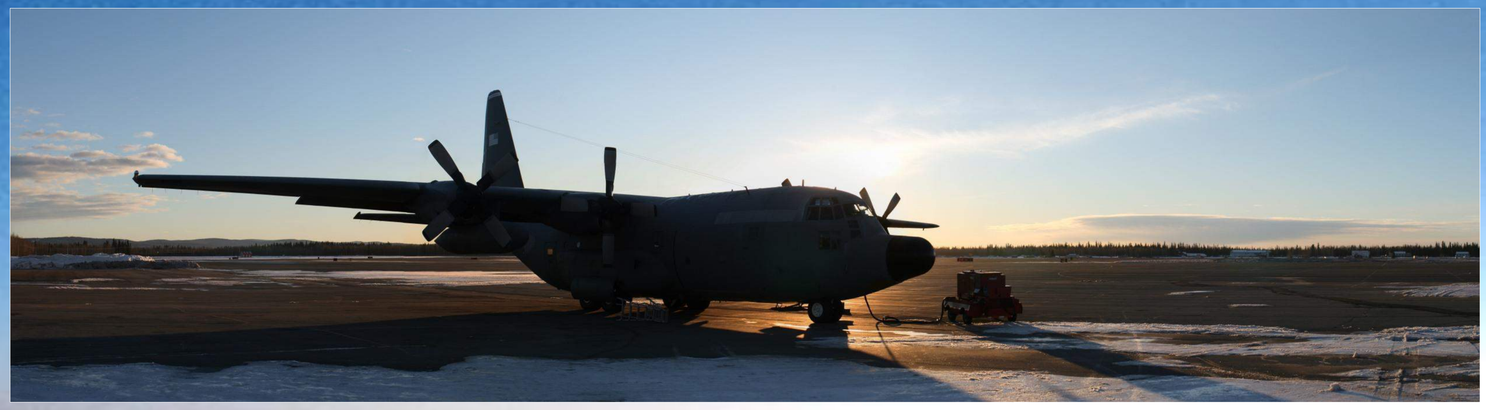
CReSIS Ka-band Radar Altimeters and Data Review

J. Li, F. Rodriguez-Morales, C. Leuschen and J. Paden



Center for Remote Sensing of Ice Sheets (CReSIS), University of Kansas

CReSIS
Center for Remote Sensing of Ice Sheets

This material is based upon work supported by the **National Science Foundation** under Grant No. **ANT-0424589**. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author[s] and do not necessarily reflect the views of the National Science Foundation.

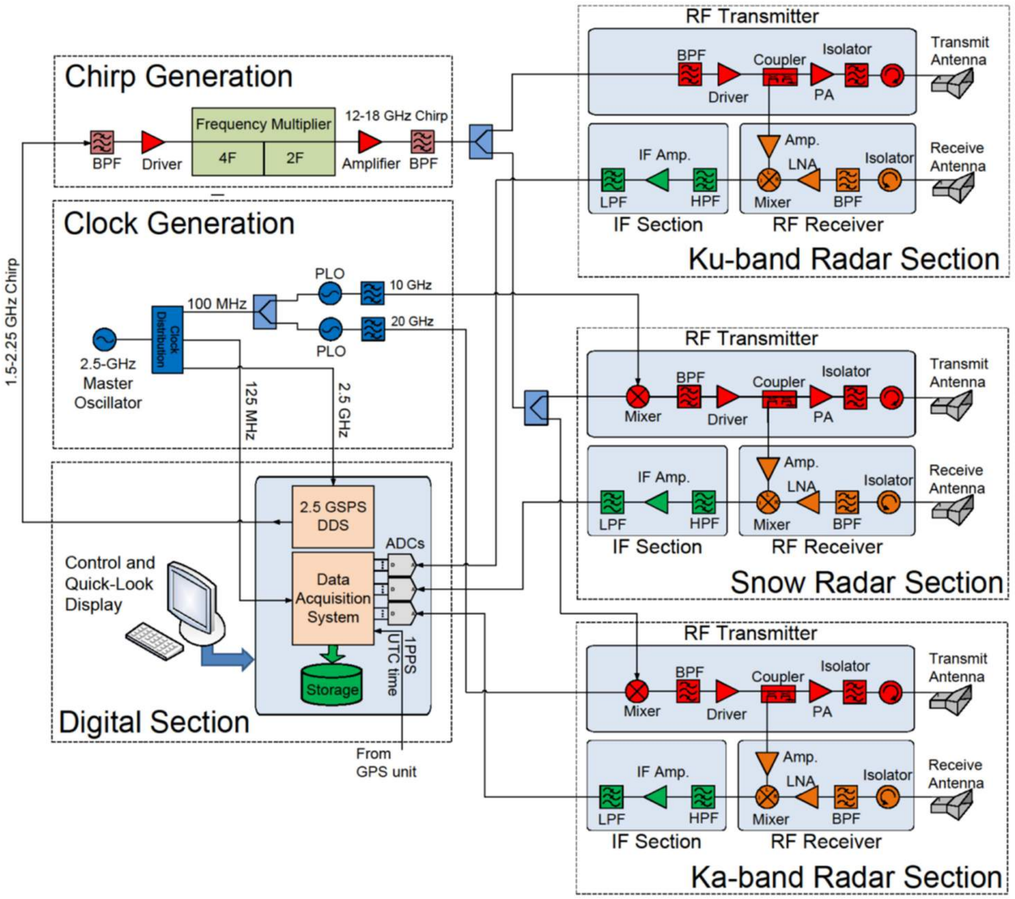
Outline

- Instrument overview.
- NASA OIB 2015 spring campaign.
- 2019 dual-band tests (ESA/CryoVex with DTU).
- Data review and system performance evaluation.
- Waveform comparisons with AltiKa.
- Snow grain size estimation using Ka-band data.
- Conclusions and future work.

This material is based upon work supported by the **National Science Foundation** under Grant No. **ANT-0424589**. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author[s] and do not necessarily reflect the views of the National Science Foundation.

Instrument Overview

2. NASA OIB 2015 Multi-band Instrument Package



System parameters	Snow radar	Ku-band	Ka-band
f_c (GHz)	5	15	35
BW (GHz)	6 (2-8)	6 (12-18)	6 (32-38)
λ (cm)	6	2	0.86
δR (m)	0.025	0.025	0.025
ΔS (m)	4.5	4.5	4.5
FP (m)	14	14	14
Tx power (W)	0.1	0.1	0.1
Antenna type	Vivaldi	Horn	Horn
HPBW (deg)	12	19	19

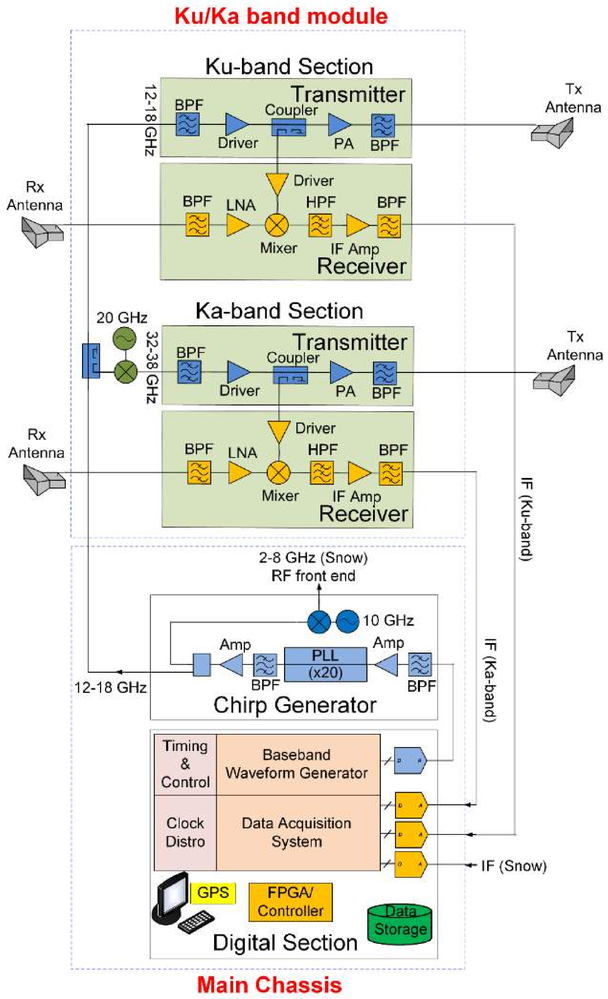
Large and heavy (160 lbs.)

