# Thin Sea Ice Thickness From Combined SMOS and SMAP L-band Satellite Microwave Radiometer Observations

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## Introduction

- Sea ice changes the albedo of ocean surface, the energy transfer between the atmosphere and ocean and provides a solid surface for snow to deposit
- Sea Ice Thickness (SIT) up to 0.5 m first was retrieved from Soil Moisture Ocean Salinity (SMOS, launched in 2009) satellite observations [1]
- Algorithm is transferred to Soil Moisture Active Passive (SMAP, launched 2015) observations [3]
- Both satellites have a near-polar sun-synchronous orbit and carry a L-band microwave radiometers at 1.4 GHz, SMOS has a large incidence angle range (0-65°) while SMAP is conically scanning at 40°

## Summary and Conclusions

- Using fit functions for SMOS Tbs reduces data removal due to RFI filtering and the resulting SIT has a 2.2 cm RMSD relative to the daily mean method
- RMSD of calibrated SMAP data and SMOS 40° fit Tbs is less than <3 K making SMAP a good replacement for SMOS in case of malfunction
- Merged SMAP and SMOS Tbs result in consistent and stable SIT maps with less gaps [2]

## Thin Sea Ice Thickness retrieval

- Input: (i) SMOS L1C daily mean Top Of the Atmosphere (TOA) brightness temperature (Tbs); (ii) 40-50° incidence angle range; (iii) three training areas in Kara and Barents Sea from 1 October to 26 December 2010 used for retrieval training; (iv) RFI filtering is done by eliminating complete snapshots containing Tbs over 300 K
- Thermodynamic sea ice thickness using Cumulative Freezing Degree Days (CFDD) data is found correlated to intensity and anticorrelated to polarization difference (Fig. 1)

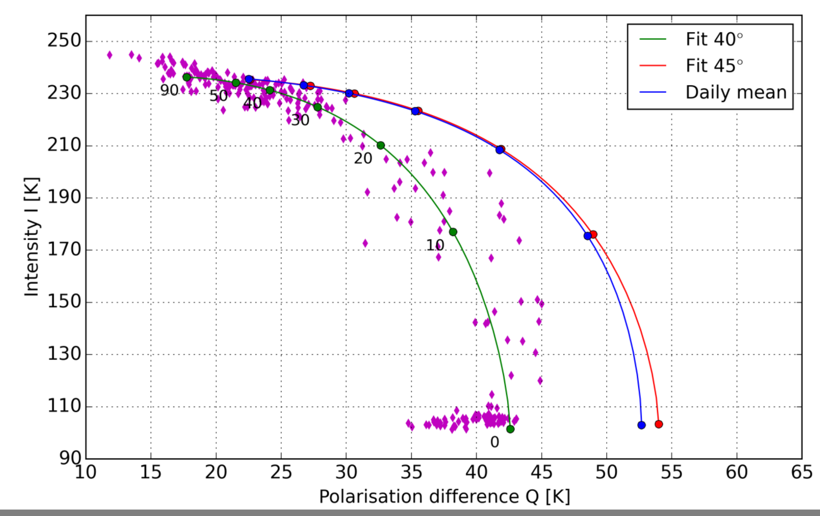



Fig. 1 – SIT retrieval curves in dependence of intensity and polarization difference with two methods: daily mean Tbs (blue) and Tbs obtained from fit curves at fixed incidence angle 40° (green) and 45° (red). Dots represent the data used for 40° retrieval curve generation. Numbers on the curve represent the thickness in cm

## SMOS Brightness temperatures fit

- For each grid point the number of data points and the covered incidence angle range is highly variable, and can result in shifting averaged incidence angle observation from expected value
- The fit function [3] using the dependence of brightness temperature on incidence angle is applied for each polarization for each grid point and is done iteratively with a maximum of five iterations. Data with the highest absolute difference from the fit are removed

$$Tb_h(\theta) = a_h \cdot \theta^2 + \frac{C}{2} \cdot [b_h \cdot sin^2(\theta) + cos^2(\theta)]$$

$$Tb_v(\theta) = a_v \cdot \theta^2 + \frac{C}{2} \cdot [b_v \cdot sin^2(d_v \cdot \theta) + cos^2(d_v \cdot \theta)]$$

