Validation Report for
The Global Sea Ice Concentration Level-2

OSI-410

Version: 1.0

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Document Change record

Document version	Software version	Date	Author	Change description
V 0.1	V1.0	06-03-2020	JOL	First version prepared for ORR review
V 1.0	V1.0	07-07-2020	RTT	Updated after ORR. Specified that the used satellites are still operational. Changed Figur 1.

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1. Introduction

1.1. The EUMETSAT Ocean and Sea Ice SAF

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

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

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

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

1.2. Disclaimer

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

Acknowledgement and citation
Use of the product(s) should be acknowledged with the following citations:
OSI-410 : OSI SAF (2020): Global Sea Ice Concentration Level 2, EUMETSAT SAF on Ocean and Sea Ice.

1.3. Scope of this document

This report presents the validation results of the OSI SAF Level-2 Sea Ice Concentration product OSI-410 version 0.1.

The quality assessment of the OSI SAF Global Sea Ice Concentration Level 2 is done first just before becoming an operational/pre-operational product distributed by the OSI SAF. This first assessment is explained in this scientific validation report. Then continuous monitoring of the product quality is done by the OSI SAF team and presented in the half-yearly operations reports available on the OSI SAF web site project documentation.

The quality assessment of the OSI SAF Global Sea Ice Concentration Level 2 is done against the target accuracy requirement defined in the OSI SAF Product Requirement Document [AD.1].

The target accuracy corresponds to the desired performance level (the breakthrough accuracy). If the values are not compliant to the target accuracy requirement, we consider that the product is still useful/useable as long as the values are compliant to the threshold requirement.

Target accuracy: 10 % for NH and 15 % for SH

Optimal accuracy: 5 %

The accuracy numbers are standard deviation of the difference between sea ice concentration and sea ice charts, averaged over one year.

Please note that the initial quality assessment exercise was done in 2019 on data from 01/01/2018 to 31/12/2018.

The validation method described in this report is similar to the methodology that is used for the ongoing validation of the ice concentration product and documented in the half-year operations report. The validation is a comparison between the OSI SAF ice concentrations, derived from satellite microwave radiometer data, and ice charts produced manually on the basis of satellite and reconnaissance data for ship navigation support.

1.4. Reference and applicable documents

1.4.1. Reference documents

[1] EUMETSAT OSI SAF
Algorithm Theoretical Basis Document for Global Sea Ice Concentration Level-2
SAF/OSI/CDOP3/DMI/SCI/MA/341, version 1.2, 06/03/2020

[2] EUMETSAT OSI SAF
Product User Manual for Global Sea Ice Concentration Level-2
SAF/OSI/CDOP3/DMI/TEC/MA/377, version 0.1, 06/03/2020

1.4.2. Applicable documents

[1] EUMETSAT OSI SAF
Product Requirements Document

1.5. Acronyms

AMSR	Advanced Microwave Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
DMI	Danish Meteorological Institute
FTP	File Transfer Protocol
MODIS	Moderate Resolution Imaging Spectroradiometer
NH	Northern Hemisphere
NIC	National Ice Center
OSI SAF	Ocean and Sea Ice Satellite Application Facility
SAR	Synthetic Aperture Radar
SH	Southern Hemisphere
SIGRID	Sea Ice Chart Grid Format
SSMIS	Special Sensor Microwave Imager Sounder
TUD	Technical University of Denmark
OSHD	OSI SAF Hybrid Dynamic
WMO	World Meteorological Organization

2. Validation dataset

2.1. Input satellite data

The product is derived from the Advanced Microwave Scanning Radiometer (AMSR-2) satellite measurements and the SSMIS (Special Sensor Microwave Imager Sounder) series of satellites: F16, F17 and F18. For the AMSR-2 based product, two ice concentration fields are computed: the primary one, which is computed with the OSI SAF Hybrid Dynamic (OSHD) ice concentration algorithm and utilises the 19 GHz vertical, 37 GHz vertical and 37 GHz horizontal channels and a second which is computed using the Technical University of Denmark (TUD) algorithm with the 19 GHz vertical, 37 GHz vertical, 89 GHz vertical, and 89 GHz horizontal channels. For the SSMIS based product, one ice concentration field is computed using the OSHD algorithm. These algorithms are described in the Algorithm Theoretical Basis Document (ATBD) [RD.1], and further information can be found in the Product User Manual (PUM) [RD.2]. The OSHD product uses the same frequency channels and ice concentration algorithm as the SSMIS OSI SAF product, whereas the TUD product utilizes the high frequency channels for higher spatial resolutiuon SIC. However these channels are more susceptible to noise due to water vapour and clouds .

