Snow depth on Arctic sea ice derived from airborne radar measurements

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Photo credit: Stefan Hendricks

Key results

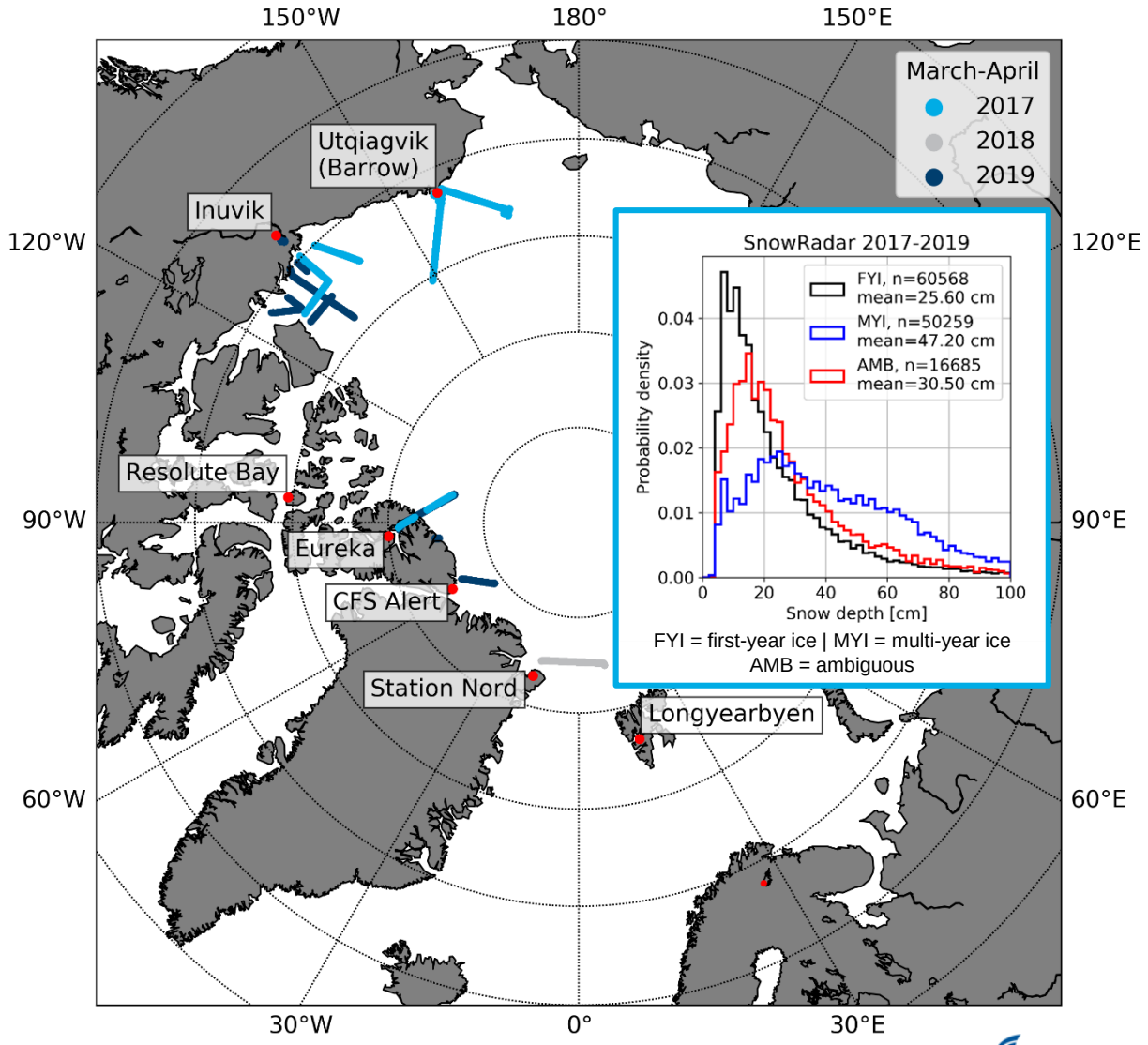
Novel dataset of 650 000+ measurements of snow depth on sea ice in 2017-2019

- Part of a unique instrumentation setup
- Includes areas not surveyed by Operation IceBridge in 2019

Ground validation over a 2-D grid

- RMSE 7.20 cm
- Mean bias 6.35 cm
- Correlation 0.62
- Uncertainty 6.52 cm

Novel interface picker software

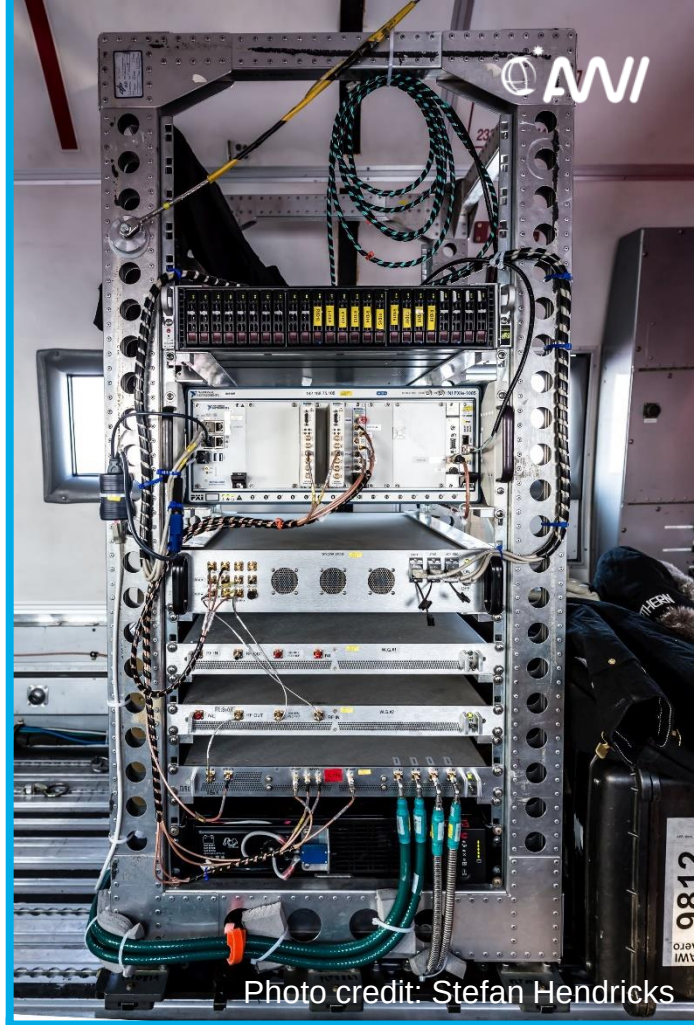


SnowRadar

2-18 GHz frequency-modulated continuous-wave ultra-wideband microwave radar developed by the Center for Remote Sensing of Ice Sheets (CReSIS) at the University of Kansas

	AWI IceBird missions		NASA OIB
Nominal survey altitude [ft]	200	1600	1600
Nominal survey velocity [kn]	110	160	250
Cross-track footprint[1] [m]	2.1	6.0	6.0
Along-track footprint[2] [m]	2.0	10.8	13.8
Range resolution[3] [cm]	0.94 – 1.14		0.94 – 1.14
Transmit power [mW]	100	1000	1000

[1] Cross-track footprint is calculated using a pulse limited footprint over a flat surface.
[2] Along-track footprint is calculated using the length of the unfocussed SAR aperture.
[3] Range resolution is calculated considering free space and snow density of 300 kg m^{-3}, respectively.

