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S2 MPC

L1C Data Quality Report

Ref. S2-PDGS-MPC-DQR

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Table of contents

1. INTRODUCTION 6
1.1 Scope of the document 6
1.2 Main points for the Reporting Period 6
2. MEASURED PRODUCT PERFORMANCES 7
2.1 Performances Overview 7
2.2 Geometric Performance 7
2.2.1 Geometric Calibration Status 7
2.2.1.1 S2A 7
2.2.1.2 S2B 8
2.2.2 Geometric Refinement and Global Reference Image (GRI) 8
2.2.3 Absolute Geolocation 8
2.2.4 Multi-Spectral Registration 9
2.2.5 Multi-Temporal Registration 10
2.3 Radiometric Performance 11
2.3.1 Radiometric Calibration Status 11
2.3.1.1 Sun-diffuser model improvement 11
2.3.1.2 S2A 11
2.3.1.3 S2B 12
2.3.2 Radiometric Uncertainty 12
2.3.3 Noise 14
2.3.4 Modulation Transfer Function 15
3. PROCESSING CHAIN STATUS 17
3.1 Product Format 17
3.2 Acquisitions with low illumination conditions 17
3.3 Off-line products 17
3.4 Reprocessed products 17
3.5 Status of Processing Baselines and Known Processing Anomalies 19
3.6 Processing Baseline Status 24
3.6.1 Baseline 02.07 24
3.6.2 Baseline 02.08 26
3.6.3 Baseline 02.09 26
3.6.4 Baseline 02.10 26
4. PRODUCT ANOMALIES 27
4.1 Introduction 27
4.2 Instrument Measurement Time metadata (#4) 28
4.3 Missing Physical Gains metadata (#7) 28
4.4 Striping of SWIR Bands (#9) 28
4.5 Striping due to lost source packets (#10) 29
4.6 Missing viewing angles (#11) 30
4.7 Anomalous Pixels (#12) 30

4.8 Saturation noise on Band 10 Images (#13) 30
4.9 Geolocation and Co-registration Error (#14) 31
4.10 Strong Misregistration (#15) 32
4.11 Stretching of 60 m Bands (#16) 32
4.12 Misaligned detectors on band 1 (#17) 32
4.13 Geolocation Error (#18) 33
4.14 Product footprint on the ante-meridiem (#19) 33
4.15 Degraded AUX files (#20) 34
4.16 Acquisition with shutter closed (#23) 34
4.17 Imprecise technical quality mask (#24) 34
4.18 Geolocation error on orbit 7174 (#25) 35
4.19 Incomplete manifest (#26) 35
4.20 Inaccurate footprint and incomplete metadata (#27) 35
4.21 Incorrect cloud coverage metadata (#29) 35
4.22 Corrupted metadata (#30) 35
4.23 Missing viewing angles metadata (#32) 35
4.24 Missing files (#33) 35
4.25 Missing ECMWF auxiliary files (#34) 36
4.26 Wrong quantification value (#35) 36
4.27 Misregistration on bands 9 and 10 (#36) 36
4.28 "Null" folder (#38) 36
4.29 Incorrect S2A Spectral Response Function (#39) 36
4.30 Incorrect Product Name (#40) 37
4.31 Incorrect Instrument Temperature metadata (#41) 37
4.32 Incorrect NODATA mask format (#42) 37
4.33 Geolocation error due to GPS anomaly (#43) 37
4.34 Incorrect cloud coverage percentage (#44) 38
4.35 Pixels with 0 value (#5) 38
4.36 Incorrect equalization (#45) 39
4.37 Missing corners (#46) 39
4.38 S2A products processed as S2B (#47) 40
4.39 Geolocation Error after orbit control manoeuvre (#48) 40
4.40 Misregistration of some S2A products (#49) 40
4.41 Collision Avoidance Manoeuvre: missing pixels (#50) 41
4.42 Collision Avoidance Manoeuvre: Major geolocation error (#51) 41
4.43 Corrupted footprint (#52) 41
4.44 Missing AUX ECMWF files (#53) 41
4.45 Empty AUX ECMWF files (#54) 42
4.46 Spurious viewing angle metadata (#64) 42
4.47 Platform mismatch (#67) 42
5. PIXELS STATUS 43
5.1 Defective pixels 43

5.1.1.1 S2A 43
5.1.1.2 S2B 44
5.2 Reset Spike pixels 44
6. PRODUCT FEATURES 47
6.1 Spectral Response Non-uniformity 47
6.2 Parallax effects 47
6.2.1 Surface reflectance effects 48
6.2.2 Misregistration of High Altitude Objects 48
6.3 Gradient cross-talk 49
6.4 Data-strip overlap 50
6.5 Valid pixels 50

1. Introduction

1.1 Scope of the document

This document provides the data quality status of Copernicus Sentinel-2 mission L1C products.

It documents:

- ✓ the measured product performance vs. specifications (Section 2),
- ✓ processing chain improvements associated to each Processing Baseline (Section 3),
- ✓ an overview on L1C product evolution (Section 3.6),
- ✓ observed anomalies and known issues (Section 4),
- ✓ the list of defective pixels (Section 5).

Note that a reference article provides an in-depth presentation of Sentinel-2 Calibration and Validation methods and results after one year in operation (F. Gascon *et al.*, "Copernicus Sentinel-2 Calibration and Products Validation Status", RSE, 2017).

Since May 2018, a Data Quality Report for Level 2A products is also available from the Sentinel-2 Document Library.

1.2 Main points for the Reporting Period

- ✓ No new points for this month

2. Measured Product Performances

2.1 Performances Overview

The following overview table provides a summary of the Level-1C products data quality performances measured on products in Processing Baselines 02.01 and higher, for a set of key mission requirements.

Similar performances are observed for S2A and S2B, except for the geolocation performance which is not yet stabilized for S2B.

Table 2-1: Summary of Sentinel-2 L1C products measured performances for mission key requirements.

Requirement	Description	Measured performance
Absolute geolocation (without ground control points)	The geo-location uncertainty shall be better than 20 m at 2σ confidence level (without Ground Control Points).	< 11 m at 95.5% confidence (baseline 02.04)
Multi-spectral registration	The inter-channel spatial co-registration of any two spectral bands shall be better than 0.30 of the coarser achieved spatial sampling distance of these two bands at 3σ confidence level.	< 0.3 pixel at 99.7% confidence
Absolute radiometric uncertainty	The absolute radiometric uncertainty shall be better than 5 % (goal 3%).	B1 to B12, excl. B10: < 5%±2%
SNR	The Signal-to-Noise Ratio (SNR) shall be higher than specified values (see Table 2-5 in this document)	All bands compliant with > 27% margin

Measured performances are detailed in the following sections.

2.2 Geometric Performance

2.2.1 Geometric Calibration Status

2.2.1.1 S2A

An improvement of the yaw angle bias correction was performed on May 30th 2016. Before this date, a relatively large along-track bias can be observed between different repeat orbits in the overlap region at the edges of the swath. The multi-temporal co-registration performance reported in this document is computed for products acquired after this date.

The geometric calibration of S2A has been updated on 10/01/2019.

On May 20th 2019 the alignment of the Star Trackers have been improved to prevent a re-occurrence of anomaly #18. This operation has no impact on geolocation performance in nominal conditions.

2.2.1.2 S2B

A new geometric calibration for S2B was implemented on 30/03/2020.

2.2.2 Geometric Refinement and Global Reference Image (GRI)

The L1C processing chain implements a geometric refinement step which aims at improving the repetitiveness of the image geolocation, in order to reach the multi-temporal geolocation target (< 0.5 pixel at 95%). The refinement step will be activated upon completion of the GRI and the final validation of the refining algorithm.

The GRI is a set of Level 1B images (in sensor frame) covering the whole globe with highly accurate geolocation information obtained through a spatio-triangulation algorithm using reference Ground Control Points. The images use the reference band (B04) and are mostly (but not entirely) cloud-free. The GRI is an internal database used only for processing and not for dissemination. In particular, the GRI is not meant to be a cloud-free mosaic of the globe. Once the geometric refinement is activated, all images will have essentially the same geolocation accuracy.

The validation of the refinement method is currently in progress.

2.2.3 Absolute Geolocation

Absolute geolocation is constantly monitored for S2A and S2B. The long-term performance is close to 11 m at 95% for both satellites.

The geolocation performance of S2A has remained good since the last calibration in January 2019.

A new calibration for S2B has been implemented on 30/03 to improve the absolute geolocation of products located in the Northern hemisphere.

Note that the geolocation performance has a latitude-dependent component. This effect is particularly visible on the along-track component, and more pronounced for S2B than S2A. Images are shifted of 5 m Southward (approximately) in the Northern latitudes, to 5 m Northward in the Southern latitudes. This will be corrected with the introduction of the geometric refinement.

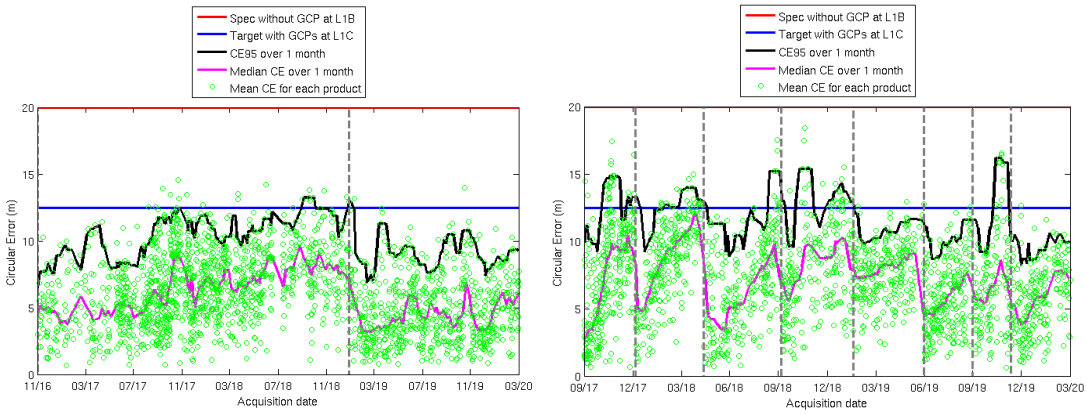

Figure 1: Geolocation performance for S2A (left) and S2B (right). The performance is computed over a sliding window of 30 days. Number of products used in the sliding window indicated for each point. (ACT= across track, ALT= along track). A vertical line indicates a geometric calibration event.

2.2.4 Multi-Spectral Registration

The co-registration requirement (< 0.3 pixel at 99.7% confidence) is met for all measured band couples. The performance for S2B has been improved with respect to S2A thanks to a better control of on-board vibrations.

Table 2-2: Multi-Spectral co-registration performance (per band couple and detector number) for S2A (top) and S2B (bottom). Requirement is 0.3 pixel.

S2A				
Bsec/Bref	**B01**	**B04**	**B05**	**B11**
B02		0,188		
B03		0,236		
B06			0,146	
B07			0,199	
B08		0,199		
B8A			0,240	
B09	0,184			
B11			0,260	
B12			0,270	0,215

S2B				
Bsec/Bref	**B01**	**B04**	**B05**	**B11**
B02		0,124		
B03		0,092		
B06			0,069	
B07			0,077	
B08		0,123		
B8A			0,092	
B09	0,238			
B11			0,172	
B12			0,167	0,104

2.2.5 Multi-Temporal Registration

The multi-temporal registration error for one tile is estimated as the mean measured error for all control points of the tile. Then the global performance is taken as the 95.5% percentile of the mean shift for all tiles. The performance is measured on the reference band (B04). According to this methodology, the current performance is around 12 m. Figure 2 shows the histogram of the distribution of multi-temporal registration errors for S2A and S2B respectively. Table 2-3 presents the observed statistical distribution of the observed multi-temporal registration performance for S2A and S2B products (separately and with respect to each other).

