Ocean & Sea Ice SAF

Global Sea Ice Edge and Type

Product User's Manual

OSI-402-c & OSI-403-c

Version 2.4

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The EUMETSAT Network of Satellite Application Facilities

OSI SAF

Ocean and Sea Ice

Documentation Change Record

Document version	Software version	Date	Description	Responsible
1.0	5.0	30.01.2015	First version[(1)]	SAA
1.1	5.0	10.04.2015	Amended according to comments from ice review	SAA
1.2	5.0	19.05	Included quality indexes for GRIB format (sec 5.4), and corrected coordinates for grid characteristics (tab 5).	SAA
1.3	5.0	May 2016	Switch from SSMIS-F17 to SSMIS-F18	SAA
2.0	5.0	May 2016	Inclusion of ASCAT-METOP-B and AMSR2-GW1	SAA
2.1	5.1	September 2016	Amended according to comments from ice review	SAA
2.2	5.1	Sep 2017	Products now also available on NetCDF on EUMETCast. GRIB and HDF5 formats will be discontinued on 05-04-2018.	SAA
2.3	5.1	May 2018	Since 04-04-2018, GRIB and HDF5 formats are no longer produced. Products are accessible on NetCDF format only. Included date of release for OSI-402/403-c	SAA, S. Eastwood
2.4	5.2	September 2020	Using new version of sea ice concentration product (OSI-401-b) for dynamical PDFs	SAA, S. Eastwood

The software version number gives the corresponding version of the OSI SAF High Latitude software chain for which the product manual is valid.

(1) While this is the first version of the Product User Manual for the OSI SAF products OSI-402-b and OSI-403-b, the present document is a continuation of the previous Product User Manual for OSI-401-a, OSI-402-a and OSI-403-a, version 3.11, September 2014.

CONTENTS

1. Introduction

1.1 The EUMETSAT Ocean and Sea Ice SAF

For complementing its Central Facilities capability in Darmstadt and taking more benefit from specialized expertise in Member States, EUMETSAT created Satellite Application Facilities (SAFs), based on co-operation between several institutes and hosted by a National Meteorological Service. More on SAFs can be read from www.eumetsat.int.

The Ocean and Sea Ice Satellite Application Facility (OSI SAF) is producing 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, sea ice edge, sea ice type and sea ice drift and sea ice surface temperature (from mid 2013).

The OSI SAF consortium is hosted by Météo-France. Sea ice products are produced at the OSI SAF 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. User feedback to the OSI SAF project team is highly valued. The comments we get from our users is important argumentation when defining development activities and updates. We welcome anyone to use the data and provide feedback.

1.2 Scope

This document is dedicated to the OSI SAF product users and describes organization and layout of the sea ice edge (OSI-402-c) and type products (OSI-403-c).

1.3 Overview

The global sea ice edge and sea ice type products are classification products here given with their associated quality flags:

- Sea ice edge (OSI-402-c) - distinguish between open water, open sea ice and closed sea ice
- Sea ice type (OSI-403-c) - distinguish between first-year sea ice and multi-year sea ice.

Both products are derived from passive microwave and active microwave scatterometer data combined in a Bayesian approach.

In the start of operational production in 2005 the sea ice products used passive microwave data from SSM/I aboard DMSP satellites. In 2009 the ASCAT scatterometer from METOP-A was introduced in the ice edge (OSI-402) and ice type product (OSI-403). In January 2013, the SSM/I data was replaced with SSMIS data, and the products thereby changed label to OSI-402-a and OSI-403-a, respectively. July 2015 the two products improved by introducing a dynamical training data set and changed label to OSI-402-b and OSI-403-b, respectively. For the recent upgrade, OSI-402-c and OSI-403-c, the following new data are introduced to the analysis:

• ASCAT data from Metop-B, which for a period will run parallel with Metop-A.

• SSMIS data from F18.

• AMSR2 from JAXA's GCOM-W1 is introduced as an additional sensor.

The official release of the OSI-402-c and OSI-403-c products was on the 26-05-2017.

The scientific background and algorithm is described in details in the ATDB, [RD.3].

Note, that at present the OSI SAF sea ice type product delivered for Southern Hemisphere classify all sea ice as *"ambiguous"*. Similarly for the Northern Hemisphere, in the summer period mid-May until end-September the sea ice is classified as *"ambiguous"*.

On 23.09.2020 there was a small change to the processing chain for these products. The input sea ice concentration product used in the dynamical PDF generation was changed (see 3.2.1), giving a small positive improvement in the product quality. The change had not impact on product format or product delivery.

The products are delivered in NetCDF, format through FTP, THREDDS, EUMETCast and EUMETSAT Data Center.

See http://osisaf-hl.met.no for real time examples of the products and updated information. General information about the OSI SAF is given at http://www.osi-saf.org.

Section 2 describes the input data, section 3 presents a brief description of the algorithms and section 4 gives an overview of the data processing. Section 5 provides detailed information on the file content and format, with more details in the Appendix.

1.4 Glossary

AMSR2	Advanced Microwave Scanning Radiometer – 2
AMSR-E	Advanced Microwave Scanning Radiometer - EOS
ASCAT	Advanced Scatterometer
ATBD	Algorithm Theoretical Basis Document
AVHRR	Advanced Very High Resolution Radiometer
BUFR	Binary Universal Form for the Representation of meteorological data
CDOP	Continuous Development and Operations Phase
DMI	Danish Meteorological Institute
DMSP	Defence Meteorological Satellite Programme
ECMWF	European Centre for Medium range Weather Forecast
EDC	EUMETSAT Data Center
ERS	European Remote Sensing Satellites
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FTP	File Transfer Protocol

FY	First-Year ice
GRIB	GRIdded Binary form
HDF	Hierarchical Data format
HL	High Latitudes
LDAP	Lightweight Directory Access Protocol
MET-Norway	Norwegian Meteorological Institute
MODIS	Moderate-Resolution Imaging Spectroradiometer
MY	Multi-Year ice
NASA	National Aeronautics and Space Administration
NetCDF	Network Common Data Form
NH	Northern Hemisphere
NOAA	National Oceanic and Atmospheric Administration
NSIDC	National Snow and Ice Data Center
NWP	Numerical Weather Prediction
OSI SAF	Ocean and Sea Ice SAF
PDF	Probability Density Function
PMW	Passive Microwave
RMDCN	Regional Meteorological Data Communication Network
SAF	Satellite Application Facility
SAR	Synthetic Aperture Radar
SH	Southern Hemisphere
SMMR	Scanning Multichannel Microwave Radiometer
SSM/I	Special Sensor Microwave/Imager
SSMIS	Special Sensor Microwave Imager/Sounder
TB	Brightness Temperature
THREDDS	Thematic Real-Time Environmental Distributed Data Services
UTC	Coordinated Universal Time
WMO	World Meteorological Organization

1.5 Reference Documents

[RD.1] OSI SAF Service Specifications Document, v.2.8, May 2016.

[RD.2] OSI SAF Validation report for the change from SSM/I to SSMIS in the Global OSI SAF Sea Ice products, v1.1, December 2013.

[RD.3] OSI SAF Algorithm Theoretical Basis Document for the Global Sea Ice Edge and Type product, v2.2, May 2016.

[RD.4] OSI SAF Validation report for the Sea Ice Edge and Type product, v.2.1, May 2016.

Reference to a Reference Document within the body of this document is indicated as reference in the list above, e.g. [RD.1].

2. Input data

Input data are passive microwave (PMW) satellite data, SSMIS and AMSR2, and active microwave scatterometer data ASCAT. In addition, numerical model data from the European Centre for Medium-Range Weather Forecasts (ECMWF) are used.

2.1 PMW data

The Special Sensor Microwave/Imager (SSM/I) was flown on the DMSP satellites from 1987 on the DMSP satellites from F08 to F15. Its follower, the Special Sensor Microwave Imager/Sounder (SSMIS), has been carried on board the DMSP satellite since F16, and the SSMIS data has replaced completely the use of SSM/I data (for more details see [RD.2]). In April 2016, a calibration problem on one of the channels on DMSP F17 resulted in a necessary sudden switch to the SSMIS onboard DMSP F18. The switch was done the 12th of April (see information from April 2016 on the OSI SAF High Latitude web page http://osisaf.met.no/news/).

The Advanced Microwave Scanning Radiometer 2 (AMSR2) on-board the GCOM-W1 (GW1) satellite is a passive microwave radiometer similar to the SSM/I and SSMIS but with the larger differences of having a higher spatial resolution than SSM/I and SSMIS. For SSMIS the sampling interval is 25 km and 12.5 km for the two lower frequencies and the higher frequency, respectively, while for AMSR2 the corresponding grid sampling is 10 km and 5 km. Since 26th May 2017, AMSR2 data is introduced as a new sensor in the OSI SAF multi-sensor products of ice edge and type.

The SSMIS and AMSR2 imaging system is a passive microwave radiometer rotating continuously about an axis parallel to the local spacecraft vertical and measure the upwelling surface microwave brightness temperature (TB), see illustration on Figure 1.

