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

Snow depth on sea ice from airborne Ku/Ka-band and ultra-wide band radars

ESA CryoVEX / ESA Cryo-seaNice / AWI IceBird Teams

Workshop on dual-band Altimetry of the Cryosphere

Snow Depth on Sea Ice - Challenges

Dual-Band Altimetry driver for remote sensing

CryoSat-2/AltiKa | CryoSat-2/ICESat-2 | CRISTAL

Sea ice and snow layer are heterogenous

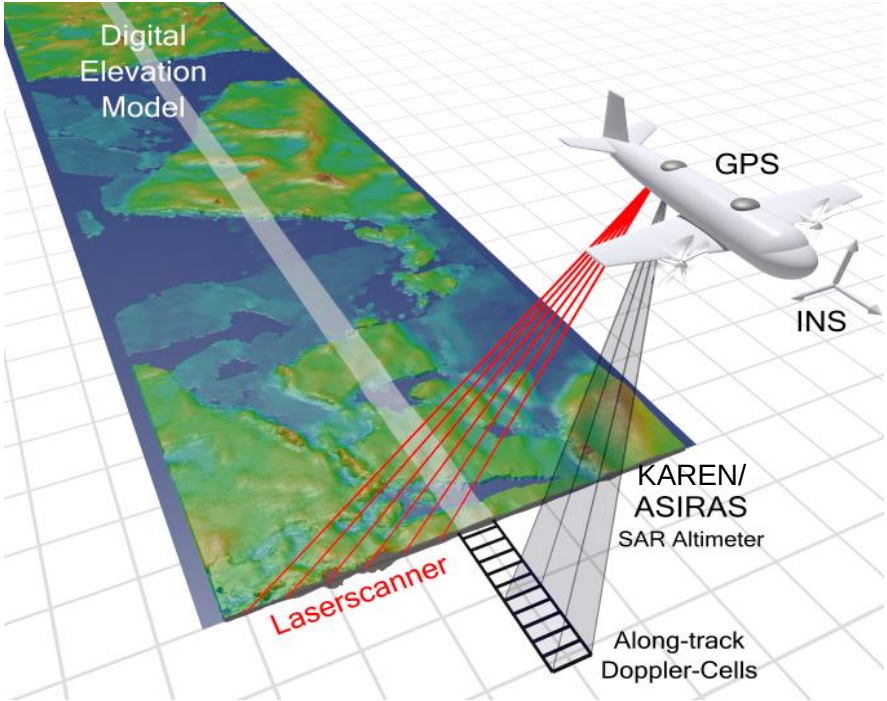
Surface roughness | Snow distribution & Stratigraphy

Airborne observations bridge resolution & coverage between in-situ and satellite remote sensing

Two sets of objectives for airborne observation:

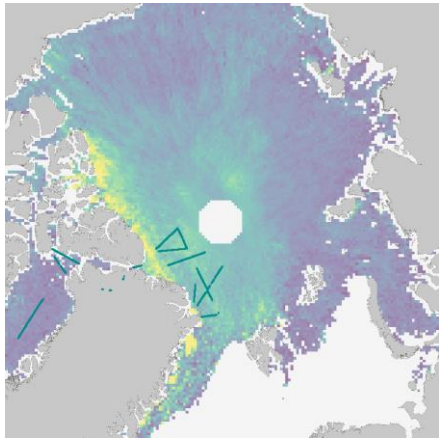
1. Method validation and development
   Dual-Band Altimeters (Satellite sensor demonstrators)
2. Reference Measurements
   Ultra-wideband Radars (Dedicated `snow radars`)

