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

S3 SLSTR Cyclic Performance Report

S3-A

Cycle No. 076

Start date: 01/09/2021

End date: 28/09/2021

S3-B

Cycle No. 057

Start date: 10/09/2021

End date: 07/10/2021



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Performance
Centre

SENTINEL 3



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Changes Log

Version	Date	Changes
1.0	14/10/2021	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	06.18 / 2.75	CGS: 18/05/2021 08:10 UTC				
		PAC: 18/05/2021 08:10 UTC				
SL2 LST	06.17 / 2.77	PAC: 14/06/2021 08:21 UTC				
SL2 FRP (NTC)	01.05 / 2.77	PAC: 14/06/2021 08:21 UTC				

IPF	IPF / Processing Baseline version	Date of deployment				
S3B						
SL1	06.18 / 1.53	PAC: 18/05/2021 08:10 UTC				
SL2 LST	06.17 / 1.55	PAC: 14/06/2021 08:21 UTC				
SL2 FRP (NTC)	01.05 / 1.55	PAC: 14/06/2021 08:21 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).

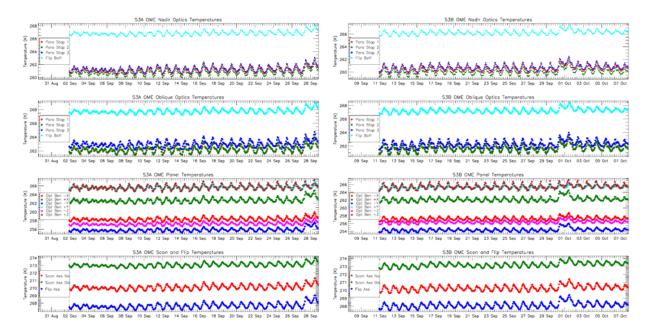


Figure 1: OME temperature trends for SLSTR-A Cycle 076 (left) and SLSTR-B Cycle 057 (right) showing the paraboloid stops and flip baffle (top two plots) and optical bench and scanner and flip assembly (lower two plots). The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit.

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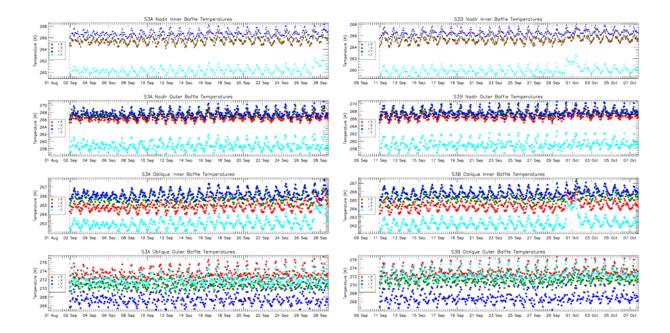


Figure 2: Baffle temperature trends for SLSTR-A Cycle 076 (left) and SLSTR-B Cycle 057 (right). The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit.



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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. A decontamination was performed for SLSTR-A at the start of Cycle 71 on 19th April 2021. Decontamination was last performed for SLSTR-B in Cycle 45 from 11th to 13th November 2020. 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 (e.g. Cycle 67 and 76 for SLSTR-A) show slightly lower average visible channel detector temperatures due to instrument operations that were performed on those days.

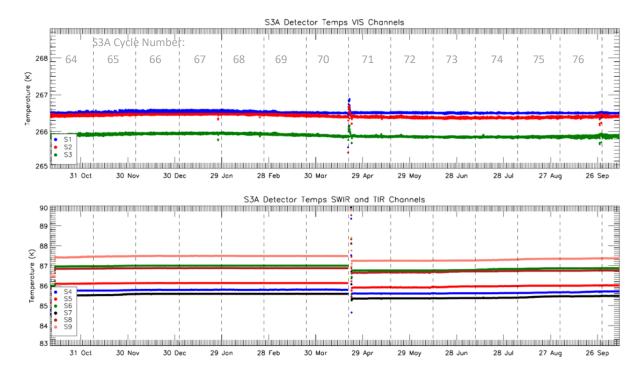


Figure 3: SLSTR-A detector temperatures for each channel for the last year of operations. Discontinuities occur for the infrared channels where the FPA was heated for decontamination. The vertical dashed lines indicate the start and end of each cycle. Each dot represents the average temperature in one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

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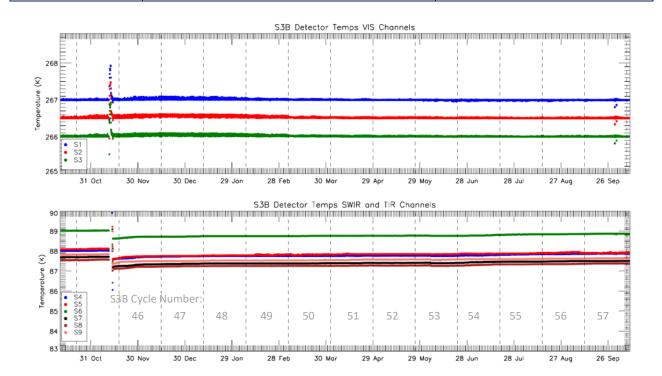


Figure 4: SLSTR-B detector temperatures for each channel for the last year of operations. Discontinuities occur for the infrared channels where the FPA was heated for decontamination. The vertical dashed lines indicate the start and end of each cycle. Each dot represents the average temperature in one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



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2.3 Scanner performance

The actual position of the scan and flip mirrors is measured by the instrument, and Figure 5 shows the statistics of the difference from the expected linear control law for each mirror in each view during SLSTR-A Cycle 076. Figure 6 shows the equivalent trends for SLSTR-B in Cycle 057. The performance has been consistent with previous operations and does not appear to be degrading. For reference, one arcsecond corresponds to roughly 4m on the ground.

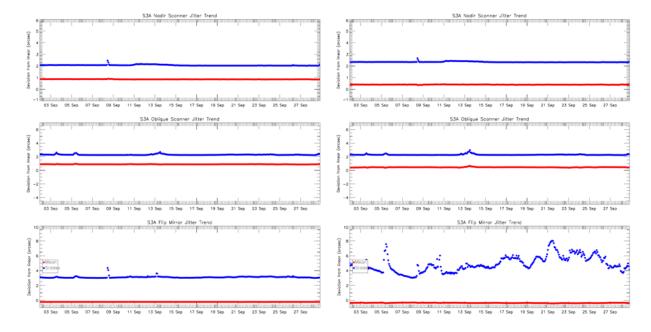


Figure 5: SLSTR-A scanner and flip jitter for Cycle 076, showing mean and stddev from expected position per orbit (red and blue respectively) for the nadir view (left) and oblique view (right). The plots show the nadir scanner (top), oblique scanner (middle) and flip mirror (bottom).

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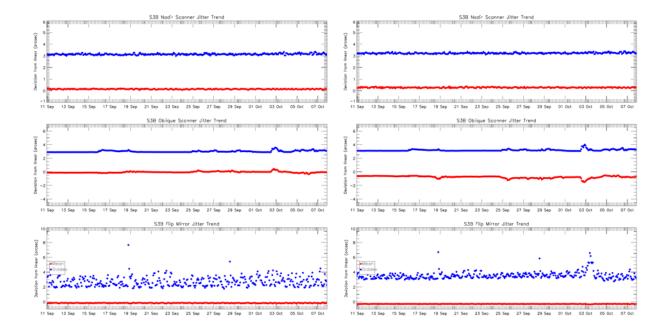


Figure 6: SLSTR-B scanner and flip jitter long term in Cycle 057, showing mean and stddev difference from expected position per orbit (red and blue respectively) for the nadir view (left) and oblique view (right). The plots show the nadir scanner (top), oblique scanner (middle) and flip mirror (bottom).



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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. Note that blackbody crossover tests were performed for SLSTR-A from 27^{th} - 29^{th} September and for SLSTR-B from 30^{th} September -2^{nd} October (see Sections 7.1 and 7.2).

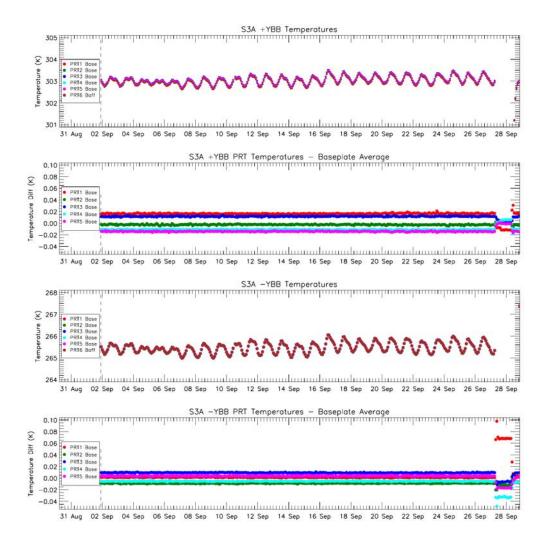


Figure 7: SLSTR-A blackbody temperature and baseplate gradient trends during Cycle 076. The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit.

