Product User Manual for the Global Sea Ice Concentration Level 2

OSI-410

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Document Change record

Document version	Software version	Date	Author	Change description
V0.1	V1.0	15/01/2020	JOL	First version prepared for ORR review
V1.0	V1.0	07/07/2020	RTT	Update after ORR. Text updated to explain uncertainty and status flags. New ncdump of files added.
V1.1	V1.0	21/06/2021	EHO	Filenames corrected after start of test dissemination, section 5.5.

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1. Introduction

1.1. The EUMETSAT Ocean and Sea Ice SAF

The Satellite Application Facilities (SAFs) are dedicated centres of excellence for processing satellite data – hosted by a National Meteorological Service – which utilise specialist expertise from institutes based in Member States. EUMETSAT created Satellite Application Facilities (SAFs) to complement its Central Facilities capability in Darmstadt. The Ocean and Sea Ice Satellite Application Facility (OSI SAF) is one of eight EUMETSAT SAFs, which provide users with operational data and software products. More on SAFs can be read at www.eumetsat.int.

The objective of the OSI SAF is the operational near real-time production and distribution of a coherent set of information, derived from earth observation satellites, and characterising the ocean surface and the energy fluxes through it: sea surface temperature, radiative fluxes, wind vector and sea ice characteristics. For some variables, the OSI SAF is also aiming at providing long term data records for climate applications, based on reprocessing activities.

The OSI SAF consortium is hosted by Météo-France. The sea ice processing is performed at the High Latitude processing facility (HL centre), operated jointly by the Norwegian and Danish Meteorological Institutes. The sea ice products include sea ice concentration, the sea ice emissivity at 50 GHz, sea ice edge, sea ice type and sea ice drift and sea ice surface temperature (from mid 2014).

1.2. Disclaimer

All intellectual property rights of the OSI SAF products belong to EUMETSAT. The use of these products is granted to every interested user, free of charge. If you wish to use these products, EUMETSAT's copyright credit must be shown by displaying the words "Copyright © <YYYY> EUMETSAT" or the OSI SAF logo on each of the products used.

Note : The comments that we get from our users is an important input when defining development activities and updates, and user feedback to the OSI SAF project team is highly valued.

Acknowledgement and citation

Use of the product(s) should be acknowledged with the following citations (product specific):
OSI-410 : OSI SAF (2020): Global Sea Ice Concentration Level 2, EUMETSAT SAF on Ocean and Sea Ice.

1.3. Scope of this document

This document is targeted at OSI SAF product users and describes the Level 2 sea ice concentration product (OSI-410).

This document gives an overview of the processing sets involved in producing the sea ice concentration products, the specification of the product and the how it may be accessed. For the AMSR-2 product, two sea ice products are generated: one using the TUD algorithm and another using with the OSHD algorithm. The OSHD product is the primary product and is recommend for operational systems. The TUD product is using the near 90GHz channels and is therefore more susceptible to noise. Because the TUD algorithm is using the near 90 GHz channels it has higher resolution that the OSHD. because of the low resolution of the reference data set used for validation the difference in resolution does not show up in the validation results (see RD.2). For the SSMIS product only one sea ice product is generated using the OSHD algorithm.

The products are delivered up to 15 times per day for each SSMIS satellite, and 30 times per day for AMSR-2. The difference in frequency is due to differences in the frequencies of the reception of input data. SSMIS is received once each full orbit while AMSR-2 is received per half-orbit. The OSI-410 products are generated out of approximately 15 SSMIS swaths per day using three satellites and 29 AMSR2 swaths per day together with NWP data from ECMWF. The input data, in the case of SSMIS it is received from EUMETSAT via EUMETCast, in the case of AMSR2 it is downloaded directly from JAXA and in the case of NWP it is received from ECMWF. There is a one to one correspondence between all level 1 input files and level 2 sea ice concentration output files. The brightness temperatures are not resampled before computing the sea ice concentration. This means that there are up to 75 files per day, one for each orbit and each of the SSMIS satellites and two for each orbit and the AMSR2 satellite.

The level 3 sea ice concentration product (OSI-401) is available 6 hours after midnight on the following days morning. Data used in the level 3 product are collected for a full day from 00 to 24 hours. The requirements to the level 2 product timeliness is that the products should be available to the user 220 minutes after satellite overpass. In practise, it is expected that the products can be available much faster than that.

The sea ice concentration algorithm is presented in the algorithm theoretical basis document [RD.1]. This document gives an overview of the processing scheme, a description of the product and how it may be accessed. The validation results of the methodology are presented in the validation report [RD.2].

