Ocean & Sea Ice SAF

# Global Sea Ice Concentration Climate Data Record

# Product User Manual

Product OSI-450

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# Documentation Change Record

| Document version | Data set version | Software version | Date | Change Description |
|---|---|---|---|---|
| v1.0 draft | v2.0 | v5.2 | 17.02.2017 | First version of PUM for OSI-450 |
| v1.0 | v2.0 | v5.2 | 22.03.2017 | Updated after review |

The software version number gives the corresponding version of the OSI SAF High Latitude software chain which was used to produce the reprocessing data set.

# CONTENTS

# 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.

OSI SAF produces (on an operational basis) a range of air-sea interface products, namely: wind, sea ice characteristics, Sea Surface Temperatures (SST), Surface Solar Irradiance (SSI) and Downward Longwave Irradiance (DLI). 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).

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.

**Note:** The ownership and copyrights of the data set belong to EUMETSAT. The data is distributed freely, but EUMETSAT must be acknowledged when using the data. EUMETSAT's copyright credit must be shown by displaying the words "copyright (year) EUMETSAT" on each of the products used. We welcome anyone to use the data. 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.

## 1.2 Scope

This report is the user documentation for the (OSI-450) OSI SAF Global Sea Ice Concentration Climate Data Record released in early 2017. It gives a high-level overview of the input data used and the processing steps involved, but is more importantly a reference for how the product files are formatted and named. Geographical and temporal coverage are described, in addition to known limitations of this data record.

## 1.3 Overview

OSI-450 is the second major version of the OSI SAF Global Sea Ice Concentration Climate Data Record. The first version was called OSI-409, and was initiated in 2006 through visiting scientist activities with the UK Met Office (Stark, 2008) and NSIDC (Meier, 2008). OSI-409 was extended at several occasions, using operational SSMIS and ECMWF data after 2009, but keeping the algorithms and processing chains unchanged. It is described in Tonboe et al. 2016. Appendix D gives an overview of the main differences and similarities between OSI-450 and OSI-409.

OSI-450 is a full reprocessing of sea ice concentration, with improved algorithms and an upgraded processing chain, covering the period 1979 to 2015. The sea ice concentration is computed from the SMMR (1979-1987), SSM/I (1987-2008), and SSMIS (2006-2015) instruments, as well as ECMWF ERA-Interim data. The basic principles that were the backbone of OSI-409 are also on board OSI-450 (e.g. atmospheric correction of brightness temperature with NWP re-analysis data, dynamic tie-points, uncertainties, etc.) but they were all revisited through dedicated R&D in the OSISAF project and, notably, through the ESA CCI Sea Ice projects.

*Figure 1: The ESA Climate Change Initiative Sea Ice project contributed to OSI-450 through a number of algorithm developments.*

From 2013 to 2018, the two ESA CCI Sea Ice projects conducted a series of thorough algorithms intercomparison exercises (Ivanova et al. 2015). They concluded that the methods and algorithms implemented in OSI-409 were the best available. In addition, they contributed to a number of algorithm developments and improvements that directly transfer into the OSI-450 algorithm baseline. In particular, OSI-450 uses the SICCI2LF algorithm that was developed during the ESA CCI Sea Ice projects. The SICCI2LF algorithm is a fully dynamic algorithm that optimizes its coefficients to minimize residual noise and achieve zero bias. It improves upon the OSISAF “hybrid” algorithm (Tonboe et al. 2016) that was used for OSI-409. This also includes additional available open water filters for reduction of false ice. These algorithms are all documented in the ATBD for OSI-450. In exchange for algorithm improvements, the OSISAF offered re-use of its processing software for production of a complementary CDR by SICCI, based on the AMSR-E and AMSR2 instruments (2002-2011 and 2012-2015). The SICCI dataset is released and available from the ESA CCI Data Portal (http://cci.esa.int/data). Potential users of the SICCI dataset are invited to visit the project's webpages (www.esa-seaice-cci.org).

## 1.4 Glossary

| **Acronym** | **Description** |
|---|---|
| AMSR | Advanced Microwave Scanning Radiometer |
| ATBD | Algorithm Theoretical Basis Document |
| CCI | Climate Change Initiative |
| CDOP | Continuous Developments and Operations Phase |
| CDR | Climate Data Record |
| DMI | Danish Meteorological Institute |
| DMSP | Defence Meteorological Satellite Program |
| ECMWF | European Centre for Medium range Weather Forecast |
| ESA | European Space Agency |
| EUMETSAT | European Organization for the Exploitation of Meteorological Satellites |
| FCDR | Fundamental Climate Data Record |
| FoV | Field Of View |
| FYI | First Year Ice |
| GR | Gradient Ratio |
| MET | Norwegian Meteorological Institute |
| NASA | National Aeronautics and Space Administration |

| | |
|---|---|
| NH | Northern Hemisphere |
| NSIDC | National Snow and Ice Data Center |
| NWP | Numerical Weather Prediction |
| OSI SAF | Ocean and Sea Ice Satellite Application Facility |
| OWF | Open Water Filter |
| PCR | Product Consolidation Review |
| RTM | Radiative Transfer Model |
| SAR | Synthetic Aperture Radar |
| SH | Southern Hemisphere |
| SIC | Sea Ice Concentration |
| SICCI | ESA CCI Sea Ice project |
| SMMR | Scanning Multichannel Microwave Radiometer |
| SSM/I | Special Sensor Microwave/Imager |
| SSMIS | Special Sensor Microwave Imager Sounder |
| Tb | Brightness Temperature |
| TBC | To Be Confirmed |
| TBD | To Be Determined |
| TBW | To Be Written |
| WF | Weather Filter |

## *1.5 Applicable documents*

[RD-1] OSI SAF CDOP-2 Product Requirement Document, v3.7

[RD-2] OSI SAF Global Sea Ice Concentration Climate Data Record (OSI-450) Algorithm Theoretical Basis Document (ATBD), v1.1

# 2. Input data

This chapter describes the SMMR, SSM/I and SSMIS satellite data as well as numerical weather prediction (NWP) data used for atmospheric correction of the brightness temperature. The SMMR, SSM/I, and SSMIS data are all from the Fundamental Climate Data Record (FCDR) V3 (2016) from the EUMETSAT Climate Monitoring Satellite Application Facility (CM-SAF, DOI: 10.5676/EUM_SAF_CM/FCDR_MWI/V003).

## *2.1 The SMMR data*

The Scanning Multichannel Microwave Radiometer (SMMR) instrument on board the Nimbus 7 satellite operated from October 1978 to August 1987 (Gloersen et al., 1992). The instrument was operated only every second day, due to power supply limitations. The instrument had 10 channels, from the six Dicke radiometers, at five frequencies (6.6, 10.7, 18.0, 21.0, 37.0 GHz) and vertical and horizontal polarization. The scanning across track was ensured by tilting the reflector from side to side while maintaining constant incidence angle on the ground of about 50.2°. The scan track on the ground formed a 780 km wide arc in front of the satellite (Gloersen and Barath, 1977). Because of the satellite orbit inclination and swath width there is no coverage poleward of 84°. The SMMR instrument is further described in http://nsidc.org/data/docs/daac/smmr_instrument.gd.html and in the CM-SAF documentation (Fennig et al 2015).

| **Frequency (GHz)** | **Polarizations** | **Sampling** (average) | **Field of view** | |
|---|---|---|---|---|
| | | | **Along-track** | **Cross-track** |
| 6.6 | H,V | 25 km | 148 km | 95 km |
| 10.7 | H,V | 25 km | 91 km | 59 km |
| 18.0 | H,V | 25 km | 55 km | 41 km |
| 21.0 | H,V | 25 km | 46 km | 30 km |
| 37.0 | H,V | 25 km | 27 km | 18 km |

*Table 1: Characteristics of the Nimbus 7 SMMR channels (Gloersen and Barath, 1977).*

## *2.2 The SSM/I data*

The Special Sensor Microwave/Imager (SSM/I) sensors on board the Defence Meteorological Satellite Program (DMSP) started its record with the F08 satellite on 9th July 1987, shortly before the SMMR ceased to operate on 20th August 1987. The different SSM/I instrument records are summarised in Table 2. The SSM/I is a total power radiometer, with a conical scan measuring the upwelling radiation from the Earth at a constant incidence angle of about 53.1° at 7 different channels. The channels are summarised in Table 3. The swath width is about 1400km, leading to a reduced size of the pole hole for SSM/I compared to SMMR, with missing data polewards of 87°.

