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

## **S3-A SLSTR Cyclic Performance Report**

Cycle No. 027

Start date: 16/01/2018

End date: 12/02/2018



Mission
Performance
Centre

SENTINEL 3



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## **S3-A SLSTR Cyclic Performance Report**

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: iii

## **Changes Log**

Version	Date	Changes
1.0	19/02/2018	First Version

## **List of Changes**

Version	Section	Answers to RID	Changes



## **S3-A SLSTR Cyclic Performance Report**

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: iv

## **Table of content**

1	PRO	CESSING BASELINE VERSION	
2	INST	TRUMENT MONITORING	2
	2.1	Instrument temperatures	2
	2.2	SCANNER PERFORMANCE	6
	2.3	DETECTOR NOISE LEVELS	8
	2.3.1	1 VIS and SWIR channel signal-to-noise	8
	2.3.2	2 TIR channel NEDT	10
	2.4	CALIBRATION FACTORS	12
	2.4.1	1 VIS and SWIR VISCAL signal response	12
3	LEVE	EL-1 PRODUCT VALIDATION	14
	3.1	GEOMETRIC CALIBRATION/VALIDATION	14
	3.2	RADIOMETRIC VALIDATION	15
	3.3	IMAGE QUALITY	15
4	LEVE	EL 2 SST VALIDATION	16
	4.1	DEPENDENCE ON LATITUDE, TCWV, SATELLITE ZA AND DATE	16
	4.2	SPATIAL DISTRIBUTION OF MATCH-UPS	17
	4.3	MATCH-UPS STATISTICS	18
5	LEVE	EL 2 LST VALIDATION	19
	5.1	CATEGORY-A VALIDATION	19
	5.2	CATEGORY-C VALIDATION	21
6	EVE	NTS	22
7	APP	PENDIX A	24



#### **S3-A SLSTR Cyclic Performance Report**

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: v

## **List of Figures**

Figure 1: Detector temperatures for each channel from 1st March 2016. Discontinuities occur for the infrared channels where the FPA was heated for decontamination or following an anomaly. The vertical dashed lines indicate the start and end of each cycle. Each dot represents the average temperature in one orbit
Figure 2: Blackbody temperature and baseplate gradient trends during cycle 27. The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit. Note that the gaps are due to data availability issues at the MPC, and are not due to any instrument or satellite problem. ————————————————————————————————————
Figure 3: Long term trends in average +YBB temperature in each cycle, showing yearly variation. The vertical dashed lines indicate the 1 <sup>st</sup> January 2017 and 20183
Figure 4: Baffle temperature trends for cycle 27. The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit 4
Figure 5: Opto-Mechanical Enclosure (OME) temperature trends for cycle 27 showing the paraboloid stops and flip baffle (top two plots) and optical bench and scanner and flip assembly (lower two plots). The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit
Figure 6: Scanner and flip jitter for cycle 27, showing mean, stddev and max/min difference from expected position per orbit for the nadir view (red, blue, green and black respectively). Note that the gaps are due to data availability issues at the MPC, and are not due to any instrument or satellite problem
Figure 7: Scanner and flip jitter for cycle 27, showing mean, stddev and max/min difference from expected position per orbit for the oblique view (red, blue, green and black respectively). Note that the gaps are due to data availability issues at the MPC, and are not due to any instrument or satellite problem
Figure 8: VIS and SWIR channel signal-to-noise of the measured VISCAL signal in each orbit since the start of the mission. Different colours indicate different detectors9
Figure 9: NEDT trend for the thermal channels in cycle 27. 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). Note that the gaps are due to data availability issues at the MPC, and are not due to any instrument or satellite problem.————————————————————————————————————
Figure 10: VISCAL signal trend for VIS channels since the beginning of the mission (nadir view). Different colours represent different detectors12
Figure 11: VISCAL signal trend for SWIR channels since the beginning of the mission (nadir view). Different colours represent different detectors13



## **S3-A SLSTR Cyclic Performance Report**

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: vi

Figure 12: Daily offset results in km from the GeoCal Tool analysis for Nadir along and across track (top two plots) and Oblique along and across track (bottom two plots). The error bars show the standard deviation. The x-axis shows the date (month/year)14
Figure 13: Daytime combined Level-1 image for visible channels on 1 <sup>st</sup> February 201815
Figure 14: Dependence of median and robust standard deviation of match-ups between SLSTR SST <sub>skin</sub> and drifting buoy SST <sub>depth</sub> for Cycle 27 as a function of latitude, total column water vapour (TCWV), satellite zenith angle and date. The data gaps at the end of the cycle are due to delays in match-up production
$Figure~15: Spatial~distribution~of~match-ups~between~SLSTR~SST_{skin}~and~drifting~buoy~SST_{depth}~for~Cycle~27.17$
Figure 16: Validation of the SL_2_LST product over the mid-July to mid-November reprocessed period at three Gold Standard in situ stations managed by the Karlsruhe Institute of Technology: Evora, Portugal (left); Gobabeb, Namibia (centre); Kalahari-Heimat, Namibia (right). [Results courtesy of Maria Martin through the GlobTemperature Project]19
Figure 17: Validation of the SL_2_LST product over the mid-July to mid-November reprocessed period at the seven Gold Standard in situ stations of the SURFRAD network plus a Gold Standard station from the ARM network: Bondville, Illinois top-(left); Desert Rock, Nevada (top-centre); Fort Peck, Montana (top-right); Goodwin Creek, Mississippi (middle-left); Penn State University, Pennsylvania (middle-centre); Sioux Fall, South Dakota (middle-right); Table Mountain, Colorado (bottom-left); and Southern Great Plains, Oklahoma (bottom-centre)20
Figure 18: S8 image from the granule starting at 08:22 on 25 <sup>th</sup> January 2018, showing the period where the instrument was being commanded to update the detector offsets22
Figure 19: The quicklook image for the granule observed between 14:26 and 14:29 on 7 <sup>th</sup> February 2018, showing the band of missing data23
Figure 20: The quicklook image for the granule observed between 14:10 and 14:13 on 9 <sup>th</sup> February 2018, showing the stripes of missing data23



