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

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The use of Ice Cloud Imager (ICI) observations for atmospheric applications in polar regions requires robust sea ice emissivity estimates. Whereas the atmosphere is nearly opaque above 200 GHz in lower latitudes, the surface contributes significantly to satellite observations up to 480 GHz under cold and dry conditions. Due to the challenging physical modelling of the sea ice radiative transfer and the limitation of current spaceborne capabilities in the polar orbit to frequencies below 200 GHz, little is known about the spectral sea ice emissivity variation at ICI frequencies.

The Tool to Estimate Land Surface Emissivity from Microwave to Submillimeter Waves (TELSEM²) provides a first-guess emissivity estimate for land and sea ice surfaces and is widely used in fast radiative transfer models. TELSEM² is anchored to an SSM/I climatology and was extrapolated up to 700 GHz in preparation for ICI using satellite observations above 100 GHz. We use sea ice emissivities calculated from observations with the passive channel of the Microwave Radar/radiometer for Arctic Clouds (MiRAC) cloud radar MiRAC-A (89H GHz) at an inclination of 25° and the nadir-viewing radiometer MiRAC-P (six double-side bands around 183.31V, 243H, 340H GHz) combined with a KT-19 infrared radiometer on-board the Polar 5 aircraft during the ACLOUD (May/June 2017) and AFLUX (March/April 2019) campaigns to validate TELSEM². Contributions by atmospheric gases are taken into account using the Passive and Active Microwave radiative TRAnsfer (PAMTRA) model with ancillary information on the thermodynamic structure of the atmosphere. In addition, data measured by the radiometers Humidity And Temperature PROfiler (HATPRO; seven K-band channels with V-pol, seven V-band channels with H-pol) and MiRAC-P deployed on the R/V Polarstern from June to August 2022 will provide information on the angular variation of the sea ice emissivity up to sub-mm waves under ICI geometries.

A comparison of the emissivity gradients between different window channels observed from the aircraft and TELSEM² shows a good agreement above 183 GHz, whereas the positive emissivity gradient from 89 to 183 GHz which is also found during past airborne campaigns is not captured by TELSEM². Additionally, a consistent bias is found between airborne nadir emissivities and TELSEM² in spring, which may be explained by the angular extrapolation from SSM/I geometries to nadir within TELSEM² or seasonal effects during the campaign period.