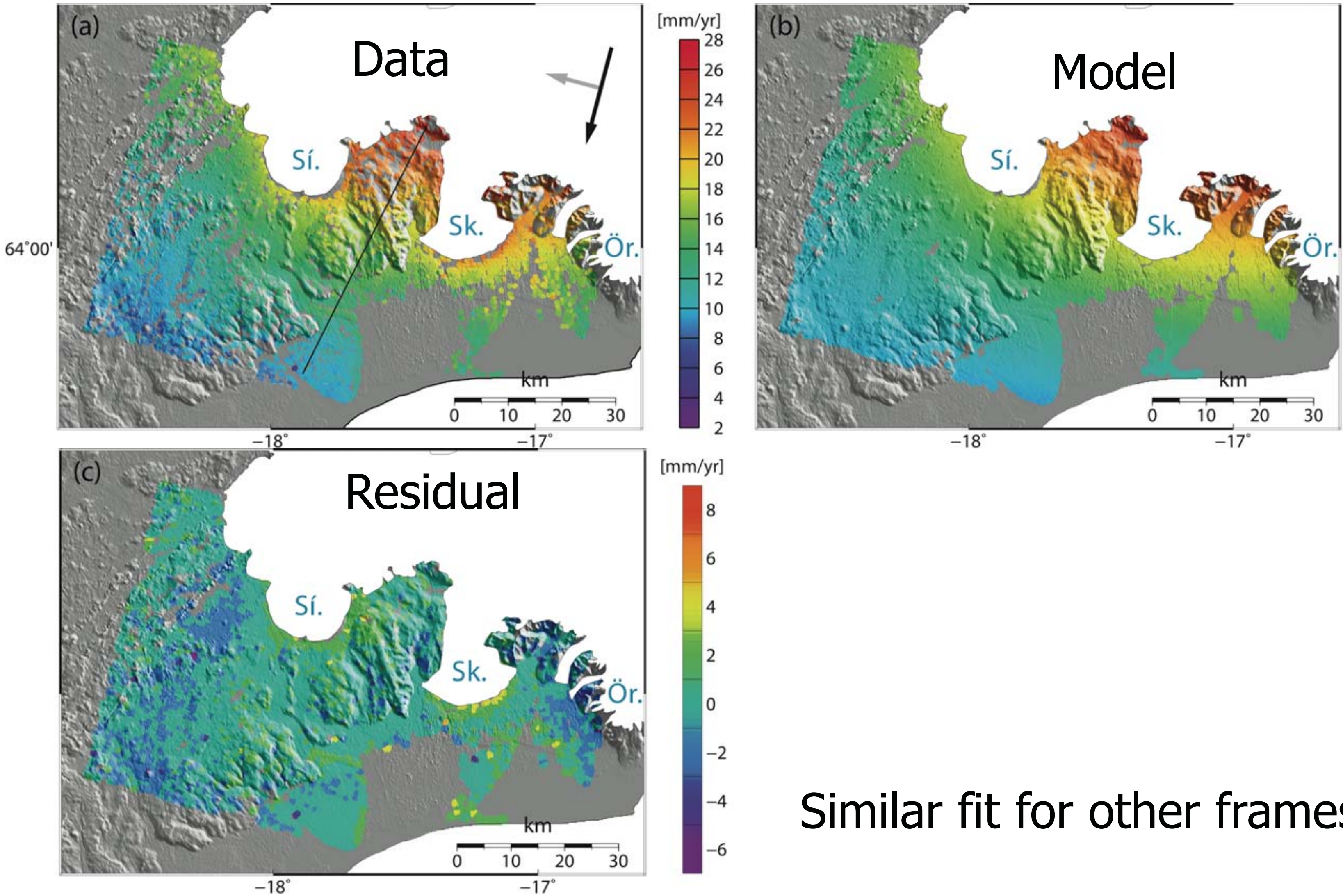


Ice loss model (Schmidt et al, EPSL, 2012)

458 km^3 since 1890

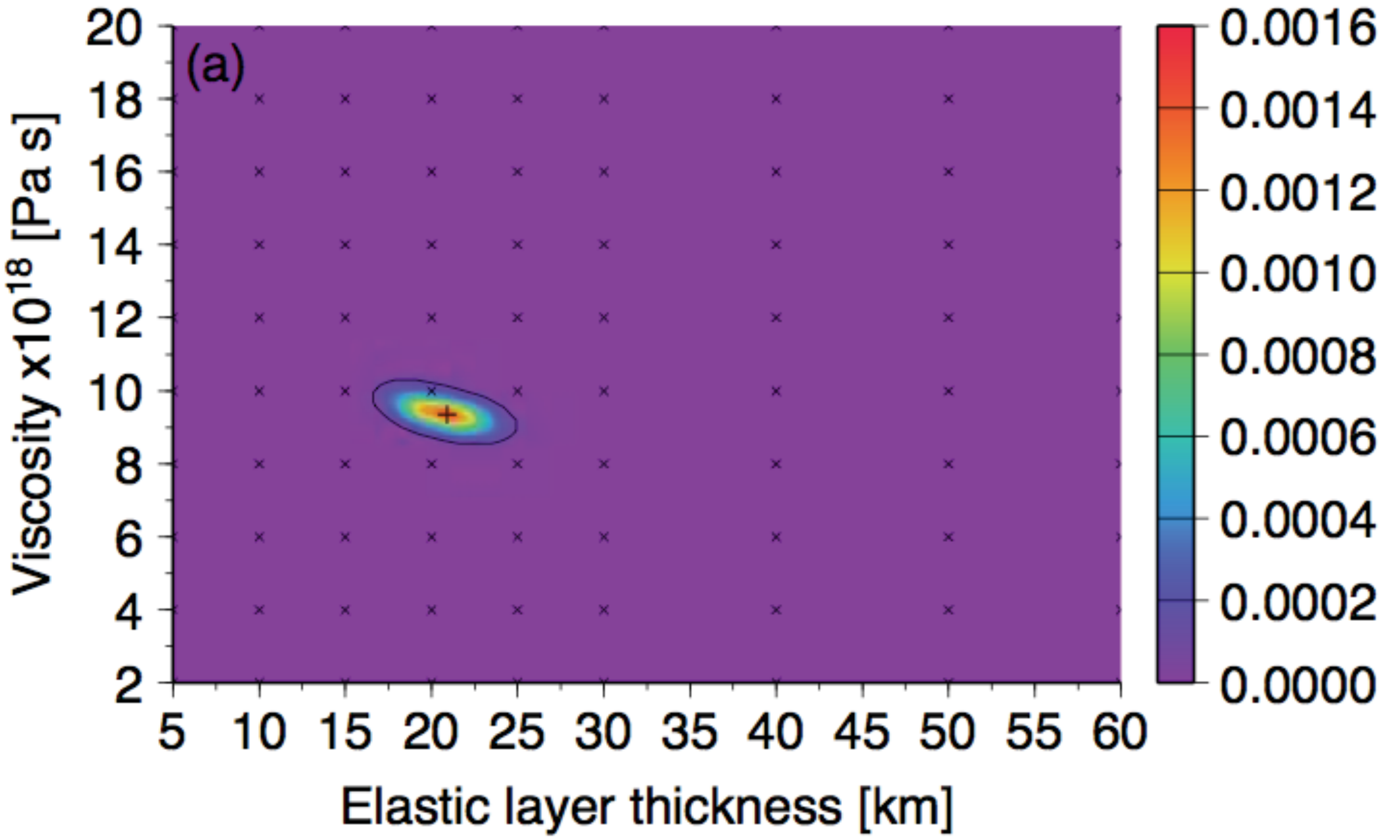
- Elastic layer overlying Maxwell viscoelastic halfspace
- Forward model using finite elements

