living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE OF OUR PLANET FROM SPACE

Polar+ Snow on sea ice: Dual-frequency snow depth on Arctic sea ice from calibrated Ku-band radar and laser satellite altimetry

Isobel Lawrence, Andy Shepherd, Jack Landy, Michel Tsamados & the Polar+ consortium

24th May 2022

Why do we care about snow depth?

- Important for local and global energy and freshwater budget

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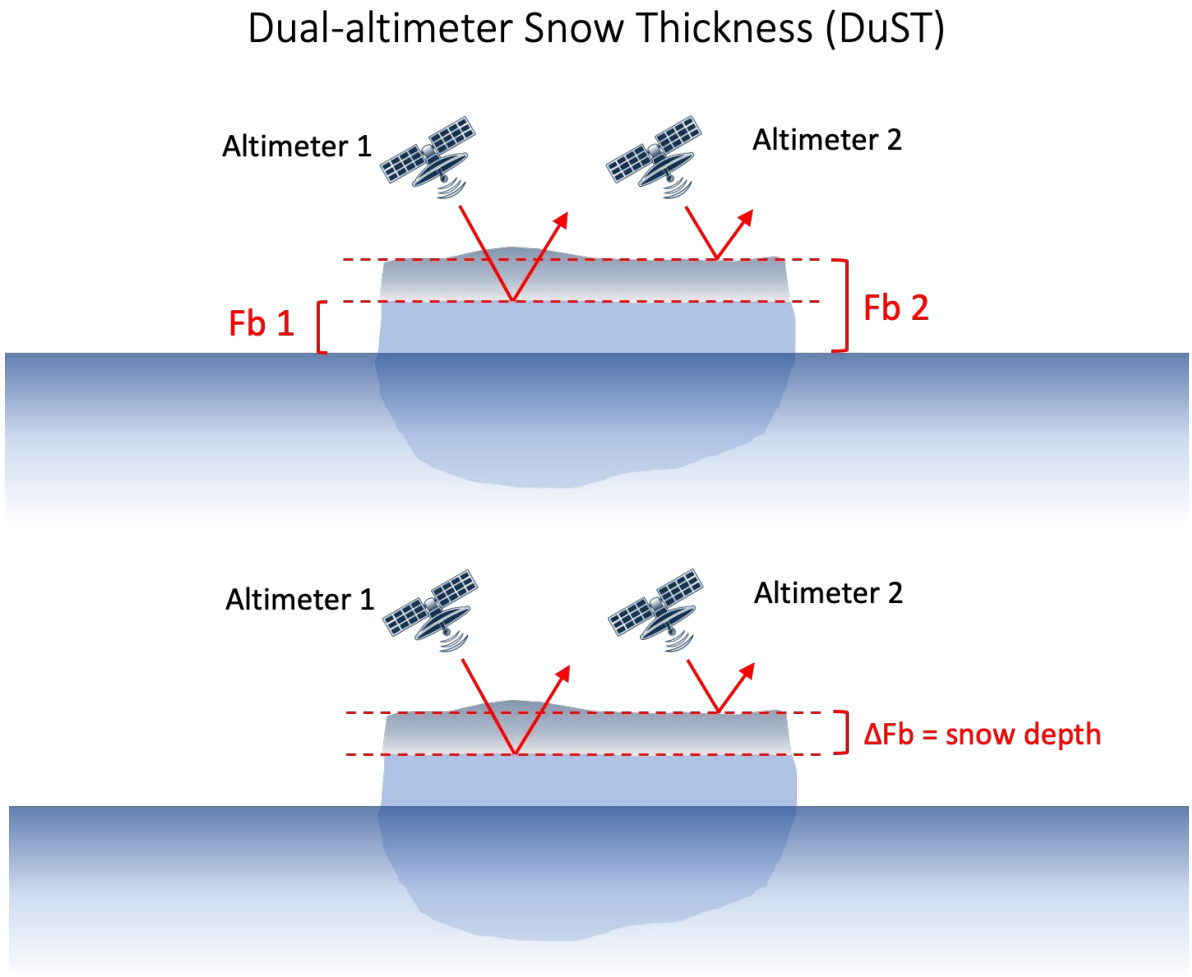
- Important for local and global energy and freshwater budget
- Essential parameter for retrieving sea ice thickness from altimetry

$$\text{Sea ice thickness} = \frac{f_i\,\rho w}{\rho_w - \rho_i} + \frac{h_s\,\rho_s}{\rho_w - \rho_i}$$

Dual-altimetry Snow Thickness (DuST) methodology

- Exploits the availability of synchronous satellite missions operating at different frequencies.
- First developed as part of the *Arctic+ Snow on Sea Ice* ESA project and detailed in Lawrence et al., (2018)



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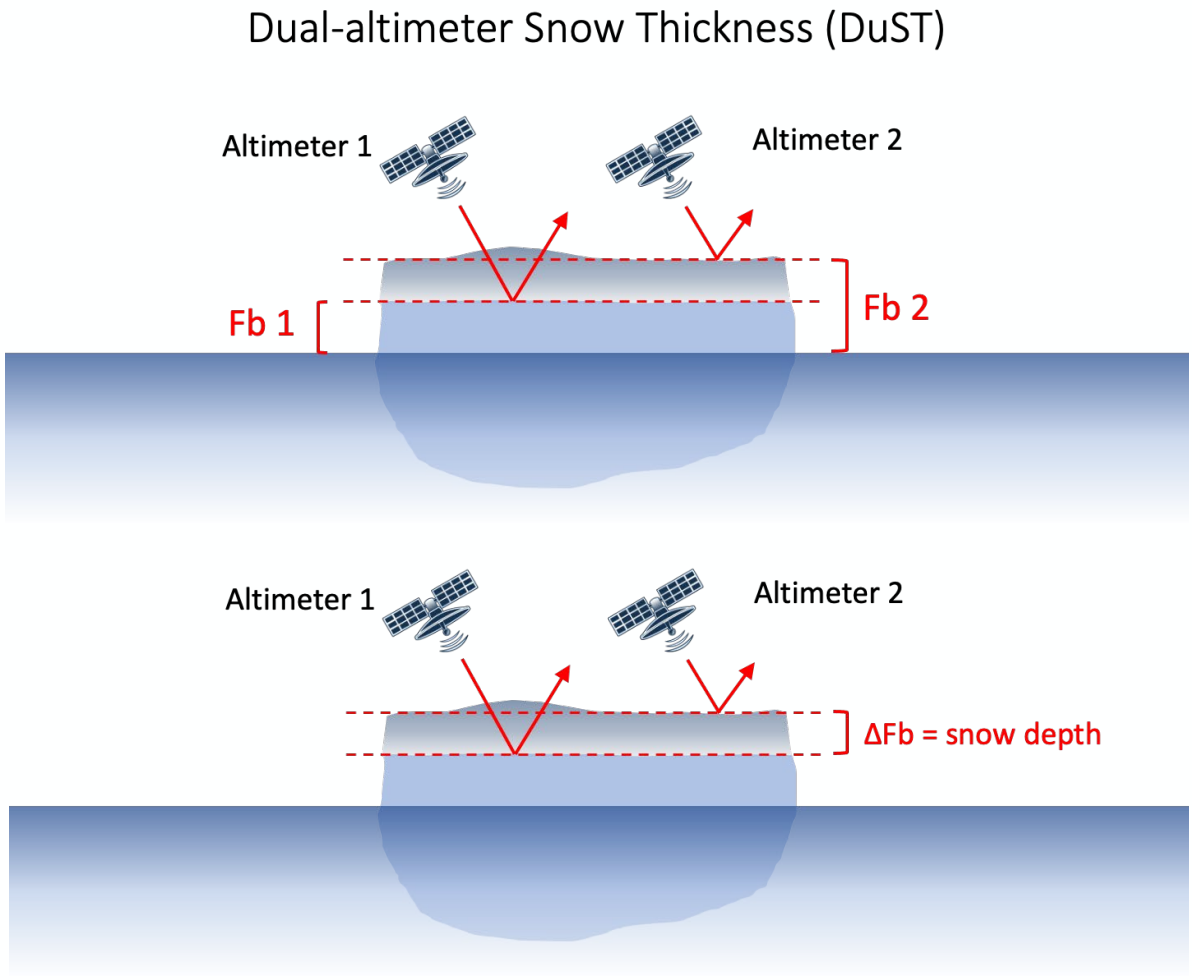

