Data Fusion to estimate sea-ice permittivity: A GNSS processor for 1-year MOSAiC data

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Photo: Sea Ice in Fram Strait, August 2016

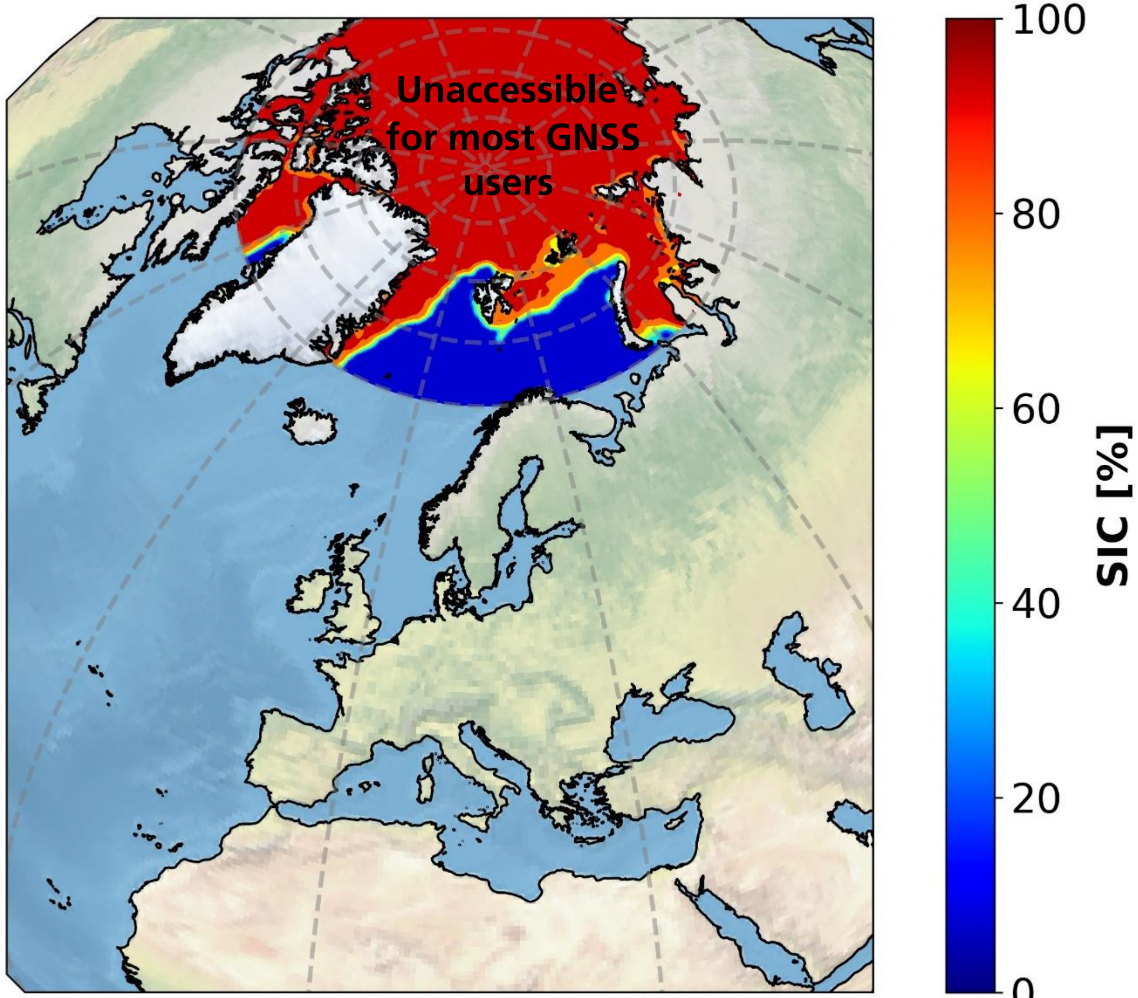
Outline

- Motivation & Concept
- Permittivity Inversion
- More Parameters
- Summary & Outlook

DLR

Motivation & Concept

Motivation to participate in MOSAiC



Arctic Sea Ice Extent, Jan 1st 2020

* GFZ GNSS-R setup * DLR GNSS scint. setup

GNSS Remote Sensing for characterization of:
- Sea Ice
- Ionospheric Irregularities

