Reference: S2-PDGS-MPC-DQR
Issue: 29
Date: 05/07/2018

S2 MPC

L1C Data Quality Report

Ref. S2-PDGS-MPC-DQR

Authors Table

	Name	Company	Responsibility	Date	Signature
Written by	S. Clerc & MPC Team	ARGANS	Technical Manager	05/07/2018	
Verified by	O. Devignot	CS	Quality Manager	05/07/2018	
Approved by	L. Pessiot	CS	Service Manager	05/07/2018	

Table of contents

1. Introduction

1.1 Scope of the document

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

It documents measured product performance vs. specifications, observed anomalies and known issues, the list of defective pixels, processing chain improvements associated to each Processing Baseline, and an outlook on product evolution.

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.

1.2 Main points for this month

- ✓ Up-coming evolution of L1C products (3.6)
- ✓ Anomaly on cloud cover percentage metadata (4.33)
- ✓ New product feature description: data-strip overlap (6.5)

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~~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 has been 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.

An update of the geometric calibration is planned in the coming weeks to avoid reoccurrence of anomaly #18 on S2A. The latter anomaly originated by an imperfect alignment of the back-up Star Tracker (STR3).

2.2.1.2 S2B

A new geometric calibration has been implemented on 26/04/2018 to cope with the evolution of the pointing biases. The calibration improves the S2B geolocation performance.

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 requirement (< 0.3 pixel at 95%). The refinement step will be activated upon completion of the GRI and the final validation of the refining algorithm. At that point the processing baseline will be updated (major version change) and the archive will be reprocessed.

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 elaboration of the GRI is currently on-going. Continental sub-blocks are first built, processed and validated individually. In a second step, the sub-blocks (Europe, Africa and Asia on one hand, North and South America on the other hand) will be consolidated to improve the consistency at the boundary of the sub-blocks. The elaboration status is presented in the table below:

GRI sub-block	Status
Europe	Ready and Validated
North-Africa/Middle-East	Ready and Validated
Australia	Ready and Validated
South-Africa	Ready and Validated
North-America	Ready and Validated
South-America	Ready and Validated
Asia	Ready and Validated
Islands	To be validated
Canada – Greenland	In progress

2.2.3 Absolute Geolocation

Absolute geolocation is constantly monitored for S2A and S2B.

For S2A, the latest performance estimation (based on 430 products since June 2017) is close to 12 m at 95%. To regain the long-term performance of 11 m, an update of the geometric calibration is planned in the coming months.

The performance for S2B reported below shows the improvement carried out with the calibration of April 2018.

