GNSS-Reflectometry-Based Mapping of Antarctic Ice Shelf Surface Characteristics

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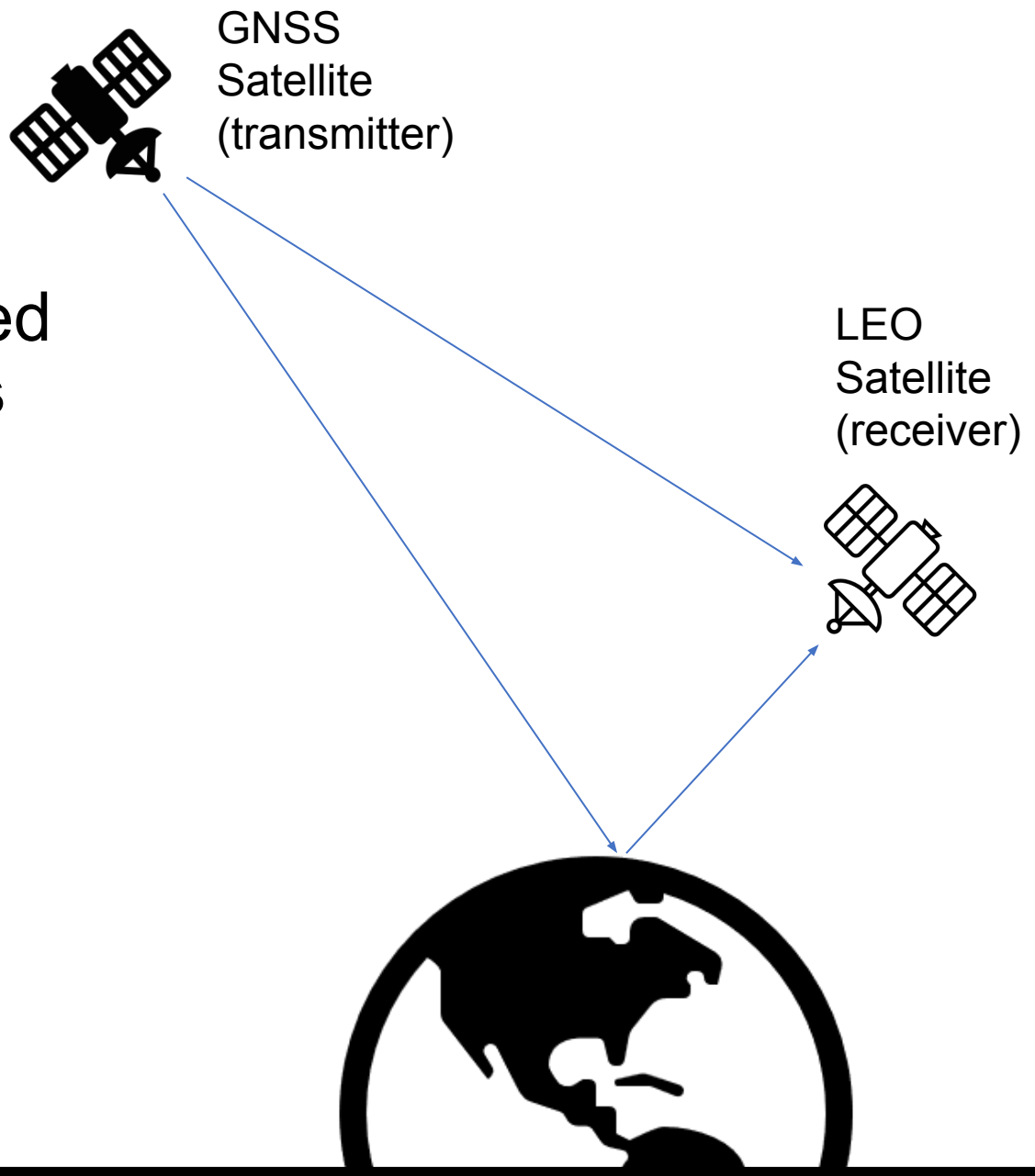
Outline

GNSS-R **signal coherence** is related to the presence of **surface features** and correlated with **surface roughness**.

1. Background: definitions, methodology, and dataset
2. Surface features
3. Surface roughness
4. Conclusions

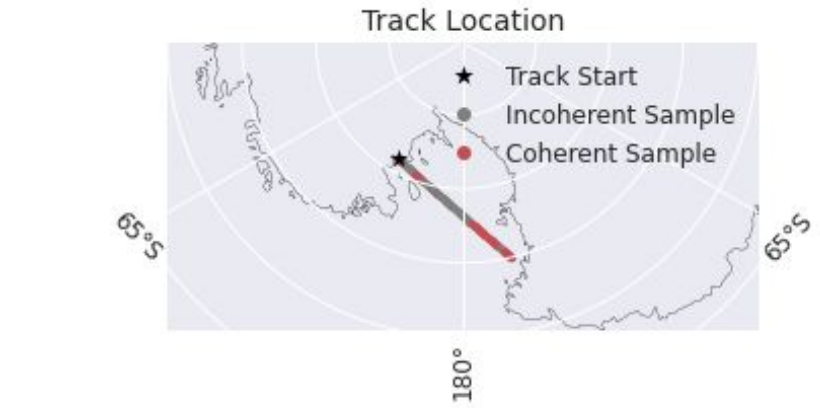


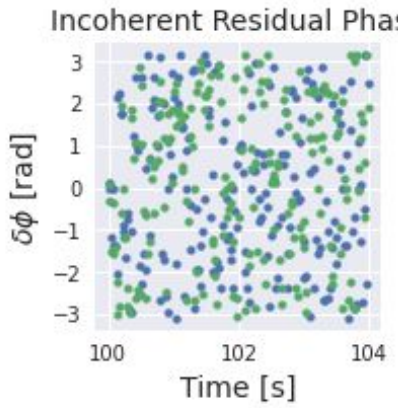
Signal Coherence

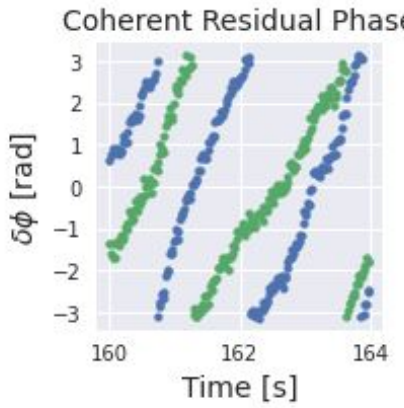
- Signal coherence is a measure of the degree to which the GNSS carrier phase is intact
- It depends on surface scattering behavior (surface roughness, wavelength, elevation angle, etc.)
- It can be used to distinguish different surface types
  - Inland water body extent
  - Sea ice extent
  - Sea ice age

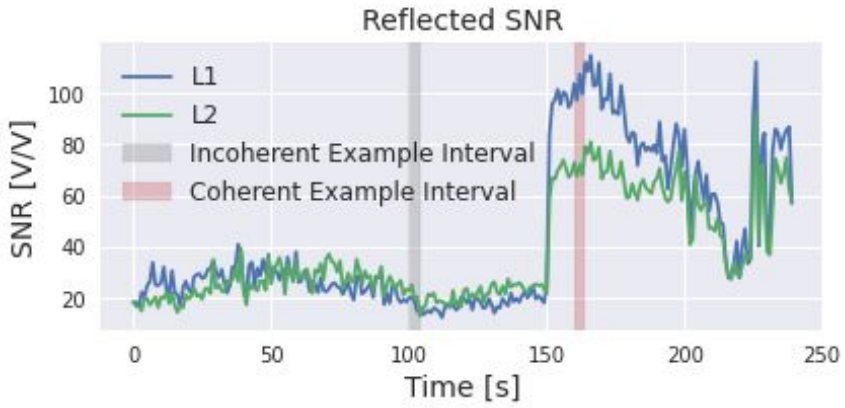
Coherence Quantification: Circular Statistics

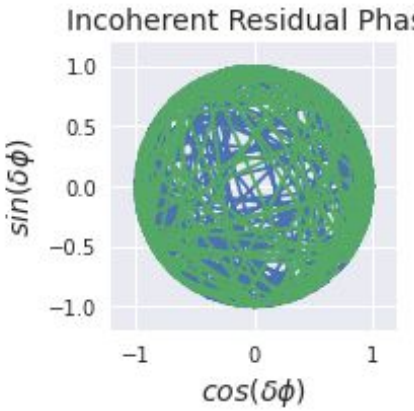
Example track from 10/31/2021, Ross Ice Shelf