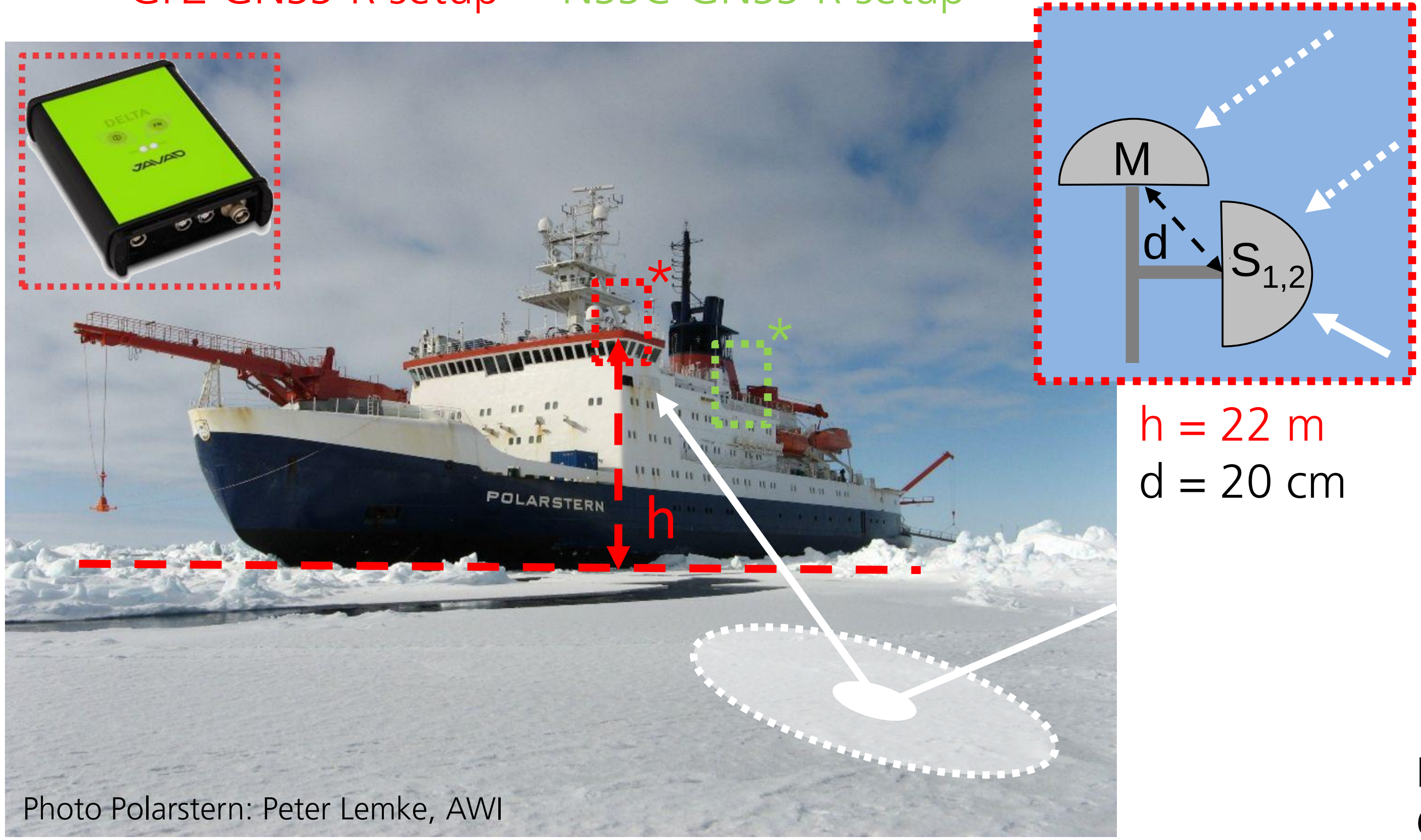
Belmonte Rivas et al. 2010

Alonso-Arroyo et al. 2017

Semmling et al. 2019

Setup & Measurements

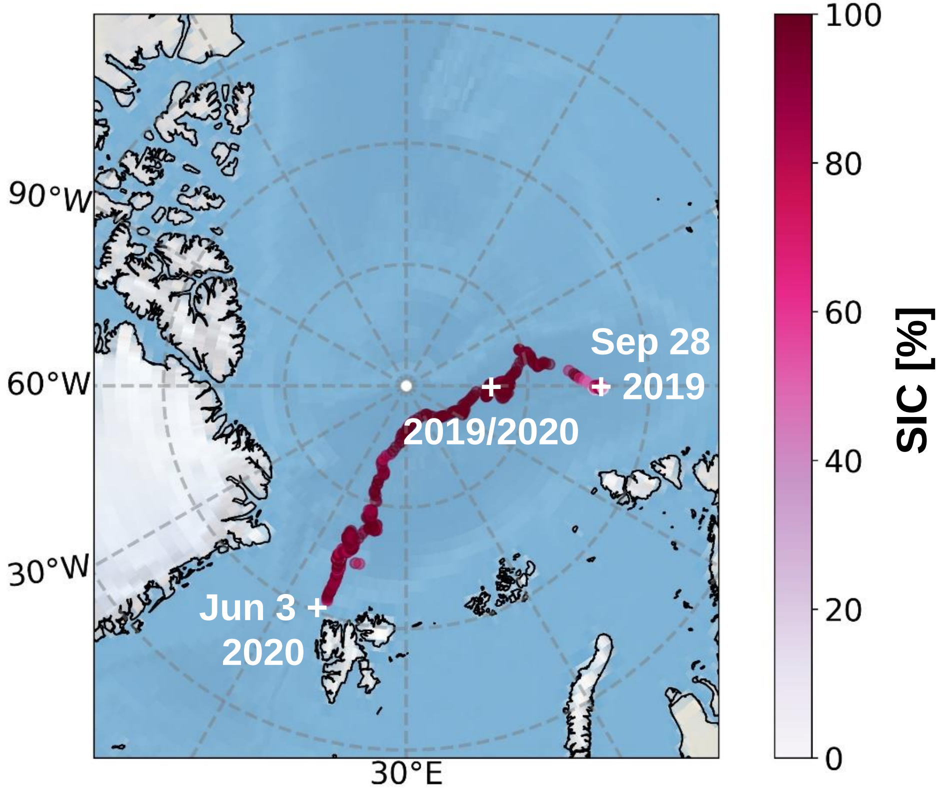
* GFZ GNSS-R setup * NSSC GNSS-R setup



Setup cf.: Helm et al. 2007; Semmling et al. 2013

