The EUMETSAT Network of Satellite Application Facilities

OSI SAF

Ocean and Sea Ice

Validation Report for the High Latitude L2 VIIRS Sea and Sea Ice Surface Temperature product

OSI-205-b

Version 1.0

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1.0	21-08-2018	Minor	Adapting for some comments after review. Added figure 5.	Steinar Eastwood

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1 Introduction

1.1 Scope

The purpose of this report is to document the level of agreement between the EUMETSAT Ocean and Sea Ice Satellite Application Facility (OSI SAF) High Latitude (HL) L2 Visible Infrared Imaging Radiometer Suite (VIIRS) Sea and Sea Ice Surface Temperature (SST/IST) product and in situ observations, the so called OSI-205-a product.

1.2 Overview

The EUMETSAT OSI SAF is producing a range of operational air-sea interface products, namely: wind, sea ice characteristics, Sea Surface Temperatures (SST), sea ice surface temperature (IST) and radiative fluxes, Surface Solar Irradiance (SSI) and Downward Longwave Irradiance (DLI). More details on the products and OSI SAF project are available at http://www.osi-saf.org.

SST, SSI and DLI products from the OSI SAF are produced using geostationary and polar orbiting satellites and are available in level 2 and level 3 formats, with different timeliness depending on the production setup.

A specific L2 High Latitude SST/IST product from NPP VIIRS data is produced covering the High Latitudes poleward of 50N, OSI-205-b. This HL L2 SST/IST product is derived from the NPP VIIRS data received locally at Norwegian Meteorological Institute. It is available on NetCDF format through the OSI SAF High Latitude FTP server (ftp://osisaf.met.no/prod) and EUMETCast. See also http://osisaf.met.no for product monitoring, validation, news messages and other information.

This report is separated in chapters describing the in situ validation data, the validation method and the results obtained. More details on the OSI SAF HL L2 VIIRS SST/IST product itself is available in the Product User Manual ([RD.1]).

1.3 Glossary

Acronym	Description
AVHRR	Advanced Very High Resolution Radiometer
CMS	Centre de Méteorologie Spatiale
DLI	Downward Longwave Irradiance
DMI	Danish Meteorological Institute
GRIB	Gridded Binary Format
HDF	Hierarchical Data Format
HL	High Latitudes

Acronym	Description
HIRLAM	High Resolution Limited Area Model
LML	Low and Mid Latitudes
METNO	Norwegian Meteorological Institute
MODTRAN	Moderate Resolution Transmittance model
MSG	Advanced Very High Resolution Radiometer
NOAA	National Oceanic and Atmospheric Administration
NAR	Near Atlantic Regional
NWC	Nowcasting
RMDCN	Regional Meteorological Data Communication Network
SAF	Satellite Application Facility
SMHI	Swedish Meteorological and Hydrological Institute
SSI	Surface Solar Irradiance
SST	Sea Surface Temperature
VIIRS	Visible Infrared Imaging Radiometer Suite

1.4 Applicable documents

[RD.1] High Latitude L2 VIIRS SST/IST Product User Manual, v1.0.

[RD.2] Validation report for the L2 SST/IST product, OSI-205, v.1.1.

[RD.3] OSI SAF CDOP 3 Product Requirement Document, v1.0.

[RD.4] The recommended GHRSST Data Specification (GDS), v2.0.

2 Validation data

The validation of the High Latitude L2 VIIRS SST/IST product is performed using a match-up database (MDB) built specifically for high latitudes. The MDB is built by collocating in situ drifting buoy observations with the OSI-205-b product. The validation data are presented here.

2.1 In situ drifter data

In situ drifting buoy data are used to validate both SST and IST in the OSI-205-b product. For SST validation the water temperature observations from drifting buoys are used. These water temperature (labeled Tw) observations are usually done at 20-50cm depth.

For IST validation the air temperature observations (labeled TTT) from drifting buoys placed on the sea ice are used. The air temperature observations are not measuring the same quantity as the IST, which is a surface skin temperature. The difference between air and skin surface temperature can be significant. But these air temperature observations are the only available in situ source with reasonable good coverage in both time and space and therefore suitable for routinely validation of the IST product. This is also why the target accuracy values are as high as they are (see 2.4). This is further discussed in the validation report for OSI-205, [RD.2] .

2.2 Source of in situ data

Separate sources for in situ data has been used for SST and IST drifter data.

