Reflectivity of second-year Arctic sea ice: Findings from the MOSAiC expedition

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Photo: Sea Ice Albedo, Isfjorden,Svalbard, Apr 2018

Outline

1. Motivation for Sea-Ice Reflectometry

2. Measurement & Model
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   - Reflection Models

3. Results for MOSAiC (first leg)
   - Reflectivity Profiles
   - Inverted Permittivity

4. Summary & Conclusions

Motivation for Sea-Ice Reflectometry

1. Importance of Sea Ice:
   - crucial effect on Earth's radiation budget
   - crucial factor for maritime activities in the Arctic

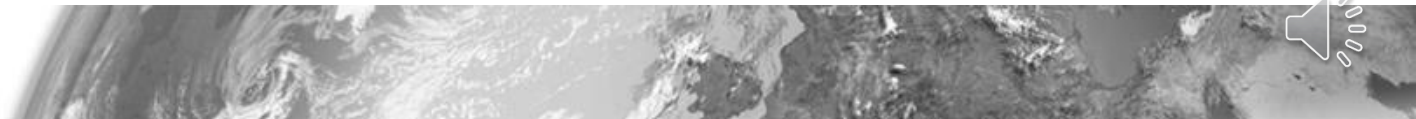
   Cardellach et al. 2018

2. Sea Ice impact on GNSS signals:
   - reflectivity decrease with increasing sea-ice concentration (SIC)
   - it decreases also for old (low-salinity) sea-ice types
   - roughness effect (elevation dependent)

   Semmling et al. 2019

3. Opportunity of MOSAiC expedition:
   - R/V Polarstern as platform for one year in Arctic sea ice
   - record GNSS data at variable sea-ice conditions

