Sea Ice Thickness Retrieval using L-band radiometry - a brief review

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JPL CCS workshop **Science of 10-km L-band Radiometry**, October 10-12, 2023

Low-frequency microwave radiometry for sea ice

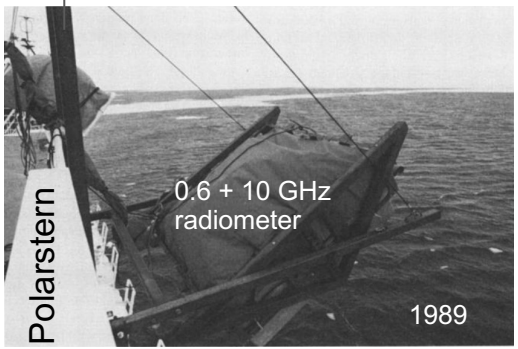
←Hallikainen et al. (1976)

ESA SMOS sea ice studies

ESA SMOSIce

MOSAiC
ESA SMOS ESL

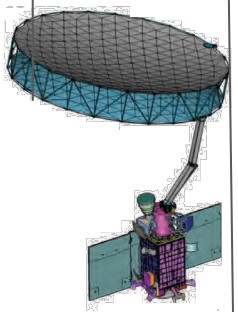
2007→ 2010→ 2011 2015→ 2019/20



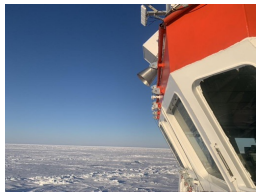
Menashi, J. D., St. Germain, K. M., Swift, C. T., Comiso, J. C., and Lohanick, A. W. (1993), Low-frequency passive-microwave observations of sea ice in the Weddell Sea, J. Geophys. Res.

