PREPARATION AND OPERATIONS OF THE MISSION PERFORMANCE CENTRE (MPC) FOR THE COPERNICUS SENTINEL-3 MISSION

S3-A SLSTR Cyclic Performance Report

Cycle No. 033

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Disclaimer

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Changes Log

Version	Date	Changes
1.0	30/08/2018	First Version

List of Changes

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1 Processing Baseline Version

IPF	IPF / Processing Baseline version	Date of deployment
SL1	06.14 / 2.17	CGS: 05/07/2017 13:15 UTC (NRT) PAC: 05/07/2017 12:34 UTC (NTC)
SL1	06.15 / 2.29	CGS: 04/04/2018 10:09 UTC PAC: 04/04/2018 10:09 UTC
SL2	06.12 / 2.17	CGS: 05/07/2017 13:16 UTC (NRT) PAC: 05/07/2017 12:42 UTC (NTC)



2 Instrument monitoring

2.1 Instrument temperatures

As a thermal infrared instrument, thermal stability and uniformity of the optical mechanical enclosure (OME) is critical to the radiometric calibration. Figure 1 and Figure 2 show the orbital average temperature of the OME and instrument baffles during Cycle 033. The temperatures were stable (on top of a daily variation cycle).

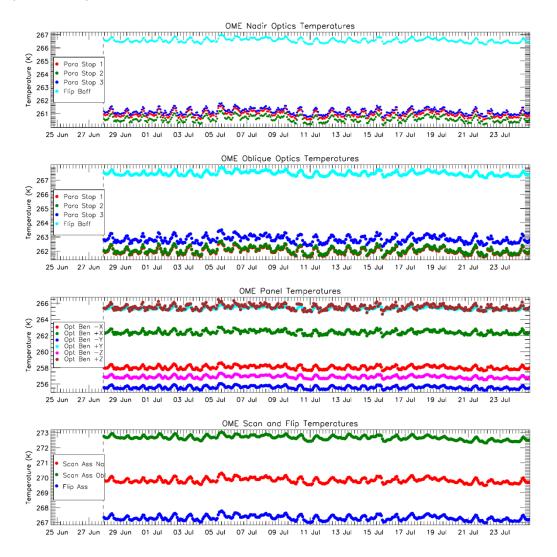


Figure 1: OME temperature trends for Cycle 033 showing the paraboloid stops and flip baffle (top two plots) and optical bench and scanner and flip assembly (lower two plots). The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit.



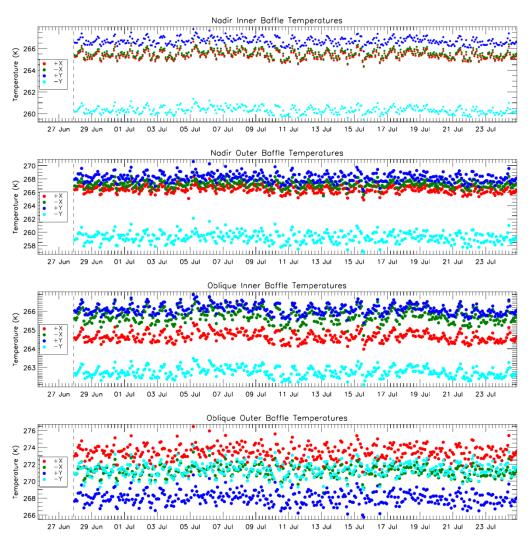


Figure 2: Baffle temperature trends for Cycle 033. The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit.



2.2 Detector temperatures

The detector temperatures in Cycle 033 were stable at their expected values following the instrument decontamination that was performed during Cycle 28 between 15th and 21st February. The decontamination involved warming up the focal plane array in order to remove water ice contamination from the cold surfaces. Figure 3 shows the detector temperatures for the past year and the decontamination is clearly visible as a rise in detector temperature (the previous decontamination was performed in Cycle 20). A few orbits in Cycle 32 show slightly lower average detector temperatures and these were due to instrument tests that were performed during that cycle. The thermal detectors show a step in temperature on 18th July and this is due to an adjustment to the cold tip temperature that was carried out on that day (see Section 6).

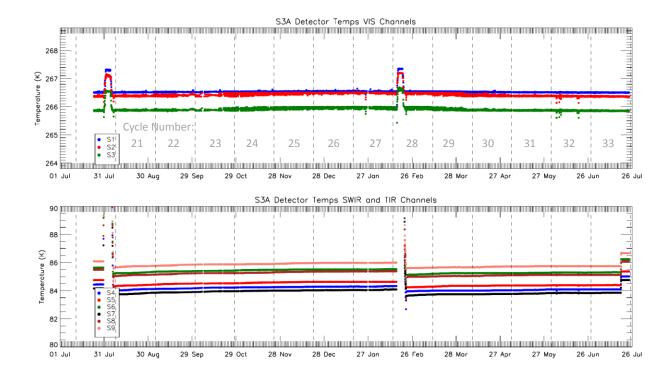


Figure 3: Detector temperatures for each channel for the last year of operations. Discontinuities occur for the infrared channels where the FPA was heated for decontamination. The vertical dashed lines indicate the start and end of each cycle. Each dot represents the average temperature in one orbit. The different colours indicate different detectors.



2.3 Scanner performance

Scanner performance in Cycle 033 has been consistent with previous operations and within required limits.

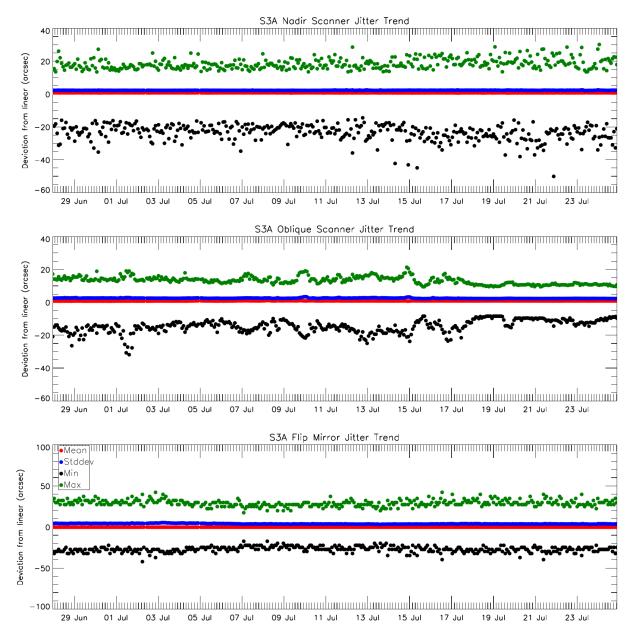


Figure 4: Scanner and flip jitter for Cycle 033, showing mean, stddev and max/min difference from expected position per orbit for the nadir view (red, blue, green and black respectively).