Measurement & Model

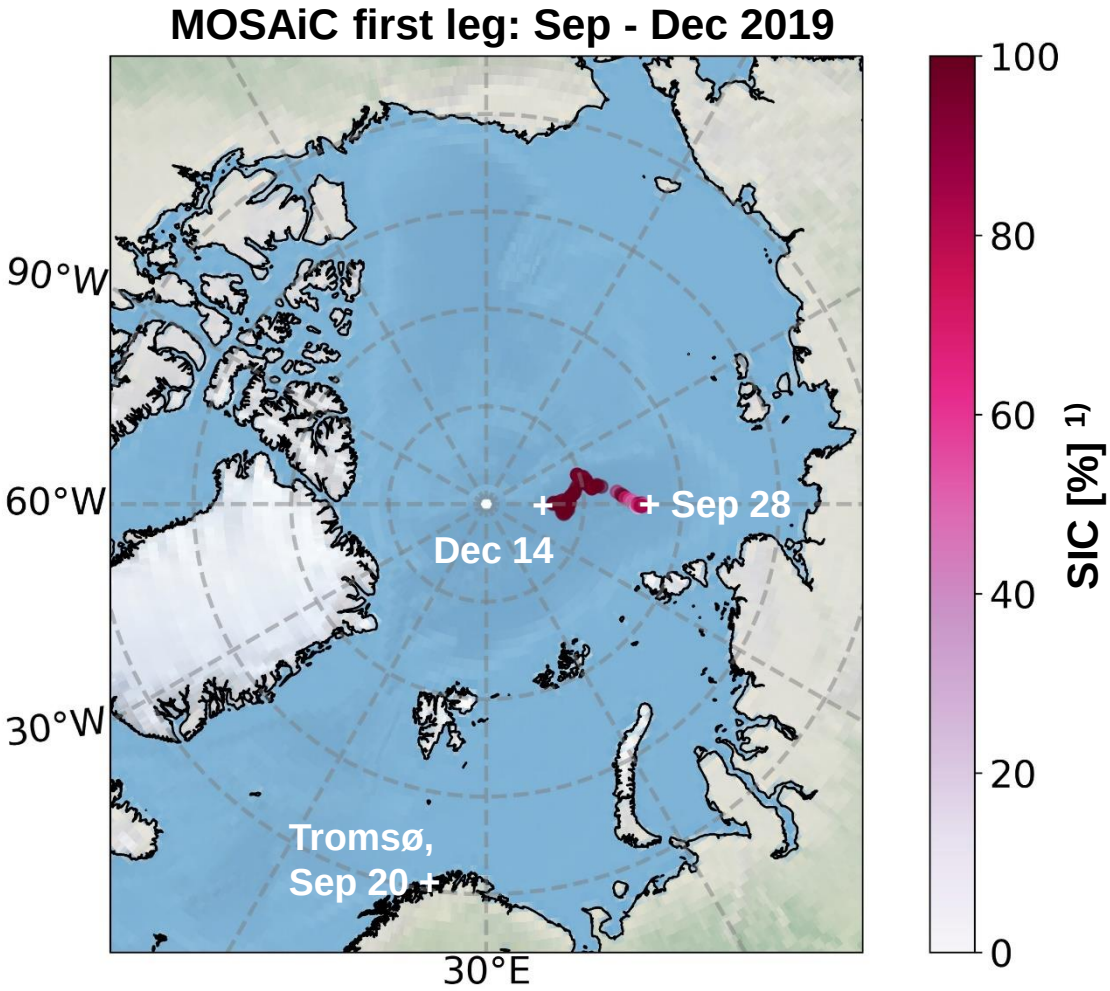


Polarstern Measurements

MOSAiC expedition 1st leg:
- from Tromsø into the central Arctic
- 86 days (Sep 20 – Dec 14, 2019)
- **data permission after Sep 26**

Marginal Ice Zone (MIZ):
- Siberian sec. lat. 82°N to 85° N
- 3 days (Sep 28 – 30, 2019)
- **variable sea-ice concentration**

Central Arctic (CA):
- during/after mooring to ice floe