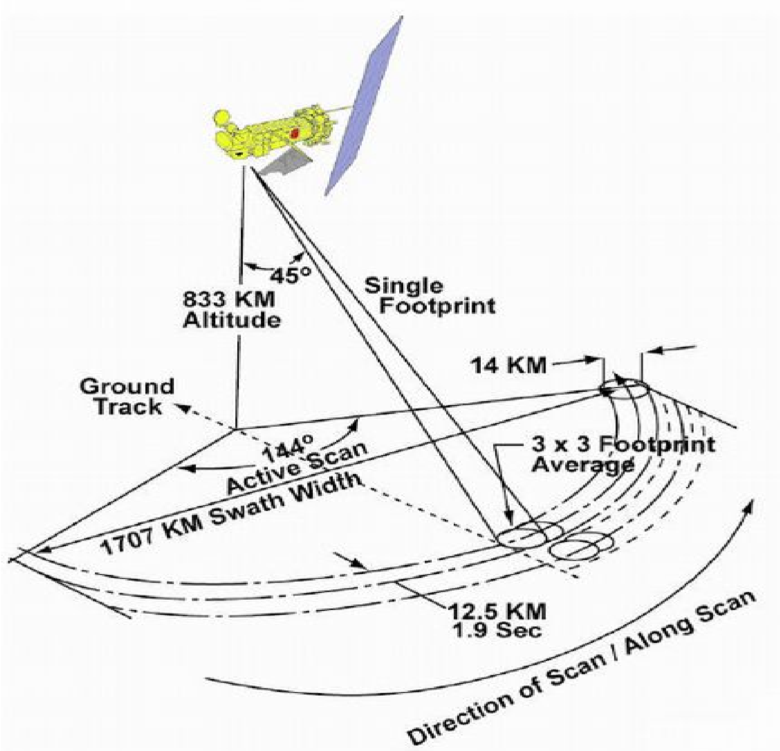

Figure 1: SSMIS scanning geometry (source NSIDC web site)

For the OSI SAF ice products is used TB measurements at three different frequencies sampled in both horizontal and vertical polarization. The channel specifications for all sensors included in the OSI SAF sea ice edge and type products are given in Table 1 in the ATBD [RD.3]. Note, that due to the smaller differences in the three frequencies between the sensor types, the higher frequency (85 GHz for SSMI, 91 GHz for SSMIS and 89 GHz for AMSR2) will in the following be referred to as the near 90 GHz or in short N90, while for the two lower resolutions we will in general just refer to 19 and 37 GHz.

Taking advantages of the different frequencies and polarization, the measured emissivity differs with different surface type:

- The measured emissivity from a calm ocean surface is strongly polarised, but generally low. Whereas with increasing surface roughness the measured emissivity also increases and becomes less polarised.
- The emissivity of sea ice undergoes a complex transition while forming from open water and gradually thickening (Comiso, 1986). First-year ice (FY) is characterized by a very high emissivity with low polarization, while multi-year ice (MY) is characterized by lower emissivity, declining with frequency, due to air pockets formed during the summer melt.

The variations in these characteristics are commonly used in algorithms to estimate ice concentration and distinguish between ice and water, see e.g. Andersen (1998). But before using the measured TB the data need to be corrected for atmospheric influence, see Section 2.3.

2.2 ASCAT data

The Advanced SCATterometer (ASCAT) currently aboard METOP-A and METOP-B consists of two sets of three antennas which are oriented at 45°, 90° and 135° with respect to the satellite's flight direction, on both sides of the satellite ground track, see illustration of the ASCAT geometry on Figure 2. The beams covers 550 km-wide swaths as the satellite moves along its orbit. Each antenna generates radar beams and measures backscatter from the sea surface. The backscatter, σ_0, is sampled on a 12.5 km grid. Each swath is divided into 42 cells. For more information, see Figa-Saldaña et al. (2002). Following Cavanie et al. (1994), the variation in viewing geometry can be utilized to detect sea ice from open water:

- Backscattering is relatively isotropic over sea ice compared to the strong anisotropic behavior over open water.
- The change of backscatter with incidence angle shows larger variation over water than over sea ice.

Over sea ice the microwave backscatter is dependent on the ice surface roughness and on the degree of volume scattering from brine pockets within the ice which again are related to the ice type and ice age. Hence, scatterometer data can be used to classify ice types (see e.g. Gohin and Cavanié, 1994):

- Usually multi-year ice has a rougher surface than first-year ice, and hence the backscatter often becomes larger over multi-year ice.
- Multi-year ice, in particular during winter, also has an additional backscatter signature compared to first-year ice as a result of volume scattering from brine pockets.

It may occur that first-year ice in some cases has a very rough surface while multi-year ice surface has been smoothed after summer melt. In such cases the ASCAT parameter becomes more uncertain in distinguishing between the surface types, and its contribution in the Bayesian multi-sensor approach will be weighted less.

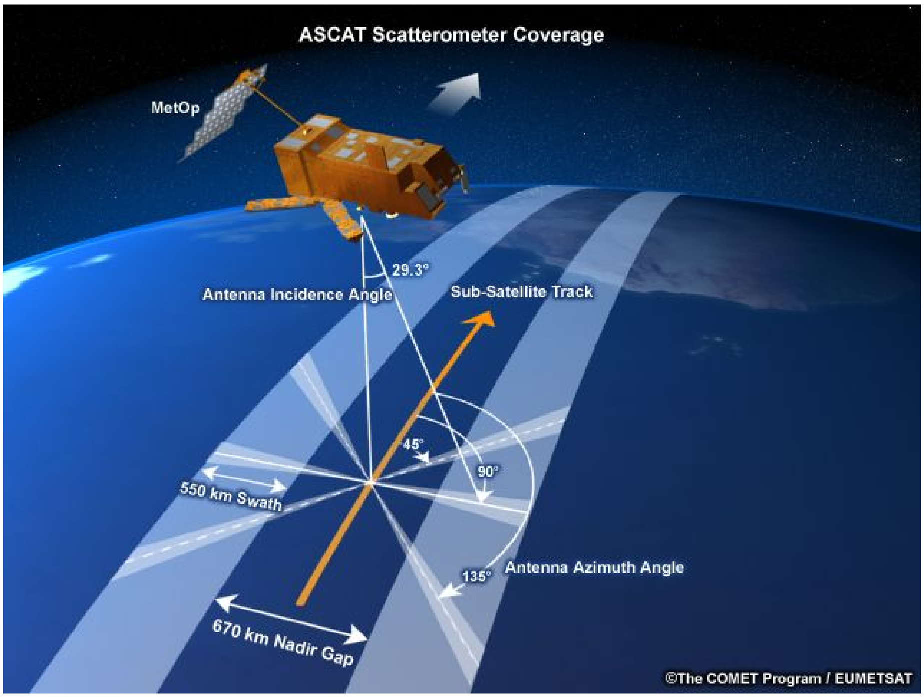

Figure 2: ASCAT geometry, Source COMET/EUMETSAT

Since 26th May 2017, ASCAT data from METOP-B is introduced as an additional scatterometer sensor in the OSI SAF multi-sensor products of ice edge and type

2.3 ECMWF data for atmospheric corrections

Contamination arising from atmospheric water vapour content and wind roughening of the open water surface is a common problem in the remote sensing of sea ice from passive microwave observations. To mitigate this problem, a correction is computed using the radiative transfer model by Wentz (1997) extended with a scheme developed by S. Kern for the 85 GHz channels (Kern, 2004), with input from ECMWF model fields of surface wind, temperature and atmospheric water content. This correction is subsequently applied to the measured TBs. Given a mixture of weather contamination and low ice concentrations, such as often experienced in the marginal ice zone, the widely used threshold based weather filtering methods such as described by Cavalieri et al. (1995) tend to either remove the ice completely or leave it untouched. The NWP model based correction method will tend to only remove the weather-induced part and give more accurate concentration estimates. Note, that this method works directly on TB and is therefore well suited for use in both the ice edge and type products as well as for the ice concentration product.

3. Algorithms

The developments of the OSI SAF sea ice algorithms have been presented in Breivik et al. (2001, 2012) and some aspects in more detail in Andersen (1998, 2000). The main principles of these developments are briefly presented here below. For detailed information it is referred to the ATBD [RD.3].

3.1 Bayesian multi sensor approach

Both scatterometer data and passive microwave data show a signature which can be utilized to detect and classify sea ice. A general tool for combining various data sources containing uncertain information is given by the Bayesian (inverse method) approach. Using this approach, several measured parameters can be combined to derive the most likely estimate of e.g. surface type. The approach is based on pre-knowledge of the averaged relationship between each surface type and the satellite-measured parameter. In addition, knowledge of the scatter of the expected measurement value for each surface type is needed. This knowledge can be expressed as a probability density distribution for the measured parameter given the surface type. As an example, allowing two surface types: “ice” and “water”, a simple algorithm for ice edge detection given a single measured parameter A can be derived. We then need to know the expected measurement of A over ice, p(A|ice), and the expected measurement of A over water, p(A|water). Setting both the a-priori probabilities for ice and water, P(ice) and P(water), equal to 50%, the Bayesian approach simplifies to an expression of the probability for having ice given the measurement :

$$p(ice|A)=\frac{p(A|ice)}{p(A|ice)+p(A|water)} \tag{1}$$

The method can be generalised for combining several measured parameters, e.g. from different satellite sensors, to an optimal surface type estimate. Assume that we have n measured parameters, $A_1, A_2, \ldots, A_n$, which are independent and related to surface type. A general expression can then be derived for the probability of a surface type I_k given the measured parameters:

$$p(I_k|A_1,\ldots,A_n)=\frac{p(A_1|I_k)\cdot p(A_2|I_k)\cdot\ldots\cdot p(A_n|I_k)}{\sum_j p(A_1|I_j)\cdot\ldots\cdot p(A_n|I_j)P(I_j)}P(I_k) \tag{2}$$

The method works in such a way that the measured parameter, which the statistics show to be the most secure in distinguishing between surface types, is the one that gives most impact on the resulting probability estimate. Further, the method not only provides an estimate of the most probable surface type, but also the uncertainty of this estimate. These benefits make the Bayesian method attractive compared to other methods based on threshold levels.

The expected values like e.g. *p(A|ice)* and *p(A|water)* are found from statistical analyses of a large training dataset with measurements of *A* over targets with known surface conditions (see Section 3.2). For the OSI SAF ice classification the a-priori probabilities, $P(I_k)$, for the different ice classes are set to be equal. In addition the probability distributions are assumed to be Gaussian.

3.2 Ice class statistics

For the *ice edge* analysis three classes ($I_{1,2,3}$, Eq. 2) are defined: *open water*, *open ice* and *closed ice*. The limit between water and open ice is defined to be 30% ice concentration. The limit between open ice and closed ice is defined around 70 % ice concentration.

