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OSI SAF

Ocean and Sea Ice

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Validation Report for OSI SAF Global Sea Ice Concentration

Product OSI-401-b

Version 1.2

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Documentation Change Record

Document version	Software version	Date	Change description
V 1.0 draft	V 1.0	05.02.2015	First version.
V 1.0	V 1.0	29.04.2016	Updates after ORR review
V 1.1	V 1.2	15.01.2016	Updated after masks modified
V 1.2	V 1.3	18.04.2017	Updated with information on filtered product

The software version number gives the corresponding version of the OSI SAF High Latitude software chain which was used to produce the sea ice concentration product.

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1 Introduction

1.1 Scope of the document

This report presents the validation results of the OSI SAF global sea ice concentration product OSI-401-b version 1.3.

The OSI-401-b product introduced improvements to the global sea ice concentration product OSI-401-a through the use of dynamical tie-points and uncertainty estimates. The use of dynamical tie-points will both improve the quality of the product and simplify the implementation of future instruments and is therefore an investment for the future. The improvements are explained in more detail in [RD-1] and [RD-2].

A new *filtered* sea ice concentration variable is introduced in the OSI-401-b version 1.3 product. This filtered variable is introduced to remove spurious ice. Spurious ice can occur in the OSI SAF sea ice concentration fields, due to weather effects and the uncertainty of the measurement over open water. The spurious ice is problematic for some users. The filtered product removes this spurious ice, at the cost of also removing some valid ice.

The unfiltered ice concentration product is available in the product files, in addition to the filtered. The validation in this report is carried out for the OSI-401-b sea ice concentration level product (i.e. the unfiltered product), which is the same as OSI-401-b version 1.2 product, except the OSI-401-b version 1.3 product has a extra variables containing the filtered sea ice concentration and the masks applied. An analysis of the differences between the filtered and unfiltered is given in Section 5.

This 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. Validation is carried out as a comparison between 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.

1.2 Reference documents

[RD-1] : OSI SAF Global Sea Ice Concentration Product User Manual.

[RD-2] : OSI SAF Product Requirement Document.

1.3 Definitions, acronyms and abbreviations

AVHRR	Advanced Very High Resolution Radiometer
DMI	Danish Meteorological Institute
DMSP	Defence Meteorological Satellite Program
FTP	File Transfer Protocol
IAC	Ice chart analysis
MODIS	Moderate Resolution Imaging Spectroradiometer
NH	Northern Hemisphere
NIC	National Ice Center
OSIC	OSI SAF ice concentration
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
WMO	World Meteorological Organization

2 Validation dataset

The OSI SAF sea ice concentration products are distributed freely through the OSI SAF Sea Ice FTP server.

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

Sensor	Launch	End
DMSP F16 SSMIS	October 2003	Present (OSI-SAF data introduced on 21 January 2013)
DMSP F17 SSMIS	December 2006	Present

List of ice charts and their availability in the validation period January 14 2013 to January 14 2014:

Hemisphere	Institute	Frequency
South	National Ice Center: www.natice.noaa.gov/	Every two weeks until 15 Oct., then weekly.
North	DMI: www.dmi.dk/en/groenland/hav/ice-charts	Twice a week

3 Validation methodology

3.1 Ice chart data

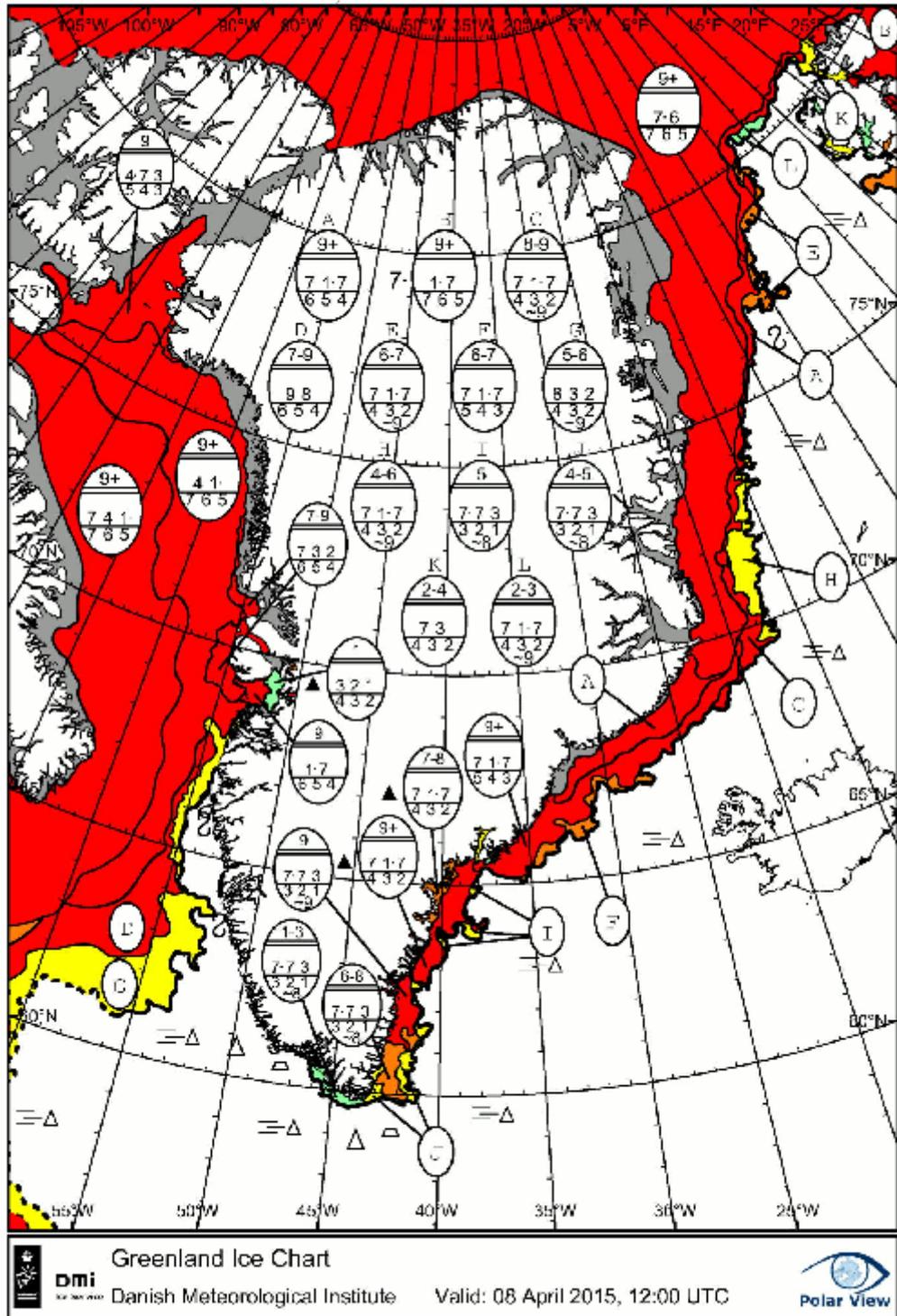
The operational sea ice charts from the Danish Meteorological Institute (DMI) and the National Ice Center (NIC) are a relatively independent source of ice information for comparing to the OSI SAF ice concentration product. The ice charts, intended for aiding navigation, are produced on a regular basis covering all seasons, both Southern and Northern hemispheres and for the entire validation period 14 Jan 2013 – 14 Jan 2014.

