Product User Manual for Global Sea Ice Concentration Level 2 and Level 3

OSI-410-a, OSI-401-d, OSI-408-a

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Document Change record

Document version	Software version	Date	Author	Change description
V0.1			FAB	First version
V1.0			FAB	Updated version following recommendations of the ORR Review. - Correction of minor typographical errors - Improved labelling and resolution of figure 4, figure 5, figure 9 - Clirify that date/time of satellite timestamp is given in UTC - Added section in appendix (Appendix A) to describe in details the changes to both L2 and L3 data files. This section should help the user to identify the changes of the variables in the L2/L3 netcdf files.
V1.1			FAB	Minor update to Appendix
V1.2		14/06/2023	EHO	Threshold for NWP skin temperature changed from 276 K to 279 K in section 4.1 and 4.2

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1. Introduction

1.1. The EUMETSAT Ocean and Sea Ice SAF

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

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

The OSI SAF consortium is hosted by Météo-France. The sea ice processing is performed at the High Latitude processing facility (HL centre), operated jointly by the Norwegian and Danish Meteorological Institutes.

The sea ice products include sea ice concentration, the sea ice emissivity at 50 GHz, sea ice edge, sea ice type, sea ice drift and sea ice surface temperature (from mid 2014).

1.2. Disclaimer

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

Acknowledgement and citation. Use of the products should be acknowledged with the following citations (product specific):

OSI-401-d: OSI SAF (2022): Global Sea Ice Concentration (SSMIS) Level 3, EUMETSAT SAF on Ocean and Sea Ice.

OSI-408-a: OSI SAF (2022): Global Sea Ice Concentration (AMSR-2) Level 3, EUMETSAT SAF on Ocean and Sea Ice.

OSI-410-a: OSI SAF (2022): Global Sea Ice Concentration (AMSR-2, SSMIS) Level 2, EUMETSAT SAF on Ocean and Sea Ice.

1.3. Scope of this document

This document is the user manual for the OSI SAF sea ice concentration products OSI-410-a, OSI-401-d and OSI-408-a. We provide a general overview of the data used by the algorithm and the processing scheme, but the main purpose of the document is to give an accurate description of the products to facilitate the usability of the data for the users.

1.4. Overview

As described in the ATBD, the near real time OSI SAF sea ice concentration operational algorithm was modified to have a unique framework which is capable of processing Level 1 passive microwave measurements from different sensors and generating the products. In analogy with the ATBD, which is a single document that describes the Level 2 and Level 3 global sea ice concentration products, the PUM has also been unified. In this user manual we provide the description of the following products:

- AMSR2 and SSMIS Level 2 products (OSI-410-a)
- AMSR2 Level 3 product (OSI-408-a)
- SSMIS Level 3 product (OSI-401-d)

The microwave sensors have different characteristics and consequently the products are characterised by diverse temporal and spatial resolutions. However, to simplify the use of different sea ice concentration datasets, in the unified processing chain, we made some changes so that the content (variables) of the Level 2 and Level 3 products (NetCDF files) is equivalent. Additionally, the content of the near real time Level 3 product files is now similar to the global sea ice concentrations climate data record (CDR) (OSI-450). This may also facilitate the comparison between the NRT and the CDR dataset.

1.5. Glossary

AMSR	Advanced Microwave Scanning Radiometer
ATBD	Algorithm Theoretical Basis Document
CC	Fraction of Cloud Cover (NWP parameter)
CDR	Climate Data Record
CIWC	Specific Cloud Ice Water Content (NWP parameter)
CLWC	Specific Cloud Liquid Water Content (NWP parameter)
CSWC	Specific Snow Water Content (NWP parameter)
DMI	Danish Meteorological Institute
DMSP	Defense Meteorological Satellite Program
ECMWF	European Centre for Medium range Weather Forecast
MARS	Meteorological Archival and Retrieval System

NRT	Near Real Time
NSIDC	National Snow and Ice Data Center
NWP	Numerical Weather Prediction
OSI SAF	Ocean and Sea Ice Satellite Application Facility
PUM	Product User Manual
RTM	Radiative Transfer Model
RTTOV	Radiative Transfer for TOVS
SIC	Sea Ice Concentration
SSMIS	Special Sensor Microwave Imager Sounder
TUD	Technical University of Denmark
UTC	Coordinated Universal Time

1.6. Reference and applicable documents

1.6.1. Applicable documents

[1] EUMETSAT OSI SAF
Product Requirements Document
SAF/OSI/CDOP3/MF/MGT/PL/2-001, version 1.9, 31/12/2021

[2] EUMETSAT OSI SAF
Service Specification Document
SAF/OSI/CDOP3/MF/MGT/PL/003, version 1.12, 31/12/2021

1.6.2. Reference documents

[1] EUMETSAT OSI SAF
The EUMETSAT OSI SAF Sea Ice Concentration Algorithm, ATBD,OSI-410-a, OSI-401-d, OSI-408-a
SAF/OSI/CDOP4/DMI/SCI/MA/403, version 1.1, 23/05/2022

[2] EUMETSAT OSI SAF
The EUMETSAT OSI SAF Sea Ice Concentration Validation Report OSI-410-a, OSI-401-d, OSI-408-a
SAF/OSI/CDOP4/DMI/SCI/MA/422, version 0.1, 22/06/2022

2. Input data

2.1. Satellite data

The primary input for the sea ice concentration algorithm is Level 1 geolocated microwave brightness temperatures. The current operational chain ingests observations collected by the passive conically scanning microwave radiometers AMSR2 and SSMIS. AMSR2 and SSMIS have channels which are very close in frequency, but different in spatial resolution. Consequently, the sea ice products generated by AMSR2 observations are characterised by higher spatial resolution. For the AMSR2 based product, two ice concentration fields are computed. The primary one is computed with the OSI SAF Hybrid algorithm which utilises 3 frequencies: 19 GHz and 37 GHz vertical polarisation, 37 GHz horizontal polarisation. The second is computed using the Technical University of Denmark (TUD) algorithm which employs 4 channels: 19 GHz and 37 GHz vertical polarisation, 89 GHz vertical and horizontal polarisation. For the SSMIS based product, one ice concentration field is computed using the OSI SAF Hybrid algorithm. These algorithms are described in the ATBD. Sections below briefly summarise the characteristics of the two microwave sensors.

2.1.1. AMSR2

AMSR2 is the successor to ADEOS-II and AMSR for EOS (AMSR-E). The AMSR2 instrument was launched in May 2012. The instrument has a 2 m diameter antenna, a constant incidence angle of 55° and a swath width of 1450 km. The instrument has a total of 14 channels covering microwave frequencies from 6.925 GHz to 89.0 GHz with both horizontal and vertical polarizations. Characteristics of the AMSR2 channels used in the sea ice concentration algorithms are given in Table 1. The original source of AMSR2 data (approximately 29 swaths per day) are Level 1B brightness temperature products (‘L1SGBTBR’) in HDF5 format which are disseminated by JAXA.

Channel Number	Central Frequency (GHz)	Polarisation	Bandwidth (MHz)	Footprint (km x km)	Sampling interval (km x km)
8	18.70	V	200	14 x 22	10 x 10
11	36.5	V	1000	7 x12	10 x 10
12	36.5	H	1000	7 x 12	10 x 10
13	89.0	H	3000	3 x 5	5 x 5
14	89.0	V	300	3 x 5	5 x 5

Table 1: Characteristics of the AMSR2 channels used in the sea ice concentration algorithms

2.1.2. SSMIS

SSMIS is the successor to the Special Sensor Microwave/Imager (SSM/I). SSMIS is flown on board the United States Air Force (DMSP) series of satellites, F-16, F-17, F-18 and F-19, which were launched respectively in 2003, 2006, 2009 and 2014 (however, F-19 has not been operational since February 2016). The SSMIS instrument has a 0.8 m diameter antenna, a constant incidence angle of 53.1° and a swath width of about 1700 km. The instrument has a total of 24 channels covering microwave frequencies from 19 to 183 GHz. A summary of the SSMIS channels which are used in the sea ice concentration algorithm is provided in Table 2. The SSMIS data (approximately 44 swaths per day considering F-16, F-17 and F-18) used in the operational chain are those which are disseminated via EUMETCast.

Channel Number	Central Frequency (GHz)	Polarisation	Bandwidth (MHz)	Footprint (km x km)	Sampling interval (km x km)
13	19.35	V	356	42.4 x 70.1	25 x 12.5
15	37.0	H	1580	27.5 x 44.2	25 x 12.5
16	37.0	V	1580	27.5 x 44.2	25 x 12.5

Table 2: Characteristics of the SSMIS channels used in the sea ice concentration algorithms

2.2. NWP data

As described in literature (Andersen et al 2006; Ivanova et al 2015; Tonboe et al 2016; Lavergne et al 2019), to improve the accuracy of the sea ice concentration retrieval and minimise the impact of the different error sources, the observed brightness temperatures are corrected for atmospheric contribution by using a radiative transfer model (RTM). To perform radiative transfer calculations, in the new version of the operational algorithm, we are using the community NWP SAF radiative transfer model RTTOV (Saunders et al., 2018, Hocking et al., 2020). More details on the calculation of the atmospheric correction and the use of RTTOV can be found in the ATBD. In this section, we only provide a description of the NWP data which are used by the processing chain. The NWP data are obtained by means of a 'MARS request' which in NRT retrieves the analysis and forecasts (grib files) of the ECMWF high resolution atmospheric model. NWP data are retrieved on a regular latitude and longitude grid (0.25 by 0.25) and, for each analysis time (00z/12z), the temporal frequency of the forecasts is 3-hour (from 0 to 24). NWP data are only retrieved at latitudes greater/less than 40/-40 degrees which consequently represent the lower NH/SH latitude limit for the Level 2 and Level 3 products. Before applying the RTM calculations, the NWP parameters must be collocated in time and space with the observations available in a satellite swath file. To do so, firstly we identify the central time of the swath file (centre of the time window calculated considering the first and the last satellite scan) and, in terms of date/time, we associate the NWP data file with the closest analysis/forecast time. After this, we use the python pyresample package to spatially interpolate the NWP data on the satellite swath by means of the nearest Gaussian weighting function (we use the pyresample 'resample_gauss' function). Finally, we apply the RTM to calculate the simulated brightness temperature at every pixel of the satellite swath. Obviously, the RTM calculations are performed for every sensor channel which is used by the sea ice concentration algorithm (e.g. Table 1 and Table 2).

Table 3 provides an overview of the NWP data which are needed according to the RTTOV configuration. In this new version of the OSI SAF sea ice concentration algorithm, we have the possibility of selecting RTTOV in two different configurations: RTTOV 'clear-sky' or simply RTTOV as well as RTTOV 'all-sky' or RTTOV-SCATT. The default RTM selected for calculating the atmospheric correction is RTTOV-SCATT.

RTM	**NWP Single level**	**NWP Model Levels**	**NWP lat/lon regular grid**	**NWP temporal resolution (FC steps at 00z/12z AN)**
RTTOV	10m U/V Wind component 2m Temperature Surface Pressure Skin Temperature	Temperature Specific Humidity CLWC (optional)	0.25 x 0.25	0, 3, 6, 9, 12, 15, 18, 21, 24
RTTOV-SCATT	10m U/V Wind component 2m Temperature Surface Pressure Skin Temperature	Temperature Specific Humidity CLWC CIWC CC CRWC CSWC	0.25 x 0.25	0, 3, 6, 9, 12, 15, 18, 21, 24

Table 3: Overview of the NWP data which are mandatory as an input to the different RTTOV configurations

3. Processing scheme

A detailed description of the steps involved in the operational processing can be found in the ATBD. However, in this section we provide a summary of the main steps which are sequentially executed in order to generate the NRT products. The general processing flow for the Level 2 and Level 3 production is highlighted in Figure 1 and the sequential logic can be summarised with the following steps:

1. The Level 1 microwave observations (AMSR2 or SSMIS) are corrected to account for land-spillover. This is a new feature implemented in this release of the algorithm and it is based on the same method as that described in Lavergne et al. (2019).

