



Visiting Scientist Activity final report

The validation methodology for the OSISAF sea ice concentration data records

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AS Proposal summary

VSA Title	Validation methodology for the OSI SAF sea ice concentration data records		
VSA Id	AVS_2021_01	Objective category	Validation of products
VSA host institute	DMI	Related OSI SAF product(s)	OSI-450-a, OSI-430-a, OSI-458
VSA supervisor	R. T. Tonboe , F. Baordo, M. B. Kreiner	Related OSI SAF WP(s)	WP 22130
Expected start date	16-08-2021 01.12.2021	Related OSI SAF review(s)	DRR/ORR for OSI-450-a, OSI-430-a and OSI-458
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VS candidate	Roberto Saldo, DTU Space	VS/AS	Associate Scientist

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1.0	21-11-2022	MBJE	Added more description after comments from OSI SAF Project manager and OSI SAF Scientific coordinator

Table of contents

1. INTRODUCTION.....	3
2. TIMELINE.....	4
3. WORK.....	4
4. SUMMARY OF THE VALIDATION RESULTS.....	5
a) The OSI-450-a climate data record.....	5
b) The OSI-430-a interim climate data record.....	6
c) The OSI-458 climate data record.....	7
d) Conclusions.....	7
5. SETUP OF VALIDATION METHODOLOGY AT DMI.....	8
6. CONCLUSION.....	8
7. REFERENCES.....	9

1. INTRODUCTION

The objective of the VSA activity was to initiate a new validation methodology for the OSI SAF sea ice concentration (SIC) climate data records (CDRs) and to learn from and transfer the experiences with the quality assessment methodology developed in the ESA CCI+ project, to the OSISAF.

In the OSI SAF Justifications of Requirements for Global Sea Ice Concentration (Interim) Climate Data Records (Lavergne and Tonboe, 2019) it was proposed to change the quality assessment method for the future OSI SAF sea ice concentration data records, so that the primary method for assessment is a direct comparison against high-quality 0% and 100% SIC reference data (SIC0 and SIC1) (the ESA CCI Round Robin Data Package (RRDP), Pedersen et al., 2019). This primary evaluation methodology is independent of and more temporally consistent than the comparison to manually made ice charts (as was done in CDOP1 and CDOP2). The primary assessment method is described in detail in both the AS activity proposal, as well as in the Scientific Validation Report (OSI SAF, 2022).

The AS candidate Roberto Saldo from the Technical University of Denmark (DTU) has set up the validation of sea ice CDRs currently operated in the ESA CCI+ project. The CCI+ project has worked in parallel to the development of the OSI SAF CDRs (2019-2022) and this AS activity, along with a close coordination of the CCI+ and OSI SAF SIC activities, will ensure that the OSI SAF and CCI+ CDRs are complementary and that their performances can be compared.

The OSI SAF SIC CDR v3 datasets that have been address in this activity are:

- OSI-450-a, CDR based on SMMR, SSM/I and SSMIS input satellite data covering the period Oct. 1978 to Dec. 2020.
- OSI-430-a, ICDR extending OSI-450-a from Jan. 2021 onwards.
- OSI-458, CDR based on AMSR-E and AMSR2 input satellite data, covering the period Jun. 2002 to Oct. 2011 (AMSR-E) and Jul. 2012 to Dec. 2020 (AMSR2).

DMI is responsible for the quality assessment and validation of OSI SAF sea ice concentration CDRs and has acted as the host institute for this AS activity. The DMI supervisors were Fabrizio Baordo and Matilde Kreiner (Rasmus Tonboe was listed as supervisor in the AS proposal, but left DMI in summer 2021). Due to the Covid-19 restrictions in winter 2021/22 most of the work was carried out at DTU, but the AS candidate participated in several virtual meetings with DMI supervisors as well as a physical one-day workshop at DMI in May 2022, with representation from MET also.

