Ocean & Sea Ice SAF

Global Sea Ice Concentration Reprocessing

Product User Manual

Product OSI-409, OSI-409-a, OSI-430

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Data set version: 1.2

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Documentation Change Record

Document version	Data set version	Software version	Date	Change Description
v1.0	v1.0	v4.0	14.01.2010	First version.
v1.1	v1.0	v4.0	30.03.2010	Updates after DRI review.
v1.2	v1.1	v4.0	23.06.2011	The uncertainties have been re-calculated with a corrected and re-implemented algorithm. Added 2008 -10.2009.
v1.3	v1.1	v4.0	21.10.2011	Updated after DRI2 review
v2.0 draft	v1.2	v5.0	16.02.2015	Included OSI-409-a data set (2009-2014) and OSI-430, ready for DRI review
v2.0	v1.2	v5.0	10.04.2015	Updated with comments from DRI review
v2.1	v1.2	v5.0	26.07.2015	Updated with final date and directory for continuous updated product.
v2.2	v1.2	v5.0	18.08.2015	Added details about different pole hole for the three sensors used.
v2.3	v1.2	v5.0	30.10.2015	Minor, added some dates for the satellite periods used.
v2.4	v1.2	v5.0	26.04.2016	Replaced SSMIS F17 with F18 for OSI-430

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 OSI SAF overview

The Ocean and Sea Ice Satellite Application Facility, OSI SAF, is a EUMETSAT project that started in 1997. The OSI SAF is a part of the EUMETSAT distributed ground segment for production of operational near real time value added satellite products. The OSI SAF delivers a range of air-sea interface products, namely: sea ice characteristics, sea surface temperature, radiative fluxes and wind. The sea ice products are sea ice concentration, sea ice edge, sea ice type, sea ice drift and sea ice emissivity.

The OSI SAF project is managed by CMS, Meteo-France. The sea ice products are produced at the OSI SAF High Latitude processing facility operated jointly by the Norwegian Meteorological Institute and Danish Meteorological Institutes.

1.2 Sea ice concentration reprocessing project

Since the start of the operational production of sea ice products in 2002 the growing user group has brought more focus on expanding the available data set. It was therefore decided to reprocess historical passive microwave data to extend the OSI SAF sea ice data set. This effort was started in 2006 as a part time EUMETSAT visiting scientist activity in collaboration with the UK Met Office. The goal was to reprocess the SSM/I data record. A collaboration was also established with NSIDC to include the SMMR data record in the project, and an EUMETSAT visiting scientist project was set up for this task. These two Visiting Scientist projects initiated the OSI SAF reprocessing and produced a first version of reprocessing data set based on the SSM/I data. Further improvements were implemented before version 1.1 was finished. In 2015, the data set was extended to cover a longer period, and in addition a continuous updates product was introduced. The user should be aware that operational non re-calibrated SSM/I and SSMIS data have been used after 15th October 2009 (see Chapter 2).

These reprocessed data sets and product fulfil the requirements for OSI-409, OSI-409-a and OSI-430 in OSI-SS-PRO-200 in the OSI SAF Service Specification Document [RD.1]. The validation results are presented in a separate validation report [RD.2]. The algorithm details are presented in the Algorithm Theoretical Basis Document [RD.6]

1.3 Data set version

This product user manual describes version 1.2 of the OSI SAF reprocessed sea ice concentration data set, which was released in May 2015. Version 1.2 consists of two parts:

- OSI-409, which was originally version v1.1, covering Oct 1978 - 14.10.2009.
- OSI-409-a, covering 15.10.2009 to 15.04.2015.

In addition, this manual describes the OSI SAF continuous sea ice concentration updates product (OSI-430), which covers the period from 16.04.2015.

1.4 Ownership and copyright of data

The OSI SAF reprocessed sea ice concentration data set has been produced under responsibility of Norwegian Meteorological Institute and Danish Meteorological Institute. The ownership and copyrights of the data set belongs to EUMETSAT. The data set 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.

1.5 Acknowledgment

We would like to thank John Stark (previously at the UK Met Office) for his effort as a visiting scientist under the OSI SAF IOP-SG06-VS01 Visiting Scientist project. His efforts are documented in Stark (2008).

We would also like to thank Walt Meier and Jeff Smith at NSIDC for their cooperation and effort during the OSI SAF CDOP-SG01-VS03 Visiting Scientist project. Their work is documentation in Meier (2008).

1.6 Glossary

ASCII	American Standard Code for Information Interchange
CMS	Centre de Météorologie Spatiale
CDL	network Common data form Description Language
CDOP	Continuous Development and Operations Phase (OSI SAF project)
CF	Climate and Forecast (Metadata Conventions)
DMI	Danish Meteorological Institute
DMSP	Defense Meteorological Satellite Program
EASE	Equal-Area Scalable Earth
ECMWF	European Centre for Medium range Weather Forecast
ERA	ECMWF Re-Analysis
FTP	File Transfer Protocol
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GCMD	Global Change Master Directory
MET	Norwegian Meteorological Institute
NASA	National Aeronautics and Space Administration
NetCDF	Network Common Data Form
NSIDC	National Snow and Ice Data Center
NWP	Numerical Weather Prediction
OSI SAF	Ocean and Sea Ice Satellite Application Facility
PMR	Passive Microwave Radiometer
RTM	Radiative Transfer Model
RSS	Remote Sensing Systems
SAR	Synthetic Aperture Radar
SIC	Sea Ice Concentration
SMMR	Scanning Multichannel Microwave Radiometer
SSM/I	Special Sensor Microwave/Imager
SSMIS	Special Sensor Microwave Imager and Sounder

1.7 Reference Documents

[RD.1] OSI SAF CDOP2 Service Specification Document, v2.4.

[RD.2] OSI SAF Sea Ice Concentration Reprocessing Product Validation Report, v.2.0.

[RD.3] OSI SAF IOP-SG06-VS01 report (Stark, 2008).

[RD.4] OSI SAF CDOP-SG01-VS03 report (Meier, 2008).

[RD.5] Adaptation of SAFOSI sea ice processing system to southern hemisphere (Toudal, 2006).

[RD.6] ATBD for the OSI SAF Global Reprocessed Sea Ice Concentration Product. Version 1.1, 2014.

2. Input data

This chapter describes the main input data that have been used for the OSI SAF sea ice concentration reprocessing.

2.1 SMMR

The Scanning Multichannel Microwave Radiometer (SMMR) instrument on board the Nimbus 7 satellite operated from 24th October 1978 to 20th 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 (see Table 1). 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°. 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 data available poleward of 84.5°, which results in a significant “pole hole” (611km in radius) without data coverage.
The SMMR instrument is further described in http://nsidc.org/data/docs/daac/smmr_instrument.gd.html and the brightness temperature data and the initial formatting of the data are described in Meier (2008).