The activation of the geometric refinement with the GRI will significantly improve this performance. Preliminary validation results show a performance better than 5 m.

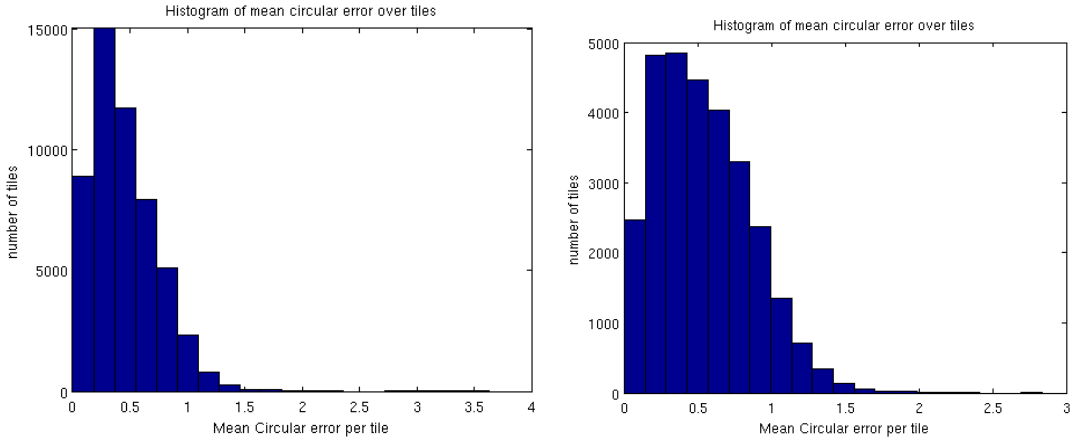

Figure 2: Histogram of the multi-temporal performance for S2A (left) and S2B (right, different scale). The current performance is 10 m (S2A) and 12 m (S2B), mean shift at 95% confidence.

Co-registration error	0<X<0.5 pixels	0.5<X<1 pixels	1<X<1.5 pixels	>1.5 pixels
S2A % of products	58%	35%	6%	1%
S2B % of products	47%	41%	11%	1%
S2A/S2B % of products*	45%	27%	26%	2%

Table 2-3: Multi-temporal performance statistics for Sentinel 2 constellation.

2.3 Radiometric Performance

2.3.1 Radiometric Calibration Status

2.3.1.1 Sun-diffuser model improvement

Product baseline 02.06 has been deployed on 23/10/2017. With this new baseline, the Sun-diffuser model used for calibration has been improved to reduce seasonal effects. The update did not result in a discrepancy in the time series of the radiometry (impact on calibration lower than 0.2% at this time of year, see DQR issue 22 for details).

2.3.1.2 S2A

Radiometric calibrations are performed routinely at the beginning of each month. Decontamination operations are scheduled once a year.

A decontamination of the instrument was performed from 22nd to 25th of September. The calibration coefficients were updated on the 26th of September. Products acquired on the 25th may be affected by a small variation of the radiometry of the SWIR bands (< 1%).

With the calibration of 10/12/2019, a correction of the spectral response function was introduced. This correction consists in removing shorter wavelengths points of the B02 response function which were affected by measurement noise. This evolution affects only the spectral response metadata of products and has no impact on the radiometry.

2.3.1.3 S2B

Radiometric calibration is performed once per month. The calibration of 12/12/2019 includes an update of the B02 relative spectral response as described for S2A in the previous section.

A decontamination was performed on 25th and 26th November 2019. Calibration coefficients were updated on the 27th of November 2019. In the interval, a small variation of the radiometric response can be expected for SWIR bands (1% typically).

Due to operational constraints, no radiometric calibration was performed during the month of April 2020.

2.3.2 Radiometric Uncertainty

Radiometric validation has been performed using several methods:

- ✓ "Rayleigh" method: measurement of the Rayleigh atmospheric backscattering over deep ocean sites.
- ✓ Comparison with in-situ data.
- ✓ Measurement over well characterized, temporally stable desert areas (Pseudo-Invariant Calibration Sites or PICS).
- ✓ Comparison with other sensors (Landsat-8 OLI (Collection-1 over Libya-4) and S2A for S2B case).

The results are presented in the figures below for S2A and S2B for all methods. Results are provided for all bands except B09 & B10. All results are compatible with the 5% (3%) radiometric accuracy requirement (Goal) respectively.

A small systematic difference in radiometry is observed between S2A and S2B:

S2A is brighter (measured reflectance higher) than S2B by about 1%. This difference is currently under study.

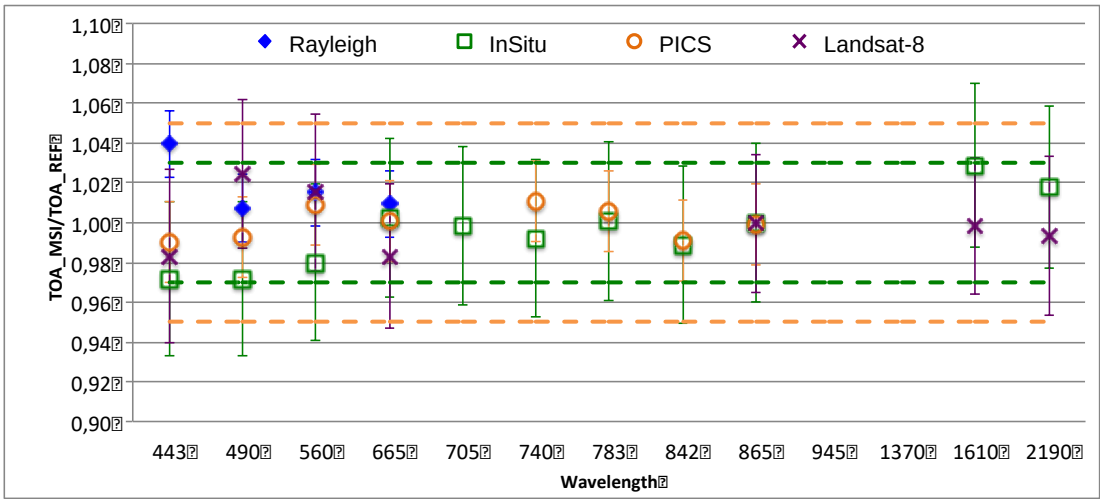

Figure 3: Comparison of radiometric accuracy for all spectral bands (except B10 and B09): ratio of S2A measurement on reference. Error bars indicate the method uncertainty.

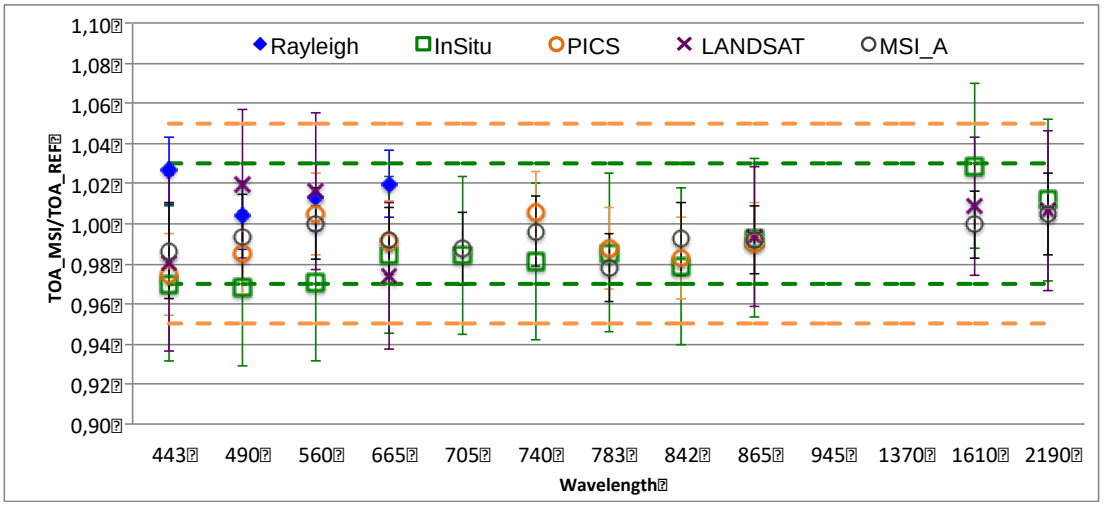

Figure 4: Comparison of radiometric accuracy for all spectral bands (except B09 & B10): ratio of S2B measurement on reference. Error bars indicate the method uncertainty.

Tabulated results for bands B01 to B12 (B09 & B10 excluded) presented below indicate the effectiveness and reliability of the on-board calibration method for both sensors S2A/MSI and S2B/MSI.

Table 2-4: Best estimate of S2A and S2B calibration gains from validation

Sensor		S2A	S2B

	Wavelength (nm)	Gain Coefficient	Standard Deviation	Gain Coefficient	Standard Deviation
B01	443	0.996	0.030	0.988	0.023
B02	490	0.999	0.022	0.994	0.020
B03	560	1.005	0.017	1.001	0.018
B04	665	0.999	0.011	0.992	0.017
B05	705	0.999	N/A	0.986	0.002
B06	740	1.001	0.013	0.994	0.012
B07	783	1.003	0.004	0.984	0.005
B08	842	0.990	0.001	0.985	0.007
B8A	865	1.000	0.001	0.992	0.002
B11	1610	1.014	0.022	1.012	0.015
B12	2190	1.006	0.017	1.008	0.004

Time series of measurements are also produced to monitor the evolution in time of the radiometric response, in particular to detect a possible degradation of the diffuser. The current assessment is compatible with the specified stability requirement for all visible and NIR bands (< 1% per year).

2.3.3 Noise

The SNR for both S2A and S2B is exceeding requirements (worst-case >160 for band B8A). The table below provides the most recent estimates (April 2020 for S2A and May 2020 for S2B).

Table 2-5: Estimated SNR performance for S2A and S2B at reference radiance.

Spectral Band	B1	B2	B3	B4	B5	B6	B7	B8	B8A	B9	B10	B11	B12
Ref. radiance [W/m²/sr/µm]	129	128	128	108	75	68	67	103	52.5	9	6	4	2
S2A	1388	210	239	222	247	215	223	216	157	219	388	158	167
S2B	1363	212	242	229	247	222	231	229	168	237	400	167	171
Requirement	129	154	168	142	117	89	105	174	72	114	50	100	100

As seen in the figure below, the noise characteristics are very stable over time.