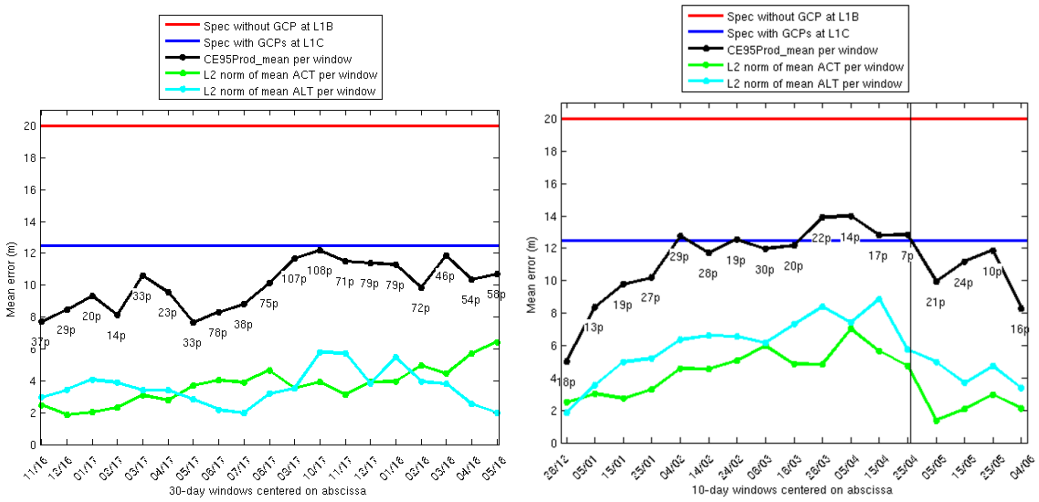


Figure 1: Geolocation performance for S2A (left) and S2B (right). The performance is computed over a sliding window of 30 (resp. 10) days. Number of products used in the sliding window indicated for each point. (ACT= across track, ALT = along track). A vertical line indicates a geometric calibration event.

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.

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.

S2A			
Bsec/Bref	B04	B05	B11
B02	0.168		
B03	0.209		
B06		0.139	
B07		0.152	
B08	0.165		
B8A		0.157	
B11		0.185	
B12		0.166	0.203

S2B			
Bsec/Bref	B04	B05	B11
B02	0.130		
B03	0.115		
B06		0.071	
B07		0.097	
B08	0.181		
B8A		0.176	
B09			
B11		0.163	
B12		0.149	0.150

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.

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 value for all tiles 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 3 present the observed statistical distribution of the observed multi-temporal registration performance for S2A and S2B products (separately and with respect to each other).

It is recalled that the objective is to meet the required 3 m performance (95.5% confidence level) with the activation of the geometric refinement using the GRI.

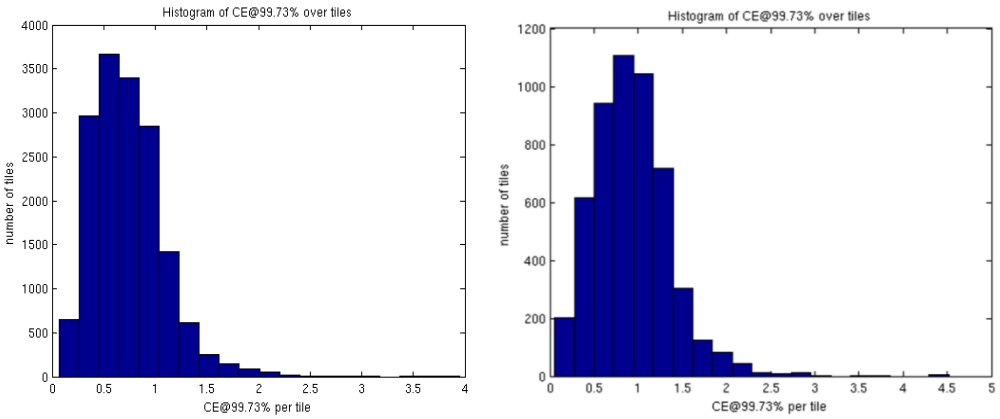


Figure 2: Histogram of the multi-temporal performance for S2A (left) and S2B (right, different scale). The 3 m requirement will be applicable only after activation of the geometrical refinement.
The current performance is 11 m (S2A) and 13 m (S2B) at 95% confidence.

Co-registration error	0<X<0.5 pixels	0.5<X<1 pixels	1<X<1.5 pixels	>1.5 pixels
S2A % of products	60%	32%	7%	1%
S2B % of products	42%	44%	13%	1%
S2A/A2B % of products*	58%	22%	18%	2%

Table 2-3: Multi-temporal performance statistics for Sentinel 2 constellation. *The performance for the S2A versus S2B is computed on a small sample.

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 every 6 months (January and July).

A decontamination was successfully performed on 04/02/2018. The post-decontamination calibration was effective on January 8th 2018. In the meantime, a variation of the order of a few % of the radiometry could be expected for SWIR bands.

As mentioned in previous editions of the DQR, an anomaly was identified on the spectral response functions of S2A, affecting mostly bands B01, B02 and B08. This anomaly was corrected on January 15th 2018 (cf. https://cophub.copernicus.eu/news/News00138) in the product metadata.

