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

S3 SLSTR Cyclic Performance Report

S3-A

Cycle No. 047

Start date: 10/07/2019

End date: 06/08/2019

S3-B

Cycle No. 028

Start date: 20/07/2019

End date: 16/08/2019



Mission
Performance
Centre

SENTINEL 3



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Changes Log

Version	Date	Changes
1.0	30/08/2019	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			
	S3A				
SL1	06.16 / 2.37	CGS: 02/08/2018 09:22 UTC			
		PAC: 02/08/2018 09:32 UTC			
SL2	06.14 / 2.47	PAC: 25/02/2019 09:33 UTC			

IPF	IPF / Processing Baseline version	Date of deployment			
	S3B				
SL1	06.16 / 1.12	PAC: 15/10/2018 15:28 UTC			
SL2	06.14 / 1.19	PAC: 25/02/2019 09:24 UTC			

Note that more details of the processing baseline version can be found in the SLSTR Product Notice.

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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 for SLSTR-A and SLSTR-B during the cycle. The temperatures were stable (on top of a daily variation cycle).

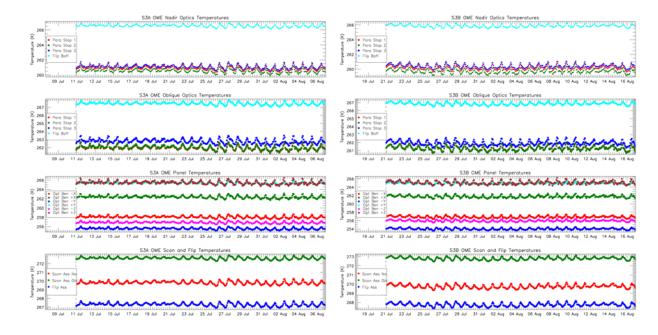


Figure 1: OME temperature trends for SLSTR-A Cycle 047 (left) and SLSTR-B Cycle 028 (right) showing the paraboloid stops and flip baffle (top two plots) and optical bench and scanner and flip assembly (lower two plots). The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit.

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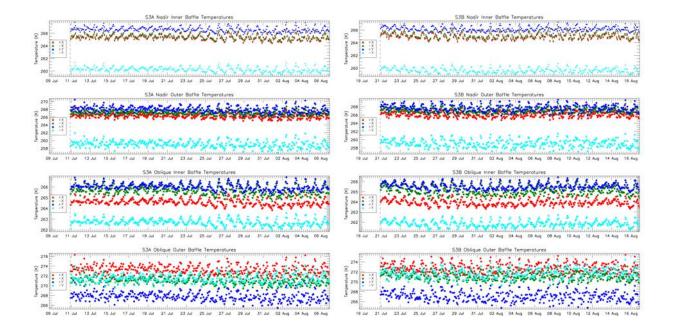


Figure 2: Baffle temperature trends for SLSTR-A Cycle 047 (left) and SLSTR-B Cycle 028 (right). The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit.



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2.2 Detector temperatures

The detector temperatures for both SLSTR-A and SLSTR-B were stable at their expected values following the latest decontamination phases. Decontamination was performed for SLSTR-A in Cycle 045 from 20th to 26th May. Decontamination was performed for SLSTR-B in Cycle 024 from 11th to 17th April 2019. Decontamination involves warming up the infrared focal plane assembly (FPA) in order to remove water ice contamination from the cold surfaces. Figure 3 and Figure 4 show the SLSTR-A and SLSTR-B detector temperatures for the past year. The decontaminations are clearly visible as a rise in detector temperature.

A few orbits (Cycle 35, 43) show slightly lower average SLSTR-A detector temperatures due to instrument tests that were performed on those days. The detector temperatures for SLSTR-B show many orbits with slightly lower VIS channel temperatures due to commissioning phase tests carried out between May and October 2018.

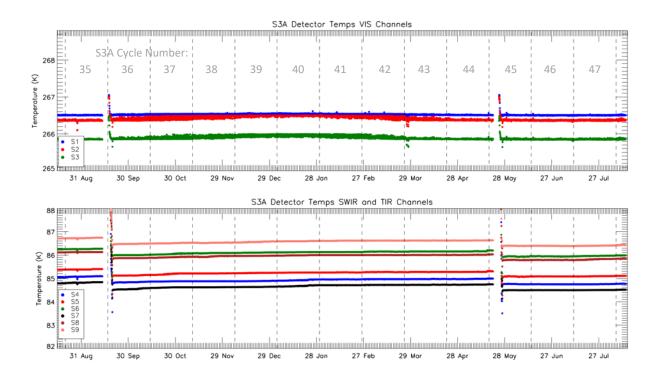


Figure 3: SLSTR-A detector temperatures for each channel for the last year of operations. Discontinuities occur for the infrared channels where the FPA was heated for decontamination. The vertical dashed lines indicate the start and end of each cycle. Each dot represents the average temperature in one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

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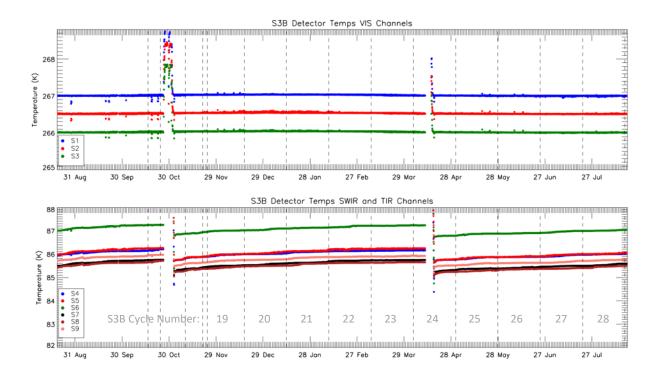


Figure 4: SLSTR-B detector temperatures for each channel for the last year of operations. Discontinuities occur for the infrared channels where the FPA was heated for decontamination. The vertical dashed lines indicate the start and end of each cycle. Each dot represents the average temperature in one orbit. The different colours indicate different detectors.



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2.3 Scanner performance

Scanner performance has been consistent with previous operations and within required limits for SLSTR-A and Figure 5 shows the trends in Cycle 047.

Figure 6 shows the trend for SLSTR-B in Cycle 028. Although the values are generally within the required limits, the scan and flip mirror deviations have larger variations than for SLSTR-A (in particular the flip mirror for the nadir view). This should be monitored carefully to make sure the jitter statistics do not get worse in the longer term.

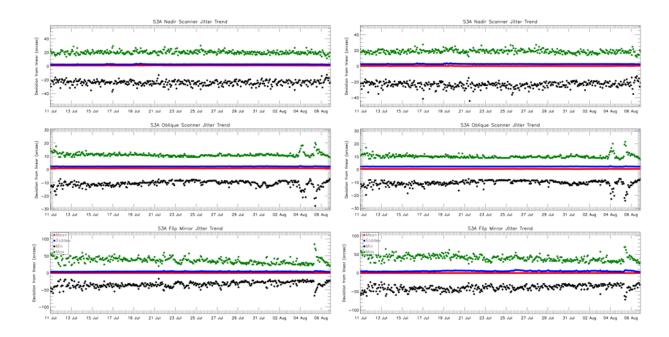


Figure 5: SLSTR-A scanner and flip jitter for Cycle 047, showing mean, stddev and max/min difference from expected position per orbit (red, blue, green and black respectively) for the nadir view (left) and oblique view (right). The plots show the nadir scanner (top), oblique scanner (middle) and flip mirror (bottom).

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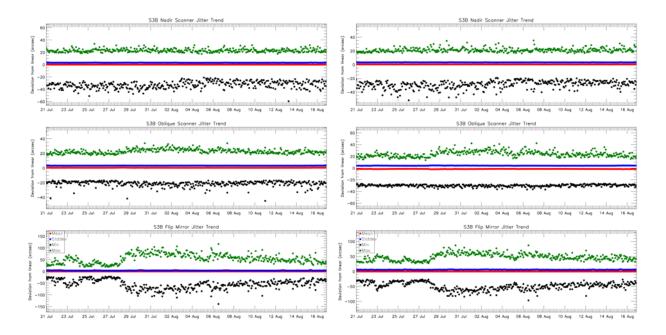


Figure 6: SLSTR-B scanner and flip jitter long term in Cycle 028, showing mean, stddev and max/min difference from expected position per orbit (red, blue, green and black respectively) for the nadir view (left) and oblique view (right). The plots show the nadir scanner (top), oblique scanner (middle) and flip mirror (bottom).



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2.4 Black-Bodies

The orbital average blackbody temperatures for SLSTR-A are shown in Figure 7, and SLSTR-B are shown in Figure 9. The temperatures were stable on top of a daily variation cycle. There are also longer term cycle-to-cycle trends which show a yearly variation, with temperatures rising as the Earth approaches perihelion at the beginning of January (see Figure 8 and Table 5). Figure 7 and Figure 9 show the gradients across the blackbody baseplate (i.e. each PRT sensor reading relative to the mean). The gradients are stable and within their expected range of ± 20 mK, except for the +YBB for SLSTR-B which has a higher gradient. This higher gradient is expected and consistent with measurements made before launch.