List of sensors on the DMSP satellites, relevant for the ice concentration product:

Sensor	AMSR-2 on JAXA's GCOM-W1 spacecraft
Launch	May 18, 2012
Status 07-2020	Operational

Sensor	SSMIS/DMSP-F16
Launch	October 18, 2003
Status 07-2020	Operational

Sensor	SSMIS/DMSP-F17
Launch	November 04, 2006
Status 07-2020	Operational

Sensor	SSMIS/DMSP-F18
Launch	October 18, 2009
Status 07-2020	Operational

2.2. Ice chart data

The operational sea ice charts from the National Ice Centre (NIC) are used as the reference dataset in the validation. They are a relatively independent source of ice information for comparison to the ice concentration products. The ice charts (intended for aiding navigation) are produced on a regular basis, covering all seasons – both Southern and Northern Hemispheres and for the entire validation period, from January 01 2018 to December 31 2018.

Ice charts are produced manually, from satellite and reconnaissance data for ship navigation support. The ice charts are a detailed interpretation of primarily satellite imagery and a subsequent mapping procedure is carried out by skilled (trained and experienced) ice analysts. The ice charts are primarily used for strategic and tactical planning within the offshore and shipping community. Requirements are strict, with demands for detailed high quality products for several areas.

The ice charts are based on satellite SAR data, e.g. Radarsat-2 (since 2008) together with visual/infrared line scanners (e.g. SSMIS, AVHRR, MODIS) whenever daylight and cloud cover conditions allow. The passive microwave data from AMSR-2 used in the EUMETSAT OSI SAF AMSR-2 Sea Ice Concentration products have also possibly been used as background in the manual analysis for making the ice charts. However, the spatial resolution of the microwave radiometer data is too coarse for making navigational ice charts and they are always used together with higher resolution data. In addition to the satellite data, ice charts are based on information from ships and aircraft reconnaissance. The ice charts are a weekly compilation of the ice conditions, and it is clear that the estimates of ice concentration in the charts is based on the judgement of the analyst. The weekly ice chart has a specific date of validity, even though the data from which it was derived can be from various dates within the week.

A comparison between Greenland and Norwegian ice charts and OSI SAF sea ice concentration shows large differences between the different products, with the difference between Greenland ice charts and the OSI SAF ice concentration having a standard deviation between 10% and 25% – largest at intermediate concentrations. The Ice-charts are systematically higher than the OSI SAF ice concentrations, especially at intermediate concentrations. The comparison between Greenland and Norwegian ice charts shows large differences, indicating that the accuracy (standard deviation of the difference) is not better than 10-30%. Similar deviations are expected for the NIC ice charts. The analysis is described in:

http://marine.copernicus.eu/documents/QUID/MYOF-OSI-QUID-ARC-SEAICE-INDEX-V1.0.pdf

Reference ice charts:

Institute	National Ice Center: www.natice.noaa.gov/
Validation Period	January 01 2018 to December 31 2018
Frequency	Once a week

3. Validation Method

3.1. Validation Calculation

The OSI SAF ice concentration is compared with the SIGRID total ice concentration of the NIC ice charts. SIGRID is the WMO standard for describing ice characteristics in ice charts.

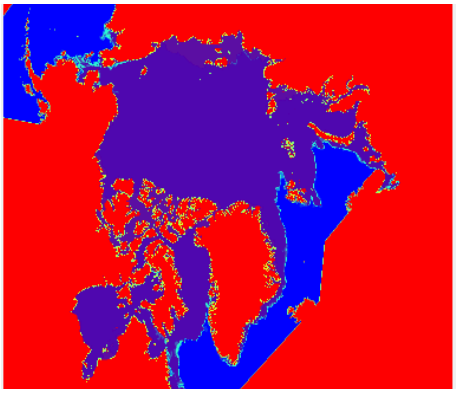

Figure 1: The ice chart total ice concentration information of a NIC ice chart, on a 10 km polar stereographic grid, on 2018-05-04.

The NIC ice chart and the OSI SAF concentration products are gridded onto a common format projection and resolution, allowing a pixel by pixel comparison to be carried out. The SIGRID code in the NIC ice chart specifies an ice concentration interval (i.e. the upper and lower bounds) of the ice concentration within a given polygon. The SIGRID codes are decoded to upper and lower bounds of ice con-

centration, projected, put on a 10 km grid and saved as NetCDF files for use in the validation. An example of a gridded ice chart is shown in Figure 1.