CryoVEx: First airborne KuKa experiments



Range resolution ASIRAS: ~ 10 cm

Range resolution KAREN: ~ 16 cm



CryoVex 2017

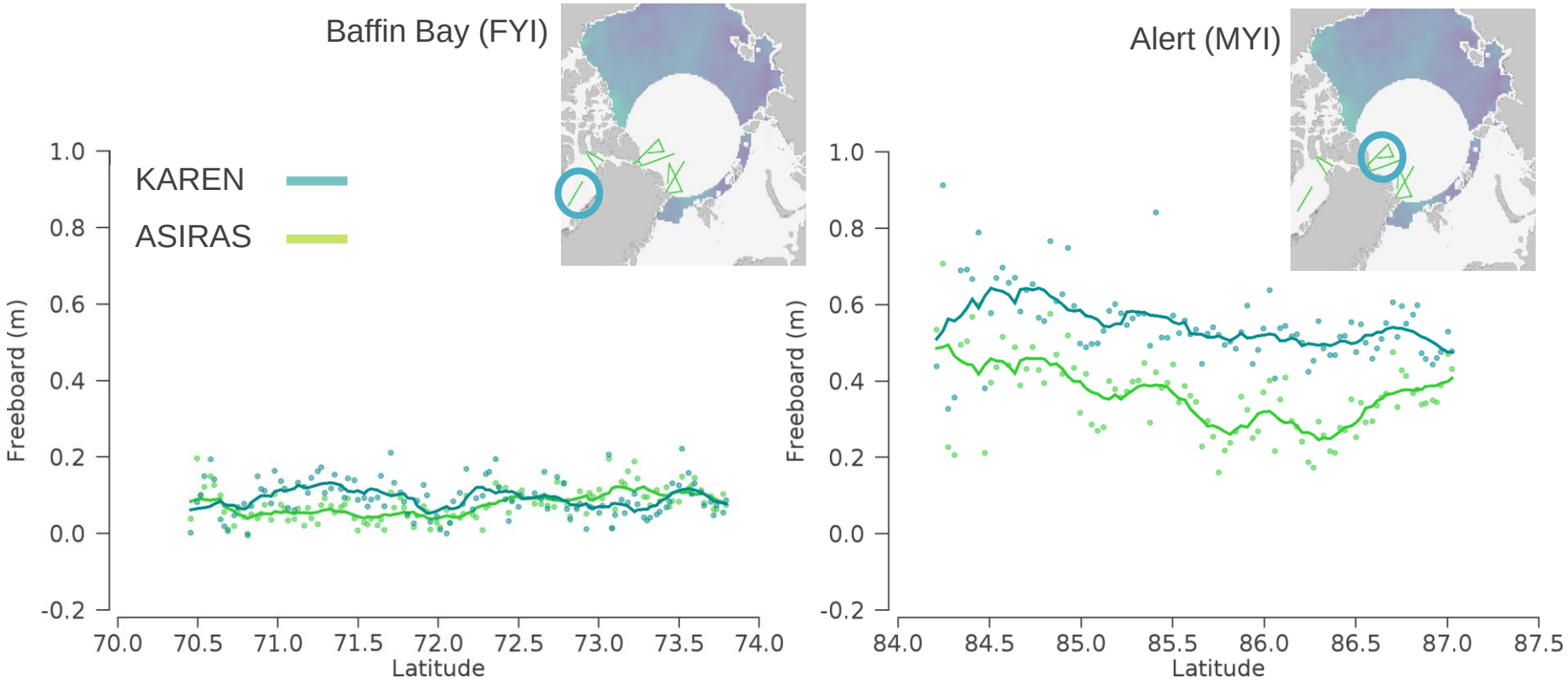
ESA & DTU

Colocated measurements of Ku-band radar (ASIRAS) and Ka-band radar (KAREN) altimeters over sea ice during ESA CryoVex 2017