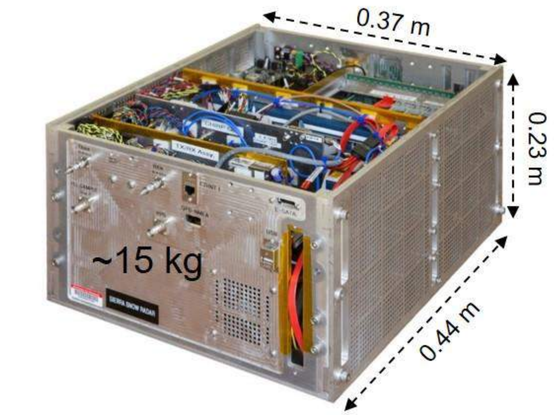
CReSIS
Center for Remote Sensing of Ice Sheets

This material is based upon work supported by the National Science Foundation under Grant No. ANT-0424589. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author[s] and do not necessarily reflect the views of the National Science Foundation.

Instrument Overview

1. Multi-UWB Compact System





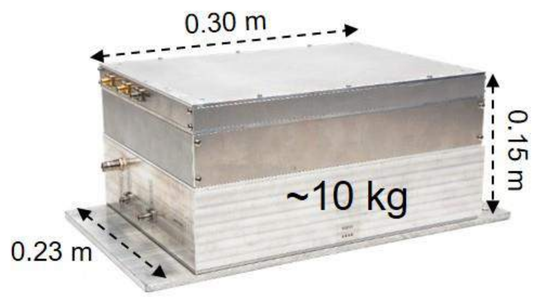
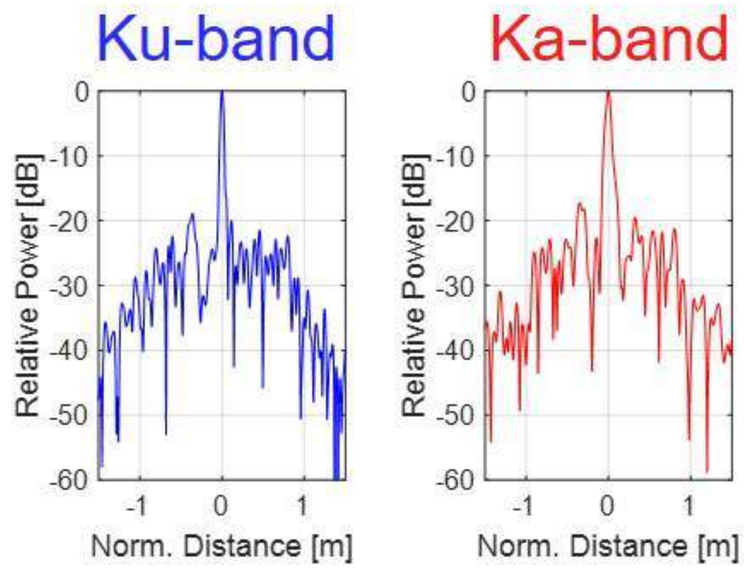


Table 1: Summary of system parameters

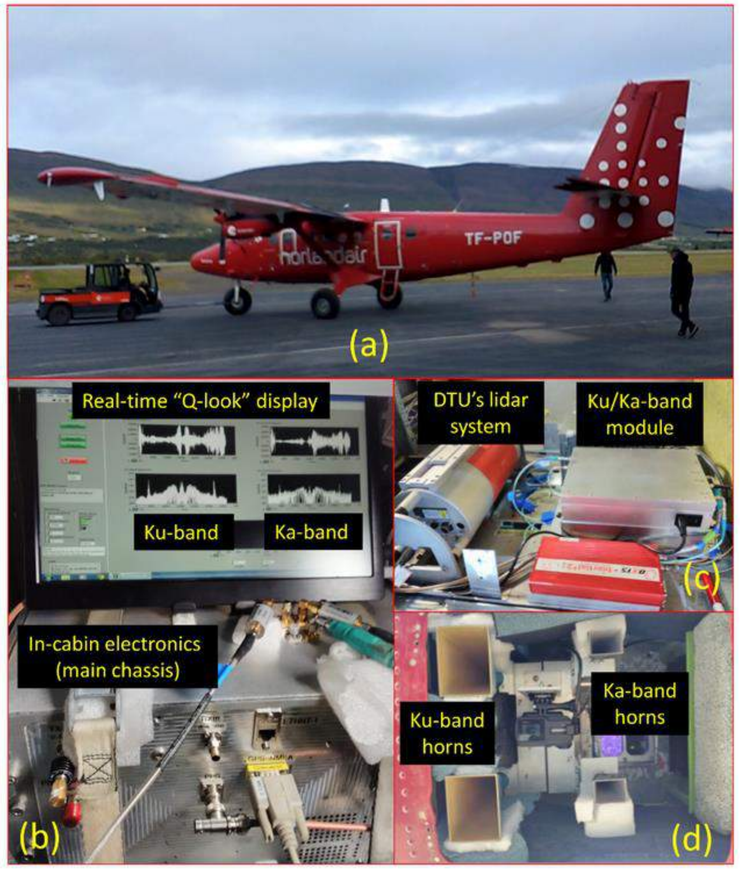
Parameter	Value	Units
Operating frequency bands	2–8; 12–18; 32–38	GHz
Bandwidth	6	GHz
Transmit power (per band)	~100	mW
Pulse duration	250	μs
Pulse repetition frequency	2	kHz
IF sampling rate	125	MSPS
Antenna type	Rectangular horn antennas	
Operating altitude (AGL)	<1.5 (full bandwidth)	km



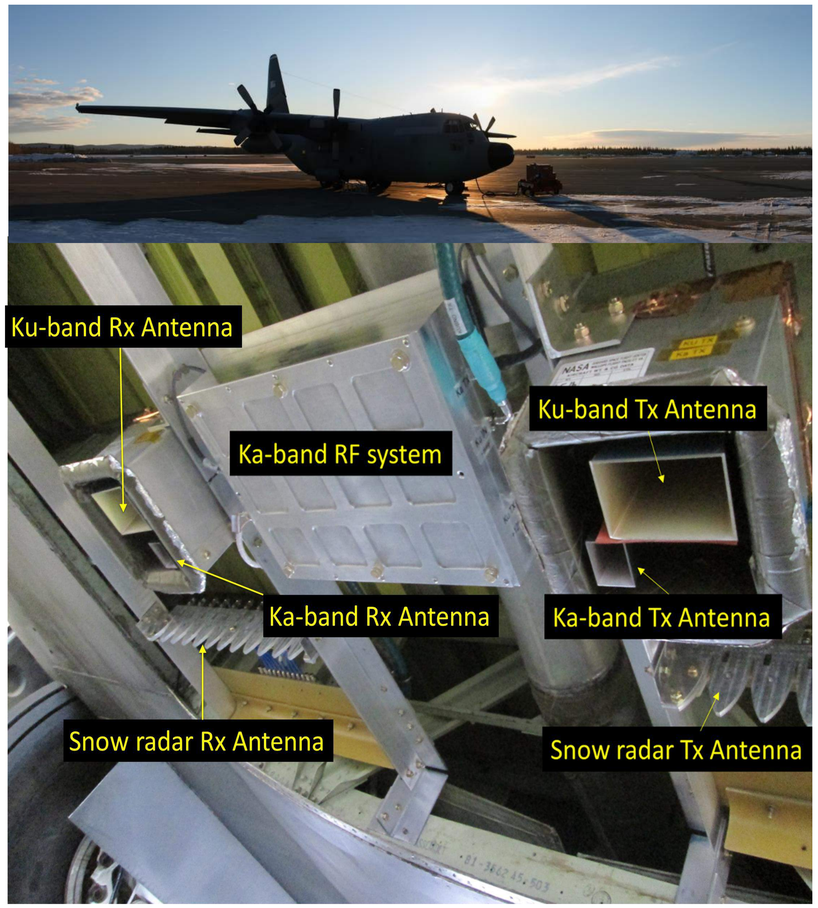
This material is based upon work supported by the National Science Foundation under Grant No. ANT-0424589. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author[s] and do not necessarily reflect the views of the National Science Foundation.