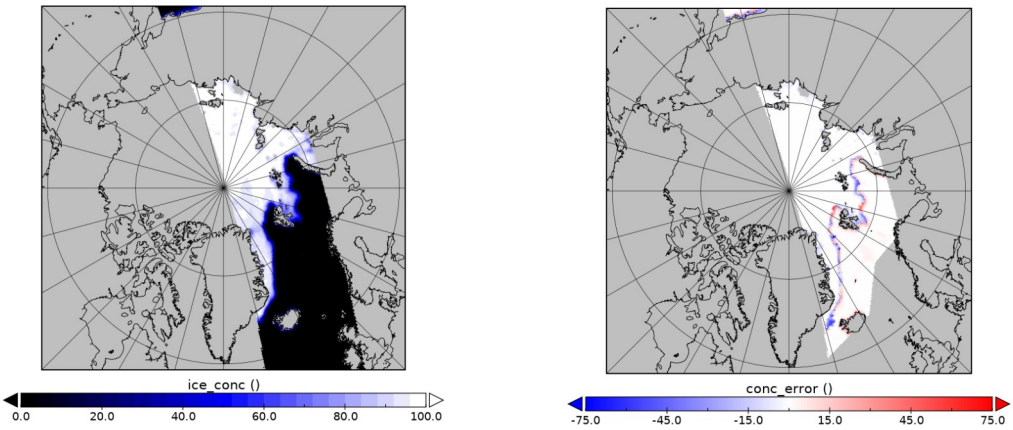

Figure 2: The OSI SAF SSMIS Level 2 ice concentration (left) and the difference between the ice concentration and the ice chart, Δ, for the Northern Hemisphere swath on 2018-01-04 07:37.

The individual Level-1 swaths, and therefore the Level-2 products, cover both hemispheres. Therefore, for each Level-2 product, two NetCDF files are generated containing the individual Level-2 products projected onto both Northern and Southern Hemisphere polar-stereographic grids (the same grids as used for the ice charts) and it is these that are used in the validation. Figure 2 (left) shows an example of the projected swaths for the Northern Hemisphere.

For each ice chart, the deviation between ice chart ice concentration and OSI SAF product ice concentration is calculated for all the Level-2 products with time stamps of the same day. The deviation, Δ, of the ice concentration product from the ice chart is calculated as follows:

$$\Delta = \begin{cases} \mathrm{ch}_{upper} - \mathrm{ic} & \mathrm{ic} \geqslant \mathrm{ch}_{upper} \\ 0 & \mathrm{ch}_{lower} < \mathrm{ic} < \mathrm{ch}_{upper} \\ \mathrm{ch}_{lower} - \mathrm{ic} & \mathrm{ic} \leqslant \mathrm{ch}_{lower} \end{cases},$$

where ch_{upper} and ch_{lower} are the upper and lower limits of the ice chart respectively. In words, the deviation is zero if the OSI SAF ice concentration value is within the interval given by the ice chart, else the deviation is the difference between the value and the closest ice chart limit. Figure 2 (right) shows Δ for the Northern Hemisphere swath. Note that Δ is only computed where the climatological mask has not been applied.

The validation metrics given here are the standard deviation and bias for a given day, where the standard deviation is given by

$$\sigma = \sqrt{\left(\frac{1}{N-1}\sum_{N}^{i=1}(\Delta - \overline{\Delta})\right)},$$

where N is the number of pixels and $\overline{\Delta}$ is the mean deviation, i.e. the bias. The standard deviation and bias are computed for two ice classes: 0% and 100% ice concentration in the ice chart.

Some of the product files have very few ice or water pixels, due to the particular path of the swath. This can cause extreme standard deviation and bias values, and therefore these metrics are only used in the evaluation if there are more than 1000 pixels of a given class.

In addition to the biases and standard deviations, the "percentage match" values are computed. The deviations are grouped into two categories: ±10% and ±20%; which are, respectively, the percentage of ice concentration measurements within 10% and 20% and of Δ .

3.2. Product Requirements

Although other performance metrics are presented here, it is the *standard deviation,* averaged over one year, that is used for the *accuracy* metric, for which the optimal and target requirements are evaluated. The year 2018 was chosen for this evaluation.

4. Validation results

Both Northern Hemisphere (NH) and Southern Hemisphere (SH) are compared for the ice concentrations computed using both the OSI SAF and TUD algorithms, for the validation period, from 01 January 2018 to 31 December 2018, using the weekly ice charts. Note that the ice chart from 22 March 2018 was unavailable from the National Ice Centre, and so this day's ice chart is not used in the validation.