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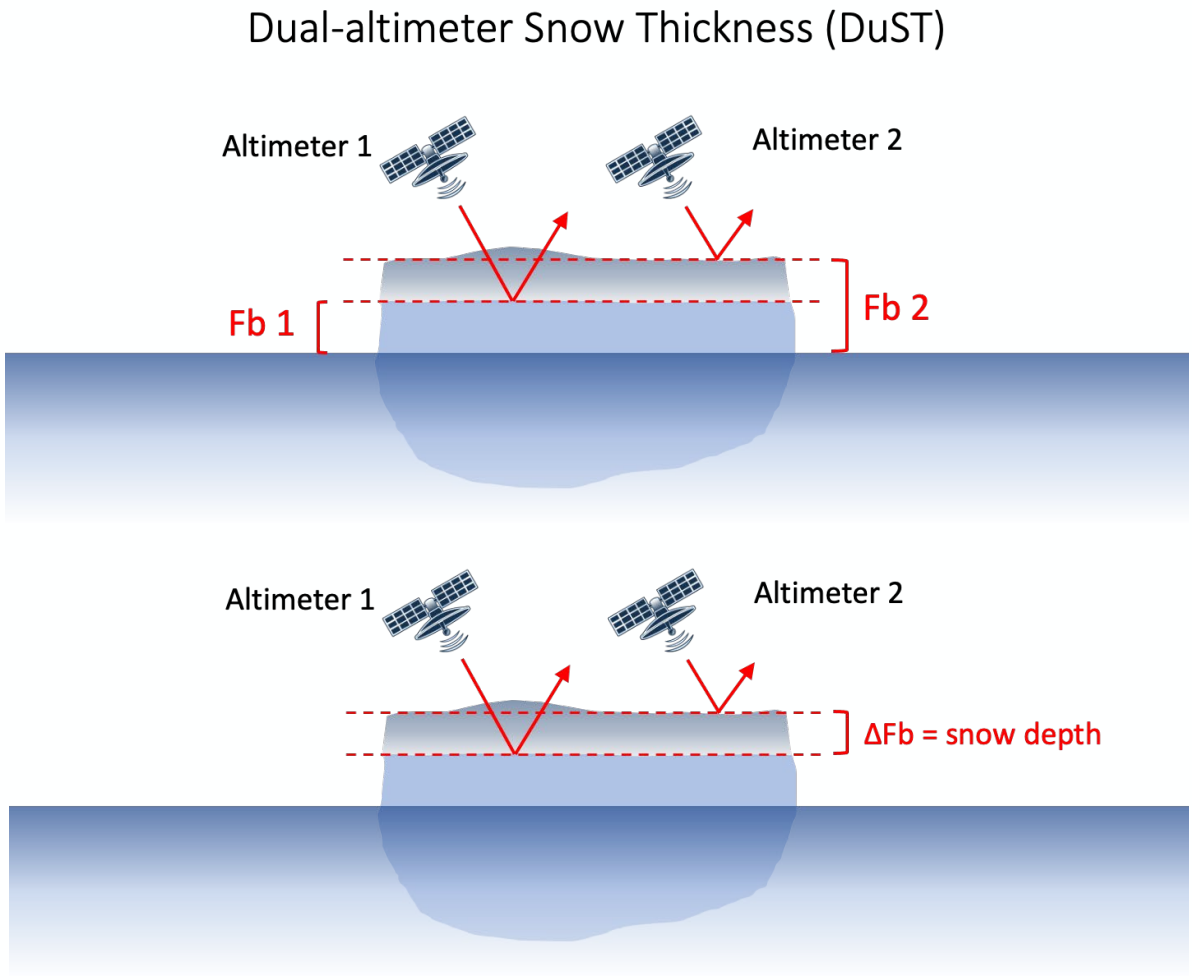
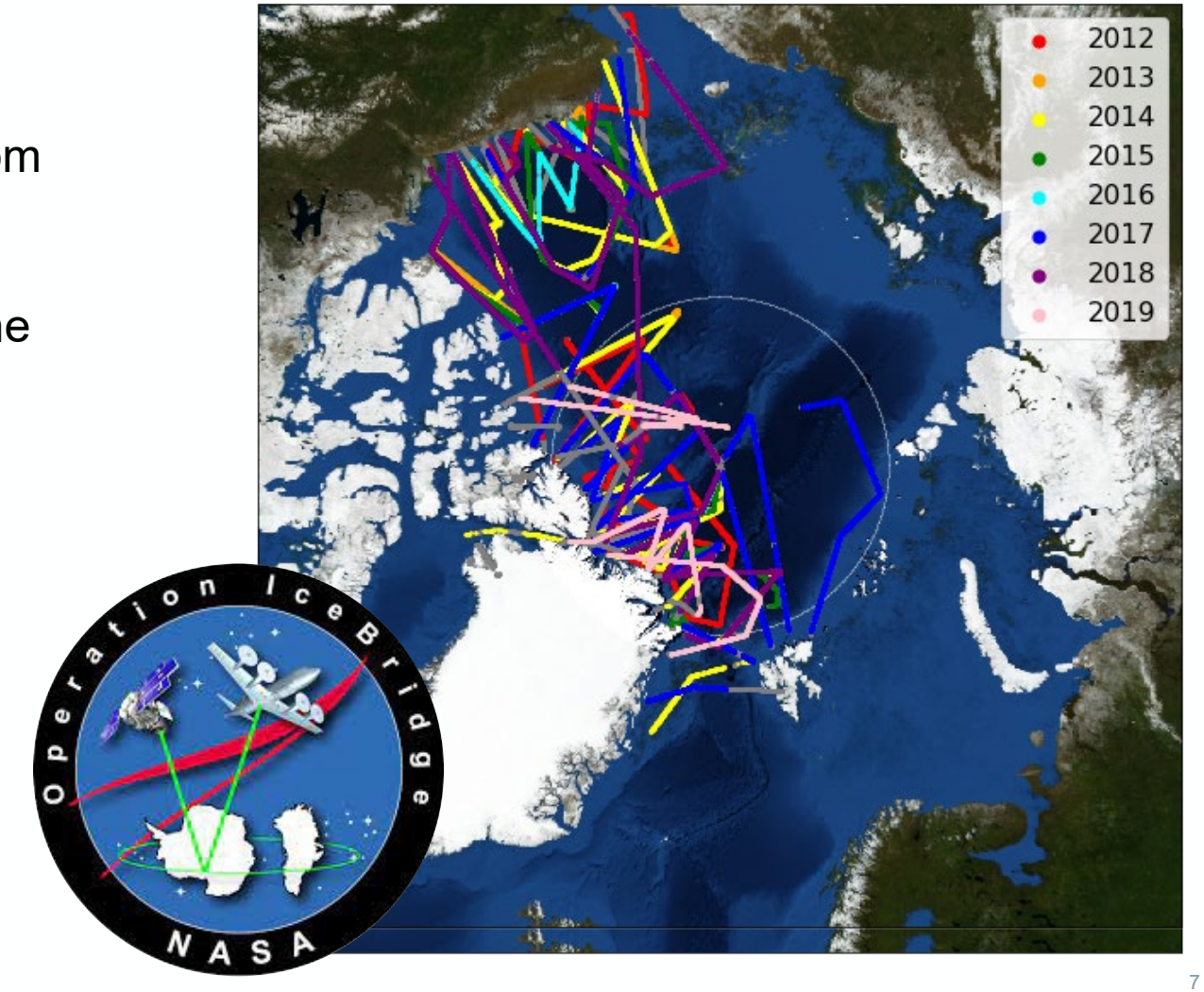
- Need to understand the penetration depths of both altimeters
- Differences in satellite footprint bias retrievals, especially over rough surfaces.