2. The Level 1 microwave observations corrected to account for land-spillover (output of step 1) are successively used to calculate the first guess sea ice concentration (FG SIC) following the NASA team algorithm (Comiso et al. 1997) which implements static tie-points.

3. Using the NWP data we compute radiative transfer calculations to derive the magnitude of the atmospheric contribution that is applied to the brightness temperatures.

4. Given the outputs of the ‘calc tp & stats’ task (tie-points and statistics) we calculate:

   a. applying the OSI-SAF hybrid or TUD algorithm, the estimate of the sea ice concentration using the 30-day average tie-points together with the atmospheric corrected brightness temperatures of point 3. At every point of the satellite swath, the retrieved sea ice concentration is checked by means of screening tests which ‘filter’ (e.g. set concentration to 0%) the original value calculated by the algorithm.

   b. the total uncertainty of the sea ice concentration at every point of the satellite swath.

Processing steps 1-4 are consistently applied to every single swath file in near real time to generate L2 sea ice concentration product (OSI-410-a) and successively all the L2 swath files are gridded to generate the final L3 product (OSI-401-d or OSI-408-a).

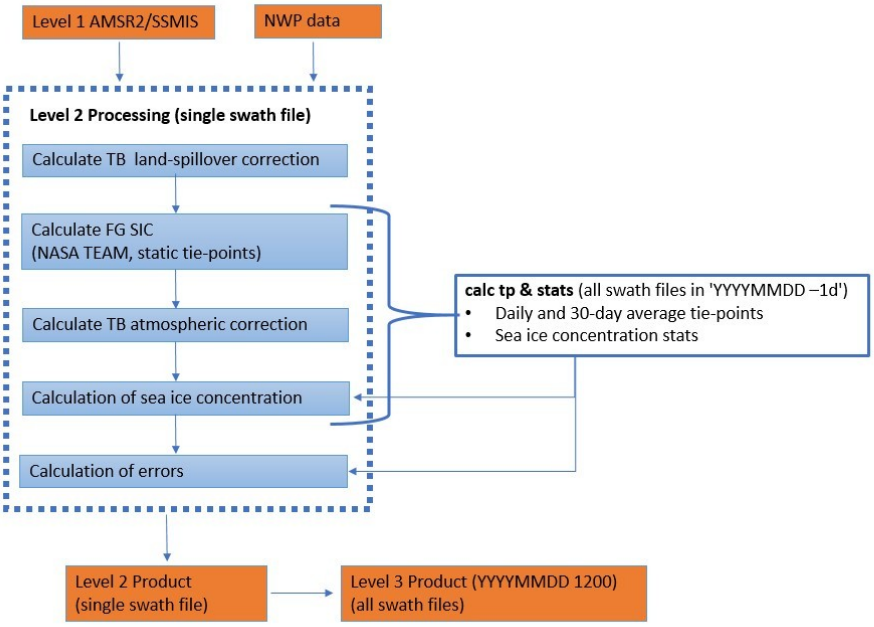

Figure 1: Flow chart for the Level 2 and Level 3 sea ice concentration processing chain.

4. Product description

In this section we provide a detailed description of the product's specifications. In this new version of the operational algorithm, we now process microwave satellite observations, both AMSR2 and SSMIS measurements, in the same equivalent framework. The update of the algorithm was also focused on improving the usability of the different sea ice concentration dataset. In this respect, we made some changes so that the content (variables) of the Level 2 and Level 3 products (NetCDF files) is equivalent. Additionally, the near real time Level 3 products are now similar to the global sea ice concentrations climate data record (OSI-450). This may also facilitate the comparison between the NRT and the CDR dataset. The NRT sea ice concentration products are categorised as follows:

- Level 2 products (OSI-410-a): AMSR2 and SSMIS
- Level 3 products: AMSR2 (OSI-408-a) and SSMIS (OSI-401-d)

As described in the ATBD, the so-called OSI-SAF hybrid algorithm is used to calculate the sea ice concentration for both the SSMIS and AMSR2 products. However, for the AMSR2, the TUD algorithm is additionally operationally implemented. In this case, to diversify the AMSR2 products, we use two different approaches:

- L2 AMSR2 product: we have 1 NetCDF file which contains the results obtained from both the algorithms.
- L3 AMSR2 product: we have 2 NetCDF files, one file is for the results derived from the OSI-SAF hybrid algorithm and an additional file for the TUD. We kept this option from the previous implementation.

Apart from the geolocation coordinates (latitude, longitude), the L2 and L3 NetCDF products are now equally characterised by the 6 variables described in Table 4. More details on the products are given in section 4.1 and 4.2.

Name in NetCDF file (L2* or L3)	Description
ice_conc	Main "filtered" sea ice concentration. It represents the sea ice concentration retrieved by the algorithm which is filtered by means of screening tests. The status_flag variable can be used to identify the screening test which is applied to the grid point
raw_ice_conc_values	This variable contains the sea ice concentration estimates as retrieved by the algorithm that are edited away by the various screening tests. Generally, the variable raw_ice_conc_values can be used together with the variable status_flag to inspect the location and the value of the retrieved sea ice concentration which was edited away by the different screening tests
total_uncertainty	Estimate of the total uncertainty for the sea ice concentration retrieved by the algorithm. The total uncertainty is estimated as the squared sum of the algorithm and smearing errors
smearing_uncertainty	Estimate of the smearing uncertainty for the sea ice concentration retrieved by the algorithm
algorithm_uncertainty	Estimate of the tie-points uncertainty for the sea ice concentration retrieved by the algorithm
status_flag	This variable identifies the screening tests which are applied to obtain the "filtered" sea ice concentration (ice_conc variable)
***** Only for the AMSR2 L2 products: to distinguish between the OSI-SAF hybrid and TUD algorithm we respectively append the string 'osi' and 'tud' to the name of the variables (e.g. 'ice_conc_osi', 'ice_conc_tud'). This is not the case for the variable 'status_flag' which does not change	

Table 4: Name and description of the variables in the L2 and L3 NetCDF products.

4.1. Level 2 products (OSI-410-a)

The spatial resolution for the Level 2 products corresponds to the resolution of the sensor, so that, at every latitude and longitude point of the satellite swath we have the estimate of the 'filtered' sea ice concentration (ice_conc) together with the other 5 variables listed in Table 4. In particular, the AMSR2 and SSMIS swath files are respectively characterised by 243 and 90 observation points multiplied by a number of scans (along track scan) which can slightly vary from one satellite swath to another. Although 1 satellite swath (ascending or descending orbit) contains all the points scanned by the sensor from south to north (or vice versa), the corresponding sea ice product is characterised by a gap (missing values) in the latitude range between -40 and 40. The southern/northern latitude limit of the L2 product is simply due to the NWP dataset which we retrieve excluding tropical and lower mid-latitudes areas.

For the L2 product, we do not apply a land/coast mask, but very simply, we check the position (latitude and longitude) of the satellite observations with respect to the land/coast mask which is used for generating the L3 product (Figure 4). Using the nearest neighbour approach, we classify the satellite points over land or 'near coast' (shore, near-shore, off-shore) according to the L3 mask which is shown in Figure 4. These observation points are very complicated to handle, due to the low spatial resolution of the microwave sensors, land and coastal areas contaminate the satellite footprint. Due to the higher

resolution of the AMSR2 footprint, the 'near coast' classification is done only considering the observation points close to 'shore' and 'near-shore', while in the classification for the SSMIS, we also include the 'off-shore'. Although the Level 1 observations are corrected to account for land-spillover, land and coastal contamination is also difficult for the radiative transfer calculations. Particularly, the forward operator (RTTOV) requires as an input the surface emissivity which, near to land and coastal regions, is very tricky to handle at the microwave frequencies used by the sea ice algorithm. As a conservative approach, in this version of the algorithm, we decided to reject the points classified as land and near coast so that we do not attempt a Level 2 SIC retrieval. As a result, all the variables listed in Table 4 have missing values where the satellite points have been classified as 'over land' or 'near coast'. Future developments of the algorithm will attempt to improve the atmospheric correction scheme in these complicated mixed surface areas (land/coast/ocean/ice) and extend the L2 SIC retrieval closer to the coast. However, as described in section 4.2, by means of an interpolation method, for the L3 product we attempt to provide an estimate of the sea ice concentration for all the 'near coast' points.

Independently of the sensor, the L2 product is identified by the initial date/time of satellite scan (times are given in UTC), as described in section 4.1.1. As soon as a new Level 1 (AMSR2 or SSMIS) swath file is received at DMI, the operational chain is triggered and the corresponding L2 product is generated and disseminated. Figure 2 and Figure 3 respectively show, as an example, the AMSR2 and SSMIS (F18) Level 2 variables (ice_conc and raw_ice_conc_values) for two satellite overpass which are close in time (25 February 2021 1643 UTC, AMSR2, and 1702 UTC, SSMIS). Although the spatial resolution of the two products is different, this example highlights the good observational coverage of the Arctic and Antarctic regions which can be achieved by using the L2 NRT products. If we consider a time interval of about 1 hour, the observational coverage is further improved taking into account that we also have two additional L2 products which correspond to F16 and F17 overpasses (at 1634 and 1740).

The ice_conc variable is obtained by filtering out the values originally retrieved by the algorithm which are stored in the raw_ice_conc_values variable. Figure 2 and Figure 3 display the L2 ice_conc and raw_ice_conc_values which are respectively derived from an AMSR2 and SSMIS overpass. The logic applied to filter the sea ice concentration can be retrieved looking at the status_flag variable. Table 5 summarises the bits which characterise the status_flag and the corresponding description of the screening test. The nominal value of the sea ice concentration retrieved by the algorithm is set to zero when 1 or a combination of the conditions listed in Table 5 is verified. It is important to highlight that sea ice concentration larger than 100% can be retrieved by the algorithm, but this generally happens in sea-ice regions where the surrounding retrievals consistently have high values of concentrations (e.g. SIC > 90%) indicating that we are presumably observing consolidated ice areas. In these cases, as filtered sea ice concentration, we simply consider ice_conc = 100% and no bit is set in the status_flag. However, the sea ice concentration larger than 100% is found in the raw_ice_conc_values variable.

More details on the screening tests of Table 5 can be found in the ATBD, however it is worth mentioning that:

- The Open water filter (OWF) screening is implemented in the same way as described in Lavergne et al. 2019: the dynamic calculation of the GR3719V threshold (T) in the 19V and 37V space is implemented so that the 10% SIC can be intercepted.
- The 37 GHz polarisation (P37) difference is used as a cloud predictor in the logic implemented for the all-sky microwave data assimilation over ocean (Geer and Baur, 2011). The P37

screening test is available only if the atmospheric correction scheme is configured to perform radiative transfer calculations using RTTOV-SCATT.