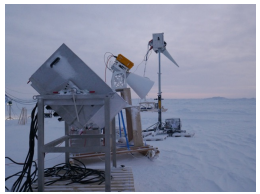
ESA SMOS

NASA Aquarius

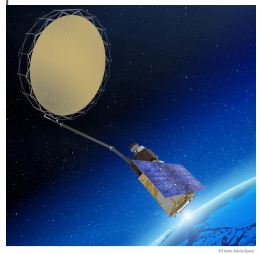


NASA SMAP



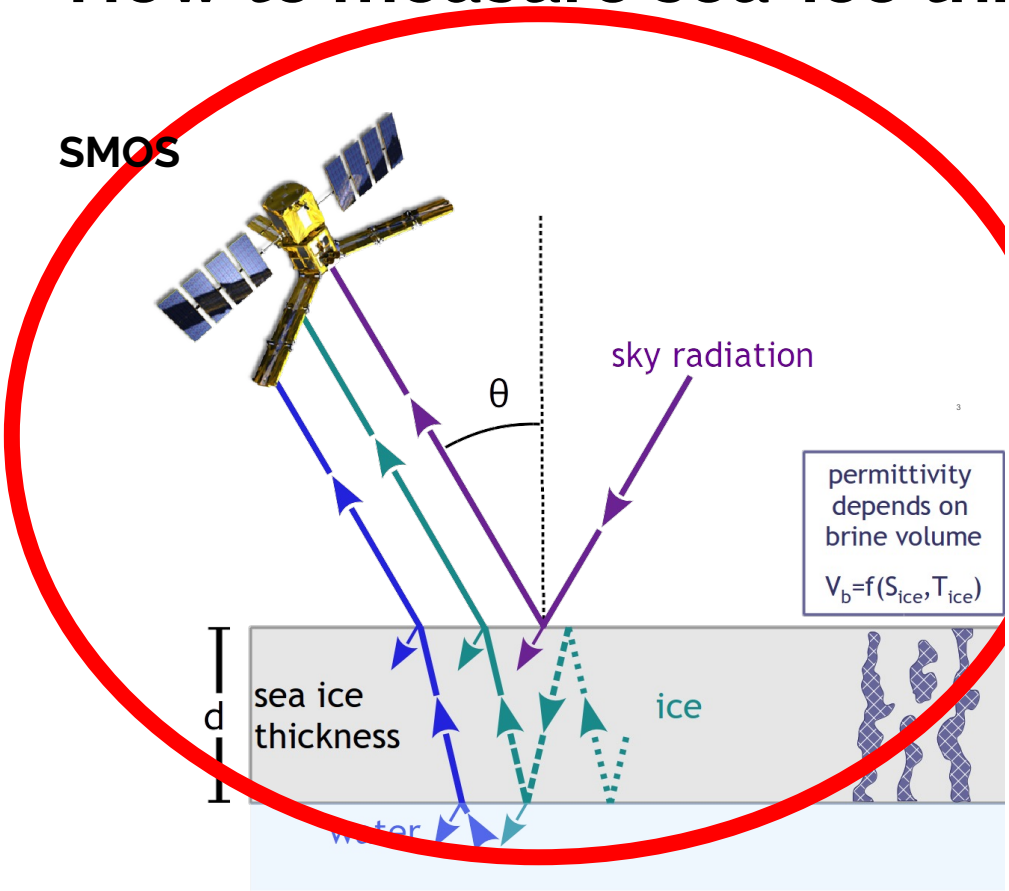


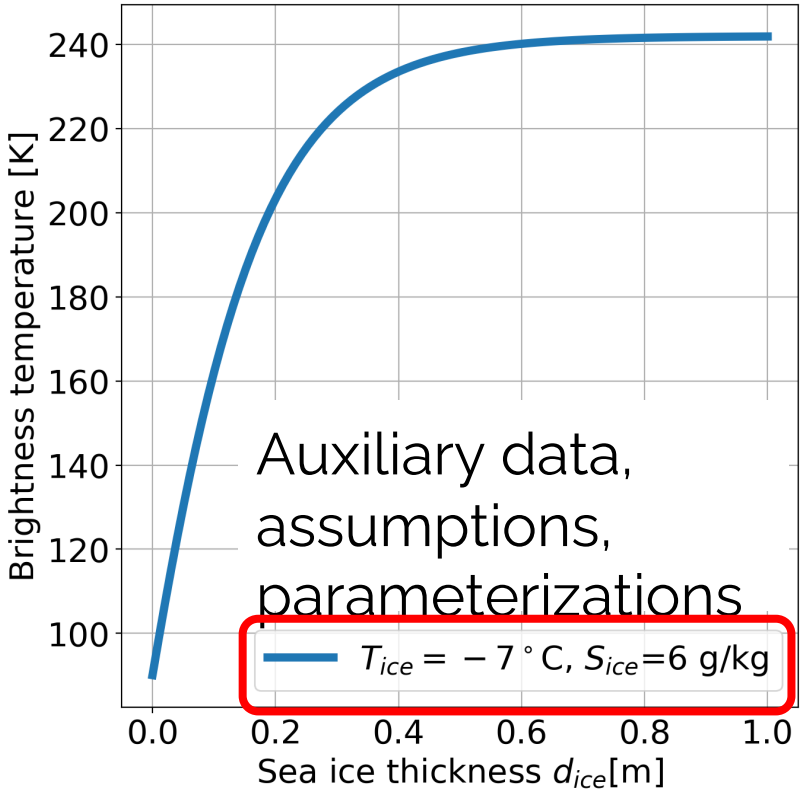
SMOS HR/next
CryoRad
PolarRad
?



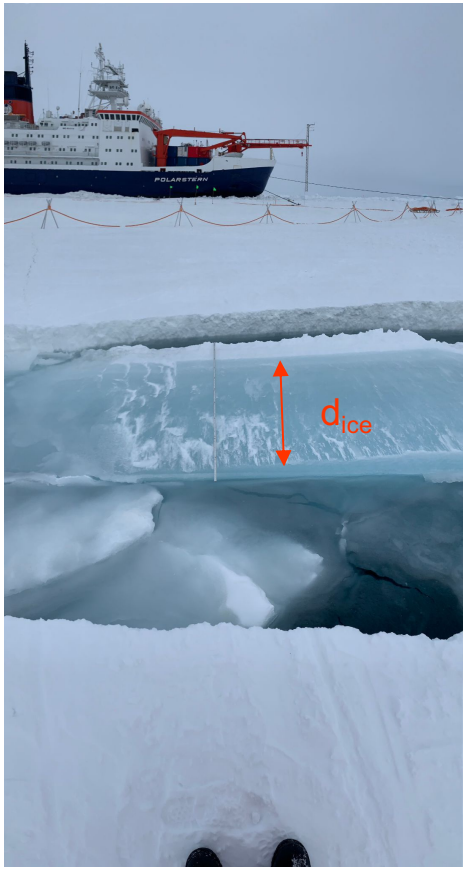
Copernicus
Imaging
Microwave
Radiometer
(CIMR)
!

