Evaluation of TELSEM² using observed sea ice emissivities up to 340 GHz in preparation for the Ice Cloud Imager (ICI)

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1. Introduction

- Use of passive MW observations from satellites for atmospheric retrievals over sea ice is limited by uncertain sea ice emissivity.
- TELSEM² provides first-guess land and sea ice emissivity estimate anchored to a satellite climatology up to 90 GHz and extrapolated to sub-mm frequencies [1].
- So far, TELSEM² was not evaluated over sea ice above 200 GHz.
  - Utilize four airborne and one ship-based campaign
  - Derive emissivity directly from observations
  - Investigate various sea ice conditions

2. Field data

- Five campaigns were conducted with varying MW instrumentation.

Campaign	Platform	Radiometers	Viewing angle
ACLOUD	Aircraft[1]	MiRAC-P, MiRAC-A	0°, 25°
AFLUX	Aircraft[1]	MiRAC-P, MiRAC-A	0°, 25°
MOSAiC-ACA	Aircraft[1]	HATPRO, MiRAC-A	0°, 25°
HALO-AC3	Aircraft[12]	HATPRO[1], MiRAC-A[1], HAMP[2]	0°, 25°, 0°
WALSEMA	Ship[3]	MiRAC-P, HATPRO	53°/10-70°

[1]Polar 5 (AWI), [2]HALO (DLR), [3]R/V Polarstern (AWI)

- Anciliary measurements by IR radiometers and dropsondes/radiosondes.

MiRAC-P: 6×183.31 (V-pol), 243, 340 GHz (H-pol) [2]
MiRAC-A: 89 GHz (H-pol) [2]
HATPRO: 7 K-, and 7 V-band frequency channels (H-pol)
HAMP: like HATPRO plus 90, 4×118.75, 7×183.31 GHz

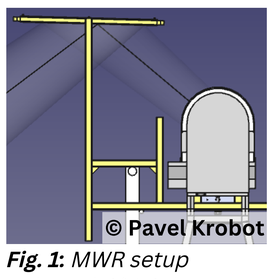

Fig. 1: *MWR setup onboard R/V Polarstern.*

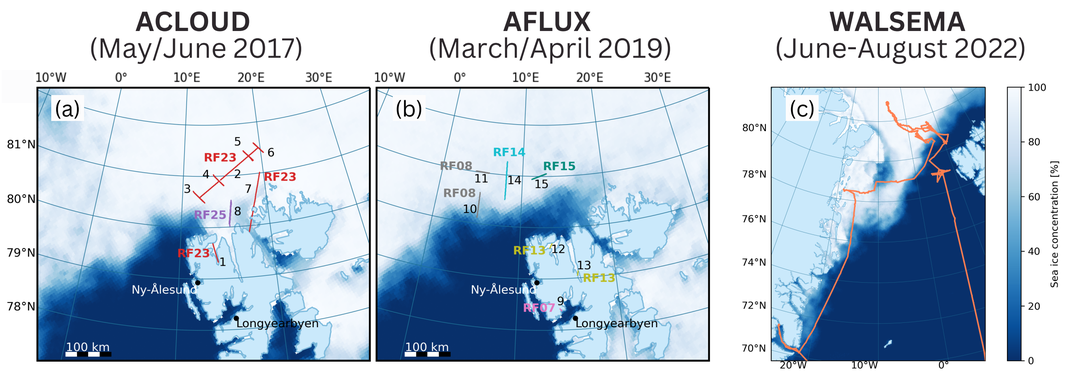

Fig. 2: *Map of clear-sky flight segments used for the sea ice emissivity calculation during the two airborne missions: (a) ACLOUD and (b) AFLUX. (c) Shows the ship track during the recent WALSEMA mission. The sea ice concentration derived from AMSR2 (Univ. of Bremen) is shown as background.*

3. Emissivity calculation

- From observed TB and PAMTRA[3] simulation of atmospheric emission.
- Surface reflection assumed either Lambertian (L) or specular (S).
- Limitation: Similar *Ts* and *Ta*↓ and low transmissivity lead to high uncertainties, especially at 340 GHz in summer (Fig. 3).

$$Tb = e \cdot Ts \cdot t(0,h) + (1-e) \cdot Ta\downarrow \cdot t(0,h) + Ta\uparrow$$

$$\Leftrightarrow e = \frac{Tb - Tb(e=0)}{Tb(e=1) - Tb(e=0)} \quad [4,5]$$

e: sea ice emissivity
Tb: observed brightness temperature [K]
Ts: IR sea ice (skin) temperature [K]
h: flight altitude [m]
Ta: atmospheric emission [K]
t: atmospheric transmissivity

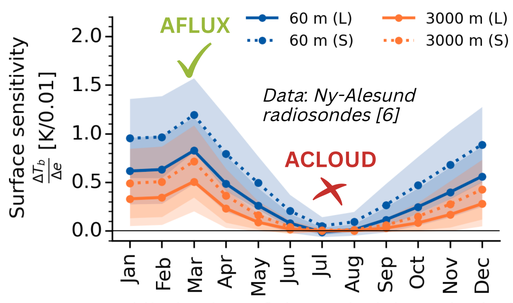

Fig. 3: *Seasonal limitation of the emissivity calculation from observed TB at 340 GHz (Constraint: Ts <= 0°C).*

4. Evaluation of campaign-based sea ice emissivity

- Sea ice emissivities at nadir show high variability depending on the sea ice structure (see upper panel in Fig. 4)
  - Compact ice floes: (*e*=0.7-0.8), snow-free leads: (*e*=0.8-0.9)
- Spectral emissivity variation above 183 GHz is limited as assumed in extrapolation of TELSEM².

