Sea Ice Climate Change Initiative: Phase 2

D3.4 Product User Guide (PUG)

This PUG covers the following Sea Ice Concentration CDRs:

ESA CCI AMSR-E and AMSR2 50.0km SIC CDR v2.0 (doi: 10.5285/70f611b0-ba82-48e6-9190-a62cf9f925f2)

ESA CCI AMSR-E and AMSR2 25.0km SIC CDR v2.0 (doi: 10.5285/c61bfe88-873b-44d8-9b0e-6a0ee884ad95)

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1 Introduction

1.1 Purpose and Scope

This document describes in detail the Sea Ice Concentration datasets for the Sea Ice ECV project produced in Phase 2 of ESA's Climate Change Initiative.

1.2 Document Structure

After this introduction and the list of references, the document provides a technical description of the Sea Ice Concentration product.

1.3 Document Status

This is the first issue of the PUG released to ESA as part of the project's second phase.

1.4 Applicable Documents

The following table lists the Applicable Documents that have a direct impact on the contents of this document.

Acronym	Title	Reference	Issue
AD-1	Sea Ice ECV Project Management Plan	ESA-CCI_SICCI_PMP_D6.1_v1.3	1.3

Table 1-1: Applicable Documents

1.5 Reference Documents

ID	Reference Details
RD-1	Algorithm Theoretical Basis Document (ATBD), Issue 2.0, Mar 2016
RD-2	Product Validation and Intercomparison Report (PVIR), Issue 1.0, Feb 2017
RD-3	Brodzik, M.J.; Billingsley, B.; Haran, T.; Raup, B.; Savoie, M.H. EASE-Grid 2.0: Incremental but Significant Improvements for Earth-Gridded Data Sets. ISPRS Int. J. Geo-Inf. 2012, 1, 32-45.
RD-4	Ashcroft, P. and F. J. Wentz. (2015): AMSR-E/Aqua L2A Global Swath Spatially-Resampled Brightness Temperatures. Version 2. Boulder, Colorado USA: NASA DAAC at the National Snow and Ice Data Center. http://dx.doi.org/10.5067/AMSR-E/AE_L2A.003.

ID	Reference Details
RD-5	Dee, D. P., Uppala, S. M., Simmons, A. J., Berrisford, P., Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M. A., Balsamo, G., Bauer, P., Bechtold, P., Beljaars, A. C. M., van de Berg, L., Bidlot, J., Bormann, N., Delsol, C., Dragani, R., Fuentes, M., Geer, A. J., Haimberger, L., Healy, S. B., Hersbach, H., Hólm, E. V., Isaksen, L., Kållberg, P., Köhler, M., Matricardi, M., McNally, A. P., Monge-Sanz, B. M., Morcrette, J.-J., Park, B.-K., Peubey, C., de Rosnay, P., Tavolato, C., Thépaut, J.-N. and Vitart, F. (2011), The ERA-Interim reanalysis: configuration and performance of the data assimilation system. Q.J.R. Meteorol. Soc., 137: 553–597. doi: 10.1002/qj.828

Table 1-2: Reference Documents

1.1 Acronyms and Abbreviations

Acronym	Meaning
AMSR-E	Advanced Microwave Scanning Radiometer aboard EOS
AMSR2	Advanced Microwave Scanning Radiometer aboard GCOM-W1
AO	Announcement of Opportunity
ASCII	American Standard Code for Information Interchange
CM-SAF	Climate Monitoring Satellite Application Facility
CRDP	Climate Research Data Package
DMSP	Defence Meteorological Satellite Program
DWD	Deutscher Wetterdienst
ECV	Essential Climate Variable
Envisat	Environmental Satellite
EOS	Earth Observing System
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FCDR	Fundamental Climate Data Record
FOC	Free of Charge
FOV	Field-of-View
FTP	File Transfer Protocol
GB	GigaByte
GCOM	Global Change Observation Mission
H	Horizontal polarization
H+V	Horizontal and vertical polarization
HDF	Hierarchical Data Format
JAXA	Japan Aerospace Exploration Agency
MB	MegaByte
MODIS	Moderate Resolution Imaging Spectroradiometer
n.a.	Not applicable

Acronym	Meaning
NetCDF	Network Common Data Format
NSIDC	National Snow and Ice Data Center
OSCAR	Observing Systems Capability Analysis and Review Tool
OSI-SAF	Ocean and Sea Ice Satellite Application Facility
PI	Principal Investigator
PMW	Passive Microwave
POES	Polar Operational Environmental Satellite
RADAR	Radio Detection and Ranging
SAR	Synthetic Aperture Radar
SIC	Sea Ice Concentration
SMMR	Satellite Multichannel Microwave Radiometer
SSM/I	Special Sensor Microwave / Imager
SSM/IS	Special Sensor Microwave / Imager+Sounder
Tb	Brightness Temperature
TB	TeraByte
t.b.d.	To be determined
URL	Uniform Resource Locator
V	Vertical polarization

Table 1-3: Acronyms

2 Preface

This Product User Guide (PUG) for the ESA Climate Change Initiative (CCI) Sea Ice Concentration (SIC) Climate Data Records (CDR) is meant as an entry point for users and prospective users of the data.