How to measure sea-ice thickness

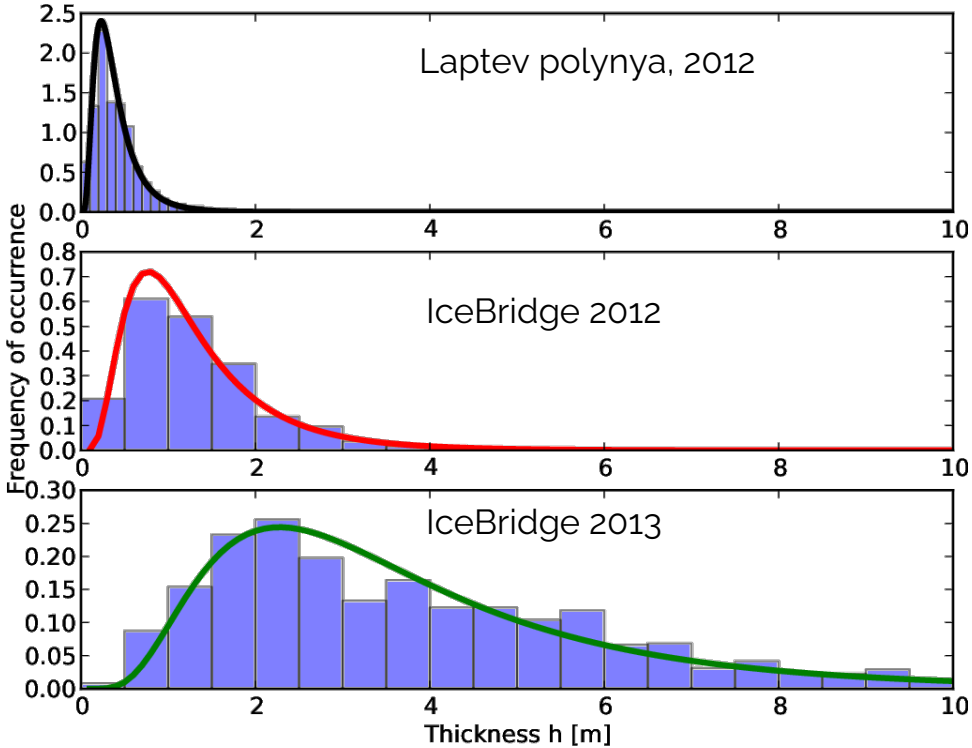


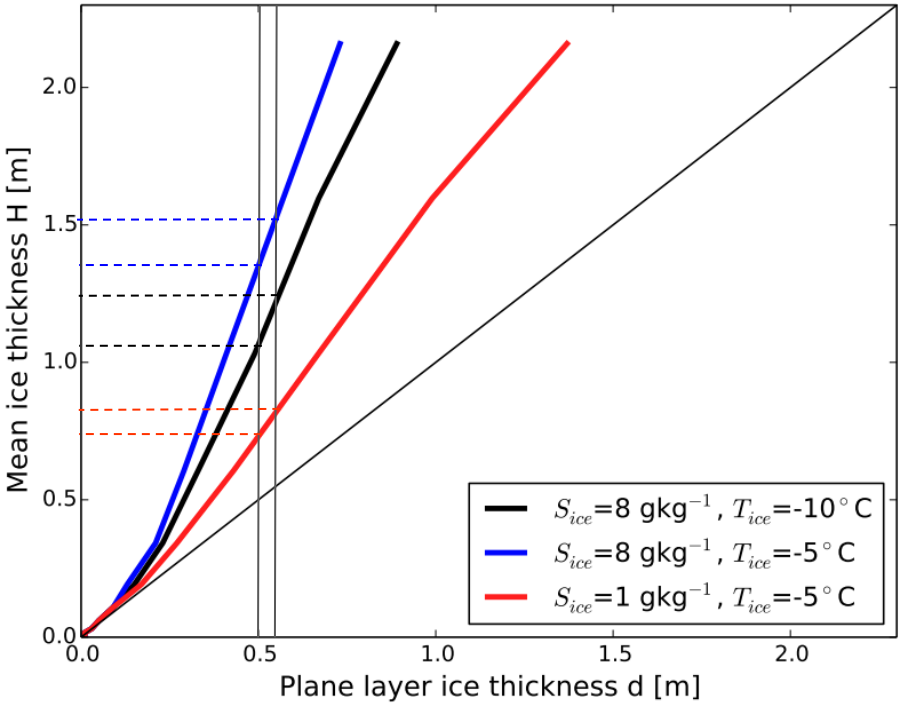


Local plane layer vs. large-scale mean thickness



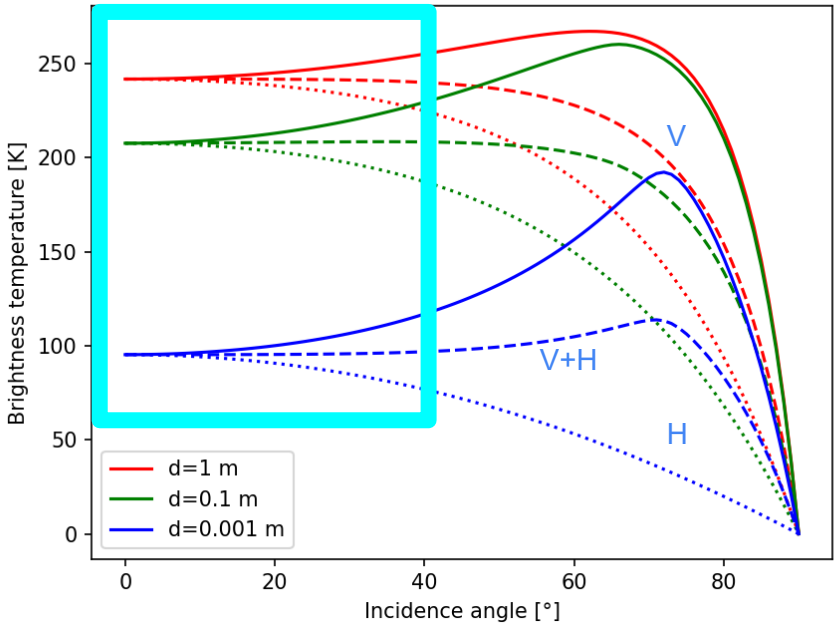
Statistical thickness distribution: log-normal parameterization

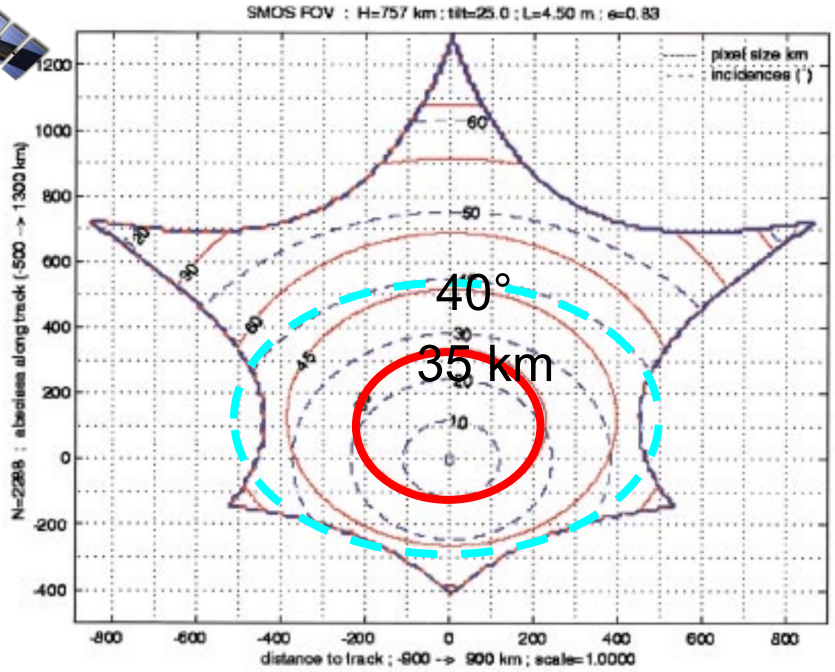




Tian-Kunze, X., Kaleschke, L., Maaß, N., Mäkynen, M., Serra, N., Drusch, M., and Krumpen, T.: SMOS-derived thin sea ice thickness: algorithm baseline, product specifications and initial verification, The Cryosphere, 8, 997-1018, 2014.

