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Snow-related variability of spectral light transmittance of Arctic First-Year-Ice in the Lincoln Sea

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Universität Bremen

Changing Arctic Ocean NERC

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NERC SCIENCE OF THE ENVIRONMENT

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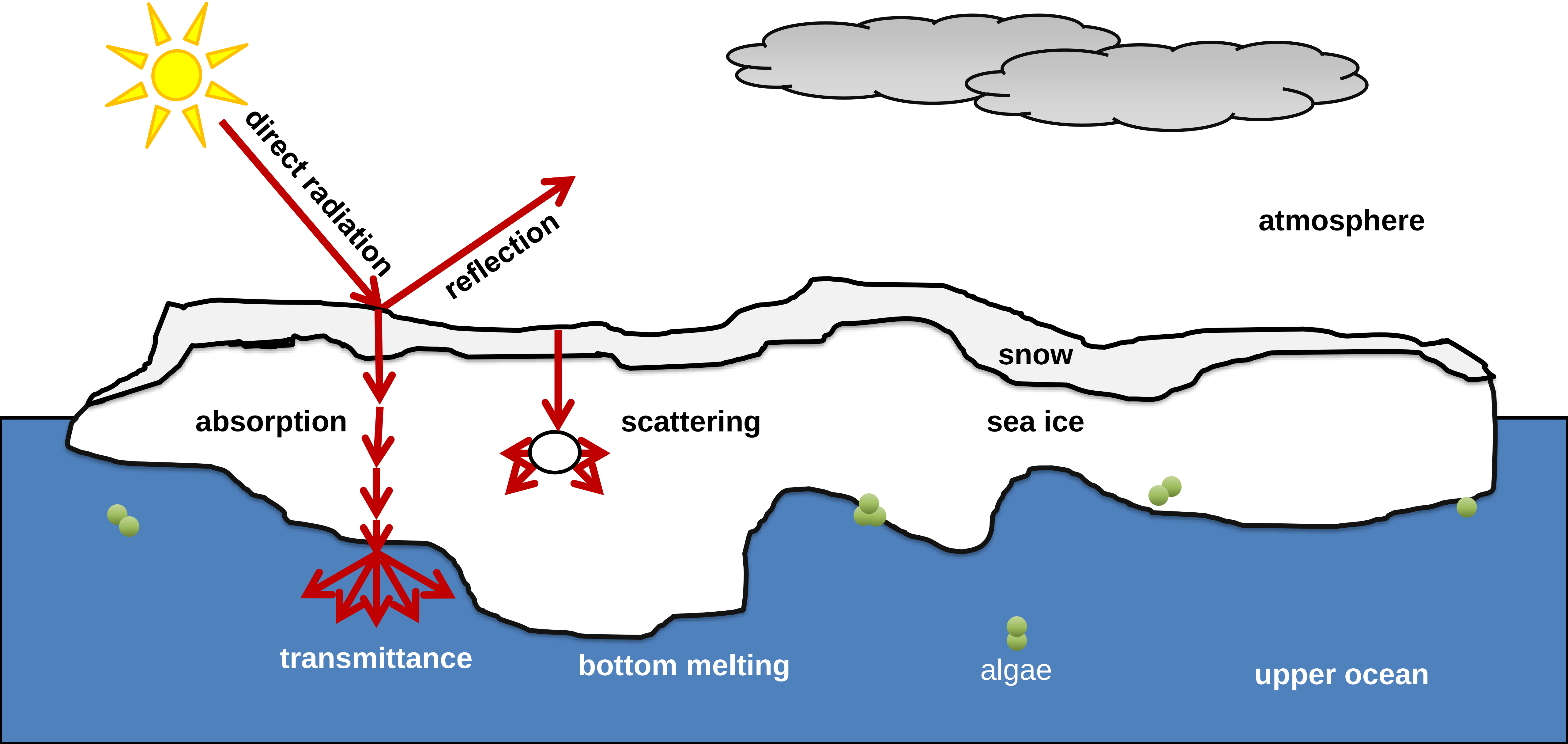
Introduction