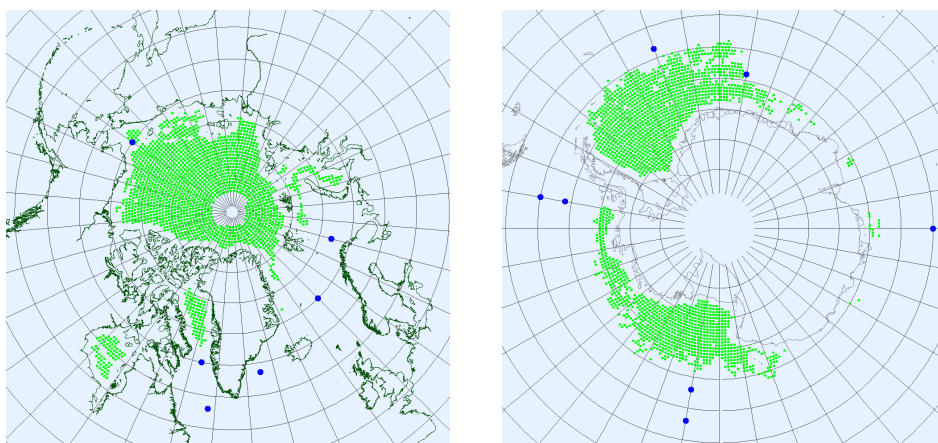


Figure 1: Map of the location of SIC0 (blue) and SIC1 (green) reference data in the Northern Hemisphere (left) and Southern Hemisphere (right) that is used in the comparison with OSI SAF CDR and ICDR products. The location of the SIC0 data are fixed, but their use in the comparison is seasonally dependent. 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. This figure is reproduced from (OSI SAF, 2022).

2. TIMELINE

The AS activity proposal was approved by the OSISAF steering Group in June 2021. A dependency for the activity to be carried out, was the availability of the Sea ice concentration version 3 CDRs (OSI-450-a, OSI-430-a, OSI-458) from MET. The CDRs were however delayed as with regards to the original delivery date foreseen in the AS proposal. The AS activity was initiated with the delivery of the first draft CDR data sets from MET in December 2021. From December 2021 to May 2022 more draft versions of the CDR data sets were provided from MET and these were processed and the assessment method conducted to address the accuracy of the different versions of CDR data set. The final version CDR data sets were delivered in May 2022 and the assessment was conducted and the results delivered for the Scientific Validation Report (OSISAF, 2022) in late June 2022. In parallel, the AS candidate has assisted OSISAF scientists at DMI in the handover and setup of the primary assessment methodology in the DMI framework. The AS activity is considered completed with the successful end of the ORR review in September 2022.

3. WORK

The AS activity tasks (as listed also in the AS proposal) that have been conducted are reviewed below:

- *Update the 0% SIC dataset (for the CDRs and ICDR time series) and 100% SIC SAR based dataset (for the period 2007 to 2020).*
This first task was conducted and completed in connection with the delivery of the first draft CDR data sets in December 2022. See Figure 1.
- *Do the RRDP collocation of 100% and 0% SIC locations against the CDR and ICDR records.*
Following the update of the database of the SIC0 and 2007-2020 SIC1 reference data for the CDRs time series, the data was collocated with the CDR products. This task was repeated for a number of draft CDR data sets that were delivered from MET between December 2021 and May 2022. For each draft CDR data set the collocated data was analysed and plotted for statistical scrutiny and inter-comparison.
- *Conduct the validation for the CDR and ICDR records and output statistics relevant to the product accuracy metrics.*
From December 2021 to May 2022 more draft versions of the CDR data sets were provided from MET and these were processed, the assessment method conducted and statistics outputted to address the accuracy of the different versions of CDR data set. The final version CDR data sets were delivered in May 2022 and the assessment was conducted and the output statistics (text, tables and figures) delivered for the Scientific Validation Report (OSISAF, 2022) in late June 2022.
- *Deliverable: validation results as contribution to the sea ice CDR validation report (OSISAF, 2022).*
DMI has been responsible for the sea ice CDR validation and validation report, with contribution from the AS candidate and MET. The AS work has contributed with validation results to the Scientific Validation Report (OSISAF, 2022) that was delivered for the ORR in August 2022. With the successful end of the ORR review this task is considered completed. The below Section 4. briefly describes the results of the primary assessment method that is reported in detail in (OSISAF, 2022) Section 2.4.
- *Assist OSISAF scientists at DMI in setting up the methodology in the DMI framework.*
In parallel to the processing of the different versions of SIC CDR version data sets, the AS candidate has been assisting the DMI scientist in a handover of the primary validation methodology in a DMI framework. This task is considered completed from the AS candidate side, as the remaining work is now on DMI side to do the final implementation of the methodology.
- *Deliverable: Write a brief AS report that documents the work done.* Cf. this AS Activity End Report.

