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Observing the Relationship Between Freeboard, Snow Depth, and Sea-Ice Thickness: Recent Advances in the AWI IceBird Campaigns

ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

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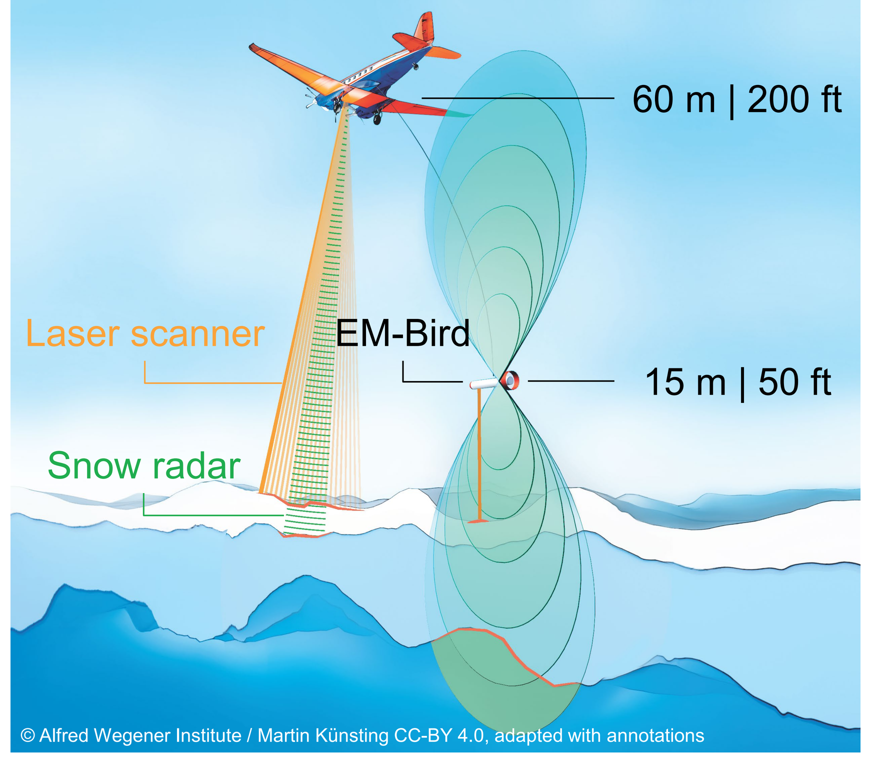
Background

- Airborne high-resolution monitoring of Arctic sea ice since 2010
- Winter (April, Western Arctic) and summer (August, North of Fram Strait) campaigns
- Instrument configuration with snow radar since winter 2017

AWI IceBird
Program webpage



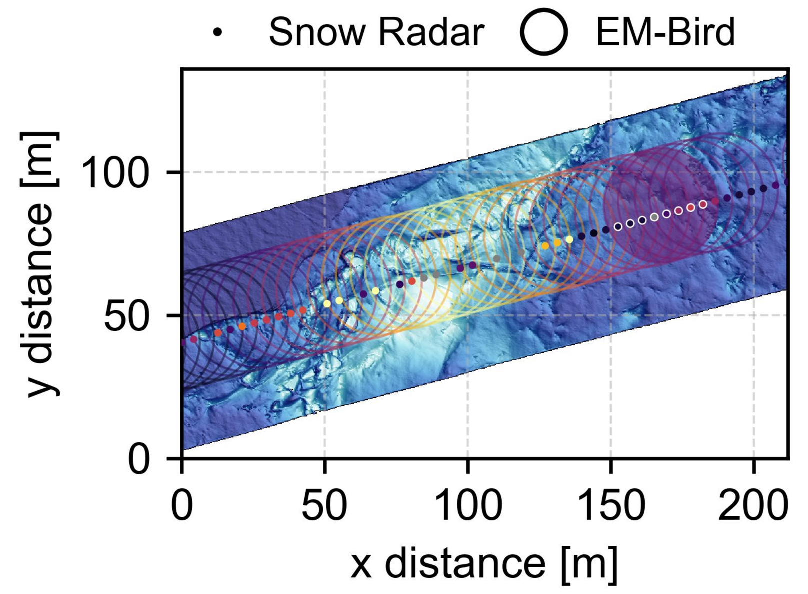
Instrument	Parameter	Data specification
EM-Bird electromagnetic induction sounding	total (ice+snow) thickness	accuracy: 0.1 m footprint: 40 m sample spacing: 5–6 m
Laser scanner line-scanning Riegl VQ-580, 1064 nm	surface elevation (snow freeboard)	accuracy: 25 mm (0.1 m) swath width: 60 m grid size: 0.25 m
Snow radar CReSIS 2–18 GHz FMCW quad-pol.	snow depth	range resolution in snow: 1.14 cm across/along track footprint: 2.6/1.0 m sample spacing: 4–5 m
Infrared radiation pyrometer Heitronics KT19.85II	surface temperature	accuracy: 0.5 °C footprint: 3.1 m sample spacing: 1 m