Ice charts are produced manually on the basis of 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 (experienced and trained) 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 partly on satellite SAR data e.g. Radarsat-2 since 2008, together with visual/infrared line scanners e.g. AVHRR, MODIS, whenever daylight and cloud cover conditions allow. Also the passive microwave data from SSMIS used in the OSI SAF ice concentration product have possibly been used as background in the manual analysis for making the NIC 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 DMI ice charts are produced two times a week. The NIC 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 date of validity even though the data input can be from various dates within the week. The OSI SAF ice concentration is compared to this specific day. A comparison between Greenland and Norwegian ice charts and OSI SAF sea ice concentration shows large differences between the different products with 10-25% standard deviation of the difference between Greenland ice charts and the OSI SAF ice concentration, 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%. The analysis is described in:

<http://www.myocean.eu/documents/QUID/MYOF-OSI-QUID-SEAICE-V1.10.pdf>

The Greenland ice charts are covering Greenland waters as seen in the figure below.



3.1.1 Representation of ice chart information

The NIC and DMI ice chart and the OSI SAF concentration product are gridded onto a common projection and resolution. Following this a cell by cell comparison is carried out. For each ice chart concentration level the deviation between ice chart concentration and OSI SAF ice concentration is calculated. Afterwards deviations are grouped into categories, i.e. $\pm 10\%$ and $\pm 20\%$. Furthermore the bias and standard

deviation is calculated for each concentration level. The bias and standard deviation are reported for *ice* (> 0% ice concentration), for *water* (0% ice concentration) and for both ice and water as a *total*. The standard deviation is the measure for the target accuracy in [RD-2].

3.1.2 Validation parameters

The OSI SAF ice concentration is compared with the SIGRID total ice concentration of the ice charts. SIGRID is the WMO standard for describing ice in ice charts. The total ice concentration SIGRID variable used for comparison is the total ice concentration given by the ice chart. The total concentration is an ice concentration interval where the average of the interval bounds is used in the comparison with the OSI SAF ice concentration. The ice charts are compared with OSI SAF polar stereographic ice concentration product.

The parameters shown in the validation plots are defined as follows. The ice chart analysis concentration will be referred as IAC and OSI SAF ice concentration as OSIC:

Parameter	Description
match_10_pct	The fraction of points where IAC shows ice and OSIC is within $\pm 10\%$ of the IAC
match_20_pct	The fraction of points where IAC shows ice and OSIC is within $\pm 20\%$ of the IAC
total_bias	Average of OSIC – IAC for all valid points
ice_bias	Average of OSIC – IAC for all points where IAC shows ice
water_bias	Average of OSIC – IAC for all points where IAC shows water
total_stddev	Standard deviation of OSIC – IAC for all valid points
ice_stddev	Standard deviation of OSIC – IAC for all points where IAC shows ice
water_stddev	Standard deviation of OSIC – IAC for all points where IAC shows water

3.1.3 Masking of data near land

Land spillover affected data near the coast in regions, such as the Baltic, where the water is surrounded, or partly surrounded, by land. These regions are masked out.

Data is provided for the central region of lakes that have sufficiently large dimensions for the central region measurements to have low spillover noise. In Figure 1, the plots of ice concentration for the 25 February 2015 (with ice on the Lake Superior) and Lake Huron and 05 January 2016 (with the lakes ice free) correspond to measurements given on the U.S. National Ice Centre Naval Ice Center's website. As the sea ice algorithm has been applied to lakes, these measurements should be treated with caution, and only used as indicative of the presence of ice. The lake ice measurements are not used for validation given in this report.

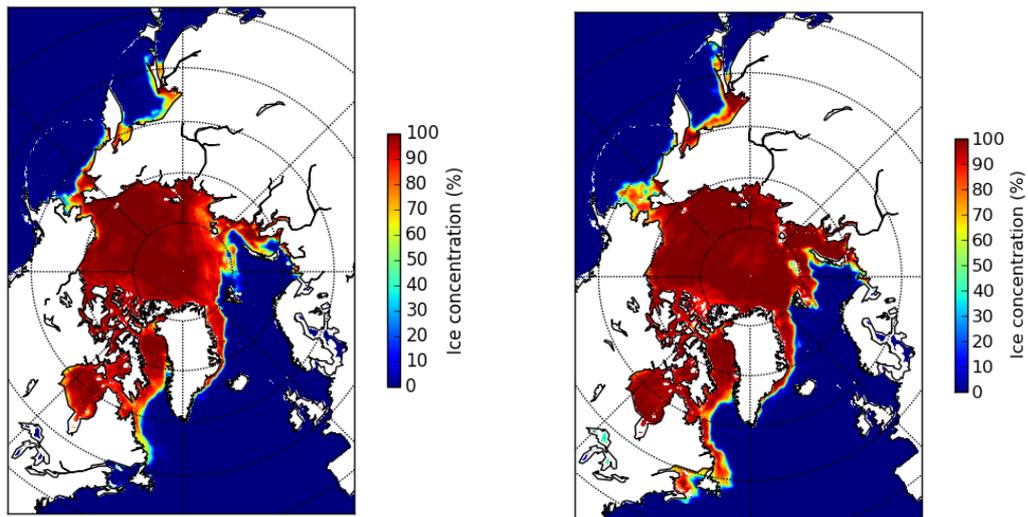


Figure 1: The ice concentration at the Northern Hemisphere on 25 February 2015 (left) on 05 January 2016 at the (right)

3.2 Product Requirements

The OSI SAF product requirement document states about the sea ice concentration product that:

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. This improvement is not reflected in the comparison with ice charts.

Further, the specific product requirements listed in the table OSI-PRD-PRO-200 are addressed in the conclusions.

4 Validation results

4.1.1 Comparison of the OSI-401-b product with DMI ice charts for Northern Hemisphere

Figures below show the comparison between Danish Meteorological Institute (DMI) ice charts for Northern Hemisphere (NH) and the OSI SAF ice concentration product for the validation period of the OSI-401-b product from January 2013 to January 2014.

Figure 1, displaying the match between ice chart and OSI SAF ice concentrations, shows a clear seasonal cycle with 80% to 90% of matches within 10% of each other during Arctic winter and only 40% to 60% during summer, June – August. On an annual mean the criterias are met. Uncertainties in the sea ice concentration product and the ice chart are larger during summer. This is clearly reflected in the product uncertainty estimate during summer.