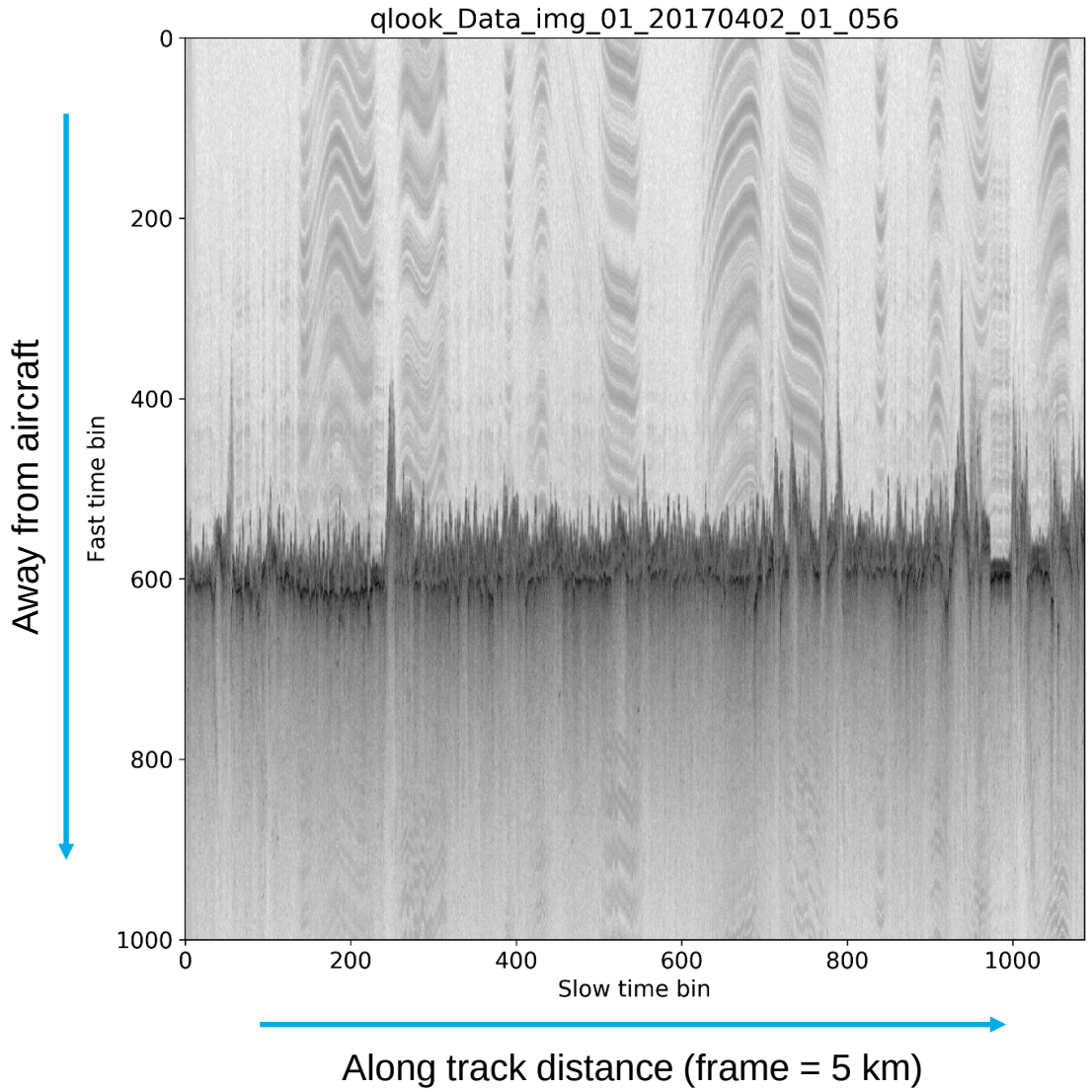


Processing - I

cresis-toolbox (MATLAB)

Quicklook

- In the field

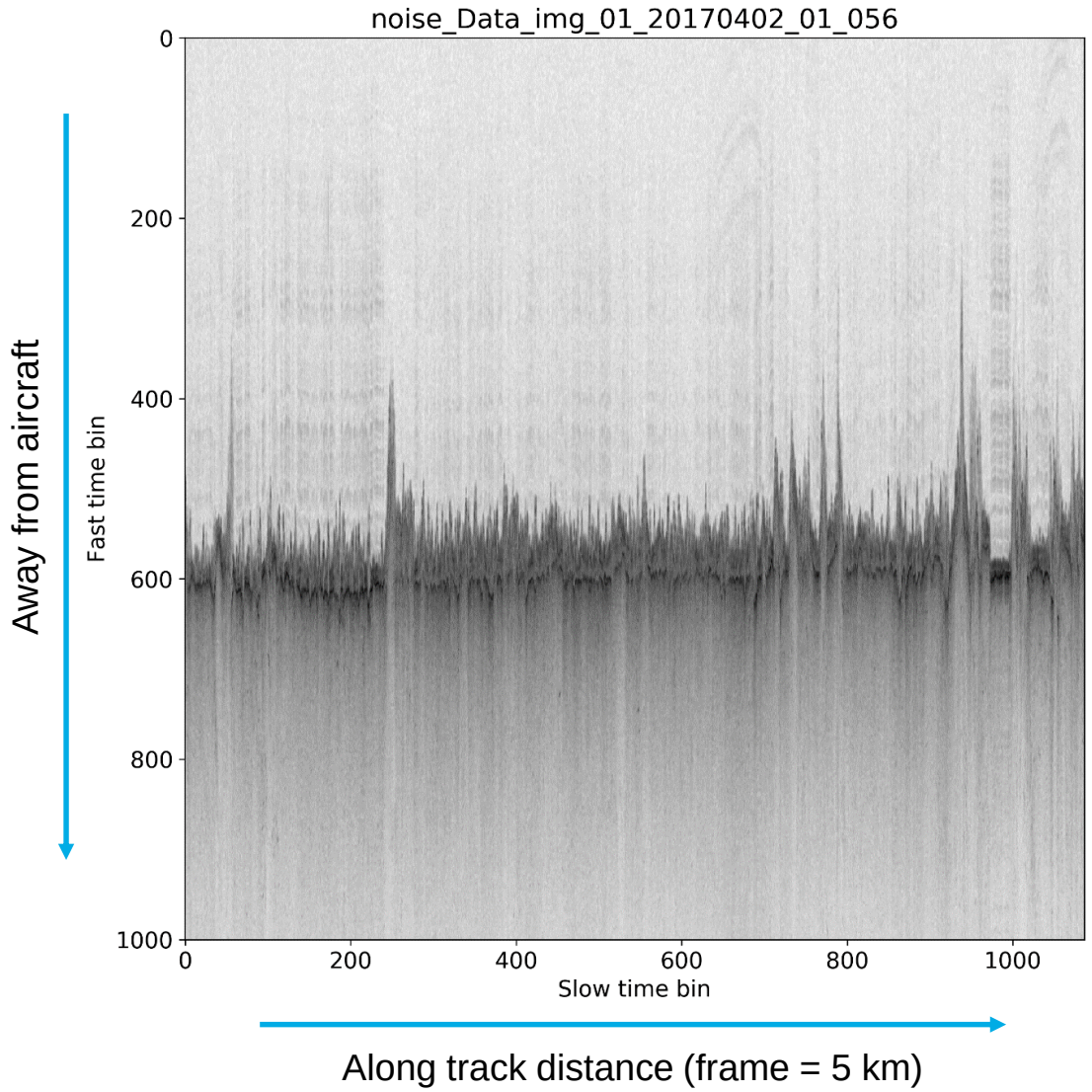


Processing - I

cresis-toolbox (MATLAB)