As an example, in section 4.2 for the L3 product, we display the raw_ice_conc_values which is selected searching for the active bit that corresponds to a specific screening test.

status_flag (bit mask)	**Description**
status_flag = 0, no bit set	Nominal value of the sea ice concentration (SIC) retrieved by the algorithm
bit 2 on: 00010	Open water filter (OWF) screening applied. SIC = 0, if GR3719V >= T or SIC <= 10%
bit 3 on: 00100	NWP skin temperature (Ts) screening applied. SIC = 0, if Ts > 279 K, but only below/above the latitude of 66/-66 degree
bit 4 on: 01000	37 GHz polarisation (P37) difference screening applied. SIC = 0, if P37 < 0.7, but only below/above the latitude of 60/-60 degree
bit 5 on: 10000	Maximum sea ice climatology extent screening applied. SIC = 0, if the geographical location is outside the maximum sea ice climatology. We use the sea ice extent climatology mask (Figure 5) to gross check if the satellite observation point (latitude and longitude) is outside the expected range

Table 5: Summary of the bits which can be set in the status_flag variable and the corresponding description of the screening test applied to the sea ice concentration retrieved by the algorithm. The status_flag is a bit mask variable, so that we can have more than 1 bit set at the same time, e.g: ‘00110’ which means that bit 2 and bit 3 are on. When searching for a specific screening test it is recommended to search for the corresponding bit and not look for the corresponding status_flag integer value. For instance, if we search for status_flag = 2 which means bit 2 on (‘00010’), the mixed cases such as status_flag = 6 (that means ‘00110’) are lost.

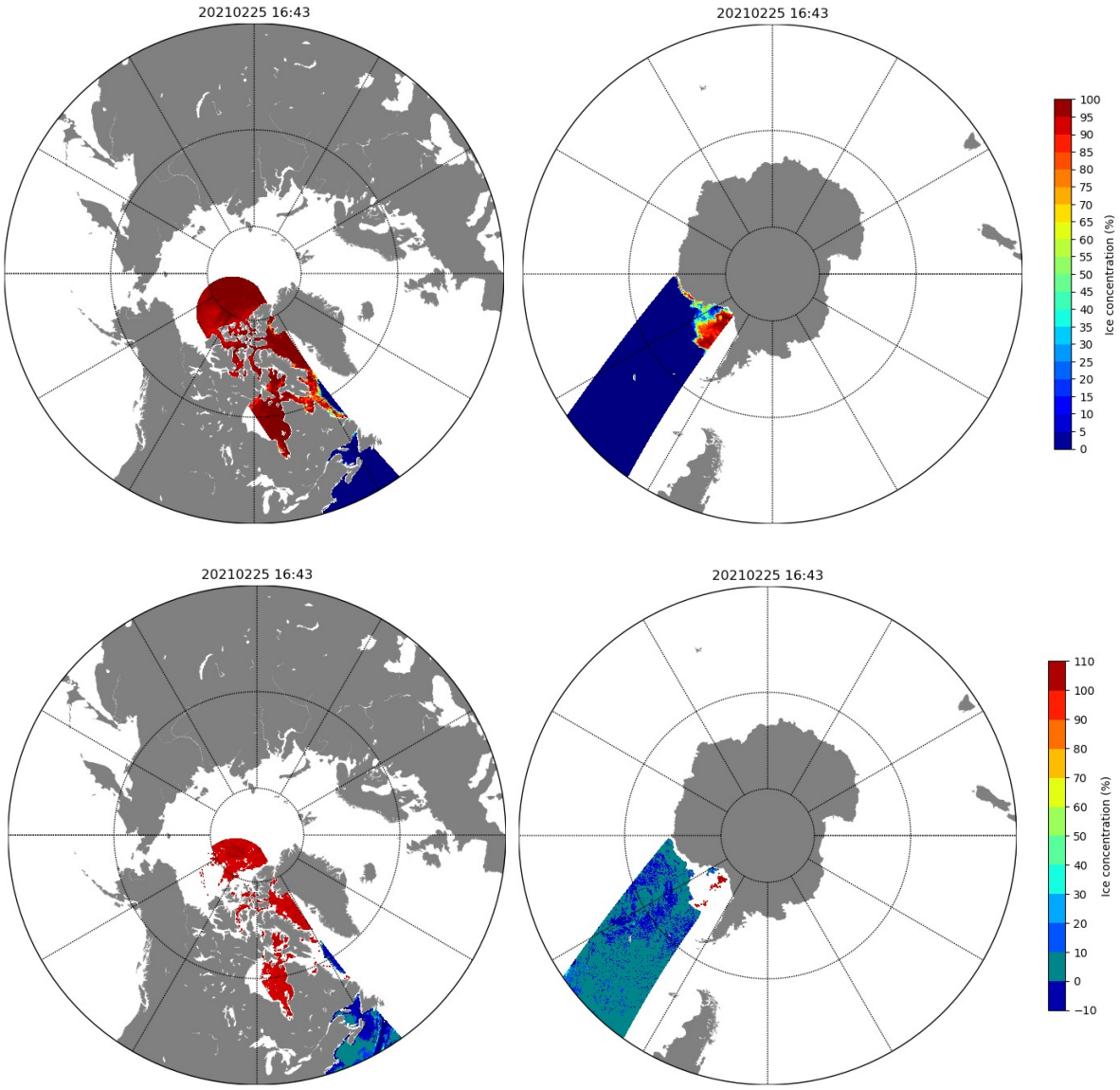

Figure 2: AMSR2 Level 2 sea ice concentration (OSI-SAF hybrid sea ice concentration) for the Northern and Southern Hemisphere. Starting date/time of satellite overpass is 25 February 2021 1643 UTC. Top raw shows the filtered sea ice concentration ('ice_conc' variable) and, bottom raw, the sea ice concentration retrieved by the algorithm ('raw_ice_concentration_values' variable) which was edited away by the screening tests.

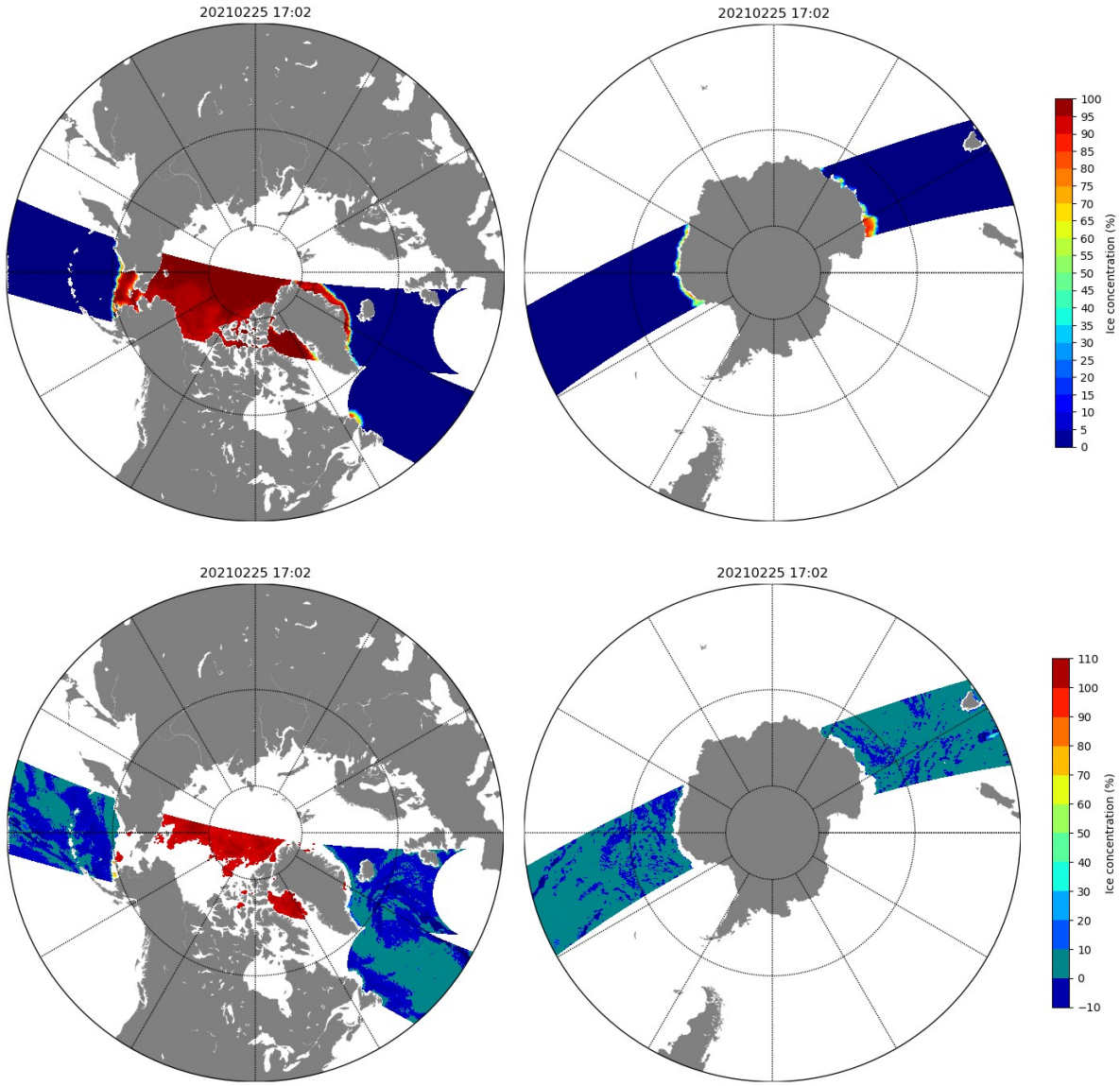

Figure 3: Same as Figure 2, but for the SSMIS F-18 Level 2 sea ice concentration (OSI-SAF hybrid sea ice concentration). Starting date/time of satellite overpass is 25 February 2021 1702 UTC.

4.1.1. L2 file naming convention

The Level 2 near real time sea ice concentration product (OSI-410-a) is a NetCDF file with the following naming convention:

ice_conc_l2_<satID>_<YYYYMMDDHHMM>.nc,

where:

<satID>: satellite and sensor identifier (amsr2_gw1, ssmis_f16, ssmis_f17, ssmis_f18);

<YYYYMMDDHHMM>: initial date/time (UTC) of the satellite scan.

The Level 2 processing is triggered as soon as a new Level 1 AMSR2 or SSMIS swath file is received at DMI. In one day (<YYYYMMDD>), we expect to receive and process the following number of satellite swath file (1 satellite swath = 1 Level 2 product):

- AMSR2: approximately 29 satellite swaths
- SSMIS: approximately 44 satellite swaths, considering F-16, F-17 and F-18

As described in section 4.3, the data distribution can be done by FTP or through EUMETCast. According to the data distribution, the L2 file naming convention is summarised as follows:

OSI SAF FTP

- L2 AMSR2: ice_conc_l2_amsr2_gw1_<YYYYMMDDHHMM>.nc
- L2 SSMIS:

  ice_conc_l2_ssmis_f16_<YYYYMMDDHHMM>.nc
  ice_conc_l2_ssmis_f17_<YYYYMMDDHHMM>.nc
  ice_conc_l2_ssmis_f18_<YYYYMMDDHHMM>.nc

EUMETCast

- L2 AMSR2: S-OSI_-DMI_—AMSR2_L2-CONC__-<YYYYMMDDHHMM>.nc.gz
- L2 SSMIS:

  S-OSI_-DMI_-SSMIS16_L2-CONC__-<YYYYMMDDHHMM>.nc.gz

  S-OSI_-DMI_-SSMIS17_L2-CONC__-<YYYYMMDDHHMM>.nc.gz

  S-OSI_-DMI_-SSMIS18_L2-CONC__-<YYYYMMDDHHMM>.nc.gz

4.2. Level 3 products (OSI-408-a and OSI-401-d)

After all the satellite swath files have been received and processed in one day (24 hours from 00z), the Level 3 processing is executed. All the variables listed in Table 4, which are the output of the Level 2 processing, are combined together to generate the L3 product. The L3 product is a file which is named with the string <YYYYMMDD1200> to easily identify the central date of the analysis. The AMSR2 and SSMIS L3 products are characterised by a polar stereographic projection with a grid spacing of 10 km. Section 4.2.1 provides more details about the L3 grid specification.