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).

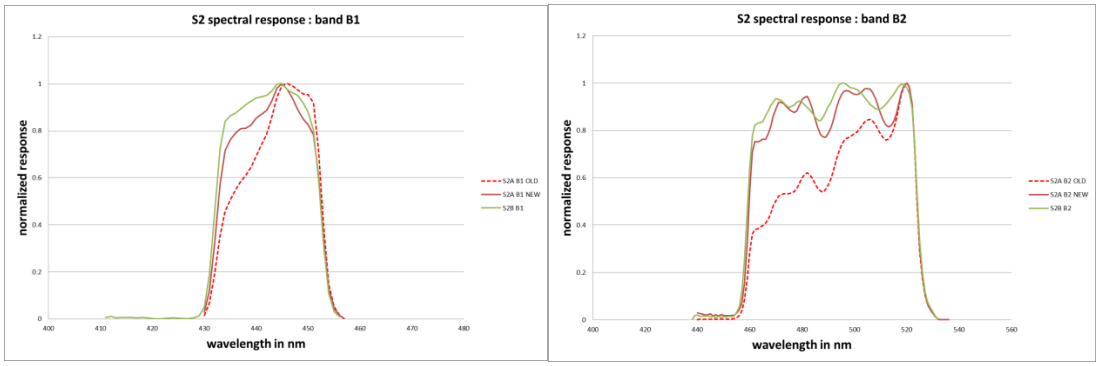


Figure 3: Spectral Response Functions for bands B01 and B02. Red – dashed: S2A before correction. Red – solid: S2A after correction. Green: S2B.

2.3.1.3 S2B

Radiometric calibration is currently performed once per month.

The S2B MSI underwent decontamination on May 27th, 2018. The calibration gains were subsequently adjusted on May 29h. In the interval, the radiometric accuracy of SWIR bands may be affected.

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 and S2A for S2B case).

The results are presented in the figures below for S2A for all methods and for S2B (except in-situ only). Results over S2A are provided for all bands, except B10 (water vapour absorption band) for which direct validation is not possible, while results over S2B are provided for all bands except B09 & B10. All results are compatible with the 5% (3%) radiometric accuracy requirement (Goal) respectively. Results for band B05 and B09 (705 and 945 nm in the figure below) are less reliable because of the significant impact of gaseous absorption (0_2 and water vapour).

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.