Data analysis in ESA Cryo-SEANICE project

ALONG-TRACK CLS LEGOS esa

Airborne Dual-Band Altimetry – Results



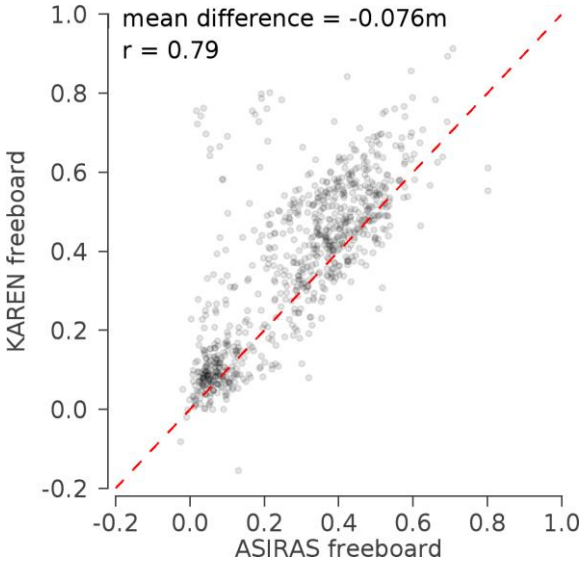
Airborne Dual-Band Altimetry – Summary

Clear range/freeboard differences between Ku (ASIRAS) and Ka-Band (Karen) correlating with snow depth …

… but below expected value:

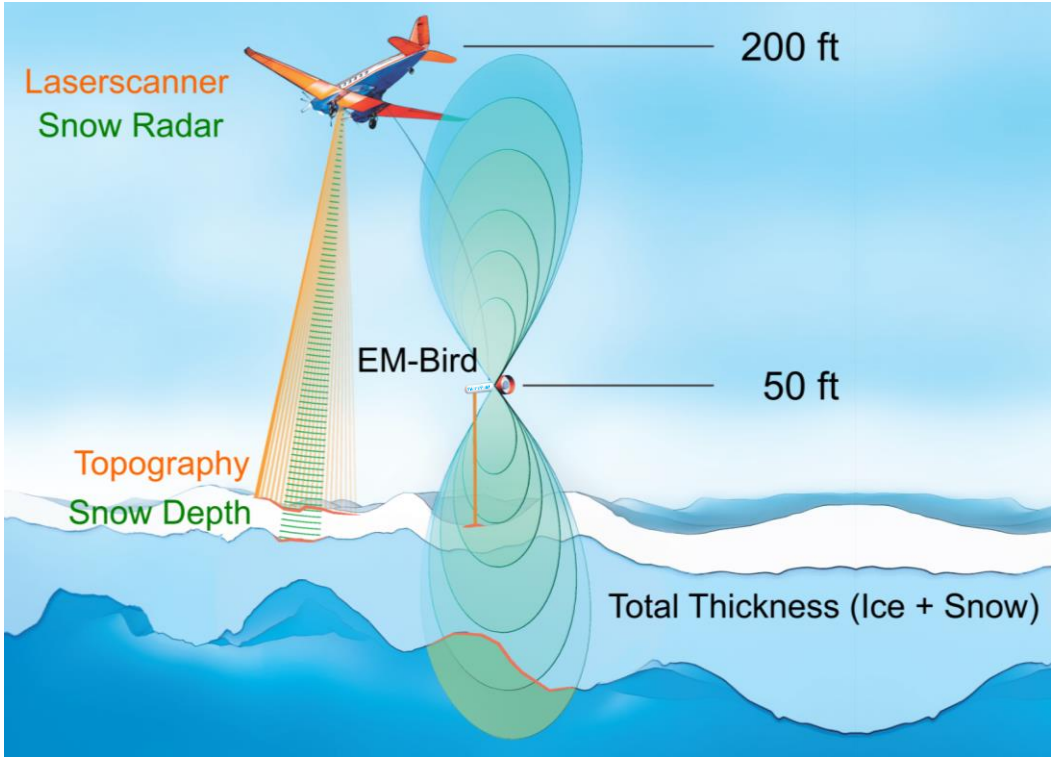
- over MYI (Alert): range difference (~ 19 cm) does not seem to represent the full snow depth (~ 28 cm: OIB),
- over FYI (Baffin Bay): KAREN and ASIRAS freeboard do not show significant difference.