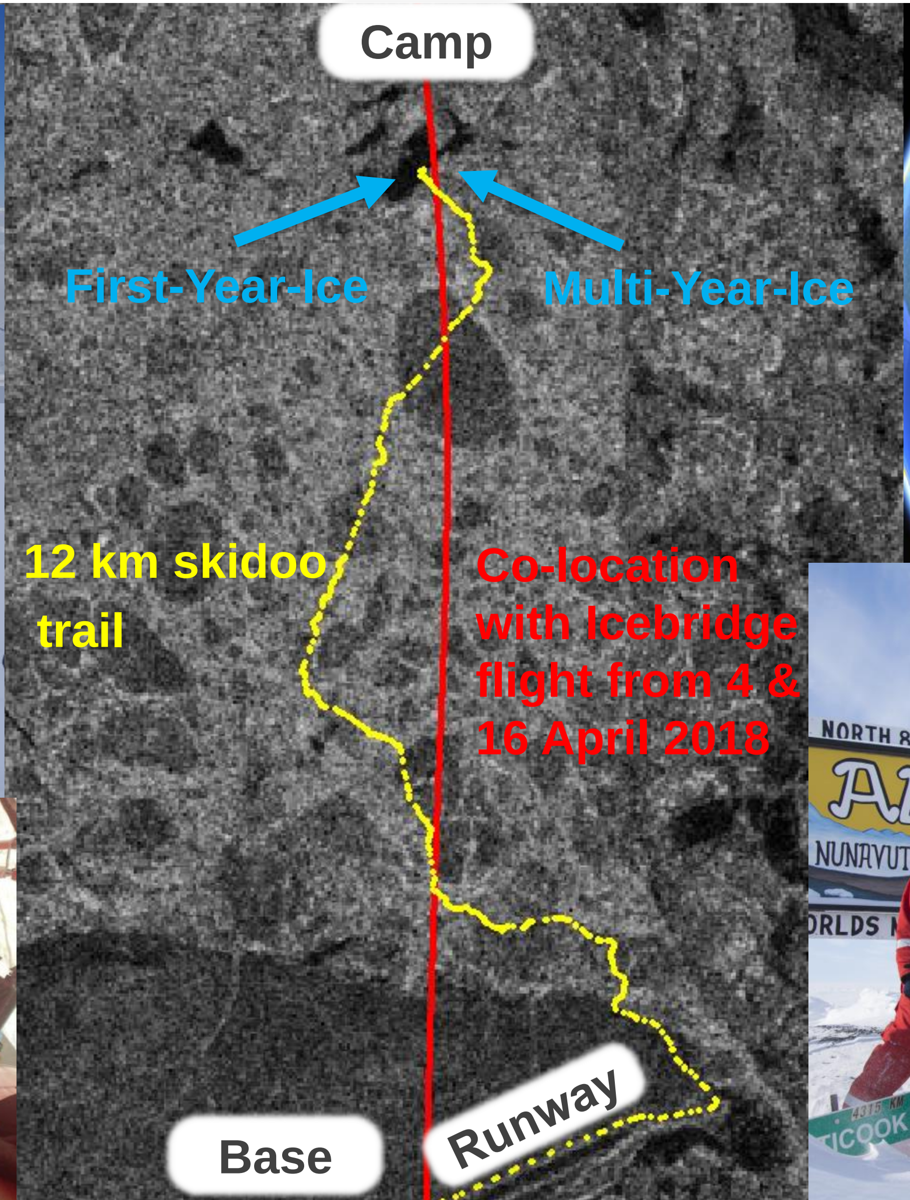


Motivation

- Snow depth measurements are lacking for e.g. co-locating with ROV and AUV measurements
- Time consuming to measure large areas
- Logistic challenges for hardly accessible areas (very thin ice)
- Destructive surface after snow depth measurements
- Lack of high spatial coverage and resolution snow depth measurements