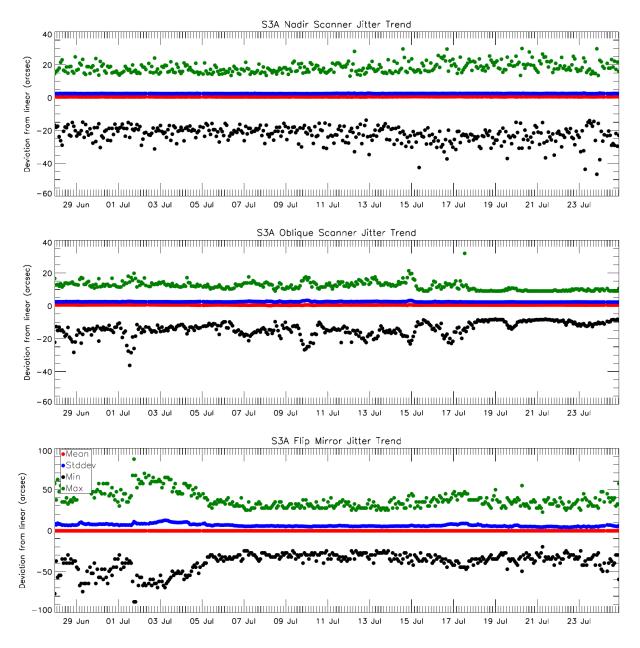


Figure 5: Scanner and flip jitter for Cycle 033, showing mean, stddev and max/min difference from expected position per orbit for the oblique view (red, blue, green and black respectively).

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2.4 Black-Bodies

Figure 6 shows the orbital average blackbody temperatures during Cycle 033. The temperatures were stable (on top of a daily variation cycle). Longer term analysis also shows a yearly variation, with temperatures rising as the Earth approaches perihelion at the beginning of January. Cycle 033 falls after this yearly peak with +YBB temperatures around 302.7 K (see Figure 7 and Table 3). Figure 6 shows that gradients across the blackbody baseplate are stable and within their expected range (±20mK).

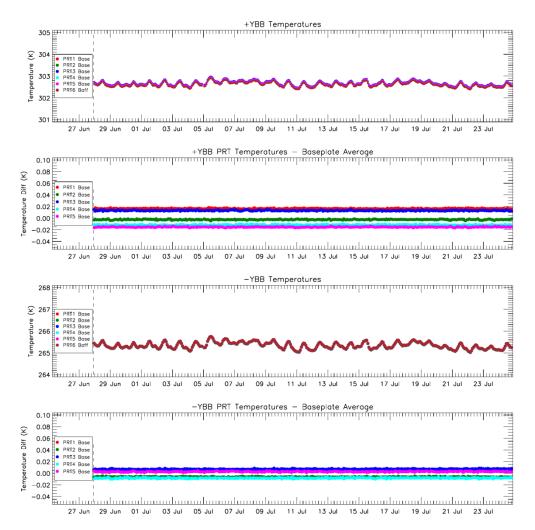


Figure 6: Blackbody temperature and baseplate gradient trends during Cycle 033. The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit.

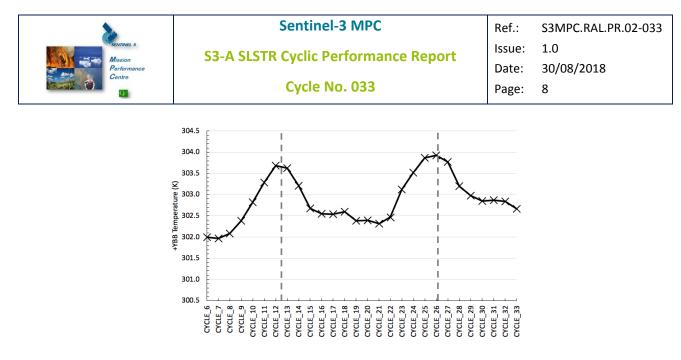


Figure 7: Long term trends in average +YBB temperature in each cycle, showing yearly variation. The vertical dashed lines indicate the 1st January 2017 and 2018.



2.5 Detector noise levels

2.5.1 VIS and SWIR channel signal-to-noise

The VIS and SWIR channel noise in Cycle 033 was stable and consistent with previous operations - the signal-to-noise ratio of the measured VISCAL signal over the mission so far is plotted in Figure 8. Table 1 and Table 2 give the average signal-to-noise in each cycle (excluding the anomaly/decontamination period in cycles 20 and 28). Note that this averages over the significant detector-detector dispersion for the SWIR channels that is shown in Figure 8.

Table 1: Average reflectance factor, and signal-to-noise ratio of the measured VISCAL signal for cycles 022-033, averaged over all detectors for the nadir view.

	Average					Nad	ir Signal-1	to-noise r	atio				
	Reflectance Factor	Cycle 022	Cycle 023	Cycle 024	Cycle 025	Cycle 026	Cycle 027	Cycle 028	Cycle 029	Cycle 030	Cycle 031	Cycle 032	Cycle 033
S1	0.187	232	234	235	234	228	226	223	228	232	234	226	233
S2	0.194	235	239	236	237	233	232	229	232	237	233	231	232
S3	0.190	229	234	232	234	227	227	223	229	228	228	221	223
S4	0.191	136	139	140	142	141	138	138	138	140	139	139	137
S5	0.193	229	236	236	235	238	235	236	232	233	235	236	232
S6	0.175	139	142	146	145	146	143	143	143	142	143	143	142

Table 2: Average reflectance factor, and signal-to-noise ratio of the measured VISCAL signal for cycles 022-033,averaged over all detectors for the oblique view.