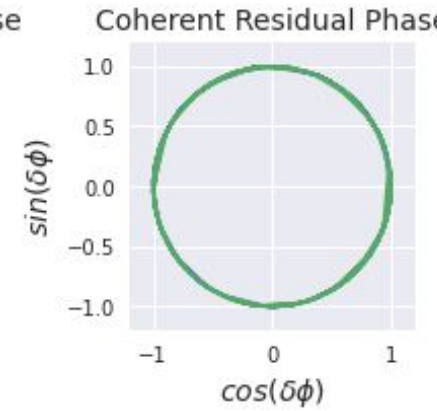


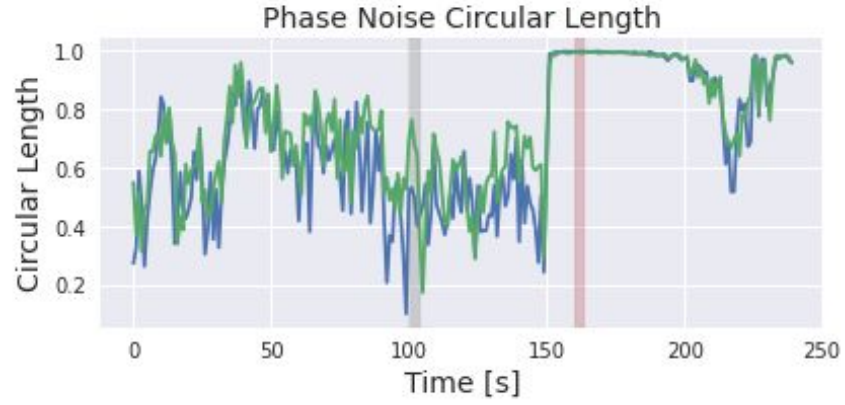


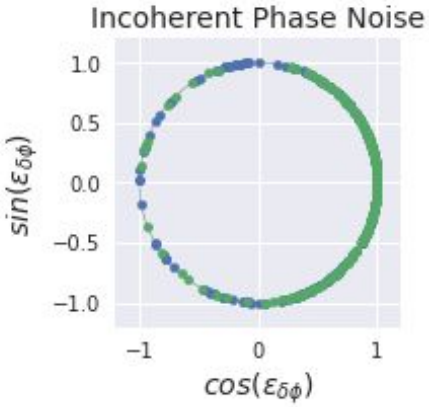


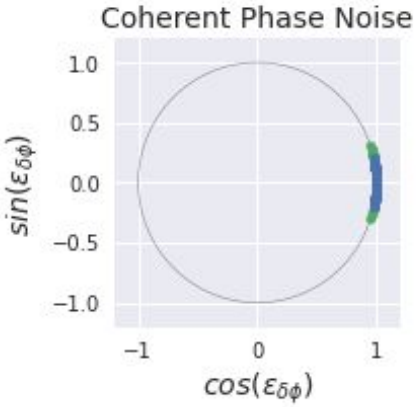








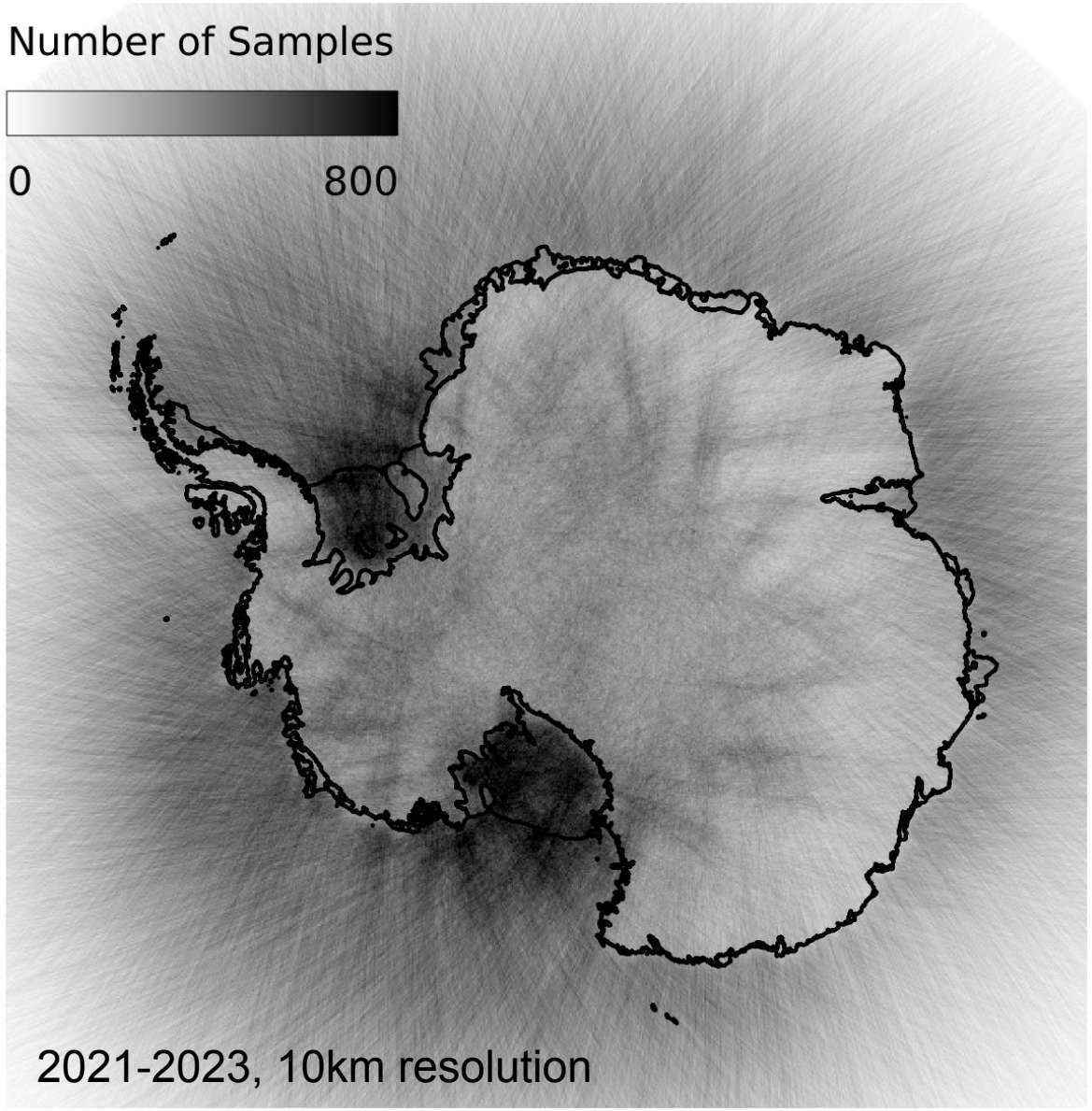




C. Roesler, Y. J. Morton, Y. Wang, and R. S. Nerem, “Coherent GNSS-Reflections Characterization Over Ocean and Sea Ice Based on Spire Global Cubesat Data,” IEEE TGRS, 2022

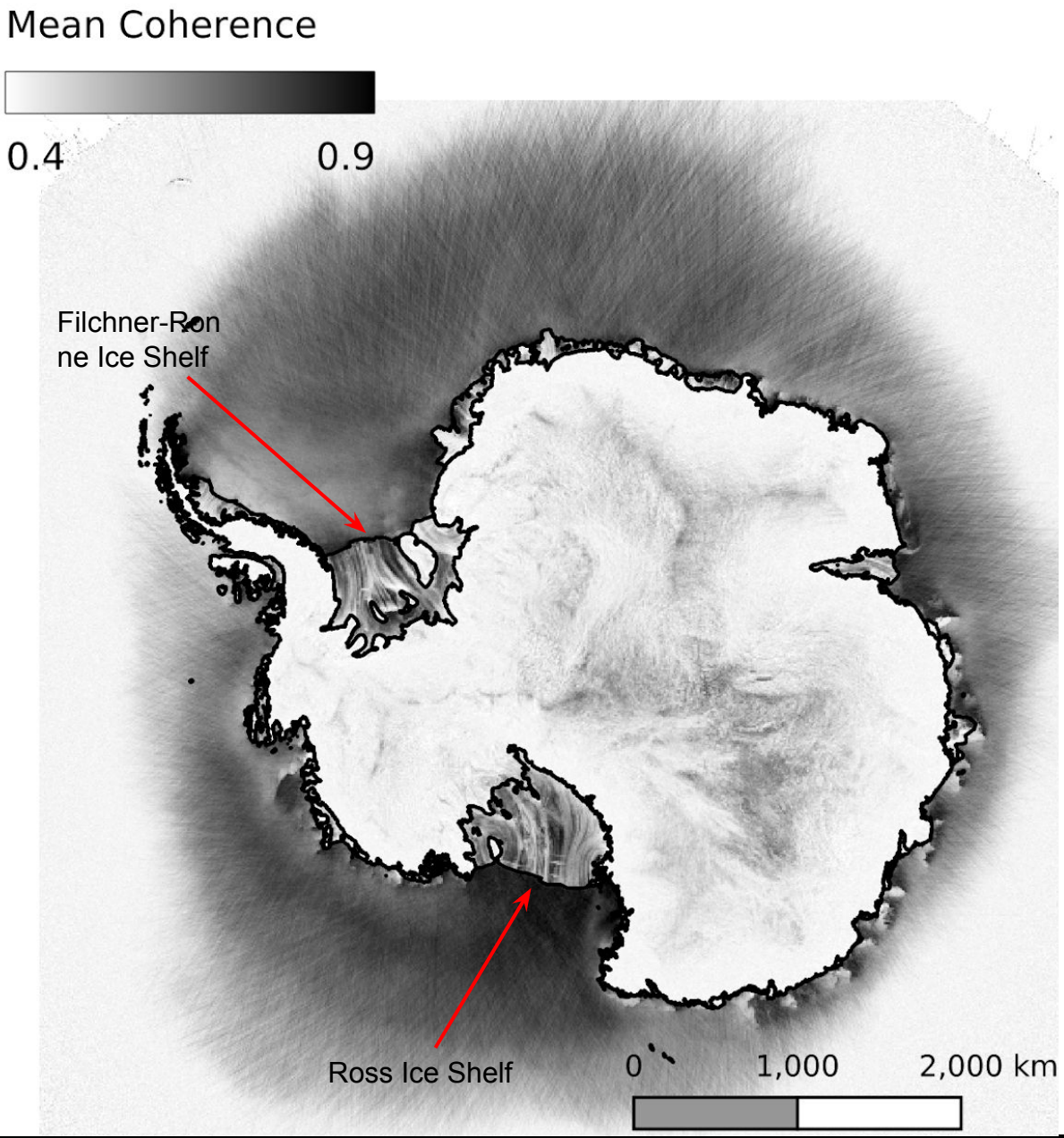
Dataset

- Spire Global Inc. commercial GNSS-R data, L1B Grazing Angle Reflectometry dataset
- Data collected in LEO at 5-30˚ elevation angle using adapted RHCP radio occultation antennas
- 924,843 total tracks collected between 2021 and 2023 in Antarctic region, 493,038 are used here



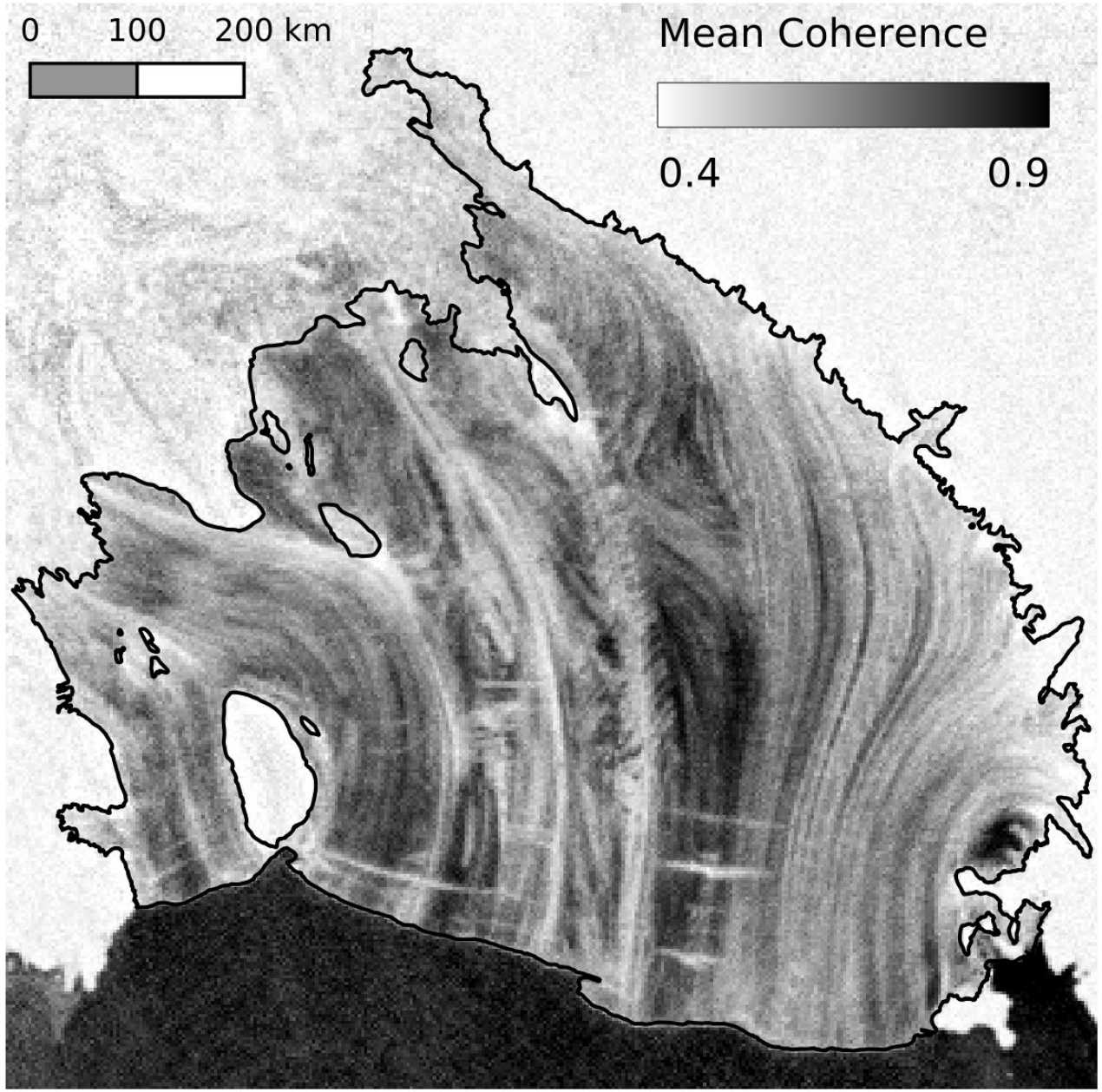
Signal Coherence Map: Antarctica

- Computed L1 and L2 phase noise circular length for ~500,000 tracks, saved maximum value (L1 or L2)
- Established 10km grid, took mean coherence value in each grid cell
- Observations:
  - Sea ice extent
  - Interesting coherence patterns in ice sheet interior
  - Detailed features visible in ice shelves