The Special Sensor Microwave/Imager (SSM/I) data set used for this reprocessing was prepared by EUMETSAT CM SAF and covers the period of available satellites with SSMI/I instruments from 1987 to 2008 with daily data. The different satellites and covered periods are listed in Table 2. Note that the dates in Table 2 are for the available SSM/I data in the CM-SAF FCDR. The lifetime of the instruments or platforms might be longer.

The SSM/I instrument has five low frequency channels similar to SMMR. In addition, two higher frequency channels, with twice the sampling rate, are available on the SSM/I. The characteristics of these channels are listed in Table 3. The 85 GHz channels had a malfunction on F08, so they are only useful starting with the F10 satellite. The 85 GHz are not used for OSI-450.

| Satellite | Period covered |
|---|---|
| F08 | Jul 1987 – Dec 1991 |
| F10 | Jan 1991 - Nov 1997 |
| F11 | Jan 1992 – Dec 1999 |
| F13 | May 1995 – Dec 2008 |
| F14 | May 1997 – Aug 2008 |
| F15 | Feb 2000 – Jul 2006 |

*Table 2: The different satellite missions carrying the SSM/I instrument and the periods they cover.*

The instruments are intercalibrated and processed separately, with overlaps between them treated during the daily gridding of the results.

| Frequency (GHz) | Polarizations | Sampling | Footprint size | |
|---|---|---|---|---|
| | | | Along-track | Cross-track |
| 19.35 | H,V | 25 km | 69 km | 43 km |
| 22.235 | V | 25 km | 50 km | 40 km |
| 37.0 | H,V | 25 km | 37 km | 28 km |
| 85.5 | H,V | 12.5 km | 15 km | 13 km |

*Table 3: Characteristics of the different SSM/I channels (from Wentz, 1991).*

Readers interested in the processing, calibration and quality check steps applied in the FCDR will find many more details in the CM-SAF documentation (Fennig et al 2015).

## *2.3 The SSMIS data*

The SSMIS is a polar orbiting conically scanning radiometer with constant incidence angle around 53.1° and a swath width of about 1700 km. With this swath width the pole hole is further reduced with data missing polewards of 89° latitude. It has window channels near 19, 37, 91, and 150 GHz and sounding channels near 22, 50, 60, and 183 GHz. All channels are available in both H and V polarization. The OSI-450 is using brightness temperature swath data of the 19V, the 37V and the 37H channels. At these channels, the SSMIS frequencies, sampling, geometry, and field-of-view are identical as those of the SSM/I (see above). Daily data from three DMSP platforms are used in OSI-450: F16 (Nov 2005 - Dec 2013), F17 (Dec 2006 - Dec 2015), and F18 (Mar 2010 - Dec 2015).

## *2.4 The ERA-Interim data*

The brightness temperatures (Tb) are corrected explicitly for atmospheric contribution to the radiation. The correction uses a Radiative Transfer Model function (RTM) and requires atmosphere re-analysis data. For OSI-450, we use the global 3-hourly fields from ECMWF's ERA-Interim (Dee et al., 2011), which are accessed from the MARS archive. Note that ERA 40 and ECMWF operational forecasts were instead used in the OSI-409 series.

The following prognostic variables are taken from the ERA-Interim files and collocated with satellite swath data: wind speed, 2m air temperature, and total column water vapour.

# 3. Processing scheme

This chapter briefly describes all the processing steps in the OSI SAF sea ice concentration reprocessing scheme. The processing steps can be divided in three main steps; Level 1 and 2, Level 3 and Level 4. An overview of these three steps is shown in Figure 2, and the scope of each step is presented in more detail in the next three sections. A more detailed description of the steps and the science behind can be found in the ATBD [RD-2].

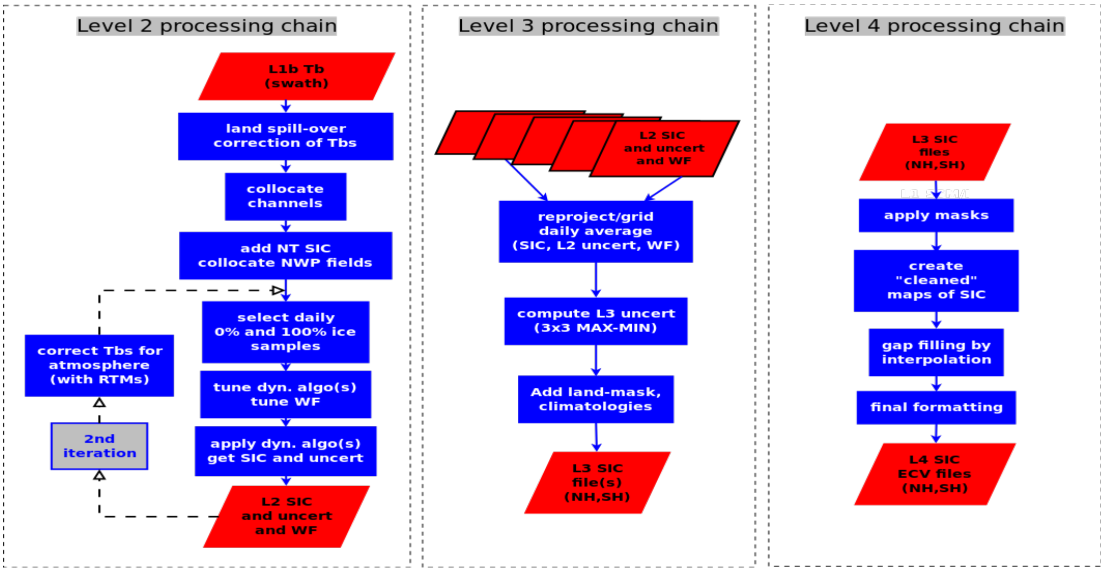


*Figure 2: The three main processing elements in the ice concentration processing chain. The processing is the same for all three data inputs; SMMR, SSM/I and SSMIS. WF in this image is the Open Water Filter (OWF).*

## 3.1 L1/L2 processing

This main step contains all processing done on the original swath data, without any gridding or averaging.

After the data has been decoded from daily CMSAF FCDR files to internal swath files there are two pre-processing steps, first the land spill-over correction of the brightness temperatures and then collocation of the data. When these steps are completed then the level 2 processing chain can start.

The Level 2 chain is where the scientific core of the data record is implemented. This includes the dynamic tuning of tie-points and algorithms, the RTM correction of the brightness temperatures for influence from the atmosphere, the computation of the sea ice concentration and algorithm uncertainties, as well as tuning of the open water filter.

More details are available in the ATBD [RD-2].

## 3.2 L3 processing

This main step contains the gridding of the swath data to daily fields, the calculation of uncertainties from smearing and gridding, and the preparation of land and climatology masks. The corrections and masking fields are not applied to the sea ice concentration field at this stage.