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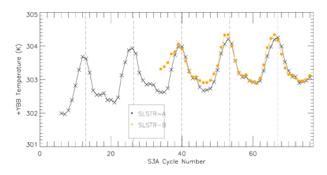


Figure 8: SLSTR-A and SLSTR-B long term trends in average +YBB temperature, showing yearly variation. The vertical dashed lines approximately indicate the 1st January 2017, 2018, 2019, 2020 and 2021.

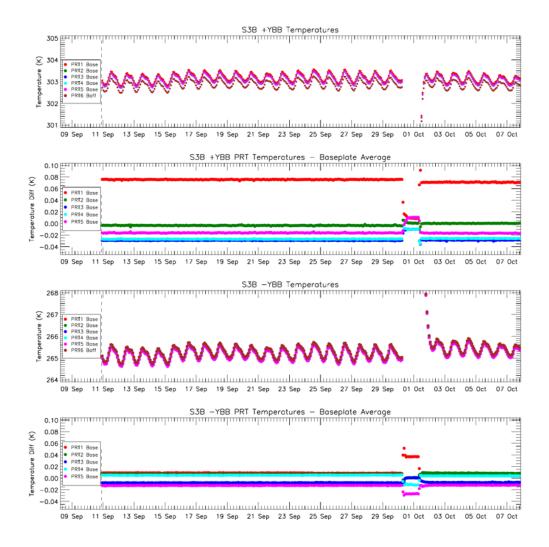


Figure 9: SLSTR-B blackbody temperature and baseplate gradient trends during Cycle 057. The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit.



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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 076 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.

Table 1: Average SLSTR-A reflectance factor, and signal-to-noise ratio of the measured VISCAL signal for the last 11 cycles, averaged over all detectors for the nadir view.

	Average		Nadir Signal-to-noise ratio									
	Reflectance Factor	Cycle 066	Cycle 067	Cycle 068	Cycle 069	Cycle 070	Cycle 071	Cycle 072	Cycle 073	Cycle 074	Cycle 075	Cycle 076
S1	0.187	241	246	244	238	240	239	236	241	240	237	240
S2	0.194	246	246	246	245	246	243	239	240	243	243	242
S3	0.190	231	234	236	232	229	230	222	221	224	228	229
S4	0.191	176	177	176	175	173	169	166	166	168	170	172
S5	0.193	288	292	291	286	283	281	280	279	280	281	283
S6	0.175	189	190	188	186	182	179	176	178	178	180	182

Table 2: Average SLSTR-A reflectance factor, and signal-to-noise ratio of the measured VISCAL signal for the last 11 cycles, averaged over all detectors for the oblique view.

	Average		Oblique Signal-to-noise ratio									
	Reflectance Factor	Cycle 066	Cycle 067	Cycle 068	Cycle 069	Cycle 070	Cycle 071	Cycle 072	Cycle 073	Cycle 074	Cycle 075	Cycle 076
S1	0.166	264	269	269	263	256	254	245	254	255	251	254
S2	0.170	273	269	264	265	265	259	247	252	259	261	260
S3	0.168	241	241	243	243	239	235	221	221	226	231	236
S4	0.166	142	141	139	140	138	136	134	135	138	138	139
S5	0.166	215	210	209	212	214	213	209	212	212	213	215
S6	0.155	136	134	131	133	133	129	129	129	129	131	132

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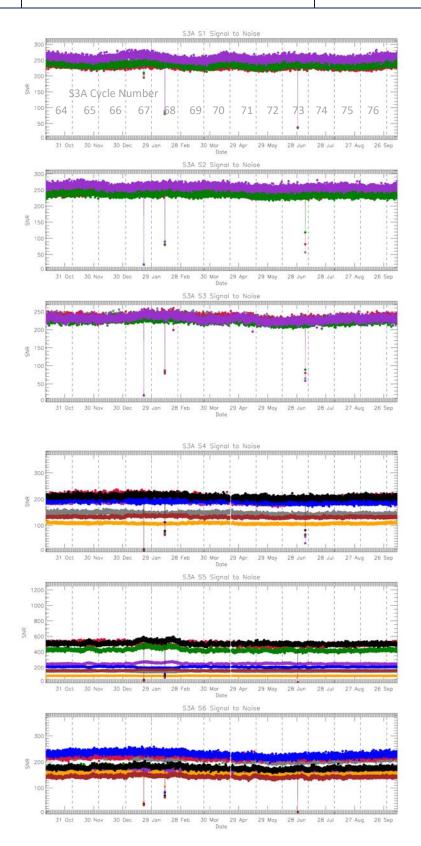


Figure 10: VIS and SWIR channel signal-to-noise of the measured VISCAL signal in each orbit for the last year of operations for SLSTR-A. Different colours indicate different detectors. The vertical dashed lines indicate the start and end of each cycle.



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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 057 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 the last 11 cycles, averaged over all detectors for the nadir view.

	Average	Nadir S	Nadir Signal-to-noise ratio												
	Reflectanc e Factor	Cycle 047	Cycle 048	Cycle 049	Cycle 050	Cycle 051	Cycle 052	Cycle 053	Cycle 054	Cycle 055	Cycle 056	Cycle 057			
S1	0.177	232	236	231	234	224	223	221	219	227	225	225			
S2	0.192	223	224	224	218	219	216	211	214	218	217	218			
S3	0.194	233	234	227	228	227	221	217	220	225	223	220			
S4	0.186	132	131	130	129	131	130	129	128	129	129	130			
S5	0.184	246	244	244	244	241	241	241	239	240	241	241			
S6	0.162	166	167	165	162	161	161	159	159	159	160	158			

Table 4: Average SLSTR-B reflectance factor, and signal-to-noise ratio of the measured VISCAL signal for the last 11 cycles, averaged over all detectors for the oblique view.

	Average	Oblique Signal-to-noise ratio												
	Average Reflectanc e Factor	Cycl e 047	Cycl e 048	Cycle 049	Cycle 050	Cycle 51	Cycle 052	Cycle 053	Cycle 054	Cycle 055	Cycle 056	Cycle 057		
S1	0.157	227	227	225	224	217	217	211	214	216	215	220		
S2	0.168	260	260	258	254	254	246	241	243	246	247	250		
S3	0.172	269	260	257	261	254	246	246	249	249	247	250		
S4	0.168	132	129	128	128	130	128	126	126	127	127	128		
S5	0.172	249	247	247	247	248	246	248	245	245	246	244		
S6	0.152	188	186	185	186	186	182	179	179	181	181	183		



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2.5.3 SLSTR-A TIR channel NEDT

The thermal channel NEDT values for SLSTR-A in Cycle 076 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. Note that a blackbody crossover test was performed for SLSTR-A from 27th-29th September (see Section 7.1).

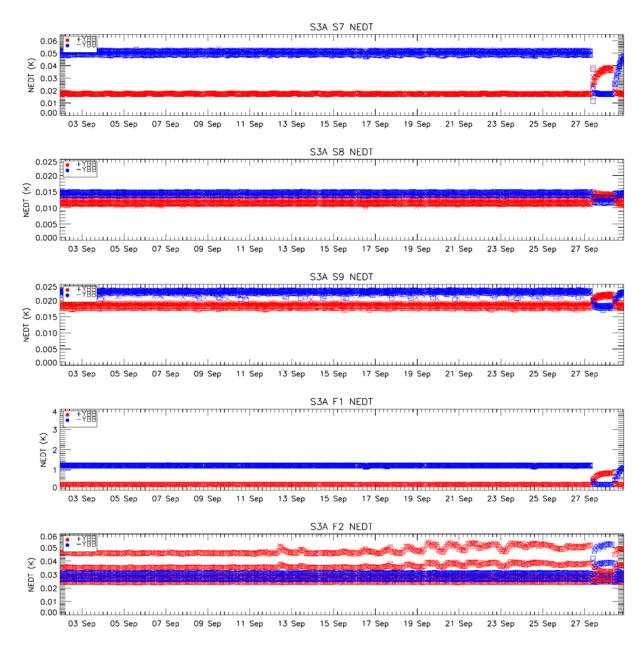


Figure 11: SLSTR-A NEDT trend for the thermal channels in Cycle 076. Blue points were calculated from the cold blackbody signal and red points from the hot blackbody. The square symbols show results calculated from the nadir view and crosses show results from the oblique view. Results are plotted for 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 the last 11 cycles averaged over all detectors for both Earth views towards the hot +YBB (top) and the cold -YBB (bottom).