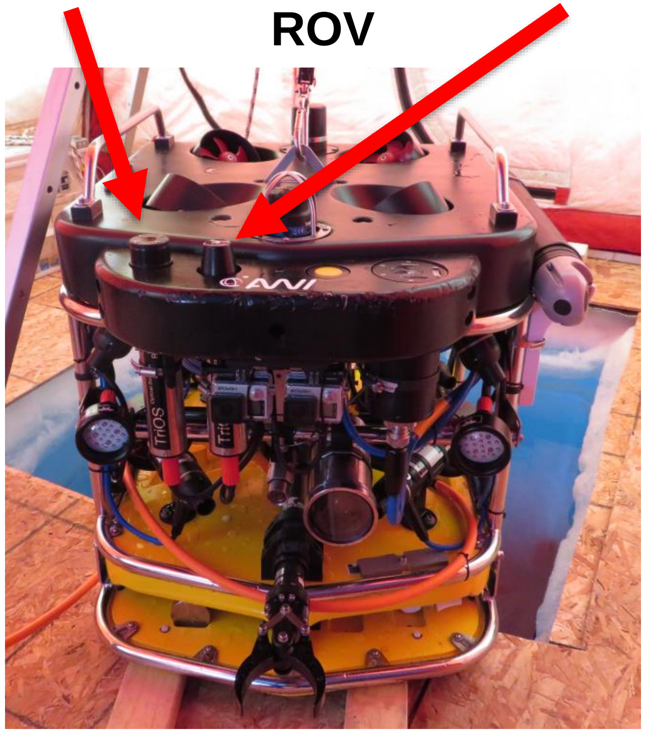
→ **Parametrization for snow depth**

Field Campaign MAP - Last Ice Area May 2018



Data

Under-ice hyperspectral radiance and irradiance
ROV



Snow Depth

Magna Probe

Laser Scanner

Total Ice Thickness

Electromagnetic Sounding Device

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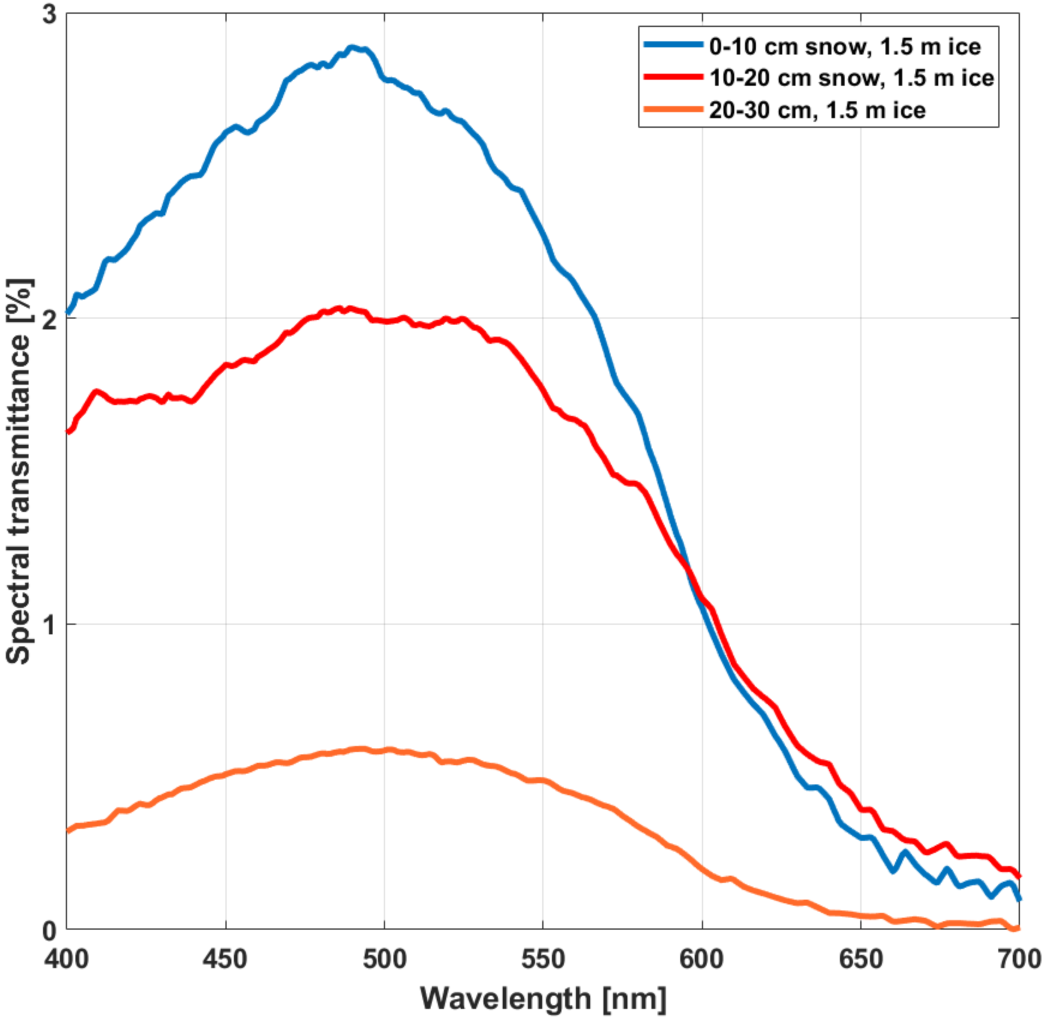
Methods



1) Normalized difference indices (NDIs)

$$\frac{\mathrm{Tm}\ (\lambda_1) - \mathrm{Tm}\ (\lambda_2)}{\mathrm{Tm}\ (\lambda_1) + \mathrm{Tm}\ (\lambda_2)}$$

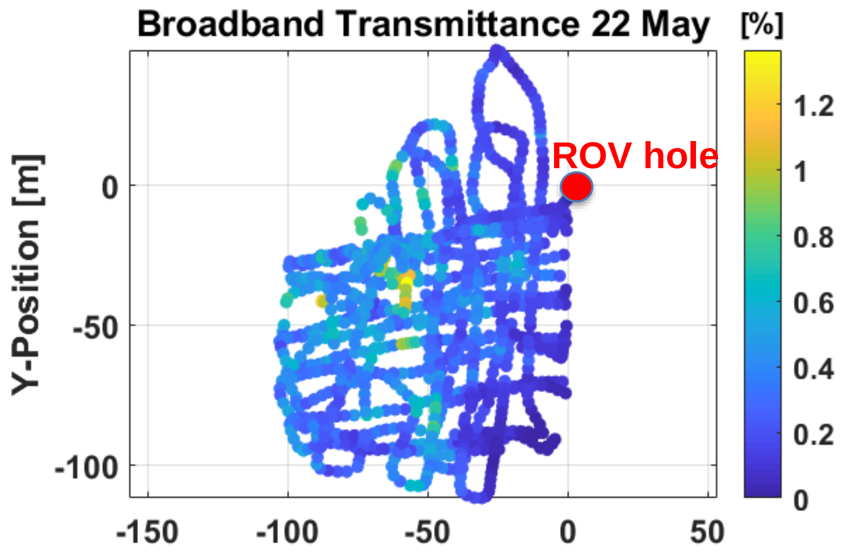
Wongpan et al., 2018; Arndt et al., 2017; Lange et al., 2016; Melbourne-Thomas et al., 2015; Mundy et al., 2007