For SST validation drifting buoy data from the Copernicus Center for Marine Services (CMEMS) In Situ Thematic Assembly Center (TAC) has been used. The In Situ TAC collects in situ observations from various sources, including drifting buoys. The drifting buoy data from the In Situ TAC are formatted on NetCDF files by Ifremer and provided at this site:

ftp://ftp.ifremer.fr/ifremer/cersat/projects/myocean/sst-tac/insitu/data/v2/

For IST validation drifting buoy data received locally through GTS at MET Norway has been used. The GTS stream of data provides global drifter data and all northern hemisphere data poleward of 50N have been collected for this validation.

2.3 Satellite data

As input data to the L2 OSI-205-b processing, locally received NPP VIIRS data and locally processed cloud mask data using the Nowcasting SAF (NWC SAF) software Polar Platform System (PPS) v2014 are used. For this validation product files from 20.01.2017 to 31.12.2017 have been used, so almost one year of data.

2.4 Target accuracy

The required accuracy of the SST and IST products are defined as monthly mean bias and standard deviation of the surface temperatures values compared with in situ measurements. Three requirement levels are defined in the PCR [RD.3] :

- *Threshold* – The model user community gain no improved model performance using data of worse quality than this.
- *Target* – This is an intermediate quality level, between the two extremes (Threshold and Optimal), at which the product quality aim at.
- *Optimal* – The model user community can not gain from improvements in the ST quality beyond this level.

The validation of the OSI-205-b product will be compared with the target accuracy requirement.

The IST accuracy requirements are split in two: 1) requirements for validation against in situ IR radiometers, and 2) requirements for validation statistics against in situ buoy data. This is discussed further in [RD.2] . All threshold accuracies are given in 1.

	Treshold, std/bias, K		Target, std/bias, K		Optimal, std/bias, K	
	Radiometer	Buoy	Radiometer	Buoy	Radiometer	Buoy
SST	--	*1.5/1.5*	--	1.0/0.7	--	*0.3/0.1*
IST	*3.0/2.5*	*4.0/4.5*	2.0/1.5	3.0/3.5	*0.8/0.5*	*1.0/0.8*

Table 1: SST and IST temperature quality requirements thresholds (from [RD.3]).

3 Validation method

For validation of OSI-205-b the data described in Chapter 2 has been used. The validation methods are described below.

3.1 SST validation methods

The central part of the SST validation is building of the validation match-up data base (MDB). The MDB has been built by collocating the L2 HL SST product with the SST in situ data. In this collocation a set of rules have been applied, amongst other to make the match-ups as representative as possible:

1. Match-ups have maximum 1 hour in time difference.
2. In situ observations are matched to the SST product pixel (5km pixel size) they lie within, labeled the center pixel.
3. A 5x5 box of pixels around this center pixel are kept.
4. Only match-ups with cloud free (that is valid SST) center pixel are kept.

The SST validation is performed mainly by calculating monthly statistics for the difference between the center SST pixel and in situ SST values, SSTc-SSTinsitu. Standard mean difference (bias) and standard deviation are used. In addition, the margin of the bias and standard deviation when compared with the accuracy requirement is calculated, in percentage.

A set of filters are applied to the match-ups before the statistics are calculated. This is partly to only validate the data that users are advised to use quantitatively, partly because the quality control of the in situ observations is limited.

- quality_level >= 3
- abs(SSTc-SSTclimatology) <= 10°C
- abs(SSTc-SSTinsitu) <= 3.0°C
- Meteo-France CMS buoy black list is applied

3.2 IST validation methods

For the IST validation the methods are very similar as for SST validation, except that a different in situ data set is used. The same rules 1-4 are applied as for SST, except using IST instead.

For the quality control, the following filters are applied for IST:

- quality_level >= 3
- abs(ISTc-ISTinsitu) <= 10.0°C

This last filter has a much less strict threshold. This is because the ISTinsitu value is less representative of the ice surface temperature, than for the SST equivalent.

4 Validation results

The validation results are split in two sections. First one section with the results for the SST validation and then one for the IST validation.

4.1 HL L2 SST validation results

The validation experiment has been run with almost one year of data (20.01.2017 to 31.12.2017) to assess the quality of the HL L2 VIIRS SST product. The results are split in daytime and night time validation, using the mean time of each data point to decide the time. Daytime is defined as solar zenith angle less than 85 degrees, night time as solar zenith angle more than 95 and twilight as between 85 and 95 degrees.

The monthly SST validation results are presented in Table 3. For daytime and night time bias and standard deviation are shown, with accuracy target requirement and margin. For twilight there is no target requirement, so it is not shown.