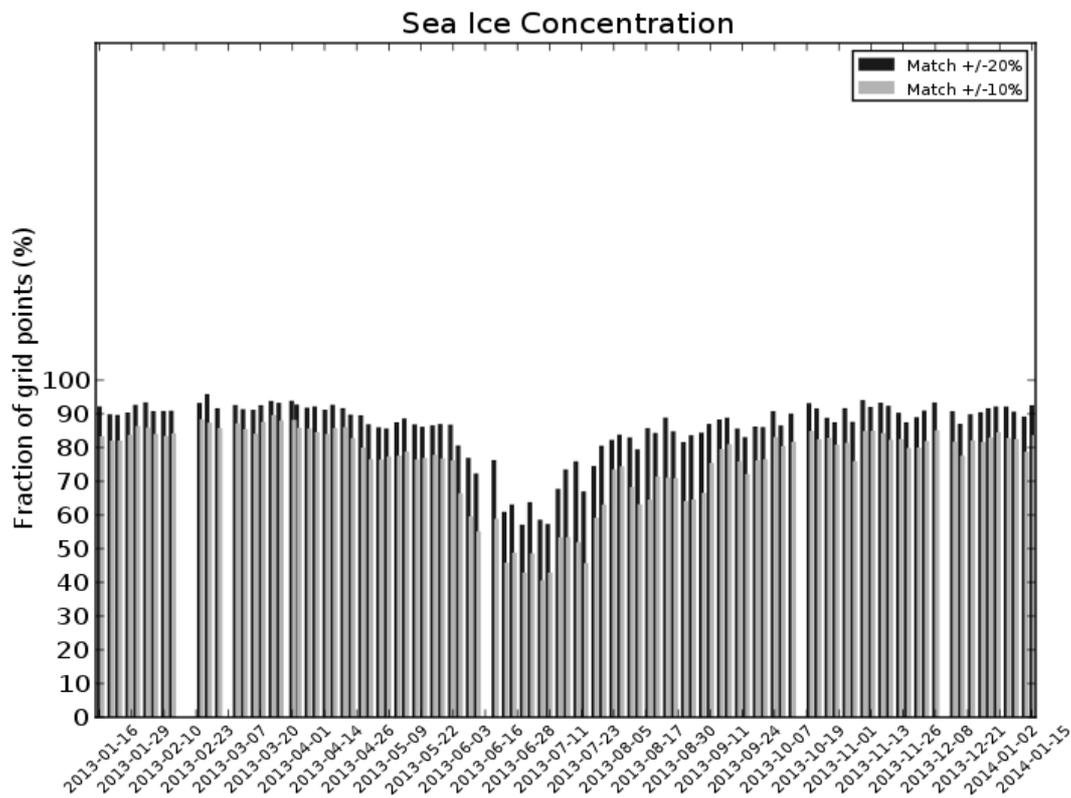


Figure 2: Comparison between DMI ice charts and OSI-SAF ice concentration, for the validation period. The grey and the black bars show the percentage of cases where the two products match within by 10% and 20%, respectively.

Figure 2, displaying the bias between the ice chart and OSI SAF ice concentrations, shows that the OSI SAF ice concentrations are higher than ice chart ice concentrations over open water (blue curve). This is due to the fact that the radiometer ice concentration is affected by atmospheric noise which increases the ice concentration above zero, see ATBD [RD-1]. The ice charts have a nominal value of zero over open water. The ice bias (OSI SAF minus ice chart) has a clear seasonal cycle with a larger summer bias, of 17% in June – August and a stable negative bias around 5% over the rest of the year. The large summer differences are due to melt ponds on the ice, which looks as open water in the SSMIS dataset.

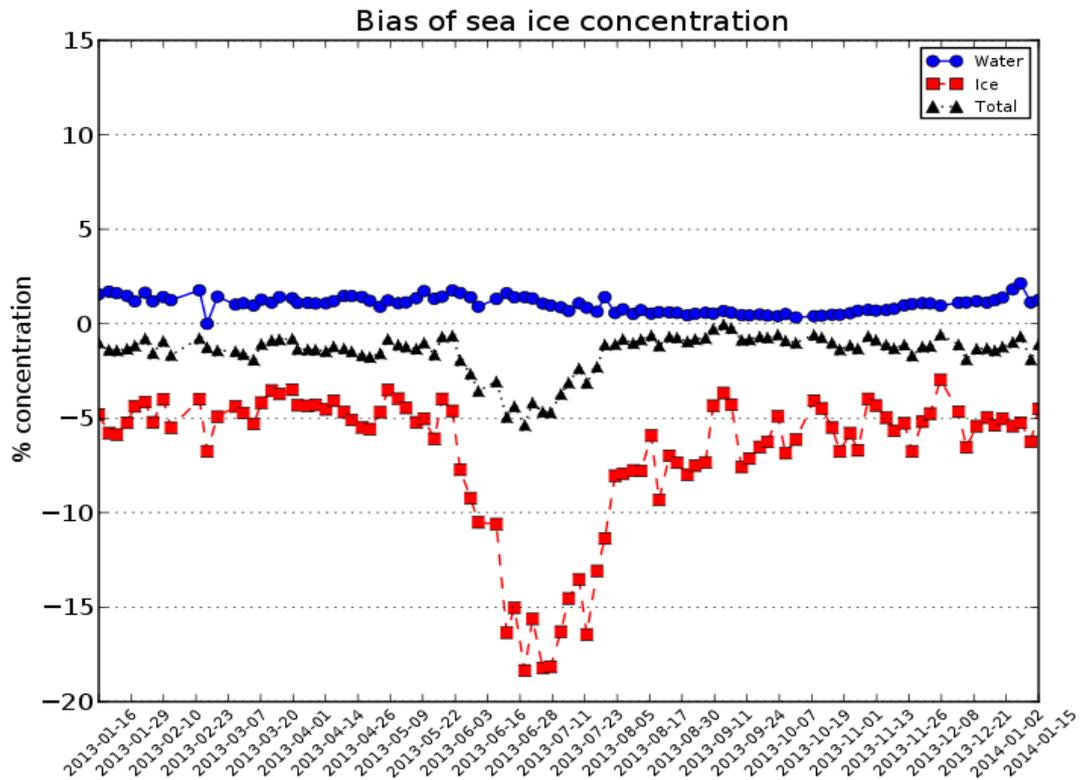


Figure 3: The total bias between DMI ice charts and OSI-SAF ice concentration, for the validation period (OSI SAF ice concentration minus DMI ice charts). The total bias is shown with the black curve, the negative bias in ice covered regions with the red curve and the positive bias in water areas with the blue curve.

Figure 3, displaying the standard deviation of the difference between the ice chart and OSI SAF ice concentrations, shows that there is a clear seasonal cycle with higher standard deviations during April to August than during the rest of the year over ice. The total standard deviation (black curve) yearly average is 10%.

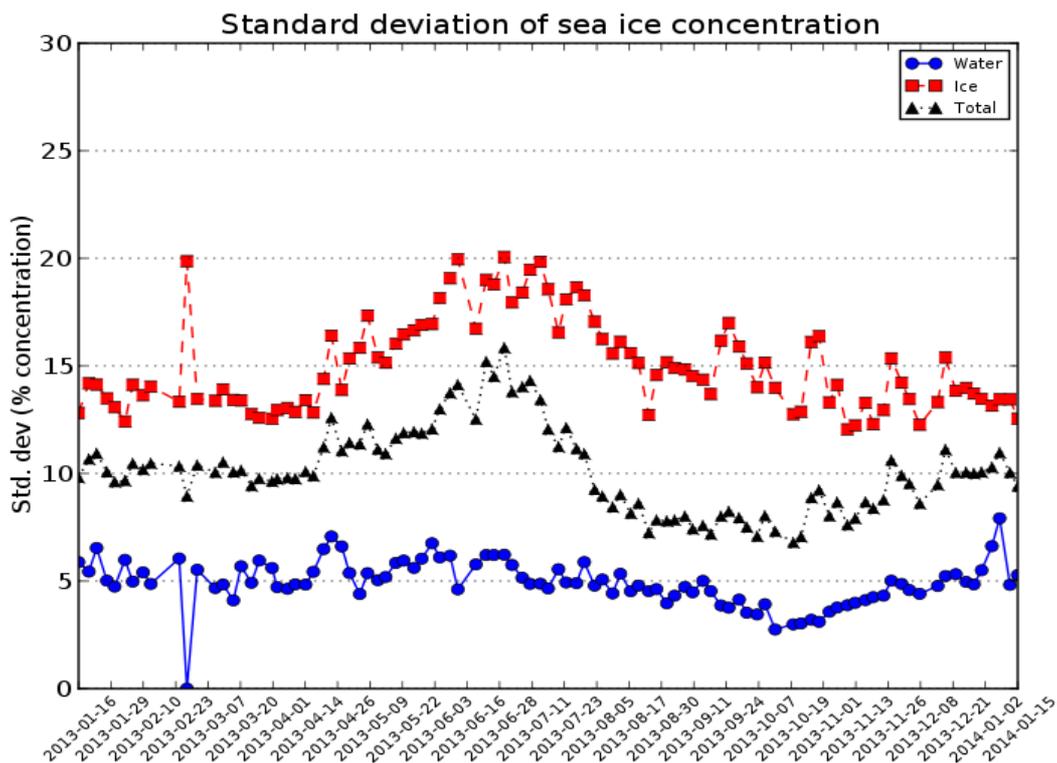


Figure 4: The standard deviation of the difference between the DMI ice charts and OSI-SAF ice concentration, for the validation period. The black curve shows the total standard deviation of the difference in ice concentration, for both ice and open water regions. The red and the blue curves show standard deviation of the difference for ice and water regions, respectively.