### 3.3 L4 processing

The final step involves spatial or temporal interpolation in areas of missing data as well as the application of masks and corrections. This includes setting some concentrations to zero, where they are either outside the climatological maximum extent (see Appendix A) or are to be removed by the open water filter. This produces the final ice concentration product. The processing status flag variable (section 4.1.4) is also computed during these steps.

# 4. Product description

This chapter gives a description of the product specification, meta data, data format and product availability.

## 4.1 Product specification

The product files contain six variables (in addition to latitude, longitude, time, and other CF-related information):

- main (filtered) sea ice concentration (`ice_conc`)
- raw sea ice concentration values (`raw_ice_conc_values`)
- total uncertainty (`total_standard_error`)
- smearing uncertainty (`smearing_standard error`)
- algorithm uncertainty (`algorithm_standard_error`)
- status flag (`status_flag`)

The definitions of these fields are given in the sections below. These fields are all covering the same grid.

### 4.1.1 Sea ice concentration (ice_conc)

Sea ice concentration is the ocean area fraction of a cell covered by sea ice. It is given as a real number in percentage, with a range from 0-100%. An example is shown in Figure 3. This variable holds sea ice concentration maps after several filters (e.g. the open water filter) and post-processing steps (e.g. interpolation) have been applied. It is the main variable for users of this Climate Data Record.

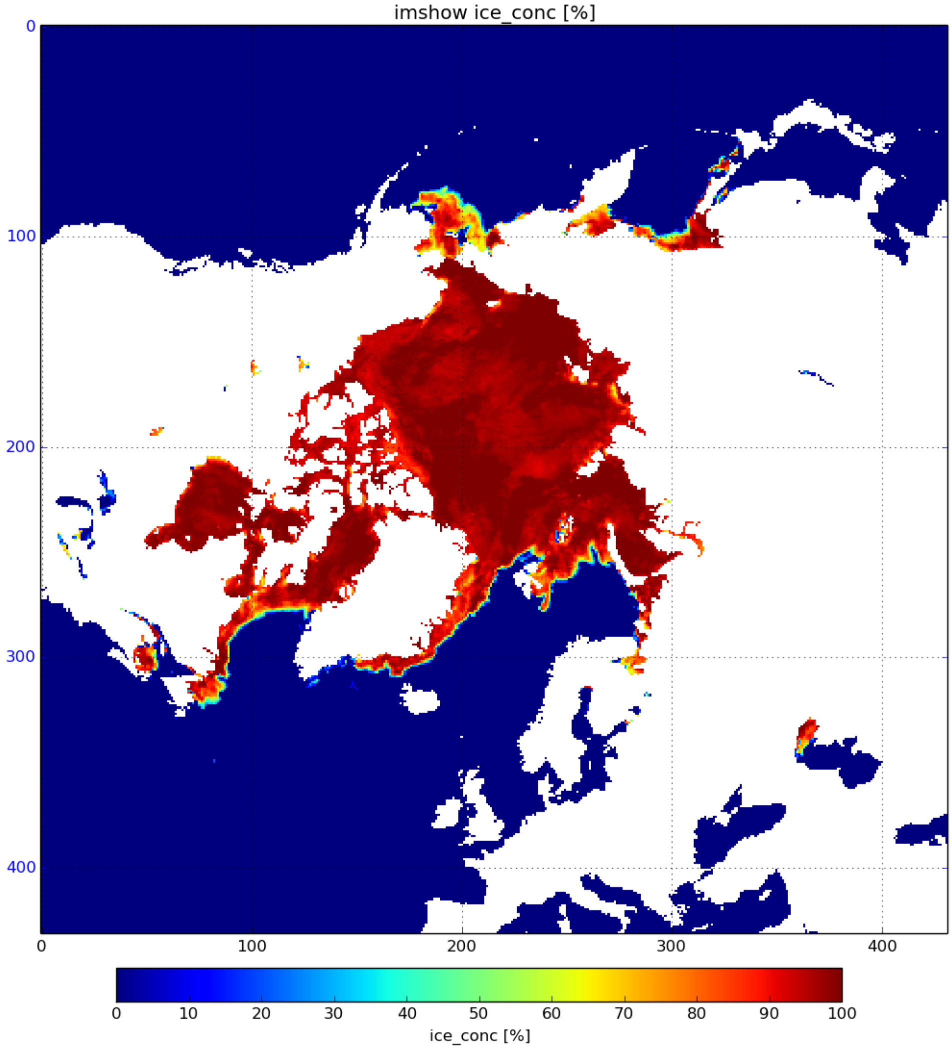


*Figure 3: Sea ice concentration on 16th February 2015*

### *4.1.2 Raw sea ice concentration values*

Variable `raw_ice_conc_values` contains the original ("raw") values of the sea ice concentration where it has been altered during the filtering process in the level 4 step. For example, if the concentration was set to 0 in `ice_conc` due to the open water filter, then the original (raw) value will be available here. This variable is masked outside the maximum sea ice climatology and where the sea ice concentration is unaltered. This variable can also contain un-physical ice concentration values such as values below 0% and above 100%. **This variable is for use by more advanced users**, who can take advantage of information with less filtering applied, e.g. via Data Assimilation techniques. An example can be seen in Figure 4.