Table 3 shows that the SST validation results are mostly within the target requirement for both bias and standard deviation, both at daytime and night time. The exception is that standard deviation is slightly above target requirement during night in October 2017.

The validation has also been done per quality level, and the time series of monthly results are presented in Figure 1 and Figure 2. The overall statistics per quality level for the full period are presented in Table 2. These are the numbers that are used in the so called Sensor Specific Error Statistics (SSES), as defined by GHRSST in the Data Specification document [RD.4] . The numbers for the monthly statistics are given in chapter 8.

4.2 HL L2 IST validation results

The validation for IST was run over the same period as for the SST validation using the same methods and definitions. The monthly IST validation results are presented in Table 4. Table 4 shows that for daytime the IST validation results are within the accuracy target requirement for standard deviation for all months, except March which is slightly outside. There is a systematic cold bias and the results are within the target requirement, except March and April. It is within the *threshold* requirement for these months.

For nighttime, the IST validation results are worse than for daytime. The standard deviation is within the target requirement, except in March and October. It is within the *threshold* requirement for these months. The bias is within the target requirement in April, September and October, and outside the target requirement with a systematic cold bias the other months. For November and December it is also outside the *threshold* requirement.

The validation has also been done per quality level, and the time series of monthly results are presented in Figure 3 and Figure 4. The overall statistics per quality level for the full period are presented in Table 2. The numbers for the monthly statistics are given in chapter 8.

SST	Bias	Std dev	Num obs
CL=2	-1.09	1.04	1302
CL=3	-0.73	0.94	4086
CL=4	-0.34	0.81	6926
CL=5	0.01	0.53	5133

IST	Bias	Std dev	Num obs
CL=2	-4.71	2.97	406
CL=3	-4.03	3.46	599
CL=4	-4.32	2.77	1228
CL=5	-3.12	2.39	638

Table 2: HL L2 VIIRS SST and IST error statistics per quality level for OSI-205-b, day time, twilight and night time together, for 2017.

			Bias			Std deviation		
	Date	**Nobs**	**Bias**	**Req**	**Margin**	**Std**	**Req**	**Margin**
Day time	201701	86	-0.22	0.7	69.24	0.57	1.0	43.10
	201702	279	-0.37	0.7	47.35	0.67	1.0	32.55
	201703	685	-0.36	0.7	48.80	0.65	1.0	35.31
	201704	722	-0.22	0.7	68.84	0.75	1.0	25.48
	201705	728	-0.18	0.7	73.88	0.63	1.0	37.19
	201706	519	-0.18	0.7	73.87	0.69	1.0	31.05
	201707	431	-0.04	0.7	93.64	0.63	1.0	36.82
	201708	907	-0.15	0.7	78.79	0.62	1.0	37.76
	201709	1049	-0.14	0.7	80.20	0.65	1.0	35.11
	201710	837	-0.30	0.7	56.49	0.69	1.0	31.46
	201711	318	-0.25	0.7	64.42	0.71	1.0	28.93
	201712	170	-0.32	0.7	54.11	0.66	1.0	33.96
Night time	201701	196	-0.47	0.7	32.19	0.86	1.0	14.29
	201702	404	-0.34	0.7	51.39	0.88	1.0	12.25
	201703	687	-0.41	0.7	41.98	0.89	1.0	10.89
	201704	320	-0.52	0.7	25.45	0.98	1.0	2.35
	201705	238	-0.34	0.7	51.82	0.84	1.0	15.62
	201706	56	-0.38	0.7	45.41	0.74	1.0	26.04
	201707	95	-0.18	0.7	74.98	0.84	1.0	16.38
	201708	287	-0.27	0.7	60.81	0.84	1.0	15.88
	201709	756	-0.35	0.7	50.04	0.96	1.0	3.65
	201710	1063	-0.53	0.7	24.27	1.02	1.0	-1.56
	201711	1472	-0.45	0.7	35.14	0.95	1.0	5.38
	201712	1624	-0.41	0.7	40.83	0.92	1.0	8.24
Twilight	201701	26	-0.49			0.81		
	201702	66	-0.61			0.97		
	201703	58	-0.13			0.77		
	201704	135	-0.30			0.77		
	201705	231	-0.39			0.69		
	201706	113	-0.37			0.73		
	201707	100	-0.09			0.64		
	201708	187	-0.43			0.90		
	201709	189	-0.35			0.96		
	201710	199	-0.40			0.87		
	201711	492	-0.43			0.79		
	201712	413	-0.34			0.71		

Table 3: Monthly SST validation results for 2017, using quality levels 3, 4 and 5. The requirements and margins are only for daytime and nighttime, and not shown for twilight.