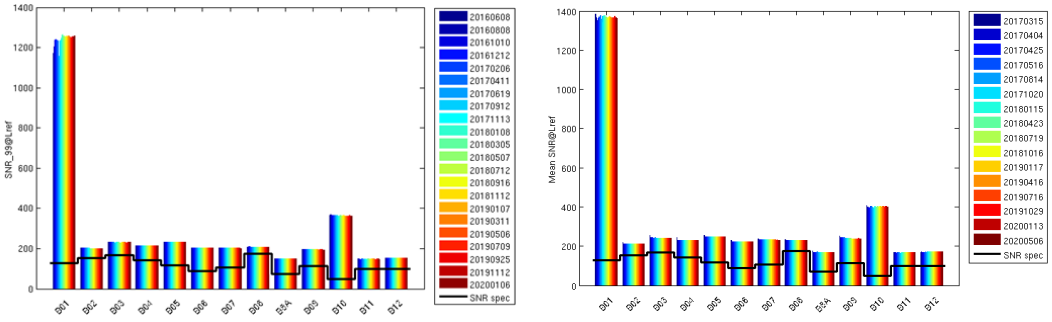

Figure 5: Evolution of the SNR performance or S2A since 08/06/2016 (left) and S2B since 15/03/2017 (right)

Another aspect of the image noise is the so-called Fixed Pattern Noise: this is the residual pixel radiometric error after equalization. The performance is better than the specification for all bands except for a few pixels on Bands B11 and B10.

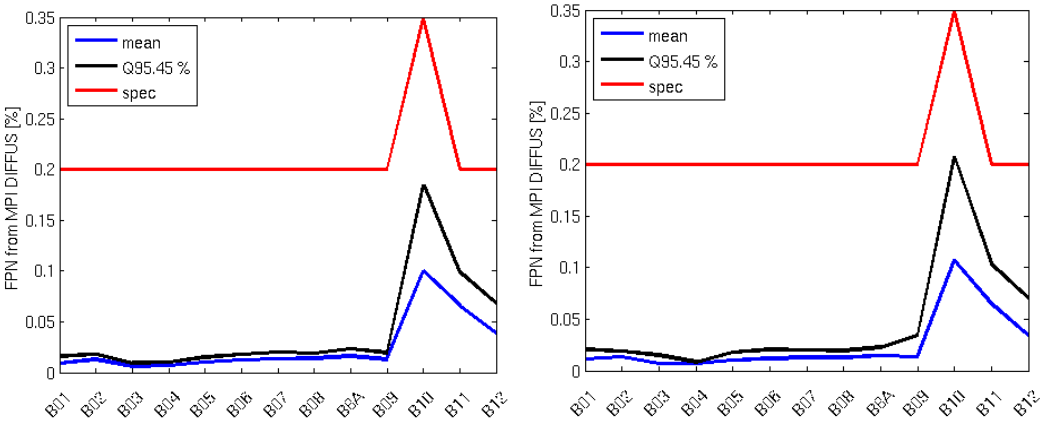

Figure 6: Fixed Pattern Noise (residual error after equalization) measured on diffuser images for S2A (left) and S2B (right). Blue curve: mean FPN, black: 95 percentile, red: specified value.

2.3.4 Modulation Transfer Function

The Modulation Transfer Function (MTF) has been estimated by analysing images with sharp edges for all bands (except B10 for which in-orbit assessment is difficult).

Globally the across track values measured in flight are lower than those expected from ground measurements. The MTF is above the maximum value requirement for B5, B6, B7 and B8A for the across track direction. For the along track direction, the requirement is generally met (marginally in some cases). Note that only the minimum value requirement has a direct impact on image quality. This requirement is satisfied for all bands.

Table 2-6: S2A MTF performance assessment.

Spectral Band	Measured ACT	Measured ALT	Requirement
B01	0.34±0.03	0.28±0.03	0.15 < MTF
B02	0.25±0.06	0.27±0.06	0.15 < MTF
B03	0.27±0.03	0.28±0.04	0.15 < MTF
B04	0.25±0.04	0.23±0.03	0.15 < MTF
B05	0.42±0.03	0.34±0.05	0.15 < MTF
B06	0.35±0.12	0.33±0.05	0.15 < MTF
B07	0.35±0.07	0.34±0.03	0.15 < MTF
B08	0.26±0.11	0.25±0.06	0.15 < MTF
B8A	0.36±0.06	0.31±0.04	0.15 < MTF
B09	0.25±0.10	0.27±0.03	0.15 < MTF
B11	0.20±0.04	0.24±0.04	0.15 < MTF
B12	0.24±0.07	0.22±0.06	0.15 < MTF

Table 2-7: S2B MTF performance assessment.

Spectral Band	Measured ACT	Measured ALT	Requirement
B01	0.35±0.02	0.30±0.02	0.15 < MTF
B02	0.31±0.13	0.27±0.06	0.15 < MTF
B03	0.33±0.11	0.23±0.06	0.15 < MTF
B04	0.31±0.10	0.22±0.05	0.15 < MTF
B05	0.39±0.03	0.31±0.02	0.15 < MTF
B06	0.36±0.03	0.29±0.00	0.15 < MTF
B07	0.36±0.03	0.30±0.01	0.15 < MTF
B08	0.24±0.06	0.22±0.04	0.15 < MTF
B8A	0.33±0.03	0.29±0.01	0.15 < MTF
B09	0.36±0.02	0.30±0.02	0.15 < MTF
B11	0.21±0.02	0.17±0.00	0.15 < MTF
B12	0.25±0.01	0.23±0.01	0.15 < MTF

3. Processing Chain Status

3.1 Product Format

On December 6th 2016, a new naming convention has been introduced (Product Specification Document version 14). The new convention leads to shorter product paths with less redundancy of information. The product name now includes the acquisition date and a "product discriminator" which is related to the acquisition date but can be different in some instances.

A reformatting of the Data Hub product archive to the single-tile, short name format is currently in progress. The JP2000 images are not affected by the reformatting.

Note that the product footprint for all products generated before July 20th 2016 include areas of No Data, while for the later product the footprint outlines valid pixels only.

3.2 Acquisitions with low illumination conditions

Since October 23rd, 2019, the acquisition plan of Sentintel-2B has been extended to include high-latitude areas with low illumination conditions (Sun Zenith Angle up to 85°), https://scihub.copernicus.eu/news/News00610. Users can identify these products through the metadata field: *Level-1C_Tile_ID>Geometric_Info > Tile_Angles>Mean_Sun_Angle.*

3.3 Off-line products

Beginning 23rd September 2019, Sentinel-2 products older than one year will not be available on-line in the Copernicus data hubs. Instead, they will be retrieved on demand from the Long-Term Archive (LTA). Products retrieved from the LTA will be different from the original ones delivered in Near Real Time production:

- ✓ The product discriminator (the second date in the product) will be different. However, the zip file provided with the delivery will keep the name of the original product.
- ✓ The product will be restored using the latest applicable format (currently compact, single tile format, PSD v14.2).
- ✓ The GENERATION_TIME field in the User Product metadata will also reflect the date of the retrieval from the LTA.

See https://scihub.copernicus.eu/userguide/LongTermArchive for more details.

3.4 Reprocessed products

Two situations can lead to a recovery reprocessing and update of the SciHub archive:

- ✓ Products affected by major anomalies tracked in the Sentinel-2 anomaly database
- ✓ Datastrips with missing L1C tiles. In this case the products are not tracked in the anomaly database.

In both cases, the original products are removed and replaced by products with a more recent generation time. However in the latter case the original products can still be considered as valid.

3.5 Status of Processing Baselines and Known Processing Anomalies

The table below summarizes recent evolutions of the processing baseline and the known processing anomalies affecting the production. The dates mentioned in the table refer to the product creation date.

Note that anomaly #37, which was duplicating #11, has been deleted.

Table 3-1: Summary of identified processing anomalies and associated processing baselines. Red: systematic anomaly. Orange: random anomaly affecting only a few products

Anomaly ID	Baseline number	02.02	02.03	02.04			02.05	02.06	02.07	02.08	02.09
	Deployment date	03/05/2016	09/06/2016	15/06/2016	03/08/2016	26/01/2017	27/04/2017	23/10/2017	06/11/2018	08/06/2019	04/02/2020
	Anomaly title										
4	Instrument Measurement Time metadata										
5	Pixels with 0 value										
7	Missing Physical Gains metadata										
15	Strong Misregistration										

Anomaly ID	Baseline number	02.02	02.03	02.04			02.05	02.06	02.07	02.08	02.09
	Deployment date	03/05/2016	09/06/2016	15/06/2016	03/08/2016	26/01/2017	27/04/2017	23/10/2017	06/11/2018	08/06/2019	04/02/2020
	Anomaly title										
19	Wrong footprint on ante-meridiem										
23	Degraded AUX files										
24	Imprecise technical quality mask										
25	Geolocation error on orbit 7174				Orbit S2A 7174						
26	Incomplete manifest										
27	Incorrect footprint and missing metadata										
29	Incorrect cloud MTD					A few products					
30	Corrupted metadata					one occurrence					

Anomaly ID	Baseline number	02.02	02.03	02.04			02.05	02.06	02.07	02.08	02.09
	Deployment date	03/05/2016	09/06/2016	15/06/2016	03/08/2016	26/01/2017	27/04/2017	23/10/2017	06/11/2018	08/06/2019	04/02/2020
	Anomaly title										
32	Missing viewing angles at ante-meridiem										
33	Missing files						A few products				
34	Missing ECMWF files						Sensing time near 9AM or 9PM				
35	Wrong quantification value						Orbit S2A 10724 to 10729				
36	Misregistration B09 and B10						Orbit S2A 11799				
38	'Null' Folder			A few products							
39	Incorrect S2A spectral response										
40	Incorrect file name							A few products			

Anomaly ID	Baseline number	02.02	02.03	02.04			02.05	02.06	02.07	02.08	02.09
	Deployment date	03/05/2016	09/06/2016	15/06/2016	03/08/2016	26/01/2017	27/04/2017	23/10/2017	06/11/2018	08/06/2019	04/02/2020
	Anomaly title										
41	Incorrect instrument temperature MTD										
42	Incorrect NODATA mask format							A few products			
44	Incorrect Cloud Cover percentage										
45	Incorrect equalization							18/07/18 to 18/07/30			
46	Missing Corners							18/07/18 to 18/08/06			
47	S2A product processed as S2B							Orbit 10722			
49	Misregistration of some S2A products								A few products		
51	Corrupted product footprint							A few products			

Anomaly ID	Baseline number	02.02	02.03	02.04			02.05	02.06	02.07	02.08	02.09
	Deployment date	03/05/2016	09/06/2016	15/06/2016	03/08/2016	26/01/2017	27/04/2017	23/10/2017	06/11/2018	08/06/2019	04/02/2020
	Anomaly title										
52	Missing AUX files								A few products		
53	Empty AUX files								A few products		
64	Spurious viewing angle metadata	A few products									
67	Platform mismatch										Orbits S2A 21551 and S2B 16603

3.6 Processing Baseline Status

3.6.1 Baseline 02.07

On 06/11/2018, a new Processing Baseline (02.07) has been deployed. This version introduces several improvements and evolutions:

- ✓ **Accurate tile sensing date**. The L1C granule metadata "tile sensing time" is now computed accurately at tile level
- ✓ **Straightening of image boundaries**. Staircase patterns on image boundaries have been smoothed out.

Figure 7: Swath boundary with the processing baseline 02.06 (Left) and new processing baseline 02.07 (Right). The coarse staircase-like boundary has been refined. More valid pixels are provided.

- ✓ **Accurate detector footprint mask**. The overlap area between detectors has been removed, which provides the exact location of the interface.