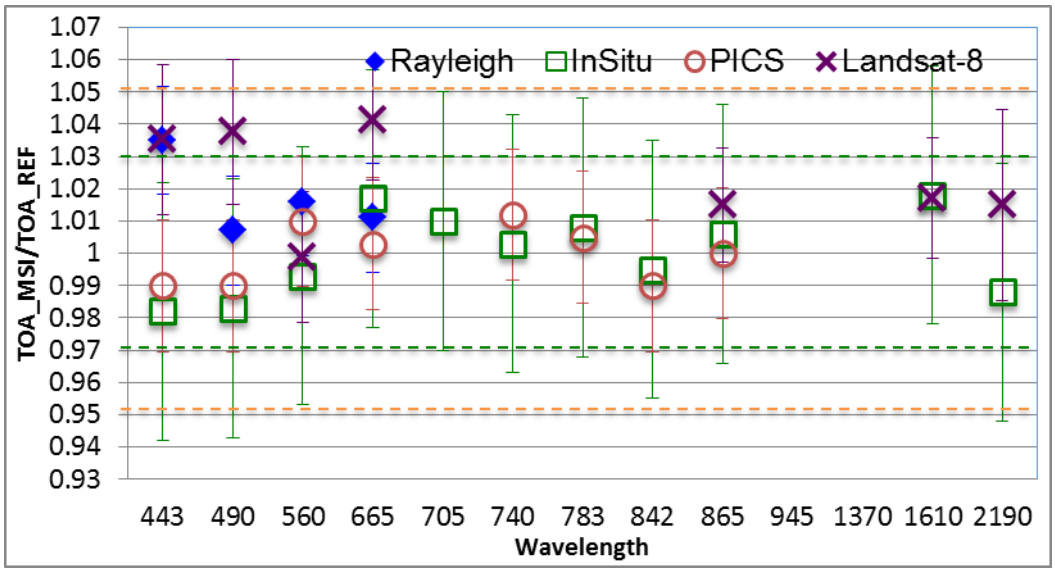


Figure 4: Comparison of radiometric accuracy for all spectral bands (except B10 and B09): ratio of S2A measurement on reference. Error bars indicate the method uncertainty.

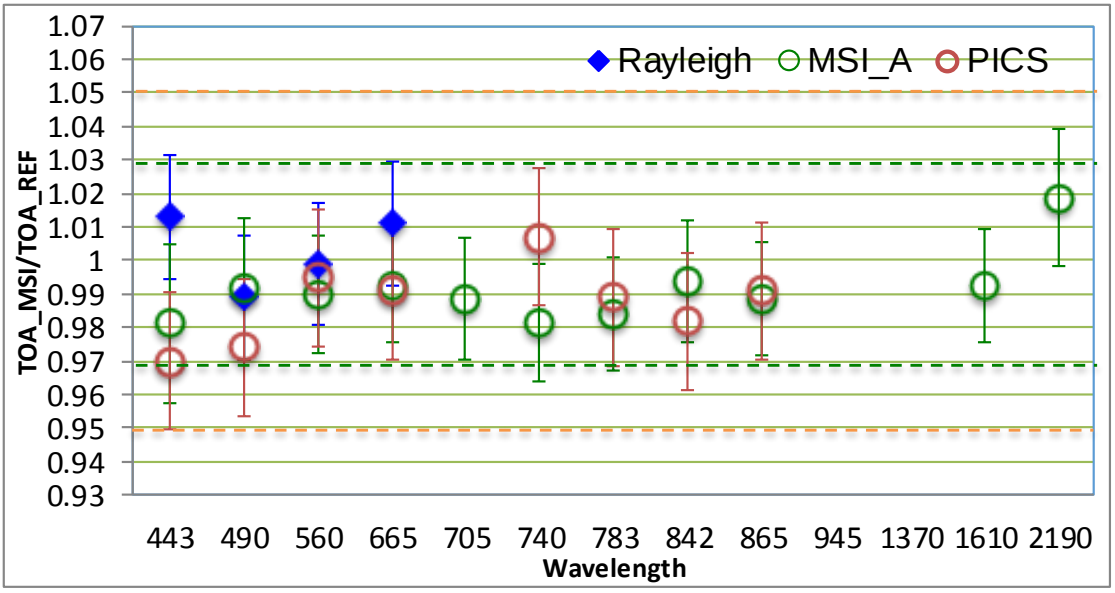


Figure 5: Comparison of radiometric accuracy for all spectral bands (except B09 & B10): ratio of S2B measurement on reference. Error bars indicate the method uncertainty.

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	**1.02**	**0.03**	**0.99**	**0.02**
B02	490	**1.01**	0.03	0.99	0.01
B03	560	**1.01**	0.01	1.00	0.01
B04	665	**1.02**	0.02	1.00	0.02
B05	705	**1.02**	NA	0.99	NA
B06	740	**1.01**	0.00	0.99	0.01
B07	783	**1.01**	0.01	0.99	0.00
B08	842	**0.99**	0.01	0.99	0.02
B8A	865	**1.01**	0.01	0.99	0.00
B11	1610	**1.02**	0.00	0.99	NA

Sensor		S2A		S2B	
	Wavelength (nm)	Gain Coefficient	Standard Deviation	Gain Coefficient	Standard Deviation
B12	2190	**1.01**	0.01	1.02	NA

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), and no-trend is detectable yet for S2B.

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 (August 2017 for S2A and September 2017 for S2B).

