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SMOS Sea Ice Thickness Product Description Document (PDD)

Document Version

Version	Date	Description	Author
1.0	25/10/2018	Draft of the Product Description Document	Xiangshan Tian-Kunze (AWI)

Applicable Documents

Abbreviation	Name	Description
ATBD	AWI_ESA_SMOS_ATBD_v1.0	Algorithm Theoretical Basis Document
RM_TN	AWI_ESA_SMOS_RM-TN_v1.0	ReadMe-first Technical Note

1. Purpose of this Document

The purpose of this document is to describe the content of the **SMOS Sea Ice Thickness 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. SMOS Sea Ice Thickness Product

Version	Date	Comments
v3.2	Since 15.10.2018	Official ESA release

Rationale

The European Space Agency's (ESA) Earth Explorer SMOS satellite can detect thin sea ice, due to the large penetration depth of L-band in sea ice. Up to 1.5m ice thickness information can be derived from brightness temperatures measured by the L-band radiometer onboard of SMOS.

Methods

We retrieve sea ice thickness from daily averaged brightness temperature. The measured L-band brightness temperature mainly depends on the ice concentration, the molecular temperatures of the sea and the ice, and their emissivities (Menashi et al., 1993). The sea ice emissivity depends on the microphysical sea ice structure, but the inhomogeneities, like brine pockets and air bubbles, are much smaller than the SMOS wavelength of 21 cm (Kaleschke et al., 2010, Kaleschke et al., 2012). Therefore, we can consider sea ice as a homogeneous medium and neglect volume scattering. For the assumption of 100 % ice coverage, the sea ice emissivity mainly depends on ice thickness, ice temperature, and ice salinity (Kaleschke et al., 2010). Tian-Kunze et al. (2014) has further improved the retrieval algorithm of Kaleschke et al., (2012), based on a thermodynamic sea ice model and a three-layer radiative transfer model, which explicitly takes variations of ice temperature and ice salinity into account. In addition, ice thickness variations within the SMOS spatial resolution are considered through a statistical thickness distribution function derived from high-resolution ice thickness measurements from NASA's Operation IceBridge campaign. More details of the sea ice retrieval algorithm can be found in Tian-Kunze et al. (2014) and in the ATBD.

Data Coverage and Grid

Coverage and spatial resolution of L3B SMOS Brightness Temperature data and L3C SMOS Ice Thickness data:

- Northern hemisphere poleward of 50°N
- Spatial resolution: 12.5 km x 12.5 km, polar-stereographic grid of the NSIDC polar-stereographic projection at standard latitude of 70°N (Table 1)
- Geographic longitude: 0°E to 360°E
- Geographic latitude: 50°N to 90°N

Table1: Northern Hemisphere Grid Coordinates of NSIDC Polar Stereographic Grids (ref.: https://nsidc.org/data/polar-stereo/ps_grids.html)

X (km)	Y (km)	Latitude (deg)	Longitude (deg)	position
-3850	5850	30.98	168.35	corner
0	5850	39.43	135.00	midpoint
3750	5850	31.37	102.34	corner
3750	0	56.35	45.00	midpoint
3750	-5350	34.35	350.03	corner
0	-5350	43.28	315.00	midpoint
-3850	-5350	33.92	279.26	corner
-3850	0	55.50	225.00	midpoint

Data Sources

V620 L1C SMOS brightness temperature measurements are collected during one day and averaged and interpolated to build L3B daily brightness temperature in 12.5 km NSIDC polar stereographic grid. Two auxiliary data sets are used as boundary conditions in the retrieval: 2 m Surface Temperature from JRA55 reanalysis and Sea Surface Salinity from model outputs of MIT General Circulation Model from 2002-2009 (Tian-Kunze et al., 2014). Both auxiliary data sets are interpolated to 12.5 km grids to match the L3B brightness temperature.