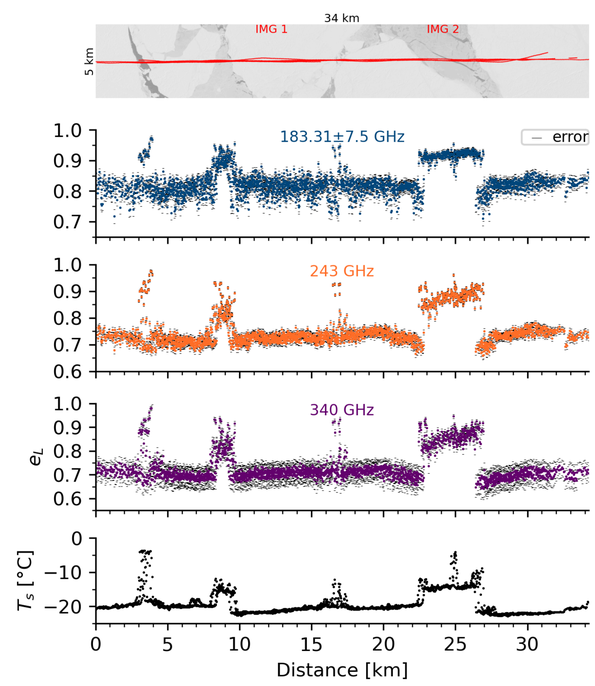

Fig. 4: *Emissivity variation over two sea ice types in the marginal ice zone between 183 and 340 GHz. (Leg 15)*

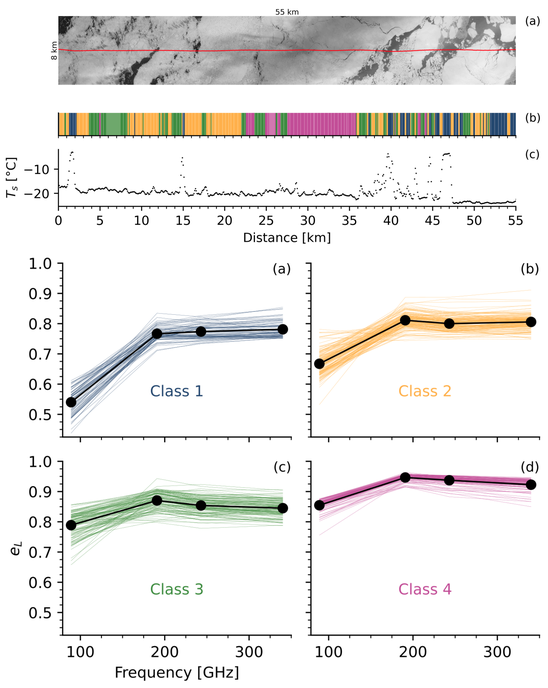

Fig. 5: *Spatial variation of emissivity spectra classified using K-Means between 89 and 340 GHz. (Leg 10)*

5. Difference between TELSEM² and observations

- Good agreement during ACLOUD under specular reflection, except for 89 GHz, but high uncertainty at 340 GHz (Fig. 3).
- Consistently higher TELSEM² emissivities during AFLUX, where airborne estimates are accurate up to 340 GHz
- Frequency extrapolation does not explain the observed difference

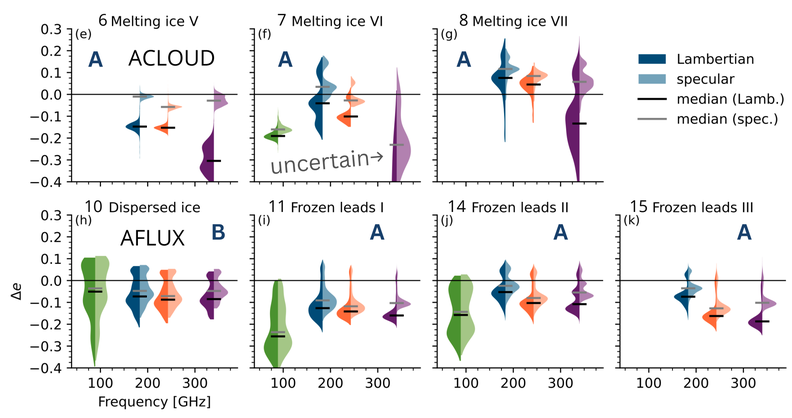

Fig. 6: *Distributions of the difference between airborne emissivities and TELSEM² (e(MiRAC)-(TELSEM²)) along the flight track for all legs north of Svalbard. The number indicates the location of the flight leg in Fig. 2.*

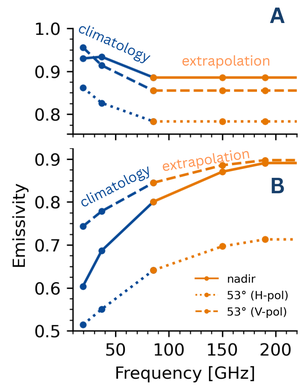

Fig.7: Spectral emissivity extrapolation of TELSEM² for regions with mostly multi-year ice (top) and the marginal ice zone (bottom).

6. Conclusions and outlook

- Airborne-derived emissivities show clear dependence on sea ice properties such as snow cover, causing high spatial emissivity variations.
- Assumption of constant emissivities above 183 GHz is reasonable.
- Consistent offsets between TELSEM² and the airborne estimates occur, which require further investigation.
- The angular emissivity variation might be one explanation, which will be studied from shipborne observations.
- Co-locations with MW satellite instruments will be investigated.

References:

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