4.1.2 Comparison of the OSI-401-b product with National Ice Center (NIC) ice charts for Southern Hemisphere

Figures below show the comparison between National Ice Center (NIC) ice charts for Southern Hemisphere (SH) and the OSI SAF ice concentration product for the validation period from January 2013 to January 2014.

Figure 4, displaying the match between ice chart and OSI SAF ice concentrations, shows a clear seasonal cycle with 60% to 80% of cases matches within 10% during Antarctic winter (June - August) and only 40% to 70% during the melt season, December – February. The gaps in the data in the Figure are due to missing NIC ice charts. The comparison is made every time there is a NIC ice chart.

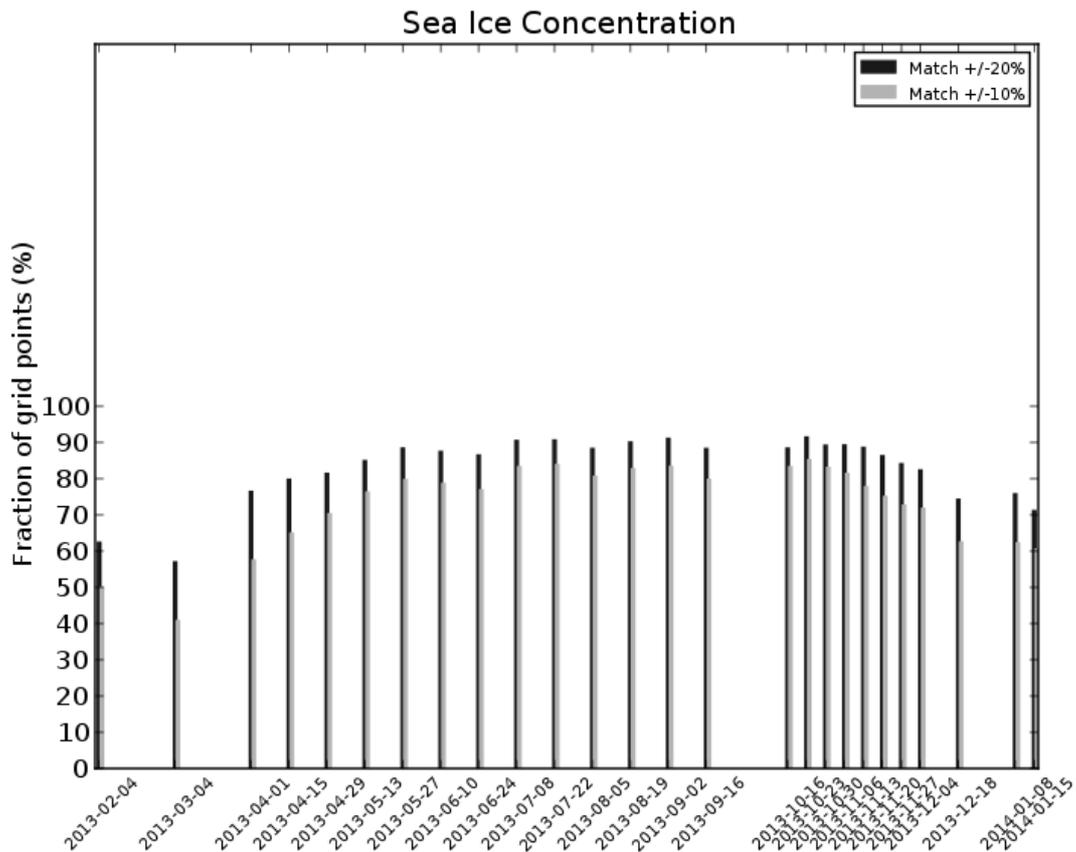


Figure 5: Comparison between NIC ice charts and OSI SAF ice concentration, for the validation period. The grey and the black bars show the percentage of cases where the two products match within 10% and 20%, respectively.

Figure 5, displaying the bias between the ice chart and OSI SAF ice concentrations, shows that the OSI SAF ice concentrations are slightly higher than ice chart ice concentrations over open water. This is due to the fact that the radiometer ice concentration is affected by atmospheric noise which increases the ice concentration above zero. The ice charts has a nominal value of zero over open water. The water bias is smaller than for the Northern Hemisphere comparison which is most likely due to the difference in proportion of coastal zone to ocean waters and atmospheric conditions. The very small open water bias shows that the dynamical tie-points and the atmospheric correction are performing well in the Southern Hemisphere. The ice bias has a clear seasonal cycle with a negative winter bias around 7% and larger summer bias, of 20% in December – February. The sea ice concentration estimates are affected by emissivity changes in the snow pack during melt.