The generation of the L3 product can be briefly summarised as follows: firstly, all the separate swath files are concatenated together so that all the variables, which have been generated during the L2 processing (listed in Table 4), are grouped together in a single array. Secondly, the array of every L2 variable (ice_conc, raw_ice_conc_values, total_uncertainty and so on) is resampled according to the specification of the L3 grid resolution. The resultant value of the variable in the target grid cell is influenced by different points of the satellite swath. In particular, the final L3 value in one grid cell is given by the average of the L2 swath grid points which is calculated by a Gaussian weighting function. The Gaussian weighting, provided by the 'resample gauss' method of the 'pyresample' package, is given by the function $\exp(-R^2/\sigma^2)$, where R is the radius of influence (which is referred to the centre of the L3 grid cell) and σ is calculated from 3 dB FoV levels. R and σ are chosen according to the satellite sensor: 36 km and 18 km for AMSR2 and 75 km and 56 km for SSMIS. This logic is applied to all the L3 grid points apart from the near coast points. Figure 4 provides the image of the L3 target grid as well as

the mask which is used to classify the 'near coast points'. As discussed in section 4.1, the sea ice retrieval is not attempted over the shore, near-shore and off-shore points for SSMIS and over the shore and near-shore points for AMSR2. However, for the L3 product, we search for a sea ice concentration interpolated value which can be assigned to the 'near coast points'. The interpolation is done by the 'resample custom' method of the 'pyresample' package and we calculate the sea ice concentration as the weighted average of the L2 SIC retrievals where the weighting function is given by 1 - r/R, where r is the distance between the observation and the centre of the L3 grid cell and R is the radius of influence (the weight assigned is zero when the distance of the observation is equal to the radius of influence). R is chosen independently of the satellite sensor and equal to 100 km to possibly give an estimation of sea ice concentration in those complex inner coastal regions. If we do not find at least 8 L2 swath grid points, we assign a missing value. When we are not observing an open water scenario, the interpolated value, especially in difficult intracoastal areas, is a very gross estimate of the sea ice concentration and must be handled with caution.

Following the equivalent logic for the L2 product, we define the status_flag for the L3 product which can be used to control the screening tests and the corresponding raw_ice_conc_values variable. The L3 status_flag is described in Table 6. The bits which identify a screening test are identical to those of the L2 status_flag and there are additional bits that can be used for the following purpose:

- Control the lake mask (bit 6): over the lakes in the Northern hemisphere (location of lakes is shown in Figure 4), the sea ice concentration estimation is only provided during the following months: December, January, February, March and April. In these months bit 6 is always off. For all other times of the year, the ice_conc is set to zero and bit 6 is on.
- Control the land mask (bit 7): in this case, we can use the integer value 'status_flag = 64' (that means '1000000') to unequivocally identify the L3 land mask (shown in Figure 4). No data is provided where bit 7 is on.
- Control the 'near coast' grid points (bit 8): the user can control the L3 'near coast' grid points where the interpolation method is applied. Although we provide a sea ice concentration estimate, the interpolated value should be used with caution by the user depending on the region and the scenario. Bit 8 of the status_flag can help the user to isolate and/or reject near coast grid points.
- Control missing values (bit 9): in this case, we can use the integer value 'status_flag = 256' (that means '100000000') to unequivocally identify the missing values. Sea ice concentration missing values can be found: a) in some 'near coast' grid points where the L3 interpolated value is not found (e.g. it is not possible to find at least 8 L2 nearby observations to interpolate). For instance, due to the low SSMIS footprint resolution, the coastal screening in the L2 SSMIS processing is more conservative (off-shore points are also classified as 'near coast' grid points). As a result, in some complex coastal regions of the Northern hemisphere, the L3 SSMIS sea ice concentration is missing, but it is provided in the corresponding L3 AMSR2 product. b) in areas where satellite data are missing. For example, due to the AMSR2 satellite orbit, the L3 AMSR2 product is always characterised by missing values over the North Pole.

Finally, as done for the L2 product, we simply consider ice_conc = 100% where the retrieved sea ice concentration is larger than 100% and we do not use a bit in the status_flag variable, but SIC > 100% can be found in the raw_ice_concentration_values variable.

As an example, Figure 6 and Figure 7 respectively give an outlook of the L3 AMSR2 and L3 SSMIS products for the Northern and Southern Hemisphere (analysis date is 25 February 2021). As previously shown for the L2 product, the raw_ice_concentration_values is also displayed to highlight the sea ice concentration retrievals which are edited away by the screening tests. Figure 8, instead, shows the map of the land mask and the near coast points which is derived by looking at the status_flag variable in the L3 AMSR2 product.

To conclude, in Figure 9 for the L3 AMSR2 product, we explore the raw_ice_concentration_values which is derived by selecting all the grid points where the bit 2 (Figure 9a) or 3 (Figure 9b) or 4 (Figure 9c) or 5 (Figure 9d) in the status_flag variable are on. From Figure 9, we can draw the following conclusions:

- The open water filter (OWF) screening (Figure 9a) is the main test to 'filter' the sea ice concentration which is retrieved by the algorithm. The OWF is applied with no restrictions in latitude and can as a result impact the ice edge. The user, to possibly modify the ice_conc variable in some ice edge regions, may check the raw_ice_concentration_values where status_flag bit 2 is on.
- The screening based on the NWP skin temperature (Figure 9b) shows that we consistently identify the same geographical regions of those identified by the OWF screening with the addition of checking the 'near coast' points where the OWF is not active. Broadly speaking, advances in the quality of the NWP skin temperature over the ocean give us the opportunity to safely use a threshold of 279 K below/above the latitude of 66/-66 degree. In this way, depending on the season, we marginally interact with some ice edge regions and, as it is shown in Figure 9, the Ts screening does not remove additional ice on the ice edge, but it is the OWF which plays the main role in the screening. Additionally, the white regions below 66N in Figure 9, which means that the Ts screening is not applied (NWP Ts < 279 K), look very well correlated with areas (Figure 6) where the sea ice concentration > 0.
- The P37 screening test (Figure 9c) is available only if the atmospheric correction scheme is configured to perform radiative transfer calculations using RTTOV-SCATT. The 37 GHz polarisation (P37) difference, over ocean, can be seen as a cloud predictor which can help to identify those locations which may be largely affected by cloud contamination and precipitation. The sea ice concentration filtering is already well managed by the OWF and the NWP Ts screening test, consequently the P37 screening does not add particular information about that. However, we implemented this test to possibly investigate the use of the P37 within the tie-point selection over open water in future versions of the algorithm. The user can simply disregard this test or, in case of necessity, evaluate this test to possibly check locations (and surrounding areas) which are likely affected by precipitation or deep convection. As shown in Figure 9, the P37 screening looks to be correlated with those regions where we observe the largest SIC retrievals. In these open water regions where ice cannot be real, we are observing brightness temperatures which are largely affected by cloud and precipitation and this signature is wrongly interpreted by the algorithm as ice.
- The maximum sea ice climatology extent screening (Figure 9d) is applied if a retrieved SIC > 0 is found outside the expected monthly climatology mask. Also in this case, Figure 9 highlights that this screening is redundant and all the cases are already captured by the first 2 screening tests. However, the user can always monitor the job done by this screening test and get back sea ice concentrations which were filtered out.

status_flag (bit mask)	Description
status_flag = 0, no bit set	Nominal value of the sea ice concentration (SIC) retrieved by the algorithm
bit 2 on: 000000010	OWF screening (as described in Table 5)
bit 3 on: 000000100	NWP skin temperature screening (as described in Table 5)
bit 4 on: 000001000	P37 screening (as described in Table 5)
bit 5 on: 000010000	Maximum sea ice climatology extent screening applied
bit 6 on: 000100000	Lake mask
bit 7 on: 001000000	Land mask
bit 8 on: 010000000	Near coast grid points
bit 9 on: 100000000	Missing value

Table 6: Summary of the bits which can be set in the status_flag variable for the L3 product.

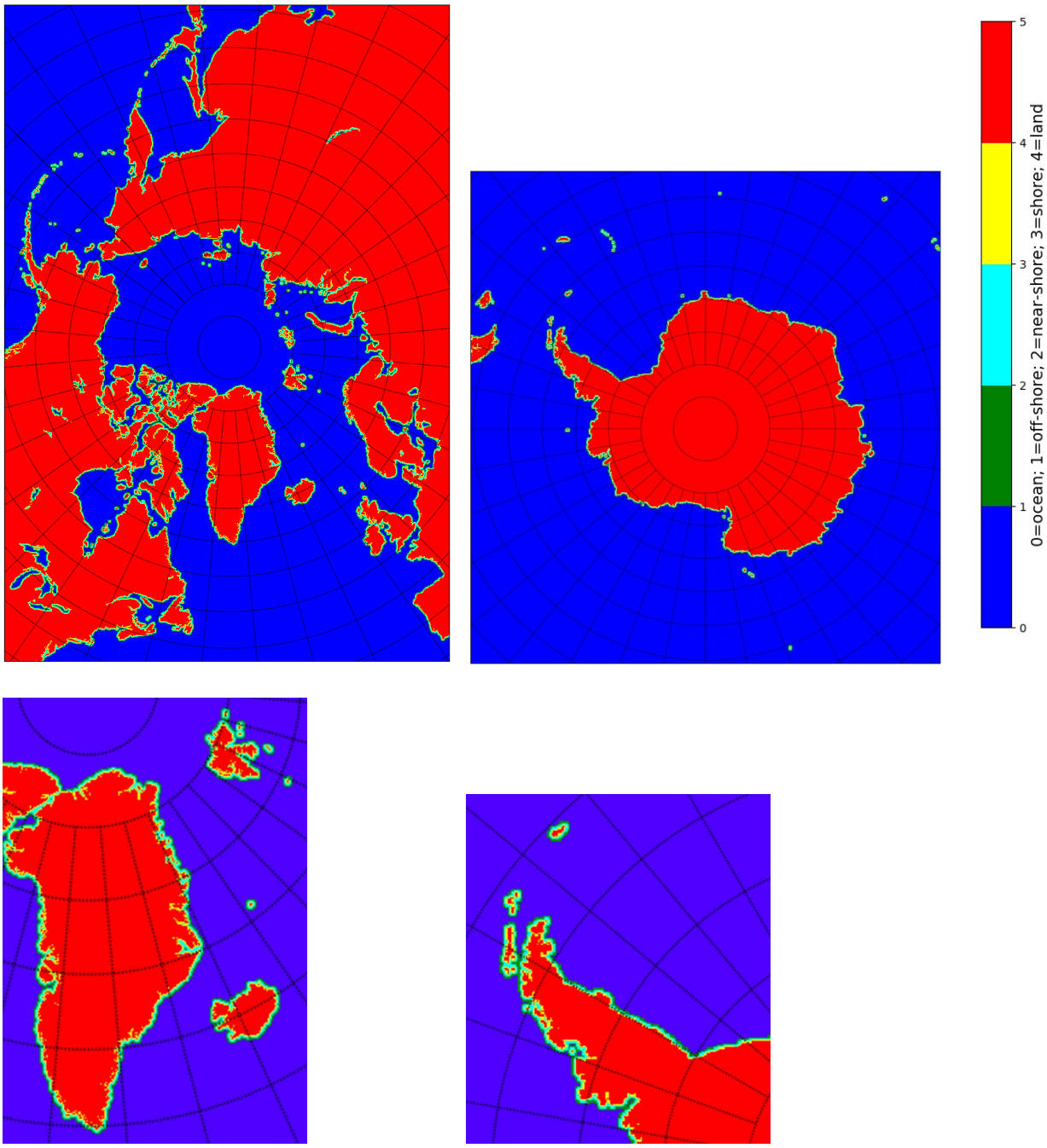

Figure 4: Polar Stereographic (10 km grid spacing) ocean/lakes/coast/land mask for the Northern (left) and the Southern (right) hemisphere. To better display the 'near coast' points the plots in the second row show a zoomed area of the Northern and Southern hemisphere. The coastline has been derived from the World Vector Shoreline. The 'near coast' points are classified as shore (yellow), near-shore (cyan), off-shore (green) which extend from the land (red) over sea (blue) areas. The mask is derived so that the off-shore points are about 12.5 km distant from the coastline. In the Northern hemisphere, all the lakes have been masked out with the exception of those displayed in the plot.

