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

S3-A SLSTR Cyclic Performance Report

Cycle No. 037

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Performance
Centre

SENTINEL 3



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Changes Log

Version	Date	Changes
1.0	16/11/2018	First Version

List of Changes

Version	Section	Answers to RID	Changes



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1 Processing Baseline Version

IPF	IPF / Processing Baseline version	Date of deployment
SL1	06.16 / 2.37	CGS: 02/08/2018 09:22 UTC
		PAC: 02/08/2018 09:32 UTC
SL2	06.14 / 2.37	CGS: 02/08/2018 09:19 UTC (NRT)
		PAC: 02/08/2018 09:36 UTC (NTC)

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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 037. The temperatures were stable (on top of a daily variation cycle, and a longer term rise as the Earth approaches perihelion at the beginning of January).

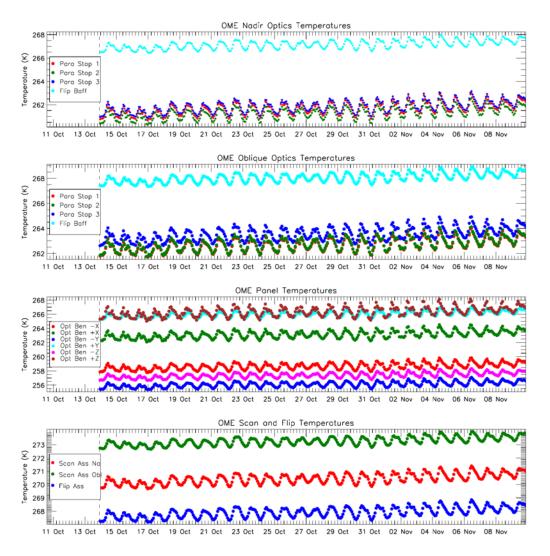


Figure 1: OME temperature trends for Cycle 037 showing the paraboloid stops and flip baffle (top two plots) and optical bench and scanner and flip assembly (lower two plots). The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit.

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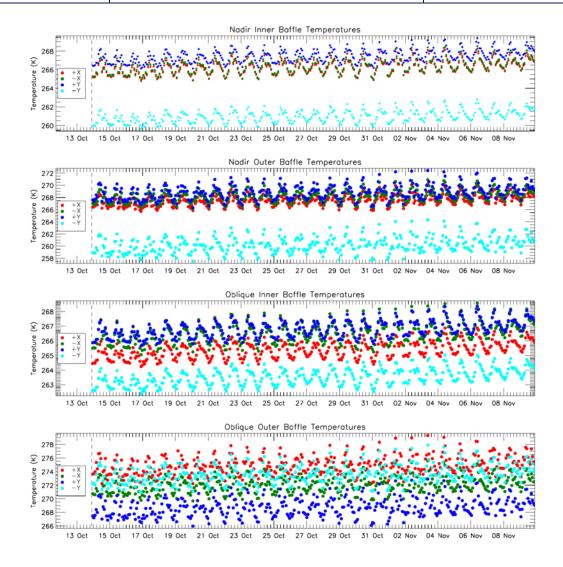


Figure 2: Baffle temperature trends for Cycle 037. The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit.



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2.2 Detector temperatures

The detector temperatures in Cycle 037 were stable at their expected values following the latest decontamination performed at the end of Cycle 035 and start of Cycle 036. 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. The decontaminations are clearly visible as a rise in detector temperature (February and September). The step in temperature for the SWIR and TIR channels (18th July) is due to an increase in the cooler cold tip temperature which was designed to allow an increased time between decontaminations. A few orbits in Cycle 32 and Cycle 35 show slightly lower average detector temperatures and these were due to instrument tests that were performed connected to the commissioning of S3B.

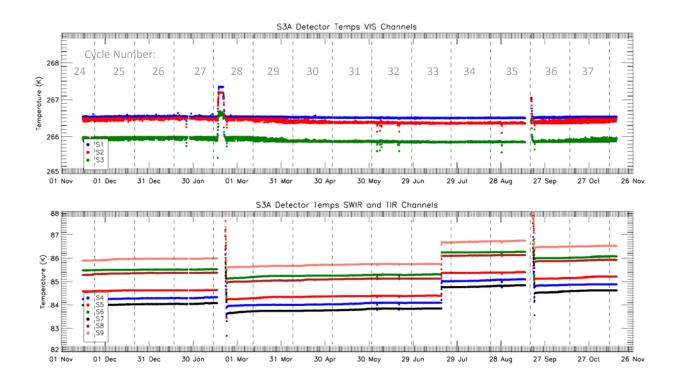


Figure 3: Detector temperatures for each channel for the last year of operations. Discontinuities occur for the infrared channels where the FPA was heated for decontamination. The vertical dashed lines indicate the start and end of each cycle. Each dot represents the average temperature in one orbit.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

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2.3 Scanner performance

Scanner performance in Cycle 037 has been consistent with previous operations and within required limits.