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

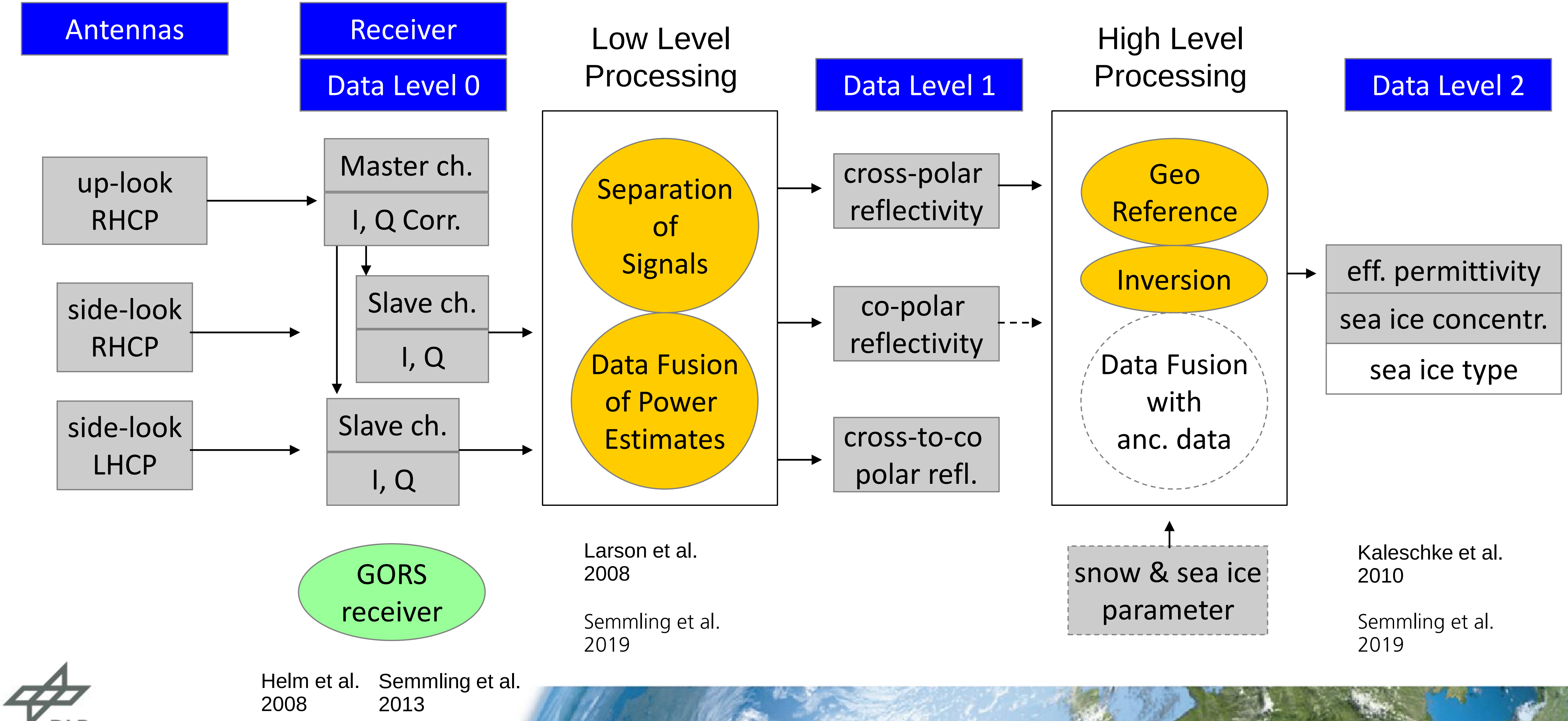
MOSAiC first drift: Sep 2019 - Jun 2020



Marginal Ice Zone (MIZ): late Sep 2019, SIC increase
Compact Ice Zone (CIZ): Dec 2019, permanent high SIC