SLSTR	-A	Cycle 066	Cycle 067	Cycle 068	Cycle 069	Cycle 070	Cycle 071	Cycle 072	Cycle 073	Cycle 074	Cycle 075	Cycle 076
+YBB temp	(K)	304.19 0	304.25 0	303.98 9	303.52 6	303.26 1	303.08 3	303.08 7	302.89 6	302.93 2	302.96 3	303.062
	S7	16.9	16.9	17.0	17.3	17.3	17.3	17.4	17.7	17.6	17.5	18.0
NED	S8	11.8	11.9	11.9	11.9	11.9	11.6	11.7	11.8	12.0	11.8	11.8
T	S9	18.6	18.6	18.7	18.7	18.6	18.2	18.3	18.4	18.3	18.4	18.5
(mK)	F1	266	267	273	275	275	273	279	286	335	283	299
	F2	35.5	35.4	35.3	35.7	35.5	33.6	33.7	33.7	33.7	33.8	34.1

SLSTR-	Α	Cycle 066	Cycle 067	Cycle 068	Cycle 069	Cycle 070	Cycle 071	Cycle 072	Cycle 073	Cycle 074	Cycle 075	Cycle 076
-YBB to	emp	266.93 0	266.93 0	266.55 2	265.98 5	265.76 6	265.66 4	265.78 4	265.51 9	265.48 7	265.42 5	265.470
	S7	47.0	47.1	48.7	49.6	50.4	50.8	50.5	50.8	50.7	50.6	49.1
	S8	14.5	14.6	14.7	14.8	14.8	14.5	14.5	14.5	14.6	14.5	14.5
NEDT (mK)	S9	22.8	22.8	23.0	23.1	23.2	22.5	22.5	22.5	22.6	22.6	22.5
	F1	1118	1128	1165	1182	1198	1201	1213	1229	1233	1223	1180
	F2	28.9	28.9	29.0	29.0	29.2	28.7	28.8	28.8	28.8	28.8	29.1



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2.5.4 SLSTR-B TIR channel NEDT

The thermal channel NEDT values for SLSTR-B in Cycle 057, calculated from the hot and cold blackbody signals are shown in Figure 12 and Table 6. Note that a blackbody crossover test was performed for SLSTR-B from 30th September – 2nd October (see Section 7.2).

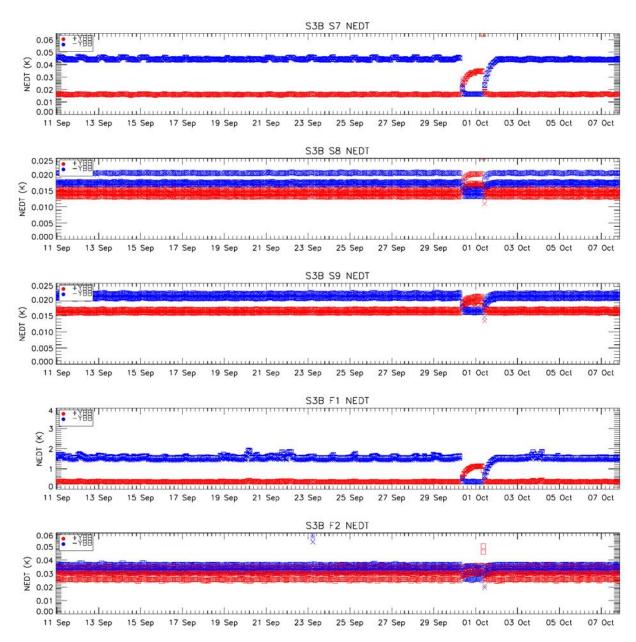


Figure 12: SLSTR-B NEDT trend for the thermal channels in Cycle 057. Blue points were calculated from the cold blackbody signal and red points from the hot blackbody. The square symbols show results calculated from the nadir view and crosses show results from the oblique view. Results are plotted for 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 the last 11 cycles averaged over all detectors for both Earth views towards the hot +YBB (top) and the cold -YBB (bottom).

SLSTR-B		Cycle 047	Cycle 048	Cycle 049	Cycle 050	Cycle 051	Cycle 052	Cycle 053	Cycle 054	Cycle 055	Cycle 056	Cycle 057
+YBB temp (K)		304.33 9	304.16 8	303.75 6	303.34 4	303.15 5	303.13 8	303.04 1	302.95 8	302.96 5	302.99 6	303.12 0
	S7	15.8	15.8	16.1	16.0	16.0	16.1	16.2	16.3	16.2	16.2	16.7
	S8	13.8	13.9	14.0	14.0	14.0	14.3	14.1	14.2	14.2	14.2	14.3
NEDT (mK)	S9	15.8	15.8	15.9	16.0	16.0	16.1	16.1	16.2	16.2	16.3	16.4
	F1	404	339	358	363	359	402	371	363	364	363	389
	F2	30.9	30.7	30.5	30.4	30.3	30.4	30.3	30.3	30.2	30.2	30.4

SLSTR-	В	Cycle 047	Cycle 048	Cycle 049	Cycle 050	Cycle 051	Cycle 052	Cycle 053	Cycle 054	Cycle 055	Cycle 056	Cycle 057
-YBB temp (K)		266.64 3	266.35 7	265.80 6	265.33 2	265.22 2	265.34 9	265.29 0	265.14 9	265.08 2	265.03 4	265.20 6
	S7	42.5	42.5	43.7	44.1	44.0	44.2	44.1	44.0	44.4	44.6	43.3
	S8	17.9	17.9	17.9	17.9	17.9	18.0	18.0	18.0	18.0	18.1	18.0
NEDT (mK)	S9	20.1	20.3	20.4	20.5	20.6	20.7	20.7	20.7	20.8	20.9	20.8
	F1	1717	1396	1480	1521	1501	1494	1537	1482	1501	1516	1479
	F2	33.0	33.1	33.2	33.3	33.3	33.4	33.4	33.4	33.5	33.6	33.5



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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 in Cycles 54, 58 and 71. For SLSTR-B, decontaminations were performed during Cycle 30 and Cycle 45.

There is a step in the SWIR channel radiometric response for SLSTR-A in Cycle 64 due to the change in temperature of the detectors caused by the cooler set point change.



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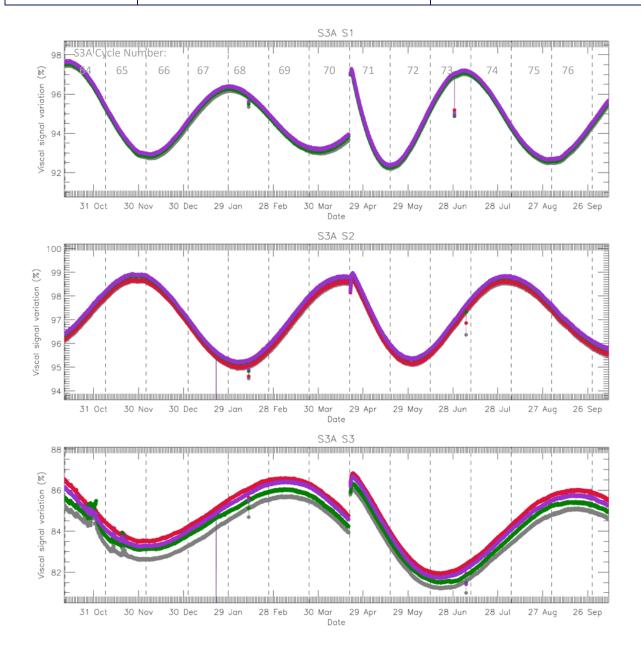


Figure 13: Variation of the radiometric gain derived from the VISCAL signals for SLSTR-A VIS channels for the last year of operations (nadir view). Different colours represent different detectors. The vertical dashed lines indicate the start and end of each cycle.



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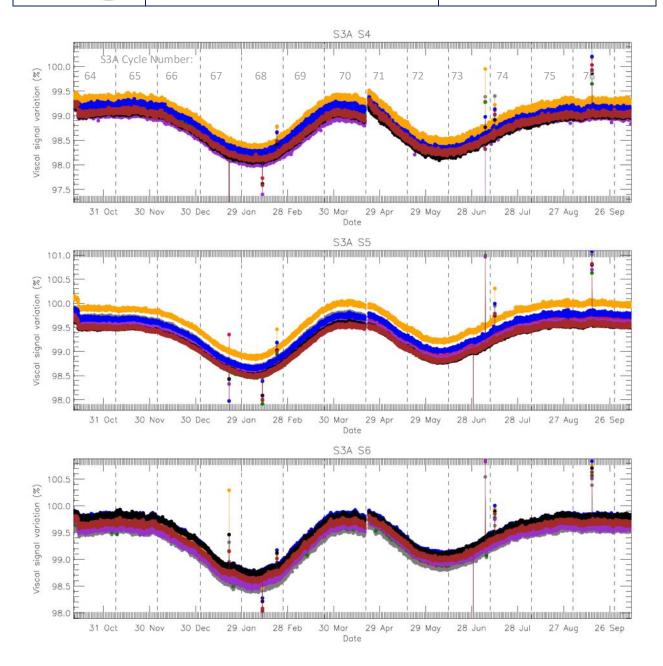


Figure 14: Variation of the radiometric gain derived from the VISCAL signals for SLSTR-A SWIR channels for the last year of operations (nadir view). Different colours represent different detectors. The vertical dashed lines indicate the start and end of each cycle.