Limitations in sensor capabilities (range resolution) and waveform interpretation (empirical retrackers)

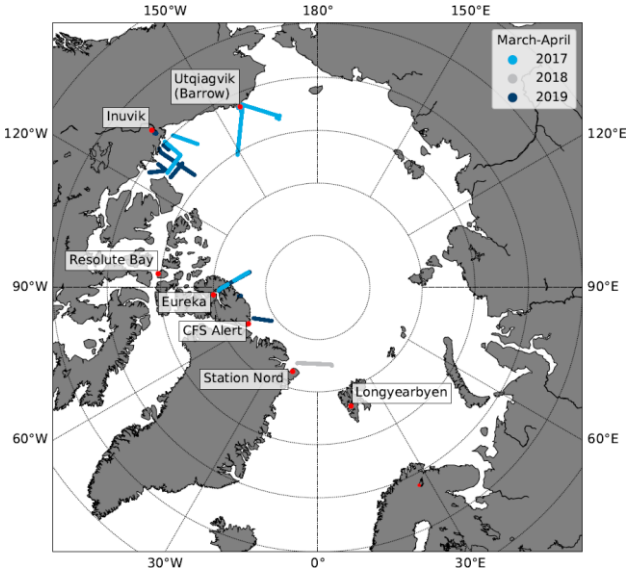


All CryoVEx 2017 flights

AWI IceBird Winter Campaign Series

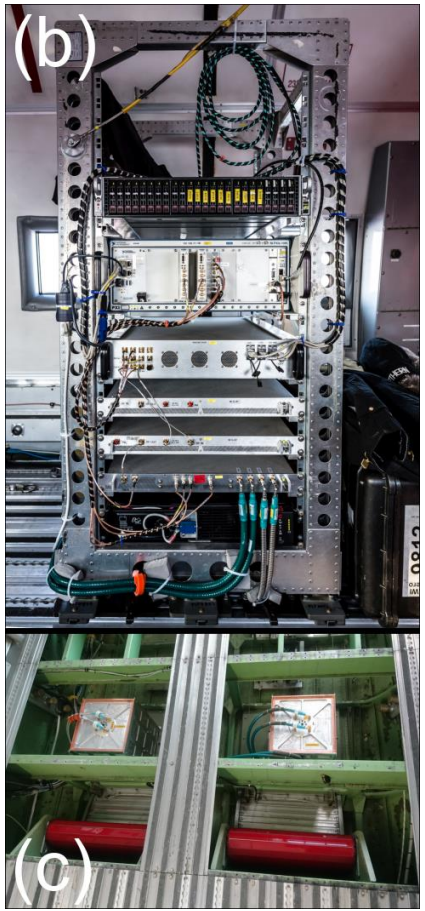


https://www.awi.de/en/science/climate-sciences/sea-ice-physics/projects/ice-bird.html



With snow radar:	2017-2019
Spring 2020	cancelled
Spring 2021 (CRYO2ICE)	planned
Spring 2023	proposed