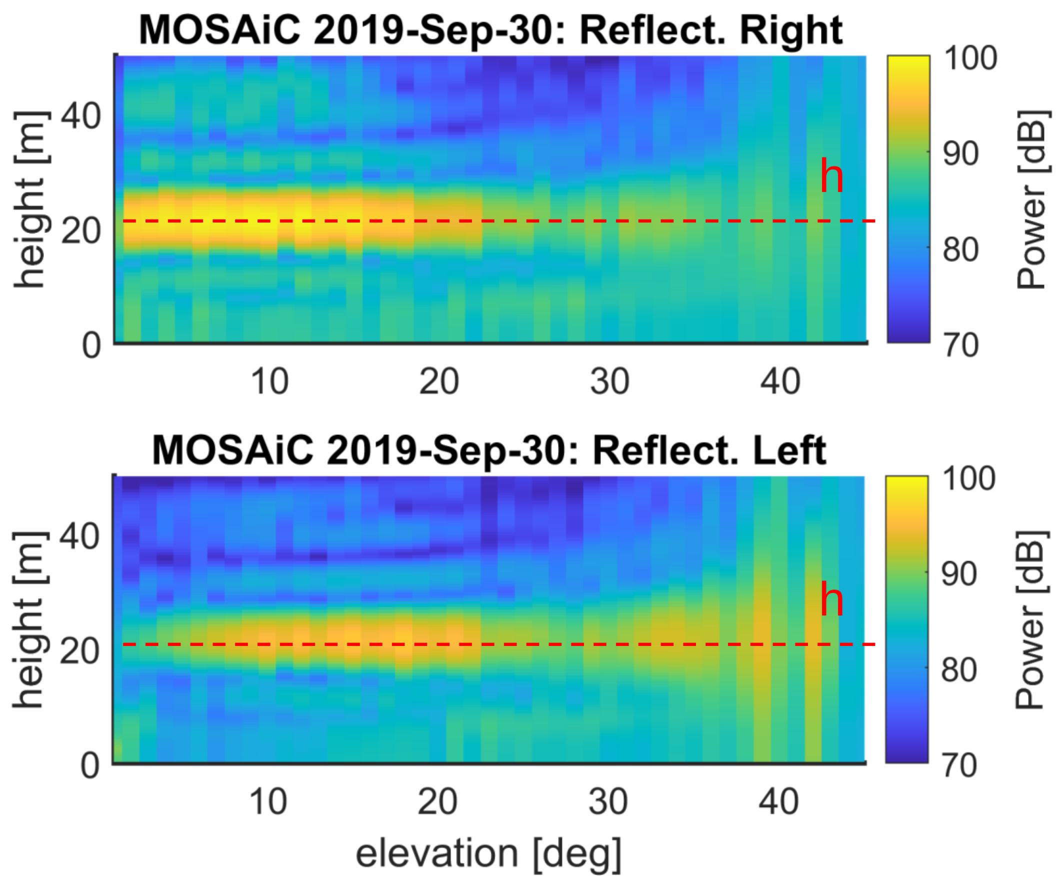
Semmling et al. 2021, 2022

Processing Scheme for Permittivity Inversion

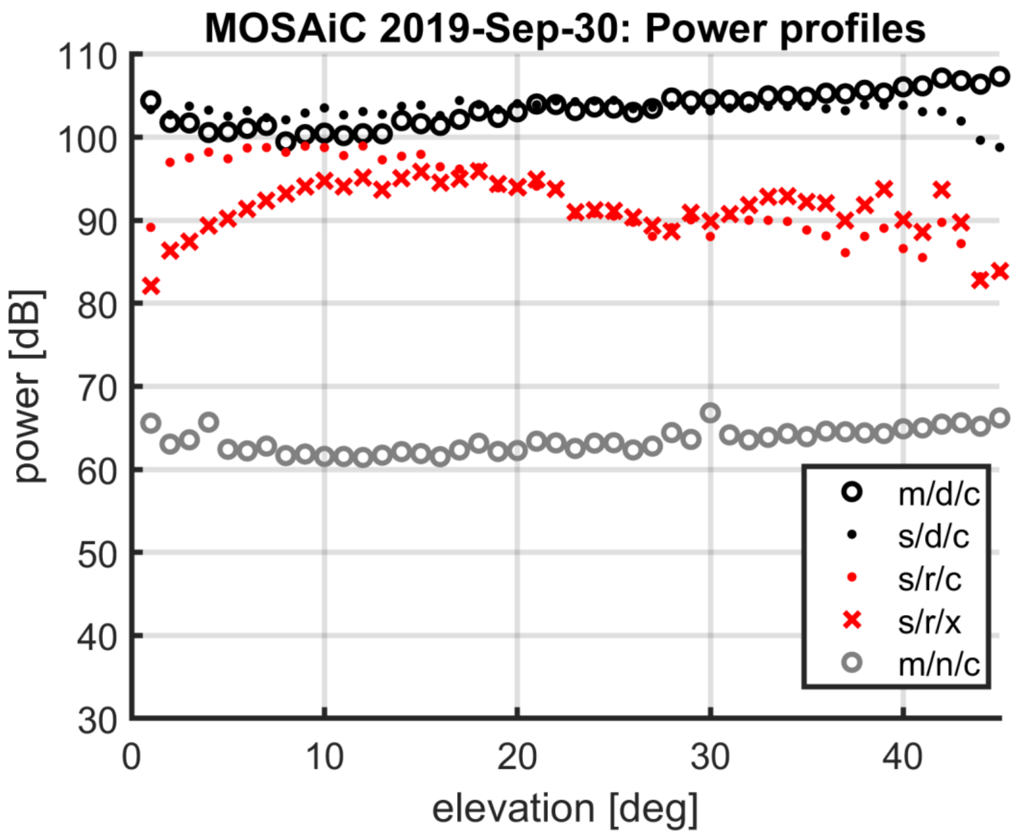


Permittivity Inversion

Low Level Processing



Peraza et al. 2017 Semmling et al. 2019

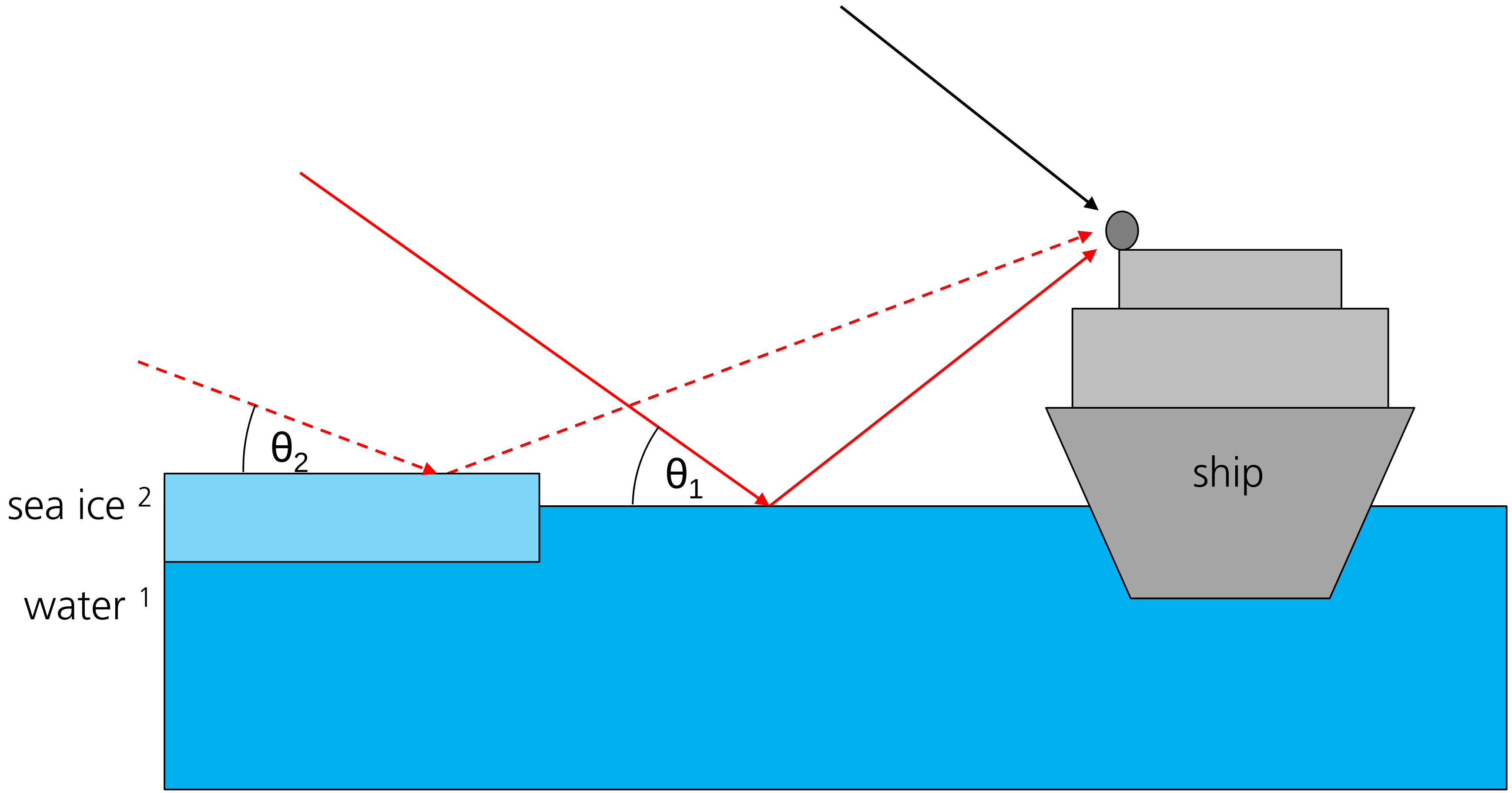


Fusion of Power Estimates

- cross-pol. reflectivity
- co-pol. reflectivity

Semmling et al. 2022

Coherent Reflection Model



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

reflectivity: $P_r(\varepsilon)/P_d$ ⇨ SIC ⇨ ice type

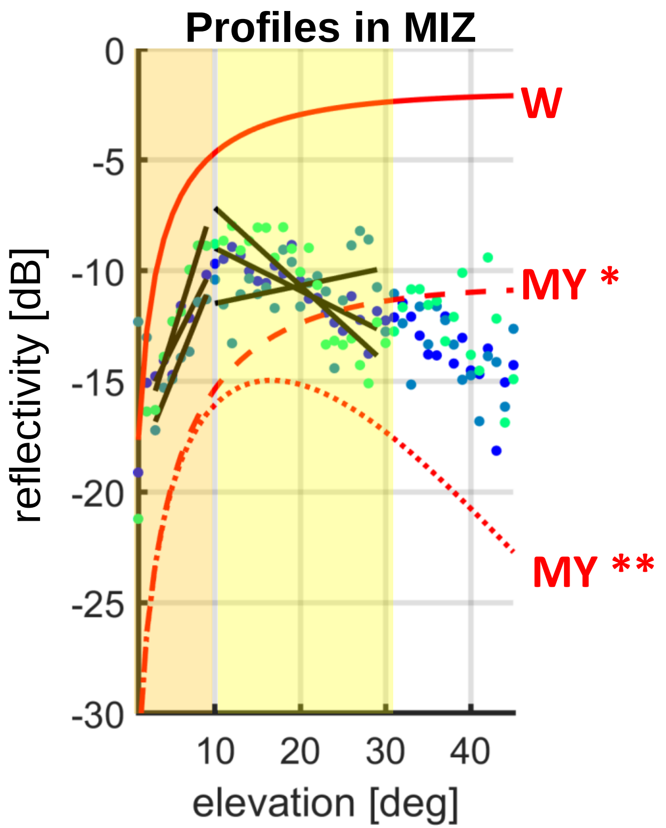