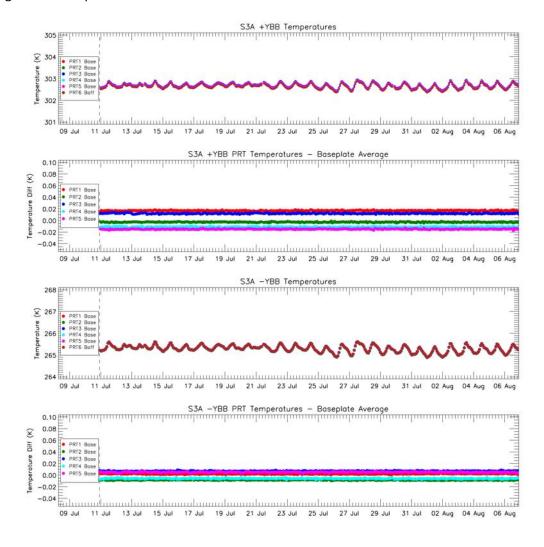


Figure 7: SLSTR-A blackbody temperature and baseplate gradient trends during Cycle 047. The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit.

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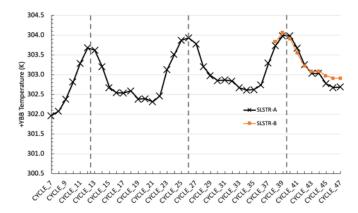


Figure 8: SLSTR-A and SLSTR-B long term trends in average +YBB temperature, showing yearly variation. The vertical dashed lines indicate the 1st January 2017, 2018 and 2019.

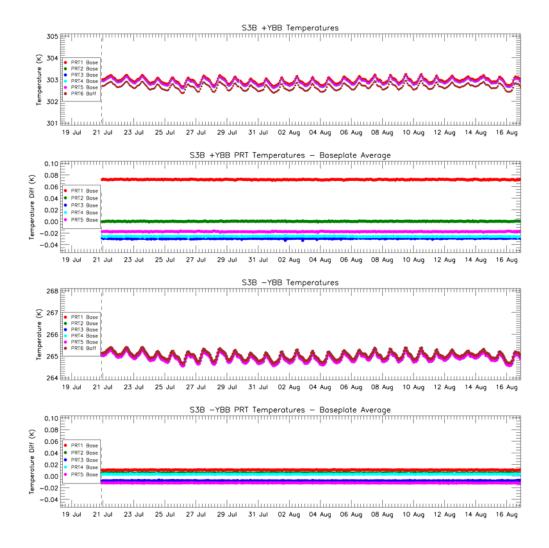


Figure 9: SLSTR-B blackbody temperature and baseplate gradient trends during Cycle 028. The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit.



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2.5 Detector noise levels

2.5.1 SLSTR-A VIS and SWIR channel signal-to-noise

The VIS and SWIR channel noise for SLSTR-A in Cycle 047 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 10. Table 1 and Table 2 give the average signal-to-noise in each cycle (excluding the instrument decontaminations). These values average over the significant detector-detector dispersion for the SWIR channels that is shown in Figure 10.

Note that the algorithm to calculate the noise on the VISCAL peak was updated in Cycle 038 to use a narrower window, and this gives a slightly lower noise. Although it appears from the plots and tables that there has been a step change in signal-to-noise ratio, this is purely due to the algorithm change and the actual instrument behaviour has not changed.

Table 1: Average SLSTR-A reflectance factor, and signal-to-noise ratio of the measured VISCAL signal for cycles 036-047, averaged over all detectors for the nadir view. Note the increase in cycle 38 is due to an improved algorithm not due to an instrument change.

	Average					Nad	ir Signal-	to-noise r	atio				
	Reflectance Factor	Cycle 036	Cycle 037	Cycle 038	Cycle 039	Cycle 040	Cycle 041	Cycle 042	Cycle 043	Cycle 044	Cycle 045	Cycle 046	Cycle 047
S1	0.187	233	232	247	242	248	243	243	245	240	236	241	237
S2	0.194	235	236	247	249	248	250	246	244	244	240	241	242
S3	0.190	225	229	243	238	244	243	235	233	236	230	229	234
S4	0.191	140	140	171	172	173	173	171	170	167	161	161	161
S5	0.193	234	235	286	287	292	291	286	284	282	280	279	279
S6	0.175	141	142	183	184	187	185	183	181	179	173	174	175

Table 2: Average SLSTR-A reflectance factor, and signal-to-noise ratio of the measured VISCAL signal for cycles 036-047, averaged over all detectors for the oblique view. Note the increase in cycle 38 is due to an improved algorithm not due to an instrument change.

	Average		Oblique Signal-to-noise ratio													
	Reflectance Factor	Cycle 036	Cycle 037	Cycle 038	Cycle 039	Cycle 040	Cycle 041	Cycle 042	Cycle 043	Cycle 044	Cycle 045	Cycle 046	Cycle 047			
S1	0.166	240	240	272	267	272	268	265	267	257	246	257	252			
S2	0.170	245	251	270	276	272	269	271	265	260	250	256	260			
S3	0.168	234	238	261	254	256	261	252	243	243	233	232	242			
S4	0.166	107	109	138	139	139	137	138	137	137	134	134	136			
S5	0.166	168	171	218	215	211	210	214	216	215	210	213	213			
S6	0.155	112	110	135	134	133	131	133	133	131	131	131	131			



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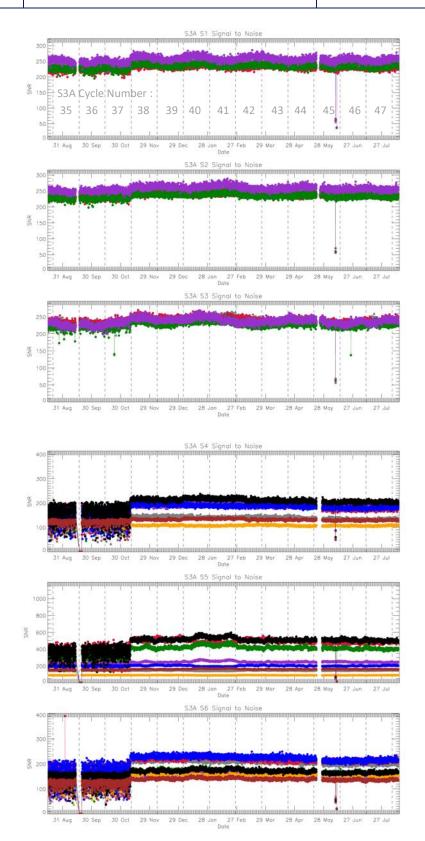


Figure 10: VIS and SWIR channel signal-to-noise of the measured VISCAL signal in each orbit for the last year of operations for SLSTR-A. Different colours indicate different detectors. The vertical dashed lines indicate the start and end of each cycle. Note the change at the beginning of cycle 38 is not due to a change in instrument behaviour but rather an improvement in the way the noise has been calculated.



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2.5.2 SLSTR-B VIS and SWIR channel signal-to-noise

The average VIS and SWIR channel signal-to-noise ratios for SLSTR-B in Cycle 028 are shown in Table 3 and Table 4. These values average over a significant detector-detector dispersion for the SWIR channels.

Table 3: Average SLSTR-B reflectance factor, and signal-to-noise ratio of the measured VISCAL signal for cycle 019-028, averaged over all detectors for the nadir view.

	Average		Nadir Signal-to-noise ratio													
	Reflectance Factor	Cycle 019	Cycle 020	Cycle 021	Cycle 022	Cycle 023	Cycle 024	Cycle 025	Cycle 026	Cycle 027	Cycle 028					
S1	0.177	234	236	238	237	232	228	224	224	225	226					
S2	0.192	226	226	229	226	223	220	215	214	215	216					
S3	0.194	240	239	243	240	237	231	230	229	228	228					
S4	0.186	133	132	132	133	131	129	129	129	128	130					
S5	0.184	246	246	245	246	244	241	240	240	239	239					
S6	0.162	164	167	168	167	163	161	160	159	158	159					

Table 4: Average SLSTR-B reflectance factor, and signal-to-noise ratio of the measured VISCAL signal for cycle 019-028, averaged over all detectors for the oblique view.

	Average		Oblique Signal-to-noise ratio												
	Reflectance Factor	Cycle 019	Cycle 020	Cycle 021	Cycle 022	Cycle 023	Cycle 024	Cycle 025	Cycle 026	Cycle 027	Cycle 028				
S1	0.157	232	232	229	228	226	223	219	218	217	218				
S2	0.168	262	262	261	259	257	254	250	247	246	248				
S3	0.172	281	281	279	274	272	267	263	261	261	258				
S4	0.168	129	128	127	128	128	129	129	128	128	129				
S5	0.172	253	253	251	250	251	251	250	251	249	250				
S6	0.152	189	191	188	187	187	187	185	183	183	185				



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2.5.3 SLSTR-A TIR channel NEDT

The thermal channel NEDT values for SLSTR-A in Cycle 047 are consistent with previous operations and within the requirements. NEDT trends calculated from the hot and cold blackbody signals are shown in Figure 11. NEDT values for each cycle, averaged over all detectors and both Earth views, are shown in Table 5.