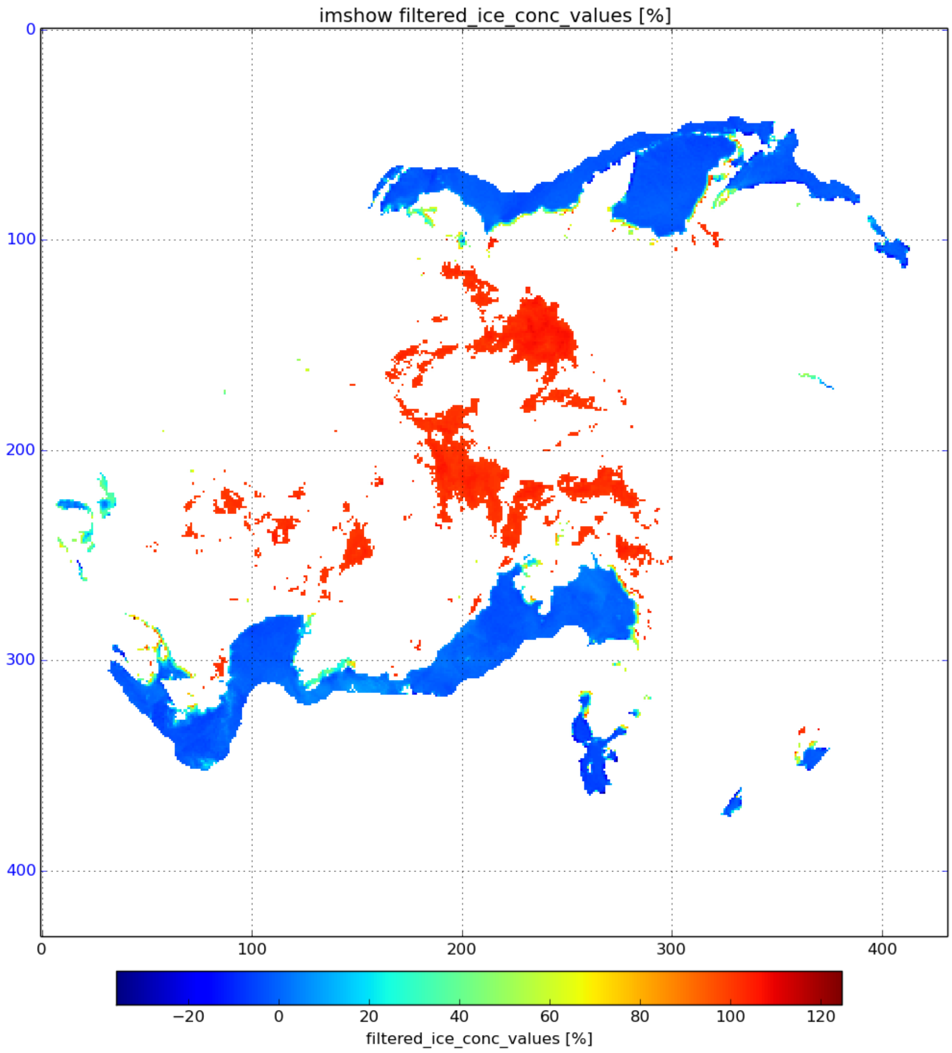


*Figure 4: Raw sea ice concentration values from 16th February 2015*

Another example of raw_ice_conc_values variable is shown in Figure 5. The blue belt is the region where the open water filter was triggered. The corresponding grid cells in variable `ice_conc` will show exactly 0%, removing a lot of the weather-induced noise in this region (values in the range -4%;+4%). Note also how a few pixel wide zone of potentially true, low concentration sea ice (+5%;+15%) is removed by the filter. This is the major drawback of using open water filters (*aka* weather filters) for sea ice concentration filtering: some true ice is removed at the marginal ice zone (see section 4.7.1).

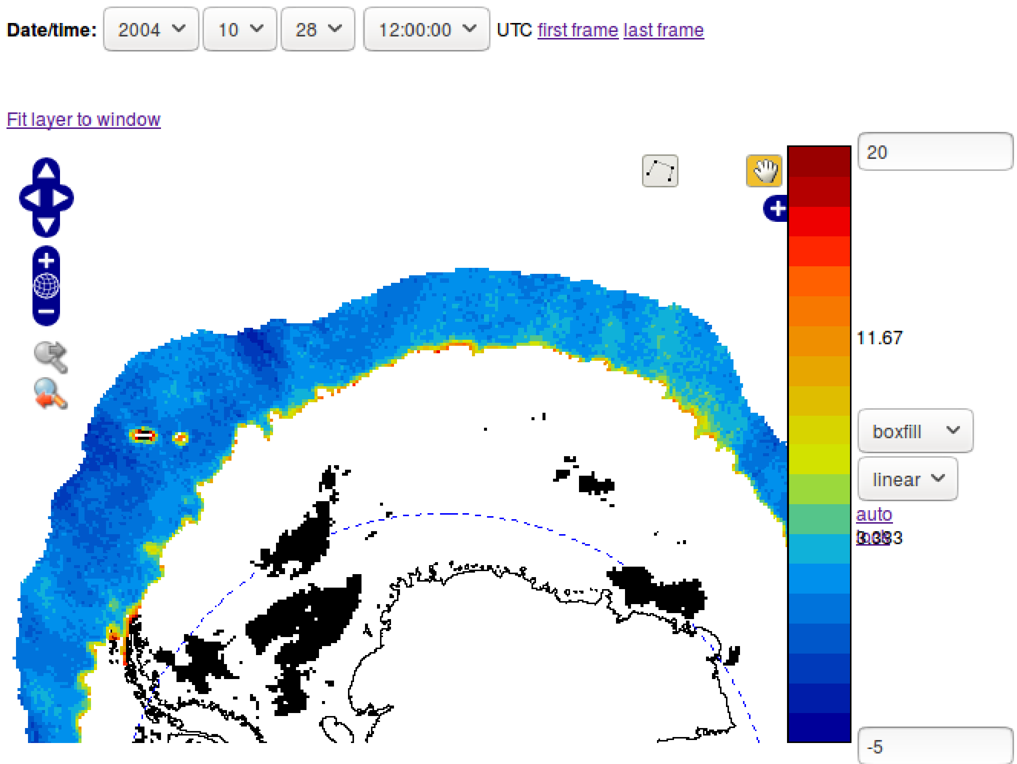


*Figure 5: Example of raw_ice_conc_values field on 28th October 2004 in the Southern Hemisphere. The blue belt is where the open water filter was triggered (note the range of the color bar).*

Grid cells near land (e.g. South Georgia, Graham Land) in Figure 5 are not affected by the open water filter, but are present as a result of land spill-over correction.

### *4.1.3 Uncertainty estimates*

An estimate of the uncertainty of the sea ice concentration value in a grid cell is given in the separate standard_error fields. The uncertainty is given as one standard deviation in percentage. An example is shown in Figure 6. Three maps of uncertainty information are provided in each file, the algorithm standard error, the smearing standard error, and the total standard error. The total uncertainty is the combination (the square root of the sum of variances) of the two other components of the uncertainty budget.

More information about the calculation of the uncertainty can be found in the ATBD.

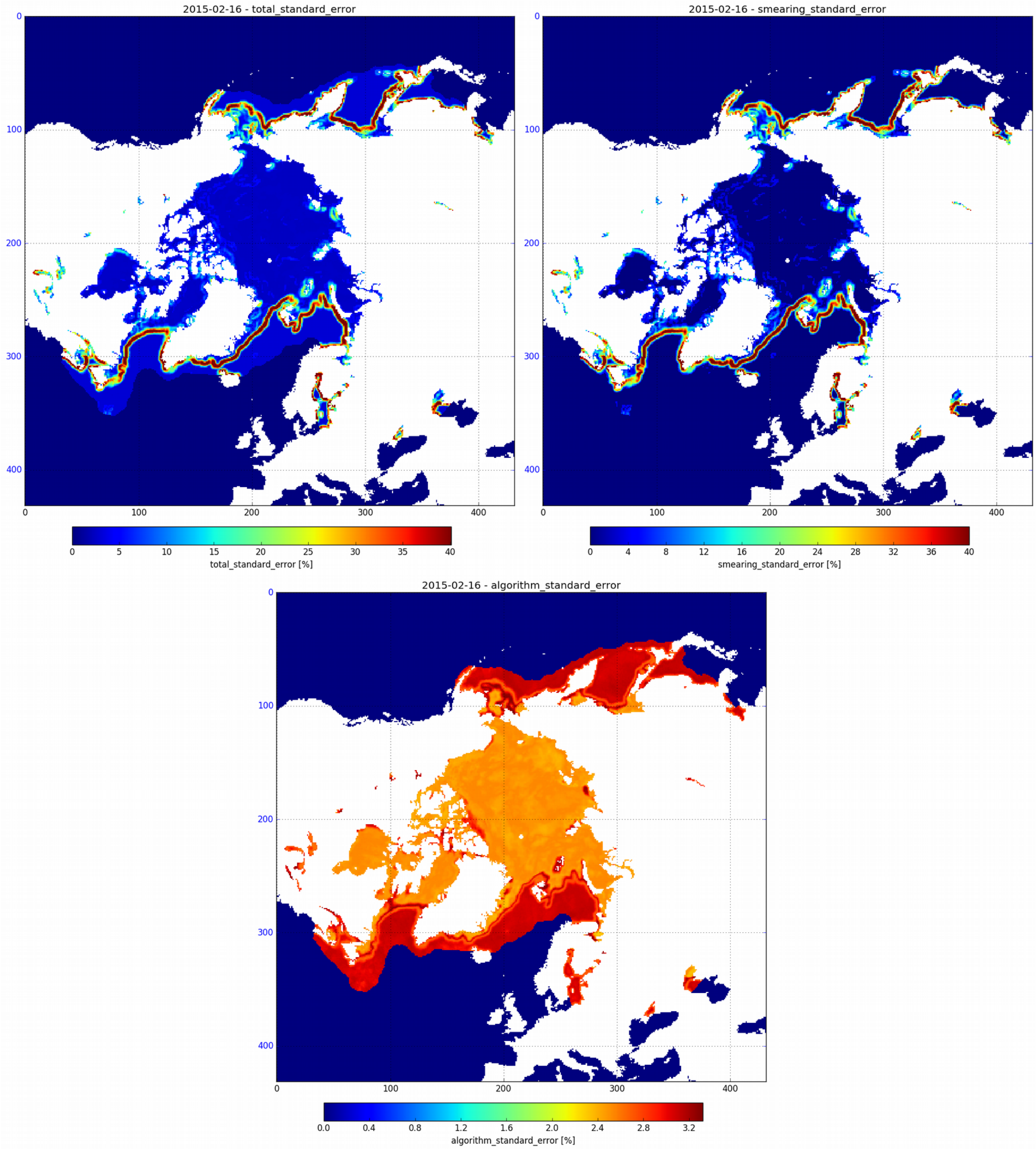


*Figure 6: Total, smearing and algorithm standard errors from 16th February 2015*