Table 2-5: Estimated SNR performance for S2A and S2Bat 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	74.5	68	67	103	52.5	9	6	4	1.5
S2A	1347	211	239	222	246	215	224	216	157	222	391	159	167
S2B	1371	213	242	230	248	223	232	230	169	239	396	166	172
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.

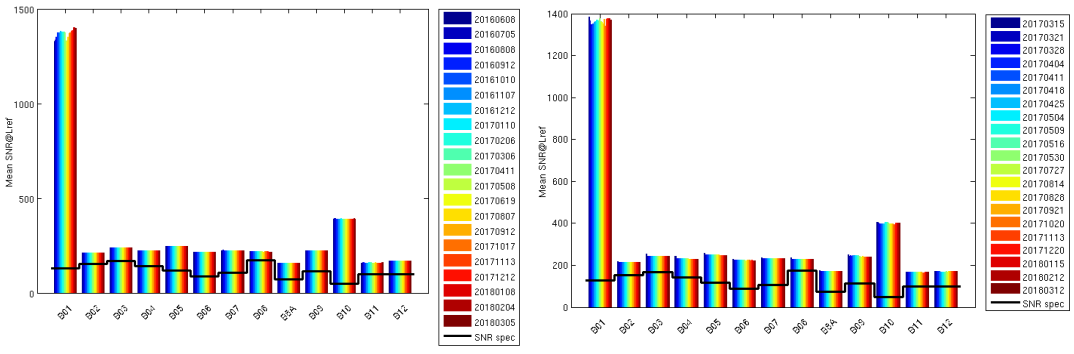


Figure 6: Evolution of the SNR performance or S2A since 08/06/2016 (left) and S2B since 15/03/2017 (right)

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.

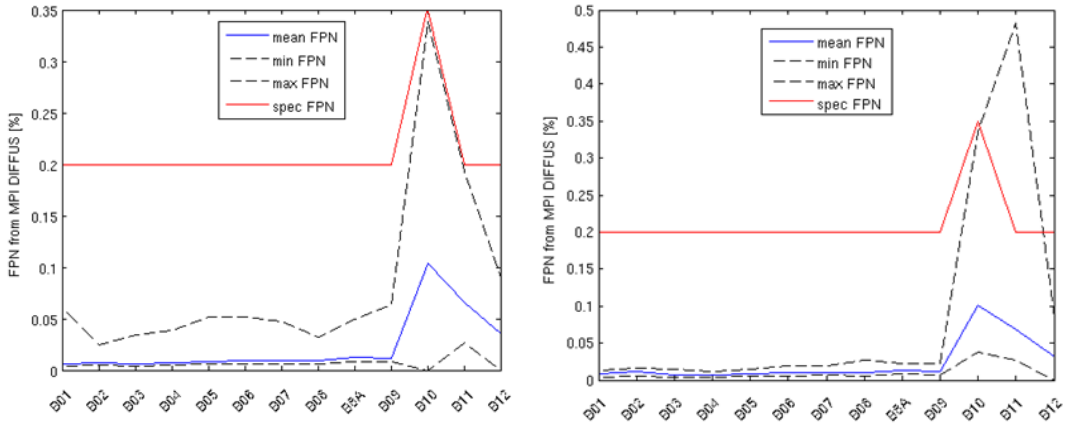


Figure 7: Fixed Pattern Noise (residual error after equalization) measured on diffuser images for S2A (left) and S2B (right). Blue curve: mean FPN, red: maximum specified value. Dashed: best- and worst-case pixels.

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, see Table 2-6~~Table 2-6~~ and Table 2-7~~Table 2-7~~, 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

Spectral Band	Measured ACT	Measured ALT	Requirement
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.

On 23/10/2017 a new processing baseline (02.06) and a new product format (PSD version 14.2, minor changes only) have been introduced.

3.2 Status of Processing Baselines and Known Processing Anomalies

The table below summarizes recent evolutions of the 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.