1.4. Reference and applicable documents

1.4.1. Reference documents

[1] EUMETSAT OSI SAF
Algorithm Theoretical Basis Document for Global Sea Ice Concentration Level-2
SAF/OSI/CDOP3/DMI/SCI/MA/341, version 1.2, 15/01/2020

[2] EUMETSAT OSI SAF
Validation Report for Global Sea Ice Concentration Level-2
SAF/OSI/CDOP3/DMI/TEC/MA/378, version 1.0, 15/01/2020

1.4.2. Applicable documents

[1] EUMETSAT OSI SAF
Product Requirements Document
SAF/OSI/CDOP3/MF/MGT/PL/2-001, version 1.4, 20/12/2018

[2] EUMETSAT OSI SAF
Service Specification Document
SAF/OSI/CDOP3/MF/MGT/PL/003, version 1.8, 08/07/2019

1.5. Definitions, acronyms and abbreviations

AMSR	Advanced Microwave Scanning Radiometer
ATBD	Algorithm Theoretical Basis Document
CF	Climate and Forecast (Metadata Conventions)
CLW	Cloud liquid water
DLI	Downward Longwave Irradiance
DMI	Danish Meteorological Institute
ECMWF	European Centre for Medium-Range Weather Forecasts
EDC	EUMETSAT Data Center
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
FTP	File Transfer Protocol
GCMD	Global Change Master Directory
GCOM	Global Change Observation Mission
LDAP	Lightweight Directory Access Protocol
MET Norway	Norwegian Meteorological Institute
NASA	National Aeronautics and Space Administration
NetCDF	Network Common Data Form
NH	Northern Hemisphere
NSIDC	National Snow and Ice Data Center
NWP	Numerical Weather Prediction
OSHD	OSI SAF Hybrid Dynamic
OSI SAF	Ocean and Sea Ice Satellite Application Facility
RMDCN	Regional Meteorological Data Communication Network
RTM	Radiative Transfer Model
SAF	Satellite Application Facilities
SD	Standard deviation
SH	Southern Hemisphere
SMMR	Scanning Multichannel Microwave Radiometer
SSI	Surface Solar Irradiance
SSM/I	Special Sensor Microwave/Imager
SSMIS	Special Sensor Microwave Imager/Sounder
SST	Sea Surface Temperatures
Tb	Brightness temperature
TUD	Technical University of Denmark
UCS	User Coordinate System
WMO	World Meteorological Organization

2. Input data

The product is derived from the Advanced Microwave Scanning Radiometer (AMSR-2) satellite measurements and the SSMIS (Special Sensor Microwave - Imager/Sounder) series of satellites : F16, F17 and F18. For the AMSR-2 based product, two ice concentration fields are computed: the primary one, which is computed with the OSI SAF Hybrid Dynamic (OSHD) ice concentration algorithm and utilises the 19 GHz vertical, 37 GHz vertical and 37 GHz horizontal channels and a second which is computed using the Technical University of Denmark (TUD) algorithm with the 19 GHz vertical, 37 GHz vertical, 89 GHz vertical, and 89 GHz horizontal channels. For the SSMIS based product, one ice concentration field is computed using the OSHD algorithm. These algorithms are described in the Algorithm Theoretical Basis Document (ATBD) [RD.1]. The OSHD product uses the same frequency channels and ice concentration algorithm as the SSMIS OSI SAF product, whereas the TUD product utilizes the high frequency channels and therefore is more susceptible to noise due to water vapour but then it has higher spatial resolution.

3. Product input data

The Level 2 product is computed from SSMIS and AMSR-2 Level 1 data. SSMIS and AMSR-2 instruments are polar orbiting conically scanning radiometers. The AMSR-2 has a larger antenna, giving it a higher spatial resolution.

3.1. SSMIS

SSMIS is the successor to the Special Sensor Microwave/Imager (SSM/I). SSMIS is flown on board the United States Air Force (DMSP) series of satellites, F-16, F-17, F-18 and F-19, which came into operation on November 2005, March 2008, March 2016 and May 2016, respectively (however, F-19 has not been operational since February 2016). The SSMIS instrument has a 0.8 m diameter antenna, a constant incidence angle of 53.1° and a swath width of about 1700 km. The instrument has 24 channels from 19 to 183 GHz; the sea-ice concentration algorithm uses the channels given in Table 1.

Centre freq. (nominal) (GHz)	Polarization	Bandwidth (MHz)	Footprint (km x km)	Sampling Interval (km)
19.35 (19)	V	356	42.4 × 70.1	12.5
37 (37)	H & V	1.580	27.5 × 44.2	

Table 1: SSMIS channels used in the sea ice concentration algorithms.

3.2. AMSR-2

AMSR-2 is the successor to ADEOS-II and AMSR for EOS (AMSR-E). The AMSR-2 instrument was launched in May 2012. The instrument has a 2 m diameter antenna, a constant incidence angle of 55° and a swath width of 1450 km. The instrument has channels covering from 6.925 GHz to 89.0 GHz, with both horizontal and vertical polarizations. The sea-ice concentration algorithms use the channels given in Table 2.

Centre freq. (nominal) (GHz)	Polarization	Bandwidth (MHz)	Footprint (km x km)	Sampling Interval (km)
18.70 (19)	V	200	14 × 22	10
36.50 (37)	H & V	1.000	7 × 12	
89.00 (89)	V	3.000	3 × 5	5

Table 2: AMSR-2 channels used in the sea ice concentration algorithms. The footprint size is the instantaneous footprint size.