- For each step $C$ is determined by averaging the sum of polarizations for each observation, $a_h$, $b_h$, $a_v$, $b_v$ *and* $d_v$ are determined by least square procedure
- Fig. 4 shows a slight positive bias of daily means compared to the fit function

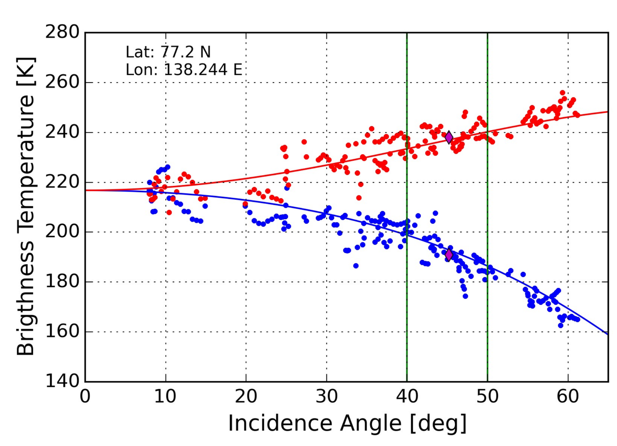
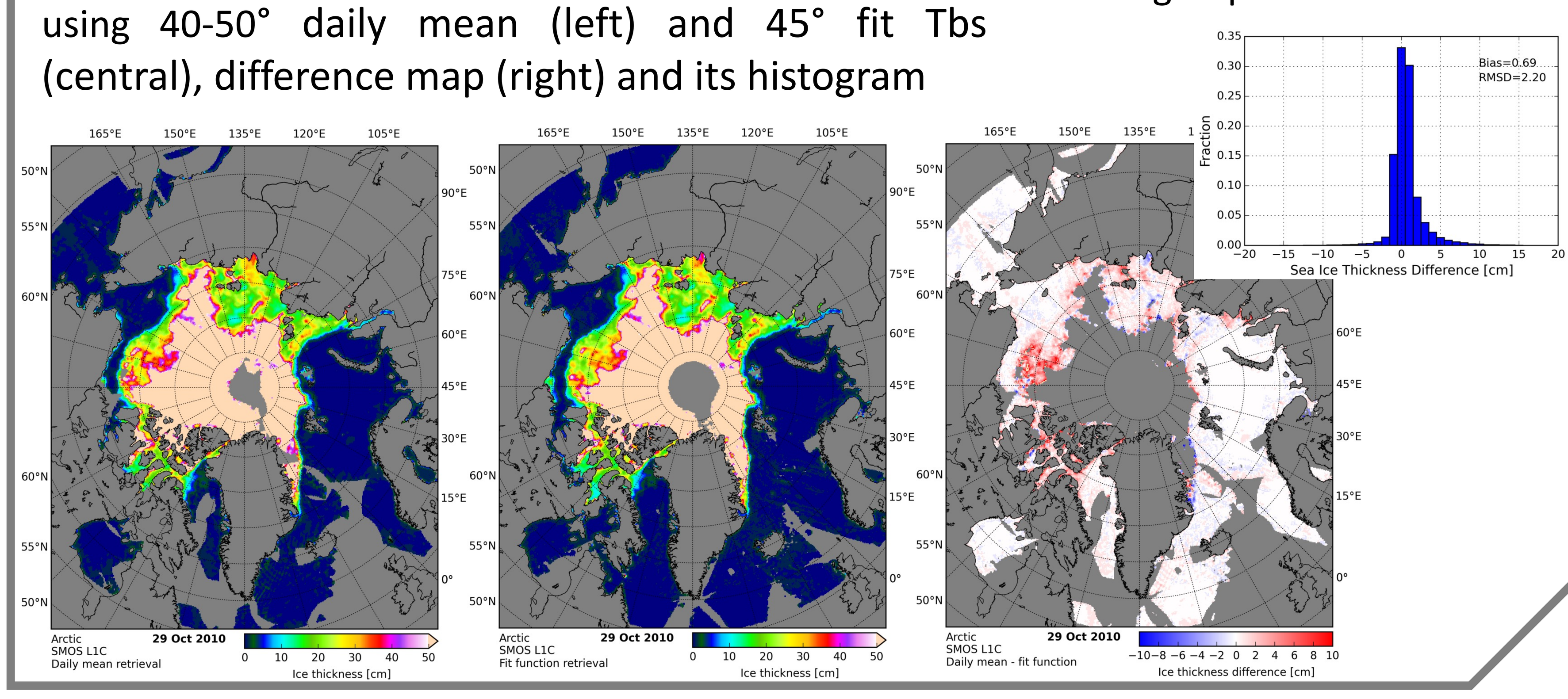



