ReadMe-first Technical Note (RM-TN)

Document Version

Version	Date	Description	Author
1.5	08/11/2022	Refers to CryoSat-2 SMOS Merged Product version v205	Stefan Hendricks (AWI) Lars Kaleschke (AWI)
1.4	01/11/2021	Refers to CryoSat-2 SMOS Merged Product version v204	Stefan Hendricks (AWI)
1.3	07/10/2020	Refers to CryoSat-2 SMOS Merged Product version v203	Robert Ricker (AWI)
1.2	27/09/2019	Refers to CryoSat-2 SMOS Merged Product version v202	Robert Ricker (AWI)
1.1	19/10/2018	Revision after comments from ESA	Robert Ricker (AWI)
1.0	15/06/2018	Draft of the ReadMe-first Technical Note	Robert Ricker (AWI)

Applicable Documents

Abbreviation	Name	Description
ATBD	AWI_ESA_CS2SMOS_ATBD_v2.4	Algorithm Theoretical Basis Document

PDD	AWI_ESA_CS2SMOS_PDD_v1.5	Product Description Document

Read-me-first note for the release of theCryoSat-2/SMOS Merged Sea Ice Thickness (CS2SMOS)	
Product version	v205
Release date by ESA	29.11.2022
Author(s)	Robert Ricker, Stefan Hendricks, 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 ca be found in the Product description document (PDD): The documents are available here: https://earth.esa.int/eogateway/catalog/smos-cryosat-l4-sea-ice-thickness Information on how to access the CS2SMOS ice thickness data from AWI can be found here: https://spaces.awi.de/confluence/x/DwVmEQ Information on how to access the CS2SMOS 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: Ricker, R., Hendricks, S., Kaleschke, L., Tian-Kunze, X., King, J., and Haas, C.: A weekly Arctic sea-ice thickness data record from merged CryoSat-2 and SMOS satellite data, The Cryosphere, 11, 1607-1623, https://doi.org/10.5194/tc-11-1607-2017, 2017. 2. Include the following phrase into the acknowledgment: "The production of the merged CryoSat-SMOS sea ice thickness data was funded by the ESA project SMOS & CryoSat-2 Sea Ice Data Product Processing and Dissemination Service, and data of version 2.05 from DATE to DATE were obtained from (AWI or ESA)."
Contact for helpline	For all issues related to data access, please contact ESA's HelpDesk at eohelp@esa.int

Comments to CryoSat-2/SMOS merged product	For questions and feedback, please contact: cs2smos-support@awi.de

1. Introduction

The read-me-first note provides information about improvements with regard to the previous releases, data caveats, and instruction about how to use auxiliary data and uncertainties contained in the product.

The current product version v205 is available from October 2022 to present. It will replace v204, after reprocessing is completed.
v205 is continuously generated within the framework of the ESA project **SMOS & CryoSat-2 Sea Ice Data Product Processing and Dissemination Service**. The product is only available for the Northern Hemisphere from October to April.

2. Main Improvements and Changes in the current Data Set

The current version is v205. It is available since October 2022. The main changes in v205 compared to previous version v204 are algorithm updates of the CryoSat-2 source sea ice thickness data sets:

CryoSat-2 version 2.5 update

- Update of surface type classification (lead & sea ice discrimination of individual altimeter waveforms). Leads to thin ice due to addition of sea ice waveforms in thin ice areas
- Add marginal ice zone filter flag that indicates biased sea ice thickness values in scenarios with wave / swell penetration into the marginal ice zone.
- Fixed minor issues with algorithm implementation.

CryoSat-2/SMOS data fusion update

- Use CryoSat-2 marginal ice zone flag to filter biased CryoSat-2 sea ice thicknesses

3. Product Performance

CS2SMOS, CryoSat-2 and SMOS Ice Thickness Uncertainties

The uncertainties of the CryoSat-2 and SMOS sea ice thickness observations are crucial for the data merging and the interpolation. Figure 1 shows the relative uncertainties of CryoSat-2 and SMOS for November 2013 and April 2014. While the SMOS relative uncertainties are lowest for very thin ice, CS2 relative thickness uncertainties are smaller over thick ice and rise asymptotic towards thickness values < 1 m, which is due to the different methodical approach. The merged product (CS2SMOS) takes advantage of the complementary uncertainties. CS2SMOS merged ice thickness shows a significant reduction in the relative uncertainty with regard to the thickness uncertainties of the thin ice in the CryoSat-2 product, and the thick ice in the SMOS product.