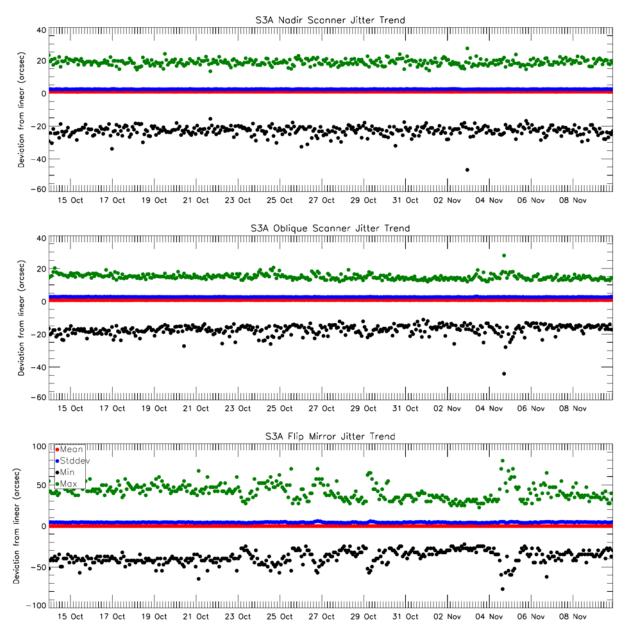


Figure 4: Scanner and flip jitter for Cycle 037, showing mean, stddev and max/min difference from expected position per orbit for the nadir view (red, blue, green and black respectively).

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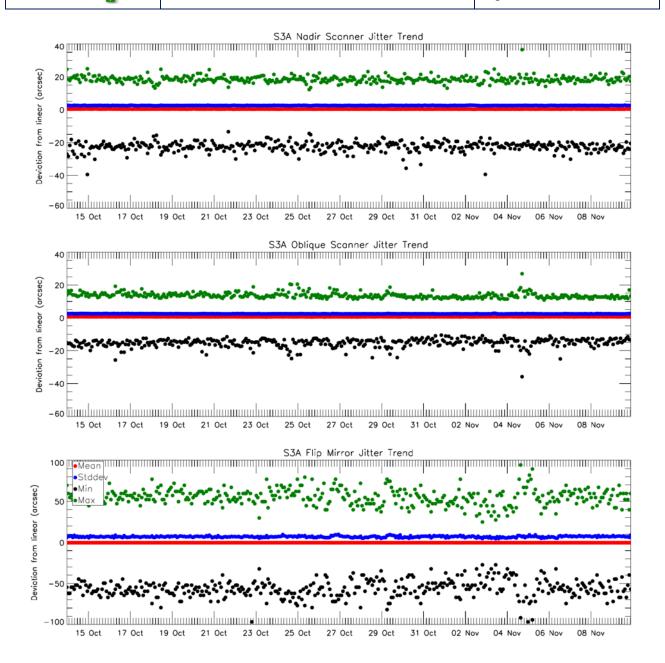


Figure 5: Scanner and flip jitter for Cycle 037, showing mean, stddev and max/min difference from expected position per orbit for the oblique view (red, blue, green and black respectively).



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2.4 Black-Bodies

Figure 6 shows the orbital average blackbody temperatures during Cycle 037. The temperatures were stable on top of a daily variation cycle and a slight rise through the cycle. The rise in temperature through the cycle is part of a longer term trend which shows a yearly variation, with temperatures rising as the Earth approaches perihelion at the beginning of January (see Figure 7 and Table 3). Figure 6 shows that gradients across the blackbody baseplate are stable and within their expected range (±20mK).

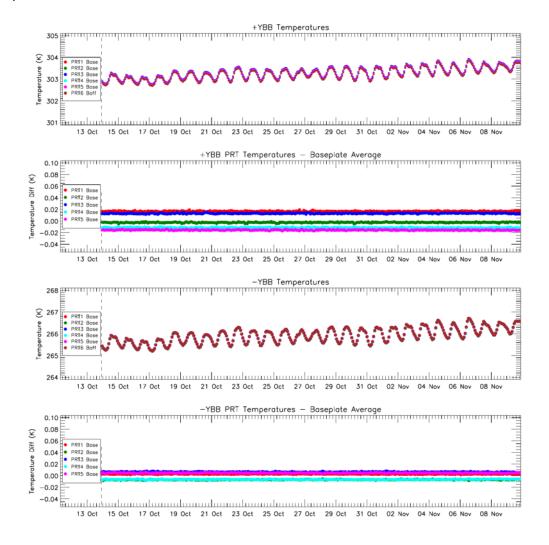


Figure 6: Blackbody temperature and baseplate gradient trends during Cycle 037. The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit.