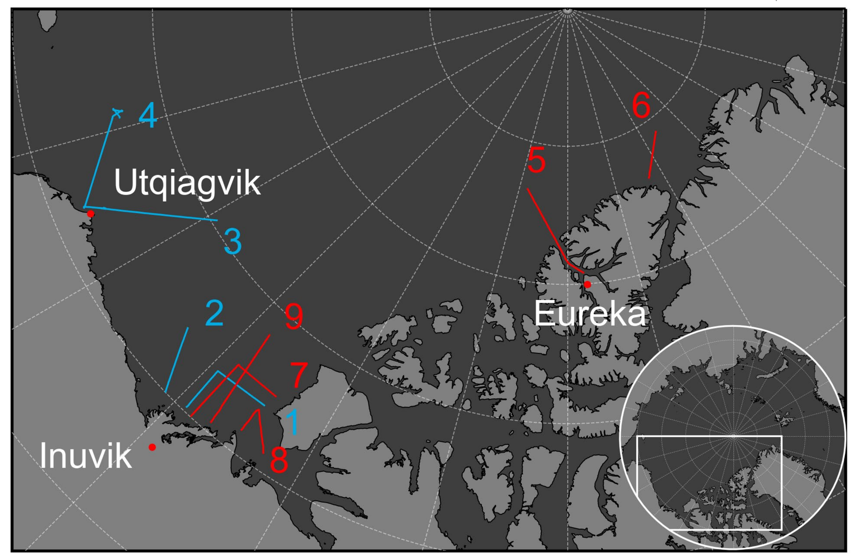
Motivation

- Together with snow mass, unknown **sea-ice density is a major uncertainty factor** in freeboard-to-thickness conversion for satellite altimetry

