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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 revised 3/11/2021	Update changes in SMOS sea ice thickness product v3.3	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_v3.0	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	3rd November 2021
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) The documents are available here: https://earth.esa.int/eogateway/catalog/smos-l3-sea-ice-thickness 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 the data	1. Please cite: 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. 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. 2. 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
Comments to SMOS 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**.

Operational production of version v3.3 SMOS sea ice thickness data for the northern hemisphere begins on 15 October 2021 on daily basis. The data from October 2010 to April 2021 will be reprocessed using algorithm v3.3 and v724 L1C brightness temperature in October 2021 and will be available soon thereafter from AWI and ESA data dissemination services.   Release of *operational* ice thickness in the southern hemisphere is planned for April 2022. The data set acquired during 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 not be used for long term data exploitation. SMOS sea ice data users are recommended to use this new version data set, which supersedes the previous ones generated by the algorithm baseline version v2.1, v3.1 and v3.2, and to read this note carefully to ensure optimal exploitation of the version 3.3 dataset.

2. Overview of version changes in L3 data

Table1. Overview of L3 SMOS sea ice thickness data versions.

	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 available	15 Oct. 2010 - 15 Apr. 2017	15 Oct. 2010 - 15 Apr. 2019	15 Oct. 2010 - 15 Apr. 2021	15 Oct. 2010 -
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	Bug correction in GMT surface.c command.	Change in L1C data; Change in NSIDC polar stereographic projection; Output in NetCDF v4.

		heterogeneous layer ice thickness; improvement of ice thickness uncertainty.		

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 L3B v724 TB data shows lower uncertainty compared to v620 (Fig. 4). The resulting changes in mean brightness temperature and mean sea-ice thickness are very small.

- Polar stereographic projection update: In v3.3 we use more up-to-date NSIDC EPSG 3413 for the northern hemisphere instead of EPSG 3411. (https://nsidc.org/data/polar-stereo/ps_grids.html).

- NetCDF format update: Furthermore, the output of L3 data is updated to NetCDF v4.
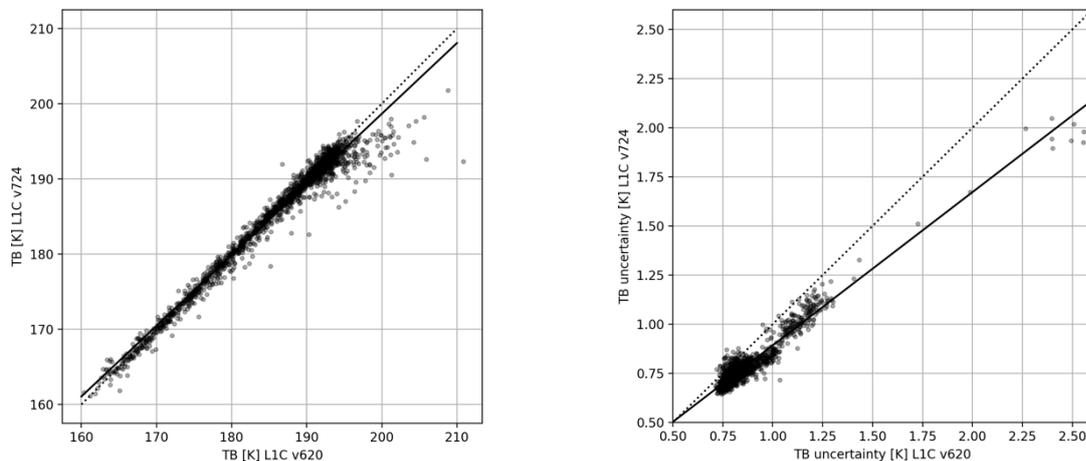

Fig. 4. Left panel: comparison between the re-gridded brightness temperatures v620 and v724 (TB unit: K). For the re-gridding, L1C sea product is used which includes about 200 km land along the coastlines. Right panel: comparison between the re-gridded brightness temperatures uncertainty v620 and v724 (TB uncertainty unit: K). Each dot represents the mean over the entire northern hemisphere grid calculated daily over the Winter seasons 2010-2020.