	Within 10%	Within 20%	Ice Bias	Ice Std.	Water Bias	Water Std.
NH AMSR2 OSI	90.36	94.11	-3.96	5.57	2.91	6.31
NH AMSR2 TUD	90.95	94.47	-2.74	4.41	3.06	6.63
NH SSMIS	88.07	93.03	-3.98	5.36	4.87	7.96
SH AMSR2 OSI	87.48	93.18	-12.44	11.07	0.82	2.91
SH AMSR2 TUD	89.24	93.56	-11.51	11.51	0.81	2.96
SH SSMIS	87.36	93.22	-11.64	10.34	0.95	3.36

Table 1 : Metrics summarising the performance of the TUD and OSI SAF algorithms, in the Northern and Southern Hemisphere (NH and SH respectively) for the validation period of 2018. As explained in the text, the following metrics are given: the mean grid points within a 10% and 20% match; the mean difference between the product and the reference, split into open water, ice regions; and the mean standard deviation, also by region.

Table 1 contains the yearly mean of the individual swath comparisons, where the swath has been split into Northern and Southern Hemispheres, within the validation period. For all instruments and algorithms, the accuracy is better for the Northern Hemisphere than for the Southern. The results are discussed further in Section 5.

Plots of validation statistic are shown in the Appendix. Figures 5, 7 and 9 show plots of the percentage match. There are multiple percentage match values for each day (two for each Level-1 swath, as the swaths are split into Northern and Southern Hemispheres and there are multiple Level-1 swaths for a given day) for which there is an ice chart; however, it is not possible to distinguish the individual percentage match values in these plots and it is difficult to present this information for all the swaths in

such a bar plot. In Figure 3, which shows the results for only three days, it is possible to distinguish the individual percentage match values.

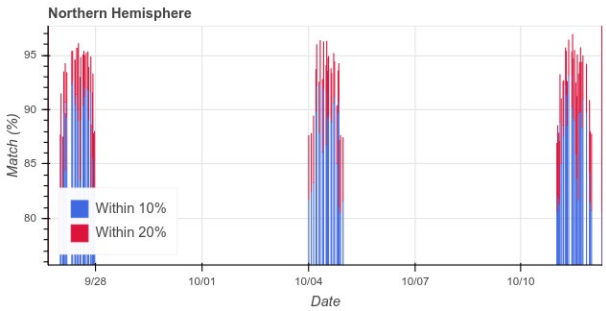

Figure 3: The percentage match for three days for the SSMIS Level 2 product.

Figures 4, 6 and 8 show the bias and standard deviation values for the individual swaths, covering the Northern and Southern Hemispheres, for both the ice and water classes, for each of the validations. For each ice chart, multiple bias and standard deviation values are calculated, which correspond to each of the Level-2 swaths, for that day's ice chart, split into Northern and Southern Hemispheres. For many of the days, there is a large spread of bias and standard deviation values. This is due to the statistics being calculated on relatively few pixels (compared to a Level-3 product validation) for each Level-2 swath on the given hemisphere, and a correlation, in both the product and ice chart, of nearby pixel values.

5. Conclusions

The target accuracy requirement for the OSI-410 product is 10% for the NH-product and 15% for SH-product (yearly average – for both the TUD and OSI SAF algorithm computed ice fields). Three ice concentration fields were validated for the Level-2 product; one for the SSMIS based product, and two for the AMSR2 (from two different algorithms). The target requirements are meet for each of the ice concentration fields evaluated, and, within the limits of the reference (ice chart) data, it can be said that the performance of each is similar according to the metrics which were used in the evaluation.

The tolerance is larger for the Southern Hemisphere product, since there are typically more intermediate concentrations there, which is more difficult to estimate in the ice chart. For all the ice concentration fields, the product is more accurate in the winter than the summer. The main sources of error in the ice concentration measurements are atmospheric noise and melt ponds on the ice (which have a similar signal to open water). Melt ponds (which occur most frequently during the summer) are the main reason for the worse performance during the summer.

The pixelwise evaluation (percentage match) shows a similar result for both hemispheres and for each of the ice concentration fields. The ice bias and standard deviation values are much worse in the Southern Hemisphere than the Northern for the three set of ice concentration fields; there is an overall

bias and standard deviation (grand bias and grand standard deviation) of -11.86 % and 10.97 %, respectively, in the Southern Hemisphere compared to -3.56 % and 5.11 % in the Northern. However, when considering only the water class statistics, the product performs better in the Southern, with a grand bias and grand standard deviation, across the three ice concentration fields, of 0.86 % and 3.08 %, respectively.

