SWOT in the Cryosphere: Promise, Progress, and Challenges

T. Snow, S. Fleury, C. Stuurman, M. Dabboor, L. Padman, S. L. Howard, Z. Katz, S. F. Sherpa, E. Abrahams, M. R. Siegfried, I. Garlick, R. Willatt, F. L. Müller, A. Bonaduce, A. Thompson, C. Kluetmeier, P. Rampal, S.. Kacimi, K. Bakhtiari Asl, J. T. Minear, and remaining members of the SWOT Cryosphere Working Group

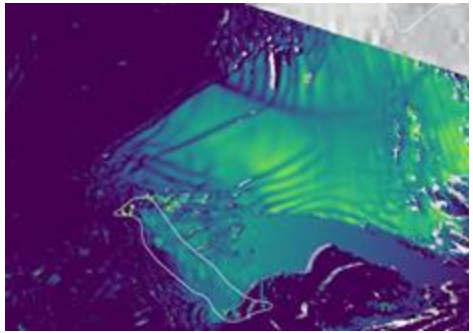
Roadmap to SWOT in the cryosphere

(A teaser for our sessions tomorrow)

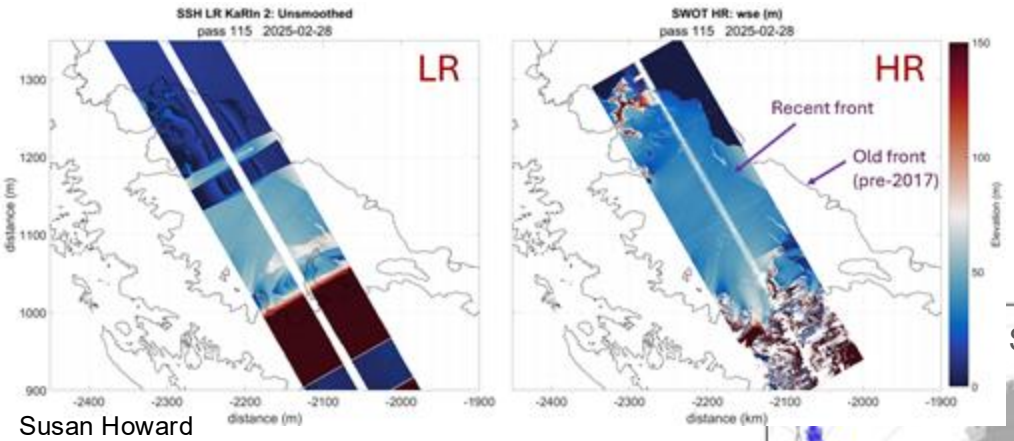
New frontiers with SWOT

Performance in the cryosphere

Outstanding challenges and opportunities for collaborations

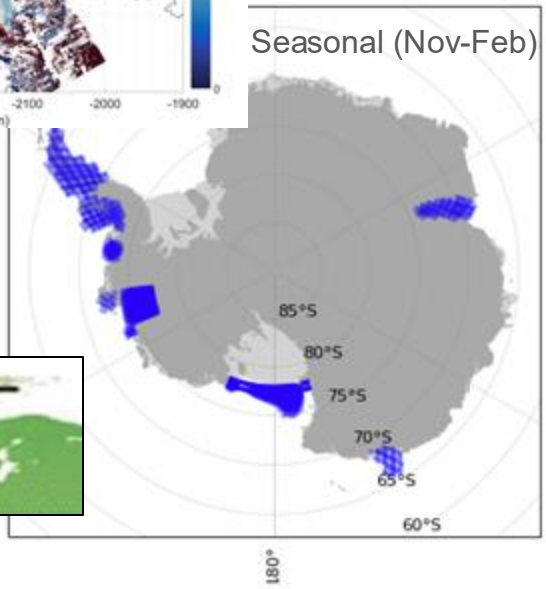


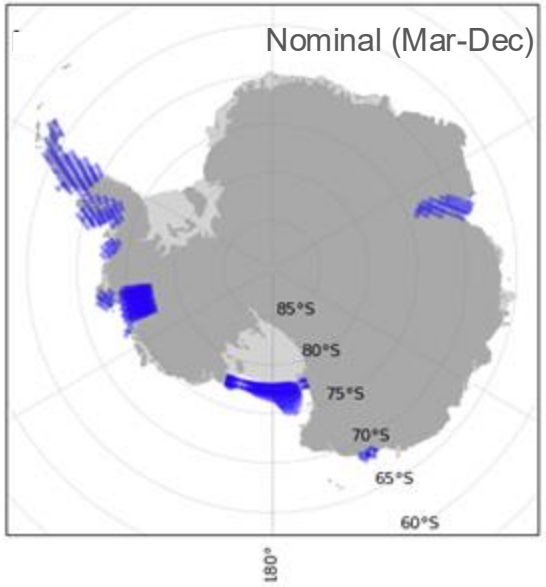
The first HR tasking for the Antarctic plus more Arctic