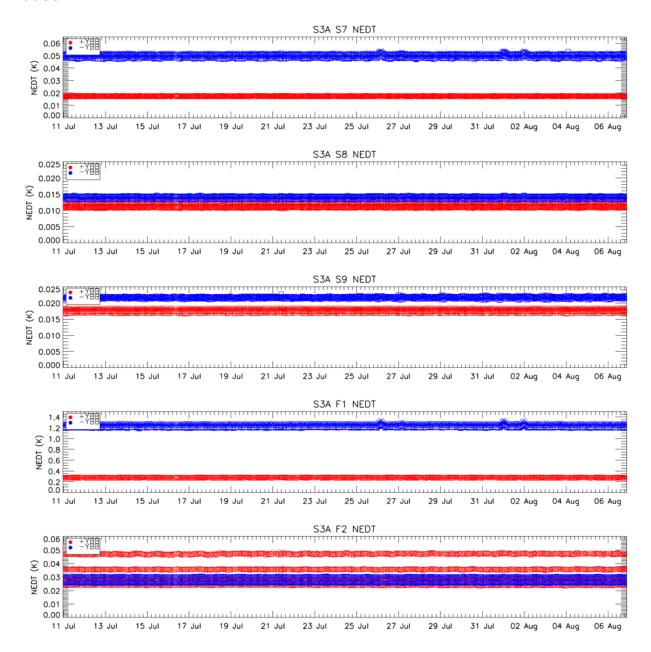


Figure 11: SLSTR-A NEDT trend for the thermal channels in Cycle 047. Blue points were calculated from the cold blackbody signal and red points from the hot blackbody. The square symbols show results calculated from the nadir view and crosses show results from the oblique view. Results are plotted for 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 5: NEDT for SLSTR-A in cycles 036-047 averaged over all detectors for both Earth views towards the hot +YBB (top) and the cold -YBB (bottom).

SLSTF	SLSTR-A		Cycle 037	Cycle 038	Cycle 039	Cycle 040	Cycle 041	Cycle 042	Cycle 043	Cycle 044	Cycle 045	Cycle 046	Cycle 047
+YBB temp (K)		302.744	303.295	303.738	303.985	303.985	303.670	303.257	303.036	303.036	302.773	302.672	302.691
	S7	17.6	17.4	17.3	17.0	17.0	17.3	17.3	17.4	17.3	17.6	17.6	17.6
NEDT	S8	12.1	12.3	11.7	11.3	11.4	11.5	11.5	11.5	11.5	11.5	11.4	11.4
NEDT (mK)	S9	17.7	17.7	17.8	17.8	17.9	18.0	18.1	18.2	18.2	17.7	17.7	17.7
(,	F1	277	273	271	266	267	272	275	279	281	280	281	282
	F2	33.9	34.0	34.1	34.2	34.5	34.0	33.8	33.7	33.7	33.7	33.9	33.9

SLSTR-A		Cycle 036	Cycle 037	Cycle 038	Cycle 039	Cycle 040	Cycle 041	Cycle 042	Cycle 043	Cycle 044	Cycle 045	Cycle 046	Cycle 047
-YBB temp (K)		265.245	265.920	266.506	266.817	266.724	266.266	265.767	265.604	265.769	265.503	265.354	265.286
	S7	50.7	49.6	48.7	47.9	48.3	48.8	50.1	50.4	50.4	50.5	49.9	49.9
NEDT	S8	14.2	14.2	14.1	14.1	14.1	14.2	14.3	14.3	14.3	14.1	14.2	14.1
NEDT (mK)	S9	21.7	21.7	21.8	21.8	21.9	22.0	22.2	22.3	22.4	21.6	21.7	21.7
(iiiit)	F1	1229	1199	1168	1144	1153	1176	1223	1245	1253	1230	1233	1235
	F2	28.1	28.1	28.1	28.0	28.1	28.1	28.3	28.3	28.4	27.9	28.0	28.0

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2.5.4 SLSTR-B TIR channel NEDT

The thermal channel NEDT values for SLSTR-B in Cycle 028, calculated from the hot and cold blackbody signals are shown in Figure 12 and Table 6.

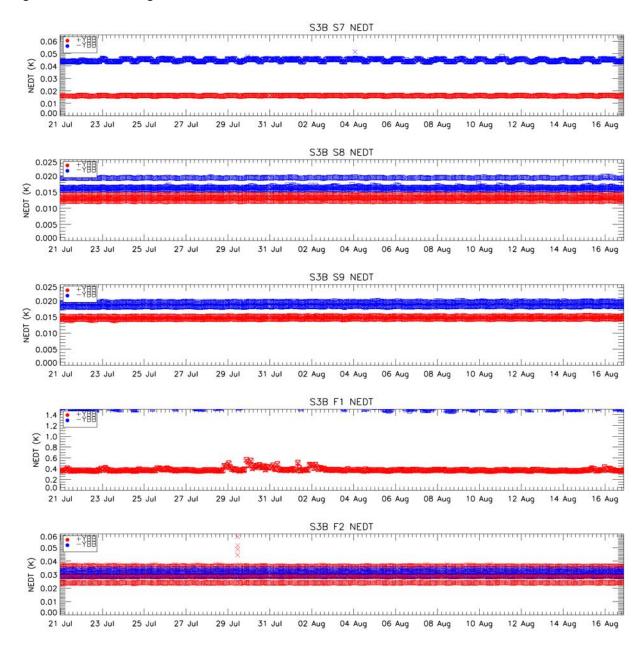


Figure 12: SLSTR-B NEDT trend for the thermal channels in Cycle 028. Blue points were calculated from the cold blackbody signal and red points from the hot blackbody. The square symbols show results calculated from the nadir view and crosses show results from the oblique view. Results are plotted for 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 6: NEDT for SLSTR-B in cycles 019-028 averaged over all detectors for both Earth views towards the hot +YBB (top) and the cold -YBB (bottom).

SLSTR-B		Cycle 019	Cycle 020	Cycle 021	Cycle 022	Cycle 023	Cycle 024	Cycle 025	Cycle 026	Cycle 027	Cycle 028
+YBB temp (K)		303.830	304.065	303.908	305.550	303.216	303.079	303.086	303.972	302.907	302.910
	S7	16.0	15.8	16.0	16.1	16.0	16.0	16.0	16.2	16.3	16.2
	S8	13.0	13.1	13.2	13.4	13.4	13.1	12.9	13.0	13.1	13.2
NEDT (mK)	S9	14.5	14.7	14.9	15.2	15.3	14.5	14.3	14.4	14.6	14.7
(11114)	F1	389	433	430	474	436	400	366	378	390	379
	F2	30.4	30.3	30.3	30.1	29.8	30.0	30.0	30.0	30.0	29.9

SLSTR-B		Cycle 019	Cycle 020	Cycle 021	Cycle 022	Cycle 023	Cycle 024	Cycle 025	Cycle 026	Cycle 027	Cycle 028
-YBB temp (K)		266.185	266.428	266.141	265.647	265.256	265.092	265.205	265.117	265.002	264.927
	S7	42.6	42.3	42.7	43.9	44.0	43.8	43.9	43.9	44.5	44.8
NEDT	S8	16.8	16.9	17.0	17.2	17.2	16.9	16.8	16.8	16.9	17.0
NEDT (mK)	S9	18.4	18.7	19.1	19.4	19.6	18.6	18.2	18.4	18.6	18.8
(F1	1604	1844	1805	2048	1870	1754	1574	1615	1675	1633
	F2	30.9	31.1	31.2	31.5	31.6	31.0	30.7	30.7	30.9	31.1



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2.6 Calibration factors

2.6.1 VIS and SWIR radiometric response

The visible channels show oscillations in their radiometric response due to the build-up of ice on the optical path within the focal plane assembly (FPA). Similar oscillations were observed for the corresponding channels on ATSR-2 and AATSR. As described in Section 2.2, periodic decontamination of the infrared FPA is necessary to remove the water ice contamination.

The radiometric responses of the SWIR channels appear to be more stable and not affected by the buildup of water ice contamination, although there is a seasonal cycle of the response that could be caused by variations in the solar zenith angle on the diffuser or partial vignetting of the Sun's disc by the VISCAL baffle.

It should be noted that the data from the VISCAL unit and blackbodies calibrates the signal and counteracts the degradation of the optics and other variations in signal.

Figure 13 and Figure 14 show the variation of the radiometric gain derived from the VISCAL signals for SLSTR-A over the past year, and Figure 15 and Figure 16 show the variation of the radiometric gain for SLSTR-B since the start of the S3B mission. Note that the period of the oscillations depends on the rate of build up of the ice layer, which is faster for SLSTR-B because it has had less time to decontaminate.

Note that decontaminations for SLSTR-A were performed at the end of Cycle 35 and in Cycle 45. For SLSTR-B, a decontamination was performed during Cycle 24.