3.3. NWP data and radiative transfer model correction

The brightness temperatures (Tb) are corrected explicitly for emission from the geophysical noise sources, including air temperature, wind roughening over open water and water vapour in the atmosphere, prior to the calculation of ice concentration. The correction uses a radiative transfer model function (RTM) and NWP data. Over areas with both ice and water the influence of open water roughness on the Tbs and the ice emissivity is scaled linearly with the ice concentration. The emissivity of ice is given by standard tie-point emissivities (Comiso et al. 1997). The correction procedure is described in the ATBD [RD.1] and in Andersen et al. (2006A). The NWP model grid points are co-located with the satellite swath data in time and space and a correction to the Tbs is applied. The ECMWF High Resolution Atmospheric Model is used, which has a native resolution of 9 km and a time resolution of three hours; the closet 3-hour forecast is used.

The representation of atmospheric liquid water column in the NWP data is not suitable for use with the Tb correction (see Andersen et al., 2006A). The issue has been revisited several times but the conclusion from the reference still holds. The Cloud Liquid Water (CLW) is an important error source in SIC retrieval over open water and in the mixed zone and its representation in the NWP is problematic. Over near 100% ice it is not important. It is highly correlated with other error sources e.g. water vapour in the atmosphere and it is therefore hard to quantify each individual error source. The problem is that the representation of CLW in the NWP model data is not sufficiently quantified or co-located with the satellite observations and the inclusion of CLW adds noise rather than reducing it. The Tbs are therefore not corrected for the influence of CLW. It is constrained to zero in the RTM. The RTM is described in Wentz and Meissner, 2000 and this specific implementation is described in the ATBD [RD.1].

4. Processing scheme

This section describes the steps in the OSI SAF 410 sea ice concentration processing scheme. The Level 1 swath data is processed to produce the Level 2 sea ice concentration product.

For the AMSR-2 product, two ice concentration fields are produced: one computed using the OSHD algorithm and another using the TUD. The SSMIS product file files only have one field, from the OSHD algorithm. The OSHD algorithm utilizes the 19 GHz and 37 GHz channels. The TUD utilizes the 89

GHz, 19 GHz and 37 GHz channels, falling back on only the 19 GHz and 37 GHz channels in regions with low ice concentration.

This main step contains all processing done on the original swath data, without re-sampling or averaging. Numerical Weather Prediction (NWP) data from ECMWF HRES model were interpolated in time and space to the position of each brightness temperature swath grid point. The NWP model has a spatial resolution of ~9 km and temporal resolution of 3 hours.

4.1. Dynamical tie-points

Using the channels featured on the AMSR-2 and SSMIS instruments in combination with the radiative characteristics of sea ice, it is possible to distinguish Arctic multiyear and first-year ice concentrations during winter. In order to achieve this it is necessary to provide typical emissivities or brightness temperatures, called tie-points, of ice and open water. Errors and inconsistencies in the estimated ice concentrations may arise when deviations from the tie-point emissivities occur over time due to e.g. melting, flooding, snow cover effects and wind roughening of the ocean surface as well as spatially due to geographical differences in chemical and physical conditions. Nevertheless, tie-point sets, supplied with the various sea ice concentration algorithms, are usually hemispheric and constant in time, although Comiso et al. (1997) have defined sets to cover the summer period for the Bootstrap algorithm. Finally, it is common to define the water tie-point based on minimum observed brightness temperatures, corresponding to a minimum atmospheric influence. However, due to the average atmospheric contribution, this results in a bias over open water and frequent spurious ice concentrations. In order to improve on this, here we use dynamical tie-points based on the actual mean signatures of ice and of open water. The dynamical tie-point method described in the ATBD [RD.1] uses principal component analysis to determine clusters of sea ice and open water.

The swath data for one day is collected and every swath brightness temperature is corrected for atmospheric influence. An initial estimate of the ice concentration is then computed by the NASA Team ice concentration algorithm. The following sea ice parameters are computed:

- The number of near 100% sea ice brightness temperature data points
- The number of open water (near the ice edge) brightness temperature data points
- Using a principal component analysis in the space spanned by the brightness temperatures:
    - the coordinates of the open water tie-point
    - the vector describing the ice line

Dynamic tie-points are used in both the OSHD and TUC algorithms. A weighted hemispheric mean over the last 30 days is computed based on the daily information. The 30 day mean is then used as the tie-point in the sea ice concentration algorithm. The 30 days window is a compromise between capturing the rapid tie-point changes observed at the onset of melt and avoiding the influence of individual weather systems affecting the signatures on shorter time-scales. In addition, the 30 day period is consistent with the OSISAF sea ice climate dataset which uses the same methodology and tie-point selection method.

4.2. Estimation of sea ice concentration

The OSHD and TUC algorithms which are used to compute the sea ice concentration are described in the ATBD [RD.1].

4.3. Climatology and land mask

Monthly climatology fields of maximum sea ice extent are provided by NSIDC (see http://nsidc.org for details). The ice extents from which the climatology mask is derived can be download from ftp://sidads.colorado.edu/DATASETS/NOAA/G02135/. This dataset is currently based on data from SMMR and SSM/I spanning the period from 1979 through 2019.