The focus of the document is thus the technical description of the product, covering file content, format, naming, and data access mechanisms. It also describes the known limitation and areas of potential challenges of such SIC CDRs.

It provides an overview of the data used as input for building the dataset, and of the processing steps and algorithms needed to transform input satellite data into the final product files. Users seeking more in-depth understanding of the science behind the algorithms are referred to the Algorithm Theoretical Basis Document (ATBD) [RD-1]. Likewise, users interested in results from the extensive product validation experiments conducted with these SIC CDRs during the project are referred to the Product Validation and Intercomparison Report (PVIR) [RD-2].

2.1 Scope of the document

This Product User Guide (PUG) for the ESA Climate Change Initiative (CCI) Sea Ice Concentration (SIC) Climate Data Records (CDR) is meant as an entry point for users and prospective users of the data.

The focus of the document is thus the technical description of the product, covering file content, format, naming, and data access mechanisms. It also describes the known limitation and areas of potential challenges of such SIC CDRs.

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2.2 The ESA CCI SIC CDRs produced during Phase 2 (2015-2018)

During its 2nd phase (2015-2018), the ESA CCI Sea Ice project worked on three complementary SIC CDRs.

Each of the three CDRs pertains of daily global maps of sea ice concentration, with associated processing flags and per grid-cell uncertainties. The ice concentration values are processed from medium resolution, space-borne Passive Microwave Radiometer (PMR) data, namely the Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) (2002-2010 on board Aqua US satellite) and Advanced Microwave Scanning Radiometer 2 (AMSR2) (2012-today on board GCOM-W1 Japanese satellite). The three CDRs cover the periods June 2002 to October 2010 (AMSR-E) and July 2012 to December 2015 (AMSR2).

The three CDRs differ by the brightness temperature (Tb) channels used, and as a result, by their spatial resolution. The three CDRs are:

- The 12.5km SIC CDR based on Tb channels 18.7 GHz V-pol, 89 GHz V-pol, and 89 GHz H-pol;

- The 25.0km SIC CDR based on Tb channels 18.7 GHz V-pol, 37 GHz V-pol, and 37 GHz H-pol;

- The 50.0km SIC CDR based on Tb channels 6.9 GHz V-pol, 37 GHz V-pol, and 37 GHz H-pol.

To differentiate these CDRs from those released in the 1st phase of the CCI Sea Ice team (v1.11 CDRs), the new CDRs from phase 2 use a version number starting with v2.0. The three new CDRs have each a Digital Object Identifier (DOI).

In February 2017, both the 25.0km SIC CDR and the 50.0km CDR are released on the CCI Data Portal. The 12.5km SIC CDR is more experimental at this stage, and requires further inspection and validation by the project team to assess if it is a dataset worthy for release.

2.3 Links to the EUMETSAT OSISAF

The ESA CCI SIC CDRs from phase 2 are developed in full coordination with the EUMETSAT OSISAF. In early 2017, the OSISAF also releases its updated SIC CDR. CCI and OSISAF teams used the same algorithms and a common processing chain and infrastructure to produce their CDRs. The main difference between the datasets is that the OSISAF CDR is produced from the suite of coarse resolution passive microwave instruments available since the late 1970s, namely the Satellite Multichannel Microwave Radiometer (SMMR), the Special Sensor Microwave / Imager (SSM/I), and the Special Sensor Microwave Imager and Sounder (SSMIS). This is illustrated in Figure 2-1.

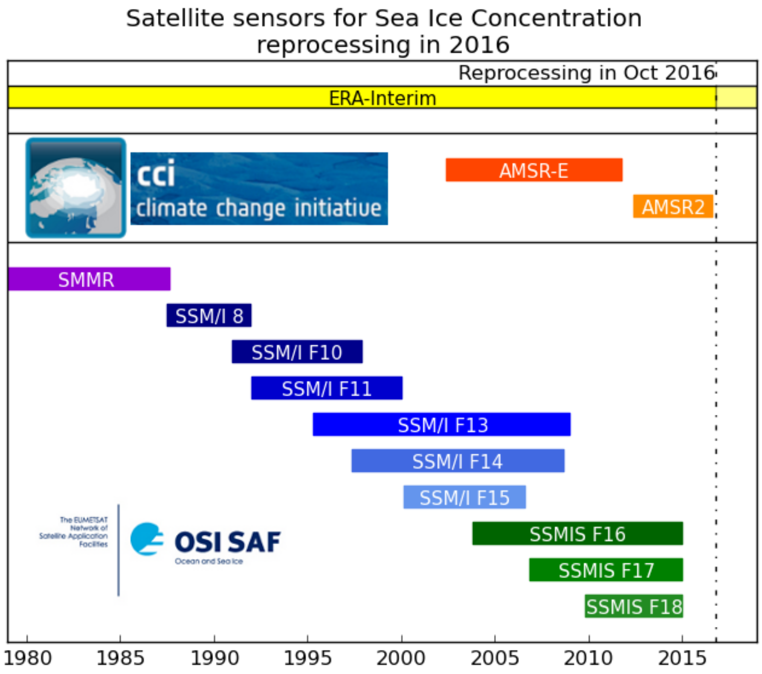

Figure 2-1: Time-coverage diagram for the CCI and OSISAF SIC CDRs to be released in early 2017. The ESA CCI CDR is based on medium resolution AMSR-E and AMSR2 sensors, while the EUMETSAT OSISAF CDR uses the coarse resolution SMMR, SSM/I, and SSMIS instruments. Both use fields from the ERA-Interim atmosphere re-analysis.