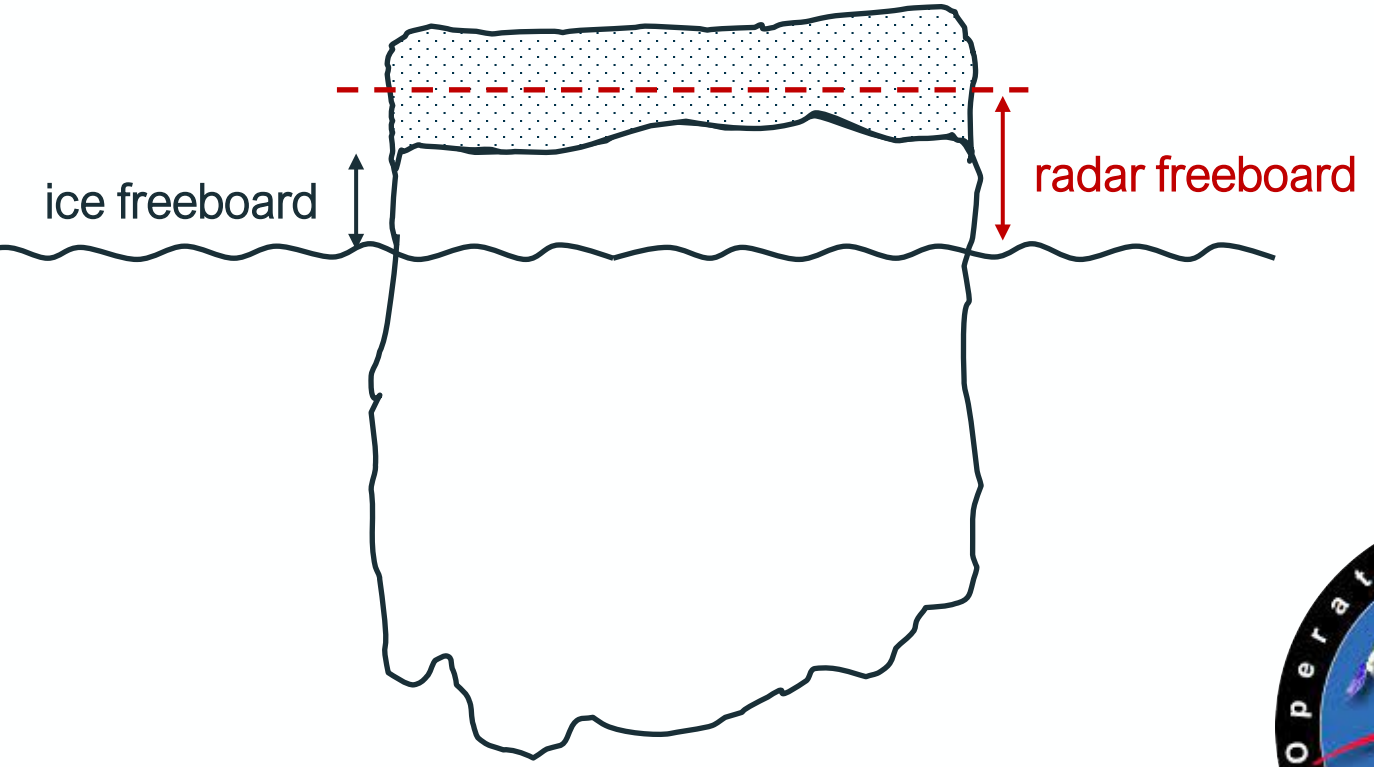


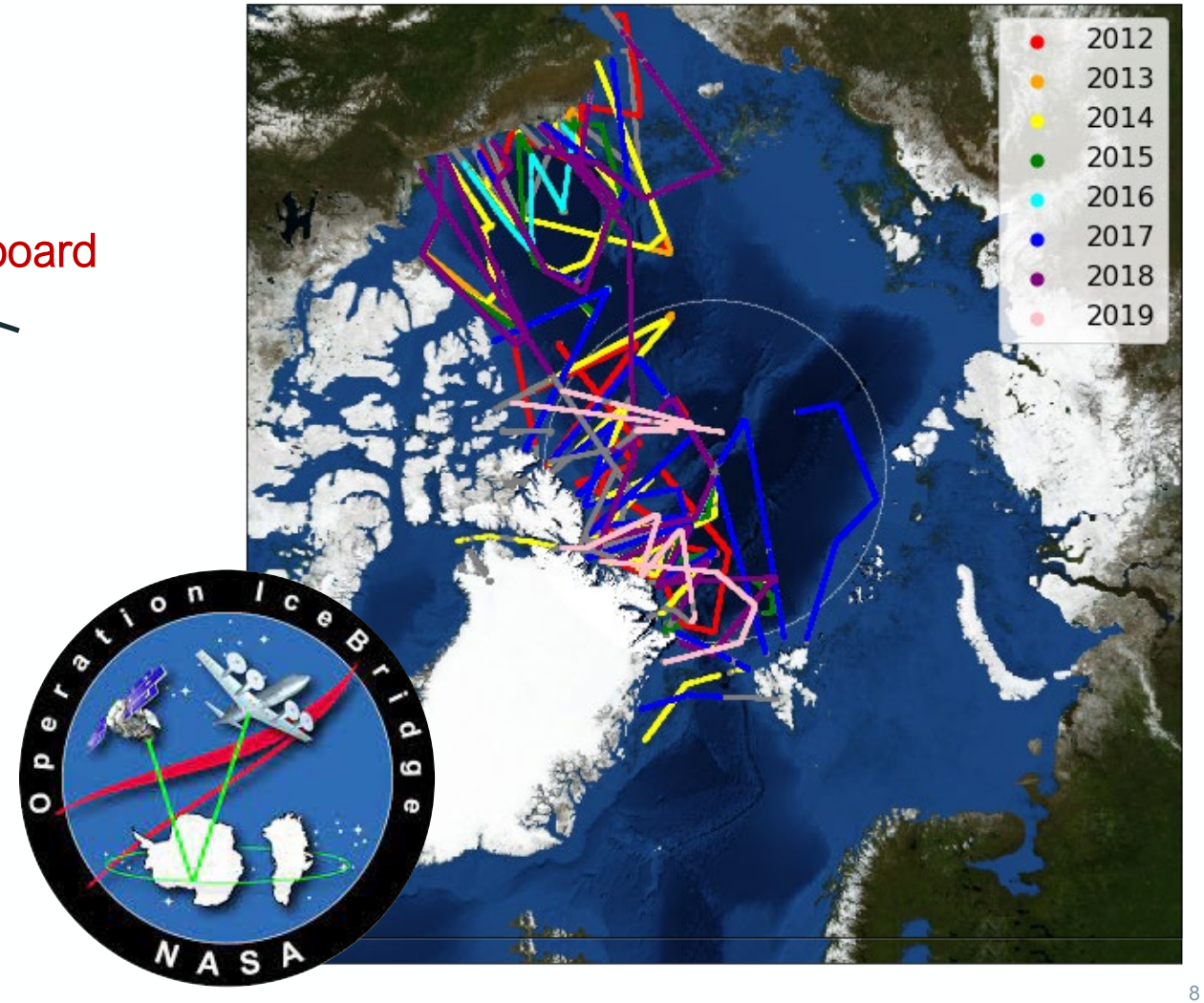
Calibration of radar freeboard with Operation IceBridge

- Methodology requires calibrating satellite radar freeboards with independent freeboard data from NASA's Operation IceBridge.
- We now have 8 years of OIB data to perform the calibrations…
- …but only in the western Arctic and the spring!