Susan Howard

HR critical for acquiring quality land ice measurements



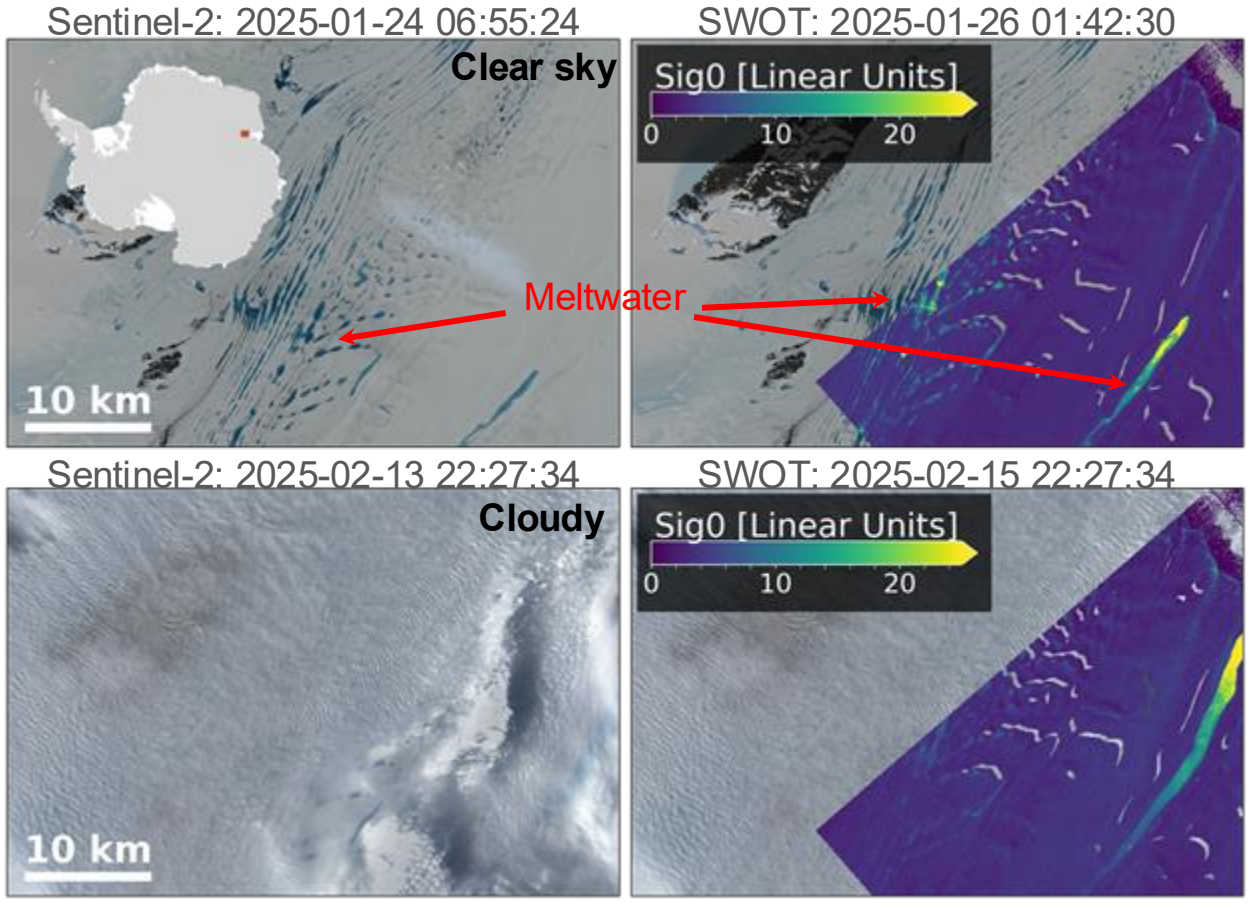


New HR coverage in BLUE

Upcoming seasonal Arctic additions (blue)

Advancing SWOT beyond its core mission

Watching ice shelves crack open: Meltwater and crevasse evolution from SWOT

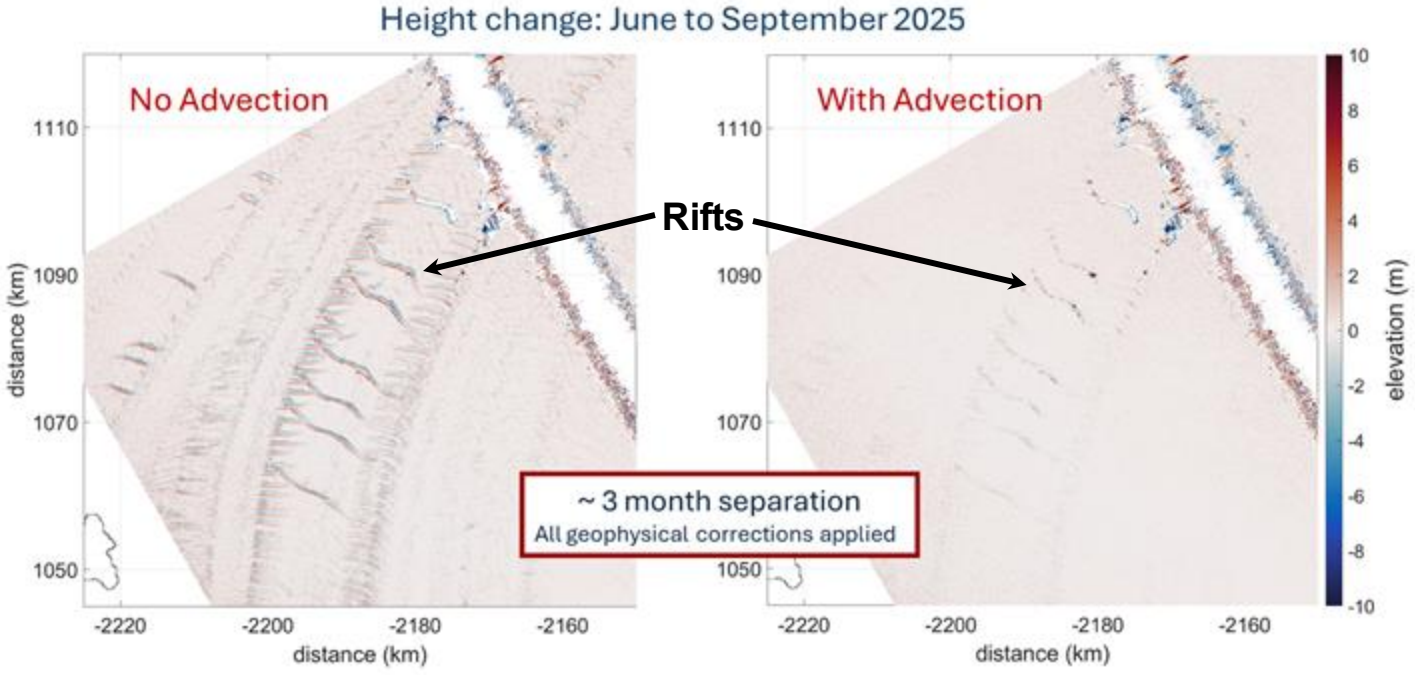


Simultaneous height and backscatter measurements provide the first cloud-agnostic, high res, 2D monitoring

Critical for understanding ice shelf stability

Zachary Katz
zachary_katz@mines.edu
COLORADO SCHOOL OF MINES

SWOT reveals active rift evolution on Antarctic ice shelves



Repeat SWOT passes show rift changes and processes

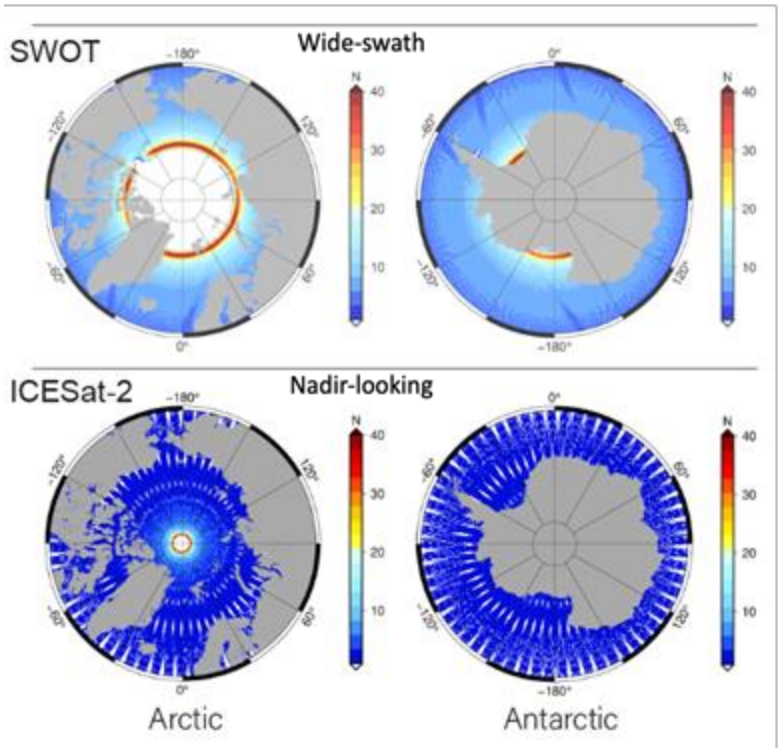
SWOT HR is **GREAT** for ice shelf process studies!