The OSISAF v2 CDR due to be released in early 2017 thus covers the time period January 1979 to December 2015. It comes on the same grid as the CCI SIC 25.0km product, and uses similar Tb channels, namely around 19 GHz at V-polarization, and around 37 GHz at both V- and H-polarization. Harmonization of the algorithm and processing steps ensure that the OSISAF and CCI 25km SIC CDRs are consistent with each other. They share the same file format.

In the overlap period of the OSISAF and CCI 25km SIC CDRs, the SIC CDR offers a finer spatial resolution thanks to the better spatial resolution of the AMSR sensors compared to that of SSM/I and SSMIS.

In the future, the EUMETSAT OSISAF will also take over the operational responsibility for the further development and extension of the AMSR-based CDRs initiated in ESA CCI.

3 Input data

This chapter describes the AMSR-E and AMSR2 satellite data as well as numerical weather prediction (NWP) data used for atmospheric correction of the brightness temperature.

3.1 The AMSR-E data

The AMSR-E instrument on board the Earth Observing System (EOS) satellite Aqua provides us with passive microwave data from 1st June 2002 until 4th October 2011, well beyond the satellite's expected lifetime. This instrument measures vertically and horizontally polarized brightness temperatures at 6 different frequencies, 12 channels in all.

Frequency (GHz)	Polarizations	Sampling (km)	Footprint size (km)	
			Along-track	Cross-track
6.9	V,H	10	75	43
10.7	V,H	10	51	29
18.7	V,H	10	27	16
23.8	V,H	10	21	14
36.5	V,H	10	14	9
89.0	V,H	5	6	4

Table 3-1: Characteristics of the Aqua AMSR-E instrument from OSCAR.

The different CDRs use different channels for their algorithms, as stated in section 2.2.

The planned lifetime of the Aqua satellite was from 2002 to 2008, but the current life expectancy is into the early 2020s. The AMSR-E instrument however ceased rotating 4th October 2011, and is now providing data for cross-calibration data only.

The AMSR-E data we use is provided by NSIDC, specifically we use the NSIDC FCDR V003 data set. This data set has the id "AE_L2A" and title "AMSR-E/Aqua L2A Global Swath Spatially-Resampled Brightness Temperatures, Version 3" [RD-4].

3.2 The AMSR2 data

The AMSR2 instrument on board the Global Change Observation Mission – Water (GCOM-W1) satellite provides similar data to the AMSR-E instrument above, though with some slight changes. From this instrument we have data from the 23rd July 2012 until 31st December 2015, the end of our planned period.

Frequency (GHz)	Polarizations	Sampling (km)	Footprint size (km)	
			Along-track	Cross-track
6.9	V,H	10	62	35
7.3	V,H	10	62	35
10.7	V,H	10	42	24
18.7	V,H	10	22	14
23.8	V,H	10	19	11
36.5	V,H	10	12	7
89.0	V,H	5	5	3

Table 3-2: Characteristics of the GCOM-W AMSR2 instrument from OSCAR.

The GCOM-W1 satellite was launched in May 2012, and while the planned lifespan is 5 years it is expected to last longer.

The AMSR2 data we use is provided by JAXA as L1R files.

3.3 The ERA-Interim data

The brightness temperatures (Tb) of AMSR-E and AMSR2 are corrected explicitly for atmospheric contribution to the radiation. The correction uses a Radiative Transfer Model function (RTM) and requires atmosphere re-analysis data. For these ESA CCI CDRs, we use the global 3-hourly fields from ECMWF's ERA-Interim [RD-5], which are accessed from the MARS archive.

The following prognostic variables are taken from the ERA-Interim files and collocated with satellite swath data: 10m wind speed, 2m air temperature, and total column water vapour.