			Bias			Std deviation		
	Date	Nobs	Bias	Req	Margin	Std	Req	Margin
Day time	201701	0						
	201702	0						
	201703	148	-3.77	3.5	-7.58	3.02	3.0	-0.75
	201704	498	-3.90	3.5	-11.31	2.72	3.0	9.22
	201705	412	-3.10	3.5	11.54	2.66	3.0	11.22
	201706	43	-3.12	3.5	10.84	1.67	3.0	44.36
	201707							
	201708	20	-2.72	3.5	22.31	1.79	3.0	40.32
	201709	18	-1.97	3.5	43.81	2.60	3.0	13.37
	201710	0						
	201711	0						
	201712	0						
Night time	201701	131	-4.65	3.5	-32.76	2.74	3.0	8.83
	201702	341	-4.38	3.5	-25.19	2.75	3.0	8.18
	201703	260	-3.78	3.5	-7.98	3.21	3.0	-7.08
	201704	6	-2.26	3.5	35.52	2.60	3.0	13.27
	201705	0						
	201706	0						
	201707	0						
	201708	0						
	201709	10	-2.23	3.5	36.43	2.77	3.0	7.58
	201710	30	-3.50	3.5	0.13	3.91	3.0	-30.44
	201711	25	-8.07	3.5	-130.48	1.73	3.0	42.22
	201712	33	-7.03	3.5	-100.76	2.58	3.0	14.14
Twilight	201701	0						
	201702	13	-1.46			5.41		
	201703	287	-4.32			2.64		
	201704	116	-4.63			2.54		
	201705	1	-3.92			0.00		
	201706	0						
	201707	0						
	201708	7	-0.05			0.70		
	201709	47	-4.04			3.06		
	201710	16	-2.99			3.31		
	201711	1						
	201712	0						

Table 4: Monthly IST validation results for 2017, using quality levels 3, 4 and 5. The requirements and margins are only for daytime and nighttime, and not shown for twilight.

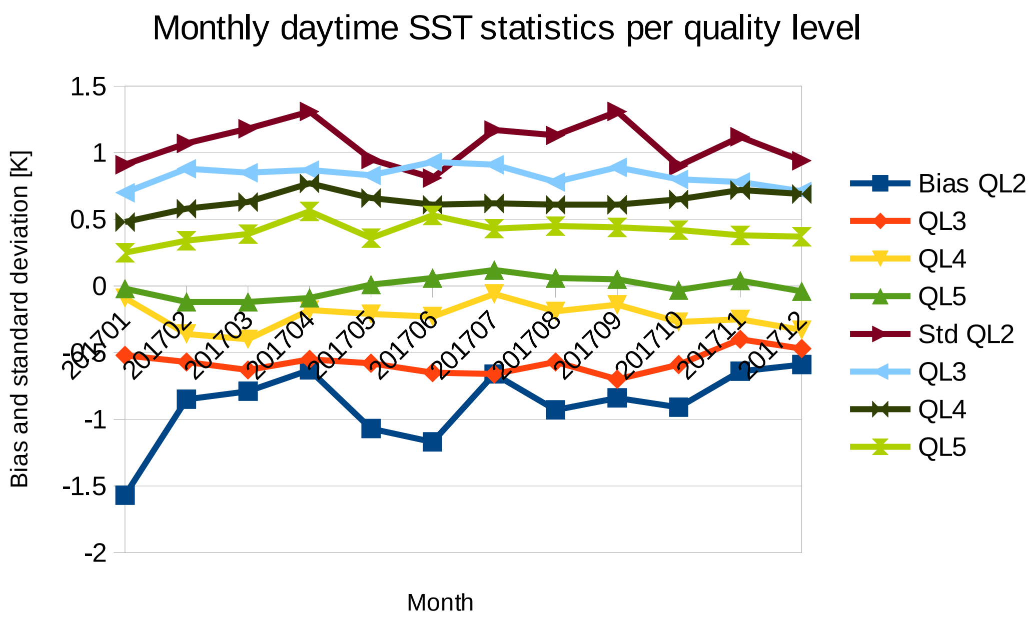

Figure 1: Monthly daytime SST bias and standard deviation per quality level.