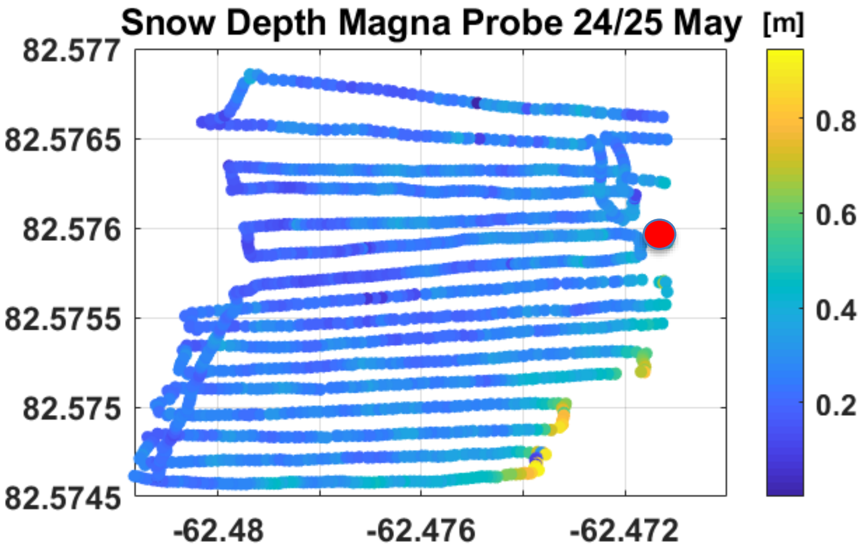
2) Multiple exponential regression model

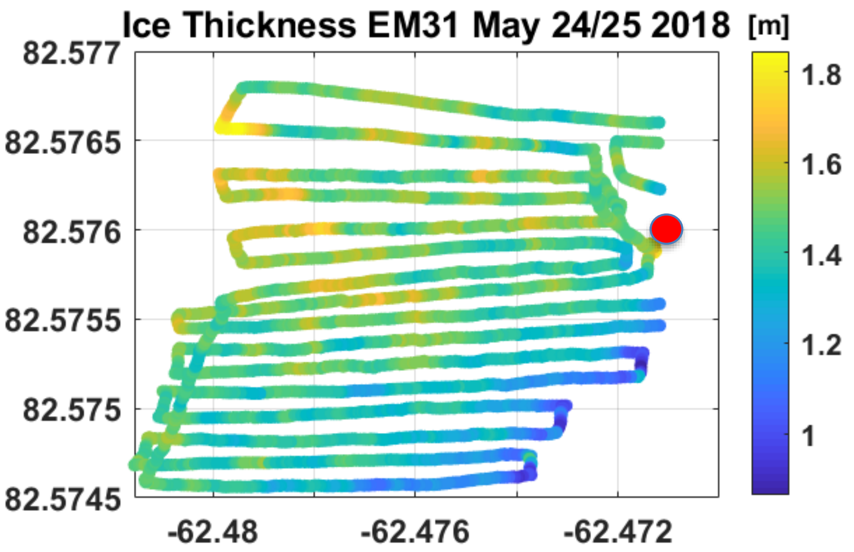
$$\mathrm{Tm}\ (z_{snow}, z_{ice}, \lambda) = \exp(-\,k_{snow}(\lambda) \cdot z_{snow} - \ k_{ice}(\lambda) \cdot z_{ice})$$

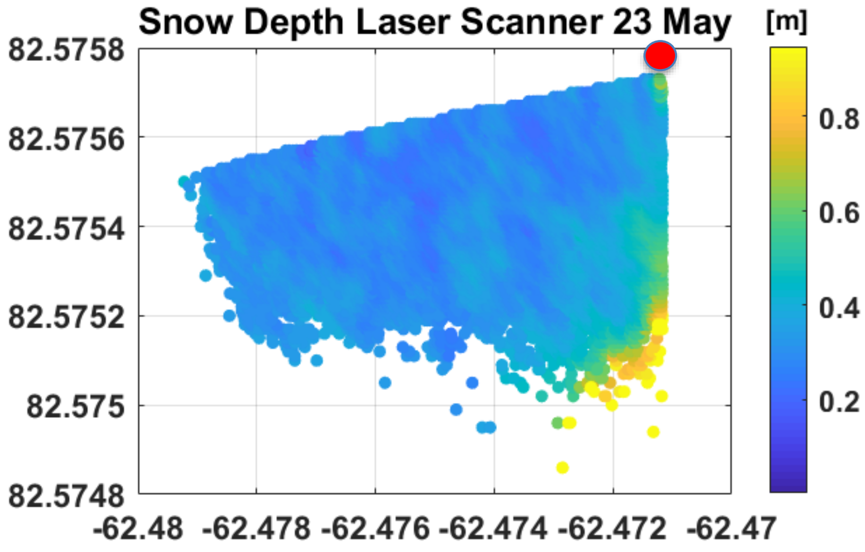
Arndt et al., 2017; McDonald et al., 2015; Nicolaus et al., 2010

Data


Broadband Transmittance 22 May
[%]
ROV hole
Y-Position [m]
0
-50
-100
-150
-100
-50
0
50
1.2
1
0.8
0.6
0.4
0.2
0