In operational sea ice charting *ice classes* are defined according to established practice in the Ice Service community and as defined by the WMO sea ice nomenclature terminology, which is found in the WMO publication No. 259, Suppl. No. 4 on Sea Ice Nomenclature, or at *http://jcomm.info/index.php?option=com_oe&task=viewDocumentRecord&docID=4914*. Following this terminology the relationship between ice classes and ice concentration ranges are shown in the table below.

Ice service class	*Concentration range*	*Sea Ice Edge class*
Open water	less than 1/10	Open water
Very open drift ice	1/10 - 4/10	Open water / open ice
Open drift ice	4/10 - 7/10	Open ice
Closed drift ice	7/10 - 9/10	Closed ice
Fast ice	More than 9/10	Closed ice

Table 1: Correspondence between sea ice classes as used by operational Sea Ice Services, ice concentration range and the sea ice class chosen for the OSI SAF ice edge classification.

Ice type is divided in two classes*: first-year* (FY) and *multi-year* (MY) sea ice, where multi-year ice means ice that has survived at least one summer season.

The first step in building the analysis system based on the Bayesian approach (Eq. 2) is to derive the probability density functions (PDF's) for each measured quantity given a certain surface class. To obtain this statistical knowledge of the average, as well as of the scatter, of the expected measurement values, a large training data set of SSMIS, AMSR2 and ASCAT observations are collocated with background sea ice information from a set of target areas that has been defined in the Arctic and the Antarctic. Each target area is representative for a certain surface class: closed ice, open ice, open water, MY, FY and mixed ice. To differentiate between open and closed ice the operational OSI SAF ice concentration estimates (OSI-401b) are used as background information. To differentiate between MY and FY ice in the Arctic, a sector north of Greenland and Canada between 30 W and 120 W are defined as MY while data from the Kara Sea, Baffin Bay, Laptev Sea and Bay of Bothnia are defined as FY.

We get two sets of PDF's – one set for the Arctic which is based on data from NH, and one for Antarctica which is based on data from SH.

Note, that at present OSI SAF gives no information on ice type in the Antarctica. This is due to that the Antarctica sea ice classes has still not been studied enough to be included in the algorithm. Therefore, in the OSI SAF sea ice type product delivered for SH all the sea ice is classified as *"ambiguous"*.

3.2.1 Dynamical PDF's

The sea ice properties influencing the measurements vary over the seasons. The statistics defining the PDF's, the average and the scatter of the measured parameters, therefore also need to vary over the seasons. To achieve this the statistics are derived continuously throughout the year. This is different from the previous version of the algorithm where the training data set was based on static monthly PDF's based on a fixed year of observations, March 2007 to February 2008. In the present version of the algorithm, the statistics are derived daily based on a training data set continuously updated from the preceding 15 days. That is, the algorithm is now operating with dynamical PDF's. Examples of the dynamical PDF statistics derived for the year 2014 are given in Figure 3 and 4. Dynamical PDF's are introduced for two reasons:

1) To account for new sensors:

   In the operational satellites programs the satellites are regularly renewed and replaced. METOP-B is following METOP-A with a new ASCAT instrument and DMSP F16 follows F15 (SSMIS follows SSM/I). The instruments are the same or similar, but the performance of the algorithms need to be checked and tuned. Instead of recalculating the statistics for one year and use this for the new instrument, dynamical PDF's allow for a smooth transition between the instruments.

2) To account for inter-annual sea ice variations from different years:

   Seasonal variabilities of the ice properties also vary from year to year largely depending on the weather conditions, in particular the start and end of the melting and freezing seasons.

It may happen however that in some 15-days periods there is not enough observations for some or for all targets for carrying out the statistical calculations. This can especially occur during the summer months where ice is melting or is transformed into MY. In such cases the algorithm will search for data in a period with increasing length back in time until enough observations are found for the statistics.

For the special case where targets are completely missing within the 15-days period, the algorithm use static PDF's instead.

3.3 Multi sensor analysis

3.3.1 PMW parameters

From PMW data three parameters are used to distinguish between ice classes. These are:

- *PR19* - The polarisation ratio (normalised difference between horizontal and vertical brightness temperature) in the 19 GHz channel
- *PRn90* - The polarisation ratio in the near 90 GHz channel
- *GR1937* - The spectral gradient ratio, *GR1937* (normalised difference in brightness temperature between 37 and 19 GHz)

The parameters are derived from the brightness temperatures corrected for atmospheric influence as described in Section 2.3. Thus, collecting statistics from training data as described above, the probabilities, e.g. $p(PR19 \mid I_k)$, needed in Equation 2 are found (also see Figures 3 and 4 showing examples of PDF's for Antarctic and Arctic, respectively).

3.3.2 ASCAT parameters

From ASCAT data two parameters are used to distinguish between ice classes. These are:

- *anisFMB* - a parameter defined in order to include information on both the backscatter dependency on the incidence angle and the isotropic/anisotropic behaviour, see Breivik and Eastwood (2009) or [RD.3] for more details.
- *bscatt* – normalised backscatter

Thus, collecting statistics as described above, the probabilities, e.g. $p(anisFMB \mid I_k)$, needed in Equation 2 are found (also see Figures 3 and 4 showing examples of PDF's for Antarctic and Arctic, respectively).

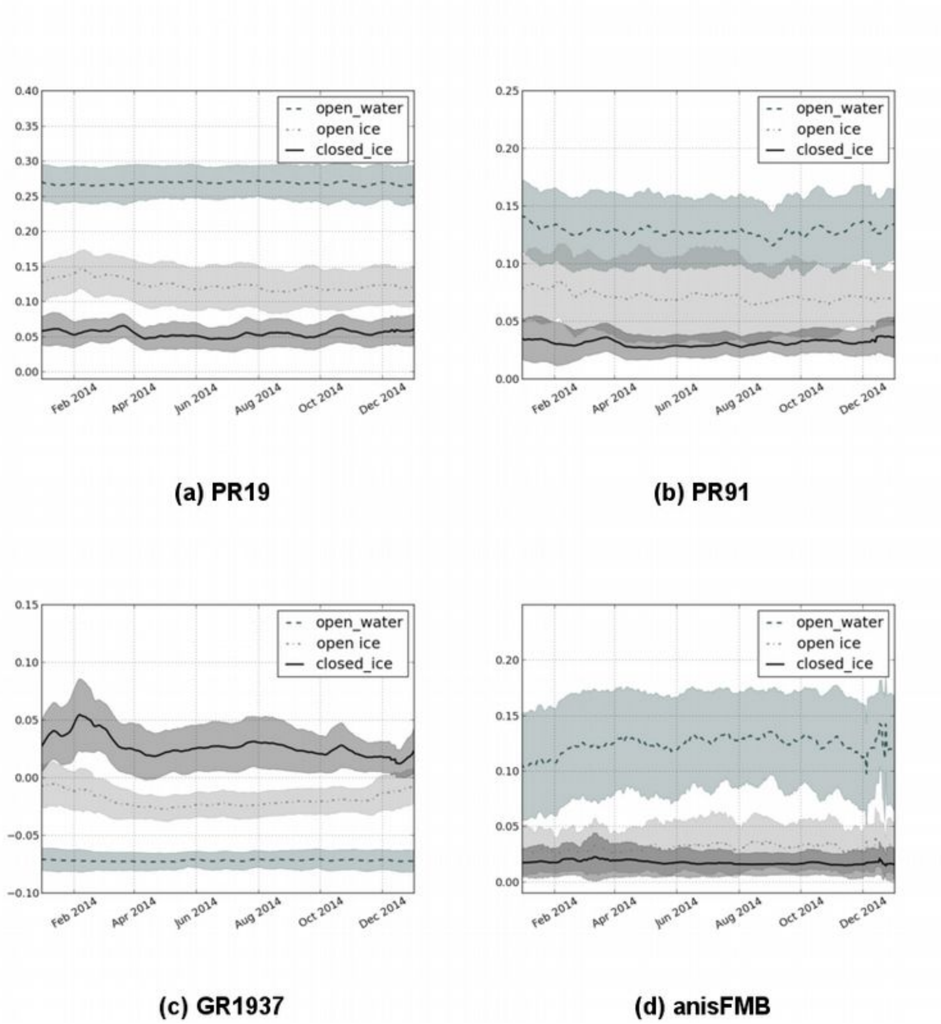

Figure 3: Southern Hemisphere dynamical PDF's (mean ± std) for selected surface types (see legend-text) during 2014 for the following parameters: a) PR19, b) PRn90, c) GR1937, d) anisFMB (cell nr = 0).