## **S3-A SLSTR Cyclic Performance Report**

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: vii

## **List of Tables**

Table 1: Average reflectance factor, and signal-to-noise ratio of the measured VISCAL signal for cycles 016-027, averaged over all detectors for the nadir view 8
Table 2: Average reflectance factor, and signal-to-noise ratio of the measured VISCAL signal for cycles 016-027, averaged over all detectors for the oblique view 8
Table 3: NEDT for cycles 016-027 averaged over all detectors for both Earth views towards the +YBB (hot)11
Table 4: NEDT for cycles 016-027 averaged over all detectors for both Earth views towards the -YBB (cold)11
Table 5: SLSTR drifter match-up statistics for Cycle 2718



## **S3-A SLSTR Cyclic Performance Report**

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: 1

## 1 Processing Baseline Version

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



#### S3-A SLSTR Cyclic Performance Report

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: 2

## 2 Instrument monitoring

#### 2.1 Instrument temperatures

- ❖ Instrument temperatures were stable and consistent with expected values following the decontamination phase which was performed towards the end of Cycle 20 (see Figure 1). There are a few orbits with slightly lower visible channel temperature in Cycle 27 – this is due to the S8 detector offset test that was performed on 25<sup>th</sup> January – see Section 6 for more details.
- Figure 2, Figure 4 and Figure 5 show the orbital average blackbody, baffle and OME temperatures during cycle 27. The temperatures were stable (on top of a daily variation cycle). Longer term analysis also shows a yearly variation, with temperatures rising as the Earth approaches perihelion at the beginning of January. Cycle 27 falls just after this yearly peak with +YBB temperatures around 303.8 K (see Figure 3 and Table 3). Figure 2 shows that gradients across the blackbody baseplate are stable and within their expected range (±20mK).

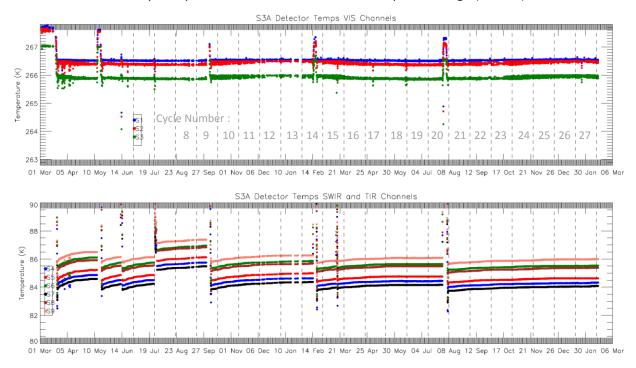


Figure 1: Detector temperatures for each channel from 1st March 2016. Discontinuities occur for the infrared channels where the FPA was heated for decontamination or following an anomaly. The vertical dashed lines indicate the start and end of each cycle. Each dot represents the average temperature in one orbit.



#### **S3-A SLSTR Cyclic Performance Report**

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

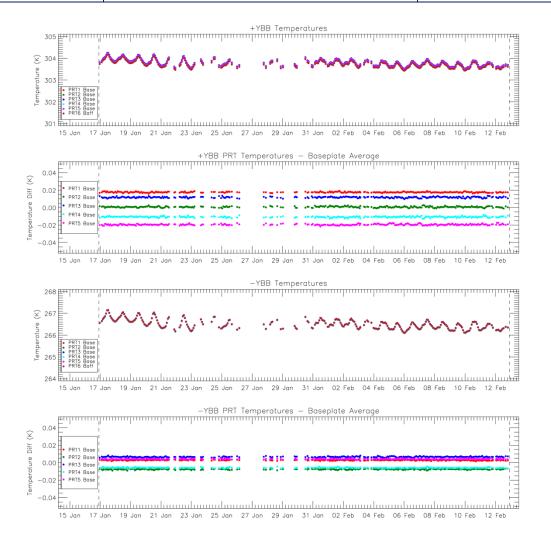


Figure 2: Blackbody temperature and baseplate gradient trends during cycle 27. The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit. Note that the gaps are due to data availability issues at the MPC, and are not due to any instrument or satellite problem.

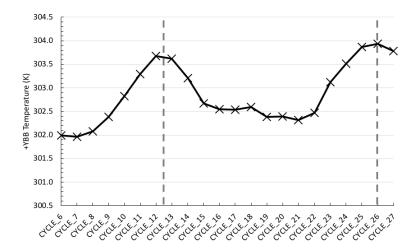


Figure 3: Long term trends in average +YBB temperature in each cycle, showing yearly variation. The vertical dashed lines indicate the 1<sup>st</sup> January 2017 and 2018.

# SENTINEL 3 Mission Performance Centre

#### Sentinel-3 MPC

#### **S3-A SLSTR Cyclic Performance Report**

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

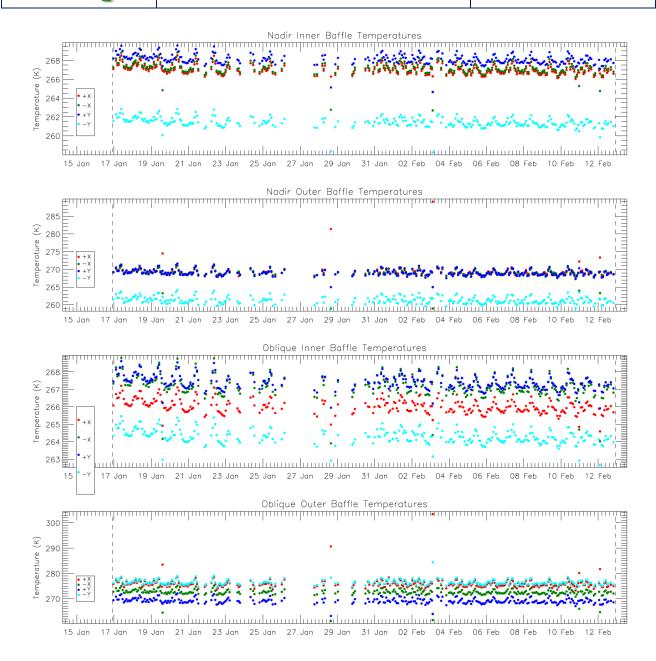


Figure 4: Baffle temperature trends for cycle 27. The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit.

