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CryoSat-2/SMOS Merged Product Description Document (PDD)

Document Version

Version	Date	Description	Author
1.1	19/10/2018	Revision after comments from ESA	Robert Ricker (AWI)
1.0	15/06/2018	Draft of the Product Description Document	Robert Ricker (AWI)

Applicable Documents

Abbreviation	Name	Description
ATBD	AWI_ESA_CS2SMOS_ATBD_v1.0	Algorithm Theoretical Basis Document
RM_TN	AWI_ESA_CS2SMOS_RM-TN_v1.1	ReadMe-first Technical Note

1. Purpose of this Document

The purpose of this document is to describe the content of the **CryoSat-2-SMOS Data Merging Product.** The document contains a description of the product and its format. Information about scientific algorithms used to generate the product is available in the Algorithm Theoretical Baseline Document [ATBD].

2. CryoSat-2 SMOS Merged Product

Version	Date	Comments
v201	15.10.2018	Official ESA release

Rationale

The European Space Agency's (ESA) Earth Explorer SMOS satellite can detect thin sea ice, whereas its companion CryoSat-2, designed to observe thicker perennial sea ice, lacks sensitivity. Using these satellite missions together completes the picture of the changing Arctic sea ice and provides a more accurate and comprehensive view on the actual state of Arctic sea-ice thickness.

Methods

We use an optimal interpolation scheme (OI) similar to Böhme and Send (2005); Boehme et al. (2008); McIntosh (1990) that allows the merging of datasets from diverse sources on a predefined analysis grid. The data are weighted differently based on known uncertainties of the individual products and modeled spatial covariances. OI minimizes the total error of observations and provides ideal weighting for the observations at each grid cell. The data merging methods are described in more detail in Ricker et al. (2017) and in the ATBD.

We retrieve weekly analysis fields of sea ice thickness, based on calendar weeks with a time span from Monday to Sunday. Melting does not allow to retrieve sea-ice thickness estimates from CryoSat-2 and SMOS during summer between May and September. Hence, the merged product is limited to the period from October to April.

For the complete processing, the background field is constructed by using SMOS (CryoSat-2) data one (two) week(s) prior to the target week and one (two) week(s) after the target week. This causes a delay in the distribution of the merged product of at least two weeks with regard to the data acquisition. Therefore, we also maintain a near-real-time processing using a background field that utilizes only data acquired two weeks prior to the target week and apply a phase shift correction to accommodate for the advancing ice growth. For the reprocessing campaigns we will then use the full background field.