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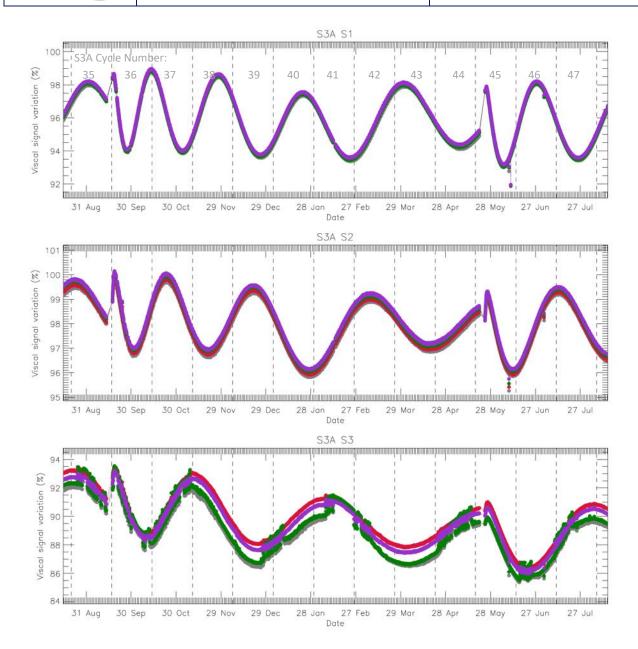


Figure 13: Variation of the radiometric gain derived from the VISCAL signals for SLSTR-A VIS channels for the last year of operations (nadir view). Different colours represent different detectors. The vertical dashed lines indicate the start and end of each cycle.



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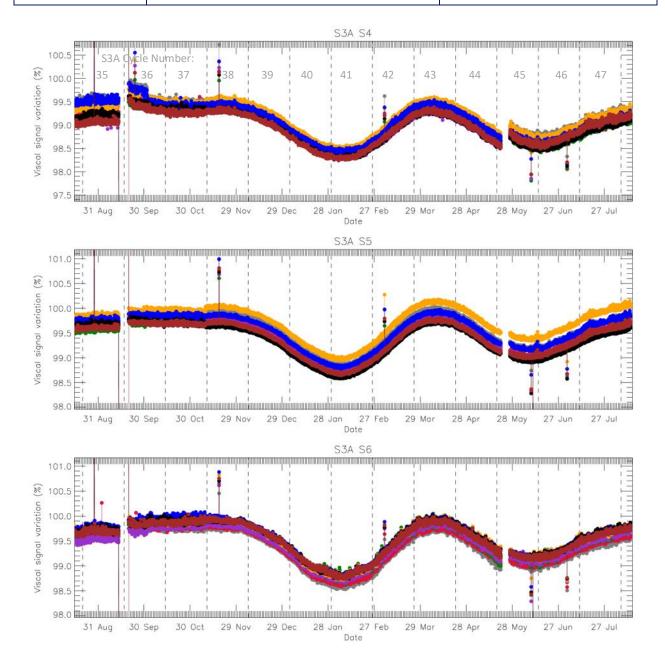


Figure 14: Variation of the radiometric gain derived from the VISCAL signals for SLSTR-A SWIR channels for the last year of operations (nadir view). Different colours represent different detectors. The vertical dashed lines indicate the start and end of each cycle. Note that there was a change at the beginning of Cycle 38 due to the change in the algorithm (see Section 2.5.1).



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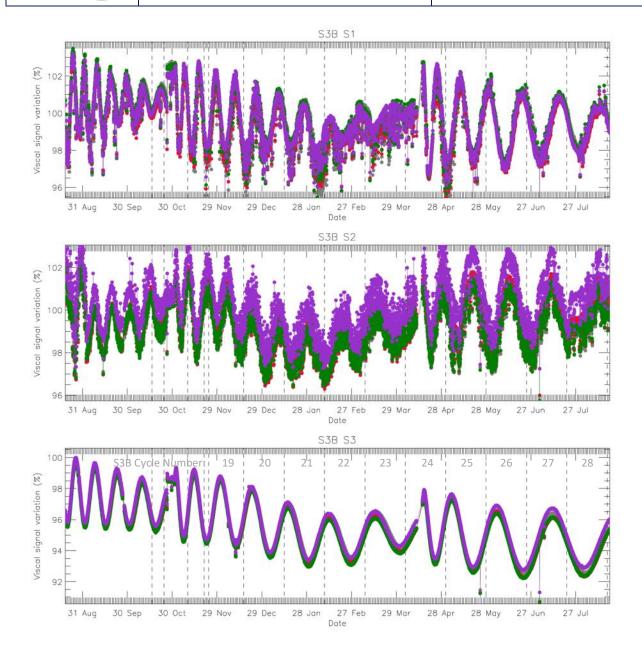


Figure 15: Variation of the radiometric gain derived from the VISCAL signals for SLSTR-B VIS channels for the past year (nadir view). Different colours represent different detectors. The vertical dashed lines indicate the start and end of each cycle.



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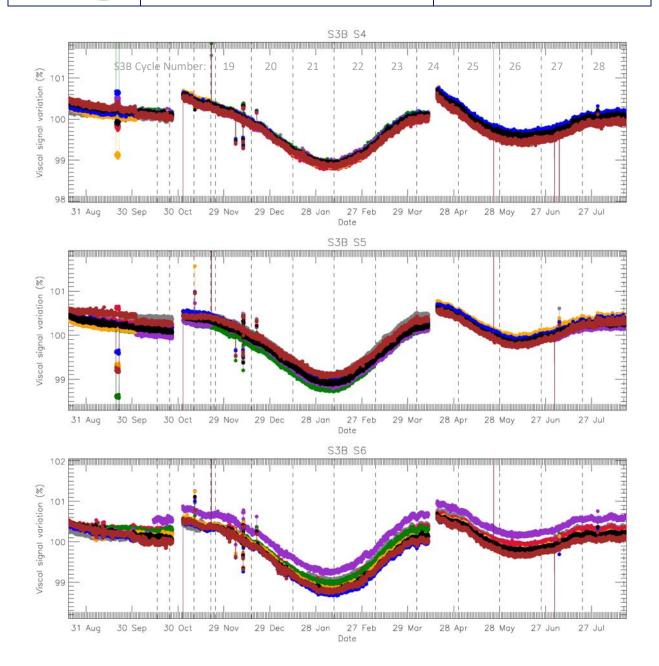


Figure 16: Variation of the radiometric gain derived from the VISCAL signals for SLSTR-B SWIR channels for the past year (nadir view). Different colours represent different detectors. The vertical dashed lines indicate the start and end of each cycle.



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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 17 for SLSTR-A in Cycle 047 and Figure 18 for SLSTR-B in Cycle 028, giving the average positional offsets in kilometres for Nadir and Oblique views.

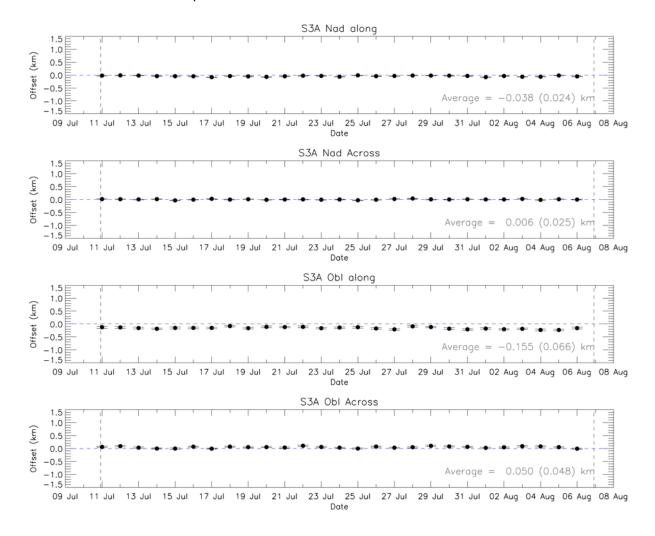


Figure 17: SLSTR-A daily offset results in km from the GeoCal Tool analysis for Nadir along- and across-track (top two plots) and Oblique along- and across-track (bottom two plots) for Cycle 047. The error bars show the standard deviation.

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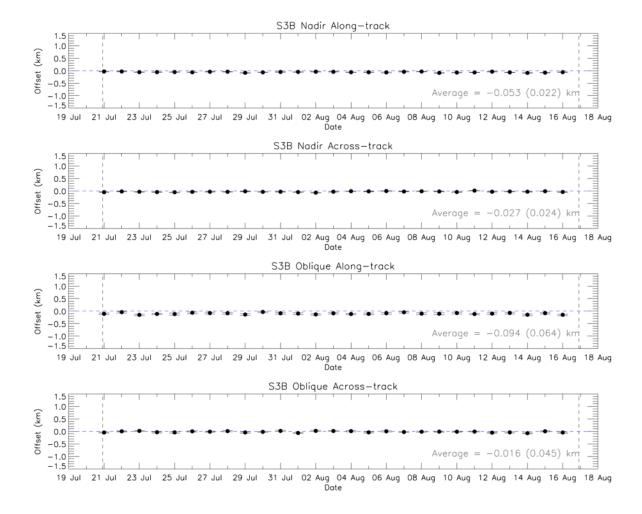


Figure 18: SLSTR-B daily offset results in km from the GeoCal Tool analysis for Nadir along- and across-track (top two plots) and Oblique along- and across-track (bottom two plots) for Cycle 028. The error bars show the standard deviation.