Difference of repeat SWOT HR Raster (100m) passes over Larsen C Ice Shelf

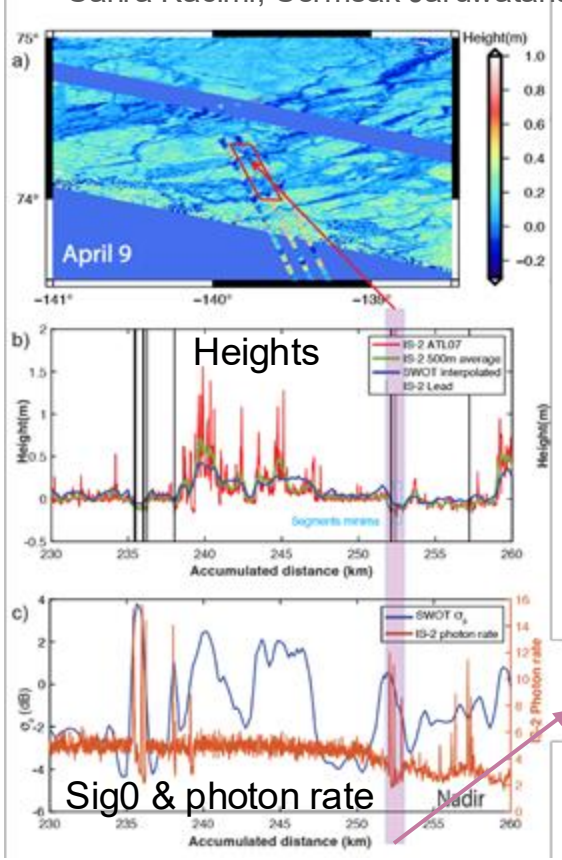
Susan Howard
Earth and Space Research

SWOT's potential for sea ice monitoring

Sahra Kacimi, Sermsak Jaruwatanadilok and Ron Kwok



Orbit revisits in a 21-day period over the same area



SWOT and ICESat-2 near-coincident 30-km Arctic segments

SWOT can meet the needs of sea ice applications requiring higher spatial coverage and temporal sampling (process studies, seasonal forecasts, and navigation)

Freeboard differences show variabilities of 0.08 and 0.09m

Quasi-specular leads in SWOT are associated with high radar backscatter and low heights, especially near nadir

Kacimi, S., Jaruwatanadilok, S., & Kwok, R. (2025). SWOT observations over sea ice: A first look. *Geophysical Research Letters*, 52, e2025GL116079. https://doi.org/10.1029/2025GL116079

Multifrequency sea ice monitoring using coincident SWOT and RADARSAT backscatter in Labrador sea

Mohammed Dabboor

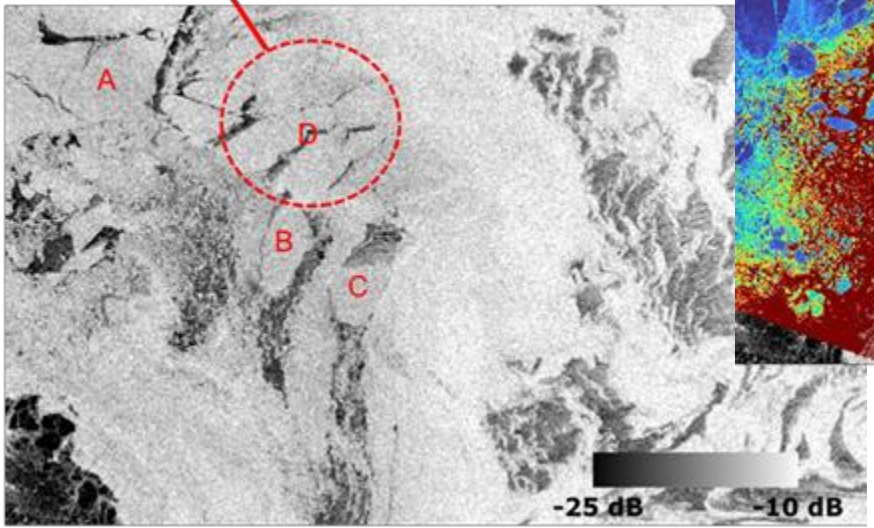
Environment and Climate Change Canada
Environnement et Changement climatique Canada

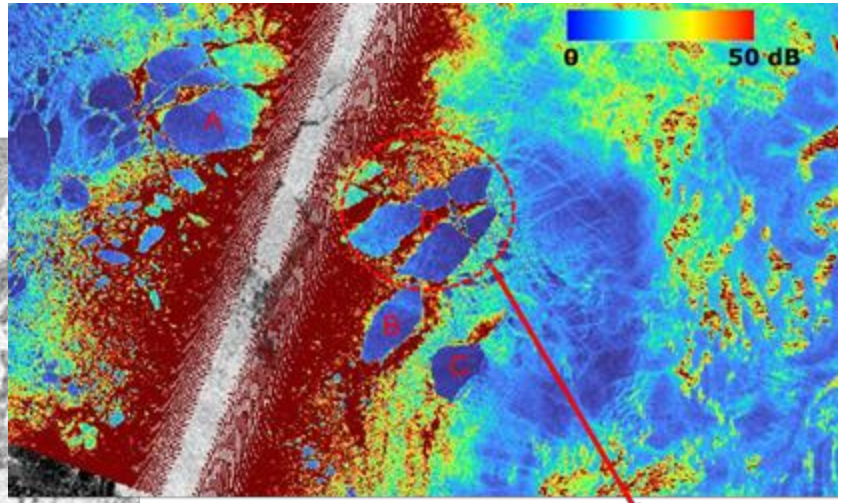
SWOT backscattering response behaves inversely to RADARSAT

