SMOS Sea Ice Thickness
ReadMe-first Technical Note
(RM-TN)

Document Version

Version	Date	Description	Author
1.0	01/11/2018	Draft of the ReadMe-first Technical Note	Xiangshan Tian-Kunze (AWI)
2.0	13/10/2021	Update changes in SMOS sea ice thickness product v3.3	Xiangshan Tian-Kunze Lars Kaleschke (AWI)
3.0	19/05/2022	Add information of Antarctic sea ice product	Xiangshan Tian-Kunze Lars Kaleschke (AWI)
3.1	15/10/2023	Reference for dataset DOI and Antarctic validation paper (preprint)	Xiangshan Tian-Kunze Lars Kaleschke (AWI)

Applicable Documents

Abbreviation	Name	Description
ATBD	AWI_ESA_SMOS_ATBD_v1.1	Algorithm Theoretical Basis Document
PDD	AWI_ESA_SMOS_PDD_v4.0	Product Description Document
SMP	AWI_ESA_SMOS_SMP_v1.0	Service Migration Plan

Read-me-first note for the release of SMOS Sea Ice Thickness	
Processor version	3.3
Release date by ESA	October 2021 (Arctic), October 2023 (Antarctic)
Author(s)	Xiangshan Tian-Kunze, Lars Kaleschke

Further information	A detailed description of the processing algorithm can be found in the Algorithm Theoretical Basis Document (ATBD). Information about the data product can be found in the Product description document (PDD). Information on how to access the SMOS ice thickness data from AWI can be found here: https://spaces.awi.de/confluence/x/DwVmEQ Information on how to access the SMOS ice thickness data from ESA can be found here: https://smos-diss.eo.esa.int/oads/access/
How to cite	**1. Please cite:** **Data set:** Tian-Kunze, X., Hendricks, S., and Kaleschke, L. (2023). ESA/AWI SMOS L3 Sea Ice Thickness, Version 3.3 [Data Set]. https://doi.org/10.57780/sm1-5ebe10b Date Accessed YYYY-MM-DD **Method:** 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, doi:10.5194/ tc-8-997-2014, URL http://www.the-cryosphere.net/8/997/2014/, 2014. **Validation Arctic:** Kaleschke, L. et al. (2016), SMOS sea ice product: Operational application and validation in the Barents Sea marginal ice zone, Remote Sensing of Environment, Volume 180, July 2016, Pages 264-273, ISSN 0034-4257, http://dx.doi.org/10.1016/j.rse.2016.03.009. **Antarctic**: 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. Include the following phrase into the **acknowledgment**: "The production of SMOS sea ice thickness data was funded by the ESA project SMOS & CryoSat-2 Sea Ice Data Product Processing and Dissemination Service, and data from DATE to DATE were obtained from AWI."
Contact for helpline	For all issues related to data access, please contact ESA's HelpDesk at eohelp@esa.int
Contact for SMOS sea ice product	For questions and feedback, please contact: cs2smos-support@awi.de

1. Introduction

This read-me-first note provides information about improvements regarding to the previous releases, data caveats, and instruction about how to use auxiliary data and uncertainties contained in the SMOS sea ice thickness product generated within the ESA project **SMOS &**

CryoSat-2 Sea Ice Data Product Processing and Dissemination Service. The data are available from AWI and ESA data dissemination services and are also mirrored at various other sites.

The ability to detect thin sea- ice thicknesses using L-band brightness temperatures is limited to cold conditions. SMOS sea ice data are only recommended for use from about mid-October to mid-April in the Arctic and usually from March/April to mid-October in the Antarctic (see caveats).

The scope of application of SMOS L3 sea ice thickness data is limited to special cases, such as the study of sea ice growth. For more general applications that comprise the entire sea ice thickness range, not just thin sea ice, we recommend using the merged CryoSat-2/SMOS L4 product. However, the L4 product is still in development for Antarctica.

Operational daily sea ice thickness data (L3) with v3.3 has been produced in the Arctic since mid-October 2021. As usual with a new version, all available data have been reprocessed to create a consistent time series. The next major update to the SMOS sea ice retrieval algorithm can be expected together with a new SMOS Level 1 version, planned for 2024/2025. For an overview of previous algorithm versions see Table in the next section.