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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 19 and Figure 20 show the results of the inter-comparison analysis of SLSTR-A with OLCI-A and SLSTR-B with OLCI-B over desert sites. Figure 21 and Figure 22 show the results of an inter-comparison analysis of SLSTR-A and SLSTR-B with AATSR, and Figure 23 and Figure 24 show the results of the inter-comparison analysis with MODIS. Average ratios in each case are given in the figures.

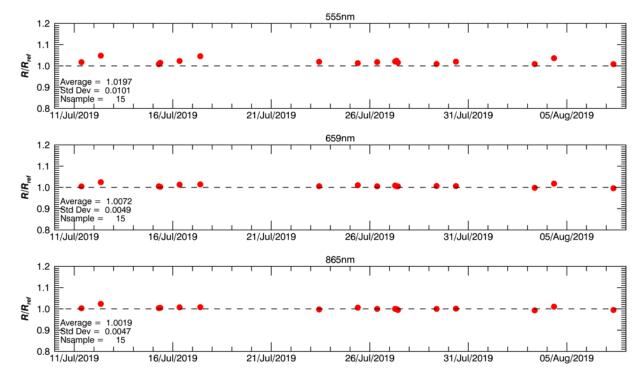


Figure 19: Ratio of SLSTR-A and OLCI-A radiances for the visible channels in Nadir view using combined results for all desert sites processed in Cycle 047.

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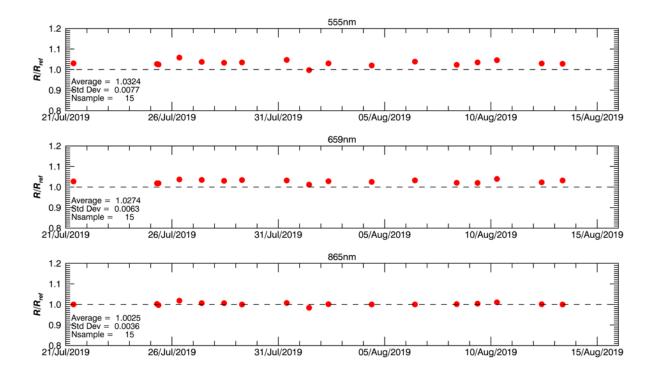


Figure 20: Ratio of SLSTR-B and OLCI-B radiances for the visible channels in Nadir view using combined results for all desert sites processed in Cycle 028.

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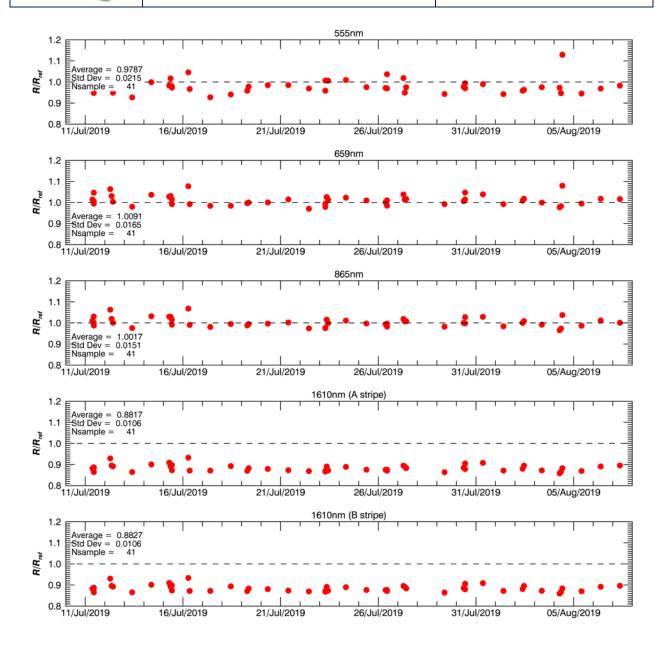


Figure 21: Ratio of SLSTR-A and AATSR radiances in Nadir view using combined results for all desert sites processed in Cycle 047.

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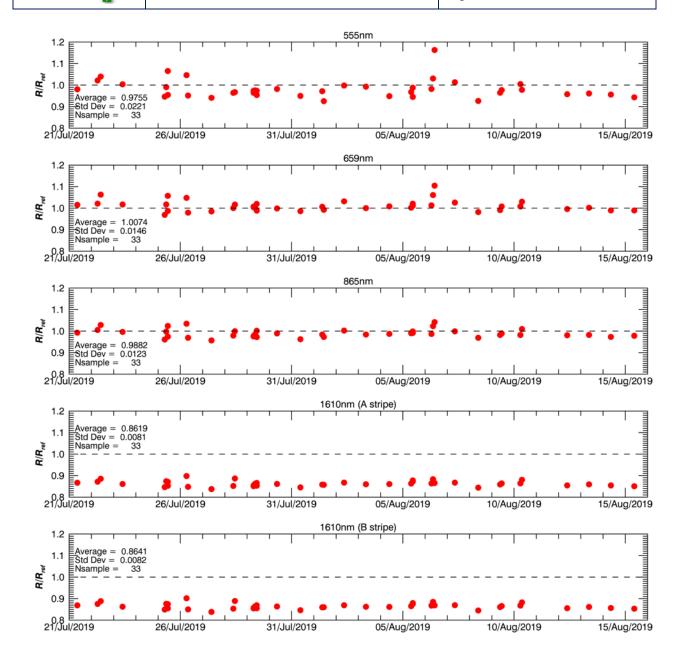


Figure 22: Ratio of SLSTR-B and AATSR radiances in Nadir view using combined results for all desert sites processed in Cycle 028.

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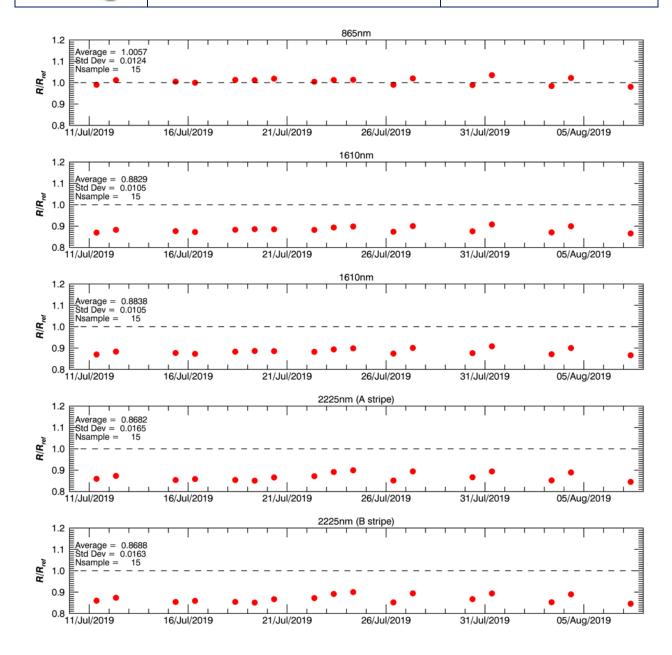


Figure 23: Ratio of SLSTR-A and MODIS radiances in Nadir view using combined results for all desert sites processed in Cycle 047.

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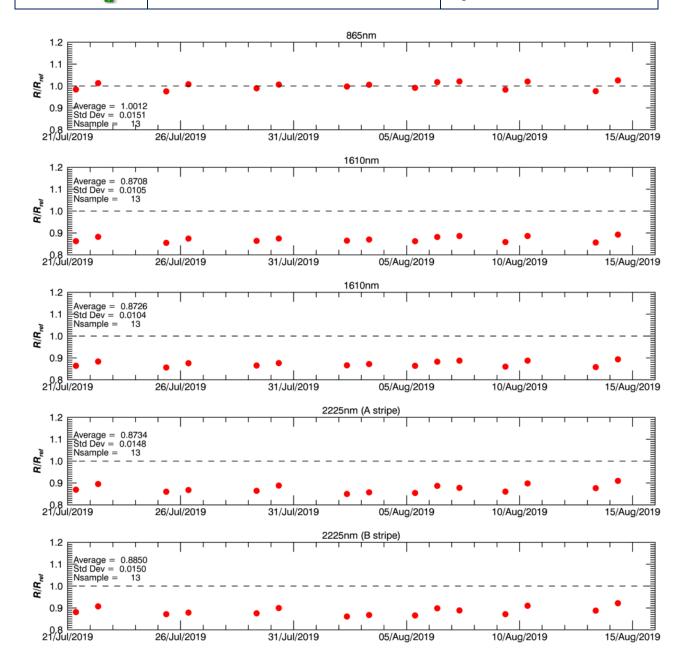


Figure 24: Ratio of SLSTR-B and MODIS radiances in Nadir view using combined results for all desert sites processed in Cycle 028.

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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. The S3A and S3B satellites are configured to be 140 degrees out of phase in order to observe complimentary portions of the earth. Figure 25 shows an example combined SLSTR-A/SLSTR-B image for the visible channels from 31st July 2019 (daytime only).