Model results (west)



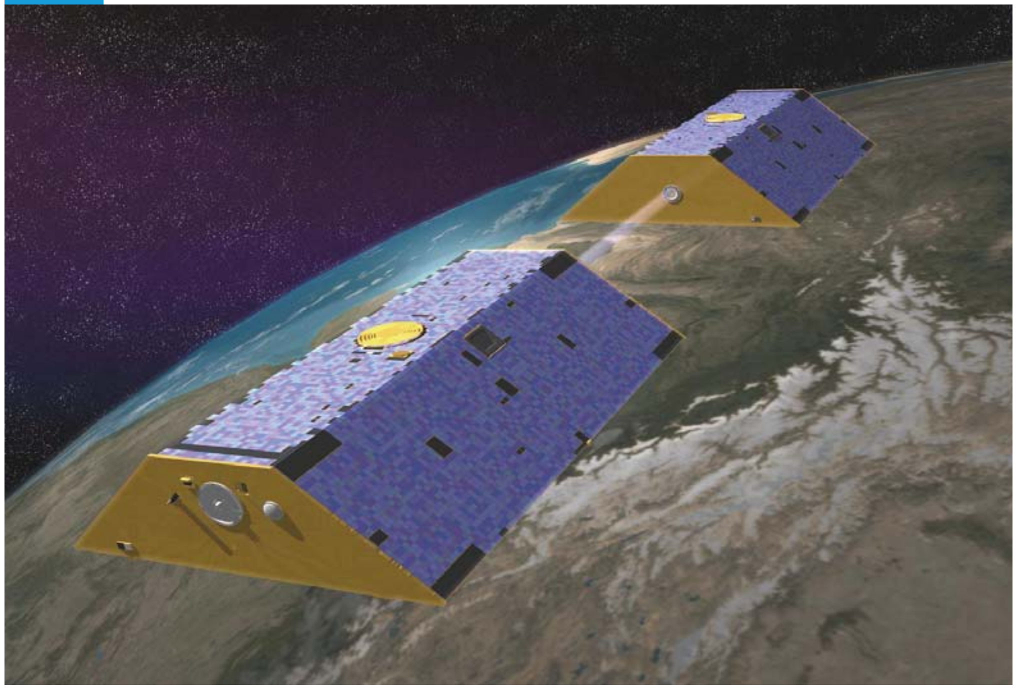
Similar fit for other frames

Model results (probability distribution)



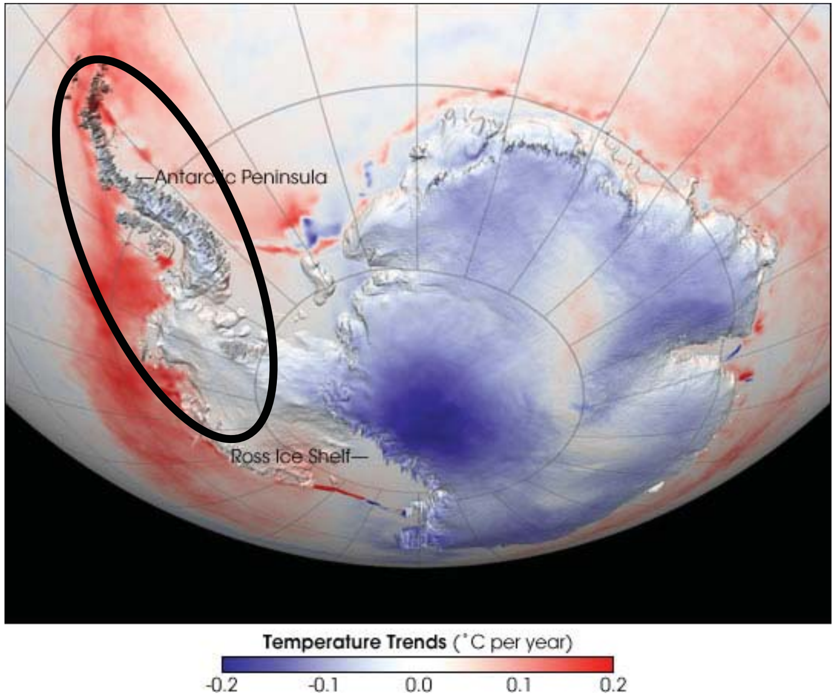
- Assuming multivariate Gaussian distribution of errors
- Better constrained than from GPS alone

Antarctic ice loss



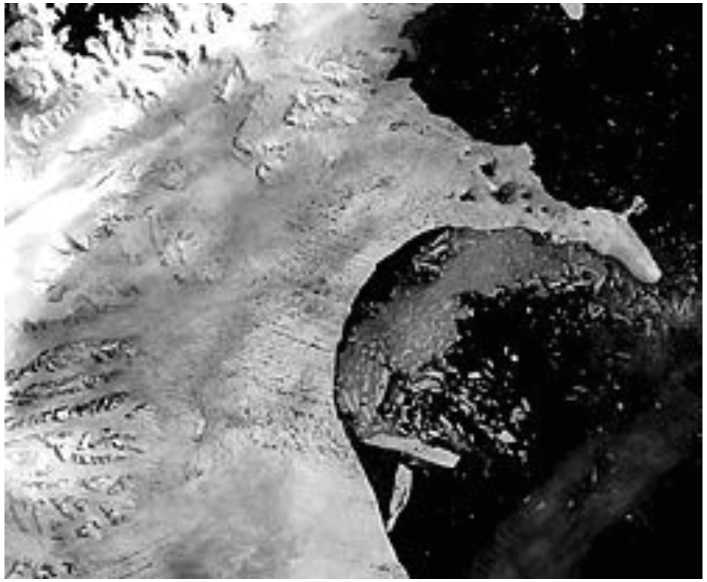
Present-day ice loss can be constrained by satellite gravity measurements, BUT solid Earth response needs to first be subtracted