	Average		Oblique Signal-to-noise ratio											
	Reflectance Factor	Cycle 022	Cycle 023	Cycle 024	Cycle 025	Cycle 026	Cycle 027	Cycle 028	Cycle 029	Cycle 030	Cycle 031	Cycle 032	Cycle 033	
S1	0.166	241	243	246	246	239	236	235	237	242	249	239	245	
S2	0.170	246	253	249	251	243	239	238	243	249	249	247	246	
S3	0.168	238	247	239	244	234	227	229	235	234	239	234	232	
S4	0.166	108	110	111	111	110	107	107	109	109	110	108	109	
S5	0.166	168	172	173	173	172	170	171	170	170	169	172	168	
S6	0.155	107	111	110	113	109	107	107	109	109	110	110	108	



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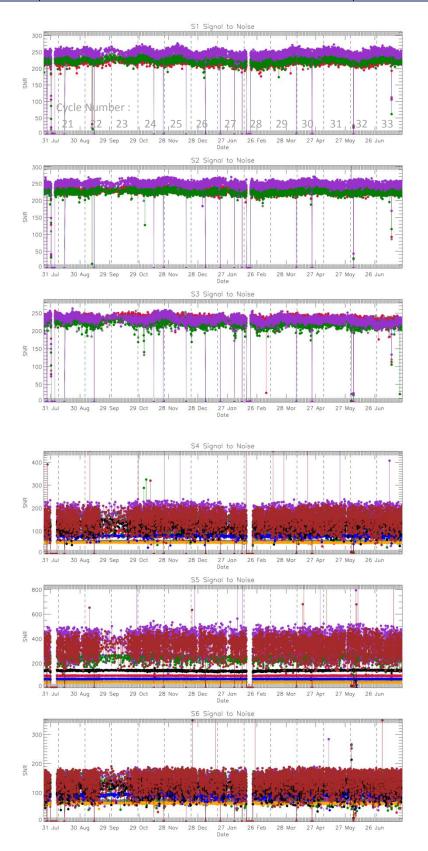


Figure 8: VIS and SWIR channel signal-to-noise of the measured VISCAL signal in each orbit for the last year of operations. Different colours indicate different detectors. The vertical dashed lines indicate the start and end of each cycle.



2.5.2 TIR channel NEDT

The thermal channel NEDT values in Cycle 033 are consistent with previous operations and within the requirements. NEDT trends calculated from the hot and cold blackbody signals are shown in Figure 9. NEDT values for each cycle, averaged over all detectors and both Earth views, are shown in Table 3 and Table 4. The moment at which the cooler cold tip temperature was increased can be seen as a small increase in NEDT on 18th July for channels S8 and S9.

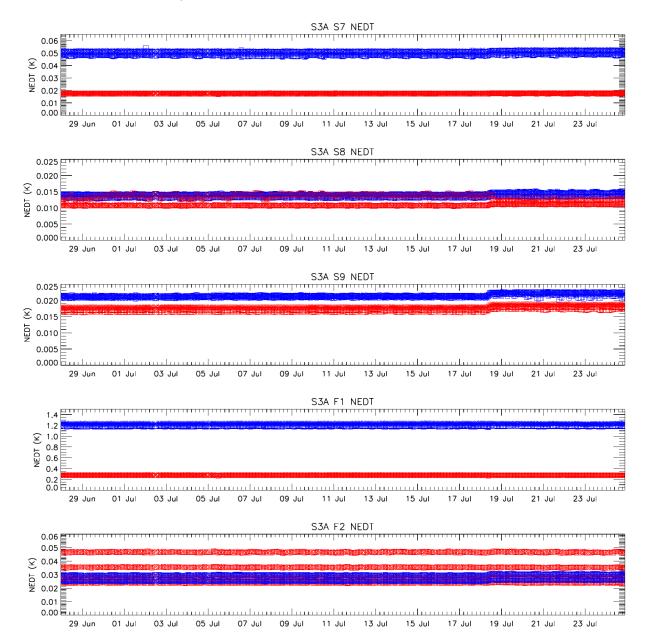


Figure 9: NEDT trend for the thermal channels in Cycle 033. Blue points were calculated from the cold blackbody signal and red points from the hot blackbody. The square symbols show results calculated from the nadir view and crosses show results from the oblique view. Results are plotted for all detectors and integrators, which is why there are several different levels within the same colour points (particularly for S8 and F2).



Table 3: NEDT for cycles 022-033 averaged over all detectors for both Earth views towards the +YBB (hot).

		Cycle 022	Cycle 023	Cycle 024	Cycle 025	Cycle 026	Cycle 027	Cycle 028	Cycle 029	Cycle 030	Cycle 031	Cycle 032	Cycle 033
+YBB t (K)	-	302.466	303.125	303.515	303.871	303.931	303.776	303.203	302.977	302.850	302.868	302.841	302.669
	S7	17.6	17.3	17.2	17.1	17	17.1	17.1	17.2	17.5	17.4	18.1	17.6
NEDT	S8	11.4	11.8	12	12	12.1	12.2	11.7	11.6	11.8	12.0	12.1	12.2
NEDT (mK)	S 9	17.2	17.3	17.4	17.4	17.5	17.7	16.9	16.8	16.9	17.0	17.3	17.6
(F1	277	270	269	266	265	268	265	268	273	274	295	279
	F2	31.6	31.8	32	33.7	33.4	34.5	34	33.7	33.7	33.8	33.6	33.6

 Table 4: NEDT for cycles 022-033 averaged over all detectors for both Earth views towards the -YBB (cold).

		Cycle 022	Cycle 023	Cycle 024	Cycle 025	Cycle 026	Cycle 027	Cycle 028	Cycle 029	Cycle 030	Cycle 031	Cycle 032	Cycle 033
-YBB te (K)	-	265.012	265.790	266.251	266.754	266.760	266.479	265.683	265.460	265.439	265.600	265.621	265.337
	S7	50.8	49.4	48.7	48.0	48.0	48.2	49.3	49.8	49.9	49.9	48.8	50.0
NEDT	S8	13.7	13.7	13.7	13.7	13.7	13.9	13.8	13.8	13.8	13.9	13.9	14.0
NEDT (mK)	S9	21.1	21.2	21.2	21.3	21.5	21.5	20.8	20.8	20.9	21.1	21.0	21.5
()	F1	1223	1183	1161	1145	1144	1150	1179	1201	1207	1206	1195	1207
	F2	26.8	26.8	26.8	26.8	26.8	27.4	27.3	27.3	27.3	27.5	27.8	27.6



2.6 Calibration factors

2.6.1 VIS and SWIR VISCAL signal response

Signals from the VISCAL source for the VIS channels show oscillations due to the build up of ice on the optical path within the FPA. Decontamination must be carried out periodically in order to warm up the FPA and remove the ice. The latest decontamination cycle was successfully performed at the beginning of Cycle 28, and the previous one was performed in Cycle 20. The VISCAL signal has behaved as expected following the decontamination.