# Mission Performance Centre

#### **Sentinel-3 MPC**

#### S3-A SLSTR Cyclic Performance Report

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

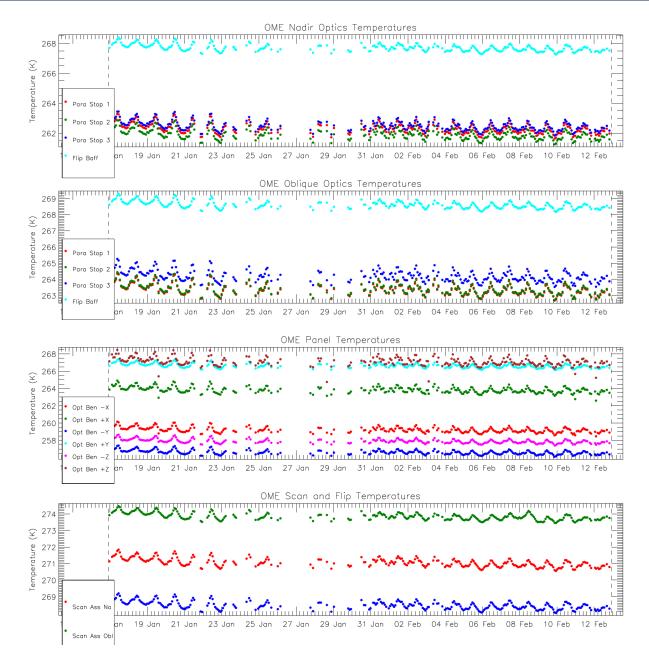


Figure 5: Opto-Mechanical Enclosure (OME) temperature trends for cycle 27 showing the paraboloid stops and flip baffle (top two plots) and optical bench and scanner and flip assembly (lower two plots). The vertical dashed lines indicate the start and end of the cycle. Each dot represents the average temperature in one orbit.



## S3-A SLSTR Cyclic Performance Report

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: 6

#### 2.2 Scanner performance

Scanner performance in cycle 27 has been consistent with previous operations and within required limits.

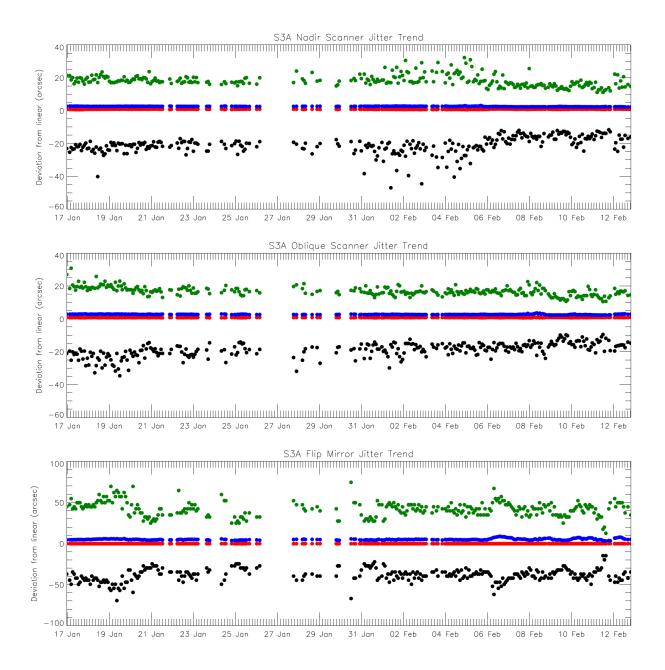


Figure 6: Scanner and flip jitter for cycle 27, showing mean, stddev and max/min difference from expected position per orbit for the nadir view (red, blue, green and black respectively). Note that the gaps are due to data availability issues at the MPC, and are not due to any instrument or satellite problem.

## SENTINEL 3 Mission Performance Centre

#### Sentinel-3 MPC

### S3-A SLSTR Cyclic Performance Report

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

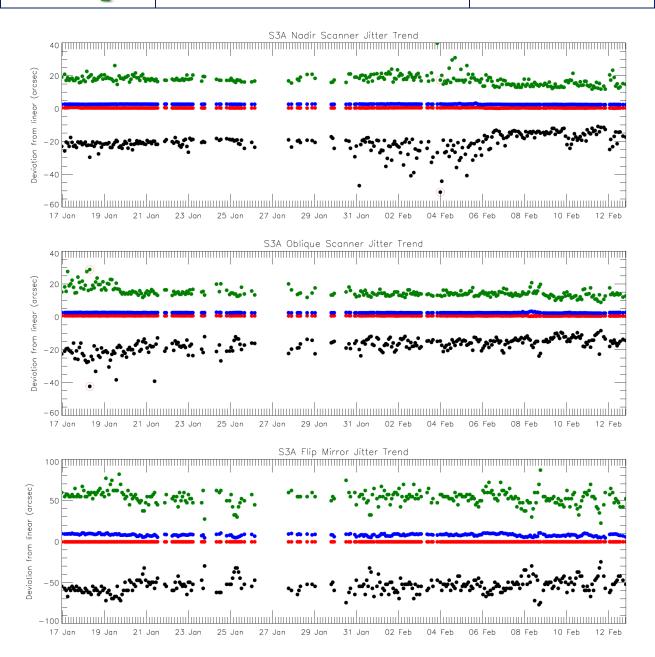


Figure 7: Scanner and flip jitter for cycle 27, showing mean, stddev and max/min difference from expected position per orbit for the oblique view (red, blue, green and black respectively). Note that the gaps are due to data availability issues at the MPC, and are not due to any instrument or satellite problem.