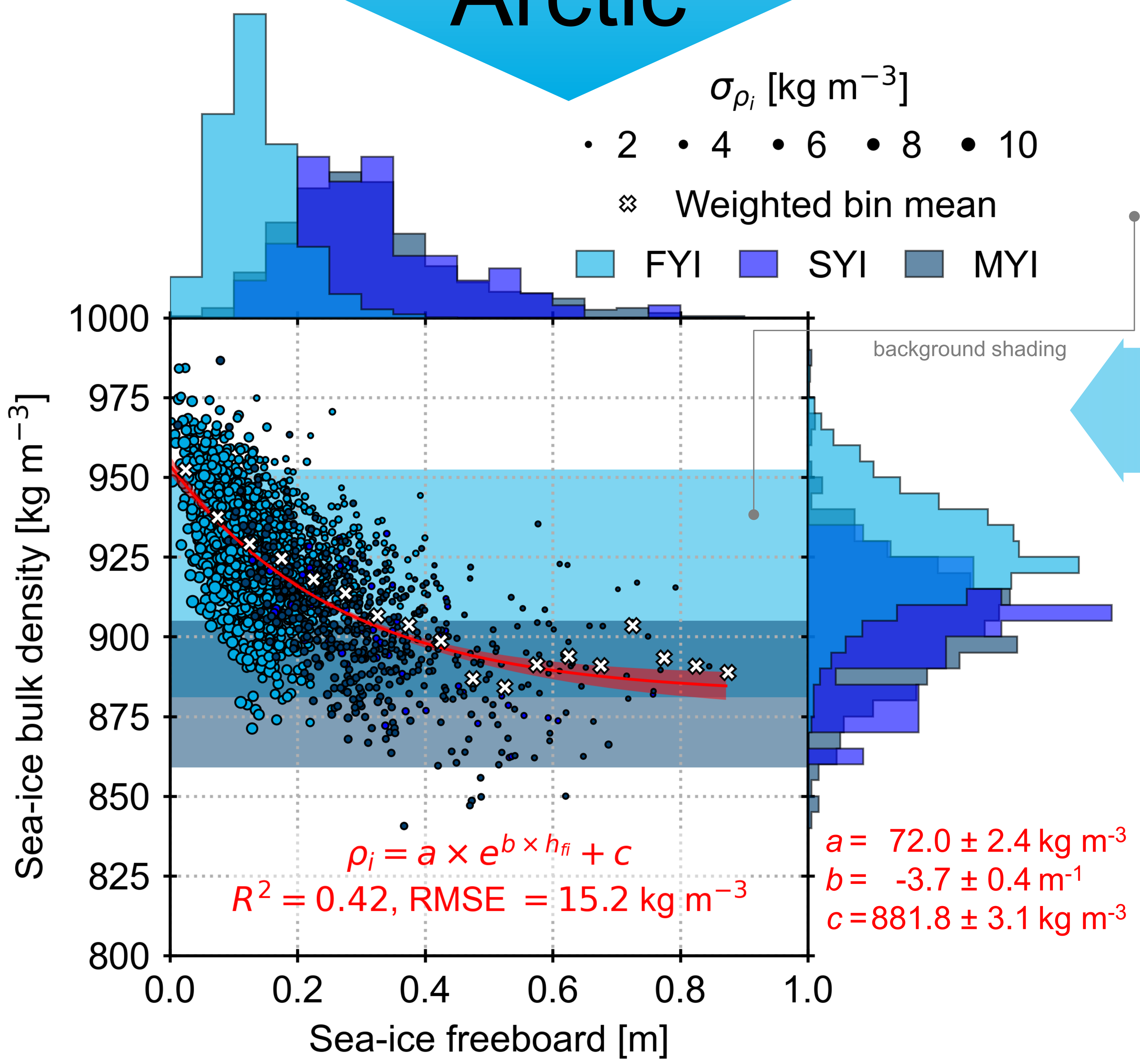
Data

- Nine surveys, a total of 3410 km, in early April 2017 and 2019
- Unique data set of simultaneous and collocated snow depth, snow freeboard, sea-ice thickness, and surface temperature
- Auxiliary data: sea-ice age (NSIDC)