SMOS angular viewing angle and resolution



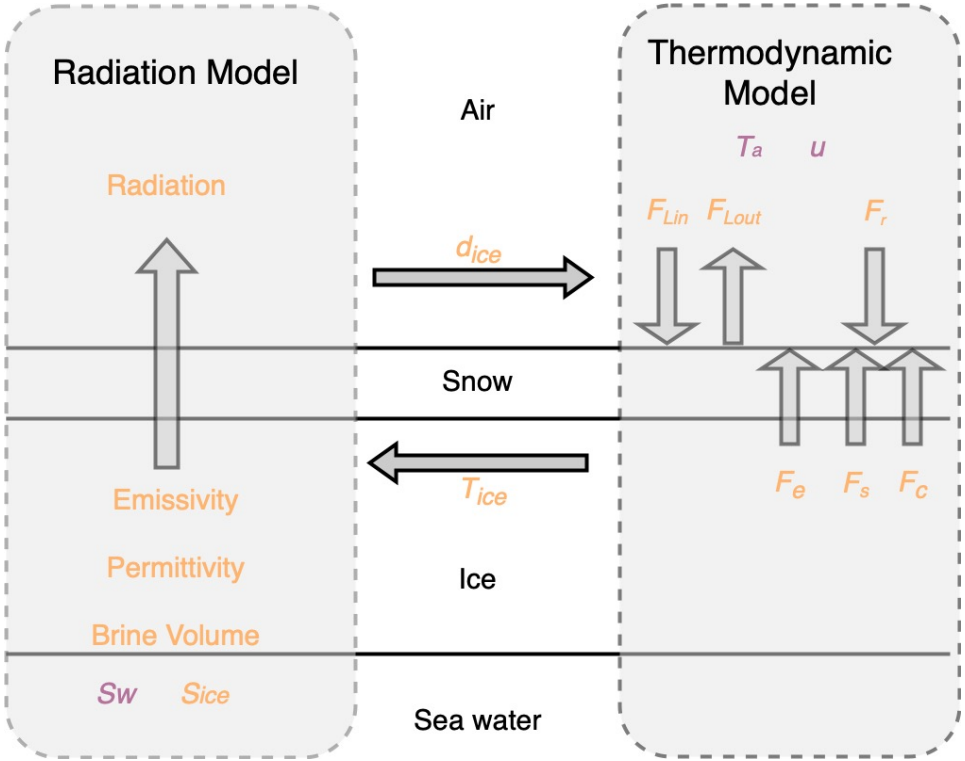


Design choice for sea ice thickness retrieval

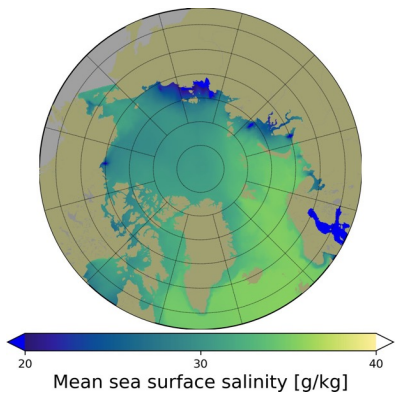
- average intensity over incidence angle range 0˚-40˚
- >100 single measurements / grid point / day
- spatial resolution is about 35 km on 12.5 km grid

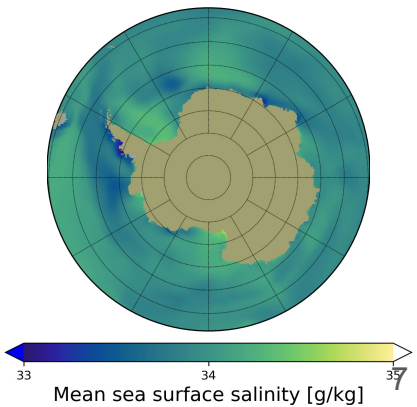
equi resolution (red solid lines)
equi incidence angle (dashed lines)
Kerr et al. 2001

Retrieval concept

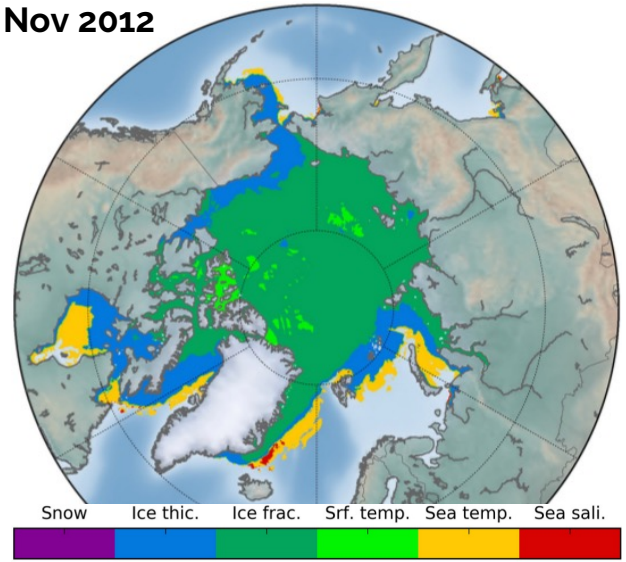


- Based on physical models
- No tuning / tie points
- Improved physical parameterizations lead in general to better retrieval results
- Radiation model can be used for assimilation in ocean-ice models as a “forward operator”
- Auxiliary data
  - Thermodynamic state from atmospheric reanalysis (JRA55)
  - Parent sea water salinity from ocean reanalysis (GECCO2)





