Inferring the surface velocity fields of glaciers in central Iceland using UAVSAR repeat-pass interferometry

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Project goals

- Study subglacial physics
  - Influence of meltwater on glacier velocity
  - Test models of subglacial motion (basal slip)
  - Infer temporal variations in hydrological properties
- Infer bulk rheology of temperate ice
- Contribute to InSAR methodology
- Develop SAR tools for glaciology

Why study subglacial physics?

- Glacier ice moves due to:
  - Internal (viscous) deformation
  - Basal slip
- Basal slip accounts for
  - Up to 50% (hard bed)
  - Up to 90% (soft bed)

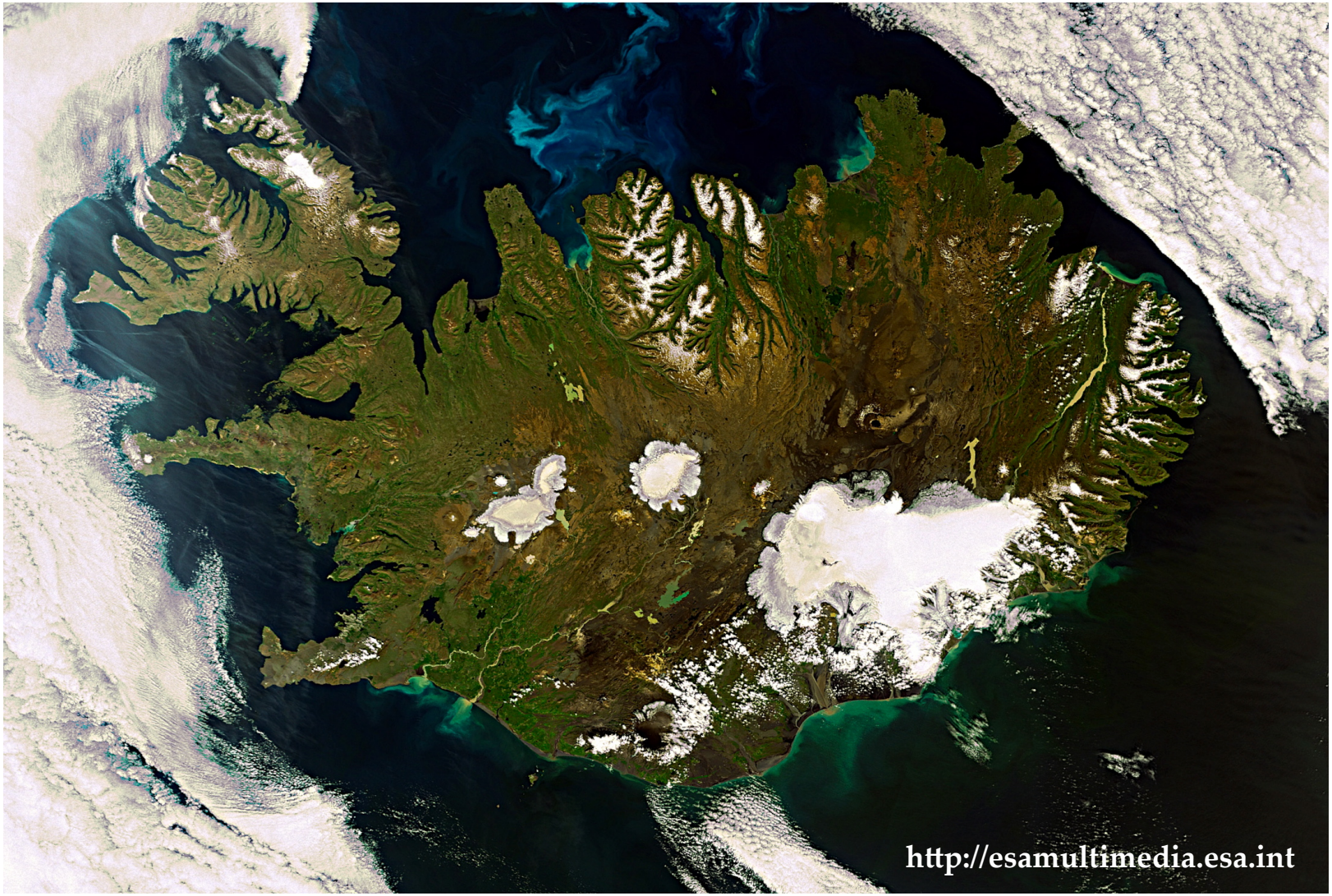
  of the the total surface velocity
- Links meltwater flux and ice velocity
- Governs erosion
- Not well understood

Approach

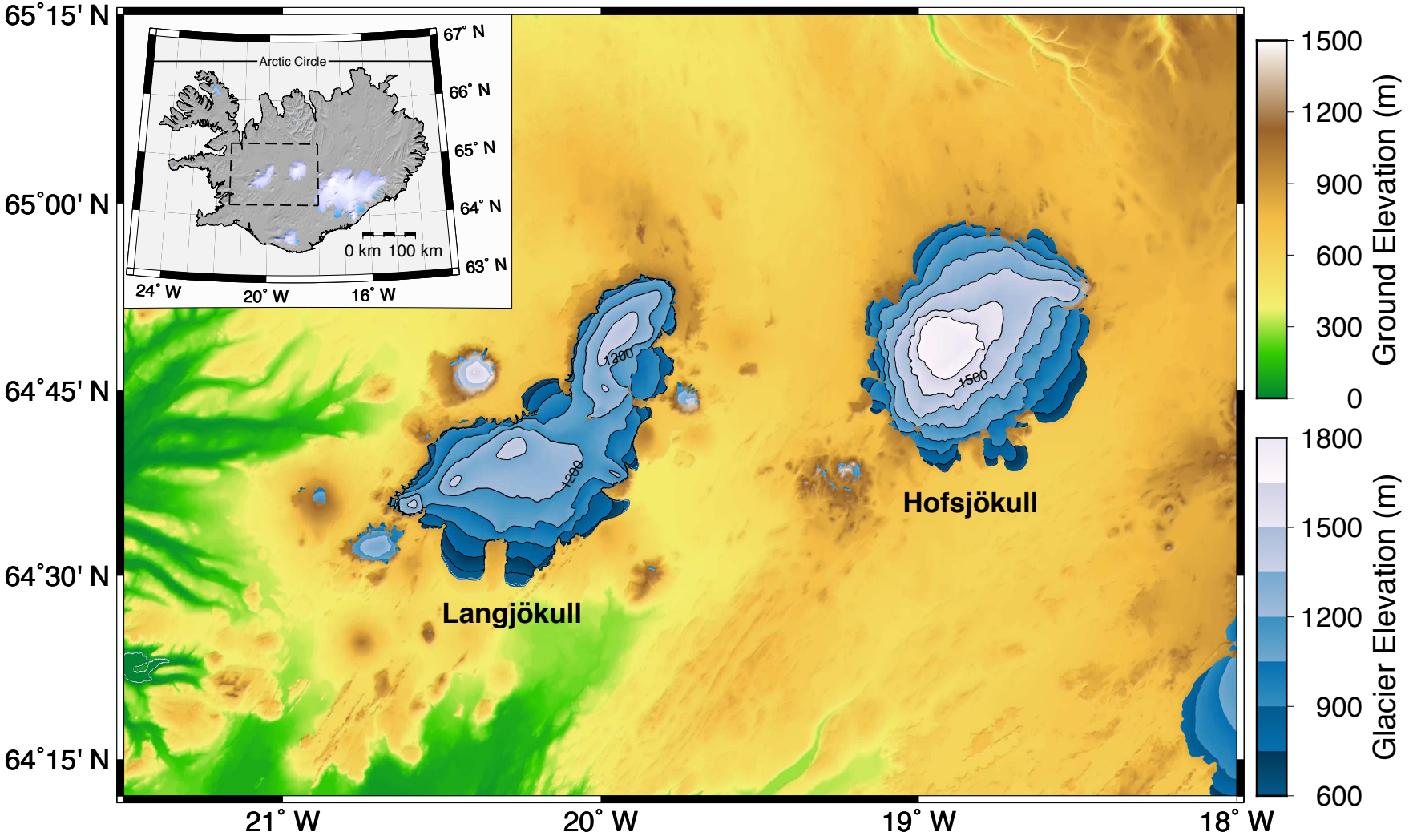
- Amass as complete a data set as possible for the early melt season and winter:
  - InSAR data collected from various LOS
  - *In situ* meteorological data (melt)
  - GPS data at selected locations
  - Accurate DEMs
- Assemble with existing bedrock topography
- Use winter data to constrain ice rheology
- Apply ice rheology to study basal stress