Fig. 3 – Tbh (blue) and Tbv (red) dependence on incidence angle, their fit curves, and 40-50° mean (diamonds) for a sea ice grid point

Fig. 4 – Sea ice thickness retrieved on 29 Oct. 2010 using 40-50° daily mean (left) and 45° fit Tbs (central), difference map (right) and its histogram




## SMAP calibration

- Linear regression of SMAP TOA Tbh and Tbv (Fig. 2) for the period 1 October to 31 December 2015 used to bring them to equivalent SMOS 40° Tbs
- Both show very good agreement (R > 0.99; RMSD < 3 K)

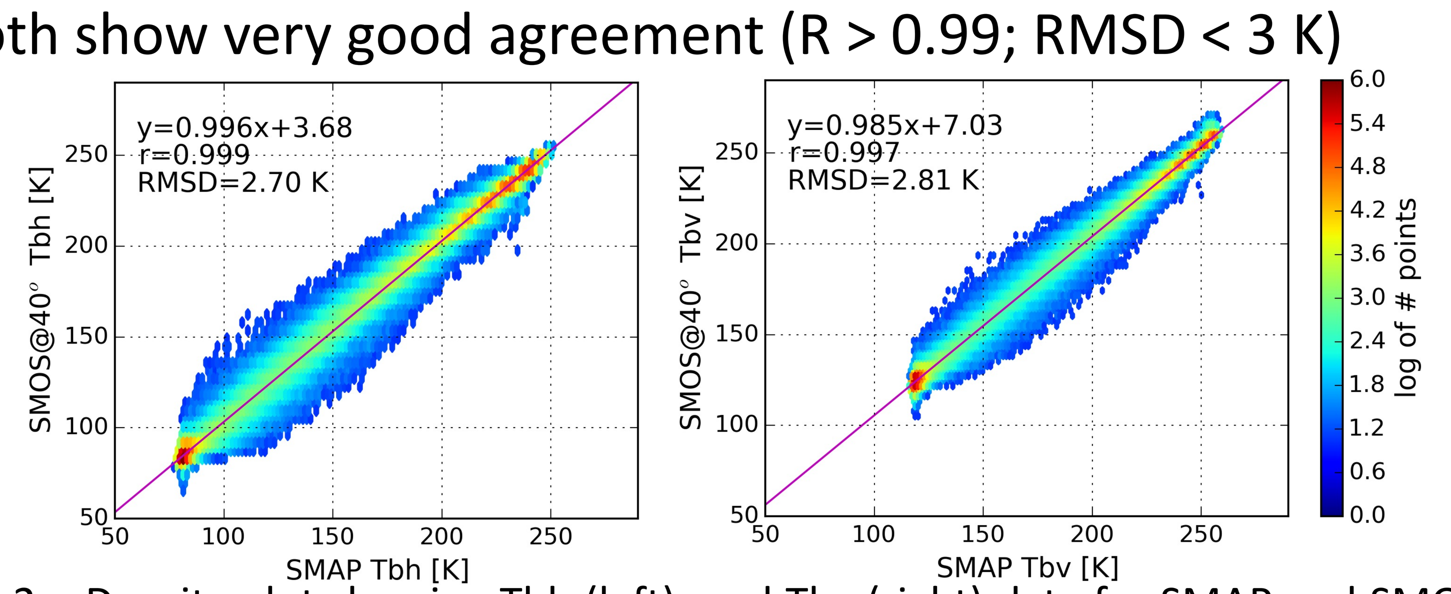



Fig. 2 – Density plot showing Tbh (left) and Tbv (right) data for SMAP and SMOS for the period 1 October to 31 December 2015. Magenta lines represent the linear regression between the two datasets

