Ocean & Sea Ice SAF

Global Sea Ice Concentration Climate Data Records

Scientific Validation Report

Document version: 3.0
Data set version: 3.0

OSI-450-a: 10.15770/EUM_SAF_OSI_0013
OSI-430-a: 10.15770/EUM_SAF_OSI_0014
OSI-458: 10.15770/EUM_SAF_OSI_0015

August 2022

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OSI SAF
Ocean and Sea Ice

Documentation Change Record

Document version	*Date*	*Author*	*Comment*
3.0 - draft	17.06.2022	OSI SAF HL team	Prepared for ORR/DRR
3.0	24.08.2022	OSI SAF HL team	Revised after ORR/DRR

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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 utilize specialist expertise from institutes based in Member States. EUMETSAT created Satellite Application Facilities (SAFs) to complement its Central Facilities capability in Darmstadt. The Ocean and Sea Ice Satellite Application Facility (OSI SAF) is one of eight EUMETSAT SAFs, which provide users with operational data and software products. More on SAFs can be read at www.eumetsat.int.

OSI SAF produces (on an operational basis) a range of air-sea interface products, namely: wind, sea ice characteristics, Sea Surface Temperatures (SST), Surface Solar Irradiance (SSI) and Downward Longwave Irradiance (DLI). The sea ice products include sea ice concentration, sea ice emissivity at 50 GHz, sea ice edge, sea ice type, sea ice drift and sea ice surface temperature (from mid 2014).

The OSI SAF consortium is led 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.

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Acknowledgement and citation

Use of the product(s) should be acknowledged with the following citations:

EUMETSAT Ocean and Sea Ice Satellite Application Facility, Global sea ice concentration climate data record 1978-2020 (v3.0, 2022), OSI-450-a, doi: 10.15770/EUM_SAF_OSI_0013, data (for [extracted period], [extracted domain],) extracted on [download date]

EUMETSAT Ocean and Sea Ice Satellite Application Facility, Global sea ice concentration interim climate data record (v3.0, 2022), OSI-430-a, doi: 10.15770/EUM_SAF_OSI_0014, data (for [extracted period], [extracted domain],) extracted on [download date]

EUMETSAT Ocean and Sea Ice Satellite Application Facility, Global medium resolution sea ice concentration climate data record 2002-2020 (v3.0, 2022), OSI-458, doi: 10.15770/EUM_SAF_OSI_0015, data (for [extracted period], [extracted domain],) extracted on [download date]

1.3 Scope

This report is the Scientific Validation Report (SVR) for three OSI SAF Sea Ice Concentration Climate Data Records, the OSI-450-a, OSI-430-a and OSI-458, that together constitute the *third major release* of the OSI SAF Global Sea Ice Concentration Climate Data Records.

The SVR describes and presents the results of the validation assessments of the *version 3* OSI SAF Sea Ice Concentration Climate Data Records against reference data sets and evaluates the assessment results against the OSI SAF accuracy requirements.

1.4 Overview

This report is the Scientific Validation Report (SVR) for three OSI SAF Sea Ice Concentration Climate Data Records, the OSI-450-a, OSI-430-a and OSI-458, that together constitute the *third major release* of the OSI SAF Global Sea Ice Concentration Climate Data Records. In short, these three CDRs can be summarized as:

- OSI-450-a: The Global Sea Ice Concentration Climate Data Record, based on coarse resolution imagery from SMMR, SSM/I, and SSMIS and covering 1978-2020.
- OSI-430-a: The Global Interim CDR (ICDR) based on coarse resolution imagery from SSMIS and providing an extension of OSI-450-a starting January 2021.
- OSI-458: The Global Sea Ice Concentration Climate Data Record based on medium resolution imagery from AMSR-E (2002-2011) and AMSR2 (2012-2020). OSI-458 is a Research to Operations transfer from ESA CCI.

The *first major version* of the OSI SAF sea-ice concentration CDRs was called OSI-409 and was initiated in 2006 (Tonboe et al, 2016). The *second major version* was OSI-450, complemented by the ICDR OSI-430-b (Lavergne et al, 2019). Some of the algorithms implemented in OSI-450 and OSI-430-b were contributed by the ESA CCI Phase 1 and 2 projects. ESA CCI also released their own SIC CDR at medium resolution (based on AMSR-E and AMSR2 data), notably the SICCI-25km data set. For this *third major version*, new R&D contributions from ESA CCI (now CCI+) are acknowledged.

The SVR describes and presents the results of the comparison of the three *version 3* OSI SAF Sea Ice Concentration Climate Data Records against the reference data sets that are described in Section 2.4 and 2.5. The assessment methods and metrics are explained in Section 2.2. The comparison results are matched against the OSI SAF accuracy requirements presented in Section 2.1.

In addition to this, to justify the release of the version 3 data sets, the assessment results are compared to those of the OSI SAF v2 OSI-450 CDR in the common years to evaluate the relative algorithm improvements.

The v3 Global Interim CDR OSI-430-a assessment results are compared to those of the OSI-450-a CDR in common years, to examine the CDR-to-ICDR temporal-consistency. Moreover, the ICDR OSI-430-a validation results are compared to those of the predecessor, the OSI-430-b ICDR, to show its relative improvements.

Finally, the SVR presents sea ice extent and area monthly trends derived from the version 3 OSI SAF CDR data sets to examine trends etc.

1.5 Glossary

AMSR2	Advanced Microwave Scanning Radiometer 2
AMSR-E	Advanced Microwave Scanning Radiometer for EOS
AVHRR	Advanced Very High Resolution Radiometer
SI-CCI	(ESA) Sea Ice Climate Change Initiative
CDR	Climate Data Record
DMSP	Defence Meteorological Satellite Program
EASE	Equal-Area Scalable Earth
ECMWF	European Centre for Medium-Range Weather Forecasts
FCDR	Fundamental Climate Data Record
FTP	File Transfer Protocol
ICDR	Interim Climate Data Record
MODIS	MODerate resolution Imaging Spectroradiometer
MTSU	Mean Total Standard Uncertainty
NH	Northern Hemisphere
NIC	National Ice Center
NWP	Numerical Weather Prediction
OLS	Optical Line Scanner (on DMSP)
OSI SAF	Ocean and Sea Ice SAF
RRDP	Round Robin Data Package
SAF	Satellite Application Facility
SAR	Synthetic Aperture Radar
SH	Southern Hemisphere
SIA	Sea ice area
SIE	Sea ice extent
SIGRID	Sea ice chart grid format
SII	Sea Ice Index
SMMR	Scanning Multichannel Microwave Radiometer (on NIMBUS 7)
SSMI	Special Sensor Microwave Imager
SSMIS	Special Sensor Microwave Imager Sounder

1.6 Reference and Applicable documents

1.6.1 Reference documents

[RD-1] EUMETSAT OSI SAF Validation Report for the Global Sea Ice Concentration Climate Data Records v3 (OSI-450-a, OSI-430-a, OSI-458), SAF/OSI/CDOP3/DMI/SCI/RP/285, version v3.0, August 2022

[RD-2] EUMETSAT OSI SAF Algorithm Theoretical Baseline Document for the Global Sea Ice Concentration Climate Data Records v3 (OSI-450-a, OSI-430-a, OSI-458), SAF/OSI/CDOP3/DMI_Met/SCI/MA/270, version v3.0, August 2022

1.6.2 Applicable documents

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

[AD-2] OSI SAF
Lavergne, T. and Tonboe, R.T.: Justifications of Requirements for Global Sea Ice Concentration (Interim) Climate Data Records and Global Sea Ice Drift Climate Data Record.
SAF/OSI/CDOP3/METNO/TEC/TN/374, V1.0, 02/12/2019

[AD-3] OSI SAF
Global Sea Ice Concentration Climate Data Record Justifications of Requirements, OSI-450
SAF/OSI/CDOP2/DMI/TEC/TN/241, version 1.1., 16/11/2015

2. Validation methodologies

The following methods are performed on the CDR and ICDR products for evaluating their accuracy. The methods involve using two different reference data sets that are described in Section 2.4 and 2.5 and are complementary in assessing the performance of the products. The results of the comparisons against reference data sets are presented in Chapter 3 and 4.

- Primary Method: Direct comparison against high-quality 0% and 100% SIC reference data (Kern et al, 2019). This method stems from the ESA CCI Sea Ice project and was adopted for these and future OSI SAF sea-ice concentration data records [AD-2].
- Additional: Comparison against US National Ice Center charts (U.S National Ice Center, 2020), to document the temporal consistency since 1979 (but limited by the low consistency of ice charts).
- Additional: Comparison of Monthly Sea Ice Extent and Area time series with those of the US NSIDC Sea Ice Index to examine data record trends etc.
- Additional: An evaluation of the OSI SAF product uncertainties at 0 % and 100 % (similar to that presented in Lavergne et al. (2019).

The accuracy requirements, presented in Section 2.1, will be assessed using the primary assessment method. The additional assessment methods are included in this report for documentation purposes.

2.1 Requirements

The specific product requirements that apply to the sea ice concentration CDR products, OSI-450-a, OSI-430-a and OSI-458, are given by the OSI SAF product requirement document [AD-1] and listed in the table below.

Table 1: Description of the three accuracy requirements levels that are applicable for the OSI SAF sea ice concentration products. The requirements are on the root mean square error of the difference (bias) between the reference ice concentration data and OSI SAF sea ice concentration product, averaged over one year. (From the OSI SAF product requirement document [AD-1] table OSI-PRD-PRO-200.)

Accuracy requirement	*Value*	*Description*
Threshold accuracy	15%	The minimum requirement to be met to ensure that data are useful.
Target accuracy	8%	The intermediate level between "threshold" and "optimum" which, if achieved, would result in a significant improvement for the targeted application.
Optimal accuracy	5%	The ideal requirement above which further improvements are not necessary.

The accuracy requirements three levels listed in Table 1 are applicable for the OSI SAF sea ice concentration products. The requirements are on the *root mean square error* of mismatch of the OSI SAF product sea ice concentration to reference data ice concentration, averaged over one year. (The mismatch between sea ice concentration from ice charts and from passive microwave radiometers is expected to be largest in summer.) These statistics are evaluated for the *open water* category and *closed ice* category, separately, see validation

parameter description in Section 2.2. The [AD-3] document gives the details for the product requirements for OSI-450 and explains the reasons for having the requirements on the *closed ice* and *open water* categories, and not the *intermediate ice* category.

Further, the OSI SAF product requirement document [AD-1] states about the reprocessed sea ice data that:

OSI-PRD-PRO-205: The OSI SAF shall reprocess the time series of SMMR, SSM/I and SSMIS data back to 1978 to expand the time series of global sea ice products.

OSI-PRD-PRO-206: The OSI SAF shall test new methods for ensuring a climate consistent data set.

OSI-PRD-PRO-207: The OSI SAF shall improve the coverage of the existing sea ice concentration, edge and type products by adding interpolation in the coastal zone and the area close to the pole where there is no satellite data coverage.

All of these three requirements have been met at the completion of the OSI SAF global reprocessed sea ice concentration data set.

2.2 Validation parameters

The product target requirements listed in Section 2.5.1 address the *closed ice* and *open water* categories only and validation statistics for the two categories are shown in this report: The *bias (*the mean difference to the reference data) and the *root mean square error* (RMSE) are reported for two categories; *closed ice* (100% ice concentration) and *open water* (0% ice concentration) and are calculated as described in the table below. The OSI SAF ice concentration is referred as OSI_{SIC} and the reference data ice concentration as Ref_{SIC} (SIC0 and SIC1 reference data and ice chart analysis concentration, respectively).

Table 2: Statistical parameters that are output from the comparison analysis conducted for this report. The OSI SAF ice concentration is referred as OSI_{SIC} and the reference data ice concentration as Ref_{SIC}.

Parameter	Description
Ice bias	Average of OSI_{SIC} – Ref_{SIC} for all grid cells where Ref_{SIC} = 100% ice (closed ice).
Water bias	Average of OSI_{SIC} – Ref_{SIC} for all grid cells where Ref_{SIC} = 0% (open water).
Ice RSME	Root mean square error of OSI_{SIC} – Ref_{SIC} for all grid cells where Ref_{SIC} = 100% ice (closed ice)
Water RSME	Root mean square error of OSI_{SIC} – Ref_{SIC} for all grid cells where Ref_{SIC} = 0% (open water).

2.3 OSI SAF Global Sea Ice Concentration data availability

The three OSI SAF Global Sea Ice Concentration data sets that are subject to the validation described in this report, are all based on the algorithm version 3 and part of the same release.

The OSI-450-a Climate Data Record product is available for the period November 1978 to December 2020 at this address: ftp://osisaf.met.no/reprocessed/ice/conc/v3p0

The OSI-430-a Interim Climate Data Record product is available for the period January 2020 and onwards at this address: ftp://osisaf.met.no/reprocessed/ice/conc-cont-reproc/v3p0

The OSI-458 Climate Data Record product is available for the period June 2002 to December 2020 at this address: ftp://osisaf.met.no/reprocessed/ice/conc/v3p0

All three CDRs are on Lambert Azimuthal Equal Area Northern and Southern Hemisphere grids (EASE2).

Some of the daily sea ice concentration products have not been produced as a result of missing satellite data (due to satellite malfunction, planned maintenance or missing archive). The SMMR instrument was operated every second day. More details on this is provided in the Product User Manual [RD-1]. Below are listed the different satellite missions and the periods they are used for the CDR and ICDR data sets.

Table 3: Satellite mission instruments and the periods they are used for the OSI-450-a product. The F17 and F18 sensor data is used for the OSI-430-a ICDR product from 2020 and on.

Sensor	Data since	End
Nimbus 7 SMMR	October 1978	August 1987
DMSP F8 SSMI	July 1987	December 1991
DMSP F10 SSMI	January 1991	November 1997
DMSP F11 SSMI	January 1992	December 1999
DMSP F13 SSMI	May 1995	December 2008
DMSP F14 SSMI	May 1997	August 2008
DMSP F15 SSMI	February 2000	July 2006
DMSP F16 SSMIS	November 2005	December 2013
DMSP F17 SSMIS	December 2006	December 2020
DMSP F18 SSMIS	March 2010	December 2020

Table 4: Satellite mission instruments and the periods they are used for the OSI-458 product.

Sensor	Data since	End
AMSR-E	June 2002	October 2011
AMSR2	July 2012	December 2020

2.4 SIC0 and SIC1 reference data

The primary assessment method for the validation of the OSI SAF sea ice (I)CDR products is to compare the OSI SAF products for both Hemispheres with a high-quality, global wintertime

near-100% sea ice concentration (SIC1) reference data set for closed pack ice conditions and a global year-round 0% (SIC0) reference SIC data set for open water conditions. The evaluation methodology is independent of and more temporally consistent than the comparison to manually made ice charts that has been the only method used for evaluating the accuracy of the prior versions of the OSI SAF CDR and ICDR products.

The assessment method is applied to the *unfiltered,* original ("raw") sea ice concentration data also available in the product files. As a consequence of how the OSI SAF SIC algorithm works, this variable can contain unphysical 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). Using the raw SIC values allows to really assess the bias and spread of the product as it gives access to the full (symmetric) distribution of the errors (Kern et al., 2019). See [RD-1] for more information. The results from this validation will assess the CDR and ICDR stability and are more easily used to diagnose the SIC algorithms and therefore foster improvements [AD-2].