How can we compare satellite observations and models better



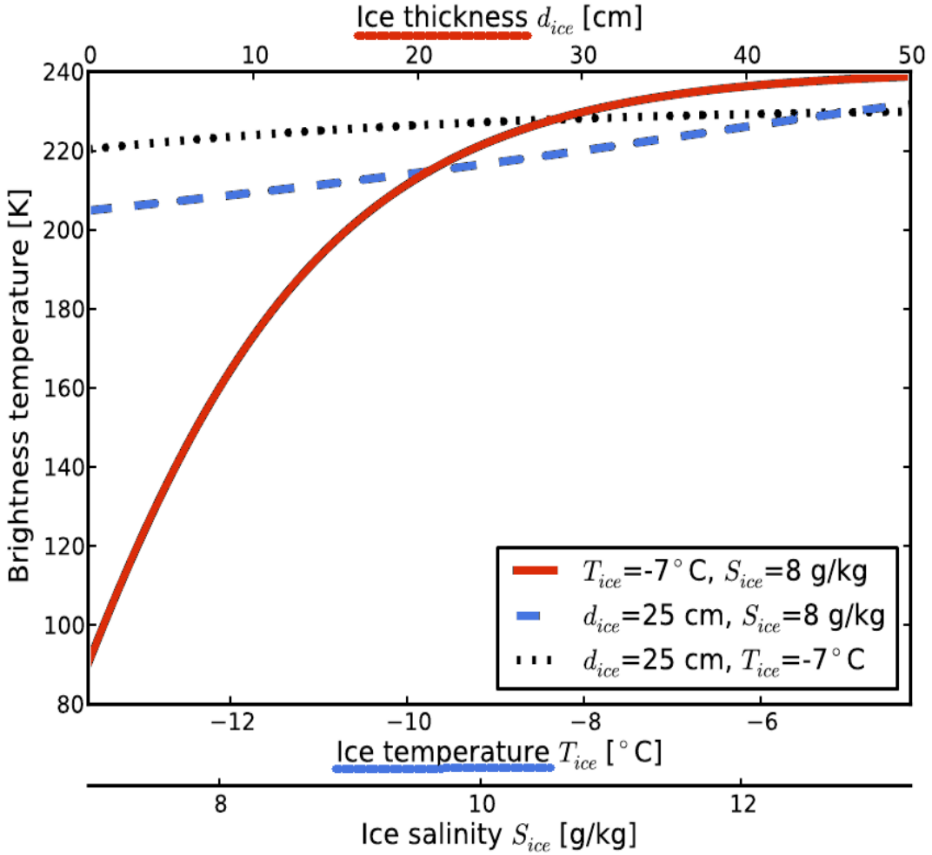
Most influential parameters on brightness temperature changes based on ORAP5 and Kaleschke et al. (2010).

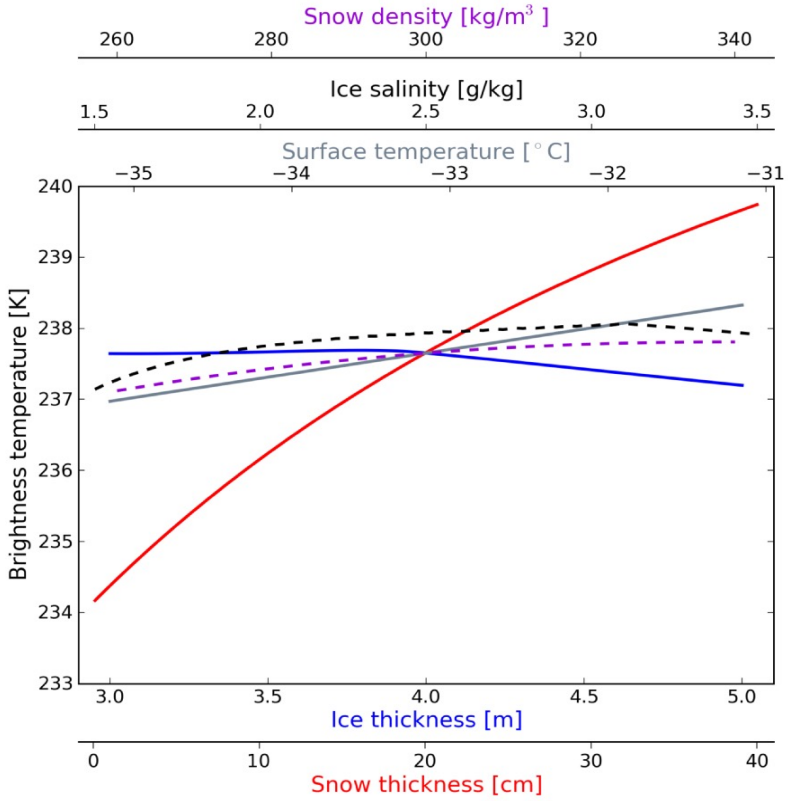
Satellite simulator / observation operator

- Brightness temperatures from ocean-ice model and radiative transfer model
- Allows consistent comparison of observations and models
- Sensitivity of the brightness temperatures with respect to geophysical model parameters
- Path to assimilating brightness temperatures in coupled ocean-ice models
- The spatial resolution of the model and observations should match

Richter, F., Drusch, M., Kaleschke, L., et al..: Arctic sea ice signatures: L-Band brightness temperature sensitivity comparison using two radiation transfer models. The Cryosphere, 12, 1–13, 2018

Model sensitivity to key sea ice parameters





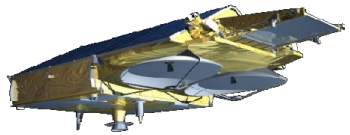
Kaleschke et al., GRL 2012

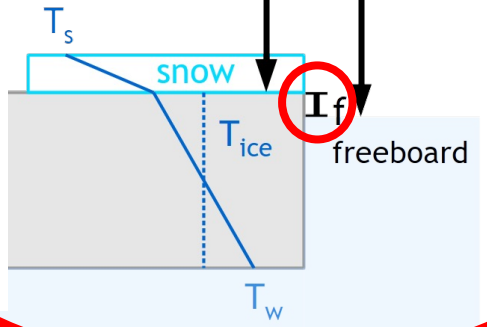
Sea-ice thickness from SMOS and CryoSat2

Sea ice thickness from freeboard f

$$\frac{f\rho_w + d_s(\rho_s - \rho_w)}{\rho_w - \rho_i}$$

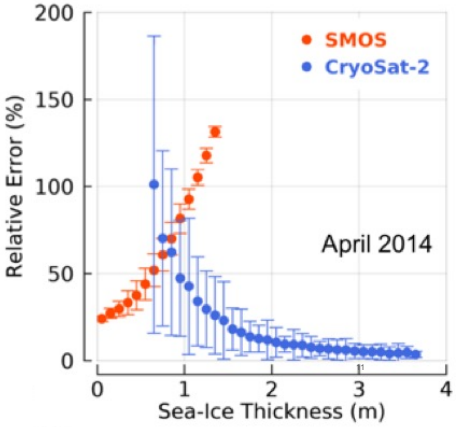
- snow thickness d_s
- snow density ρ_s
- ice density ρ_i
- water density ρ_w