Antarctic temperature trends

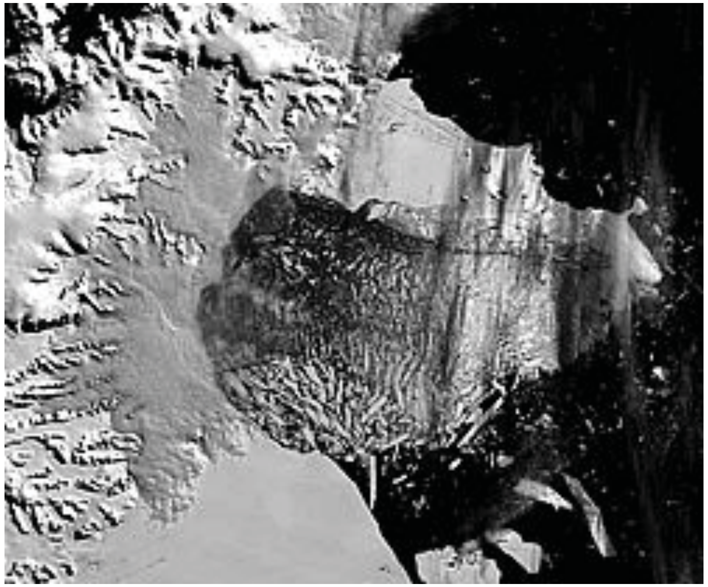


Ongoing temperature change leads to temporally-varying ice mass change

2002 Larsen B ice shelf collapse

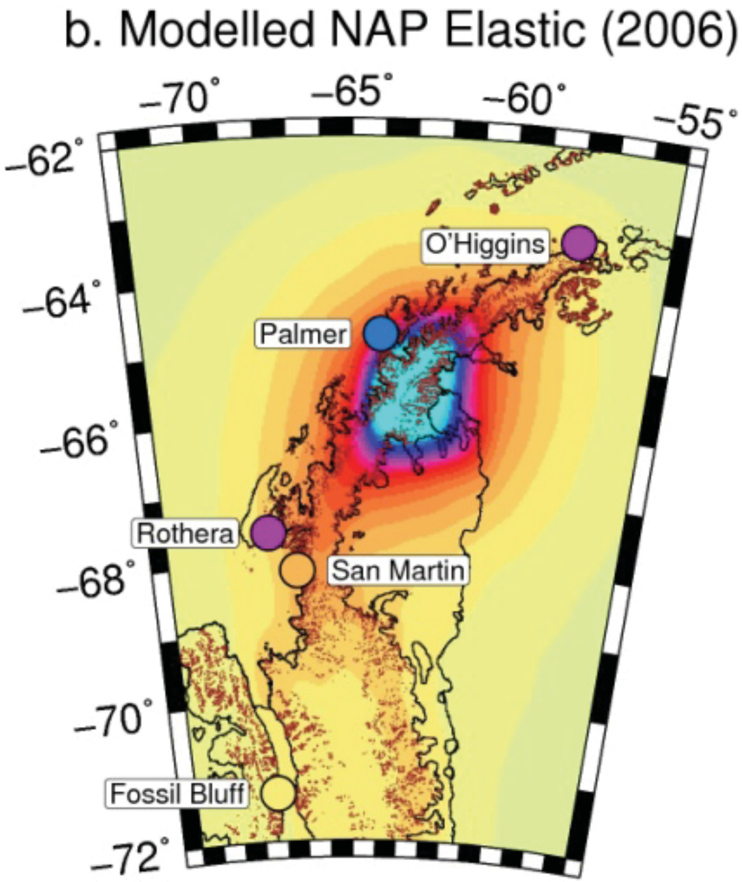


17th Feb 2002

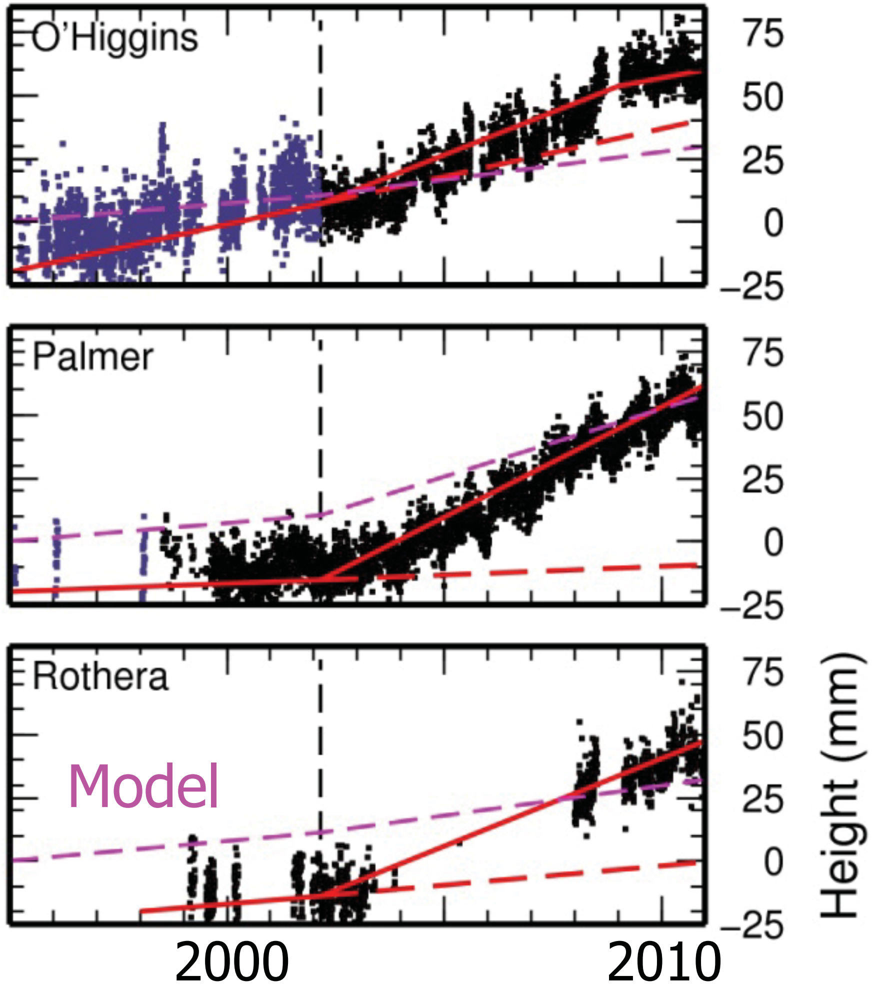


5th March 2002

Response to recent ice loss



GPS time series

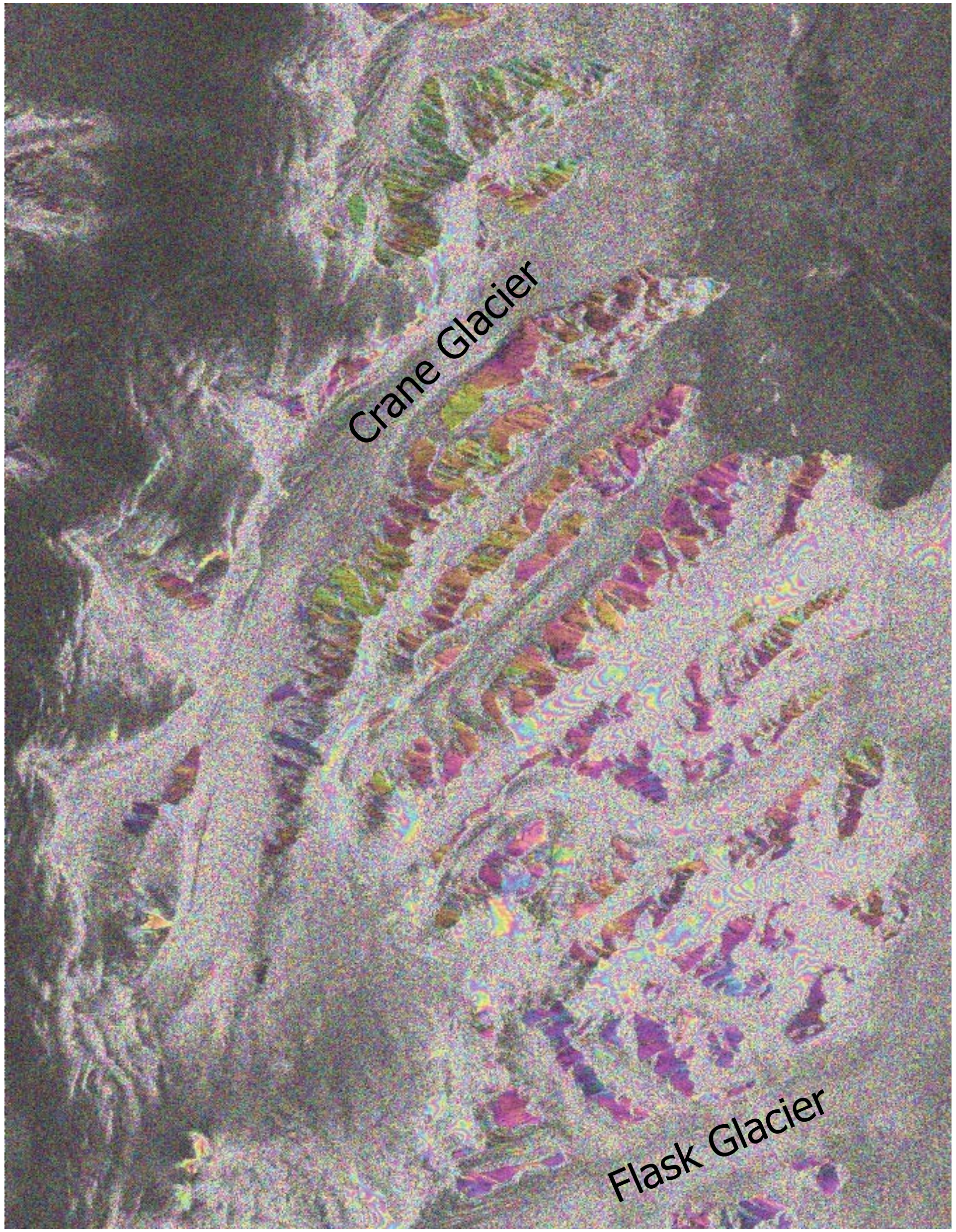