Can we estimate sea ice permittivity for ice type characterization?

Bulk-medium reflection

- signal penetration neglected
- applies for high-loss media, especially water

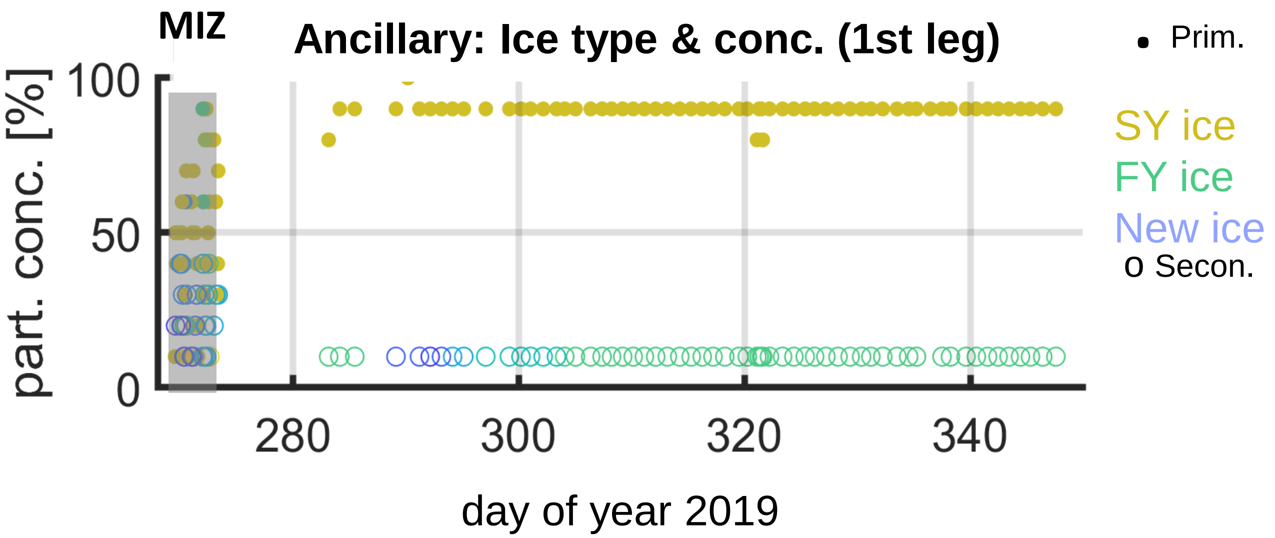
Semmling et al. 2019

Reflectivity Profiles



*** smooth; ** rough**

- daily-averaged obs. (day color-coded)



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

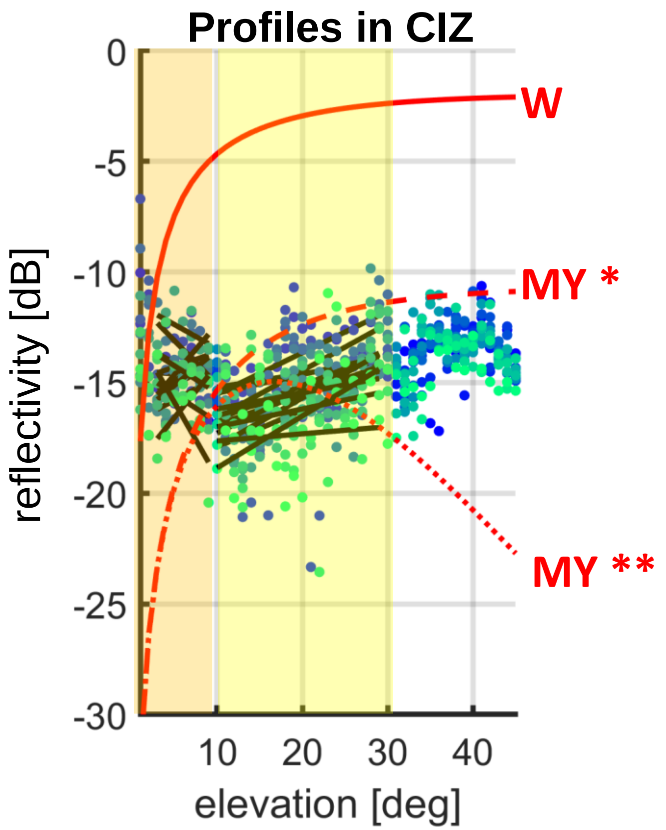
Mid-Elevation Range (10° to 30°)
- reflect. above MY
- moderate slope (decrease)
- small roughness effect