- 14 days (Dec 1 – 14, 2019)
- **permanently compact sea ice**



1) in-situ obs. from the ship, ASSIST protocol

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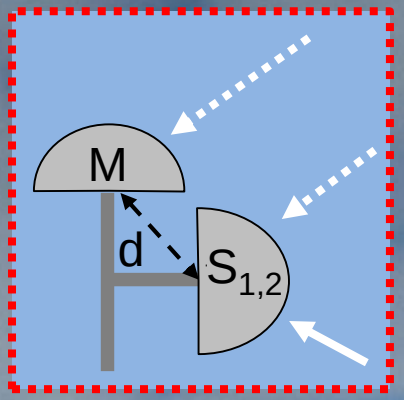
Polarstern Measurements



h = 22 m

d = 20 cm

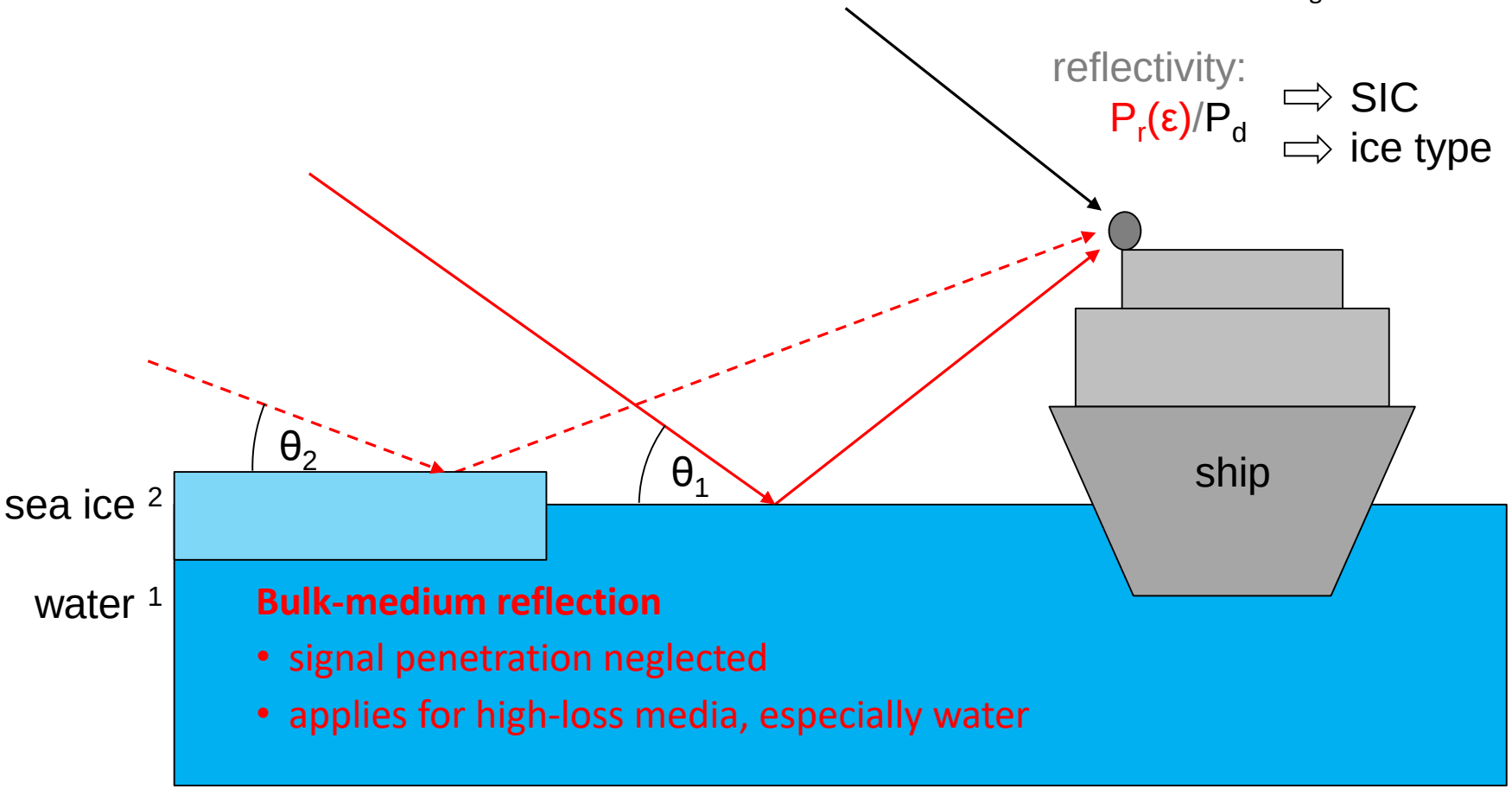
Master link (M): up-looking ant. RHCP
Slave links ($S_{1,2}$): side-looking ant. LHCP, RHCP