Recent viscoelastic modelling fits better (Nield et al, EGU, 2013

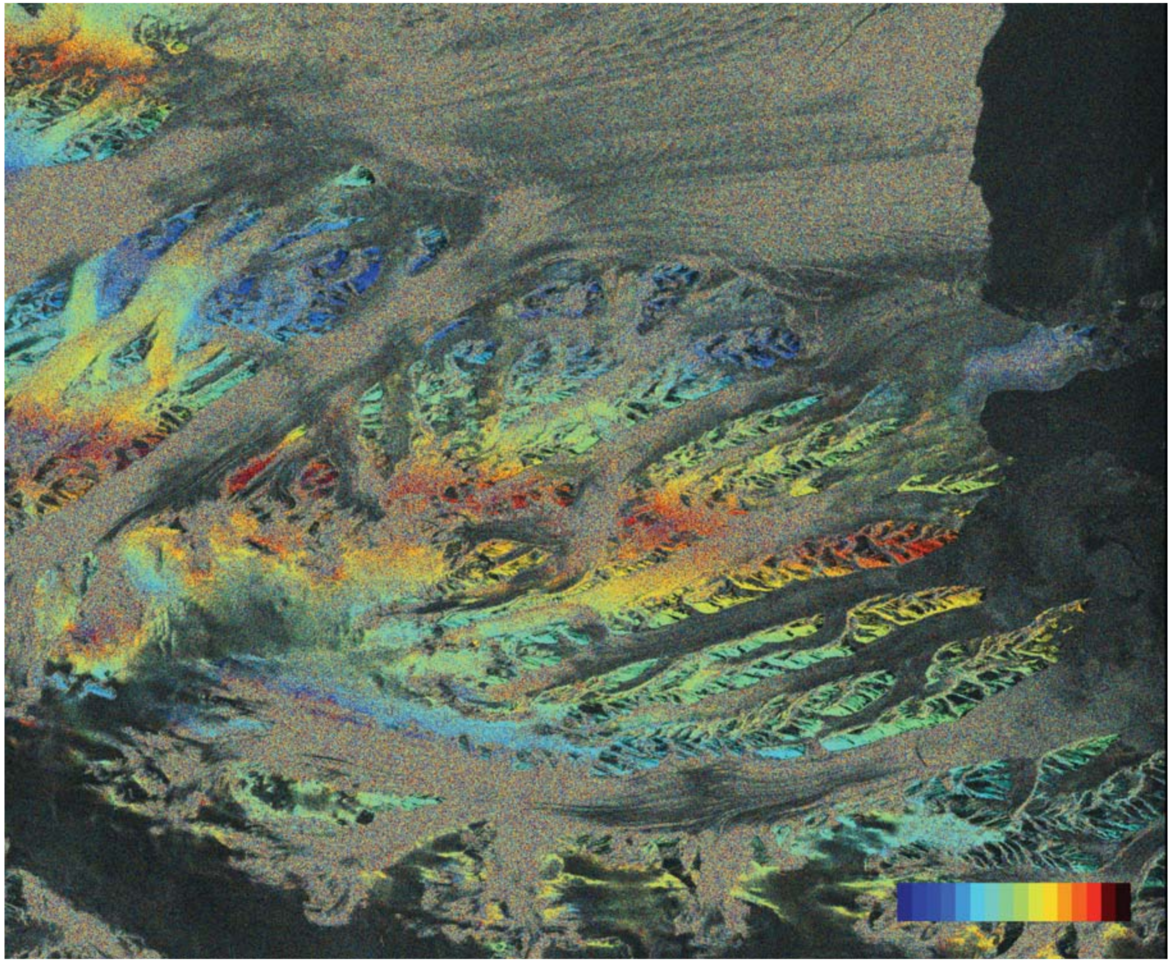
Thomas et al., GRL, 2011

InSAR Challenges in Antarctic

- Few outcrops
- Seasonal snow
- Coregistration of images
- DEM accuracy
- Integrating the phase ("unwrapping") between outcrops
- Strong tropopheric and ionospheric delay variation