⇩

permittivity inversion

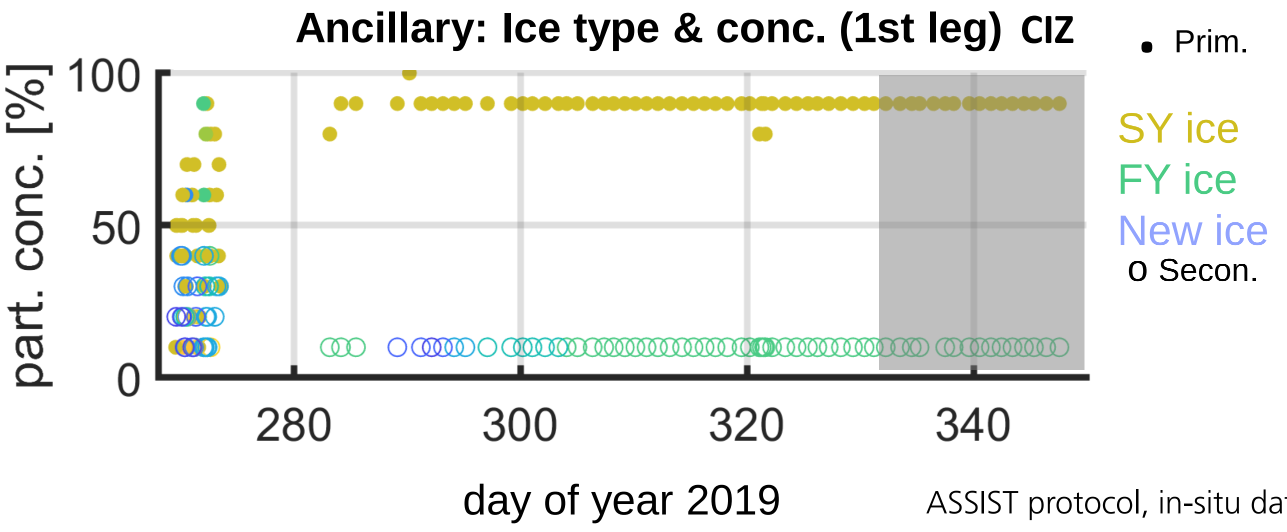
Semmling et al. 2022

Reflectivity Profiles



* smooth; ** rough

- daily-averaged obs. (day color-coded)



ASSIST protocol, in-situ data

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

⇩

anomaly of slope

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

⇩

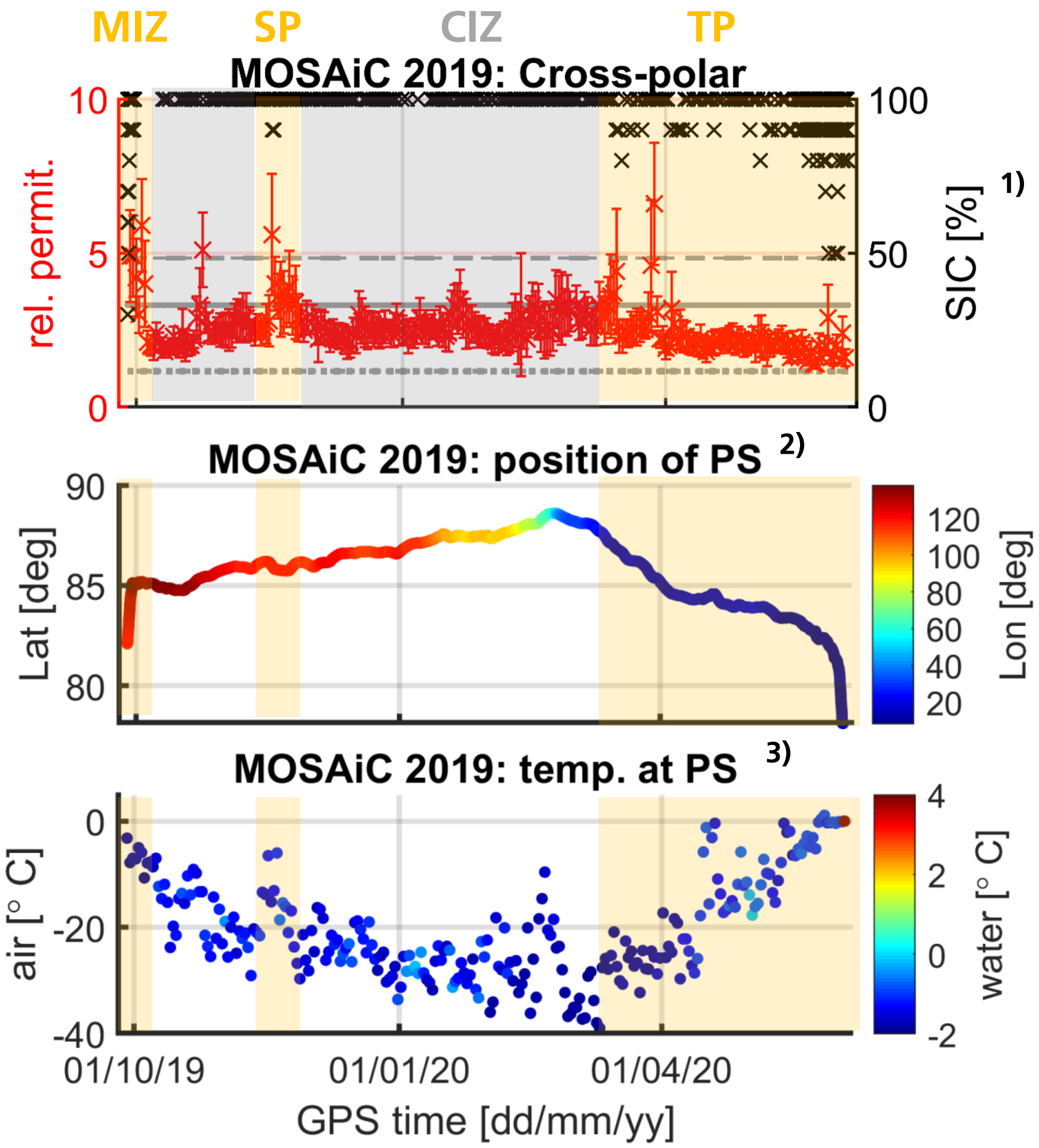
permittivity inversion

Semmling et al. 2022

Inverted Permittivity – First drift

Features & Anomalies

- **Marginal Ice Zone** (**MIZ**)
  ship sailing, SIC < 100%,
  permit. peak > 5
- **Compact Ice Zone** (**CIZ**)
  ship drifting, SIC at 100%,
  permit. baseline < 3
- **Storm Period** (**SP**)
  ship drifting, ice breaking,
  permit. peak > 5
- **Compact Ice Zone** (**CIZ**)
  ship drifting, SIC at 100%,
  permit. baseline < 3
- **Transition Period** (**TP**)
  ship drifting, SIC decreasing,
  however baseline < 3