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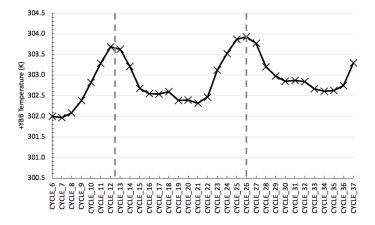


Figure 7: Long term trends in average +YBB temperature in each cycle, showing yearly variation. The vertical dashed lines indicate the 1st January 2017 and 2018.



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2.5 Detector noise levels

2.5.1 VIS and SWIR channel signal-to-noise

The VIS and SWIR channel noise in Cycle 037 was stable and consistent with previous operations - the signal-to-noise ratio of the measured VISCAL signal over the past year is plotted in Figure 8. Table 1 and Table 2 give the average signal-to-noise in each cycle (excluding the instrument decontaminations). 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 026-037, averaged over all detectors for the nadir view.

	Average		Nadir Signal-to-noise ratio										
	Reflectance Factor	Cycle 026	Cycle 027	Cycle 028	Cycle 029	Cycle 030	Cycle 031	Cycle 032	Cycle 033	Cycle 34	Cycle 035	Cycle 036	Cycle 037
S1	0.187	228	226	223	228	232	234	226	233	231	234	233	232
S2	0.194	233	232	229	232	237	233	231	232	236	235	235	236
S3	0.190	227	227	223	229	228	228	221	223	229	226	225	229
S4	0.191	141	138	138	138	140	139	139	137	139	138	140	140
S5	0.193	238	235	236	232	233	235	236	232	231	230	234	235
S6	0.175	146	143	143	143	142	143	143	142	141	141	141	142

Table 2: Average reflectance factor, and signal-to-noise ratio of the measured VISCAL signal for cycles 026-037, averaged over all detectors for the oblique view.

	Average		Oblique Signal-to-noise ratio											
	Reflectance Factor	Cycle 026	Cycle 027	Cycle 028	Cycle 029	Cycle 030	Cycle 031	Cycle 032	Cycle 033	Cycle 34	Cycle 035	Cycle 036	Cycle 037	
S1	0.166	239	236	235	237	242	249	239	245	236	241	240	240	
S2	0.170	243	239	238	243	249	249	247	246	245	246	245	251	
S3	0.168	234	227	229	235	234	239	234	232	232	237	234	238	
S4	0.166	110	107	107	109	109	110	108	109	111	109	107	109	
S5	0.166	172	170	171	170	170	169	172	168	169	170	168	171	
S6	0.155	109	107	107	109	109	110	110	108	109	109	112	110	

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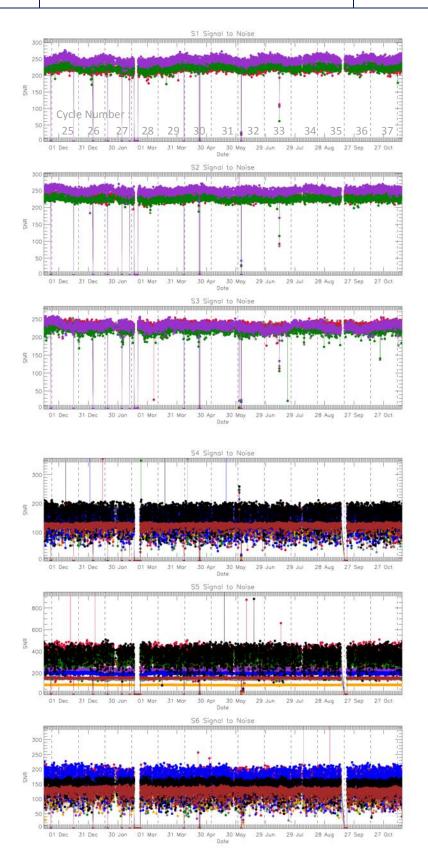


Figure 8: VIS and SWIR channel signal-to-noise of the measured VISCAL signal in each orbit for the last year of operations. Different colours indicate different detectors. The vertical dashed lines indicate the start and end of each cycle.



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2.5.2 TIR channel NEDT

The thermal channel NEDT values in Cycle 037 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.