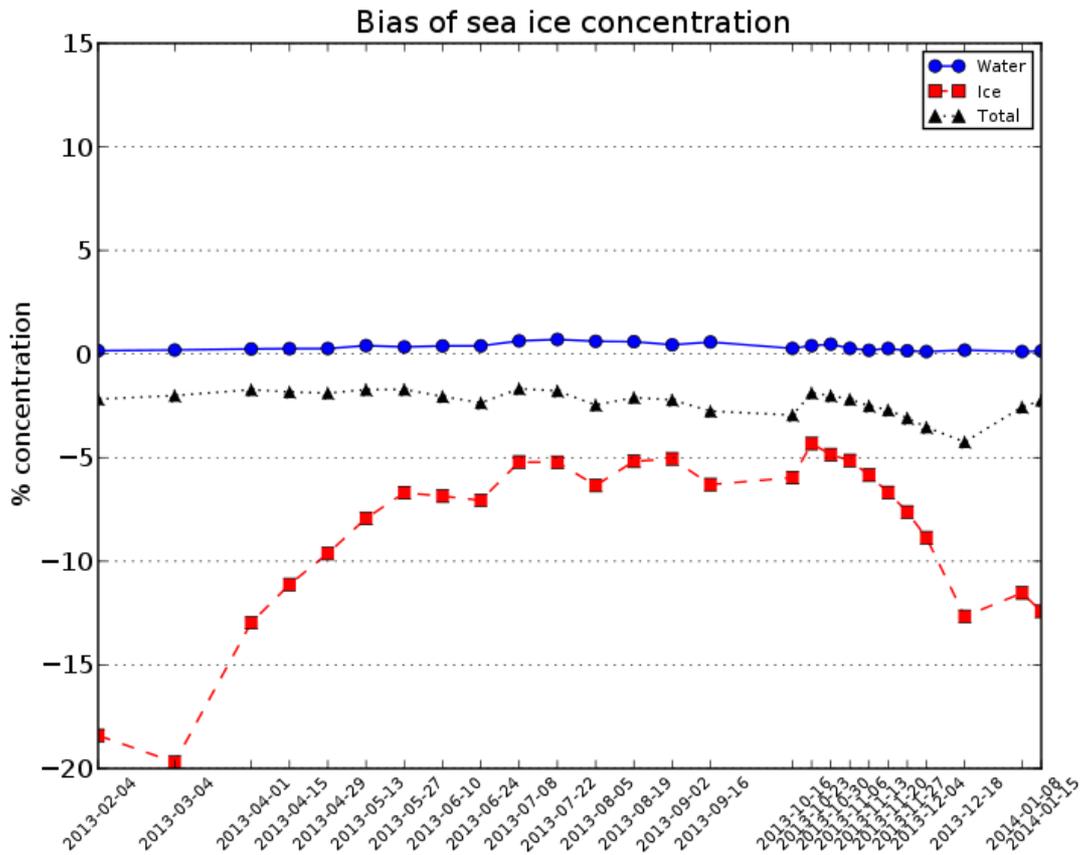


Figure 6: The total bias between NIC ice charts and OSI SAF ice concentration, for the validation period (OSI SAF ice concentrations minus NIC ice charts). The total bias is shown with the black curve, the negative bias in ice covered regions with the red curve and the positive bias in water areas with the blue curve.

Figure 6, displaying the standard deviation of the difference between the ice chart and OSI SAF ice concentrations, shows that there is a clear seasonal cycle with higher standard deviations during summer than during winter. For the water standard deviation (blue curve) is higher during winter than during summer. The total standard deviation (black curve) yearly average is 9%.

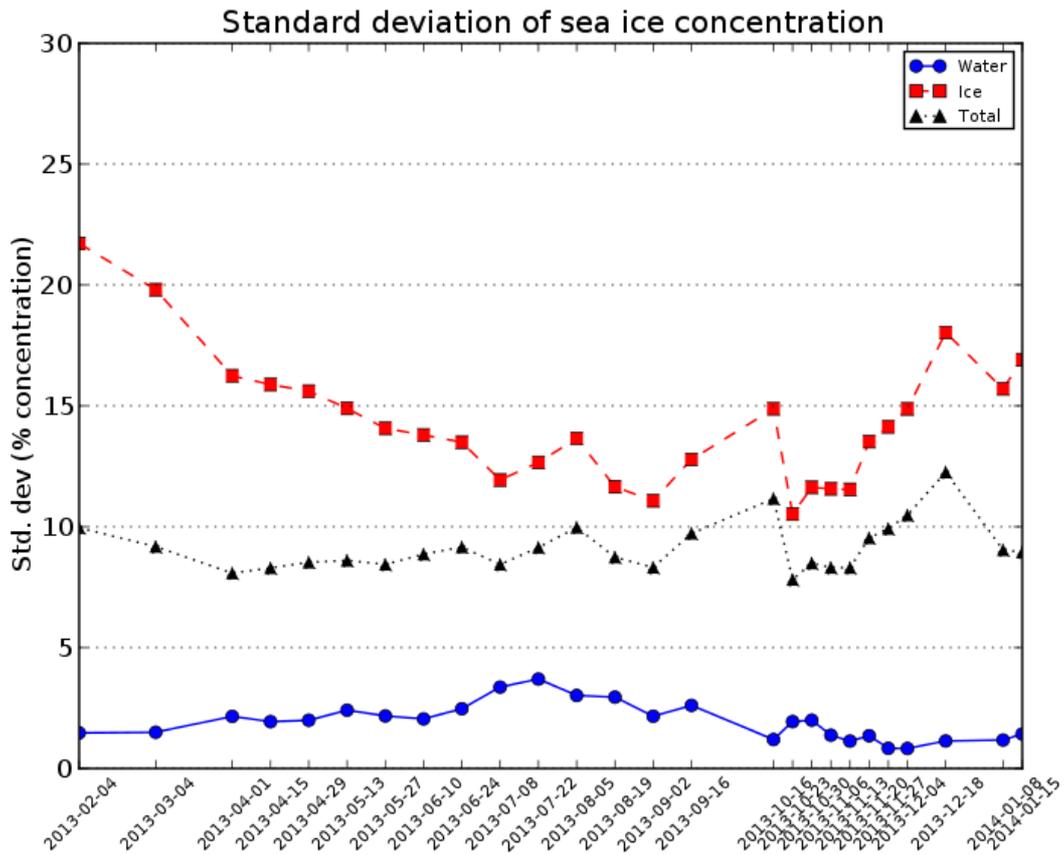


Figure 7: The standard deviation of the difference between the NIC ice charts and OSI SAF ice concentration, for the validation period. The black curve shows the standard deviation of the difference in ice concentration for both ice and open water regions. The red and the blue curves show standard deviation of the difference for ice and water regions, respectively.

5 The Filtered Product

In the OSI-401b version 1.3. product, the filtered ice concentration is given, in addition to the unfiltered ice concentration, in the product's netCDF and HDF5 files. Here, the filtered and unfiltered ice concentration fields are compared by analysing the reprocessed ice concentration fields from 2015-01-01 to 2015-12-31.

A mask used to filter out spurious ice. It is created from a combination of four masks:

- The Open Water Filter mask
- The 2 m air temperature mask
- The climatology mask
- The land mask

For the Open Water Filter, a gradient threshold is applied to the dynamic tie-points, which tunes dynamically for the instrument and season. The threshold used in the Open Water Filter is 10 %. The Open Water Filter also removes some valid ice at the ice edge, in addition to spurious ice.

The 2 m temperature mask removes ice where the air temperature at 2 m is greater or equal to 7 °C .

The climatology mask is based on historical records and there is one for each month. The land mask has been dilated, in order to include a greater area near the coast, and thereby reduce the land spillover. Where any of the masks is true the effective mask, which is used to filter the product, is true. An example of the masks for a given day is shown in Figure 8.