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

Table 1: Characteristics of the Nimbus 7 SMMR channels (Gloersen and Barath, 1977). Channels in italic are not used.

2.2 SSM/I

The Special Sensor Microwave/Imager (SSM/I) sensors on board the Defence Meteorological Satellite Program (DMSP) started its record with the F08 satellite on 9. July 1987 shortly before the SMMR ceased to operate on 20. 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 up-welling radiation from the Earth at a constant incidence angle of about 50° at 7 different channels. The channels are summarised in Table 3. The swath width is about 1400km. Because of the satellite orbit inclination and swath width there is no data available poleward of 87.2°. This results in a “pole hole” 311km in radius without data coverage, which is significant smaller than the SMMR pole hole.

The Special Sensor Microwave/Imager (SSM/I) data set used for the reprocessing v1.1 (OSI-409) was purchased by EUMETSAT from Remote Sensing Systems (RSS) and covers the whole period of available satellites with SSMI/I instruments from 1987 to 14th October 2009. We have used the version 6 of the RSS SSM/I data set. The different satellites and covered periods are listed in Table 2.

The SSM/I data were received as antenna temperatures from RSS. These antenna temperatures were converted to brightness temperatures (Tb's) using a software provided by RSS, as described in chapter 4.1.1.

The SSM/I instrument have 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 85GHz channels had a malfunction on F08, so they are only useful starting with the F11 satellite. The F10 has not been used because data is more noisy than F11 and it was not needed for a complete coverage.

Satellite	**Period covered**
F08	10th Jul 1987 – 18th Dec 1991
F11	4th Dec 1991 – 14th May 2000
F13	4th Dec 1995 – 23rd Oct 2009
F14	9th May 1997 – 8th Aug 2008
F15	19th Dec 1999 – 18th Jan 2013

Table 2: The different satellite missions carrying the SSM/I instrument and the periods they have been used in this reprocessing.

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

Table 3: Characteristics of the different SSM/I channels (from Wentz, 1991). Channels in italic are not used.

The RSS SSM/I version 6 data set incorporates geolocation correction, sensor calibration and quality control procedures, as well as inter calibration between the different satellites from overlapping periods. These procedures are documented in the RSS SSM/I User's Manuals (Wentz, 1991; Wentz, 1993; Wentz, 2006).

The RSS SSM/I data set is constrained with a license for use and distribution, and the brightness temperatures on swath format used in the OSI SAF reprocessing product can therefore not be distributed.

For the period from 15th October 2009 (until 18th January 2013), the reprocessing is based on operational SSM/I data from NOAA. These are the same data as used for the operational OSI SAF sea ice concentration product and they are received from NOAA through UK Met Office. No re-calibration has been applied to these data. So OSI-409 uses the RSS re-calibrated data set, while OSI-409-a and OSI-430 uses operational data where no re-calibration has been applied. Since the sea ice concentration processing uses dynamical tie-points, the effect of different input data sources is expected to be minimal.

In this period where operational data are used, missing dates might be more frequent compared to the data based on SSM/I data from the re-calibrated time-series from RSS. See the appendix for a list of missing dates.

2.3 SSMIS

The SSMIS is a polar orbiting conically scanning radiometer with constant incidence angle around 50° and a swath width of about 1700km. Because of the satellite orbit inclination and swath width there is no data available poleward of 89.18°. This results in a pole hole 94km in radius without data coverage, considerable smaller than the pole hole for the SSM/I data period.

It has window channels near 19, 37, 91, and 150GHz and sounding channels near 22, 50, 60, and 183 GHz. The SSMIS temperature sounding channels 1-4 near 50GHz vertical polarization penetrate into the lower troposphere and partially to the surface (Kunkee et al., 2008). The sea ice concentration algorithm uses brightness temperature swath data from the 19V, 37V and 37H channels. These channels have very similar characteristics to the equivalent channels on the SSM/I radiometer, as described in Table 3.

The SSMIS data from the F17 satellite is used from 19th January 2013 to 12th April 2016, and SSMIS from the F18 satellite from 13th April 2016 onwards. These data are received through EUMETCast, originally coming from NOAA. These are operational data where no recalibration has been applied.

2.4 ECMWF NWP

The brightness temperatures (Tb) are corrected explicitly for wind roughening over open water and water vapour in the atmosphere prior to the calculation of ice concentration. The correction uses a radiative transfer model function (RTM) and NWP data. The model function used for correction of the SMMR and SSM/I Tbs using ECMWF NWP input is denoted by (Wentz, 1983):

$$Tb = f(Ts, U^*, V, L, Ta) \quad , \qquad \text{(Eq. 1)}$$

where *Ts* is the physical surface temperature, *U** is the sea surface wind friction velocity, *V* is the integrated atmospheric water vapour column, *L* is the atmospheric liquid water column, and *Ta* is the surface (2 m) air temperature. Over areas with both ice and water the influence of open water roughness on the Tb's and the ice emissivity is scaled linearly with the ice concentration. The emissivity of ice is given by standard tie-point emissivities. The correction procedure is described in detail in Andersen et al. (2006B). The NWP model grid points are co-located with the satellite swath data in time and space and a correction to the Tb's using Eq. 1 is applied. ECMWF ERA 40 data are used for the period from 1978 to 2002, and ECMWF data from the operational model are used from 2002 onwards. So OSI-409 is partly using ERA 40, while OSI-409-a and OSI-430 are using operational model data. A description of the ERA 40 data archive and the reprocessing can be found in Kålberg et al. (2004). These two NWP model data sets are not completely consistent, however the inconsistencies are expected to be small and the residual error are incorporated in the sea ice concentration algorithm error estimate (see [RD.6]).

The representation of atmospheric liquid water column (L) in the NWP data is not suitable to use for Tb correction (see Andersen et al., 2006B). The Tb's are therefore not corrected for the influence of L. Assuming neutral atmospheric conditions, the wind speed at 10 m, given by the NWP model, is converted to the surface friction velocity using the factor 0.047. The other NWP variables are used directly.

3. Processing scheme

This chapter describes all the processing steps in the OSI SAF sea ice concentration reprocessing scheme. The same algorithm and processing modules is used for OSI-409, OSI-409-a and OSI-430. The only difference between these three are the top-level job-control scripts and the source of input data.

The processing steps can be divided in three main steps; Level 1/2, Level 3 and Level 4. An overview of these three steps are shown in Figure 1, and the technical details are presented in more detail in the next three sections. The science behind some of these steps are discussed in the ATBD [RD.6].

There is a overlapping period between SMMR and SSM/I, and between SSM/I and SSMIS. For these reprocessed data sets, SSM/I is used in the overlapping period with SMMR. For the change between SSM/I and SSMIS, the change is made instantly on the 19th January 2013, and the data are not merged, except for the definition of the dynamical tie-points (see section 3.1.6).