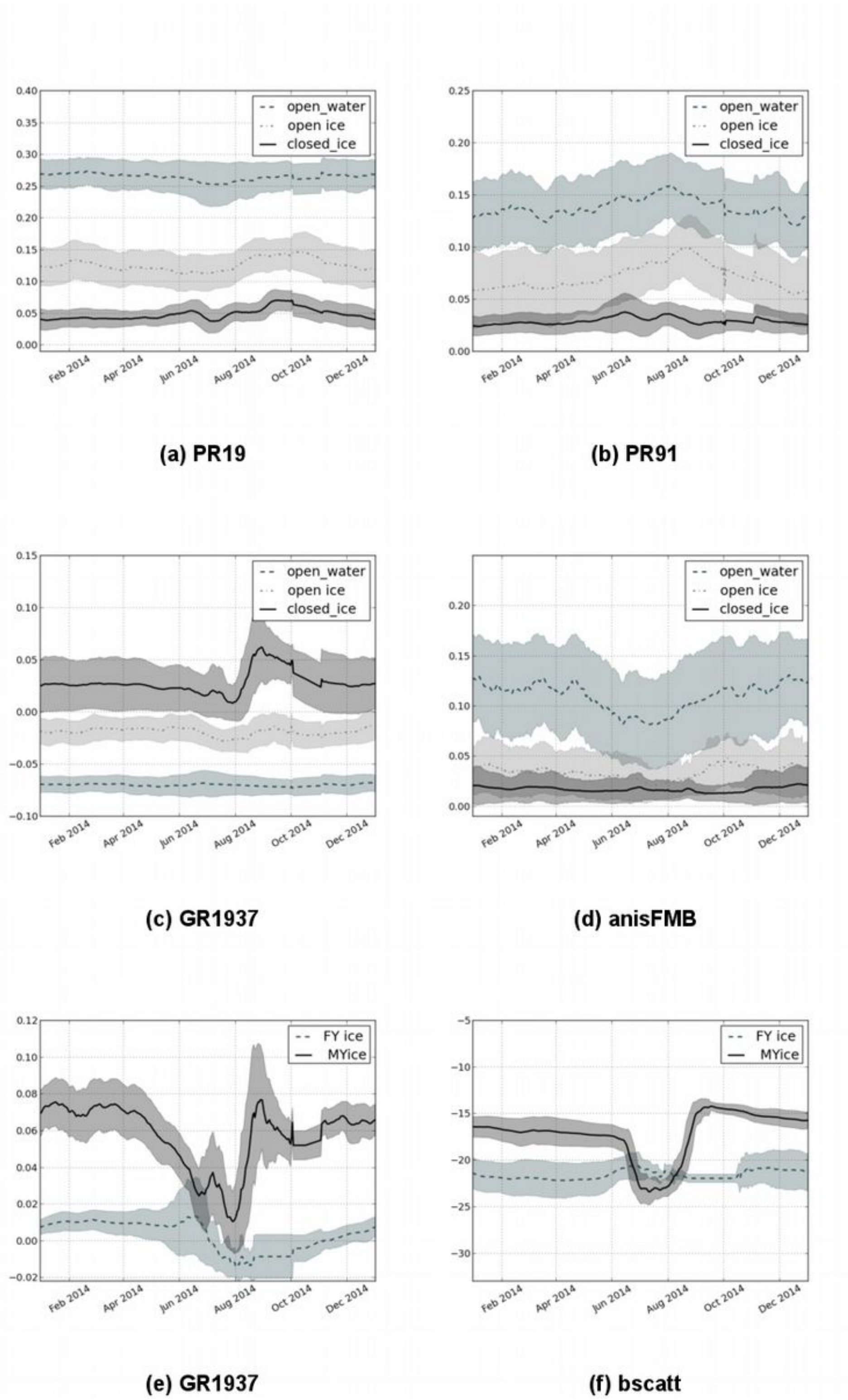

Figure 4: Northern Hemisphere dynamical PDF's (mean ± std) for selected surface types (see legend-text) during 2014 for the following parameters: a) PR19, b) PRn90, c) GR1937, d) anisFMB (cell nr = 0), e) GR1937, f) bscatt (cell nr = 0).

3.3.3 Multi sensor ice edge analysis, OSI-402-c

The OSI SAF ice edge product is using the three PMW parameters, *PR19*, *GR1937* and *PRn90* and the ASCAT parameter, *anisFMB*. See the corresponding PDF's for 2014 in Figures 3 and 4 (*a,b,c* and *d*).

In the first step, ice class-probabilities are estimated on the satellite swath projection for each passage. A direct application of Eq. 2 on the four parameters unfortunately gives a result dominated by the lower resolution data from *PR19* and *GR1937* where details in the ice edge are smoothed away. So instead, at this first step, Eq. 2 is used to get three estimates on the ice probabilities. These are:

- $p(I_k \mid PR19,GR1937)$ which combines the two low-resolution parameters
- $p(I_k \mid PRn90)$ and
- $p(I_k \mid anisFMB)$

In the second step the ice class probabilities for each of the three estimates above are gridded onto the OSI SAF grid based on one day of swath-data. The OSI SAF grid is a polar-stereographic grid with 10 km spatial resolution.

To utilize more of the smaller scale information in ASCAT and *PRn90*, the final step introduces a new approach where $p(I_k \mid PRn90)$ and $p(I_k \mid anisFMB)$ are combined in a multi-sensor approach and $p(I_k \mid PR19,GR1937)$ is instead used as a filter. So, the final step in the multi-sensor analysis is carried out in the following two steps:

1. The daily ice class probabilities on the grid are estimated from the gridded probabilities based on *PRn90* and *anisFMB* by using a form of Eq. 2.
2. The probabilities based on *PR19* and *GR1937* are then used as a filter where:
    - A grid point where *p(water | PR19,GR1937)* exceed 50 % is classified as water.
    - A grid point where *p(closed ice | PR19,GR1937)* exceed 50 % is classified as closed ice.
    - A grid point without *PR19,GR1937* data is not processed but classified as “no data”.

The result is a sharper ice edge with more details still with limited spurious ice due to atmospheric noise. For more details and examples, see the ASCAT algorithm development report, Breivik and Eastwood (2009) and Breivik et al. (2012).

Figure 5 shows examples from both hemispheres of the daily gridded OSI SAF sea ice edge product based on dynamical PDF's. The colors *white*, *light gray* and *blue* represent the regions of *closed ice*, *open ice* and *open water*, respectively, whereas *dark gray* represents *unclassified* pixels due to e.g. land or coastal area, and *black* is *missing* data. In Figures 6 and 7 are shown the additional quality information, the “status flag” and the “confidence level” respectively, which corresponds to the sea ice edge product in Figure 5 (more about these quality indices in section 5.3).

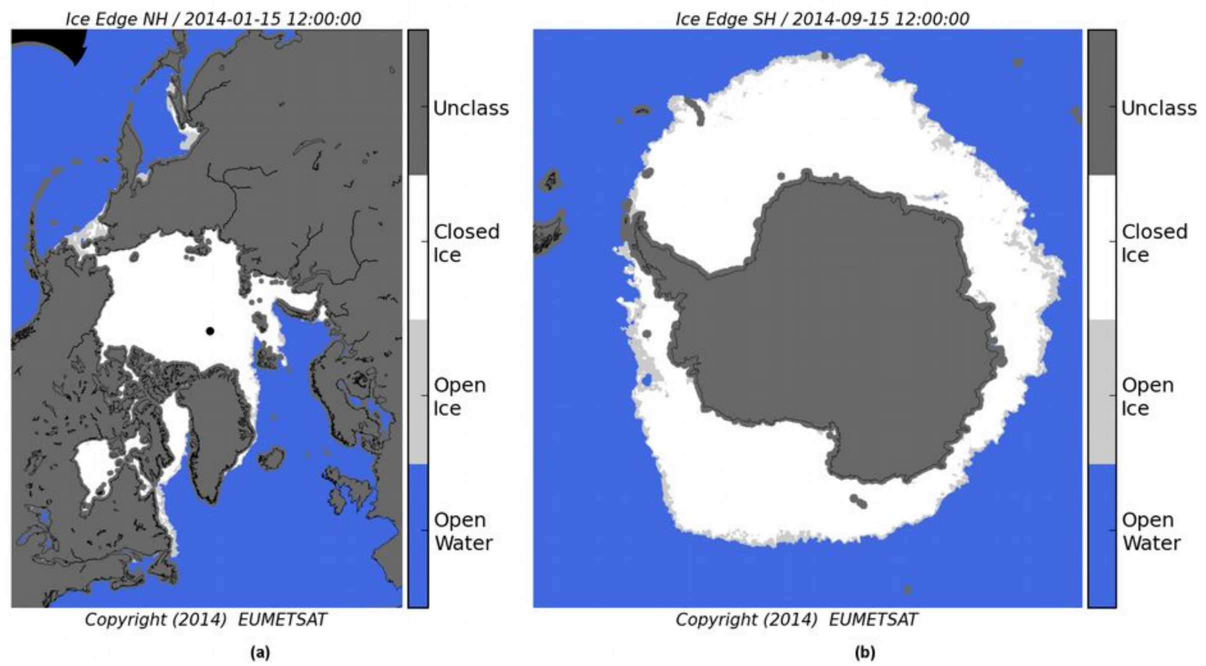

Figure 5: OSI SAF sea ice edge for (a) Northern Hemisphere, January 15 2014, and (b) Southern Hemisphere, September 15 2014. Colors represent the surface types as: blue=open water, light gray=open ice, white=closed ice, dark gray=unclassified, and black=missing data.