A new version of the L1C processing chain has been deployed on 06/06/2018 (still with processing baseline 02.06). This version:

corrects anomaly #29 (see Table 3-1~~Table 3-1~~),

- improves the accuracy of the TECQA quality mask,
- improves the quality of the Preview image (PVI).

Another processing baseline will be introduced in the coming month, see section 3.6.

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	02.01		02.02	02.03	02.04			02.05	02.06
	Deployment date	15/12/2015	31/03/2016	03/05/2016	09/06/2016	15/06/2016	03/08/2016	26/01/2017	27/04/2017	23/10/2017
	Anomaly title									
4	Instrument Measurement Time metadata									
7	Missing Physical Gains metadata									
12	Anomalous Pixels	At end of datastrips								
15	Strong Misregistration									
16	Stretched 60 m bands		Orbit S2A 4427							
19	Wrong footprint on antemeridiem									
23	Degraded AUX files									

Anomaly ID	Baseline number	02.01		02.02	02.03	02.04			02.05	02.06
	Deployment date	15/12/2015	31/03/2016	03/05/2016	09/06/2016	15/06/2016	03/08/2016	26/01/2017	27/04/2017	23/10/2017
	Anomaly title									
24	Imprecise technical quality mask									
25	Geolocation error on orbit 7174						Orbit S2A 7174			
26	Incomplete manifest		Until 18/05/2017							
27	Incorrect footprint and missing metadata									
29	Incorrect cloud MTD							A few products		
30	Corrupted metadata							Orbit S2A 9095 Tile 50SQA 20/03/2017		
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	
37	Missing viewing angles	Some products								
38	'Null' Folder					A few products				
39	Incorrect S2A spectral response	Until January 15th 2018								
40	Incorrect file name									A few products

Anomaly ID	Baseline number	02.01		02.02	02.03	02.04			02.05	02.06
	Deployment date	15/12/2015	31/03/2016	03/05/2016	09/06/2016	15/06/2016	03/08/2016	26/01/2017	27/04/2017	23/10/2017
	Anomaly title									
41	Incorrect instrument temperature metadata									
42	Incorrect NODATA mask format									A few products
44	Incorrect Cloud Cover percentage	Partially acquired tiles only								

3.3 Archive Reprocessing

A reprocessing campaign of images acquired during the commissioning period (from launch till 30/11/2015) has been completed. Another reprocessing has been started on products with baseline 02.00, originally affected with a wrong tile numbering. The new products will be created with baseline 02.04, multi-tile format.

The following products from the reprocessing campaign are defective:

- ✓ Products from orbits 1296 to 1304 processed on October 2016 (large geolocation error due to a GPS anomaly, see anomaly #43)
- ✓ Orbits 2148, 2154, 2159, 2171, 2195, 2204, 2216, 2220, 2225 (large geolocation error: these orbits have been reprocessed and the archive will be updated
- ✓ Orbit 1147 (too dark): this orbit has been removed from the archive

Finally a minor anomaly affects some products from September 2015 (see anomaly #9 in the next chapter). SWIR bands are strongly degraded. However VISNIR bands are meeting quality standards, so these products will remain available in the future.

3.4 Level 2A production

Since 26/03/2018, Level 2A products are produced systematically over Europe and distributed in the Sentinel Data Hub (product type "MSIL2A"). A dedicated Data Quality Report is available for these products.

3.5 Archive reformatting

Since May 22 2018, a reformatting campaign has been launched to homogenize the product format (single-tile, short naming convention). The reformatting will be performed on monthly batches, starting from December 2016 and progressing backward in time toward mission start.

Old products will be kept online for a short time then permanently removed.

The content of the products (images and metadata) are unchanged.