The Global Self-consistent, Hierarchical, High-resolution Geography Database (GSHHG) (shown in Figure 1) is used to mask out observations over land.

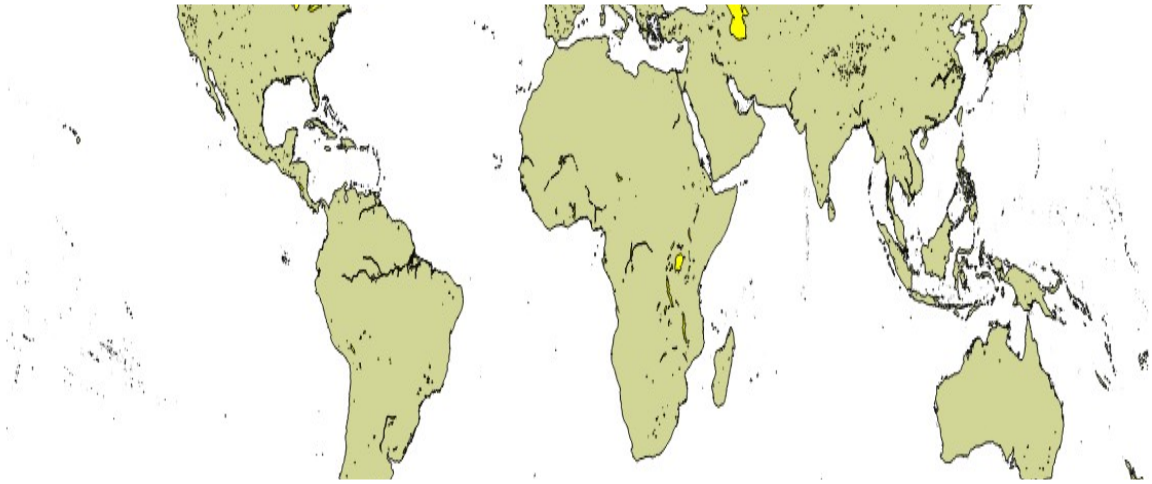

Figure 1: The land mask used to mask land pixels in the Level 2 product

Ice is only calculated for lakes which have areas greater than 15,000 km^2 and only for months 1, 2, 3, 4 and 12, otherwise the ice concentration is set to zero over the regions of the lakes that are not masked out.

Measurement which are near land can be affected by land spil-over. Land spill-over is due to the contamination of the sea pixel measurements by emissions from land, due to the instrument's field of view intersecting with the land (Markus, T. et al. 2009). Land spill-over is not corrected for in the Level 2 product and therefore measurements which are near the land are less reliable.

4.4. Sea ice concentration uncertainties

Uncertainty estimates are needed when the ice concentration data are compared to other data sets or when the ice concentrations are assimilated into numerical models. The mean accuracy of some of the more common algorithms, used to compute ice concentration from SSM/I data, such as NASA Team and Bootstrap are reported to be 1-6 % in winter (Andersen et al., 2006B). In summer the uncertainties are much larger and melt-ponds are included as part of the open water fraction (Kern et al., 2016). This is also achieved with the OSHD algorithm measured as the standard deviation of the difference relative to a reference (open water or 100% ice).

Atmospheric emission and scattering is an error source for retrievals in atmospheric windows. Additionally, tie points are only representative on a hemispheric scale, and deviations from the typical ice and water signatures. Deviations from the typical surface emission signatures result in ice concentration uncertainties.

The AMSR-2 instrument has large footprints on the ground, and the algorithms with the lowest sensitivity to both atmospheric and surface emissivity variability use Tb's at different frequencies with different footprint sizes. Representing these large footprints on a finer, predefined grid results in a representativeness error. This is sometimes called smearing. Additional sources of error are the geolocation error, sensor noise, drift, and sea ice variability over the sampling period.

The representativeness error is computed as a function of ice concentration using a model Tonboe (2016). The tie-point uncertainty (which is the algorithm uncertainty) including residual atmospheric noise, sensor noise and ice surface emissivity variability, is derived from measurements. The total uncertainty is the square root of the sum of the uncertainties squared components:

$$\varepsilon_{total}^2 = \varepsilon_{algorithm}^2 + \varepsilon_{smearing}^2,$$

where the algorithm uncertainty is the inherent uncertainty of the concentration algorithm and the smearing uncertainty due to re-sampling to a grid where the sensor footprint covers more than one pixel. These are the three uncertainties given in the ice concentration product. The sea ice concentration uncertainty algorithm is described in detail in the ATBD [RD.1].

5. Product description

This chapter gives a description of the product specification, metadata, data formats and product distribution.

5.1. Product specification

The product consists of these major fields:

- sea ice concentration
- algorithm uncertainty

Sea ice concentration

Sea ice concentration indicates the fraction of a given ocean grid point covered by ice. It is given as a decimal number, with range from 0-100%.