File naming convention

Untill end of 2018/2019 winter season, the NetCDF files are named as
SMOS_Icethickness_v3.2_north_<date>.nc

From October 2019 on the files will be named using the following convention:
W_XX-ESA,SMOS,NH_12P5KM_NSIDC_YYMMDD_o_v320_01_l3sit.nc (North)

Variables and global attributes

The files are saved in NetCDF v3 format. Here is an example of the variables and global attributes.

```
netcdf SMOS_Icethickness_v3.2_north_20181019.nc {
dimensions:
        time = 1 ;
        x = 608 ;
        y = 896 ;
variables:
        float latitude(y, x) ;
                latitude:units = "degrees_north" ;
                latitude:scale_factor = 1.f ;
```

```
        latitude:standard_name = "latitude" ;
        latitude:long_name = "latitude coordinate" ;
    float longitude(y, x) ;
        longitude:units = "degrees_east" ;
        longitude:scale_factor = 1.f ;
        longitude:standard_name = "longitude" ;
        longitude:long_name = "longitude coordinate" ;
    float y(y) ;
        y:standard_name = "projection_y_coordinate" ;
        y:long_name = "y coordinate of projection" ;
        y:units = "km" ;
        y:grid_spacing = "12.5 km" ;
    float x(x) ;
        x:standard_name = "projection_x_coordinate" ;
        x:long_name = "x coordinate of projection" ;
        x:units = "km" ;
        x:grid_spacing = "12.5 km" ;
    float sea_ice_thickness(time, y, x) ;
        sea_ice_thickness:standard_name = "sea ice thickness" ;
        sea_ice_thickness:long_name = "SMOS sea ice thickness" ;
        sea_ice_thickness:units = "m" ;
        sea_ice_thickness:scale_factor = 1.f ;
        sea_ice_thickness:missing_value = -999.f ;
        sea_ice_thickness:coordinates = "longitude latitude" ;
    float ice_thickness_uncertainty(time, y, x) ;
        ice_thickness_uncertainty:long_name = "sea ice thickness total uncertainty" ;
        ice_thickness_uncertainty:units = "m" ;
        ice_thickness_uncertainty:missing_value = -999.f ;
        ice_thickness_uncertainty:coordinates = "longitude latitude" ;
    short saturation_ratio(time, y, x) ;
      saturation_ratio: long_name = "ratio of retrieved ice thickness and maximal retrievable
ice thickness " ;
        saturation_ratio:units = "%" ;
        saturation_ratio:missing_value = -999 ;
        saturation_ratio:coordinates = "longitude latitude" ;
    float TB(time, y, x) ;
        TB:long_name = "brightness temperature intensity (TBh+TBv)/2 " ;
        TB:units = "K" ;
        TB:scale_factor = 1.f ;
        TB:missing_value = -999.f ;
        TB:coordinates = "longitude latitude" ;
    float TB_uncertainty(time, y, x) ;
        TB_uncertainty:long_name = "brightness temperature uncertainty defined as one
standard deviation of TB devided by the sqrt(nPair)" ;
        TB_uncertainty:units = "K" ;
        TB_uncertainty:scale_factor = 1.f ;
```

```
            TB_uncertainty:missing_value = -999.f ;
            TB_uncertainty:coordinates = "longitude latitude" ;
      float Tsurf(time, y, x) ;
            Tsurf:long_name = "SMOS derived snow surface temperature  " ;
            Tsurf:units = "K" ;
            Tsurf:scale_factor = 1.f ;
            Tsurf:missing_value = -999.f ;
            Tsurf:coordinates = "longitude latitude" ;
      float Sice(time, y, x) ;
            Sice:long_name = "Bulk ice salinity " ;
            Sice:units = "psu" ;
            Sice:scale_factor = 1.f ;
            Sice:missing_value = -999.f ;
            Sice:coordinates = "longitude latitude" ;
      short nPair(time, y, x) ;
            nPair:long_name = "number of TBh and TBv pairs available" ;
            nPair:missing_value = -999 ;
            nPair:coordinates = "longitude latitude" ;
      float RFI_ratio(time, y, x) ;
            RFI_ratio:units = "percent" ;
            RFI_ratio:long_name = "percent of RFI-contaminated measurements in total
measurements" ;
            RFI_ratio:missing_value = -999.f ;
            RFI_ratio:coordinates = "longitude latitude" ;
      byte land(time, y, x) ;
            land:standard_name = "land_binary_mask" ;
            land:long_name = "land_mask" ;
            land:units = "1" ;
            land:valid_range = 0, 1 ;
            land:coordinates = "longitude latitude" ;
      double time(time) ;
            time:units = "hours since 2010-01-01 00:00:00" ;
            time:standard_name = "time" ;

//global_attributes:
          :title = "Daily gridded sea-ice thickness and auxiliary parameters from satellite L-band
radiometry data";
          :project = "CS2SMOS PDS CR-1: SMOS Sea Ice Data Product Processing and
Dissemination Tasks, supported by ESA";
          :institution = "Alfred-Wegener-Institut Helmholtz Zentrum für Polar und
Meeresforschung (AWI), http://www.awi.de";
          :contributor_name = "Xiangshan Tian-Kunze (AWI), Lars Kaleschke (MPI-M), Robert
Ricker (AWI), Stefan Hendricks (AWI)";
          :publisher_email = "xiangshan.tiankunze@awi.de";
          :platform = "ESA Soil Moisture and Ocean Salinity (SMOS) mission";
          :sensor = "Microwave Imaging Radiometer using Aperture Synthesis (MIRAS)";
```