For the production of Antarctic sea ice thickness data the current retrieval algorithm version v3.3 is the same as for the Arctic, with only modified auxiliary data. For further details see Kaleschke et al. (2023).

Data from the SMOS mission commissioning phase (from January 2010 to 31 May 2010) has been acquired during periods when the MIRAS instrument underwent several tests and was operated in different modes causing drifts not fully compensated by the on-ground calibration processing. For that reason, this data set is only available upon request and should be used with caution for long term data exploitation.

2. Overview of version changes in L3 data

L3 SMOS sea ice thickness data has undergone a continuous algorithm development and the data version changed accordingly. Table 1 and 2 show an overview of different data versions in the Arctic and in the Antarctic.

Table1. Overview of L3 SMOS sea ice thickness data versions in the Arctic

	V2.1	V3.1	V3.2	V3.3
Start date of operational service	15. Oct. 2014	15. Oct. 2017	15. Oct. 2019	15. Oct. 2021
Period with data availability	15 Oct. 2010 - 15 Apr. 2017	15 Oct. 2010 - 15 Apr. 2019	15 Oct. 2010 - 15 Apr. 2021	15 Oct. 2010 - present
L1C data version	V620	V620	V620	V724
Changes compared with previous version		Pixel-based RFI filtering; smoother look-up table for the correction of plane layer ice thickness to heterogeneous layer ice thickness; improvement of ice thickness uncertainty.	Bug correction in GMT surface.c command.	Change in L1C data; Change in NSIDC polar stereographic projection; Output in NetCDF v4.

Table2. Overview of L3 SMOS sea ice thickness data versions in the Antarctic

	V3.2	V3.3
Start date of operational service	Not operational	Operational dissemination planned for 2024
Period with data availability	15 Apr. 2010 - 15 Oct. 2020	2010 - present
L1C data version	V620	V724
Changes compared with previous version		Change in L1C data; Change in NSIDC polar stereographic projection; Output in NetCDF v4.

2.1 Changes from v3.2 to v3.3

The main improvements introduced in the version v3.3 are the following:

- Transition of L1C data from v620 to v724: In v3.3, v724 L1C data is used instead of v620 L1C. Re-gridded L3 v724 TB data show lower uncertainties compared to v620 (Fig. 1).
- Polar stereographic projection update: In v3.3 we use more up-to-date NSIDC EPSG 3413 for the northern hemisphere instead of EPSG 3411 and EPSG 3976 instead of EPSG 3412 in the southern hemisphere (https://nsidc.org/data/polar-stereo/ps_grids.html).
- NetCDF format update: the output of L3 sea ice thickness data is updated to NetCDF v4.

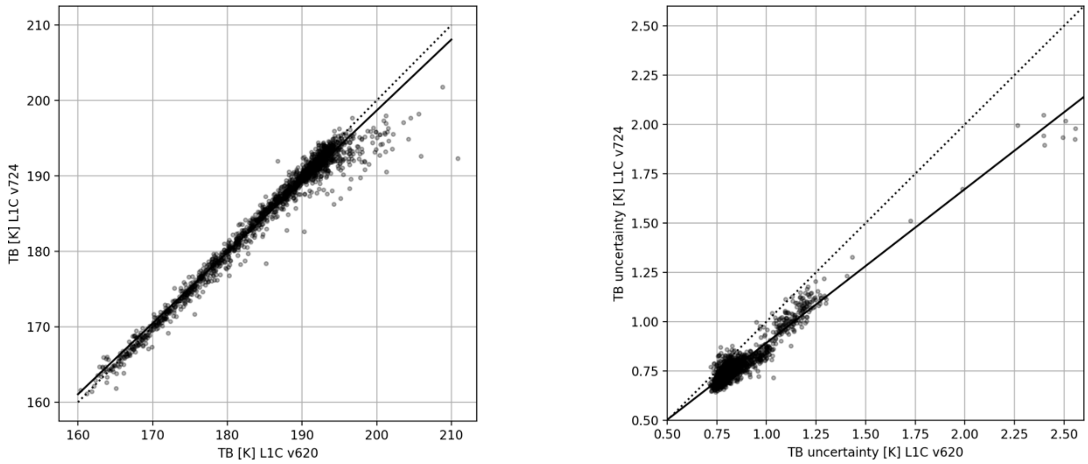

Fig. 1. Left panel: comparison between the daily averaged brightness temperatures v620 and v724 (TB unit: K). Right panel: comparison between the re-gridded brightness temperatures uncertainties of v620 and v724 (TB uncertainty unit: K). Each dot represents the mean over the entire northern hemisphere grid calculated daily over the Winter seasons 2010-2020. The L1C sea product is used which includes about 200 km land along the coastlines. The plot includes all measurements including ocean and land.