Instrument Overview

3. Platforms



Antenna installation on Twin Otter

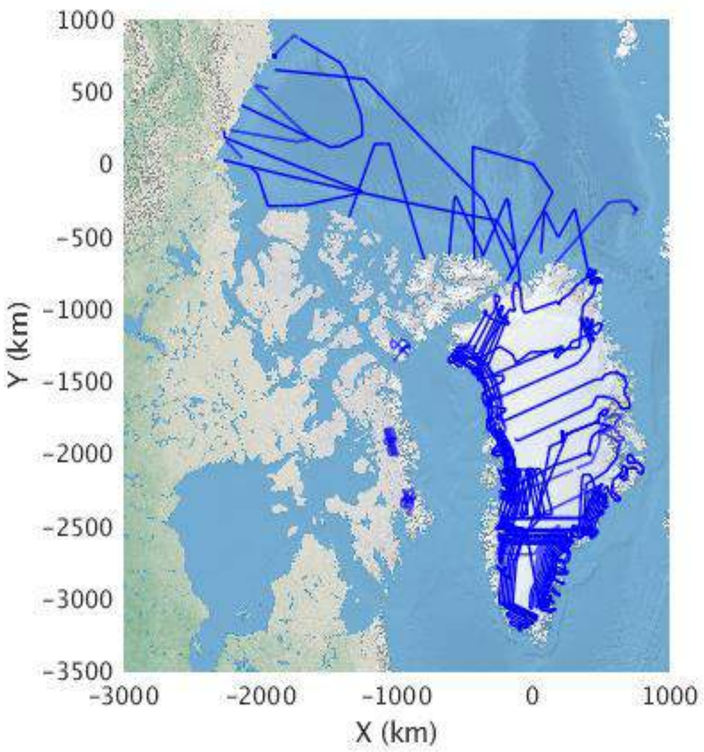


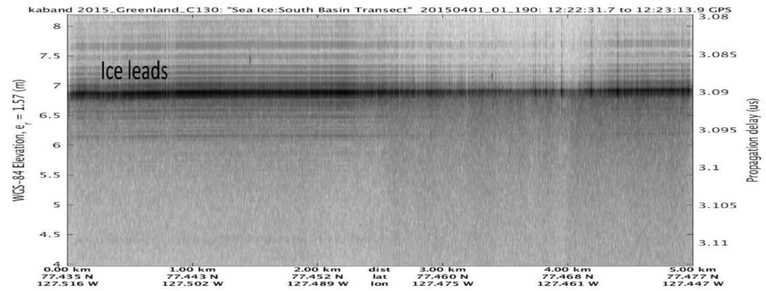
Antenna installation on C-130

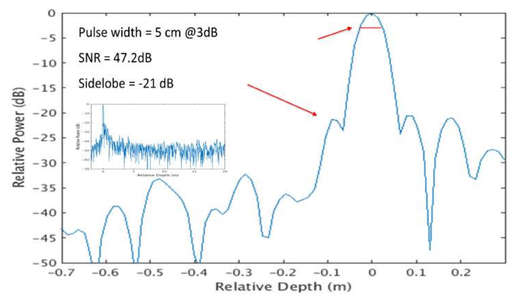
CReSIS
Center for Remote Sensing of Ice Sheets

This material is based upon work supported by the **National Science Foundation** under Grant No. **ANT-0424589**. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author[s] and do not necessarily reflect the views of the National Science Foundation.

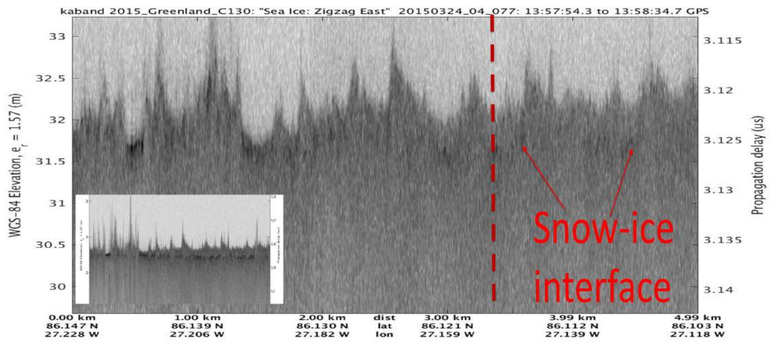
NASA OIB 2015 Spring Campaign



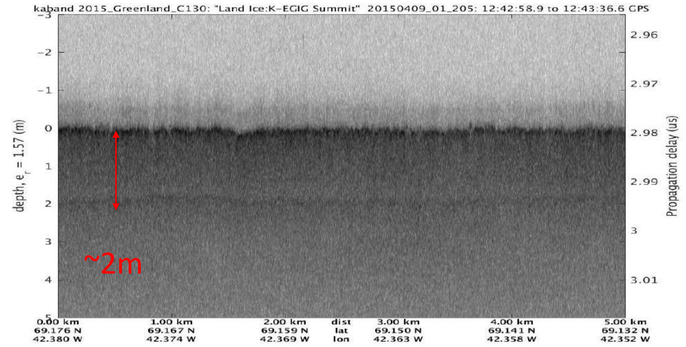




(a) Ice lead measurements



(b) Sea ice measurements



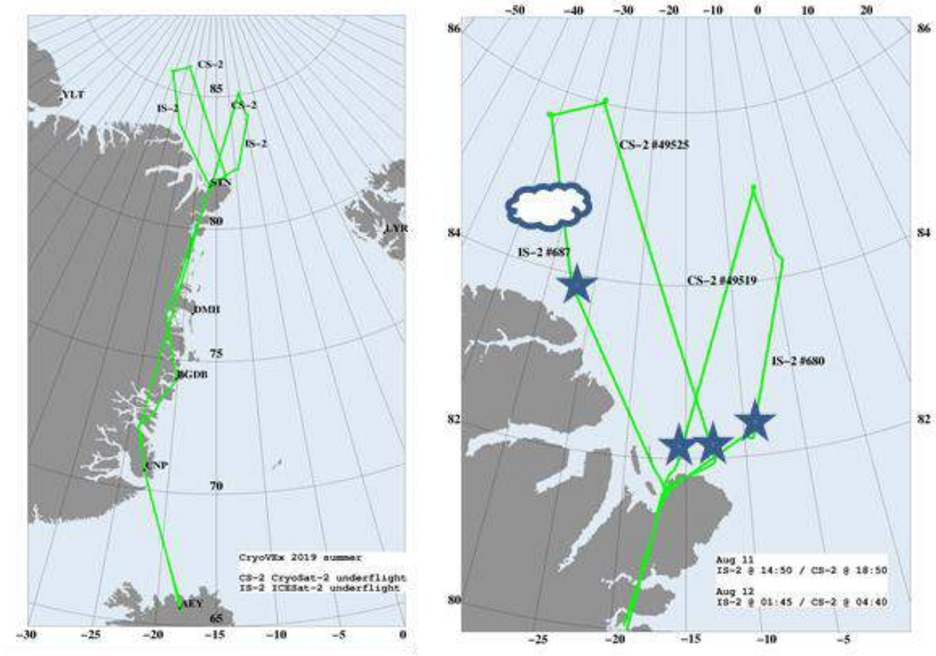
(c) Land ice (dry snow zone)

- March-May 2015
- 9 sea ice missions
- 24 land ice missions
- Coincidental multi-band data (S/C, Ku, Ka)
- https://data.cresis.ku.edu/data/kaband/2015_Greenland_C130/
- ftp://data.cresis.ku.edu/data/kaband/2015_GReenland_C130/