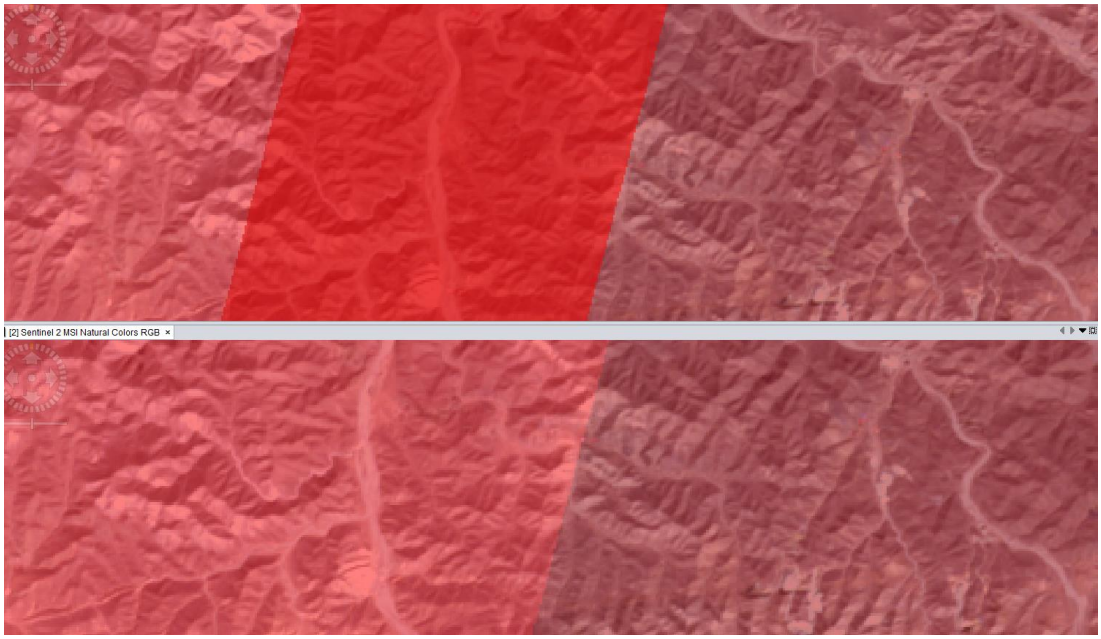

Figure 8: Detector footprints for the current processing baseline 02.06 (top) and new processing baseline 02.07 (bottom). The detector footprint does no longer include the overlap area.

- ✓ **Improved dark current processing**. This evolution removes the across-track noise that can be observed on some dark images (see paragraph 6.3 and figure below).

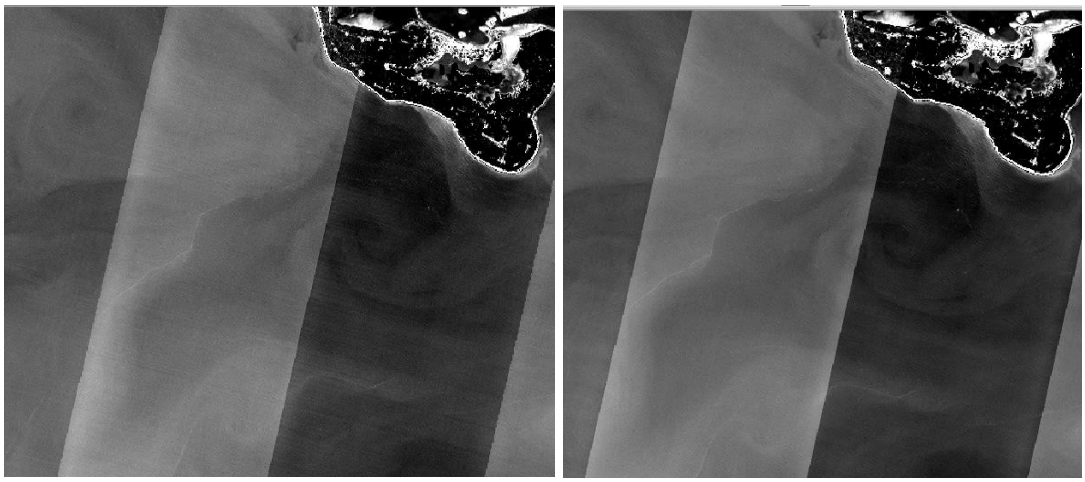

Figure 9: B01 image over sea with the current processing baseline 02.06 (Left) and the new processing baseline 02.07 (Right). Across-track lines due to correlated dark signal noise have been filtered.

Note that this evolution does not affect the product format. Products are still compliant with PSD v14.5.

Baseline 02.07 also corrects anomaly #44 affecting the cloud coverage percentage metadata.

3.6.2 Baseline 02.08

On July 8th, 2019 a new processing baseline 02.08 has been introduced. This baseline fixes anomaly #41 (incorrect temperature metadata).

3.6.3 Baseline 02.09

On 04/02/2020, a new processing baseline has been introduced, with the following evolutions:

- ✓ Correction of anomaly #52 (degenerated product footprint)
- ✓ Correction of anomaly #64 (spurious viewing angle metadata)
- ✓ Improvement of the NO DATA mask (removing pixels outside of the footprint)
- ✓ Alignment of ECMWF GRIB reference time to the tile sensing time.

3.6.4 Baseline 02.10

In the coming period, a new processing baseline will be introduced, with the following evolutions: following evolutions:

- ✓ Final fix of anomaly #24 (accuracy of technical quality mask)
- ✓ Minor improvement of the accuracy of the resampling in the L1C grid
- ✓ Improvement of cloud mask for high altitude terrain, see example Figure 10 below.

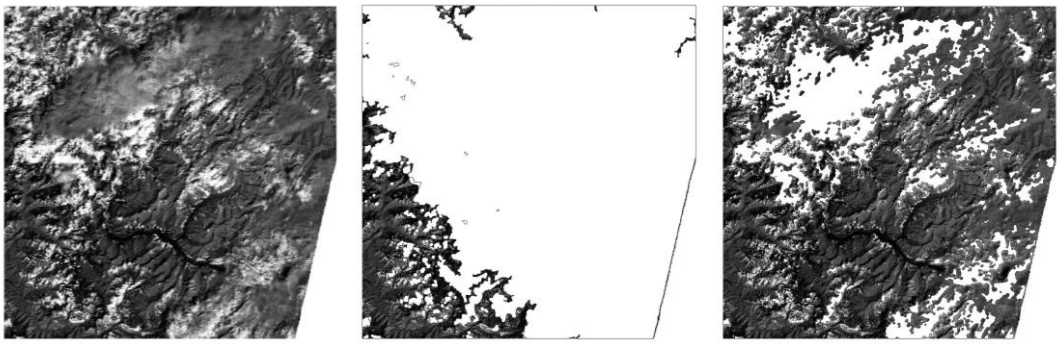

Figure 10: Evolution of the cloud mask algorithm. Left: B11 image; cloudy areas appear in white and light grey. Middle: Current Cloud mask (white) with over-detection over high-altitude terrain. Right: new cloud mask algorithm (in white).

4. Product Anomalies

4.1 Introduction

This section describes all known product anomalies. Each anomaly is tagged with a code "#N" allowing linking it to a given Processing Baseline through Table 3-1.

The table below provides the status of anomalies which are not related to processing and can therefore not be corrected through reprocessing. It complements Table 3-1 above.

Anomalies affecting obsolete products (baseline 02.00) are no longer described in this report.

The complete list of anomalies is available on-line in the Sentinel-2 anomaly database https://sentinels.copernicus.eu/web/sentinel/user-guides/sentinel-2-msi/sentinel-2-anomalies/.

Table 4-1: On-board Anomalies.

Anomaly ID	Anomaly title	Criticality	Unit	Affected products	Product status
9	Striping of SWIR bands	Minor	S2A	A few orbits, not systematic	Available
10	Striping of Visible bands	Major	S2A	A few orbits, not systematic	Removed from archive
13	B10 saturation	Minor	S2A	Products with high reflectances	Available
14	Geolocation error	Major	S2A	Orbits 3218, 4080 and 4081	Removed from archive
17	Misaligned detectors on band 1	Minor	S2A	A few orbits impacted (beginning of the datastrip)	Available
18	Geolocation Error	Major	S2A	Orbits 6003 to 6011 Orbits 16381 to 16392	Removed from archive
23	Acquisition with shutter closed	Major	S2A	Orbit 1037	To be removed
43	Geolocation error	Major	S2A	Orbits 1296 to 1304	Removed from archive
48	Geolocation error following orbit control manoeuvre	Minor	S2AB	Orbit 8366	Available

Anomaly ID	Anomaly title	Criticality	Unit	Affected products	Product status
50	CAM – missing pixels	Major	S2B	Orbits 10439-10440	Not disseminated
51	CAM – major geolocation error	Major	S2A	Orbit 19751	Removed

4.2 Instrument Measurement Time metadata (#4)

Within the satellite ancillary metadata, the value of Instrument Measurement Time (IMT) is not represented correctly due to a formatting error. This anomaly is corrected with product baseline 02.05.

4.3 Missing Physical Gains metadata (#7)

Band 12 is missing in the "physical gains" metadata of the user product. However the full list of physical gains is present in the metadata at granule level. This error was corrected early August 2016 and recent products are not anymore affected.

4.4 Striping of SWIR Bands (#9)

This anomaly is characterized by along-track stripes on some detectors of SWIR band images (see image below). Other detectors are also misaligned (along-track shift).

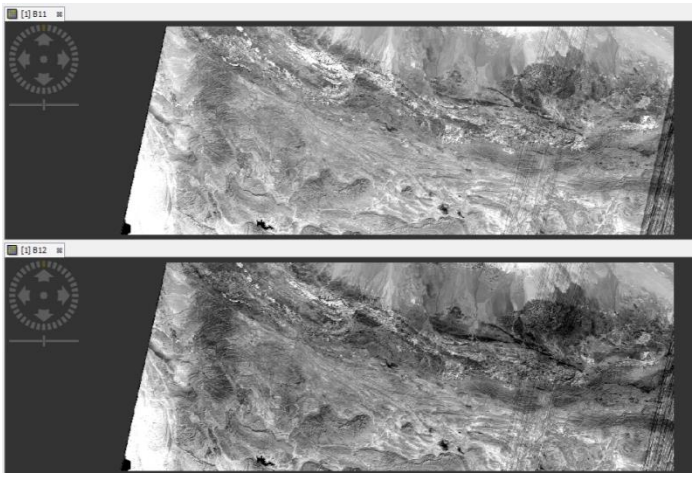

Figure 11: Striping of SWIR bands (anomaly #9). Top: B11, Bottom, B12.

This anomaly occurred during commissioning as a result of an incorrect instrument configuration. Users are advised to use only VISNIR bands for the corresponding orbits.

Table 4-2: List of orbits affected by anomaly #9.

1118	1205	1302	1404
1143	1218	1308	
1146	1227	1314	
1151	1234	1319	
1156	1244	1326	
1159	1246	1329	
1171	1251	1337	
1175	1256	1342	
1186	1261	1343	
	1272	1348	
	1274	1391	
	1298	1394	

4.5 Striping due to lost source packets (#10)

Data downlink issue sometimes lead to missing instrument source packets. This results in missing or corrupted pixels in L1C image, typically affecting only odd or even detectors and some spectral bands. The figure below presents an example of product affected by missing packets.

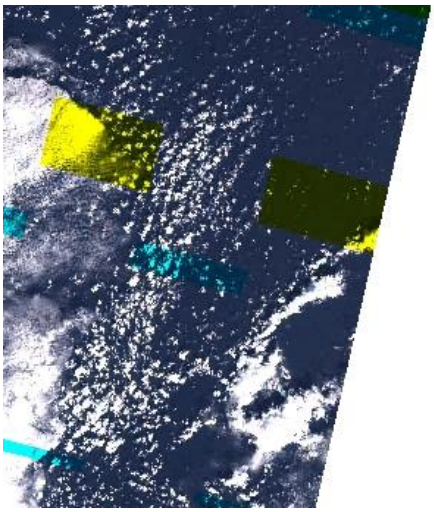

Figure 12: L1C product affected by a large number of missing packets. This type of feature is not considered as an anomaly and will not lead to removal of affected products.