Uncertainties

The algorithm uncertainty, the smearing uncertainty and the resulting total uncertainty of each sea ice concentration grid cell value are given in three separate fields. These, absolute, uncertainties are given in percentages, with a range from 0-100%. The algorithm is described in the ATBD [RD.1]. The uncertainties are described in detail section 7 of the ATBD. The total uncertainty consists of two independent components: 1) the algorithm uncertainty including instrument and geophysical noise, and 2) the representativeness uncertainty which is computed with an algorithm and includes the radiometer footprint mismatch error. The per pixel uncertainties are spatially and temporally varying and given as a 68% confidence interval i.e. one standard deviation around the SIC value.

5.2. Product sample

Figures 2 and 3 show a plots of the AMSR2 and SSMIS Level 2 sea ice concentration product.

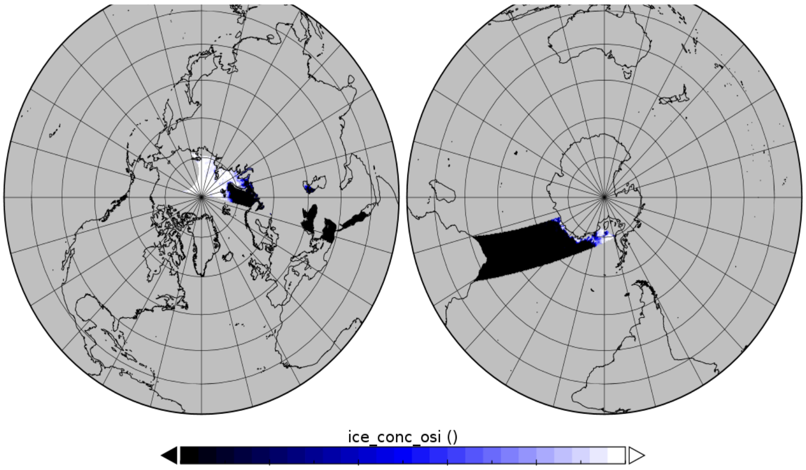

Figure 2: A plot of the Level 2 product from the AMSR2 satellite derived from the OSHD algorithm.

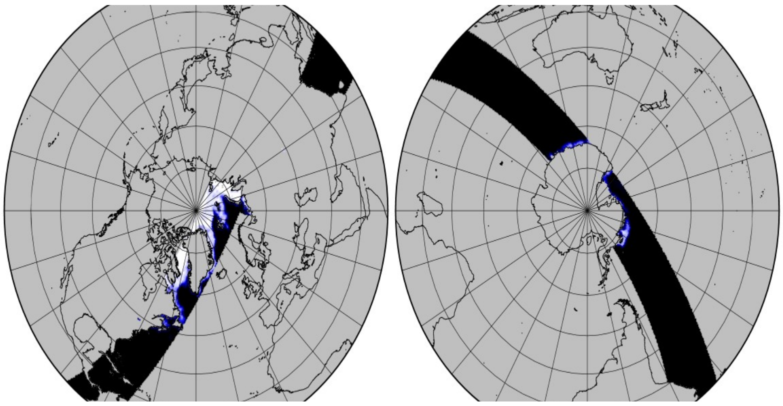

Figure 3: A plot of the Level 2 product from the SSMIS satellite derived from the OSHD algorithm.

5.3. File formats

NetCDF4 format

The NetCDF4 format is a public format, with documentation available at:

https://unidata.github.io/netcdf4-python/netCDF4/index.html

The OSI SAF sea ice products use the CF 1.6 standard for metadata in the NetCDF4 files. The metadata in the NetCDF4 files are described in Appendix A.

5.4. Data distribution

There are two main sources for obtaining the OSI SAF Sea Ice products in near-real time; by FTP or through EUMETCast.

At the OSI SAF Sea Ice FTP server [ftp://osisaf.met.no/prod/ice] the products are available in NetCDF format. Here products from the last month are available. In addition, there is a separate directory with an archive of all previously produced sea ice products (up to the last available product) at [ftp://saf.met.no/archive/ice]. The file name convention for these products is given in the table Section 5.5.

Different file name conventions have been chosen for the Sea Ice products at EUMETCast since many different products are disseminated through EUMETCast. More information on the EUMETCast and EDC dissemination can be found in the EUMETSAT product navigator: http://navigator.eumetsat.int/

5.5. Filename convention

File name convention for Level-2 NetCDF4 files on OSI SAF FTP and server	
Ice concentration AMSR-2	ice_conc_l2_amsr2_gw1_<date12>.nc
Ice concentration SSMIS	ice_conc_l2_ssmis_XXX_<date12>.nc

<date12>: Date and time of the product on format YYYYMMDDhhmm, e.g. 201501011200.
XXX: Corresponding to the operating satellite F16, F17 and F18.

Only the OSHD-algorithm product (in NetCDF format) will be distbributed through EUMETCast, not the TUD product. The following table gives the file name convention used for the product disseminated through EUMETCast.