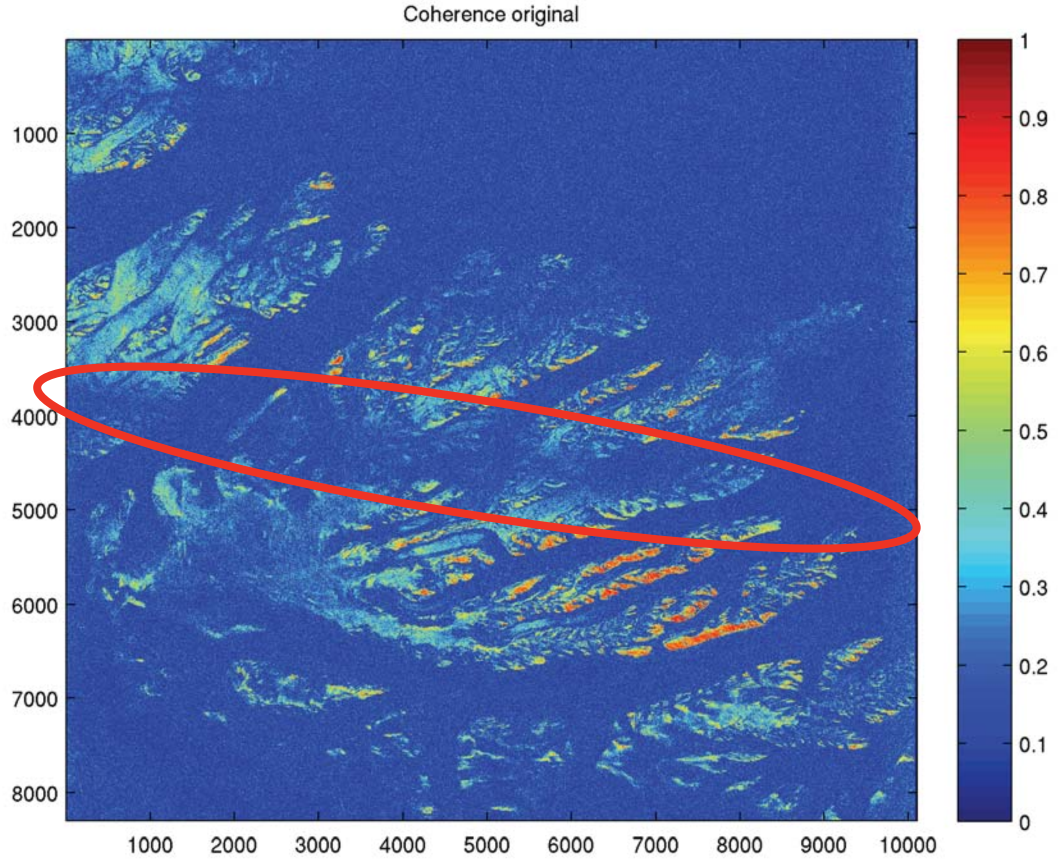


Ionosphere

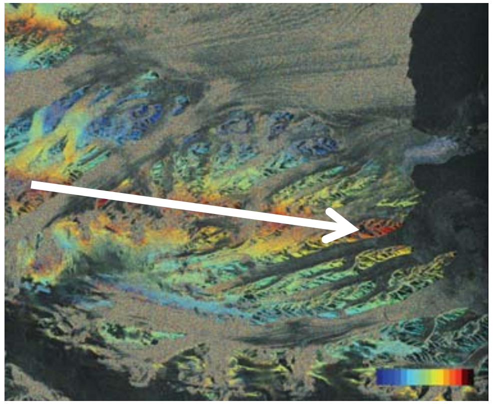


From spectral diversity in azimuth (Scheiber and Moreira, 2000)
(also known as MAI)

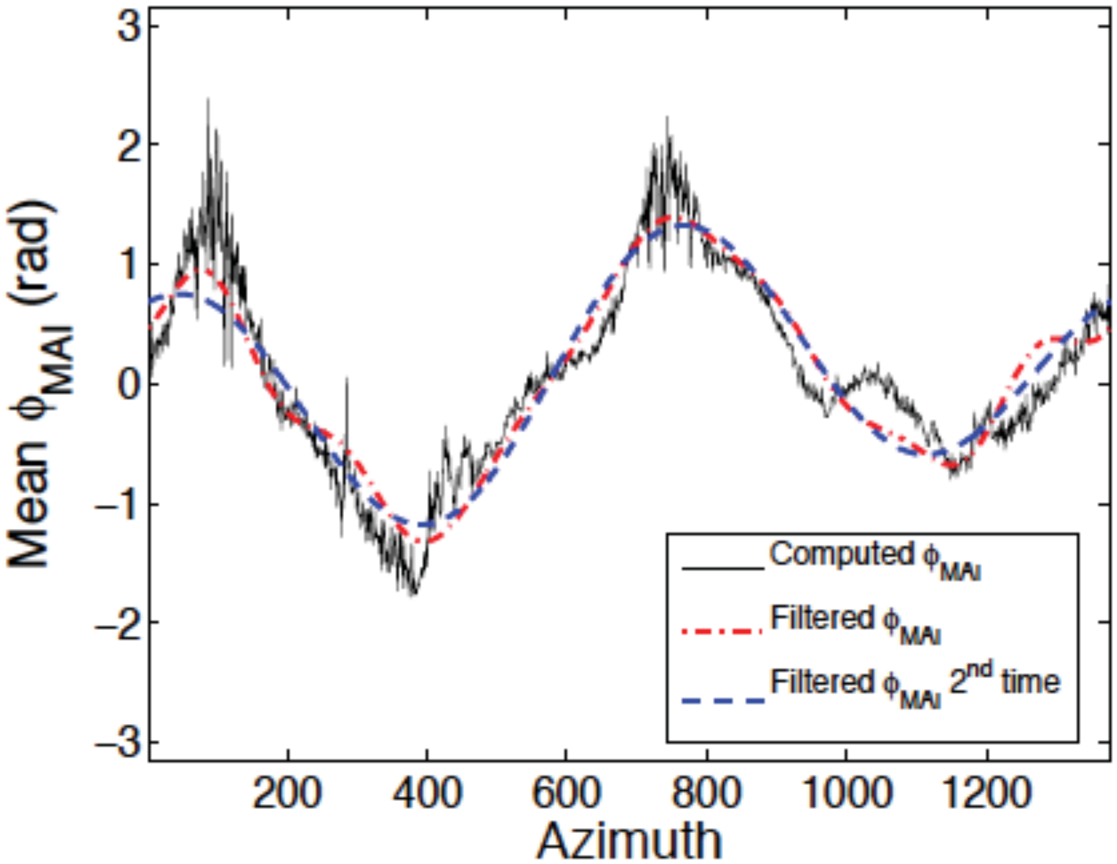
Coherence


Coherence original
1000
2000
3000
4000
5000
6000
7000
8000
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

Integrated azimuth offsets (from spectral diversity)