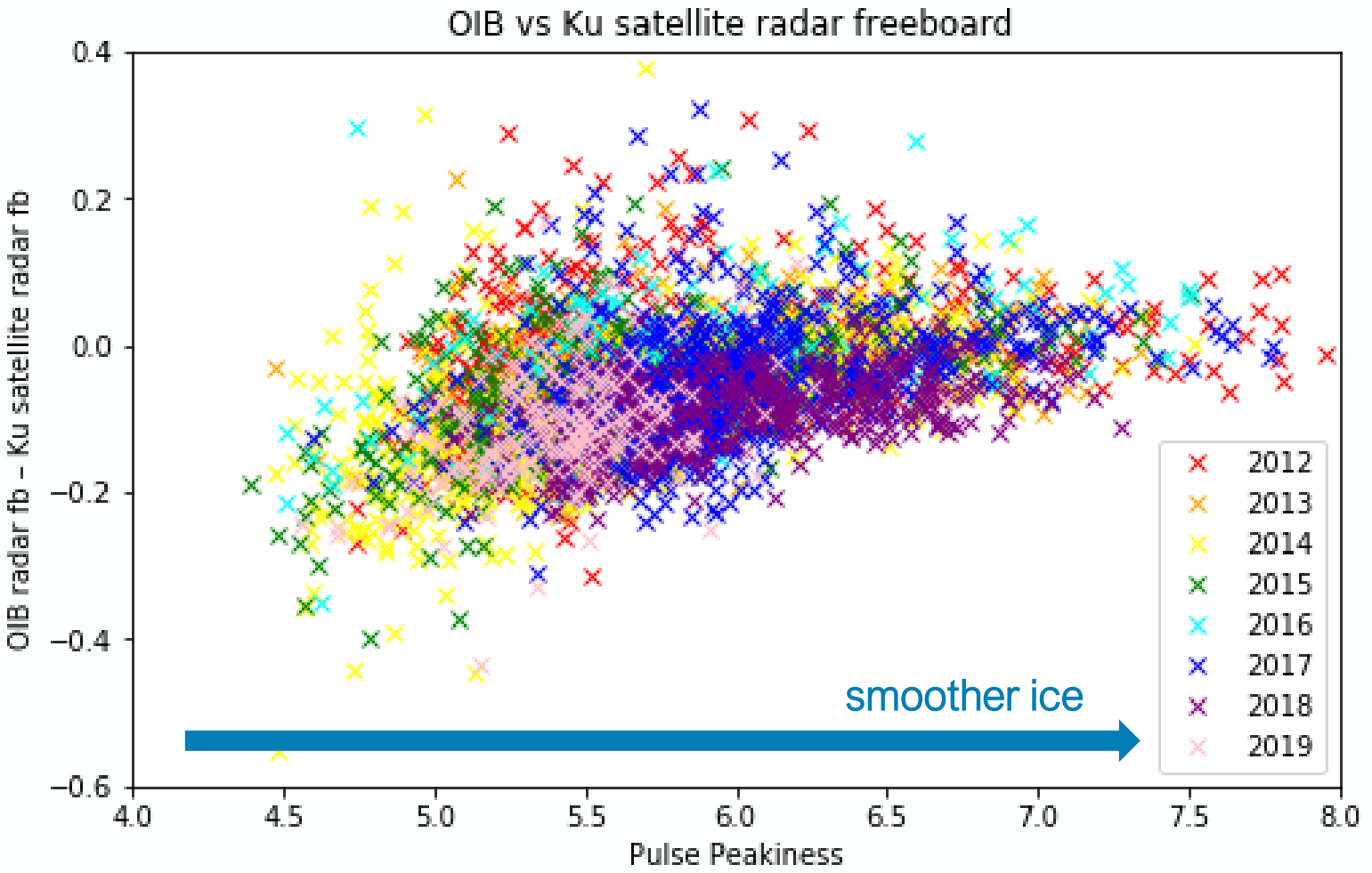


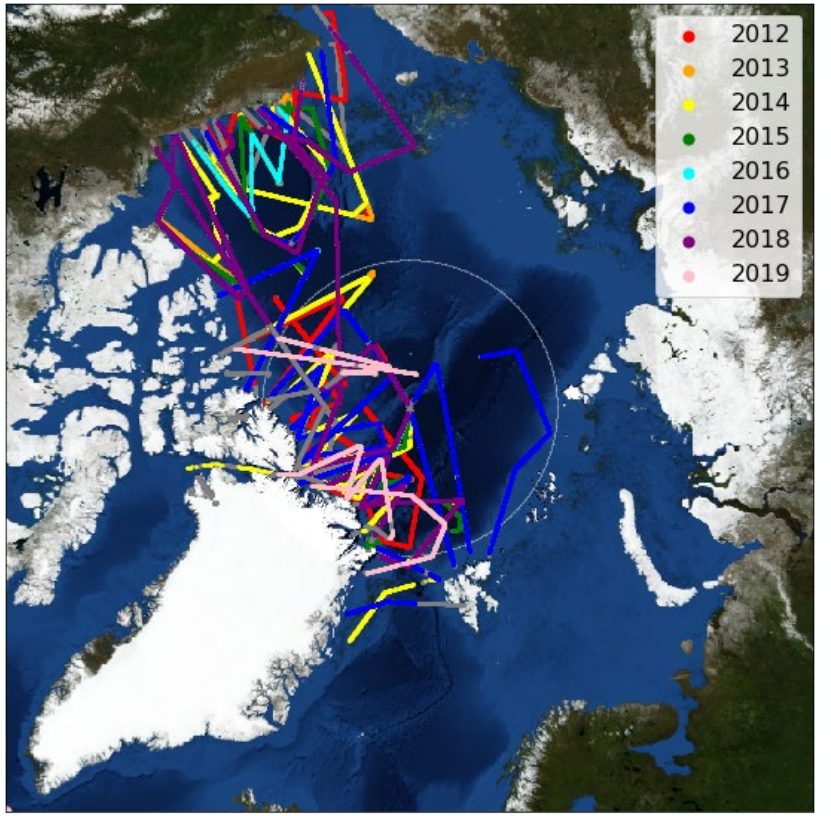
Calibration of radar freeboard with Operation IceBridge