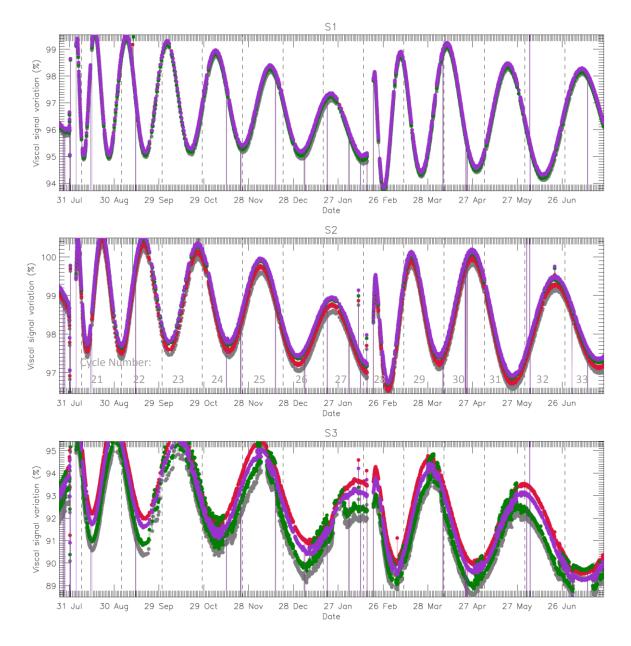


Figure 10: VISCAL signal trend for VIS channels for the last year of operations (nadir view). Different colours represent different detectors. The vertical dashed lines indicate the start and end of each cycle.

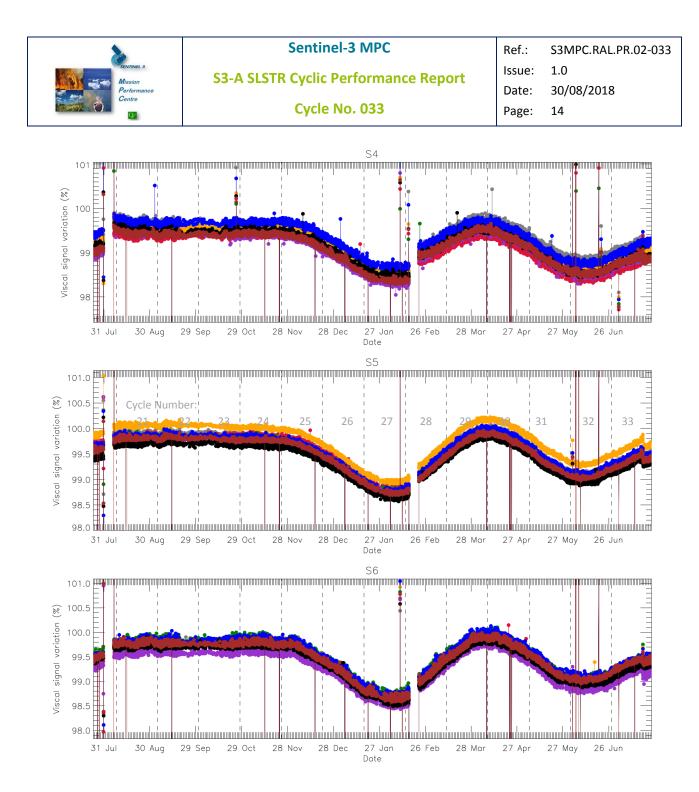


Figure 11: VISCAL signal trend for SWIR channels for the last year of operations (nadir view). Different colours represent different detectors. The vertical dashed lines indicate the start and end of each cycle.



3 Level-1 product validation

3.1 Geometric calibration/validation

Regular monitoring using the GeoCal Tool implemented at the MPC is being carried out. This monitors the geolocation performance in Level-1 images by correlation with ground control point (GCP) imagettes. Each Level-1 granule typically contains several hundred GCPs, which are filtered based on signal-to-noise to obtain a daily average in the across and along track directions. The results are plotted in Figure 12 for Cycle 033, giving the average positional offsets in kilometres for Nadir and Oblique views.

Figure 13 shows the global positional offset distribution during the Cycle 033. In Nadir view, the maps show larger positional offsets at latitudes >60 degrees. In Oblique view, the offsets are larger than in the Nadir view across the whole globe, especially in the along-track direction.

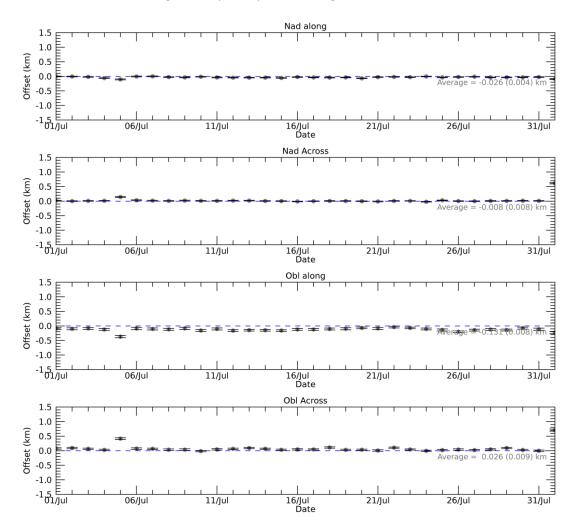


Figure 12: Daily offset results in km from the GeoCal Tool analysis for Nadir along- and across-track (top two plots) and Oblique along- and across-track (bottom two plots). The error bars show the standard deviation. The x-axis shows the date (day/month).