File name convention for Level-2 files through EUMETCast	
Sea Ice Product: NetCDF	
Ice concentration ASMR2	S-OSI_-DMI_---AMSR2_L2-CONC__-<date12>Z.nc.gz
Ice concentration SSMIS	S-OSI_-DMI_-SSMIS18_L2-CONC__-<date12>Z.nc.gz S-OSI_-DMI_-SSMIS17_L2-CONC__-<date12>Z.nc.gz S-OSI_-DMI_-SSMIS16_L2-CONC__-<date12>Z.nc.gz

6. References

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Andersen, S., R. Tonboe, S. Kern, and H. Schyberg. Improved retrieval of sea ice total concentration from spaceborne passive microwave observations using Numerical Weather Prediction model fields: An intercomparison of nine algorithms. *Remote Sensing of Environment104, 374-392*, 2006A.

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Comiso J.C, D.J. Cavalieri, C.L. Parkinson, and P. Gloersen. Passive microwave algorithms for sea ice concentration: A comparison of two techniques. *Remote Sensing of Environment* 60, 357-384, 1997.

Comiso J.C. Characteristics of arctic winter sea ice from satellite multispectral microwave observations. *Journal of Geophysical Research* 91(C1), 975-994, 1986.

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Kern, S., Rösel, A., Pedersen, L. T., Ivanova, N., Saldo, R., and Tonboe, R. T.: The impact of melt ponds on summertime microwave brightness temperatures and sea ice concentrations, The Cryosphere Discuss., doi:10.5194/tc-2015-202, in review, 2016.

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Smith, D. M. Extraction of winter sea ice concentration in the Greenland and Barents Seas from SSM/I data. *International Journal of Remote Sensing 17*(13), 2625-2646, 1996.

Tonboe, R. T., Eastwood, S., Lavergne, T., Sørensen, A. M., Rathmann, N., Dybkjær, G., Pedersen, L. T., Høyer, J. L., and Kern, S.: The EUMETSAT sea ice concentration climate data record, The Cryosphere, 10, 2275–2290, https://doi.org/10.5194/tc-10-2275-2016, 2016.

Wentz, F. J. A well-calibrated ocean algorithm for SSM/I. *Journal of Geophysical Research* 102(C4), 8703-8718, 1997.