Appendix

SSMIS, OSHD Algorithm

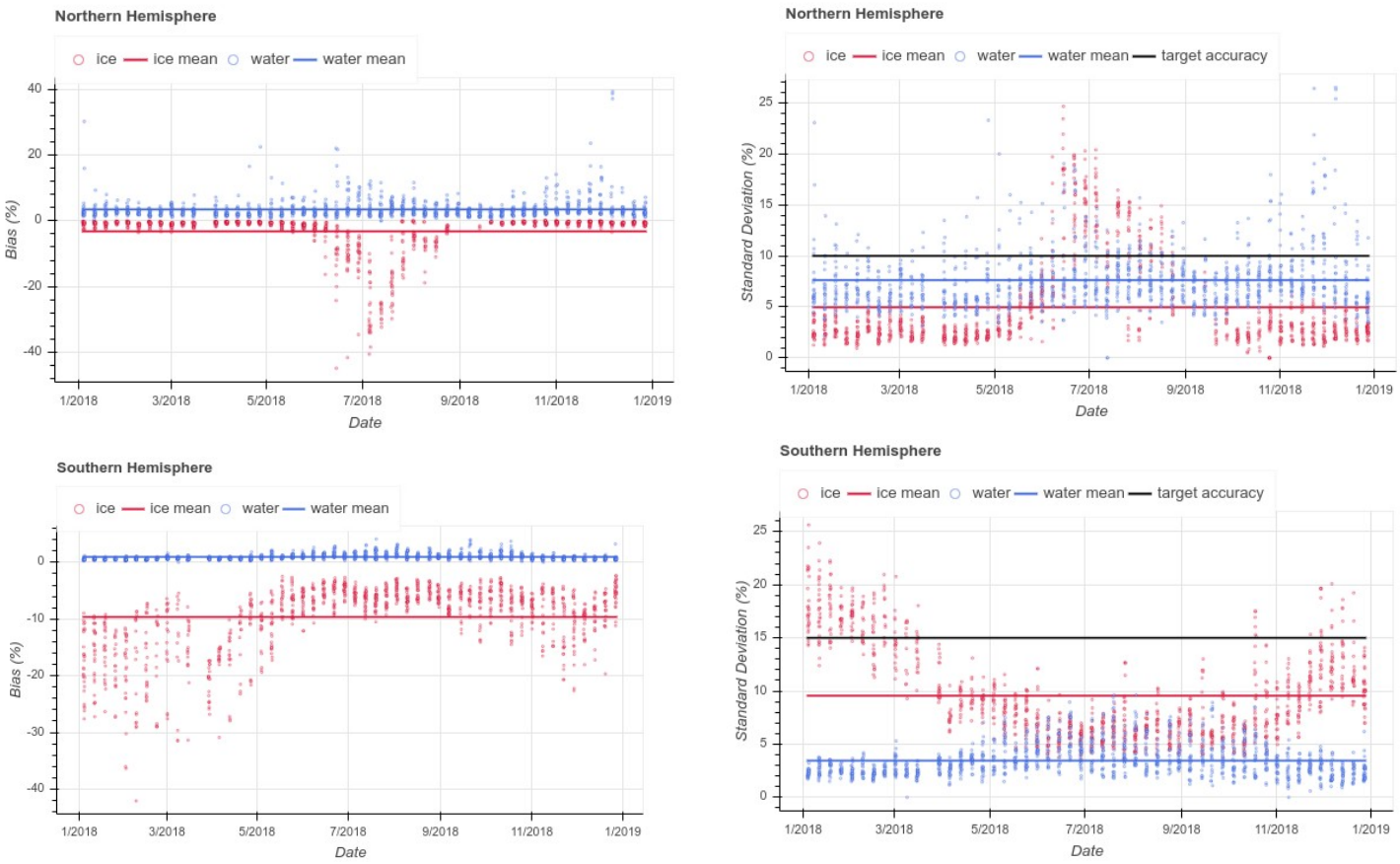

Figure 4: Daily validation results, showing bias (left) standard deviation (right) for the Northern (top) and Southern (bottom) Hemispheres, together with the mean values for the year.