Setup cf.: Helm et al. 2007; Semmling et al. 2019

Photo Polarstern: Peter Lemke, AWI

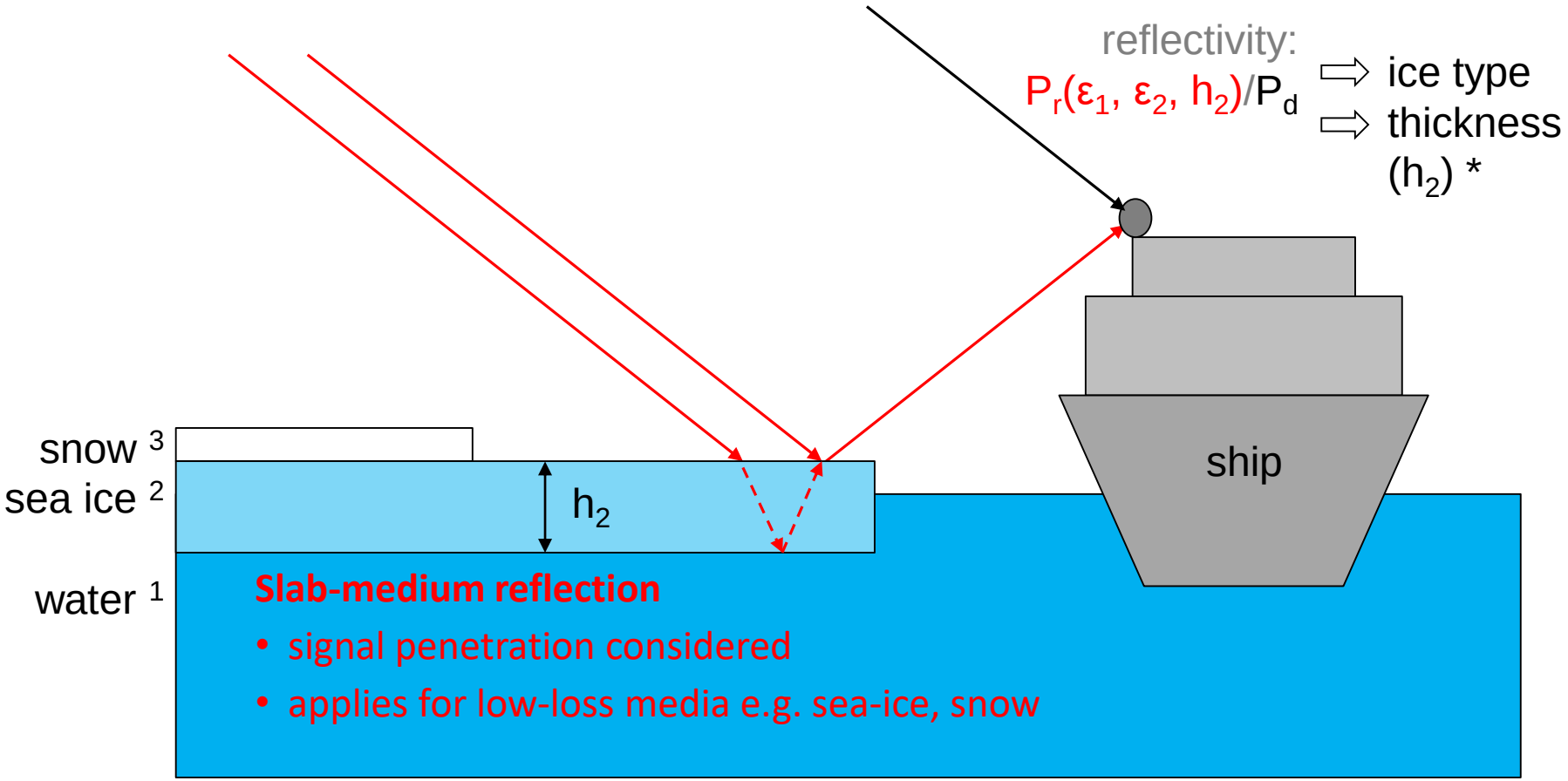
Reflection Model

Semmling et al. 2019



rel. permittivity: $\varepsilon_1 = 76.4 + i\ 48.5$; $\varepsilon_2 = 3.31 + i\ 0.11$

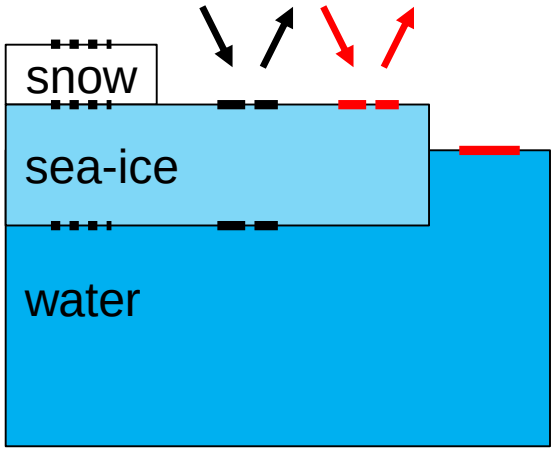
Reflection Model



rel. permittivity: $\varepsilon_1 = 76.4 + i\ 48.5$; $\varepsilon_2 = 3.31 + i\ 0.11$; $\varepsilon_3 = 1.76 + i\ 0.00$