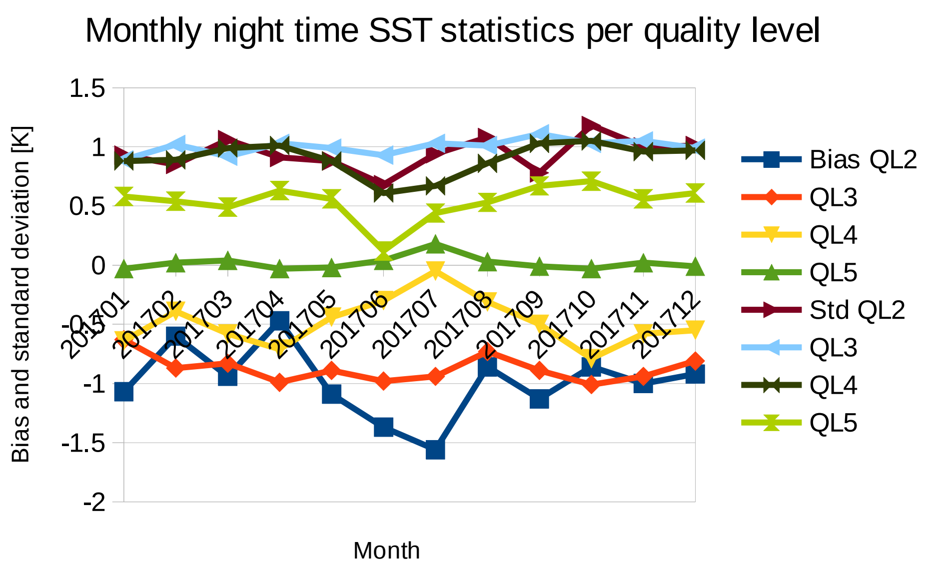

Figure 2: Monthly night time SST bias and standard deviation per quality level.

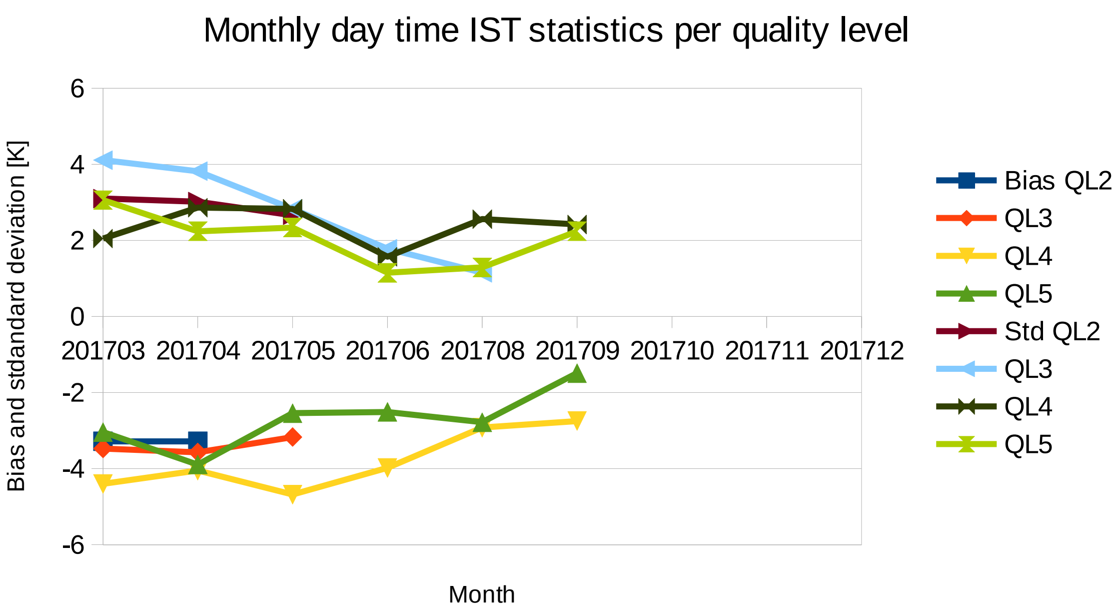

Figure 3: Monthly daytime IST bias and standard deviation per quality level.