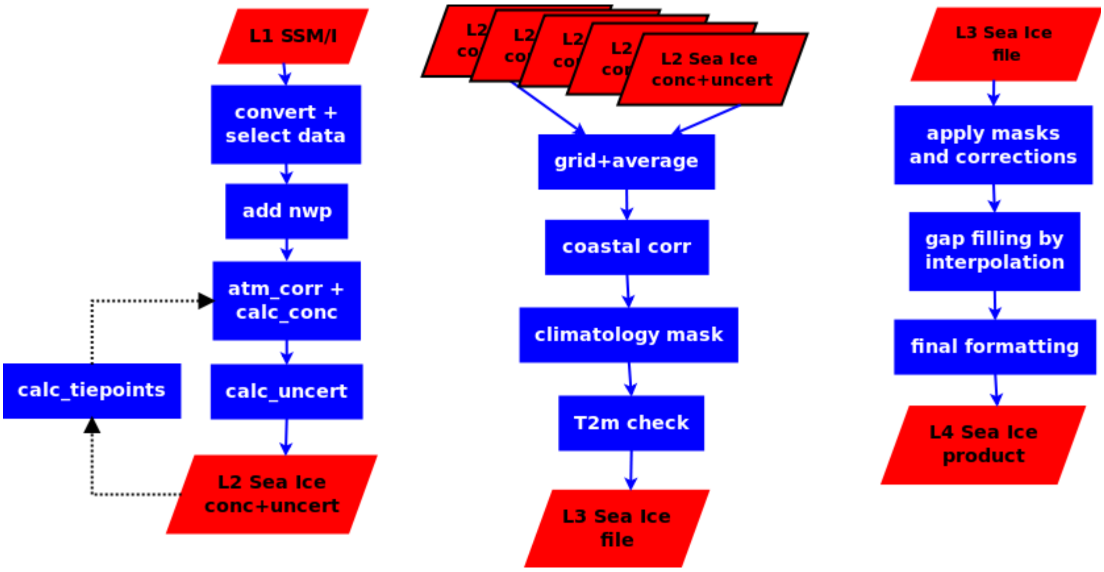

Figure 1: The three main processing elements in the ice concentration processing chain. The processing is the same for all three data inputs; SMMR, SSM/I and SSMIS.

3.1 L1/L2 processing

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

3.1.1 Converting antenna temperature to brightness temperature

The antenna temperatures measured by the radiometer are different from the brightness temperatures, due to antenna pattern effects such as antenna side-lobe contributions and cross polarization coupling (Njoku et al. 1980; Njoku, 1980). The SSM/I data provided by the RSS are converted from antenna temperatures to brightness temperatures using the method described in Wentz (1991).

3.1.2 Selection of data

The SMMR, SSM/I and SSMIS data sets provide almost global coverage (see also chapter 2.1 and 2.2). The exception is a circular area around each pole which is not covered due to the inclination of the satellite orbit and the limited swath width. For SMMR there are no data available poleward of 84°, for SSM/I this limit is at 87° and for SSMIS the limit is at 89°.

To reduce the amount of data to be processed the global data sets are filtered by selecting only data from areas where ice is ever likely to occur. For this purpose a sea ice maximum extend climatology from NSIDC is used. This mask has been extended with 300km to be sure no ice is missed. All land data more than 100km from the coast are excluded.

3.1.3 Adding NWP data

NWP data from ECMWF (see also Chapter 2.3) are interpolated in time and space to the position of each set of low resolution brightness temperatures. The following parameters are collected:

- surface temperature at 2 m height
- total column water vapour
- total column liquid water
- wind speed and wind direction at 10m height

Total column liquid water is not used in the processing, but is kept for reference.

3.1.4 RTM correction and ice concentration calculations

The NWP model grid points are co-located with the satellite swath Tb's in time and space, and a correction for water vapour and open water roughness is applied. Over fractions of both ice and water the influence of open water roughness on the Tb's and the ice emissivity is scaled linearly with the ice concentration using iteration. The emissivity of ice is given by standard tie-point emissivities. The correction procedure is described in detail in Andersen et al. (2006B).

The ice concentration is calculated as part of the correction procedure. This gives ice concentration estimates both for uncorrected and corrected brightness temperatures. The uncorrected ice concentration estimates are only kept for reference. More details are given in Chapter 2.3 and the ATBD [RD.6].

3.1.5 Uncertainty calculations

The representativeness error is computed as a function of ice concentration for each algorithm and sensor using a model. The remaining error sources (including the instrument noise, residual atmospheric noise, surface emissivity noise) are estimated in combination using the hemispheric variability of the measurements. The total uncertainty is the sum of the partial uncertainties squared as described in [RD.6]

3.1.6 Dynamical tie-points

The L1/L2 processing is done in two steps. The two last steps are done twice, as shown in Figure 1. This is necessary for the generation of the dynamical tie-points. First, a primary tie-point set is generated based on uncorrected brightness temperatures and corrected brightness temperatures are calculated. Secondly, a secondary tie-point set is generated using the corrected brightness temperatures. With these corrected brightness temperature tie-points the final ice concentration calculations are made. More details are given in [RD.6]

3.2 L3 processing

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

3.2.1 Daily gridding

The daily gridding searches for all observations within 24 hours, centered on 12:00 UTC, and grids these to the final output grid. The observations within one grid cell are averaged, using a weight defined as:

$$weight = 1.0 - (dist / inflrad) * 0.3 \quad , \qquad \text{(Eq. 5)}$$

where *dist* is the distance between the observation and center of grid point, and *inflrad* is the radius of influence. The influence radius depends on the sampling radius for the channel. For low resolution channels (19, 22 and 37 GHz) 18 km is used and for 85GHz 9 km is used. The 85GHz is kept for internal use, and no ice concentration product based on this sensor is provided.

The gridding is done for all areas with data coverage, including the coastal zone. A gridded field is made for all the ice concentration estimates, based on both uncorrected and corrected brightness temperatures, and for the algorithms present in the L2 files. A similar gridding/averaging is applied for the uncertainty estimates.

In the averaging, observations from multiple satellite missions are available in overlapping periods. During overlaps in the SSM/I period, observations from different satellites are averaged. The dynamical tie-point approach handles the possible inter satellite differences, which is shown in the validation report [RD.2]. Data during the overlap period between SMMR and SSM/I data are not mixed, as these instruments are more different. SSM/I and SSMIS data are also not mixed in the daily gridding.

3.2.2 Coastal correction

Observations in the coastal zone are a mixture between land and water/sea ice. Land has similar signatures to sea ice, and the algorithms therefore overestimate the sea ice concentration in these areas. To correct for these so-called land spill-over effects, an extra coastal correction step has been implemented. The method implemented is described in detail in Cavalieri et al. (1999). In short, this method first calculates monthly average ice concentration for all the months in a selected year and then finds the minimum ice concentration from these averages. This minimum is then used to correct the ice concentration values in the coastal zone if adjacent non-coastal grid points are ice free. The minimum monthly average ice concentration fields has been calculated using data from 1985 for SMMR and 1992 for SSM/I and SSMIS. Separate fields is calculated for all algorithms processed.