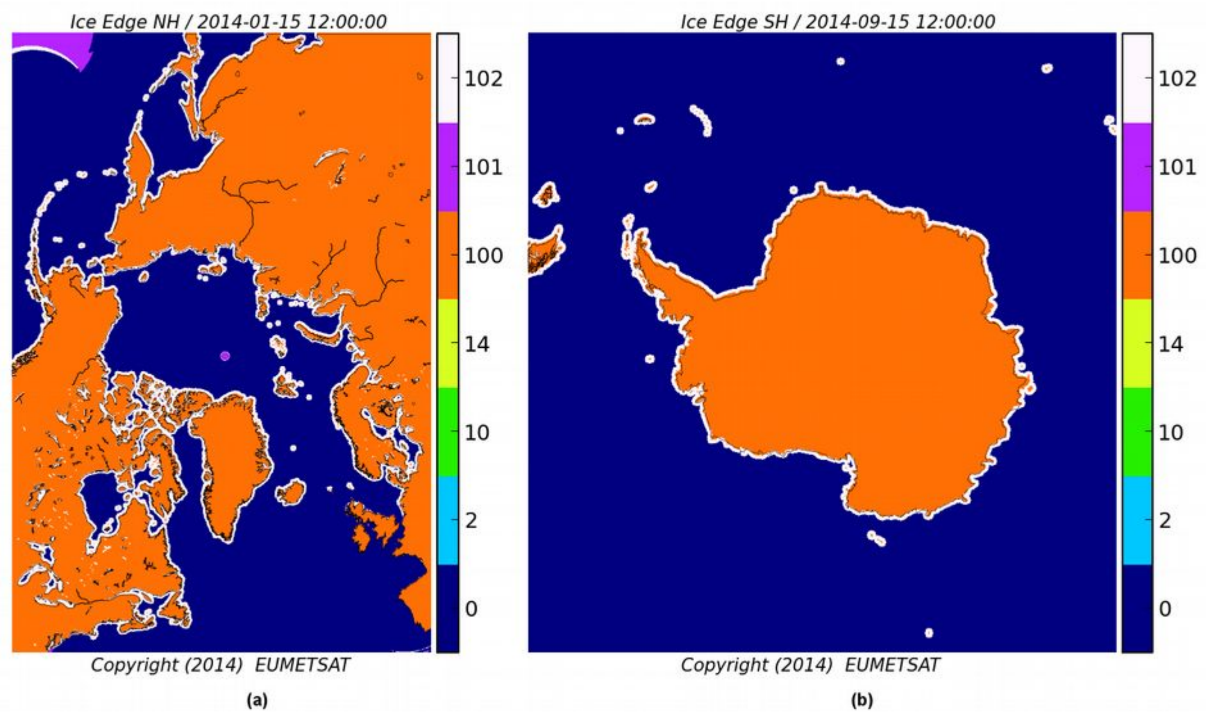

Figure 6: Status flag of the OSI SAF sea ice edge product for (a) Northern Hemisphere, January 15 2014, and (b) Southern Hemisphere, September 15 2014. The color coding for status flag: 0=nominal, 2=lake, 10=background, 14=type_mask, 100=land, 101=missing, 102=unclassified.

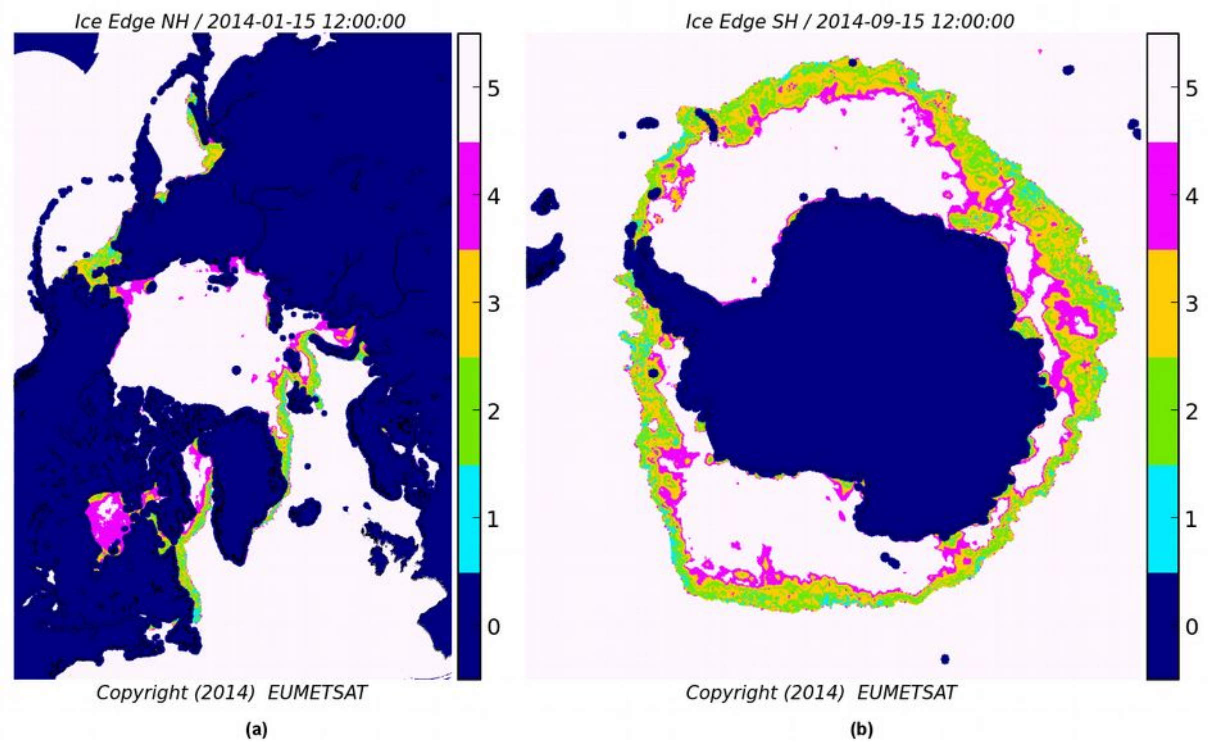

Figure 7: Confidence level of the OSI SAF sea ice edge product for (a) Northern Hemisphere, January 15 2014, (b) Southern Hemisphere, September 15 2014.The colour coding for confidence level: 0=unprocessed, 1=erroneous, 2=unreliable, 3=acceptable, 4=good, and 5=excellent.

3.3.4 Multi sensor ice type analysis, OSI-403-c

The OSI SAF ice type product is using the PMW spectral gradient *GR1937* and the ASCAT normalized backscatter *bscatt.* See corresponding PDF's for 2014 in Figure 4 (*e* and *f*). Using these two parameters, the probabilities of ice type is calculated in a similar manner as for the ice edge product:

1. For each of the two parameters successive estimation of ice type probability is carried out on the satellite swath data.
2. Each parameter estimation of ice type probability is gridded onto the OSI SAF grid based on data input from one day.
3. Finally, the daily multi-sensor analysis is carried out on the OSI SAF grid.

In the final step, the results from the ice edge analysis are used to classify open water. For more details and examples, see the ASCAT algorithm development report, (Breivik and Eastwood, 2009).

Note, that in summer, when the first-year ice gradually decreases or becomes multi-year ice, the distinction between ice types becomes very difficult. This is partly due to melting resulting in wet ice and water on the ice. As a result, in the summer season (the period from mid-May until end-September) the OSI SAF gives no information on ice type in the data and the ice type is classified as “ambiguous” in this period.

Figure 8 shows an example of the daily gridded OSI SAF sea ice type product from January 15 2014, based on dynamical PDF's. The colors *white*, *light gray* and *blue* represent the regions of *MY ice*, *FY ice* and *open water*, respectively, red represents *ambiguous* for regions where the algorithm has problems to differ between FY and MY ice, *dark gray* represents *unclassified* pixels due to land or coastal area, and *black* is *missing* data. In Figure 9 is shown the additional quality information, the “status flag” and the “confidence level” which corresponds to the sea ice type product in Figure 8 (more about these quality indices in section 5.3).

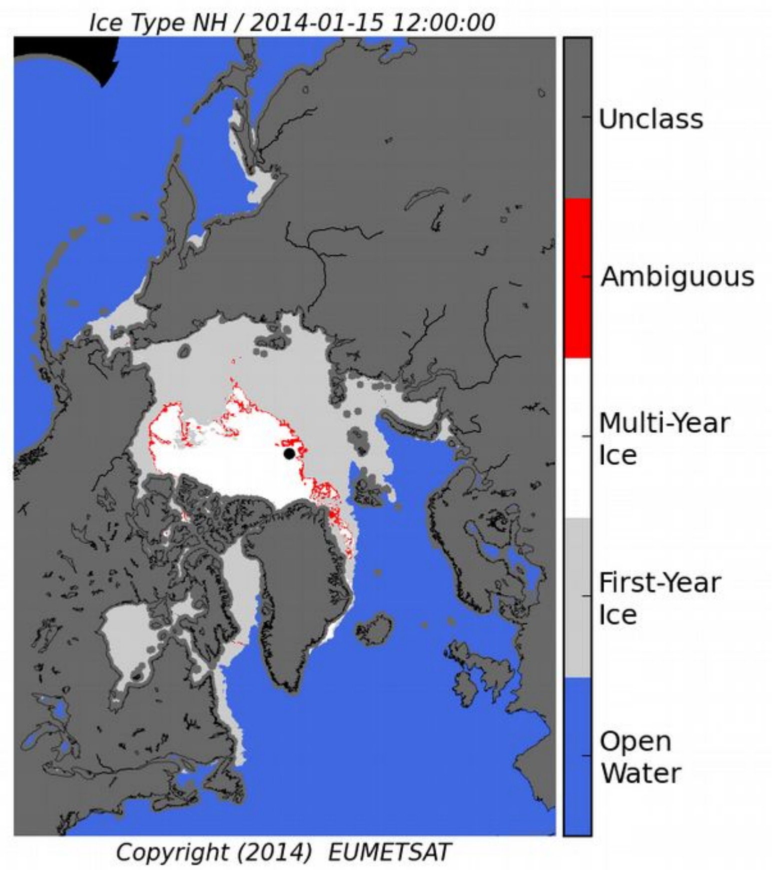

Figure 8: OSI SAF sea ice type for the Northern Hemisphere on the 15th of January 2014. Colors represent the surface types as: blue=open water, light gray=first-year ice, white=multi-year ice, red=Ambiguous, dark gray=unclassified, and black=missing data.