:source = "SMOS v620 L1C brightness temperature";
:product_version = "3.2";
:processing_level = "l3c";
:grid = "NSIDC polar stereographic projection. http://nsidc.org/data/polar_stereo/ps_grids.html";
:tracking_id = str(uuid.uuid4())
:naming_authority = "de.awi"
:cdm_data_type = "Grid"
:history = "Product generated with SMOS sea ice thickness retrieval Algorithm v3.1";
:summary = "This dataset contains Level-3 daily sea ice thickness products from satellite observations in the northern hemisphere. Northern hemisphere sea ice thickness coverage is limited to the winter month between October and April. 100% sea ice coverage is assumed, which leads to underestimation of sea ice thickness.";
:topiccategory = "Oceans Climatology Meteorology Atmosphere";
:keywords = "Earth Science > Cryosphere > Sea Ice > Ice Depth/Thickness, Earth Science > Oceans > Sea Ice > Ice Depth/Thickness, Earth Science > Climate Indicators > Cryospheric Indicators > Ice Depth/Thickness, Geographic Region > Northern Hemisphere, Vertical Location > Sea Surface, Institutions > AWI > Alfred Wegener Institute for Polar and Marine Research";
:id = "SMOS_Icethickness_v3.2_north_20181019.nc";
:doi = "None";
:date_created = "20181020" ;
:geospatial_lat_min = 50.0;
: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;
:spatial_resolution = " 12.5 km grid spacing";
:geospatial_bounds_crs = "EPSG:3411";
:time_coverage_start = "2018-10-19T00:00:00"
:time_coverage_end = "2018-10-19T23:59:59"
:time_coverage_duration = "P1D"
:time_coverage_resolution = "P1D"
:references = "(1) Kaleschke, L., X. Tian-Kunze, N. Maass, M. Maekynen, and M. Drusch (2012), Sea ice thickness retrieval from SMOS brightness temperatures during the Arctic freeze-up period, Geophys. Res. Lett., 39, L05501, doi:10.1029/2012GL050916. (2) Tian-Kunze, X., Kaleschke, L., Maass, N., Maekynen, M., Serra, N., Drusch, M., and Krumpen, T., SMOS-derived sea ice thickness: algorithm baseline, product specifications and initial verification, The Cryosphere, 8, 997-1018, doi:10.5194/tc-8-997-2014, 2014 (3) Kaleschke, L., Tian-Kunze, X., Maass, N., Beitsch, A., Wernecke, A., Miernecki, M. and others, SMOS sea ice product: operational application and validation in the Barents Sea marginal ice zone, Remote Sensing of Environment 180 (2016), 264-273. doi: 10.1016/j.rse.2016.03.009 (4) Tietsche, S., Alonso-Balmaseda, M., Rosnay, P., Zuo, H., Tian-Kunze, X., and Kaleschke, L.: Thin Arctic sea ice in L-band observations and an ocean reanalysis, The Cryosphere, 12, 2051-2072, https://doi.org/10.5194/tc-12-2051-2018, 2018.";

}

3. Sample data record

Figure 1 shows an example of SMOS sea ice thickness map in the Arctic, on 19 November, 2018.