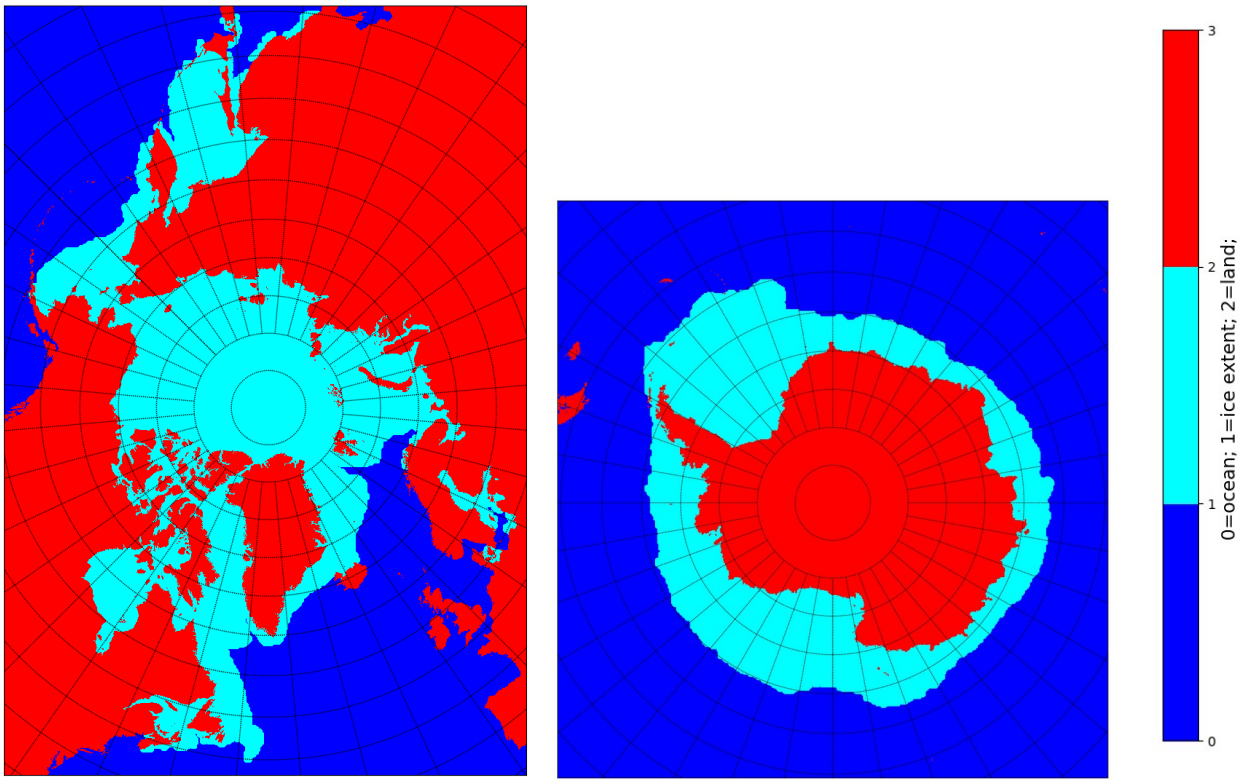

Figure 5: Polar Stereographic (10 km grid spacing) sea ice climatology extent (cyan) for the Northern (left) and the Southern (right) Hemisphere. As an example, the sea ice climatology extent is for February. The climatology has been produced by NSIDC using SMMR and SSM/I monthly averaged ice concentrations and finding the maximum extent for each month between 1979 and 2007.

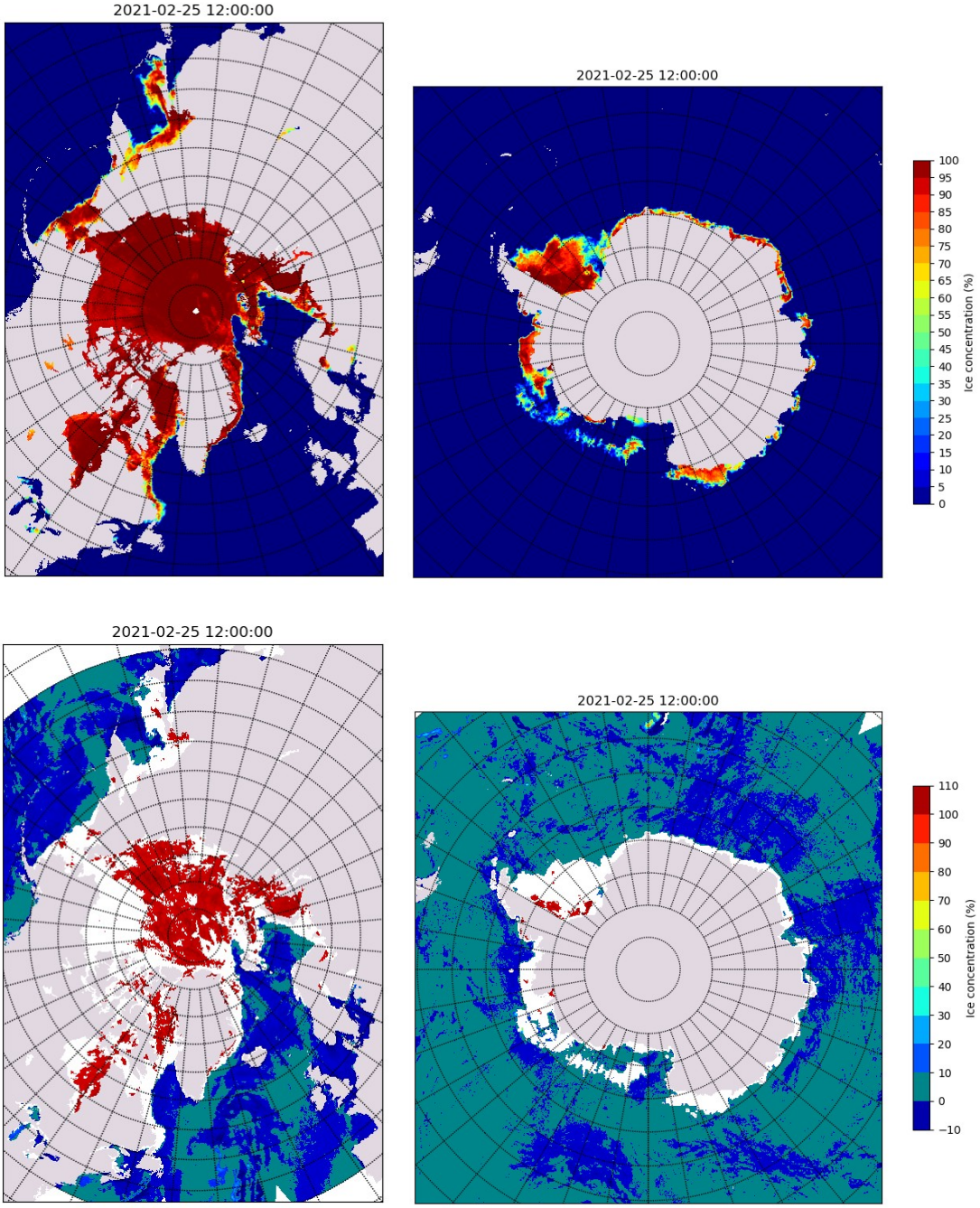

Figure 6: Level 3 AMSR2 (Polar Stereographic grid) sea ice concentration (OSI-SAF hybrid sea ice concentration) for the Northern and Southern Hemisphere. The Level 3 product analysis date is 25 February 2021. Top row shows the filtered sea ice concentration ('ice_conc' variable) and, bottom row, the sea ice concentration retrieved by the algorithm ('raw_ice_concentration_values' variable) which was edited away by the screening tests.

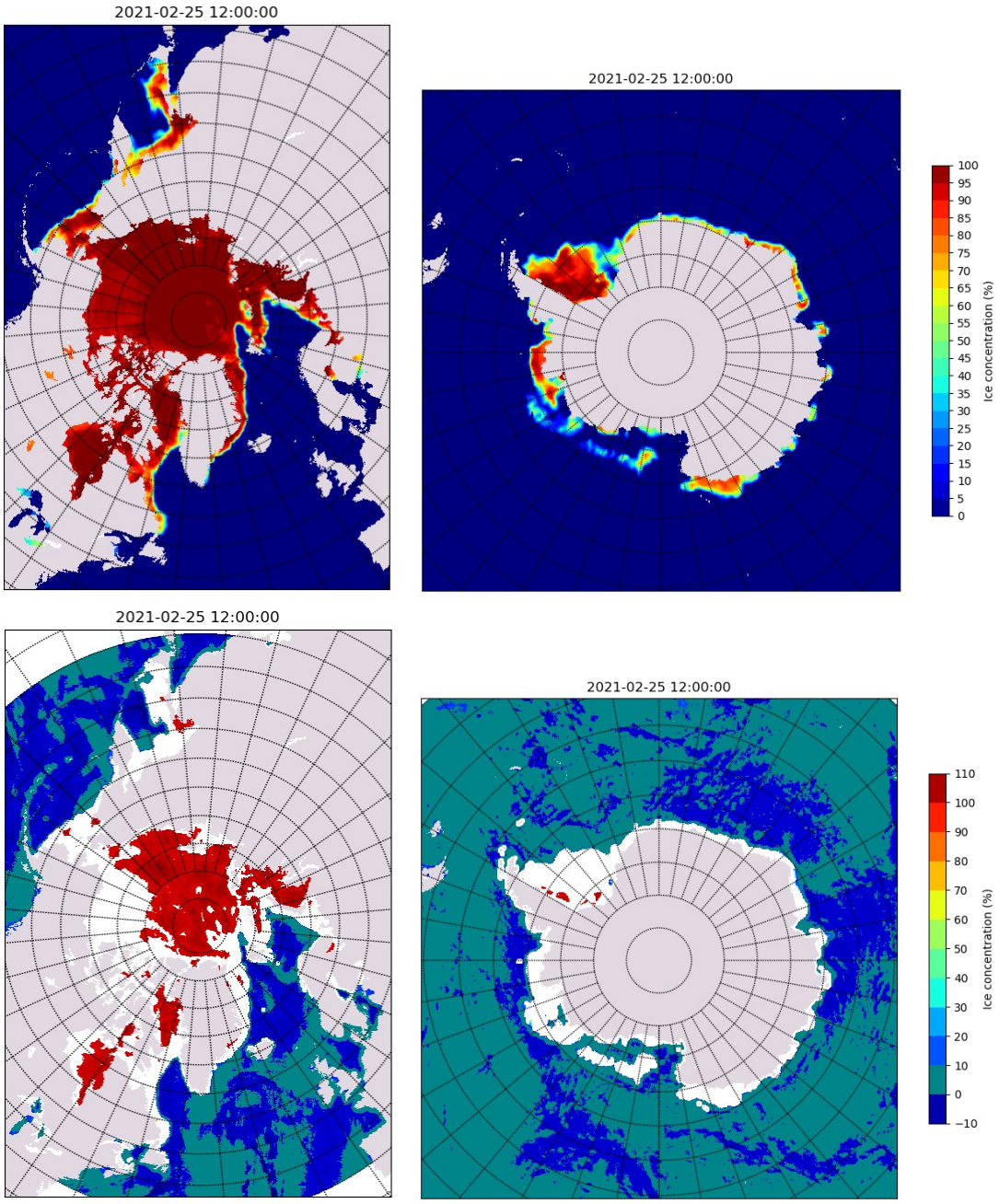

Figure 7: Same as Figure 6, but for the Level 3 SSMIS.