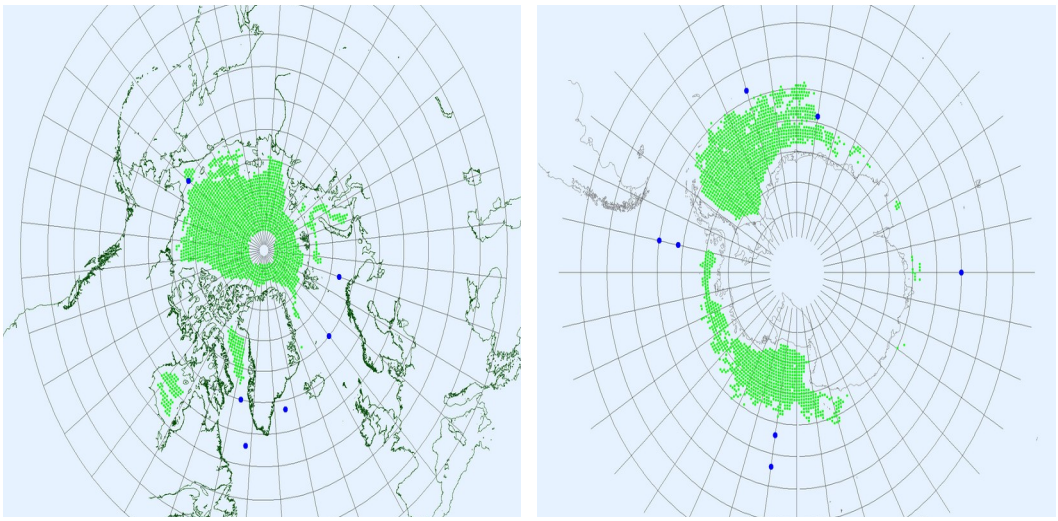

Figure 1: Map of the location of SIC0 (blue) and SIC1 (green) reference data in the Northern Hemisphere (left) and Southern Hemisphere (right) that is used in the comparison with OSI SAF CDR and ICDR products. The location of the SIC0 reference data (blue) are fixed, but their use in the comparison is seasonally dependent. The SIC1 data locations vary spatially and over time and the map shows the sum of all locations where SIC1 data is used throughout the comparison from 2007 to 2020.

The reference SIC0 samples are the result of filters based on location and date, while the 100% (SIC1) reference samples are derived from zones of converging sea ice motion detected by satellite synthetic aperture radar (SAR) data. See (Kern et al, 2019) for more information about the methods for retrieving the SIC0 and SIC1 reference data. The SIC0 samples are available from 1978 and the SIC1 samples from 2007. They are in the SIC Round Robin Data Package (RRDP) (Pedersen et al, 2019) produced in the ESA CCI projects. The SIC0 data is a static data set with fixed sample locations for each month of the year. The SIC0 samples are few, but due to the thorough retrieving method they are considered high-quality reference data. Only SIC0 samples that are located within the OSI SAF climatological water mask (see [RD-1] for details) are used in the assessment. The locations of SIC0 samples used in the assessment are shown in Figure 1.

The SIC1 data is available only in the Synthetic Aperture Radar (SAR) satellite sensor era from 2007 and on. The amount of SIC1 samples for comparison with the daily OSI SAF CDR and ICDR products depends on the availability and quality of SAR imagery from the different SAR sensors operated throughout the years. When deriving overall, multi-year bias and RMSE, we thus use the yearly count of SIC0 and SIC1 samples as weight. The SIC1

samples can only be considered high-quality 100% SIC samples during the winter season (November – April in NH, May – October in SH). In the summer melt season, high sea-ice motion convergence does not necessarily equate to 100% SIC. For this validation exercise the SIC1 data set has been updated to cover the CDR and ICDR time series up to 2020.

The SIC0 and 2007-2020 SIC1 reference data have been collocated with the daily CDR products on grid scale. The bias and root mean square error (RMSE) have been calculated for the two SIC categories, *closed ice* (100% ice concentration) and *open water* (0% ice concentration), as described in Section 2.2 and in Table 2 above. The results of the comparison are presented in Chapter 3.

2.5 Ice chart data

2.5.1 About the NIC ice chart data set

The OSI SAF global sea ice concentration reprocessed products are compared to the National Ice Center (NIC) ice charts (U.S National Ice Center, 2020), which are considered a relatively independent source of ice information. Since 1972, NIC has produced ice charts on a regular basis covering all seasons for both Southern and Northern Hemispheres. Thus, the time series cover the entire OSI SAF reanalysis period (see Table 5) except for the period 1995 to 2006 in the Southern Hemisphere where we have been unable to acquire digital ice charts.

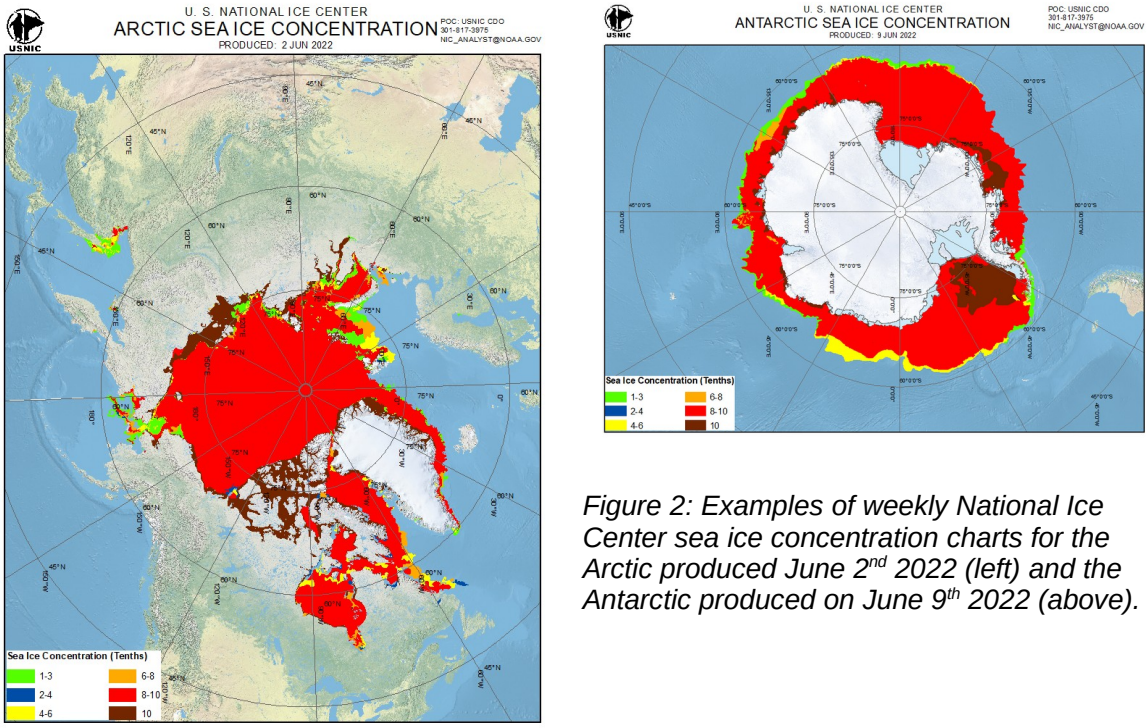

Figure 2: Examples of weekly National Ice Center sea ice concentration charts for the Arctic produced June 2nd 2022 (left) and the Antarctic produced on June 9th 2022 (above).

Ice charts are produced manually on the basis of all available satellite imagery, in-situ reports (ships and aircraft reconnaissance) and meteorological/oceanographic guidance data for the purpose of supporting ship navigation. The NIC ice charts are a compilation of the ice conditions over a period (see ice chart frequency in Table 5), using any data up to 72 hours old. This applies both to the biweekly, weekly and twice-weekly ice charts. Therefore, the ice charts are composite charts rather than snapshots of the ice coverage on a certain day or

time. The ice charts are primarily used for strategic and tactical planning within the offshore and shipping community. A detailed manual interpretation and mapping procedure is carried out by skilled (experienced and trained) ice analysts and the estimates of ice concentration in the charts are based on the subjective judgement of the analyst. Ice charts are more accurate and detailed at the ice edge than passive microwave data because they are often made using higher resolution data. Also, analysts pay particular attention to regions near the ice edge because the characteristics and extent of ice in the marginal ice zone are important for operations taking place within or near that region. Conversely, analysts generally do not characterize the central pack ice with as much attention to detail, because most of the time there are no supported operations there. Studies of the differences between ice charts from different ice centres covering the same region show relatively large (up to 30%) discrepancies in ice concentrations standard deviation of the differences especially at intermediate concentrations. See (Tonboe et al, 2016) for further information and references.

Table 5: List of the ice chart data sets produced by the National Ice Center (http://www.natice.noaa.gov/) and availability during the OSI SAF ice concentration reanalysis period. Ice chart data files have been acquired from different online data archives.

Hemi-sphere	Period	Frequency	Format
North	Jan. 1978 – Dec. 2021	Jan. 1978 – Jun. 2001, Weekly Jun. 2001 – Feb. 2006, Every second week Feb. 2006 – Dec. 2007, Weekly Dec. 2007 – Oct. 2013, Every second week Oct. 2013 – Jan. 2015, Twice a week Jan. 2015 – 2022, Weekly	Jan. 1978 – Dec. 2007, Binary files from ftp://sidads.colorado.edu Feb. 2006 – 2023, shapefiles from http://www.natice.noaa.gov
South	Jan. 1978 – Dec. 1994 Feb. 2006 – Dec. 2021	1978 – Dec. 1994, Weekly Feb. 2006 – Oct. 2013, Every second week Oct. 2013 – 2022, Weekly	Jan. 1978 – Dec. 1994, SIGRID shapefiles from http://wdc.aari.ru Feb. 2006 – 2023, shapefiles from http://www.natice.noaa.gov

It is important to realize that the relative accuracy and level of analysis detail vary considerably through the sea-ice chart data set. Early ice charts are partly based on the passive microwave data from SMMR and SSM/I, also used in the OSI SAF CDR, together with visual/infrared sensor data e.g. from AVHRR and OLS. The more recent ice charts are based on optical data when daylight and cloud-free conditions occur (e.g. MODIS) and partly on satellite SAR data for the Northern Hemisphere (e.g. Radarsat since 1995). Passive microwave radiometer data (e.g. SSMIS, AMSR-2) is only used if and where none of the other data sources are available. Until 1996, NIC produced all ice charts using imagery in a hardcopy format and traditional cartography techniques. Early analysis shortfalls resulted from: 1) poor resolution of early hardcopy (analogue) satellite imagery, 2) the absence of verifiable in-situ data and 3) the degradation of image quality due to the high frequency of clouds.

The recent improvement in NIC analysis capabilities can be attributed to three factors: 1) a progressive increase in volume of incoming satellite data, 2) an improvement in the resolution of data used in each analysis and 3) the ability to process and enhance remotely sensed data in digital format.

After having collected the NIC ice chart data set from the sources listed in Table 5 the quality of the data set was inspected and the data set filtered for making it more homogeneous and suitable for the assessment against the OSI SAF CDR data sets. Throughout the time series the ice charts are inconsistent with regards to the use of different land masks and periodic data-gaps/mask-out of regions (e.g. parts of the North Atlantic and the Baltic sea is masked out in 2014-2016; and Canadian archipelago). A common land and water mask has been applied to the filtered ice chart data set for this exercise.

The ice charting methodology changes with time, especially in the period 1979-1995, which is evident from the level of analysis detail and inconsistent use of ice concentration intervals. Changes in how closed ice is charted as either intervals (e.g. 9-10/10) or exact concentrations (e.g. 10/10) affect how many grid points are considered in the assessment (the closed ice category being defined as Ref_{SIC} = 100%, cf. Table 2). Northern Hemisphere ice charts in 2007 and 2008 have different land masks and data gaps. Consequently, 43 ice charts were filtered out of the data set. In the Southern Hemisphere, only one ice chart from 1978 and one from 2008 have been filtered out due to data gaps.

An important fact is, that the quality of the comparison of OSI SAF CDR data sets with the NIC ice chart data set highly depends on the ice chart frequency and in those periods where ice charts are only available every second week the assessment is very sensitive to the above mentioned changes/inconsistencies in the ice charts.

2.5.2 Representation of ice chart information

The OSI SAF ice concentration is compared with the ice charts CT (Total ice Concentration) code variable of the SIGRID and shapefiles. The SIGRID code is the WMO standard for describing ice information in ice charts. The CT SIGRID variable used for comparison is the total ice concentration given by the ice chart. The ice chart methodology allows for CT to be either specific ice concentration values (e.g. 100%) or ice concentration intervals (e.g. 40-60%). This information is available in the ice chart SIGRID and shapefiles. See the Table 5 of ice chart file format availability.

The ice chart and the OSI SAF product from the same valid day are gridded onto the OSI SAF CDR data set EASE2-grid projection in 25 km resolution. Following this a cell by cell comparison is carried out. For each ice chart concentration the deviation between ice chart concentration and OSI SAF ice concentration is calculated. When an OSI SAF ice concentration lies within an ice chart concentration interval, the deviation is zero. When an OSI SAF ice concentration lies outside an ice chart concentration interval, the deviation from OSI SAF ice concentration to the closest ice chart concentration interval value is calculated.

The assessment method is applied to the (conventional) OSI SAF sea ice concentration data that has been filtered and lie within the sea ice concentration range of 0 – 100% (as opposed to the primary assessment method that is applied to the *unfiltered* OSI SAF sea ice concentration value data). In the OSI SAF ice concentration product interpolated grid cells (e.g. the polar observation hole) and the cells outside the monthly climatological maximum ice extent masks, cf. [RD-1], are not included in the comparison analysis.

3. Comparison with SIC0 and SIC1 reference data

This chapter presents the results of the primary validation assessment of the OSI SAF version 3 Sea Ice Concentration Climate Data Records against the SIC0 and SIC1 reference data set. The assessment metrics and method are explained in Chapter 2. In Chapter 6 Conclusions the comparison results are matched against the OSI SAF accuracy requirements presented in Section 2.1.

All results from the assessment of the OSI SAF version 3 data sets against reference data are plotted in Figure 3 as time series of the annual mean bias and annual mean RMSE of the differences, for the Northern and Southern Hemispheres. The statistics are presented for each of the OSI SAF version 3 CDR data sets in the sections below.