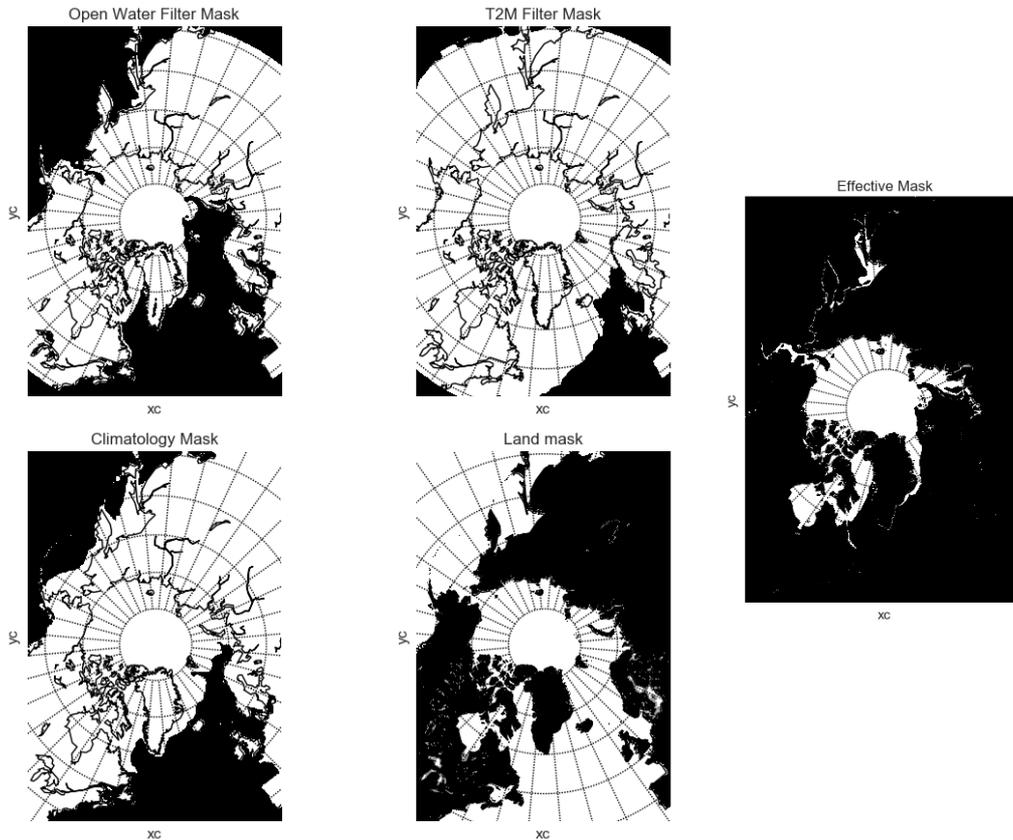


Figure 8: The four plots on the left show four masks used to filter the ice concentration product for 2016-12-20; they are combined to give the effective mask, used to filter the ice concentration product.

The Open Water Filter and 2 m temperature masks change on a daily basis, whereas, the climatology mask changes every month. Additional areas around Iceland, Denmark and Japan are masked out for this 2015 dataset in order to remove noise in those areas. These areas will be unmasked if the ice extends to these regions in the future.

In the following subsections, the difference between the filtered and unfiltered sea ice concentration is analysed. The difference in sea ice concentration is given by

$$diff_{xy} = unfilt_{xy} - filt_{xy} \quad \text{Equation 1}$$

where $unfilt_{xy}$ and $filt_{xy}$ are the unfiltered and filtered ice concentration fields, with coordinates x and y , respectively. The percentage of sea ice concentration removed is given by

$$removed = 100 \frac{\sum_{x=1}^{n_x} \sum_{y=1}^{n_y} diff_{xy}}{\sum_{x=1}^{n_x} \sum_{y=1}^{n_y} unfilt_{xy}} \quad \text{Equation 2}$$

5.1 The difference in sea ice concentration in the Northern Hemisphere

5.1.1 Analysis of filtered ice concentration field maps

Figure 9 *left* and *right* show the ice concentration averaged across the timeseries of $diff_{xy}$ fields (given by Equation 1) and the right plot shows the maximum values across the timeseries of $diff_{xy}$ fields; the locations of where the ice is removed correspond to the locations of the ice edge and the spurious ice.

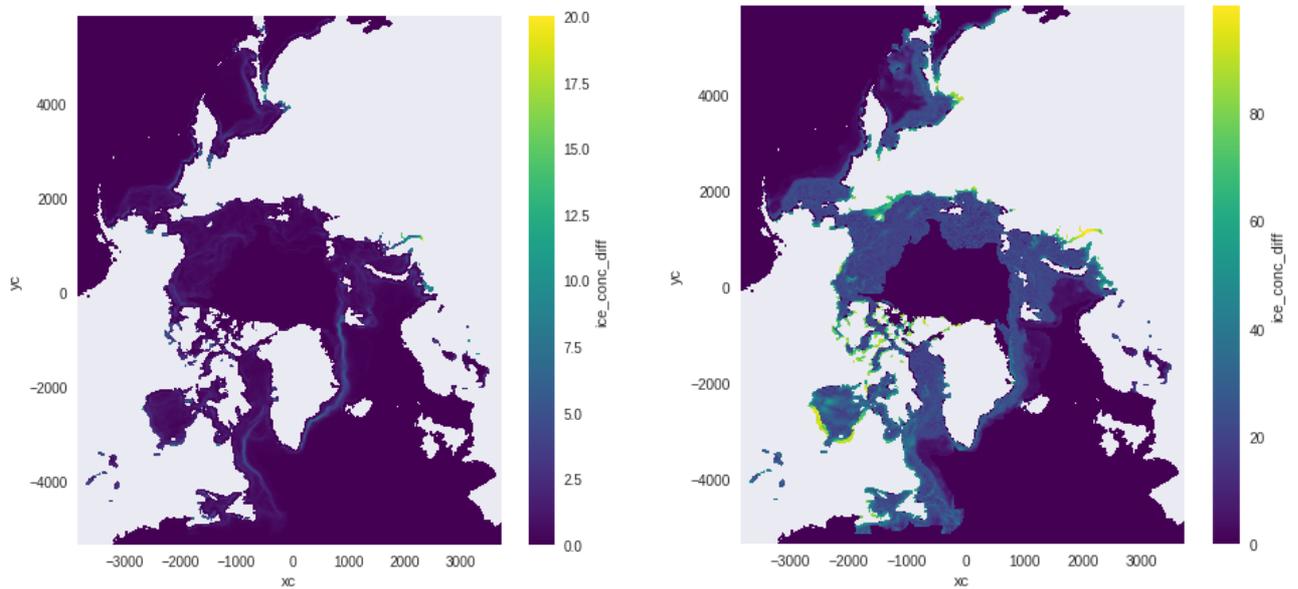


Figure 9: The difference between the filtered and unfiltered product, in the Northern Hemisphere. Left: The mean difference between the filtered and unfiltered sea ice concentration for all days in 2015. Right: The maximum difference between the filtered and unfiltered sea ice concentration for all days in 2015.

Figure 10 shows the unfiltered and filtered ice concentration maps and the difference between the two for a particular day. Spurious ice is removed east of Newfoundland and in the Sea of Okhotsk, in addition to valid ice from the the ice edge.