* Munoz-Martin et al. 2020

Reflection Model

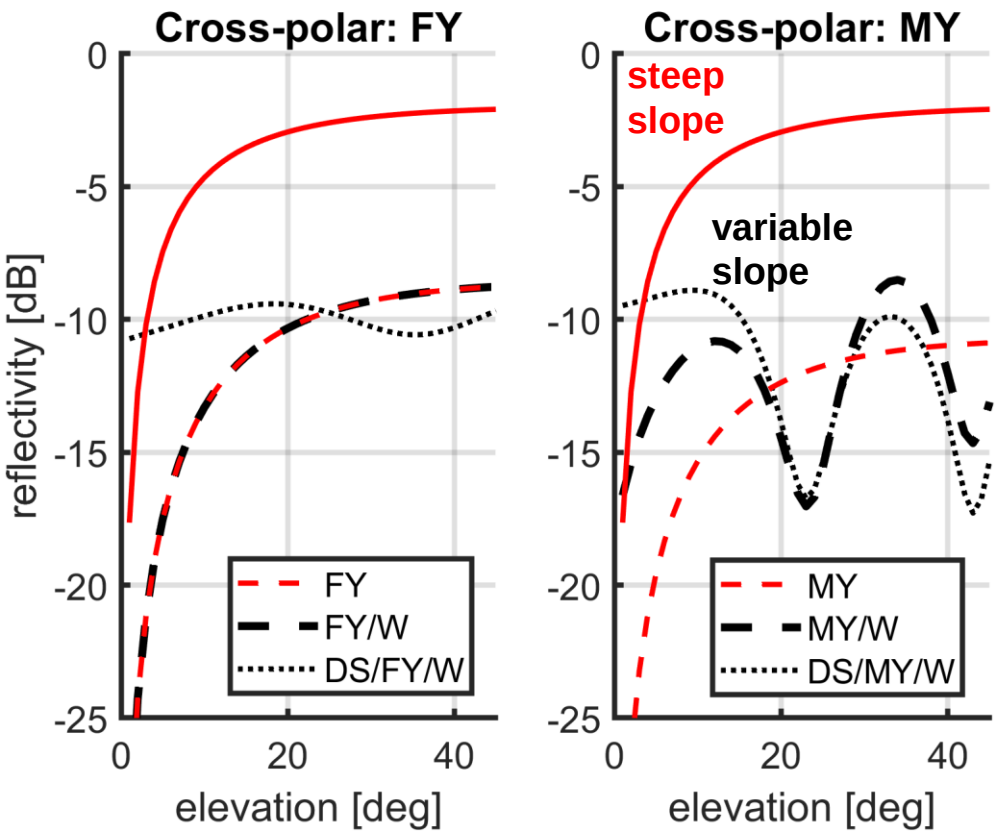


Bulk-medium reflection

Slab-medium reflection

Kaleschke et al. 2010

Semmling et al. (under review)



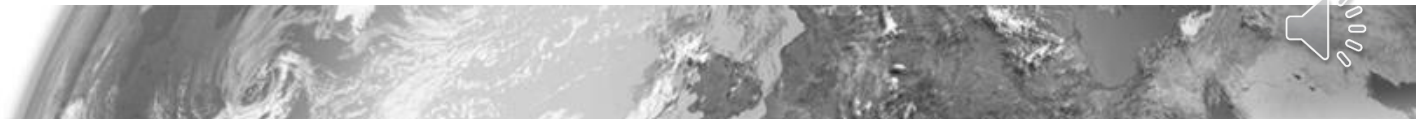
Water (W)
ε = 76.4 + i 48.5
at 2°C
„opaque“

First-year (FY) ice type:
ε = 4.75 + i 0.91
at -1°C, 1m thick
„opaque“

Multiyear (MY) ice type:
ε = 3.31 + i 0.11
at -1°C, 1m thick
„transparent“

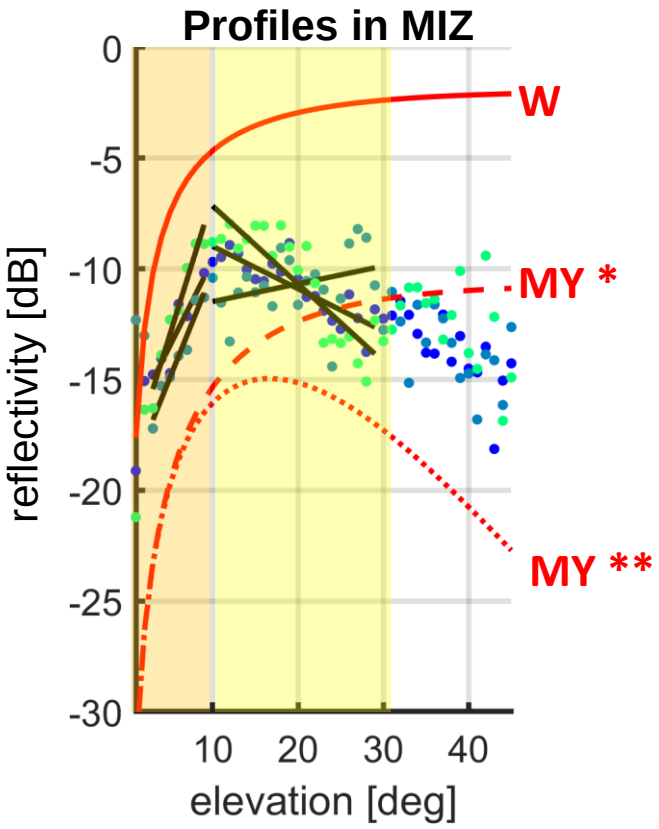
Dry Snow (DS) cover:
ε = 1.76 + i 0.00
20cm thick
„transparent“

Results for MOSAiC (first leg)



Semmling et al. (under review)

Reflectivity Profiles



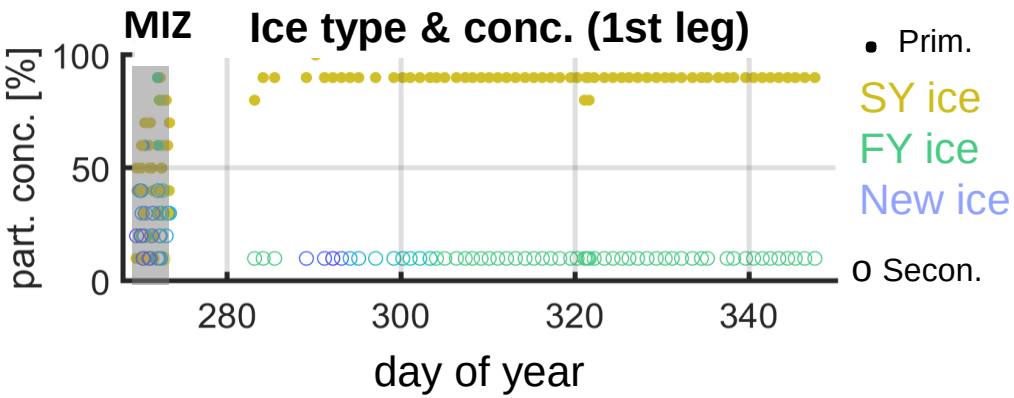
*** smooth; ** rough**

- obs. (day color-coded)