Integration direction



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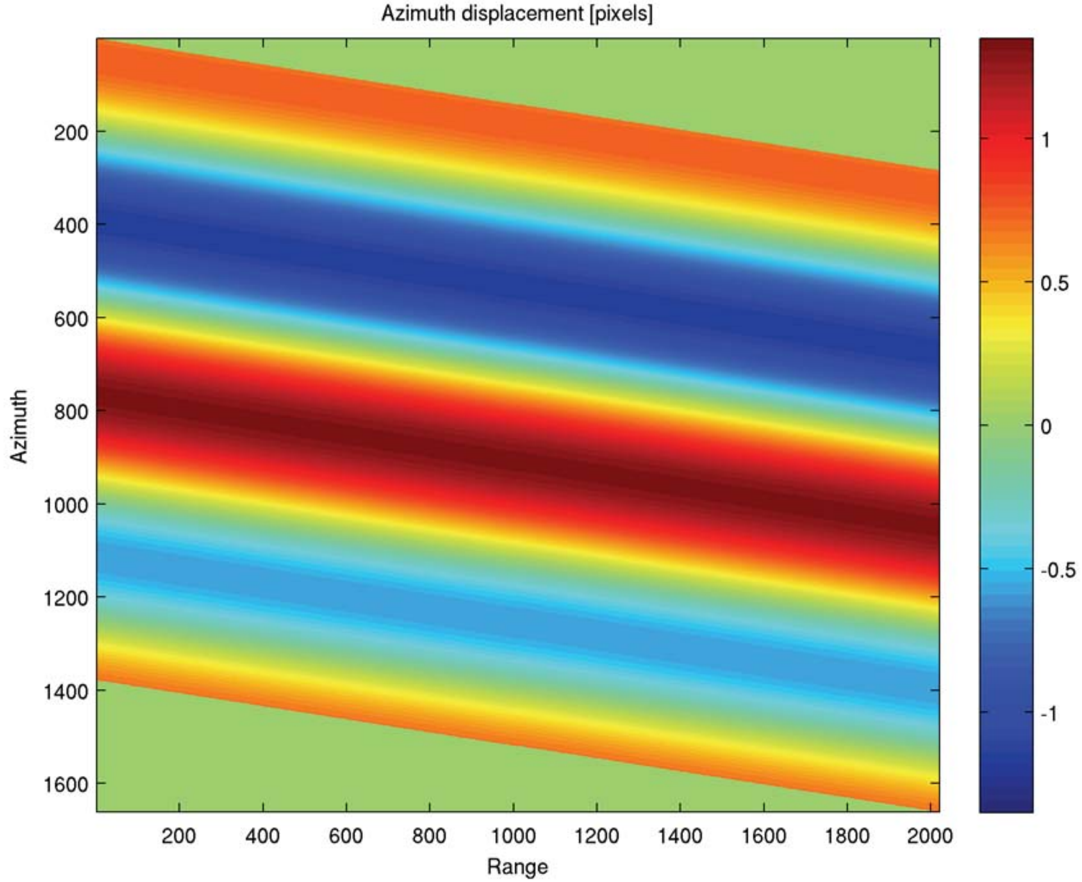
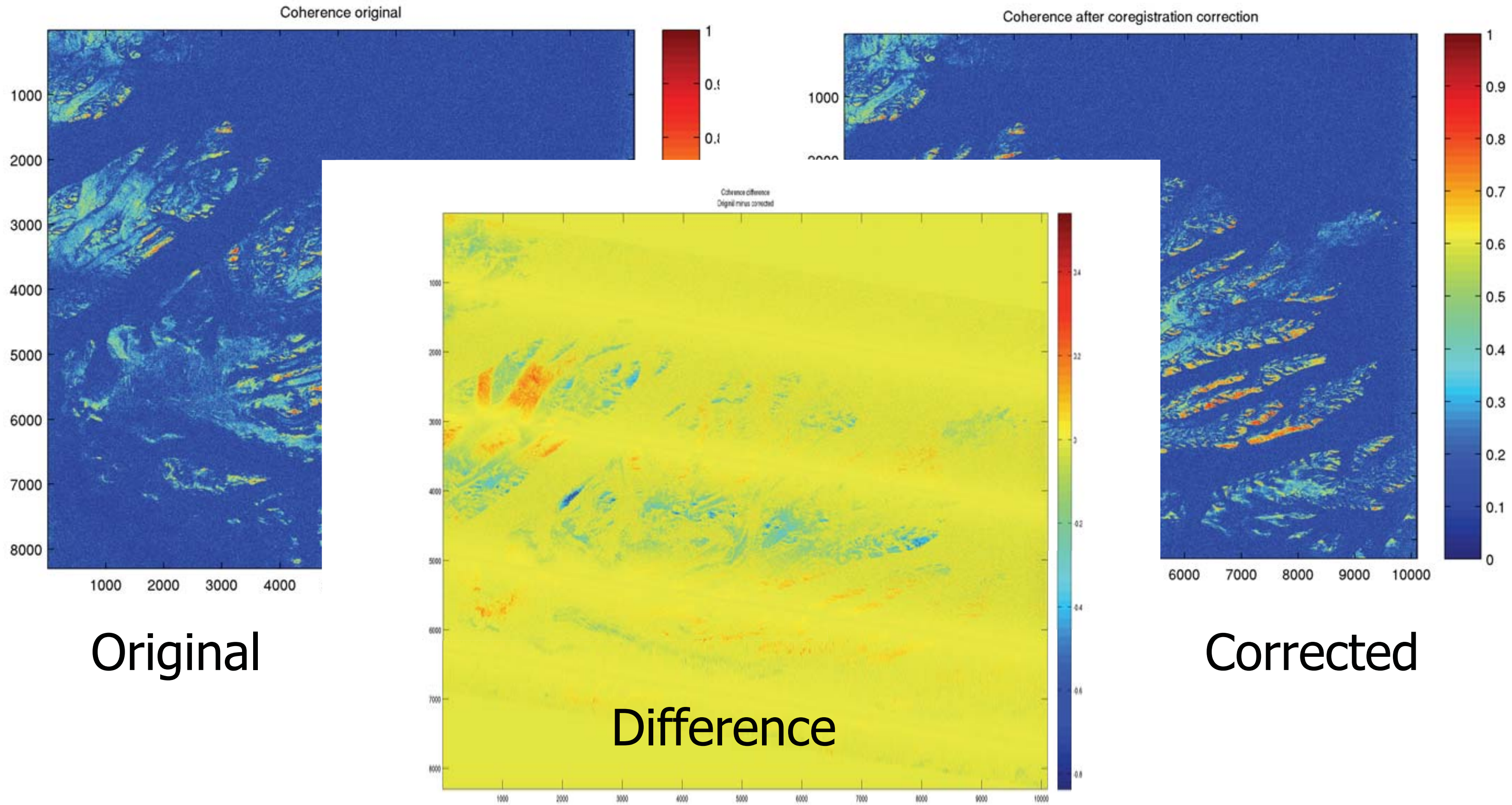
Modelled azimuth offsets