4 Processing scheme

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

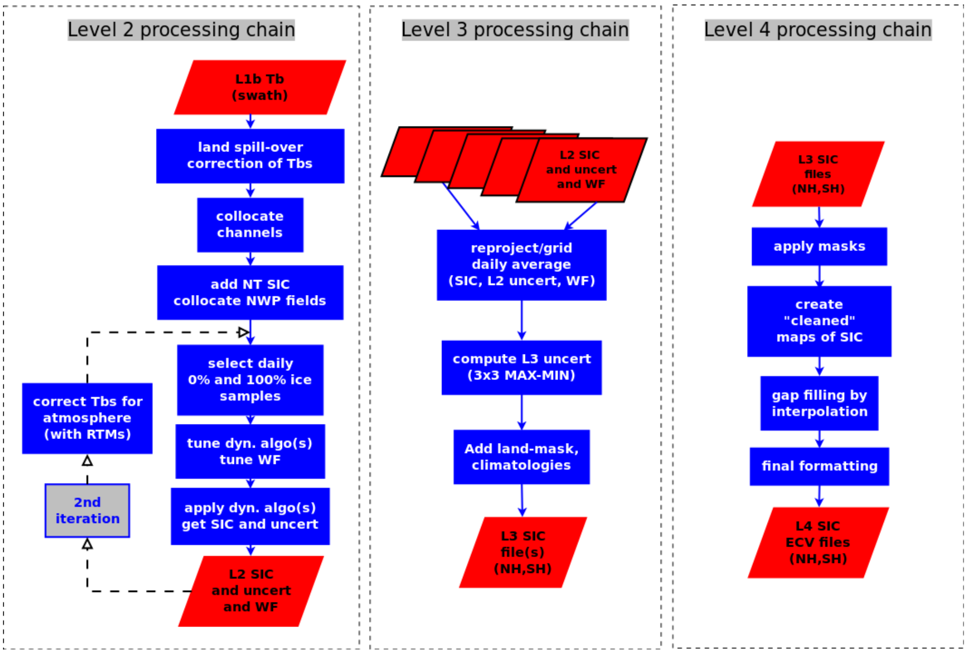

Figure 4-1: The three main processing elements in the ice concentration processing chain.

4.1 L1/L2 processing

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

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

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

More details are available in the ATBD [RD-1].

4.2 L3 processing

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

4.3 L4 processing

This final main step contains filling of areas with missing data by interpolation and applying masks and corrections to present the final ice concentration product. The processing status flag variable (section 5.1.4) is computed during these steps.

5 Product description

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

5.1 Product Specification

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

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

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

5.1.1 Sea ice concentration (ice_conc)

Sea ice concentration is the ocean area fraction of a cell covered by sea ice. It is given as a real number in percentage, with a range from 0-100%. An example is shown in Figure 5-1. This variable holds sea ice concentration maps after several filters (e.g. the open water filter) and post-processing steps (e.g. interpolation) have been applied. It is the main entry point for users of this Climate Data Record.

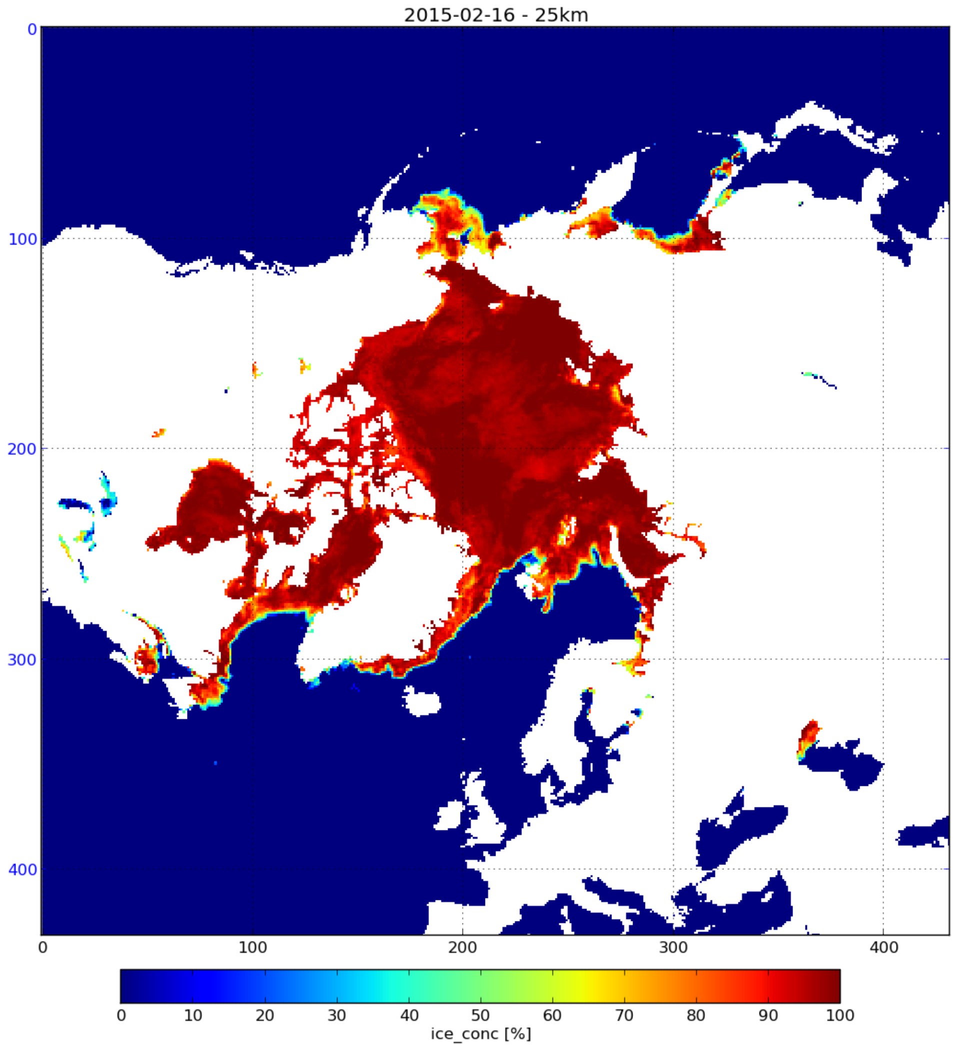

Figure 5-1: Sea ice concentration from 16th February 2015.