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. 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 not be used.
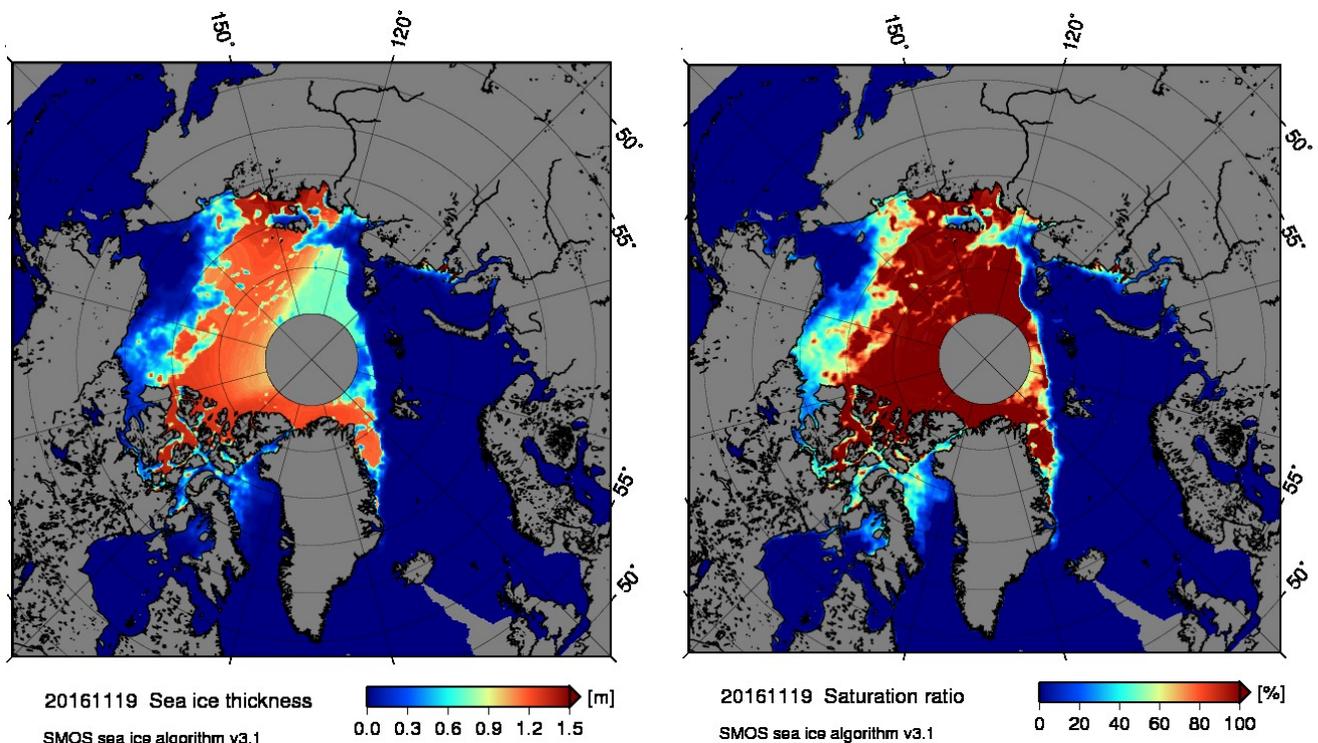

Fig. 5. An example of sea ice thickness and saturation ratio maps under warm conditions: large region of lower-biased ice thickness can be observed in the east part of Arctic Ocean. In this region the saturation ratio is near 100%, which means that the ice thickness data should not be used.

Annex changes from v2.1 to v3.1

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

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- 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.
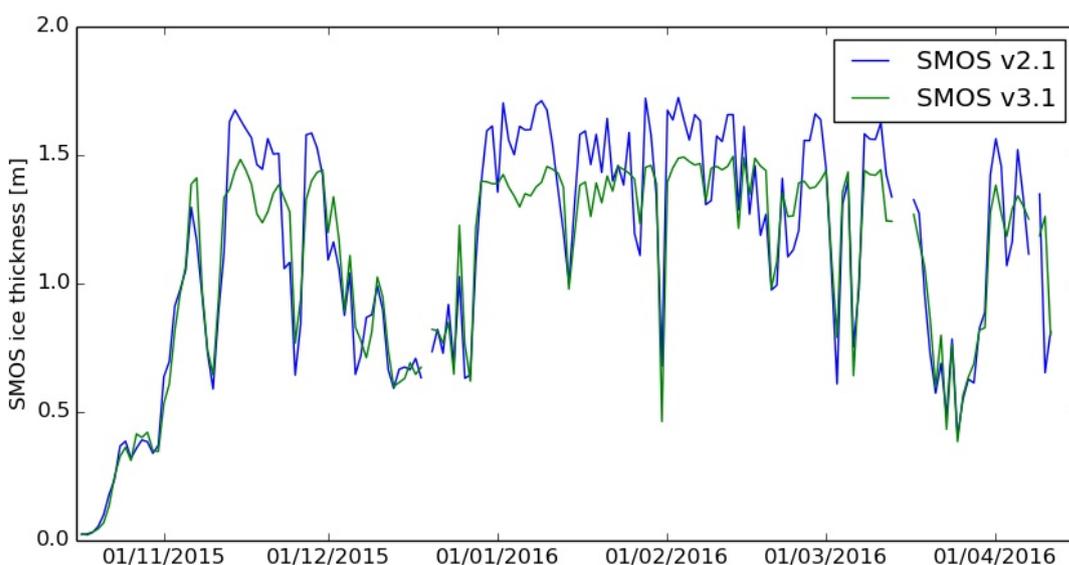

Fig. 1. Comparison of v2.1 and v3.1 sea ice thickness data at (74.5 N,127.0 E), both level 3 sea ice thickness data are based on v620 L1C data.