### *4.1.4 Status flag*

The status flag contains information about the processing steps that have influenced the ice concentration value. It is coded as a signed character. The different values are described in Table 4.

| Bit Nr | Value | Definition |
|---|---|---|
| 1 | 1 | Position is over land |
| 2 | 2 | Position is lake |
| 3 | 4 | SIC is set to zero by the open water filter |
| 4 | 8 | SIC value is changed for correcting land spill-over effects |
| 5 | 16 | Handle with caution, the 2m air temperature is high at this position, and this might be false ice |
| 6 | 32 | Value is the result of spatial interpolation |
| 7 | 64 | Value is the result of temporal interpolation |
| 8 | 128 | SIC is set to zero since position is outside maximum sea ice climatology |

*Table 4: Definition of sea ice concentration status flag bits.*

This value is a bit array with each bit representing a different status, so grid cell values can be a combination of several statuses. One example of this that may occur is an area where the concentration has been gapfilled using spatial interpolation and where the open water filter kicks in setting the concentration to zero. This cell would then have the value 36 (a combination of the spatial interpolation (32) and open water filter (4) values) since the individual flag values are combined.

Most combinations of flags are theoretically possible, with the exception of the eight (outside maximum climatology) and the first (land) bit that both override other flags in the grid cells. Another excluded possibility is a combination of the third (open water filter) and fourth (land spill-over correction) bit, but this is due to their applicable areas not overlapping. Also, the value in a grid cell can’t be both spatially and temporally interpolated.

## *4.2 Noticeable differences to OSI-409*

Apart from more accurate algorithms and different input data sources, a noticeable difference (amongst others in Table 8 of Appendix D) between OSI-450 and OSI-409 is the new open water filter that has been applied in OSI-450 (see Section 4.7.1 and ATBD for further information). Indeed, the open water regions in OSI-409 exhibited weather induced noise, which is taken away by the open water filter implemented in OSI-450.

As an example, OSI-409 and OSI-450 maps are plotted for the same day (2003-10-01) in figures 7 and 8. At this time of the year, the Baffin Bay is largely ice free, as well as the Southern East Greenland Sea, Southern Laptev Sea, and Southern Kara Sea (as reported by the National Ice Service navigation charts). Nevertheless, on figure 7, OSI-409 exhibits non-zero ice concentration values (light-blue shades) in all these regions. These false sea ice concentration values are caused by atmospheric noise. On the contrary, as seen on figure 8, OSI-450 reports open water in all these regions (exactly 0%). However, these improvements come at the cost of removing some potentially true sea ice along the ice edge, as can be seen for example in the Fram Strait region (see also the discussion in section 4.7.1).

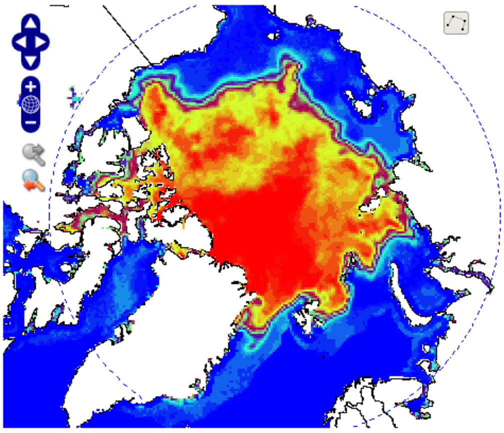

*Figure 7: Example OSI-409 NH ice_conc map for 2003-10-01.*

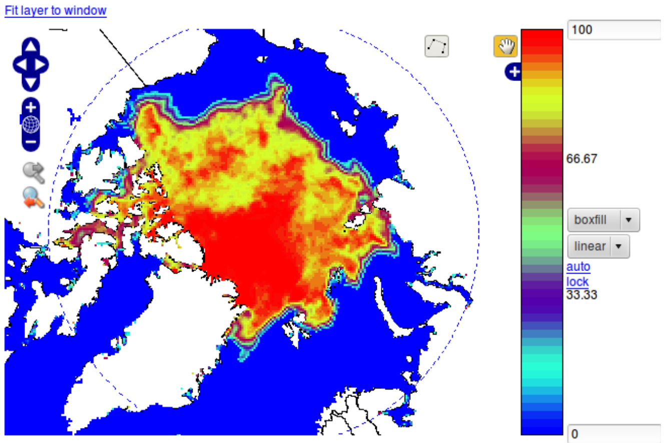


*Figure 8: Same as left panel but from the new OSI-450 record.*

It is fully possible to use the variables `ice_conc`, `raw_ice_conc_values` and `status_flag` from a OSI-450 file to re-create a OSI-409-like ice concentration field should this be required in an application. Users seeking the OSI-409-like sea ice concentration should read the `ice_conc` variable and then replace the values of that with the values from `raw_ice_conc_values` where the `status_flag` indicates that the open water filter has been applied and the `raw_ice_conc_values` is above 0.

## 4.3 Grid specification

For a given day, northern and southern hemisphere maps of sea ice concentration are available in two separate files. For both hemispheres, the sea ice concentration product is presented on a Lambert Azimuthal Equal Area polar projection, with a grid spacing of 25.0 km. The Lambert grid is also called the EASE2 grid, and is used by NSIDC for several of their sea ice and snow products. More documentation about the EASE2 grid can be found on their web site: [http://nsidc.org/data/ease/](http://nsidc.org/data/ease/).

The details of the grid definitions are given in Table 5 and illustrated on Figure 9. Projection definitions in the form of PROJ-4 initialization strings are also given.

| | |
|---|---|
| Projection: | Lambert Azimuthal Equal Area (EASE2) |
| Resolution: | 25.0 km |
| Size: | 432 columns, 432 rows |
| Central Meridian: | 0° |
| Datum/Earth: | WGS84 (a=6378137.0 m , b=6356752.314245 m) |
| PROJ-4 string: | NH: +proj=laea +ellps=WGS84 +datum=WGS84 +lat_0=90 +lon_0=0<br>SH: +proj=laea +ellps=WGS84 + datum=WGS84 +lat_0=-90 +lon_0=0 |

*Table 5: Geographical definition for the EASE2 25.0 km grid, Northern and Southern Hemisphere.*

## 4.4 Meta data specification

The meta data included in the product file are given as NetCDF attributes to the variables and to the file (Global Attributes). Attributes associated to the variables are those required by the CF convention (http://cfconventions.org/), and all attributes follow the Attribute Convention for Data Discovery (ACDD) v1.3 (http://wiki.esipfed.org/index.php/Attribute_Convention_for_Data_Discovery_(ACDD)). NASA GCMD and IMO keywords were also selected.