Appendix A: Sea Ice products in NetCDF format

The OSI SAF Sea Ice products have been made available in NetCDF4 format.
Below is an example of the NetCDF header of a AMSR2 derived sea ice concentration file, computed using the OSHD and TUD algorithm.

```
netcdf file: ice_conc_l2_amsr_gw1_202007120446.nc {
  dimensions:
    time = 1;
    atrack = 2036;
    xtrack = 243;
  variables:
    float ice_conc_tud(time=1, atrack=2036, xtrack=243);
      :_FillValue = -999.0f; // float
      :least_significant_digit = 2L; // long
      :coordinates = "dtime lat lon";
      :_ChunkSizes = 1, 2036, 243; // int

    float ice_conc_osi(time=1, atrack=2036, xtrack=243);
      :_FillValue = -999.0f; // float
      :least_significant_digit = 2L; // long
      :coordinates = "dtime lat lon";
      :_ChunkSizes = 1, 2036, 243; // int

    float algorithm_uncertainity_tud(time=1, atrack=2036, xtrack=243);
      :least_significant_digit = 2L; // long
      :_FillValue = -999.0f; // float
      :coordinates = "dtime lat lon";
      :_ChunkSizes = 1, 2036, 243; // int

    float algorithm_uncertainity_osi(time=1, atrack=2036, xtrack=243);
      :_FillValue = -999.0f; // float
      :least_significant_digit = 2L; // long
      :coordinates = "dtime lat lon";
      :_ChunkSizes = 1, 2036, 243; // int

    float smearing_uncertainity_tud(time=1, atrack=2036, xtrack=243);
      :least_significant_digit = 2L; // long
      :_FillValue = -999.0f; // float
      :coordinates = "dtime lat lon";
      :_ChunkSizes = 1, 2036, 243; // int

    float smearing_uncertainity_osi(time=1, atrack=2036, xtrack=243);
      :_FillValue = -999.0f; // float
      :least_significant_digit = 2L; // long
      :coordinates = "dtime lat lon";
      :_ChunkSizes = 1, 2036, 243; // int

    float total_uncertainity_tud(time=1, atrack=2036, xtrack=243);
      :least_significant_digit = 2L; // long
      :_FillValue = -999.0f; // float
      :coordinates = "dtime lat lon";
      :_ChunkSizes = 1, 2036, 243; // int

    float total_uncertainity_osi(time=1, atrack=2036, xtrack=243);
      :_FillValue = -999.0f; // float
      :least_significant_digit = 2L; // long
      :coordinates = "dtime lat lon";
      :_ChunkSizes = 1, 2036, 243; // int

    byte status_flag(time=1, atrack=2036, xtrack=243);
      :flag_descriptions = "bit 0 (no bits set): no flags are set\nbit 1: ice concentration
algorithm applied over lake\nbit 2: missing value due to over land\nbit 3: mask for sea ice maximum
climatology set";
      :flag_meanings = "lakemask landmask imask";
      :flag_values = 0, 1, 2, 3; // int
      :coordinates = "dtime lat lon";
      :long_name = "flags bitmask";
```

```
      :_FillValue = -1UB; // byte
      :_Unsigned = "true";
      :_ChunkSizes = 1, 2036, 243; // int

    long time(time=1);
      :standard_name = "time";
      :long_name = "reference time of product";
      :units = "seconds since 1978-01-01 00:00:00";
      :calendar = "gregorian";
      :_CoordinateAxisType = "Time";

    short dtime(atrack=2036, xtrack=243);
      :comment = "time plus dtime gives seconds since 00:00:00 UTC January 1, 1978";
      :standard_name = "delta_time";
      :long_name = "time difference from reference time";
      :units = "seconds";
      :_ChunkSizes = 2036, 243; // int

    float lat(atrack=2036, xtrack=243);
      :standard_name = "latitude";
      :long_name = "latitude";
      :units = "degrees_north";
      :_FillValue = -999.0f; // float
      :least_significant_digit = 6L; // long
      :_ChunkSizes = 2036, 243; // int
      :_CoordinateAxisType = "Lat";

    float lon(atrack=2036, xtrack=243);
      :_FillValue = -999.0f; // float
      :least_significant_digit = 6L; // long
      :standard_name = "longitude";
      :long_name = "longitude";
      :units = "degrees_east";
      :_ChunkSizes = 2036, 243; // int
      :_CoordinateAxisType = "Lon";

  // global attributes:
  :institution = "EUMETSAT OSI SAF";
  :orbit_number = 43365; // int
  :satellite = "gw1";
  :history = "Created 2020-07-17 08:10:24";
  :fromfile = "GW1AM2_202007120447_228D_L1SGBTBR_2220220.h5";
  :start_date = "2020-07-12 04:46:29";
  :stop_date = "2020-07-12 05:37:21";
  :title = "Level-2 Sea Ice Concentration Analysis from OSI SAF EUMETSAT";
  :product_id = "OSI-410";
  :product_name = "osi_saf_ice_conc_l2";
  :product_status = "operational";
  :abstract = "The Level-2 analysis of sea ice concentration is obtained from operation satellite
images of the polar regions. It is based on atmospherically corrected signal and a carefully
selected sea ice concentration algorithm. This product is freely available from the EUMETSAT Ocean
and Sea Ice Satellite Application Facility (OSI SAF).";
  :topiccategory = "Oceans Climatology Meteorology Atmosphere";
  :keywords = "Sea Ice Concentration, Sea Ice, Oceanography, Meteorology, Climate, Remote Sensing";
  :gcmd_keywords = "Cryosphere > Sea Ice > Sea Ice Concentration, \nOceans > Sea Ice > Sea Ice
Concentration, \nVertical Location > Sea Surface, \nEUMETSAT/OSISAF > Satellite Application Facility
on Ocean and Sea Ice, European Organisation for the Exploitation of Meteorological Satellites";
  :activity_type = "Space borne instrument";
  :area = "Global";
  :instrument_type = "AMSR2";
  :platform_name = "GW1";
  :project_name = "EUMETSAT OSI SAF";
  :PI_name = "Rasmus Tonboe";
  :contact = "osisaf-manager@met.no";
  :distribution_statement = "Free";
  :copyright_statement = "Copyright 2020 EUMETSAT";
  :references = "Product User Manual for OSI SAF Global Sea Ice Concentration, \nRasmus Tonboe et
al. (editor), \nv1.0, May 2019, \nhttp://www.osi-saf.org";
  :product_version = "1.0";
  :software_version = "1.0";
  :netcdf_version = "4.6.0";
```

```
  :Conventions = "CF-1.6";
  :_NCProperties = "version=2,netcdf=4.6.3,hdf5=1.10.4";
  :_CoordSysBuilder = "ucar.nc2.dataset.conv.CF1Convention";
}
```

Below is an example of the NetCDF header of a SSMIS derived sea ice concentration file.