Ku radar freeboard calibration





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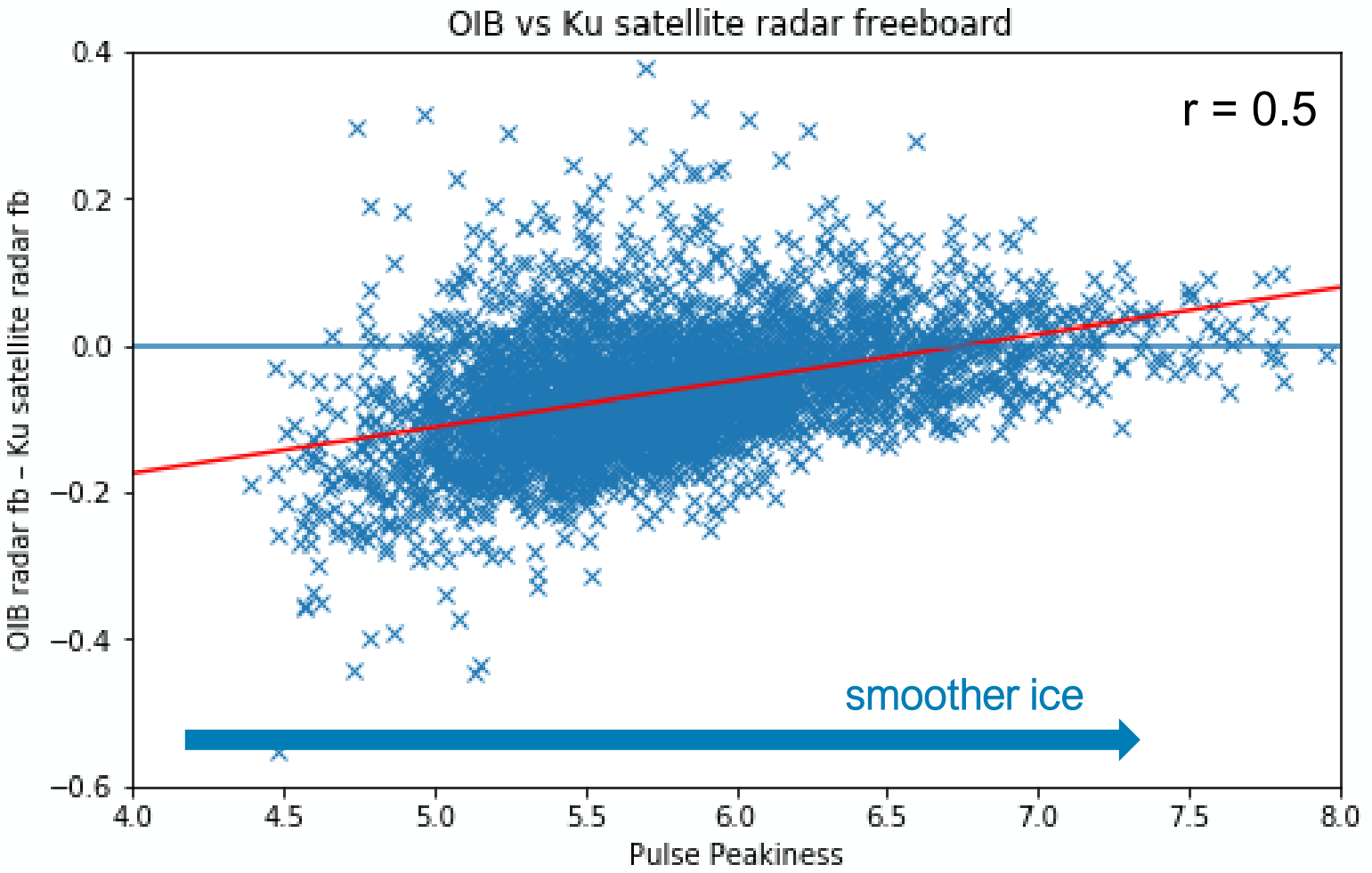

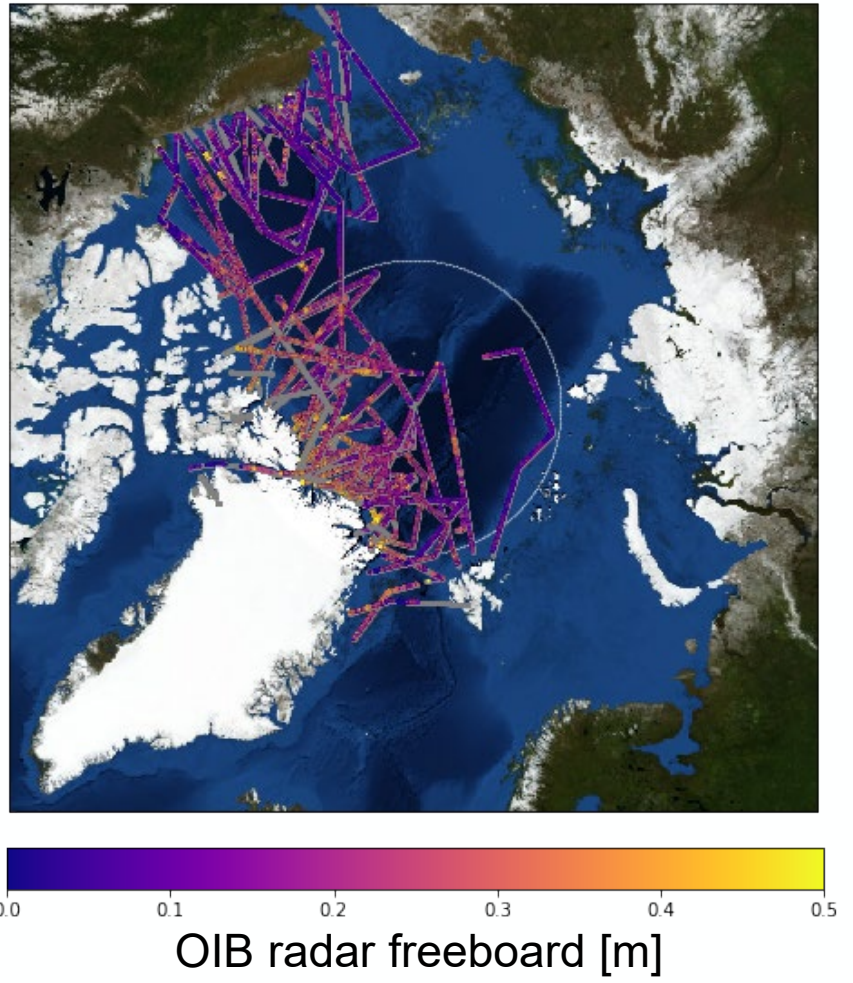

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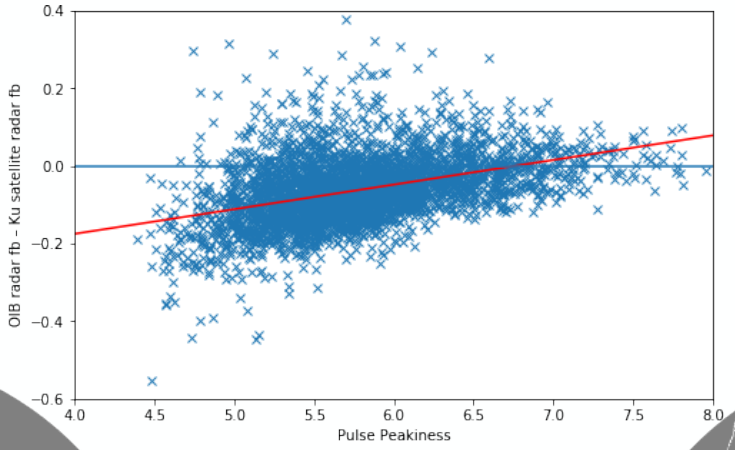
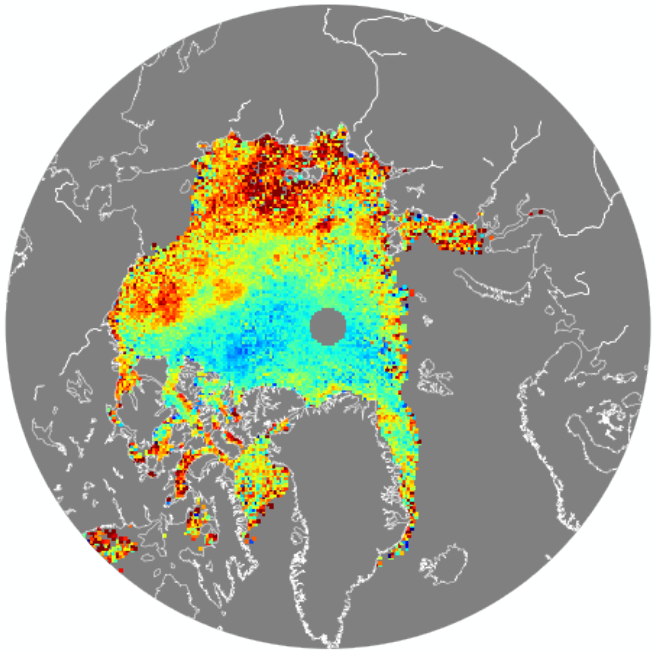
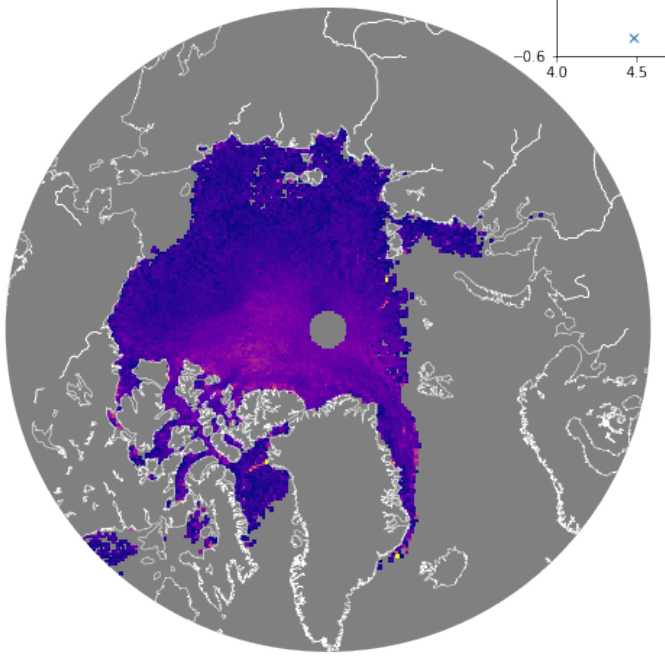