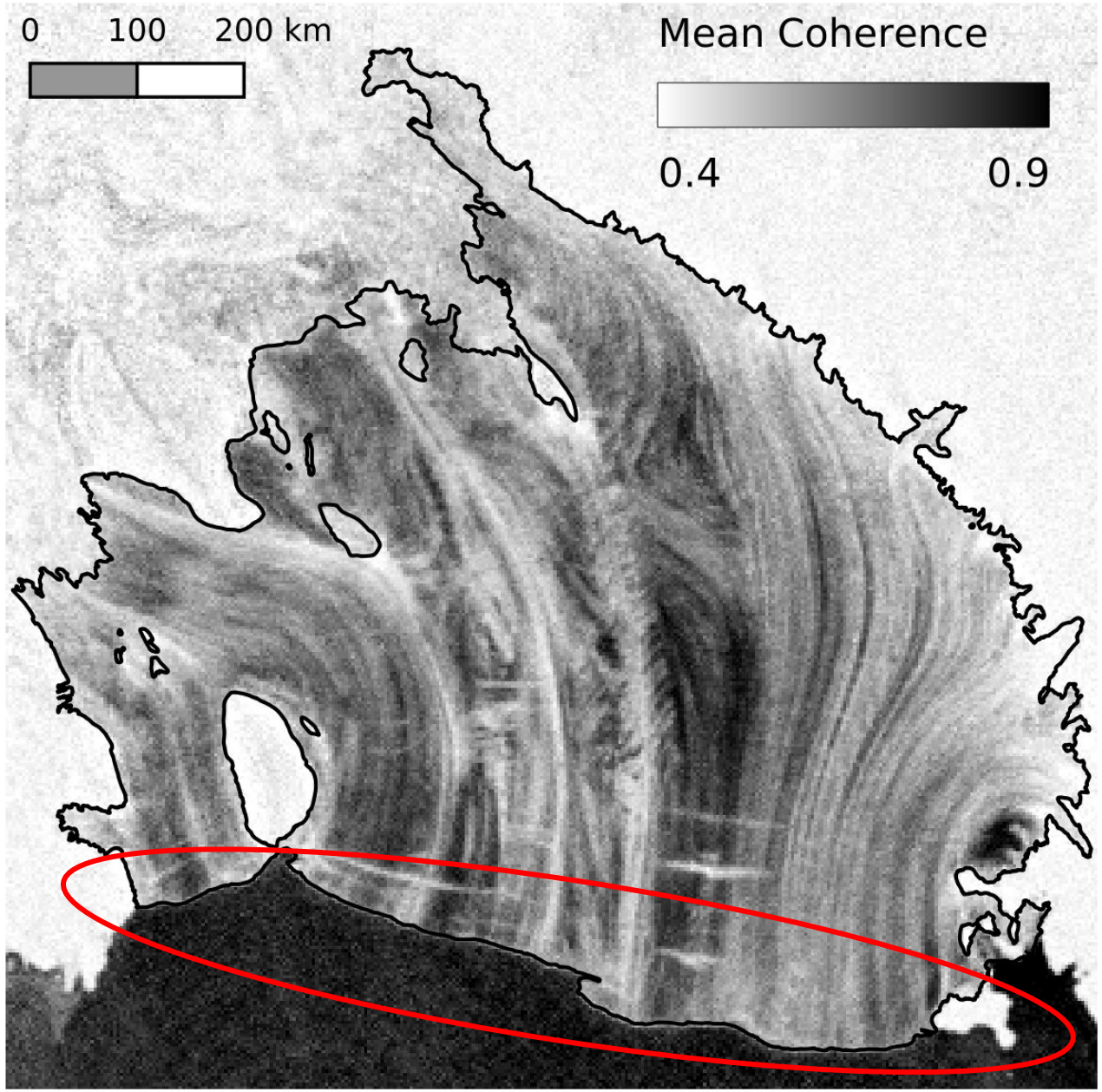
Ross Ice Shelf

Gridded mean phase noise circular length for 2021-2023 data, 3km resolution



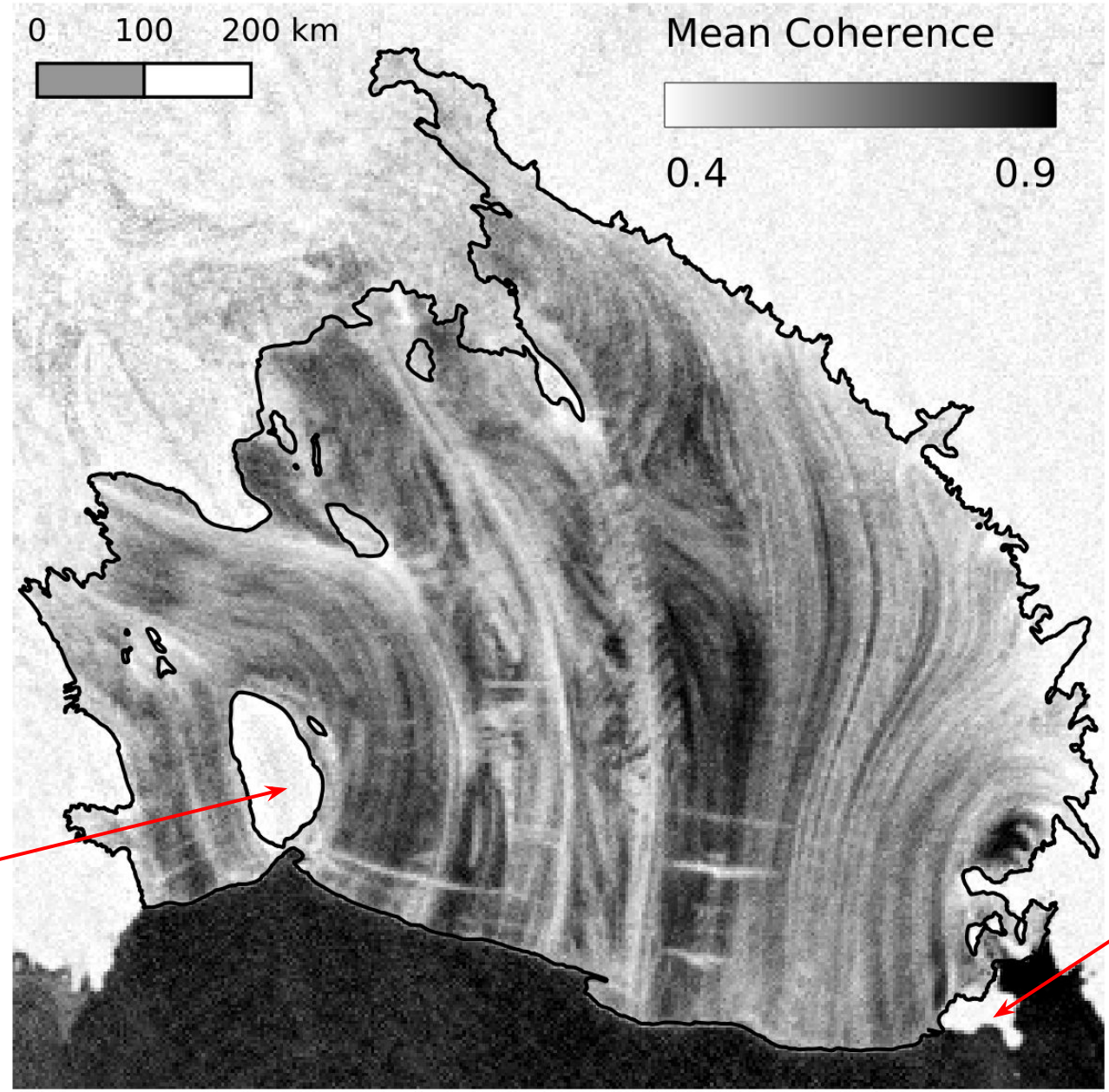
Ross Ice Shelf

- Ross Ice Shelf/Ross Sea boundary



Ross Ice Shelf

- Ross Ice Shelf/Ross Sea boundary
- Lack of coherence at Roosevelt Island, Ross Island, outside of ice shelf