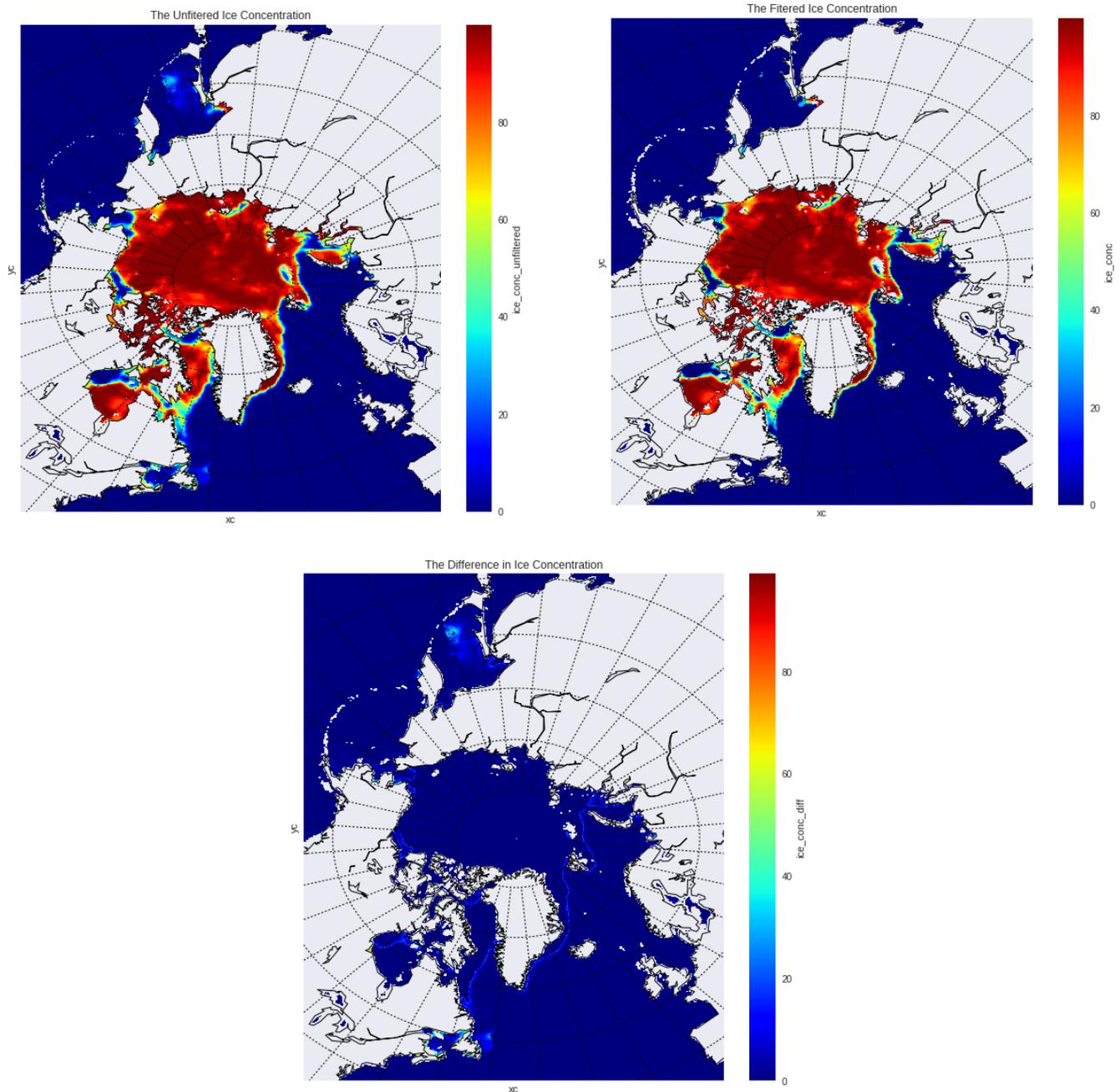


Figure 10: A comparison of the filtered and unfiltered sea ice concentration on the Northern Hemisphere for 2015-05-31. Top Left: the unfiltered percentage sea ice concentration. Top Right: the filtered percentage sea ice concentration. Bottom: the difference between the filtered and unfiltered percentage sea ice concentration.

Figure 11 shows the percentage of ice removed by the mask for each day in 2015, given by Equation 2. The percentage of ice removed is related to the length of the ice edge. More ice is removed in the summer, because the length of the ice edge is greater relative to the total sea ice area. The mean percentage of sea ice removed is 1.4 %.

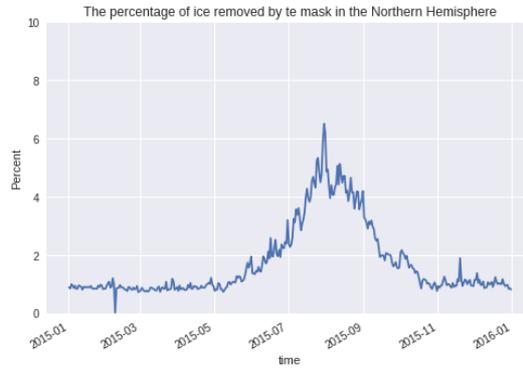


Figure 11: The percentage of sea ice concentration removed by filtering, for the Northern Hemisphere.

5.2 The difference in sea ice concentration in the Southern Hemisphere

Figure 12 *left* and *right* show the ice concentration averaged across the timeseries of $diff_{xy}$ fields and the right plot shows the maximum values across the timeseries of $diff_{xy}$ fields; the locations of where the ice is removed correspond to the locations of the ice edge.

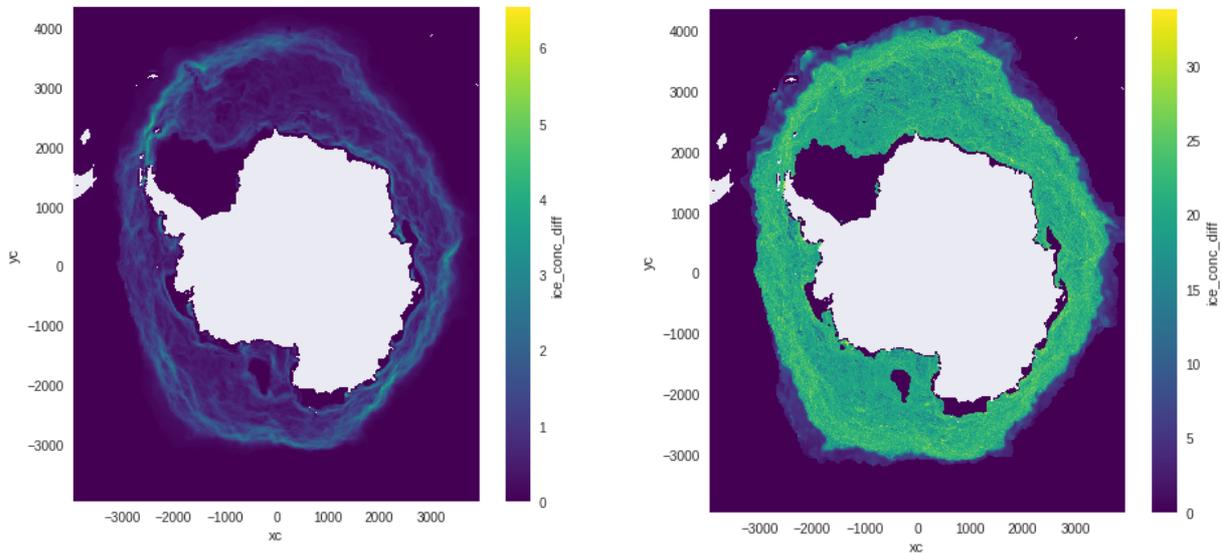


Figure 12: Plots showing the difference between the filtered and unfiltered product, in the Southern Hemisphere. Left: The mean difference between the filtered and unfiltered sea ice concentration for all days in 2015. Right: The maximum difference between the filtered and unfiltered sea ice concentration for all days in 2015.

Figure 13 shows the unfiltered and filtered ice concentration maps and the difference between the two, for a particular day. Valid ice is removed from the the ice edge.