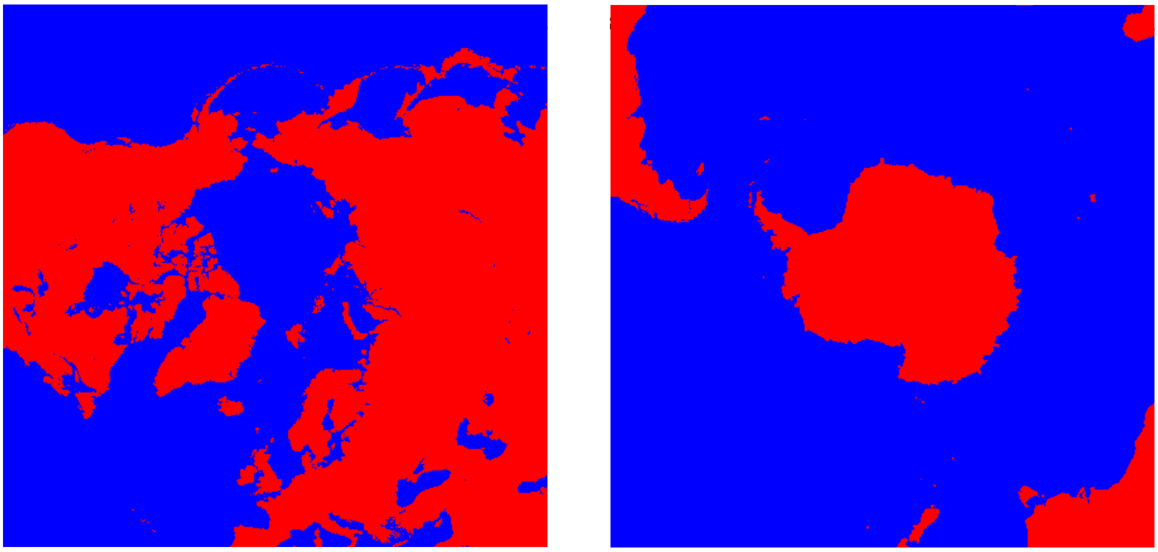

*Figure 9: Area covered by the EASE2 25.0 km grids for Northern (left) and Southern (right) hemispheres.*

## 4.5 File naming convention

### 4.5.1 FTP file name convention

On the OSI SAF FTP server the NetCDF/CF product files have the following naming convention:

ice_conc_<area>_ease2-250_cdr-<version>_<date12>.nc ,

where:

<area> : <nh> (Northern Hemisphere) and <sh> (Southern Hemisphere)

<version> : version (starting at <v2p0>).

<date12> : central date of the analysis <YYYYMMDD1200>, e.g. 199112021200.

### 4.5.2 EUMETSAT Data Centre file name convention

In the EUMETSAT Data Centre the NetCDF product files have the following naming convention:

S-OSI_-NOR_-<prodtype>-GL_<area>_CONC__-<date12>Z.nc.gz ,

where:

<prodtype> : <REPR> for reprocessed data set and <CREP> for continuous reprocessed product

<area> : <NH> (Northern Hemisphere) and <SH> (Southern Hemisphere)

<date12> : central date of the analysis <YYYYMMDD1200>, e.g. 199112021200.

The additional metadata for these files are described in Appendix C.

## 4.6 Product availability

### 4.6.1 Climate data record OSI-450

This OSI SAF sea ice concentration climate data record covers the period from 01.01.1979 to 31.12.2015. Some dates are missing due to lack of satellite data. These dates are listed in Appendix B.

The data set is distributed freely through the OSI SAF Sea Ice FTP server, available at this address:

ftp://osisaf.met.no/reprocessed/ice/conc/v2p0/

The data are organized in year and month directories.

The same data files are serviced through THREDDS, HTTP, OpenDAP, WMS, and netCDF Sub-setter protocols at http://thredds.met.no/thredds/osisaf/osisaf.html.

Finally, the data set is also available in the EUMETSAT Data Centre. More information about this is available here:

http://www.eumetsat.int/website/home/Data/DataDelivery/EUMETSATDataCentre/index.html

### 4.6.2 Continuous updates product (ICDR)

At present there is no continuous update (aka Interim Climate Data Record – ICDR) associated with OSI-450. This is planned for 2018. The ICDR will be reprocessed to 01.01.2016 to avoid data gaps.

### 4.6.3 Associated ESA CCI data record from AMSR-E and AMSR2 data

A global sea ice concentration dataset is prepared for release by the ESA CCI Sea Ice project (http://esa-seaice-cci.org). It uses the same algorithms (and processing chain) as OSI-450 but processes the AMSR-E (2002-2011) and AMSR2 (2012-onwards) satellite sensors. Prospective users are invited to visit the ESA CCI project website to be updated with data release and access the data.

## 4.7 Product limitations

Known limitations of the reprocessed sea ice concentration products are listed in this section. All the aspects listed apply in large extent to the other existing Sea Ice Concentration datasets based on Passive Microwave Radiometer (PMR) measurements. Users of the OSI SAF and other similar data sets, should be fully aware of these so that not to bias their conclusions.

### 4.7.1 Removal of true ice by the open water filters

The open water filter (aka weather filter) implemented in OSI-450 is based on combination of the PMR channels around 19 GHz and 37 GHz (Gloersen and Cavalieri, 1986). Although the filter is efficient at detecting and removing weather-induced noise over open water, it is also known to remove some amount of true low-concentration ice, especially in the marginal ice zone. The tuning of the open water filter is a trade-off between a) ensuring that no weather induced false ice is found in the maps and b) keeping the low range of true sea ice concentration as close to reality. It is also of prime importance that the open water filter is consistent throughout the time-series and across the changes of sensing frequencies.

For OSI-450, a dynamic tuning of the filter was adopted. The tuning is done in such a way that the filter detects as open water (and thus sets 0% in the `ice_conc` variable) 1) all weather-induced false ice over ocean, and 2) true sea ice up to 10% concentration. This 10%

target is however only valid on average atmospheric conditions, and more compact ice might be affected by the filter as well (Andersen et al. 2006B; Ivanova et al. 2015).

See also the discussion in section 4.1.2.

The effect of the open water filter is not included in the uncertainty variables. The uncertainty variables are pertaining to the un-filtered (raw) ice concentration values. It is noted that the open water filters are a new feature of OSI-450, that OSI-409 did not have.

### *4.7.2 Summer melt-ponding*

Virtually all SIC algorithms based on the PMR channels around 19GHz, 37GHz, and 90GHz are very sensitive to melt-pond water on top of the ice. The radiation emitted at these wavelengths comes from a very thin layer which does not allow for distinguishing between ocean water (in leads) and melt water (in ponds). The `ice_conc` variable of OSI-450 thus holds an estimate of 1 minus the open water fraction in each grid cell, irrespective if this water is from ocean or ponds. The impact of melt-pond water on PMR-based ice concentration algorithms was recently discussed in Kern et al. 2016. The mis-interpretation of melt water as open water is not included in the uncertainty variables. The uncertainties embedded in the files are those for “1 minus the open water fraction”.

### *4.7.3 Thin sea-ice*

Concentration of thin sea-ice (< 30cm) is underestimated by most of the “classic” PMR SIC algorithms, due to the radiometric contribution of water below the ice. A complete, 100% cover of thin sea-ice indeed does not act as a radiometric insulator for the PMR frequencies around 19 and 37 GHz that are the base for this OSI SAF dataset, and many others. This is for example discussed in Ivanova et al. 2015.
The mis-interpretation of thin 100% sea ice coverage as ice with a lower concentration is not included in the uncertainty variables.