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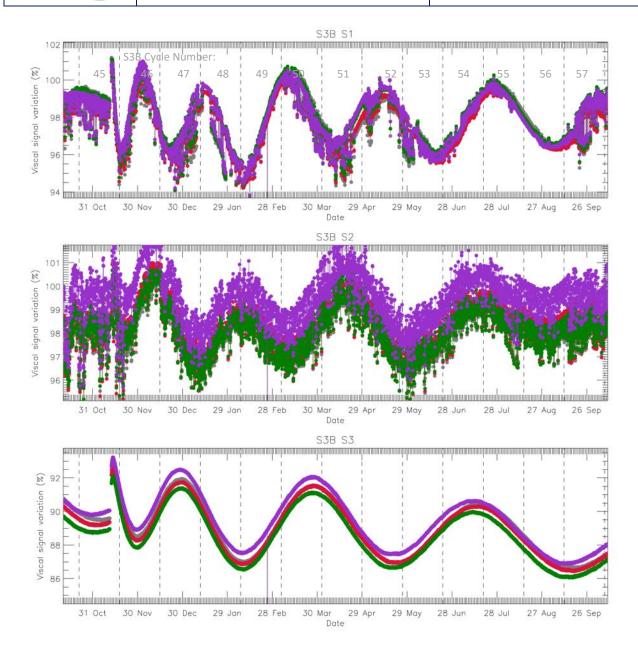


Figure 15: Variation of the radiometric gain derived from the VISCAL signals for SLSTR-B VIS channels for the past year (nadir view). Different colours represent different detectors. The vertical dashed lines indicate the start and end of each cycle.



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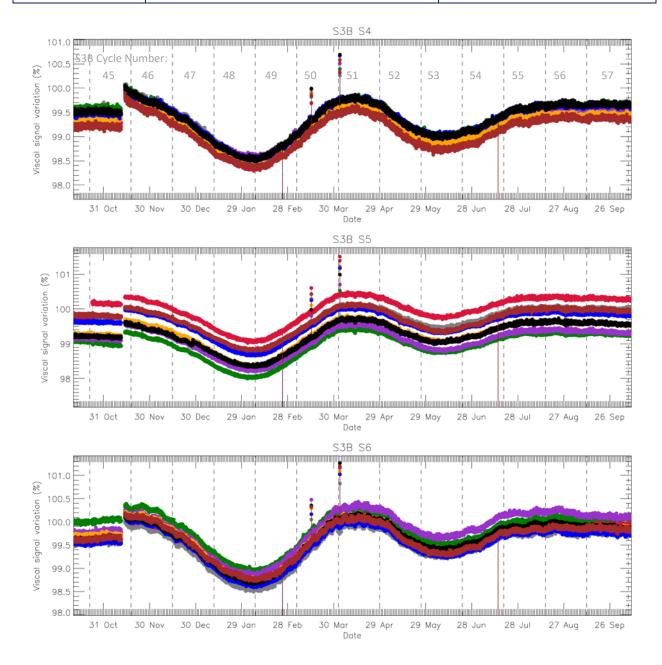


Figure 16: Variation of the radiometric gain derived from the VISCAL signals for SLSTR-B SWIR channels for the past year (nadir view). Different colours represent different detectors. The vertical dashed lines indicate the start and end of each cycle.



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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 076 and Figure 18 for SLSTR-B in Cycle 057, giving the average positional offsets in kilometres for Nadir and Oblique views.

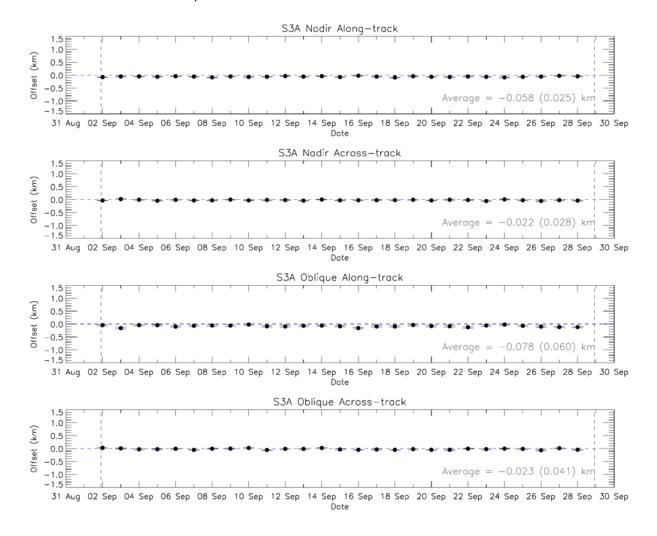


Figure 17: SLSTR-A daily offset results in km from the GeoCal Tool analysis for Nadir along- and across-track (top two plots) and Oblique along- and across-track (bottom two plots) for Cycle 076. The error bars show the standard deviation.

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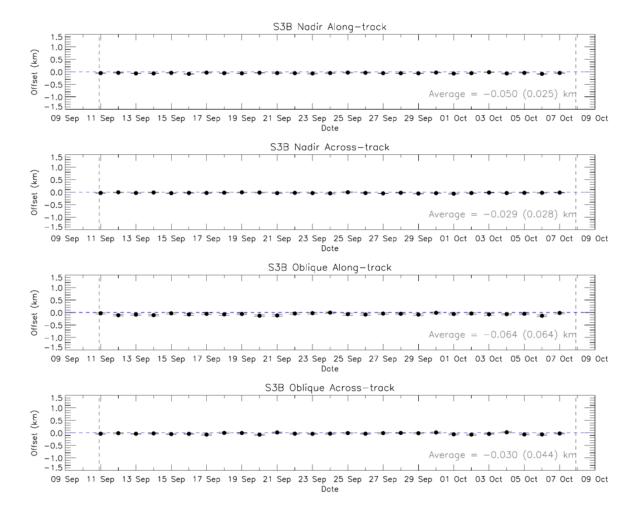


Figure 18: SLSTR-B daily offset results in km from the GeoCal Tool analysis for Nadir along- and across-track (top two plots) and Oblique along- and across-track (bottom two plots) for Cycle 057. The error bars show the standard deviation.



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

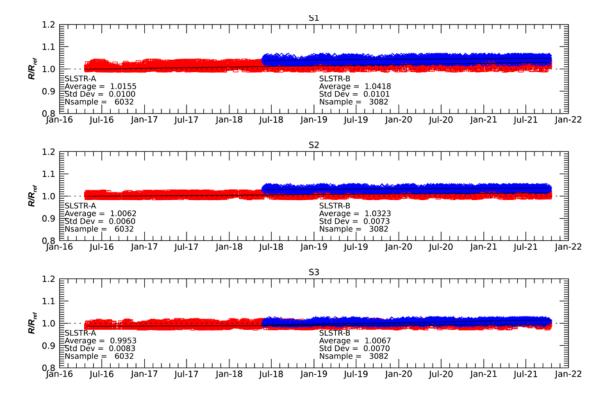


Figure 19: Ratio of SLSTR-A and OLCI-A radiances (red) and SLSTR-B and OLCI-B radiances (blue) for the visible channels in Nadir view using combined results for all desert sites.

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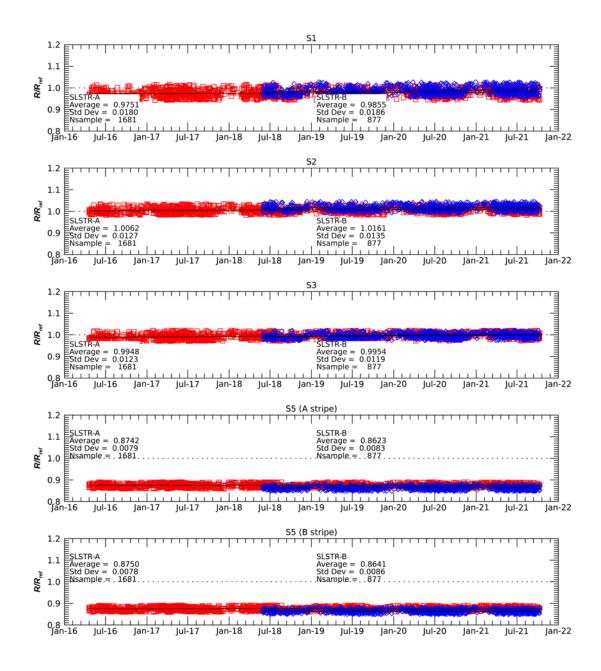


Figure 20: Ratio of SLSTR-A (red) and SLSTR-B (blue) with AATST radiances in Nadir view using combined results for all desert sites.