Quicklook
- In the field

Coherent noise removal



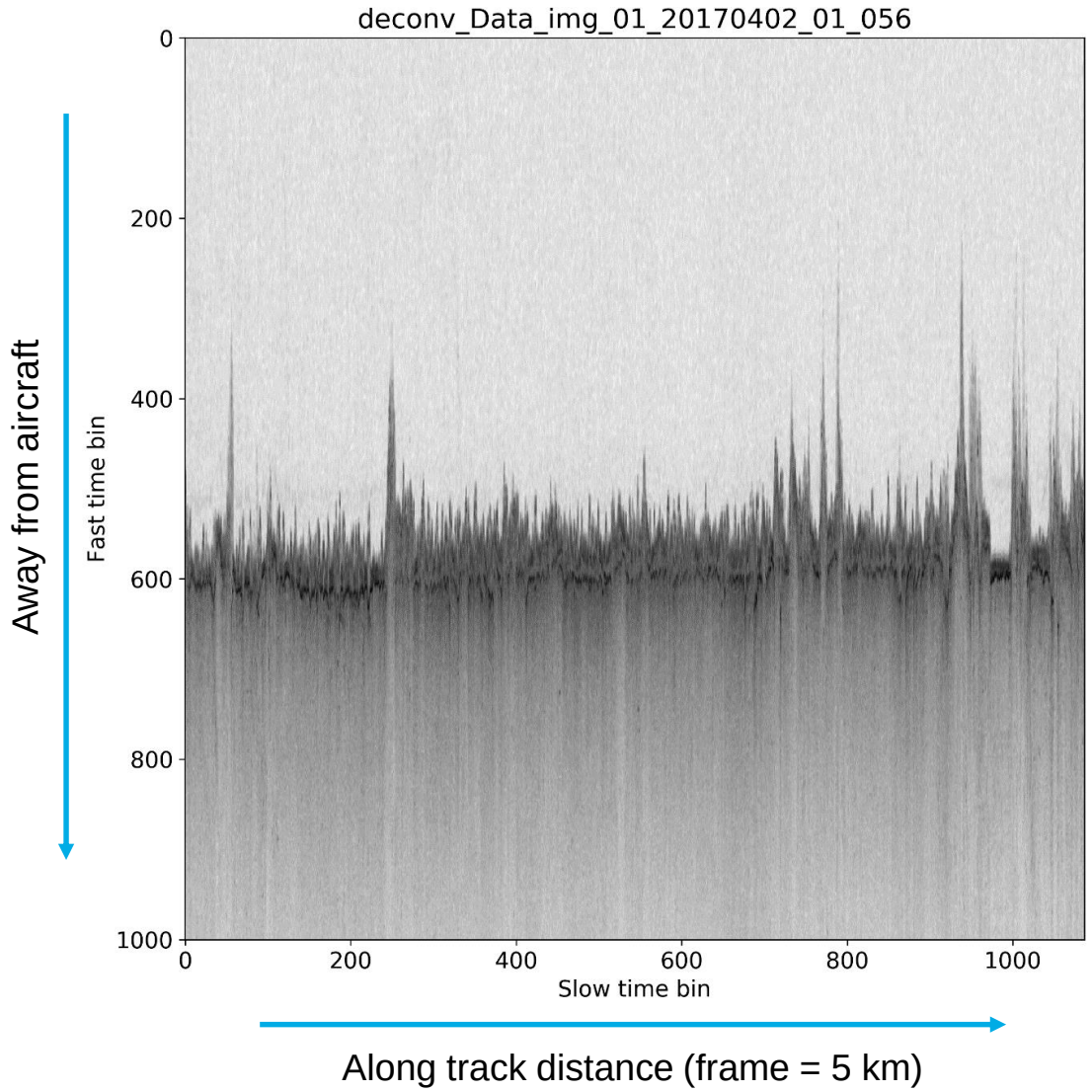
Processing - I

cresis-toolbox (MATLAB)

Quicklook
- In the field

Coherent noise removal

Deconvolution



Processing - II

Interface detection using modified Wavelet algorithm *(Newman et al., 2014)*

- Handles each radar trace independently and finds abrupt changes in signal
  - Haar & Ricker wavelets, continuous wavelet transform
- Does not depend on thresholds, transmitted power, or receiver noise
- Precision due to radar system parameters ~1.5 cm
- pySnowRadar Python package will be made public soon

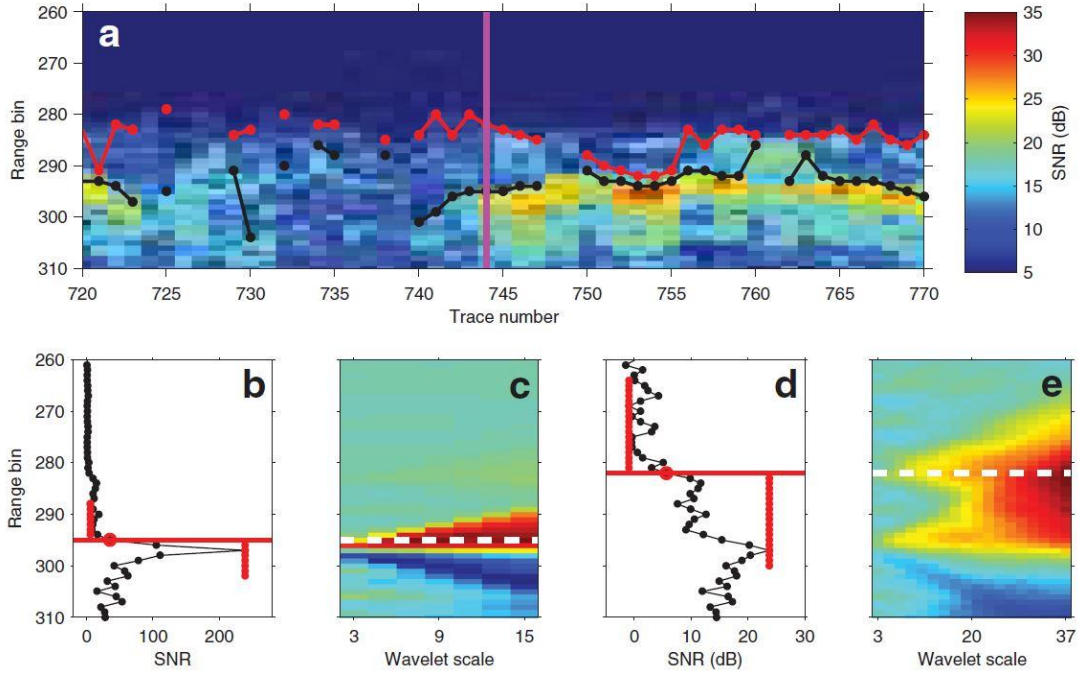
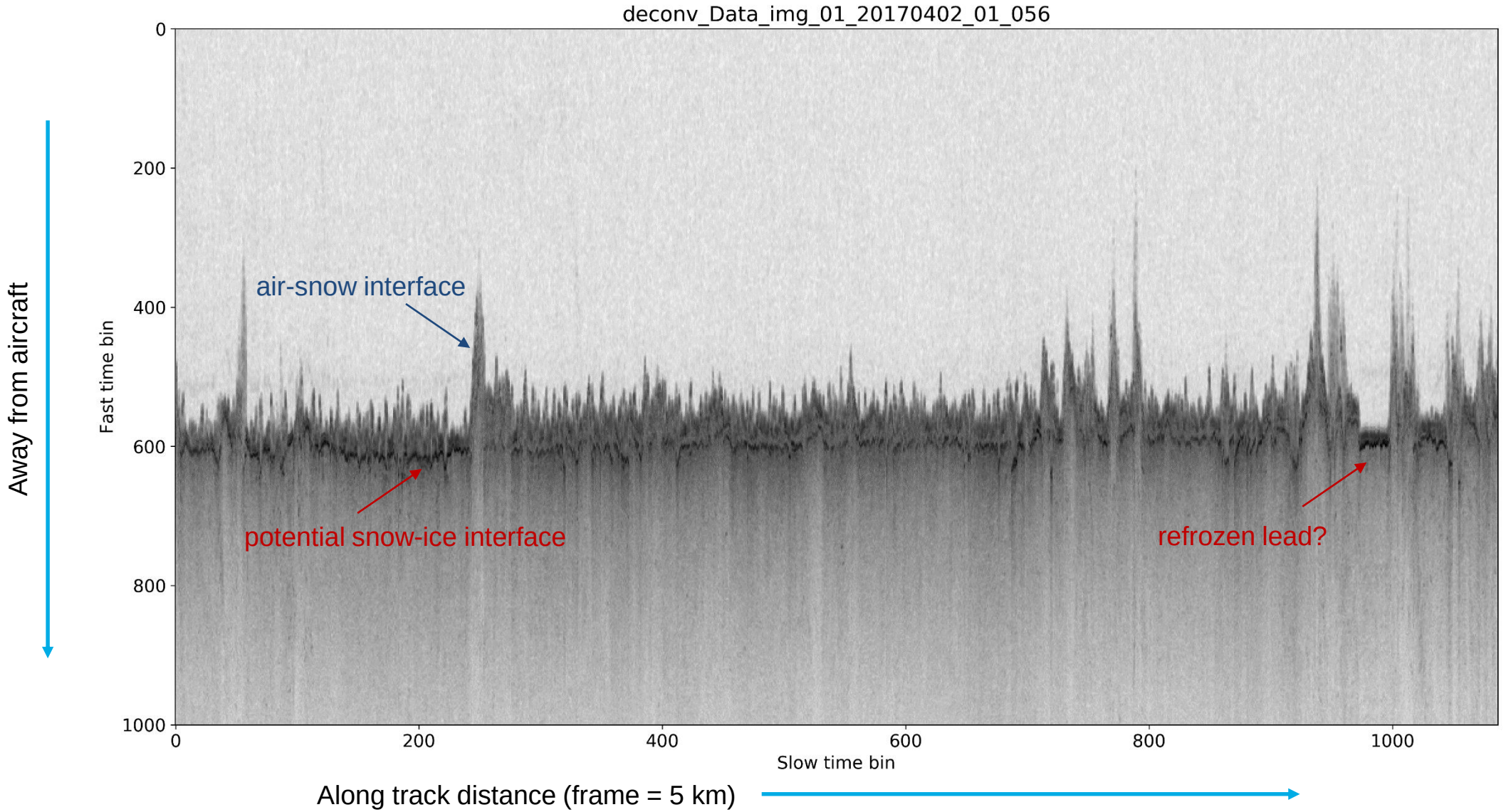