3. Caveats

The assumption of 100% ice concentration in the retrieval leads to an underestimation of ice thickness for the grid cells with ice concentration less than 100%. Strong underestimation exists for the thick ice due to the saturation of SMOS brightness temperature with thickness (Fig. 2). The maximum retrievable ice thickness is limited, it depends on sea ice salinity and temperature. Accordingly, the maximum retrievable ice thickness varies with region and season. Therefore, the sea ice thickness should always be combined with its uncertainty and/or with the saturation ratio (ratio between retrieved and maximum retrievable sea ice thickness). Data with an uncertainty > 1 m or with a saturation ratio above 95% should be used with caution.

Data at the beginning and in particular at the end of processing periods (i.e. for April in the Arctic and for October in the Antarctic), as well as data in the marginal ice zone in lower latitudes should be used with greater caution due to the possible influence of warm air temperatures on the retrieval. The retrieval algorithm is currently being revised to achieve a more realistic sensitivity to the influence of air temperature, which is currently somewhat overestimated due to the simplifications in the model.

A list of limitations of the present SMOS sea-ice thickness product for Antarctica is provided in Kaleschke et al. (2023).

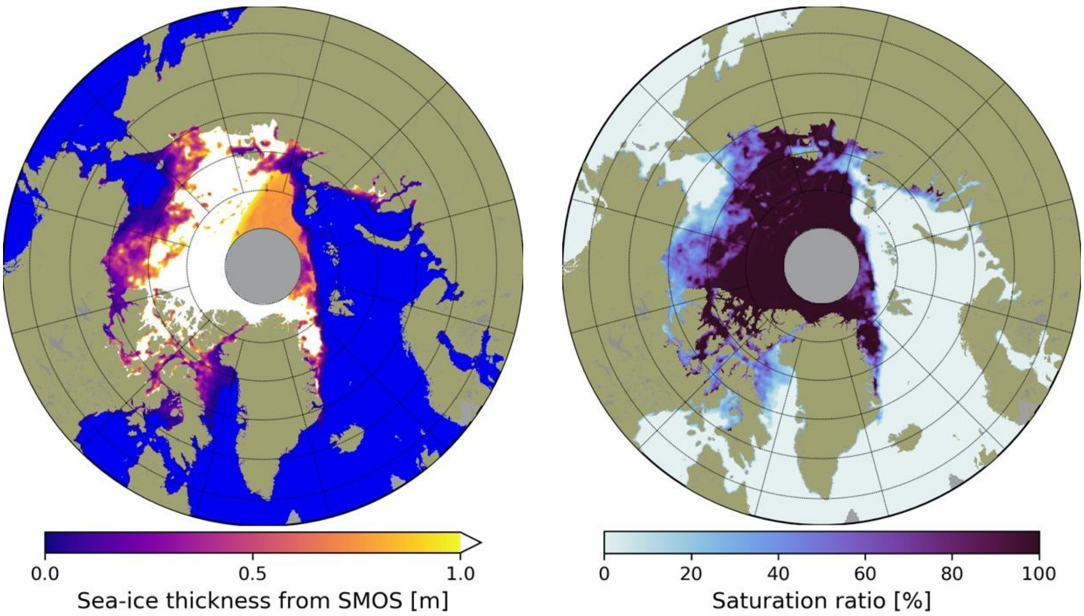

Fig. 2. An example (Date: 2016-11-19) of sea ice thickness (left) and saturation ratio (right) maps under warm conditions: large region of lower-biased ice thickness can be observed in the east part of Arctic Ocean. In this region the saturation ratio is near 100%, which means that the ice thickness data should be used with caution.