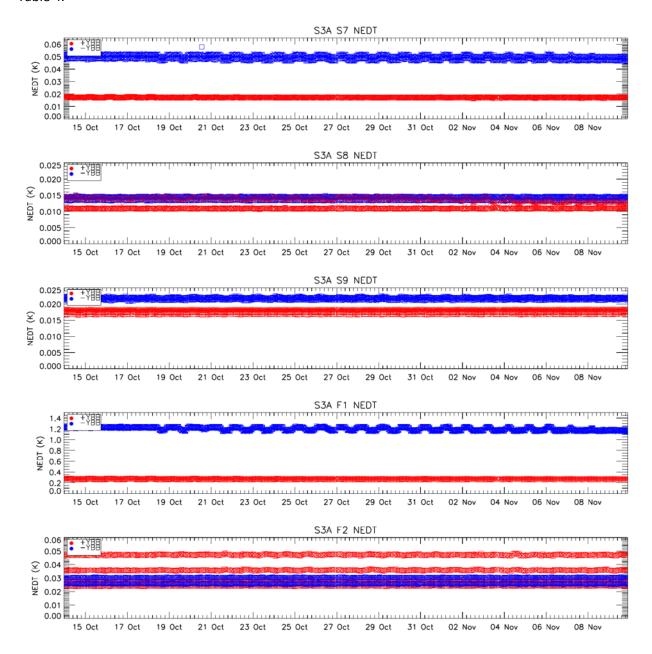


Figure 9: NEDT trend for the thermal channels in Cycle 037. Blue points were calculated from the cold blackbody signal and red points from the hot blackbody. The square symbols show results calculated from the nadir view and crosses show results from the oblique view. Results are plotted for all detectors and integrators, which is why there are several different levels within the same colour points (particularly for S8 and F2).



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Table 3: NEDT for cycles 026-037 averaged over all detectors for both Earth views towards the +YBB (hot).

		Cycle 026	Cycle 027	Cycle 028	Cycle 029	Cycle 030	Cycle 031	Cycle 032	Cycle 033	Cycle 034	Cycle 035	Cycle 036	Cycle 037
+YBB t	-	303.931	303.776	303.203	302.977	302.850	302.868	302.841	302.669	302.622	302.624	302.744	303.295
	S7	17	17.1	17.1	17.2	17.5	17.4	18.1	17.6	17.7	17.7	17.6	17.4
NEDT	S8	12.1	12.2	11.7	11.6	11.8	12.0	12.1	12.3	12.4	12.6	12.1	12.3
NEDT (mK)	S9	17.5	17.7	16.9	16.8	16.9	17.0	17.3	17.6	18.3	18.3	17.7	17.7
(,	F1	265	268	265	268	273	274	295	279	279	279	277	273
	F2	33.4	34.5	34	33.7	33.7	33.8	33.6	33.6	33.7	33.6	33.9	34.0

Table 4: NEDT for cycles 026-037 averaged over all detectors for both Earth views towards the -YBB (cold).

		Cycle 026	Cycle 027	Cycle 028	Cycle 029	Cycle 030	Cycle 031	Cycle 032	Cycle 033	Cycle 034	Cycle 035	Cycle 036	Cycle 037
-YBB te	-	266.760	266.479	265.683	265.460	265.439	265.600	265.621	265.337	265.203	265.110	265.245	265.920
	S7	48.0	48.2	49.3	49.8	49.9	49.9	48.8	50.0	50.6	51.0	50.7	49.6
NEDT	S8	13.7	13.9	13.8	13.8	13.8	13.9	13.9	14.0	14.4	14.4	14.2	14.2
NEDT (mK)	S9	21.5	21.5	20.8	20.8	20.9	21.1	21.0	21.5	22.3	22.5	21.7	21.7
(,	F1	1144	1150	1179	1201	1207	1206	1195	1207	1209	1224	1229	1199
	F2	26.8	27.4	27.3	27.3	27.3	27.5	27.8	27.6	28.2	28.3	28.1	28.1



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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 started at the end of Cycle 35 and finished at the beginning of Cycle 36. The previous decontamination was performed in Cycle 28.