4. SUMMARY OF THE VALIDATION RESULTS

Here follows a summary of the primary assessment results that has been delivered for the Scientific Validation Report (OSI SAF, 2022). The methodology and assessment results are described in detail in the (OSI SAF, 2022) Section 2.4 and Chapter 3, respectively.

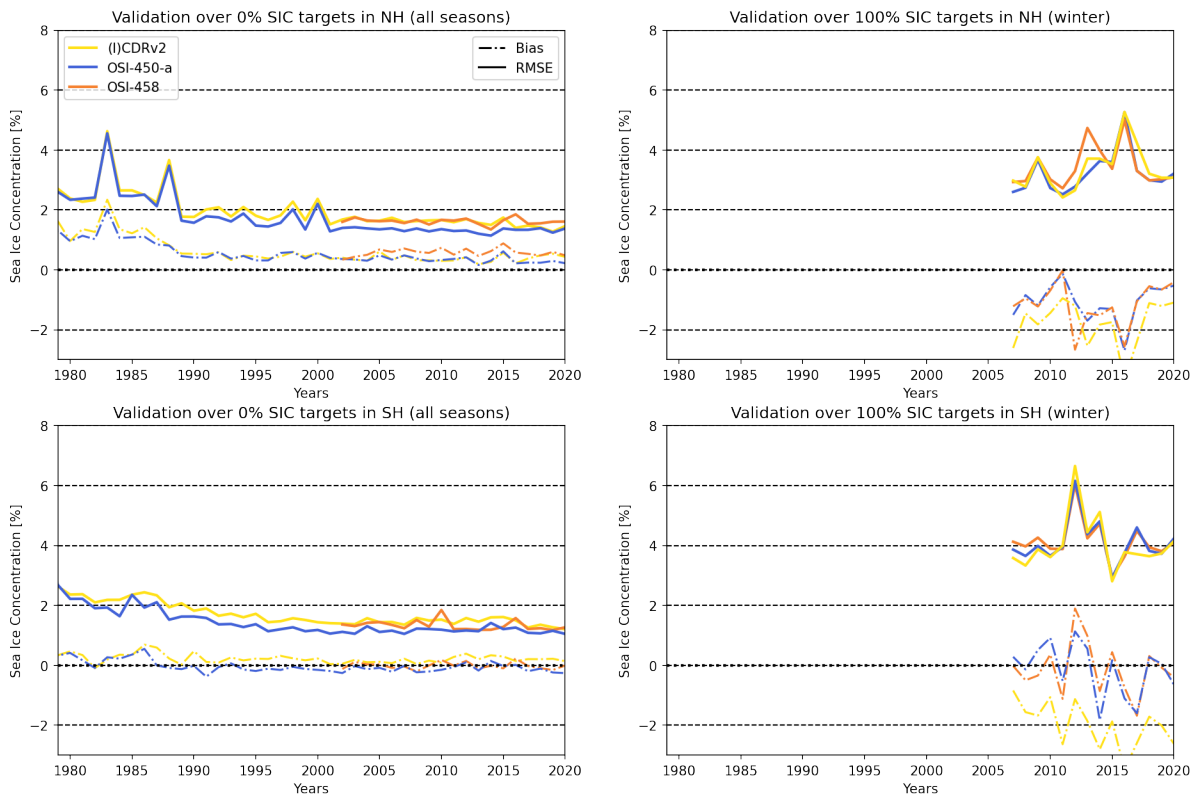


Figure 2: Time series plots of the results from the comparison of SIC0 (left plots) and SIC1 (right plots) reference data with the OSI SAF CDRs v3, OSI-450-a (blue line) and OSI-458 (orange line), and the OSI SAF v2 CDR+ICDR, OSI-450 and OSI-430-b (yellow line) for the Northern Hemisphere (top plots) and Southern Hemisphere (bottom plots). The figure shows the annual average bias (dotted lines) and RMSE (solid lines). This figure is reproduced from (OSI SAF, 2022).