#### S3-A SLSTR Cyclic Performance Report

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: 8

#### 2.3 Detector noise levels

#### 2.3.1 VIS and SWIR channel signal-to-noise

The VIS and SWIR channel noise in cycle 27 was stable and consistent with previous operations - the signal-to-noise ratio of the measured VISCAL signal over the mission so far is plotted in Figure 8. Table 1 and Table 2 give the average signal-to-noise in each cycle (excluding the anomaly/decontamination period in Cycle 20). Note that this averages over the significant detector-detector dispersion for the SWIR channels that is shown in Figure 8.

Table 1: Average reflectance factor, and signal-to-noise ratio of the measured VISCAL signal for cycles 016-027, averaged over all detectors for the nadir view.

	Average		Nadir Signal-to-noise ratio											
	Reflectance Factor	Cycle 016	Cycle 017	Cycle 018	Cycle 019	Cycle 020	Cycle 021	Cycle 022	Cycle 023	Cycle 024	Cycle 025	Cycle 026	Cycle 027	
<b>S1</b>	0.187	233	234	231	230	232	230	232	234	235	234	228	226	
<b>S2</b>	0.194	236	236	232	231	235	235	235	239	236	237	233	232	
<b>S3</b>	0.190	236	238	228	231	229	231	229	234	232	234	227	227	
<b>S4</b>	0.191	142	140	140	139	137	135	136	139	140	142	141	138	
<b>S5</b>	0.193	233	235	236	234	232	232	229	236	236	235	238	235	
<b>S6</b>	0.175	142	143	143	142	139	138	139	142	146	145	146	143	

Table 2: Average reflectance factor, and signal-to-noise ratio of the measured VISCAL signal for cycles 016-027, averaged over all detectors for the oblique view.

	Average		Oblique Signal-to-noise ratio											
	Reflectance Factor	Cycle 016	Cycle 017	Cycle 018	Cycle 019	Cycle 020	Cycle 021	Cycle 022	Cycle 023	Cycle 024	Cycle 025	Cycle 026	Cycle 027	
<b>S1</b>	0.166	243	247	246	242	240	240	241	243	246	246	239	236	
<b>S2</b>	0.170	248	251	249	247	246	245	246	253	249	251	243	239	
<b>S3</b>	0.168	245	249	244	242	238	238	238	247	239	244	234	227	
<b>S4</b>	0.166	108	111	110	109	108	108	108	110	111	111	110	107	
<b>S5</b>	0.166	169	169	171	168	167	168	168	172	173	173	172	170	
<b>S6</b>	0.155	109	109	110	108	106	108	107	111	110	113	109	107	

Note that there may be very small differences in the average signal-to-noise values in Table 1 and Table 2 for recent cycles compared to previous Cyclic Reports because additional products may have been received from the MPC since those reports were published.

## Mission Performance Centre

#### **Sentinel-3 MPC**

#### **S3-A SLSTR Cyclic Performance Report**

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

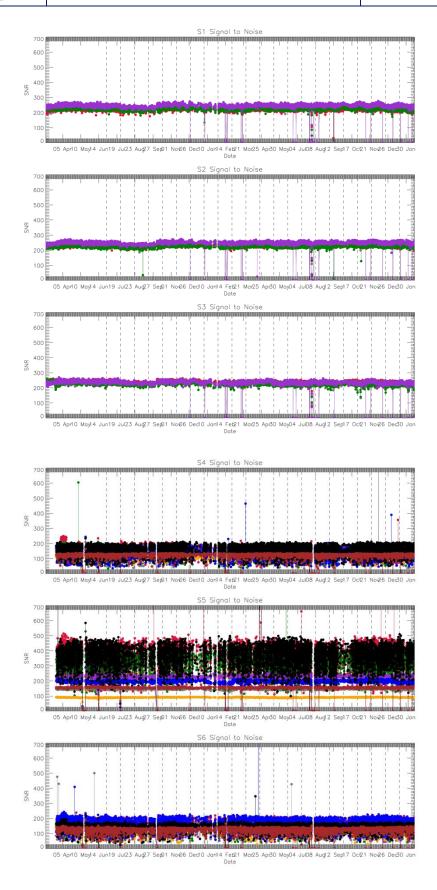


Figure 8: VIS and SWIR channel signal-to-noise of the measured VISCAL signal in each orbit since the start of the mission. Different colours indicate different detectors.



#### S3-A SLSTR Cyclic Performance Report

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: 10

#### 2.3.2 TIR channel NEDT

The thermal channel NEDT values in cycle 27 are consistent with previous operations and within the requirements. NEDT values for each cycle, averaged over all detectors and both Earth views, are shown in Table 3 and Table 4.