ISSM

Iceland

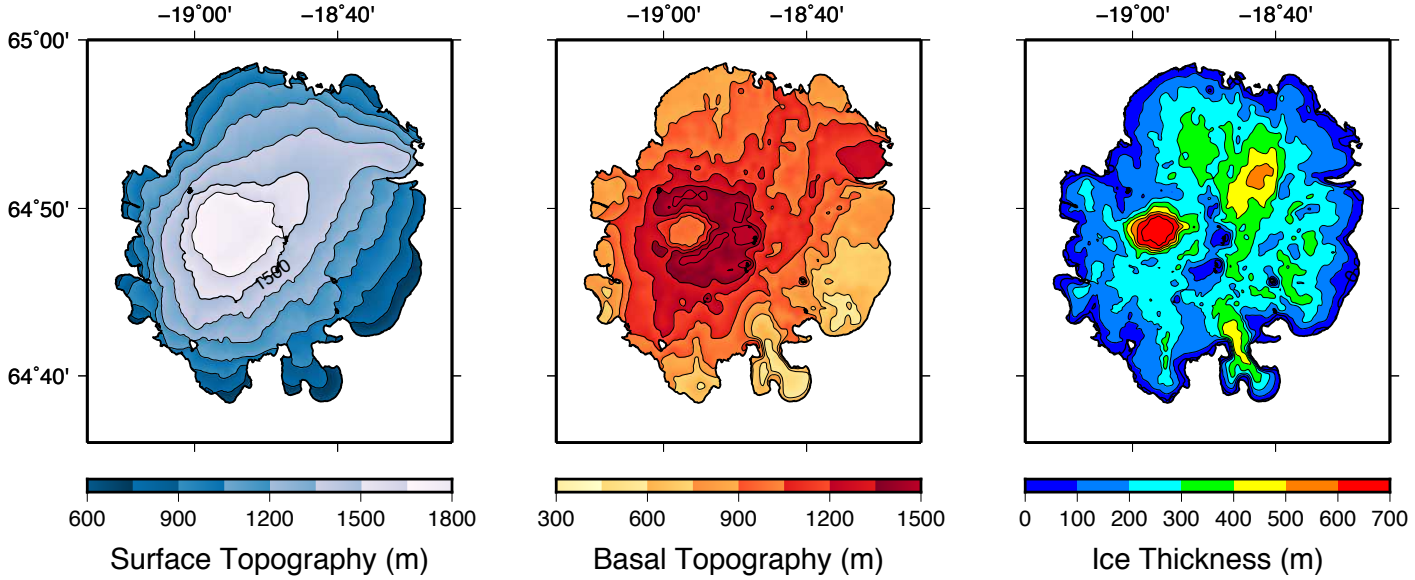


Langjökull and Hofsjökull

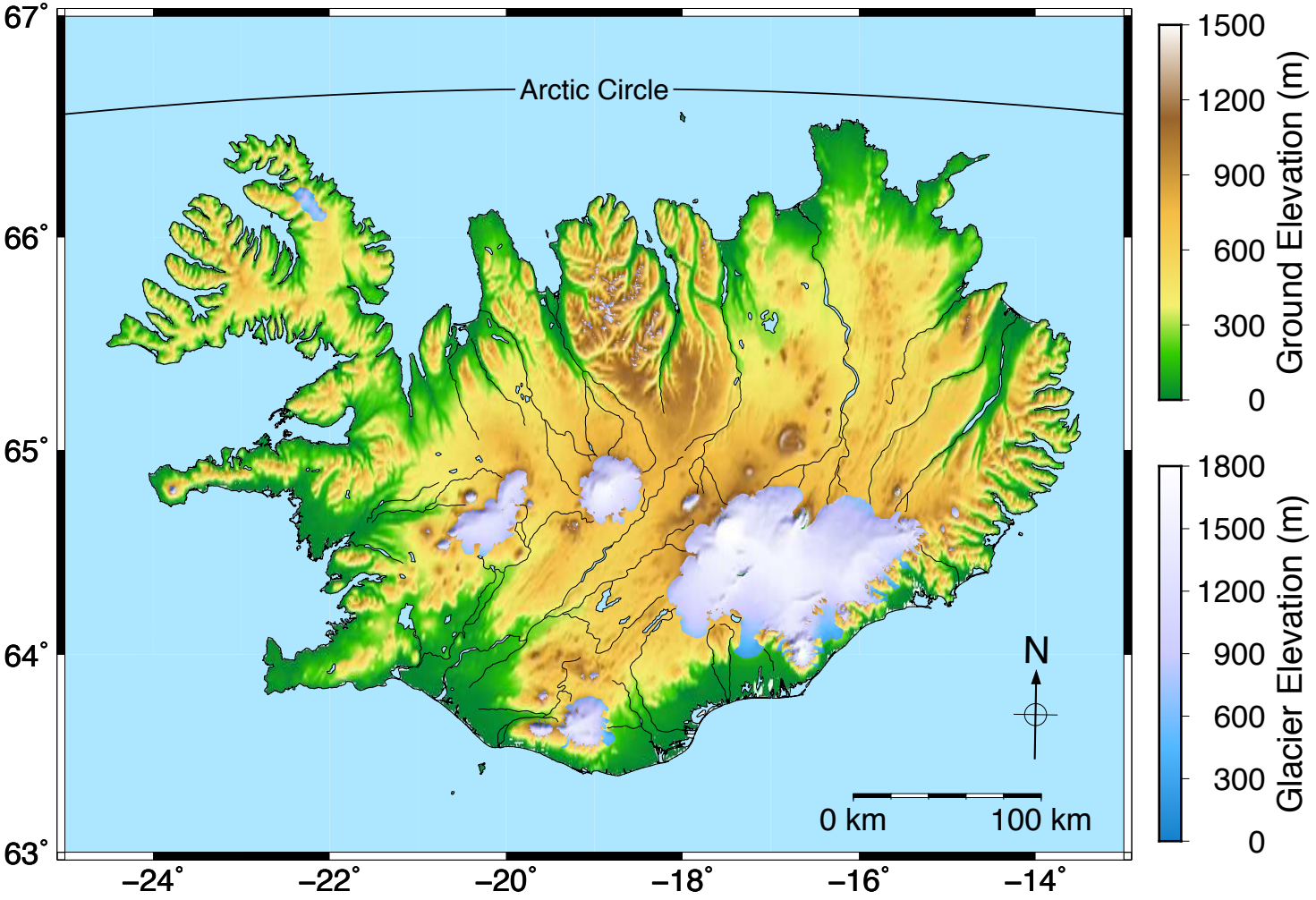


Natural laboratory

- Relatively small
- Easily accessible
- Temperate climate
- Land-terminating
- Lots of existing data
- Excellent collaborators
- Geological constraints
- Advantageous geometry