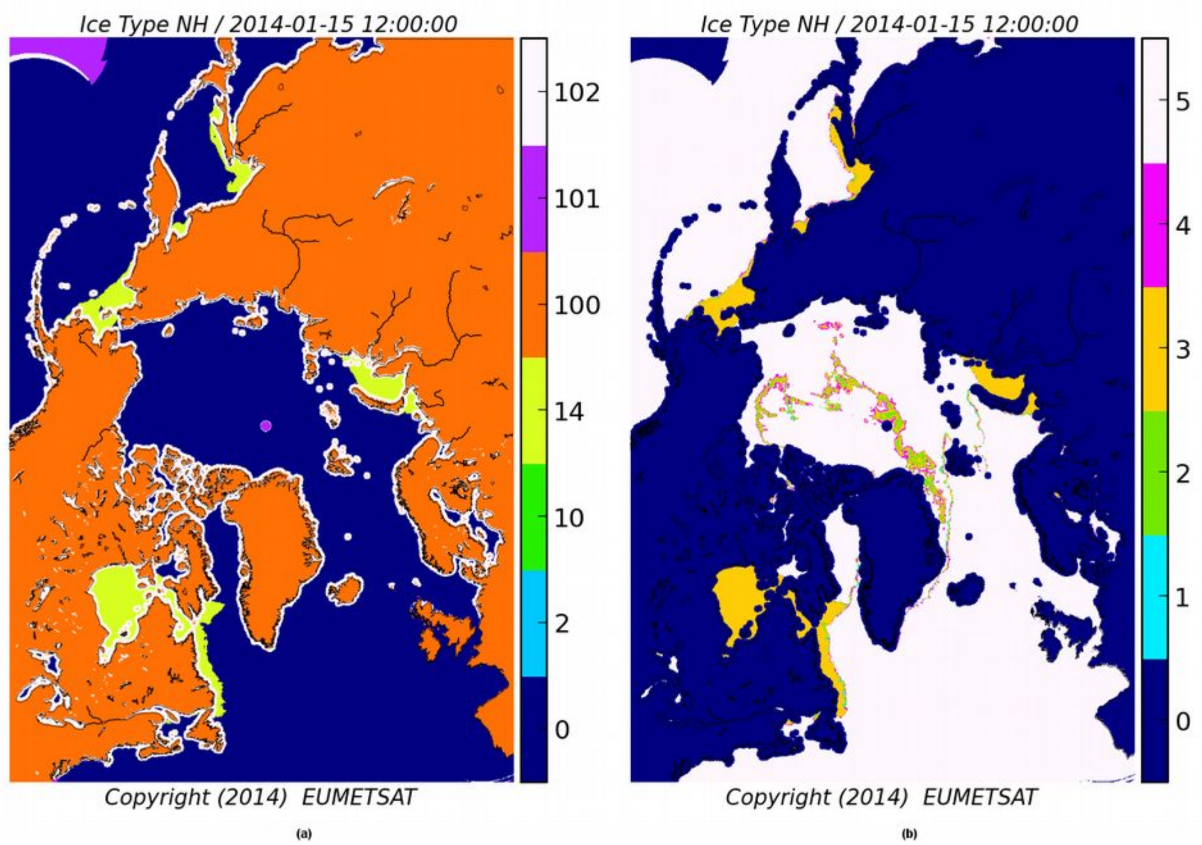

Figure 9: OSI SAF sea ice type product (15th of January, 2014), (a) "Status flag" and (b) "confidence level". The color coding for status flag: 0=nominal, 2=lake, 10=background, 14=type_mask, 100=land, 101=missing, 102=unclassified. The color coding for confidence level: 0=unprocessed, 1=erroneous, 2=unreliable, 3=acceptable, 4=good, and 5=excellent.

4. Processing scheme

4.1 Overview

The delivered products are daily means centered on noon. Since 26th May 2017 the sea ice products are derived from SSMIS data from the DMSP F18 satellite and ASCAT data from METOP-A and -B, both received via EUMETCast, and AMSR2 data from GCOM-W1 (GW1) Data Providing Service.

Section 4.2 describes the primary processing made on the individual satellite passes. The merging of the data from various origins is presented in section 4.3. To this basic processing is added the validation and quality control described in section 4.4.

4.2 Primary processing

4.2.1 Satellite data

PMW
SSMIS pass data are received through EUMETCast by the OSI SAF High Latitude processing centre and AMSR2 data from GCOM-W1 data service. Each pass is subsetted to cover both the Northern and Southern hemisphere. Atmospheric corrections, based on ECMWF model output, are then applied to the brightness temperatures. The data is reformatted and stored in NetCDF.

ASCAT
ASCAT pass data are received in BUFR format on EUMETCast by the OSI SAF High Latitude processing centre. Each pass is subsetted to cover both the Northern and Southern hemisphere. The data is reformatted and stored in NetCDF.

4.2.2 Ancillary data

Ancillary data are given on the OSI SAF grid and used to mask away land and coast and erroneous ice. The uses of the ancillary data are marked as a flag for each grid point in the processing flags, see section 5.3.2.

Land-sea-coast: contains land, coast and sea occurrences. It has been derived on the OSI SAF grids from the World Vector Shoreline. In the Southern Hemisphere, information on ice shelf coverage has been added from the NASA AMSR-E landmasks and a mask based on inspection of recent VIS-IR imagery developed by S. Kern, University of Hamburg. The atlas includes 3 types of pixels: “land”, “coast” and “sea”. Sea ice calculations are done over the “sea” pixels. The “coast” pixels are pixels within a fixed distance from the coastline over sea areas. This fixed distance is chosen in accordance with the size of the footprint of the SSMIS data. Observations within these pixels are not processed since they are most likely contaminated by land. These pixels are given the value “unclassified” in the data products.

Sea ice climatology: contains monthly fields of maximum sea ice extent (Ocean Masks) provided by NSIDC (see http://nsidc.org for details). This dataset is based on data from SMMR and SSM/I spanning the period from 1979 through 2002.

Background data: To make the product more useful for automatic use, obviously erroneous classified sea ice is removed by use of background information derived from the NWP model. The parameter chosen for this purpose is the NWP temperature analysis field at 2m (T2m). A spurious ice filtering is implemented by setting all grid points with T2m>8.0˚C to open water. Experience shows that the value, T2m>8.0˚C, is high enough to account for uncertainty in the NWP analysis and ensure proper distance from the ice edge. The value is however tunable and given as an input parameter. To avoid the erroneous removal of extreme ice extents, the NSIDC climatological maximum sea ice edge is expanded towards open water by 50 km before being added to the NWP background data. Finally, the ice edge (delineated by the 15 % ice concentration contour) from the day before is expanded towards open water by 100 km and added.

Ice type mask: To reduce noise in the ice type products an ice type mask is defined. Areas where multi-year ice never occur, e.g. the Bay of Bothnia is masked as first-year. This mask is used to overrule the erroneous classification and ensure first-year ice.

4.3 Daily calculations

As described in section 3 the first step of the analysis is performed successively as the data arrive. In this step the probabilities for ice classes (closed ice, open ice, open water, first-year ice and multi-year ice) are calculated on each observation point in satellite projection.

In the next step, daily calculations are then performed each day at *0400* UTC and are based on data collected from the previous day. The offset of four hours is used because the SSMIS data are delayed by up to 3 hours.

4.4 Validation and quality control

Validation and assessments of product performance information is published on a monthly basis in the OSI SAF half-yearly operations reports and is based on both objective and subjective comparisons with high quality navigational sea ice analyses produced at the operational Sea Ice Services at DMI and MET-Norway. These navigation ice charts have requirements very different from the OSI SAF products one. They are therefore to a large extent based on subjective interpretation of high resolution SAR and AVHRR data. However, in areas where SAR or AVHRR data is not available for subjective analysis the sea ice analysts might use PMW data and OSI SAF products. The sea ice analysts at DMI and MET-Norway are aware of this potential problem when validating the OSI SAF sea ice products. **Therefore only navigation ice charts based on subjective interpretation of high resolution SAR, MODIS and AVHRR data are used in the evaluation of the OSI SAF products.**

4.4.1 Objective evaluation

For the objective comparisons the following parameters have been defined:

Product	Quality parameter	Definition
Ice edge	Area of discrepancy	Where the navigational ice edge is classified as certain, the number of HL grid pixels is counted where the SAF classification does not match the navigational classification.

Table 2: Criteria for comparing ice charts with OSI SAF sea ice products.

The quality of the products is rated against requirements given in the Service Specifications Document [RD.1].

The evaluation procedure is currently running operationally at DMI for the Greenland area and at MET-Norway for the Svalbard area.

At DMI the products are compared twice a week statistically with the DMI Overview Ice Chart for the entire Greenland area. These navigational ice analyses, that are made for operational use, compile all available satellite data, including SAR from RADARSAT-2 and Sentinel-1, NASA MODIS and NOAA AVHRR for a reference date at 12 UTC (± 24 hours). No additional ice products are believed to have a better accuracy compared with coverage. An example of the ice analysis is available at (non OSI SAF site):

http://www.dmi.dk/en/groenland/hav/ice-charts/.

At MET-Norway the products are compared with the daily (weekdays) ice charts to produce similar statistics as described for DMI. The trained ice analysts use synthetic aperture radar (SAR) data, predominantly Sentinel-1 Extra-Wide and RADARSAT-2 ScanSAR Wide but also some COSMO SkyMed, MODIS optical images, and AMSR-2 sea ice concentration (SIC) from University of Bremen. The products are compared only in areas selected by the ice analysts, where detailed satellite data are available that has not been used on the OSI SAF product. The daily ice analysis for operational use from MET-Norway is available at (non OSI SAF site):

http://met.no/Hav_og_is.

For validation of the Southern Hemisphere product, weekly ice charts from the National Ice Service (USA) are used. There are some limitations using these charts, since they are only weekly, and less high resolution SAR data are used. The validation results for the Southern Hemisphere products might therefore not be as precise as for the Northern Hemisphere.

The results of the validation and quality control in the form of updated tables and figures are found partly in the half-yearly operations report available at the OSI SAF central web portal http://www.osi-saf.org for registered users, and partly in the validation report [RD.4] which are available at the OSI SAF High Latitude Processing Centre web portal http://osisaf.met.no under “Documents”.