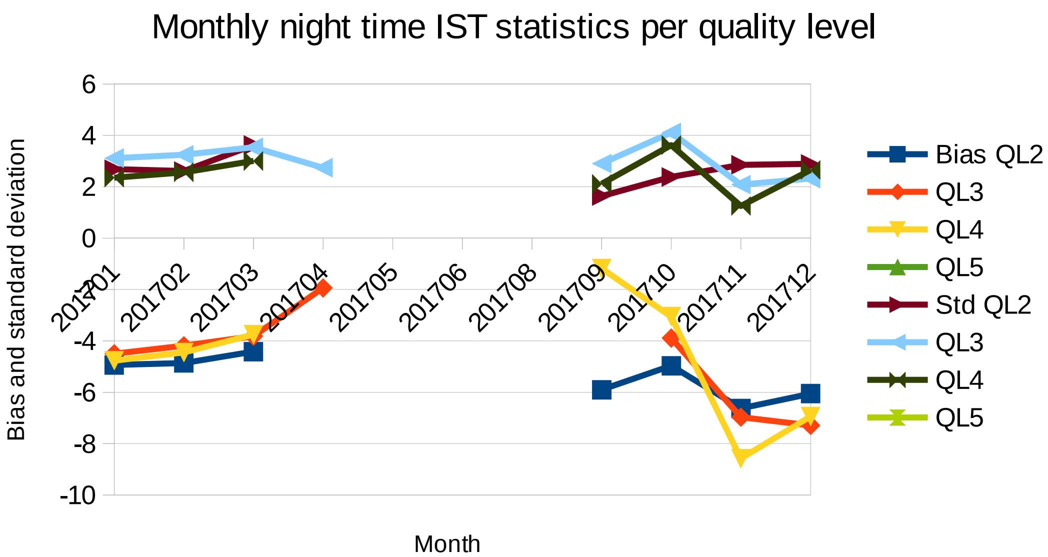

Figure 4: Monthly nighttime IST bias and standard deviation per quality level.

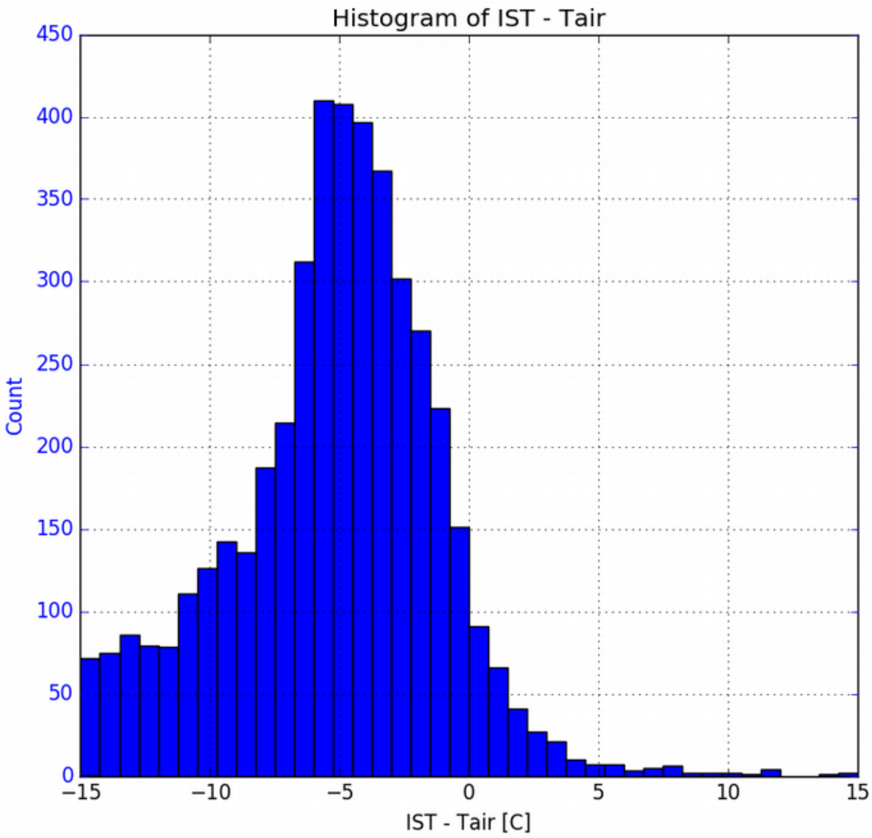

Figure 5: Distribution of difference between satellite IST and in situ Tair.

The distribution of the difference between IST and Tair is shown in Figure 5. This distribution peaks at -5C, with a more dominant tail towards colder bias. If the cold bias for IST was only due to failing cloud masking, the peak would be closer to 0C. When the L2 input IST data are compared with in situ IR measurements ([RD.2]), the cold bias is indeed closer to 0C. So, we can expect that the large cold bias observed for IST when compared with Tair is at least partly caused by the fact the Tair observations do not well represent the IST.