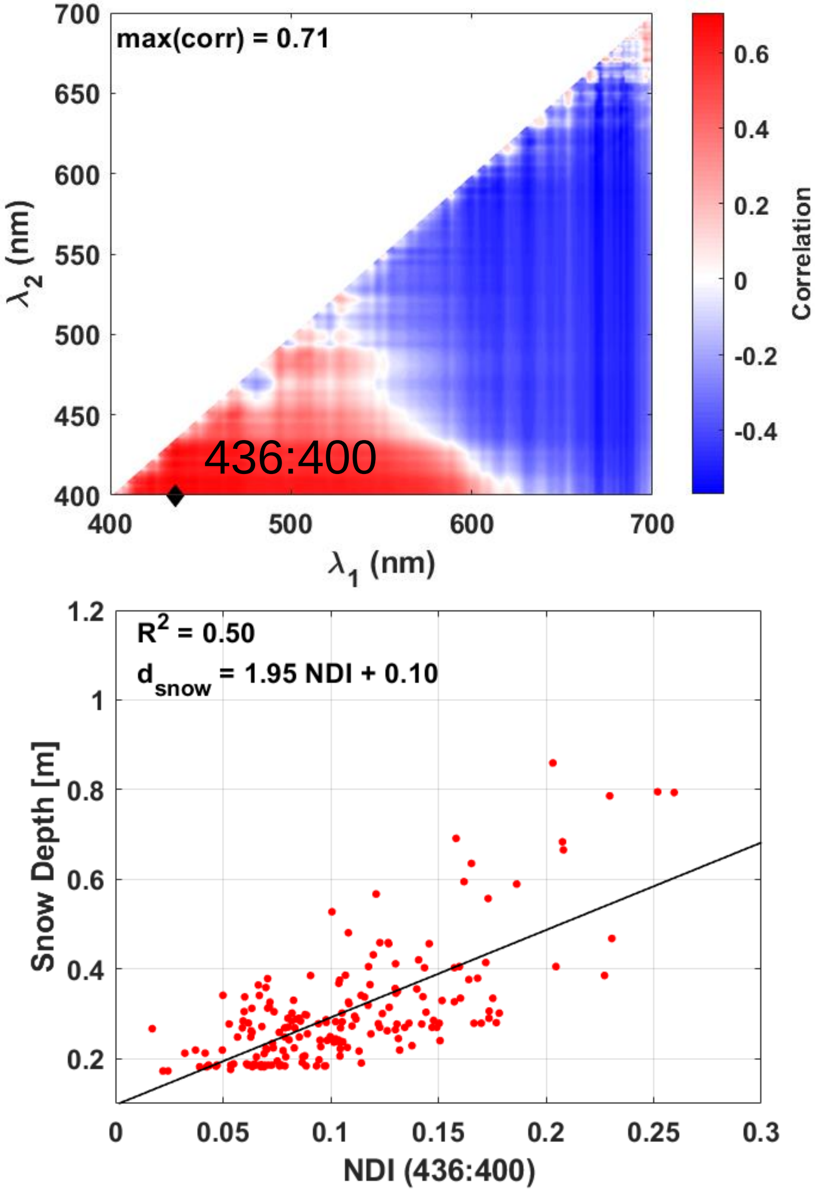

Snow Depth Magna Probe 24/25 May
[m]
82.577
82.5765
82.576
82.5755
82.575
82.5745
-62.48
-62.476
-62.472
0.8
0.6
0.4
0.2