5. Data description

5.1 Overview

The two daily OSI SAF sea ice products, edge and type, are available for users on the NetCDF file format. Each ice product file contains the following parameters:

- a sea ice parameter
- a confidence level field
- a status flag field

5.2 Sea ice products

5.2.1 Sea ice edge

The parameter for sea ice edge indicates whether a given grid point is covered by open water, open sea ice or closed sea ice, and is given as an integer code:

- 1: No ice (less than 30% ice concentration)
- 2: Open ice (30-70% ice concentration)
- 3: Closed ice (more than 70% ice concentration)
- -1: Fillvalue

5.2.2 Sea ice type

The parameter for sea ice type indicates the dominant ice type in terms of first-year or multi-year ice. Multi-year ice has by definition survived one yearly cycle of freeze and melt, first-year ice has been formed during the past year. Sea ice type is given as an integer code:

- 1: No ice
- 2: First-year ice
- 3: Multi-year ice
- 4: Ambiguous ice type
- -1: Fillvalue

5.2.3 Unclassified

Fillvalues (= -1) used in both ice products represent pixels that are over land, near the coast, or for some reason are missing data (outside of swath, etc.). The fillvalue pixels can be diagnosed with the help of the status flag field. See example of this in Figures 8-9. This approach has been chosen so that the product is compliant with other products delivered from the OSI SAF.

5.3 Quality information

5.3.1 Confidence level

The confidence level is defined using the calculated probabilities of the present sea ice class. When making the averaged ice field, the product pixels of the highest possible confidence level are preferred. The confidence levels are defined as follows:

- 0: Unprocessed (No data)
- 1: Erroneous (Computation failed)

- 2: Unreliable (50-74% probability)
- 3: Acceptable (75-94% probability)
- 4: Good (95-98% probability)
- 5: Excellent (99-100% probability)

5.3.2 Status flag

The status flag gives information whether the ice parameter has a nominal value or if not: why? The integer code for status flag:

- 0: nominal value from algorithm used
- 2: sea ice algorithm applied over lake
- 10: background data was used for setting the value
- 14: value set using an ice type mask
- 100: missing value due to over land
- 101: missing value due to missing data
- 102: unclassified pixel

5.4 Grid characteristics

The product grids are adapted from the 25 km resolution Goddard Space Flight Center projections used to disseminate various SSM/I and SSMIS based products available at the National Snow and Ice Data Center (see http://nsidc.org for details). There is one grid for the Northern Hemisphere product (NH) and one grid for the Southern Hemisphere product (SH), as seen in Figure 10.

Below are given the details of the grid definitions and approximate maps of the grid extents, corner coordinates are referenced to pixel center. Projection definitions in the form of PROJ-4 initialization strings are also given (see http://trac.osgeo.org/proj/ for details).

Geographical definition for Northern Hemisphere Grid, NH	
Projection:	Polar stereographic projection true at 70°N
Grid cell size:	10 km
Size:	760 columns, 1120 lines
Central Meridian:	45°W
Center coordinate for corner grid points:	
Upper left grid point	31.0294°N, 168.3380°E
Upper right grid point	31.4141°N, 102.3516°E
Lower right grid point	34.3960°N, 9.9828°W
Lower left grid point	33.9755°N, 80.7299°W
Radius of Earth:	6378273 x 6356889.44891 m
PROJ-4 string:	+proj=stere +a=6378273 +b=6356889.44891 +lat_0=90 +lat_ts=70 +lon_0=-45
Geographical definition for Southern Hemisphere Grid, SH	
Projection:	Polar stereographic projection true at 70°S
Grid cell size:	10 km
Size:	790 columns, 830 lines
Central Meridian:	0°
Center coordinate for corner grid points:	
Upper left grid point	39.2845°S, 42.2376°W
Upper right grid point	39.2845°S, 42.2376°E
Lower right grid point	41.5015°S, 135.0000°E
Lower left grid point	41.5015°S, 135.0000°W
Radius of Earth:	6378273 x 6356889.44891 m
PROJ-4 string:	+proj=stere +a=6378273 +b=6356889.44891 +lat_0=-90 +lat_ts=-70 +lon_0=0

Table 3: Definition of NH and SH grids.

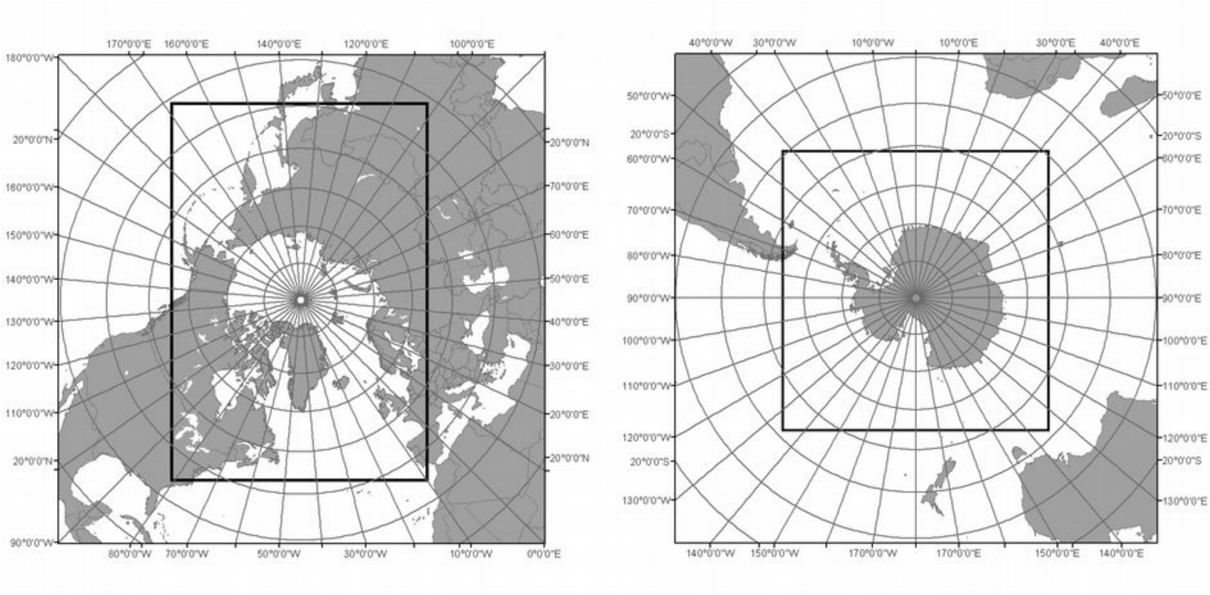

Figure 10: Coverage of the Northern (left) and Southern (right) Hemisphere grids, marked with the black box (from NSIDC).

5.5 File format

The products are available in Unidata NetCDF3 format. The NetCDF3 (Network Common Data Form) format is a public format, with documentation available at: http://www.unidata.ucar.edu/software/netcdf The OSI SAF sea ice products use the CF 1.4 standard for metadata in the NetCDF files. The metadata in the NetCDF files are described in Appendix C.

More product information about the OSI SAF sea ice data format can be found at: http://osisaf.met.no under Products.

5.6 Data distribution

There are two main sources for collecting the OSI SAF Sea Ice products; by FTP or through EUMETCast. In addition, the product archive is available from the OSI SAF THREDDS or the EUMETSAT Data Center.

5.6.1 Sea Ice FTP server and THREDDS server

At the OSI SAF Sea Ice FTP server ftp://osisaf.met.no/prod/ice the products are available on NetCDF3 format (under the directories *edge* or *type*). Here products from the last month can be collected. In addition there is a separate directory with archive of all previously produced sea ice products (up to the last available product) at ftp://osisaf.met.no/archive/ice (under the directories *edge* or *type*). The file name convention for these products is given in the table below.

The NetCDF files are also available on this THREDDS server (through the OpenDAP protocol):

http://thredds.met.no/thredds/osisaf.html

More information about THREDDS is available here:

http://www.unidata.ucar.edu/software/thredds/current/tds/TDS.html

5.6.2 EUMETCast dissemination and archiving at EDC

Through the EUMETSAT EUMETCast service the OSI SAF Sea Ice products are available on NetCDF. The distributed files have been compressed with `gzip`. Different file name conventions have been chosen for the Sea Ice products at EUMETCast since many different products are disseminated through EUMETCast. More information about the EUMETCast service can be found at http://www.eumetsat.int. The product files are archived at the EUMETSAT Data Center (EDC), which can be accessed through this link: http://www.eumetsat.int/website/home/Data/DataDelivery/EUMETSATDataCentre/index.html

5.6.3 File name convention

The following table gives the file name convention used at the OSI SAF FTP and THREDDS servers, and on EUMETCast.

Sea Ice NetCDF3 files on FTP and THREDDS	
Sea Ice Edge	ice_edge_<area>_polstere-100_multi_<date12>.nc
Sea Ice Type	ice_type_<area>_polstere-100_multi_<date12>.nc
Sea Ice NetCDF3 files on EUMETCast	
Sea Ice Edge	S-OSI_-NOR_-MULT-GL_<area>_EDGEn__-<date12>.nc.gz
Sea Ice Type	S-OSI_-NOR_-MULT-GL_<area>_TYPEn__-<date12>.nc.gz

Table 4: File name convention for the sea ice files on the OSI SAF FTP server and on EUMETCast.

<area>: nh for Northern Hemisphere products, sh for Southern Hemisphere.

<date12>: Date and time of the product on format YYYYMMDDHHMM, e.g. 200701221200.

5.7 History of products

The sea ice edge and type products have been available on a daily basis since the start in 2005. Due to regular upgrades some inconsistencies exist in time. Below the most important upgrades of the operational products are listed:

- 2009-12-08 Scatterometer data was introduced into the retrievals (OSI-402, OSI-403)
- 2013-01-19 Sensor switch from SSM/I to SSMIS (OSI-402-a, OSI-403-a)
- 2015-07-07 Introduction of a dynamical tuning of the algorithm (OSI-402-b, OSI-403-b)
- 2017-05-26 AMSR-2 data was introduced into the multi-sensor products. Scatterometer data from METOP-B was also introduced, in addition to METOP-A (OSI-402-c, OSI-403-c)

6. References

Andersen, S. (1998) Monthly Arctic sea ice signatures for use in passive microwave algorithms. DMI Technical Report 98-18, Danish Meteorological Institute, Copenhagen.

Andersen, S. (2000) Evaluation of SSM/I sea ice algorithms for use in the SAF on Ocean and Sea Ice. DMI Scientific Report 00-10, Danish Meteorological Institute, Copenhagen.