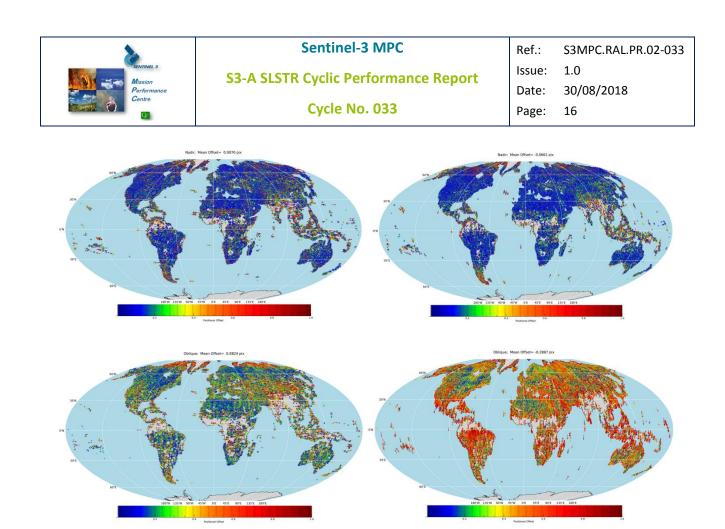
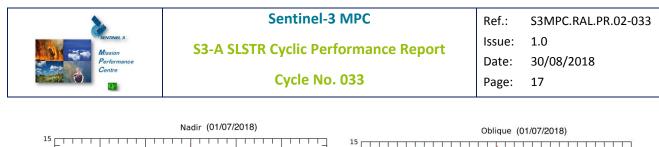


Figure 13: Worldwide positional offset distribution in across- (left) and in along-track (right) directions for Nadir (top) and Oblique (bottom) views during Cycle-033. Different colours represent the size of the offset.

On 5th July, there was an increase in the positional offsets up to 0.5 km in the across- and in the alongtrack directions for the Nadir and Oblique views due to a period of missing data from the satellite (see Section 6). The effect is shown clearly in Figure 14. As shown in Figure 15, the missing data affected the positional offset throughout orbit 102 passing over Australia and the Kamchatka peninsula.



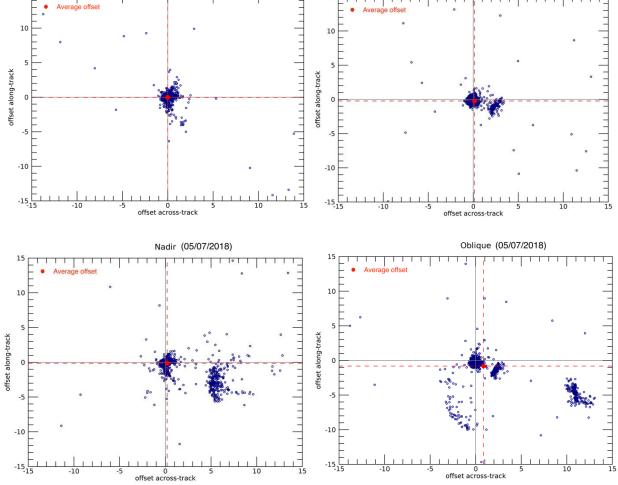


Figure 14: Top: Positional offsets in along-track with respect to across-track for Nadir (left) and Oblique (right) views on 1st July 2018. Bottom: Positional offsets in along-track with respect to across-track for Nadir (left) and Oblique (right) views on 5th July showing a large dispersion in the positional offset.

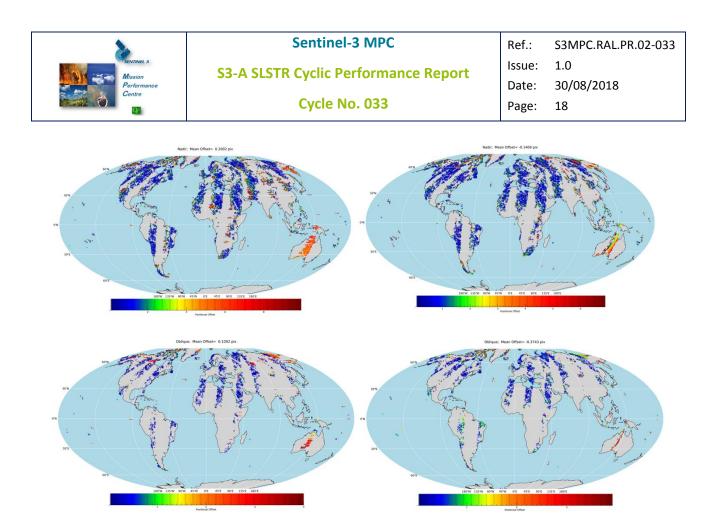


Figure 15: Worldwide positional offset distribution in across- (left) and in along-track (right) directions for Nadir (top) and Oblique (bottom) views on the 5th of July. Offsets increased along orbit 102.



3.2 Radiometric validation

The radiometric calibration of the visible and SWIR channels is monitored using the S3ETRAC service. The S3ETRAC service extracts OLCI and SLSTR Level-1 data and computes associated statistics over 49 sites corresponding to different surface types (desert, snow, ocean maximising Rayleigh signal, and ocean maximising sunglint scattering). These S3ETRAC products are used for the assessment and monitoring of the VIS and SWIR radiometry by the ESL.

Details of the S3ETRAC/SLSTR statistics are provided on the S3ETRAC website <u>http://s3etrac.acri.fr/index.php?action=generalstatistics#pageSLSTR</u>

- Number of SLSTR products processed by the S3ETRAC service
- Statistics per type of target (DESERT, SNOW, RAYLEIGH, SUNGLINT)
- Statistics per site
- Statistics on the number of records

Figure 16 shows the results of the inter-comparison analysis of SLSTR with AATSR over desert sites processed in Cycle 033. SLSTR agrees with AATSR for the visible channels, but channel S5 differs from AATSR by 12%.