Under the current quality control policy, this effect is not considered as an anomaly. Products affected by missing packets will remain in the archive.

This type of behaviour is expected and traced in the product:

- ✓ a technical quality check is performed at datastrip level and reported in the End User product metadata in case of failure;
- ✓ the number of missing packets is reported in the datastrip metadata;

- ✓ the affected area is described in the technical quality masks (TECQUA gml files).

4.6 Missing viewing angles (#11)

This anomaly affected a few products of baseline 02.01: the viewing angles (part of the granule Metadata) are missing for some spectral bands. It has been corrected on 31/03/2016.

4.7 Anomalous Pixels (#12)

This anomaly is characterized by anomalous pixel values at the boundary of a datastrip. This anomaly has been corrected with baseline 02.02.

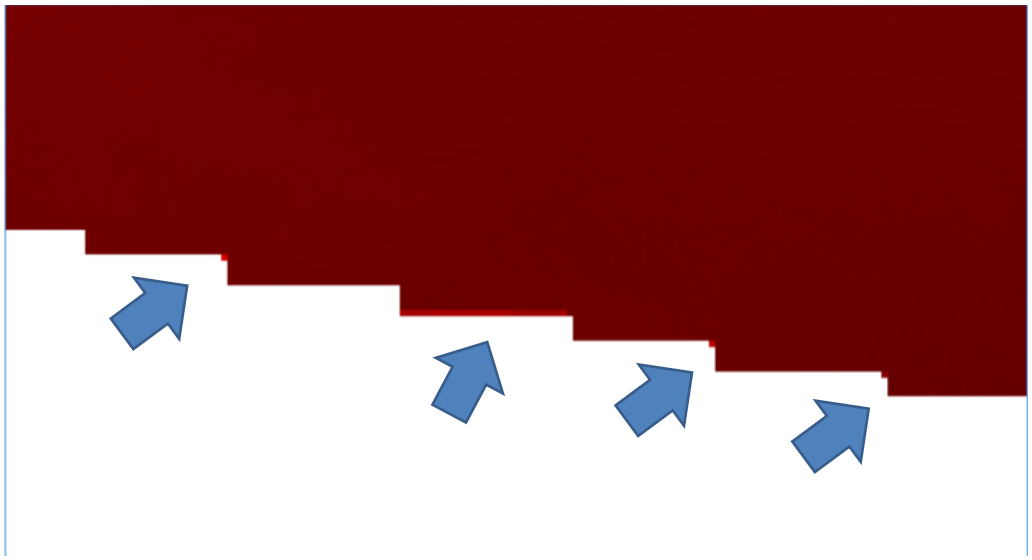

Figure 13: Anomalous pixels on band B4 (anomaly #12).

4.8 Saturation noise on Band 10 Images (#13)

This feature is characterized by noise patterns on bright images. It has now been identified as generated by saturation of the detector. This effect is not an anomaly in itself, however the saturation is currently not correctly reported in the image quality masks. A modification of the processor is in progress to solve this issue.

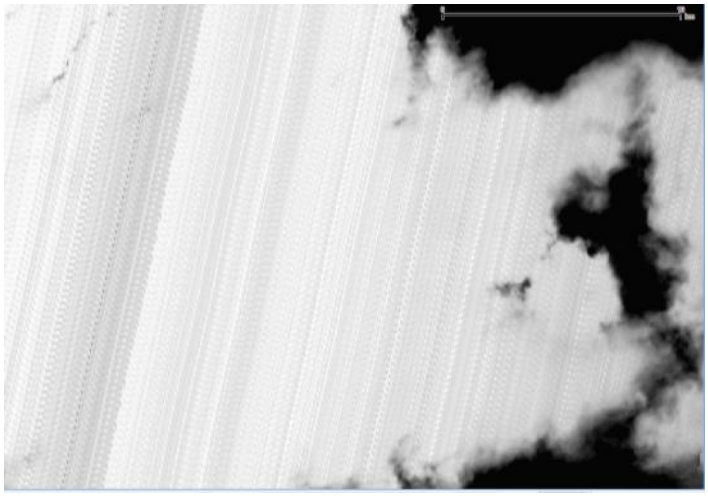

Figure 14: Along-track noise pattern on B10 images over bright clouds (#13).

4.9 Geolocation and Co-registration Error (#14)

A major anomaly has led to a strong and temporary geolocation and spectral registration errors. The anomaly occurred on February 3rd (orbit 3218) and April 3rd, 2016 (orbits 4080, 4081 and 4082). This anomaly has been correctly identified by the automatic on-line quality control and the degraded geometric performance is reported in the product metadata (geometric quality check status is "FAILED"). After identification of the anomaly, the defective products have been removed from the public archive.

The root cause of this anomaly has been identified. Missing data from attitude control telemetry is at the origin of the anomaly. An optimization of the management of the on-board telemetry has been implemented since and should avoid any re-occurrence.

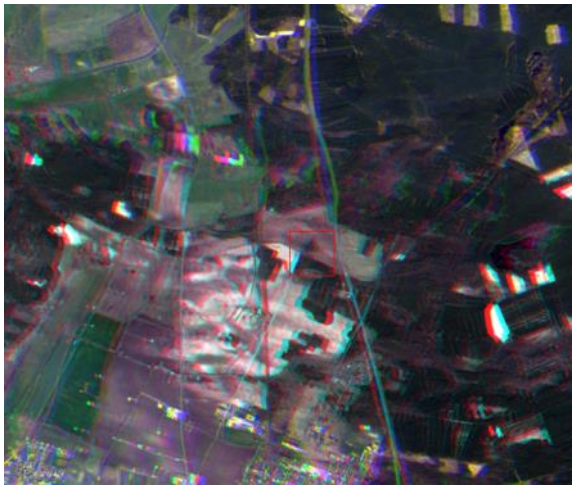

Figure 15: Spectral co-registration error (anomaly #14).

4.10 Strong Misregistration (#15)

Processing Baseline 02.03 deployed on 09/06/2016 was affected by an anomaly due to an incorrect configuration of the processing centres. This anomaly results in a strong spectral misregistration. This issue was rapidly identified, defective products have been removed from the archive and subsequently reprocessed with baseline 02.02. After correction of the configuration error, baseline 02.04 was deployed on 15/06/2016.

4.11 Stretching of 60 m Bands (#16)

This anomaly is characterized by an incorrect appearance of the 60 m bands: images are stretched across-track and discontinuities are visible between detector boundaries. A few occurrences have been observed, and none since 27/04/2016.

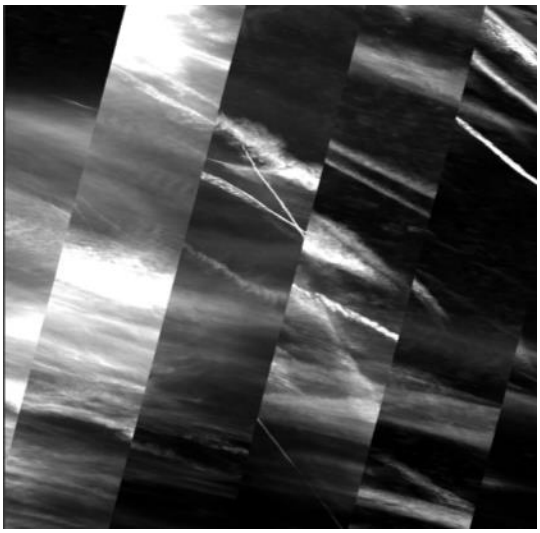

Figure 16: Stretching of 60 m bands (anomaly #16).

4.12 Misaligned detectors on band 1 (#17)

An anomaly on the receiving ground station occurred on 12th of July 2016 and led to corrupted products for a few orbits (5509 to 5525). The anomaly affects only band 1 and is limited to the first products of the datastrips (Northern part). It is characterized by a misalignment of the odd and even detectors, as illustrated in the figure below.

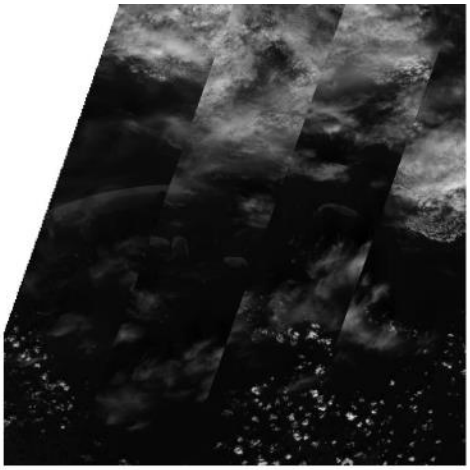

Figure 17: Detector misalignment on band B1 (anomaly #17).

A possible correction of this anomaly by an ad-hoc reprocessing is under study.

4.13 Geolocation Error (#18)

This anomaly occurred while the satellite was performing a collision avoidance manoeuvre on 16th August 2016. One Star Tracker was temporarily blinded by the Sun, which led to a degradation of the attitude estimation. As a result, the geolocation of the products acquired during this period (orbits 6003 to 6011) is affected by a variable geolocation error of up to 100 meters.

Another occurrence of the same anomaly was detected on 12/08/2018 and affects S2A orbits 16 381 to 16 392.

The anomaly is related to the handling of the redundant Star Tracker in the attitude estimation system. A realignment of the Star Trackers has been performed on 20/05/2019 to prevent any new occurrence.

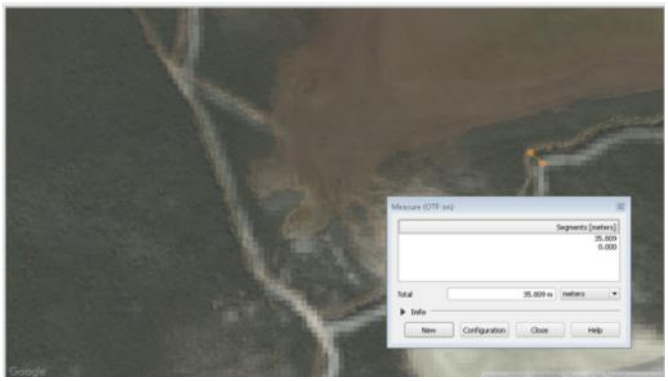

Figure 18: S2 image superimposed with reference map, showing a geolocation error of 35 m (anomaly #18).

4.14 Product footprint on the ante-meridiem (#19)

With the introduction of single tile products in October 2016, an issue has been identified in the product footprint for tiles crossing the ante-meridiem (180°

longitude). The footprint should be composed of two polygons (above -180° and below +180°). Instead, only the second polygon is present.

This anomaly has been fixed on 26/01/2017. All points are now present but in a single polygon.

4.15 Degraded AUX files (#20)

This anomaly affects the ECMWF auxiliary files, for some specific tiles. The files are truncated and contain aberrant values. This anomaly is fixed with production baseline 02.05.

4.16 Acquisition with shutter closed (#23)

On 03/09/2015 S2A orbit 1037 has been acquired with the shutter closed in order to verify the instrument straylight performance. The product was released by mistake to the public archive. The images are almost completely dark (< 5 digital counts). This orbit will be removed from the archive shortly.