Low-Elevation Range (1° to 10°)
- reflect. between MY and W
- steep slope of bulk model
- no roughness effect

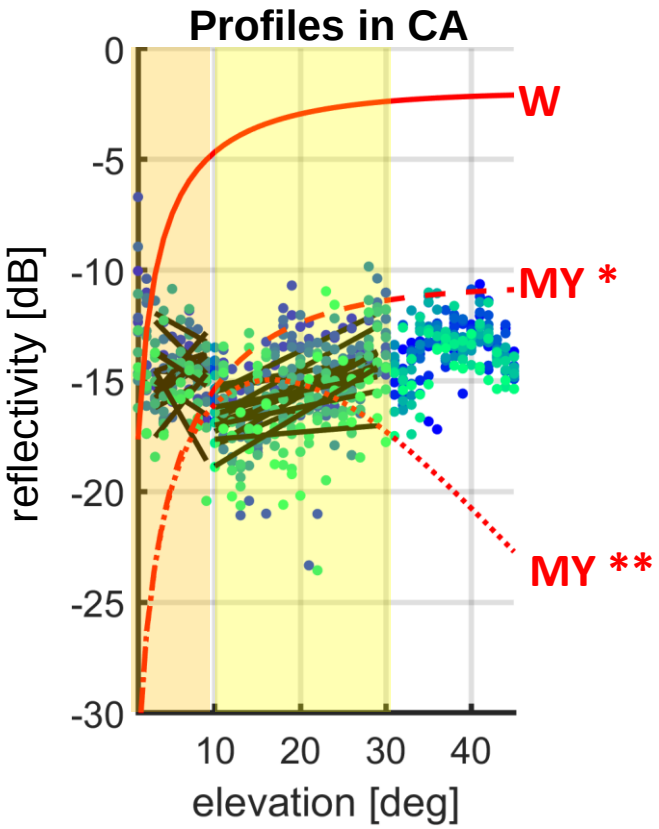
Mid-Elevation Range (10° to 30°)
- reflect. above MY
- moderate slope (decrease)
- small roughness effect

⇨ permittivity inversion



Reflectivity Profiles

Semmling et al. (under review)



*** smooth; ** rough**

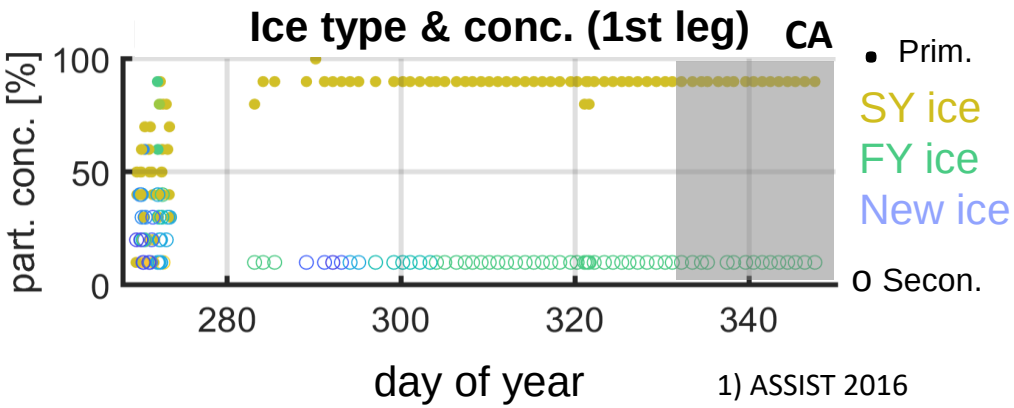
- obs. (day color-coded)

Low-Elevation Range (1° to 10°)
- reflect. between MY and W
- slope deviates from bulk model
- no roughness effect

⇨ slab anomaly

Mid-Elevation Range (10° to 30°)
- reflect. below MY
- slope of slight increase
- no roughness effect