Iceland campaign



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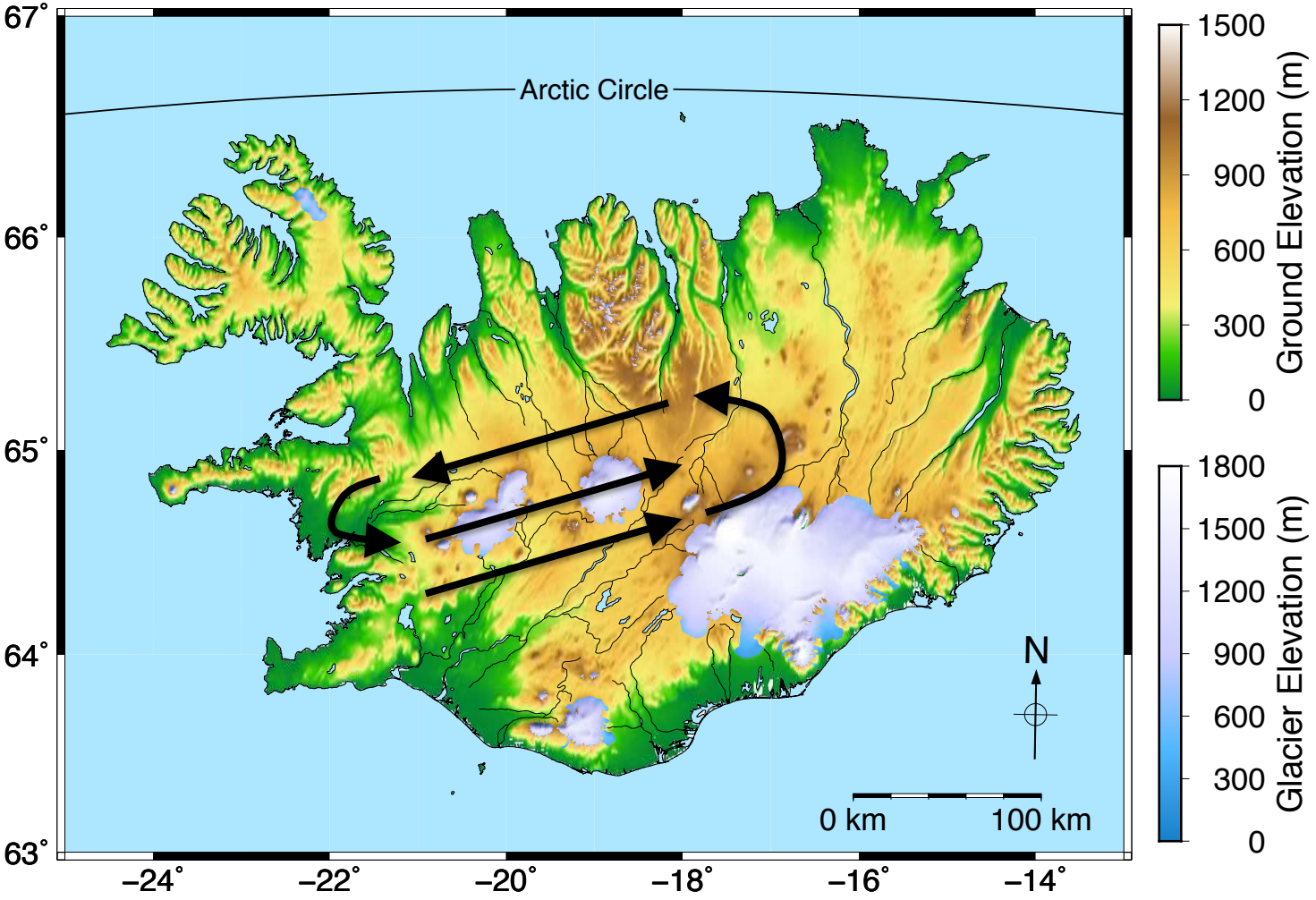

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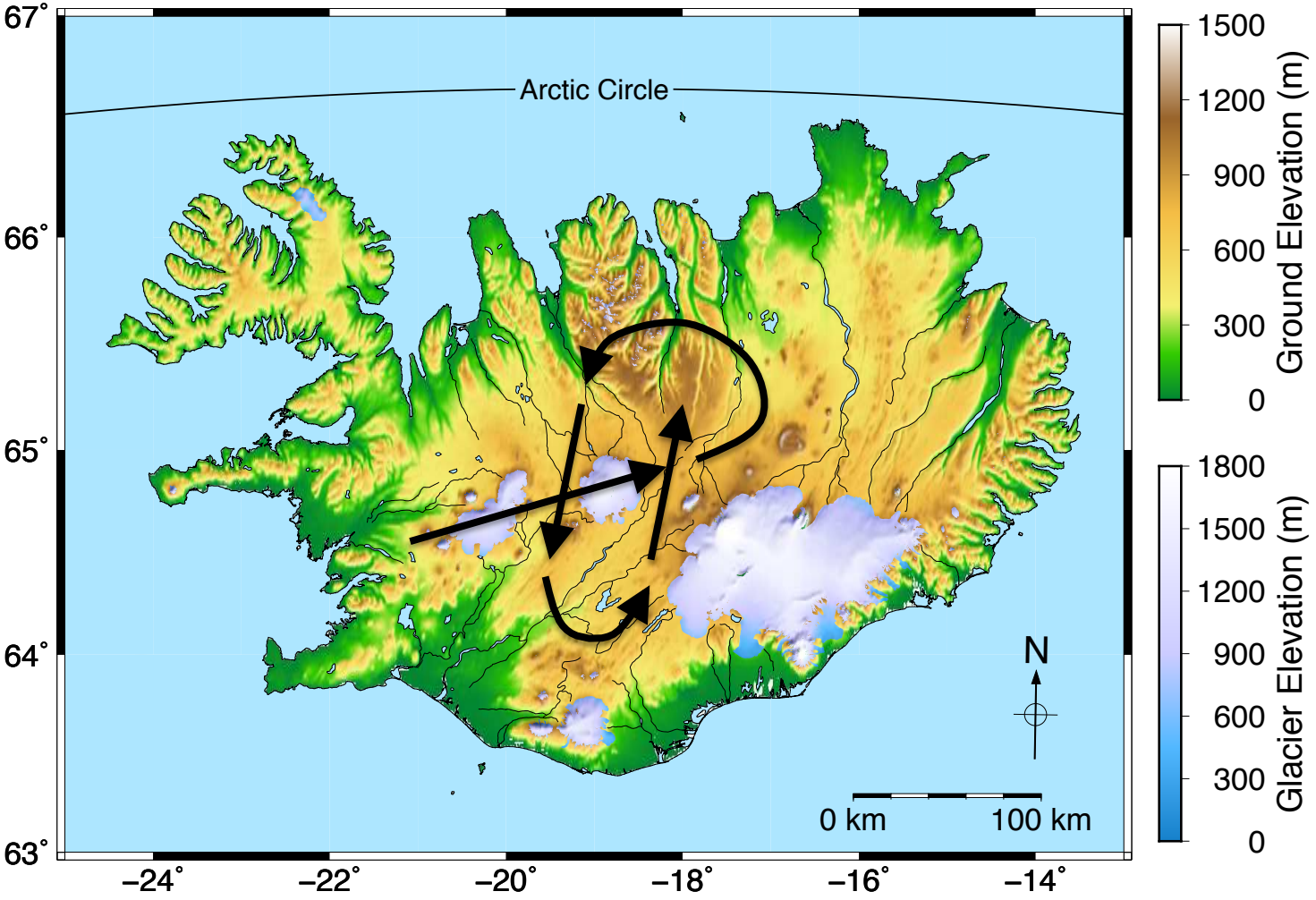