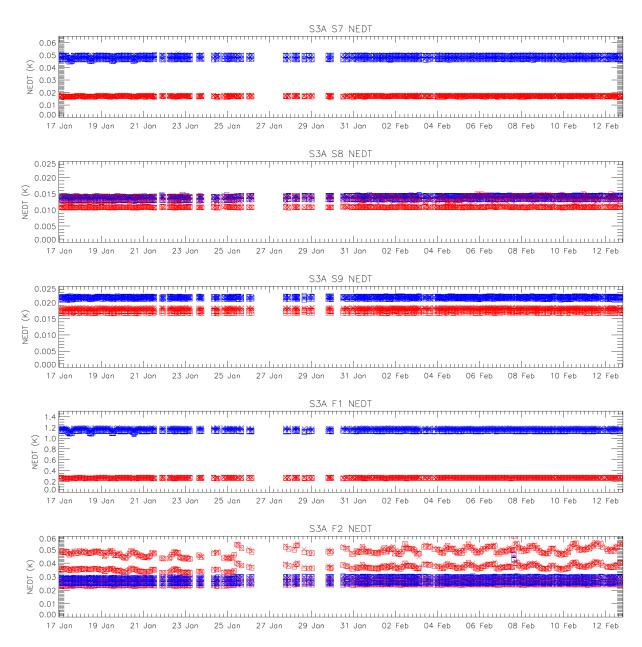


Figure 9: NEDT trend for the thermal channels in cycle 27. Blue points were calculated from the cold blackbody signal and red points from the hot blackbody. The square symbols show results calculated from the nadir view and crosses show results from the oblique view. Results are plotted for all detectors and integrators, which is why there are several different levels within the same colour points (particularly for S8 and F2). Note that the gaps are due to data availability issues at the MPC, and are not due to any instrument or satellite problem.

# Mission Performance Centre

#### **Sentinel-3 MPC**

#### **S3-A SLSTR Cyclic Performance Report**

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: 11

#### Table 3: NEDT for cycles 016-027 averaged over all detectors for both Earth views towards the +YBB (hot).

		Cycle 016	Cycle 017	Cycle 018	Cycle 019	Cycle 020	Cycle 021	Cycle 022	Cycle 023	Cycle 024	Cycle 025	Cycle 026	Cycle 027
+YBB t	•	302.544	302.541	302.593	302.385	302.395	302.316	302.466	303.125	303.515	303.871	303.931	303.778
	<b>S7</b>	17.2	17.2	18.1	17.2	17.2	17.1	17.2	16.9	16.8	16.7	16.7	16.8
NEDT	<b>S8</b>	10.9	11.0	11.1	11.0	11.1	10.9	10.9	10.9	10.8	10.8	10.8	10.9
NEDT (mK)	<b>S9</b>	17.0	17.2	17.5	17.4	17.5	16.7	16.9	17.0	17.1	17.1	17.2	17.4
()	F1	268	271	297	276	276	269	270	265	265	263	263	265
	F2	27.6	27.8	27.8	27.8	27.8	27.4	27.6	27.7	27.9	28.0	27.9	28.2

#### Table 4: NEDT for cycles 016-027 averaged over all detectors for both Earth views towards the -YBB (cold).

			=	-	_			-			-	-	
		Cycle 016	Cycle 017	Cycle 018	Cycle 019	Cycle 020	Cycle 021	Cycle 022	Cycle 023	Cycle 024	Cycle 025	Cycle 026	Cycle 027
-YBB te	-	265.136	265.260	265.412	265.122	265.054	264.900	265.012	265.790	266.251	266.754	266.760	266.482
NEDT (mK)	<b>S7</b>	49.0	48.8	46.9	49.2	49.4	49.4	49.0	47.6	47.0	46.3	46.3	45.6
	S8	14.2	14.3	14.2	14.3	14.4	14.2	14.1	14.2	14.1	14.0	14.1	14.2
	S9	21.4	21.6	21.6	22.0	22.0	21.1	21.3	21.4	21.4	21.5	21.6	21.8
	F1	1191	1199	1163	1231	1233	1212	1202	1161	1139	1124	1123	1142
	F2	29.3	29.3	29.4	29.6	29.7	29.2	29.2	29.3	29.3	29.2	29.3	29.8

Note that there may be very small differences in the average NEDT values in Table 3 and Table 4 for recent cycles compared to previous Cyclic Reports because additional products may have been received from the MPC since those reports were published.



#### **S3-A SLSTR Cyclic Performance Report**

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: 12

#### 2.4 Calibration factors

#### 2.4.1 VIS and SWIR VISCAL signal response

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

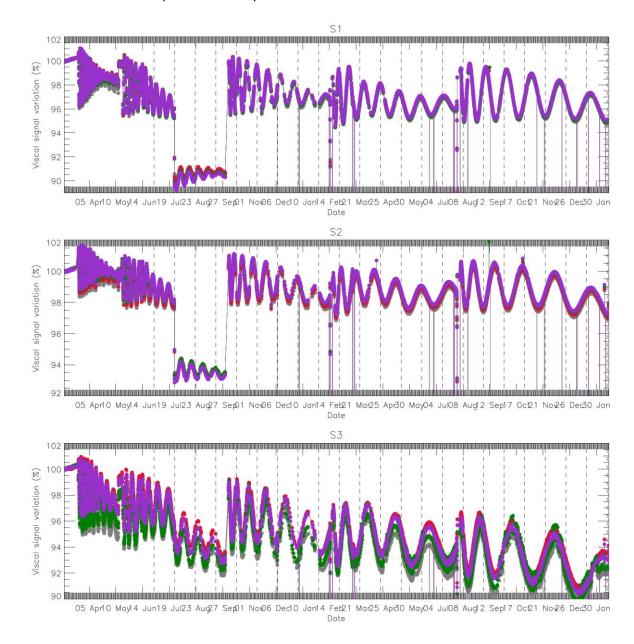


Figure 10: VISCAL signal trend for VIS channels since the beginning of the mission (nadir view). Different colours represent different detectors.