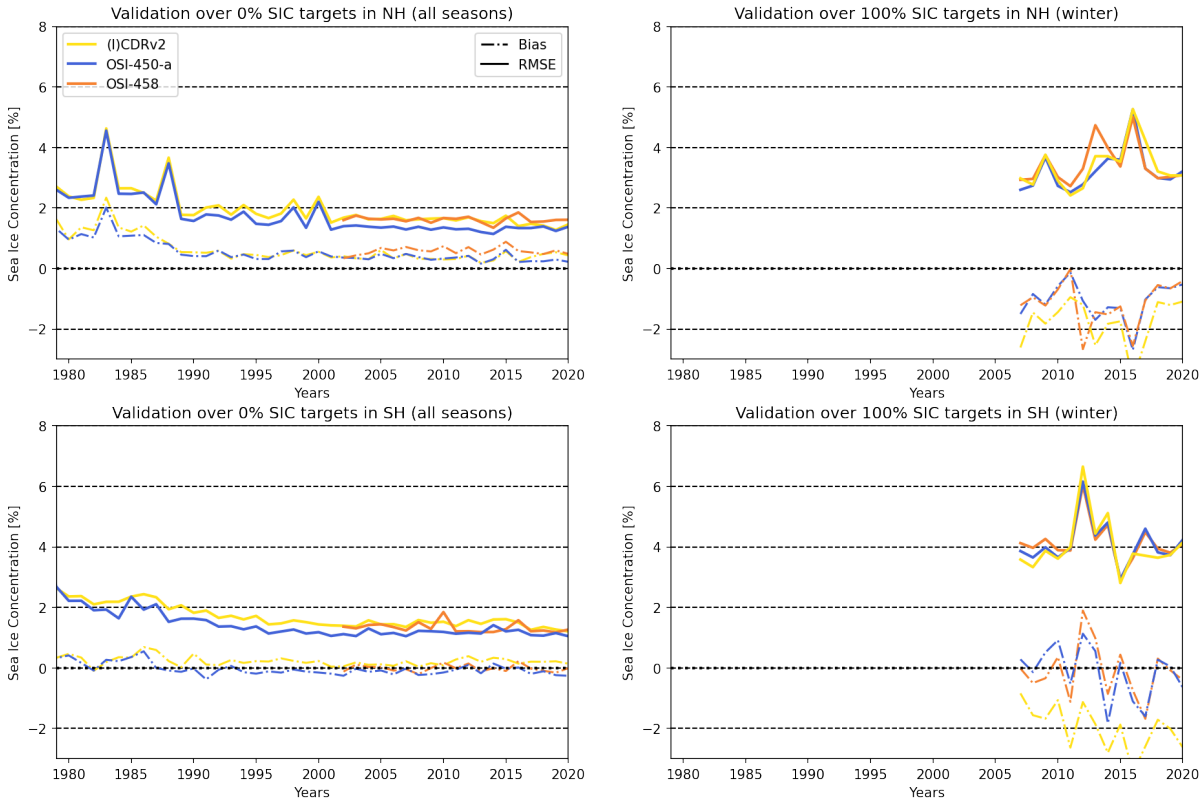

Figure 3: Time series plots of the results from the comparison of SIC0 (left plots) and SIC1 (right plots) reference data with the OSI SAF CDRs v3, OSI-450-a (blue line) and OSI-458 (orange line), and the OSI SAF v2 CDR+ICDR, OSI-450 and OSI-430-b (yellow line) for the Northern Hemisphere (top plots) and Southern Hemisphere (bottom plots). The figure shows the bias (dotted lines) and RMSE (solid lines), calculated as described in Table 2 and plotted here as annual averages.

3.1 The OSI-450-a climate data record

The results of the comparison of OSI-450-a version 3 CDR against the 0% SIC samples (SIC0) in the full reanalysis time series from 1979 to 2020 are shown in the Figure 3 left plots for the Northern and Southern Hemisphere, respectively. The assessment results for the OSI-450 version 2 CDR are presented in the same plots for the common years of 1979 to 2015 (continued by OSI-430-b version 2 ICDR data from 2015 to 2020) to evaluate the

relative version 3 algorithm improvements, which will justify the release of the version 3 data sets.

For both Hemispheres the OSI-450-a CDR annual mean bias and RMSE are below or of the same order as those same metrics of the OSI-450. Differences between the OSI SAF data sets and the reference data are a little higher in the first half, than in the second half of the data record, but bias and RMSE are generally at a low level of a few % sea ice concentration. The Southern Hemisphere bias over open water is at the level of 0%.

The results of the comparison of the OSI-450-a and the OSI-450 against the 100% SIC samples (SIC1) for the last third of the reanalysis time series from 2007 to 2020 (SIC1 samples are available in the SAR era only) are shown in the Figure 3 right plots for the Northern and Southern Hemisphere, respectively. As for the SIC0 assessment, the OSI-450-a CDR annual mean bias and RMSE for the 100% ice samples are below or of the same order of those same metrics of the OSI-450. The negative bias of OSI-450 is reduced in OSI-450-a, by about 0.5% SIC in the NH and 2% SIC in the SH. We note that the year-to-year variability of the bias and RMSE can to a large extent be explained by the varying number of SIC1 samples for comparison with the daily OSI SAF CDR and ICDR products, itself depending on the availability and quality of SAR imagery from the different SAR sensors operated throughout the years.

The results for the OSI-450-a and OSI-450 assessments are reported in Table 6 as interannual mean bias and RMSE weighted by the yearly count of samples in each of the categories, closed ice (SIC1, from 2007 to 2015) and open water (SIC0, from 1979 to 2015). The OSI-450-a *positive* bias over 100% ice in the SH is caused by the assessment method being applied to the *unfiltered* (“raw”) OSI SAF sea ice concentration values, which can contain unphysical ice concentration values below 0% and above 100%. The same explanation applies to the OSI-450-a *negative* bias over open water in the SH.

The OSI-450-a performs better or equally well as the OSI-450 for all the derived statistical measures reported in Table 6 that are highlighted in green (except for a slight negative difference for the RMSE over 100% ice samples). Notably, OSI-450-a has less negative SIC1 bias in the NH and SH, and better SIC1 bias and RMSE.

OSI-450-a assessment results for the full data set time series from 1978 to 2020 is reported in Table 8.

Table 6: Results from the comparison of the OSI-450-a CDR v3 and OSI-450 CDR v2 with SIC1 (from 2007 to 2015) and SIC0 (from 1979 to 2015*) reference data for the Northern (NH) and Southern Hemisphere (SH), respectively. Bias and RMSE are interannual weighted means.*

Statistics	SIC1 (100% SIC)				SIC0 (Open water)			
	Bias		RMSE		Bias		RMSE	
	OSI-450	OSI-450-a*	OSI-450	OSI-450-a*	OSI-450	OSI-450-a*	OSI-450	OSI-450-a*
NH	-1.6	-1.0	3.2	3.3	0.6	0.5	1.9	1.7
SH	-1.6	0.3	3.9	3.9	0.2	-0.1	1.7	1.3

3.2 The OSI-430-a interim climate data record

The OSI-430-a ICDR version 3 operationally extends the OSI-450-a from Jan 2021 onwards. It replaces the OSI-430-b ICDR v2 as the continuously updated OSI SAF sea ice concentration CDR. Three comparisons are interesting with OSI-430-a: 1) the comparison (bias and RMSE) of OSI-430-a to SIC1 and SIC0 reference data over 2019 - 2020, 2) how these statistics compare to those of OSI-450-a over the same period (time consistency of the v3 ICDR to v3 CDR) and 3) how these statistics compare to those of OSI-430-b (comparison of the v3 ICDR to the v2 ICDR). The results are reported for the Northern and Southern Hemisphere, respectively. The results are reported in Table 7 as interannual mean bias and RMSE weighted by the yearly count of samples in the closed ice (SIC1) and open water (SIC0) categories.

For all the derived statistical measures reported in Table 7, the OSI-430-a performs better than the OSI-430-b ICDR, and equally well as or only slightly worse than the OSI-450-a CDR. Overall, both the bias and RMSE are at very low levels, indicating excellent performance in these two years. Particularly, OSI-430-a has a reduced SIC bias in NH and SH (wrt to OSI-430-b). The remaining differences between the OSI-430-a and OSI-450-a data sets can be explained by the use of different satellite data (operational data stream vs carefully calibrated FCDR).

*Table 7: Results from the comparison of the OSI-430-a v3 ICDR, OSI-430-b v2 ICDR and OSI-450-a v3 CDR with SIC1 and SIC0 reference data in the *common years 2019 and 2020 for the Northern (NH) and Southern Hemisphere (SH). Bias and RMSE are annual weighted means.*

Statistics	SIC1 (100% SIC)						SIC0 (Open water)					
	Bias			RMSE			Bias			RMSE		
	OSI-430-a	OSI-430-b	OSI-450-a*	OSI-430-a	OSI-430-b	OSI-450-a*	OSI-430-a	OSI-430-b	OSI-450-a*	OSI-430-a	OSI-430-b	OSI-450-a*
NH	-0.6	-1.1	-0.6	3.1	3.1	3.1	0.2	0.5	0.3	1.3	1.4	1.3
SH	-0.7	-2.3	-0.3	4.1	4.0	4.0	-0.5	0.2	-0.3	1.1	1.2	1.1

3.3 The OSI-458 climate data record

The results of the comparison of OSI-458 version 3 CDR against the 0% SIC samples (SIC0) in the reanalysis time series from 2002 to 2020 are shown in the Figure 3 left plots for the Northern and Southern Hemisphere, respectively. The OSI-458 CDR is based on medium resolution imagery from AMSR-E and AMSR2 and thus can not be directly compared to the two CDRs based on coarser resolution SSMIS imagery. However, we compare the OSI-458 assessment results against those of the SSMIS CDRs for reference. The OSI-458 annual mean bias and RMSE are on the same level as the same metrics of the OSI-450 – and slightly above those of the OSI-450-a - in both Hemispheres. The Southern Hemisphere bias over open water is at the level of 0%.

The results of the comparison of the OSI-458 against the 100% SIC samples (SIC1) for the last third of the reanalysis time series from 2007 to 2020 are shown in the Figure 3 right plots for the Northern and Southern Hemisphere, respectively. As for the SIC0 assessment, the OSI-458 CDR annual mean bias and RMSE for the 100% ice samples are of the same order of those same metrics of the OSI-450-a. The variability of the annual mean bias and RMSE can to a large extent be explained by the varying number of SIC1 samples for comparison with the daily OSI SAF CDR and ICDR products that is depending on the availability and quality of SAR imagery from the different SAR sensors operated throughout the years.

The results of the OSI-458 assessment are reported in Table 8 as interannual mean bias and RMSE weighted by the yearly count of samples in each of the categories, closed ice (SIC1, from 2007 to 2020) and open water (SIC0, from 2002 to 2020). Results from the OSI-450-a assessment (for the full time series from 1978 to 2020) is included in the table as a reference.

The OSI-458 performs equally well as the OSI-450-a for all the derived statistical measures reported in Table 6. There are a few cases of slightly worse performance, but the differences are on the first decimal.

Table 8: Results from the comparison of the OSI-458 v3 ICDR with SIC1 (from 2007 to 2020) and SIC0 reference data (from 2002 to 2020) for the Northern (NH) and Southern Hemisphere (SH), respectively. Results from the OSI-450-a assessment (for the full time series from 1978 to 2020) is included for reference. Bias and RMSE are interannual weighted means.

Statistics	SIC1 (100% SIC)				SIC0 (Open water)			
	Bias		RMSE		Bias		RMSE	
	OSI-458	OSI-450-a	OSI-458	OSI-450-a	OSI-458	OSI-450-a	OSI-458	OSI-450-a
NH	-1.0	-1.0	3.4	3.3	0.6	0.5	1.6	1.6
SH	-0.4	-0.3	4.0	4.0	0.0	-0.1	1.3	1.3

3.4 Evaluation of product uncertainties

An estimate of the uncertainty (standard error) of the OSI SAF sea ice concentration value in a grid cell is provided in the CDR and ICDR data set product files. The (total) uncertainty is a combination (the square root of the sum of variances) of the two components of the uncertainty budget; the algorithm standard error and the smearing standard error, and given as one standard deviation in percentage. More information about the calculation of the OSI SAF product uncertainty can be found in [RD-1].

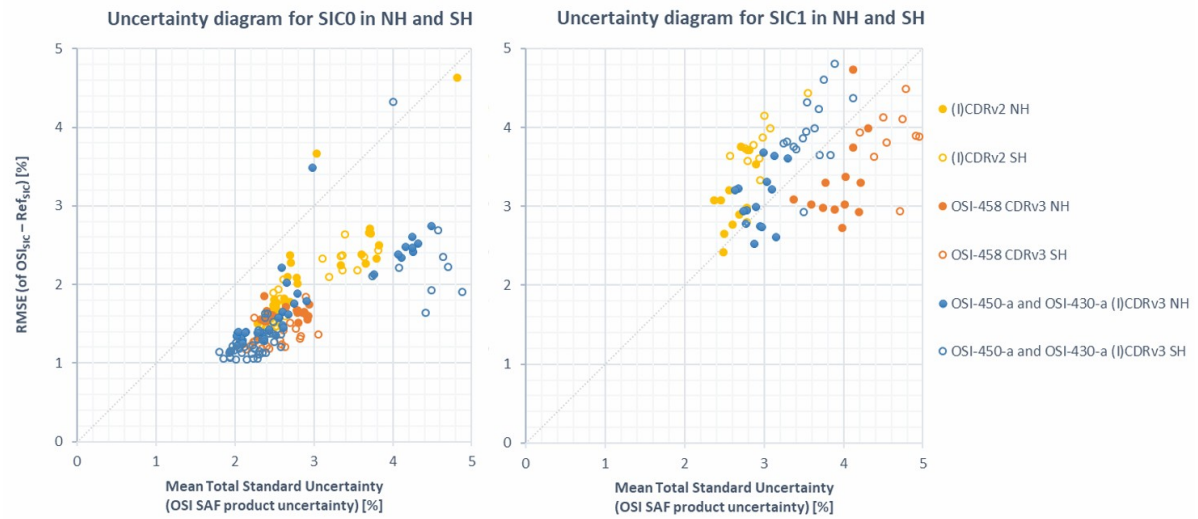

Figure 4: Uncertainty diagrams comparing the OSI SAF product mean total standard uncertainty with the root mean square error from the comparison of SIC0 (left plot) and SIC1 (right plot) reference data with the v3 CDR+ICDR, OSI-450-a and OSI.430-a (blue dots) and OSI-458 (orange dots), and the (I)CDR v2, OSI-450 and OSI-430-b (yellow dots), for both Hemispheres.

Here, the OSI SAF (I)CDR products uncertainties are evaluated against the results from the assessment with the reference data; The OSI SAF product *mean total standard uncertainty/error* (MTSU) is calculated from the OSI SAF product uncertainties provided in each grid cell where collocation to the RRDP dataset occurred, and the annual MTSU is derived. The MTSU is evaluated against the RMSE derived from the assessments of the OSI SAF version 3 CDR data sets against SIC0 and SIC1 reference data. Moreover, the OSI-450 version 2 CDR product uncertainties are shown. The results are presented in Figure 4 for SIC0 (left) and SIC1 (right) assessment results.

The uncertainty diagram for SIC0 samples in Figure 4 left plot shows that the annual mean OSI SAF product uncertainties (MTSU) are generally higher than the RMSE on the difference to the reference data, for all the OSI SAF products. This suggests that the product uncertainties are a little overestimated (but the uncertainty values are generally at a low level of 2-5%). The “cloud” of higher uncertainties (MTSU=> 3% and RMSE=>2%) are associated

with the first ~10 years of the reanalysis time series and data from the less advanced SMMR sensor. The uncertainty estimates of OSI-450-a for the remaining years of the reanalysis time series and of the OSI-458 (during the AMSR-E – AMSR2 era from 2002-2020) are at a low level of ~2-3%. The comparison against RMSE suggests that these product uncertainties are overestimated in the order of ~1%. The OSI-450-a uncertainties in the last years of the time series are slightly lower than those of its predecessor, the OSI-450 v2 CDR.