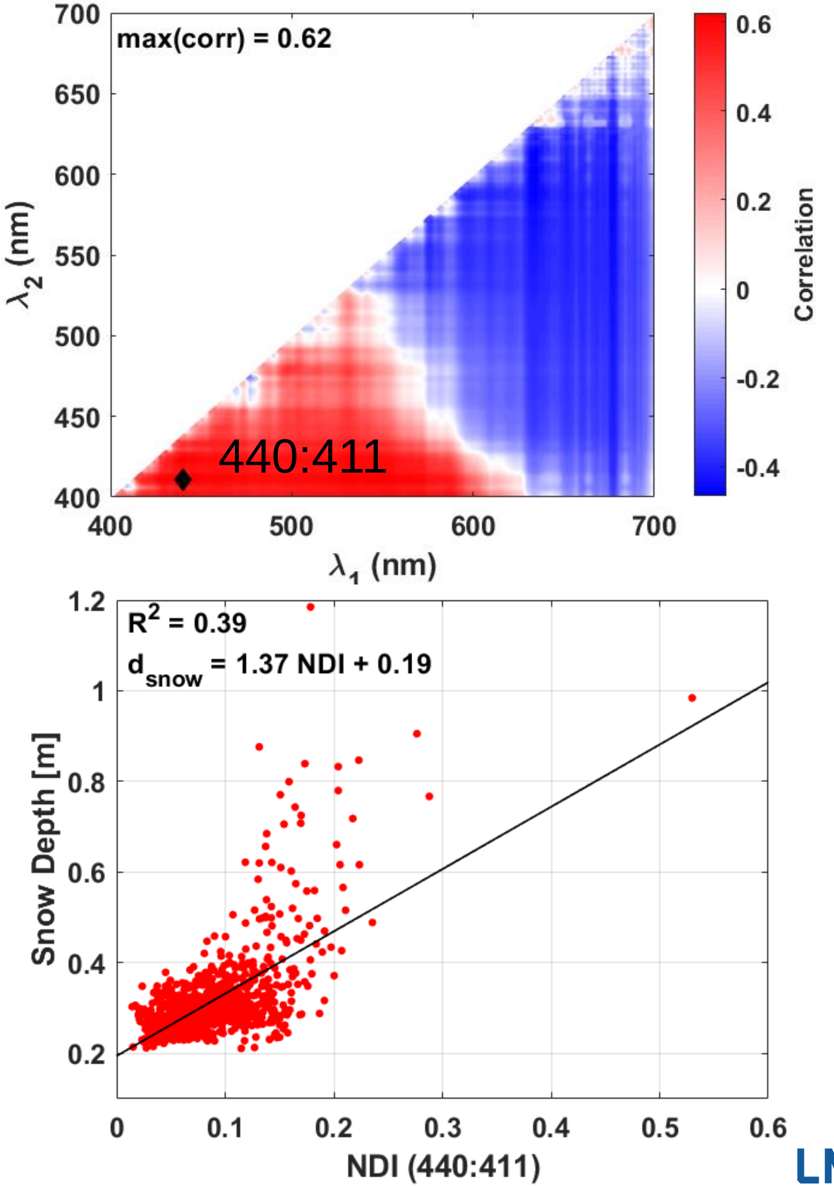

Ice Thickness EM31 May 24/25 2018
[m]
82.577
82.5765
82.576
82.5755
82.575
82.5745
-62.48
-62.476
-62.472
1.8
1.6
1.4
1.2
1


Snow Depth Laser Scanner 23 May
[m]
82.5758
82.5756
82.5754
82.5752
82.575
82.5748
-62.48
-62.478
-62.476
-62.474
-62.472
-62.47
0.8
0.6
0.4
0.2