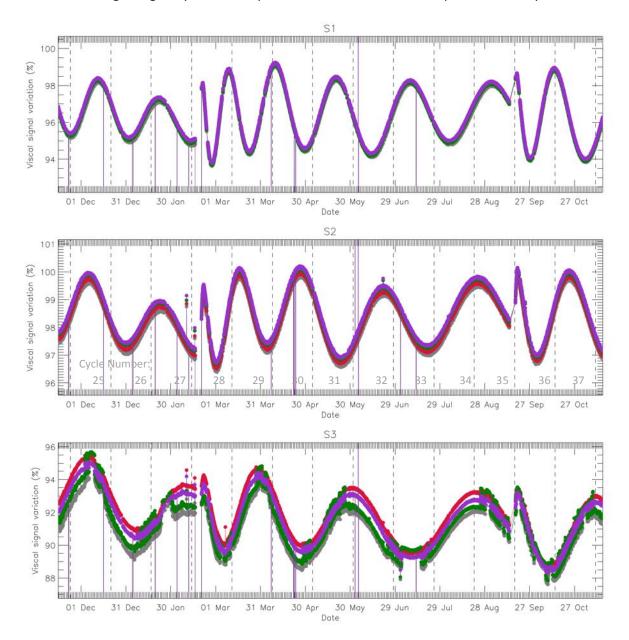


Figure 10: VISCAL signal trend for VIS channels for the last year of operations (nadir view). Different colours represent different detectors. The vertical dashed lines indicate the start and end of each cycle.

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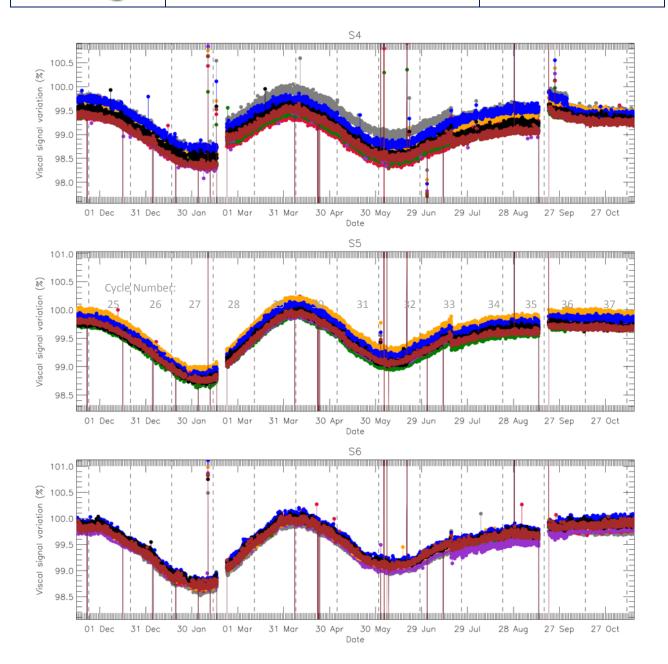


Figure 11: VISCAL signal trend for SWIR channels for the last year of operations (nadir view). Different colours represent different detectors. The vertical dashed lines indicate the start and end of each cycle.



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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 037, giving the average positional offsets in kilometres for Nadir and Oblique views.

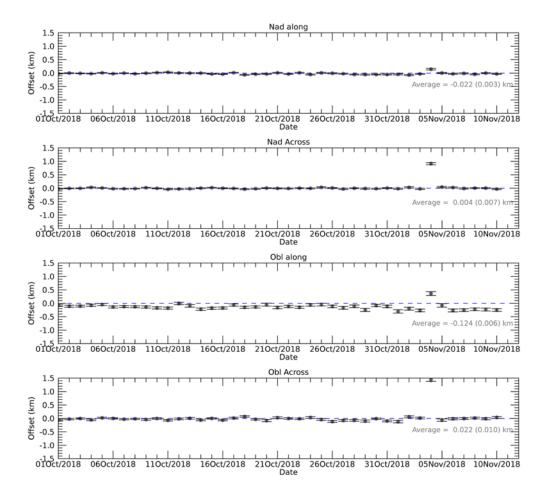


Figure 12: Daily offset results in km from the GeoCal Tool analysis for Nadir along- and across-track (top two plots) and Oblique along- and across-track (bottom two plots). The error bars show the standard deviation.

On 4th November, a collision avoidance manoeuvre was executed, increasing the positional offsets in the across-track direction for the Nadir and Oblique views in one orbit (relative orbit 306), as shown in Figure 13.



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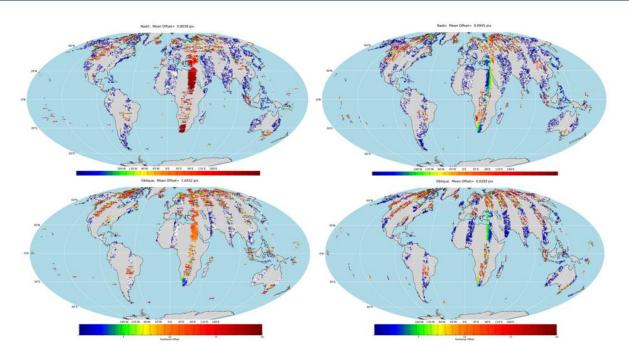


Figure 13: Worldwide positional offset distribution in across- (left) and in along-track (right) directions for Nadir (top) and Oblique (bottom) views for 4th November. Different colours represent the size of the offset.