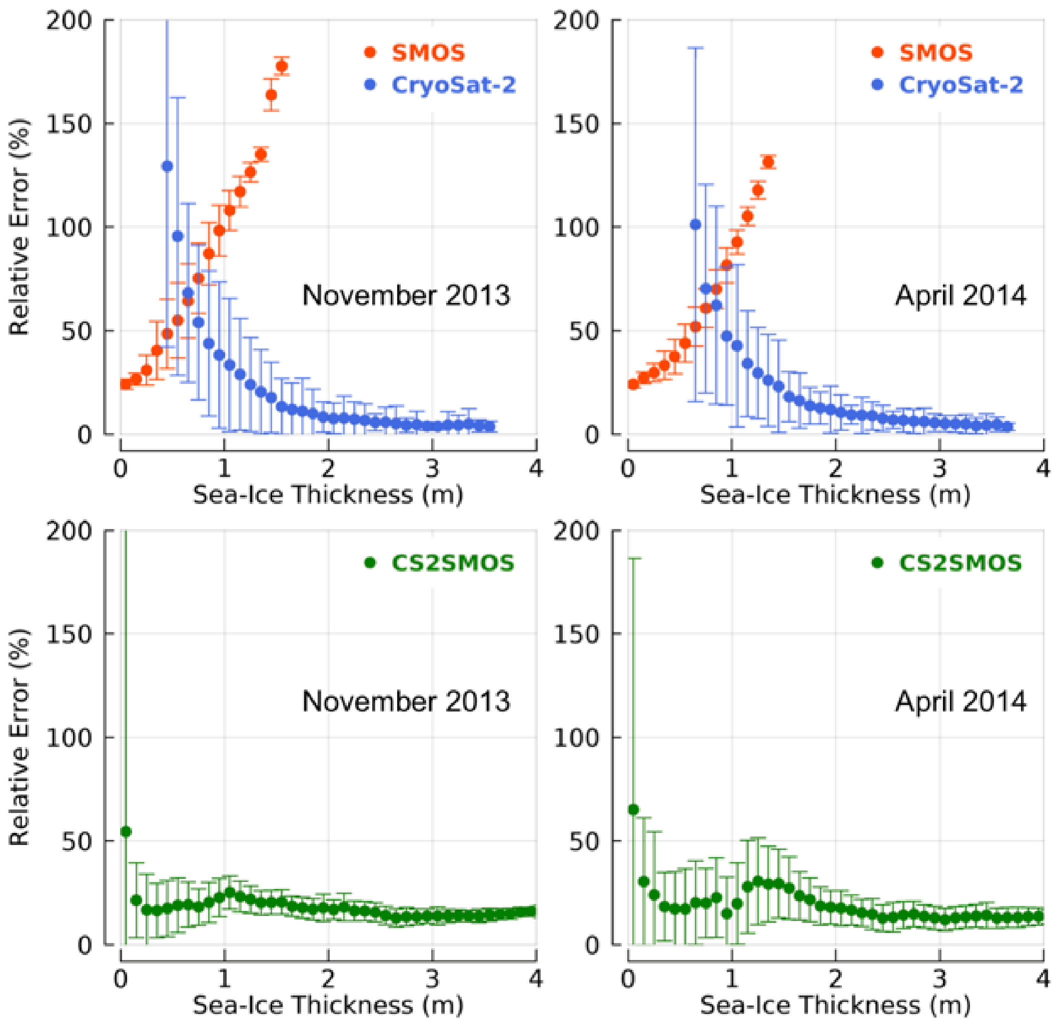

Figure 1: Binned Relative uncertainties for November 2013 and April 2014. Error bars indicate the standard deviation of relative uncertainties within the 10 cm bin width.