Ross Ice Shelf

- Ross Ice Shelf/Ross Sea boundary
- Lack of coherence at Roosevelt Island, Ross Island, outside of ice shelf
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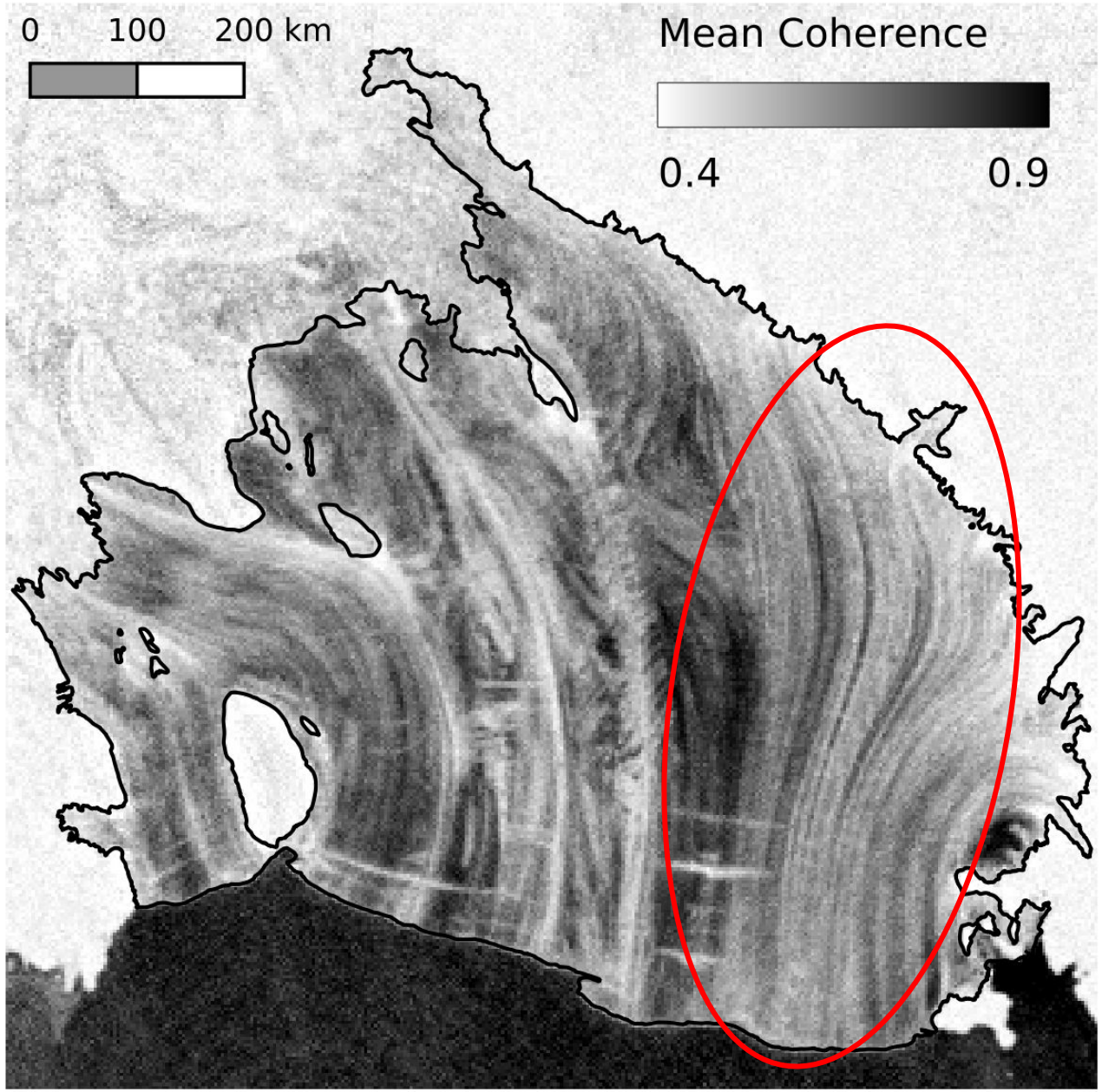
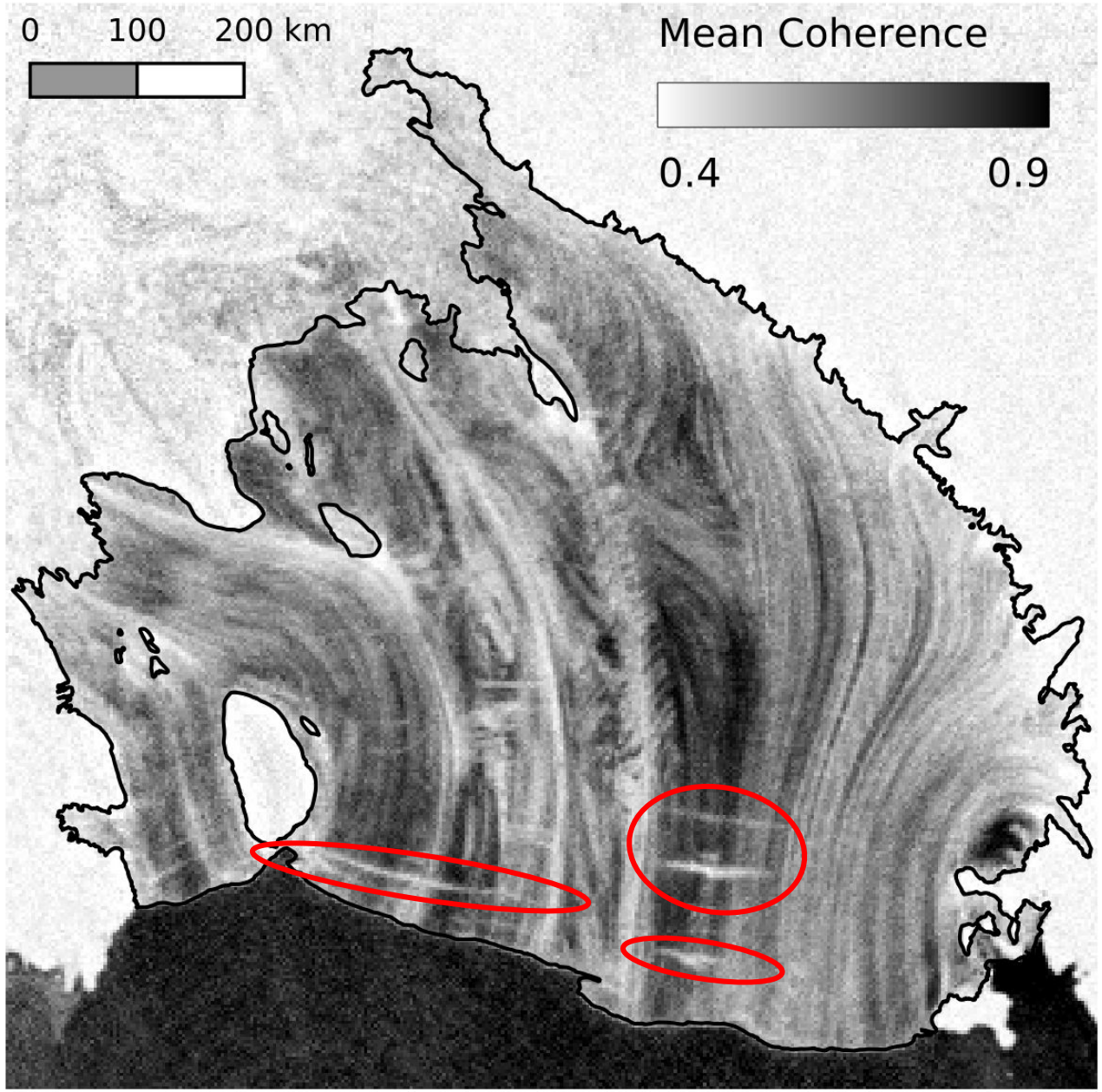
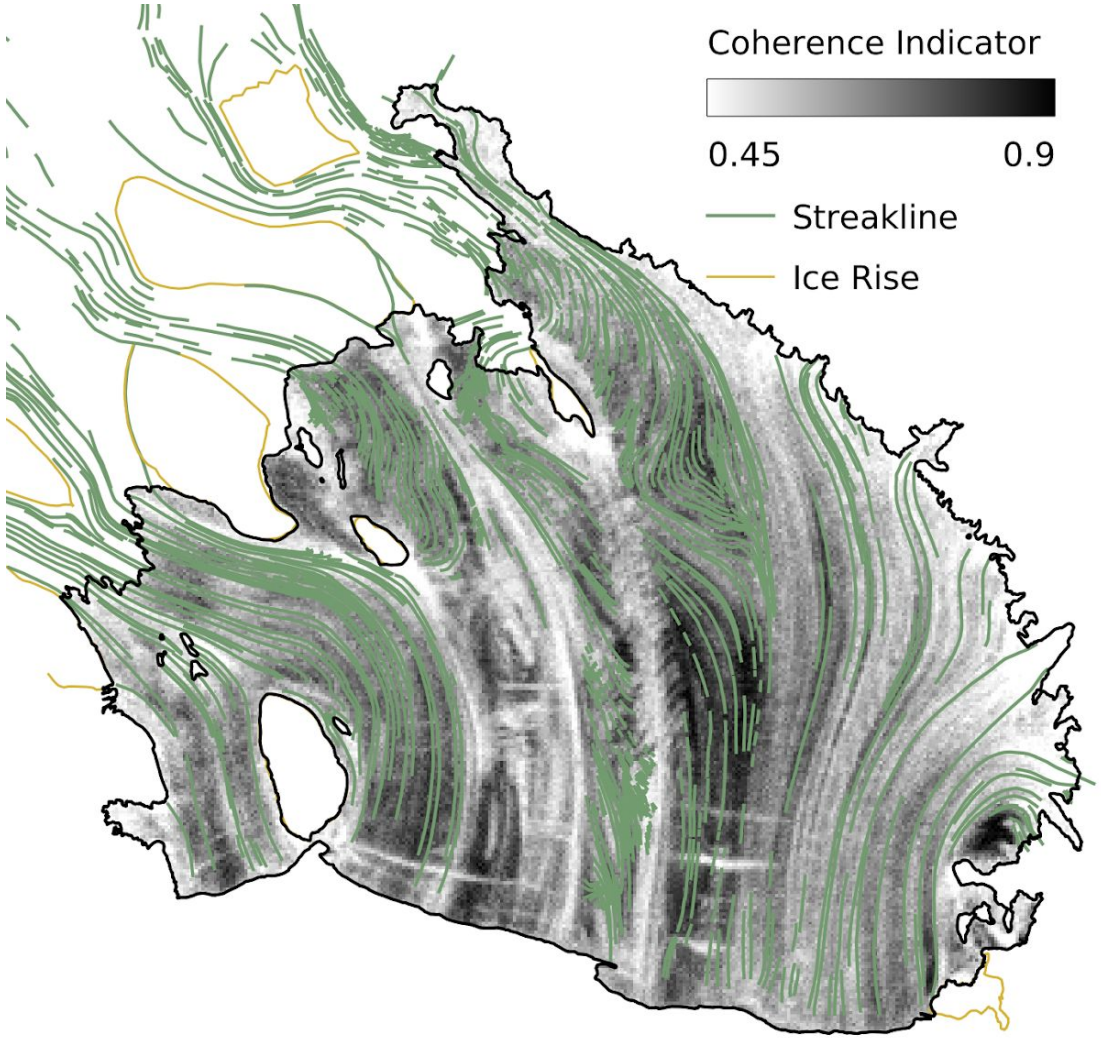