The uncertainty diagram for SIC1 samples from 2002 to 2020 in Figure 4 right plot shows that the annual mean OSI SAF product uncertainties (MTSU) are generally higher and more ‘scattered’ than the uncertainties over open water (left plot). The OSI-450-a uncertainties over 100% ice are more realistic than those over open water, when compared against RMSE. The plot suggests that the uncertainties of the predecessor, OSI-450, were a little underestimated, and thus that the 100% ice uncertainties have become more realistic with the version 3 CDR products. The OSI-458 product uncertainties are a little higher than those of the OSI-450-a and overestimated when compared to the RMSE on the difference to the reference data.

4. Comparison with ice charts

This chapter presents the results of the secondary/additional validation assessment of the OSI SAF version 3 Sea Ice Concentration Climate Data Records against the NIC ice chart reference data set. The assessment metrics and method are explained in Chapter 2. In Chapter 6 Conclusions the comparison results are matched against the OSI SAF accuracy requirements presented in Chapter 2.

All results from the assessment of the OSI SAF version 3 data sets against reference data are plotted in Figure 5 as time series plots of the annual mean bias and annual mean RMSE of the differences, for the Northern and Southern Hemisphere. The statistics are presented for each of the OSI SAF version 3 CDR data set in the sections below. Note that ice chart data for the Southern Hemisphere is lacking in the period from 1994 to 2006 cf. Table 5.

4.1 The OSI-450-a climate data record

The results of the comparison of OSI-450-a version 3 CDR against the NIC ice charts in the full reanalysis time series from 1979 to 2020 are shown in Figure 5 and Figure 6 for the Northern and Southern Hemisphere, respectively. The assessment results for the OSI-450 version 2 CDR are presented in the same plots for the common years of 1979 to 2015 to evaluate the relative version 3 algorithm improvements, that will justify the release of the version 3 data sets. The results for the OSI-450-a and OSI-450 assessments are reported in Table 9 as interannual mean bias and RMSE for the ice (100% SIC) and open water (0% SIC) categories for the full data set and the four seasons (DJF, MAM, JJA, SON).

Seasonal statistics for the 100% ice category show the highest agreement between the data sets in the wintertime (DJF in the Northern Hemisphere and JJA in the Southern Hemisphere) and lower agreement in summertime with higher biases and RMSE due to the effect of summer melt on the radiometer sensor data. The high summertime RMSE over 100% ice in both Hemispheres has a big impact on the total RMSE.

Figure 5 and Figure 6 show that there is overall an increased agreement between the OSI SAF CDR datasets with ice charts across the period, especially in the transition from SMMR to SSMI data in summer 1987 and throughout the 1990's. This could partly be due to the introduction of Radarsat SAR data as input to the ice chart analysis and due to a change in NIC ice chart methodology to digital techniques, mentioned in Section 2.3. The Southern Hemisphere figures are unfortunately lacking important information in the period 1994-2006, but it is clear that there is better correspondence between data sets after the data gap, likely due to the above mentioned factors. Part of the bias and RMSE variability throughout the time series are likely linked to the shifts in ice charting frequency (cf. Table 5 of ice chart data set availability) and methodology/masking (this is also suggested by the sudden shifts that occur in the count plot) as well as the temporal differences of the two data sets (OSI SAF being a daily product and ice charts being a compilation of the ice conditions over several days).

The plots of the Northern Hemisphere open water bias and RMSE shown in Figure 5 show that the OSI SAF data sets show some ice where ice charts says open water, especially in the first half of the time series. This could be partly due to the OSI SAF radiometer-based ice concentrations being affected by atmospheric noise which increases the ice concentration above zero, and not all of this is removed by the open water filter. The v3 CDRs show an improved performance over open water in the Southern Hemisphere, especially in the last half of the time series. Neither the bias nor the RMSE for the open water category in the Southern Hemisphere show any changes with the OSI SAF version 3 data sets compared to the v2 CDR. This is simply due to the vast open water area in the Southern Ocean, which is also evident from the high number of counts for the category.

The temporal changes in the count (number) of grid cells included for the categories closed ice (100% SIC, left plots) and open water (0% SIC, right plots) are due to partly the shifts in

ice charting masking of areas (described in Section 2.5.1), the difference in land masks used in v2 and v3 OSI SAF CDRs, and the difference in ice grid cell included in the 100% ice category for the three CDR data sets.

For all the derived statistical measures reported in Table 9 it is seen that the OSI-450-a performs better (numbers highlighted in green) or equally well as the OSI-450 overall and for all four seasons.

OSI-450-a assessment results for the full data set time series from 1978 to 2020 are reported in Table 11.

*Table 9: Results from the comparison of National Ice Center ice charts with the OSI-450-a v3 CDR and the OSI-450 v2 CDR, respectively, *for their common time series 1979-2015. The bias and RMSE are calculated as decribed in Table 2 and reported in the table as interannual averages for the four seasons (DJF, MAM, JJA, SON) and for the full time series (ALL). Numbers highlighted in green are were the OSI-450-a perform better than the OSI-450 CDR.*

Seasonal Statistics	Northern Hemisphere							
	Compact ice (100% SIC)				Open water (0% SIC)			
	Bias		RMSE		Bias		RMSE	
	OSI-450	OSI-450-a*	OSI-450	OSI-450-a*	OSI-450	OSI-450-a*	OSI-450	OSI-450-a*
DJF	-2.0	-1.6	5.6	5.1	1.6	1.4	7.4	7.0
MAM	-2.4	-2.1	6.6	6.3	1.3	1.2	6.8	6.2
JJA	-9.7	-9.1	17.5	17.2	1.5	1.0	7.1	5.6
SON	-2.4	-1.9	6.3	5.7	1.8	1.6	8.1	7.3
ALL	-4.1	-3.7	9.0	8.6	1.6	1.3	7.3	6.5
	Southern Hemisphere							
DJF	-7.7	-6.9	18.4	17.5	0.8	0.8	5.1	5.0
MAM	-6.5	-4.5	15.2	12.3	1.0	1.0	5.8	5.7
JJA	-3.0	-1.9	8.5	6.7	1.4	1.3	7.3	7.3
SON	-3.8	-2.3	9.8	7.5	1.1	1.0	6.0	6.0
ALL	-5.2	-3.9	12.9	10.9	1.1	1.0	6.1	6.0

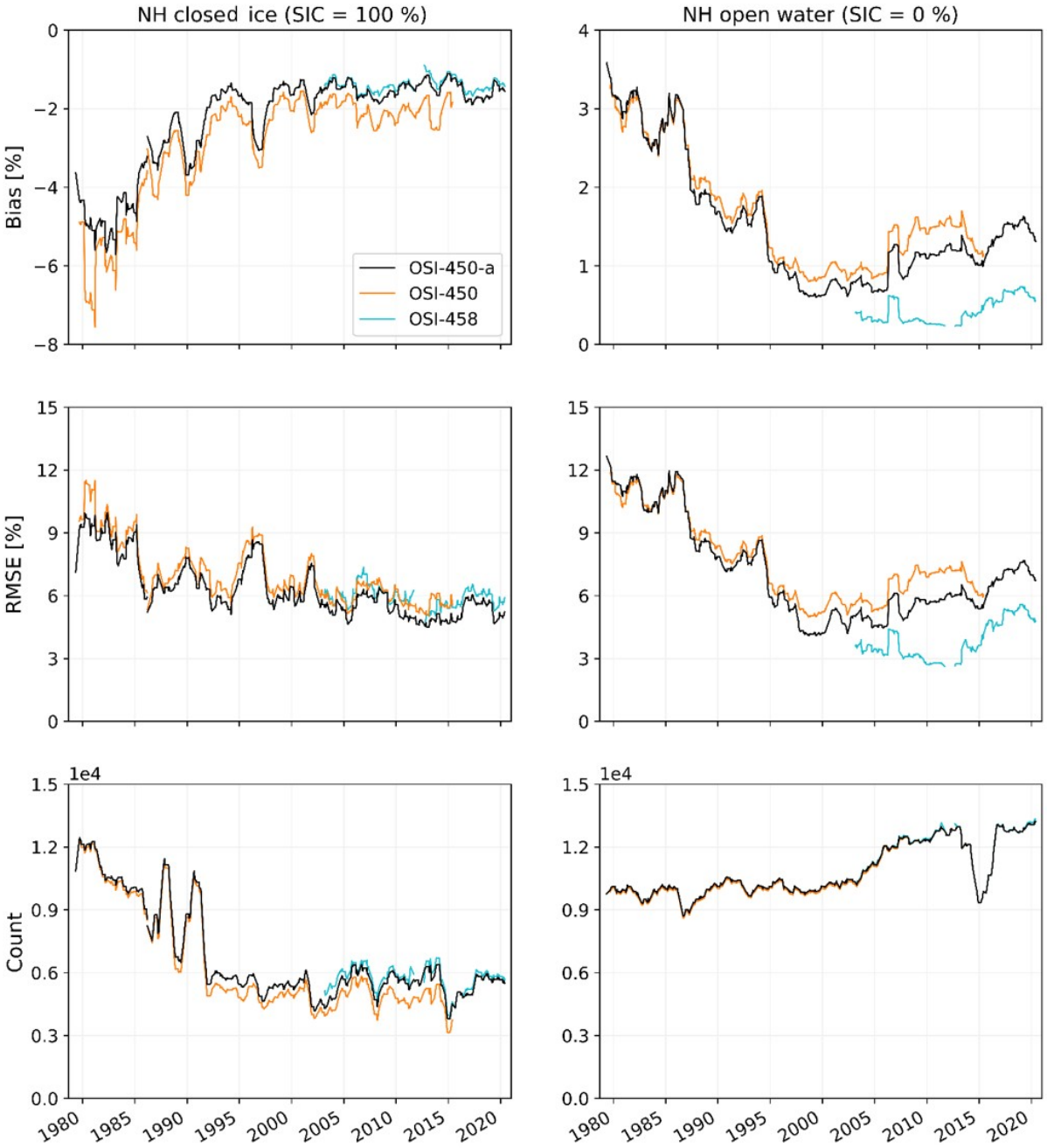

Figure 5: Northern Hemisphere time series plots of the results from the comparison of National Ice Center ice charts with the OSI SAF CDRs v3, OSI-450-a (black line) and OSI-458 (green line), and the OSI SAF v2 CDR, OSI-450 (orange line). The bias (top plots) and RMSE (middle plots) are calculated as described in Table 2 and plotted here as a running yearly average. The count (bottom plots) are the number of grid cells included for the categories closed Ice (100% SIC, left plots) and open water (0% SIC, right plots).

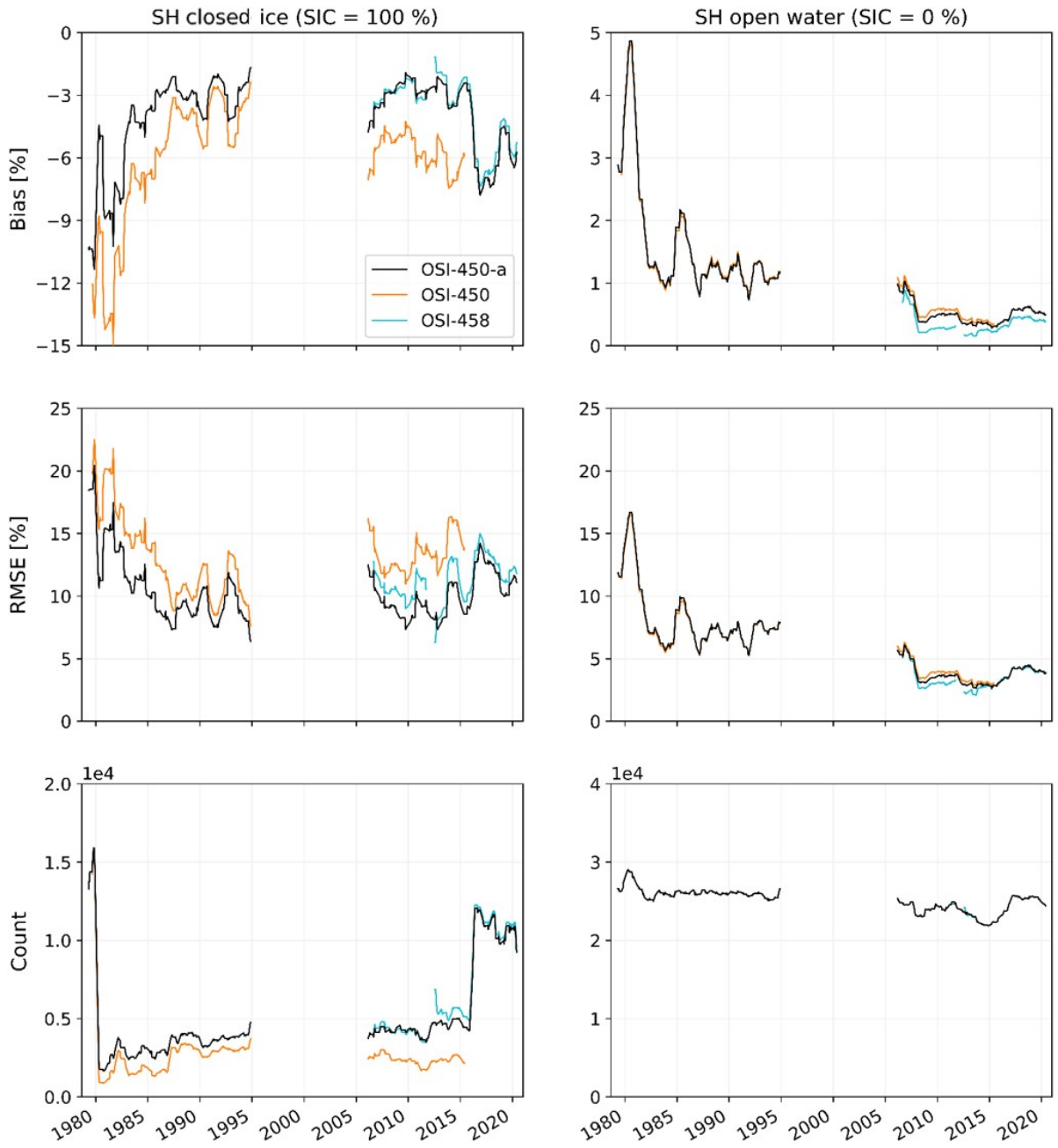

Figure 6: Southern Hemisphere time series plots of the results from the comparison of National Ice Center ice charts with the OSI SAF CDRs v3, OSI-450-a (black line) and OSI-458 (green line), and the OSI SAF v2 CDR, OSI-450 (orange line). The bias (top plots) and RMSE (middle plots) are calculated as described in Table 2 and plotted here as a running yearly average. The count (bottom plots) are the number of grid cells included for the categories closed ice (100% SIC, left plots) and open water (0% SIC, right plots).