5.1.2 Raw sea ice concentration values

Variable raw_ice_conc_values contains the original ("raw") values of the sea ice concentration where it has been altered during the filtering process in the level 4 step. For example, if the concentration was set to 0 in ice_conc due to the open water filter, then the original (raw) value will be available here. This variable is masked outside the maximum sea ice climatology and where the sea ice concentration is unaltered. This variable can also contain un-physical ice concentration values such as values below 0% and above 100%. This variable is for use by more advanced users, who can take advantage of information with less filtering applied, e.g. via Data Assimilation techniques. An example can be seen in Figure 5-2.

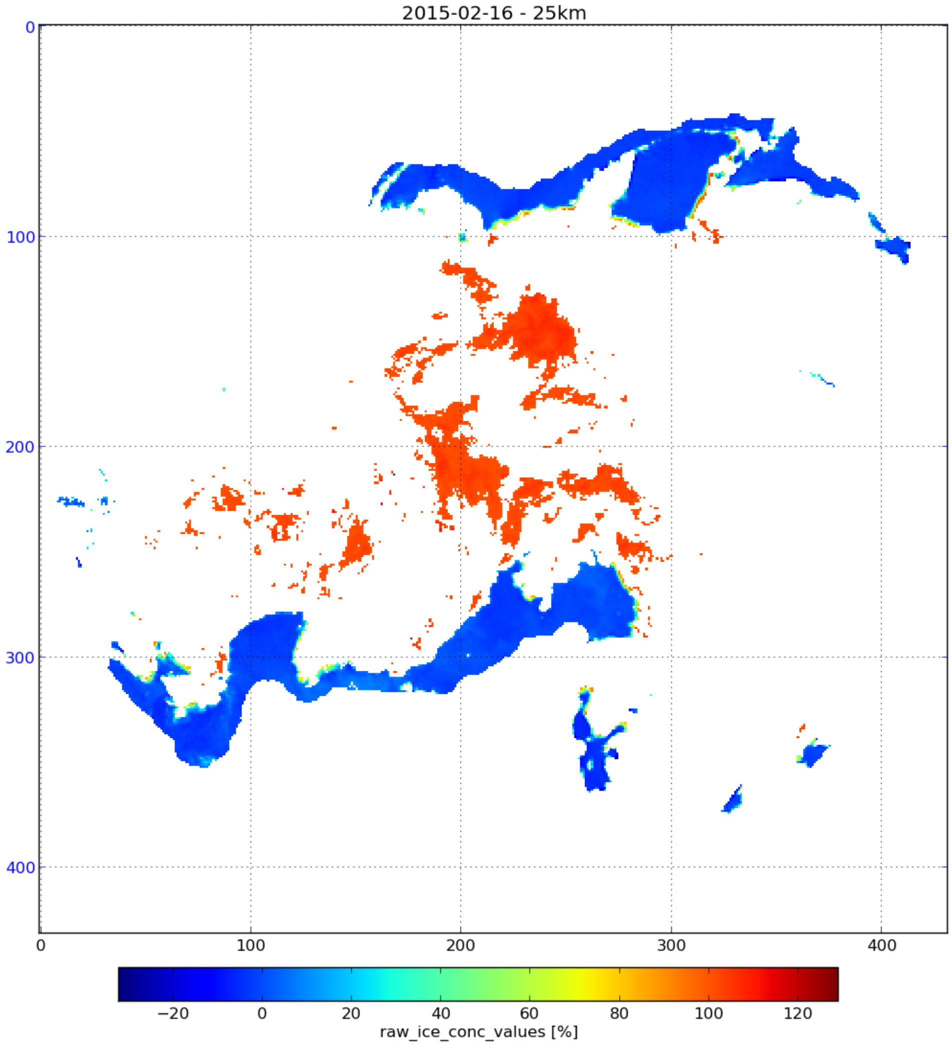

Figure 5-2: Raw sea ice concentration from 16th February 2015.

Another example of raw_ice_conc_values variable is shown in Figure 5-3. The blue belt is the region where the open water filter was triggered. The corresponding grid cells in variable ice_conc will show exactly 0%, removing a lot of the weather-induced noise in this region (values in the range -4%;+4%). Note also how a few pixel wide zone of true, low concentration sea ice is removed by the filter. This is the major drawback of using open water filters (aka weather filters) for sea ice concentration filtering: some true ice is removed at the marginal ice zone.