RADARSAT

FYI floes (30-70cm): High backscatter

New ice (<10cm): Low backscatter





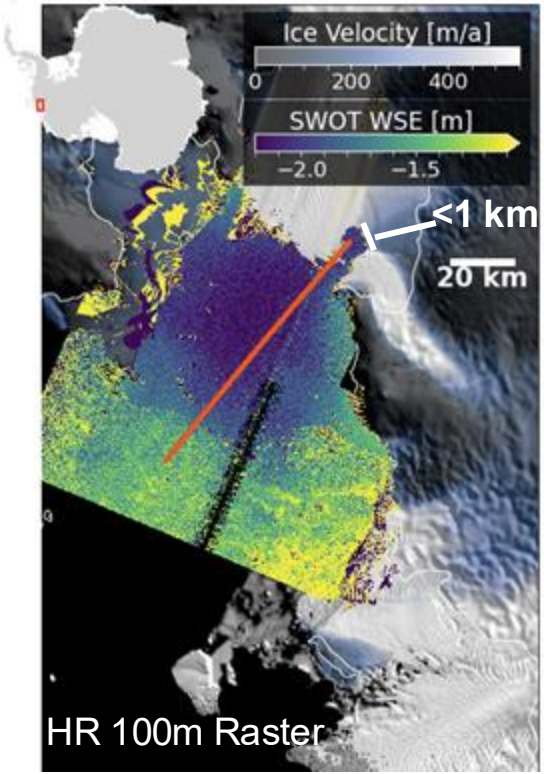
SWOT

FYI floes: Low backscatter

New ice: High backscatter

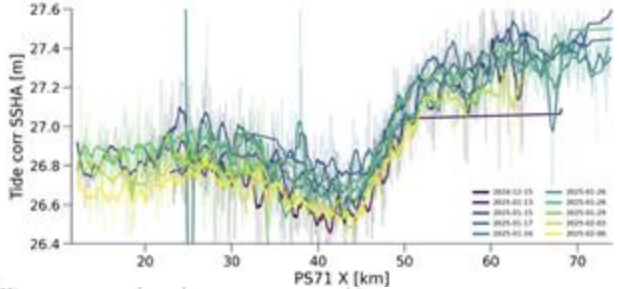
Good delineation of thin FYI floes

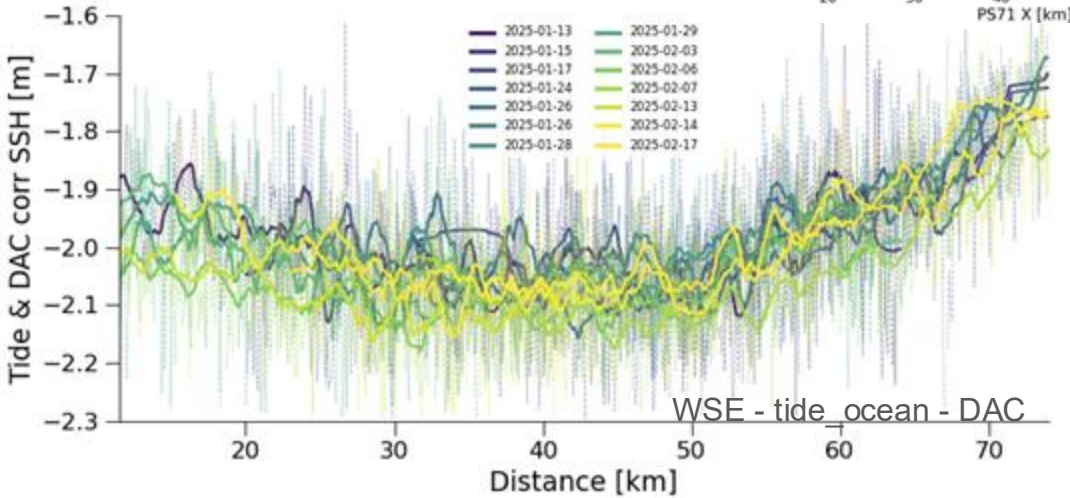
Ocean dynamics in rarely observed systems



Dearth of field and remote sensing observations of surface currents around ice sheets

SWOT HR can provide but we need better products





Snow, et al. (in prep)

Tasha Snow

Performance in the cryosphere

Good agreement between SWOT HR and in situ GNSS data over lake/river ice near Fairbanks, AK

Mean bias: 15cm Mean absolute bias: 37cm

Performance varies spatially and warrants further investigation

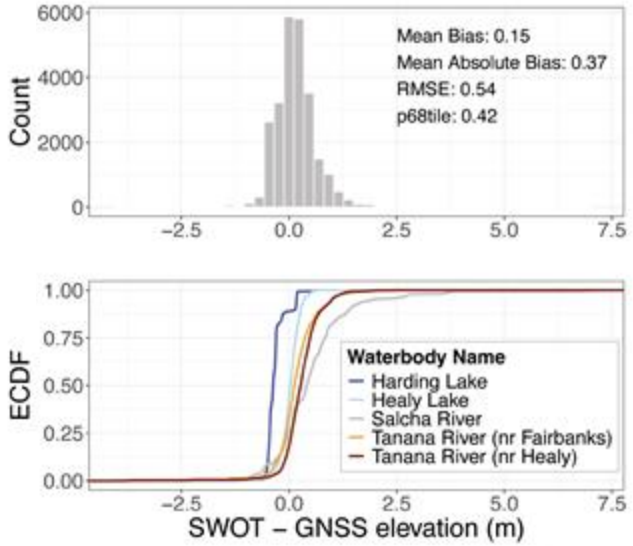
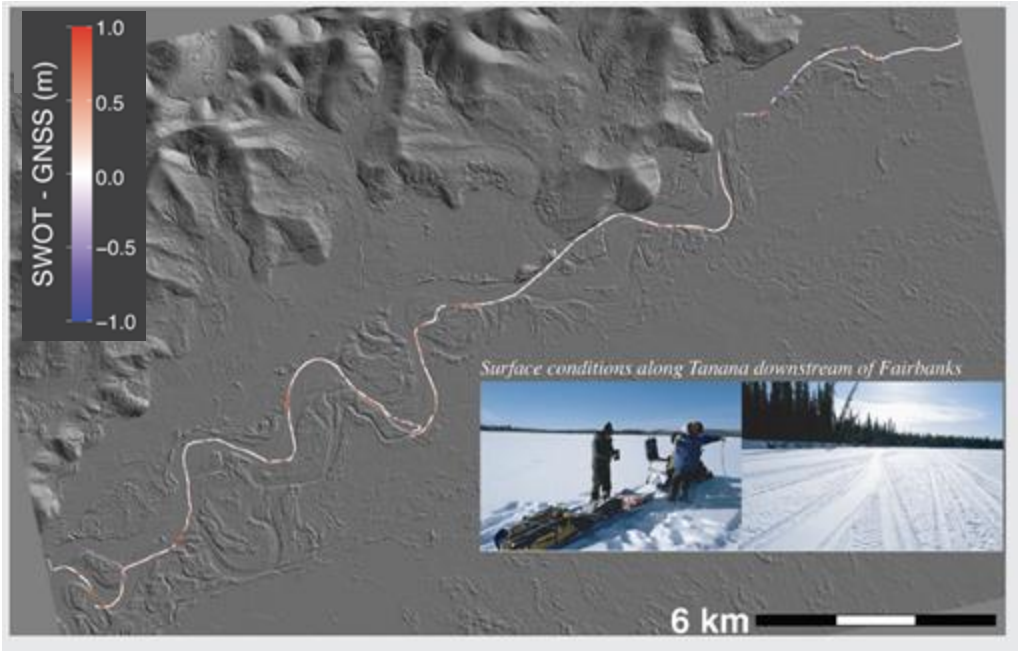
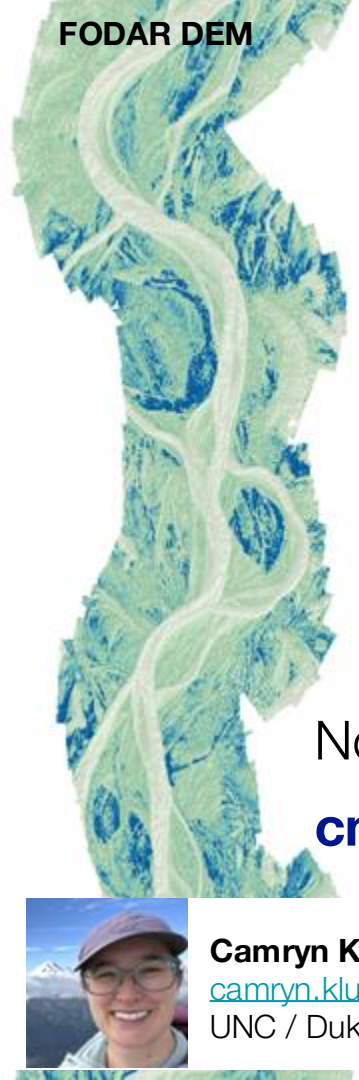


Figure 2. A. Histogram of the elevation difference between SWOT and GNSS agreement and B. Empirical cumulative distribution function for each waterbody.