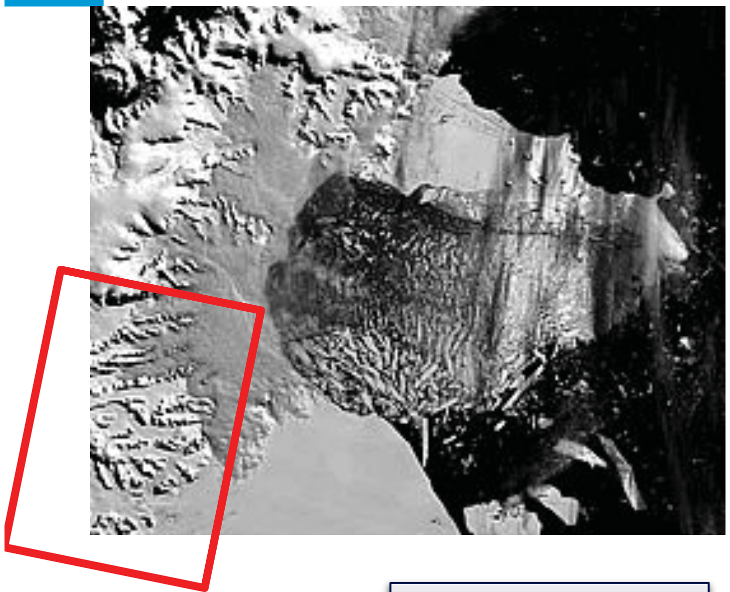


Coregistration corrected for ionosphere

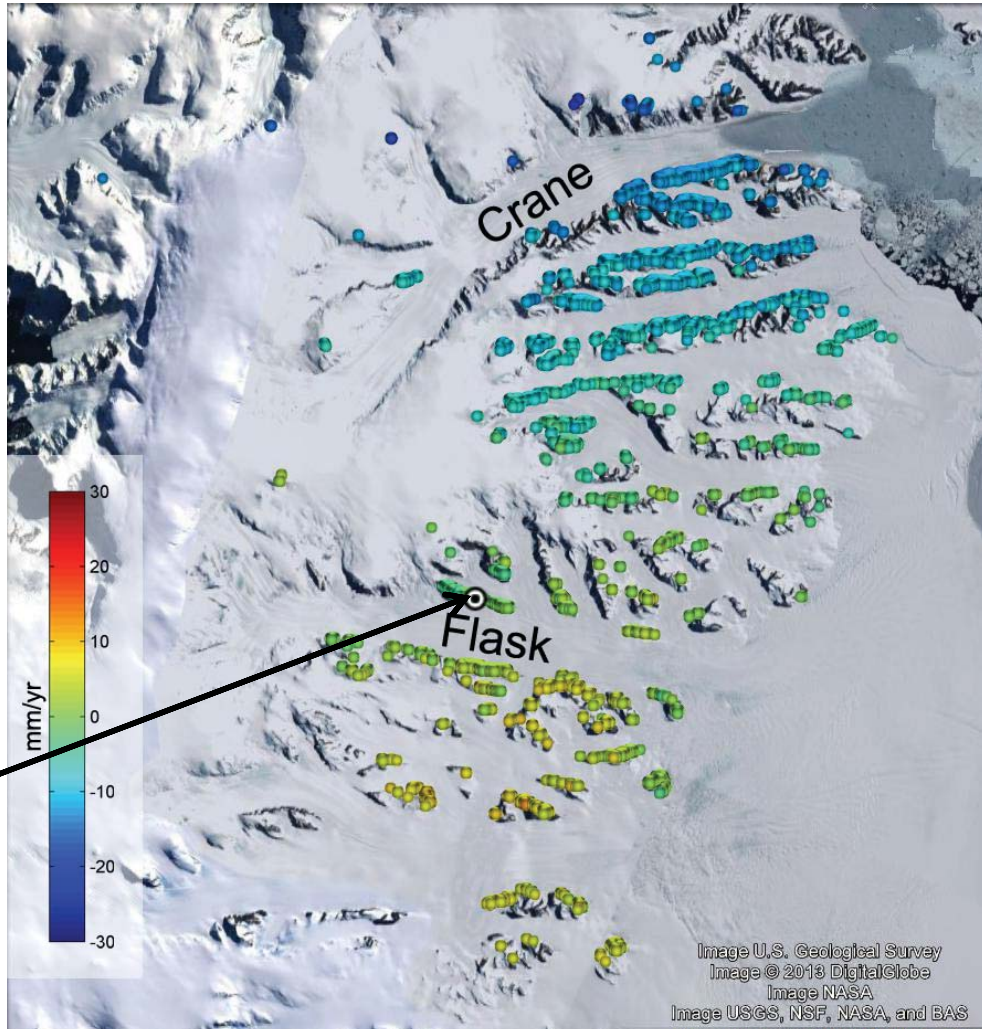


- Azimuth offsets can then be resestimated, and used to correct interferometric phase