a) 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 2 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 2 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 1 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 1: 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

b) 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 2 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 2, 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 2: 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

c) 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 2 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 3 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 3: 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

d) Conclusions

All results from the assessment of the OSI SAF products against reference data have been evaluated against the OSI SAF accuracy requirements on the inter-annual mean RMSE for both the NH and SH hemisphere products. The primary assessment results showed that all the three version 3 CDRs – the OSI-450-a, OSI-430-a and OSI-458 - meets the requirements on optimal accuracy (5% threshold) for both closed ice (SIC1) and open water (SIC0) categories. The assessment results also showed that the OSI-430-a ICDR was temporally consistent with the OSI-450-a CDR, and that the OSI-450-a and OSI-430-a perform better than their respective predecessors; the version 2 OSI-450 CDR and the OSI-430-b ICDR. The overall conclusion from the primary assessment was, that all three version 3 CDRs were found to be ready for release.

5. SETUP OF VALIDATION METHODOLOGY AT DMI

The AS candidate Roberto Saldo from the Technical University of Denmark (DTU), has set up the validation software for the evaluation of the sea ice CDR quality, that is currently operated in the ESA CCI+ project. With the AS activity the OSI SAF team wished to learn from and transfer the experiences with the quality assessment methodology developed in the ESA CCI+ project, to the OSISAF.

In parallel to the processing of the different versions of SIC CDR version 3 data sets, the AS candidate has been assisting the DMI scientists in a handover of the primary validation methodology. The methodology is similar to that described in Kern et al. (2019) and Lavergne et al. (2019) and the journal papers give an introduction to the principles behind the generation of the SIC0 reference data (retrieved by certain selection criteria/filters based on location and date) and the SIC1 reference data, which are derived from zones of converging sea ice detected by satellite synthetic aperture radar (SAR) data. The SIC0 data is a one-year static dataset with different SIC0 data points for each month, that is available from the ESA CCI Round Robin Data Package (RRDP) (Pedersen et al., 2019).

The SIC1 reference data, on the contrary, is a daily set of data points that can be used in the assessment of the OSI SAF SIC CDR daily data products. With the conclusion of this AS activity the RRDP has been updated to contain SIC1 reference data up to the end of the OSI SAF SIC v3 CDR and ICDR datasets with 2021. The goal of setting up the validation methodology at DMI has been to make DMI able to generate and update/expand the SIC1 data timeseries beyond 2021. When the reference dataset timeseries are updated, the collocation of the derived SIC0 and SIC1 reference data with a next version OSI SAF SIC CDR data sets can be done independently by DMI.

it was not feasible, nor in the interest of DTU or DMI, to have DMI adopt the validation software developed in the CCI project, since the software was developed years ago and in a programming language that does not comply with the DMI framework. Instead, DMI has developed and implemented the following software in the DMI validation framework, supervised by the AS candidate:

- Set up of a routine for download of the DTU High Resolution SAR Sea Ice Drift product, available as NRT and reprocessed datasets in Copernicus Marine Service (link to product: <https://doi.org/10.48670/moi-00135>).
- Developed code for derivation of the SIC1 reference data, that takes the sea ice drift products as input and calculates the zones of converging sea ice based on area calculations that follow the curvature of the Earth. The DMI code has improved the resolution of the output, resulting in more SIC1 validation points.
- Developed code to do the match-up of the derived SIC1 (and SIC0) reference data points with OSI SAF SIC CDR products in the OSI SAF product grid.

This task is considered completed from the AS candidate side, as the remaining work is now on DMI side to do the final optimization and implementation of the methodology.

6. CONCLUSION

The AS activity with Roberto Saldo (DTU) was initiated in December 2021 and the work was completed with the successful completion of the ORR review in September 2022.

The AS work have led to the setup of a new and more suitable validation methodology for the OSI SAF sea ice CDRs. The results from the new validation method assess the CDR stability and is more easily used to diagnose the SIC algorithms and therefore foster improvements.

The AS work have had a direct impact on the successful ORR review of the OSI SAF SIC CDR v3 products (OSI-450-a, OSI-430-a, OSI-458) with estimated release in October 2022.

Furthermore, the AS work has been beneficial to OSI SAF and to DMI that that wished to implement this new validation methodology for the upcoming OSI SAF CDRs. The AS works thus also have implications for the quality assessment of all upcoming OSI SAF sea ice concentration climate data records (CDRs).

7. REFERENCES

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