4.2 The OSI-430-a interim climate data record

The OSI-430-a ICDR v3 operationally extends the OSI-450-a from Jan 2021 onwards and replaces the OSI-430-b ICDR v2 as the continuously updated OSI SAF sea ice concentration CDR. Results of the assessment of the OSI-430-a ICDR against National Ice Center (NIC) ice charts in the Northern and Southern Hemisphere are reported in Table 10. The validation results of the OSI-430-b ICDR are here compared to those of the OSI-450-a CDR in the overlapping years of 2019 and 2020 to evaluate the temporal consistency between the CDR

and the ICDR products. The results are reported as interannual mean bias and RMSE for the *closed ice* (100% SIC) and *open water* (0% SIC) categories.

For all the derived statistical measures reported in Table 10 the OSI-430-a performs equally well as, or slightly worse than the OSI-450-a CDR (with less than 1% difference in both bias and RMSE). These small differences between the OSI-430-b and OSI-450-a data sets can be explained by the use of different input satellite data (operational data stream versus a carefully calibrated FCDR).

The comments on the individual metrics and their seasonal and hemispheric differences that are given for the OSI-450-a assessment results in also apply to the OSI-430-a.

Table 10: Results from the comparison of National Ice Center ice charts with the OSI SAF ICDRs v3, OSI-430-a and the CDR OSI-450-a, respectively, for the common years 2019-2020 (*). The bias and RMSE are calculated as decribed in Table 2 and reported in the table as interannual averages for the four seasons (DJF, MAM, JJA, SON) and for the two years (ALL).

Statistics	Compact ice (100% SIC)				Open water (0% SIC)			
	Bias		RMSE		Bias		RMSE	
	OSI-430-a	OSI-450-a*	OSI-430-a	OSI-450-a*	OSI-430-a	OSI-450-a*	OSI-430-a	OSI-450-a*
	Northern Hemisphere							
DJF	-1.0	-0.9	3.7	3.6	1.3	1.3	6.9	6.9
MAM	-1.8	-1.8	6.1	6.1	1.1	1.0	6.2	6.0
JJA	-11.1	-10.8	19.6	19.2	1.8	1.8	8.2	8.0
SON	-0.7	-0.6	3.6	3.4	1.9	1.9	8.4	8.1
ALL	-3.6	-3.5	8.2	8.0	1.6	1.5	7.4	7.2
	Southern Hemisphere							
DJF	-6.7	-6.5	16.1	16.0	0.3	0.3	2.8	2.6
MAM	-6.9	-6.4	14.6	14.0	0.7	0.6	4.6	4.3
JJA	-3.9	-3.6	7.8	7.5	0.6	0.6	4.5	4.3
SON	-5.1	-4.8	9.1	8.8	0.4	0.4	3.3	3.2
ALL	-5.7	-5.3	12.1	11.8	0.5	0.4	3.8	3.6

4.3 The OSI-458 climate data record

The results of the comparison of OSI-458 version 3 CDR with National Ice Center ice charts in the reanalysis time series from 2002 to 2020 are shown in the Figure 5 and Figure 6 for the Northern and Southern Hemisphere, respectively. The OSI-458 CDR is based on medium resolution imagery from AMSR-E and AMSR2 and thus can not be directly compared to those two CDRs based on coarser resolution SSMIS imagery. However, we compare the OSI-458 assessment results against those of the SSMIS CDRs for reference. Note that data is missing in the OSI-458 product between October 2011 and July 2012 due to the gap between AMSRE and AMSR-2 sensor data, cf. Table 4.

The results of the OSI-458 assessment are reported in Table 11 as interannual mean bias and RMSE for the categories, closed ice (100% SIC) and open water (0% SIC), and for both Hemispheres. Results from the OSI-450-a assessment for the full time series from 1978 to 2020 is included in the table for reference.

The annual mean bias reported in table 11 and plotted in Figure 5 and 6 show that the OSI-458 correspondence with ice charts are slightly better than that of the OSI-450-a CDR for both Hemispheres, especially over SIC0. The RMSE can be higher than that for the OSI-450-a. This could be due to the way the RMSE is derived; with RMSE the errors/differences are squared before deriving the sum, as opposed to bias. Inspection of the cause for the higher RMSE has revealed that the OSI-458 have a few data “outliers” being coastal observations where the ice chart says 100% ice and the OSI-458 says 0% ice. Those data outliers, because they are squared, have enough influence to increase RMSE.

In the Southern Hemisphere both the OSI-458 bias and RMSE are better than those of the OSI-450-a. The plots of counts in the Northern and Southern Hemisphere show differences between the OSI SAF v2 and v3 CDR products that are partly due to the new improved land masking and the improved land-spillover corrections in the version 3 CDR.

Table 11: Results from the comparison of the OSI-458 v3 CDR with National Ice Center ice charts. Results from the OSI-450-a v3 CDR assessment (for the full time series from 1978 to 2020) is included in the table for reference. The bias and RMSE are calculated as decribed in Table 2 and reported in the table as interannual averages for the four seasons (DJF, MAM, JJA, SON) and for the full time series (ALL).

Statistics	Compact ice (100% SIC)				Open water (0% SIC)			
	Bias		RMSE		Bias		RMSE	
	OSI-458	OSI-450-a	OSI-458	OSI-450-a	OSI-458	OSI-450-a	OSI-458	OSI-450-a
	Northern Hemisphere							
DJF	-1.0	-1.5	4.7	4.9	0.4	1.4	4.2	6.9
MAM	-1.5	-2.0	6.7	6.2	0.3	1.2	3.5	6.2
JJA	-7.5	-9.2	17.5	17.3	0.3	1.2	2.9	6.0
SON	-0.7	-1.8	4.3	5.5	0.6	1.7	4.4	7.5
ALL	-2.7	-3.6	8.3	8.5	0.4	1.4	3.8	6.7
	Southern Hemisphere							
DJF	-6.4	-7.2	18.5	17.6	0.1	0.7	1.7	4.5
MAM	-5.0	-5.1	14.5	12.9	0.4	0.9	3.7	5.4
JJA	-2.5	-2.4	8.2	7.0	0.5	1.2	4.4	6.7
SON	-3.4	-3.2	9.4	8.3	0.2	0.9	2.7	5.5
ALL	-4.3	-4.4	12.5	11.3	0.3	0.9	3.1	5.5

4.4 Coastal zone validation results

Part of the update of the OSI SAF CDR algorithms to version 3 has been to improve the land spill-over correction scheme, cf. [RD-2]. Here we use two different approaches to assess the performance of the OSI-450-a v3 CDR in the coastal region, compared to that of the OSI-450 v2 CDR;

(i) The results of the assessment of the OSI-450-a and the OSI-450 against ice charts, respectively, are masked over a 60 km wide Coastal zone (0-60 km off the land mask) in the Northern Hemisphere. The results in that Coastal zone are shown in Figure 7 as time series plots (corresponding to the “full Hemisphere” plots in Figure 5 and 6).

The overall performance “pattern” of the three CDR data sets that are plotted in Figure 7 are very much like those shown in Figure 5 for the “full” Northern Hemisphere, with OSI-450-a performing a little better than the predecessor, OSI-450. However, the level of the biases and RMSE are higher for the Coastal zone than for the full Hemisphere. A higher, negative bias over 100% ice means that the OSI SAF data sets show less ice than in the ice charts along the coast.

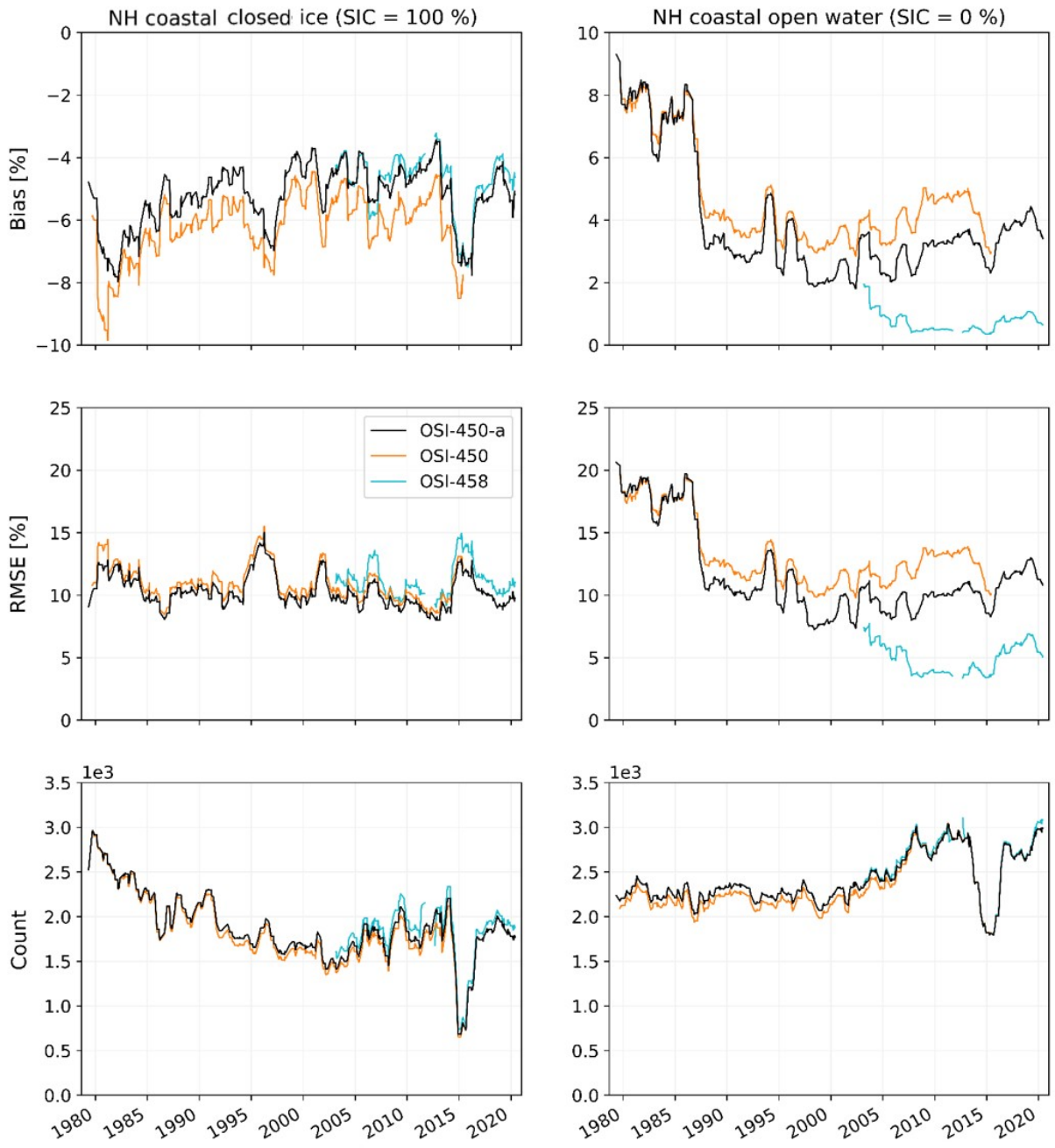

Figure 7: Northern Hemisphere Coastal zone time series plots of the results of the assessment of National Ice Center ice charts against the OSI SAF CDRs v3, OSI-450-a (black line) and OSI-458 (green line), and the OSI SAF v2 CDR, OSI-450 (orange line). The bias (top plots) and RMSE (middle plots) are calculated as described in Table 2 and plotted here as a running yearly average. The count (bottom plots) are the number of grid cells included for the categories closed ice (100% SIC, left plots) and open water (0% SIC, right plots).

(ii) The results of the assessment of the OSI-450-a and the OSI-450 against ice charts, respectively, are used to derived the change in "hit days" from OSI-450 to OSI-450-a. A "hit day" is here defined as a day of zero bias/difference between the Ice chart SIC and OSI SAF SIC product in a given grid cell (i.e. the OSI SAF SIC lies within the ice chart SIC interval, cf. the explanation in Section 2.5.2). The bias is calculated as described in Table 2. The sum of hit days for a given grid cell in the OSI-450-a and OSI-450, respectively, is calculated for their common time series (note that this is only for the days where an OSI SAF product match with an ice chart) and the total numbers are subtracted to derive the change in hit days from the version 2 to the version 3 CDR (hit-day-change = $\text{hit-days}_{\text{osi-450-a}}$ - $\text{hit-days}_{\text{osi-450}}$).

A positive number of hit days means that the correspondence between ice chart SIC and OSI-450-a SIC is better than that between the Ice Chart SIC and OSI-450 SIC in a given grid cell for the common CDR time series. The results are plotted geographically in the Figure 8 map of the Northern Hemisphere and zoomed map on the Baltic Sea.

The focus is on the Northern Hemisphere, where the coastline is more complex (more islands, large bays and fjords) than in the Southern Hemisphere, and where the product performance in the coastal region is relevant to more users. The Baltic Sea is shown in a zoom-in map in Figure 8, being an ice-infested hotspot in Europe for marine information users. The map of the Northern Hemisphere and the zoom-in plot of the Baltic Sea show predominantly positive differences in hit days and that the large positive differences in hit days (darkest blue areas) are located along the coast, meaning that the OSI-450-a better matches the ice chart sea ice concentrations in the coastal zone, than the OSI-450 v2 CDR does. This is interpreted as an improved product performance in the coastal zone due to the land-spillover correction scheme in the v3.

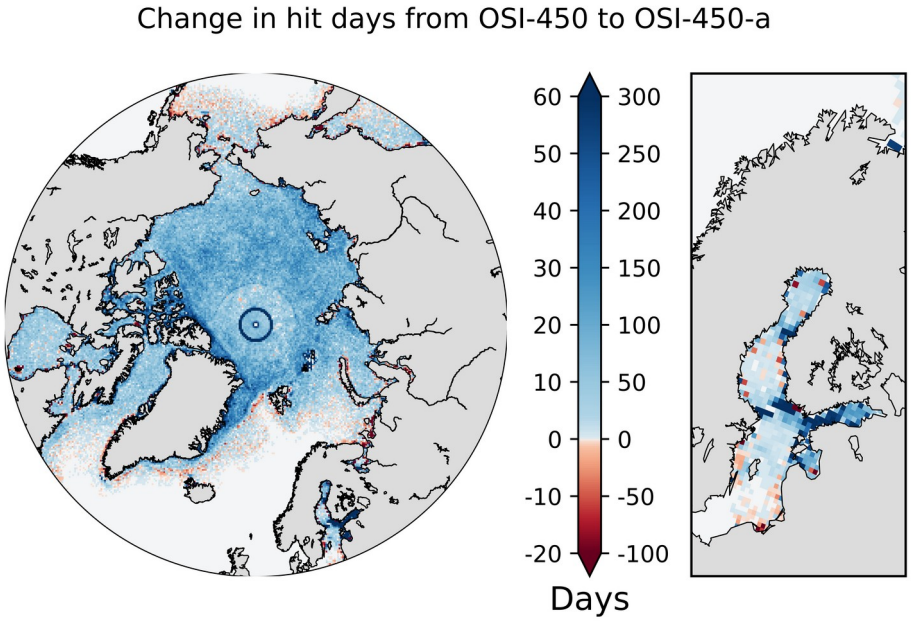

Figure 8: Map of the Northern Hemisphere (left) and with a focus on the Baltic Sea (right) results from the comparison of National Ice Center ice charts with the OSI SAF CDRs OSI-450-a and OSI-450: showing the change in "hit days" from OSI-450 to OSI-450-a. A "hit day" is a day of zero bias/difference between the Ice chart SIC and OSI SAF product SIC in a given grid cell. The bias is calculated as described in Table 2. A positive number of hit days means that the correspondence between Ice Chart SIC and OSI-450-a SIC is better than that between the Ice Chart SIC and OSI-450 SIC in a given grid cell on average throughout the common CDR time series. Note that hit days are calculated only for the days where an OSI SAF product matches with an ice chart.