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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 http://s3etrac.acri.fr/index.php?action=generalstatistics#pageSLSTR

- 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 14 and Figure 15 show the results of the inter-comparison analysis of SLSTR with OLCI and AATSR over desert sites processed in Cycle 037. SLSTR agrees with OLCI and AATSR for the visible channels, but channel S5 differs from AATSR by 12%.

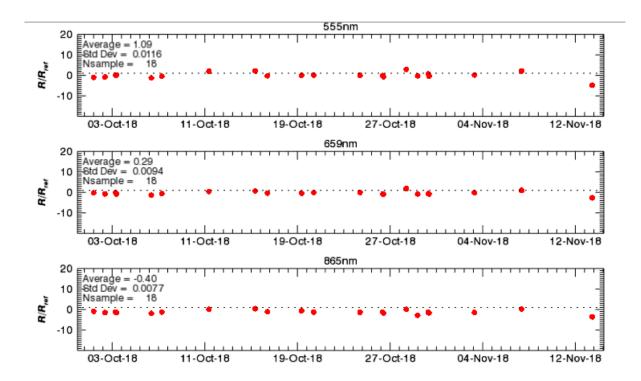


Figure 14: Ratio of SLSTR and OLCI radiances for the visible channels in Nadir view (shown as a percentage) using combined results for all desert sites processed in Cycle 037.

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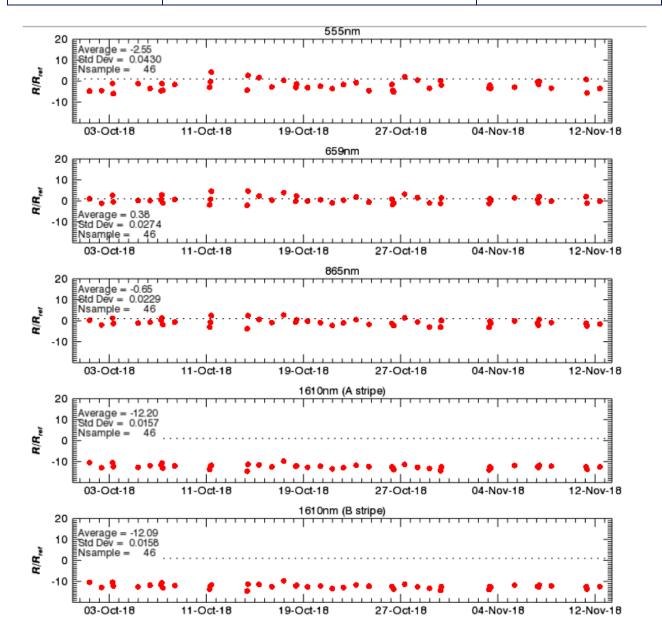


Figure 15: Ratio of SLSTR and AATSR radiances in Nadir view (shown as a percentage) using combined results for all desert sites processed in Cycle 037.

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 modelling 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



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As described in the latest Product Notice for processing baseline v2.37, 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 for processing baseline v2.37.

	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 16 shows an example combined image for the visible channels from 22nd October 2018 (daytime only).

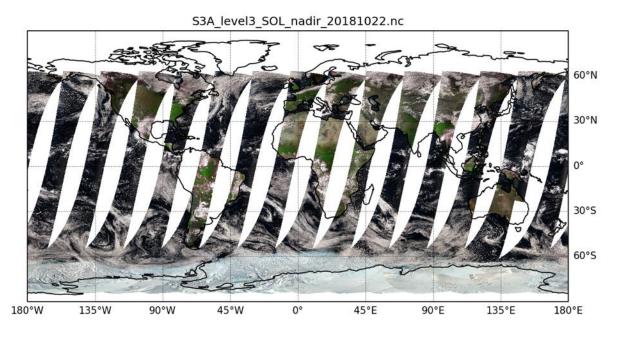


Figure 16: Daytime combined Level-1 image for visible channels on 22nd October 2018.



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4 Level 2 SST validation

SLSTR A level 2 WST SSTs have been validated for Cycle 037 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 037. 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 17. 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 17 are the number of 1-km pixels contributing to each average and the mean difference to OSTIA (dt_analysis).