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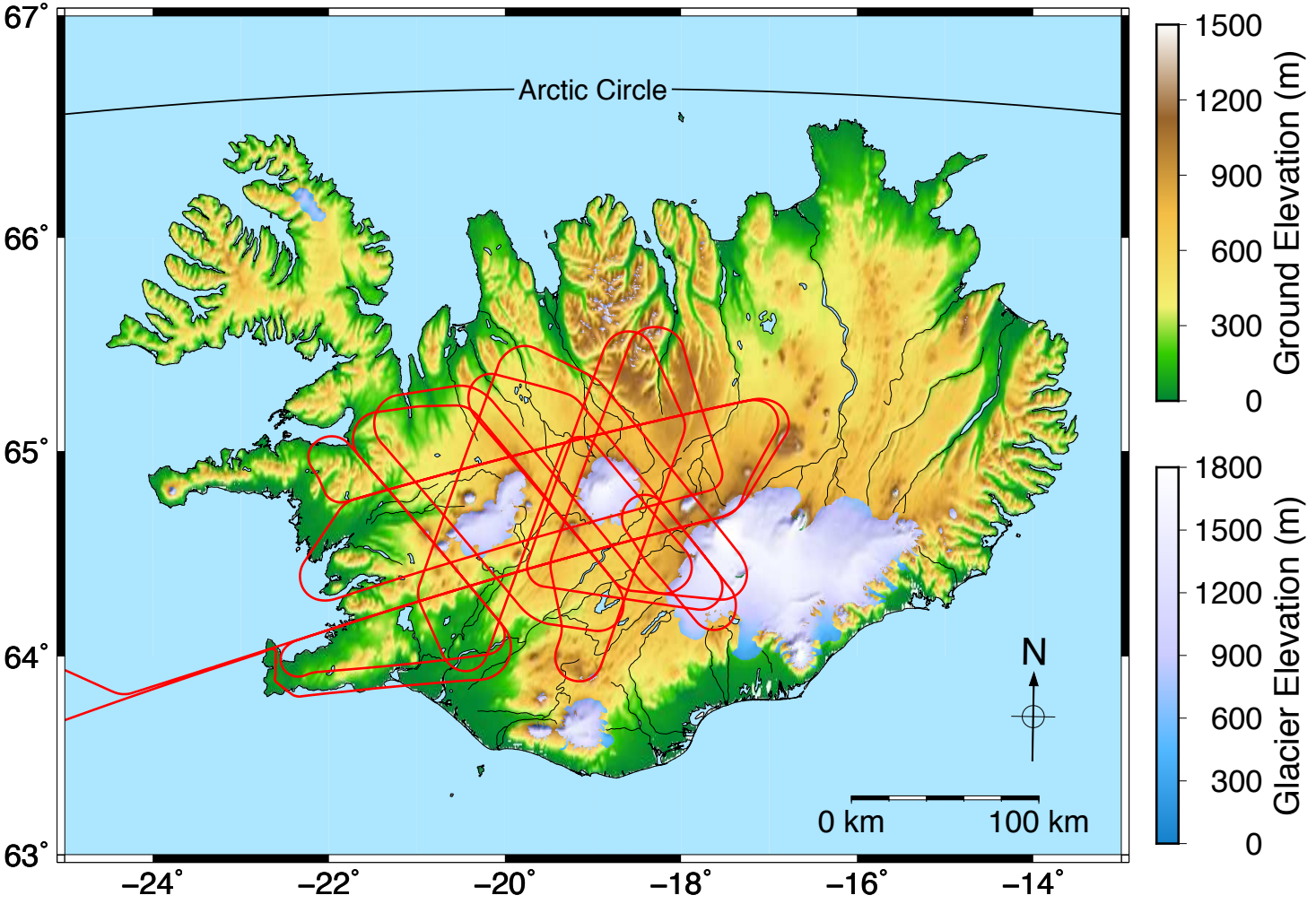
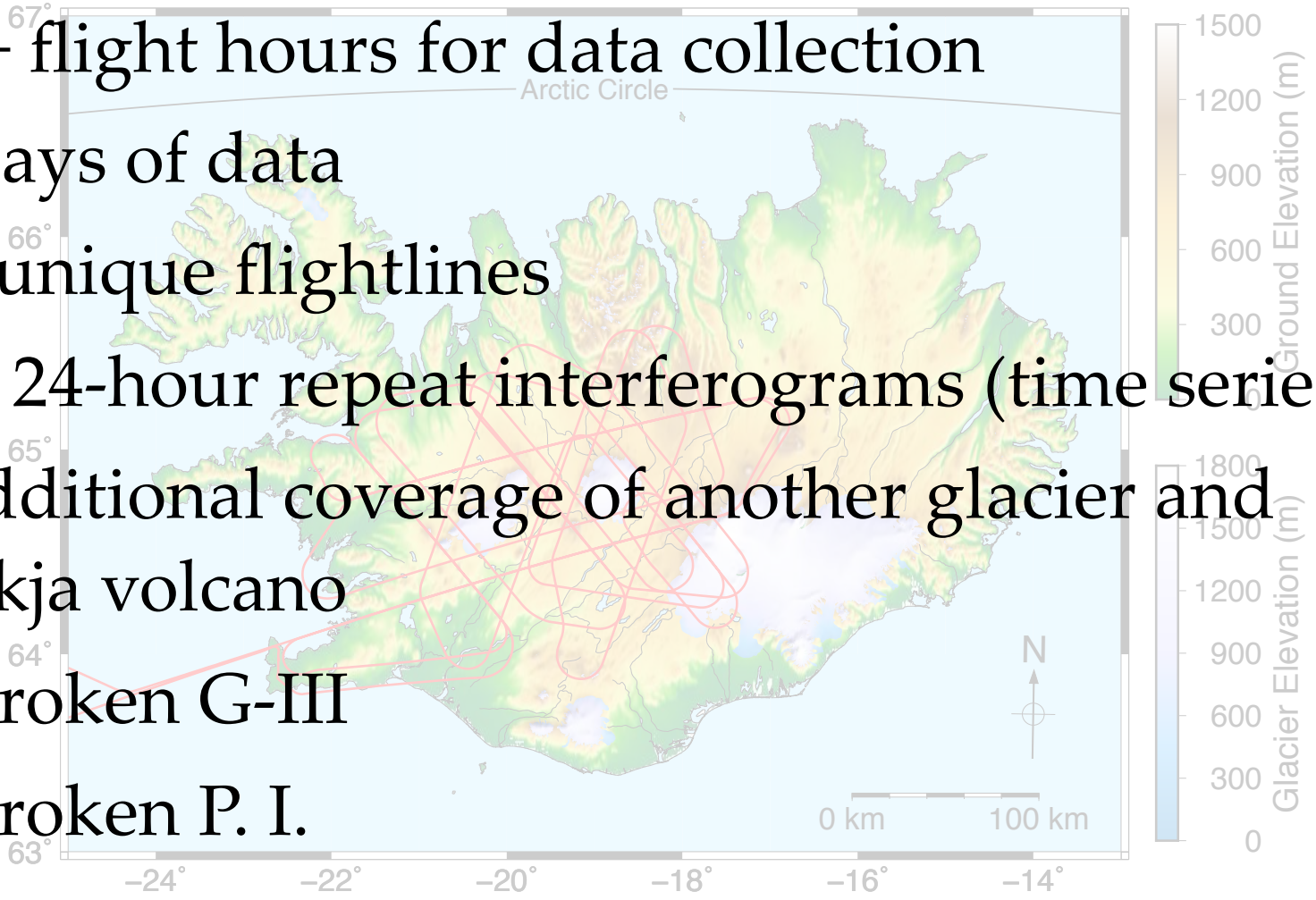


Iceland campaign 2012

- 40+ flight hours for data collection
- 7 days of data
- 15 unique flightlines
- 4 x 24-hour repeat interferograms (time series)
- Additional coverage of another glacier and Askja volcano
- 1 broken G-III
- 1 broken P. I.