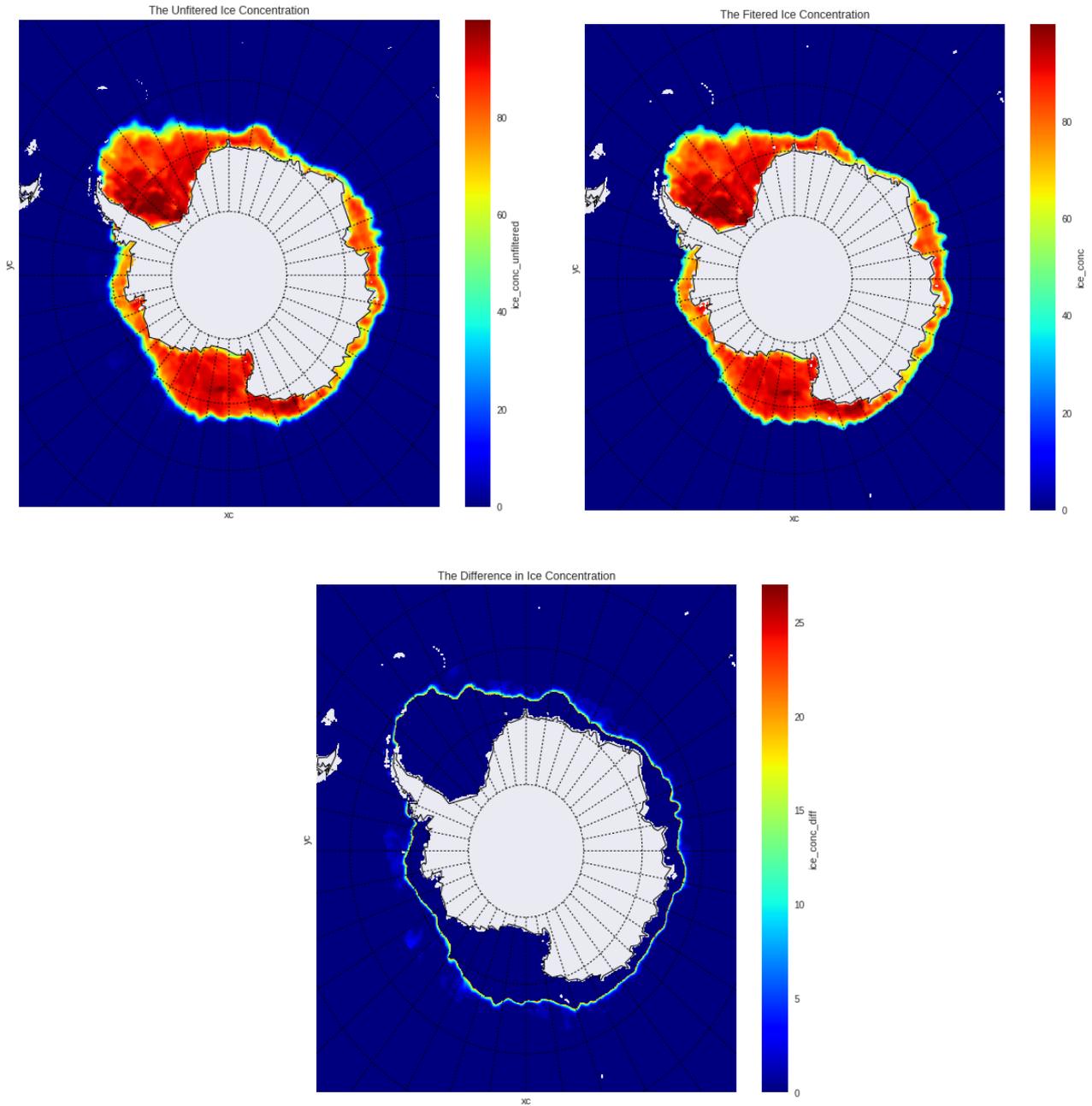


Figure 13: A comparison of the filtered and unfiltered sea ice concentration on the Southern Hemisphere for 2015-04-11. Top Left: the unfiltered percentage sea ice concentration. Top Right: the filtered percentage sea ice concentration. Bottom: the difference between the filtered and unfiltered percentage sea ice concentration.

Figure 14 shows the percentage of ice removed by the mask for each day in 2015, given by Equation 2. The percentage of ice removed is related to the length of the ice edge. More ice is removed in the summer, because the length of the ice edge is greater relative to the total sea ice area. The mean percentage of sea ice removed for the year is 1.9 %.

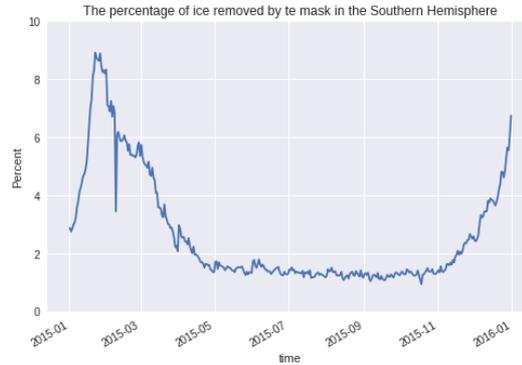


Figure 14: The percentage of sea ice concentration removed by filtering, for the Northern Hemisphere.

Figure Error: Reference source not found shows the binned sea ice concentration, before and after filtering. The filtering removes sea ice concentration values in the range $[0, 40]$; most of the ice is removed at low sea ice concentration values, below 20%.

5.3 Validation of the filtered product

The validation statistics were calculated for the 2015 dataset, as described in Section 4, except the statistics are calculated for ice, water and intermediate classes, defined as follows :

	Interval
Ice	[0.1)
Intermediate	[1. 99]
water	(99. 100]

These classes have been introduced since the OSI-401-b validation, described in Section 4, was carried out, and are more useful for investigating the effect of the filters.

For the Northern Hemisphere, the mean of the individual standard deviations between the product and the ice charts (both filtered and unfiltered) is as follows:

	Filtered	Unfiltered
Ice Std. Dev.	4.7	4.5
Intermediate Std. Dev.	15.5	14.2
water Std. Dev.	6.1	7.5

For the Southern Hemisphere, the mean of the individual standard deviations between the product and the ice charts (both filtered and unfiltered) is as follows:

	Filtered	Unfiltered
Ice Std. Dev.	8.0	7.9
Intermediate Std. Dev.	16.7	15.4
water Std. Dev.	3.4	4.3

For both hemispheres, there is a slight increase in the standard deviation for the ice and intermediate classes for the filtered compared to the unfiltered, whereas the water-class standard deviation is reduced.

6 Conclusions

There are two scientific requirements listed in the Product requirement document table OSI-PRD-PRO-200, which apply to the OSI-401-b product: (i) the requirement on spatial resolution which is met since the spatial sampling of the product is 10 km and (ii) the target accuracy of the product on a yearly basis. Here the accuracy of the OSI SAF ice concentration product is evaluated using ice chart information for comparison.

The requirement for the OSI-401-b product on target accuracy is 10% for the NH-product and 15% for SH-product (yearly average). The tolerance is larger for the SH-product, since there in general are more intermediate concentrations in the Southern Hemisphere, which is more difficult to estimate in the ice chart.

For NH the target requirement on accuracy of 10% is met in the comparison with DMI ice charts. The yearly average of the total standard deviation is 10%. For SH the target requirement on accuracy of 15% is met in the comparison with NIC ice charts. The yearly average of the total standard deviation is 9%.

The standard deviations between the OSI SAF products and the ice charts are large over ice covered areas during summer melt: up to 20% in both hemispheres, while during the winter the ice standard deviation is 10-15%. Over open water areas the standard deviation of the differences is 2-4% for SH and somewhat higher for the NH; around 5%.

For OSI-401-b version 1.3, a filtered ice concentration field is added to the product. The ice concentration is filtered to remove spurious ice. The filtering of ice concentration removed less than 2% of the ice concentration for the 2015 dataset analysed, in both hemispheres. Valid ice was removed in addition to the spurious, but the proportions of each are not quantified here. The standard deviation given by the validation is similar for both the filtered and unfiltered ice concentrations and the target accuracy, given in the requirements, of 10% and 15% accuracy for the Northern and Southern Hemispheres respectively is met for both the filtered and unfiltered products.

It is clear that the ice charts over ice covered areas do not necessarily represent the truth; rather a fairly independent dataset for comparison. Therefore the change of methodology does not necessarily result in improved validation results.