202011

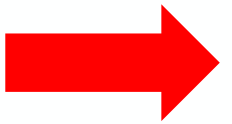


4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0
Ku pulse peakiness

202011



0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
Ku freeboard [m]



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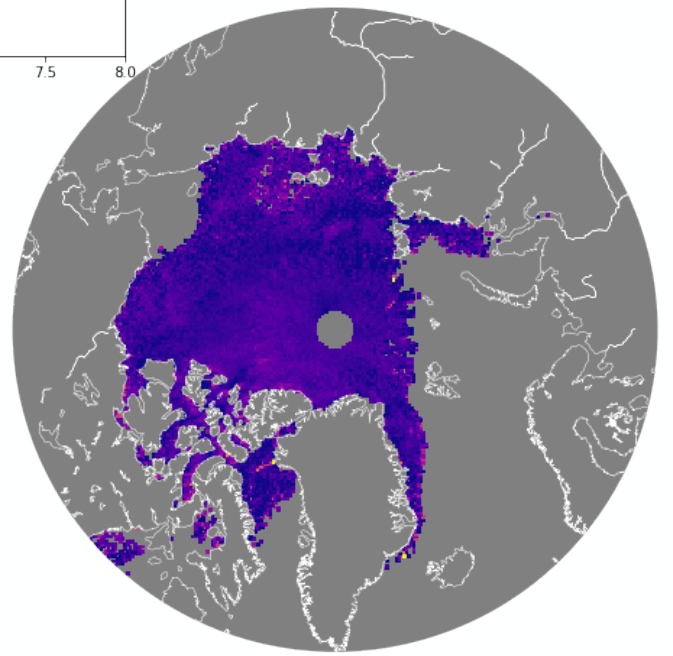


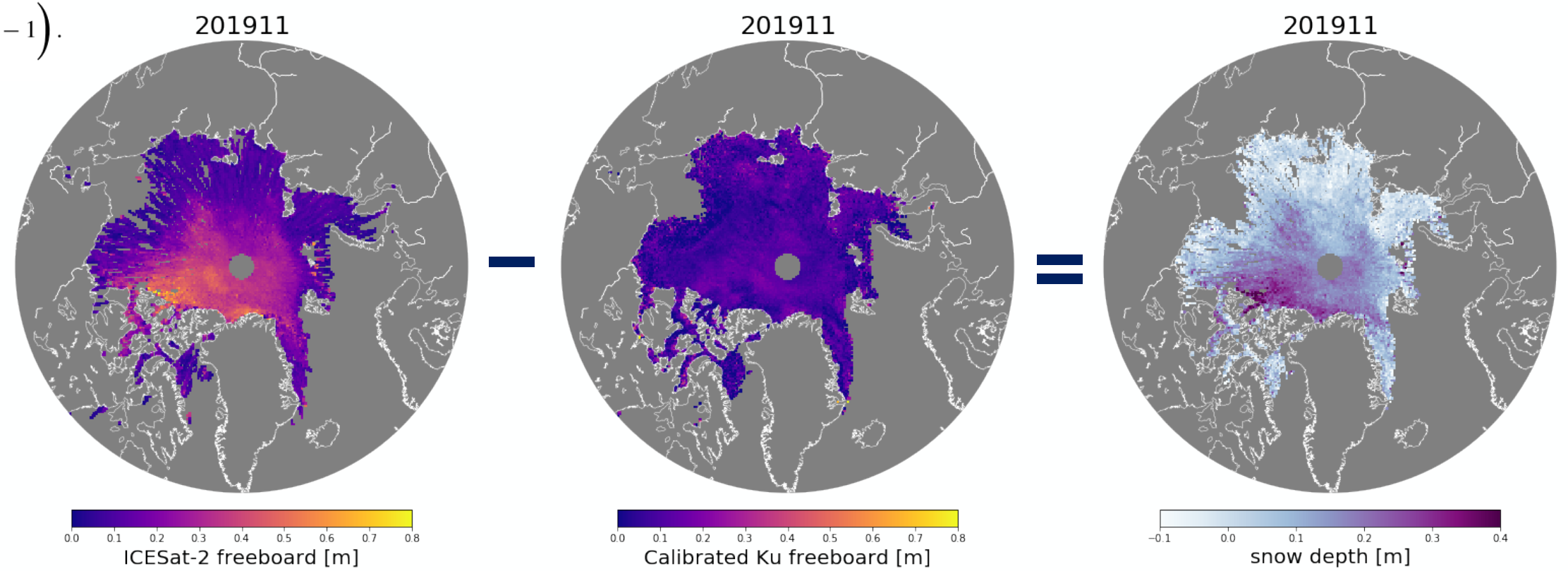
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
Calibrated Ku freeboard [m]

KuLa snow depth

- **KuLa snow depth** = (ICESat-2 freeboard – Calibrated Ku freeboard) x 0.781

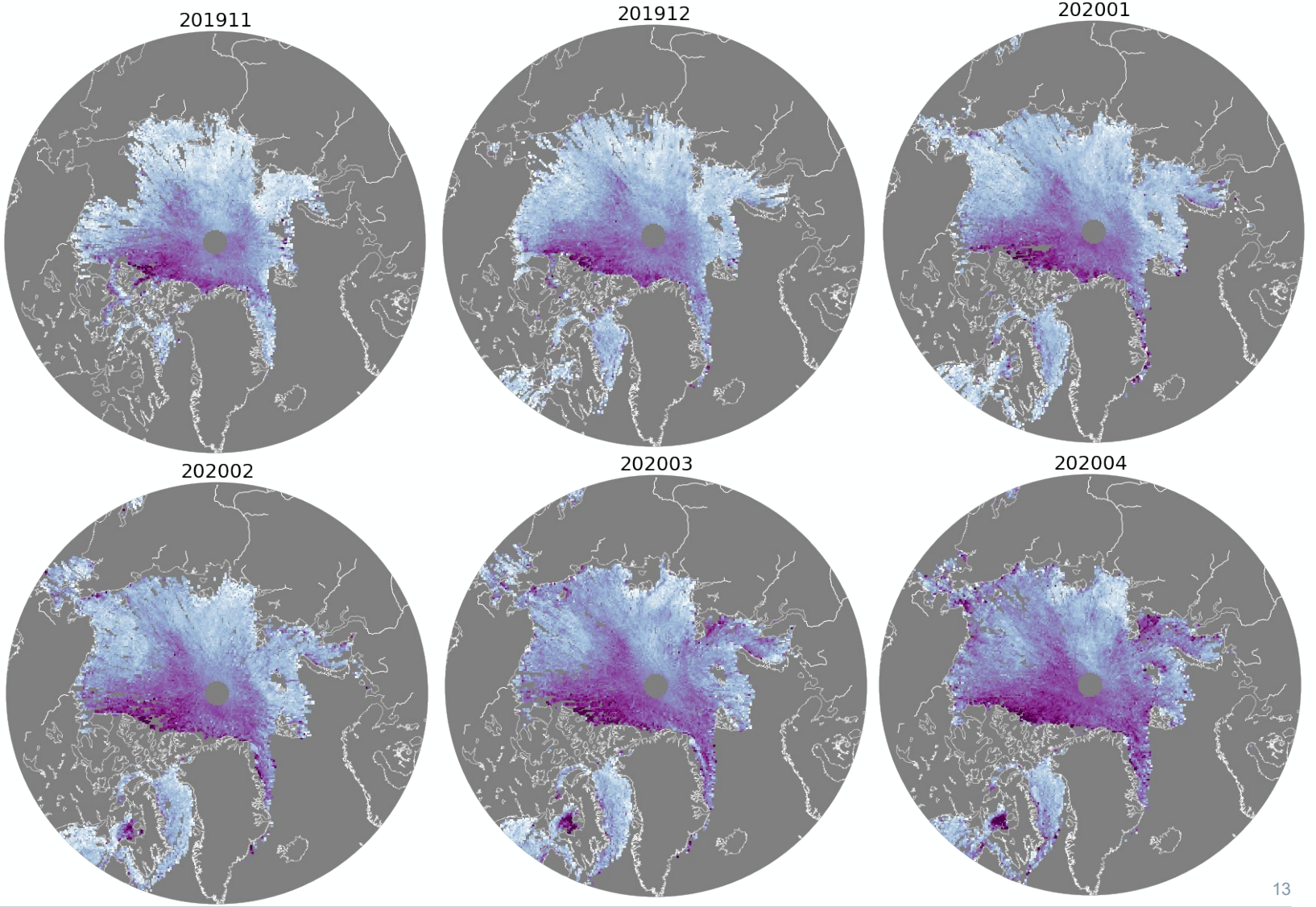
$$f_r = f_i - h_s\left(\frac{c}{c_s} - 1\right).$$