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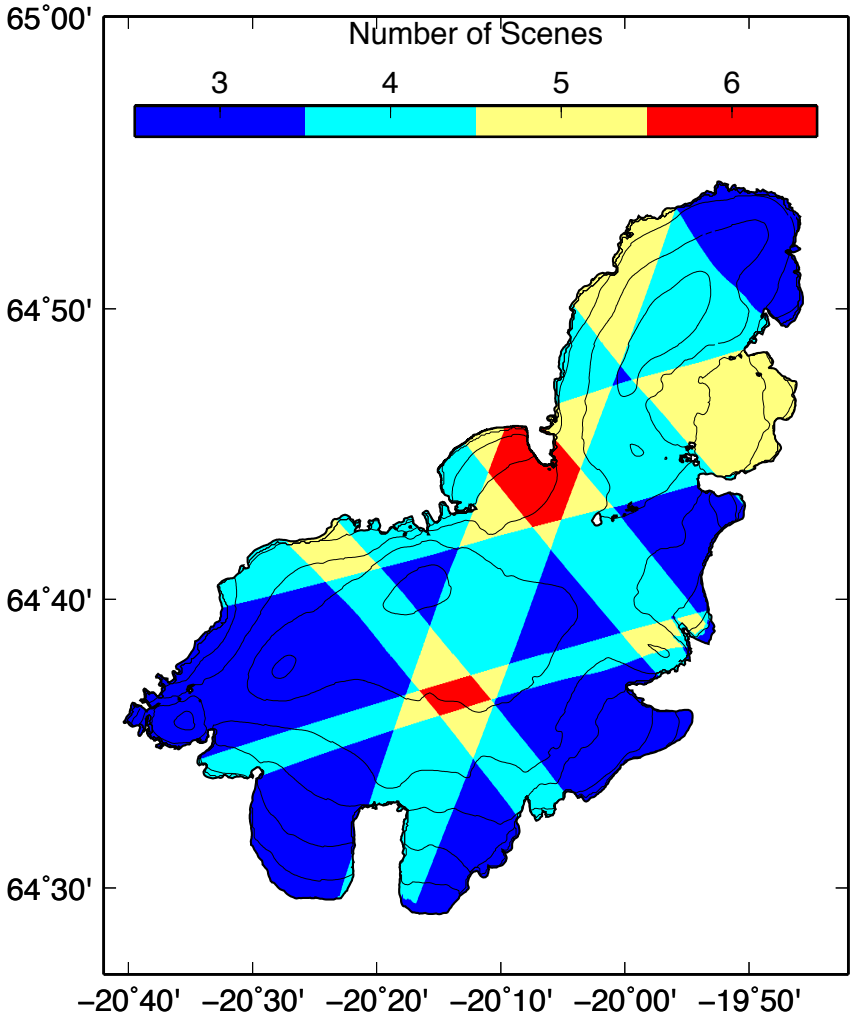
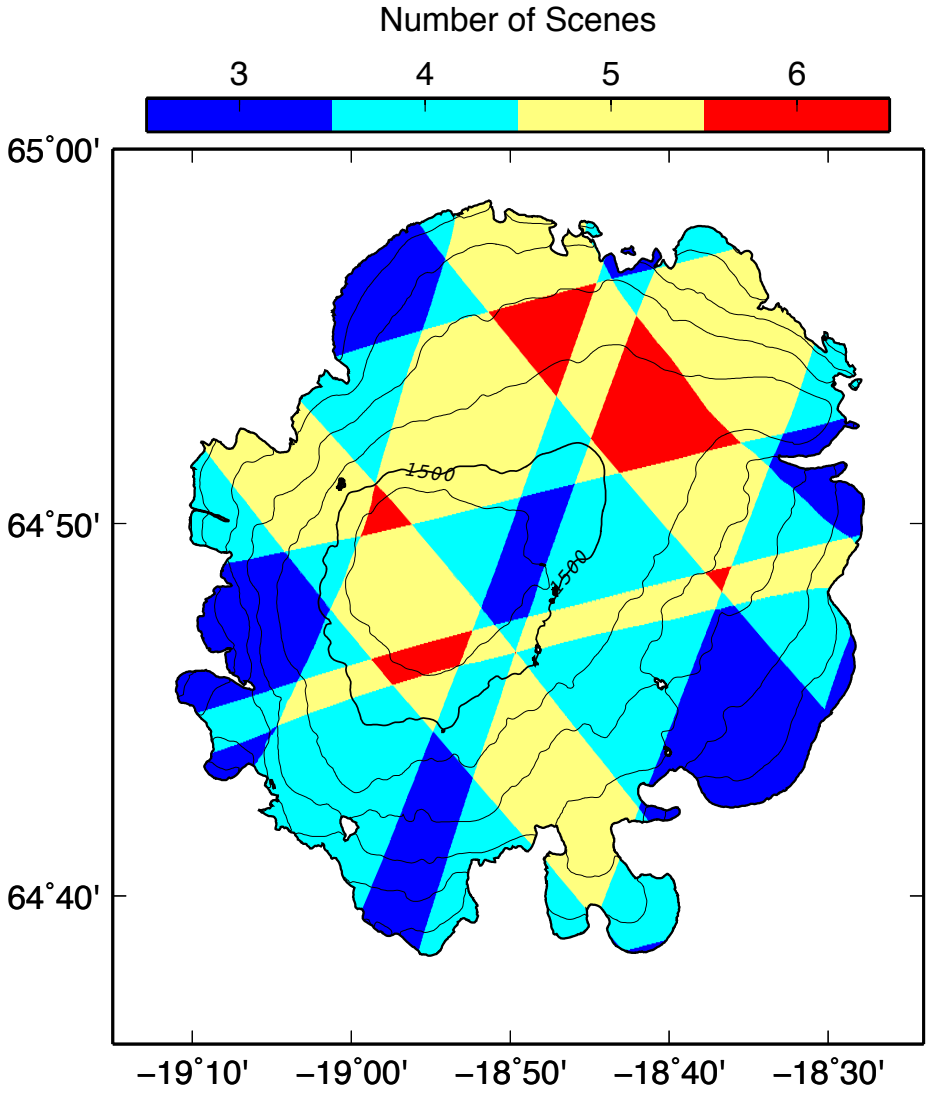
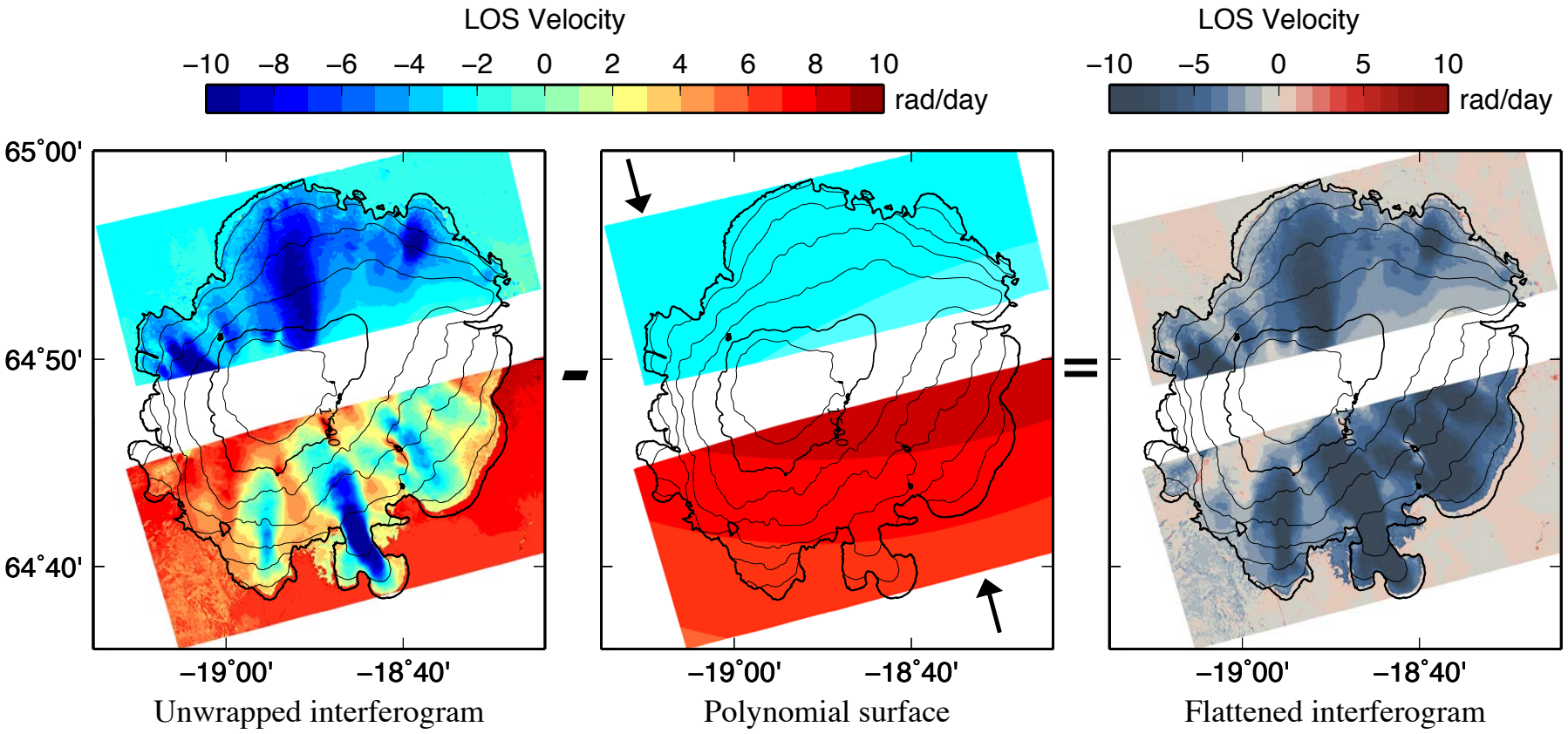
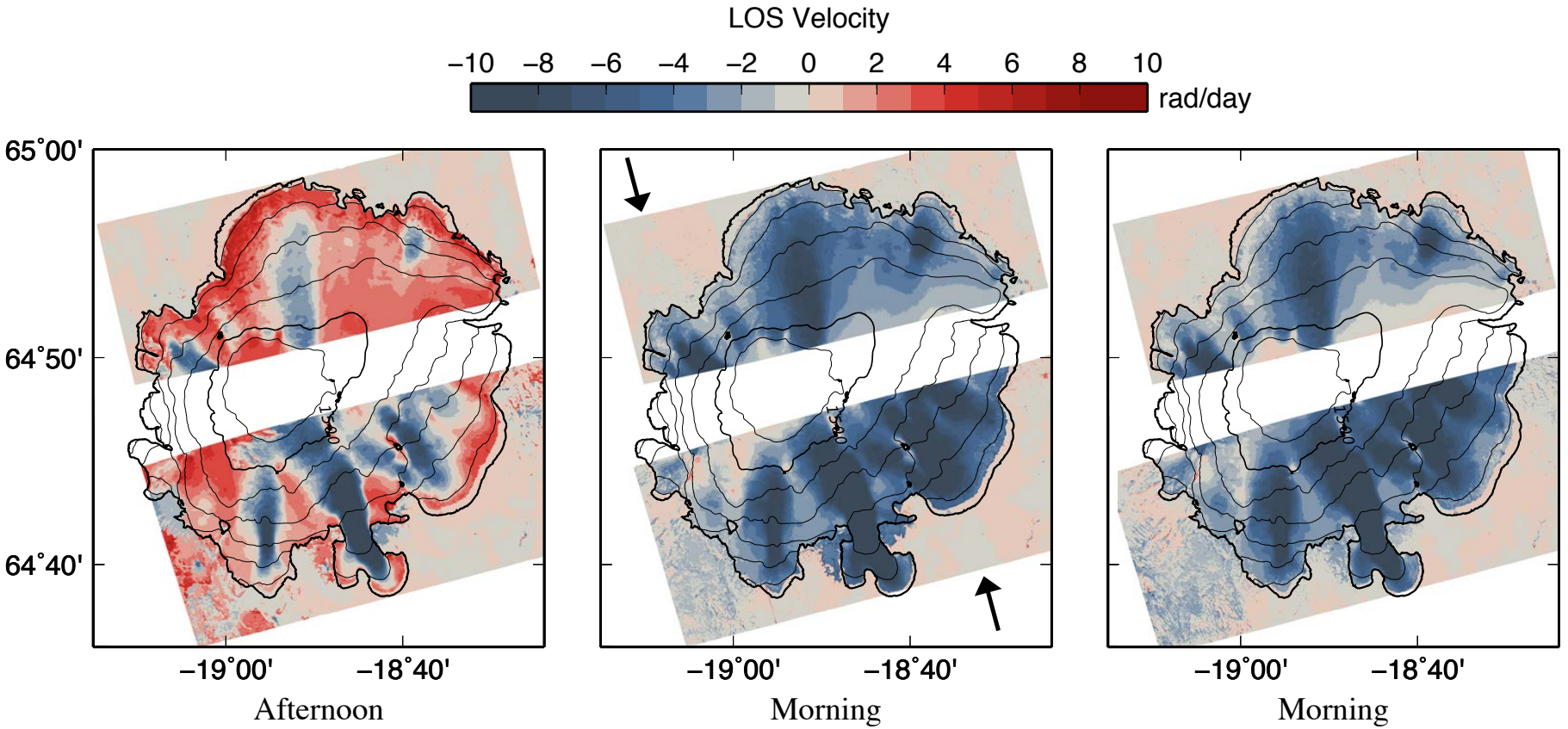