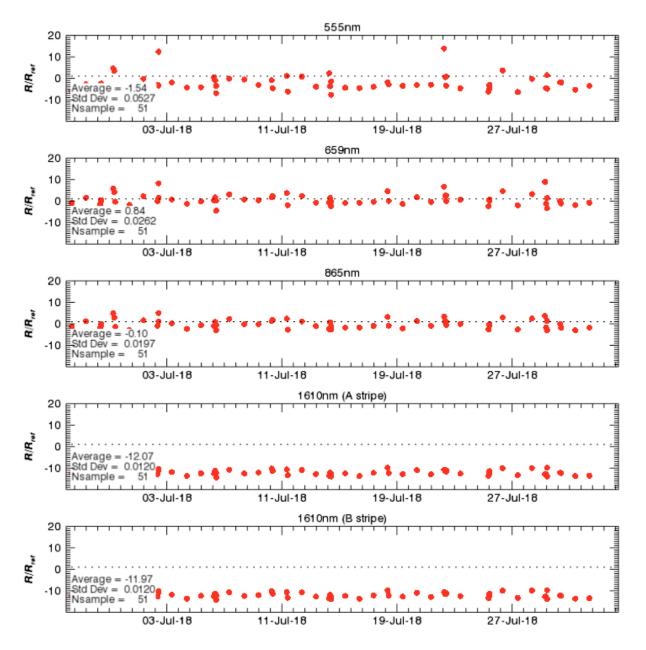


Figure 16: Ratio of SLSTR and AATSR radiances in Nadir view (shown as a percentage) using combined results for all desert sites processed in Cycle 033.

Oblique view comparisons using desert sites are not available due to geometric differences between the different sensors. A full analysis for visible and SWIR channels in Nadir and Oblique views was made using radiative transfer modeling of sun-glints. Results can be found in the presentation, "WED-0900-SL-Etxaluze WEB.pdf" in the Joint SLSTR session of the fourth S3VT meeting:

https://www.eumetsat.int/website/home/News/ConferencesandEvents/DAT_3645214.html



As described in the latest Product Notice for processing baseline v2.29, the recommendation for users is to adjust the S5 and S6 radiometric calibration as shown in Table 5.

Table 5: Recommended correction factors for channel S5 and S6 radiances as given in the Product Notice forprocessing baseline v2.29.

	Nadir view	Oblique view
S5 correction	1.12	1.15
S6 correction	1.20	1.26

3.3 Image quality

The Level-1 image quality is assessed when data are available at the MPC. For example by combining all granules over one day into a single combined image. Figure 17 shows an example combined image for the visible channels from 12th July 2018 (daytime only).

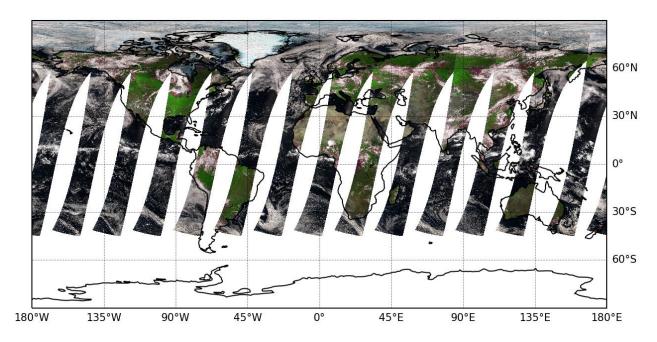


Figure 17: Daytime combined Level-1 image for visible channels on 12th July 2018.



4 Level 2 SST validation

SLSTR A level 2 WST SSTs have been validated for Cycle 033 by binning to level 3 across the entire cycle and compared to the Met Office OSTIA L4 analysis.

SLSTR A level 2 WCT SSTs have been validated using CMEMS *in situ* data for Cycle 033. Match-ups between SLSTRA and *in situ* data are provided by the EUMESAT OSI-SAF.

4.1 Level 3

Level 3 spatially averaged SST maps for daytime and nighttime are shown in Figure 18. The figures are produced by spatial and temporal binning of quality_level = 5 1-km pixels from all available SL_2_WST granules within the cycle. Also shown in Figure 18 are the number of 1-km pixels contributing to each average and the mean difference to OSTIA (dt_analysis).

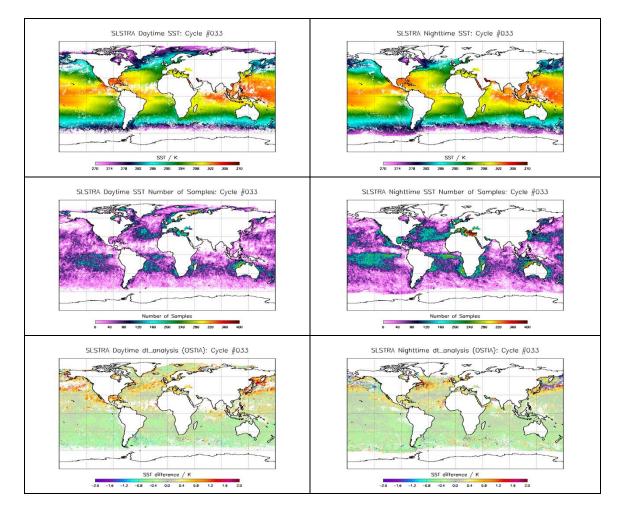


Figure 18: (Top) Level 3 spatially average SST for Cycle 033 at a resolution of 0.05 degrees. Maps are shown for daytime (left) and nighttime (right). Also shown are (middle) number of 1-km samples in each average and (bottom) mean difference to OSTIA L4 SST analysis.



4.2 Dependence on latitude, TCWV, Satellite ZA and date

The dependence of the difference between SLSTRA SST_{skin} and drifting buoy SST_{depth} for Cycle 033 is shown in Figure 19. No adjustments have been made for difference in depth or time between the satellite and in situ measurements. SLSTRA SSTs are extracted from the SL_2_WCT files. Daytime 2-channel (S8 and S9) results are shown in red, night time 2-channel results are shown in blue and night time 3-channel results are shown in green. Solid lines indicate dual-view retrievals, dashed lines indicate nadir-only retrievals. Bold lines indicate statistically significant (95% confidence) results.

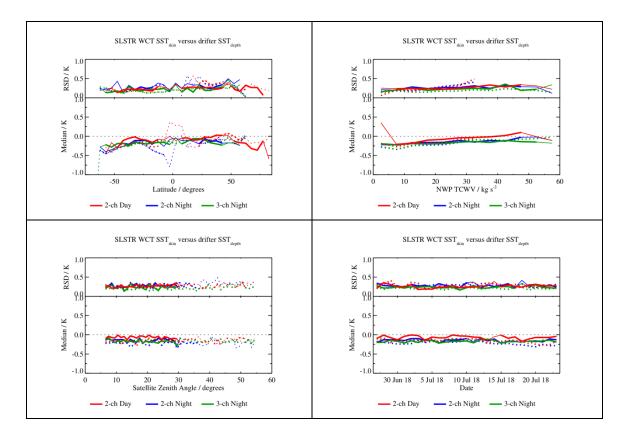


Figure 19: Dependence of median and robust standard deviation of match-ups between SLSTRA SST_{skin} and drifting buoy SST_{depth} for Cycle 033 as a function of latitude, total column water vapour (TCWV), satellite zenith angle and date. Any data gaps are due to delays in match-up processing.