4.17 Imprecise technical quality mask (#24)

Since October 2016, technical quality masks (TECQUA) are reporting instance of lost data packets (see anomaly #10). However it has been found that the masks are not perfectly accurate (see figure below). This anomaly is essentially corrected with production baseline 02.05. Some residual errors have been observed, which led to a further improvement deployed the 07/06/2018.

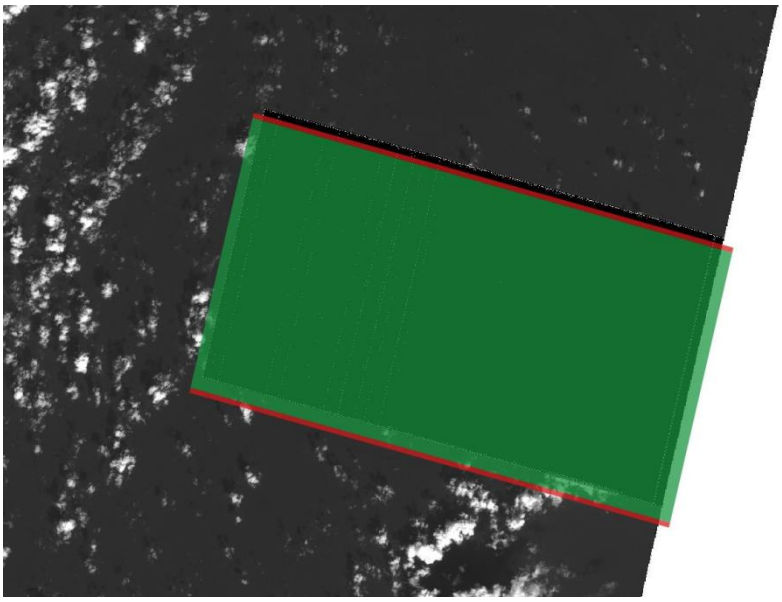

Figure 19: Technical Quality masks (green: lost packets, red: degraded packets) overlayed over an affected image. A small gap exists between the mask and the affected area (anomaly #24).

As of 03/05/2019, further correction is still needed for missing packets at the end of a datastrip (under analysis).

4.18 Geolocation error on orbit 7174 (#25)

A geolocation error of more than 100 m has been observed on the first datastrip of orbit 7174 (acquired 05/11/2016). A reprocessing is planned for this datastrip to correct this anomaly.

4.19 Incomplete manifest (#26)

In products generated before 18/05/2017, the meteorology Auxiliary files are missing from the file listing in the manifest.safe.

4.20 Inaccurate footprint and incomplete metadata (#27)

This anomaly occurred on January 20th 2017 following a change in the user product generation chain, and was solved on January 26th 2017. The anomaly affected the diffusion of products on the SciHub, and as a result few products affected by this anomaly have been disseminated. The characteristics of this anomaly are:

- ✓ Coarse precision of product footprint (1/3°)
- ✓ Missing Datastrip Identifier and granule Identifier attributes.

4.21 Incorrect cloud coverage metadata (#29)

Two products have been found affected by this anomaly. The products have very small data coverage and are completely cloudy. The cloud mask is accurate but the cloud coverage metadata is reported as zero. The affected products are 30UXB on 11/02/2017 and 50KQL on 12/04/2017.

The issue has been fixed the 07/06/2018.

4.22 Corrupted metadata (#30)

The product for tile 50SQA generated on 20/03/2017 has several metadata with an incorrect "0" value (quantification value, spectral irradiances). No other product has been found with this anomaly so far.

4.23 Missing viewing angles metadata (#32)

Viewing angles metadata (part of L1C granule metadata) are systematically missing for tiles of UTM zone 01 crossing the ante-meridiem. This anomaly is fixed with baseline 02.06.

4.24 Missing files (#33)

Some recent products have been found with one or several files missing (spectral bands or metadata files). This anomaly is now corrected for real time processing and the archive is progressively cleaned.

4.25 Missing ECMWF auxiliary files (#34)

In some products from baseline 02.06, the meteorology auxiliary files (ECMWF data) are missing in the products. The issue has been solved in February 2018.

4.26 Wrong quantification value (#35)

An incorrect calibration file has been deployed by error for S2A on 12/06/2017 and affected orbits 10724 to 10729. The quantification value is 1,000 instead of 10,000. The affected products have been reprocessed and the archive will be updated. A new occurrence was found on orbits 634, 704 and 705. The remediation is in progress.

4.27 Misregistration on bands 9 and 10 (#36)

On 25/09/2017, an anomaly at the reception station led to a severe loss of instrument source packets. As a side effect, a misregistration of bands B09 and B10 has been observed downstream of the area affected by missing packets. In view of this strong degradation, the affected orbit (S2A orbit 11 799) will be removed from the archive.

4.28 "Null" folder (#38)

A few products of baseline 02.04 have been generated with an additional empty Granule folder with a name ending with "null". As a side effect, this generates a failure with Sen2cor. This very minor anomaly can be corrected by deleting the empty folder.

4.29 Incorrect S2A Spectral Response Function (#39)

The spectral response functions provided in the metadata of the S2A products are affected by errors affecting mostly bands B01, B02 and B08. The anomaly has been corrected on January 15th 2018 (cf. https://cophub.copernicus.eu/news/News00138).

Note that this issue has negligible impact on the radiometry of the L1C reflectance products. On the other hand the conversion to radiance values and the computation of downstream products relying on the spectral response function can be impacted (such as L2A products).

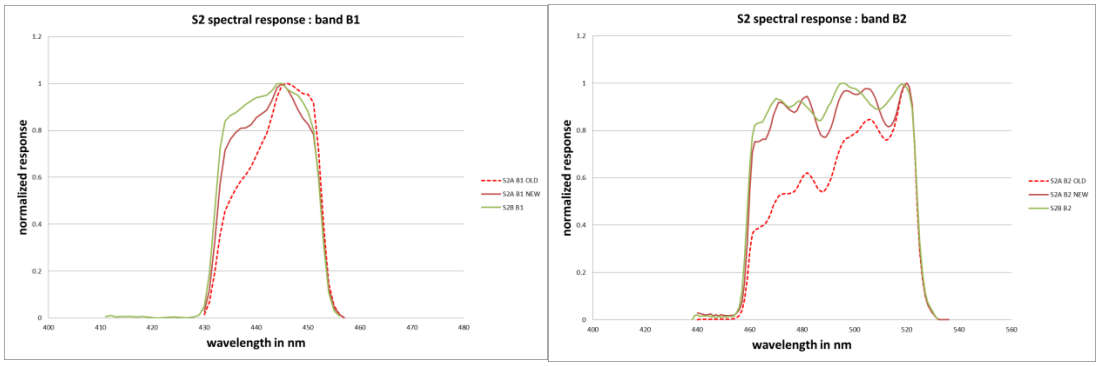

Figure 20: Spectral Response Functions for bands B01 and B02. Red – dashed: S2A before correction. Red – solid: S2A after correction. Green: S2B.

4.30 Incorrect Product Name (#40)

A few S2B products have been found with an additional number (0 or 1) at the end of the product discriminator field. This minor anomaly has been understood and correction actions are in progress to prevent re-occurrence. In the meantime the products will be removed and replaced with new ones with the correct naming.

4.31 Incorrect Instrument Temperature metadata (#41)

This anomaly affects the Instrument temperature data reported in the "expertise" section of the Datastrip metadata. The temperatures are not converted to degrees Celsius as they should be. In addition the GPS time is not correctly reported. This minor anomaly affects all products of baseline 02.06 and earlier. Remediation is in progress.

4.32 Incorrect NODATA mask format (#42)

A few products from baseline 02.06 have been generated which use a comma ',' instead of a decimal point '.' in the description of the mask polygon (NODATA and DEFECT masks). This minor error is due to an incorrect language setting which has been corrected. It does not prevent the handling of the products by such tools as SNAP, QGIS or Sen2cor. The issue has been finally solved on 24/05/2018.

4.33 Geolocation error due to GPS anomaly (#43)

Due to an anomaly on the GPS receiver of S2A in September 2015, orbits 1296 to 1304 (inclusive) were affected with a large geolocation error (up to 1000 m). Affected products have been removed from the archive.

4.34 Incorrect cloud coverage percentage (#44)

This anomaly affects the "Cloud_Coverage_Assessment" parameter reported in the user product metadata as well as the "CLOUDY_PIXEL_PERCENTAGE" of the tile metadata for products with a partial acquisition. The percentage is not correctly computed and can lead to over- or under-estimation of the percentage.

Since the Sentinel Data Hub uses this metadata to record catalogue entries, requests using filtering on cloud percentage can be affected.

On the other hand the cloud mask itself is correct.

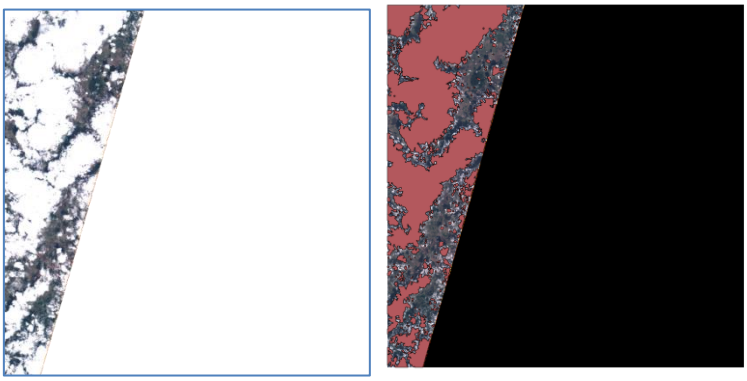

Figure 21: Tile 40UGE acquired on 12/06/2018 by S2B. Left: RGB composite, Right: cloud mask (in red). The cloud coverage percentage is incorrectly reported as 19.3% (anomaly #44).

Anomaly #44 is corrected with baseline 02.07.

4.35 Pixels with 0 value (#5)

Until product baseline 02.01, several products had valid pixels with a reflectance value of 0 (No Data) instead of 1 (minimal reflectance). This anomaly was essentially fixed with baseline 02.01. However errors induced by compression noise can still be found on very dark areas (e.g. over topographic shadows or water on SWIR bands).

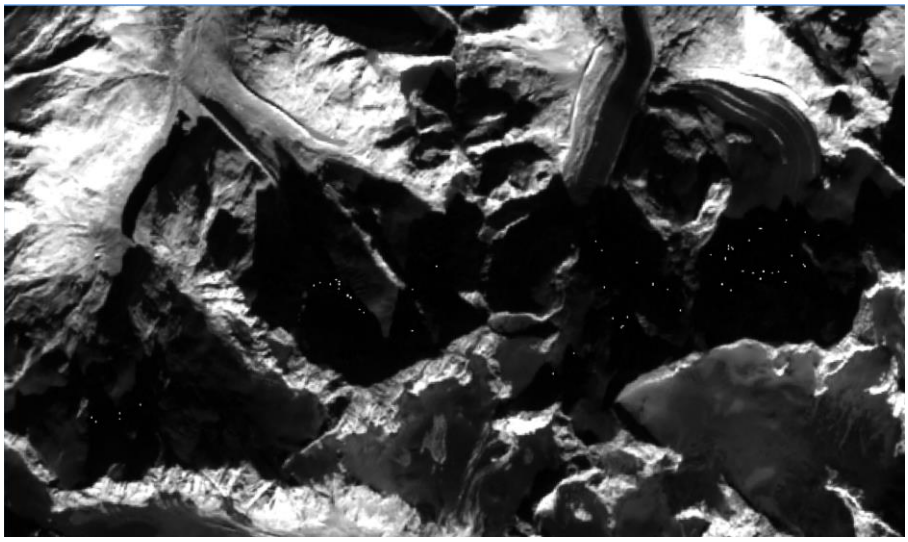

Figure 22: Pixels with 0 value (No Data) shown here as transparent, in a dark area of a B12 image (Anomaly #5).