0.781 ×



KuLa snow depth

- Snow depth for two winters (2018->19 to 2019->20).
- +1 year Latency with ATL-20 data.
- Small pole hole north of 88ºN allows interpolation within sea ice margin



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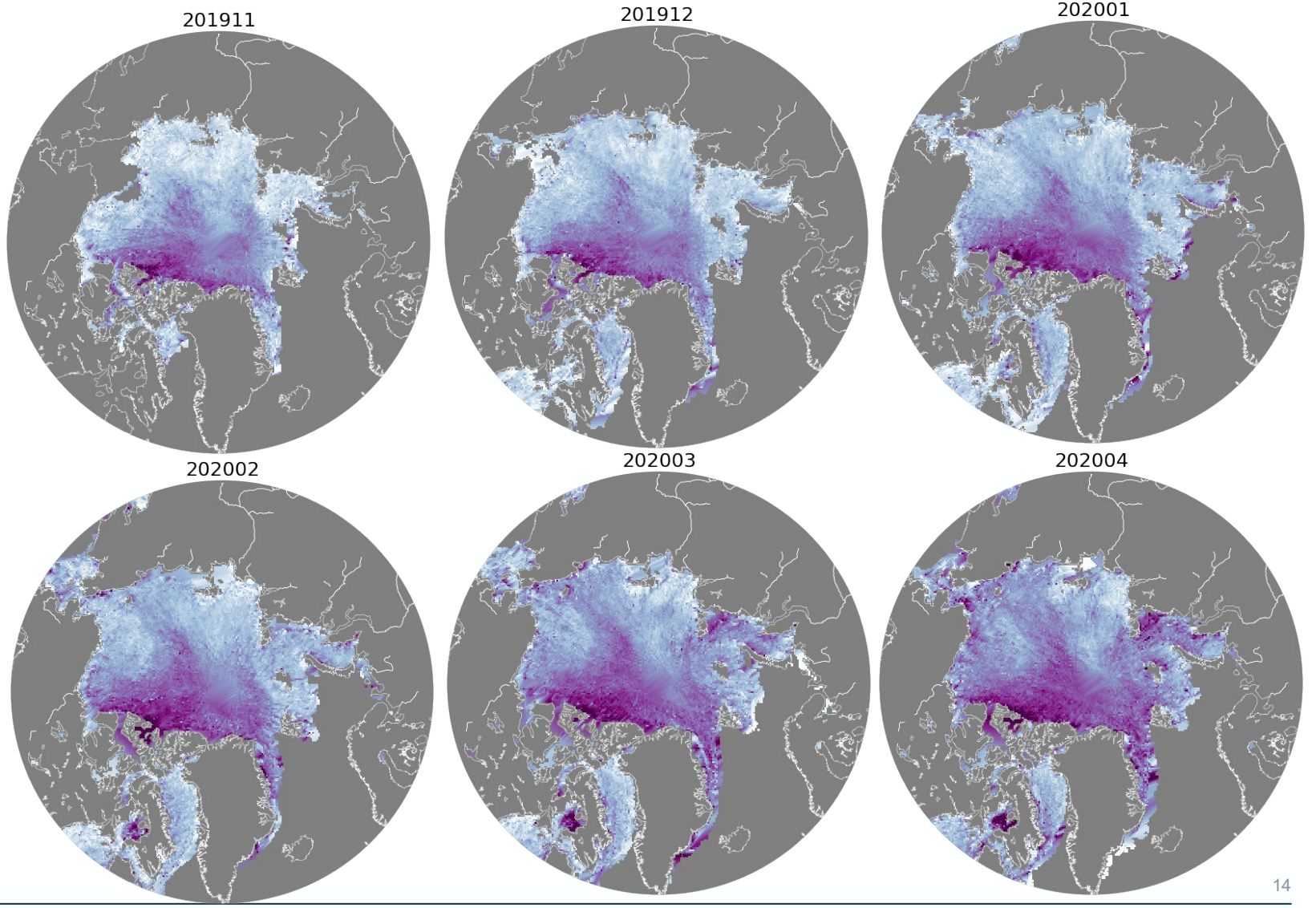


Comparison to other snow products

JGR Oceans

RESEARCH ARTICLE
10.1029/2019JC016008

Key Points:

- Our current understanding of snow depth is based largely on climatology developed during last century and from recent airborne surveys
- We present a first examination of Arctic sea ice snow depth estimates from differencing satellite ICESat-2 and CryoSat-2 freeboards
- Sea ice thickness can now be calculated with snow loading from satellite retrievals without resorting to climatology or reconstructions