Post processing



Influence of moisture



- Background phase differs in sign between afternoon (wettest) and morning (driest) acquisitions
- Baseline errors and SNR cannot account for phase shift

Inferring the velocity field

InSAR scalar phase:

$$\phi_i^{(x)} = \hat{\boldsymbol{\ell}}_i^{(x)} \cdot \mathbf{v}^{(x)}$$

Multiple observations

$$\boldsymbol{\Phi}^{(x)} = \mathbf{G}^{(x)} \bar{\mathbf{v}}^{(x)}$$

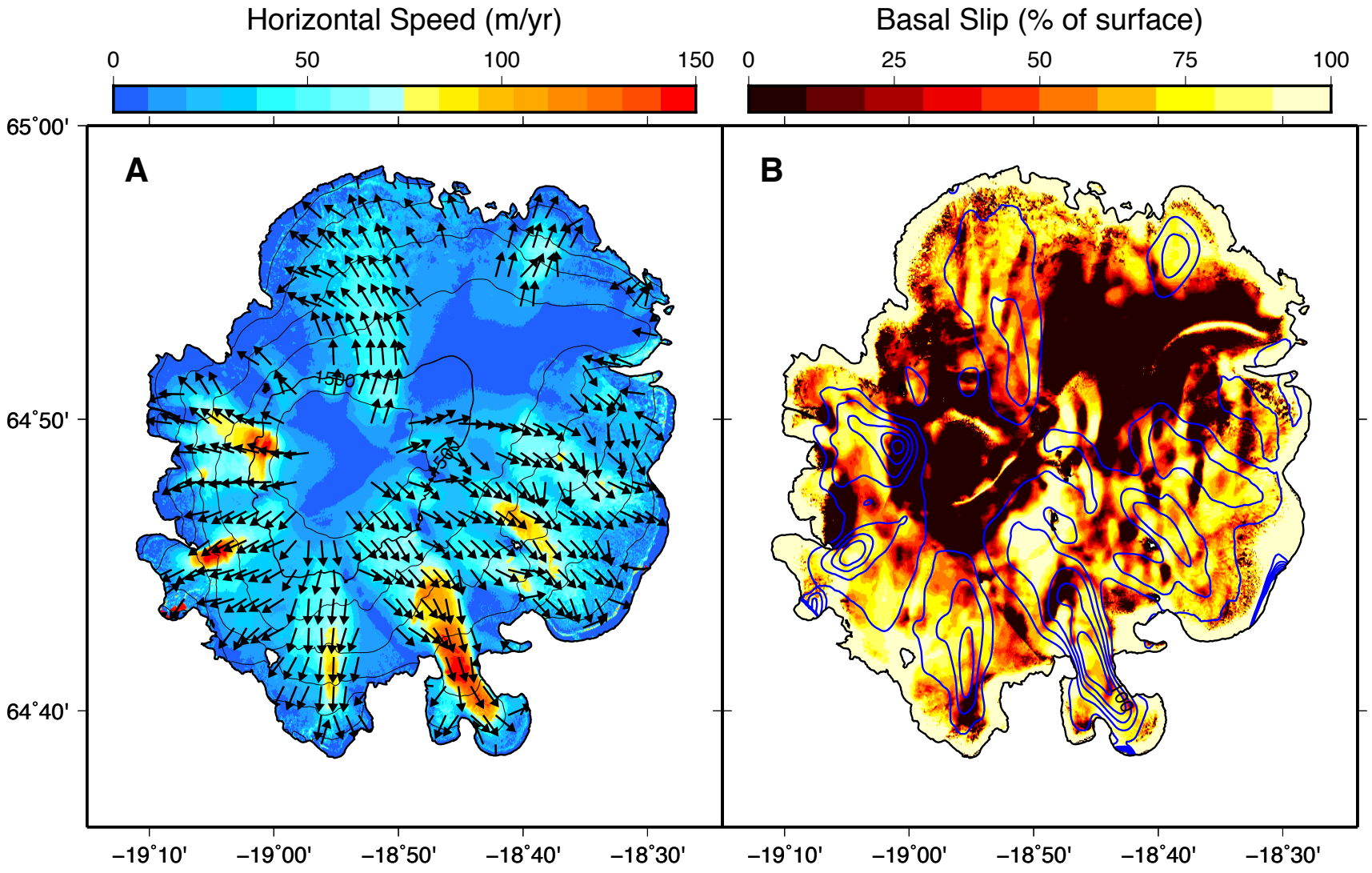
$$\tilde{\mathbf{m}} = \left(\mathbf{G}^T \mathbf{C}_\phi{}^{-1} \mathbf{G}\right)^{-1} \mathbf{G}^T \mathbf{C}_\phi{}^{-1} \boldsymbol{\Phi}$$

$$C_{\phi_{ij}} = \sigma_{\phi_i}^2 \delta_{ij}$$

$$\sigma_{\phi_i}^2 = \frac{1}{2N_i} \frac{1 - |\gamma_i|^2}{|\gamma_i|^2}$$

$$\gamma_i = \frac{\left\langle E_{pq}^a E_{rs}^{b*} \right\rangle_i}{\sqrt{\left\langle E_{pq}^a E_{pq}^{a*} \right\rangle \left\langle E_{rs}^b E_{rs}^{b*} \right\rangle}} \qquad 0 \le |\gamma_i| \le 1$$