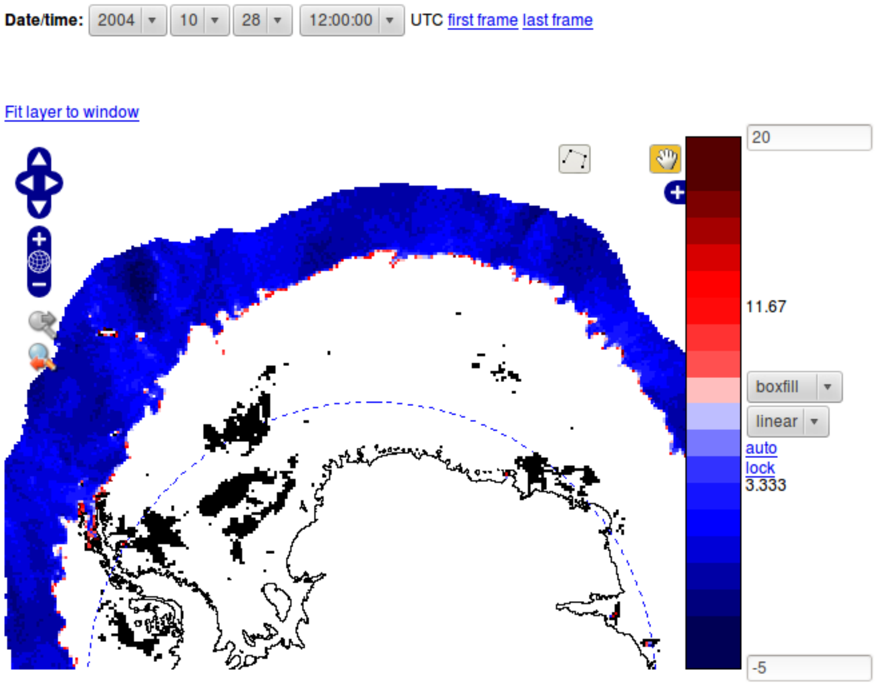

Figure 5-3: Example of raw_ice_conc_values field on 28th October 2004 in the Southern Hemisphere. The blue belt is where the open water filter was triggered (note the range of the color bar).

5.1.3 Uncertainty estimate

An estimate of the uncertainty of each sea ice concentration value is given in a separate field. The uncertainty is given as one standard deviation in percentage. An example is shown in Figure 5-4. Three maps of uncertainty information are provided in each file, the algorithm uncertainty, the smearing uncertainty, and the total uncertainty. The total uncertainty is the combination (the square root of the sum of variances) of the two other components of the uncertainty budget.

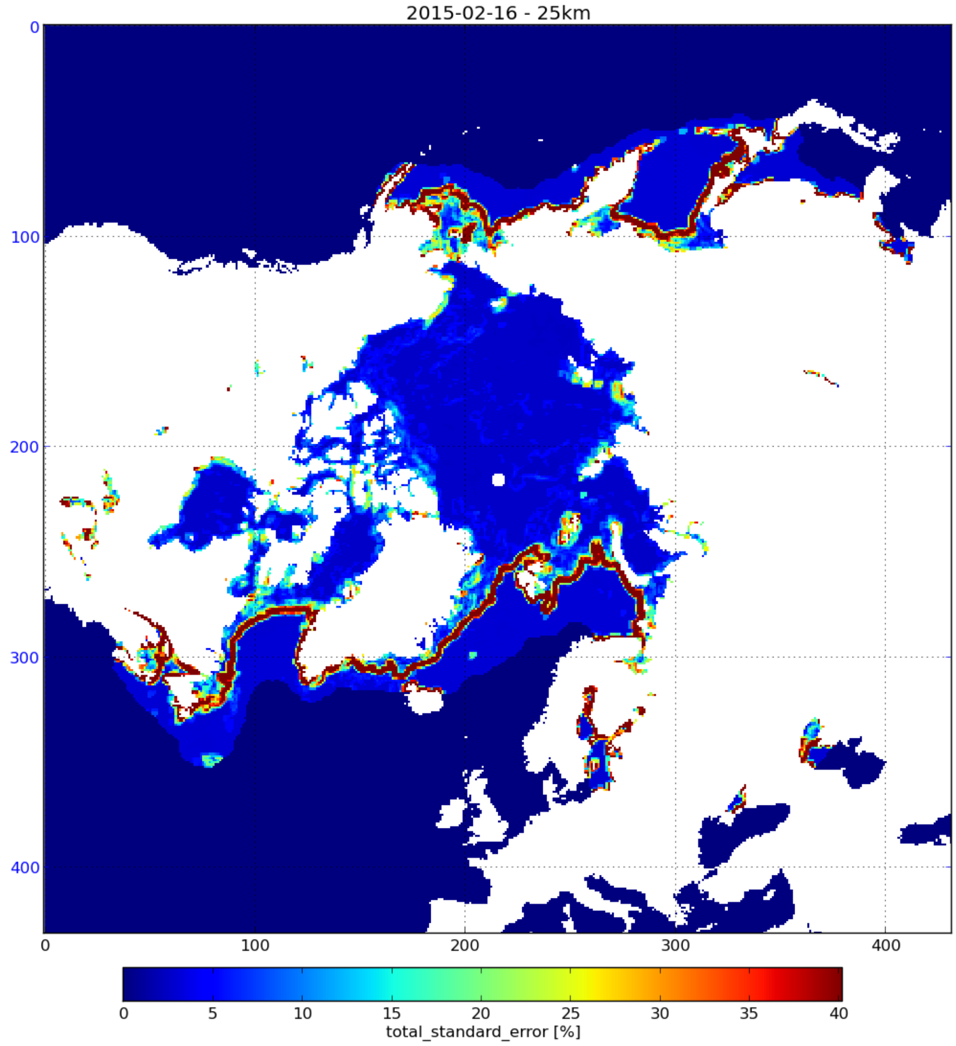

Figure 5-4: Total uncertainty from 16th February 2015.