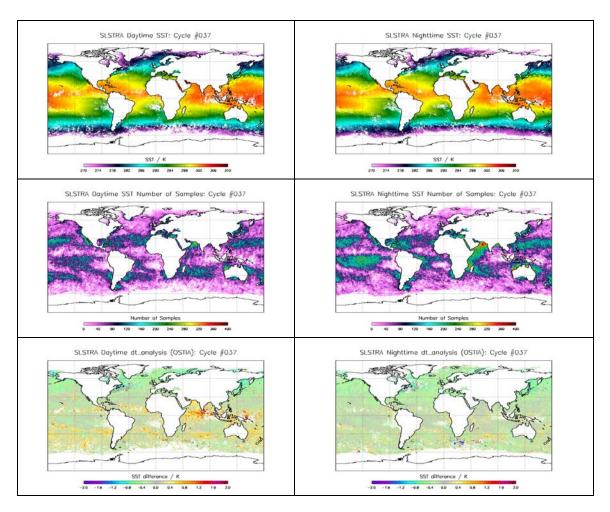


Figure 17: (Top) Level 3 spatially average SST for Cycle 037 at a resolution of 0.05 degrees. Maps are shown for daytime (left) and nighttime (right). Also shown are (middle) number of 1-km samples in each average and (bottom) mean difference to OSTIA L4 SST analysis.



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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 037 is shown in Figure 18. 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.

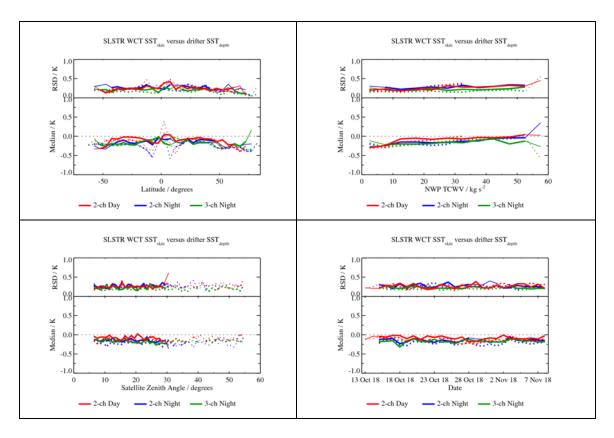


Figure 18: Dependence of median and robust standard deviation of match-ups between SLSTRA SST_{skin} and drifting buoy SST_{depth} for Cycle 037 as a function of latitude, total column water vapour (TCWV), satellite zenith angle and date. Any data gaps are due to delays in match-up processing at the time this report was generated.



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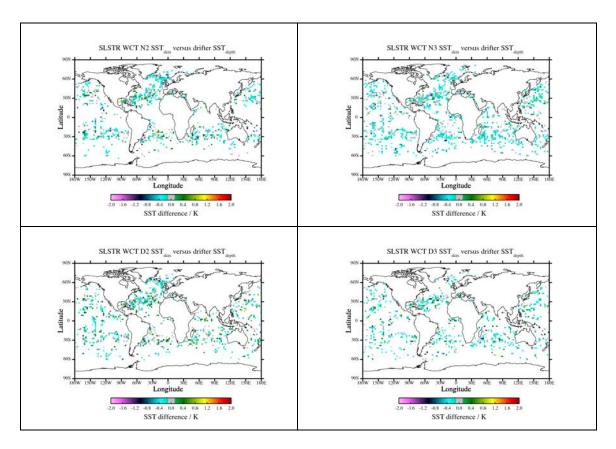
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4.3 Spatial distribution of match-ups

The spatial distribution of SLSTR-A/drifter match-ups for Cycle 037 is shown in Figure 19. No adjustments have been made for difference in depth or time between the satellite and in situ measurements.



 $\textit{Figure 19: Spatial distribution of match-ups between SLSTR-A SST}_{\textit{skin}} \textit{ and drifting buoy SST}_{\textit{depth}} \textit{ for Cycle 037.}$



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4.4 Match-ups statistics

Match-ups statistics (median and robust standard deviation, RSD) of SLSTR-A/drifter match-ups for Cycle 037 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).

Table 6: SLSTR drifter match-up statistics for Cycle 037.

Retrieval	Number	Median (K)	RSD (K)
N2 day	2087	-0.13	0.27
D2 day	2014	-0.08	0.25
N2 night	2355	-0.22	0.27
N3 night	3086	-0.16	0.19
D2 night	1496	-0.15	0.28
D3 night	1497	-0.17	0.22



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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 20):

Average absolute accuracy (vs. Gold Standard):

Daytime: 1.0K

Night-time: 0.9K

Both day-time and night-time accuracies are within the mission requirement of < 1K, even though they are impacted to some extent by very small number of matchups for some stations in the cycle due to cloud, and slightly larger bias at the most heterogeneous stations.