Fig. 3 from Newman et al. (2014), Assessment of radar-derived snow depth over Arctic sea ice, *J. Geophys. Res. Oceans*

Processing - II



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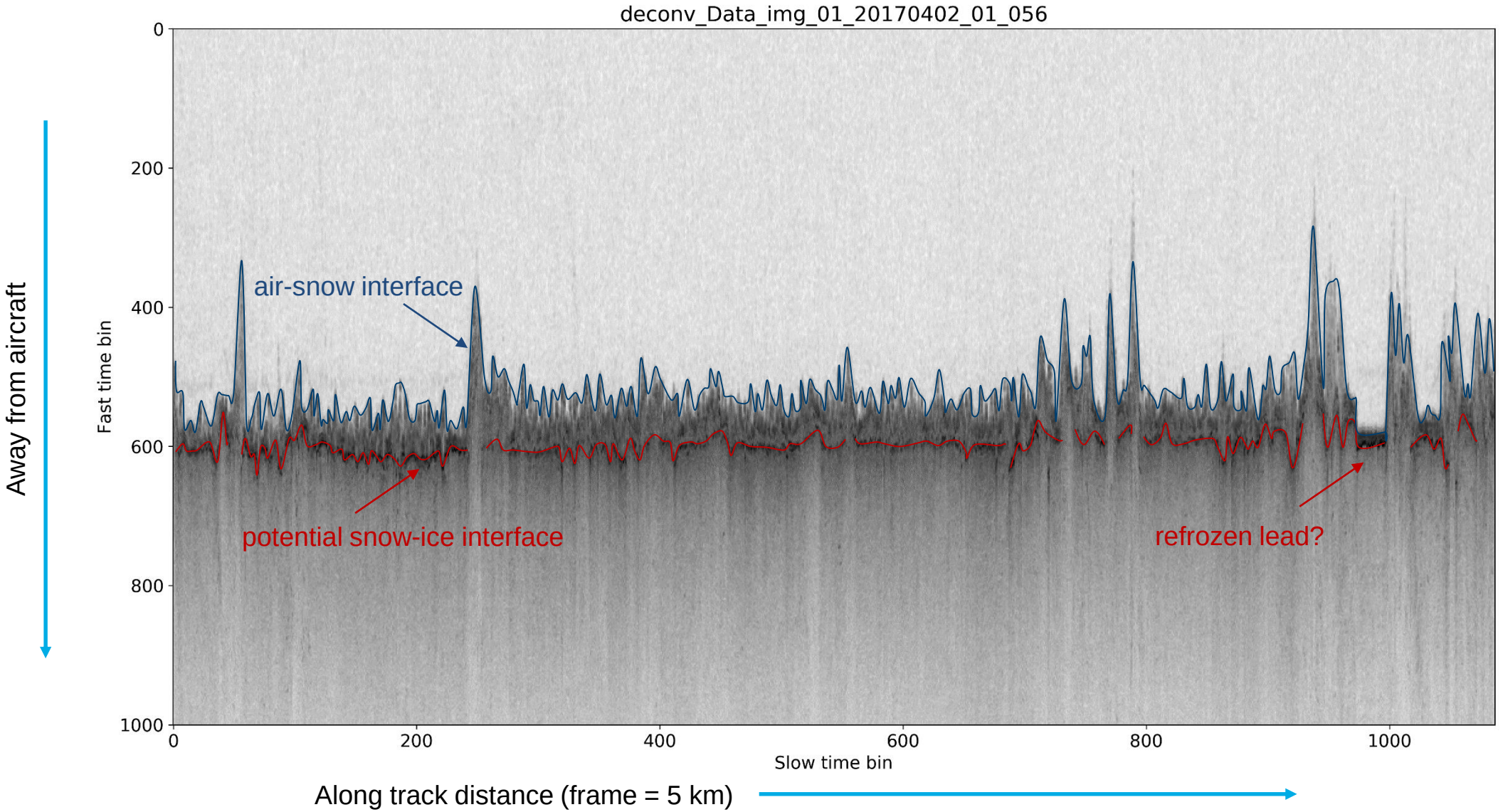