## SMOS/SMAP merged product

- SMOS retrieval curve retrained using Tb fit function to the fixed incidence angle of 40° of SMAP (Fig. 1)
- RMSD between mixed sensor SIT and the original daily mean algorithm is 2.23 cm

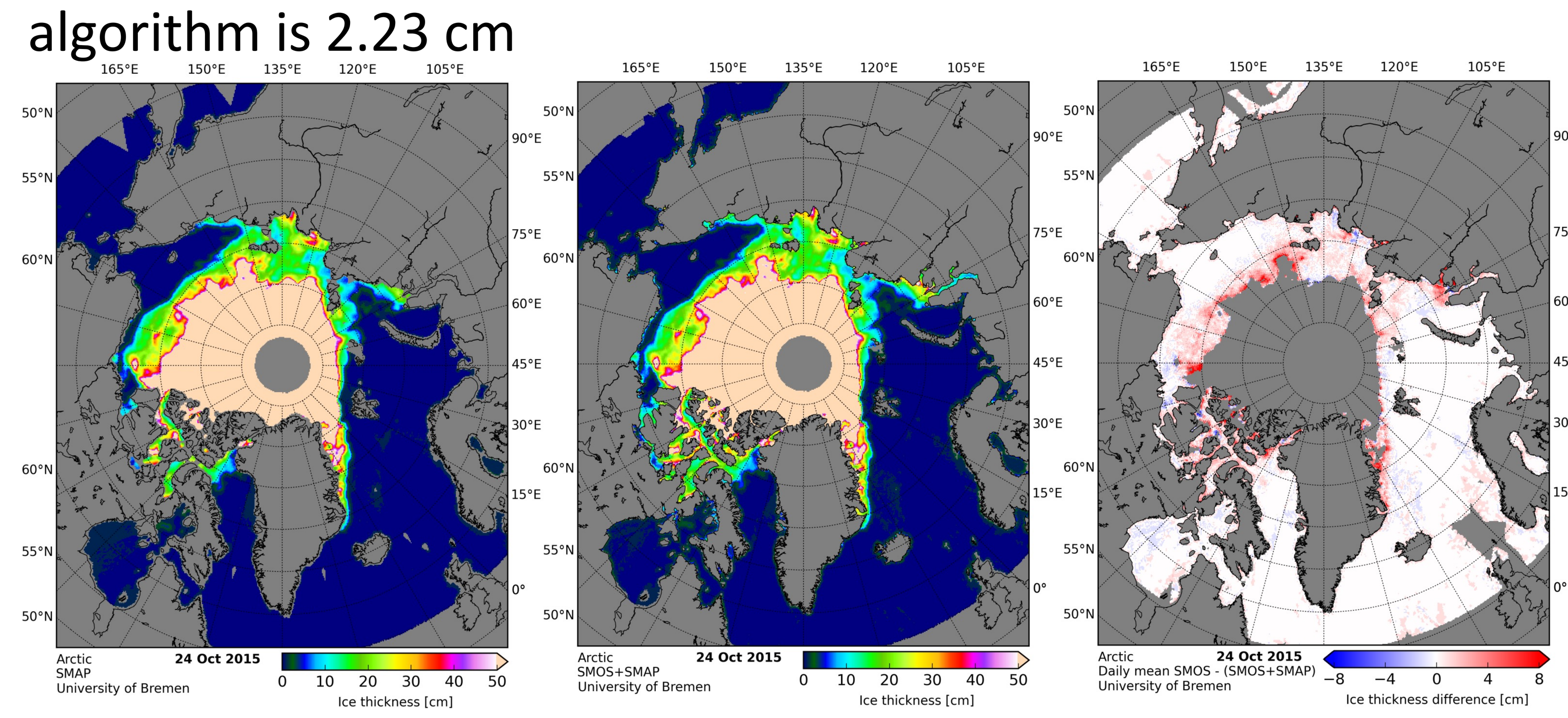



Fig. 5 – SIT for 24 Oct. 2015 using SMAP observations (left), mixed SMOS+SMAP Tbs (center) and difference map between mixed and daily mean retrieval