Ultra-Wideband „Snow“ Radar

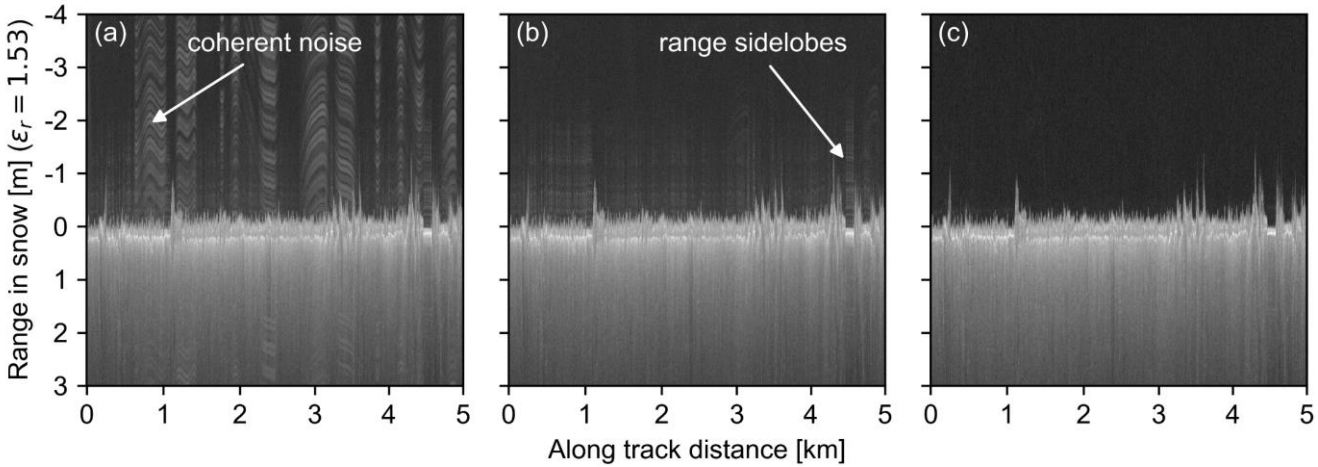


Radar Specifications (Comparable to NASA OIB)

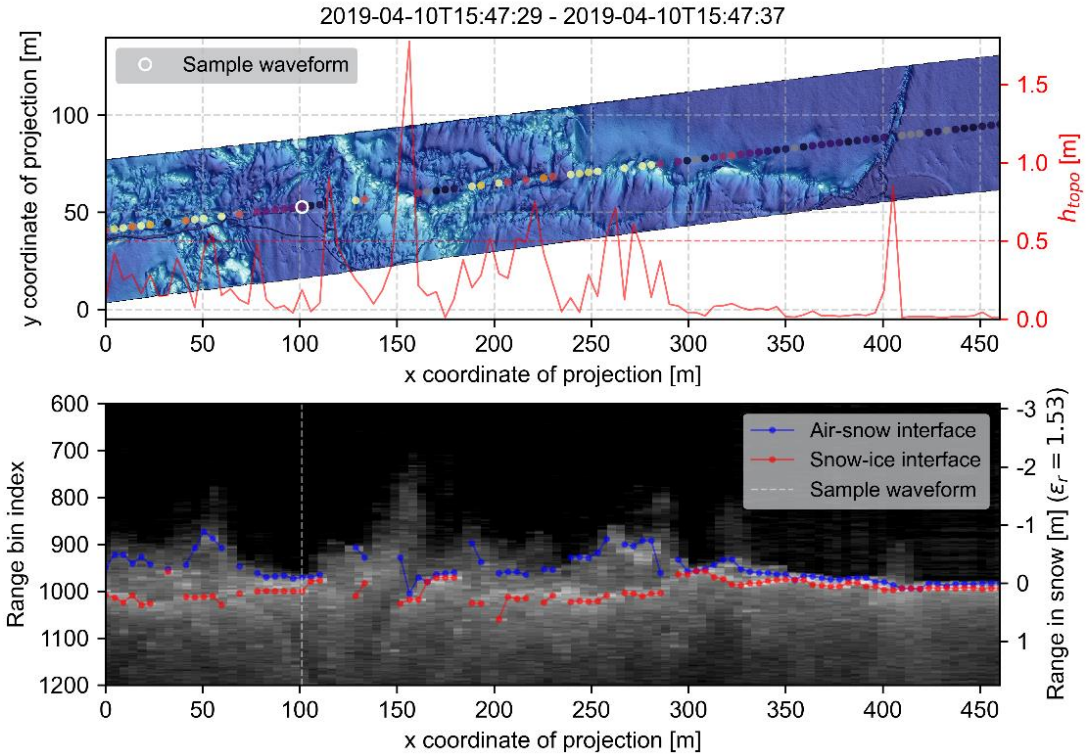
CReSIS ultra-wideband FMCW, quad-polarized 2-18 GHz

Data Specification (Low altitude surveys 200ft/110kn)

range resolution in snow	1.14 cm	bias (FYI)	0.64 cm
across/along-track footprint	2.6/1.0 m	RMSE (FYI)	3.98 cm
sample spacing	4-5 m		



IceBird Snow Radar (Early) Results



Custom air-snow and snow-ice interface detection algorithm [1]

Implemented in open-source, python-based **pySnowRadar** package [2]