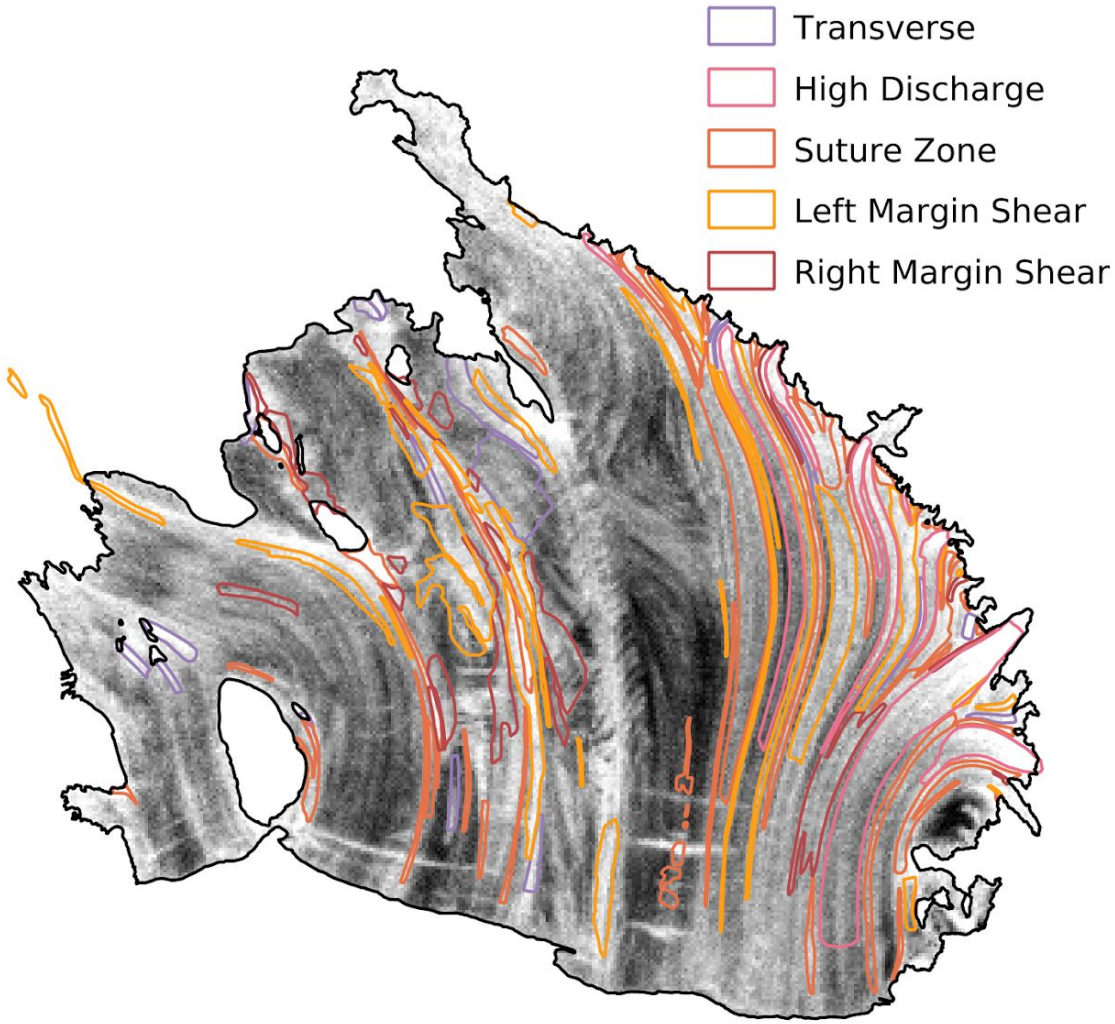
Ross Ice Shelf

- Ross Ice Shelf/Ross Sea boundary
- Lack of coherence at Roosevelt Island, Ross Island, outside of ice shelf
- Flow stripes (streaklines)
- Large open rifts



Ross Ice Shelf “Structural Provinces”





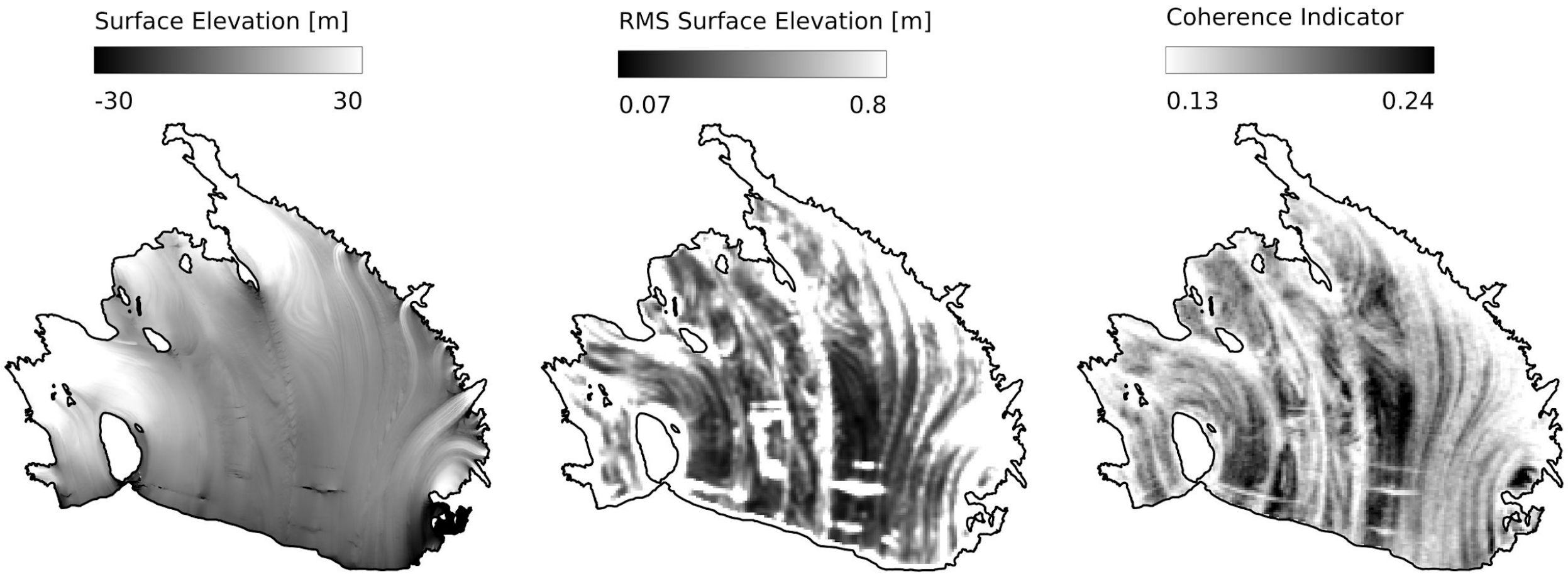
C. M. LeDoux, C. L. Hulbe, M. P. Forbes, T. A. Scambos, and K. Alley, “Structural Provinces of the Ross Ice Shelf, Antarctica,” Annals of Glaciology, 2017

Ross Ice Shelf Surface Roughness

- Reference Elevation Model of Antarctica (REMA) Digital Elevation Model (DEM) has 2m resolution
- Surface roughness dataset: standard deviation of REMA DEM using 5km grid size
- Calculated coherence at 5km resolution, regridded to match roughness dataset for comparison

I. Howat, et al., “The Reference Elevation Model of Antarctica - Mosaics, Version 2,”

Ross Ice Shelf Surface Roughness



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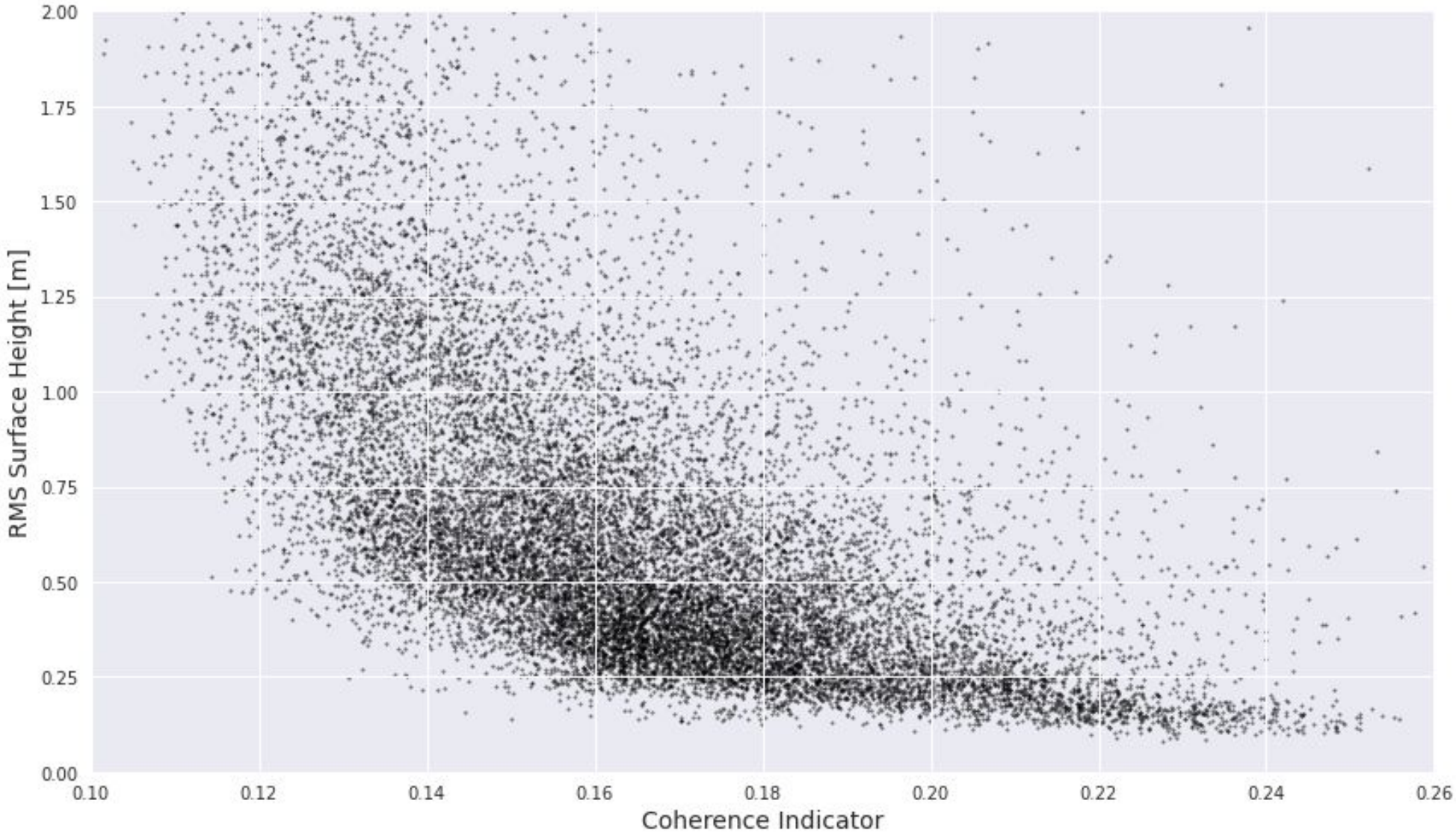