⇨ permittivity inversion



1) ASSIST 2016

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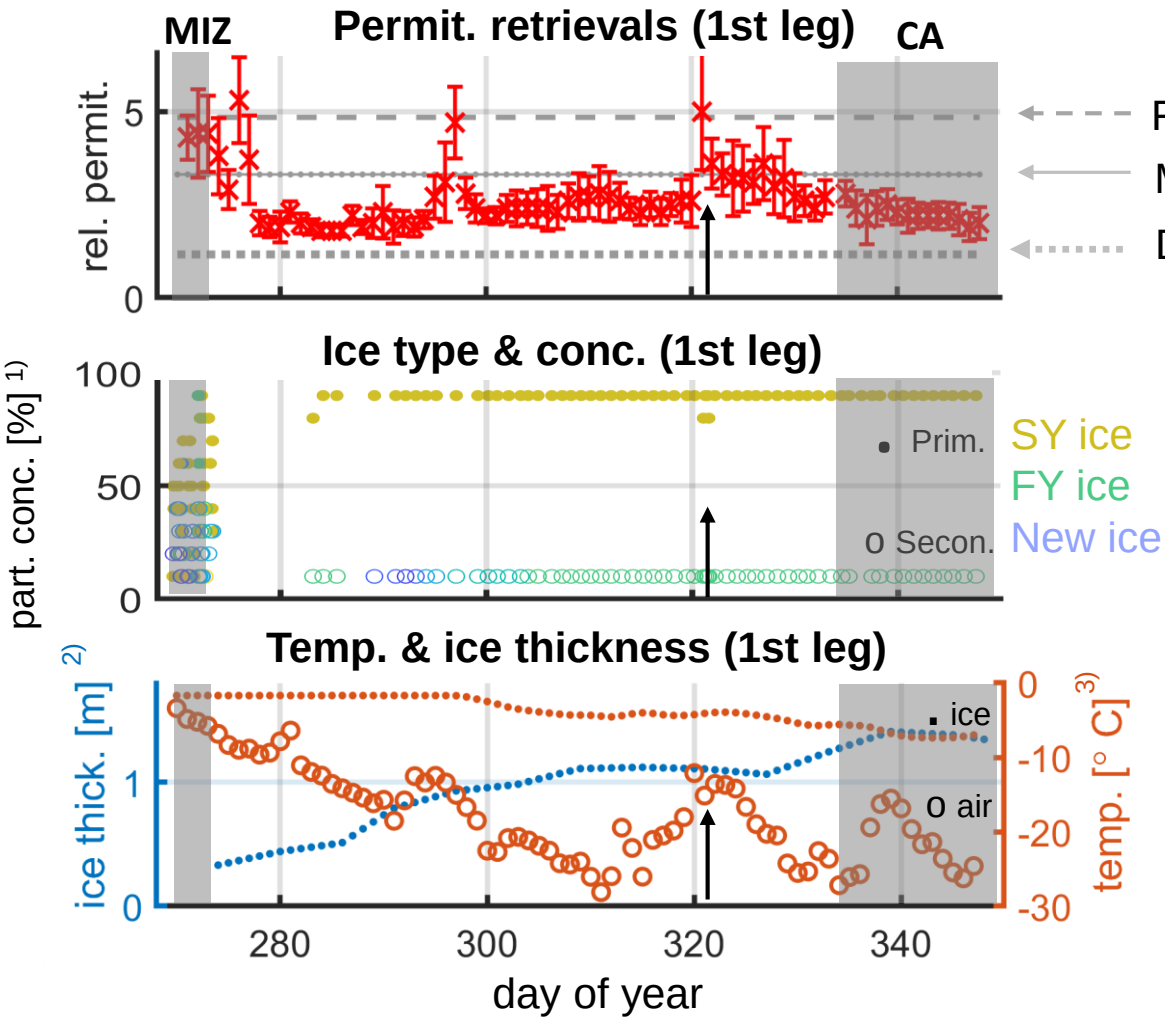
Semmling et al. (under review)

Inverted Permittivity



Ice Concentration Impact
- MIZ: SIC < 1 (ε rather high)
- CA: SIC = 1 (ε low)
- Storm: SIC decrease (ε increase)

Ice Type Impact
- MIZ: mixed types (ε rather high)
- CA: SY dominates (ε low)
- often: ε below MY level

Ice Thickness & Temp. Impact
- in general: ε no clear effect of thick. (increase) and temp. (decrease)

1) Assist protocol (in-situ)
2) AWI 2020 (sat. rem. sens.)
3) ECMWF 2020 (global model)