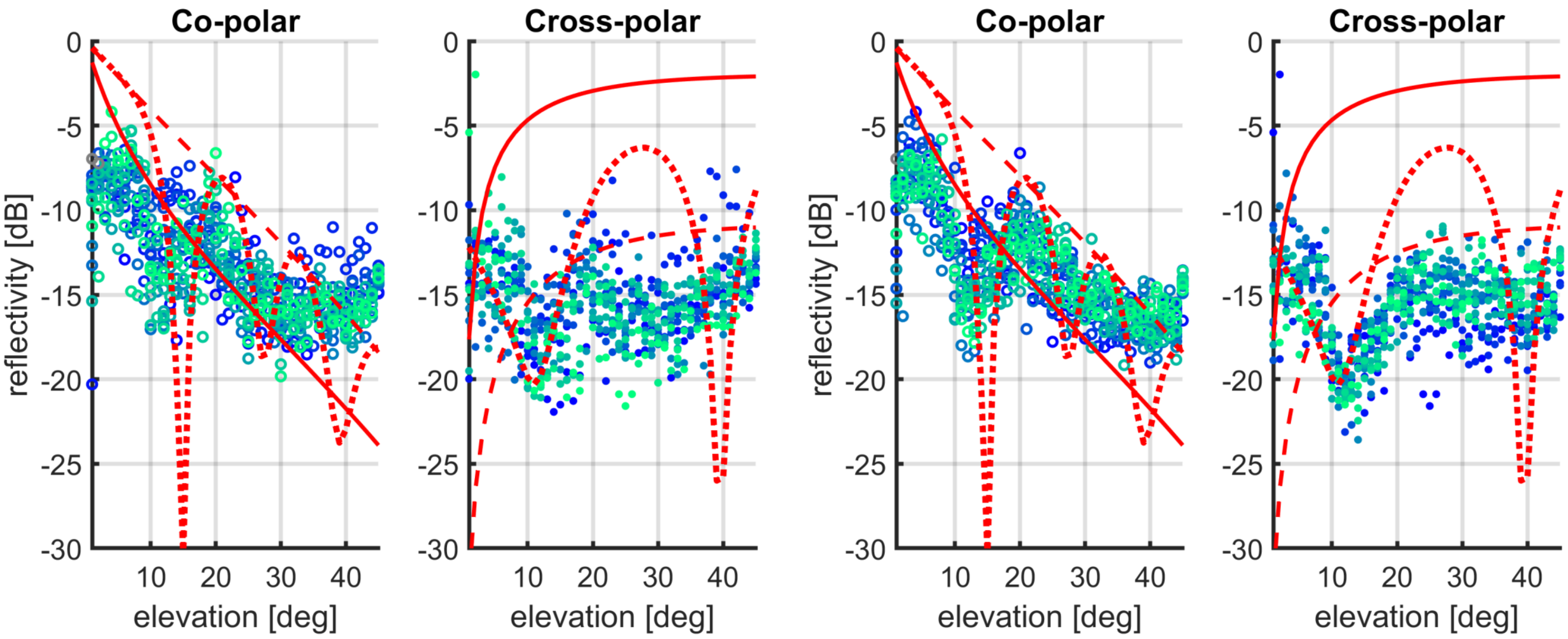
1) ASSIST protocol, in-situ data
2) GNSS based data, GFZ/DLR
3) DSHIP data base, AWI

DLR

More Parameters

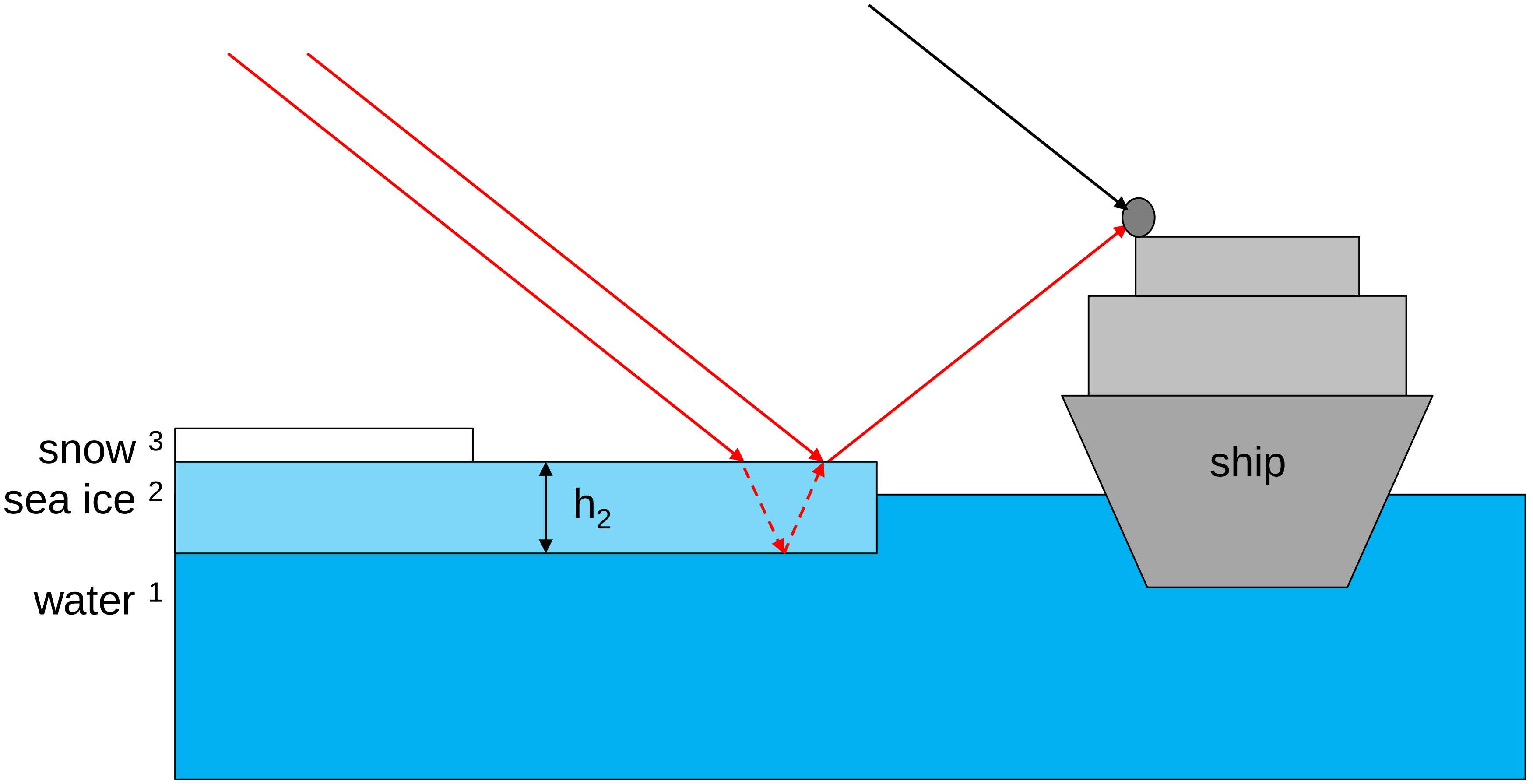
Reflectivity Profiles in Transition Period