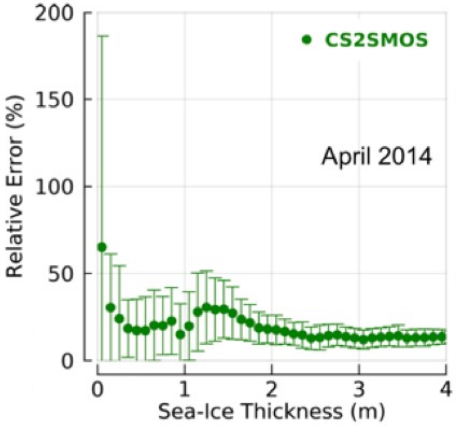
Fusion of SMOS and CryoSat-2 reduces uncertainties

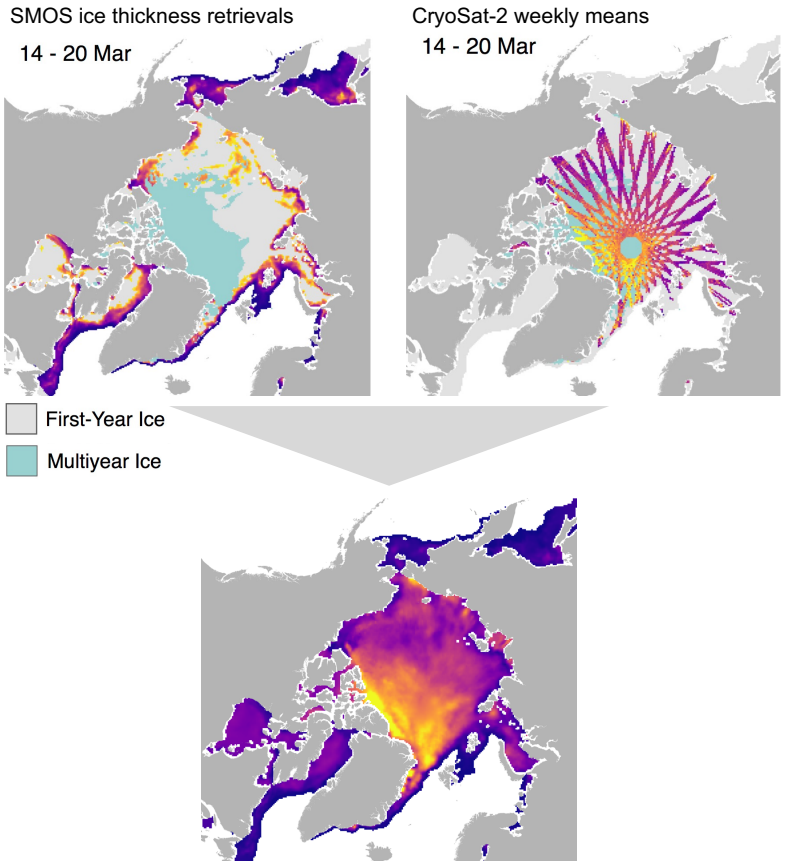
Taking advantage of the complementary thickness retrievals, derived from the CS2 altimeter and the SMOS radiometer