References

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Annex changes from v2.1 to v3.1

The major improvements introduced in the version 3.1 were the following:

- Improved brightness temperature data RFI filtering: Additionally to the 300 K threshold method used in the previous algorithms (Algorithm I, II and II*), we also implement pixel-based RFI flagging provided in the L1C data from v3.1 on (Kaleschke et al., 2017).
- Parameterization of look-up table for the correction of plane layer ice thickness to heterogeneous layer ice thickness with polynomial functions: An analysis of the v2.1 SMOS ice thickness data retrieved with Algorithm II* has shown gaps in the histogram of the data, caused by the coarse-resolved look-up table. To avoid this inconsistency, we parameterized the look-up table with a polynomial fit function (degree = 3) for each ice temperature and ice salinity. The polynomial fit function minimizes the gaps in the histograms of ice thickness data, therefore, this will replace the look-up table for the ice thickness correction from v3.1 on (Tietsche et al., 2018).
- Including ice thickness uncertainty caused by the lognormal thickness distribution function: In v3.1 data, besides the uncertainty factors which were considered in v2.1 data, we also consider the uncertainty caused by the thickness distribution function. The uncertainty caused by this function can be estimated using the standard deviation of logsigma, which is assumed as constant in the lognormal thickness distribution function (Kaleschke et al., 2017).
- In v3.1 the surface air temperature fields are the average of three previous days. In v2.1 we use one previous day JRA55 surface air temperature field.
- Logsigma is changed to 0.6 in v3.1 compared to 0.7 in v2.1. The adaption of logsigma is based on more validation data from different air campaigns.

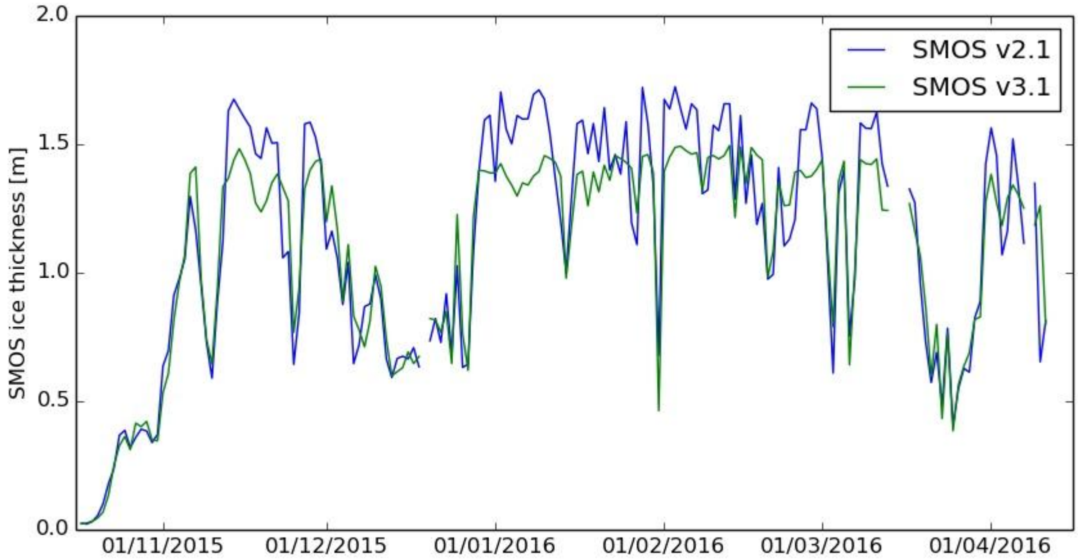

Fig. A1. Comparison of v2.1 and v3.1 sea ice thickness data at (74.5 N,127.0 E), both level 3 sea ice thickness data are based on v620 L1C data.

Fig. A1 shows the comparison of v2.1 and v3.1 sea ice thickness data in the Laptev Sea for the winter season of 2015/16. Both data are based on v620 L1C data, therefore the underlying brightness temperature measurements are the same. The v3.1 sea ice thickness data have minor difference to the v2.1 data where thin ice dominates. However, over thicker ice (thicker than 1 m), v3.1 shows less variability from one day to another and lower ice thickness. This is caused partly by the surface air temperature fields, which are averaged over three previous days in v3.1 instead of one as in v2.1, and partly caused by the lower logsigma, which is 0.6 in v3.1 compared to 0.7 in v2.1.