5. Comparison of sea ice area and extent monthly timeseries

There does not exist ground-truth data for sea-ice indexes like sea-ice extent (SIE) or area (SIA). Therefore, it is interesting to compare the sea-ice indeces computed from the v3 SIC data with other indexes, since many users will approach our data through these integrated quantities.

Here, we document a comparison of the to-be OSI SAF Sea Ice Index v3 with the Sea Ice Index of NSIDC (v3, Fetterer et al. 2017). The NSIDC index is based on the Nasa Team algorithm. We note up-front that the OSI SAF Sea Ice Index values are not tuned towards the NSIDC values.

We also document a comparison between the to-be OSI SAF Sea Ice Index v3 and the current official OSI SAF Sea Ice Index v2.1 (OSI-420), which is based on the v2 SIC CDR+ICDR (OSI-450 and OSI-430-b). Both OSI SAF Sea Ice Index are computed in the same way, the only difference is the input SIC data (v3 vs v2).

We finally also compare the sea-ice index from the ICDR OSI-430-a with that of the CDR OSI-450-a during the two overlap years 2019-2020.

We note that the comparison of the v3 SIE and SIA to the v2 timeseries is mostly to inform the release of the v3 SIC CDRs. It will be repeated and extended for the release of the v3 sea-ice index (next version of OSI-420, based on the v3 SIC CDRs).

5.1 Comparison to the NSIDC Sea Ice Index

Figure 9 (resp. Figure 10) shows the OSI SAF and NSIDC time-series of sea-ice extent and area for the Northern Hemisphere (resp. Southern Hemisphere). In the Northern Hemisphere (Figure 9), the two SIE agree quite well with each other, but that is less true for SIA. The SIA reported by NSIDC is substantially lower than that of the OSI SAF in the first part of the time series (1978-1987). This difference is attributed to the polar observation hole (down to 84N in the 1978-1987 period). The polar observation hole is treated differently by the two services. Indeed, the SIC maps used as input for the OSI SAF SII are spatially interpolated on a daily basis to close the polar observation hole. These spatially interpolated values contribute to the SIE and SIA time series. Conversely, the SIC maps used as input for the NSIDC SII are not interpolated: the polar observation hole does not contribute to SIA, but is counted as “ice-covered” for the SIE.

In the Southern Hemisphere (Figure 10), we also observe a better agreement between the two products for SIE than for SIA. However, the NSIDC SIA seems to report lower values than OSI SAF throughout the years. We attribute this difference to the NSIDC SIC maps being processed with the Nasa Team algorithm (Cavalieri et al. 1992), which is known to underestimate SIC in the Southern Hemisphere, especially during the Austral winter season (see e.g. Fig. 14 b) and Fig. 7 a) in Kern et al. 2019).

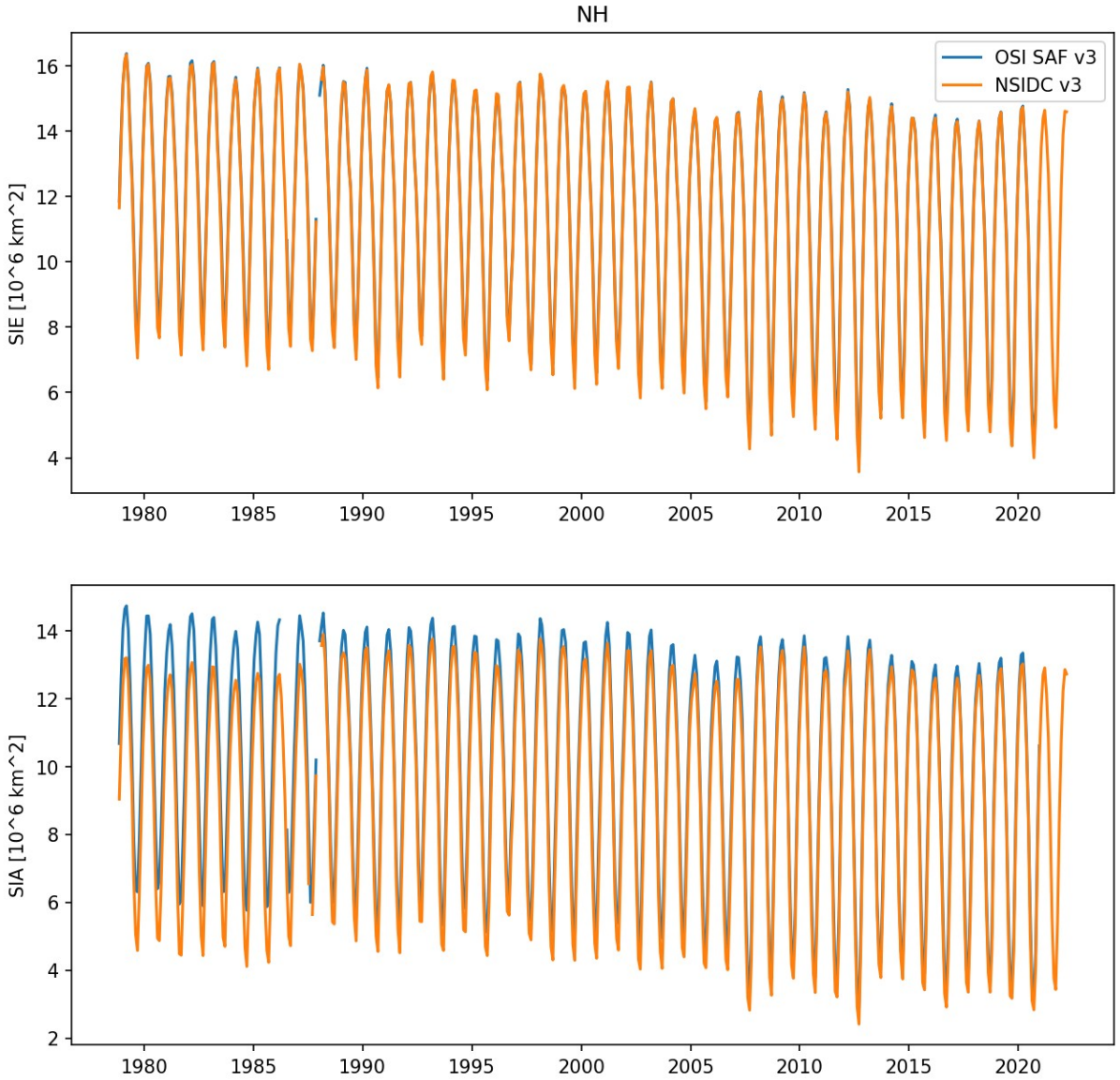

Figure 9: Time series plot of two sea-ice indexes for the Northern Hemisphere (top: SIE, bottom: SIA): OSI SAF v3 (blue, 1978-2020) and NSIDC v3 (orange, 1978-2022).

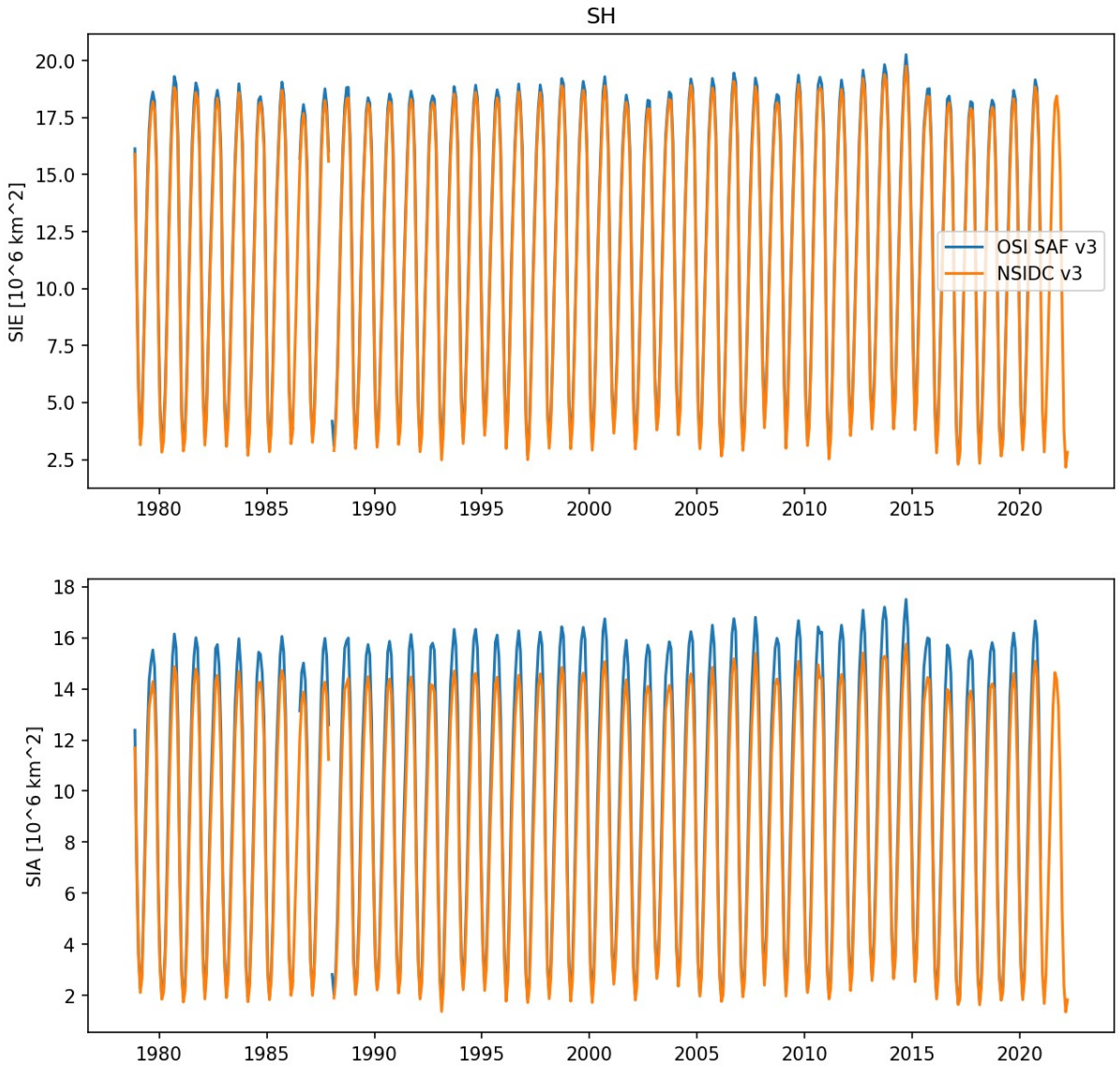

Figure 10: Same as Figure 9 but for the Southern Hemisphere.

Figure 11 (resp. Figure 12) shows a comparison between OSI SAF SII v3 (y-axis) and NSIDC SII v3 (x-axis) for Northern Hemisphere (resp. Southern Hemisphere) Sea Ice Extent (left) and Area (right) over the period 1979-2020.

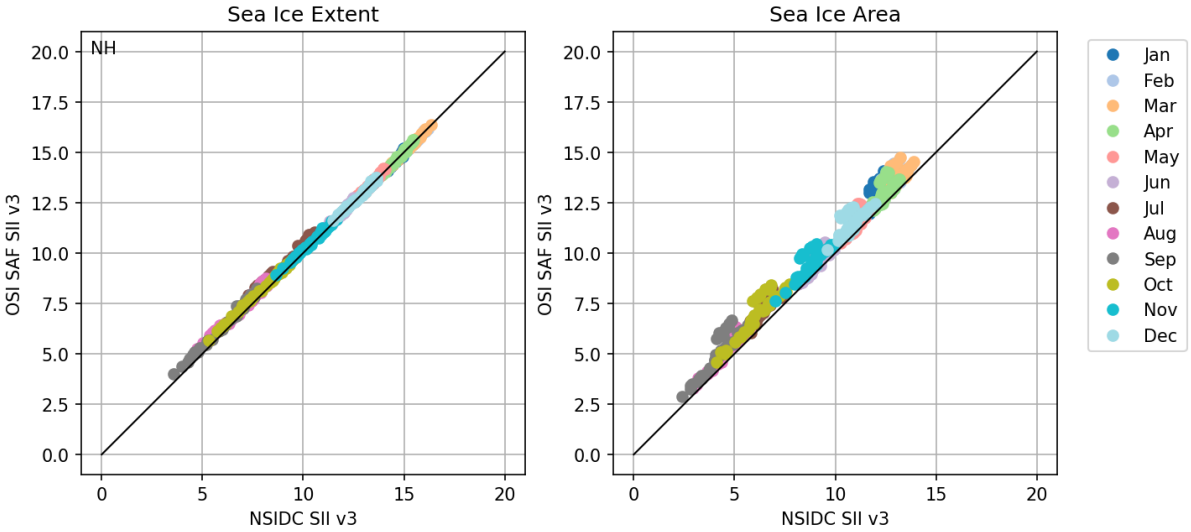

Figure 11: Scatterplot of Northern Hemisphere OSI SAF SII v3 (y-axis) vs NSIDC SII v3 (x-axis) SIE (left) and SIA (right). The pairs are colored by month.

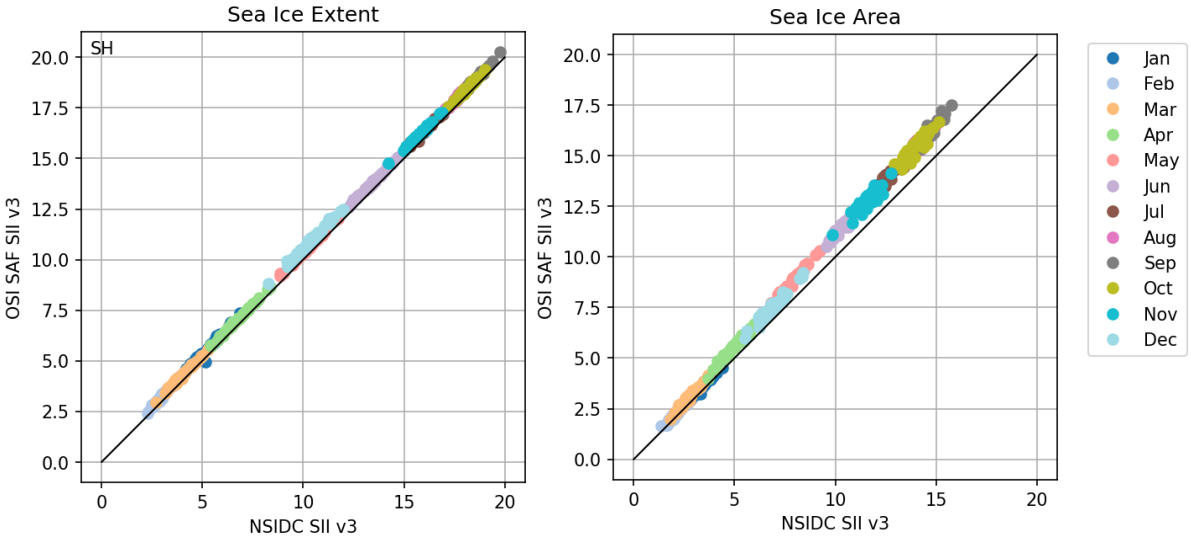

Figure 12: Same as Figure 11, but for the Southern Hemisphere.