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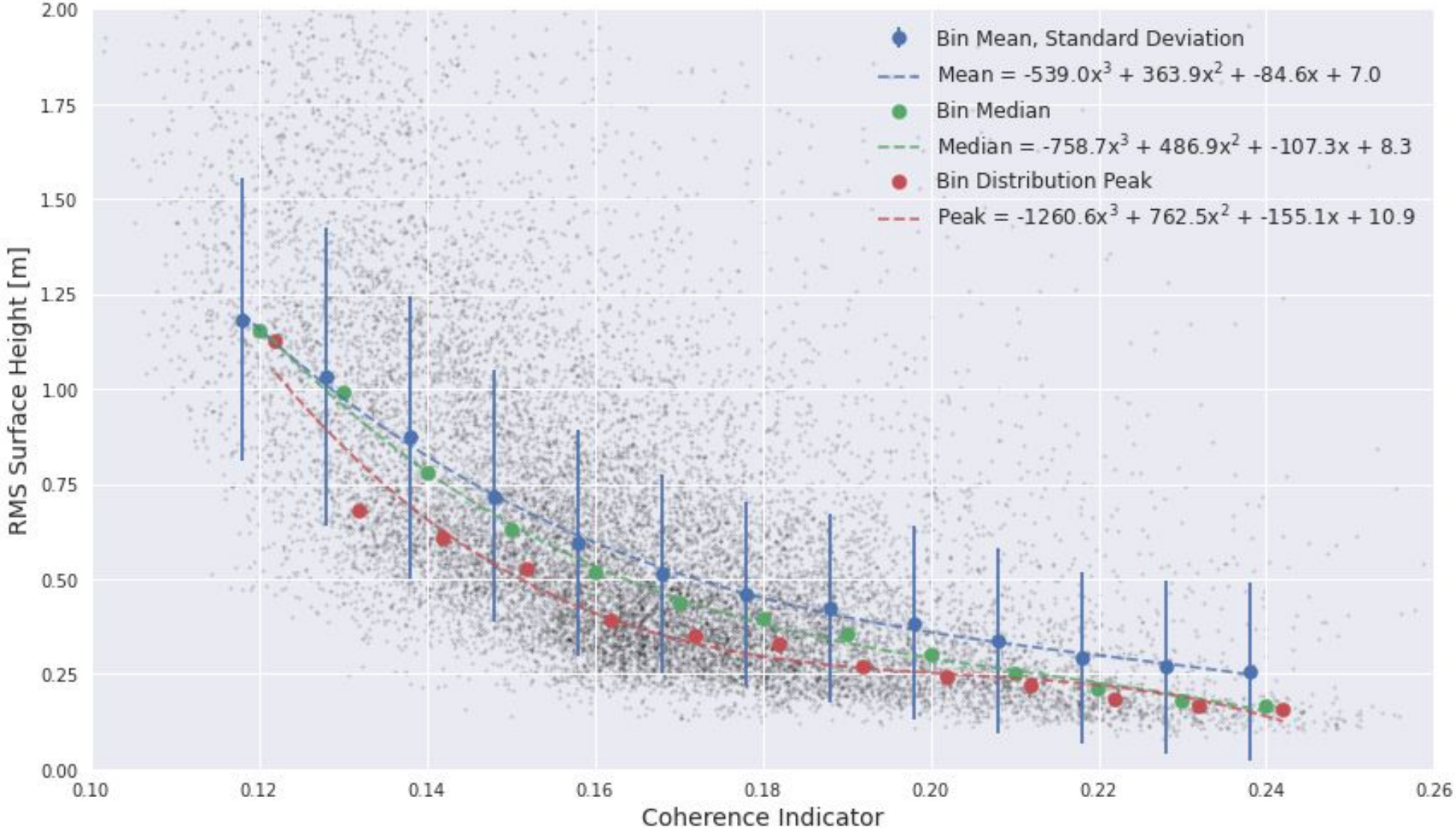
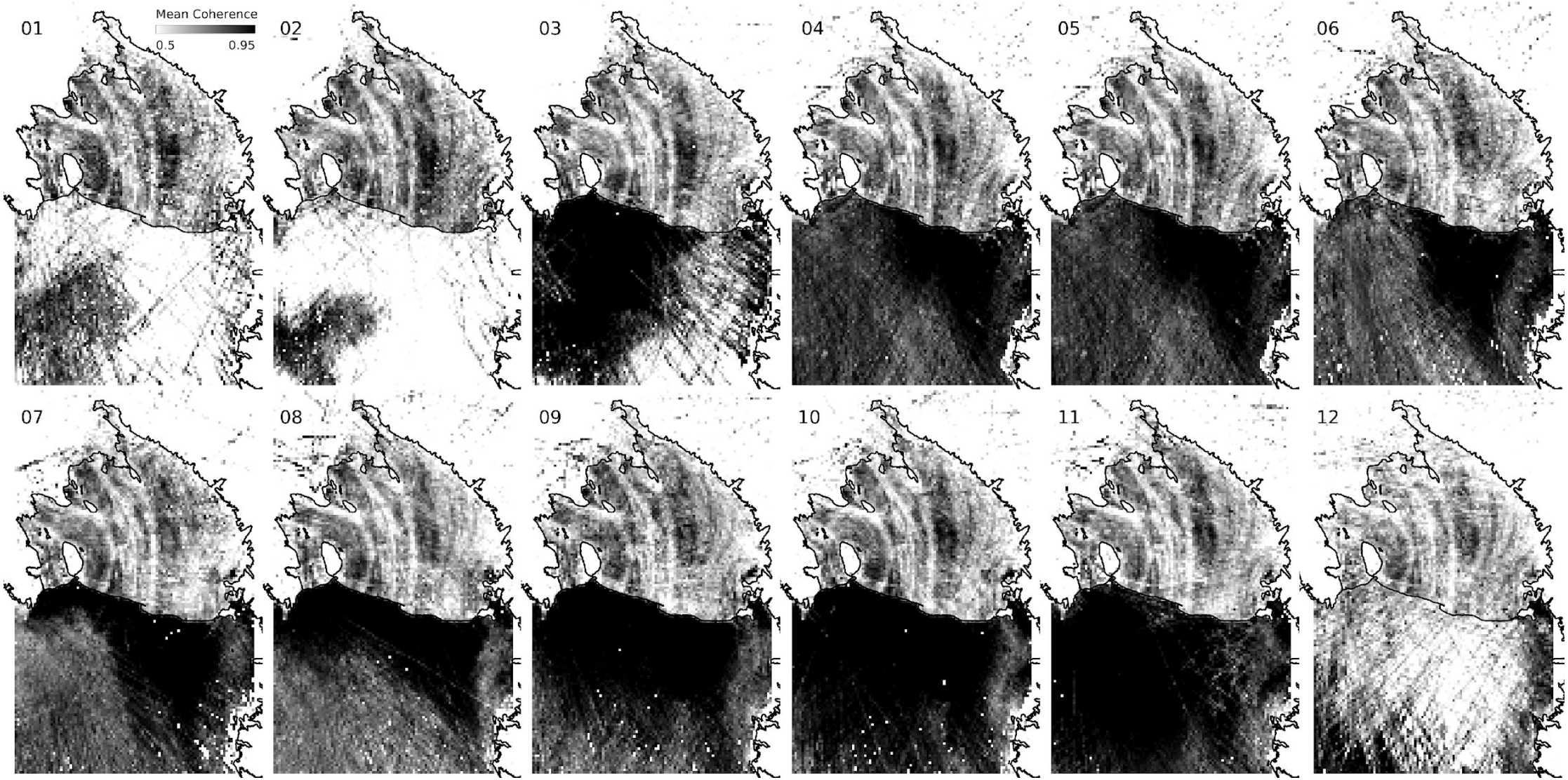


Ross Ice Shelf Monthly Coherence (2021)

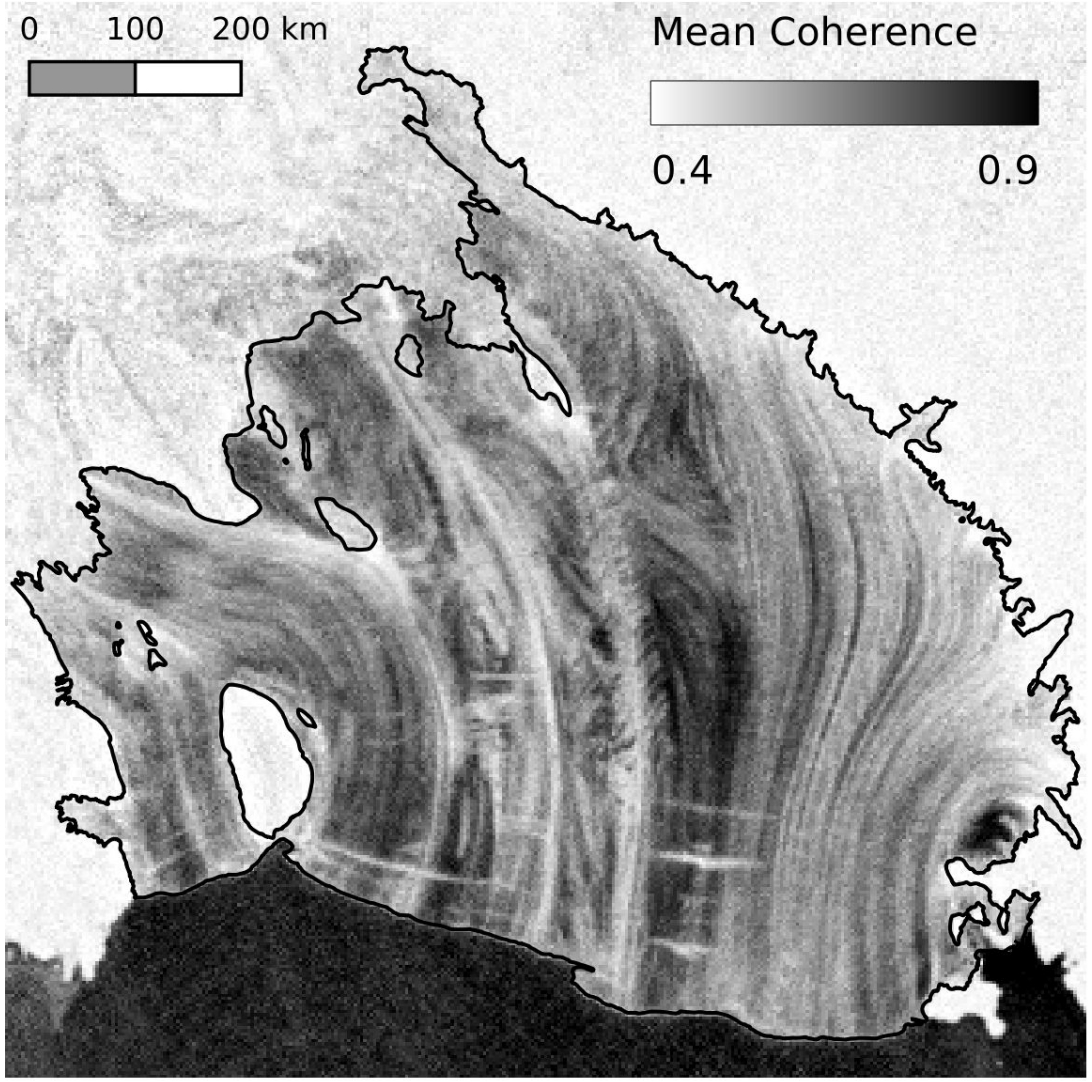


Conclusions

- Ice shelves cover 75% of the perimeter of the Antarctic coastline and play an important role in buttressing the ice sheet.
- Ice shelf surface roughness is related to stability and mass balance.
- L-band GNSS-R measurements can augment existing remote sensing data as we try to improve understanding of ice sheet and ice shelf mass balance and better predict sea level rise.

Questions?