4.36 Incorrect equalization (#45)

Since 18/07/2018, equalization issues have been observed on S2A products. The issue is especially visible on Band 10 if the contrast is enhanced. This issue also affects the cirrus cloud mask which may exhibit discrepancies between detectors. Note that the impact on the radiometry is limited to a few percent. The anomaly has been corrected on 30/07/2018.

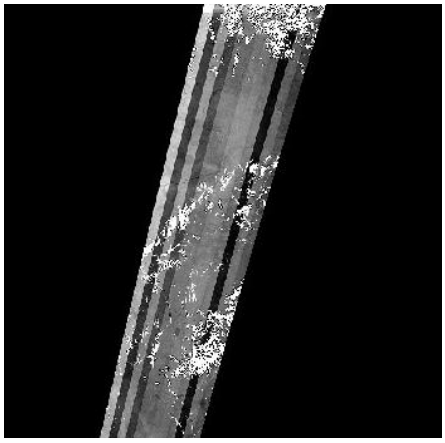

Figure 23: Incorrect equalization of B10 for S2A (anomaly #45).

4.37 Missing corners (#46)

Since 22/06/2018 an anomaly affects all L1C products. A triangular area of 50 to 100 pixels is systematically missing on the top-right and bottom-left corners of each tile. The affected area can be larger at high latitudes.

These pixels are flagged by the "No-Data" mask so no impact on downstream processing is expected.

Figure 24: Top-right corner of the image of the same L1C tile from orbit 7053 (unaffected, left) and orbit 7196 (affected, right). (Anomaly #46)

This anomaly has been fixed on 08/09/2018. Affected products are still present on the archive.

4.38 S2A products processed as S2B (#47)

On 25/09/2018, 132 products from S2A orbit 17022 have been incorrectly processed as S2B products. This induces large discrepancies on radiometric and geometric performances. This anomaly was corrected on 02/10/2018 (affected products removed and reprocessed as S2A products).

4.39 Geolocation Error after orbit control manoeuvre (#48)

On 12/10/2018 (orbit 8366) a geolocation error of up to 40 m has been observed. This error is caused by a collision avoidance manoeuvre performed during observation time. The products are available from the archive but should be used with caution. The manoeuvre planning procedures have been updated in order to avoid a repetition of this anomaly.

4.40 Misregistration of some S2A products (#49)

This anomaly occurred during 05/02/2019 and 12/02/2019. Some S2A products were affected by a variable spectral misregistration (up to 2 pixels). This anomaly has been fixed and the affected products have been reprocessed.

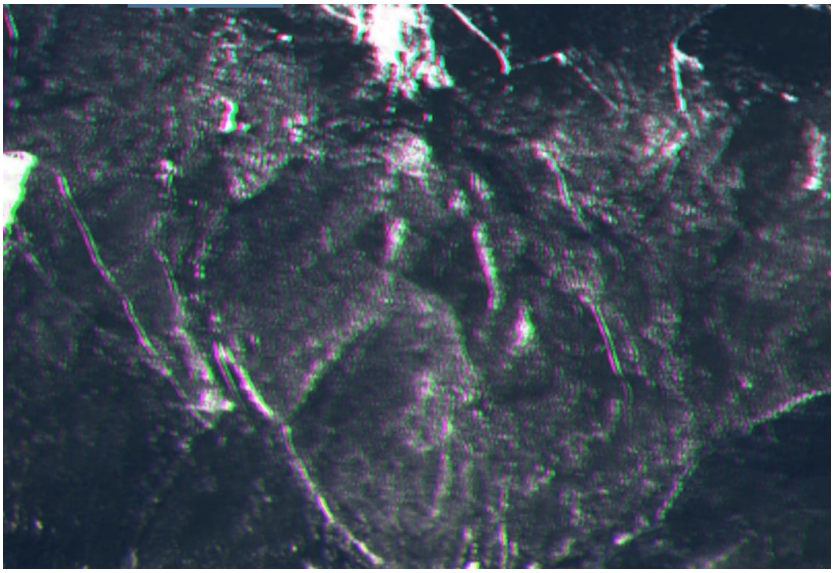

Figure 25: Spectral misregistration (anomaly #49). Affected S2A products (between 04/02/2019 and 14/02/2019) have been removed from the archive and reprocessed.

4.41 Collision Avoidance Manoeuvre: missing pixels (#50)

On 07/03/2019 S2B performed an emergency collision avoidance manoeuvre which required a slew performed during acquisition. Several orbits were lost while products from orbit 10439 and 10440 were affected by missing data at the interface between detectors. Another occurrence was reported on 31/01/2020 (S2B orbit 15170).

Affected products have been removed from the archive.

4.42 Collision Avoidance Manoeuvre: Major geolocation error (#51)

Products acquired shortly after a collision avoidance manoeuvre (S2A orbit 19751 on 04/04/2019) are affected with a geolocation error larger than 50 m. Products have been removed from the archive.

4.43 Corrupted footprint (#52)

The product footprint is reduced to a very small triangle. This anomaly occurs randomly with a very low rate. This anomaly is fixed with processing baseline 02.09.

4.44 Missing AUX ECMWF files (#53)

This anomaly is similar to #34 affecting some products of the archive. This new occurrence affected products from S2A orbit 20681, as well as S2B orbits 11772

and 11773. Affected products have been deleted from the archive and reprocessed on 01/07/2019.

4.45 Empty AUX ECMWF files (#54)

This anomaly concerned orbits S2A 20892 and S2B 11983 and 11984, which were produced with an empty ECMWF file.

Products have been deleted and reprocessed on 07/07/2019.

4.46 Spurious viewing angle metadata (#64)

In some cases, the L1C user product metadata MSIL1C_MTD.xml contain viewing angle information for detectors which are not present in the product. This minor anomaly is corrected with processing baseline 02.09

4.47 Platform mismatch (#67)

On 13/05/2020 and 14/05/2020, a few S2A products were processed as S2B. As a result, the radiometric and geometric performance of the products were severely degraded. This anomaly affected products from sensing orbit S2A 25511. Affected products have been removed from the archive and replaced with correct products on 26/05/2020.

5. Pixels Status

5.1 Defective pixels

5.1.1.1 S2A

In the following tables are listed all the identified defective pixels which are currently replaced by an interpolation of neighbouring pixels.

On 04/06/2018, a SWIR reselection operation has been performed. This operation has allowed reverting some defective status to nominal as indicated in the table below.

On 20/04/2020, a new potentially defective pixel has been identified on B11. This was not confirmed by subsequent observations, so the pixel is still considered healthy.

Table 5-1: Defective pixels on S2A

Band B10			Current status & R2DEPI defective pixels	
Band	**Detector**	**Pixel number (from 0)**	**Current status**	**Last updated**
B10	4	1104	Nominal	18/07/2018
B10	10	879	Defective	23/06/2015
B10	10	1174	Defective	23/06/2015
B11	2	1055	Monitored	20/04/2020
B12	1	440	Defective	26/08/2015
B12	1	703	Nominal	18/07/2018
B12	5	174	Nominal	18/07/2018

In addition to the defective pixels listed above, a group of pixels (570 to 600) of Band 11 D11 are affected by a non-linear radiometric response. This effect generates a darker along-track area in dark B11 images (e.g. on snow, see figure below).

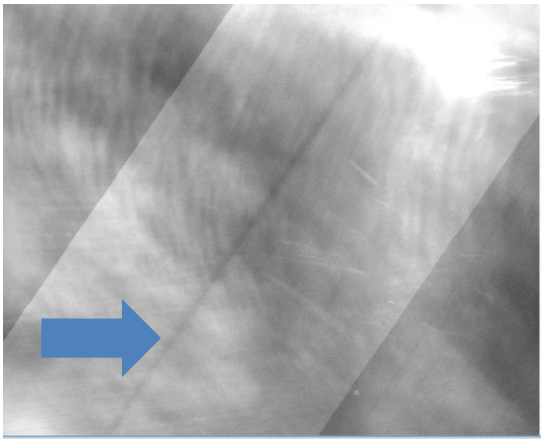

Figure 26: Along-track stripe on B11 image due to a non-linear response on D11 (contrast strongly enhanced).

5.1.1.2 S2B

Table 5-2: Defective pixels on S2B band 12.

Band B12			Current status & R2DEPI defective pixels	
Band	**Detector**	**Pixel number (from 0)**	**Current status**	**Last updated**
B12	D3	1132	Defective	30/05/2017
B12	D11	760	Defective	30/06/2018

5.2 Reset Spike pixels

During the MSI design phase, it has been identified that a few pixels of the 10 m bands are affected by an electronic cross-talk during detector read-out. This results in errors which can reach a few digital counts, depending on the observed scene.

The following tables provide the list of affected pixels.

Table 5-3: S2A Pixel affected by reset spike noise.

Band	pixel number		Current status
	Odd detector number	Even detector number	
B02, B03, B04	35	2556	Pixel Reset Noise
	489	2102	Pixel Reset Noise

Band	pixel number		Current status
	Odd detector number	Even detector number	
	781	1810	Pixel Reset Noise
	961	1630	Pixel Reset Noise
	1036	1555	Pixel Reset Noise
	1177	1414	Pixel Reset Noise
	1252	1339	Pixel Reset Noise
	1724	867	Pixel Reset Noise
	1822	769	Pixel Reset Noise
B08	35	2556	Pixel Reset Noise

Table 5-4: S2B Pixel affected by reset spike noise.

Band	Pixel number		Current status
	Odd detector number	Even detector number	
B2	618	1973	Pixel Reset Noise
	619	1972	Pixel Reset Noise
	715	1876	Pixel Reset Noise
	895	1696	Pixel Reset Noise
	1047	1544	Pixel Reset Noise
	1539	1052	Pixel Reset Noise
	1596	995	Pixel Reset Noise
	1612	979	Pixel Reset Noise
	1669	922	Pixel Reset Noise
B3,B4	187	2404	Pixel Reset Noise
	619	1972	Pixel Reset Noise
	715	1876	Pixel Reset Noise
	895	1696	Pixel Reset Noise
	1047	1544	Pixel Reset Noise
	1539	1052	Pixel Reset Noise
	1596	995	Pixel Reset Noise

Band	Pixel number		Current status
	Odd detector number	Even detector number	
	1612	979	Pixel Reset Noise
	1669	922	Pixel Reset Noise
B5	1243	52	Pixel Reset Noise
B7	1273	22	Pixel Reset Noise
B8	87	2504	Pixel Reset Noise

6. Product Features

6.1 Spectral Response Non-uniformity

In this section we report on a known feature of Sentinel 2 products created by the spectral response non-uniformity. This feature has been anticipated since the design phase and is compliant with mission specification.

This feature is characterized by along-track soft-edged darker or brighter stripes near the detector boundaries, as shown on the figure below. Indeed, the spectral response is slightly different at the edges of the detectors, especially for bands B03 and B05. When the spectrum of the scene has strong gradient over the spectral bandwidth of the detector, a difference in the measured radiometry can be observed (up to 2% in worst-cases).