### *4.7.4 Interpolation of missing values*

The OSI SAF SIC dataset aims at addressing needs from all users needing access to climate sea ice concentration data, from interested general public to climate modelers. It was decided to provide interpolated sea ice concentration values in places where original input satellite data was missing, aiming at most complete daily maps. Both temporal and spatial interpolation is used. The locations where interpolation was used are clearly identified in the status_flag layer (see 4.1.4).
These interpolated sea ice concentration values should generally be used with caution for scientific applications, especially the values obtained from spatial interpolation. The uncertainty variables are not interpolated where data was missing.

### *4.7.5 Grid resolutions*

The OSI-450 data record is presented at 25km grid spacing. However, a spatial sampling of 25 km does not fully represent the true spatial resolution of the product. Indeed, the footprint of the SSM/I channels used in the product are roughly 43x69km at the 19GHz channel and 28x37km at the 37GHz channel (see Table 3). So the true resolution is coarser than the spatial sampling of the product grids.

The mismatch of grid spacing to the true resolution of the instrument footprint is taken into account in the uncertainty model of OSI-450 and is a key contribution to the *smearing* uncertainty. The smearing uncertainty model of OSI-450 is expected to be much more reliable than that of OSI-409.

### *4.7.6 Coastal regions*

The radiometric signature of land is similar to sea ice at the wavelengths used for estimating the SIC. Because of the large foot-prints and the relatively high brightness temperatures of land and ice compared to water, the land signature is “spilling” into the coastal zone open water and it will falsely look as intermediate concentration ice. This land-spill-over effect is corrected for as described in the ATBD. However, this coastal correction procedure is not perfect, and a level of false sea-ice remains along some coastlines. The uncertainty variables have larger values in the coastal regions where land spill-over effects are detected. The land spill-over correction scheme was improved from OSI-409 and OSI-450.

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# 6. Appendix A: Examples of monthly climatological maximum extent masks

Figure 10 shows examples of the climatological maximums. We allow for ice in the purple areas while the red areas are where open water tie-points are collected. Yellow areas are areas also in the open water band but where we don't select tie-point samples.

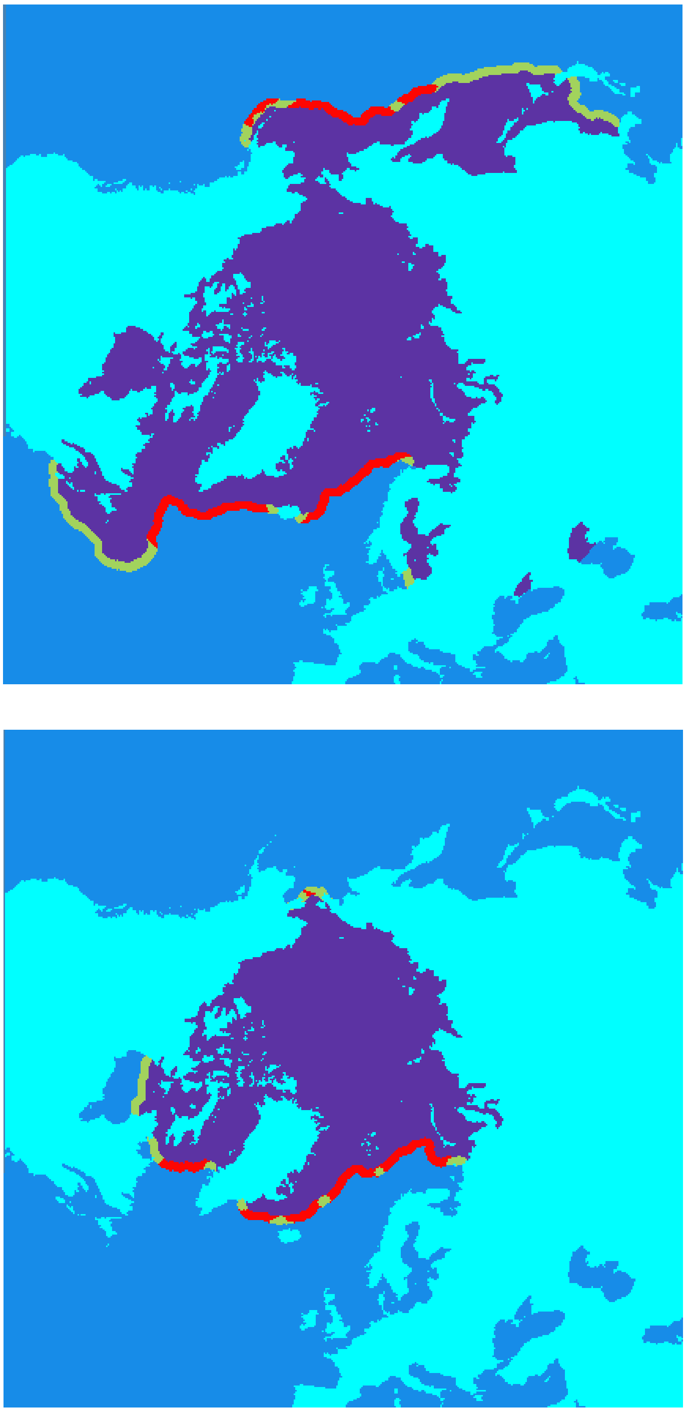

*Figure 10: Climatological maximum sea ice extent during March (upper) and September (lower)*

# 7. Appendix B: Missing dates

The reprocessing data set covers the period from 01.01.1979 to 31.12.2015. During the SMMR period only every second day is available. The SMMR data have been used until 20.08.1987. Table 6 below lists the dates with no product due to lack of satellite data, except the expected missing SMMR days (every second day).

| ***Year*** | ***Missing dates*** |
|---|---|
| ***SMMR*** | |
| 1979 | 21/5-27/5 |
| 1980 | 4/1-10/1, 27/2-4/3, 16/3-22/3, 9/4-15/4 |
| 1981 | 27/2-5/3 |
| 1982 | 14/7-16/7, 30/7-1/8, 3/8-5/8, 15/8-17/8 |
| 1984 | 12/8-24/8 |
| 1985 | 22/9-28/9 |
| 1986 | 29/3-23/6, 8/12-10/12, 16/12-18/12 |
| 1987 | 3/1-15/1, 7/4-9/4 |
| ***SSM/I*** | |
| 1987 | 25/08-26/08, 06/10-07/10, 03/12-31/12 |
| 1988 | 01/01-12/01, 06/05-09/05, 23/09, 25/12-27/12 |
| 1989 | 14/01, 07/06, 21/07 (SH), 22/07-24/07, 23/10 |
| 1990 | 13/08, 25/08-26/08, 21/10-22/10, 26/10-28/10, 21/12 (NH), 22/12-26/12 |
| 2000 | 01/12 |
| ***SSMIS*** | |
| | None |

*Table 6: Dates with no reprocessing product due to lack of satellite data. SMMR (25.10.1978-20.08.1987) was operated every second day and the table shows only the periods with missing SMMR data for more than one day.*

# 8. Appendix C: Meta data list for EUMETSAT Data Centre files

The EUMETSAT Data Centre meta data parameters [RD.6] applicable to the reprocessed OSI SAF Sea Ice Concentration product are listed in Table 7. These meta data parameters are available in XML formatted files, one for each product file. These XML meta data files are available through the EUMETSAT Data Centre.