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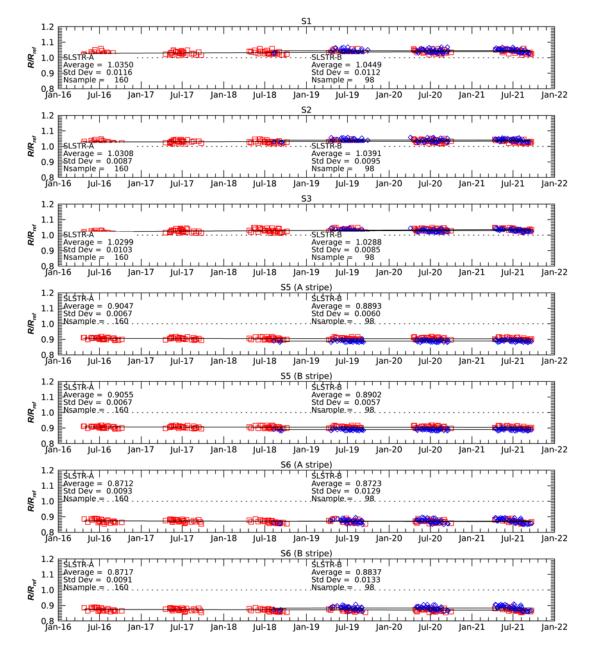


Figure 21: Ratio of SLSTR-A (red) and SLSTR-B (blue) with MODIS radiances in Nadir view using combined results for all desert sites.

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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 22 shows an example combined SLSTR-A/SLSTR-B image for the visible channels from the previous cycle on 16th September 2021 (daytime only).

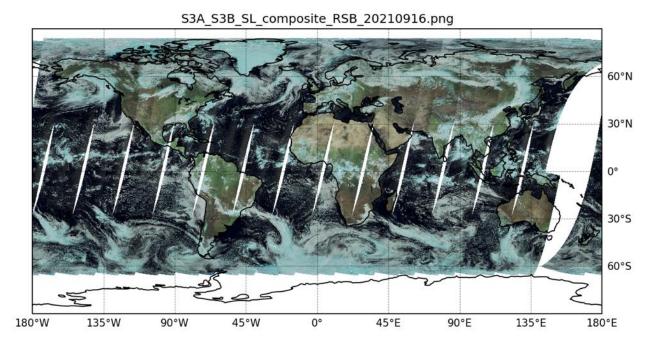


Figure 22: Daytime combined SLSTR-A and SLSTR-B Level-1 image for visible channels on 16th September 2021.

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4 Level-2 SST validation

Level-2 SST validation is under the responsibility of EUMETSAT.



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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 twelve "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 076 for SLSTR-A and 057 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. In each case the latest temporal interpolation for the probabilistic cloud mask is applied following the L1 operational release on 15th January 2020. The updated cloud coefficients ADF was applied on 23rd October 2020.

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 twelve "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 three from the USCRN network (Williams, Arizona; Des Moines, Iowa; Manhatten, Kansas). The results can be summarised as follows:

Satellite	Average absolute accuracy vs. Gold Standard (K)							
Satemite	Day	Night						
S3A	1.0	0.8						
S3B	1.0	0.7						

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 actual cloud, or over-masking. The number of matchups across most stations for daytime are very low particularly during the day, and have impacted the biases to an extent. An updated cloud coefficients ADF was delivered on 23rd October 2020.



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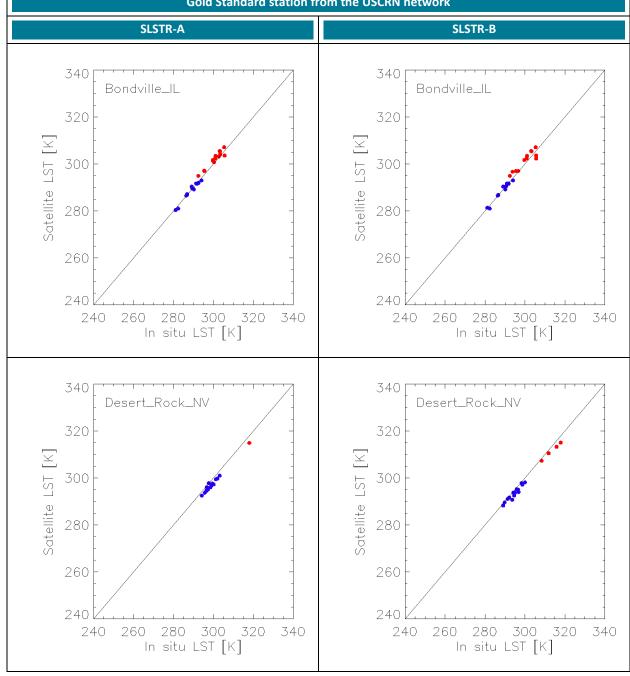
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Validation of the SL_2_LST product over Cycle 076 (SLSTR-A) and Cycle 057 (SLSTR-B) at seven Gold Standard in situ stations of the SURFRAD network plus two Gold Standard station from the ARM network, and two Gold Standard station from the USCRN network