## SENTINEL 3 Mission Performance Centre

#### **Sentinel-3 MPC**

#### **S3-A SLSTR Cyclic Performance Report**

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

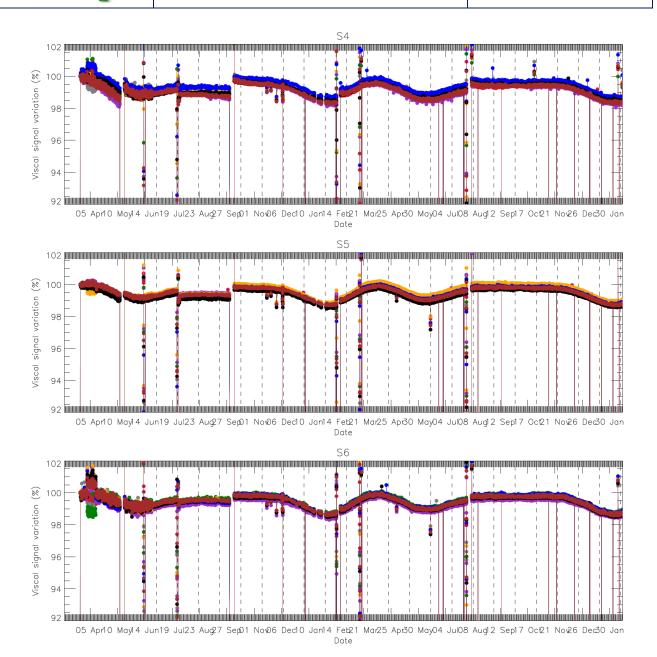


Figure 11: VISCAL signal trend for SWIR channels since the beginning of the mission (nadir view). Different colours represent different detectors.



#### **S3-A SLSTR Cyclic Performance Report**

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: 14

## 3 Level-1 product validation

#### 3.1 Geometric calibration/validation

Regular monitoring using the GeoCal Tool implemented at the MPC is being carried out. This monitors the geolocation performance in Level-1 images by correlation with ground control point (GCP) imagettes. Each Level-1 granule typically contains several hundred GCPs, which are filtered based on signal-to-noise to obtain a daily average in the across and along track directions. The results are plotted in Figure 12 from September 2017 to 15<sup>th</sup> February 2018, giving the average positional offsets in kilometres for Nadir and Oblique views. A comparison of Nadir and Oblique results shows that the offset difference between views has been gradually drifting. This will be carefully monitored to determine whether it is due to a seasonal drift or another effect.

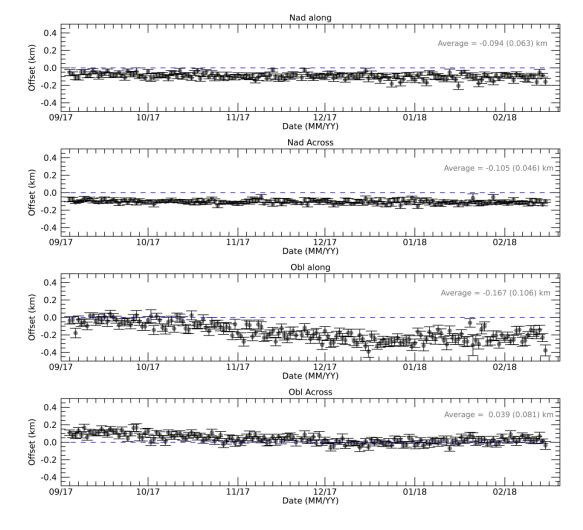


Figure 12: Daily offset results in km from the GeoCal Tool analysis for Nadir along and across track (top two plots) and Oblique along and across track (bottom two plots). The error bars show the standard deviation. The x-axis shows the date (month/year).



#### S3-A SLSTR Cyclic Performance Report

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: 15

#### 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 <a href="http://s3etrac.acri.fr/index.php?action=generalstatistics#pageSLSTR">http://s3etrac.acri.fr/index.php?action=generalstatistics#pageSLSTR</a>

- 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

Analysis of S3ETRAC results for SLSTR radiometric validation is ongoing and will be presented in future cyclic reports.

#### 3.3 Image quality

The Level-1 image quality is assessed when data are available at the MPC. For example by combining all granules over one day into a single combined image. Figure 13 shows an example combined image for the visible channels from 1<sup>st</sup> February 2018 (daytime only).

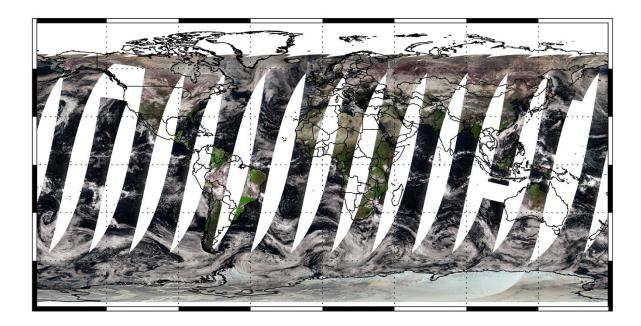


Figure 13: Daytime combined Level-1 image for visible channels on 1<sup>st</sup> February 2018.



#### S3-A SLSTR Cyclic Performance Report

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: 16

### 4 Level 2 SST validation

Level 2 WCT SSTs have been validated using CMEMS *in situ* data for Cycle 27. Match-ups between SLSTR and *in situ* data are provided by the EUMESAT OSI-SAF.

#### 4.1 Dependence on latitude, TCWV, Satellite ZA and date

The dependence of the difference between SLSTR SST<sub>skin</sub> and drifting buoy SST<sub>depth</sub> for Cycle 27 is shown in Figure 14. No adjustments have been made for difference in depth or time between the satellite and in situ measurements. SLSTR SSTs are extracted from the SL\_2\_WCT files. Daytime 2-channel (S8 and S9) results are shown in red, night time 2-channel results are shown in blue and night time 3-channel results are shown in green. Solid lines indicate dual-view retrievals, dashed lines indicate nadir-only retrievals. Bold lines indicate statistically significant (95% confidence) results.