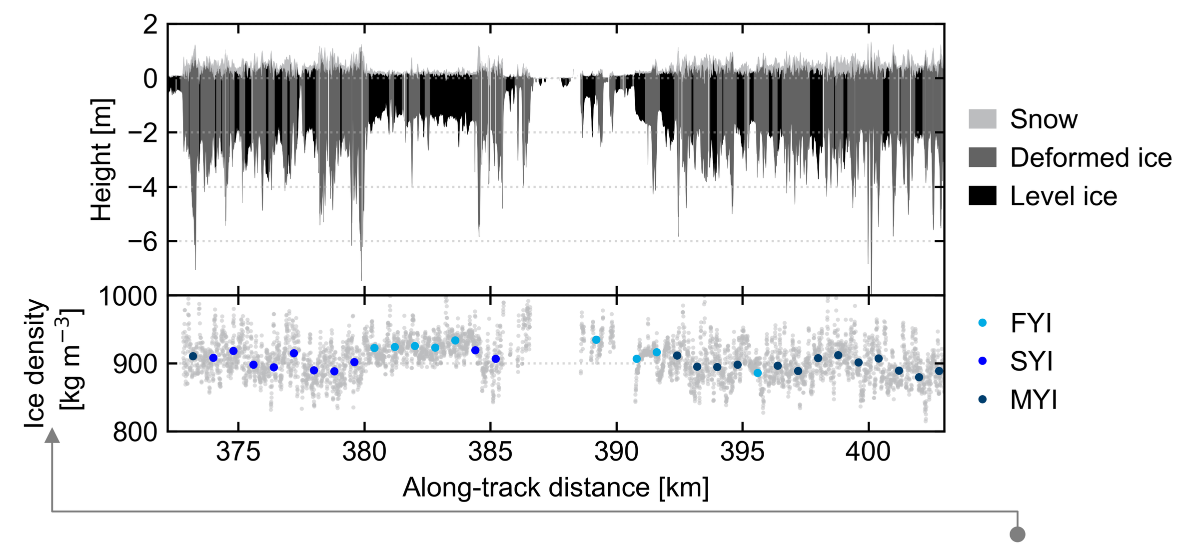


New freeboard-based parametrisation of sea-ice bulk density to improve satellite-based sea-ice thickness and volume estimates in the Arctic



Results

- Along-track profiles of the snow and sea-ice layers and freeboard

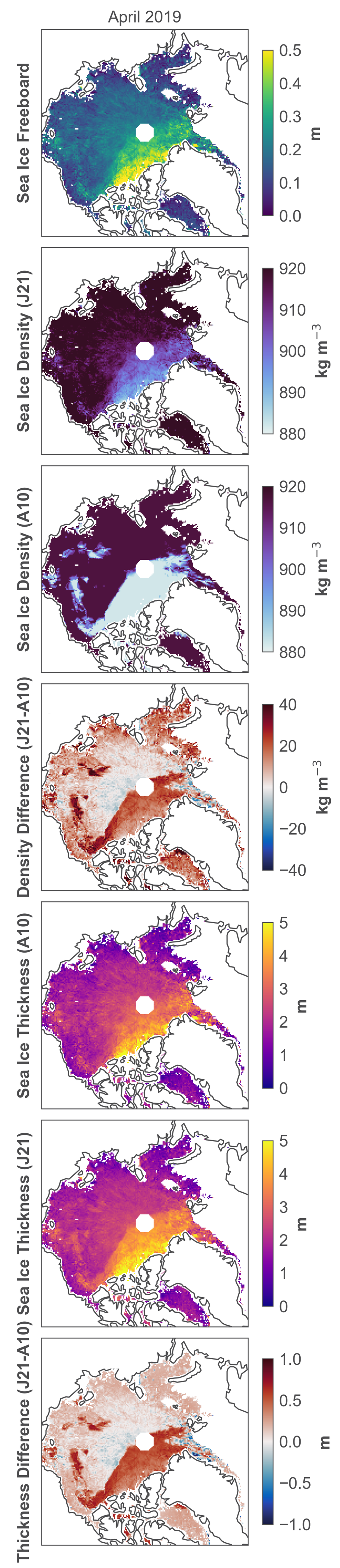


- From layer thicknesses to **sea-ice bulk density:** isostatic equilibrium over a satellite altimeter footprint scale (800 m)
- Average FYI and MYI bulk densities are higher and do not differ from each other as much as earlier studies suggested due to younger and deformed sea ice

Sea-ice density [kg m^{-3}]	Year	FYI	SYI	MYI
This study level & deformed ice	2017	929.3 ± 16.0	N/A	N/A
	2019	925.4 ± 17.7	899.3 ± 17.4	902.4 ± 19.4
Alexandrov et al. (2010) *level FYI, MYI from literature*	*1978–1988*	*916.7 ± 35.7*	*N/A*	*882 ± 23*

Sea-ice bulk density parametrisation

- We found a functional, exponential relationship between sea-ice bulk density and sea-ice freeboard
- We applied the parametrisation (J21) to the monthly gridded AWI CryoSat-2 product which uses fixed sea-ice density values (A10) and the modified Warren snow climatology
- Differences in sea-ice density and thickness are the largest on MYI in proximity to FYI, highlighting the impact of the snow mass parametrisation (previously counteracted by A10)



AWI CryoSat-2

Outlook

- Evaluation of the freeboard-to-thickness conversion from satellite altimetry for dedicated underflights and orbit collections (ICESat-2, CryoSat-2, Sentinel-3A, AltiKa)
- Impact assessment of the density parametrisation on decadal sea-ice thickness data record

Paper & data

Online poster

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