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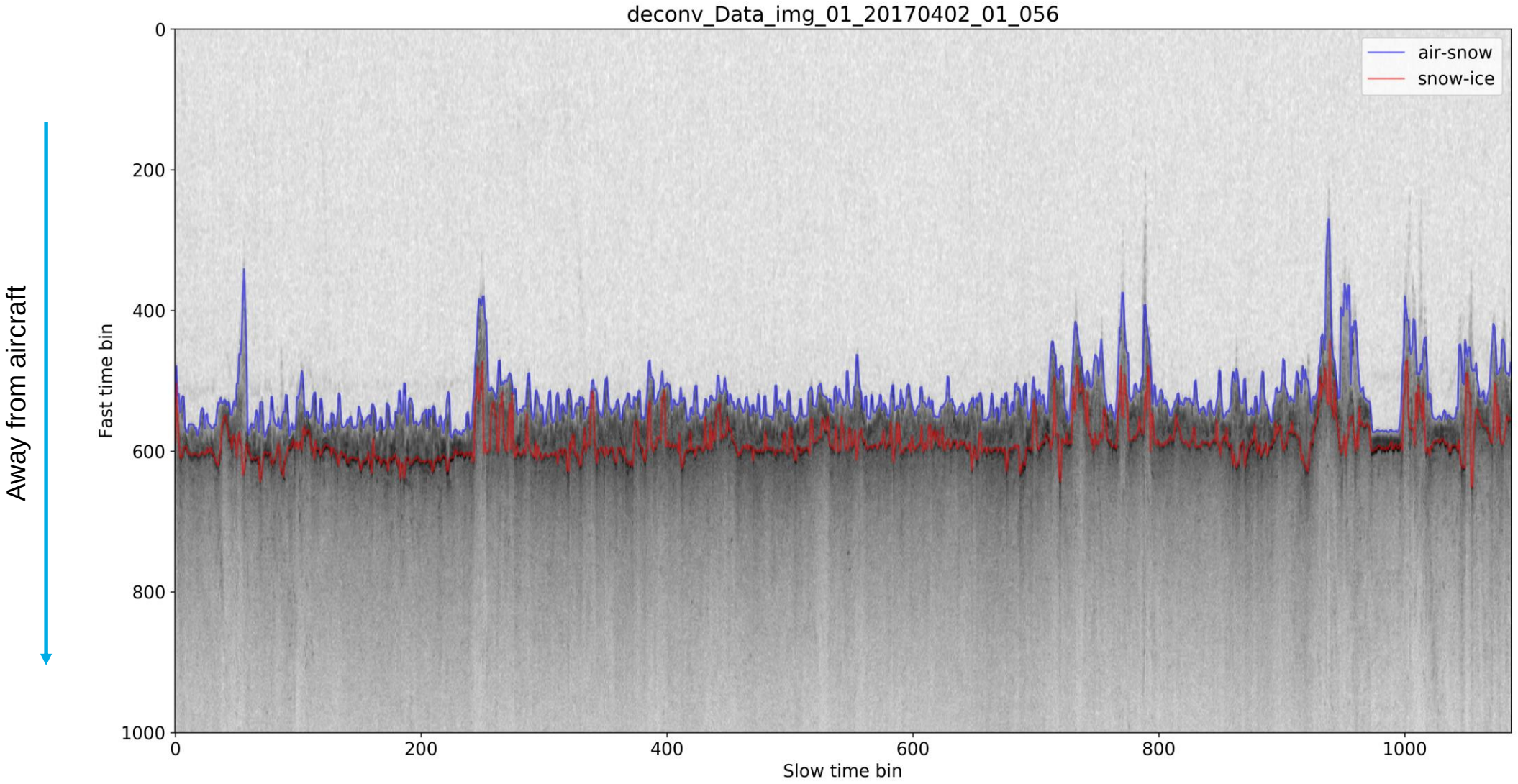
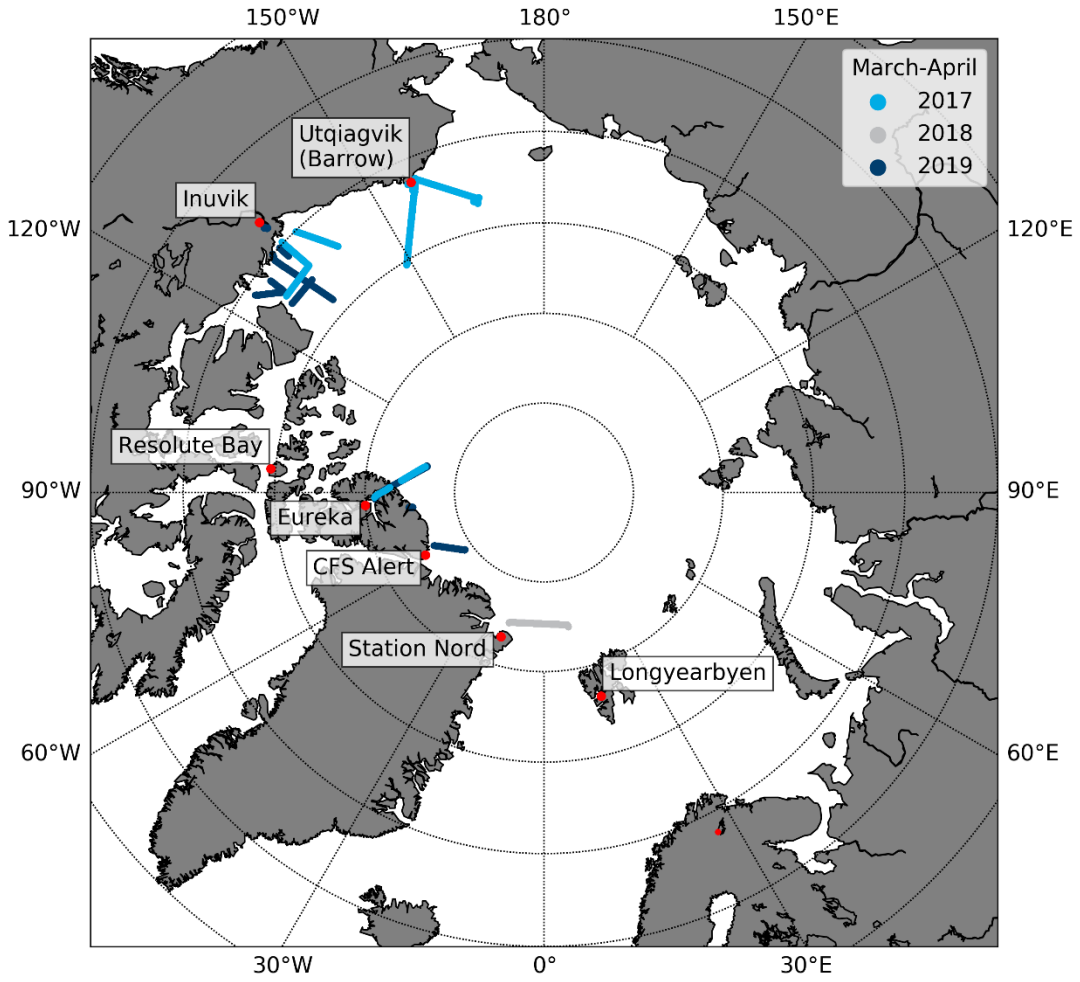
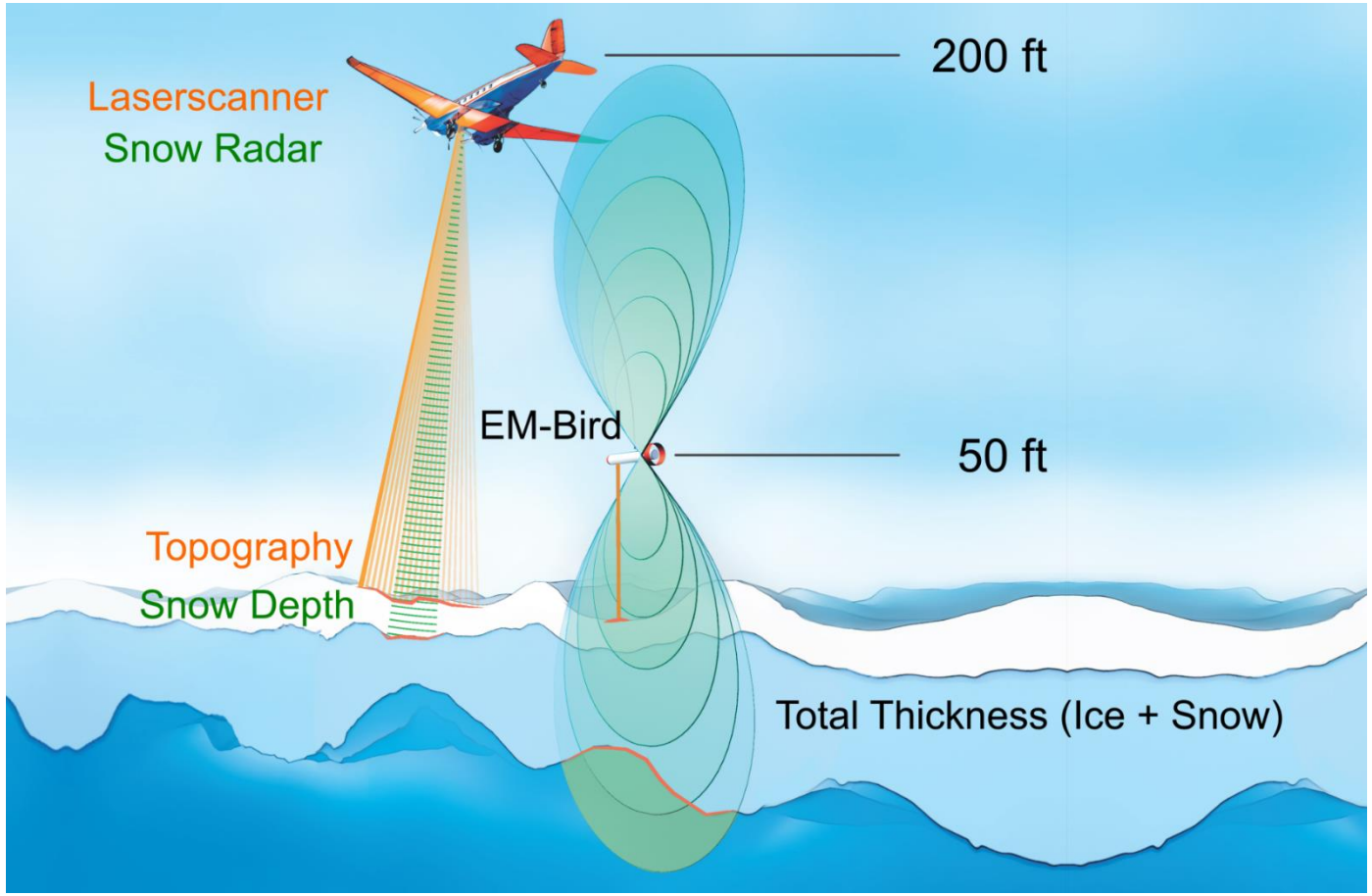