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4.3 Spatial distribution of match-ups

The spatial distribution of SLSTRA/drifter match-ups for Cycle 033 is shown in Figure 20. No adjustments have been made for difference in depth or time between the satellite and *in situ* measurements.

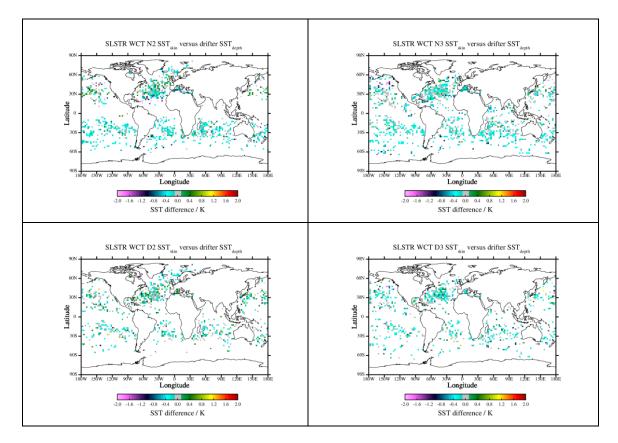


Figure 20: Spatial distribution of match-ups between SLSTR-A SST_{skin} and drifting buoy SST_{depth} for Cycle 033.



4.4 Match-ups statistics

Match-ups statistics (median and robust standard deviation, RSD) of SLSTR-A/drifter match-ups for Cycle 033 are shown in Table 6. No adjustments have been made for difference in depth or time between the satellite and *in situ* measurements and so at night time (in the absence of diurnal warming) an offset of around -0.17 K is expected. The RSD values indicate SLSTR-A is providing SSTs mostly within its target accuracy (0.3 K).

Retrieval	Number	Median (K)	RSD (K)
N2 day	2901	-0.16	0.28
D2 day	2052	-0.06	0.27
N2 night	2623	-0.22	0.28
N3 night	3456	-0.15	0.21
D2 night	1629	-0.14	0.28
D3 night	1629	-0.17	0.24

Table 6: SLSTR drifter match-up statistics for Cycle 033.



5 Level 2 LST validation

Level 2 Land Surface Temperature products have been validated against *in situ* observations (Category-A validation) from ten "Gold Standard" Stations, and intercompared (Category-C validation) with respect to an independent operational reference product (SEVIRI from LSA SAF). In all cases it is the NTC products that are validated, and the Probabilistic cloud masking implementation is used for all cloud masking. Level-3C products for the full Cycle are evaluated for identifying any gross problems.

5.1 Category-A validation

Category-A validation uses a comparison of satellite-retrieved LST with *in situ* measurements collected from radiometers sited at a number of stations spread across the Earth, for which the highest-quality validation can be achieved. Here we concentrate on eleven "Gold Standard" stations which are installed with well-calibrated instrumentation. The results can be summarised as follows (see Figure 21):

- Average absolute accuracy (vs. Gold Standard):
 - Daytime: 0.8K
 - o Night-time: 0.8K

Both the day-time and night-time accuracies are within the mission requirement of < 1K, even with some impact by very small number of matchups for some stations in the cycle due to cloud, and slightly larger bias at the most heterogeneous stations. Note, in this cycle no cloud free matchups were obtained from the Sioux Falls, South Dakota site.

As with the past two cycles cloud has reduced the number of matchups per station to single figures for most stations during day or night, with some missing statistics entirely. It is therefore challenging to determine robust statistics. Nonetheless, it can be seen that overall the matchups are in general close to the 1:1 line with very few outliers. No systematic bias is evident from these matchups.

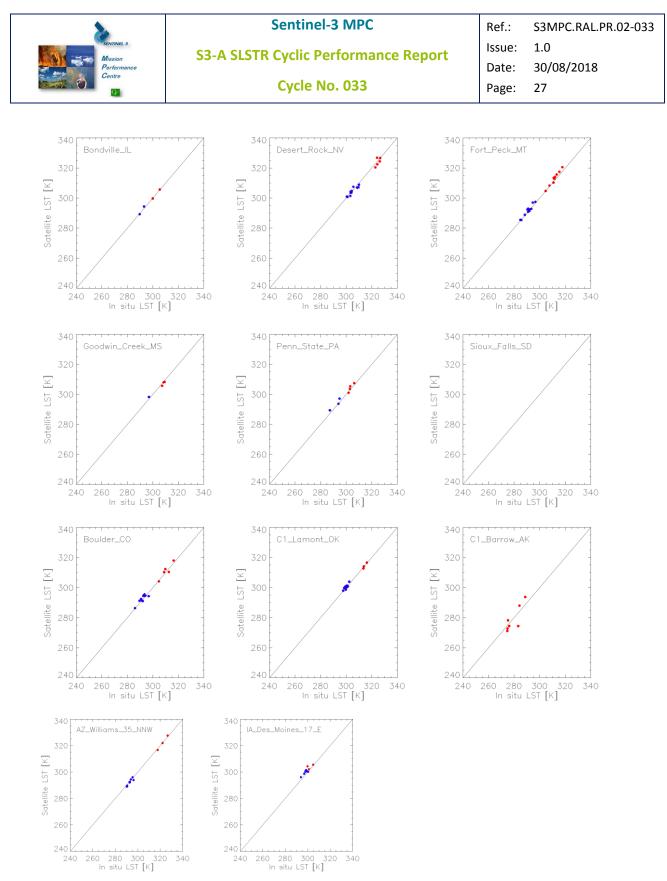


Figure 21: Validation of the SL_2_LST product over Cycle 33 at seven Gold Standard in situ stations of the SURFRAD network plus two Gold Standard station from the ARM network, and two Gold Standard station from the USCRN network: Bondville, Illinois (1st row, left); Desert Rock, Nevada (1st row, centre); Fort Peck, Montana (1st row, right); Goodwin Creek, Mississippi (2nd row, left); Penn State University, Pennsylvania (2nd row, centre); Sioux Fall, South Dakota (2nd row, right); Table Mountain, Colorado (3rd row, left); Southern Great Plains, Oklahoma (3rd row, centre); Barrow, Alaska (3rd row, right); Williams, Arizona (4th row, left); Des Moines, Iowa (4th row, centre).