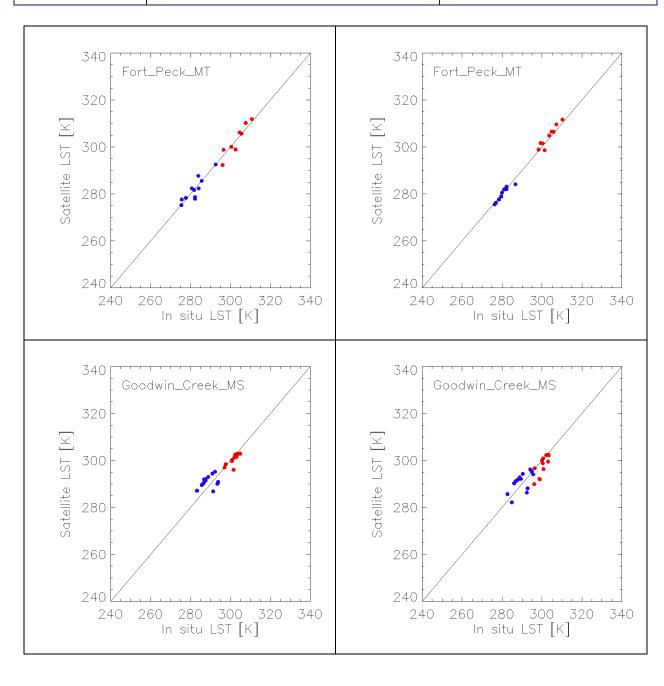
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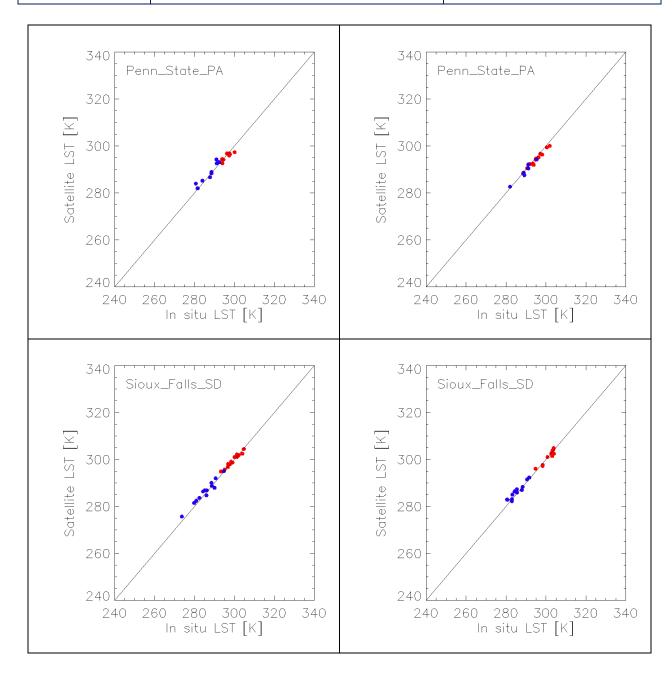
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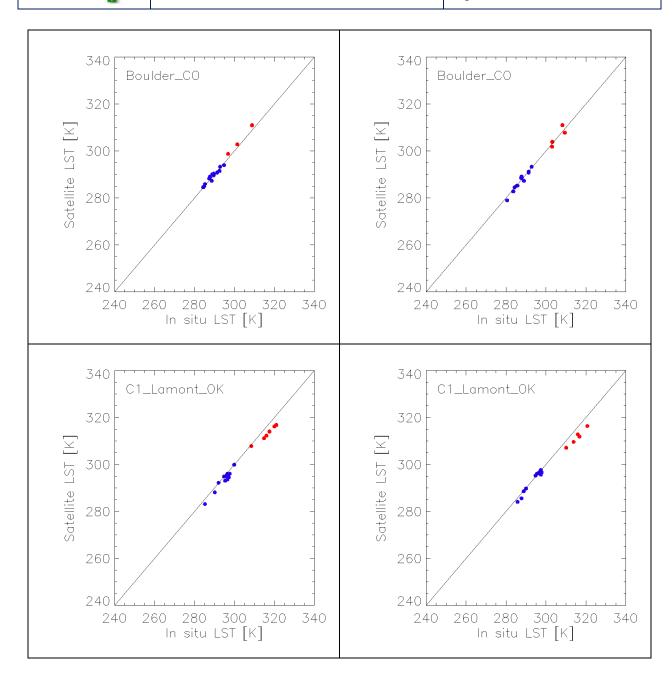
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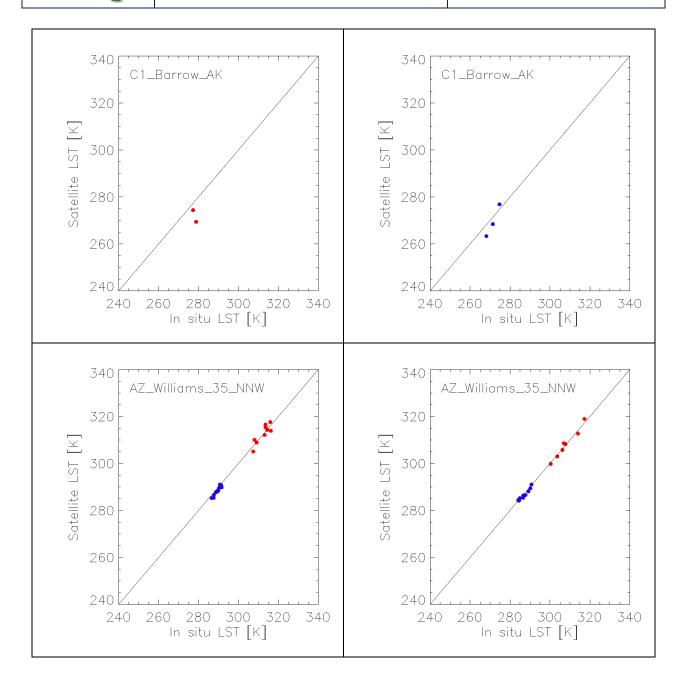
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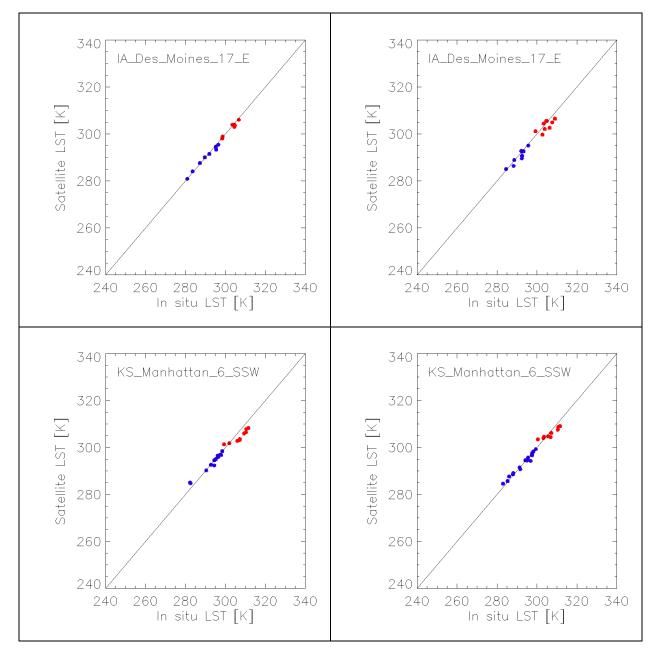
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As with past cycles cloud has reduced the number of matchups per station to single figures for most stations during day or night, with some missing statistics entirely. It is therefore challenging to determine robust statistics. Nonetheless, it can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



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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 076 (SLSTR-A) and Cycle 057 (SLSTR-B)			
	SLSTR-A		SLSTR-B	
	Day	Night	Day	Night
Africa	-0.2	0.2	-0.1	0.3
Europe	0.1	0.6	-0.2	0.6

For both Africa and Europe, 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 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 and north-eastern Europe) 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 mainly < 1K for Africa for both SLSTR-A and SLSTR-B. During daytime differences are over 1K for Europe as a result of increasing differences due to geometry as days get warmer. 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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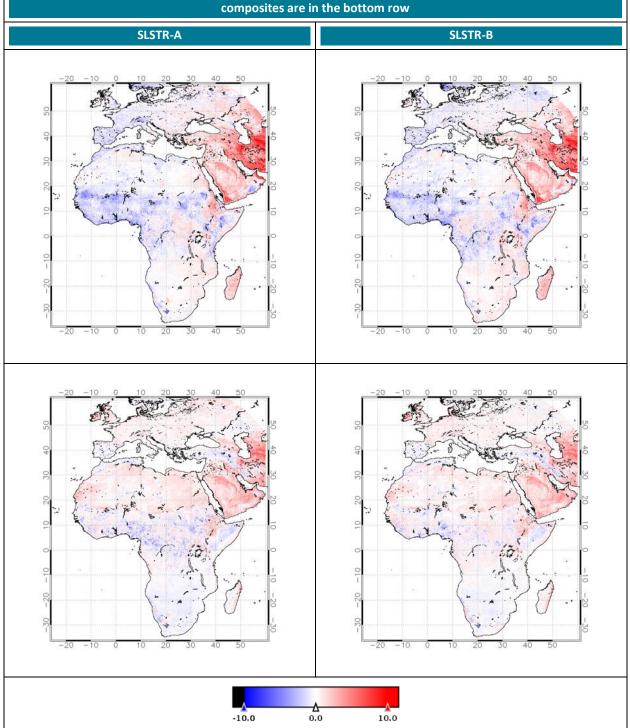
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Intercomparison of the SL_2_LST product with respect to the operational LSA SAF SEVIRI LST product for the period of Cycle 076 (SLSTR-A) and Cycle 057 (SLSTR-B). Daytime composites are in the top row and Night-time composites are in the bottom row



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. An area of stronger differences is evident over the northest Sahara which is being investigated. Some residual cloud contamination is evident from the large



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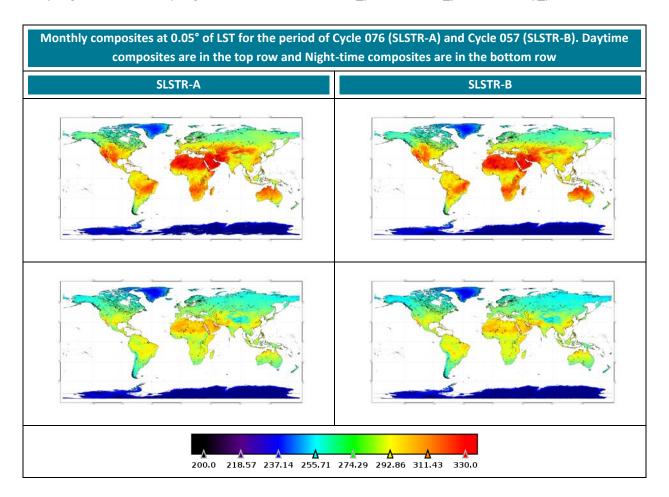
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differences at the edge of cloud cleared features. While the cloud contamination is seen for both SLSTR (strong negative differences) and SEVIRI (strong positive differences), compared with cycles where the basic cloud mask was used the contamination 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.

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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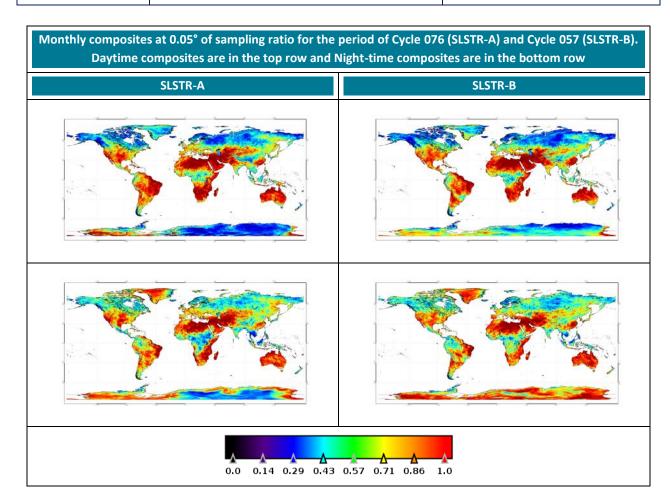
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The LST fields indicate the SL_2_LST product is producing values in line with expectations for both SLSTR-A and SLSTR-B. There are no distinct issues or non-physical values evident. The sampling ratio is now closer to what would be expected across the globe following the implementation of the temporal interpolation for the probabilistic cloud mask on 15th January 2020. Cloud contamination appears to be low, although there appears to be some excessive cloud clearing in some regions and undermasking in other, indicating the cloud coefficients ADF will need tuning for both instruments now the issue regarding the temporal interpolation has been resolved. The update to the ADF has now been implemented as of 23rd October 2020.