This processing step generates an additional field with the coastal correction to be added to the concentration field, without applying it.

3.2.3 Climatological maximum extent masking

To mask out erroneous ice outside areas where sea ice is ever likely to occur, a monthly maximum extent climatology is used. This climatology has been produced by NSIDC using SMMR and SSM/I monthly averaged ice concentrations and finding the maximum extent for each month between 1979 and 2007. The maximum extent in the NSIDC maps has been expanded 100km in all directions to assure that the masks are surely outside the areas were sea ice is ever likely to occur. Examples of these masks are given in Appendix B. More details about these monthly climatological maximum fields (or ocean mask as called by NSIDC) are available from NSIDC:

http://nsidc.org/data/smmr_ssmi_ancillary/ocean_masks.html.

This processing step collects the respective monthly mask and adds it to the file as a separate layer.

After the OSI-409 (v1.1) data set was generated, the expansion distance of 100km showed not to be sufficient in the Southern Hemisphere for the later years. For the extension of the period in OSI-409a (v1.2) a change in the maximum extent mask was introduced, using an expansion distance of 300km instead of 100km (only for the Southern Hemisphere). This extended masking has therefore been applied on all data from 15.10.2009 onwards. For users that want to look into these differences and possibly change the maximum extent masking, the mask files are available on NetCDF format here:

ftp://osisaf.met.no/reprocessed/ice/oceanmasks

3.2.4 T2m check

A quality check using the NWP T2m (air temperature at 2 meters) field is used in the processing. The T2m NWP values that have been interpolated in time and space to each observation in the 'add NWP step' (section 3.1.3), are gridded and averaged as for the sea ice concentrations. This field is then added as a separate layer for later use. The test applying the T2m value is based on experience from the operational OSI SAF chain, and shows useful for removing gross errors far from the sea ice edge. In the reprocessing data sets it is not used for modifying the nominal value, just for flagging questionable data.

3.3 L4 processing

This final main step contains filling of some areas with missing data by interpolation and applying masks and corrections to present the final ice concentration product. The processing status flag variable (section 4.1.3) is computed during these steps.

3.3.1 Applying masks and coastal correction

A sea ice concentration analysis step is performed where the various masking steps, the coastal correction and the T2m check (as described in sections 3.2.2, 3.2.3 and 3.2.4) are applied.

The nominal values of the sea ice concentrations and uncertainties are modified (except the T2m test), and a variable holding the processing status flags is created. The flags are described in section 4.1.3.

3.3.2 Gap filling by interpolation

For easing the use of the reprocessing data set, some level of spatial interpolation are performed for reducing the occurrence of gaps. Only missing data are interpolated. Interpolated data points are clearly marked in the product file (see section 4.1.3) so that users can choose to discard them and only ingest retrievals that rely on satellite observations.

Data gaps can occur in several forms, such as missing scan lines, missing orbits and polar observation hole. While spatial interpolation might be efficient in filling small gaps (e.g. one or two missing scan lines), it necessarily blurs the sea ice concentration features. This effect becomes overwhelming when large areas are missing. To overcome this issue, yet implementing a general approach for all cases, the ice concentration estimates from the previous and next daily products are used in the interpolation as well. In the case of SSM/I and SSMIS, it means that interpolation on a given date D uses pixels from 3 data files: D-1, D and D+1. More details are given in [RD.6].

Be aware that since the pole hole (see sections 2.1, 2.2 and 2.3) is different for the three types of satellite sensors that are used in this data record (SMMR, SSM/I and SSMIS), the will be a systematic difference in the area covered by gap filling at the Northern Hemisphere.

3.3.3 Final formatting

This step formats the data sets into a CF compliant NetCDF file. A limited number of variables (ice concentration, uncertainties, processing flags, latitude, longitude) for the selected algorithm are extracted to a new file where global attributes are added. The format of this final product file is described in the next chapter.

Since SMMR and SSM/I are processed separately, there is a period with overlapping products in July and August 1987. The quality is better for SSM/I and SSM/I is therefore used during the overlapping period. Products based on SMMR data from the overlapping period are provided for reference, see section 4.5.1.

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 consists of three major fields:

- sea ice concentration
- uncertainty estimate
- status flag

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

4.1.1 Sea ice concentration

Sea ice concentration indicates the areal fraction of a given grid point covered by ice. It is given as a real number in percentage, with a range from 0-100%. An example is shown in Figure 2.

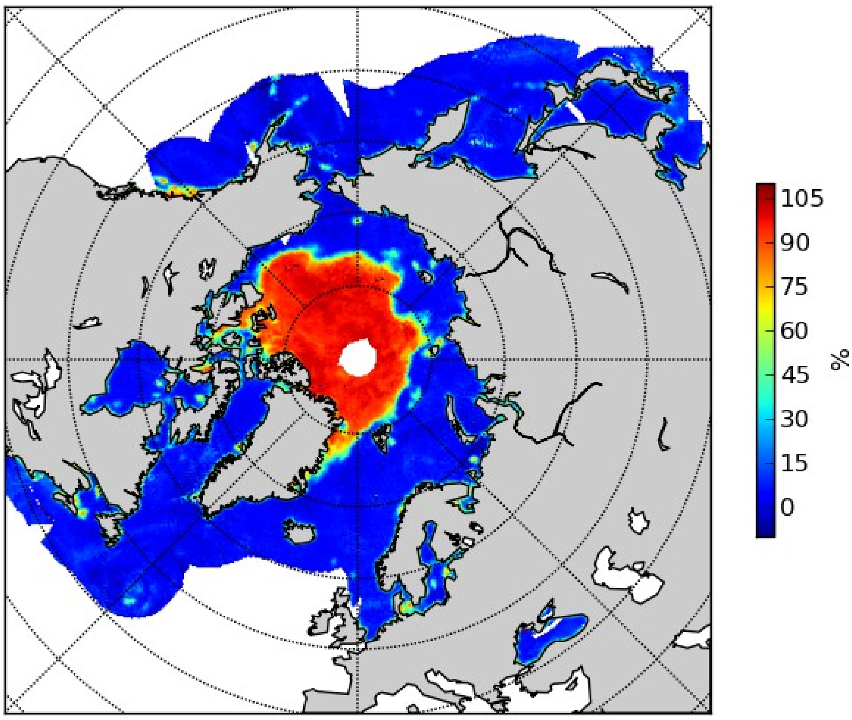

Figure 2: Sea ice concentration from 5th September 2005 derived from SSMI data. The white areas are areas where data are not processed since climatologically they are always open water (climatology described in section 3.2.3). The pole hole is also white. These areas are filled in the final product.