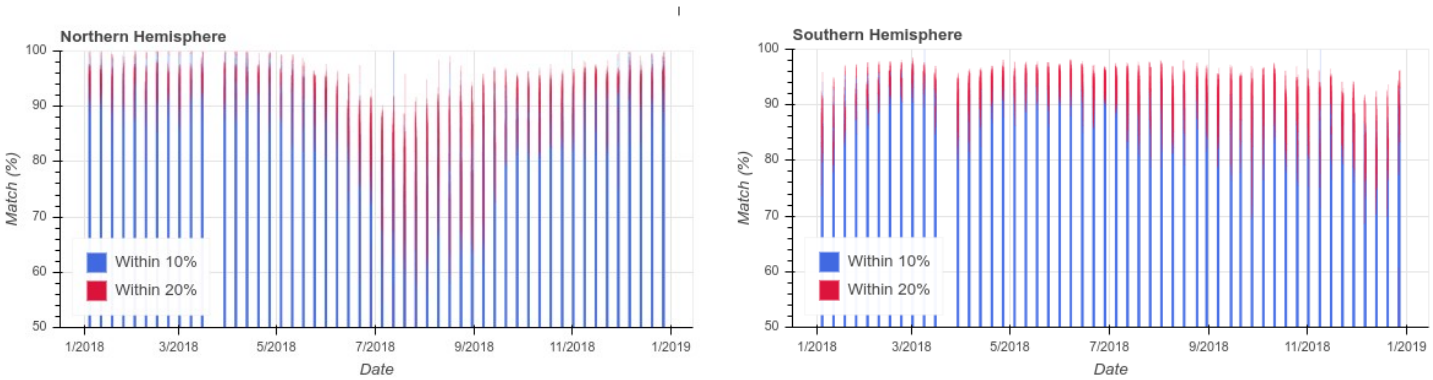

Figure 5: The percentage match values for the Northern Hemisphere (left) and the Southern Hemisphere (right).