Surface velocity field



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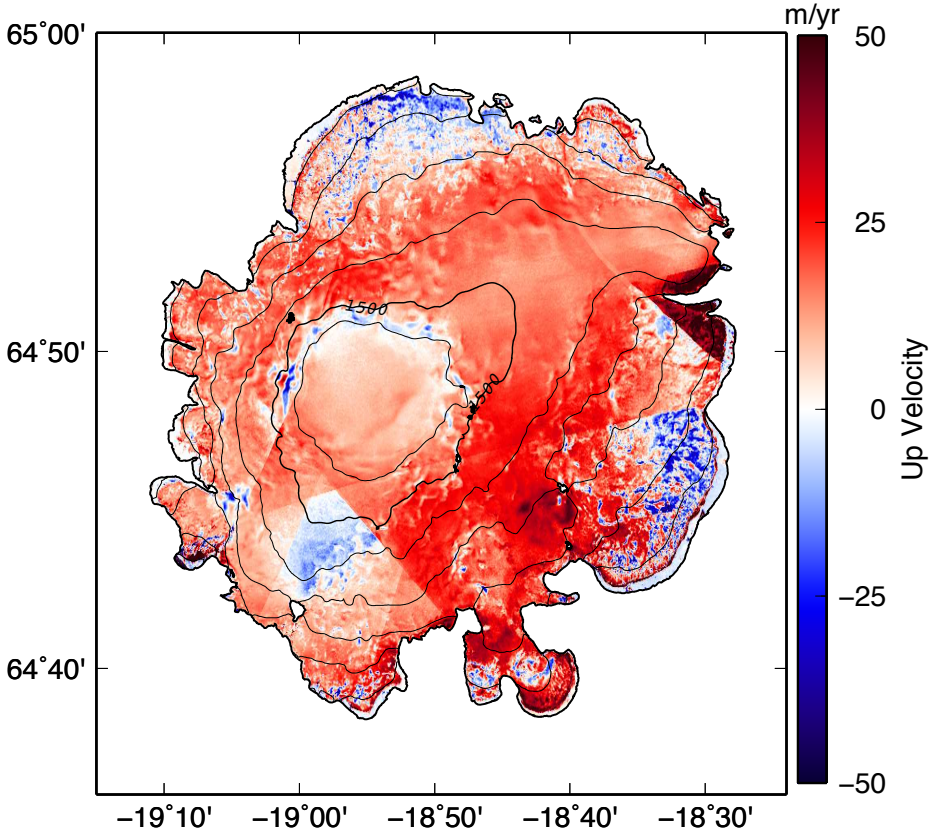

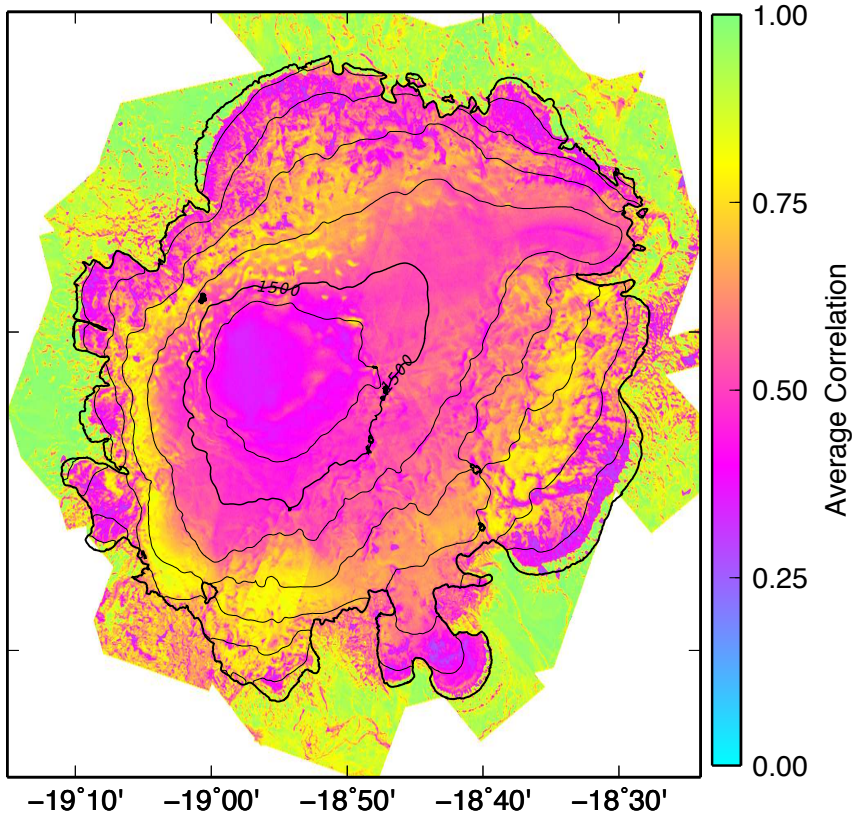

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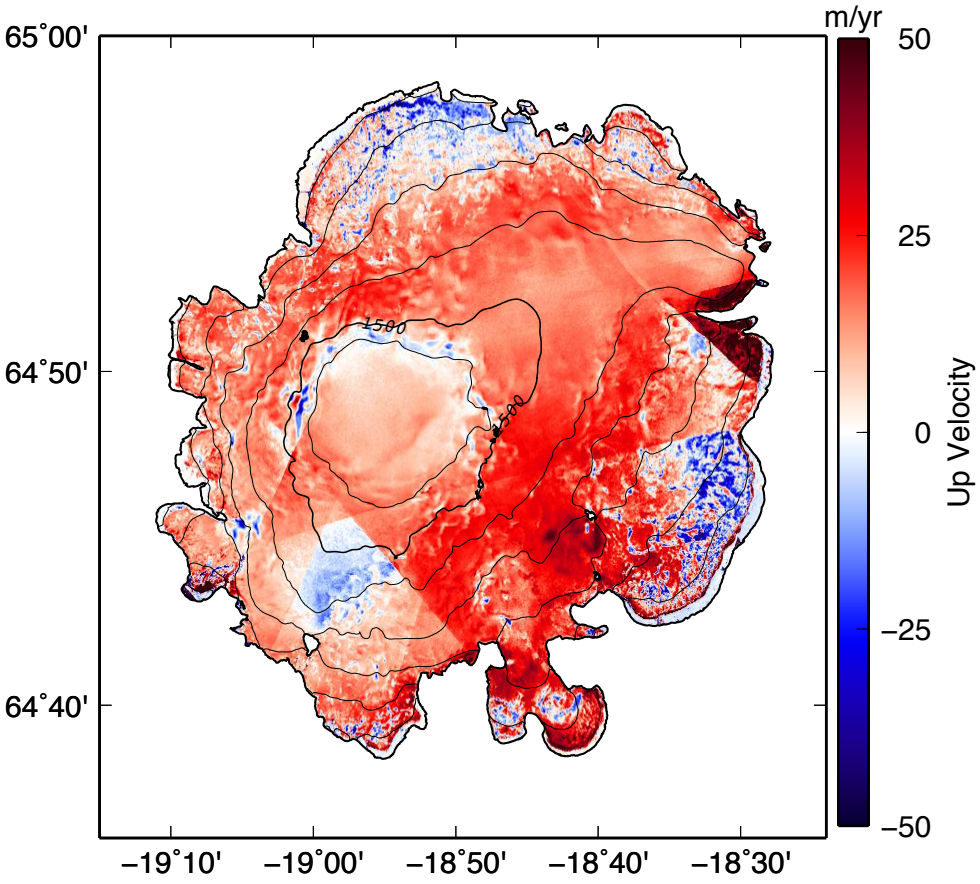