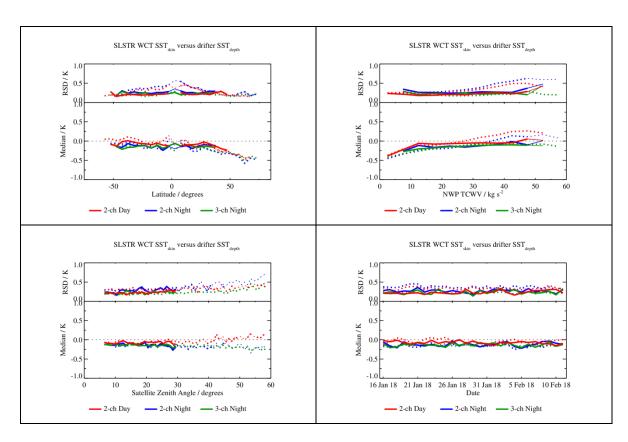


Figure 14: Dependence of median and robust standard deviation of match-ups between SLSTR SST<sub>skin</sub> and drifting buoy SST<sub>depth</sub> for Cycle 27 as a function of latitude, total column water vapour (TCWV), satellite zenith angle and date. The data gaps at the end of the cycle are due to delays in match-up production.



#### **S3-A SLSTR Cyclic Performance Report**

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: 17

## 4.2 Spatial distribution of match-ups

The spatial distribution of SLSTR/drifter match-ups for Cycle 27 is shown in Figure 15. No adjustments have been made for difference in depth or time between the satellite and *in situ* measurements.

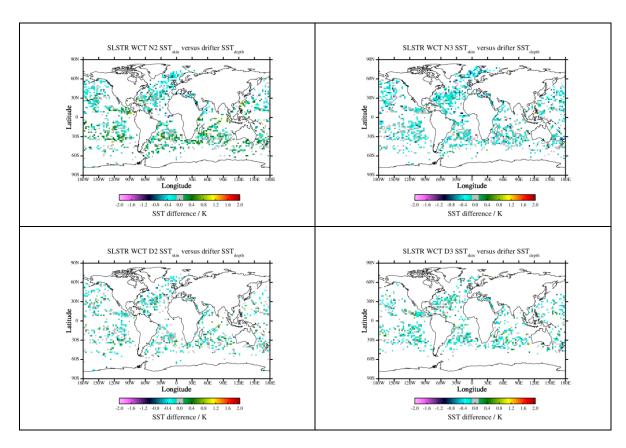


Figure 15: Spatial distribution of match-ups between SLSTR SST $_{\rm skin}$  and drifting buoy SST $_{\rm depth}$  for Cycle 27.



#### **S3-A SLSTR Cyclic Performance Report**

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: 18

## 4.3 Match-ups statistics

Match-ups statistics (median and robust standard deviation, RSD) of SLSTR/drifter match-ups for Cycle 27 are shown in Table 5. 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 is providing SSTs mostly within its target accuracy (0.3 K).

Table 5: SLSTR drifter match-up statistics for Cycle 27.

Retrieval	Number	Median (K)	RSD (K)						
N2 day	5492	-0.04	0.33						
D2 day	2478	-0.08	0.22						
N2 night	6313	-0.16	0.36						
N3 night	6313	-0.15	0.22						
D2 night	2506	-0.13	0.27						
D3 night	2506	-0.14	0.23						



#### S3-A SLSTR Cyclic Performance Report

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: 19

#### 5 Level 2 LST validation

Level 2 Land Surface Temperature products have been validated against *in situ* observations (Category-A validation), and intercompared (Category-C validation) with respect to three independent reference products from the ESA DUE GlobTemperature Project (MODIS, GOES, and SEVIRI).

#### 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. The results can be summarised as follows (see Figure 16 and Figure 17):

- Average absolute accuracy (vs. Gold Standard):
  - Daytime: 0.81K
  - Night-time: 1.07K

This daytime accuracy meets the mission requirement of < 1K. The night-time accuracy is very close to this mission requirement. This also is in line with the GCOS climate requirements of 1 K accuracy.

- Average precision (vs. Gold Standard):
  - O Daytime: 0.72K
  - Night-time: 1.21K

While there is no Sentinel-3 mission requirement for precision, the daytime precision meets the GCOS climate requirement of 1K. The night-time accuracy is also very close to this climate requirement.

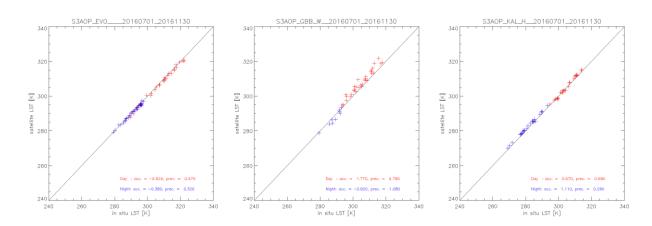


Figure 16: Validation of the SL\_2\_LST product over the mid-July to mid-November reprocessed period at three Gold Standard in situ stations managed by the Karlsruhe Institute of Technology: Evora, Portugal (left); Gobabeb, Namibia (centre); Kalahari-Heimat, Namibia (right). [Results courtesy of Maria Martin through the GlobTemperature Project]