4.1.2 Uncertainty estimate

An estimate of the uncertainty of each sea ice concentration value is given in a separate field. The uncertainty is given as standard deviation in percentage, with at range from 0-100%. An example is shown in Figure 3.

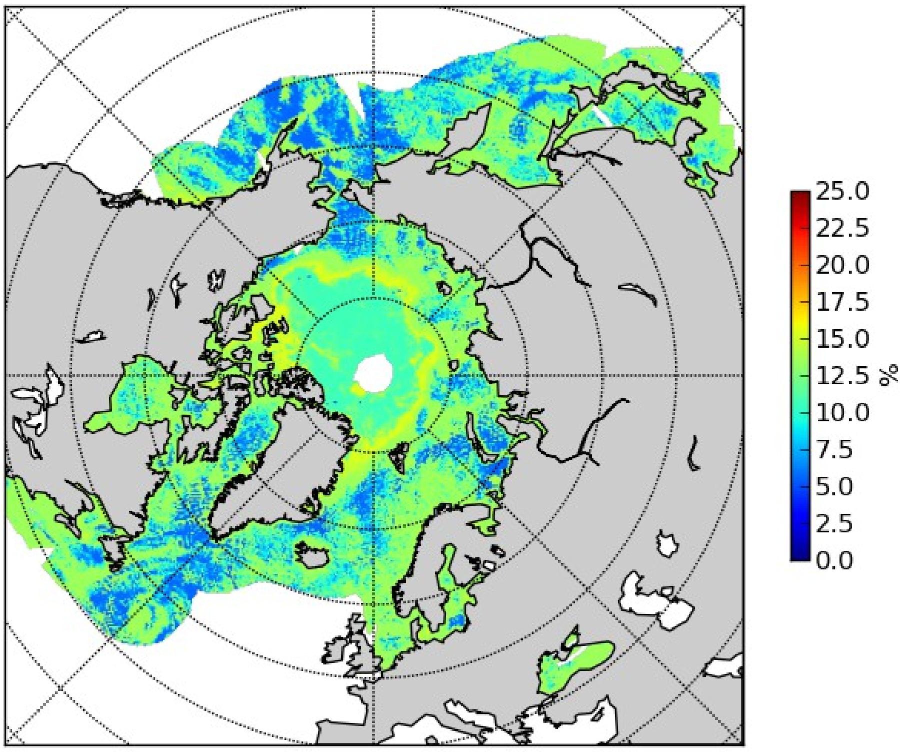

Figure 3: Total uncertainty (standard deviation) field of example shown in Figure 2.

4.1.3 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, with one flag value for each ice concentration value. The different values are described in Table 4. These flags are not additive, so all the values are exclusive (e.g. coastal correction and gap filling can not occur for the same data point).

Value	Quality indication	Definition
0	Nominal	Nominal ice concentration value given.
1	Nominal value questionable	Nominal value, but T2m check indicates possibility of false ice due to high surface air temperature (> +10°C).
2		Nominal value, but quality questionable because of lake ice.
10	Nominal value changed	Coastal correction has been applied.
11		Climatological maximum extent mask has been applied inside data area.
12		As value 11, but outside of data coverage area.
13		Gap filling has been applied.
100	Missing value	Missing value due to land.
101		Missing value due to missing data.

Table 4: Definition of sea ice concentration status flags.

4.2 Grid specification

The sea ice concentration product is available on two projections and grids, each with one product for each hemisphere. The projections used are a Lambert Azimuthal Equal Area projection with grid a resolution of about 12.5 km, and a Polar Stereographic projection with a grid resolution of 10.0km. The Lambert grid is also called the EASE grid, and it is used by NSIDC for several of their sea ice products. More documentation about the EASE grid can be found on their web site: http://nsidc.org/data/ease/.

The details of the grid definitions are given in Table 5 and Table 6 below. Maps of the areas are shown in Figure 4 and Figure 5. Projection definitions in the form of PROJ-4 initialization strings are also given (see [http://www.remotesensing.org/proj] for details).

Projection:	Lambert Azimuthal Equal Area
Resolution:	12.5337625 km
Size:	849 columns, 849 lines
Central Meridian:	0°
Radius of Earth:	Spherical: 6371228.0 m
PROJ-4 string:	NH: +proj=laea +R=6371228.0 +lat_0=90 +lon_0=0 SH: +proj=laea +R=6371228.0 +lat_0=-90 +lon_0=0

Table 5: Geographical definition for the EASE 12.5 km grid, Northern and Southern Hemisphere.

Projection:	Polar Stereographic
Resolution:	10.0 km
Size:	NH: 860 columns, 1120 lines SH: 790 columns, 830 lines
Central Meridian:	-45°
Radius of Earth:	Elliptical: a=6378273.0m , b=6356889.44891 m
PROJ-4 string:	NH: +proj=stere +a=6378273 +b=6356889.44891 +lat_0=90 +lat_ts=70 +lon_0=-45 SH: +proj=stere +a=6378273 +b=6356889.44891 +lat_0=-90 +lat_ts=-70 +lon_0=0

Table 6: Geographical definition for the Polar Stereographic 10.0 km grid, Northern and Southern Hemisphere.

4.3 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. The Global Attributes have been selected for matching requirements from the International Polar Year projects DAMOCLES and iAOOS-Norway (http://dokipy.met.no). GCMD and IMO keywords were also selected. An ASCII version of the NetCDF header, on CDL form as given by the program `ncdump`, is given in Appendix A.
The Lambert Azimuthal 12.5km files are also available in the EUMETSAT Data Centre. The additional meta data for these files are described in Appendix D.