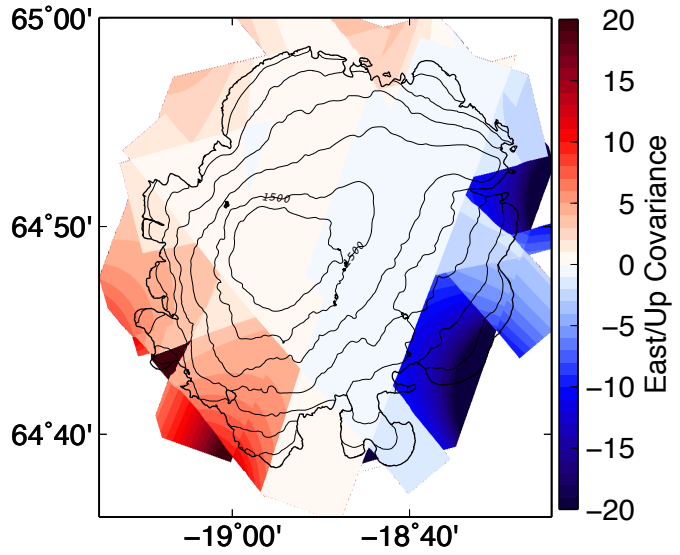

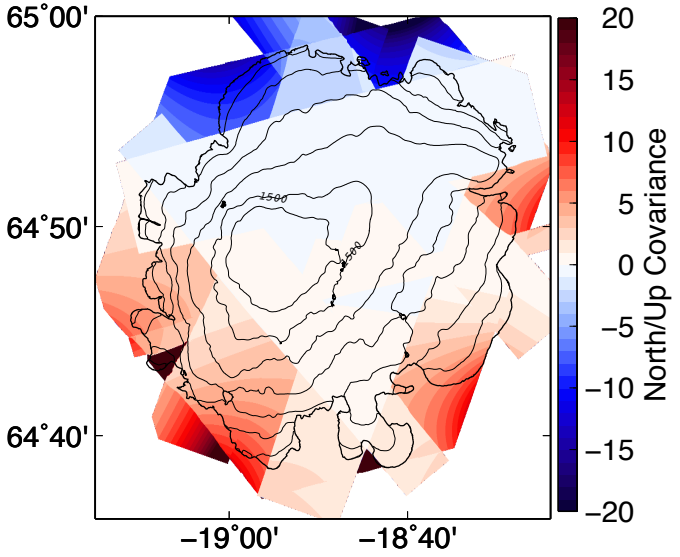

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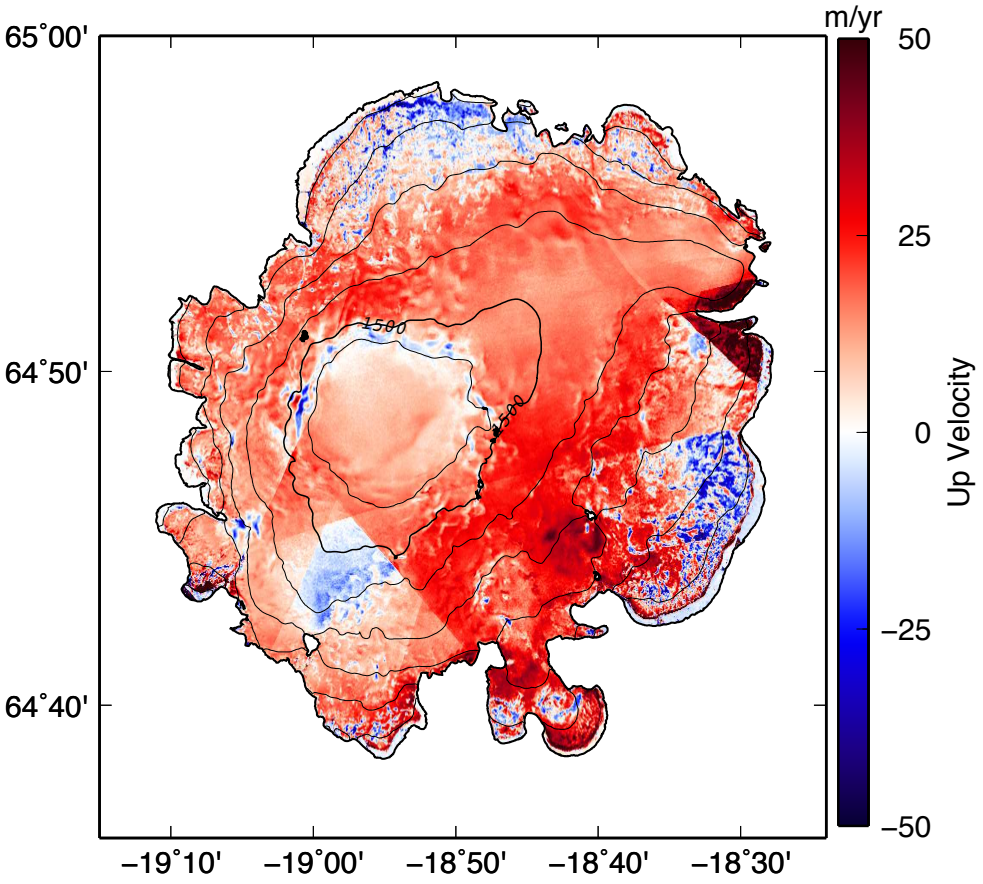

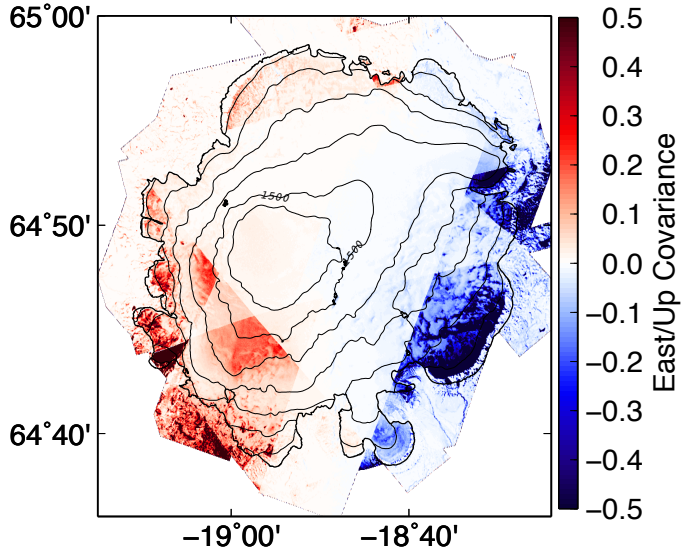

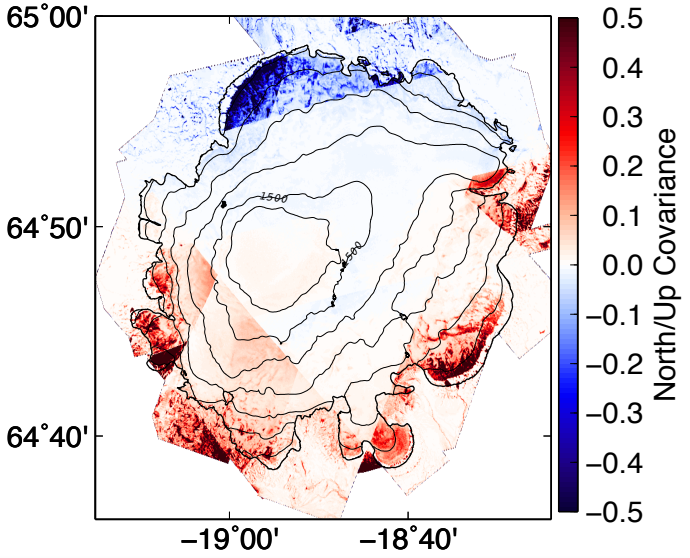

Summary

- Goal: Study the basal physics of glaciers
- Employ UAVSAR RPI
- 3 or more LOS → 3D velocity field
- Geometric and correlation constraints
- Future work: Use 3D velocity fields as boundary conditions in ice flow models
- Future deployment to Iceland in Feb. 2014

Questions?

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U. of Iceland Earth Sciences Department