Grid

All grids are projected onto the 25 km EASE2 Grid, which is based on a polar aspect spherical Lambert azimuthal equal-area projection (Brodzik et al., 2012). The grid dimension is 5400 km x 5400 km, equal to a 432 x 432 grid. The grid is centered on the geographic Pole, meaning that the Pole is located at the intersection of center cells (Figure 1).
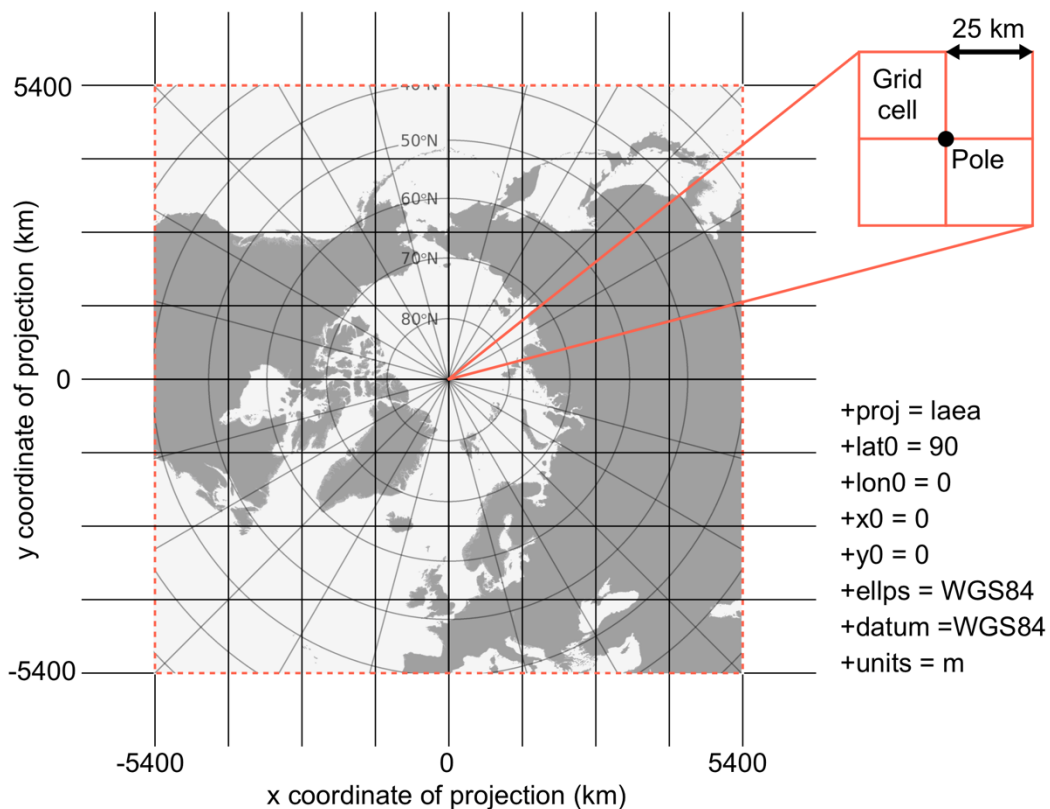
Figure 1: Specifications of the EASE2 25 km grid, which is used for the merged product.

Data Sources

For the data merging, we use the AWI CS2 product (processor version 2.1), and the SMOS sea-ice thickness retrieval from the University of Hamburg (processor version 3.1) (Tian-Kunze et al., 2014; Kaleschke et al., 2016). Besides the sea ice thickness data, the data merging requires sea ice concentration and sea ice type (Identification of first-year and multiyear sea ice) provided by the Ocean and Sea Ice Satellite Application Facility (OSI SAF). Table 1 summarizes the different input grids, their spatial resolution, and temporal sampling.

Table 1: Properties of input and output data grids, which are used to obtain the merged product.

Product	Source	Frequency	Spatial coverage	Grid/ resolution
SMOS sea ice Thickness	icdc.zmaw.de/daten	Daily	Entire Arctic	Polarstereo 12.5 km
CS2 sea ice Thickness	ftp.awi.de/sea_ice	Weekly	Incomplete	EASE2 25 km
Ice Concentration	osisaf.met.no/p/ice/	Daily	Entire Arctic	Polarstereo 10 km
Ice Type	osisaf.met.no/p/ice/	Daily	Entire Arctic	Polarstereo 10 km
Merged Product	ftp.awi.de/sea_ice	Weekly	Entire Arctic	EASE2 25 km

3. Product Description

Overview

Parameter	Sea ice thickness
Spatial covergae	N: 90°, S:16.6°, E:180°, W:-180°
Spatial Resolution	25 km x 25 km
Temporal Coverage:	November 2010 to present
Temporal Resolution	7 days
Data Format(s)	NetCDF
Platforms	CryoSat-2, SMOS
Version	V200, v201

File naming convention

NetCDF files are named using the following convention:
```
<convention-prefix>_<regional code>-
<institution>,<platform(s)>,<grid>_<time>_<mode>_<product
version>_<file version>.nc
```

`convention-prefix`	World Meteorological Organization: `W`
`regional code`	European: `XX`
`institution`	European Space Agency: `ESA`
`processing level/parameter`	level 4 sea ice thickness: `l4sit`
`platform(s)`	Satellites: `SMOS, CS2`
`grid`	25 km EASE2 grid, Northern Hemisphere: `NH_25KM_EASE2`
`time`	time span: `yyyymmdd - yyyymmdd`
`mode`	reprocessing: `r`, operational: `o`
`product version`	version 2.0.0: `v200`
`file version`	version 1: `01`