5.2 Category-C validation

Category-C validation uses inter-comparisons with similar LST products from other sources such as other satellite sensors, which give important quality information with respect to spatial patterns in LST deviations. Here we compare the SL_2_LST product with the operational SEVIRI L2 product available from the LSA SAF. The results can be summarised in Table 7.

 Table 7: Median differences from the intercomparison of the SL_2_LST product with respect to the operational

 LSA SAF SEVIRI LST product for the period of Cycle 33.

Continent	Median Difference (K)		
continent	Day	Night	
Africa	1.9	1.9	
Europe	2.9	1.4	

For Africa, the differences across the continent are relatively small, with just slightly larger differences in the East Africa Rift during the day. For Europe the differences increase towards the east into European Russia. These eastern matchups are towards the edge of the SEVIRI disk and therefore represent large viewing angles. At these extreme viewing angles it is expected that SLSTR LST would be increasingly higher than SEVIRI LST. Over Central Europe the differences are around the 2K level but even here the SEVIRI viewing angles are in general higher than for SLSTR.

Other analysis can be summarised as follows:

- Differences with respect to biomes tend to be larger during the day for surfaces with more heterogeneity and/or higher solar insolation
- Differences increase for both day and night towards the edge of the SEVIRI disk as the SEVIRI zenith angles become larger

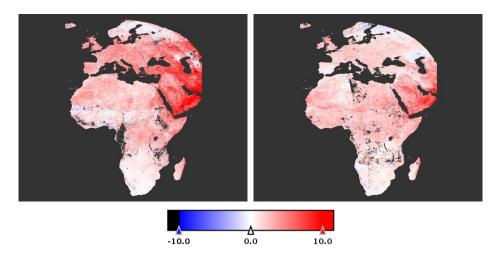


Figure 22: Intercomparison of the SL_2_LST product with respect to the operational LSA SAF SEVIRI LST product for the period of Cycle 33: daytime composite differences (left), night-time composite differences (right).

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While some of these differences are > 1 K they are all within the corresponding uncertainty of SEVIRI at the pixel-scale (> 2K), and so the **two products can be assessed as being consistent**. It should also be noted that there are no significant differences between the two products in terms of biome-dependency - the differences are consistent across biomes. Some residual cloud contamination is evident from the large differences at the edge of cloud cleared features. While the cloud contamination is seen for both SLSTR (strong negative differences) and SEVIRI (strong positive differences), compared with cycles where the basic cloud mask was used the contamination for SLSTR is lower indicating improved masking with the Probabilistic Cloud Mask. However, less matchups are evident which suggests the cloud masking could be slightly over conservative in some biomes. This will be monitored over the following Cycles to identify whether an optimisation to the cloud coefficients should be considered for some biomes.



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5.3 Level-3C Assessment

To better understand the global product and identify any gross issues Level-3 evaluation is also performed. Here we generate monthly daytime and night-time 0.05° composites (Figure 23 – top) of the LST field and corresponding sampling ratios (Figure 23 - bottom). The sampling ratios are derived as clear_pixels / (clear_pixels + cloudy_pixels).

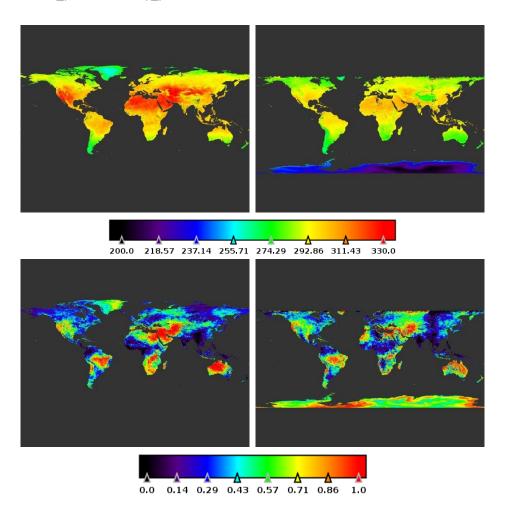


Figure 23: Monthly composites at 0.05° of LST (top) and sampling ratio (bottom) for the period of Cycle 33: daytime composites (left), night-time composites (right).

The LST fields indicate the SL_2_LST product is producing values in line with expectations. There are no distinct issues or non-physical values evident. Cloud contamination appears to be at a minimum, although there appears to be some excessive cloud clearing in some regions particularly at night. This is supported by the sampling ratio which is lower than would be expected over parts of the Sahara and Central Asia. Comparing this effect from the previous cycle indicates the same regions are subject to excessive cloud clearing. This will continue to be monitored, but is providing growing evidence that the lack of temporal interpolation of the ECMWF Skin Temperature could be a root cause.



6 Events

SLSTR was switched on and operating nominally during the cycle, with SUE scanning and autonomous switching between day and night modes, except for the following events.

- On 2nd July, radio frequency interference (RFI) at Svalbard caused a series of short gaps in data around 14:08 and again from 14:38 to 14:43.
- An antenna error at Svalbard caused one orbit of missing data between approximately 22.30 on 4th July and 00:15 on 5th July. These missing data also cause a degradation in pointing in the following orbit (see Section 3.1).
- On 18th July, the cooler cold-tip temperature was increased from 77.5K to 78.5K. This change increases the detector temperatures slightly as shown in Figure 3. The reason for the change is to put less stress on the cooler so that it can last longer between decontaminations, and therefore the downtime of the instrument can be minimised. The change in detector temperature affects the radiometric gain and therefore the dynamic range. The only noticeable difference in dynamic range after 18th July is for channel S8, where the minimum brightness temperature limit increases by approximately 4K for one of the detectors (from 183 to 187 K). This can be fixed by adjusting the detector voltage offset, which will be carried out in a future cycle.



7 Appendix A

Other reports related to the Optical mission are:

S3-A OLCI Cyclic Performance Report, Cycle No. 033 (ref. S3MPC.ACR.PR.01-033)

All Cyclic Performance Reports are available on MPC pages in Sentinel Online website, at: <u>https://sentinel.esa.int</u>

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