netcdf file: ice_conc_l2_ssmi_f18_202007170625.nc {

```
  dimensions:
    time = 1;
    atrack = 1617;
    xtrack = 90;
  variables:
    float algorithm_uncertainty(time=1, atrack=1617, xtrack=90);
      :_FillValue = -999.0f; // float
      :least_significant_digit = 2L; // long
      :coordinates = "dtime lat lon";
      :_ChunkSizes = 1, 1617, 90; // int

    float smearing_uncertainty(time=1, atrack=1617, xtrack=90);
      :_FillValue = -999.0f; // float
      :least_significant_digit = 2L; // long
      :coordinates = "dtime lat lon";
      :_ChunkSizes = 1, 1617, 90; // int

    float total_uncertainty(time=1, atrack=1617, xtrack=90);
      :_FillValue = -999.0f; // float
      :least_significant_digit = 2L; // long
      :coordinates = "dtime lat lon";
      :_ChunkSizes = 1, 1617, 90; // int

    float ct_osi_hybrid_stddev_total_sh_10(time=1, atrack=1617, xtrack=90);
      :_FillValue = NaNf; // float
      :coordinates = "dtime lat lon";

    float ice_conc(time=1, atrack=1617, xtrack=90);
      :_FillValue = -999.0f; // float
      :least_significant_digit = 2L; // long
      :coordinates = "dtime lat lon";
      :_ChunkSizes = 1, 1617, 90; // int

    float surf_l(time=1, atrack=1617, xtrack=90);
      :coordinates = "dtime lat lon";
      :_FillValue = NaNf; // float
      :_ChunkSizes = 1, 1617, 90; // int

    float surf_l_a(time=1, atrack=1617, xtrack=90);
      :coordinates = "dtime lat lon";
      :_FillValue = NaNf; // float
      :_ChunkSizes = 1, 1617, 90; // int

    byte status_flag(time=1, atrack=1617, xtrack=90);
      :flag_values = 0, 1, 2, 3, 4, 5, 6; // int
      :flag_descriptions = "bit 0 (no bits set): no flags are set\nbit 1: ice concentration
algorithm applied over lake\nbit 2: missing value due to over land\nbit 3: mask for sea ice maximum
climatology set\nbit 4: coastal region\nbit 5: near coastal region\nbit 6: open water filter set";
      :flag_meanings = "lakemask landmask imask coast near_coast owf";
      :coordinates = "dtime lat lon";
      :long_name = "flags bitmask";
      :_FillValue = -1UB; // byte
      :_Unsigned = "true";
      :_ChunkSizes = 1, 1617, 90; // int

    long time(time=1);
      :standard_name = "time";
      :long_name = "reference time of product";
      :units = "seconds since 1978-01-01 00:00:00";
      :calendar = "gregorian";
      :_CoordinateAxisType = "Time";
```

```
    short dtime(atrack=1617, xtrack=90);
      :long_name = "time difference from reference time";
      :comment = "time plus dtime gives seconds since 00:00:00 UTC January 1, 1978";
      :standard_name = "delta_time";
      :units = "seconds";
      :_ChunkSizes = 1617, 90; // int

    float lat(atrack=1617, xtrack=90);
      :standard_name = "latitude";
      :long_name = "latitude";
      :units = "degrees_north";
      :_FillValue = -999.0f; // float
      :least_significant_digit = 6L; // long
      :_ChunkSizes = 1617, 90; // int
      :_CoordinateAxisType = "Lat";

    float lon(atrack=1617, xtrack=90);
      :standard_name = "longitude";
      :long_name = "longitude";
      :_FillValue = -999.0f; // float
      :least_significant_digit = 6L; // long
      :units = "degrees_east";
      :_ChunkSizes = 1617, 90; // int
      :_CoordinateAxisType = "Lon";

  // global attributes:
  :institution = "EUMETSAT OSI SAF";
  :orbit_number = 55423; // int
  :satellite = "DMSP F18";
  :history = "Created 2020-07-17 08:50:06";
  :fromfile = "W_XX-EUMETSAT-Darmstadt_SOUNDING+SATELLITE_DMSPF18+SSMIS_C_EUMS_202007170625--
_E0807_ENVIRO.bin.nc";
  :start_date = "2020-07-17 06:25:08";
  :stop_date = "2020-07-17 08:07:43";
  :title = "Level-2 Sea Ice Concentration Analysis from OSI SAF EUMETSAT";
  :product_id = "OSI-410";
  :product_name = "osi_saf_ice_conc_l2";
  :product_status = "operational";
  :abstract = "The Level-2 analysis of sea ice concentration is obtained from operation satellite
images of the polar regions. It is based on atmospherically corrected signal and a carefully
selected sea ice concentration algorithm. This product is freely available from the EUMETSAT Ocean
and Sea Ice Satellite Application Facility (OSI SAF).";
  :topiccategory = "Oceans Climatology Meteorology Atmosphere";
  :keywords = "Sea Ice Concentration, Sea Ice, Oceanography, Meteorology, Climate, Remote Sensing";
  :gcmd_keywords = "Cryosphere > Sea Ice > Sea Ice Concentration, \nOceans > Sea Ice > Sea Ice
Concentration, \nVertical Location > Sea Surface, \nEUMETSAT/OSISAF > Satellite Application Facility
on Ocean and Sea Ice, European Organisation for the Exploitation of Meteorological Satellites";
  :activity_type = "Space borne instrument";
  :area = "Global";
  :instrument_type = "SSMIS";
  :platform_name = "DMSP F18";
  :project_name = "EUMETSAT OSI SAF";
  :PI_name = "Rasmus Tonboe";
  :contact = "osisaf-manager@met.no";
  :distribution_statement = "Free";
  :copyright_statement = "Copyright 2020 EUMETSAT";
  :references = "Product User Manual for OSI SAF Global Sea Ice Concentration, \nRasmus Tonboe et
al. (editor), \nv1.0, May 2019, \nhttp://www.osi-saf.org";
  :product_version = "1.0";
  :software_version = "1.0";
  :netcdf_version = "4.6.0";
  :Conventions = "CF-1.6";
  :_NCProperties = "version=2,netcdf=4.6.3,hdf5=1.10.4";
  :_CoordSysBuilder = "ucar.nc2.dataset.conv.CF1Convention";
}
```