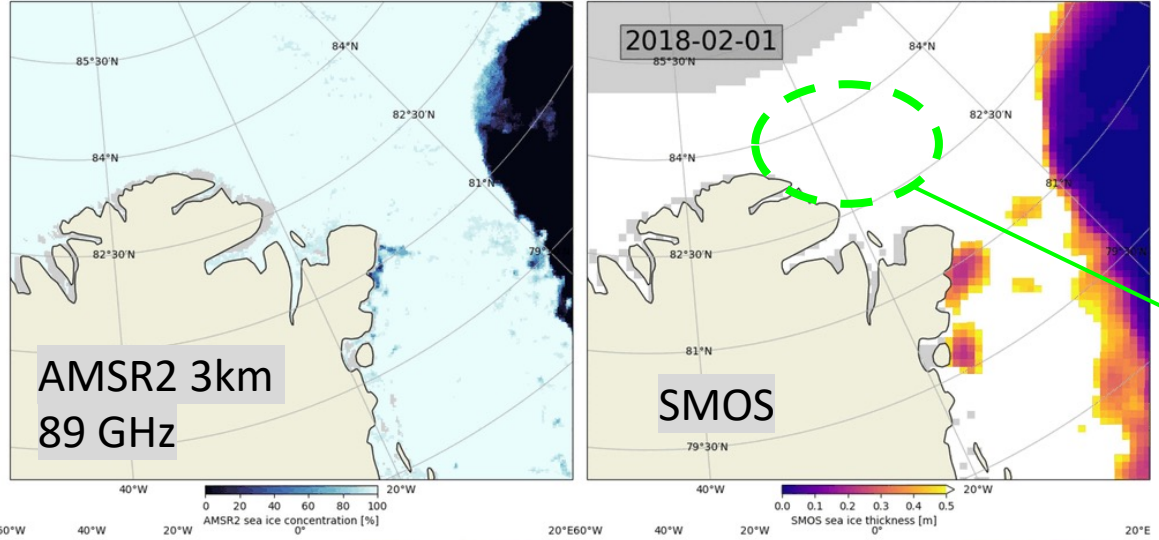


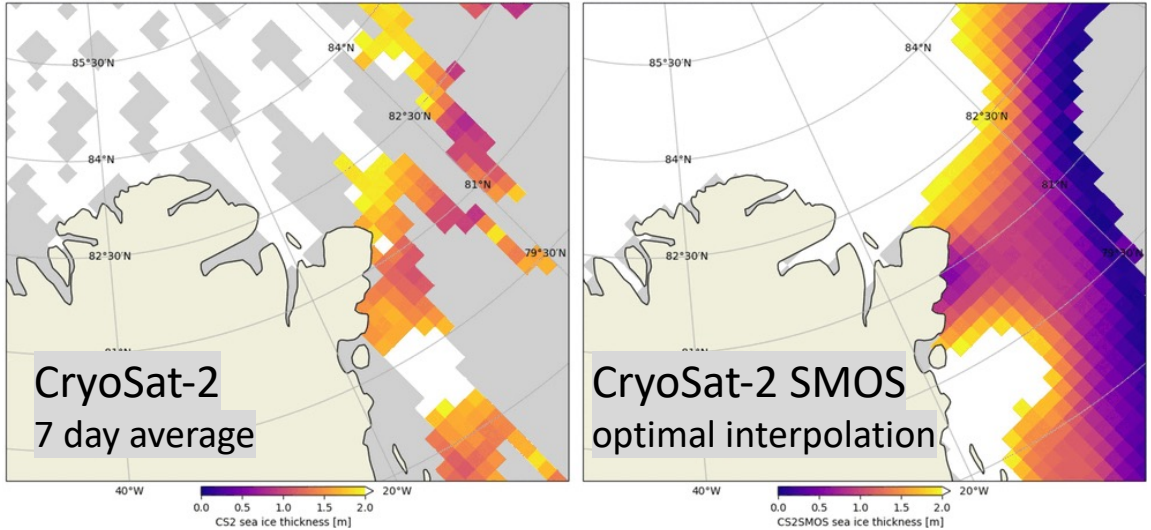
Weekly Arctic-wide sea-ice thickness fields with reduced relative uncertainties

Daily updates (7 day observation period)







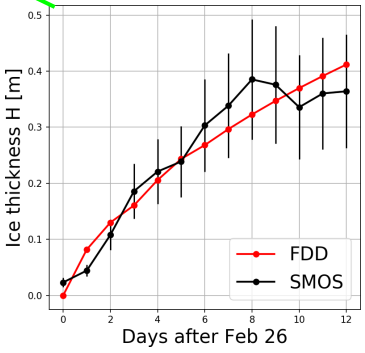


The New York Times

'There Is No Ice'

Feb. 27, 2018

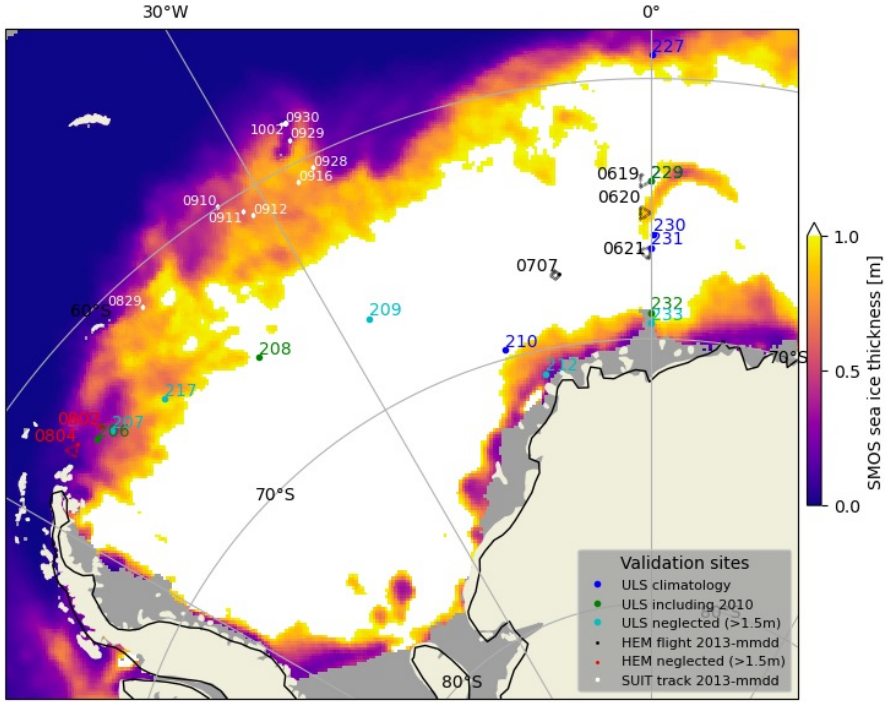
Lars Kaleschke, a German physicist, explained: "There is open water north of Greenland where the thickest sea ice of the Arctic used to be. It is not refreezing quickly because air temperatures are above" freezing.



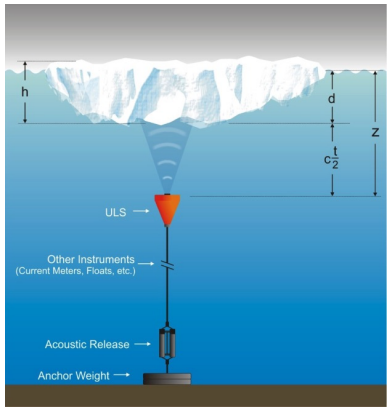
An unprecedented polynya developed north of Greenland in February 2018 as a result of an anomalous warm southerly flow. The sea ice thickness derived from SMOS agrees well with a freezing degree day (FDD) model.

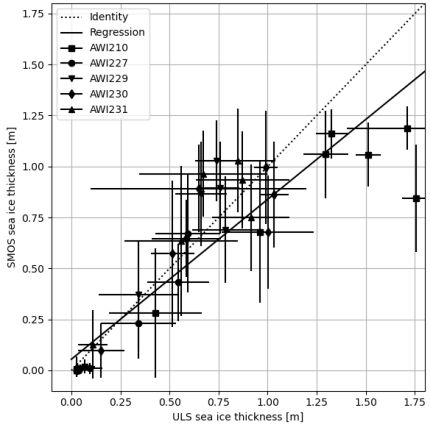
Good spatial resolution together with good temporal sampling are important to observe polynyas