Example NetCDF naming for operationally processed data:
```
W_XX-ESA,SMOS_CS2,NH_25KM_EASE2_20180326_20180401_o_v201_01_l4sit.nc
```

Example NetCDF naming for reprocessed data:
```
W_XX-ESA,SMOS_CS2,NH_25KM_EASE2_20180326_20180401_r_v201_01_l4sit.nc
```

File Format

The weekly grids are given in standardized binary data format (Network common data form: NetCDF v4). Global attributes are given in Table 2. The variables are given as grid arrays, see, therefore Table 3. NetCDF files are formatted according to CF conventions: CF-1.6 ACDD-1.3. We use a scaling factor of 10^{-3} and a fillvalue = -2147483647.

Table 2: Global attributes from an example NetCDF file, covering the week from March 26 to April 01, 2018.

Attribute	Value
title	Sea Ice Thickness derived from merging CryoSat-2 and SMOS ice thickness
description	Weekly Arctic sea-ice thickness derived from CryoSat-2 and SMOS using an optimal interpolation scheme
summary	Weekly Arctic sea-ice thickness derived from CryoSat-2 and SMOS using an optimal interpolation scheme
keywords	Cryosphere > Sea Ice > Sea Ice Thickness
product_version	201
processing_mode	r
time_of_creation	Mon Oct 22 17:27:55 2018
history	Mon Oct 22 17:27:55 2018 creation
Conventions	CF-1.6 ACDD-1.3
spatial_resolution	25.0 km grid spacing
geospatial_lat_min	16.623929977416992
geospatial_lat_max	90.0
geospatial_lon_min	-180.0
geospatial_lon_max	180.0
geospatial_vertical_min	0.0
geospatial_vertical_max	0.0
time_coverage_start	2018-03-26T00:00:00Z
time_coverage_end	2018-04-01T00:00:00Z
time_coverage_duration	P7D
time_coverage_resolution	P7D
platform	CryoSat-2, SMOS
project	CS2SMOS PDS: SMOS & CryoSat-2 Sea Ice Data Product Processing and Dissemination Service
institution	Alfred-Wegener-Institut Helmholtz Zentrum für Polar und Meeresforschung (AWI), http://www.awi.de
creator_name	Alfred-Wegener-Institut Helmholtz Zentrum für Polar und Meeresforschung (AWI), http://www.awi.de
creator_type	institution
creator_url	https://spaces.awi.de/confluence/x/DwVmEQ
publisher_email	robert.ricker@awi.de
references	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.
_CoordSysBuilder	ucar.nc2.dataset.conv.CF1Convention

Table 3: NetCDF file variables and their attributes. Type "int" refers to 32-bit long signed integer.

Variable	Attributes	Type	Dimension
Lambert_Azimuthal_ Grid	:grid_mapping_name: lambert_azimuthal_equal_area :longitude_of_projection_origin: 0.0 :latitude_of_projection_origin: 90.0 :false_easting: 0.0 :false_northing: 0.0 :semi_major_axis: 6378137.0 :inverse_flattening: 298.25723 :proj4_string: +proj=laea +lon_0=0 +datum=WGS84 +ellps=WGS84 +lat_0=90.0	int	-
time	:units: seconds since 1978-01-01 00:00:00 :long_name: reference time of product :standard_name: time :axis: T :calendar: standard :bounds: time_bnds	double	1
time_bnds	:units: seconds since 1978-01-01 00:00:00	double	1,2
xc	:units: km :long_name: x coordinate of projection (eastings) :standard_name: projection_x_coordinate	double	
yc	:units: km :long_name: y coordinate of projection (northings) :standard_name: projection_y_coordinate	double	1,432,432
lon	:units: degrees_east :long_name: longitude coordinate :standard_name: longitude	float	1,432,432
lat	:units: degrees_north :long_name: latitude coordinate :standard_name: latitude	float	1,432,432
analysis_ice_thick ness	:units: m :long_name: CS2SMOS merged sea ice thickness :standard_name: sea_ice_thickness :grid_mapping: Lambert_Azimuthal_Grid :coordinates: time lat lon :scale_factor: 0.001 :valid_min: :valid_max: :_FillValue: -2147483647	int	1,432,432
background_ice_thi ckness	:units: m :long_name: optimal interpolation background field :standard_name: sea_ice_thickness :grid_mapping: Lambert_Azimuthal_Grid :coordinates: time lat lon :scale_factor: 0.001 :valid_min: :valid_max: :_FillValue: -2147483647	int	1,432,432
weighted_mean_ice_ thickness	:units: m	int	1,432,432