Correspondence to:
R. Kwok,
ron.kwok@jpl.nasa.gov

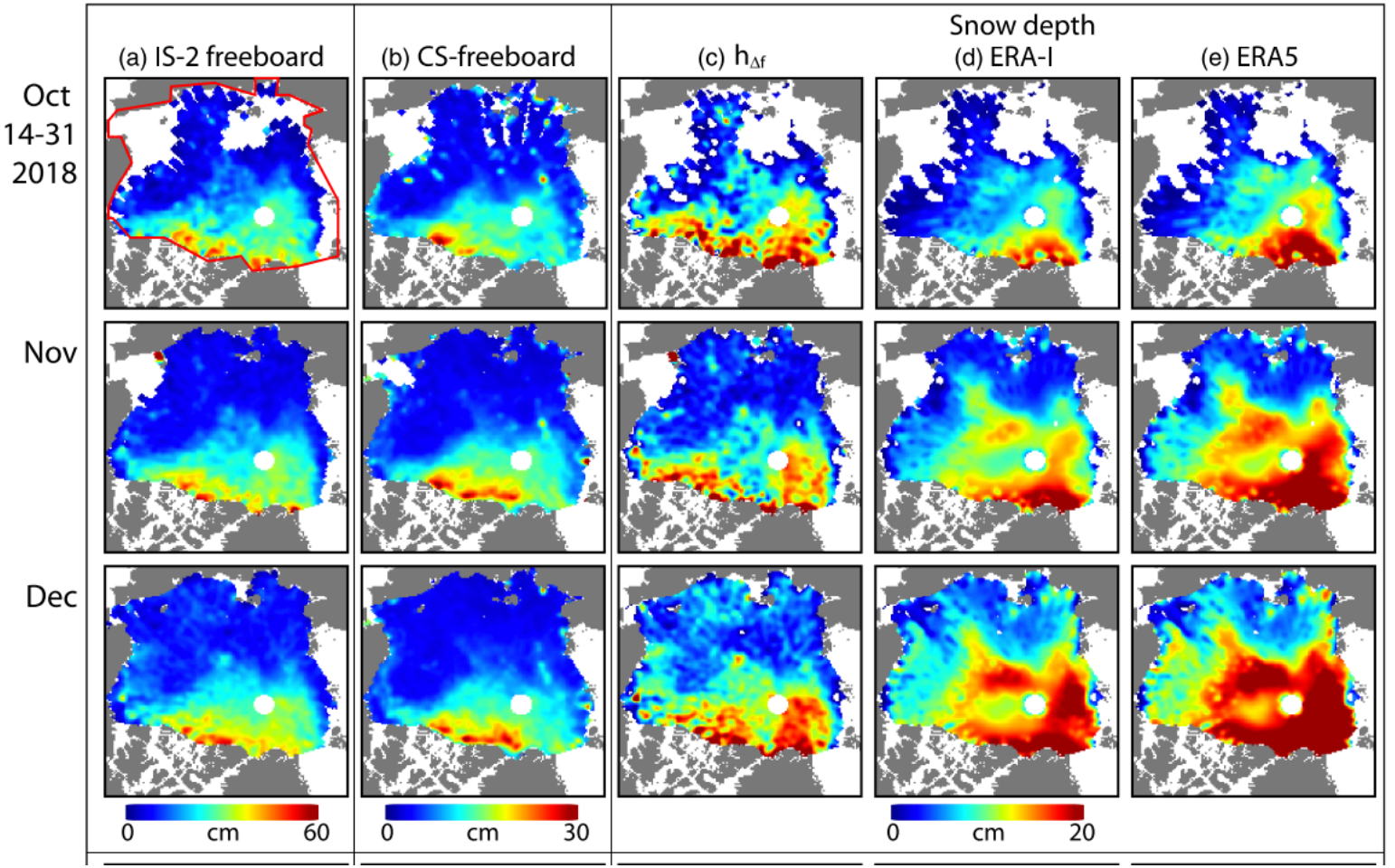
Arctic Snow Depth and Sea Ice Thickness From ICESat-2 and CryoSat-2 Freeboards: A First Examination

R. Kwok[1], S. Kacimi[1], M.A. Webster[2], N.T. Kurtz[3], and A.A. Petty[3,4]

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA, [2]Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK, USA, [3]Goddard Space Flight Center, Greenbelt, MD, USA, [4]Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD, USA

Abstract We present a first examination of Arctic sea ice snow depth estimates from differencing satellite lidar (ICESat-2) and radar (CryoSat-2) freeboards. These estimates cover the period between 14 October 2018 and the end of April 2019. Snow depth is related to freeboard differences by the refractive index/bulk density of the snow layer—the only free parameter in the approach. Area-averaged snow depth ranges from 9 cm (on first-year ice: 5 cm, multiyear ice: 14 cm) in late October to 19 cm (first-year ice: 17 cm, multiyear ice: 27 cm) in April; on average, this snow is thinner over FYI. Spatial patterns and gradients of snow depth estimates compare well with reconstructions using snowfall from ERA-Interim and ERA5, although snowfall from ERA5 is systematically higher. For all months, the results suggest that ~50% of the total freeboard is comprised of snow. Retrievals are within a few centimeters of snow depth data acquired by Operation IceBridge in April 2019. Sources of uncertainties associated with this

Comparison to other snow products



"… but the potential biases in CS-2 freeboards due to the presence of brine near the snow-ice interface in seasonal ice remain an issue to be addressed (Nandan et al., 2017)"

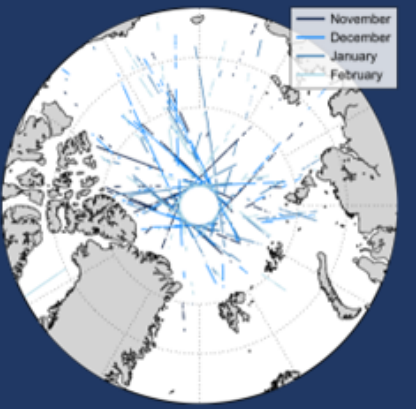
What can Cryo2ice tell us?

- Minimises differences due to shifting ice
- But are footprint sizes still a consideration and how can we learn more about radar penetration without along-track snow depth estimates?

Renée Mie Fredensborg Hansen

Freeboard and snow depth from near-coincident CryoSat-2 and ICESat-2 (CRYO2ICE) observations

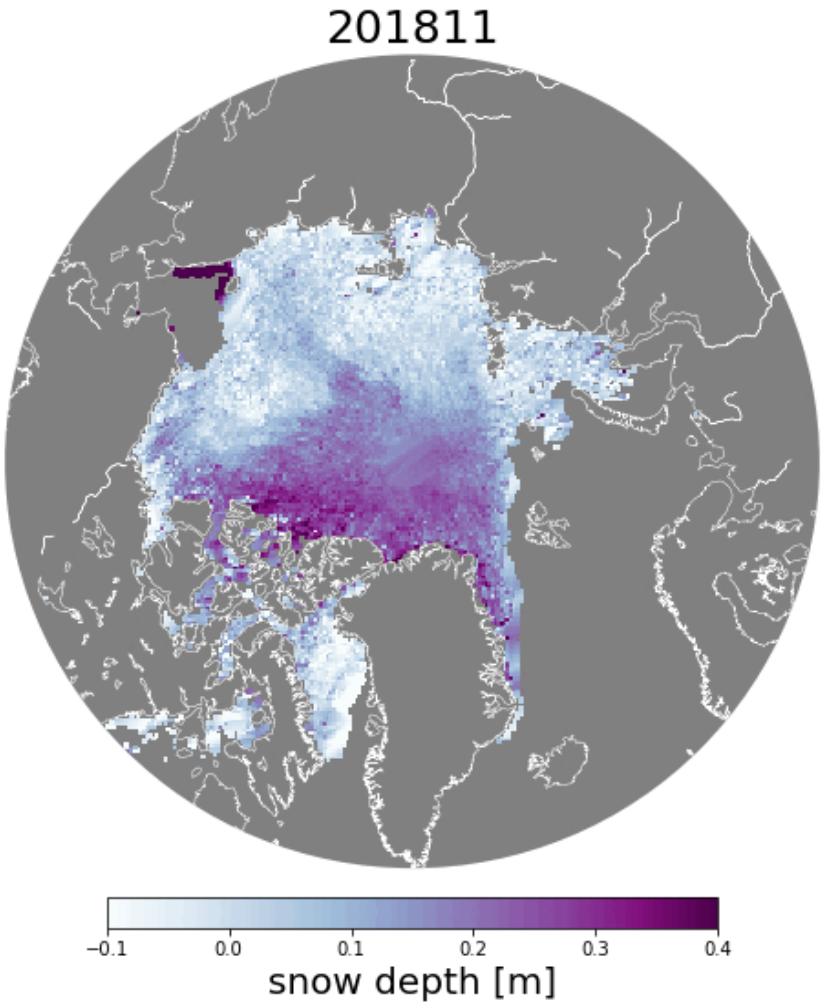
A first examination on the impact of surface roughness



Tuesday 24 May 2022
A9.02 CRYO2ICE: a multi-sensor approach to Earth science
Poster ID: 63604

Summary

- Radar freeboard from CryoSat-2 is calibrated with Operation IceBridge data (DuST methodology) to align it to the snow-ice interface.
- Snow depth for two winters from KuLa method (2018->19 to 2019->20).
- High orbit of CS2 and IS2 permit interpolation within ice extent margin.
- Comparison of this methodology to others, in particular that of Kwok and Kacimi, is next.



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