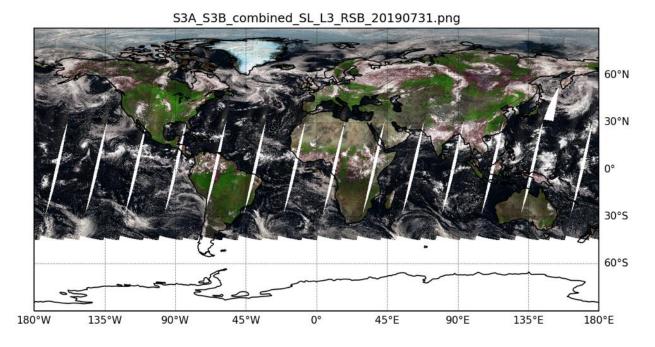


Figure 25: Daytime combined SLSTR-A and SLSTR-B Level-1 image for visible channels on 31st July 2019.

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4 Level 2 SST validation

SLSTR level 2 WST SSTs have been validated for SLSTR-A Cycle 047 and SLSTR-B Cycle 028, by binning to level 3 across the entire cycle and compared to the Met Office Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) L4 analysis. The WST product contains a single SST field derived from the best-performing SST retrieval algorithm.

SLSTR level 2 WST SSTs have been validated using Copernicus Marine Environment Monitoring Service (CMEMS) *in situ* data for SLSTR-A Cycle 047. The WCT product contains the SSTs derived from all the SST algorithms (single view, dual view, 2 and 3 channel) and is not disseminated to users. Match-ups between SLSTR and *in situ* data are provided by the EUMESAT Ocean and Sea Ice Satellite Application Facility (OSI-SAF).

4.1 Level 3

Level 3 spatially averaged SST maps for daytime and nighttime are shown in Figure 26 for SLSTR-A. 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 26 are the number of 1-km pixels contributing to each average and the mean difference to OSTIA (dt_analysis).

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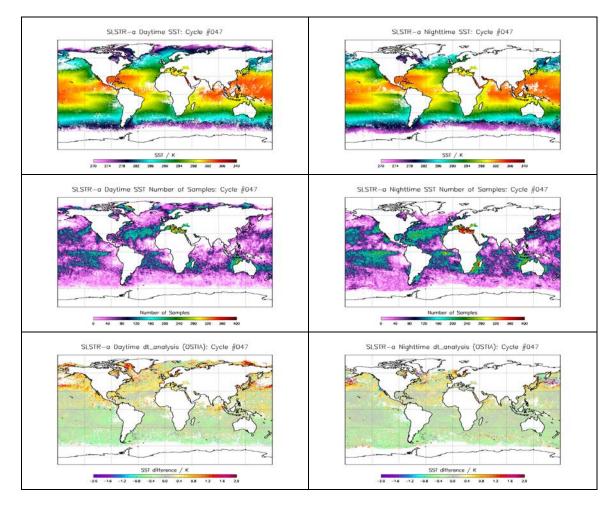


Figure 26: (Top) Level 3 spatially average SST for SLSTR-A Cycle 047 at a resolution of 0.05 degrees. Maps are shown for daytime (left) and nighttime (right). Also shown are (middle) number of 1-km samples in each average and (bottom) mean difference to OSTIA L4 SST analysis.



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Level 3 spatially averaged SST maps for daytime and nighttime are shown in Figure 27 for SLSTR-B. 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 26 are the number of 1-km pixels contributing to each average and the mean difference to OSTIA (dt_analysis).

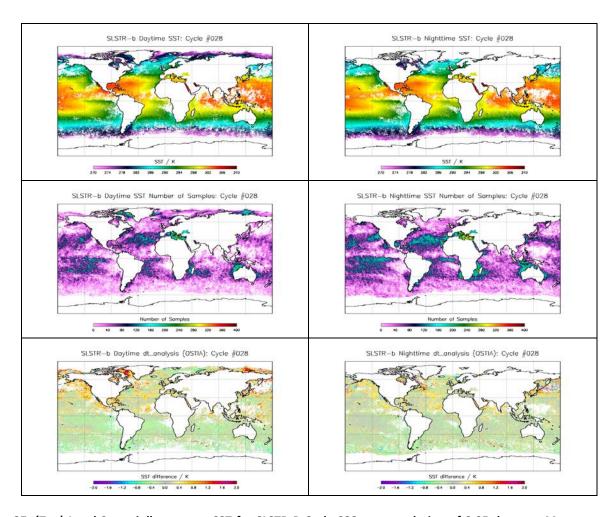


Figure 27: (Top) Level 3 spatially average SST for SLSTR-B Cycle 028 at a resolution of 0.05 degrees. Maps are shown for daytime (left) and nighttime (right). Also shown are (middle) number of 1-km samples in each average and (bottom) mean difference to OSTIA L4 SST analysis.



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4.2 Dependence on latitude, TCWV, Satellite ZA and date

The dependence of the difference between SLSTR-A SST_{skin} and drifting buoy SST_{depth} for Cycle 047 is shown in Figure 28 and for SLSTR-B in Cycle 028 in Figure 29. No adjustments have been made for difference in depth or time between the satellite and in situ measurements. SLSTR-A SSTs are extracted from the SL_2_WST files. Daytime 2-channel (S8 and S9) results are shown in red and night time 3-channel results are shown in green. Note that as the data were generated from WST files and not WCT, there are no night time 2-channel results (normally shown in blue) and no data to show the dependency with total column of water vapour. Solid lines indicate dual-view retrievals, dashed lines indicate nadir-only retrievals. Bold lines indicate statistically significant (95% confidence) results.

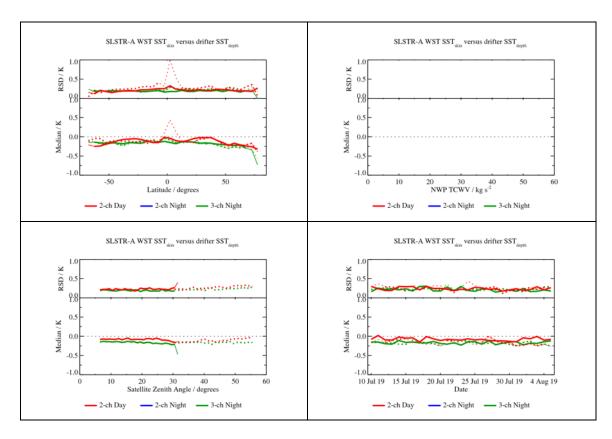


Figure 28: Dependence of median and robust standard deviation of match-ups between SLSTR-A SST_{skin} and drifting buoy SST_{depth} for Cycle 047 as a function of latitude, total column water vapour (TCWV), satellite zenith angle and date. Any data gaps are due to delays in match-up processing at the time this report was generated as well as instrument outages. Note that the dependence on TCWV could not be calculated.

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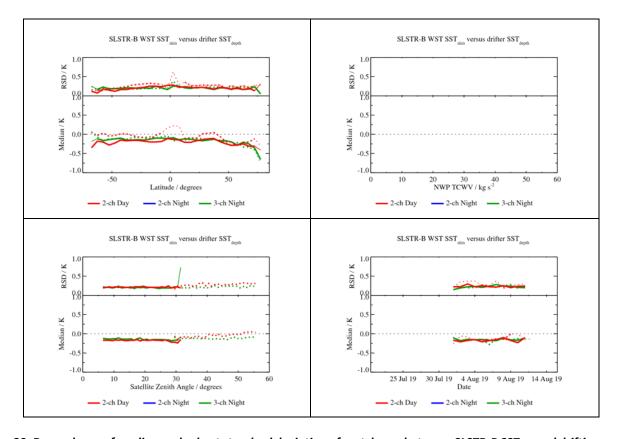


Figure 29: Dependence of median and robust standard deviation of match-ups between SLSTR-B SST_{skin} and drifting buoy SST_{depth} for Cycle 028 as a function of latitude, total column water vapour (TCWV), satellite zenith angle and date. Any data gaps are due to delays in match-up processing at the time this report was generated as well as instrument outages. Note that the dependence on TCWV could not be calculated.

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4.3 Spatial distribution of match-ups

The spatial distribution of SLSTR-A/drifter match-ups for Cycle 047 is shown in Figure 30. No adjustments have been made for difference in depth or time between the satellite and *in situ* measurements.

The spatial distribution of SLSTR-B/drifter match-ups for Cycle 028 is shown in Figure 31.

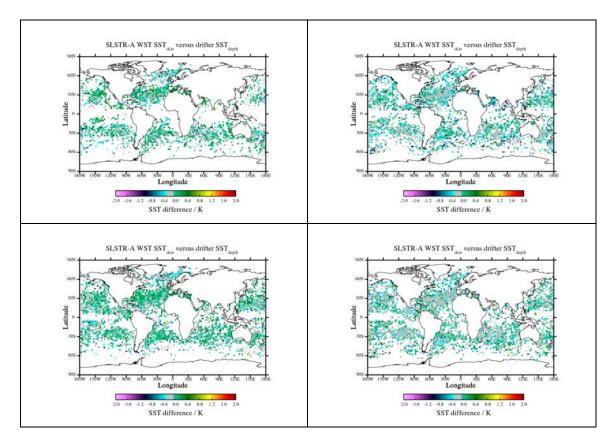


Figure 30: Spatial distribution of match-ups between SLSTR-A SST_{skin} and drifting buoy SST_{depth} for Cycle 047. Clockwise from top left, the matchups relate to the N2 day, N3 night, D3 night and D2 day retrievals.