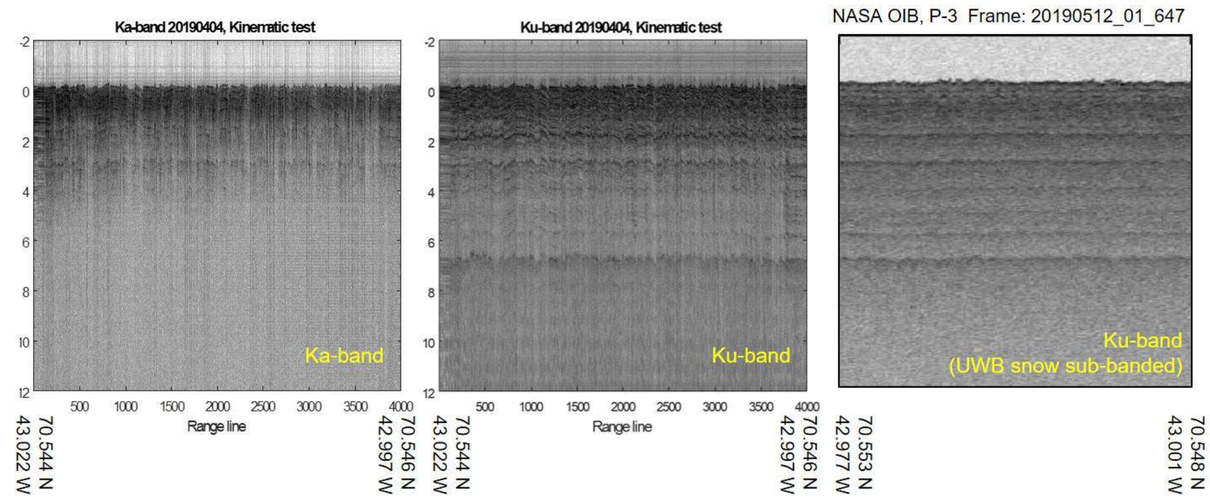
CReSIS
Center for Remote Sensing of Ice Sheets

This material is based upon work supported by the National Science Foundation under Grant No. ANT-0424589. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author[s] and do not necessarily reflect the views of the National Science Foundation.

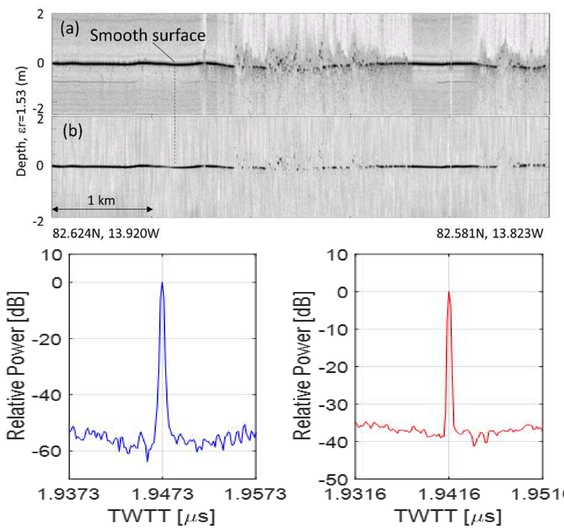
Dual Band Tests 2019 (ESA/CryoVex)



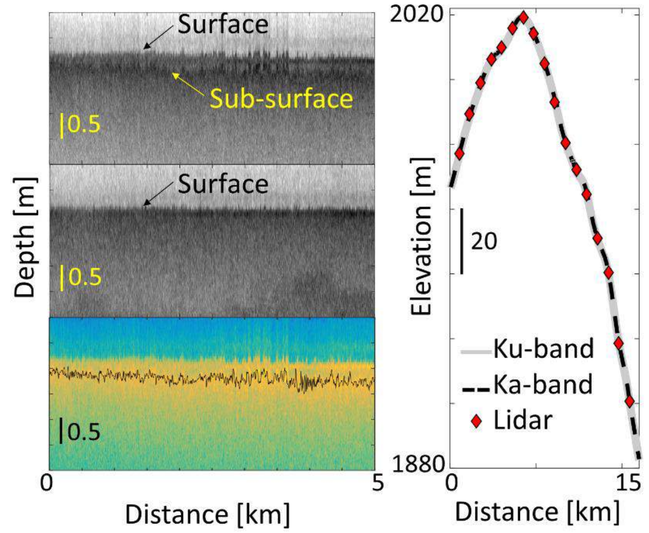
- Ground test trials in Apr. 2019 (EGIG line)
- Airborne tests in Aug. 2019
  - One transit flight over the Greenland ice sheet margin
  - Two flights over Arctic sea ice



(a) Surface-based results



(b) Sea ice



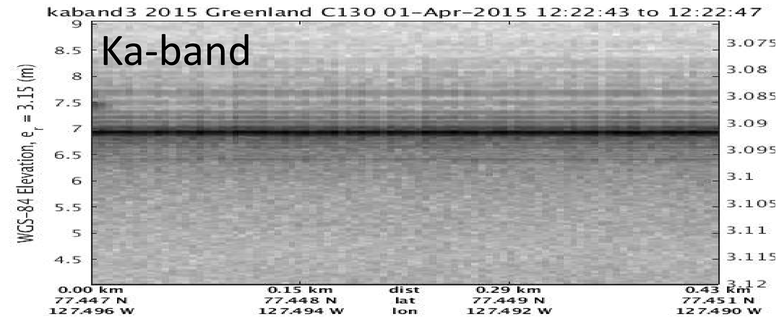
(c) Ice Sheet Margin

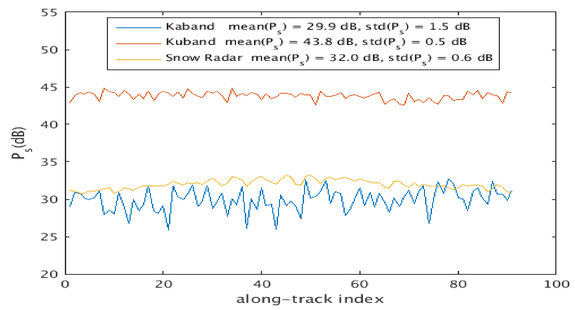
CReSIS
Center for Remote Sensing of Ice Sheets

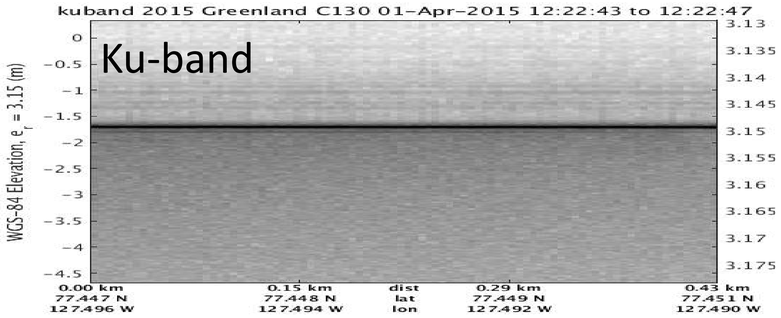
This material is based upon work supported by the National Science Foundation under Grant No. ANT-0424589. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author[s] and do not necessarily reflect the views of the National Science Foundation.

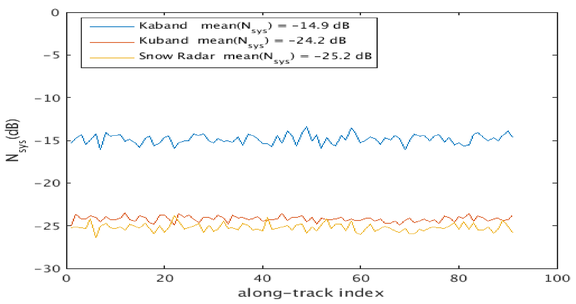
Data Review & System Performance Evaluation