Breivik, L.-A., S. Eastwood, T. Lavergne, (2012) Use of C-Band Scatterometer for Sea Ice Edge Identification, *Geoscience and Remote Sensing, IEEE Transactions on* , **vol.50**, no.7, pp.2669-2677, July 2012.

Breivik, L.-A., and S. Eastwood (2009) Upgrade of the OSI SAF Sea Ice Edge and Sea Ice Type products – Introduction of ASCAT, *OSI SAF report.*

Breivik, L.-A., S. Eastwood, Ø. Godøy, H. Schyberg, S. Andersen, R.T. Tonboe (2001) Sea Ice Products for EUMETSAT Satellite Application Facility. *Canadian Journal of Remote Sensing*, Volume 27, No. 5.

Cavalieri, D.J., K.M. St. Germain, C.T. Swft (1995) Reduction of weather effects in the calculation of sea-ice concentration with the DMSP SSM/I. *J. Glaciol.,* 41, 455-464.

Cavanie, A., F. Gohin, Y. Quilfen and P. Lecomte (1994) Identification of Sea Ice Zones using the AMI Wind: Physical Bases and Applications to the FDP and CERSAT processing chains.

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

Figa-Saldaña, J., J.J.W. Wilson, E. Attema, R. Gelsthorpe, M.R. Drinkwater, and A. Stoffelen (2002) “The advanced scatterometer (ASCAT) on the meteorological operational (MetOp) platform: A follow on for European wind scatterometers”. Can. J. Remote Sensing, Vol. 28, No. 3, pp. 404–412.

Godøy, Ø. (2005): Description of the osihdf5 format. Norwegian Meteorological Institute. 8 pages. Available at [http://osisaf.met.no], under Documents.

Gohin, F. and A. Canvanie (1994) A first try at identification of sea ice using the three beam scatterometer of ERS-1, *Int. J. Remote Sens., 15*, pp. 1221-1228

Kern, S. (2004), A new method for medium-resolution sea ice analysis using weather-influence corrected Special Sensor Microwave/Imager 85 GHz data, *Int. J. Rem. Sens., 25,* 21, 4555-4582.

Wentz, F. J, (1997) A well-calibrated ocean algorithm for SSM/I. *J. Geophys. Res*., 102, C4, pp. 8703-8718.

Appendix A: Sea Ice products on NetCDF format

Below is given an example of the NetCDF header of a sea ice edge file. The header parameters are similar for sea ice type.

```
netcdf ice_edge_nh_polstere-100_multi_201501081200 {
dimensions:
  time = 1 ;
  nv = 2 ;
  xc = 760 ;
  yc = 1120 ;
variables:
  int Polar_Stereographic_Grid ;
    Polar_Stereographic_Grid:grid_mapping_name = "polar_stereographic" ;
    Polar_Stereographic_Grid:straight_vertical_longitude_from_pole = -45.f ;
    Polar_Stereographic_Grid:latitude_of_projection_origin = 90.f ;
    Polar_Stereographic_Grid:standard_parallel = 70.f ;
    Polar_Stereographic_Grid:false_easting = 0.f ;
    Polar_Stereographic_Grid:false_northing = 0.f ;
    Polar_Stereographic_Grid:semi_major_axis = 6378273.f ;
    Polar_Stereographic_Grid:semi_minor_axis = 6356890.f ;
    Polar_Stereographic_Grid:proj4_string = "+proj=stere +a=6378273
                   +b=6356889.44891 +lat_0=90 +lat_ts=70 +lon_0=-45" ;
  double time(time) ;
    time:axis = "T" ;
    time:long_name = "reference time of product" ;
    time:standard_name = "time" ;
    time:units = "seconds since 1978-01-01 00:00:00" ;
    time:calendar = "standard" ;
    time:bounds = "time_bnds" ;
  double time_bnds(time, nv) ;
    time_bnds:units = "seconds since 1978-01-01 00:00:00" ;
  double xc(xc) ;
    xc:axis = "X" ;
    xc:units = "km" ;
    xc:long_name = "x coordinate of projection (eastings)" ;
    xc:standard_name = "projection_x_coordinate" ;
  double yc(yc) ;
    yc:axis = "Y" ;
    yc:units = "km" ;
    yc:long_name = "y coordinate of projection (northings)" ;
    yc:standard_name = "projection_y_coordinate" ;
  float lat(yc, xc) ;
    lat:long_name = "latitude coordinate" ;
    lat:standard_name = "latitude" ;
    lat:units = "degrees_north" ;
  float lon(yc, xc) ;
    lon:long_name = "longitude coordinate" ;
    lon:standard_name = "longitude" ;
```

```
    lon:units = "degrees_east" ;
  byte ice_edge(time, yc, xc) ;
    ice_edge:long_name = "sea ice edge" ;
    ice_edge:standard_name = "sea_ice_classification" ;
    ice_edge:_FillValue = -1b ;
    ice_edge:valid_min = 1b ;
    ice_edge:valid_max = 3b ;
    ice_edge:grid_mapping = "Polar_Stereographic_Grid" ;
    ice_edge:coordinates = "lat lon" ;
    ice_edge:flag_values = 1b, 2b, 3b ;
    ice_edge:flag_meanings = "open_water open_ice close_ice" ;
    ice_edge:flag_descriptions = "\n",
             "  1 -> no ice or very open ice\n",
             "  2 -> open ice cover (4 to 7 tens)\n",
             "  3 -> close, very close and fast ice" ;
  byte confidence_level(time, yc, xc) ;
    confidence_level:long_name = "confidence level" ;
    confidence_level:valid_min = 0b ;
    confidence_level:valid_max = 5b ;
    confidence_level:grid_mapping = "Polar_Stereographic_Grid" ;
    confidence_level:coordinates = "lat lon" ;
    confidence_level:flag_values = 0b, 1b, 2b, 3b, 4b, 5b ;
    confidence_level:flag_meanings = "unprocessed erroneous unreliable
                                      acceptable good excellent" ;
    confidence_level:flag_descriptions = "\n",
             "  0 -> not processed, no input data\n",
             "  1 -> computation failed\n",
             "  2 -> processed but to be used with care\n",
             "  3 -> nominal processing, acceptable quality\n",
             "  4 -> nominal processing, good quality\n",
             "  5 -> nominal processing, excellent quality" ;
  byte status_flag(time, yc, xc) ;
    status_flag:long_name = "status flag for sea ice edge retrieval" ;
status_flag:standard_name = "sea_ice_classification status_flag" ;
    status_flag:_FillValue = -1b ;
    status_flag:valid_min = 0b ;
    status_flag:valid_max = 102b ;
    status_flag:grid_mapping = "Polar_Stereographic_Grid" ;
    status_flag:coordinates = "lat lon" ;
    status_flag:flag_values = 0b, 2b, 10b, 14b, 100b, 101b, 102b ;
    status_flag:flag_meanings = "nominal lake background type_mask
                                land missing unclassified" ;
    status_flag:flag_descriptions = "\n",
             "  0 -> nominal value from algorithm used\n",
             "  2 -> sea ice algorithm applied over lake\n",
             " 10 -> background data was used for setting the value\n",
             " 14 -> value set using an ice type mask\n",
             "100 -> missing value due to over land\n",
             "101 -> missing value due to missing data\n",
             "102 -> unclassified pixel" ;
```

```
// global attributes:
  :title = "Daily Sea Ice Edge Analysis from OSI SAF EUMETSAT" ;
  :product_id = "OSI-402" ;
  :product_name = "osi_saf_ice_edge" ;
  :product_status = "operational" ;
  :abstract = "The daily analysis of sea ice edges and  extent  is  obtained from
             operation satellite images of the polar regions.  It  is based on
             atmospherically  corrected  signal  and  a  Bayesian merging approach
             to estimate sea ice class probabilities. This product is freely
             available from the EUMETSAT Ocean and Sea Ice Satellite Application
             Facility (OSI SAF)." ;
  :topiccategory = "Oceans ClimatologyMeteorologyAtmosphere" ;
  :keywords = "Sea Ice Edge, Sea Ice, Oceanography, Meteorology, Climate, Remote
             Sensing" ;
  :gcmd_keywords =  "Cryosphere > Sea Ice > Ice Edges",
             "Oceans > Sea Ice > Ice Edges",
             "Cryosphere > Sea Ice > Ice Extent",
             "Oceans > Sea Ice > Ice Extent",
             "Geographic Region > Northern Hemisphere",
             "Vertical Location > Sea Surface",
             "EUMETSAT/OSISAF > Satellite Application Facility on Ocean and
                    Sea Ice, European Organisation for the Exploitation of
                    Meteorological Satellites" ;
  :northernmost_latitude = 90.f ;
  :southernmost_latitude = 30.98056f ;
  :easternmost_longitude = 180.f ;
  :westernmost_longitude = -180.f ;
  :activity_type = "Space borne instrument" ;
  :area = "Northern Hemisphere" ;
  :instrument_type = "Multi-sensor analysis" ;
  :platform_name = "Multi-sensor analysis" ;
  :start_date = "2015-01-08 00:00:00" ;
  :stop_date = "2015-01-09 00:00:00" ;
  :project_name = "EUMETSAT OSI SAF" ;
  :institution = "EUMETSAT OSI SAF" ;
  :PI_name = "Lars-Anders Breivik" ;
  :contact = "osisaf-manager@met.no" ;
  :distribution_statement = "Free" ;
  :copyright_statement = "Copyright 2015 EUMETSAT" ;
  :references = "OSI SAF Sea Ice Product Manual, Eastwood S. (editor), v3.7,
             April 2011",
             "http://osisaf.met.no",
             "http://www.osi-saf.org" ;
  :history = "2015-01-09 creation" ;
  :product_version = "3.1" ;
  :software_version = "4.1" ;
  :netcdf_version = "3.6.3" ;
  :Conventions = "CF-1.4" ;
}
```