For SIA (right panels), we observe the consequences of underestimation in the Northern Hemisphere (Figure 11) by NSIDC SII v3 in the 1978-1987 period (see Figure 9). In the Southern Hemisphere (Figure 12), we observe the underestimation by the NasaTeam algorithm (used in the NSIDC SII) that increases in the austral Winter (e.g. Sept and Aug).

In terms of Sea Ice Extent (left panels), we confirm the general impression from Figure 9 and Figure 10 that the two sources agree rather well. The symbols (colored by months) are aligned along the 1:1 line, yet slightly above that line: the OSI SAF SII v3 values are generally larger than those of the NSIDC SII v3. This is confirmed by an analysis (not shown) of the mean Sea Ice Extent values for the period 1979-2020 : the OSI SAF v3 values are in general larger than those of NSIDC, with differences ranging from 0 millions km^2 in Jan-Feb-Mar to 0.400 millions km^2 in July-Aug-Sept. Average differences in the Southern Hemisphere are about 0.3 millions km^2 in all months.

In the Northern Hemisphere (especially in summer), we suspect the OSI SAF values are somewhat high due to land spill-over effects: at the microwave frequencies used by the SIC algorithms entering the OSI SAF and NSIDC data, land masses have similar emissivities than sea ice and can trick the sea-ice algorithms along the complex coastlines of the Arctic (e.g. in the Canadian Archipelago). This effect is exacerbated during the summer months when a longer coastline is ice-free. Both the OSI SAF and NSIDC use special algorithms to detect and correct such land spill-over effects (see e.g. sections 3.6 and 4.3 in Lavergne et al. 2019), and the v3 OSI SAF SICs seems to improve with respect to the v2 version.

In the Southern Hemisphere, we suspect that the NSIDC values are low due to the general and documented underestimation of SIC by the NasaTeam algorithm (Kern et al. 2019).

	OSI SAF (abs)	***NSIDC (abs)***	***OSI SAF (rel 81-10)***	***NSIDC (rel 81-10)***	***OSI SAF (rel 91-20)***	***NSIDC (rel 91-20)***
	[1e3 km^2 / year]		***[% / dec]***		***[% / dec]***	
Jan	-45.4	-45.4	-3.1%	-3.2%	-3.2%	-3.2%
Feb	-44.2	-44.6	-2.9%	-2.9%	-3.0%	-3.0%
Mar	-40.4	-40.6	-2.6%	-2.6%	-2.7%	-2.7%
Apr	-40.1	-39.4	-2.7%	-2.7%	-2.8%	-2.7%
May	-36.9	-36.4	-2.8%	-2.7%	-2.8%	-2.8%
Jun	-45.3	-47.5	-3.8%	-4.0%	-4.0%	-4.2%
Jul	-66.4	-70.8	-6.7%	-7.5%	-7.2%	-8.1%
Aug	-76.3	-76.8	-10.1%	-10.7%	-11.3%	-12.0%
Sep	-86.1	-83.4	-12.7%	-13.0%	-14.5%	-14.9%
Oct	-79.7	-84.3	-9.3%	-10.1%	-10.3%	-11.2%
Nov	-51.6	-54.8	-4.8%	-5.1%	-5.0%	-5.4%
Dec	-45.3	-46.6	-3.5%	-3.6%	-3.6%	-3.8%

Table 12: Monthly Northern Hemisphere Sea Ice Extent trends observed by the OSI SAF SII v3 and NSIDC SII v3 for the period 1979 - 2020. Both absolute trends (expressed in thousands km2 per year) and trend relative to the 1981-2010 and 1991-2020 periods (expressed in % per decade) are reported.

Table 12 compiles the Northern Hemisphere absolute and relative trends of monthly sea-ice extent for the OSI SAF v3 and NSIDC v3. There is generally good agreement between the two sources, especially in terms of absolute trends. The relative trends are also in the same order of magnitude, clearly showing the larger Arctic sea ice melt during the summer months than during the winter months.

5.2 Comparison to OSI SAF v2

Table 13 (Northern Hemisphere) and 14 (Southern Hemisphere) summarize a comparison of sea-ice extent (columns 2-4) and sea-ice area (columns 5-6) between the OSI SAF v3 and OSI SAF v2.1 index.

NH	***Sea Ice Extent***			***Sea Ice Area***		
	SIE v3	***SIE v2p1***	***SIE v3 - v2p1***	***SIA v3***	***SIA v2p1***	***SIA v3 - v2p1***
	[10^6 km^2]	***[10^6 km^2]***	***[10^3 km^2]***	***[10^6 km^2]***	***[10^6 km^2]***	***[10^3 km^2]***
Jan	14.263	14.398	-134.8	12.921	12.952	-30.8
Feb	15.113	15.247	-134.6	13.691	13.728	-37.2
Mar	15.289	15.384	-95.8	13.827	13.841	-14.4
Apr	14.568	14.625	-57.2	13.102	13.090	11.9
May	13.191	13.265	-74.0	11.617	11.619	-2.0
Jun	11.679	11.805	-125.9	9.489	9.527	-37.9
Jul	9.563	9.738	-174.9	7.051	7.136	-84.5
Aug	7.186	7.296	-110.2	5.124	5.166	-42.3
Sep	6.389	6.501	-112.3	4.980	5.021	-40.9

NH	Sea Ice Extent			Sea Ice Area		
Oct	8.179	8.253	-73.8	6.968	6.975	-6.4
Nov	10.575	10.641	-66.9	9.482	9.464	18.1
Dec	12.719	12.823	-103.7	11.482	11.488	-6.0

Table 13: Comparison of Sea Ice Extent and Area for the OSI SAF v3 and v2.1 indexes in the Northern Hemisphere.

SH	Sea Ice Extent			Sea Ice Area		
	SIE v3 [10^6 km^2]	**SIE v2p1 [10^6 km^2]**	**SIE v3 - v2p1 [10^3 km^2]**	**SIA v3 [10^6 km^2]**	**SIA v2p1 [10^6 km^2]**	**SIA v3 - v2p1 [10^3 km^2]**
Jan	5.334	5.357	-22.6	3.469	3.476	-6.7
Feb	3.319	3.343	-24.0	2.153	2.147	5.9
Mar	4.305	4.330	-24.5	2.987	2.941	46.4
Apr	7.145	7.167	-22.3	5.661	5.570	91.9
May	10.508	10.533	-24.4	8.801	8.692	108.6
Jun	13.760	13.785	-25.1	11.756	11.624	132.2
Jul	16.368	16.394	-25.4	14.128	13.995	133.6
Aug	18.139	18.169	-29.6	15.627	15.499	128.2
Sep	18.899	18.930	-30.5	16.159	16.022	137.0
Oct	18.487	18.509	-22.3	15.589	15.398	191.2
Nov	16.282	16.295	-13.8	12.866	12.679	187.5
Dec	10.908	10.931	-23.3	7.480	7.433	47.1

Table 14: Comparison of Sea Ice Extent and Area for the OSI SAF v3 and v2.1 indexes in the Southern Hemisphere.

The differences between v3 and v2.1 are generally small, all within -200 and +200 thousands km^2. Overall the v3 index shows slightly less sea ice than v2.1. This is the case in the Northern Hemisphere for both SIE and SIA. In the Southern Hemisphere, v3 has consistently a bit less SIE (between -20 and -30 thousands km^2) while its SIA is slightly larger in most months. This is consistent with the results of the validation against the SIC0 and SIC1 reference data (section 3.): OSI-450-a (v3) has less bias than OSI-450 (v2) at 0% and 100% SIC, especially in the SH close to 100% SIC.

From the comparison with NSIDC's sea ice index (section 5.1) we can say that OSI SAF v3 is closer to NSIDC's SIE (than OSISAF v2.1 was). NSIDC's SIA is not really used as a reference (due to the polar observation hole and the use of Nasa Team in the SH), but it can be noted that OSI SAF v3 is closer to NSIDC's SIA in the Northern Hemisphere, and further apart in the Southern Hemisphere.

All in all, the OSI SAF v3 CDR seems as robust as the v2 CDR as a base for the OSI SAF sea-ice index OSI-420.

5.3 Comparison between v3 CDR OSI-450-a and v3 ICDR OSI-430-a

In this section we compare the sea-ice index (extent and area) obtained from the CDR OSI-450-a and the ICDR OSI-430-a in two full years of overlap (2019-2020). Such a short period does not allow to compare trends, but does inform on potential offsets between the two series. The CDR and ICDR use exactly the same algorithm and processing chains, but not the same input data. In particular, the ICDR uses operational SSMI/S data which might suffer from more geo-location errors than the Fundamental Climate Data Record (FCDR) used in the CDR.

Figure 13 (NH) and 14 (SH) plot histograms of the differences between OSI-450-a and OSI-430-a in terms of SIE and SIA. In general, the differences are mostly constrained in the [-50;+50 10^3 km^2] range, which is less than the difference found above between OSI-450-a

(v3) and OSI-450 (v2) and much less than those found above between the OSI SAF and the NSIDC values.

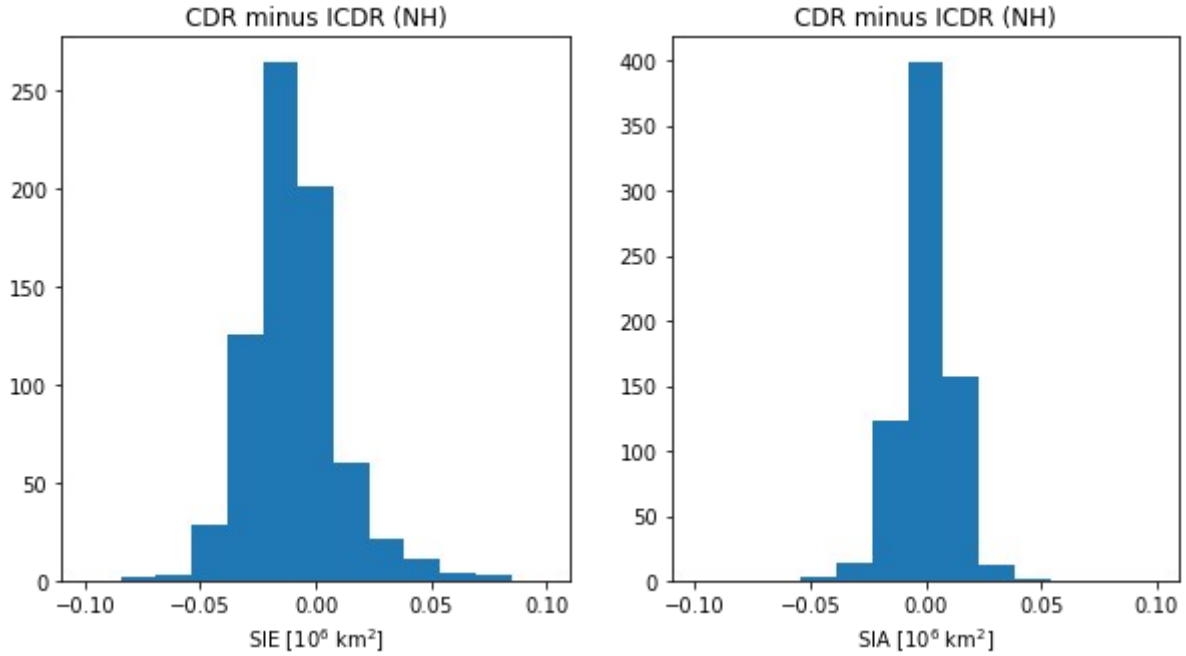

Figure 13: Histograms of difference between the v3 CDR (OSI-450-a) and the v3 ICDR (OSI-430-a) in terms of SIE (left) and SIA (right) over years 2019-2020 in the Northern Hemisphere.

The best agreement between OSI-450-a and OSI-430-a are in the Northern Hemisphere, better for SIA than SIE. The agreement is worse for the Southern Hemisphere and especially for the SIE where a bias of around -40 10^3 km^2, while the SIA has a slightly positive bias. This change of sign between the SIA and SIE difference can be attributed to the low-end of the SIC range and possibly the effect of the open water filter, since we remind that we compute SIE with a 15% SIC threshold, but have no threshold for the SIA. This will be investigated more post-release and -if deemed necessary- can be compensated for when preparing the next version of the OSI-420 sea-ice index product.

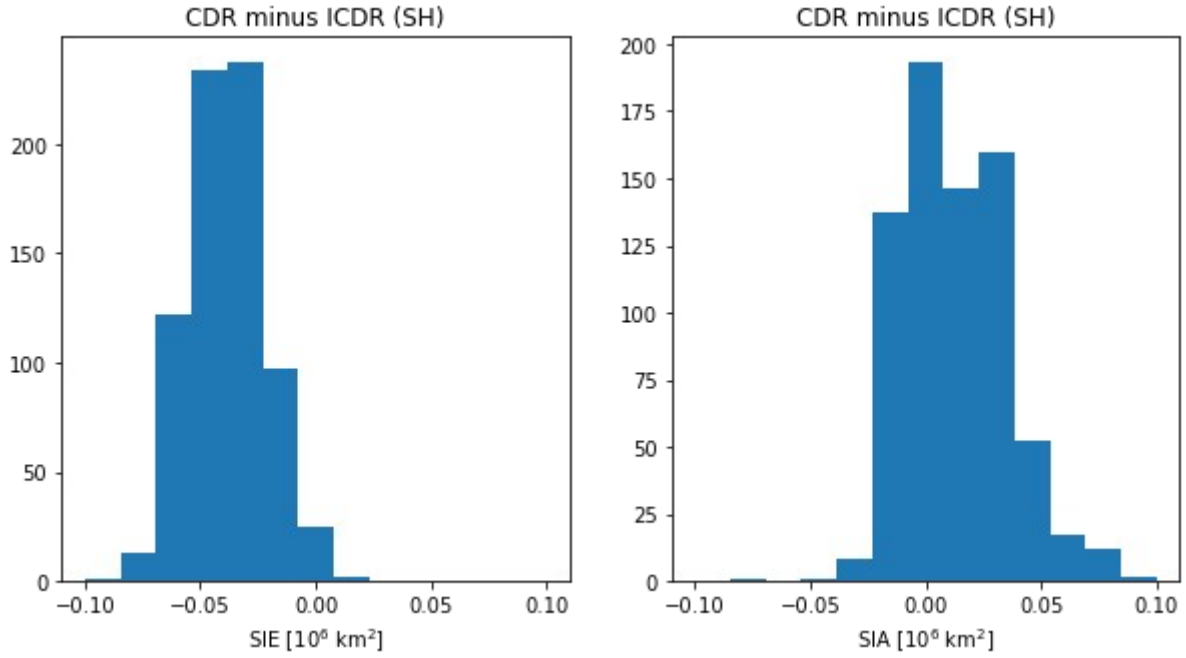

Figure 14: Same as Figure 13 but for the Southern Hemisphere

5.4 Comparison to other sources

Many studies have compared sea-ice extent and area time-series. In Kern et al. (2019), ten widely used sea-ice concentration climate data records are intercompared with each other and also compared to ground-truth data.