Annex changes from v3.1 to v3.2

Difference between v3.1 and v3.2 is minor. A critical bug is found in the interpolation command “surface.c” in the GMT version 4.5.14, which is used to interpolate JRA55 surface temperature into 12.5 km grid for the retrieval in algorithm v3.1. In the data set v3.2, an up-to-date version GMT4.5.15 is used for the interpolation. The transfer of GMT version from 4.5.14 (sea ice retrieval v3.1) to 4.5.15 (sea ice retrieval v3.2) causes up to 1 K difference in the interpolated surface air temperature, which is boundary condition in the sea ice retrieval (Fig. A2). Accordingly, the retrieved ice thicknesses show spatial differences of up to several centimeter compared to the v3.1 (Fig. A3). The differences in the resulting mean ice thickness between both versions are however negligible.

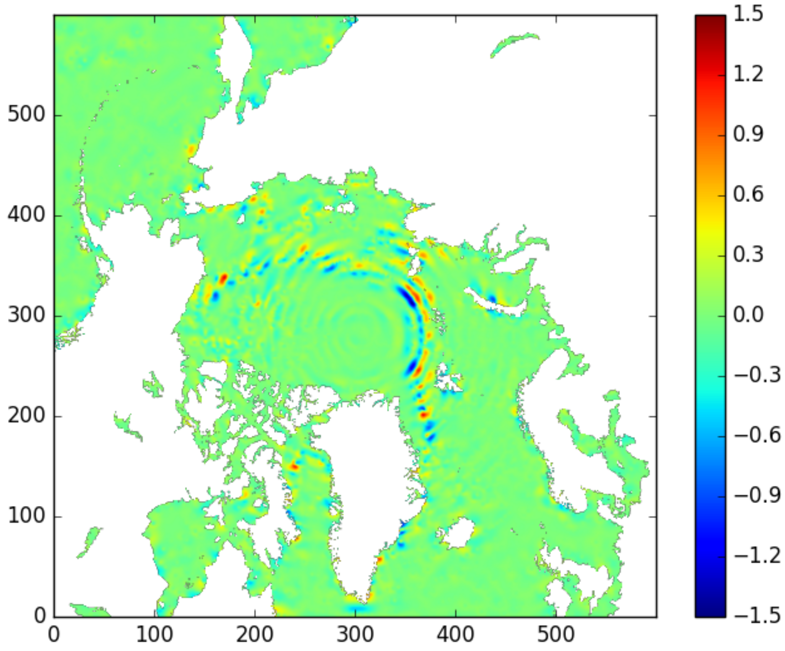

Fig. A2. Interpolated JRA55 surface temperature difference (unit: K) between v3.2 and v3.1. Date: 2018-10-27-12

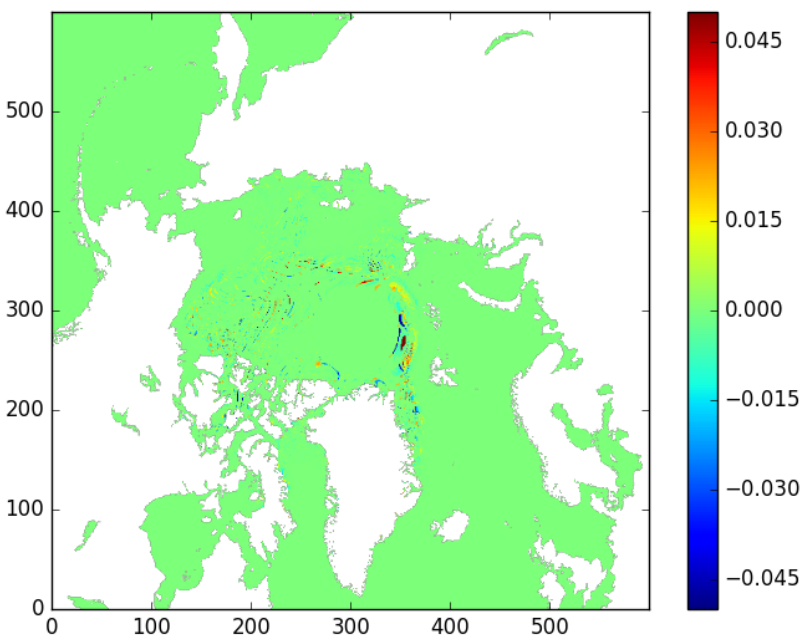

Fig. A3. Difference (unit: m) in the retrieved sea ice thicknesses between v3.2 and v3.1. Date: 2018-10-28