Deployments AWI IceBird Winter

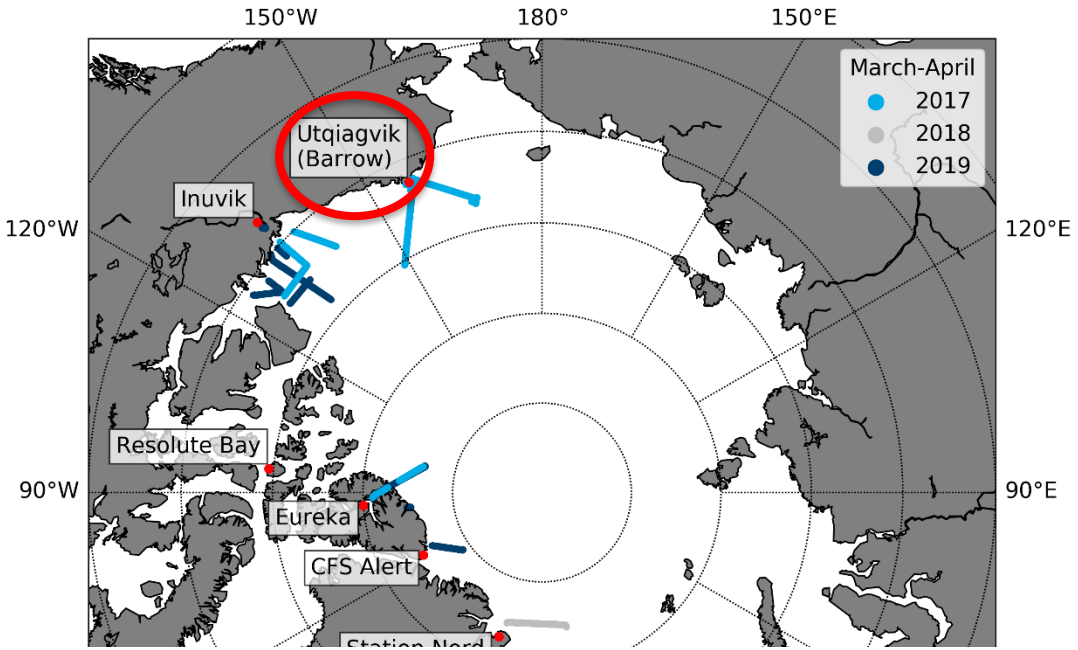


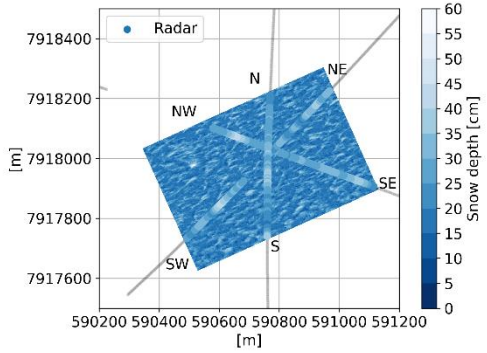


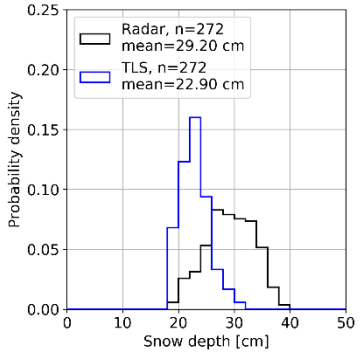
Poster 82A3292, Hendricks et al. *IceBird: a pan-Arctic airborne sea ice observation system*