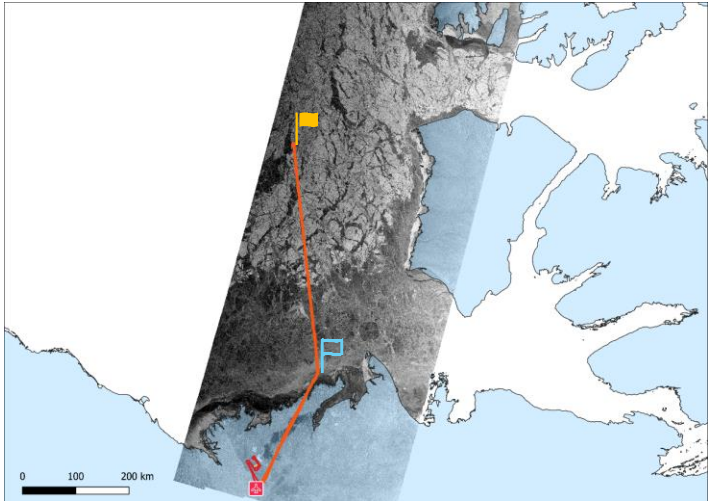
Consistent results between 200ft/110kn and 1500ft/160kn survey data

Successful retrieval rates ~ 80%

[1] Jutila, King, Paden, Ricker, Hendricks, Polashenski, Helm, Binder, Haas: **High-Resolution Snow Depth on Arctic Sea Ice From Low-Altitude Airborne Microwave Radar Data**, *under review in IEEE TGRS*, 2021.

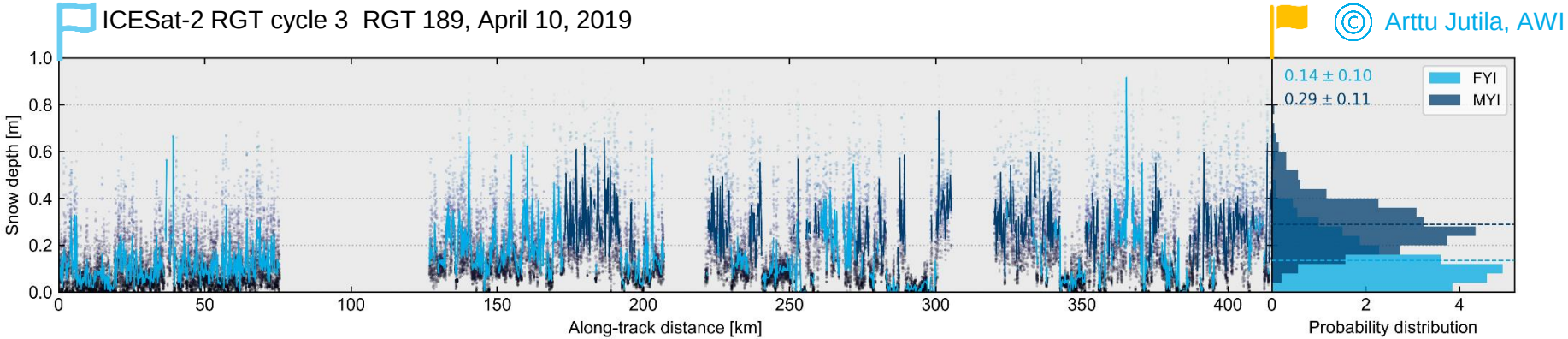
[2] Joshua King, Mike Brady, Thomas Newman. kingjml/pySnowRadar: Updated IEEE TGRS Submission (Version v1.1.1), 2020, http://doi.org/10.5281/zenodo.4071947

IceBird Snow Radar (Early) Results



Evaluation against Ku/Ka/Laser data only starting now

Data release in preparation (www.pangaea.de)



Concluding Remarks

Sea ice remains challenging surface for radar altimetry

Surface roughness | Snow distribution

Resolution is the key!

Range & spatial resolution

Improving process understanding at all scales

In-situ > airborne > satellite

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