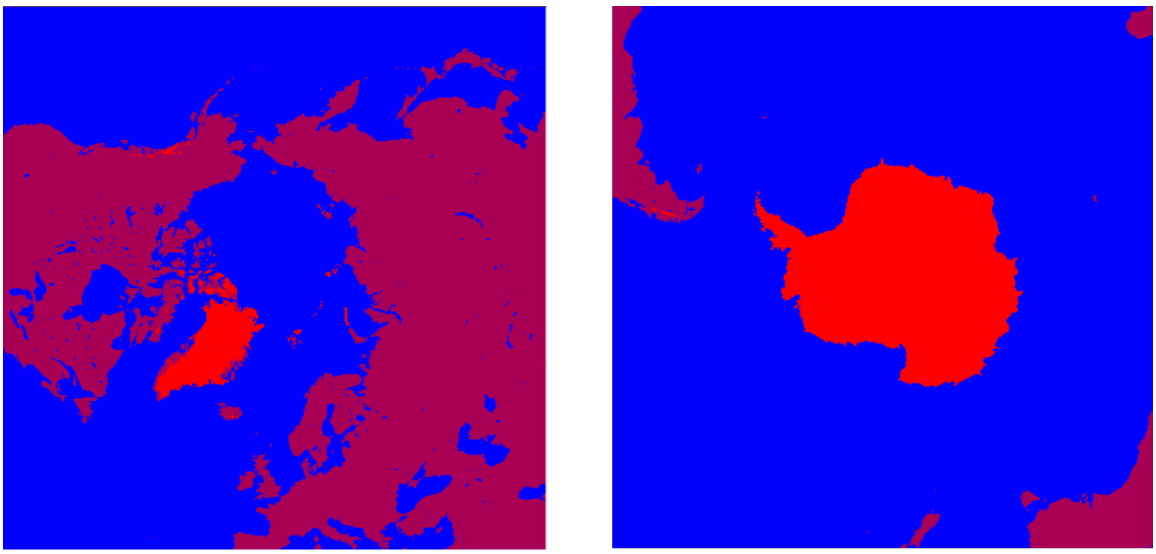

Figure 4: Area covered by the EASE 12.5 km grids for Northern (left) and Southern (right) hemispheres.

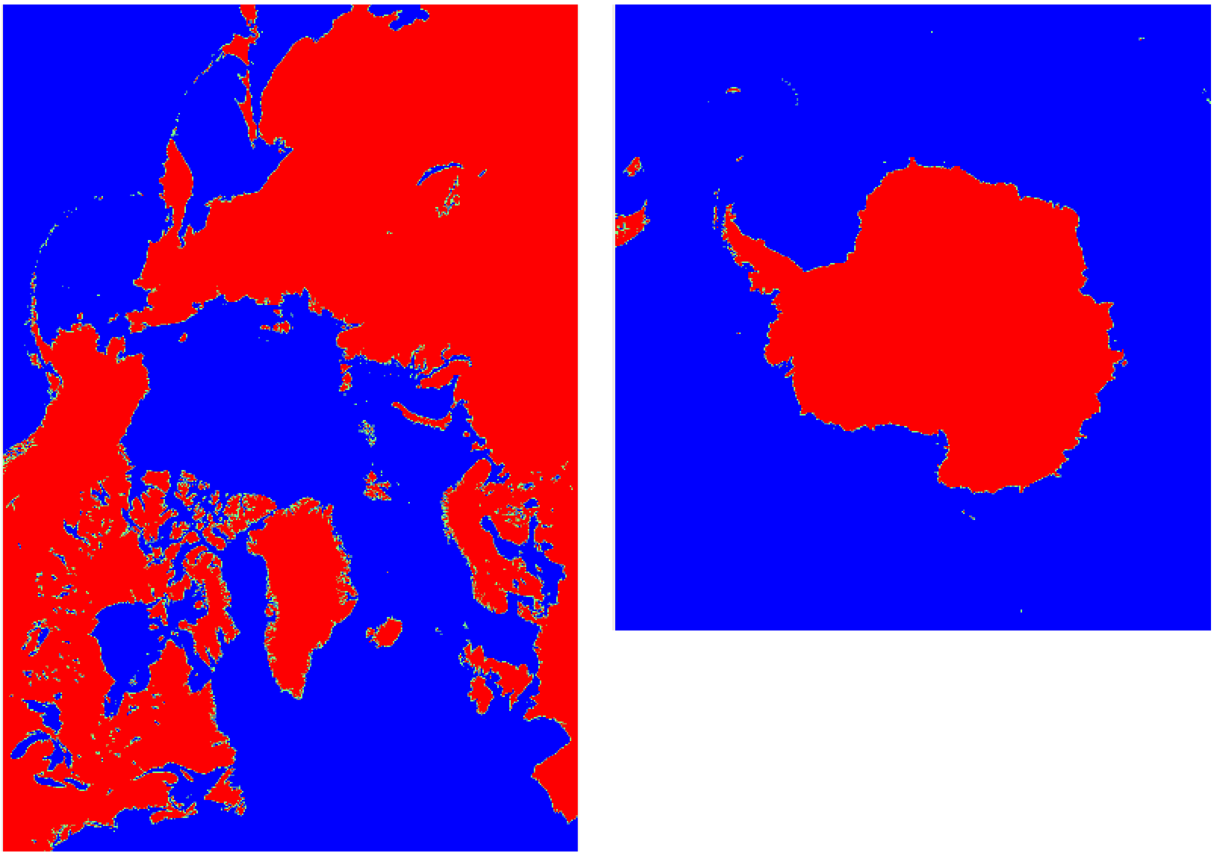

Figure 5: Area covered by the Polar Stereographic 10.0 km grids for Northern (left) and Southern (right) hemispheres.

4.4 File naming convention

4.4.1 FTP file name convention

On the OSI SAF FTP server the NetCDF product file have the following naming convention:

`ice_conc_<area>_<proj>-<gridRes>_<prodtype>_<date12>.nc` ,

where:

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

`<proj>` : `<ease>` for the equal area Lambert azimuthal projection, `<polstere>` for the Polar Stereographic projection.

`<gridRes>` : spatial resolution of the grid (`<125>` for 12.5 km, `<100>` for 100 km)

`<prodtype>` : product type, `<reproc>` for reprocessed data set (OSI-409, OSI-409a), `<cont-reproc>` for continuous reprocessed product (OSI-430)

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

4.4.2 EUMETSAT Data Centre file name convention

In the EUMETSAT Data Centre the NetCDF product file 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.

Only the Lambert Azimuthal 12.5km resolution files are available in the EUMETSAT Data Centre.

4.5 Product availability

4.5.1 Reprocessed data set

The OSI SAF sea ice concentration reprocessing data set covers the period from 26.10.1978 to 31.03.2015. Some dates are missing due to lack of satellite data. These dates are listed in Appendix C.

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/v1p2/

The data are organized in year and month directories. The SMMR data covers the period from from 26.10.1978 to 09.07.1987, the SSM/I data covers the period from 10.07.1987 to 18.01.2013, and the SSMIS data the period from 19.01.2013 onwards. SMMR data from the overlapping SMMR-SSM/I period (11.07.1987 – 20.08.1987) are made available for reference, and kept in the directory called "overlapping_smmr".

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

4.5.2 Continuous updates product

The OSI SAF reprocessed sea ice concentration continuous updates product is available since 16.04.2015 as an off-line product, and is available on the OSI SAF Sea Ice FTP-server at this address:

ftp://osisaf.met.no/reprocessed/ice/conc-cont-updates/v1p2/

The data are organized in year and month directories.

4.6 Next release of the data set

The next release of the data set (which will be named OSI-450) is planned for end of 2016, covering the full period back to 1978, and using the CM SAF FCDR for passive microwave 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 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 depth of the emitting at these wavelengths indeed do not allow for distinguishing between ocean water (in leads) and melt water (in ponds). This is the main reason why PMR SIC datasets are underestimating sea ice concentration during summer.