Part of their analysis focus on an intercomparison of monthly averaged SIE and SIA for both Hemispheres. For example, we reproduce here their Fig. 6 panel (d): September sea-ice extent in the Northern Hemisphere.

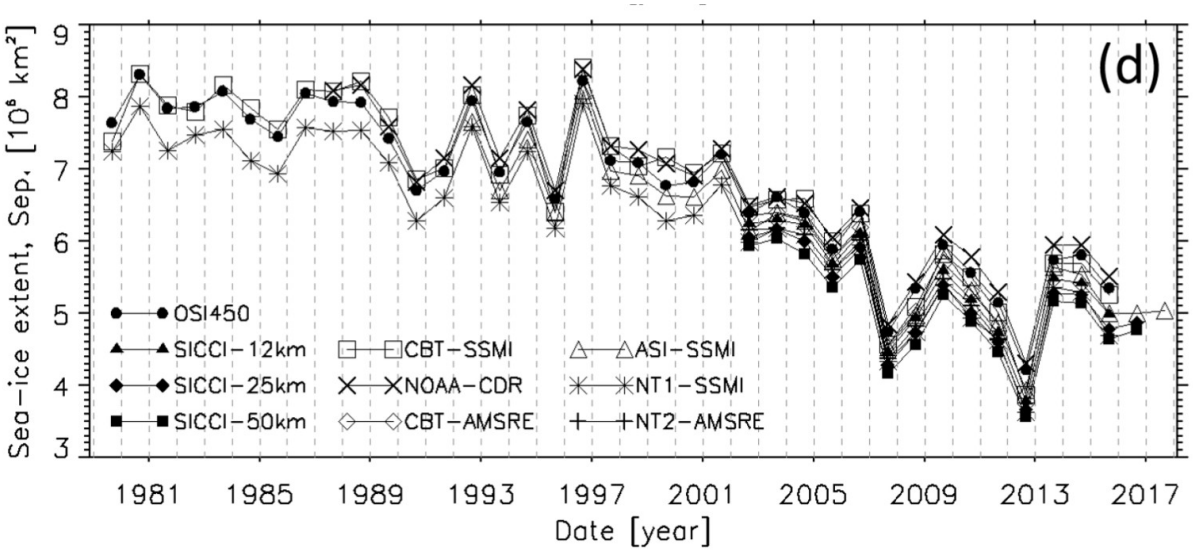

Figure 15: Northern Hemisphere sea-ice extent for September months computed from ten sea-ice concentration data records (reproduced from Fig. 6 of Kern et al. 2019).

From this figure, it is clear that NT1-SSMI (star symbols, the base for NSIDC SII v3) is at the lower end of the ensemble of other sources, while OSI-450 (black dot symbols, the base for OSI SAF SII) is at the higher end. Another widely used sea-ice concentration data, the Bootstrap data (CBT-SSMI, squares) is more in agreement with OSI-450 than with NT1-SSMI. The difference between the high-end and low-end of this ensemble of curves is larger than (in the first half of the period) and of the same order (in the second half) as the difference we documented between the OSI SAF SII and the NSIDC SII (~0.5 millions km²).

We finally underline that there is no direct correspondence between the values of the OSI SAF SII (v2p1) and NSIDC SII (v3) data on the one hand, and the curves displayed for the OSI-450 and NT1-SSMI on Figure 15 on the other hand. This is because Kern et al. (2019) re-computed all sea-ice extent and area from the sea-ice concentration maps, and that this process included regridding to a common mask. This section is nevertheless an interesting indication that different algorithms and datasets return different sea-ice extent and area values.

6. Conclusions

There are two scientific requirements listed in the Product requirement document table OSI-PRD-PRO-200: (i) the requirement on spatial resolution and (ii) the accuracy of the product on a yearly basis. Here the accuracy of the OSI SAF sea ice concentration products are evaluated using two different reference data sets; the SIC0 and SIC1 data set and NIC ice charts.

(i) The requirement on spatial sampling that applies to the OSI SAF reprocessed ice concentration products are 25km. This requirement is met for all three *version 3* CDRs, the OSI-450-a, OSI-458 and the OSI-430-a ICDR .

(ii) The requirement on target accuracy, that applies to the OSI SAF reprocessed ice concentration products are a yearly average RMSE of 8% for both the NH product and SH product, cf. Table 1.

The assessment results of the primary validation method of OSI SAF products against SIC0 and SIC1 reference data, are here evaluated against the accuracy requirements on the *interannual mean RMSE*, cf. Table 1. The assessment results are reported in tables with one decimal to better show the differences between the OSI SAF v2 and v3 data sets performances. However the results are rounded off to integers when evaluated against the product requirements. The results of the secondary/additional validation methods (against NIC ice charts; assessment of Sea ice extent and Area) are also mentioned, but not evaluated against the requirements.

OSI-450-a climate data record

The assessment of the OSI-450-a v2 CDR against SIC0 and SIC1 reference data gives an interannual mean RMSE of 3% for closed ice and 2% for open water, in the Northern Hemisphere, and an interannual mean RMSE of 4% for closed ice and 1% for open water, in the Southern Hemisphere. The OSI-450-a product thus meets the requirement on *optimal* accuracy (5% threshold) for both closed ice and open water categories. The table below summarizes the assessment results.

Statistics	SIC1 (100% SIC)				SIC0 (Open water)			
	Bias		RMSE		Bias		RMSE	
	OSI-450	OSI-450-a*	OSI-450	OSI-450-a*	OSI-450	OSI-450-a*	OSI-450	OSI-450-a*
NH	-1.6	-1.0	3.2	3.3	0.6	0.5	1.9	1.7
SH	-1.6	0,3	3.9	3.9	0.2	-0.1	1.7	1.3

The OSI-450-a version 3 CDR are assessed against the SIC0 and SIC1 reference data set for the common years of the OSI-450 v2 CDR from 1979 to 2015, to evaluate the relative version 3 algorithm improvements, that will justify the release of the version 3 data sets.

For all the derived statistical measures reported the OSI-450-a performs better (numbers highlighted in green) or equally well as the OSI-450. The results of the secondary/additional assessment of OSI-450-a against ice charts support this conclusion.

It is concluded that the OSI-450-a meets the requirements and shows an improved performance when compared to the predecessor OSI-450. Thus, the OSI-450-a is ready for release.

OSI-430-a interim climate data record

The OSI-430-a ICDR v3 operationally extends the OSI-450-a and replaces the OSI-430-b ICDR v2 as the continuously updated OSI SAF sea ice concentration CDR. The assessment against SIC0 and SIC1 reference data gives an annual mean RMSE of 3% for closed ice and 1% for open water in the Northern Hemisphere, and an annual mean RMSE of 4% for closed ice and 1% for open water in the Southern Hemisphere. The OSI-430-a product thus meets

the requirement on *optimal* accuracy (5% threshold) for both closed ice and open water categories.

The validation results of the OSI-430-b ICDR are compared to those of the OSI-430-b ICDR and the OSI-450-a CDR in 2019 and 2020. For all the derived statistical measures reported, the OSI-430-a perform better than the OSI-430-b ICDR, and equally well as or only slightly worse than the OSI-450-a CDR. Overall, both the bias and RMSE are at very low levels, indicating excellent performance in these two recent years, and the small differences between the OSI-430-b and OSI-450-a data sets can be explained by the use of different input satellite data.

The below table summarizes the assessment results.

Statistics	SIC1 (100% SIC)						SIC0 (Open water)					
	Bias			RMSE			Bias			RMSE		
	OSI-430-a	OSI-430-b	OSI-450-a*	OSI-430-a	OSI-430-b	OSI-450-a*	OSI-430-a	OSI-430-b	OSI-450-a*	OSI-430-a	OSI-430-b	OSI-450-a*
NH	-0.6	-1.1	-0.6	3.1	3.1	3.1	0.2	0.5	0.3	1.3	1.4	1.3
SH	-0.7	-2.3	-0.3	4.1	4.0	4.0	-0.5	0.2	-0.3	1.1	1.2	1.1

So, the OSI-430-b meets the requirements, performs better than its predecessor the OSI-430-b ICDR, and is found to be temporally consistent with the OSI-450-a CDR. Thus, the OSI-430-b is ready to be released.

OSI-458 climate data record

The assessment against SIC0 and SIC1 reference data give an annual mean RMSE of 3% for closed ice and 2% for open water in the Northern Hemisphere, and an annual mean RMSE of 4% for closed ice and 1% for open water in the Southern Hemisphere. The OSI-458 product thus meets the requirement on *optimal* accuracy (5% threshold) for both closed ice and open water categories.

We compare the OSI-458 assessment results against those of the OSI-450-a CDRs for reference, despite the difference in input sensor data for the two CDRs. The OSI-458 performs equally well as the OSI-450-a for all the derived statistical measures reported from the assessment against SIC0 and SIC1 reference data. There are a few cases of slight worse performance, but the differences are on the first decimal.

So, the OSI-458 meets the requirements and is found to be ready for release.

Statistics	SIC1 (100% SIC)				SIC0 (Open water)			
	Bias		RMSE		Bias		RMSE	
	OSI-458	OSI-450-a	OSI-458	OSI-450-a	OSI-458	OSI-450-a	OSI-458	OSI-450-a
NH	-1.0	-1.0	3.4	3.3	0.6	0.5	1.6	1.6
SH	-0.4	-0.3	4.0	4.0	0.0	-0.1	1.3	1.3

Evaluation of OSI SAF product uncertainties

The OSI SAF (I)CDR products uncertainties are evaluated against the results from the assessment with the reference data and compared to the OSI-450 v2 CDR product uncertainties to assess if the v3 product uncertainties are more exact. The product uncertainty should neither underestimate nor “over-shoot” when compared to the RMSE on the difference to reference data.

The uncertainty diagram for SIC0 samples show that uncertainty values are at a level of 2-5% and the comparison against RMSE suggests that the SIC0 product uncertainties are overestimated in the order of ~1%. The OSI-450-a uncertainties in the last years of the time series are slightly lower than those of its predecessor, the OSI-450 v2 CDR. The assessment suggests that the 100% ice uncertainties have become more realistic with the OSI SAF version 3 CDR product. The OSI-458 product uncertainties are a little higher than those of the OSI-450-a and overestimated, when compared to the RMSE on the difference to the reference data.

Coastal zone validation results

Part of the update of the OSI SAF CDR algorithms to version 3 has been to improve the land spill-over correction scheme, cf. [RD-2]. The performance of the OSI-450-a v3 CDR in the Northern Hemisphere coastal region, relative to that of the OSI-450 v2 CDR, was assessed from the results of the comparison of the OSI SAF data sets with ice charts. The results were masked for a 60 km wide Coastal zone. The results showed that the OSI-450-a better match the ice chart sea ice concentrations in the coastal zone, than the OSI-450 v2 CDR does. This is interpreted as, that the land-spillover correction scheme in the v3 CDR has improved the product performance in the coastal zone.

The sea ice extent and sea ice area assessment

We conducted a comparison of monthly SIE and SIA values between the OSI SAF SII and NSIDC SII v3 times series. We note up-front that this does not constitute a validation, since there is no ground-truth for such indicators. We also note that we do not tune the OSI SAF SII values towards the NSIDC SII values.

We observe that the two time series agree in terms of Sea Ice Extent trends in both Hemispheres, with the NSIDC data showing slightly larger relative trends than OSI SAF during summer, mostly due to the early period in the time series (1979-1987).

The OSI SAF SII reports rather consistently larger Sea Ice Extent values than NSIDC SII v3, both in the Northern and Southern Hemispheres, with differences reaching 0.5 million km^2 (average over the 1981-2010 period). In the Northern Hemisphere, we suspect that the OSI SAF SII v3 suffers more from land spill-over effects than NSIDC SII v3, and that the OSI SAF SIE values are probably too high but improving since OSI SAF SII v2p1. In the Southern Hemisphere however, we suspect the NSIDC SII v3 values to be too low, following the general underestimation of SIC by the NasaTeam algorithm (in the Southern Hemisphere only).

In terms of Sea Ice Area, the OSI SAF SII v3 are more realistic than those of in the NSIDC SII v3 : in the Northern Hemisphere the NSIDC time series does not fill the polar observation hole (OSI SAF interpolates SIC data there), in the Southern Hemisphere, the underestimation of SIC by the NasaTeam algorithm has a strong effect (stronger than for Sea Ice Extent).

As far as the time series of relative anomalies of annual minimum and maximum sea-ice extent in both Hemispheres, the agreement between the two datasets is remarkable as is illustrated in Figure 16. We note that the comparison of the v3 SIE and SIA to the v2 timeseries presented here is to inform the release of the v3 SIC CDRs. It will be repeated and extended for the release of the v3 sea-ice index product (next version of OSI-420, based on the v3 SIC CDRs).

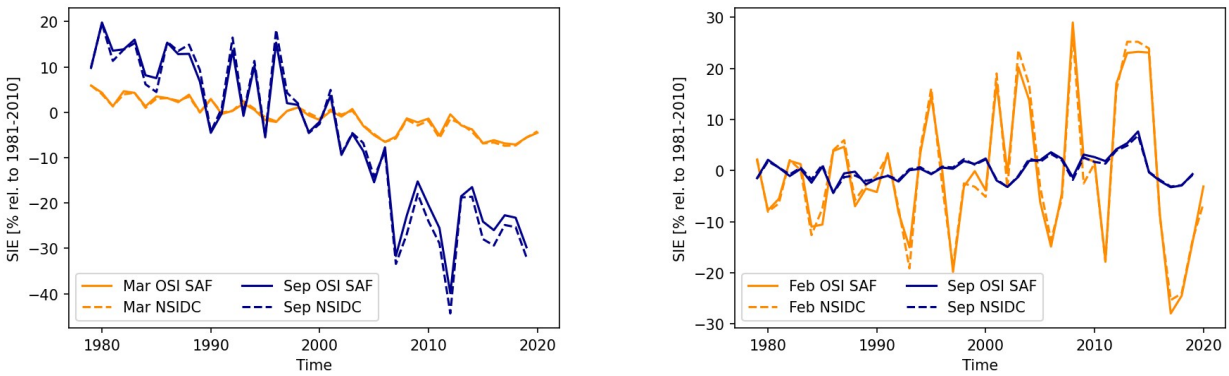

Figure 16: Timeseries of relative anomalies of OSI SAF and NSIDC SII monthly mean sea-ice extent at the annual maximum and minimum sea-ice cover in the NH (left) and SH (right)..

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