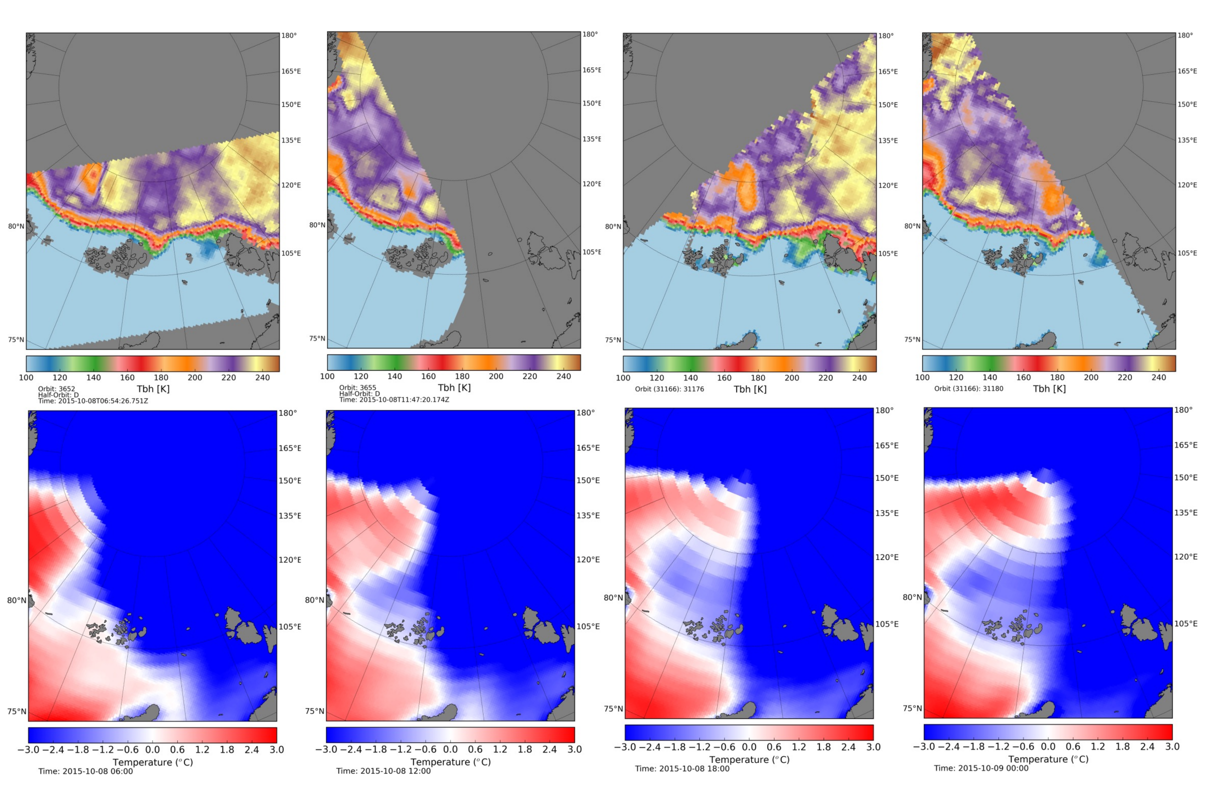


Fig. 6 – Tbh for SMAP (top left), SMOS (top right) computed swath wise and ECMWF 2m temperature at approximate 6h intervals for 8 Oct. 2015, showing possible Tb difference between the two sensors generate by the time difference of data recording of a moving geophysical phenomena

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**References**

[1] - Huntemann et al. , "Empirical sea ice thickness retrieval during the freeze-up period from SMOS high incident angle observations", **The Cryosphere, 8:439–451, 2014**

[2] - Patilea et al. , "Combined SMAP/SMOS Thin Sea Ice Thickness Retrieval", **The Cryosphere, 13:675–691, 2019**

[3] – Zhao et al., "Refinement of SMOS multiangular brightness temperature toward soil moisture retrieval and its analysis over reference targets", **IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 8(2):589–603, 2015**