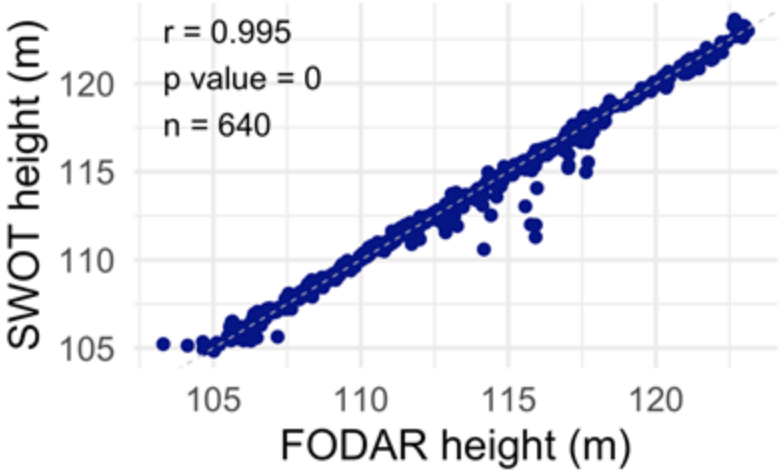


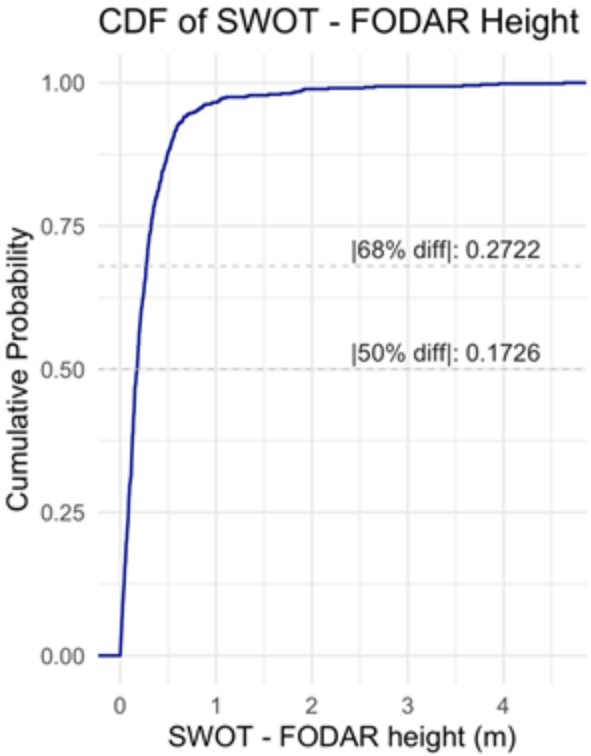
Spatially varying differences between SWOT and GNSS elevation.

Xiao Yang



SWOT PIXC ice surface height validation against FODAR DEMs for Tanana River, Alaska



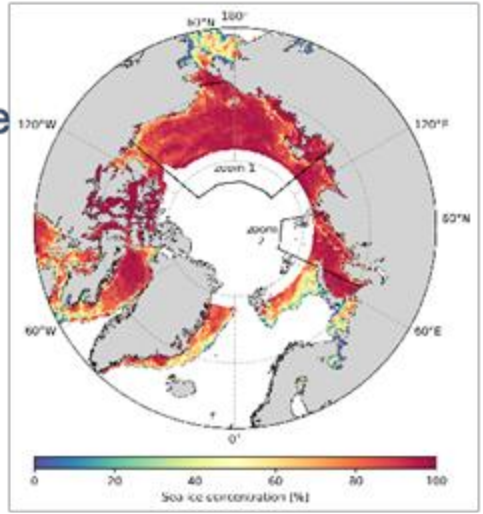


Node-scale relative height difference of **27 cm** for **FODAR vs PIXC data** at |68%|

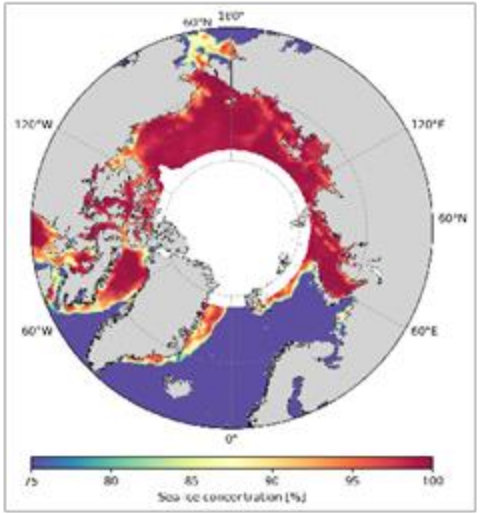
Camryn Kluetmeier
camryn.kluetmeier@duke.edu
UNC / Duke

Sea Ice Concentration

SWOT sea ice concentration



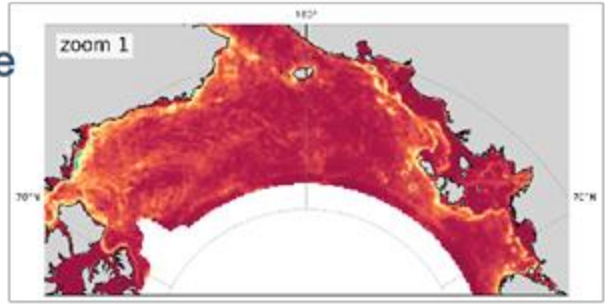
(a) Concentration derived from classification



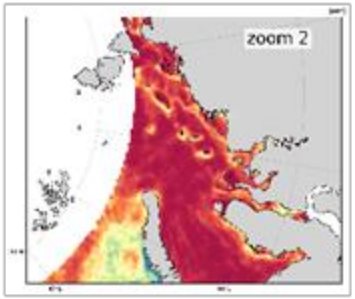
(b) OSI SAF concentration

OSI-SAF/Copernicus reference product

SWOT sea ice concentration (zooms)



(c) North of Alaska and East Siberia



(d) Kara sea islands

➢ Towards an unprecedented improvement in sea ice concentration !