| ***Short Name*** | ***Attribute Name*** | ***Notes*** |
|---|---|---|
| AAAR | Geographic Area | 'NH' or 'SH' |
| AARF | Archive Facility | UMARF |
| AIID | Instrument ID | 'SSMIS', 'SSM/I' or 'SMMR' |
| APAS | Product Actual Size | In bytes |
| APNM | Product Type | OSICOGBRE |
| ASTI | Satellite ID | Nimbus, F-08, F-10, F-11, F-13, F-14, F-15 or F-17 |
| AVBA | Base Algorithm Version | |
| AVPA | Product Algorithm Version | |
| GDMD | Disposition Mode | O = Operational |
| GGTP | Granule Type | DP = Data Product |
| GNFV | Native Product Format Version | |
| GORT | Orbit Type | LEO |
| GPLV | Processing Level | O3 |
| GPMD | Processing Mode | O = Offline |
| PPRC | Processing Center | OSNMI |
| PPST | Processing End Date and Time | |
| QQOV | Overall Quality Flag | 'OK' or 'NOK' |
| SNIT | Reference Time | |
| SSBT | Sensing Start Date and Time | |
| SSST | Sensing End Date and Time | |

*Table 7: EUMETSAT Data Center metadata parameters applicable to the reprocessed OSI SAF Sea Ice Concentration product.*

# 9. Appendix D: Main differences between OSI-450 and OSI-409

In the Table below, we list some of the main differences (and similarities) between the OSI-409 series (including the ICDR OSI-430) and the new OSI-450. This list is meant to help OSI-409 users that wish to migrate to OSI-450 and need to understand changes between the two. The list is not exhaustive (all the processing chains were revised) and users may observe some differences due to modifications that are not included here. It is recommended to contact the OSI SAF Team whenever you have questions about differences between OSI-409 and OSI-450.

| | OSI-450 | OSI-409 series | Comment |
|---|---|---|---|
| Coverage | Global | *idem* | NH and SH maps in different files |
| Projection and grid-spacing | EASE2 25km | EASE(1) 12.5km and Polar Stereographic 10km | |
| Start Date | Jan 1979 | Oct 1978 | OSI-450 starts with first ERA-Interim date |
| Stop Date | Dec 2015 | Today minus 31 days | The OSI-409 series is extended operationally with the ICDR OSI-430 . An ICDR is also planned for OSI-450. |
| Satellite Sensors | SMMR, SSM/I, SSMIS | *idem* | |
| Source of Satellite Data | EUMETSAT CMSAF FCDR R3 | Mix of Wentz/RSS, and operational data | |
| Intercalibrated and stabilized input satellite data record | Yes (an FCDR) | No (a mix of sources) | |
| Use of all available DMSP platforms | Yes | *idem* | This leads to less data gaps. It is conversely to the NSIDC SIC CDR (that uses one DMSP platform at a time). |
| Source of NWP Re-analysis Data | ECMWF ERA-Interim | Mix of ECMWF ERA-40, and ECMWF operational analysis | |
| Land-mask used | A custom made land-mask starting from a OSTIA 0.05 deg global mask. | A custom made land-mask (source unknown) | The OSI-450 mask is tuned to closely match that of the NSIDC SIC CDR (the NSIDC “SSM/I” 25km Polar Stereographic mask). For OSI-450, on average, this corresponds to setting all EASE2 25x25km grid cells with a |

| | | | |
|---|---|---|---|
| | | | fraction of land lower than 30% to water (and can thus be covered with sea ice). |
| Maximum Ice Extent climatology | A custom monthly climatology based on that of the NSIDC SIC CDR, manually edited, with visual comparison against Climatologies of Canadian and Norwegian Navigational Ice charts. | A custom monthly climatology, based on one from NSIDC, earlier than the NSIDC SIC CDR. | This monthly climatology was fully revisited between OSI-409 and OSI-450. |
| Processing of SIC on swath data | Yes | *idem* | The Level2 SICs are later gridded and daily averaged to the output grids. |
| Brightness Temperature Channels used by the Algorithms | 19GHz (V-pol and H-pol), and 37GHz (V-pol and H-pol). | *idem* | The 4 channels consistently available from SMMR, SSM/I, and SSMIS. |
| SIC algorithms used | SICCI2LF | OSISAF “hybrid” algorithm (itself a combination of Bootstrap Freq-Mode, and Bristol algorithms). | The SICCI2LF algorithm was developed in the ESA CCI Sea Ice project.<br>The NasaTeam algorithm with fixed tie-points is also used to select regions of 100% SIC (to derive dynamic tie-points). |
| Dynamic tuning of the algorithms tie-points | Yes | *idem* | The selection of 0% ice tie-point was revised for OSI-450 to be more representative of weather conditions close to the ice edge. |
| Length of the sliding window for tuning the algorithm tie-points | [-7days;+7days] (15 days) | [-15days;+15days] (31 days) | Shortening the tie-point sliding window allow the 100% ice tie- |

| | | | |
|---|---|---|---|
| | | | point to more closely follow emissivity changes at the onset of melting. |
| Use of NWP data to correct for some of the atmospheric noise, via an RTM. | Yes. Two iterations with double-difference scheme. | *idem* | OSI-409 used the method of Andersen et al. 2006B. It was simplified for OSI-450 (but performs equally). |
| NWP variables used for the RTM correction | 10m wind speed, Total Columnar Water Vapour, Temp at 2m | *idem* | |
| RTM used | Wentz (1997, JGR) | *idem* | |
| Fields of uncertainties (aka standard errors) in the product file | Yes: Three fields in each file (*algorithm* uncertainty component, *smearing* uncertainty component, and *total* uncertainty - the sum in variance of the two components) | *idem* | For OSI-450, the *algorithm* uncertainty methodology was slightly revised to give better results in the mid SIC range. The *smearing* uncertainty was heavily revised and now shows its max. values along the ice edge (where sharp SIC gradients lead to the larger uncertainty). |
| Use of an Open Water Filter (*aka* Weather Filter) | Yes | No | The OWF methodology was developed in the ESA CCI Sea Ice project (and inspired from the Weather Filter of Cavalieri). The tuning of the OWF threshold is dynamic to allow transition across the satellite sensors, and a similar effect across the seasons and |

| | | | |
|---|---|---|---|
| | | | hemispheres. A caveat of the OWF (and WF) is that it might remove true sea ice along the ice edge (on average 10% for OSI-450, but can be up to 20-30% in some conditions). |
| Maps of status flags in the product file | Yes | *idem* | The format and values are very different between OSI-409 and OSI-450. |
| Maps of “raw” SIC values in the product file | Yes | No | In OSI-450, an additional netCDF variable holds SIC values before filters are applied, as well as un-constrained SIC values (i.e. < 0% and > 100%). This extra variable is meant for expert users that can benefit from the full Gaussian/Normal distribution of SIC values, instead of just those limited to the [0%-100%] validity range. |
| Correction of land spill-over effects at swath brightness temperature level | Yes | No | Following Maass and Kaleschke (2010) |
| Correction of land spill-over effects at daily gridded level | Yes | *idem* | The methodology was improved for OSI-450. For both OSI-409 and OSI-450, tuning the correction is a trade-off and can lead to removing true ice at the coast. In OSI-450, the “raw” |

| | | | |
|---|---|---|---|
| | | | SIC values (before land spill-over correction) can be accessed, to help assess if true coastal sea ice was removed. |
| Provides interpolated SIC values where satellite data was missing | Yes | *idem* | The spatio-temporal interpolation was slightly revised for OSI-450. Note that interpolated values are provided to ease display of maps and computation of Sea Ice Extent/Area time-series. They should be used with great care in scientific applications. |
| Compatibility with the ESA CCI Sea Ice Concentration CDR (v2) | Yes | No | The ESA CCI (AMSR based) SIC CDR uses the same algorithms and processing chains as OSI-450. The same grids, climatologies and land-mask were also used. The file format is the same. It was not known how the SIC values in both CDRs compare at the time this document was written. |

*Table 8: Main differences and similarities between OSI-450 and OSI-409.*