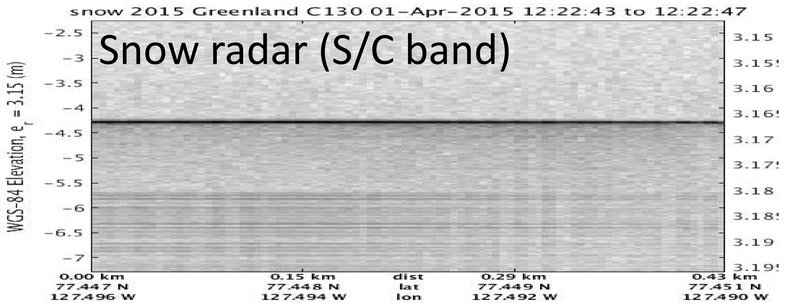
- Ice lead

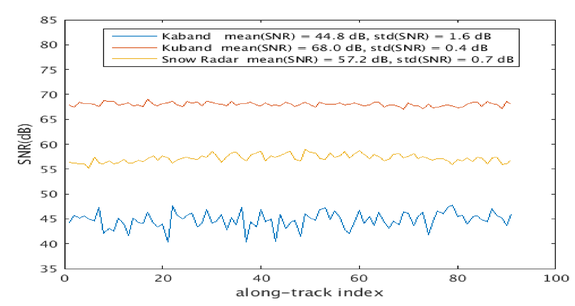




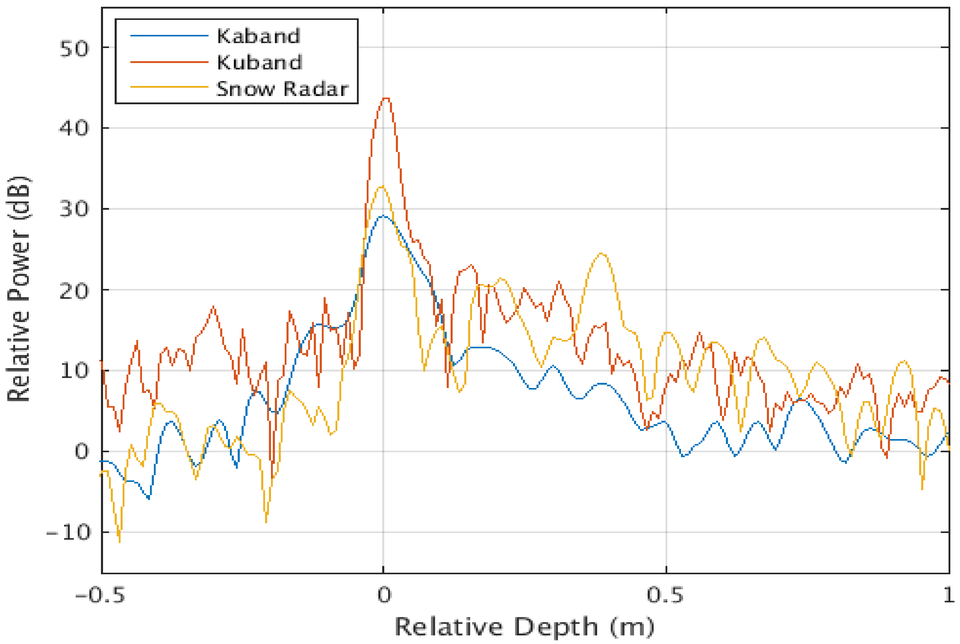








A-scopes of ice leads

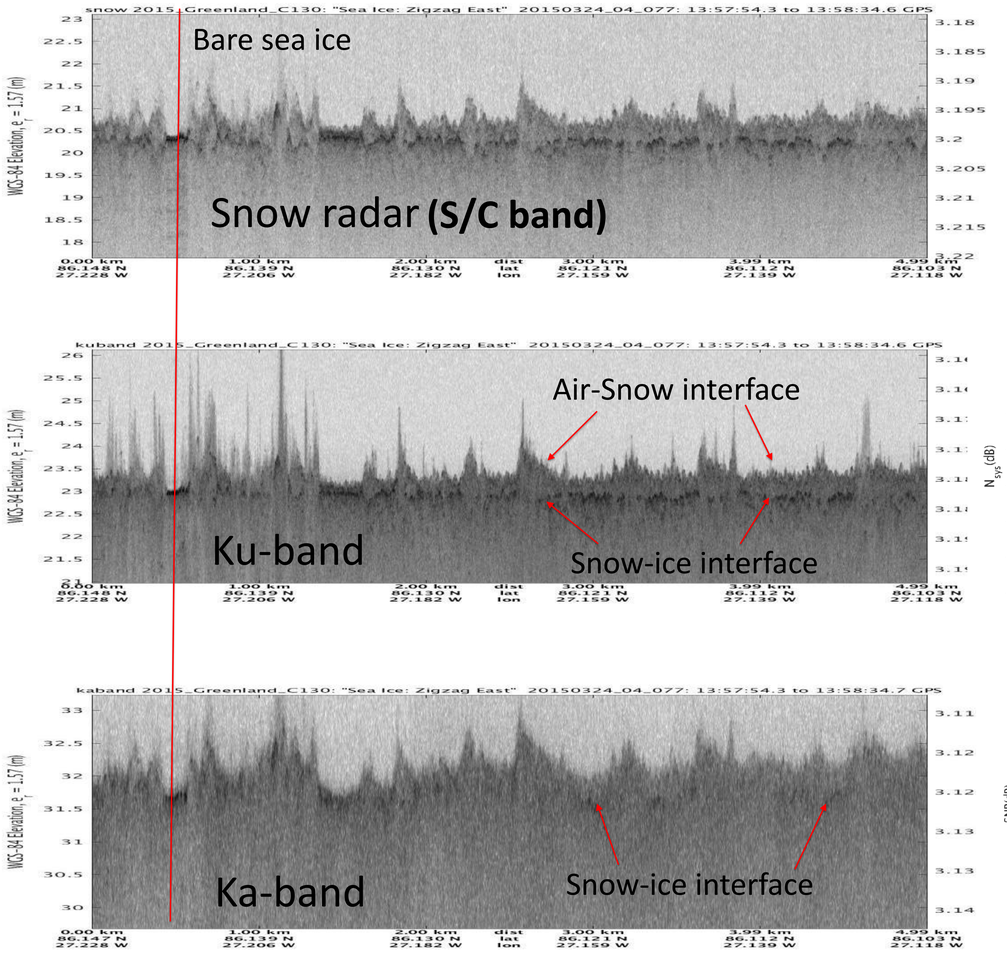


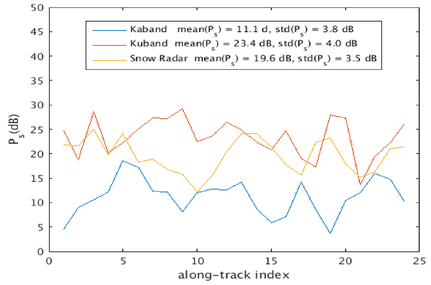
Parameters	Sw	Ku	Ka
$\overline{P_s}$ (dB)	32	43.8	29.9
σ_{Ps} (dB)	0.6	0.5	1.5
N_{sys} (dB)	-25.2	-24.2	-14.9
$\overline{SNR}$ (dB)	57.2	68.0	44.8
σ_{SNR} (dB)	0.7	0.4	1.6
δR (cm)	5	4	7

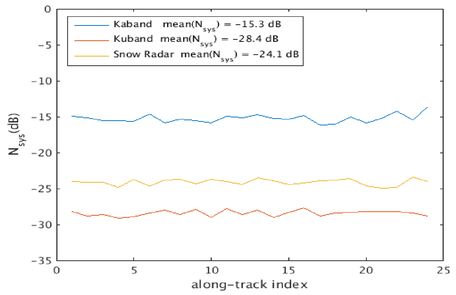
CReSIS
Center for Remote Sensing of Ice Sheets

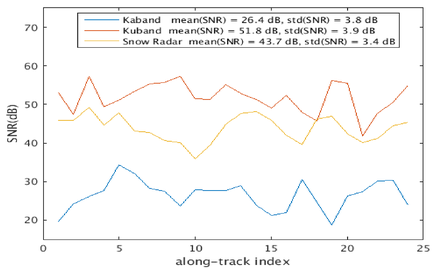
This material is based upon work supported by the National Science Foundation under Grant No. ANT-0424589. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author[s] and do not necessarily reflect the views of the National Science Foundation.