Jestin et al.

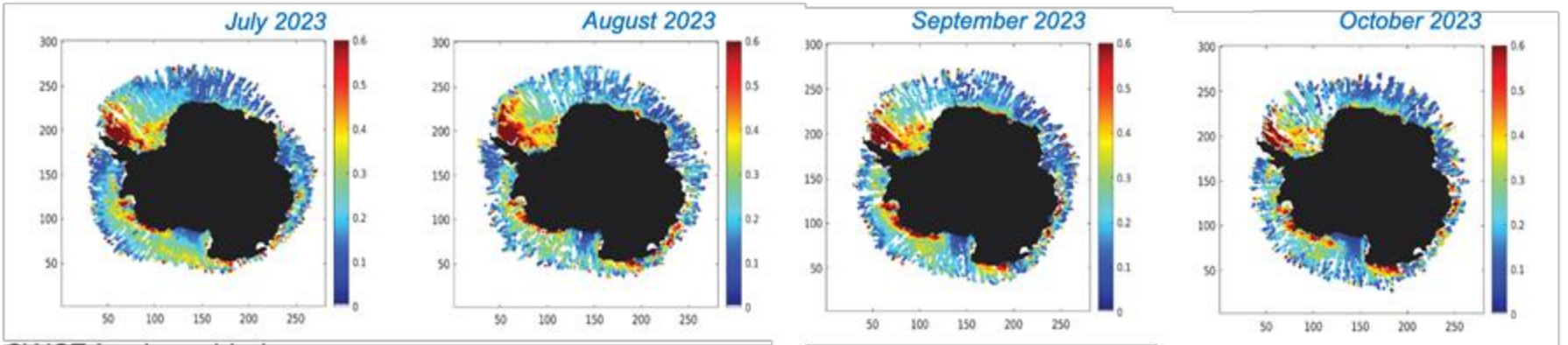
Great correspondence between SWOT and ICESat-2 freeboards

Sahra Kacimi, Sermsak Jaruwatanadilok and Ron Kwok

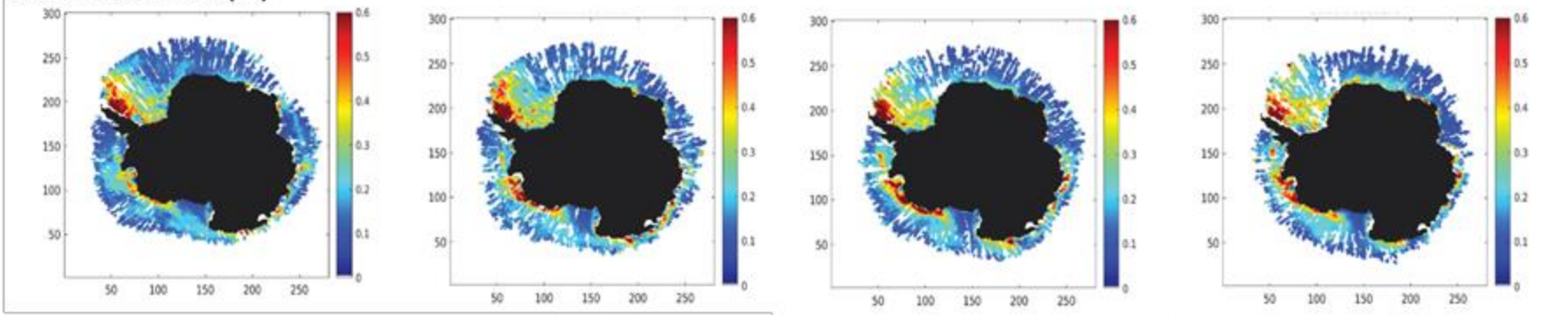
Jet Propulsion Laboratory
California Institute of Technology

AIR • SEA • ICE
Polar Science Center

ICESat-2 freeboard (m)



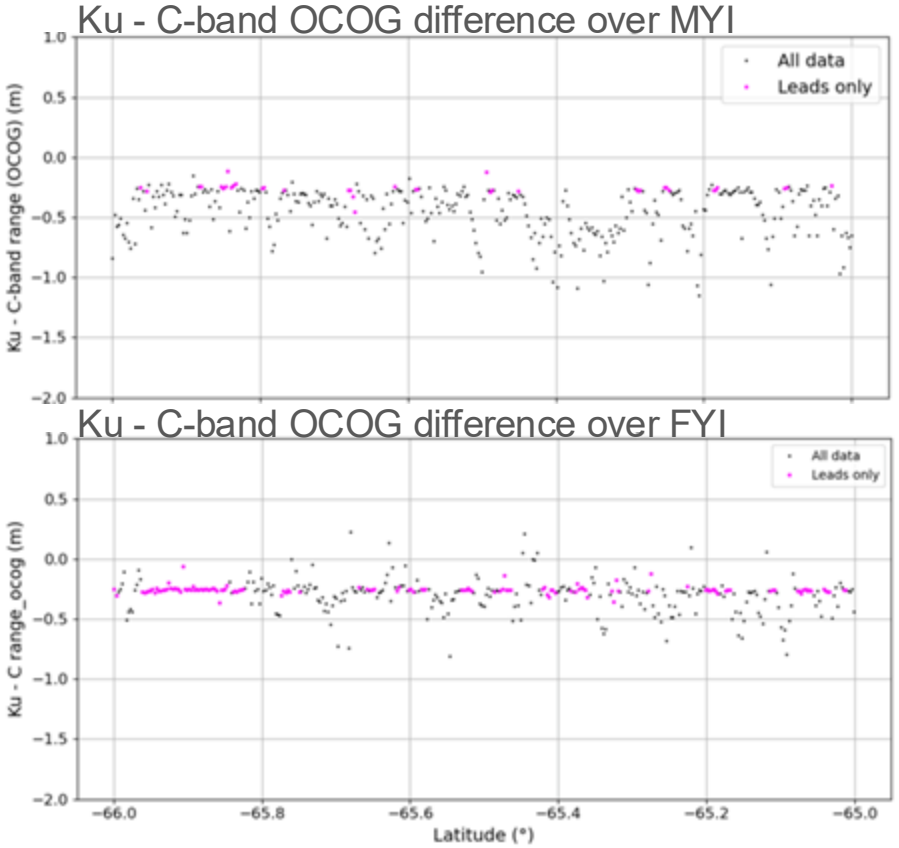
SWOT freeboard (m)



Differences likely due to sampling and penetration depth (*Ka*-band)

Only grid cells common to both datasets shown

Ice type strongly controls radar scattering depth, a key factor for freeboard and snow-depth retrieval accuracy



C-band penetrates deeper than Ku-band in both MYI and FYI

Broader spread in MYI data reveals surface roughness and snow layering influence on radar penetration and retracked range

Imogen Garlick
Supervisor: Rosemary Willatt

Advancing SWOT for All through open science and cloud collaboration

book.cryointhecloud.com/swot-hr-w-is2

September CryoCloud workshop: 40 participants

Two new tutorials for using SWOT HR alongside other datasets in the cloud

Next workshop planned for 2026 (and AGU!)