4.7.2 Thin sea-ice

Concentration of thin sea-ice (5-30cm) 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.

4.7.3 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 were interpolation was used are clearly identified in the status_flag layer (see section 3.3.2 and 4.1.3).
These interpolated sea ice concentration values should generally not be used for scientific applications, especially the values obtained from spatial interpolation.

4.7.4 Grid resolutions

The OSI SAF SIC dataset is presented on two grids, at 10km and 12.5km spatial sampling. These grids are used to be consistent with the other operational OSI SAF sea ice products. The spatial sampling of these grids do not represent the true spatial resolution of the product. 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 larger than the spatial sampling of the product grids.

4.7.5 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 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 section 3.2.2. However, this coastal correction procedure is not perfect, and a level of false sea-ice remains along some coastlines.

5. References

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6. Appendix A : Example of NetCDF format

Below is given an example of the NetCDF header of an OSI SAF sea ice concentration reprocessing file (CDL format).

```
netcdf ice_conc_nh_ease-125_reproc_199112021200 {
dimensions:
	time = 1 ;
	nv = 2 ;
	xc = 849 ;
	yc = 849 ;
variables:
	int Lambert_Azimuthal_Grid ;
		Lambert_Azimuthal_Grid:grid_mapping_name =
						"lambert_azimuthal_equal_area" ;
		Lambert_Azimuthal_Grid:longitude_of_projection_origin = 0.f ;
		Lambert_Azimuthal_Grid:latitude_of_projection_origin = 90.f ;
		Lambert_Azimuthal_Grid:false_easting = 0.f ;
		Lambert_Azimuthal_Grid:false_northing = 0.f ;
		Lambert_Azimuthal_Grid:earth_radius = 6371228.f ;
		Lambert_Azimuthal_Grid:semi_major_axis = 6371228.f ;
		Lambert_Azimuthal_Grid:proj4_string = "+proj=laea +R=6371228.0
							+lat_0=90 +lon_0=0" ;
	double time(time) ;
		time:long_name = "reference time of product" ;
		time:standard_name = "time" ;
		time:units = "seconds since 1978-01-01 00:00:00" ;
		time:axis = "T" ;
		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" ;
		xc:grid_spacing = "12.5334 km" ;
	double yc(yc) ;
		yc:axis = "Y" ;
		yc:units = "km" ;
		yc:long_name = "y coordinate of projection (northings)" ;
		yc:standard_name = "projection_y_coordinate" ;
		yc:grid_spacing = "12.5334 km" ;
	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" ;
	short ice_conc(time, yc, xc) ;
		ice_conc:long_name = "concentration of sea ice" ;
		ice_conc:standard_name = "sea_ice_area_fraction" ;
		ice_conc:units = "%" ;
		ice_conc:_FillValue = -32767s ;
		ice_conc:valid_min = 0s ;
		ice_conc:valid_max = 10000s ;
		ice_conc:grid_mapping = "Lambert_Azimuthal_Grid" ;
		ice_conc:coordinates = "lat lon" ;
		ice_conc:scale_factor = 0.01f ;
	short standard_error(time, yc, xc) ;
		standard_error:long_name = "total uncertainty (one standard deviation)
					of concentration of sea ice" ;
		standard_error:standard_name = "sea_ice_area_fraction
						standard_error" ;
		standard_error:units = "%" ;
```

```
        standard_error:_FillValue = -32767s ;
        standard_error:valid_min = 0s ;
        standard_error:valid_max = 10000s ;
        standard_error:grid_mapping = "Lambert_Azimuthal_Grid" ;
        standard_error:coordinates = "lat lon" ;
        standard_error:scale_factor = 0.01f ;
    short algorithm_standard_error(time, yc, xc) ;
        algorithm_standard_error:long_name = "algorithm uncertainty (one
                    standard deviation) of concentration of sea ice" ;
        algorithm_standard_error:standard_name = "sea_ice_area_fraction
                                        standard_error" ;
        algorithm_standard_error:units = "%" ;
        algorithm_standard_error:_FillValue = -32767s ;
        algorithm_standard_error:valid_min = 0s ;
        algorithm_standard_error:valid_max = 10000s ;
        algorithm_standard_error:grid_mapping = "Lambert_Azimuthal_Grid" ;
        algorithm_standard_error:coordinates = "lat lon" ;
        algorithm_standard_error:scale_factor = 0.01f ;
    short smearing_standard_error(time, yc, xc) ;
        smearing_standard_error:long_name = "smearing uncertainty (one
                    standard deviation) of concentration of sea ice" ;
        smearing_standard_error:standard_name = "sea_ice_area_fraction
                                        standard_error" ;
        smearing_standard_error:units = "%" ;
        smearing_standard_error:_FillValue = -32767s ;
        smearing_standard_error:valid_min = 0s ;
        smearing_standard_error:valid_max = 10000s ;
        smearing_standard_error:grid_mapping = "Lambert_Azimuthal_Grid" ;
        smearing_standard_error:coordinates = "lat lon" ;
        smearing_standard_error:scale_factor = 0.01f ;
    byte status_flag(time, yc, xc) ;
        status_flag:long_name = "status flag for sea ice concentration
                                                   retrieval" ;
        status_flag:standard_name = "sea_ice_area_fraction status_flag" ;
        status_flag:_FillValue = -128b ;
        status_flag:valid_min = 0b ;
        status_flag:valid_max = 101b ;
        status_flag:grid_mapping = "Lambert_Azimuthal_Grid" ;
        status_flag:coordinates = "lat lon" ;
        status_flag:flag_values = 0b, 1b, 2b, 10b, 11b, 12b, 13b, 100b, 101b ;
        status_flag:flag_meanings = "nominal t2m lake coastcorr maxclim_change
                              maxclim_set interpolated land missing" ;
        status_flag:flag_descriptions = "\n",
            "  0 -> nominal value from algorithm used\n",
            "  1 -> t2m check indicates possibly false ice\n",
            "  2 -> over lake caused possibly less accurate\n",
            " 10 -> value changed by coast correction method\n",
            " 11 -> value changed by applying maximum climatology\n",
            " 12 -> missing value set by applying maximum climatology\n",
            " 13 -> value set by applying interpolation\n",
            "100 -> missing value due to over land\n",
            "101 -> missing value due to missing data" ;

// global attributes:
        :title = "OSI SAF Global Reprocessed Sea Ice Concentration" ;
        :product_id = "OSI-409" ;
        :product_name = "osi_saf_ice_conc_reproc" ;
        :product_status = "offline" ;
        :abstract = "The reprocessing of sea  ice  concentration  is  obtained
                                                             from\n",
            "passive microwave satellite data over the polar  regions.
                                                               It\n",
            "is based on atmospherically corretected signal and an
                                                          optimal\n",
            "sea ice concentration algorithm. This  product  is
                                                        available\n",
            "for free from  the  EUMETSAT  Ocean  and  Sea  Ice
                                                        Satellite\n",
            "Application Facility (OSI SAF)." ;
        :topiccategory = "Oceans ClimatologyMeteorologyAtmosphere" ;
        :keywords = "Sea Ice Concentration,Sea
```

```
                                Ice,Oceanography,Meteorology,Climate,Remote Sensing" ;
             :gcmd_keywords = "Cryosphere > Sea Ice > Sea Ice Concentration\n",
                    "Ocean > Sea Ice > Sea Ice Concentration\n",
                    "Geographic Region > Northern Hemipshere\n",
                    "Vertical Location > Sea Surface\n",
                    "EUMETSAT/OSISAF > Satellite Application Facility on Ocean and
 Sea Ice, European Organisation for the Exploitation of Meteorological Satellites" ;
             :northernmost_latitude = 90.f ;
             :southernmost_latitude = 17.71581f ;
             :easternmost_longitude = 180.f ;
             :westernmost_longitude = -180.f ;
             :activity_type = "Space borne instrument" ;
             :area = "Northern Hemisphere" ;
             :start_date = "1991-12-02 00:00:00" ;
             :stop_date = "1991-12-03 00:00:00" ;
             :project_name = "EUMETSAT OSI SAF" ;
             :institution = "EUMETSAT OSI SAF" ;
             :PI_name = "Rasmus Tonboe and Steinar Eastwood" ;
             :contact = "osisaf-manager@met.no" ;
             :distribution_statement = "Free" ;
             :references = "Global Sea Ice Concentration Reprocessing Product User
                      Manual, Tonboe and Eastwood (editors), v1.1, October 2011\n",
                    "http://saf.met.no\n",
                    "http://www.osi-saf.org" ;
             :history = "2010-01-13 creation" ;
             :product_version = "1.1" ;
             :software_version = "4.0" ;
             :netcdf_version = "3.6.3" ;
             :Conventions = "CF-1.4" ;
}
```