- Sea ice

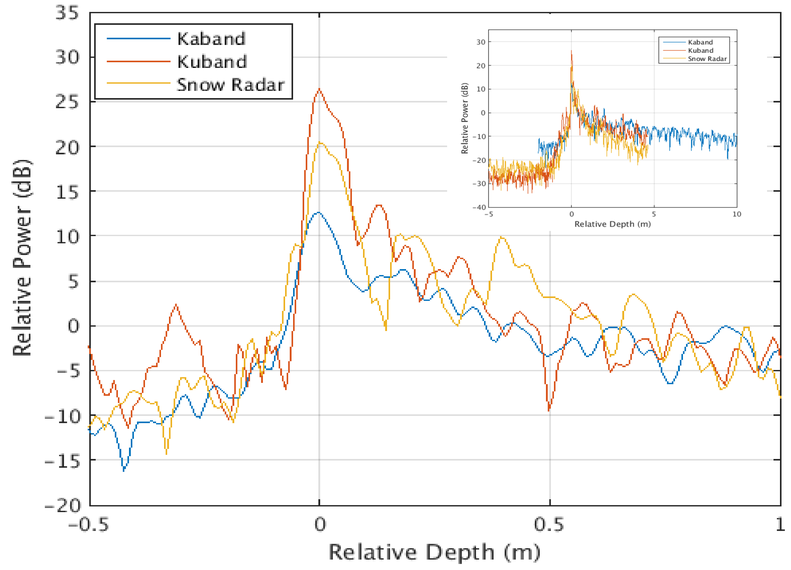








A-scopes of bare sea ice



Parameters	Sw	Ku	Ka
$\overline{P_s}\ (dB)$	19.6	23.4	11.1
$\sigma_{Ps}\ (dB)$	3.5	4.0	3.8
$N_{sys}\ (dB)$	-24.1	-28.4	-15.3
$\overline{SNR}\ (dB)$	43.7	51.8	26.4
$\sigma_{SNR}\ (dB)$	3.4	3.9	3.8

CReSIS
Center for Remote Sensing of Ice Sheets

This material is based upon work supported by the National Science Foundation under Grant No. ANT-0424589. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author[s] and do not necessarily reflect the views of the National Science Foundation.

Comparisons with Ku-band Altimeter & Snow Radar

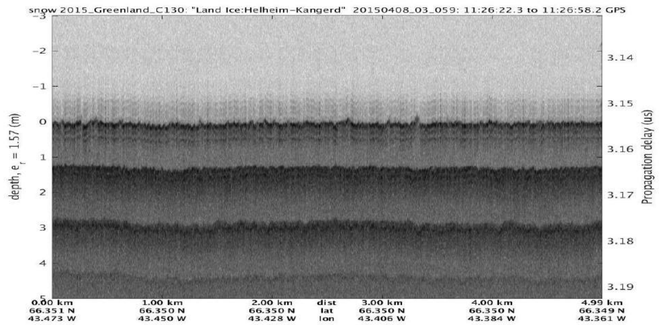
- Land ice

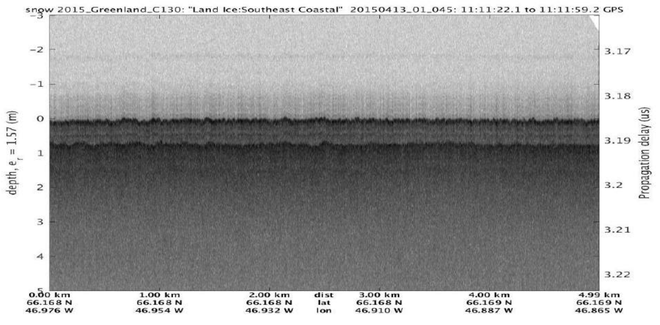
Dry snow zone

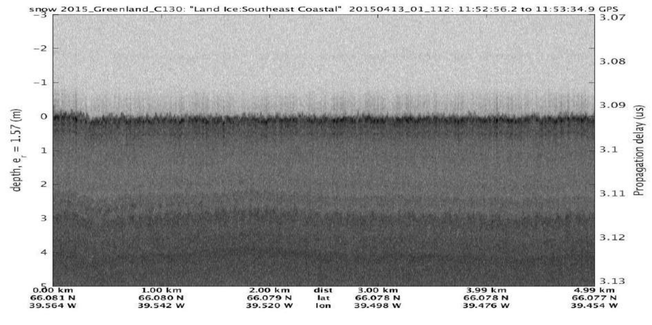
Percolation zone

Wet snow zone

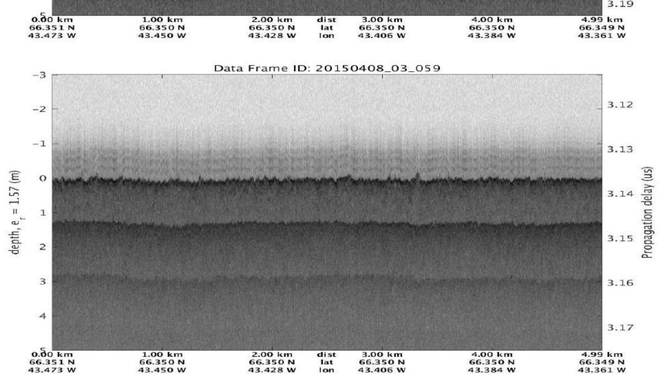
Snow Radar (S/C band)