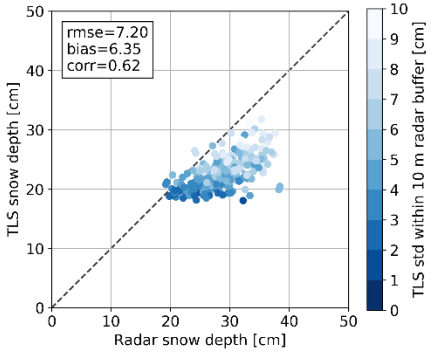
HELMHOLTZ ASSOCIATION

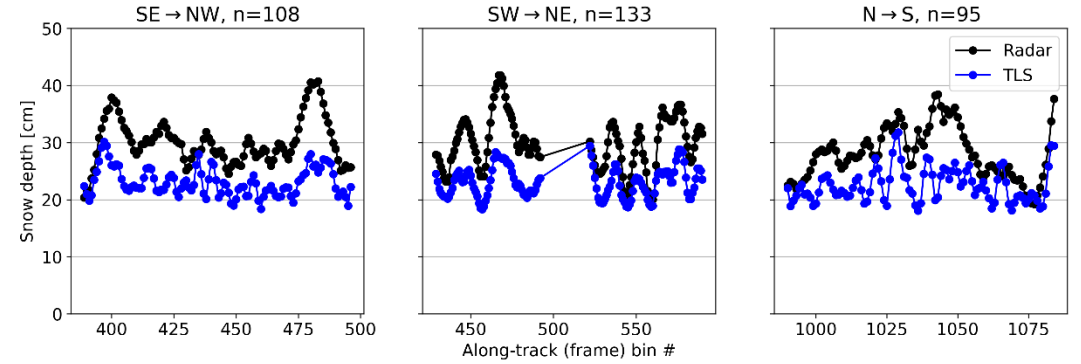
First results - validation

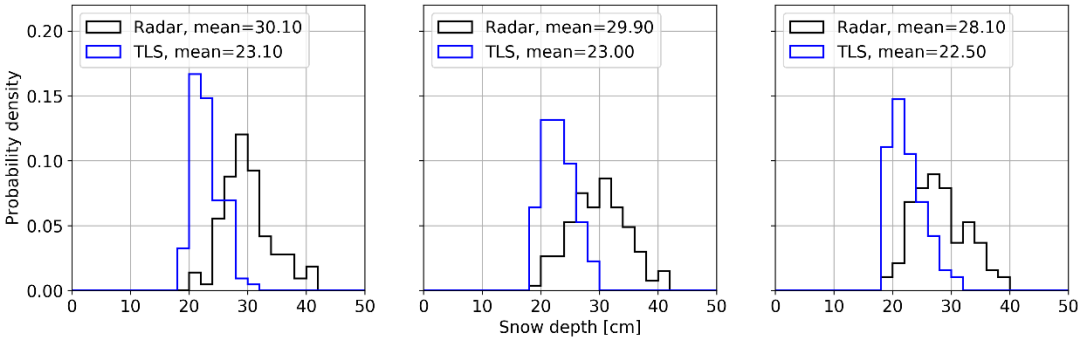


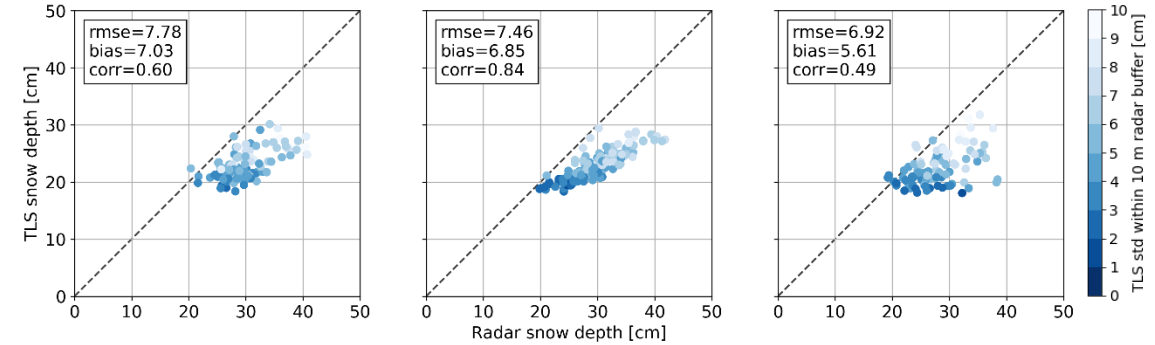






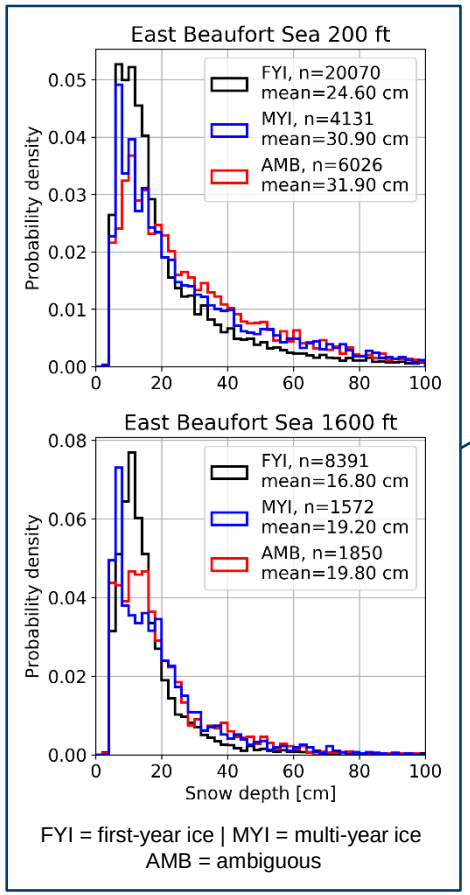


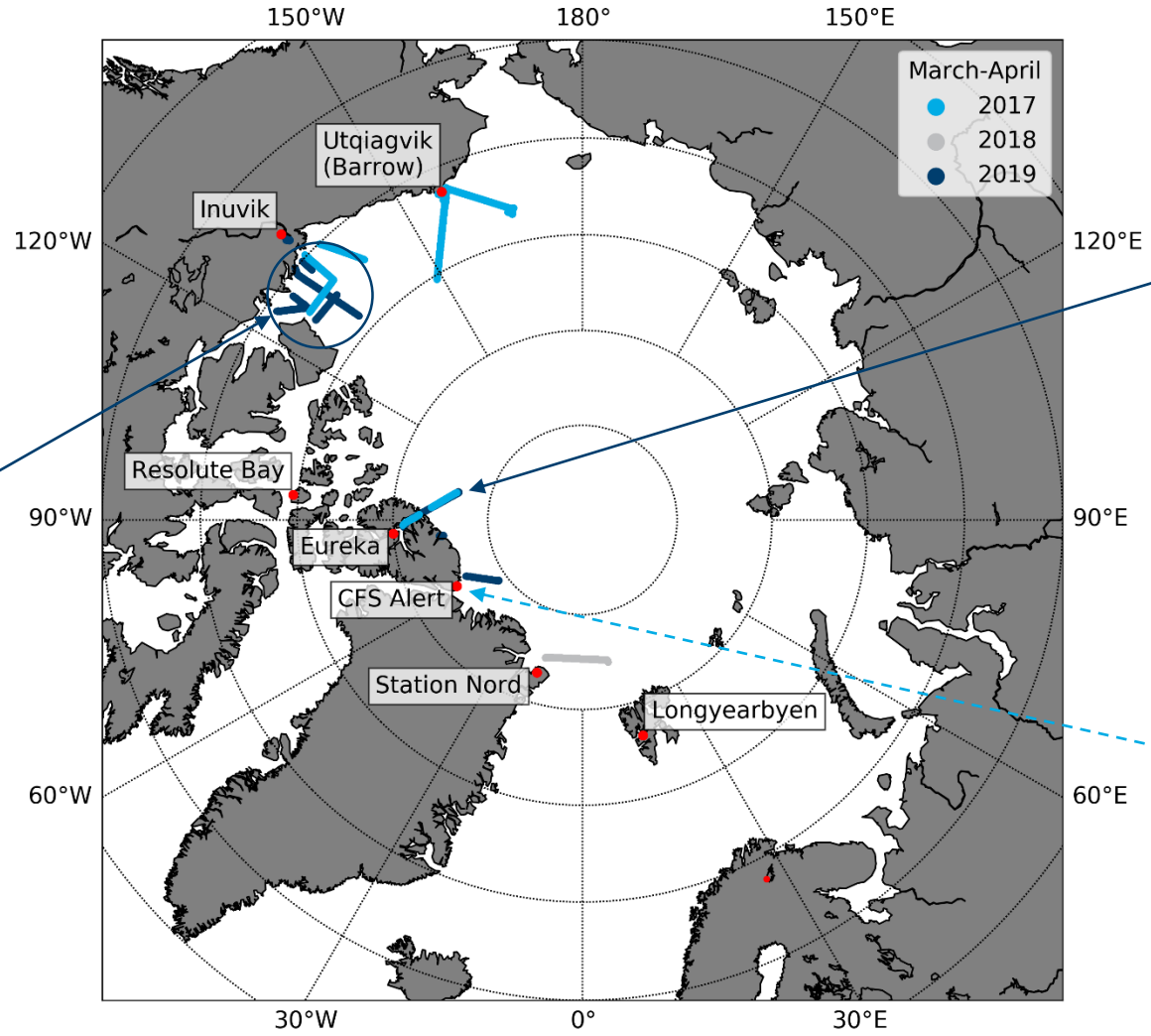


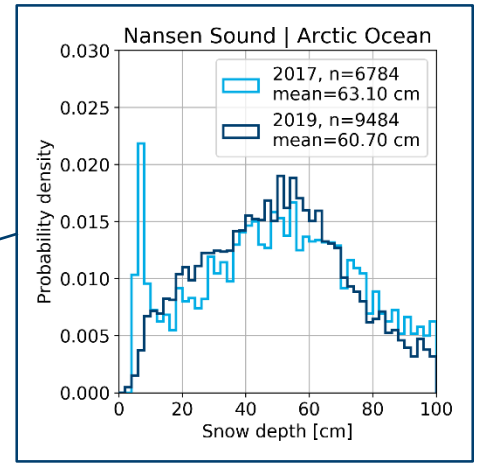


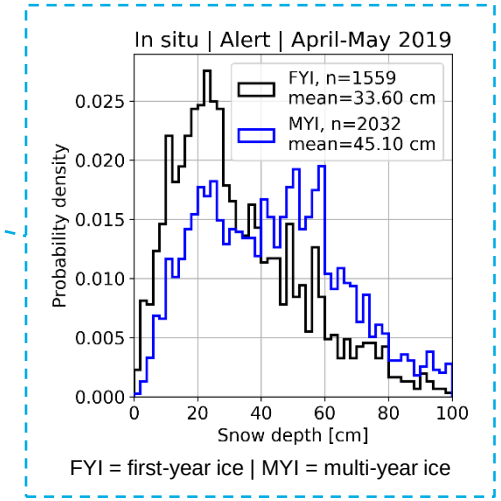
Terrestrial laserscanner (TLS) data courtesy of C. Polashenski