AMSR2, OSI Algorithm

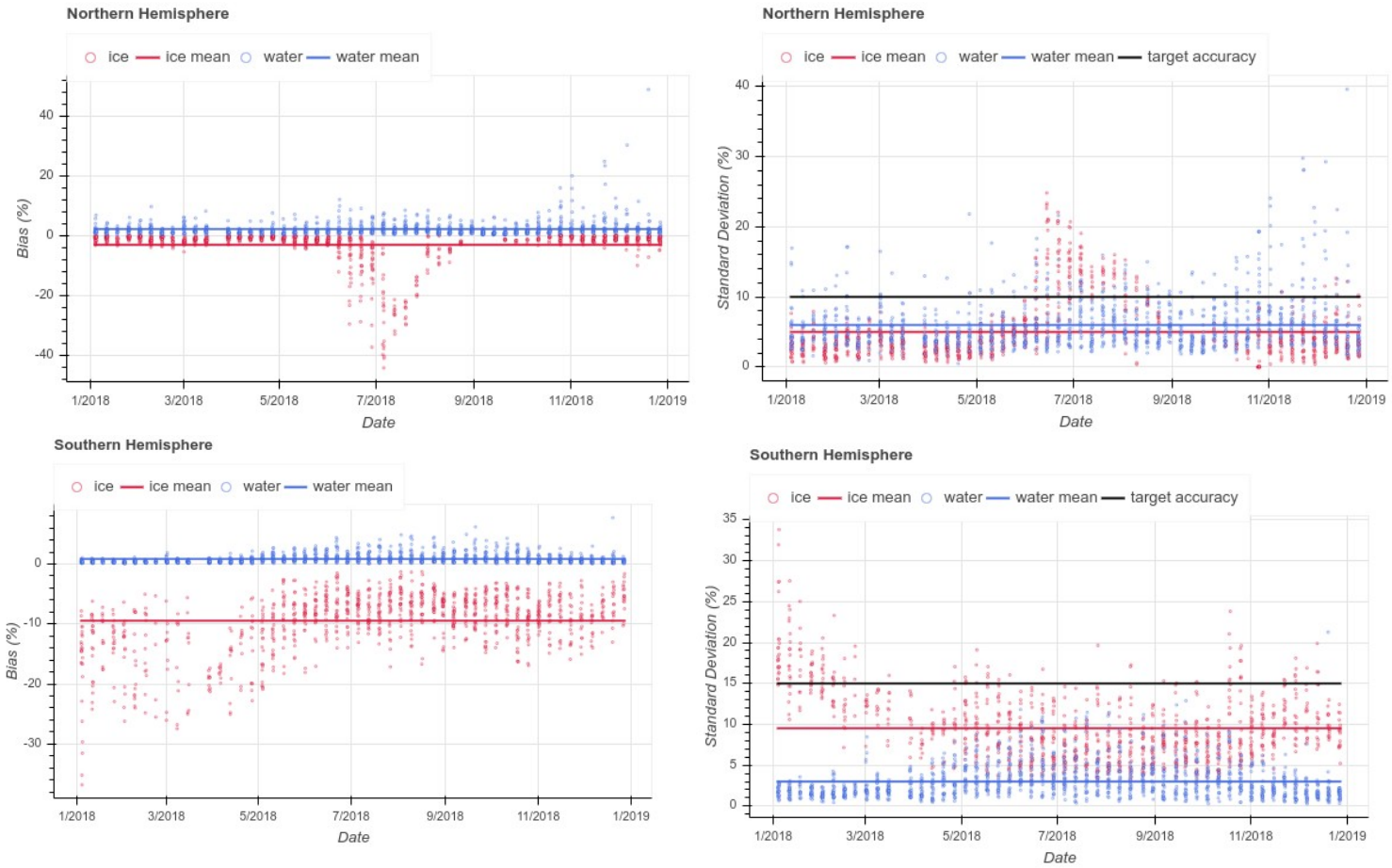

Figure 6: Daily validation results, showing bias (left) standard deviation (right) for the Northern (top) and Southern (bottom) hemispheres, together with the mean values for the year.

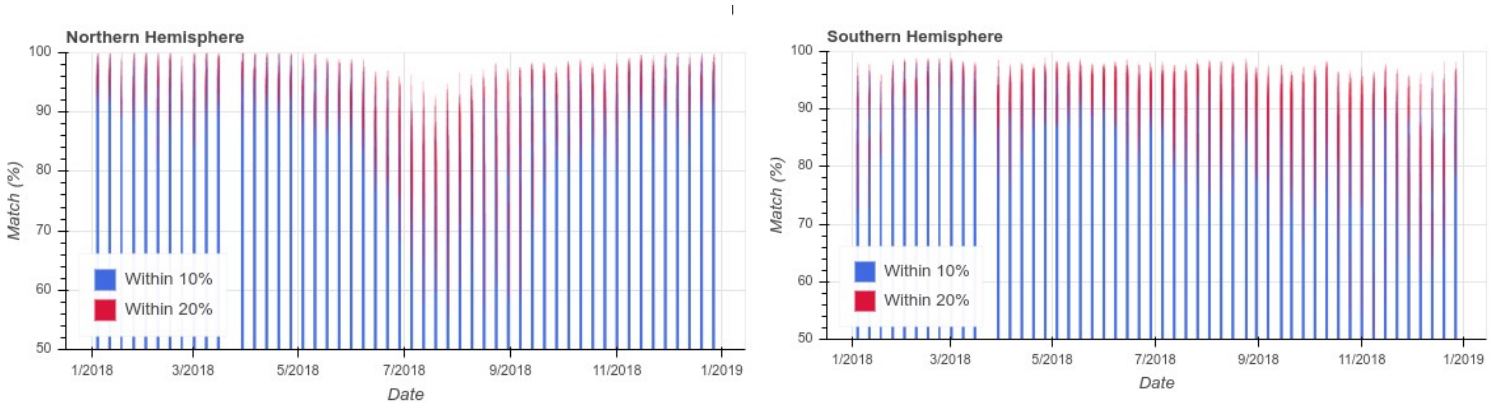

Figure 7: The percentage match values for the Northern Hemisphere (left) and the Southern Hemisphere (right).