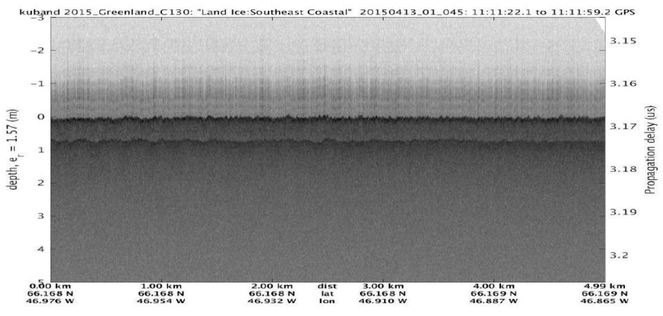


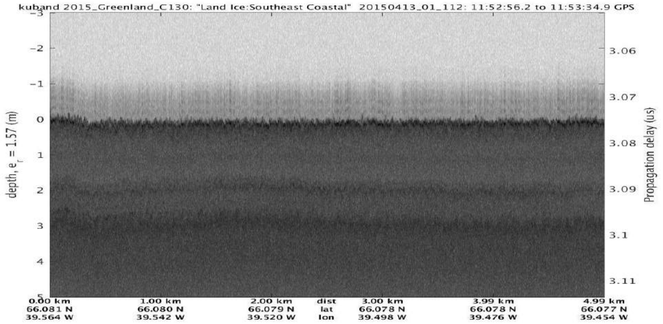




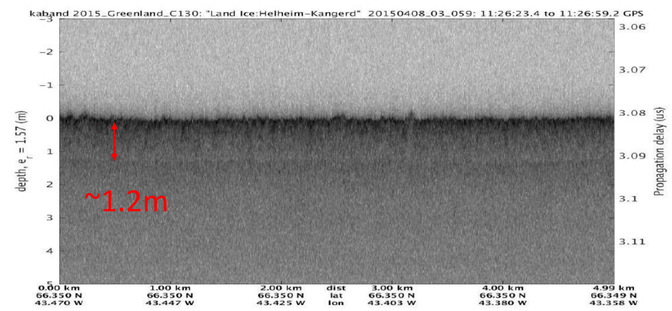
Kuband

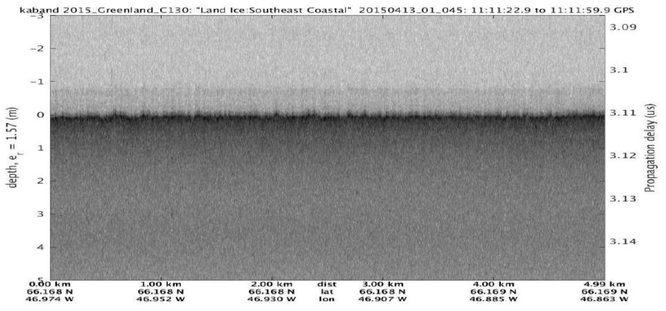


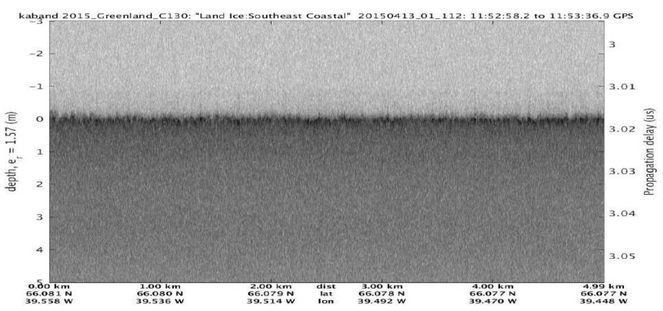




Kaband



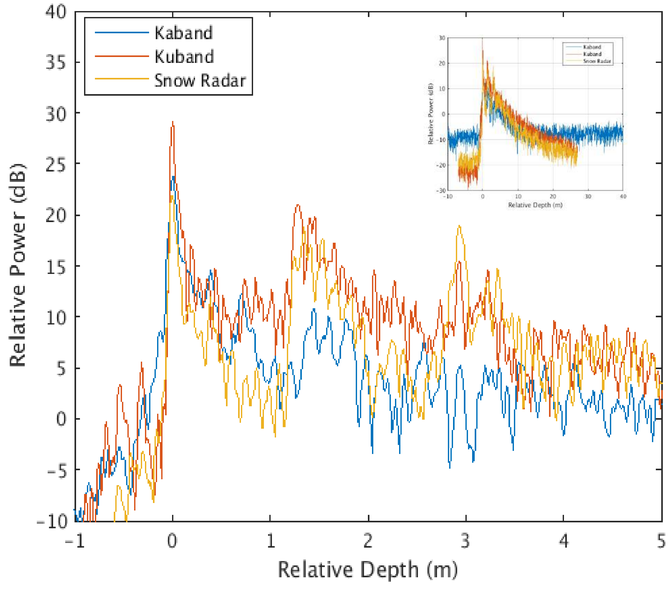




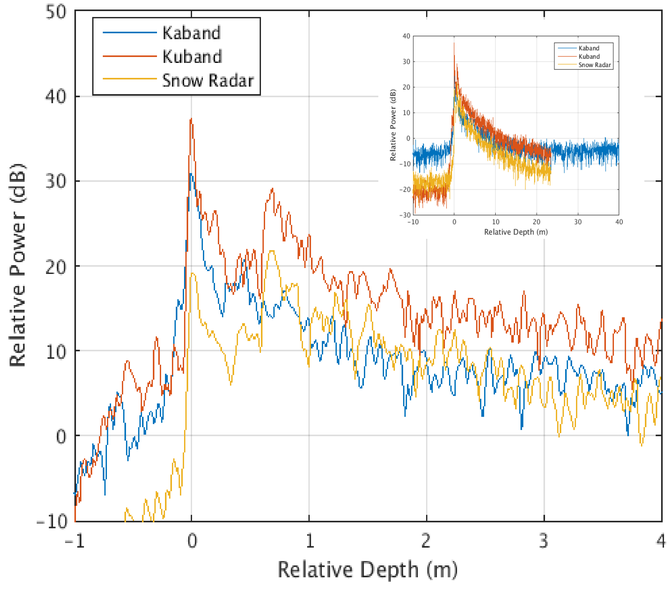
CReSIS
Center for Remote Sensing of Ice Sheets

This material is based upon work supported by the **National Science Foundation** under Grant No. **ANT-0424589**. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author[s] and do not necessarily reflect the views of the National Science Foundation.

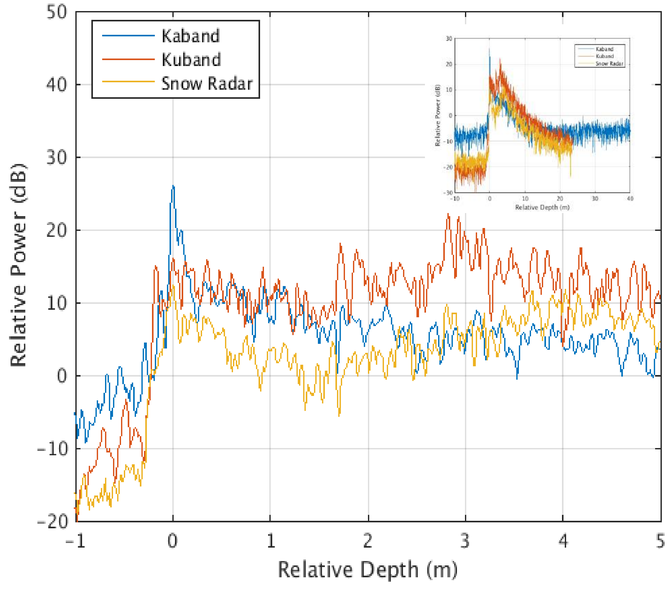
Dry snow zone



Percolation zone



Wet snow zone

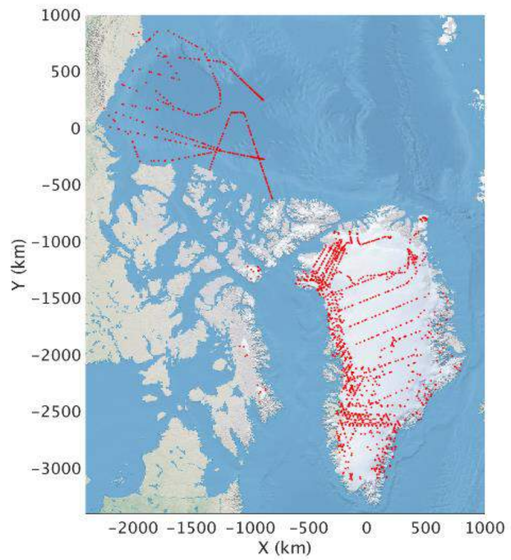


	Dry snow			Percolation zone			Wet snow		
Parameters	**Sw**	**Ku**	**Ka**	**Sw**	**Ku**	**Ka**	**Sw**	**Ku**	**Ka**
$\overline{P_s}$ *(dB)*	17.4	25.3	18.2	20.2	32.5	23.8	13.8	22.0	16.4
σ_{Ps} *(dB)*	3.1	2.7	1.9	2.4	2.9	2.0	2.9	3.0	2.4
N_{sys} *(dB)*	-18.2	-22.0	-9.5	-17.4	-21.2	-6.7	-18.6	-21.6	-8.1
$\overline{SNR}$ *(dB)*	35.6	47.3	27.6	37.6	53.6	30.6	31.9	43.6	24.5
σ_{SNR} *(dB)*	3.1	2.7	2	2.5	2.9	2.1	2.9	3.1	2.4

CReSIS
Center for Remote Sensing of Ice Sheets

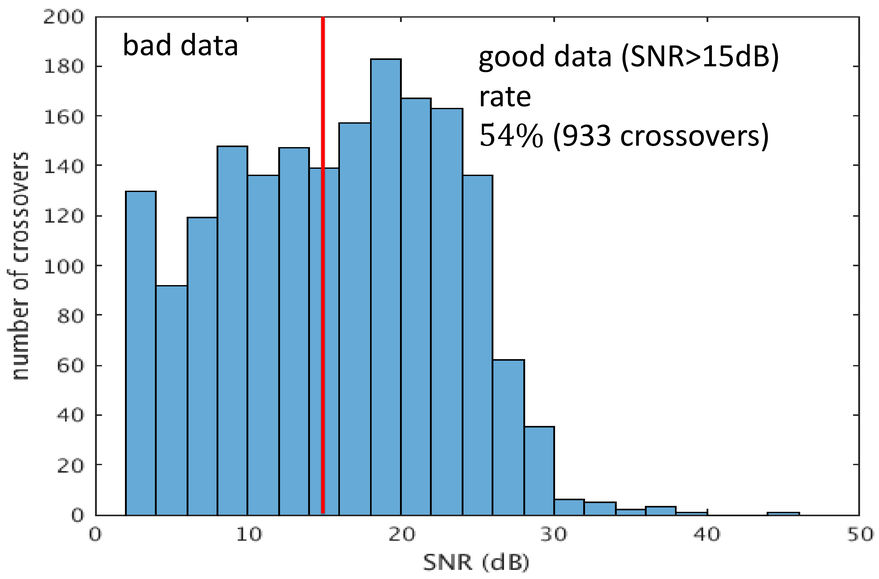
This material is based upon work supported by the National Science Foundation under Grant No. ANT-0424589. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author[s] and do not necessarily reflect the views of the National Science Foundation.