5 Discussion

5.1 L2 HL SST product

Table 3 shows that in general the daytime validation results are a bit better than the night time results, both for bias and std deviation. However, the number of validation point vary a lot since the length of day and night differ at high latitudes during the year. The bias is always negative, and standard deviation between 0.5 and 1.0. This indicates that the cloud masking is probably not optimal, as undetected clouds leaves a cold bias and increases the std deviation.

There seems to be a tendency for the summer months to have higher standard deviation and less cold bias in the SST product. This could be partly due to diurnal warming of the surface layer and influencing the validation. This has not been further investigated here.

Regarding twilight validation results, Table 3 shows that the twilight validation results are usually worse than both daytime and night time, sometimes slight better than nighttime. Cloud masking is also more difficult during twilight conditions, with visible channels giving less information and the important 3.7um channel still being affected by reflected solar radiation.

The SST validation results per quality level in Table 2 show that the quality is best for quality level 5 and decreases with quality level, as expected. This is also the overall trend in the monthly validation results per quality level in Figure 4 and Figure 2, with some variations for some of the months.

5.2 L3 NHL IST production

As for the SST validation, the number of validation data for the IST validation vary a lot, as shown in Table 4. For the IST validation not all months have validation results for daytime or nighttime. This is during periods with either polar night (November to January) or midnight sun (May to August).

At daytime the performance is within accuracy requirements, as the cloud and ice masking has a sufficient quality in polar regions during daytime. There is a significant negative bias and higher standard deviation than for the SST validation. This is expected when comparison is done against air temperature measurements from buoys on the ice. It is not know if the measurement is done in free air or buried under snow, and do not represent the skin temperature well enough.

At night time the validation results show a more negative bias and higher standard deviation. The results are not within the accuracy requirement (which is the same at daytime and night time). The degradation in quality during night time is something that must be expected in polar conditions, due to the difficulty with cloud and ice masking in polar night condition. This issue of cloud masking in polar conditions has been further studied in a federated activity between the OSI SAF and NWC SAF, and this study came to the same conclusion (see Eastwood et al, 2017).

Regarding twilight validation results, Table 4 shows that the twilight results are worse than for daytime and comparable to nighttime results when we look at those months where the number of validation data are comparable. As for SST, the cloud masking is more difficult during twilight than at daytime.

The IST validation results per quality level in Table 2 show that the quality is best for quality level 5. The bias decreases with quality level, as expected, while the standard deviation is almost constant for level 4, 3 and 2. The quality level settings might not be optimal, but it is also difficult to use air temperature observations to conclude on this. No data are given quality level 5 at night time, due to high uncertainty in the cloud masking over sea ice during night time.

6 Conclusion

The L2 VIIRS SST/IST product OSI-205-b has been validated and compared with the accuracy target requirements.

For SST, the validation shows that the OSI-205-b is mostly within the target requirement of l.0°C standard deviation and 0.7°C bias on a monthly basis, both at daytime and nighttime. So the SST part of the product is ready for distribution.

For IST, the validation shows that at daytime the OSI-205-b is within the target requirement of 3.0°C standard deviation for all months, and within or close to the target of 3.5°C bias on a monthly basis. At night time the OSI-205-b is not within the target requirement, but within the *threshold* requirement of 4.0°C standard deviation and within or close to the *threshold* requirement of 4.5°C bias.

The overall results for the OSI-205-b product are good, and we suggest that the product is distributed operationally with a notification in the Product User Manual and product file meta data that night time IST quality is lower during night time.

7 References

Eastwood, S., A. Dybbroe, R. Scheirer, N. Håkansson and Ø. Godøy (2017): OSI-SAF/NWC-SAF Federated activity on cloud and ice masking in polar conditions - Final Report. 21 pages.

8 Appendix A: Quality level validation

The tables used to generate Figure 4 and Figure 2 are presented below.