	:long_name: weighted mean of weekly cs2 and smos ice thickness retrievals :standard_name: sea_ice_thickness :grid_mapping: Lambert_Azimuthal_Grid :coordinates: time lat lon :scale_factor: 0.001 :valid_min: :valid_max: :_FillValue: -2147483647		
innovation	:units: m :long_name: difference between background and analysis ice thickness :grid_mapping: Lambert_Azimuthal_Grid :coordinates: time lat lon :scale_factor: 0.001 :valid_min: :valid_max: :_FillValue: -2147483647	int	1,432,432
ice_conc	:units: % :long_name: sea ice concentration :standard_name: sea_ice_area_fraction :grid_mapping: Lambert_Azimuthal_Grid :source: OSI-401 :source_product_version: 3.0 :coordinates: time lat lon :scale_factor: 0.01 :valid_min: :valid_max: :_FillValue: -2147483647	int	1,432,432
ice_type	:long_name: sea ice type :standard_name: sea_ice_classification :grid_mapping: Lambert_Azimuthal_Grid :source: OSI-403 :source_product_version: 4.0 :coordinates: time lat lon :_FillValue: -2147483647 :flag_values: 2 :flag_values: 3 :flag_meanings: first_year_ice :flag_meanings: multi_year_ice :flag_descriptions: 2 -> relatively young ice\n 3 -> ice that survived a summer melt	int	1,432,432
correlation_length _scale	:units: m :long_name: correlation length scale of sea ice thickness :grid_mapping: Lambert_Azimuthal_Grid :coordinates: time lat lon :valid_min: :valid_max: :_FillValue: -2147483647	int	1,432,432
analysis_thickness _unc	:units: m :long_name: uncertainty of the merged sea ice thickness :grid_mapping: Lambert_Azimuthal_Grid :coordinates: time lat lon :scale_factor: 0.001	int	1,432,432

	`:valid_min:`
	`:valid_max:`
	`:_FillValue:  -2147483647`		

`smos_ice_thickness`	`:units: m`
	`:long_name: weekly averaged SMOS ice`
	`thickness`
	`:standard_name: sea_ice_thickness`
	`:grid_mapping: Lambert_Azimuthal_Grid`
	`:source: SMOS-Icethickness`
	`:source_product_version: 3.1`
	`:coordinates: time lat lon`
	`:scale_factor:    0.001`
	`:valid_min:`
	`:valid_max:`
	`:_FillValue:  -2147483647`
		int	1,432,432

`cs2_ice_thickness`	`:units: m`
	`:long_name: weekly averaged CryoSat-2 ice`
	`thickness`
	`:standard_name: sea_ice_thickness`
	`:grid_mapping: Lambert_Azimuthal_Grid`
	`:source: AWI Sea Ice Radar Altimetry`
	`(SIRAL)`
	`:source_product_version: 2.1`
	`:coordinates: time lat lon`
	`:scale_factor:    0.001`
	`:valid_min:`
	`:valid_max:`
	`:_FillValue:  -2147483647`
		int	1,432,432