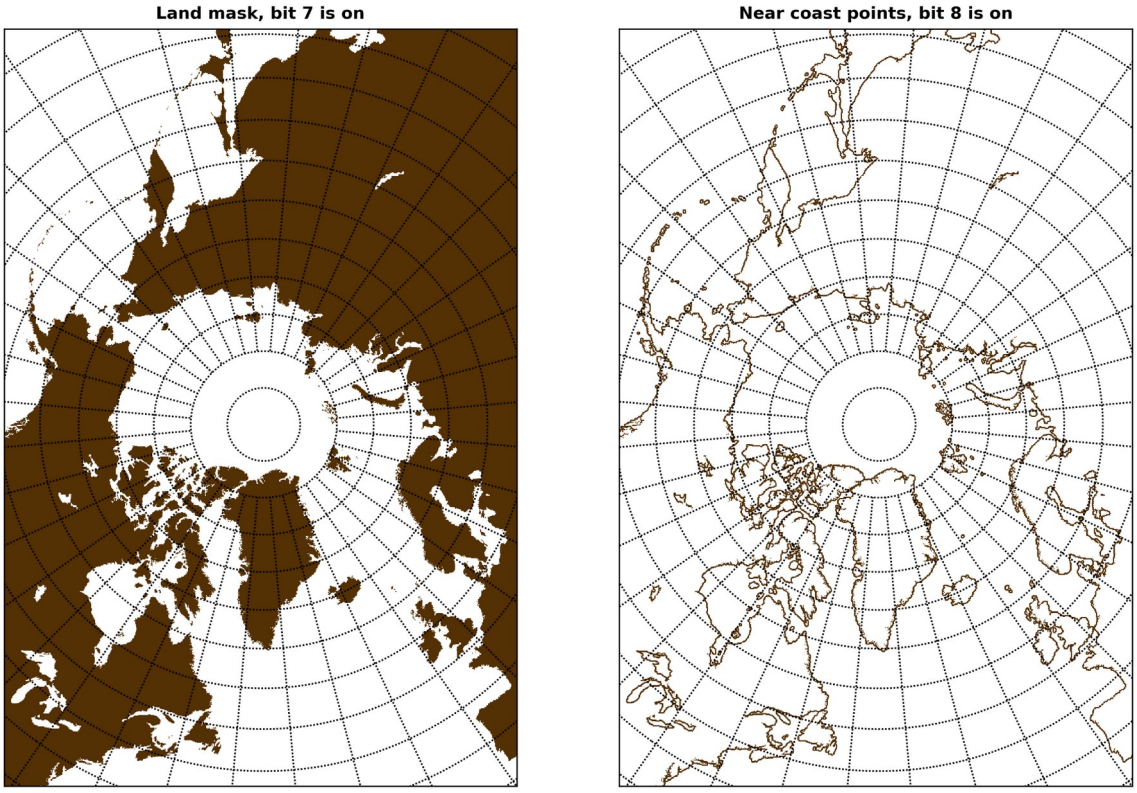

Figure 8: Maps which represent the land mask and the near coast points in the L3 AMSR2 product. The plots are derived from the status_flag variable considering all the grid points where the bit 7 and the bit 8 are respectively on.

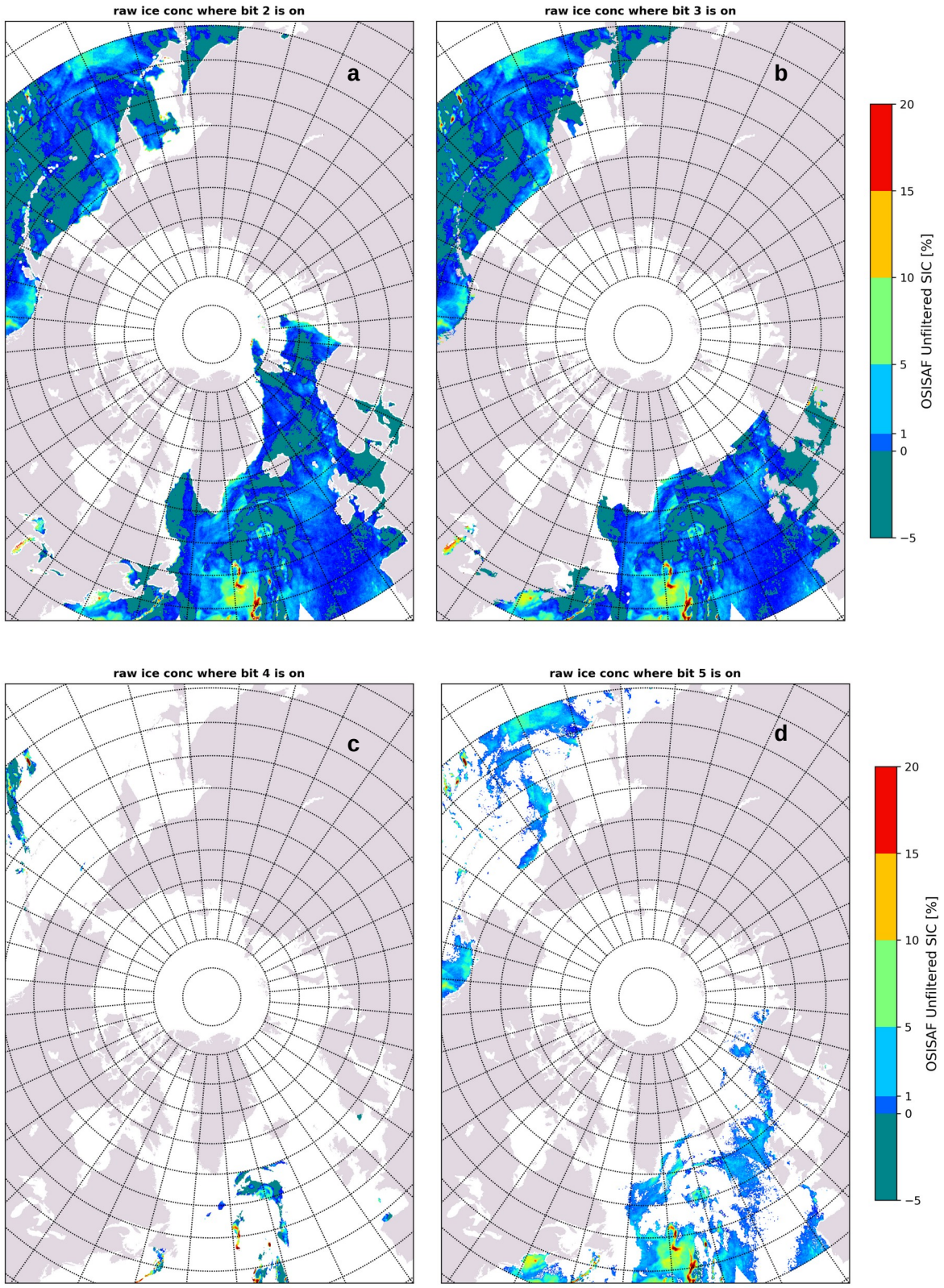

Figure 9: Maps which represent the variable 'raw_ice_concentration_values' in the L3 AMSR2 product (analysis date is 25 February 2021) where one of the bits of the status_flag (as listed in Table 6), is on: a) bit 2 (OWF screening); b) bit 3 (NWP skin temperature screening); c) bit 4 (P37 screening); bit 5 (maximum sea ice climatology extent screening).

4.2.1. L3 grid specification

The Level 3 sea ice concentration products are provided on a daily basis and they are disseminated in two separate files one for the northern hemisphere and one for the southern hemisphere. Both the AMSR2 and SSMIS Level 3 products are presented on a Polar Stereographic projection with a grid spacing of 10 km. Table 7 provides the details of the grid definitions for the Level 3 products.

Polar Stereographic, both OSI-408-a (AMSR2) and OSI-401-d (SSMIS)	
Resolution	10 km
Size	NH: 760 columns, 1120 rows SH: 790 columns, 830 rows
Central Meridian	NH: -45° SH: 0°
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 7: Geographical definition for the Polar Stereographic grid, Northern (NH) and Southern (SH) Hemisphere, which is used for the Level 3 products.

4.2.2. L3 file naming convention

As for the Level 2 NetCDF products, the Level 3 near real time sea ice concentration files are also diversified according to the satellite sensor which is used to generate the product (AMSR2 or SSMIS) and the sea ice algorithm used to generate the product (OSI-SAF Hybrid or TUD). Given the string <AREA> to identity the hemisphere (nh or sh) and the string <YYYYMMDD1200> to identify the central date of the analysis, According to the data distribution described in section 4.3, Table 9 provides an overview of the naming conventions of the Level 3 near real time sea ice concentration products.

AMSR2 Level 3 product (OSI-408-a)	
Polar Stereographic Grid & OSI-SAF Hybrid	**OSI FTP & THREDDS:** ice_conc_<AREA>_polstere-100_amsr2_<YYYYMMDD1200>.nc **EUMETCast:** S-OSI_-DMI_-AMSR-GL_<AREA>_CONC__-<YYYYMMDD1200>Z.nc.gz
Polar Stereographic Grid & TUD	**OSI FTP:** ice_conc_<AREA>_polstere-100_amsr2-tud_<YYYYMMDD1200>.nc
SSMIS Level 3 product (OSI-401-d)	
Polar Stereographic Grid & OSI-SAF Hybrid	**OSI FTP & THREDDS:** ice_conc_<AREA>_polstere-100_multi_<YYYYMMDD1200>.nc **EUMETCast:** S-OSI_-DMI_-MULT-GL_<AREA>_CONC__-<YYYYMMDD1200>Z.nc.gz

Table 9: Naming conventions of the Level 3 near real time sea ice concentration products.

4.3. Data distribution

There are three main sources for obtaining the OSI SAF Sea Ice products: by FTP, THREDDS and EUMETCast. In addition, the products can be delivered through the Regional Meteorological Data Communication Network (RMDCN) on request. At the OSI SAF Sea Ice FTP server [ftp://osisaf.met.no/prod/ice] the products are available in netCDF format. Here products from the last month are available. In addition there is a separate directory with an archive of all previously produced sea ice products (up to the last available product) at [ftp://osisaf.met.no/archive/ice]. The product can also be obtained via a THREDDS server from https://thredds.met.no/thredds/osisaf/osisaf_seaiceconc.html, in netCDF format.

Through the EUMETSAT EUMETCast service the OSI SAF Sea Ice products are available in the NetCDF format. 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/eumetcast].

4.4. Helpdesk information

Users are welcomed and encouraged to contact the OSI SAF in case of questions to or problems with OSI SAF products, and OSI SAF will support the users as best possible. Please use the helpdesk form available on the OSI SAF website: https://osi-saf.eumetsat.int

Note, that you might need to register on the web site to send the form. We also recommend users to subscribe to OSI SAF service messages (specific to the products used) to be aware of any production anomaly and of product upgrades. This is done on the OSI SAF website (above) and you need to be registered to receive service messages.