#### **S3-A SLSTR Cyclic Performance Report**

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

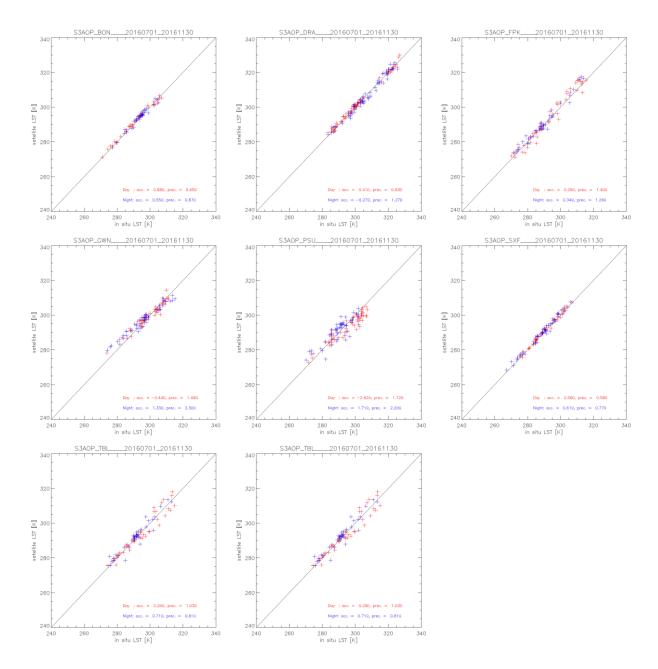


Figure 17: Validation of the SL\_2\_LST product over the mid-July to mid-November reprocessed period at the seven Gold Standard in situ stations of the SURFRAD network plus a Gold Standard station from the ARM network: Bondville, Illinois top-(left); Desert Rock, Nevada (top-centre); Fort Peck, Montana (top-right); Goodwin Creek, Mississippi (middle-left); Penn State University, Pennsylvania (middle-centre); Sioux Fall, South Dakota (middle-right); Table Mountain, Colorado (bottom-left); and Southern Great Plains, Oklahoma (bottom-centre).



#### S3-A SLSTR Cyclic Performance Report

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: 21

#### **5.2** Category-C validation

Category-C validation uses inter-comparisons with similar LST products from other sources such as AATSR, AVHRR, MODIS, SEVIRI, and VIIRS, which give important quality information with respect to spatial patterns in LST deviations. The results can be summarised as follows:

- ❖ Daytime intercomparison differences are: ~1K vs. GOES\_\_LST\_2 over North America; ~1K vs. SEVIR\_LST\_2 over Europe; and < 1K vs. MOGSV\_LST\_2 on a Global basis.</p>
- Night-time intercomparison differences are: <1K vs. GOES\_\_LST\_2 over North America; <1K vs. SEVIR\_LST\_2 over Europe; and < 1K vs. MOGSV\_LST\_2 on a Global basis.
- Differences with respect to biomes tend to be larger during the day for surfaces with more heterogeneity and/or higher solar insolation. With respect to SLSTR zenith viewing angle differences are larger in the day on the left side of the SLSTR swath in the along-track direction.



#### S3-A SLSTR Cyclic Performance Report

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: 22

### **Events**

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

On 25<sup>th</sup> January 2018, the detector offset voltage for channel S8 was updated on the satellite. This offset voltage sets the dynamic range for both the S8 and F2 detectors, and the small change was made to shift the lower brightness temperature limit for S8 from approximately 197 K to approximately 183 K. A test to determine the effect of such a change was carried out on 2<sup>nd</sup> May 2017 and it showed that the lower cutoff can be adjusted without compromising the upper limit, which is required to be above 342 K for LST measurements, and with little effect on F2.

The commands to update the S8 offsets were sent to the instrument at 08:24 on 25th January 2018. This caused a short period of unavailability for all channels, which shows up as a blank strip in the Level-1 images – see Figure 18.

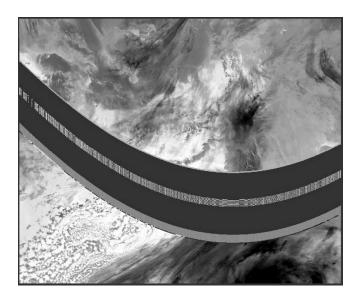


Figure 18: S8 image from the granule starting at 08:22 on 25<sup>th</sup> January 2018, showing the period where the instrument was being commanded to update the detector offsets.

After the change in detector offset voltage was made, the lower brightness temperature limit for both S8 detectors was reduced as expected. In addition, the lower limit now has approximately the same value for both detectors, whereas before the change each detector had a slightly different lower limit. The absolute calibration before and after the change has not been affected, although it should be noted that at these low temperatures, uncertainties increase with decreasing brightness temperature.

On 7<sup>th</sup> and 9<sup>th</sup> February 2018, there was a loss of transfer frames during downlink to the Svalbard ground station that caused gaps in the data stream. The gap on the 7<sup>th</sup> February affects products between approximately 14:26 and 14:32 and shows up as an empty stripe in the Level-1 image (see Figure 19). On 9<sup>th</sup> February, a series of small gaps show up as stripes in the Level-1 images between 13:48 and 14:23. During this time, some Level-1 granules are completely compromised (see Figure 20).



#### **S3-A SLSTR Cyclic Performance Report**

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

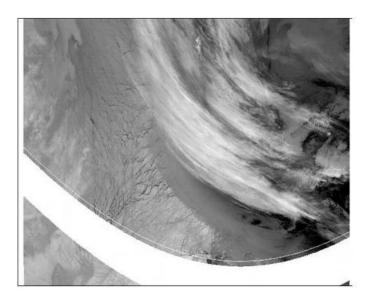


Figure 19: The quicklook image for the granule observed between 14:26 and 14:29 on 7<sup>th</sup> February 2018, showing the band of missing data.

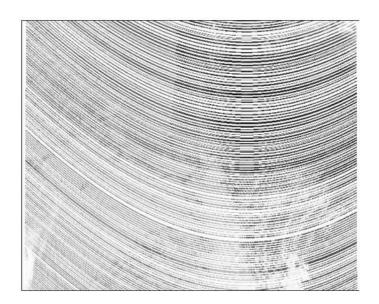


Figure 20: The quicklook image for the granule observed between 14:10 and 14:13 on  $9^{th}$  February 2018, showing the stripes of missing data.



#### **S3-A SLSTR Cyclic Performance Report**

Cycle No. 027

Ref.: S3MPC.RAL.PR.02-027

Issue: 1.0

Date: 19/02/2018

Page: 24

## 7 Appendix A

Other reports related to the Optical mission are:

S3-A OLCI Cyclic Performance Report, Cycle No. 027 (ref. S3MPC.ACR.PR.01-027)

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

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