Paper submitted to IEEE TGRS (Anderson, Wang, and Morton, “Relating GNSS Reflected Signal Coherence to Ice Shelf Surface Deformation and Roughness”)



Acknowledgements

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- NSF Graduate Research Fellowship Program
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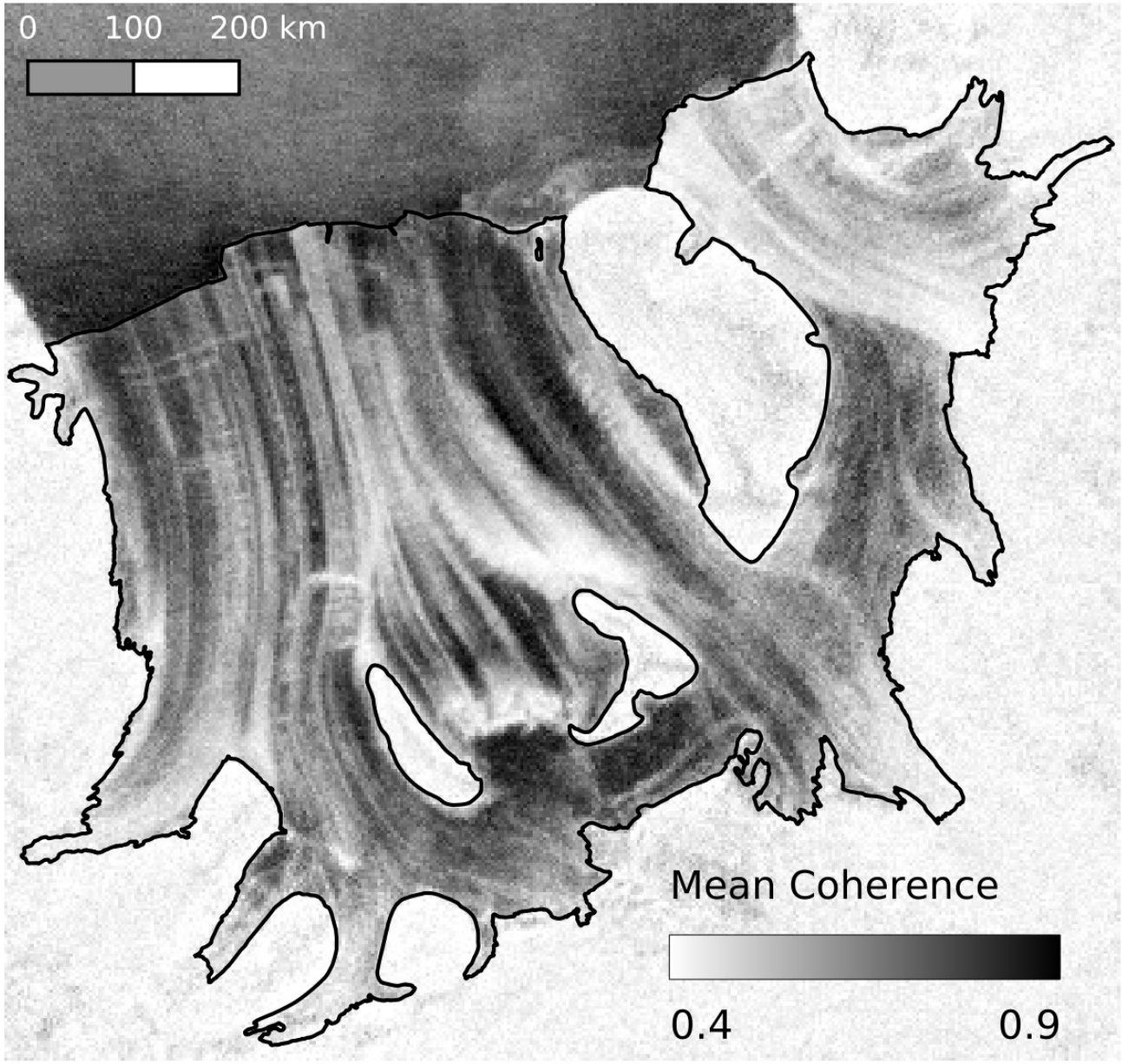
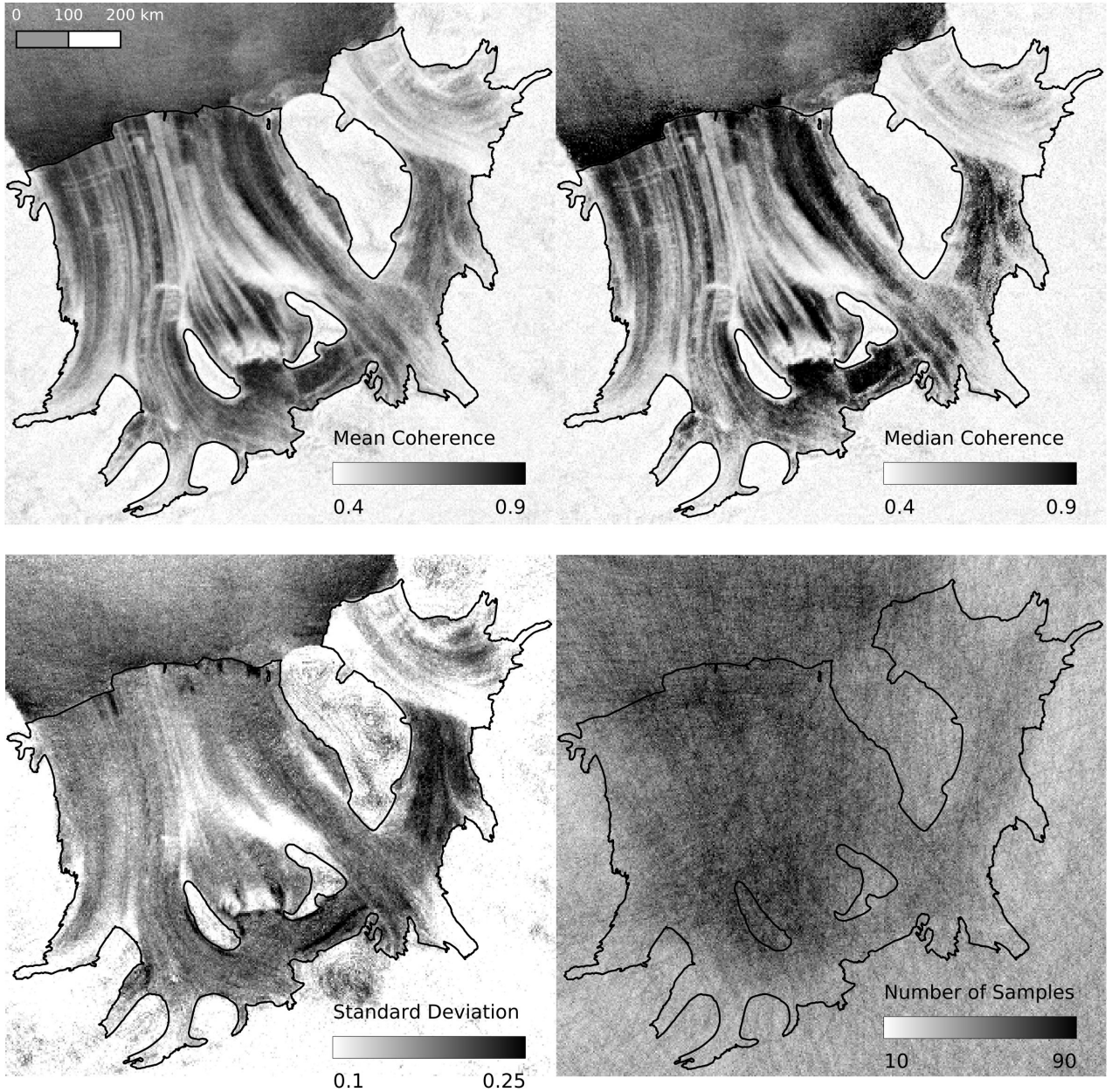
- NOAA-UCAR grant #SUBAWD005252

Extra Slides

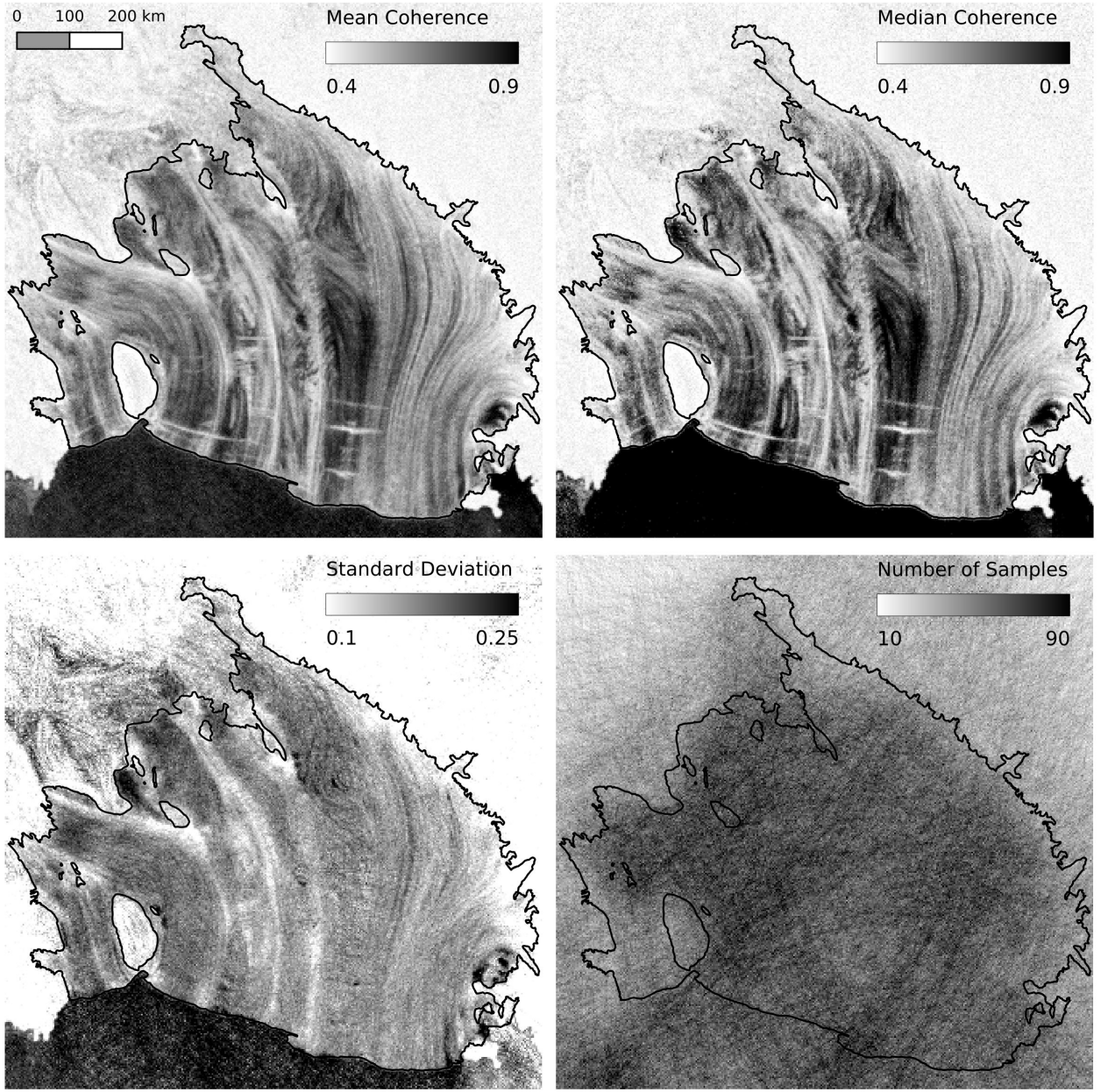
FRIS



FRIS


0 100 200 km
Mean Coherence
0.4 0.9
Median Coherence
0.4 0.9
Standard Deviation
0.1 0.25
Number of Samples
10 90