5. References

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Appendix A - Changes to Level 2 and Level 3 variables in NetCDF files

As it has been previously described, in this upgraded version of the algorithm, to simplify the use of different sea ice concentration datasets, we made some changes so that the content (variables) of the Level 2 and Level 3 products (NetCDF files) is equivalent. For the user, it is important to highlight that:

- the file naming convention of L2 and L3 NetCDF files (respectively described in section 4.1.1 and 4.2.3) has not been changed.
- Apart from latitude, longitude, time, the expected names of the variables in the L2/L3 NetCDF files are listed and described in Table 4.

To facilitate the use of the new L2/L3 products, we did not change the name of the variables in the NetCDF files, but some of the variables have a different content or have been deprecated. Broadly speaking, for the user, the sea ice concentration retrieval is always given by the 'ice_conc' variable. The main difference is that, by using the variables 'raw_ice_conc_values' (new) and 'status_flag' (changed), it is easier to control the nominal values retrieved by the algorithm and identify the screening tests applied to derived the 'filtered' sea ice concentrations ('ice_conc'). Below a detailed description of the changes for every product.

LEVEL 2

- *SSMIS*

  deprecated: 'surf_l', 'surf_l_a'

  changed content:

  - 'ice_conc': sea ice concentration (0-100) which has been filtered by the screening tests listed in Table 5. The screening tests applied to every grid point can be retrieved looking at the variable 'status_flag'
  - 'status_flag': This is a bit variable (e.g. 00110) and it identifies the screening tests (listed in Table 5) applied to every grid point . When searching for a specific screening test it is recommended to search for the corresponding bit and not look for the corresponding integer value. **Important for the user:** the meaning of the bits (listed in Table 5) is different respect to the previous version of the algorithm. If the 'status_flag' was used, the user should revise the logic adopted.

  new variable:

  - 'raw_ice_conc_values': nominal value of sea ice concentration as retrieved by the algorithm that is edited away by the screening tests listed in Table 5.

- *AMSR2*

  deprecated: none

  changed content: 'ice_conc', 'status_flag' as described above for SSMIS

new variable: *'raw_ice_conc_values' as described above for SSMIS*

LEVEL 3

- *SSMIS*

  deprecated: 'ice_conc_unfiltered', 'masks', 'confidence_level'

  changed content:

  - 'ice_conc': sea ice concentration (0-100) which has been filtered by the screening tests listed in Table 6. The screening tests applied to every grid point can be retrieved looking at the variable 'status_flag'
  - 'status_flag': This is a bit variable (e.g. 00110) and it identifies the screening tests (listed in Table 6) applied to every grid point . For the L3 product, the 'status_flag' also contains info regarding the lake and land masks, 'near coast' grid points and missing values. When searching for a specific screening test it is recommended to search for the corresponding bit and not look for the corresponding integer value. **Important for the user:** the meaning of the bits (listed in Table 6) is different respect to the previous version of the algorithm. If the 'status_flag' was used, the user should revise the logic adopted.

  new variable:

  - 'raw_ice_conc_values': nominal value of sea ice concentration as retrieved by the algorithm that is edited away by the screening tests listed in Table 6.

- *AMSR2*

  deprecated: 'confidence_level'

  changed content: 'ice_conc', 'status_flag' as described above for SSMIS

  new variable: 'raw_ice_conc_values' as described above for SSMIS

Appendix B - Example of Level 2 and Level 3 NetCDF header

As an example, in this section we provide the NetCDF header of the AMSR2 Level 2 and Level 3 products. SSMIS Level 2 and Level 3 products have the identical data structure, but there is no discrimination between OSI-SAF Hybrid and TUD ice concentration (TUD is not provided).

NetCDF header of the AMSR2 Level 2 product

- *Resolution: Satellite swath (SH & NH)*
- *NetCDF dimension: time = 1; atrack by xtrack*
- *NetCDF file name is characterised by the initial date/time (UTC) of the satellite scan ('YYYYMMDDHHMM')*
- *Ice concentration in NetCDF: OSI-SAF Hybrid (string 'osi') & TUD (string 'tud')*

ncdump -h ice_conc_l2_amsr2_gw1_202302200709.nc:

```
netcdf ice_conc_l2_amsr2_gw1_202302200709 {
dimensions:
        atrack = 2039 ;
        xtrack = 243 ;
```

```
        time = 1 ;
        nv = 2 ;
variables:
        short dtime(atrack, xtrack) ;
                dtime:standard_name = "delta_time" ;
                dtime:long_name = "time difference from reference time" ;
                dtime:units = "seconds" ;
                dtime:comment = "time plus dtime gives seconds since 00:00:00 UTC January 1, 1978" ;
        float lat(atrack, xtrack) ;
                lat:_FillValue = -999.f ;
                lat:least_significant_digit = 6LL ;
                lat:standard_name = "latitude" ;
                lat:long_name = "latitude" ;
                lat:units = "degrees_north" ;
        float lon(atrack, xtrack) ;
                lon:_FillValue = -999.f ;
                lon:least_significant_digit = 6LL ;
                lon:standard_name = "longitude" ;
                lon:long_name = "longitude" ;
                lon:units = "degrees_east" ;
        int64 time(time) ;
                time:standard_name = "time" ;
                time:long_name = "reference time of product" ;
                time:units = "seconds since 1978-01-01 00:00:00" ;
        float raw_ice_conc_osi_values(time, atrack, xtrack) ;
                raw_ice_conc_osi_values:_FillValue = -999.f ;
                raw_ice_conc_osi_values:least_significant_digit = 2LL ;
                raw_ice_conc_osi_values:standard_name = "sea_ice_area_fraction" ;
                raw_ice_conc_osi_values:long_name = "sea ice concentration estimates, as retrieved by the OSI SAF hybrid
algorithm, that were edited away (sic set to zero) by the screening listed in the status_flag variable" ;
                raw_ice_conc_osi_values:units = "%" ;
                raw_ice_conc_osi_values:comment = "this field can be used in combination with the ice_conc variable to access to
the distribution of the sea ice concentration as estimated by the algorithm" ;
                raw_ice_conc_osi_values:coordinates = "dtime lon lat" ;
        float ice_conc_osi(time, atrack, xtrack) ;
                ice_conc_osi:_FillValue = -999.f ;
                ice_conc_osi:least_significant_digit = 2LL ;
                ice_conc_osi:standard_name = "sea_ice_area_fraction" ;
                ice_conc_osi:long_name = "sea ice concentration derived applying the status_flag to the sea ice concentration
retrieved by the OSI SAF hybrid algorithm" ;
                ice_conc_osi:units = "%" ;
                ice_conc_osi:comment = "this field is the primary sea ice concentration estimate for the L2 product" ;
                ice_conc_osi:coordinates = "dtime lon lat" ;
        float total_uncertainty_osi(time, atrack, xtrack) ;
                total_uncertainty_osi:_FillValue = -999.f ;
                total_uncertainty_osi:least_significant_digit = 2LL ;
                total_uncertainty_osi:long_name = "estimate of the total uncertainty for the sea ice concentration retrieved by the
OSI SAF hybrid algorithm" ;
                total_uncertainty_osi:units = "%" ;
                total_uncertainty_osi:coordinates = "dtime lon lat" ;
        float smearing_uncertainty_osi(time, atrack, xtrack) ;
                smearing_uncertainty_osi:_FillValue = -999.f ;
                smearing_uncertainty_osi:least_significant_digit = 2LL ;
                smearing_uncertainty_osi:long_name = "estimate of the smearing uncertainty for the sea ice concentration
retrieved by the OSI SAF hybrid algorithm" ;
                smearing_uncertainty_osi:units = "%" ;
                smearing_uncertainty_osi:comment = "this field is one of the two components contributing to total uncertainty of the
sea ice concentration" ;
                smearing_uncertainty_osi:coordinates = "dtime lon lat" ;
        float algorithm_uncertainty_osi(time, atrack, xtrack) ;
                algorithm_uncertainty_osi:_FillValue = -999.f ;
                algorithm_uncertainty_osi:least_significant_digit = 2LL ;
                algorithm_uncertainty_osi:long_name = "estimate of the tie-points uncertainty for the sea ice concentration retrieved
by the OSI SAF hybrid algorithm" ;
                algorithm_uncertainty_osi:units = "%" ;
                algorithm_uncertainty_osi:comment = "this field is one of the two components contributing to total uncertainty of the
sea ice concentration" ;
                algorithm_uncertainty_osi:coordinates = "dtime lon lat" ;
        float raw_ice_conc_tud_values(time, atrack, xtrack) ;
                raw_ice_conc_tud_values:_FillValue = -999.f ;
                raw_ice_conc_tud_values:least_significant_digit = 2LL ;
```

```
                raw_ice_conc_tud_values:standard_name = "sea_ice_area_fraction" ;
                raw_ice_conc_tud_values:long_name = "sea ice concentration estimates, as retrieved by the OSI SAF tud algorithm, that were edited away by the various filters" ;
                raw_ice_conc_tud_values:units = "%" ;
                raw_ice_conc_tud_values:comment = "this field can be used in combination with the ice_conc variable to access to the distribution of the sea ice concentration as estimated by the algorithm" ;
                raw_ice_conc_tud_values:coordinates = "dtime lon lat" ;
        float ice_conc_tud(time, atrack, xtrack) ;
                ice_conc_tud:_FillValue = -999.f ;
                ice_conc_tud:least_significant_digit = 2LL ;
                ice_conc_tud:standard_name = "sea_ice_area_fraction" ;
                ice_conc_tud:long_name = "sea ice concentration derived applying the status_flag to the sea ice concentration retrieved by the OSI SAF tud algorithm" ;
                ice_conc_tud:units = "%" ;
                ice_conc_tud:comment = "this field is the primary sea ice concentration estimate for the L2 product" ;
                ice_conc_tud:coordinates = "dtime lon lat" ;
        float total_uncertainty_tud(time, atrack, xtrack) ;
                total_uncertainty_tud:_FillValue = -999.f ;
                total_uncertainty_tud:least_significant_digit = 2LL ;
                total_uncertainty_tud:long_name = "estimate of the total uncertainty for the sea ice concentration retrieved by the OSI SAF tud algorithm" ;
                total_uncertainty_tud:units = "%" ;
                total_uncertainty_tud:coordinates = "dtime lon lat" ;
        float smearing_uncertainty_tud(time, atrack, xtrack) ;
                smearing_uncertainty_tud:_FillValue = -999.f ;
                smearing_uncertainty_tud:least_significant_digit = 2LL ;
                smearing_uncertainty_tud:long_name = "estimate of the smearing uncertainty for the sea ice concentration retrieved by the OSI SAF tud algorithm" ;
                smearing_uncertainty_tud:units = "%" ;
                smearing_uncertainty_tud:comment = "this field is one of the two components contributing to total uncertainty of the sea ice concentration" ;
                smearing_uncertainty_tud:coordinates = "dtime lon lat" ;
        float algorithm_uncertainty_tud(time, atrack, xtrack) ;
                algorithm_uncertainty_tud:_FillValue = -999.f ;
                algorithm_uncertainty_tud:least_significant_digit = 2LL ;
                algorithm_uncertainty_tud:long_name = "estimate of the tie-points uncertainty for the sea ice concentration retrieved by the OSI SAF tud algorithm \n" ;
                algorithm_uncertainty_tud:units = "%" ;
                algorithm_uncertainty_tud:comment = "this field is one of the two components contributing to total uncertainty of the sea ice concentration" ;
                algorithm_uncertainty_tud:coordinates = "dtime lon lat" ;
        float status_flag(time, atrack, xtrack) ;
                status_flag:_FillValue = -999.f ;
                status_flag:least_significant_digit = 2LL ;
                status_flag:standard_name = "sea_ice_area_fraction status_flag" ;
                status_flag:long_name = "flag applied to the sea ice concentration retrievals" ;
                status_flag:flag_descriptions = "no bits set (0): nominal value of the sea ice concentration (sic) retrieved by the algorithm \n bit 2 ( 0010): Open water filter screening applied \n bit 3 ( 0100): NWP skin temperature screening applied \n bit 4 ( 1000): 37 GHz polarization difference screening applied \n bit 5 (10000): Maximum sea ice climatology screening applied" ;
                status_flag:units = "1" ;
                status_flag:coordinates = "dtime lon lat" ;
        int64 time_bnds(time, nv) ;
                time_bnds:units = "seconds since 1978-01-01 00:00:00" ;

// global attributes:
                :institution = "EUMETSAT OSI SAF" ;
                :orbit_number = 57244 ;
                :satellite = "gw1" ;
                :history = "Created 2023-02-20 10:23:34" ;
                :fromfile = "GW1AM2_202302200709_010A_L1SGBTBR_2220220.h5" ;
                :start_date = "2023-02-20 07:09:16" ;
                :stop_date = "2023-02-20 08:00:13" ;
                :title = "Level-2 Sea Ice Concentration Analysis from OSI SAF EUMETSAT" ;
                :product_id = "OSI-410-a" ;
                :product_name = "osi_saf_ice_conc_l2" ;
                :product_status = "operational" ;
                :abstract = "The Level-2 analysis of sea ice concentration is obtained from operation satellite images of the polar regions. It is based on atmospherically corrected signal and a carefully selected sea ice concentration algorithm. This product is freely available from the EUMETSAT Ocean and Sea Ice Satellite Application Facility (OSI SAF)." ;
                :topiccategory = "Oceans Climatology Meteorology Atmosphere" ;
                :keywords = "Sea Ice Concentration, Sea Ice, Oceanography, Meteorology, Climate, Remote Sensing" ;
```