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6 Level 2 FRP validation

Level 2 Fire Radiative Power products have been compared with respect to an independent operational reference product (MODIS Terra MOD14 FRP). In particular, to evaluate the performance of the nighttime algorithm, an inter-comparison between the SLSTR NTC FRP (both from SLSTR-A and SLSTR-B) and the FRP retrieved from the similar MODIS MOD14 product was designed and conducted, giving important information on both spatial patterns of fire detection and FRP quantification. The inter-comparison procedure, initially based on previous work from M. Wooster and W. Xu on the FRP Prototype and on the evaluation of SEVIRI fire data, is divided into two main parts, the first one related to active fire (AF) pixel detection and omission and commission fire pixels, and the second to fire clusters. The SLSTR FRP NTC product (both SLSTR-A and SLSTR-B) has been released to the public on the 19th August 2020. The current processing baseline for SLSTR-A FRP products is v2.77 and for SLSTR-B is v1.55. The baseline was deployed in the Land processing centres on 14th June 2021 for SLSTR-A and for SLSTR-B. AF detection is initially performed using S7, and the FRP retrieval can then be performed in two ways: either using S7 when all active fire pixels in an identified active fire cluster remain unsaturated and F1 otherwise (the so called F1 OFF option), or always using F1 regardless of S7 saturation (the F1 ON option). At present, the algorithm is predominantly delivering active fire detections and FRP data from night-time (ascending node) S3A and S3B overpasses, as the S7 (middle infrared) channel saturates frequently over warm surfaces during day-time. The current configuration makes use of the F1_ON option for the processing.

6.1 FRP validation

The SLSTR FRP validation uses inter-comparisons with similar FRP products from other sources such as other satellite sensors, which give important quality information with respect to active fire detection and fire clusters characterisation. Here we compare the SL_2_FRP product from both SLSTR-A and SLSTR-B with the operational MODIS MOD14 FRP product (from MODIS Terra) available from the LAADS DAAC. It is important to note that the employed products have slightly different overpass times, implying that the two sensors do not observe fires in the exact same configuration nor with the same atmospheric conditions. Thus, for these reasons, and for the nature of the procedure delineated below, this intercomparison should not be interpreted as a full validation exercise but rather as a check of the consistency of the FRP products derived from SLSTR with the ones from MODIS. The inter-comparison procedure is divided into two main parts. The first part is related to omission and commission fire pixels, i.e., fire pixels detected by MODIS without any SLSTR fire pixel in a 7x7 window around it (commissions), and fire pixels detected by SLSTR without any MODIS fire pixel in a 7x7 window around it (commissions). The second part is related to the characterisation of fire clusters, i.e., groups of one or more pixels spatially adjacent to each other and corresponding to a single fire. A description is given in the following.

Part 1, omission and commission fire pixels between SLSTR FRP and MODIS MOD14:

- Select areas of high fire activity during the period between 1st March 2021 and 31st May 2021 and fetch all the relative SL_2_FRP scenes (both SLSTR-A and SLSTR-B);
- Discard all scenes that do not contain active fire pixels;



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Select and download matching MODIS MOD14 data with overpass time within ± 6 minutes of those of SLSTR and covering the same area of interest, and discard all scenes that do not have a matching MOD14 product;

- Restrict observations to a scan angle of ±30° or equivalent pixel area of 1.7 km² to avoid edge-of-swath data, and restrict to the common area of detection between the two products;
- Discard all scenes that do not contain active fire pixels after the restriction step;
- Re-project the MODIS pixels to the SLSTR Level 1b data grid. If multiple MODIS active fire pixels (AFP) are present in the same equivalent SLSTR grid cell, their combined FRP is used;
- Evaluate SLSTR FRP commission fire pixels, i.e., when there is a fire pixel in the SLSTR grid without any MOD14 fire pixel in a 7x7 window around it;
- Evaluate SLSTR FRP omission fire pixels, i.e., when there is a MOD14 fire pixel without any SLSTR fire pixel in a 7x7 window around it;
- Find and evaluate fire pixels detected by both sensors.

Part 2, Fire Cluster FRP comparison between SLSTR FRP and MODIS MOD14:

- Apply an atmospheric correction to MODIS FRP data, calculated using transmittance and water vapour content of the column above the fire pixel;
- Starting from the fire pixels detected by both sensors, find all the fire clusters detected by both SLSTR and MODIS, i.e., groups of one or more pixels spatially adjacent to each other and corresponding to a single fire; cases where a single SLSTR cluster corresponds to multiple MOD14 clusters and/or vice versa are merged together and the total FRP is used;
- Compute the total FRP for all active fire pixels in each fire cluster for MODIS and SLSTR data.
- Check for cloud/water/detection flags around each fire cluster that might affect the FRP value; if none is present, the cluster is flagged as well-detected;
- If necessary, check the SLSTR S7-S8 difference for possible issues and mismatches with the detected fire clusters;
- Generate statistics and analysis based on all the fire clusters detected by both MODIS and SLSTR.

Using the procedure delineated above, fire pixels from six areas of high fire activity between 1st June 2021 and 31st August 2021 were aggregated and compared. In particular, the six areas of interest are: South America, the centre-north portion of North America near the Great Lakes region, the shouthern portion of Africa, the southeastern portion of Europe, the eastern portion of Russia, the northern regions of Australia, see Figure 23. From more than ten thousand SLSTR scenes encompassing these areas, around 120 products which respected all the criteria delineated above were selected to perform this analysis. A summary of the results is reported in Table 7.

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Table 7: Summary of the inter-comparison between SLSTR FRP and MODIS FRP.

Variable	Value	
Number of commission AFP	11,113 (36% of Total SLSTR AFP)	
Number of omission AFP	754 (2.4% of Total SLSTR AFP)	
FRP of commission AFP (MW)	60,441	
FRP of omission AFP (MW)	67,968	
Number of SLSTR AFP detected by both sensors	19,948 (64% of Total SLSTR AFP)	
Number of MOD14 AFP detected by both sensors	7,450 (90% of Total MOD14 AFP)	
Total number of AFP detected by SLSTR	31,061	
Total number of MOD14 AFP	8,304	
Mean number of SLSTR AFP per cluster	9.8	
Total SLSTR FRP within clusters (MW)	168,368	
Mean SLSTR FRP per cluster (MW)	129.3	
Median SLSTR FRP per cluster (MW)	34.0	
Mean number of MOD14 AFP per cluster	3.5	
Total MOD14 FRP within clusters (MW)	211,043	
Mean MOD14 FRP per cluster (MW)	162.1	
Median MOD14 FRP per cluster (MW)	20.8	
Mean bias of FRP per cluster (MW)	-32.8	
Median of FRP scatter per cluster (MW)	8.3	
Root-mean-square deviation of FRP per cluster	820	
25-50-75 percentiles of SLSTR clusters FRP	15.4, 34.0, 87.1	
25-50-75 percentiles of MOD14 clusters FRP	10.2, 20.8, 58.9	



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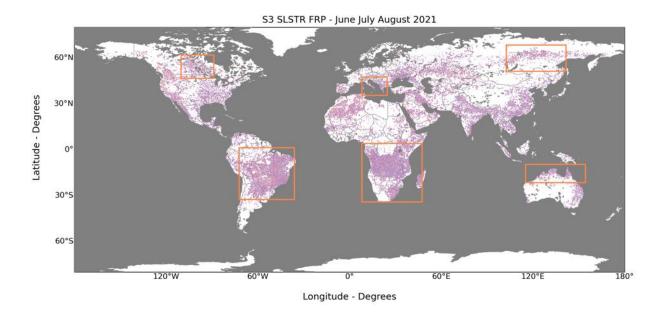
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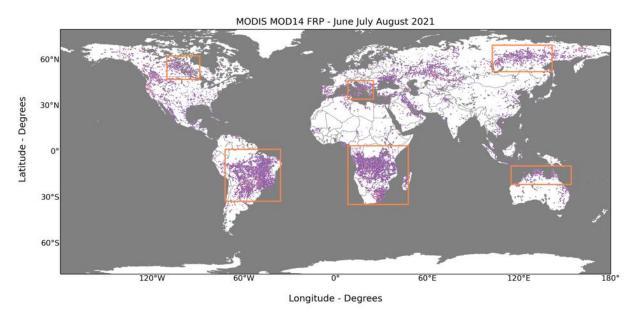