5.1.4 Status flag

The status flag contains information about the processing steps that have influenced the ice concentration value. It is coded as a signed character. The different values are described in Table 5-1.

Bit	**Definition**
1	Position is over land
2	Position is lake
3	SIC is set to zero by the open water filter
4	SIC value is changed for correcting land spill-over effects
5	Handle with caution, the 2m air temperature is high at this position, and this might be false ice

6	Value is the result of spatial interpolation
7	Value is the result of temporal interpolation
8	SIC is set to zero since position is outside maximum sea ice climatology

Table 5-1: Definition of sea ice concentration status flag bits.

This value is a bit array with each bit representing a different status, so grid cell values can be a combination of several statuses. One example of this that may occur is an area where the concentration has been gapfilled using temporal interpolation and where the open water filter kicks in setting the concentration to zero. This cell would then have the value 36 (the sum of temporal interpolation (2^6=32) and open water filter (2^2=4) flags).

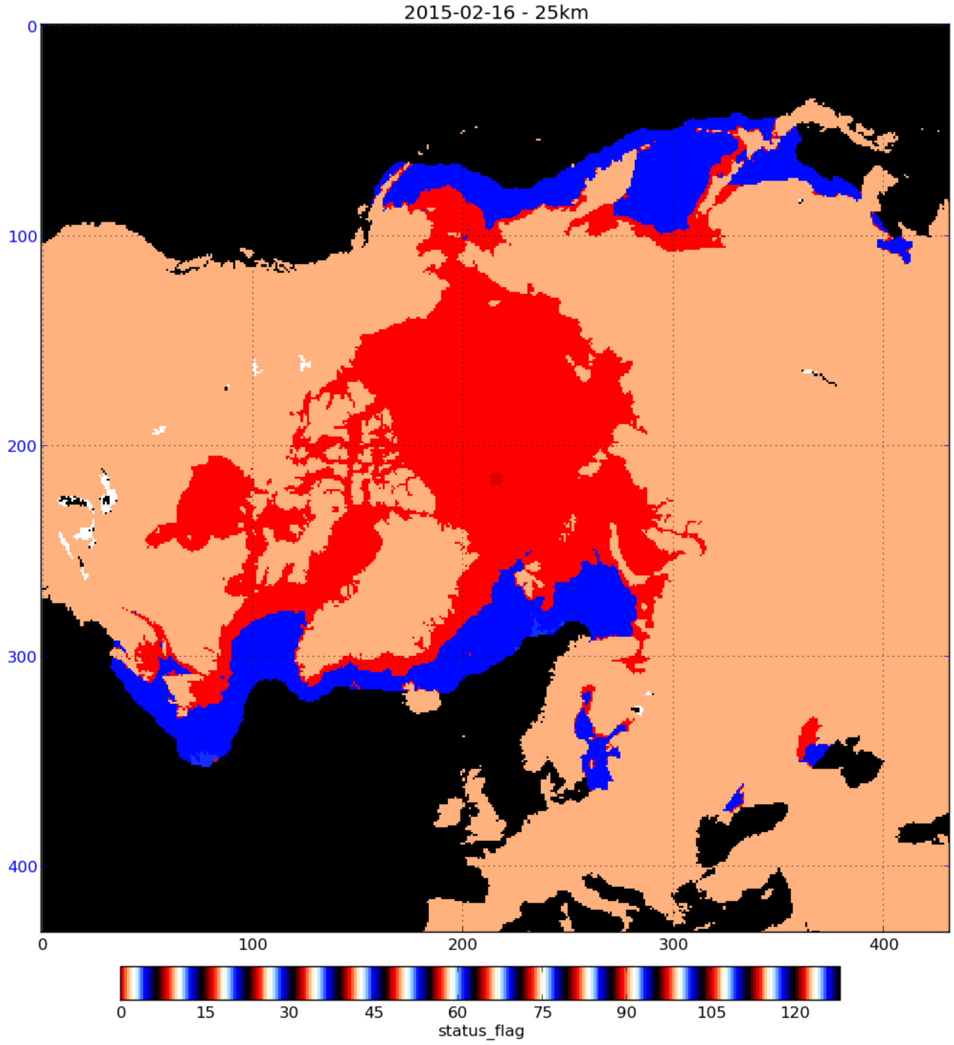

Figure 5-5: Status flag from 16th February 2015.

5.2 Grid Specification

For a given day, northern and southern hemisphere maps of sea ice concentration are available in two separate files. For both hemispheres, the sea ice concentration product is presented on a Lambert Azimuthal Equal Area polar projection, with a grid spacing of 25.0 km or 50.0km depending on the CDR. The Lambert grid is also called the EASE2 grid [RD-3], and is used by NSIDC for several of their sea ice and snow products. More documentation about the EASE2 grid can be found on their web site: http://nsidc.org/data/ease/.

The details of the grid definitions are given in Table 5-2 and Table 5-3. Projection definitions in the form of PROJ-4 initialization strings are also given.