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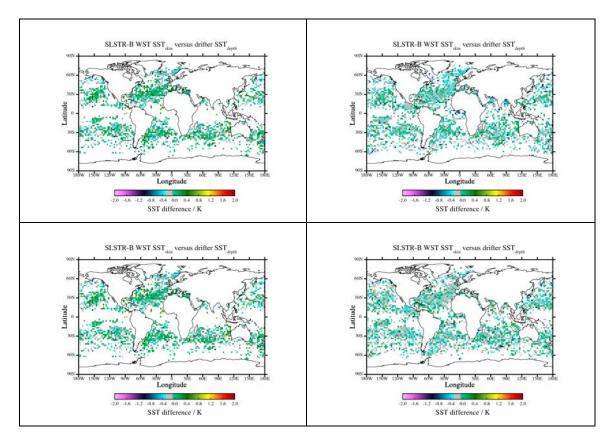


Figure 31 Spatial distribution of match-ups between SLSTR-B SST_{skin} and drifting buoy SST_{depth} for Cycle 028. Clockwise from top left, the matchups relate to the N2 day, N3 night, D3 night and D2 day retrievals.



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4.4 Match-ups statistics

Match-up statistics (median and robust standard deviation, RSD) for SLSTR-A and SLSTR-B are shown in Table 7 and in Table 8. 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). Note that no statistics for night time 2-channel results are available because the matchups were generated using WST data.

Table 7: SLSTR-A drifter match-up statistics for Cycle 047.

Retrieval	Number	Median (K)	RSD (K)
N2 day	7249	-0.110	0.267
D2 day	13898	-0.080	0.222
N2 night			
N3 night	10252	-0.160	0.222
D2 night			
D3 night	13496	-0.160	0.193

Table 8: SLSTR-B drifter match-up statistics for Cycle 028.

Retrieval	Number	Median (K)	RSD (K)
N2 day	6356	-0.040	0.282
D2 day	12206	-0.170	0.208
N2 night			
N3 night	9314	-0.120	0.208
D2 night			
D3 night	11876	-0.140	0.208



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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 eleven "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 Cycles 047 for SLSTR-A and 028 for SLSTR-B are evaluated for identifying any gross problems. Both S3A and S3B L2 products are produced with the updated LST coefficients following the operational release on 25th February 2019.

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: seven from the SURFRAD network (Bondville, Illinois; Desert Rock, Nevada; Fort Peck, Montana; Goodwin Creek, Mississippi; Penn State University, Pennsylvania; Sioux Fall, South Dakota; Table Mountain, Colorado); two from the ARM network (Southern Great Plains, Oklahoma; Barrow, Alaska); and two from the USCRN network (Williams, Arizona; Des Moines, Iowa). The results can be summarised as follows:

Satellite	Average absolute accu	Average absolute accuracy vs. Gold Standard (K)			
	Day	Night			
S3A	0.6	0.7			
S3B	1.0	0.9			

For both SLSTR-A and SLSTR-B both the daytime 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.



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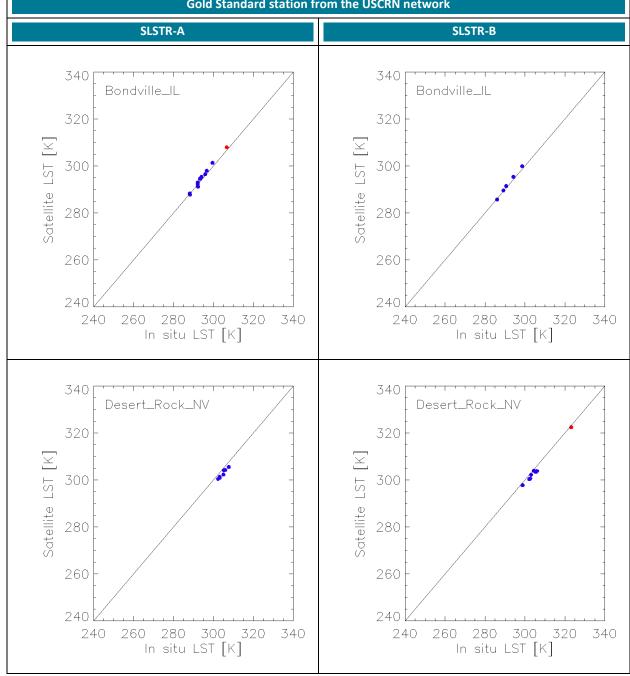
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Validation of the SL_2_LST product over Cycle 047 (SLSTR-A) and Cycle 028 (SLSTR-B) at seven Gold Standard in situ stations of the SURFRAD network plus two Gold Standard station from the ARM network, and two

Gold Standard station from the USCRN network





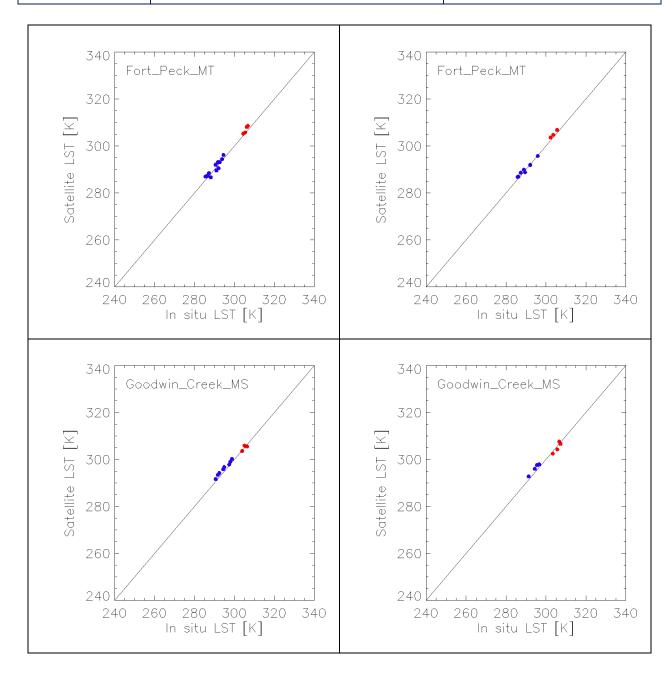
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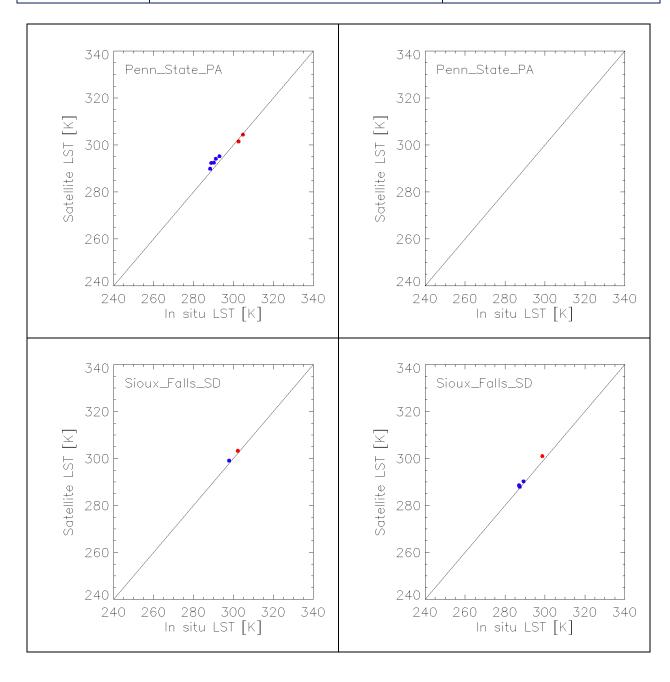
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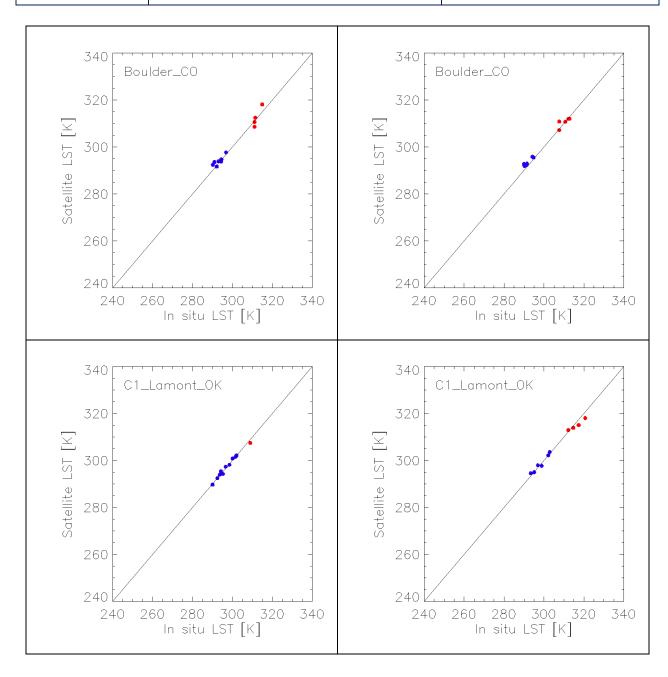
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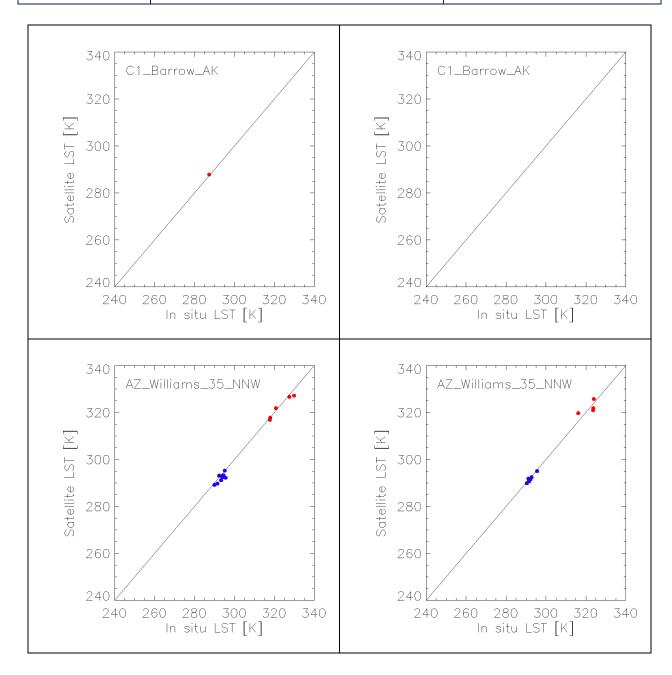
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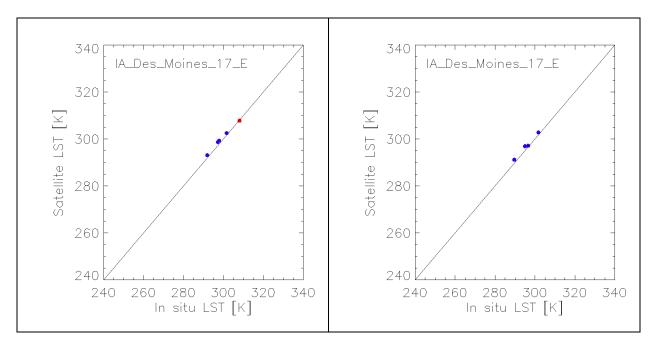
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As with past cycles cloud has reduced the number of matchups per station to single figures for most stations during day or night, with some missing statistics entirely. It is therefore challenging to determine robust statistics. Nonetheless, it can 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, and very similar patterns are evident between S3A matchups and S3B matchups.