SMOS Antarctic Sea Ice Thickness Validation

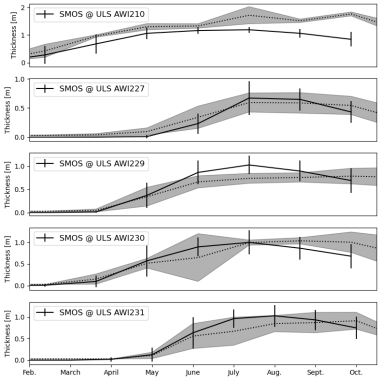


August 2010



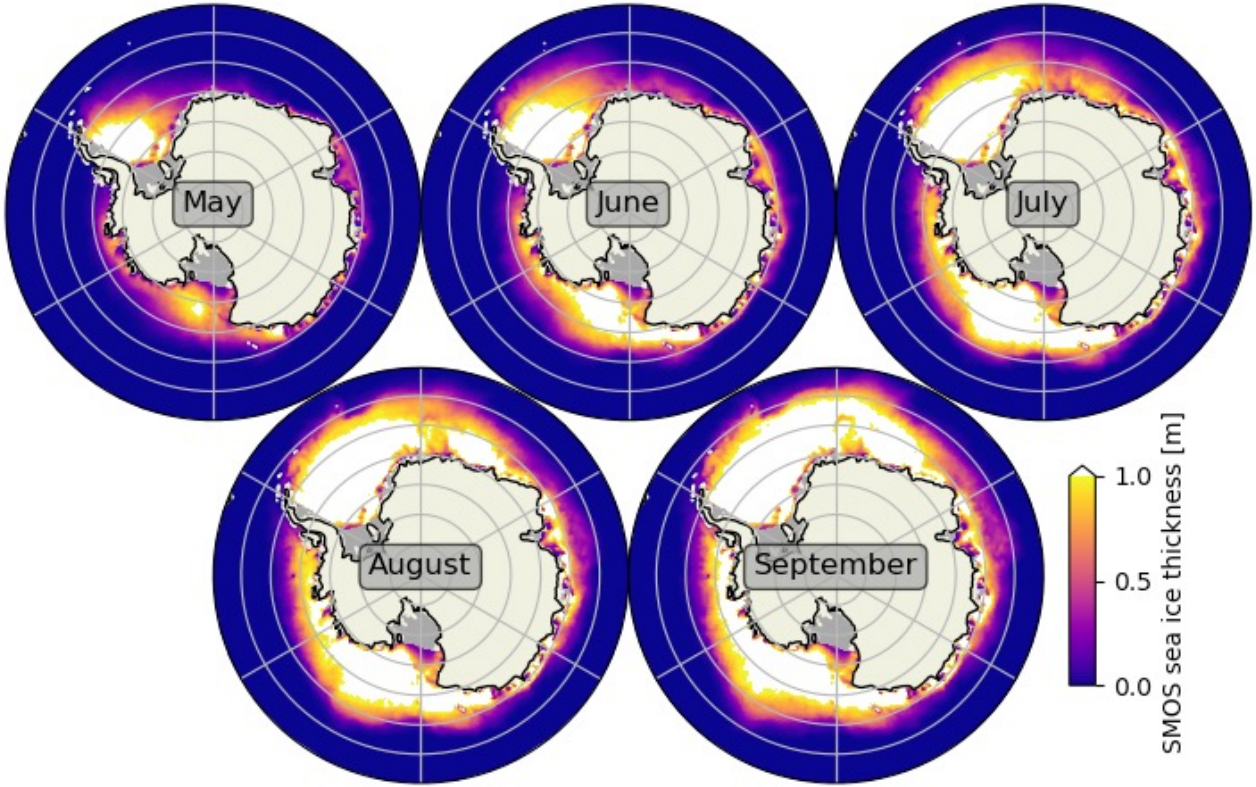


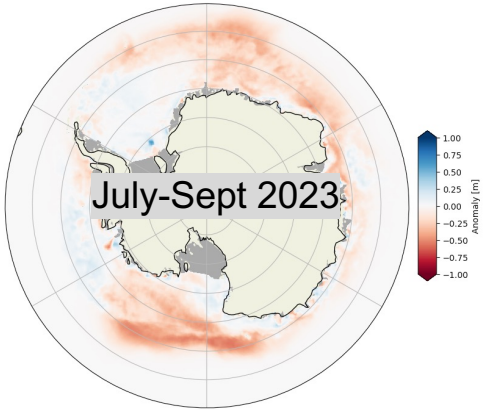
- Retrieval method with only modified auxiliary data for the Antarctic
- Validation measurements are particularly rare in Antarctica, especially during the winter season
- The overall validity for thin sea-ice up to a thickness of about 1 m has been demonstrated

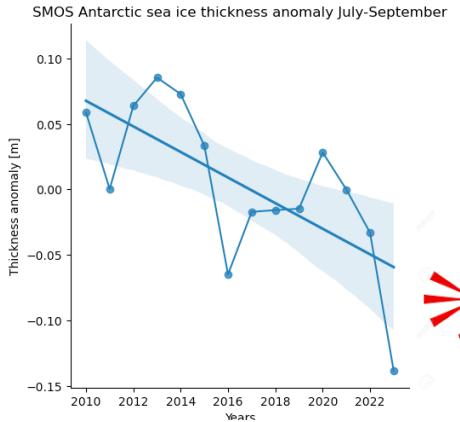


Kaleschke, L., Tian-Kunze, X., Hendricks, S., and Ricker, R.: SMOS-derived Antarctic thin sea-ice thickness: data description and validation in the Weddell Sea, Earth Syst. Sci. Data Discuss. [preprint], https://doi.org/10.5194/essd-2023-326, in review, 2023.

SMOS Antarctic Sea Ice Thickness







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Summary

- Sea ice thickness is an essential climate parameter and important for weather+ocean-ice forecasts and polar maritime applications
- L-band radiometry together with altimetry is used to measure the sea ice thickness with reduced uncertainty and better data coverage
- ESA/AWI SMOS L3 and combined CryoSat2-SMOS L4 sea ice thickness products show an increasing scientific and operational impact
- Better spatial L-band resolution would strongly reduce uncertainties and cross scientific boundaries for many applications, e.g. observation of important mesoscale and coastal ocean-ice-atmosphere exchange processes