AMSR2, TUD Algorithm

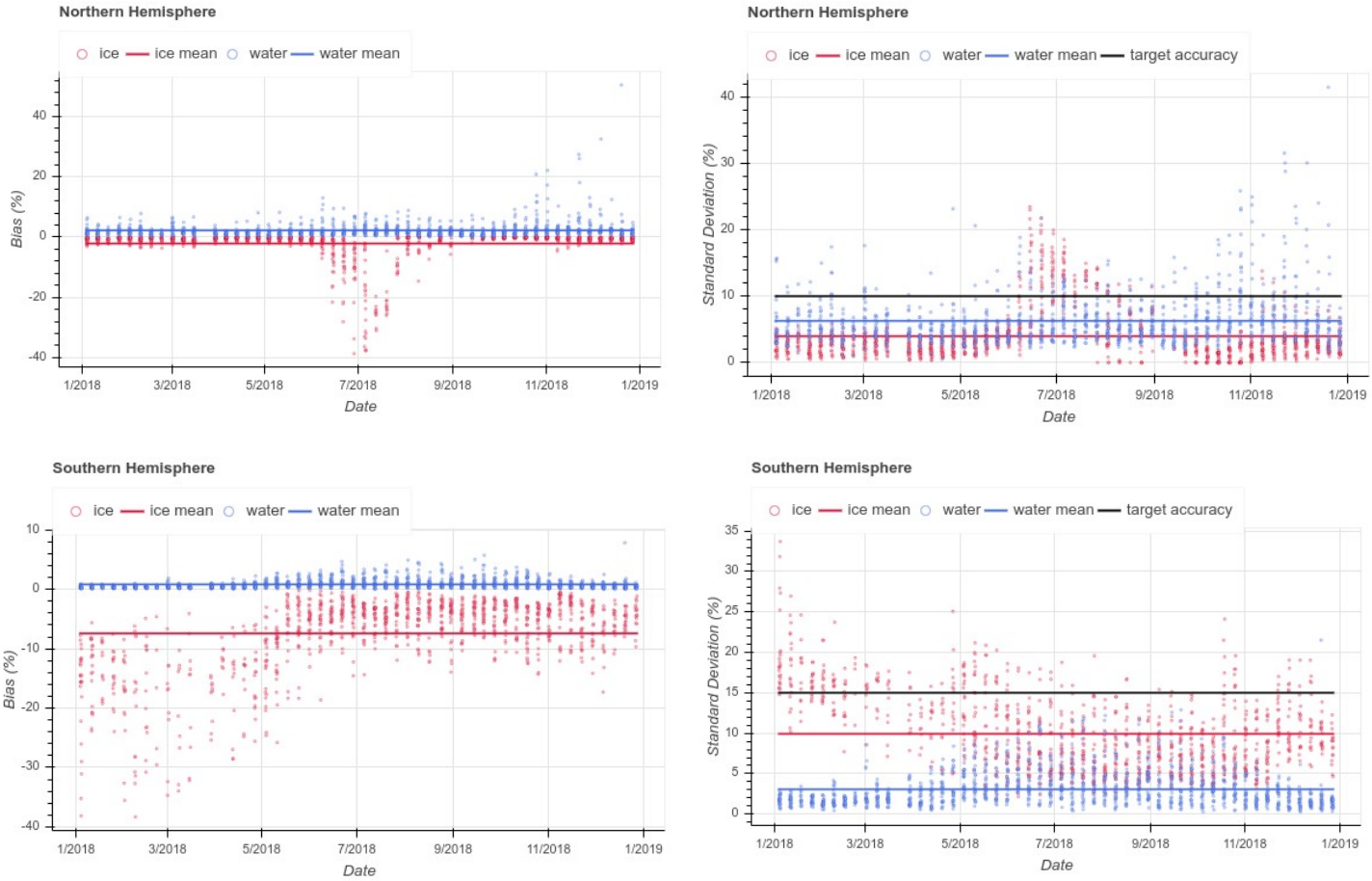

Figure 8: Daily validation results, showing bias (left) standard deviation (right) for the Northern (top) and Southern (bottom) hemispheres, together with the mean values for the year.

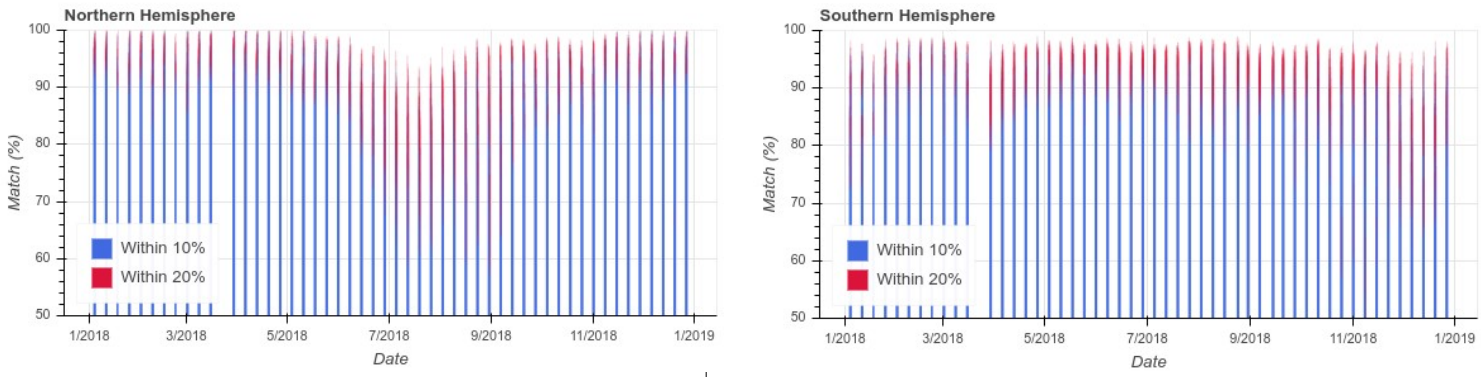

Figure 9: The percentage match values for the Northern Hemisphere (left) and the Southern Hemisphere (right).