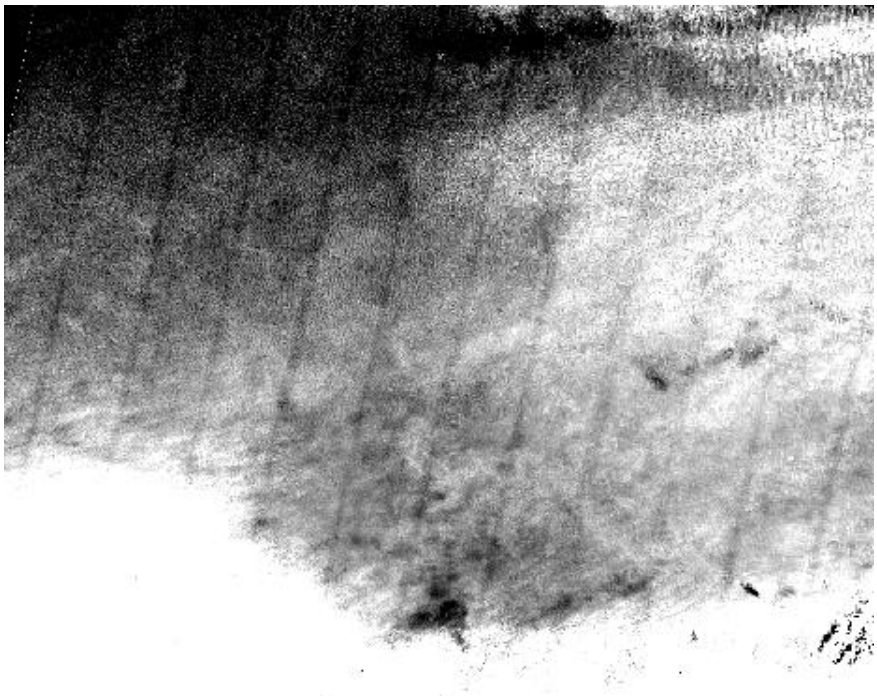

Figure 27: Along-track stripes resulting from spectral response non-uniformity (band B03).

6.2 Parallax effects

In this section we report on parallax effects created by the staggered configuration of the focal plane. Indeed the instrument swath is covered by 12 individual detectors assembled in a staggered manner. Because of this configuration, odd and even detectors do not see the ground under the same viewing angles. This can create visible effects on some images, as detailed in the next subsections.

6.2.1 Surface reflectance effects

Because the viewing angles are not the same for even and odd detectors, differences in measured radiometry can be observed on non-Lambertian surfaces. This is especially visible on Sun glint over sea surfaces (see Figure below).

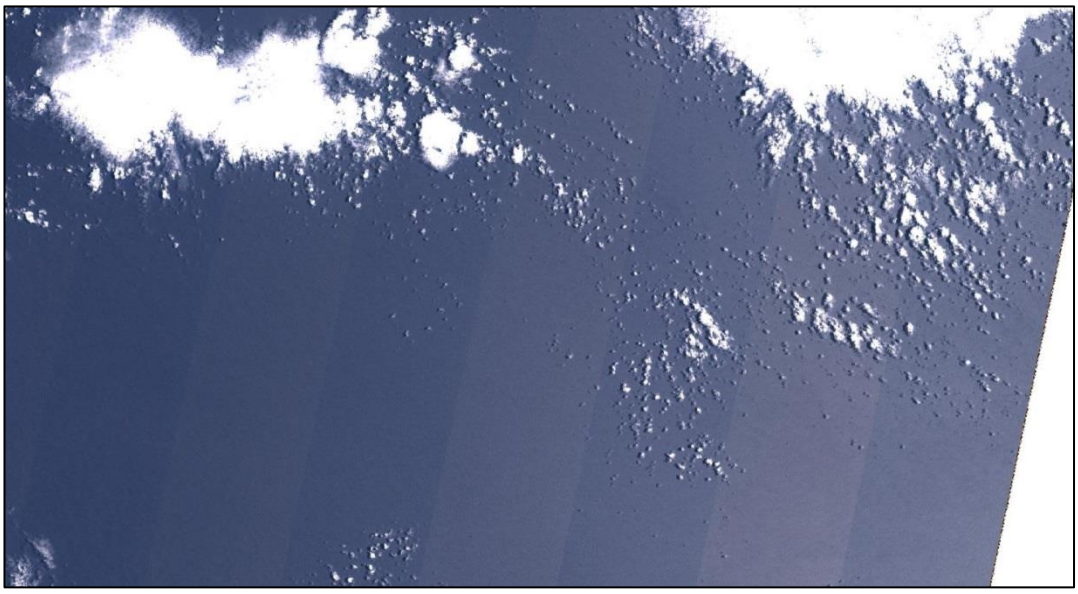

Figure 28: Stripe pattern over sea surface, due to the observation parallax effect between odd and even detectors.

6.2.2 Misregistration of High Altitude Objects

The processing algorithm ensures the co-registration of images acquired by all spectral bands and the detectors for features at ground level. Objects at a higher altitude like planes and clouds cannot be properly co-registered. As already reported in the first issue of the Data Quality Report, this effect leads to spectral misregistration ("rainbow" effect) and discontinuities between detectors.

Both effects can be seen in Figure 29 hereafter.

Figure 29: Spectral misregistration and detector misalignment for object at high altitude (plane and contrail). This feature is not an anomaly.

6.3 Gradient cross-talk

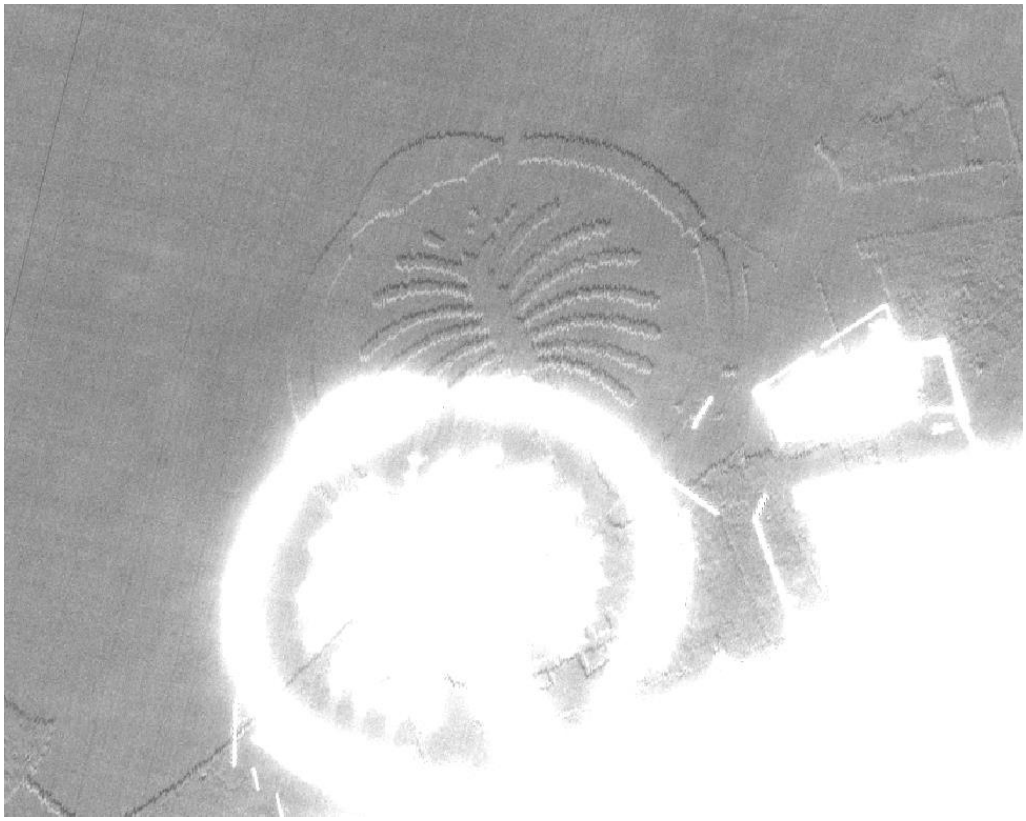

Figure 30: Gradient cross-talk on band B12 (highly enhanced contrast).

This feature can be seen on contrasted images on band B12 (typically near the coast). It can be explained by a cross-talk signal coming from the along-track

gradient of the B11 image. The typical amplitude of the effect is 10 digital counts.

6.4 Data-strip overlap

Sentinel-2 products are generated by a network of several ground stations around the globe. Data acquired by the satellites are split into processing units called "data-strips" which are processed independently, and subsequently transferred to the Sentinel Data Hub. A given continuous acquisition sequence (or "data-take") can be split into several data-strips. In that case, two different products are generated for level 1C tiles located at the interface between the data-strips. Images from the two products can be merged seamlessly.

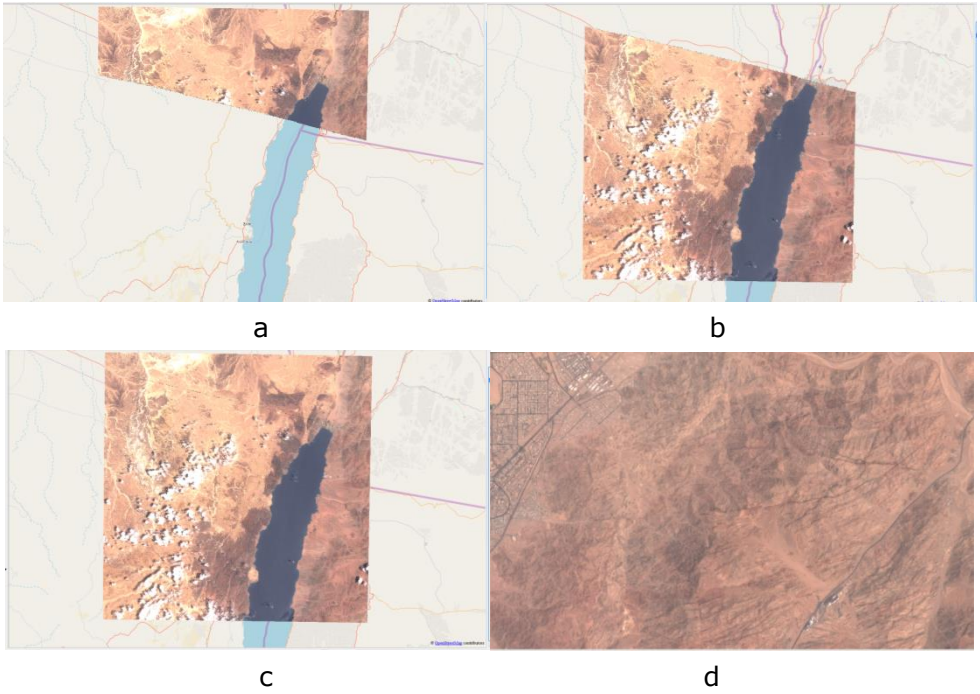

Figure 31: Example of a pair of products at the overlap between two data-strips. a: product from the first data-strip, processed at Svalbard (SGS) b: product from the second data-strip, processed at Matera (MTI). c: the two products overlap seamlessly to reconstruct the complete acquisition. d: close-up near the transition line.

6.5 Valid pixels

Users are advised that the pixel validity status may be different for different spectral bands: it is possible to have one band with valid data and one band with No Data (0) at the same location. This happens in particular at the western and eastern edges of the swath. Any multi-spectral processing should be done only on pixels having valid data for all spectral bands.

End of document