ALOS line-of-sight rates

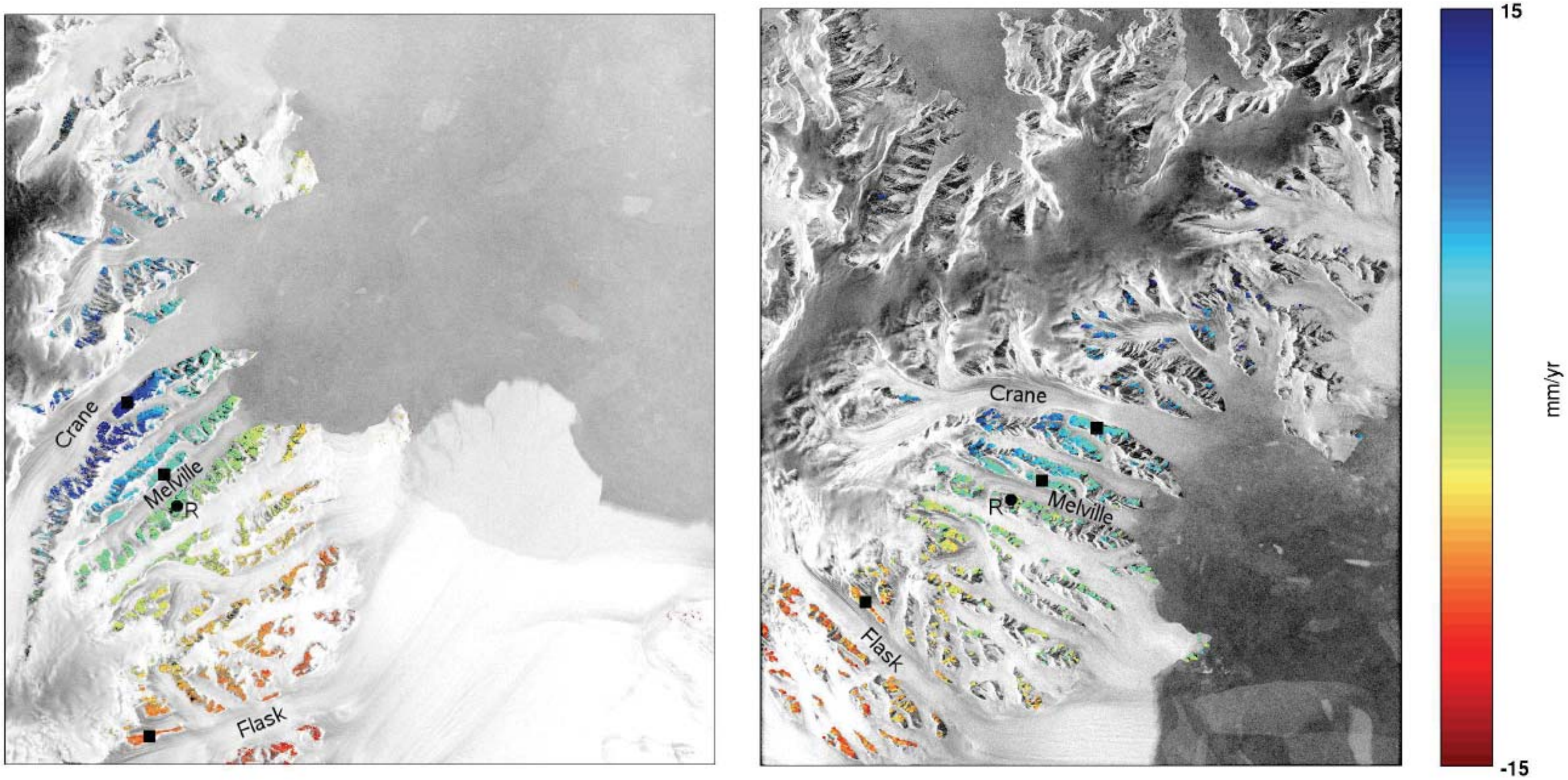


Spatial reference

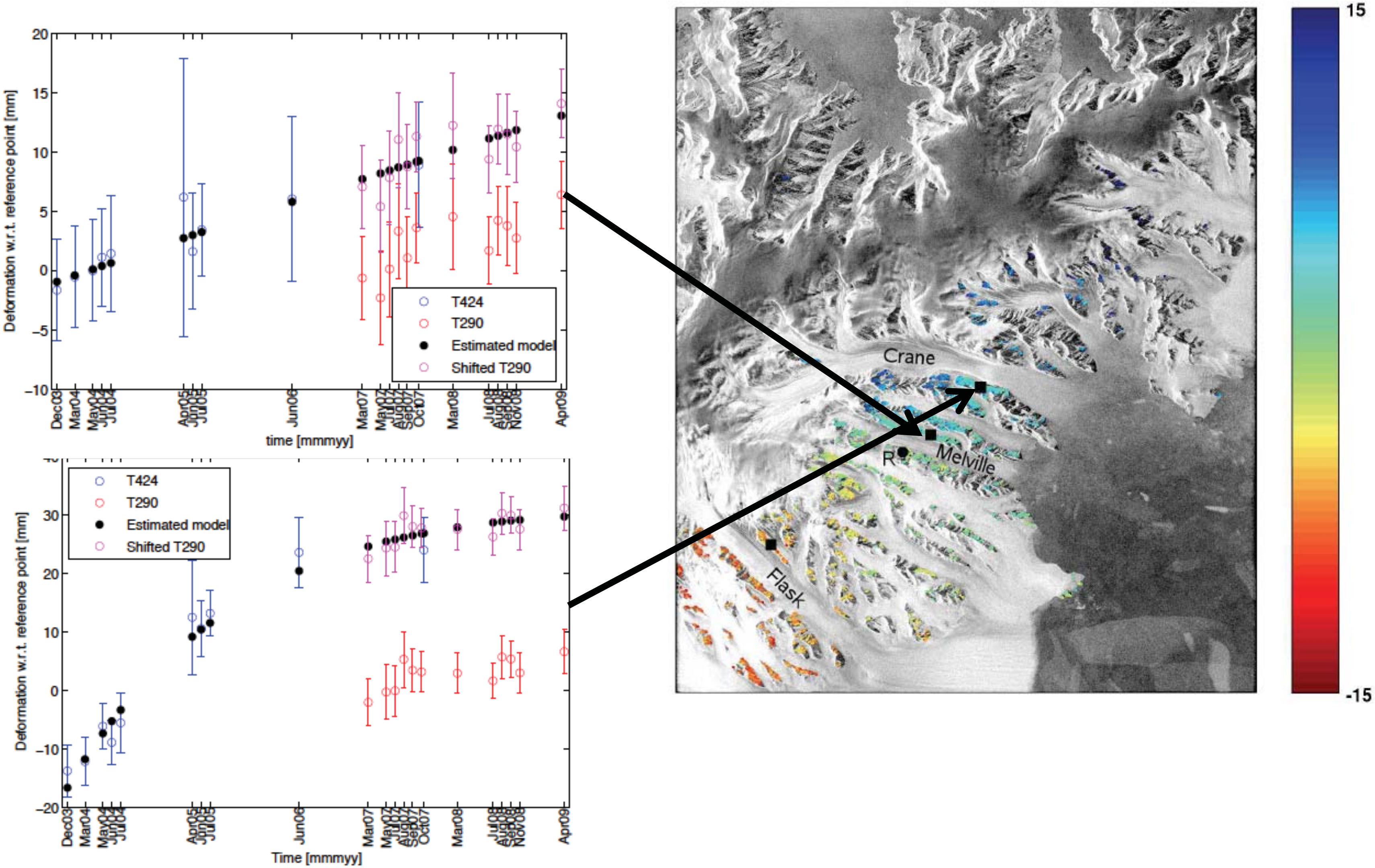


- From ALOS 2008-2011

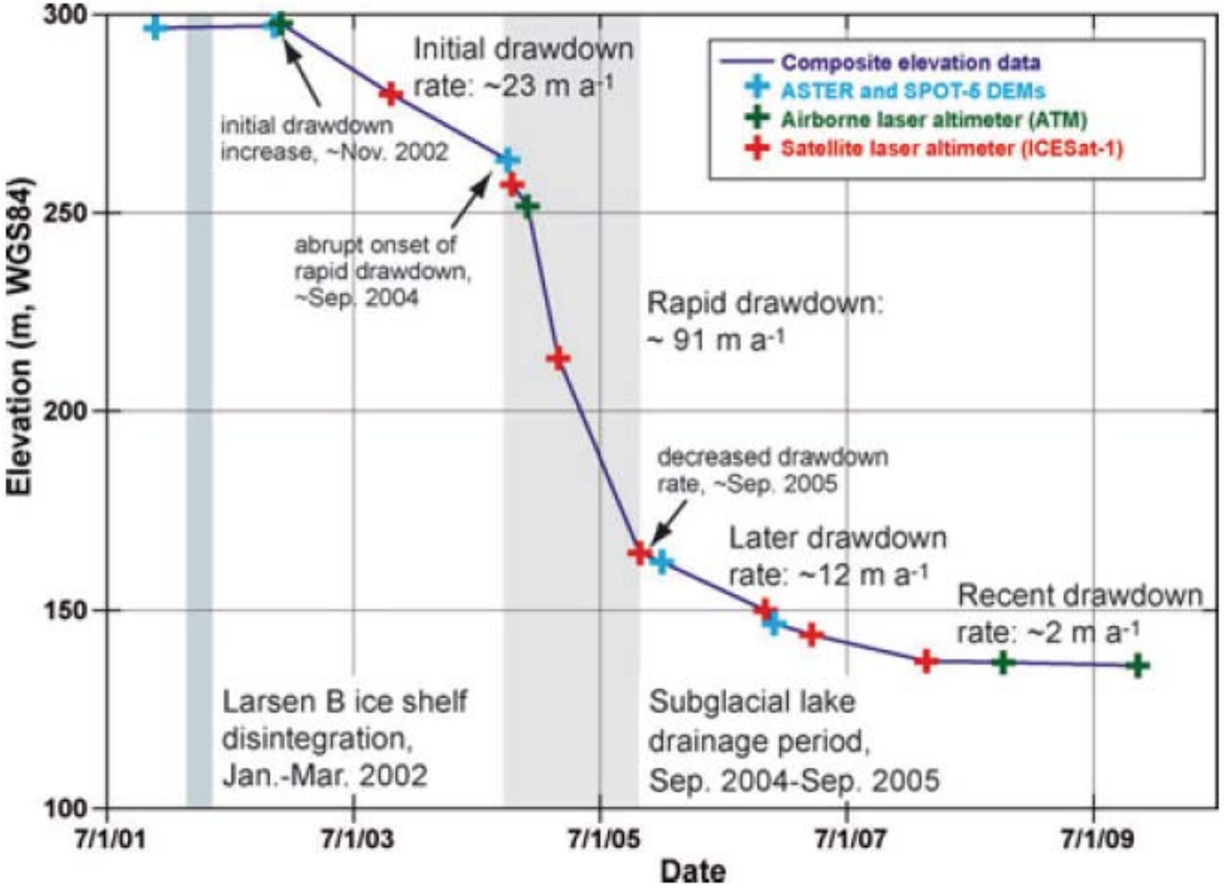
Envisat line-of-sight rates



Envisat time series

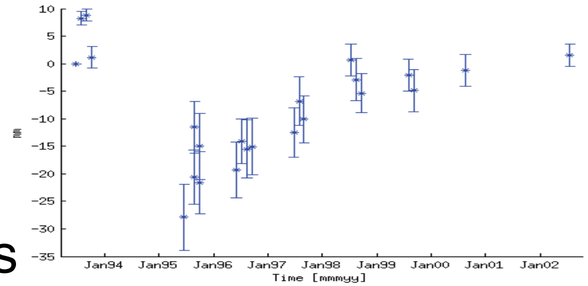


Crane Glacier Elevation

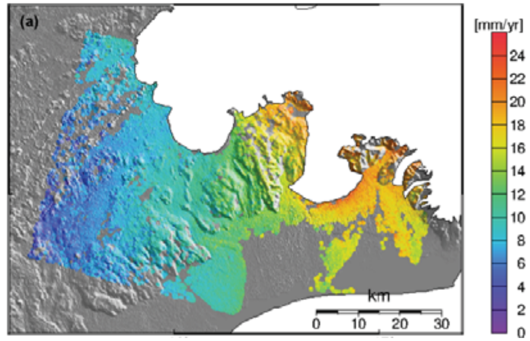


Scambos et al, 2011

Summary



- InSAR is viable for constraining the time-variable solid Earth response to ice mass changes.



- Gives greatly improved spatial resolution over GNSS alone.

- The launch of ESAs Sentinel-1 mission early 2014 will hopefully mark the beginning of a new era for InSAR ice load studies.

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