RIS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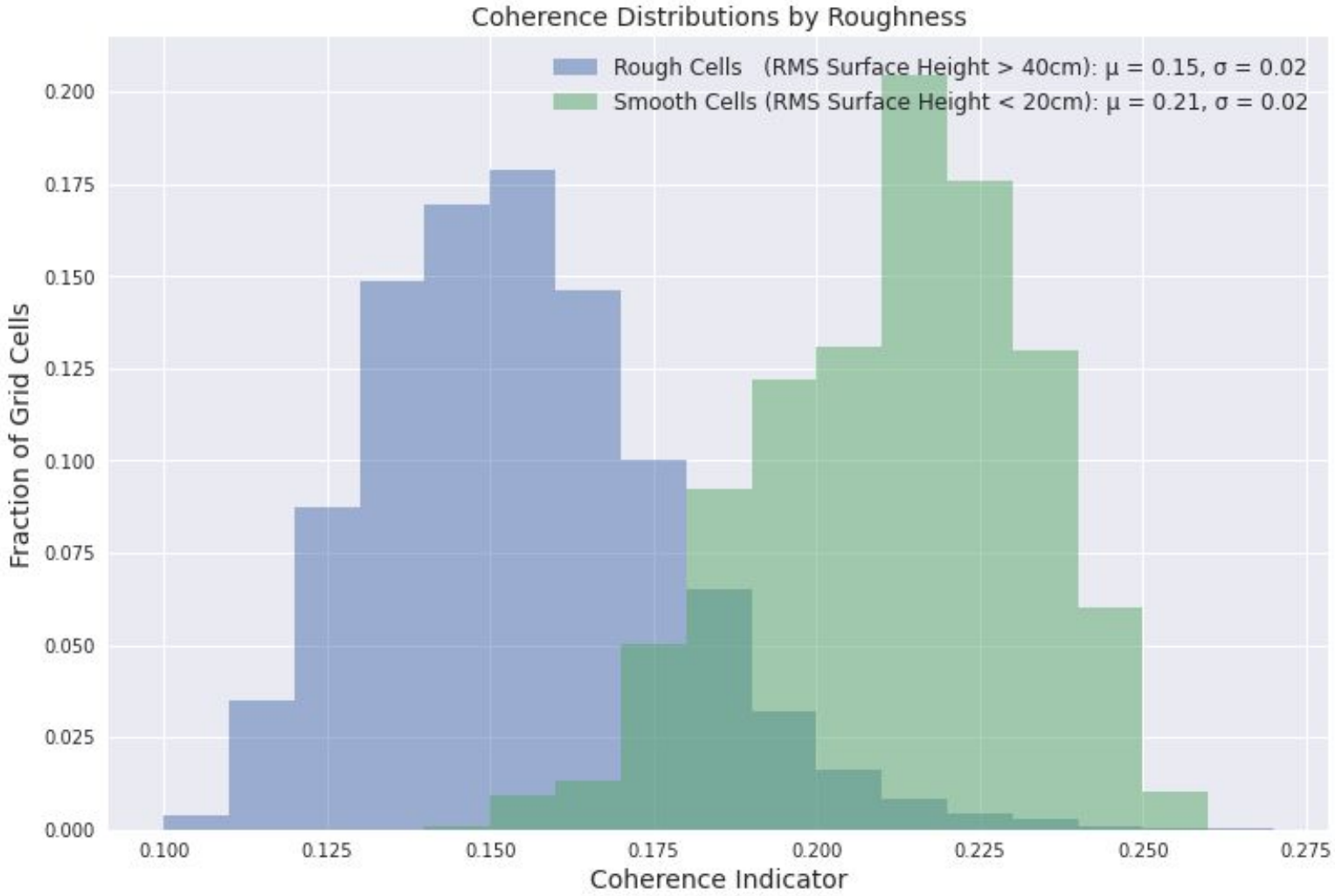
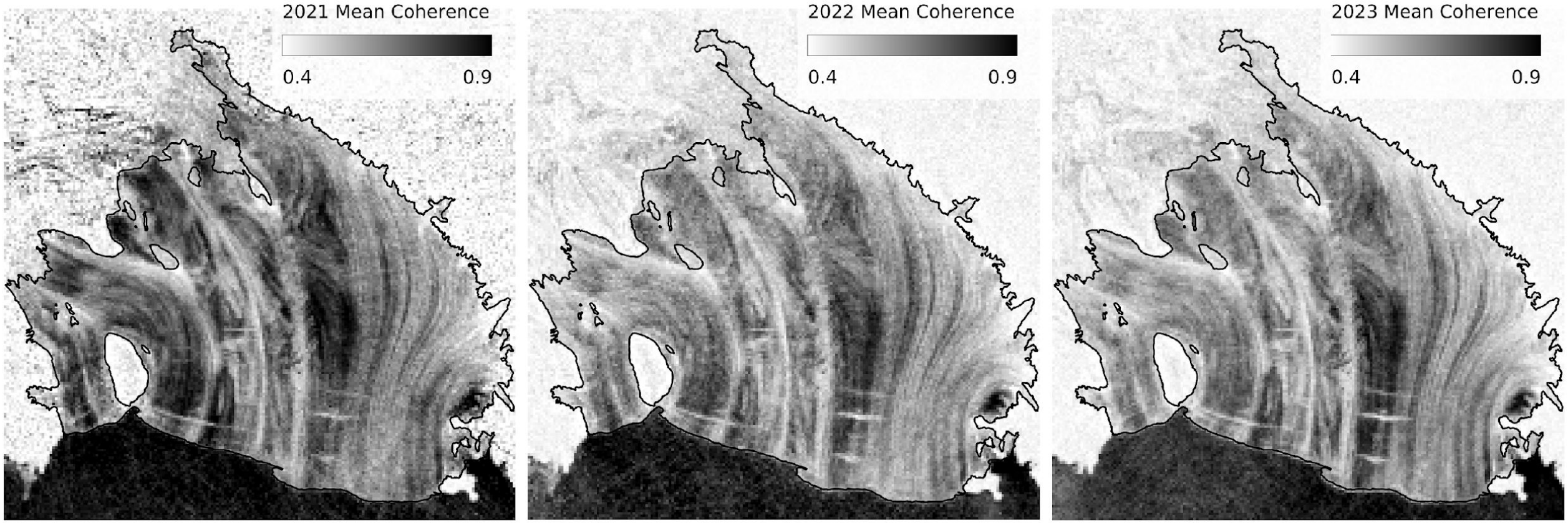
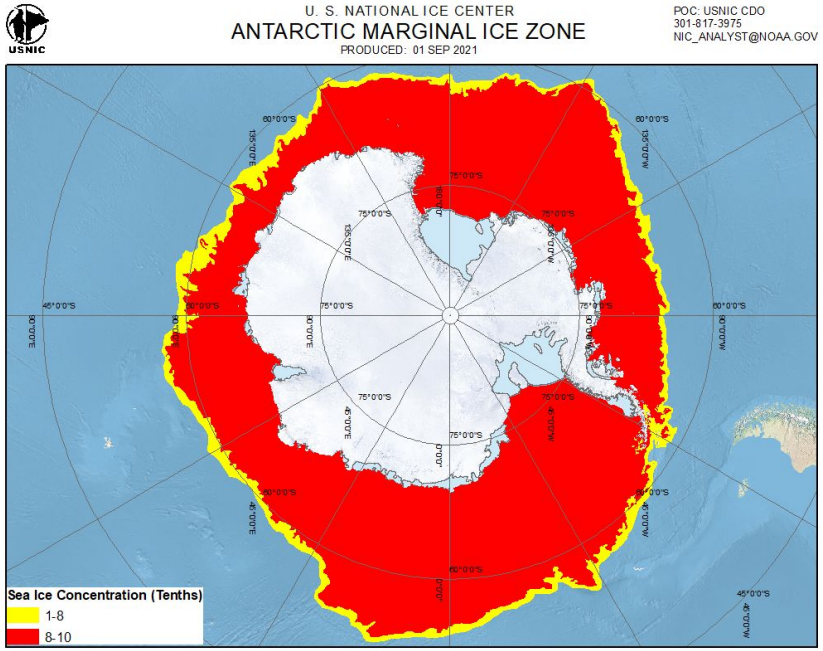
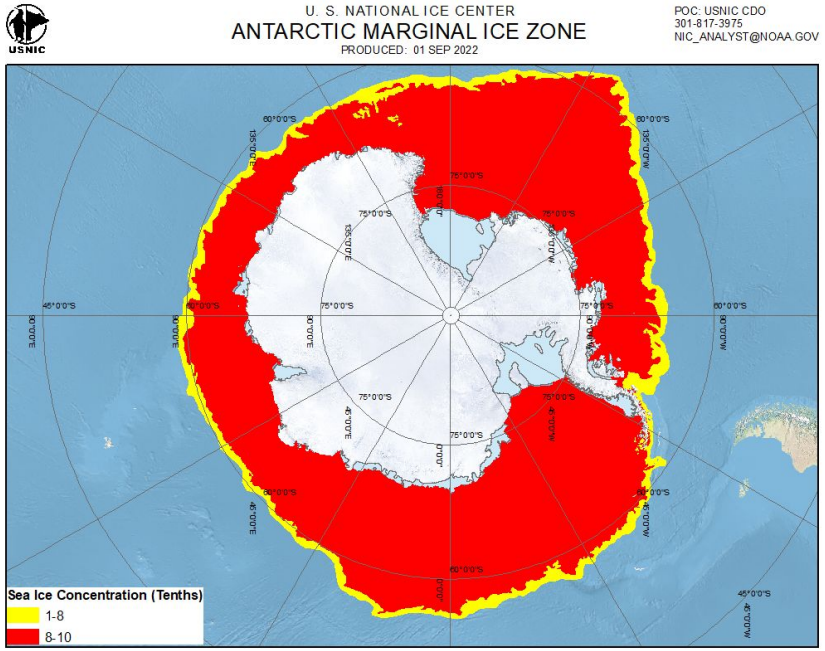


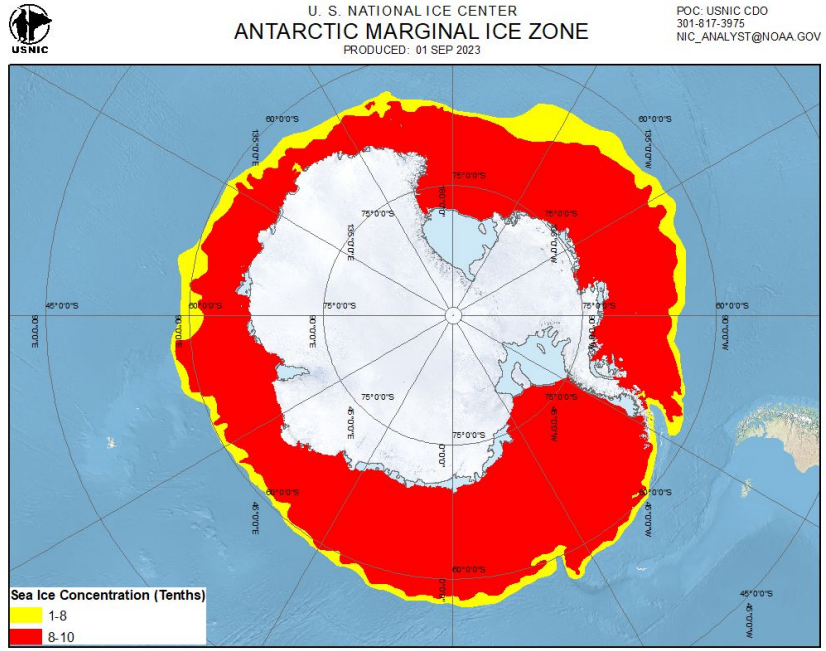
RIS 2021-2023 Evolution



RIS 2021-2023 Sea Ice Extent







https://usicecenter.gov/Products/AntarcHome

500m Elevation Contours (RAMP2 DEM)