More opportunities to come!

CryoCloud JupyterBook

CryoCloud JupyterHub

cryointhecloud.com

We need you!

Opportunities for collaboration that will could rapidly improve SWOT use for cryo

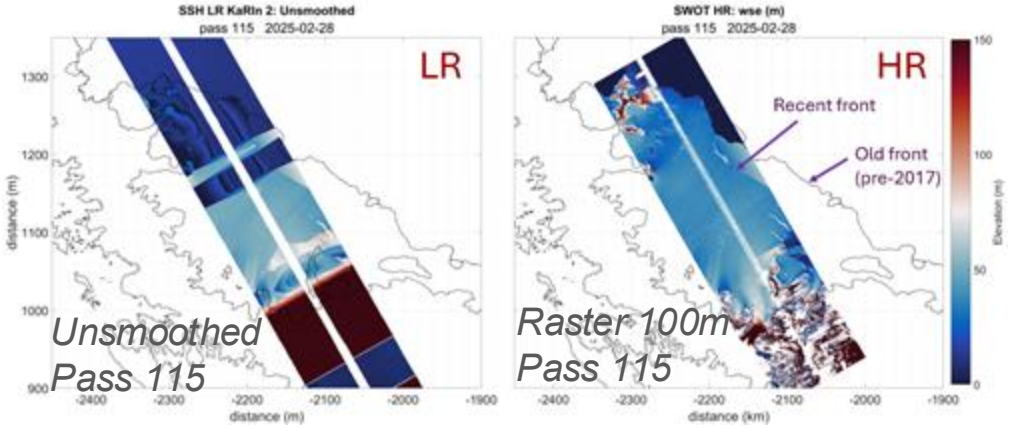
Improved DEM and processing in L2 pipelines

Collaboration on the v102 RefDEM over Greenland and Antarctica

Add DEM height variable [All products]

Improve DEM handling over ice shelves [LR, HR]

Assistance working with L1B to remove artifacts



LR interferograms improperly unwrapped over ice shelves

DEM challenges in HR

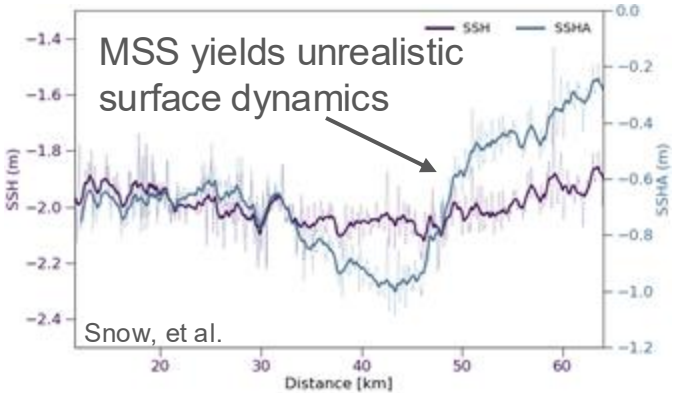
New or improved data products (MSS) for the poles

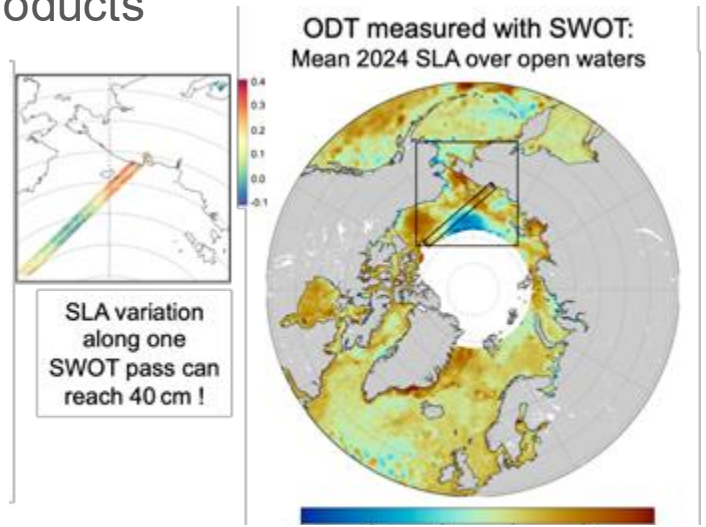
Note: XGM2019e geoid performs better around coastal Antarctica than EGM2008

Accurate mean sea surface around the Antarctic coastline and Arctic

SWOT Dynamic Ocean Topography product?

Update the outdated polar coastlines in our products



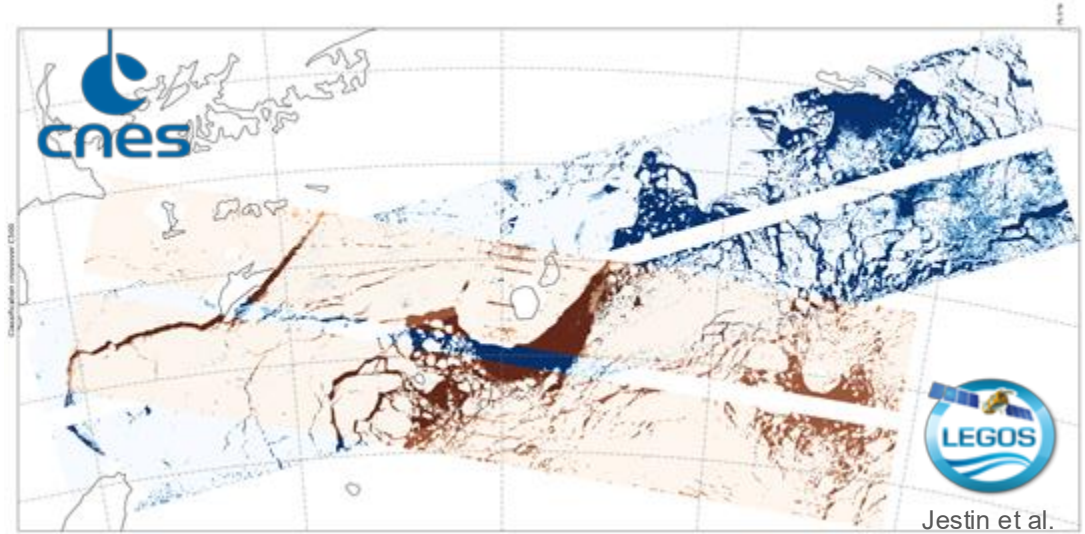


G.Jestin (LEGOS), I.Benabdillah (CNES), et al.