:gcmd_keywords = "Cryosphere > Sea Ice > Sea Ice Concentration, \nOceans > Sea Ice > Sea Ice Concentration, \nVertical Location > Sea Surface, \nEUMETSAT/OSISAF > Satellite Application Facility on Ocean and Sea Ice, European Organisation for the Exploitation of Meteorological Satellites" ;
:activity_type = "Space borne instrument" ;
:area = "Global" ;
:instrument_type = "AMSR2" ;
:platform_name = "GW1" ;
:project_name = "EUMETSAT OSI SAF" ;
:contact = "osisaf-manager@met.no" ;
:distribution_statement = "Free" ;
:copyright_statement = "Copyright 2023 EUMETSAT" ;
:PI_name = "Fabrizio Baordo" ;
:references = "Product User Manual and Algorithm Theoretical Basis Document available at https://osi-saf.eumetsat.int/documentation/products-documentation" ;
:product_version = "1.1" ;
:software_version = "2.0.1" ;
:netcdf_version = "1.5.4" ;
:Conventions = "CF-1.6" ;
}

NetCDF header of the AMSR2 Level 3 product

- Resolution: Polar Stereographic Grid (SH or NH). In the *NetCDF file name*, the string ‘nh’ or ‘sh’ identifies the hemisphere
- *NetCDF dimension: time = 1; yc by xc*
- *NetCDF file name is characterised by the the central date of the analysis (‘YYYYMMDD1200’)*
- *Ice concentration in NetCDF: OSI-SAF Hybrid or TUD. If TUD, string ‘tud’ is in the NetCDF file name*

ncdump -h ice_conc_nh_polstere-100_amsr2_202302181200 :

netcdf ice_conc_nh_polstere-100_amsr2_202302181200 {
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:false_easting = 0. ;
Polar_Stereographic_Grid:false_northing = 0. ;
Polar_Stereographic_Grid:area_extent = "\'(-3850000.0, -5350000.0, 3750000.0, 5850000.0)\'" ;
Polar_Stereographic_Grid:semi_major_axis = 6378273. ;
Polar_Stereographic_Grid:semi_minor_axis = 6356889.44891 ;
Polar_Stereographic_Grid:straight_vertical_longitude_from_pole = -45. ;
Polar_Stereographic_Grid:latitude_of_projection_origin = 90. ;
Polar_Stereographic_Grid:standard_parallel = 70. ;
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 in Cartesian system" ;
xc:standard_name = "projection_x_coordinate" ;
double yc(yc) ;
yc:axis = "Y" ;
yc:units = "km" ;

```
                yc:long_name = "y coordinate in Cartesian system" ;
                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" ;
        short ice_conc(time, yc, xc) ;
                ice_conc:_FillValue = -999s ;
                ice_conc:long_name = "sea ice concentration derived applying the status_flag to the sea ice concentration retrieved
by the OSI SAF hybrid algorithm" ;
                ice_conc:standard_name = "sea_ice_area_fraction" ;
                ice_conc:comment = "this field is the primary sea ice concentration estimate for the L3 product: the mean of the
Level2 filtered sea ice concentrations within the Level3 grid cell" ;
                ice_conc:units = "%" ;
                ice_conc:grid_mapping = "Polar_Stereographic_Grid" ;
                ice_conc:coordinates = "time lat lon" ;
                ice_conc:scale_factor = 0.01f ;
                ice_conc:add_offset = 0.f ;
        short raw_ice_conc_values(time, yc, xc) ;
                raw_ice_conc_values:_FillValue = -999s ;
                raw_ice_conc_values:long_name = "sea ice concentration estimates, as retrieved by the OSI SAF hybrid algorithm,
that were edited away (sic set to zero) by the screening listed in the status_flag variable" ;
                raw_ice_conc_values:standard_name = "sea_ice_area_fraction" ;
                raw_ice_conc_values:comment = "this field can be used in combination with the ice_conc variable to access to the
distribution of the sea ice concentration as estimated by the algorithm" ;
                raw_ice_conc_values:units = "%" ;
                raw_ice_conc_values:grid_mapping = "Polar_Stereographic_Grid" ;
                raw_ice_conc_values:coordinates = "time lat lon" ;
                raw_ice_conc_values:scale_factor = 0.01f ;
                raw_ice_conc_values:add_offset = 0.f ;
        short status_flag(time, yc, xc) ;
                status_flag:_FillValue = -999s ;
                status_flag:long_name = "flag applied to the sea ice concentration retrievals" ;
                status_flag:standard_name = "sea_ice_area_fraction status_flag" ;
                status_flag:units = "1" ;
                status_flag:grid_mapping = "Polar_Stereographic_Grid" ;
                status_flag:coordinates = "time lat lon" ;
                status_flag:flag_descriptions = "no bits set (0): nominal value of the sea ice concentration (sic) retrieved by the
algorithm\n",
                        "bit 2 (10): Open water filter screening applied \n",
                        " bit 3 (100): NWP skin temperature screening applied \n",
                        " bit 4 (1000): 37 GHz polarization difference screening applied \n",
                        " bit 5 (10000): Maximum sea ice climatology screening applied \n",
                        " bit 6 (100000): Lake mask \n",
                        " bit 7 (1000000): Land mask \n",
                        " bit 8 (10000000): Near coast grid points \n",
                        " bit 9 (100000000): Missing value" ;
        float total_uncertainty(time, yc, xc) ;
                total_uncertainty:_FillValue = -1.e+10f ;
                total_uncertainty:least_significant_digit = 3 ;
                total_uncertainty:units = "%" ;
                total_uncertainty:long_name = "estimate of the total uncertainty for the sea ice concentration retrieved by the OSI
SAF algorithm" ;
                total_uncertainty:coordinates = "time lat lon" ;
                total_uncertainty:grid_mapping = "Polar_Stereographic_Grid" ;
        float smearing_uncertainty(time, yc, xc) ;
                smearing_uncertainty:_FillValue = -1.e+10f ;
                smearing_uncertainty:least_significant_digit = 3 ;
                smearing_uncertainty:units = "%" ;
                smearing_uncertainty:long_name = "estimate of the smearing uncertainty for the sea ice concentration retrieved by
the OSI SAF algorithm" ;
                smearing_uncertainty:comment = "this field is one of the two components contributing to total uncertainty of the sea
ice concentration" ;
                smearing_uncertainty:coordinates = "time lat lon" ;
                smearing_uncertainty:grid_mapping = "Polar_Stereographic_Grid" ;
        float algorithm_uncertainty(time, yc, xc) ;
                algorithm_uncertainty:_FillValue = -1.e+10f ;
```

```
                    algorithm_uncertainty:least_significant_digit = 3 ;
                    algorithm_uncertainty:units = "%" ;
                    algorithm_uncertainty:long_name = "estimate of the tie-points uncertainty for the sea ice concentration retrieved by the OSI SAF algorithm" ;
                    algorithm_uncertainty:comment = "this field is one of the two components contributing to total uncertainty of the sea ice concentration" ;
                    algorithm_uncertainty:coordinates = "time lat lon" ;
                    algorithm_uncertainty:grid_mapping = "Polar_Stereographic_Grid" ;

// global attributes:
                    :title = "Level-3 Sea Ice Concentration Analysis from OSI SAF EUMETSAT" ;
                    :product_id = "OSI-408-a" ;
                    :instrument_type = "AMSR2" ;
                    :platform_name = "GCOM-W" ;
                    :easternmost_longitude = 180. ;
                    :westernmost_longitude = -180. ;
                    :northernmost_latitude = 90. ;
                    :southernmost_latitude = 40. ;
                    :area = "Northern Hemisphere" ;
                    :product_name = "osi_saf_ice_conc_l3" ;
                    :product_status = "operational" ;
                    :abstract = "The daily analysis of sea ice concentration is obtained from operation satellite images of the polar regions. It is based on atmospherically corrected signal and a carefully selected sea ice concentration algorithm. This product is freely available from the EUMETSAT Ocean and Sea Ice Satellite Application Facility (OSI SAF)." ;
                    :topiccategory = "Oceans Climatology Meteorology Atmosphere" ;
                    :keywords = "Sea Ice Concentration, Sea Ice, Oceanography, Meteorology, Climate, Remote Sensing" ;
                    :gcmd_keywords = "Cryosphere > Sea Ice > Sea Ice Concentration\n",
                              "Oceans > Sea Ice > Sea Ice Concentration\n",
                              "Geographic Region > Northern Hemisphere\n",
                              "Vertical Location > Sea Surface\n",
                              "EUMETSAT/OSISAF > Satellite Application Facility on Ocean and Sea Ice, European Organisation for the Exploitation of Meteorological Satellites" ;
                    :activity_type = "Space borne instrument" ;
                    :start_date = "2023-02-18 00:00:00" ;
                    :stop_date = "2023-02-19 00:00:00" ;
                    :project_name = "EUMETSAT OSI SAF" ;
                    :institution = "EUMETSAT OSI SAF" ;
                    :contact = "osisaf-manager@met.no" ;
                    :distribution_statement = "Free" ;
                    :copyright_statement = "Copyright 2023 EUMETSAT" ;
                    :PI_name = "Fabrizio Baordo" ;
                    :references = "Product User Manual and Algorithm Theoretical Basis Document available at https://osi-saf.eumetsat.int/documentation/products-documentation" ;
                    :history = "Created 2023-02-19 02:01:17" ;
                    :product_version = "4.1" ;
                    :software_version = "2.0.1" ;
                    :netcdf_version = "1.5.4" ;
                    :Conventions = "CF-1.6" ;
}
```