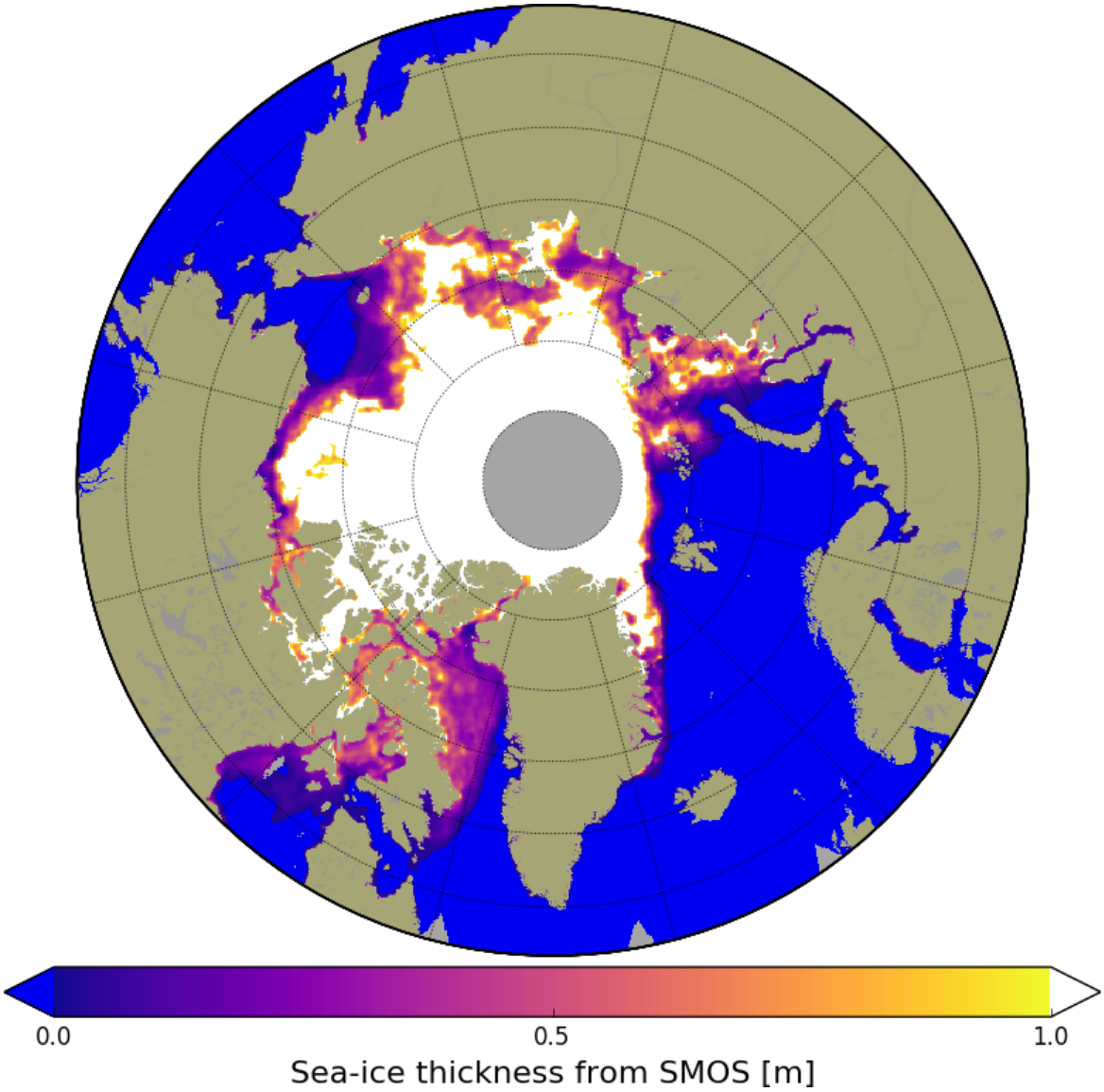

Fig. 1. Sea ice thickness map in the Arctic, 2018.11.19

References

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Menashi, J., Germain, K., Swift, C., Comiso, J., and Lohanick, A.: Low-frequency passive-microwave observations of sea ice in the Weddell Sea, J. Geophys. Res., 98, 22569–22577, 1993.

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.

Tietsche, S., Alonso-Balmaseda, M., Rosnay, P., Zuo, H., Tian-Kunze, X., and Kaleschke, L.: Thin Arctic sea ice in L-band observations and an ocean reanalysis, The Cryosphere, 12, 2051-2072, https://doi.org/10.5194/tc-12-2051-2018, 2018.