Improved geophysical corrections and variables for the poles

DAC variable added to HR

More holistic QC flags in L2 LR/HR for icy surfaces

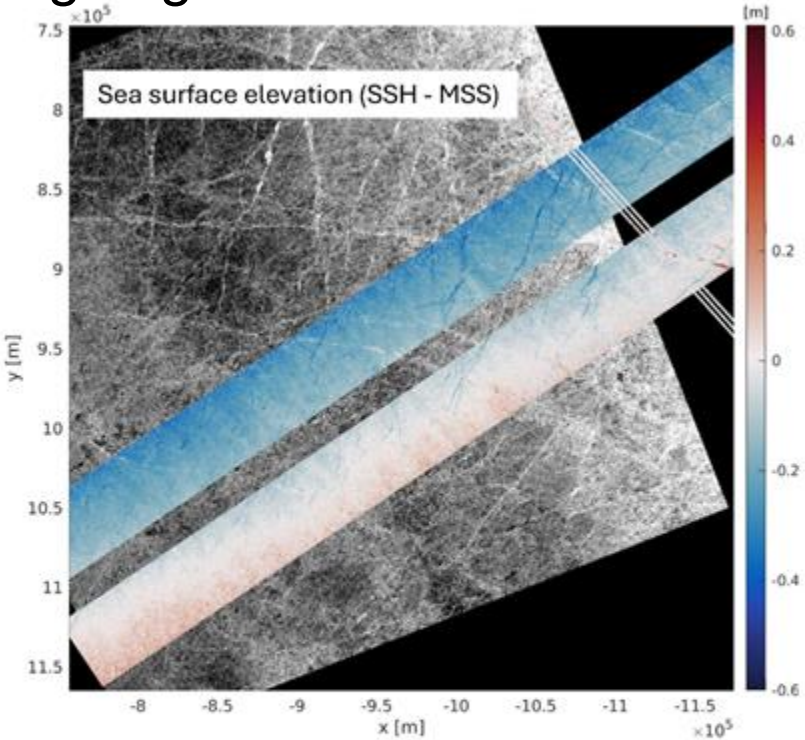


Jestin et al.

New L3 250m flags

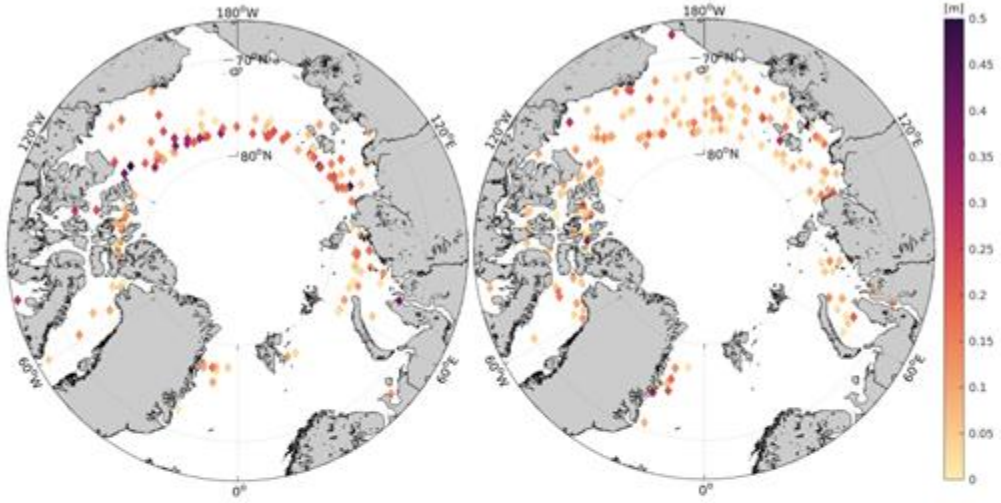
surface type	flag
ocean (including leads and polynyas)	#0
probable ocean	#18
probable ice	#19
ice pack, ice floes	#20

Ongoing issues with crossover corrections



Colored SWOT sea surface elevations, ICESat-2 profiles and a Sentinel-1 image in the Chukchi Sea (2024-01-21, Δt (Sentinel-1,SWOT) = 38 min. [Müller et al.,2025]

- Significant cross-track gradient visible in SWOT due to imperfect crossover correction
- Quality of correction is very different between the different overflights and locations.



Absolute mean sea surface elevation differences between the left and right swath for January/February 2024 (left) and March – December 2023 + March-April 2024 (right) [Müller et al.,2025]

- Winter (Jan/Feb): Left–right swath deviations reach up to 50 cm in regions with extended, dynamic sea ice (e.g., Beaufort, northern Laptev Seas). Other months: Deviations are reduced and show no pronounced regional dependence.

Ref.: Müller, F. L., Seitz, F., and Dettmering, D.: First Arctic-wide assessment of SWOT swath altimetry with ICESat-2 over sea ice, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2025-3046, 2025.

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Strengthening NASA-CNES data integration and openness

Enable full scientific and operational use of AVISO and NASA datasets through improved alignment in open data principles

AVISO frictions:

- Updated access control and authentication practices
- FAIR access outside CNES
- Streamlined documentation

By improving discoverability and access, we can leverage NASA & AVISO data to its full potential without duplicating team efforts

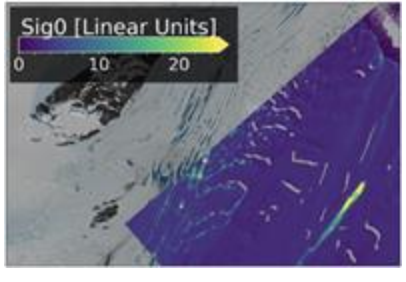
Promise, Progress, and Challenges

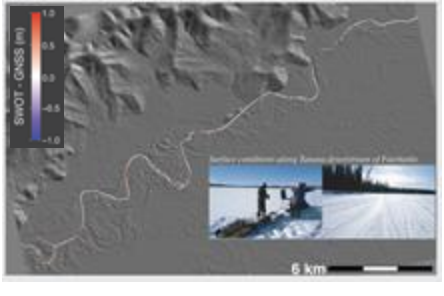
SWOT valuable for:

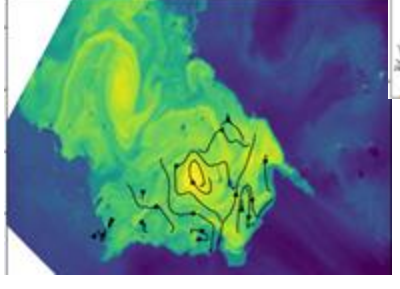
- Monitoring ice shelf rifts and supraglacial meltwater
- Observing ocean dynamics
- Tracking icebergs
- Distinguishing between different cryosphere surface types and roughnesses

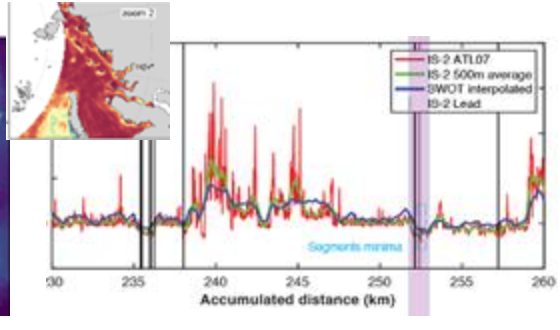
Quantified SWOT performance in HR and PIXC over lake/river ice and for LR-derived sea ice freeboards

Many collaboration opportunities to substantially improve SWOT usability for cryosphere!









Merci!
Thank You!

SWOT
SURFACE WATER & OCEAN TOPOGRAPHY

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