Product validation

For validation, we use ULS ice draft data from moorings that have been deployed at four different sites in the Beaufort Sea within the BGEP project (Woods Hole Oceanographic Institution (WHOI), Krishfield and Proshutinsky, 2006). Data are sampled at 2s intervals. Ice draft is converted to ice thickness by multiplying the draft by 1.1 (Rothrock et al., 2008). Table 2 provides the position of the moorings (A, B, D) in the Beaufort Sea and information about the ULS record periods. For the comparison of the merged CS2SMOS ice thickness and ULS ice thickness measurements, the data was averaged over 24 hours to obtain the daily mean effective ice thickness for each ULS. In the last step, daily retrievals are averaged weekly on a 25 km EASE2 grid to cover the same period as the weekly CS2SMOS products. Since the positions of the moorings are steady, one data point for each ULS is retrieved per week and is then compared with the weekly mean of the CS2SMOS ice thickness. Figure 4 shows the positions of the moorings and the corresponding differences to the CS2SMOS ice thickness. Mean differences (MD) are calculated by subtracting satellite ice thickness from the ULS ice thickness. Considering the entire ULS data set as the reference, the mean difference is 5 cm, while the root mean square deviation (RMSD) is 0.3 m. This shows an improvement compared to the previous product versions (Table 3).

Table 2: Mooring sites with ULS measurements used in this document.

Mooring Site	ULS record periods	Location
A	08/2003 – 10/2016	150.0°W 75.0°N
B	08/2003 – 09/2005 09/2006 – 09/2009 10/2010 – 10/2016	150.0°W 80.0°N
D	09/2006 – 10/2016	140.0°W 74.0°N

Table 3: Product validation with BGEP ULS measurements for different CS2SMOS product versions: mean differences (MD) and root mean square deviation (RMSD). Please note that the comparison periods changed over time. The first official ESA release was version v201.

Product version (release date)	MD [m]	RMSD [m]
v200	0.1	0.36
v201 (2018)	0.02	0.34
v202 (2019)	-0.079	0.322
v203 (2020)	-0.067	0.316
v204 (2021)	-0.078	0.316
v205 (2022)	0.05	0.302

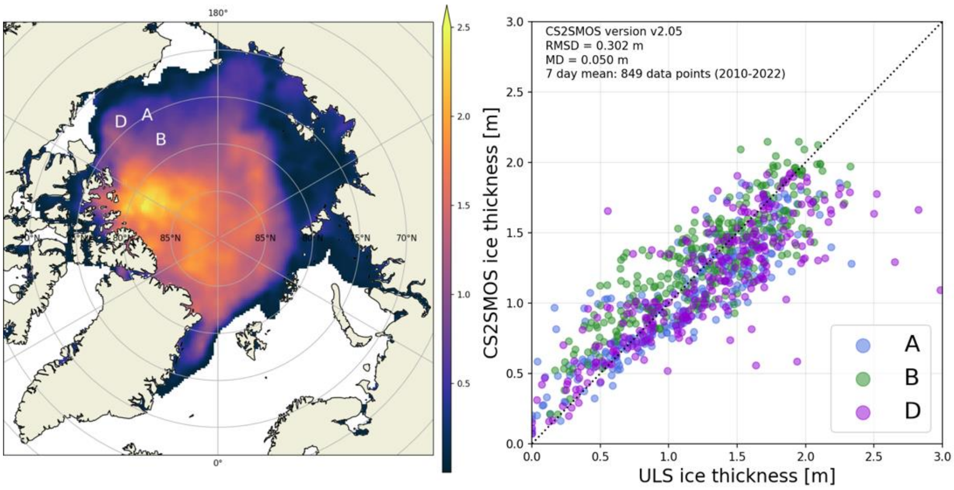

Figure 4: Example CS2SMOS sea ice thickness map (22-28 Oct. 2022) and ULS locations (left panel), and scatter plot between ULS and CS2SMOS v205 ice thickness over the period Nov 2010 – Oct 2022. The RMSD represents the root mean square deviation. MD represents the mean difference between CS2SMOS v205 and ULS ice thickness.

4. Known Issues

Major caveats are listed below:

Issue	Product Version	Status
Underestimation of SMOS ice thickness when ice concentration is lower than 100%	205	Open
Fundamental calibration of CryoSat- 2 range retracking algorithm required	205	Open
Sea ice classification (first-year / multi-year ice) auxiliary data not available in first half of October in each year with an impact on CryoSat-2 sea ice thickness. This results in a biased background field for reprocessed CS2SMOS data that uses the C3S sea ice type (interim) climate data record v2.0 for each October in the data record. This issue is no longer present in the next version of the C3S sea ice type (interim) climate data record (v3.0) that is scheduled for release in early 2023.	205	Open

5. Future algorithm evolution

We want to investigate the capability of expanding the processing to the Southern hemisphere. Moreover, we will aim to improve the retrieval algorithm. In particular, we will investigate the possibility to apply a multiyear ice concentration product to better distinguish between first-year and multiyear sea ice.

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