Waveform Comparisons with AltiKa

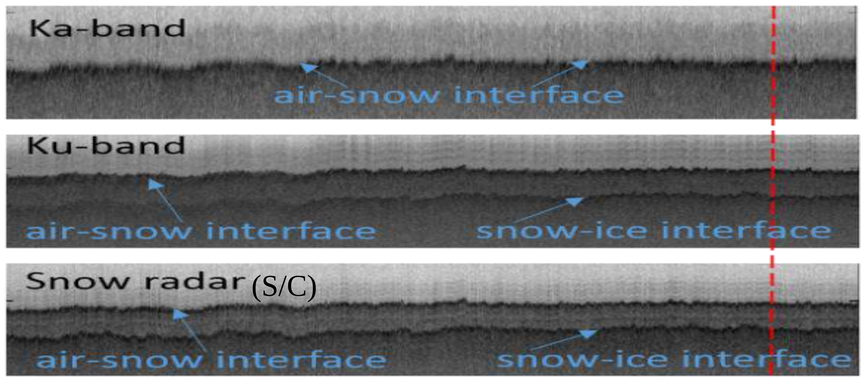


Crossovers of SARAL/AltiKa and OIB 2015 Greenland C-130 campaign

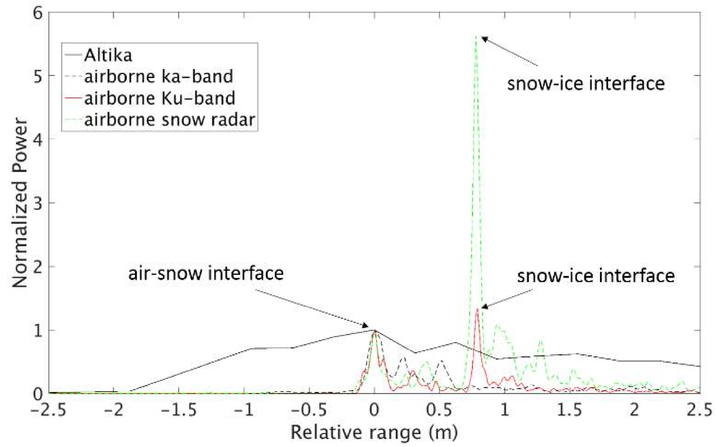
(one-week window, 1842 crossovers in total, Credit: Inès Otosaka)



SNR histogram at crossovers



Sample Echogram at crossover



Waveform comparison at crossover

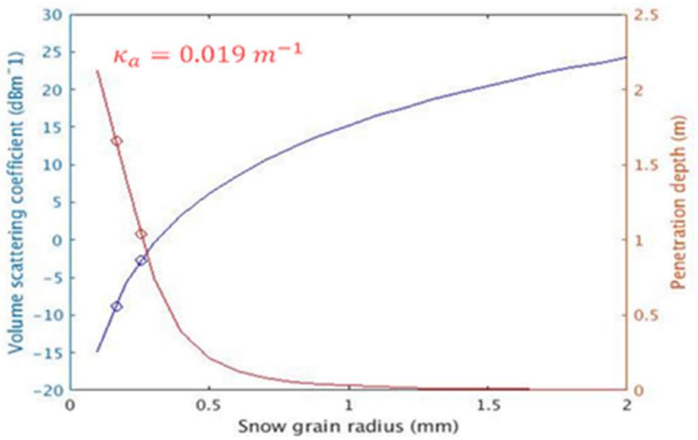
CReSIS
Center for Remote Sensing of Ice Sheets

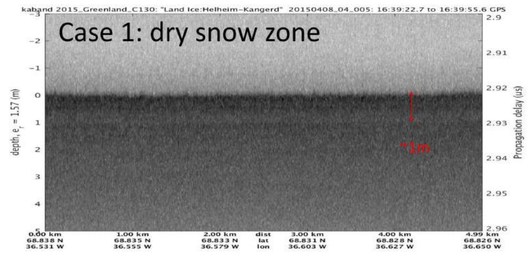
This material is based upon work supported by the National Science Foundation under Grant No. ANT-0424589. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author[s] and do not necessarily reflect the views of the National Science Foundation.

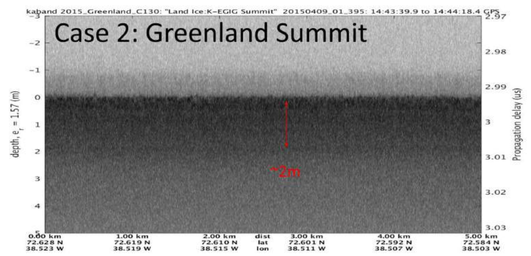
Snow Grain Size Estimation Using Ka-band Data

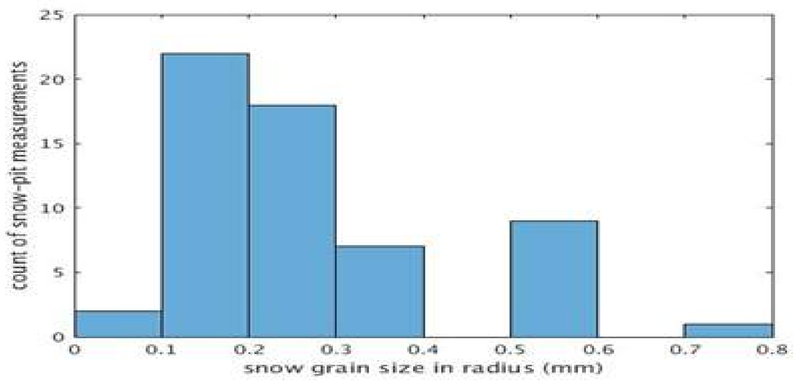
T = -20°C, ρ_s = 400 kg/m^3, ρ_i = 917 kg/m^3, ν = 0.44

ϵ_2' = 3.15, ϵ_2'' = 0.003 @ 35GHz [Ulaby, Vol. III, Fig. E.3]









Histogram of snow-pit measurements at Greenland summit

$$P(z) = P(0+)e^{-\int_{0+}^{z} k_e(z')dz'}$$

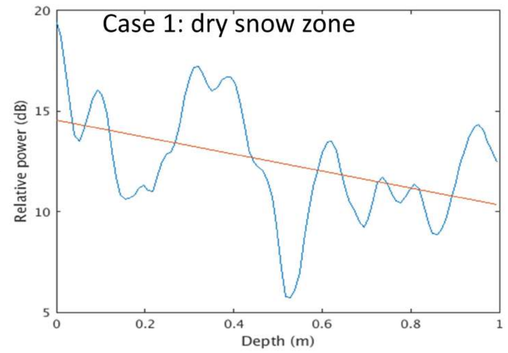
Case 1

$P(z=1)_{dB} - P(0+)_{dB}$ = -4.17 dB

$k_e = -\ln\{10^{[P(z=1)_{dB} - P(0+)_{dB}]/10}\}$ = 0.96 m^{-1}

$\delta_p = \frac{1}{K_e} = 1.04\ m$

Snow grain size: $r_s = 0.26\ mm$



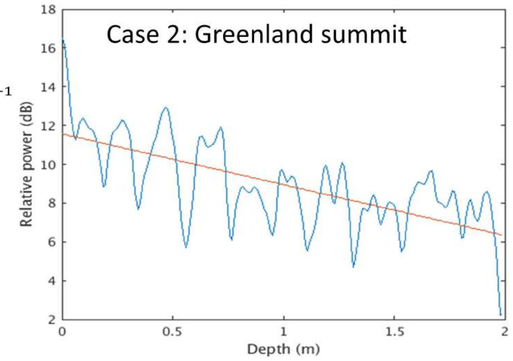
Case 2

$P(z=2)_{dB} - P(0+)_{dB}$ = -5.23 dB

$k_e = -\ln\{10^{[P(z=2)_{dB} - P(0+)_{dB}]/10}\}/2$ = 0.60 m^{-1}

$\delta_p = \frac{1}{K_e} = 1.66\ m$

Snow grain size: $r_s = 0.17\ mm$



J. Li et al., *2020 IEEE IGARSS*

CReSIS
Center for Remote Sensing of Ice Sheets

This material is based upon work supported by the **National Science Foundation** under Grant No. **ANT-0424589**. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author[s] and do not necessarily reflect the views of the National Science Foundation.

Conclusions & Future Work

- Successful initial demonstration of multi-band data collection during NASA OIB.
- Successful Ku/Ka-band airborne trials with ESA/CryoVex. Full data set to be processed.
- Snow grain size can be inferred from Ka-band data
- Characterize the spatial variations in snow penetration depth using coincident airborne Ka-band and laser measurements.
- Develop robust retracking algorithms for satellite measurements using high-resolution airborne measurements.
- Data fusion of multi-sensors and multi-bands for snow thickness retrieval over sea ice and land ice.
- A short airborne test campaign (ESA) is planned for April 2021.

CReSIS
Center for Remote Sensing of Ice Sheets

This material is based upon work supported by the National Science Foundation under Grant No. ANT-0424589. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author[s] and do not necessarily reflect the views of the National Science Foundation.