4. Sample data record

Figure 2 shows a data example from a NetCDF file, covering the week from March 26 to April 01 2018.
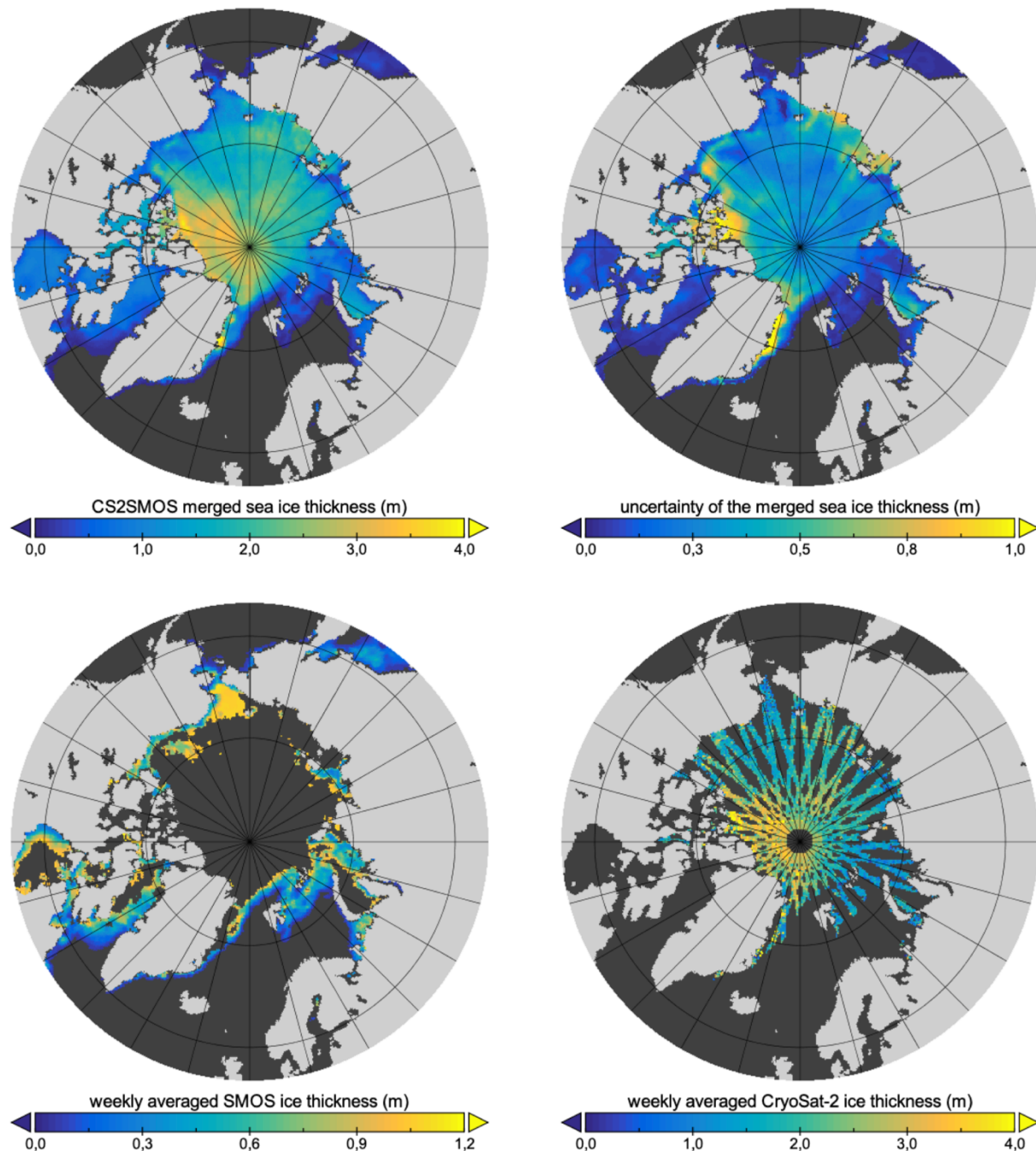

Figure 2: CryoSat-2/SMOS merged sea ice thickness (`analysis_ice_thickness`, upper left), CryoSat-2/SMOS merged sea ice thickness uncertainty (`analysis_thickness_unc`, upper right), weekly averaged SMOS sea ice thickness (`smos_ice_thickness`, lower left), and weekly averaged CryoSat-2 sea ice thickness (`cs2_ice_thickness`, lower right).

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