		Bias				Std				Num			
Type	**Date**	**QL2**	**QL3**	**QL4**	**QL5**	**QL2**	**QL3**	**QL4**	**QL5**	**QL2**	**QL3**	**QL4**	**QL5**
Day time	201701	-1.57	-0.52	-0.09	-0.02	0.91	0.7	0.48	0.25	7	28	38	20
	201702	-0.85	-0.57	-0.36	-0.12	1.07	0.88	0.58	0.34	21	91	115	73
	201703	-0.79	-0.63	-0.4	-0.12	1.18	0.85	0.63	0.39	22	140	328	217
	201704	-0.63	-0.55	-0.18	-0.09	1.31	0.87	0.77	0.56	22	133	347	242
	201705	-1.07	-0.58	-0.21	0.01	0.95	0.83	0.66	0.36	24	121	308	299
	201706	-1.17	-0.65	-0.23	0.06	0.81	0.93	0.61	0.53	18	84	234	201
	201707	-0.66	-0.66	-0.06	0.12	1.17	0.91	0.62	0.43	12	51	172	208
	201708	-0.93	-0.57	-0.19	0.06	1.13	0.78	0.61	0.45	26	145	397	365
	201709	-0.84	-0.7	-0.14	0.05	1.31	0.89	0.61	0.44	21	152	452	445
	201710	-0.91	-0.59	-0.27	-0.03	0.9	0.8	0.65	0.42	71	241	396	200
	201711	-0.64	-0.4	-0.25	0.04	1.12	0.78	0.72	0.38	38	112	147	59
	201712	-0.59	-0.47	-0.33	-0.04	0.94	0.71	0.69	0.37	17	62	73	35
Night time	201701	-1.07	-0.63	-0.64	-0.03	0.93	0.89	0.88	0.58	9	54	90	52
	201702	-0.6	-0.87	-0.39	0.02	0.85	1.02	0.89	0.54	14	94	151	159
	201703	-0.94	-0.83	-0.58	0.04	1.06	0.92	0.99	0.49	24	165	264	258
	201704	-0.47	-0.99	-0.71	-0.03	0.91	1.03	1.01	0.63	16	70	133	117
	201705	-1.09	-0.89	-0.44	-0.02	0.88	0.99	0.88	0.56	18	49	77	112
	201706	-1.37	-0.98	-0.3	0.04	0.68	0.93	0.61	0.12	2	15	25	16
	201707	-1.56	-0.94	-0.05	0.18	0.94	1.03	0.67	0.44	4	23	36	36
	201708	-0.86	-0.73	-0.31	0.03	1.08	1.01	0.86	0.53	22	70	99	118
	201709	-1.13	-0.89	-0.5	-0.01	0.78	1.11	1.03	0.67	28	151	254	351
	201710	-0.86	-1.01	-0.79	-0.03	1.18	1.03	1.05	0.71	38	237	398	428
	201711	-1	-0.94	-0.58	0.02	1	1.05	0.96	0.56	42	365	584	523
	201712	-0.92	-0.81	-0.55	-0.01	1.01	0.99	0.97	0.61	58	391	634	599

Table 5: Monthly SST validation statistics per quality level.

		Bias				Std				Num			
Type	**Date**	**Bias Q**	**QL3**	**QL4**	**QL5**	**Std Ql**	**QL3**	**QL4**	**QL5**	**QL2**	**QL3**	**QL4**	**QL5**
	201701									0	0	0	0
	201702									0	0	0	0
	201703	-3.28	-3.47	-4.4	-3.04	3.1	4.11	2.05	3.06	8	35	68	45
	201704	-3.28	-3.57	-4.05	-3.89	3.02	3.82	2.86	2.24	6	69	166	263
	201705		-3.17	-4.68	-2.54	2.66	2.83	2.83	2.34	3	33	98	281
Day time	201706			-3.98	-2.51		1.78	1.57	1.15	0	4	9	30
	201708			-2.92	-2.78		1.15	2.56	1.29	1	2	6	12
	201709			-2.75	-1.49			2.42	2.24	1	1	10	7
	201710									0	0	0	0
	201711									0	0	0	0
	201712									0	0	0	0
	201701	-4.94	-4.5	-4.77		2.68	3.11	2.35		54	61	70	0
	201702	-4.86	-4.19	-4.45		2.61	3.24	2.56		93	88	253	0
	201703	-4.42	-3.82	-3.75		3.62	3.53	3		56	98	162	0
	201704		-1.94				2.74			1	5	1	0
	201705									0	0	0	0
Night time	201706									0	0	0	0
	201708									0	0	0	0
	201709	-5.9		-1.18		1.64	2.9	2.11		7	4	6	0
	201710	-4.97	-3.89	-3.05		2.38	4.11	3.62		12	16	14	0
	201711	-6.63	-6.97	-8.58		2.85	2.08	1.25		12	8	17	0
	201712	-6.05	-7.29	-6.94		2.89	2.32	2.65		18	8	25	0

Table 6: Montly IST validation statistic per quality level. Values for months with less than 5 data values have been removed.