Results – 1) NDIs

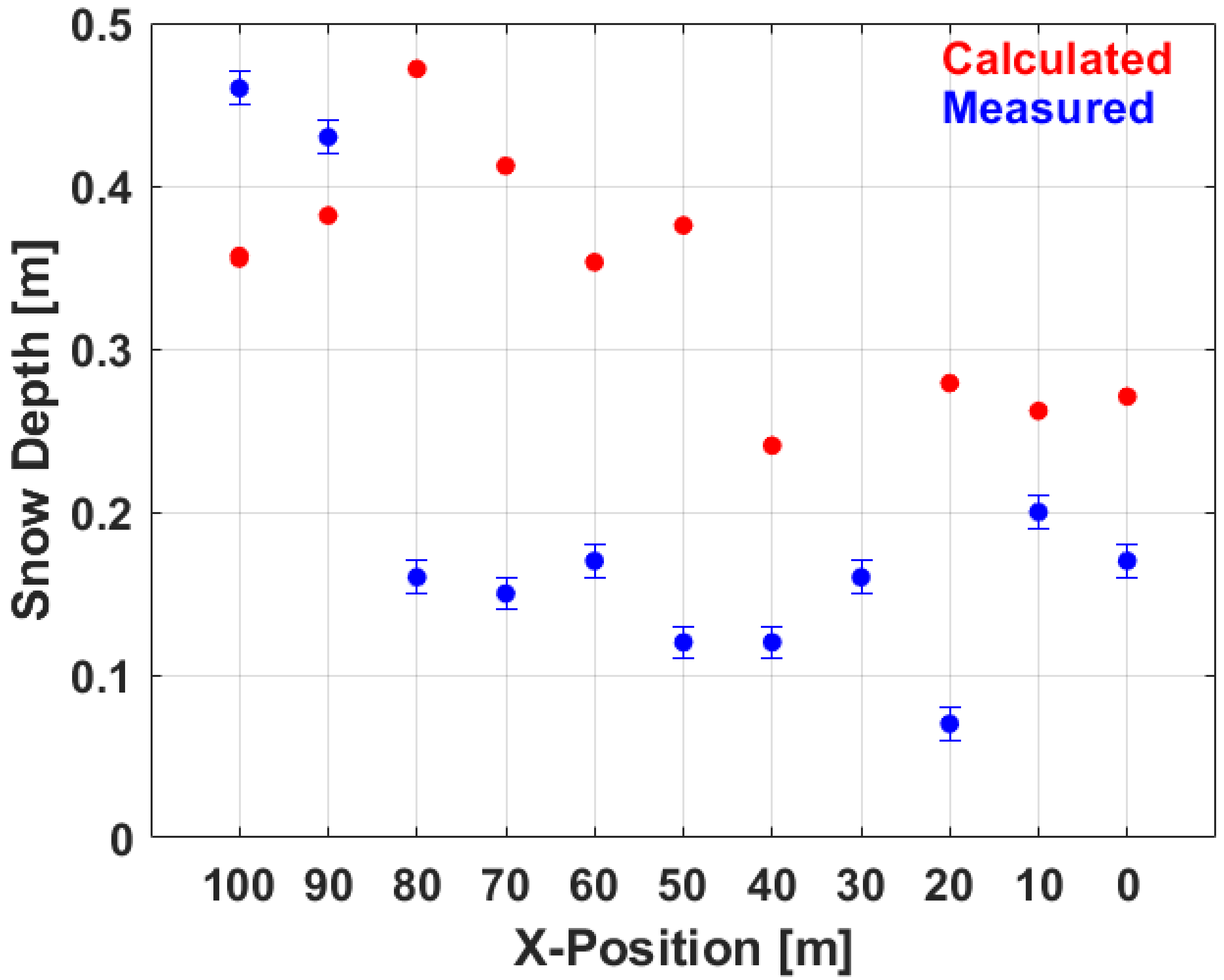
Magna Probe





Laser Scanner

Results – 1) NDIs



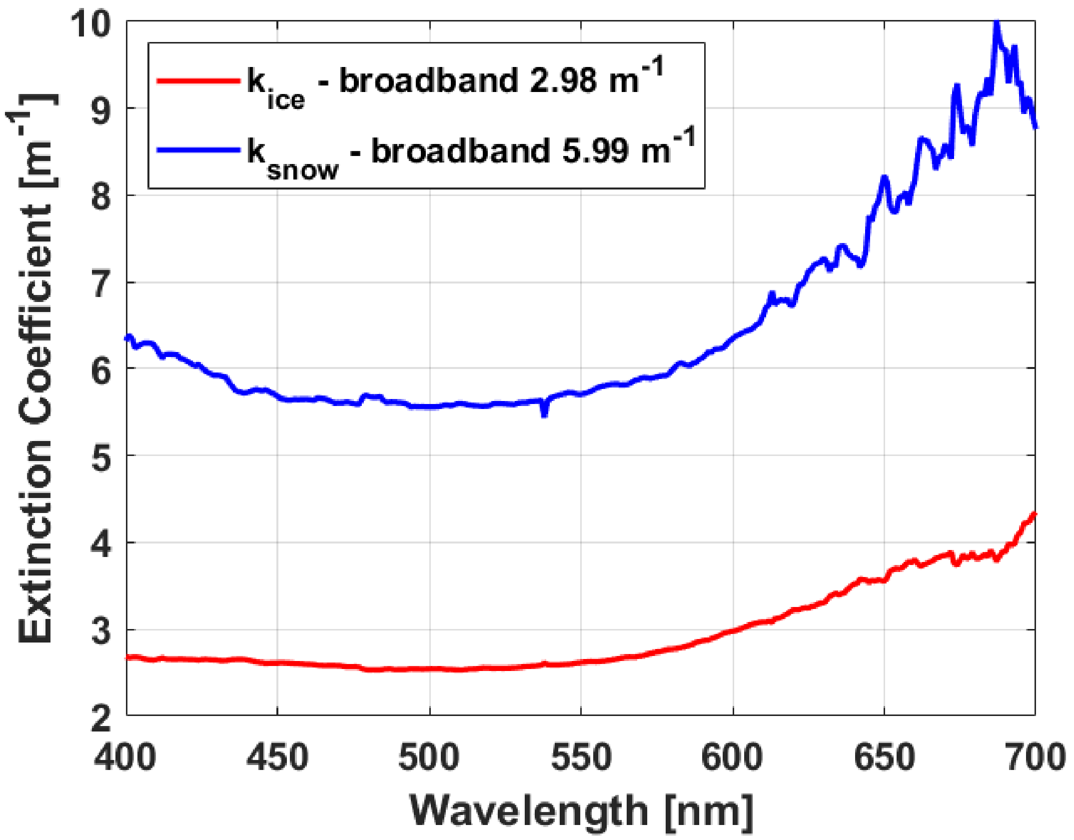
$$d_{snow} = 1.95\,NDI(436{:}400) + 0.10$$

Transmittance for NDIs from 7 May

In-situ snow depth measurements from 5 May

Results – 2) Multiple exponential regression model

$$\text{Tm}\,(z_{snow}, z_{ice}, \lambda) = \exp(-\,k_{snow}(\lambda)\cdot z_{snow} - \,k_{ice}(\lambda)\cdot z_{ice})$$