Figure 23: Areas of high fire activity selected for the inter-comparison. The basemap shows night-time fires detected by SLSTR (top) and MODIS (bottom) for the months of June, July, and August 2021

Overall, there is good agreement between SLSTR FRP and MODIS FRP, as can be seen in Table 7. The comparison shows that SLSTR detects in general more fire pixels than MODIS (31,061 vs 8,304), albeit many of them with very low FRP. Furthermore, there is a large number of commission fire pixels and a low number of omission fire pixels, 36% and 2.4%, of the total amount of SLSTR AFPs, respectively. Such pixels indicate fires that were detected only by one sensor, however, these are not necessarily incorrect/missed detections. It is important to highlight, in fact, that the two sensors observe the scenes at slightly different times (the MODIS product has to be within an interval of \pm 6 minutes with respect to the SLSTR acquisition). This difference in time translates into different conditions of the observed fires and also of the cloud coverage. A fire could move, increase/decrease in extent and power, whereas clouds could cover different portions of the image. On the other hand, a fraction of these pixels may represent

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real fires that are undetected by MODIS but are detected by the SLSTR product - for example because of the use of the smaller pixel footprint F1 channel – or vice versa. For these reasons, the reported values should not be interpreted as full validation, bur rather as indication of the consistency between the two sensors. A summary of results per dataset for omission, commission, and fire pixels detected by both sensors is visualised in Figure 24.

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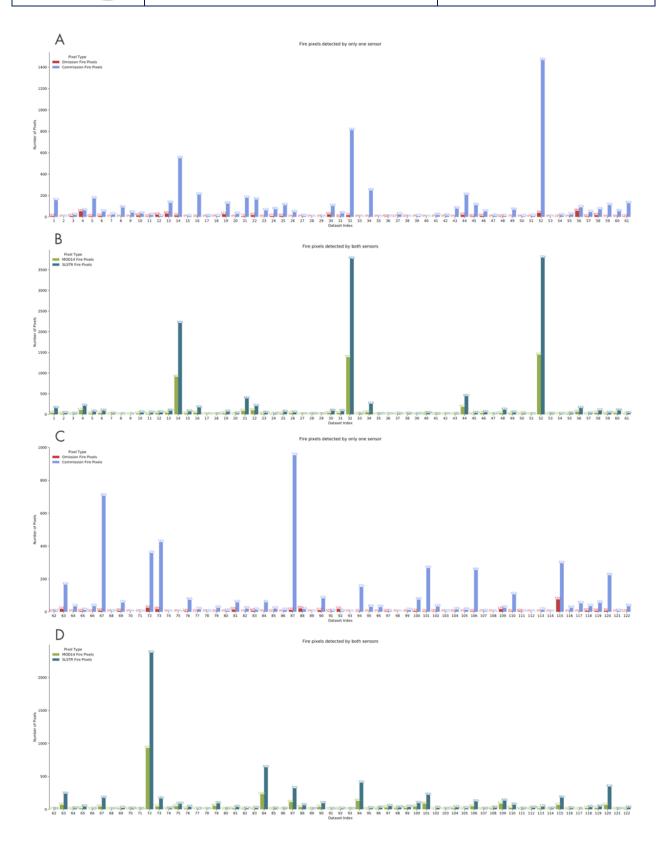


Figure 24: Amount of fire pixels detected only by one sensor (A and C) and by both sensors (B and D), per dataset. The percentages on top of each bar represent the proportion of pixels for that bar with respect to the total amount of fire pixel per dataset.



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The distribution of FRP for fire clusters detected by both sensors is quite similar between SLSTR and MODIS (see Figure 25), even though MODIS exhibits a higher peak for low FRP values and SLSTR shows a higher peak for intermediate values. Similarly, the results of a robust regression between the FRP values given by the two sensors are close to the one-to-one line, as can be seen in Figure 26, and the fire clusters appear quite similar, albeit with a few outliers. Generally, SLSTR appears to detect more fire pixels than MODIS for the same fire clusters, many of them with very low FRP, and the total FRP of all clusters is lower for SLSTR (see Table 7), although this number is heavily affected by a very low number of outliers with high FRPs. Contrary to the case of omission/commission fire pixels, the cluster analysis includes a step for checking the relevant flags associated with the fire detection, in particular those related to water or clouds in the background window around the fire cluster. Thus, results of the cluster analysis are more robust against differences in the atmospheric conditions or cloud masking algorithm. Nonetheless, the detections could still have been affected by the fact that the different sensors do not observe the fires exactly at the same time and are not perfectly equivalent. Hence, some fluctuations are expected.

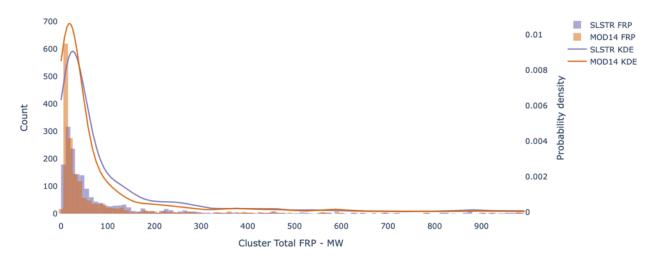


Figure 25: Distribution of the FRP for fire clusters detected by both sensors. The lines represent kernel density estimates (KDE) computed over the barplot.

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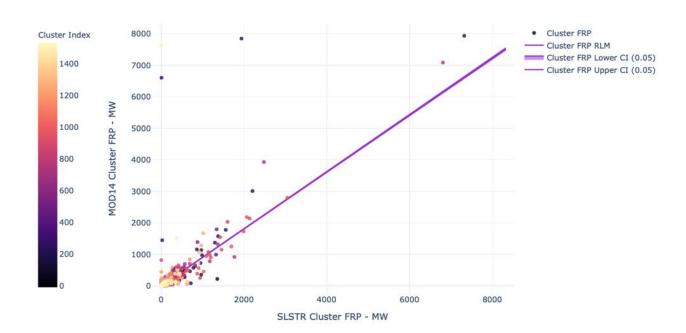


Figure 26: Scatterplot between the FRP of fire clusters detected by both sensors. SLSTR values are reported on the x-axis, whereas MODIS ones are on the y-axis. The regression line (with a shaded 0.05 confidence interval) is obtained with a robust linear method (RLM), which is less affected by outliers. The scatterpoints are color-coded according to their cluster number, so that they can be traced back to the original datasets.



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7 Events

7.1 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:

- 8th September 2021, 06:26-06:58 possible pointing errors due to scheduled out-of-plane manoeuvre
- ❖ 8th September 2021, 19:47-19:52 data gaps caused by radio frequency interference
- ❖ 14th September 2021, 08:31-08:41 data gaps caused by radio frequency interference
- ❖ 16th September 2021, 01:51-01:56 data gaps caused by radio frequency interference
- ❖ 18th September 2021, 09:17-09:22 data gaps caused by radio frequency interference
- ❖ 19th September 2021, 09:07-09:17 data gaps caused by radio frequency interference
- ❖ 27th September 2021 07:14 − 29th September 2021 04:30 − Blackbody crossover test. This test involves heating the cold blackbody and cooling the hot blackbody to swap their temperatures over, and then repeating the procedure to put the temperatures back to their nominal state. During this process, the separation in temperature between the two blackbodies changes, and therefore the TIR calibration is degraded. Uncertainty in the TIR channel calibration increases as the difference in temperature between the two blackbodies decreases. It should be noted that TIR data around the crossover in blackbody temperatures where the difference in temperature is less than 30 K are not processed to L1 and will be set to the fill value. The remaining data recorded during the time period above should be considered to have higher than normal uncertainty for the thermal channels.

7.2 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:

- ❖ 22nd September 2021, 09:45-09:50 data gaps caused by radio frequency interference
- ❖ 23rd September 2021, 05:25-05:30 − data gaps caused by radio frequency interference
- 29th September 2021, 08:35-08:45 possible pointing errors due to scheduled in-plane manoeuvre
- ❖ 30th September 2021 06:57 − 2nd October 2021 04:15 − Blackbody crossover test. As for SLSTR-A, this test involves heating the cold blackbody and cooling the hot blackbody to swap their temperatures over, and then repeating the procedure to put the temperatures back to their nominal state. During this process, the separation in temperature between the two blackbodies changes, and therefore the TIR calibration is degraded. Uncertainty in the TIR channel calibration increases as the difference in temperature between the two blackbodies decreases. It should be

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noted that TIR data around the crossover in blackbody temperatures where the difference in temperature is less than 30 K are not processed to L1 and will be set to the fill value. The remaining data recorded during the time period above should be considered to have higher than normal uncertainty for the thermal channels.



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8 Appendix A

Other reports related to the Optical mission are:

S3 OLCI Cyclic Performance Report, S3A Cycle No. 076, S3B Cycle No. 057 (ref. S3MPC.ACR.PR.01-076-057)

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

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