7. Appendix B: Examples of monthly climatological maximum extent masks

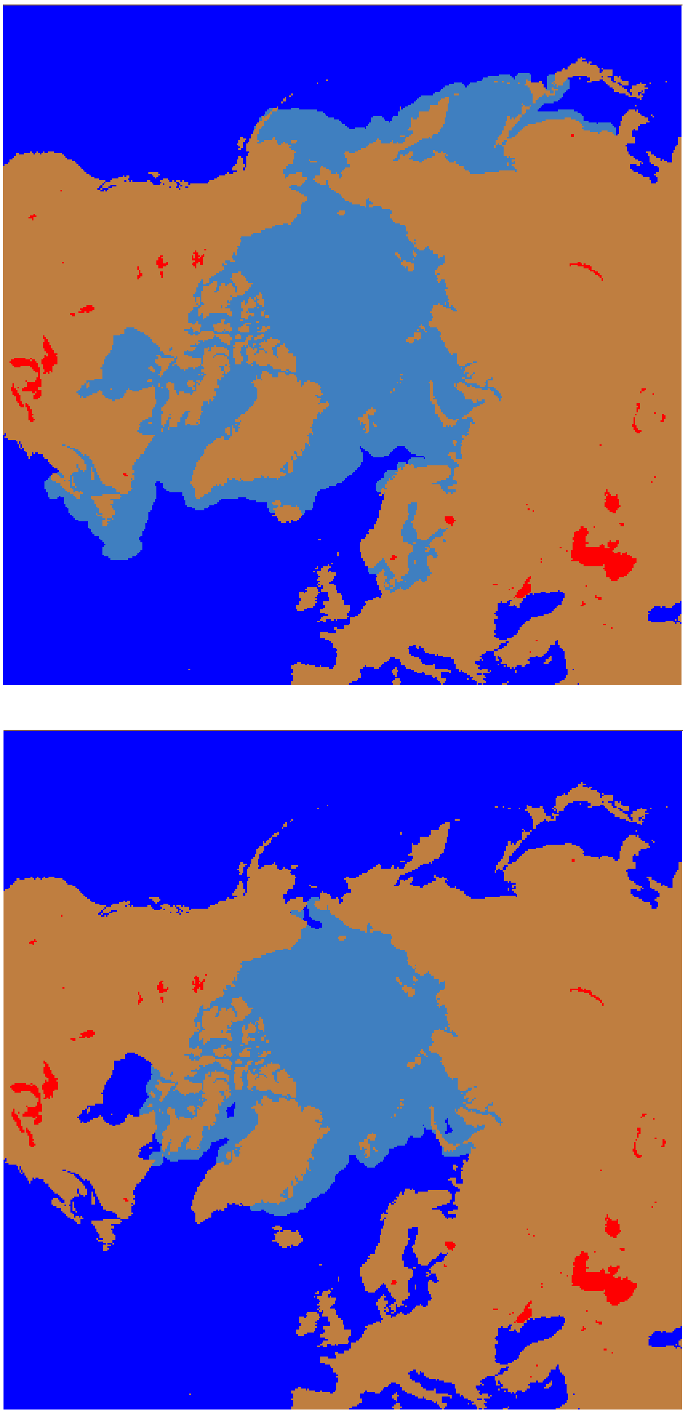

Figure 6: Climatological maximum sea ice extent during March (upper) and September (lower)

8. Appendix C: Missing dates

The reprocessing data set covers the period from 26.10.1978 to 15.04.2015. During the SMMR period only every second day is available. The SMMR data have been used until 11.07.1987. SMMR data are missing during November and December 1980, in addition to shorter periods. Table 7 below lists the dates with no product due to lack of satellite data, except the expected missing SMMR days (every second day).

From 15.10.2009 onwards the reprocessed data set is based on operational available data at MET Norway, and missing dates might be more frequent compared to the data based on SSM/I data from the re-calibrated time-series from RSS.

Year	***Missing dates***
SMMR	
1979	*21/5-27/5*
1980	*4/1-10/1, 27/2-4/3, 16/3-21/3, 9/4-15/4, 1/11-31/12*
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	*29/3-3/4, 5/4-9/4, 21/5-25/5, 27/5-6/6, 8/6-16/6, 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	01/01-21/01, 06/05-08/05, 23/09, 25/12-27/12
1989	07/06, 23/07-24/07, 23/10
1990	13/08, 25/08-26/08, 21/10-22/10, 26/10-28/10, 22/12-26/12
1992	18/06
1993	04/01
1994	20/07, 20/11-21/11
2000	01/12
SSMIS	
2014	16/10, 21/10-23/10, 30-31/10

Table 7: 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 the periods with missing SMMR data for more than two days.

9. Appendix D: 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 8. 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 8: EUMETSAT Data Center metadata parameters applicable to the reprocessed OSI SAF Sea Ice Concentration product.