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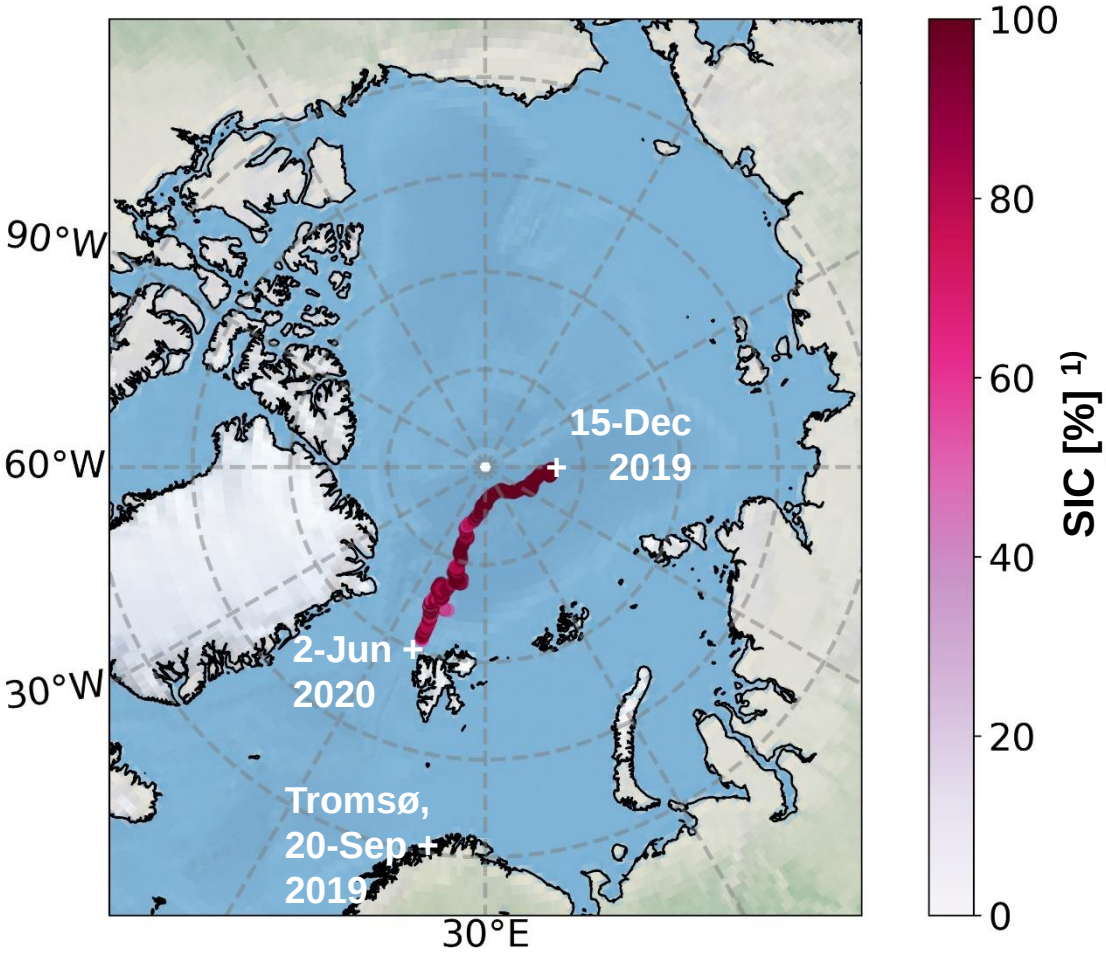
Summary & Conclusions

MOSAiC Expedition
- R/V Polarstern in Arctic over 1 yr
- GNSS reflectometry aboard
- capable to estimate direct and reflected signal power

Reflectivity Profiles
- bulk reflection in MIZ
- slab refl. with ice penetration in CA
- permittivity inversion shows impact of SIC and different ice type

More data available
- for MOSAiC's second leg
- from central Arctic to Fram Strait
- 171 days (Dec 15, 2019 – Jun 2, 2020)

More MOSAiC: Dec 2019 - Jun 2020



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Acknowledgements

Support from MOSAiC team
G. Spreen, L. Kaleschke, R. Ricker, A. Tavri
Logistics at AWI & Crew of R/V Polarstern
Werkstatt and IT of GFZ Geodesy Department

Data used here was produced as part of MOSAiC project.

Photo: Sea Ice Albedo, Isfjorden,Svalbard, Apr 2018

Thank you for your attention …

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