Perovich, 2007; Warren, 1982

10 - 100 m^{-1}

Low snow extinction coefficients k_{snow}

McDonald et al., 2015

Closer to 9-14 m^{-1} increasing from 400nm to 700nm with minimum around 500nm

Light et al., 2008; Perovich, 1996

0.8 - 1.5 m^{-1}

High sea ice extinction coefficients k_{ice}

Katlein et al., 2015

Broadband values between 1.1 to 3 m^{-1}

Katlein et al., 2019

Seasonal changes between 0.8 and 9 m^{-1}

-> high k_{ice} somewhat consistent

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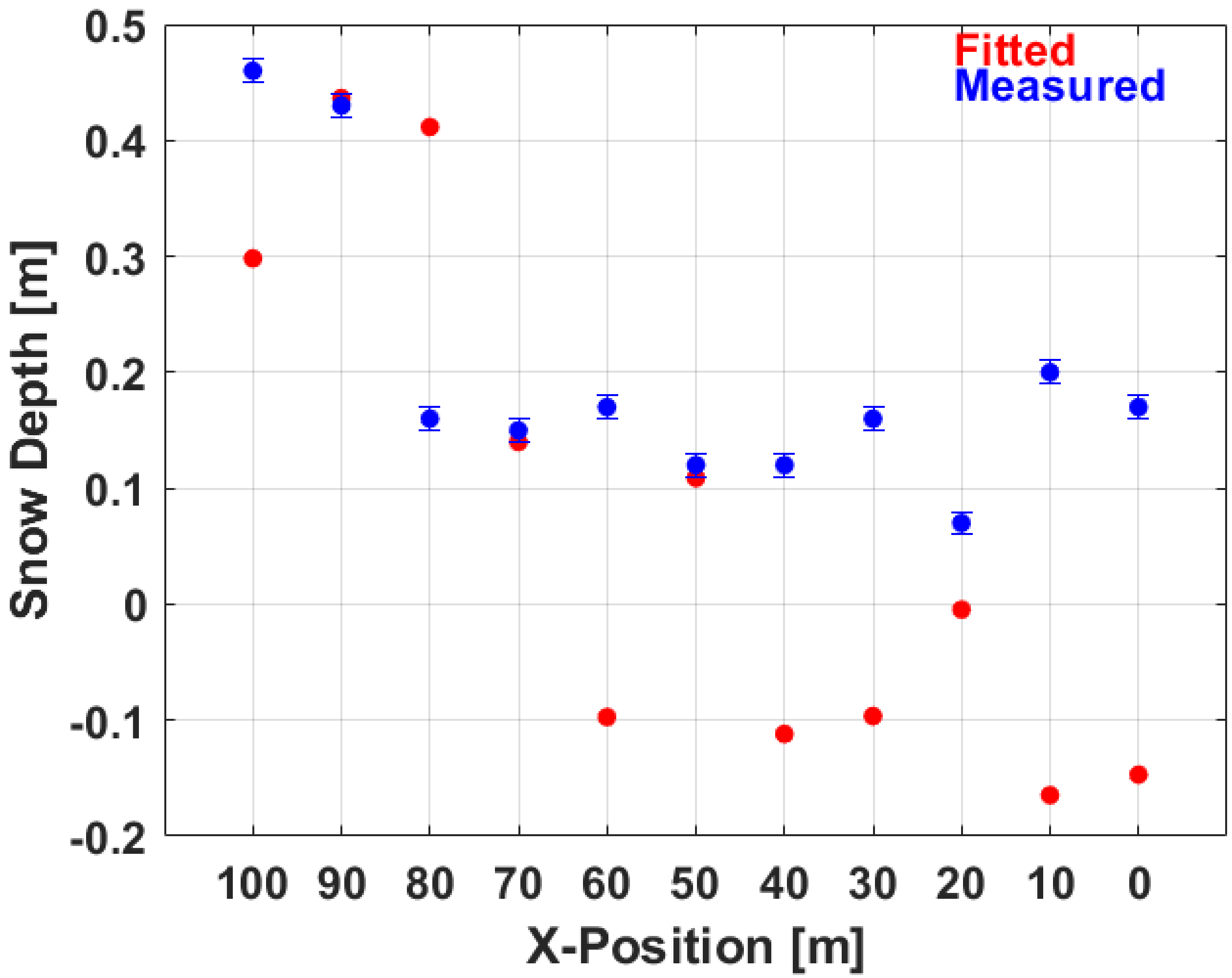
Results – 2) Multiple exponential regression model

$$\mathrm{Tm}\,(z_{snow}, z_{ice}, \lambda) = \exp(-\,k_{snow}(\lambda)\cdot z_{snow} - \,k_{ice}(\lambda)\cdot z_{ice})$$



Transmittance from 7 May

In-situ snow depth measurements from 5 May

Current challenges & future plans

Challenges

- Co-location
- More data / different dates (temporal match up)
- Check atmospheric data (snow fall events)
- Sensor footprint in relation with choice of radius for co-location
- Effects of water and biomass as well as reflection and scattering due to impurities within the snow and sea ice were neglected
- Use other retrieval methods

Plans

- Use different dataset (e.g., ODEN 2018 in the Central Arctic)
- Different ice types (e.g., Multi-Year-Ice)
- Radiative transfer model AccuRT and measured snow depth, ice thickness, and ice draft

Stamnes et al., 2018; Taskjelle et al., 2017, 2016; Hamre et al., 2004; Thomas and Stamnes, 1999

- Analyses are not done yet

Summary

- We have processed datasets consisting of under-ice spectral transmittance and transflectance, snow depth from two devices, and ice thickness

- We looked at inverse methods to derive snow depths from spectral transmittance

- First try promising and preliminary results show that there is potential

- But there are still some issues …

- Calculated snow depths do not very well compare with observed snow depths

- Limitations: co-location, footprint of sensors, different dates (temporal mismatch), atmospheric conditions

Fisheries and Oceans Canada

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