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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 from both SLSTR-A and SLSTR-B with the operational SEVIRI L2 product available from the LSA SAF. The results can be summarised:

Continent	Median differences in K from the intercomparison of the SL_2_LST product with respect to the operational LSA SAF SEVIRI LST product for the period of Cycle 047 (SLSTR-A) and Cycle 028 (SLSTR-B)				
	SLSTR-A		SLSTR-B		
	Day	Night	Day	Night	
Africa	0.4	1.1	0.6	1.1	
Europe	2.0	1.3	2.4	1.2	

For Africa, the differences across the continent for both SLSTR-A and SLSTR-B are relatively small, with very few locations with larger differences. This is the case for both day and night. For Europe the differences are small across the region for night-time but larger during the day with mostly positive differences. This is the same for both SLSTR-A and SLSTR-B and is primarily driven by differences in viewing geometry between the SLSTR instruments and SEVIRI and is expected. 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 < 1K over Africa for both SLSTR-A and SLSTR-B. Differences are not the same as previous cycles 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



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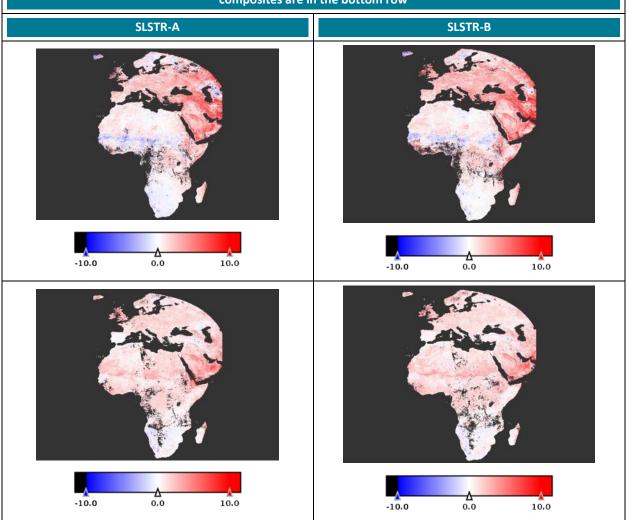
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Intercomparison of the SL_2_LST product with respect to the operational LSA SAF SEVIRI LST product for the period of Cycle 047 (SLSTR-A) and Cycle 028 (SLSTR-B). Daytime composites are in the top row and Night-time composites are in the bottom row



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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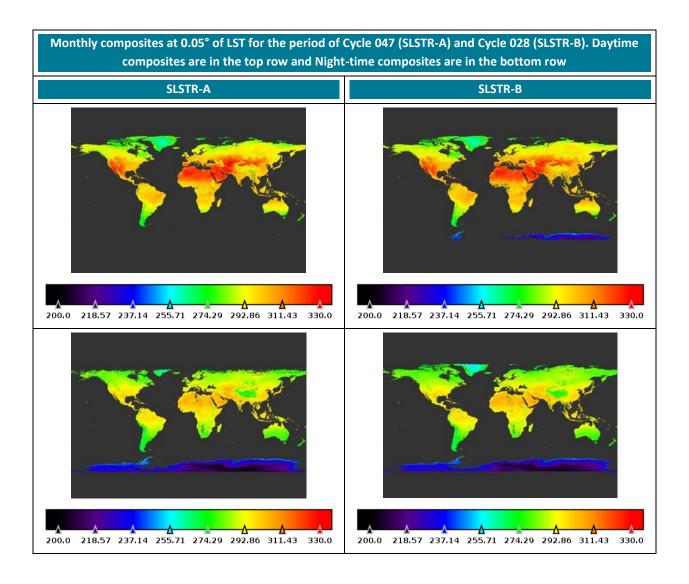
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5.3 Level-3C Assessment

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 of the LST field and corresponding sampling ratios. The sampling ratios are derived as clear_pixels / (clear_pixels + cloudy_pixels).





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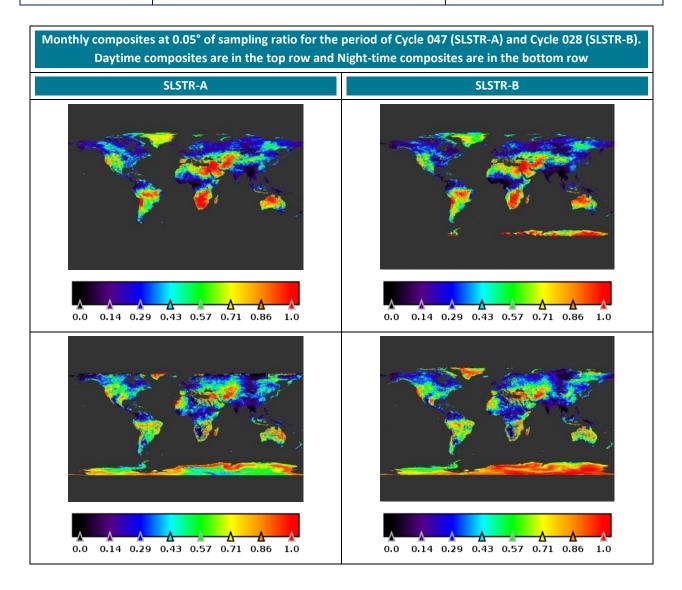
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The LST fields indicate the SL_2_LST product is producing values in line with expectations for both SLSTR-A and SLSTR-B. There are no distinct issues or non-physical values evident. Cloud contamination appears to be at a minimum, although there appears 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 Asia. The excessive cloud clearing seems to be equally evident in SLSTR-A and SLSTR-B which indicate the cloud coefficients ADF need tuning for both instruments once the ongoing issue regarding the temporal interpolation is resolved. Comparing this effect from the previous cycles indicates the same regions are subject to excessive cloud clearing. This has been raised as an SPR with the lack of temporal interpolation of the ECMWF Skin Temperature being the root cause. This issue is high priority and is being implemented into the next release.

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6 Events

6.1 SLSTR-A

SLSTR-A 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:

- 16th July 2019, 09:29-09:38 short data gap.
- 16th July 2019, 11:16-11:22 short data gap.

6.2 SLSTR-B

SLSTR-B 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:

- ❖ 29th July 2019, 10:14-10:20 data gap due to radio frequency interference.
- ❖ 30th July 2019 23:52 31st July 2019 00:01 − data gap due to hardware disconnection.



S3 SLSTR Cyclic Performance Report

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7 Appendix A

Other reports related to the Optical mission are:

S3 OLCI Cyclic Performance Report, S3A Cycle No. 047, S3B Cycle No. 028 (ref. S3MPC.ACR.PR.01-047-028)

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

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