1. – 15. April 2020 15. – 30. April 2020



Bulk water — Bulk multiyear ice – – dry-snow layer over multiyear-ice layer ·····

Coherent Reflection and Penetration Model



rel. permittivity: ε_1 = 76.4 + i 48.5 ; ε_2 = 3.31 + i 0.11 ; ε_3 = 1.76 + i 0.00

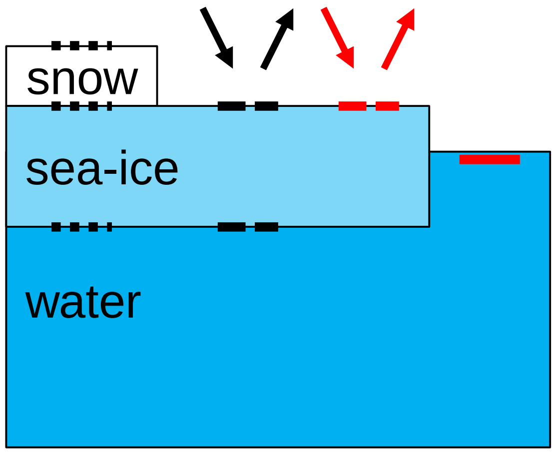
reflectivity:
$P_r(\varepsilon_1, \varepsilon_2, h_2)/P_d$ ⇨ ice type ⇨ thickness (h_2) *

Slab-medium reflection

- signal penetration considered
- applies for low-loss media e.g. sea-ice, snow

* Munoz-Martin et al. 2020

Some Simulations …



Bulk-medium reflection
Slab-medium reflection

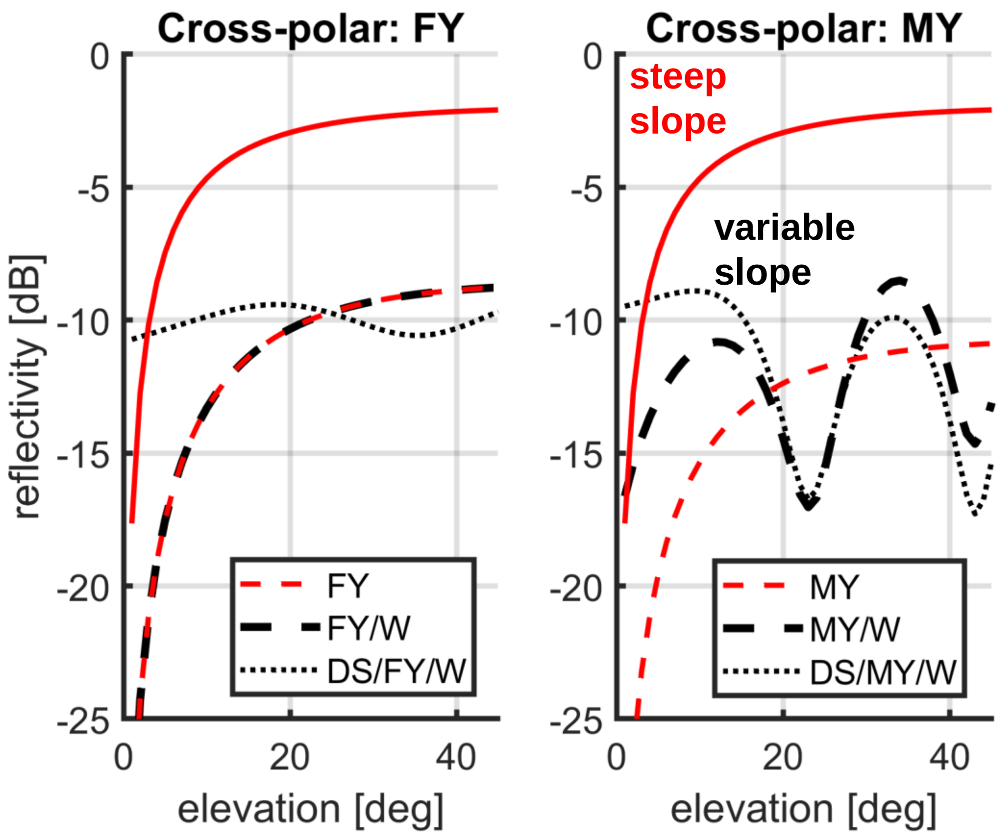
Kaleschke et al. 2010

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

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

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

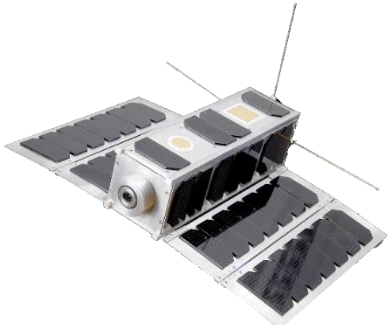
Water (W)
ε = 76.4 + i 48.5
at 2°C
„opaque“



Coherent superposition of **slab reflection** result in **reflectivity fringes** (if top media are transparent).

Semmling et al. 2022

Summary & Outlook



Motivation

- opportunity of GNSS obs. in the Central Arctic with MOSAiC
- derive reflectivity and exploit for ice type characterization

Permittivity Inversion and more Parameters

- one-year data set of direct and reflected signal power (right-, left-handed pol.)
- rel. permit. estimated and related to sea ice concentration (left-handed data)
- anomalies in transition period (April 2020) found
- slab medium feature involving ice and snow

Outlook

- studying ionospheric irregularities with GNSS obs. of MOSAiC
- data fusion for reflectivity retrieval from space ? e.g. PRETTY mission

DLR

Thank you for your attention.

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Werkstatt and IT of GFZ Geodesy Department

Data used here were produced as part of MOSAiC project.

Photo: Sea Ice in Fram Strait, August 2016

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