Fig. 1 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 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

The major improvements introduced in the version 3.2 were the following:

- 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. 2). Accordingly, the retrieved ice thicknesses show spatial differences of up to several centimeter compared to the v3.1 (Fig. 3). The differences in the resulting mean ice thickness between both versions are however negligible.
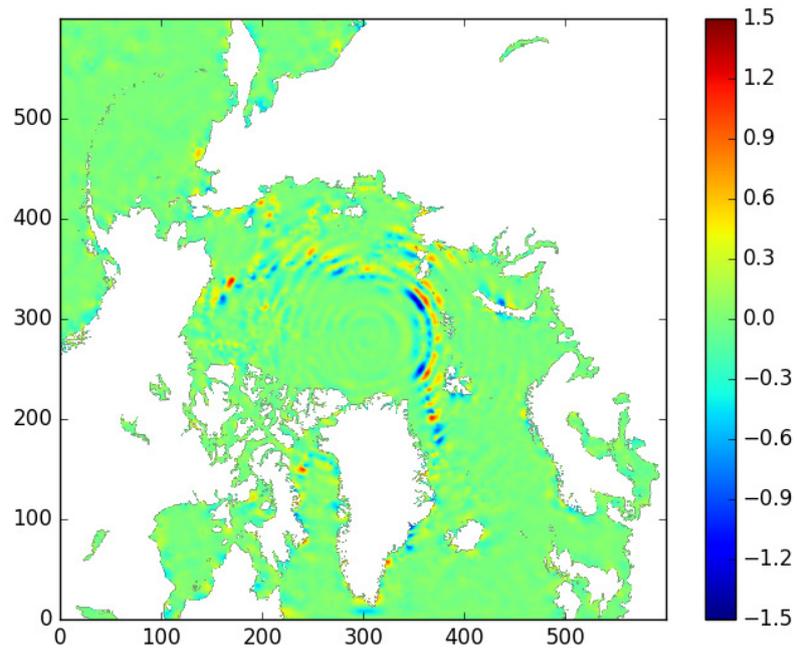
Fig. 2. Interpolated JRA55 surface temperature difference (unit: K) between v3.2 and v3.1. Date: 2018-10-27-12
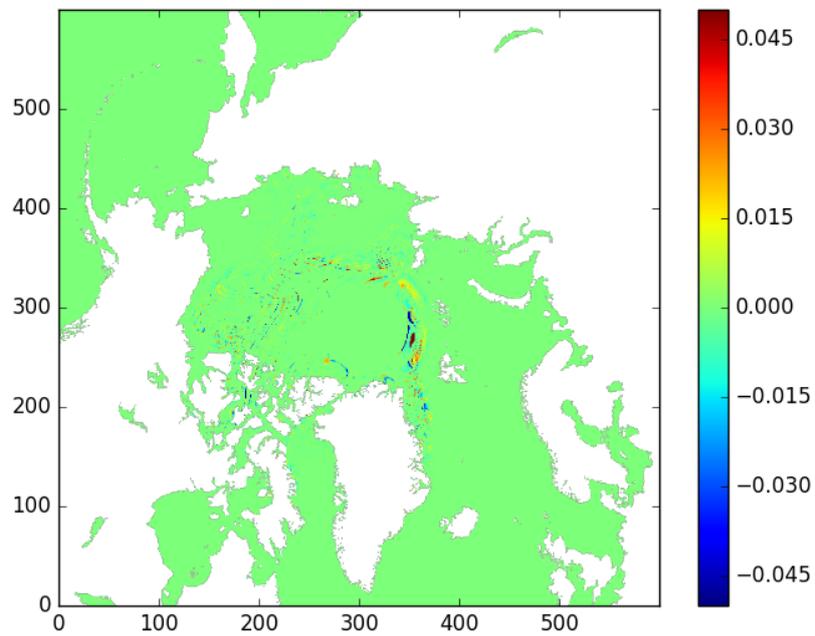

Fig. 3. Difference (unit:m) in the retrieved sea ice thicknesses between v3.2 and v3.1. Date: 2018-10-28

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