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.



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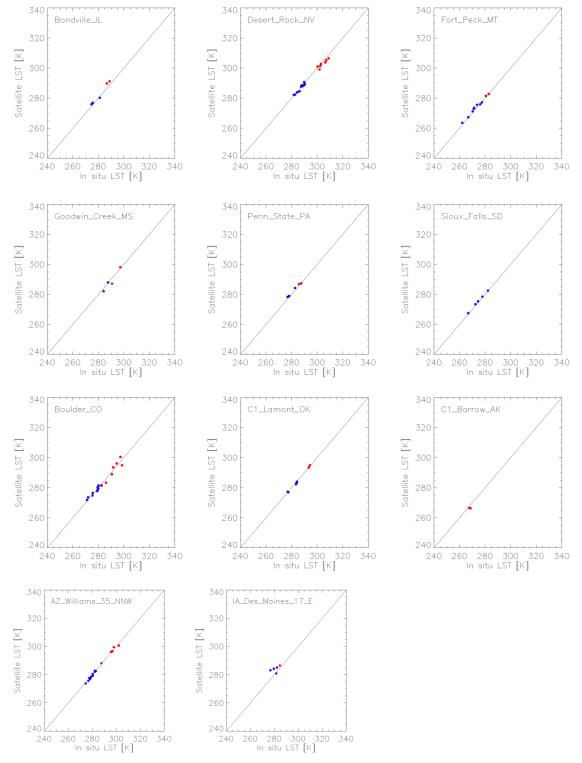


Figure 20: Validation of the SL_2_LST product over Cycle 37 at seven Gold Standard in situ stations of the SURFRAD network plus two Gold Standard station from the ARM network, and two Gold Standard station from the USCRN network: Bondville, Illinois (1st row, left); Desert Rock, Nevada (1st row, centre); 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).



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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 37.

Continent	Median Difference (K)			
Continent	Day	Night		
Africa	1.9	1.5		
Europe	-0.1	0.7		

For Africa, the differences across the continent are relatively small, with some larger differences over the Central African tropical forest and the East Africa Rift during the day, and over the Sahara at night. For Europe the differences are small across the region. Eastern matchups (such as over the Arabian Peninsula) 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. For both daytime and night-time the differences are < 2K over both continents. Compared with the previous cycle the differences are slightly reduced for both Europe and Africa which may indicate responses due to changing seasons.

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

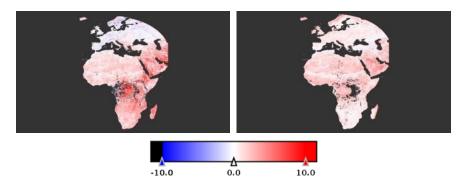


Figure 21: Intercomparison of the SL_2_LST product with respect to the operational LSA SAF SEVIRI LST product for the period of Cycle 37: daytime composite differences (left), night-time composite differences (right).



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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 22 - top) of the LST field and corresponding sampling ratios (Figure 22 - bottom). The sampling ratios are derived as clear_pixels / (clear_pixels + cloudy_pixels).

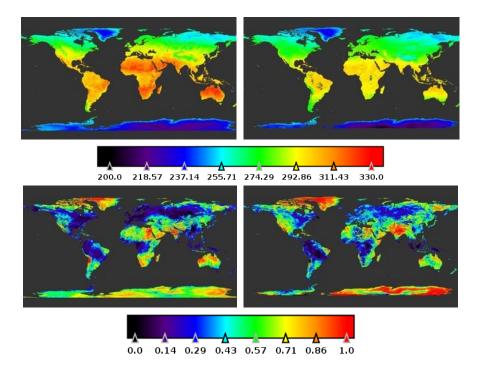


Figure 22: Monthly composites at 0.05° of LST (top) and sampling ratio (bottom) for the period of Cycle 37: daytime composites (left), night-time composites (right).

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 cycles 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 is the root cause.

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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 27th October, there was a loss of data affecting Level-1 and Level-2 granules between 00:13 and 00:22. This was due to radio frequency interference at the Svalbard ground station.

On 3^{rd} November at approximately 17:59, there was a gap in data received of ~20 seconds due to a downlink problem at Svalbard. This causes a missing stripe in the Level-1 and Level-2 images.

On 4th November, a collision avoidance manoeuvre was performed, affecting the pointing accuracy in relative orbit number 306 (see Section 3.1).



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7 Appendix A

Other reports related to the Optical mission are:

S3-A OLCI Cyclic Performance Report, Cycle No. 037 (ref. S3MPC.ACR.PR.01-037)

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

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