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

Table 5-2: Geographical definition for the EASE2 25.0 km grid, Northern and Southern Hemisphere.

Projection:	Lambert Azimuthal Equal Area (EASE2)
Resolution:	50.0 km
Size:	216 columns, 216 rows
Central Meridian:	0°
Datum/Earth:	WGS84 (a=6378137.0 m , b=6356752.314245 m)
PROJ-4 string:	NH: +proj=laea +ellps=WGS84 +datum=WGS84 +lat_0=90 +lon_0=0 SH: +proj=laea +ellps=WGS84 + datum=WGS84 +lat_0=-90 +lon_0=0

Table 5-3: Geographical definition for the EASE2 50.0 km grid, Northern and Southern Hemisphere.

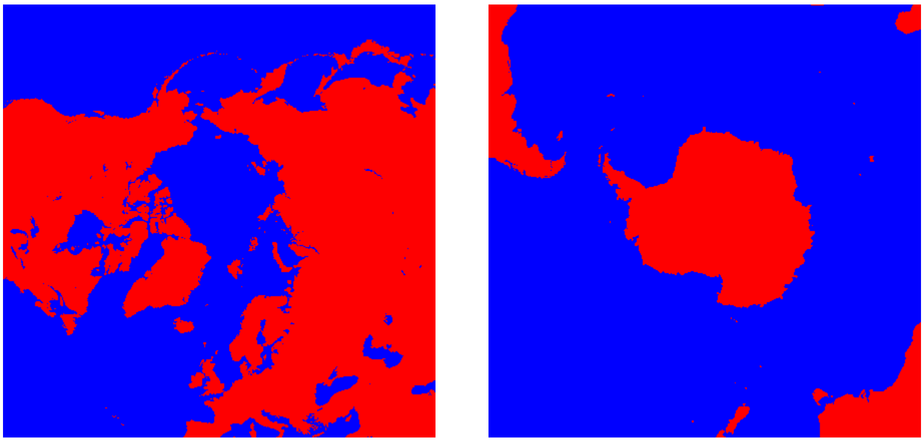

Figure 5-6: Area covered by the EASE2 25.0km grids for Northern and Southern hemispheres.

5.3 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 (http://cfconventions.org/), and all attributes follow the Attribute Convention for Data Discovery (ACDD) v1.3 (http://wiki.esipfed.org/index.php/Attribute_Convention_for_Data_Discovery_(ACDD)). NASA GCMD and IMO keywords were also selected.

6 References

See section 1.5.

Appendix A Examples of monthly climatological maximum extent charts

Figure A-1: Climatological maximum sea ice extent during march.

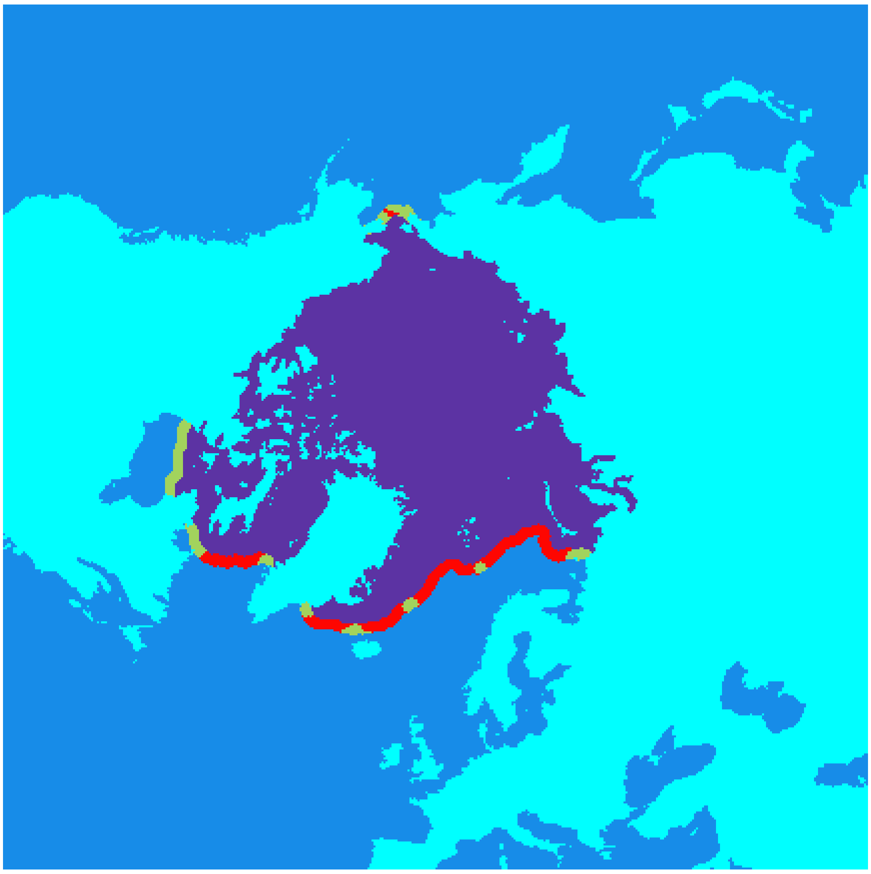

Figure A-2: Climatological maximum sea ice extent during September.

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