First results - distributions







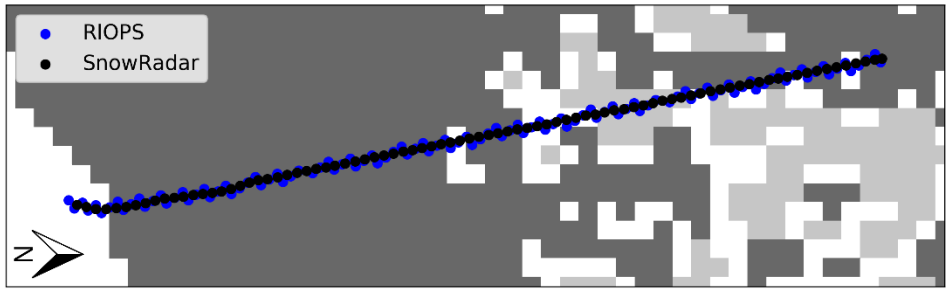


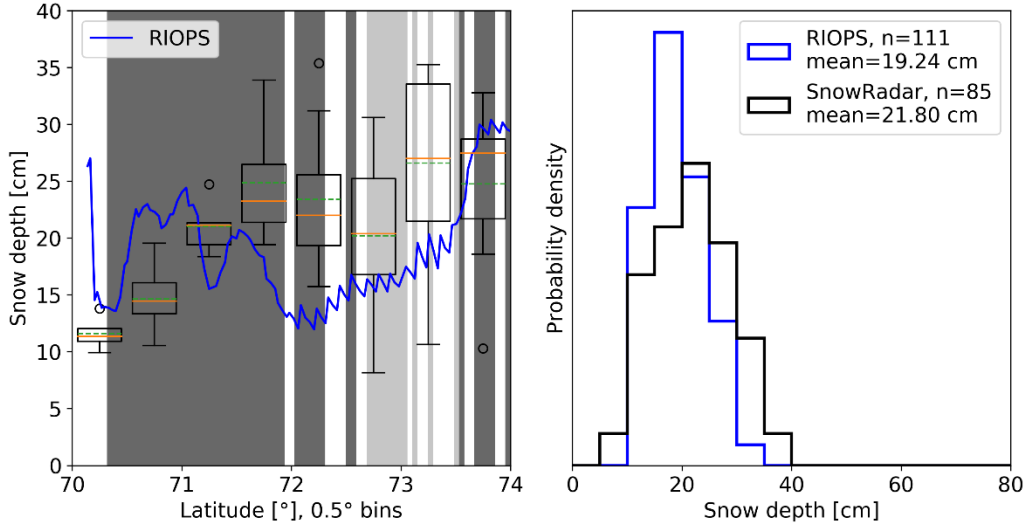
Ice type from the daily 10-km EUMETSAT OSI SAF Global Sea Ice Type product

In situ data courtesy of B. Lange & C. Michel

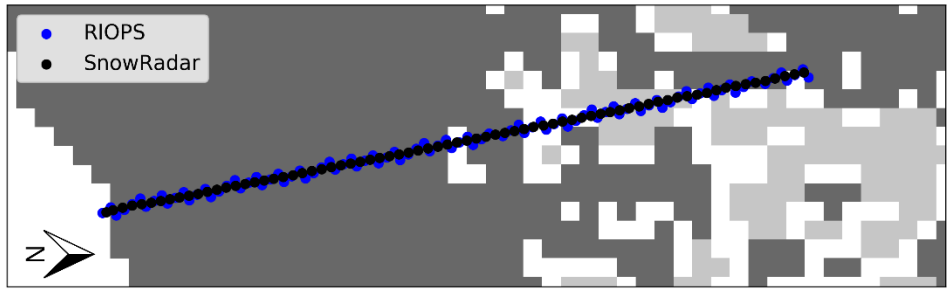
Application example

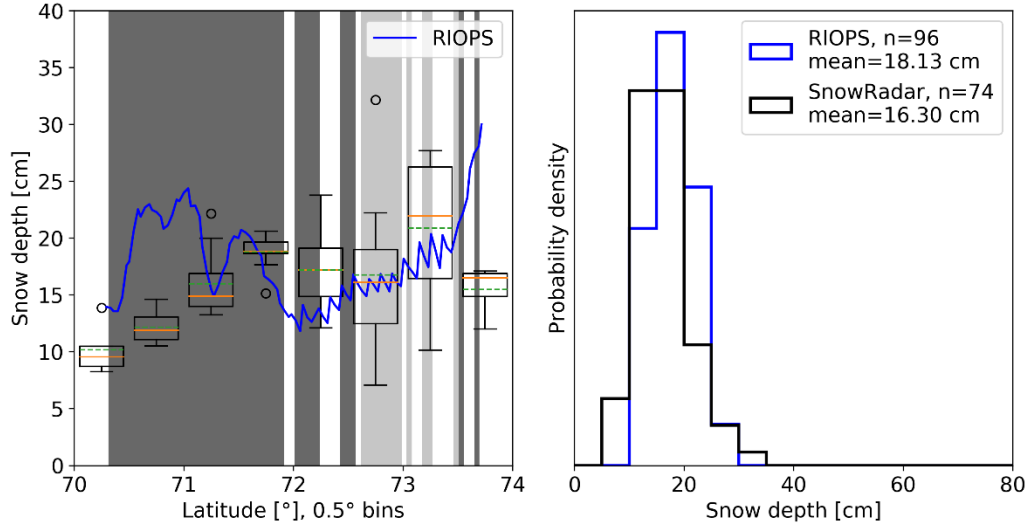
East Beaufort Sea | 10 April 2019 | 200 ft





East Beaufort Sea | 10 April 2019 | 1600 ft





Regional Ice Ocean Prediction System (RIOPS) data courtesy of Environment and Climate Change Canada
Ice type from the daily 10-km EUMETSAT OSI SAF Global Sea Ice Type product

Limitations & challenges

- Radar and wavelet algorithm sensitivity to snowpack properties
- Low survey altitude
  - Prone to turbulence
  - Radar footprint size

Outlook

- Sub-banding radar data
- Combining with ALS and other products for QA/QC
- Further validation
  - Trail Valley Creek
  - MOSAiC

Applications

- With concurrent measurements of snow freeboard and total sea ice thickness: freeboard to thickness conversion on regional scales

Acknowledgments

- Kenn Borek Air Ltd., AWI logistics and technicians, and other airborne campaign partners
- We acknowledge the use of software from CReSIS generated with support from the State of Kansas, NASA Operation IceBridge grant NNX16AH54G, and NSF grant ACI-1443054.
- pySnowRadar builds upon the wavelet algorithm, original work of Thomas Newman et al. at NOAA
- Helmholtz Graduate School for Polar and Marine Research (POLMAR): short-term research grant for a two-month stay at Environment and Climate Change Canada, Climate Research Division
- Travel Award from the 2019 IGS Sea Ice Symposium Student/ECR Travel Award Program