For further information, see:

https://cophub.copernicus.eu/news/News00191

and

https://cophub.copernicus.eu/news/News00195

3.6 Product evolution (baseline 02.07)

In the course of July, a new Production Baseline (02.07) will be deployed. This version will introduce several improvements and evolutions:

- ✓ **Accurate tile sensing date**. The L1C granule metadata contains a "tile sensing time" field which is currently filled with a "stub" value (datatake sensing time). The planned evolution will provide an accurate tile sensing time based on the average sensing time of all acquired pixels for the reference band.

- ✓ **Straightening of image boundaries**. Currently the border of images shows a staircase pattern with a step size of 45 meter approximately. The planned evolution will provide a straight boundary.
- ✓ **Accurate detector footprint mask**. Currently the mask provides the entire detector footprint, including the overlap area between detectors. After the evolution, the detector footprint will provide the actual interface between detectors as used on L1C images, accurate to one pixel. This mask will in particular enable to compute the viewing directions for each pixel. A specific SNAP plug-in will be distributed for this purpose.
- ✓ **Saturation handling**. This evolution will correct anomaly #13 thanks to an effective saturation level taking into account the characteristics of the instrument radiometric response.
- ✓ **Improved dark current processing**. This evolution will remove the across-track noise that can be observed on some dark images (see paragraph 6.3).

An evolution of the cloud mask algorithm is also under study and will be deployed later.

Note that this evolution will not affect the product format. Products will remain compliant with PSD v14.5.

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~~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~~Table 3-1~~ above.

On 26/03/2018, a large data loss occurred during downlink of orbit S2B 5499. Several products from this orbit over South America were strongly affected and it was decided to remove these products from the archive. Note all affected products are correctly flagged by quality masks and metadata.

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

Table 4-1: Anomalies not related to processing.

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	Minor	S2A	Orbits 6003 to 6011	Available
43	Geolocation error	Major	S2A	Orbits 1294 to 1306	Removed from archive

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).

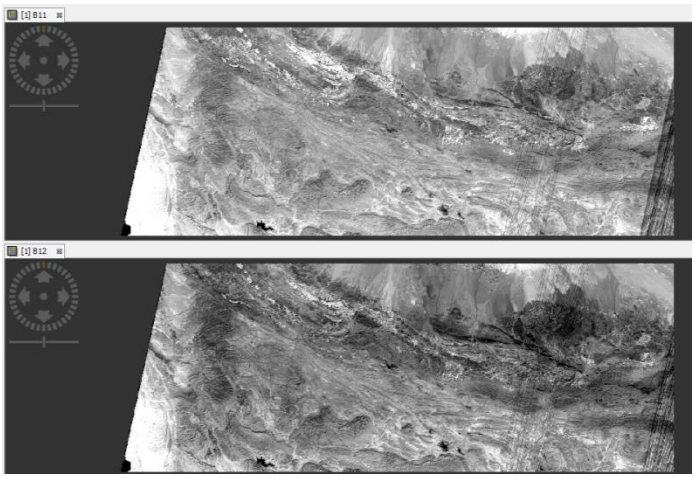


Figure 8: Striping of SWIR bands (anomaly #9). Top: B11, Bottom, B12.

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.

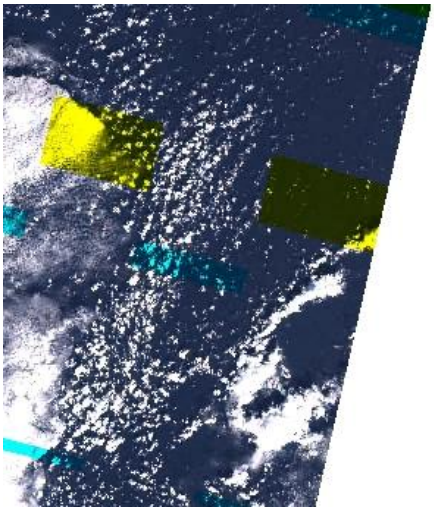


Figure 9: L1C product affected by a large number of missing packets. This type of feature is not considered as an anomaly and will not lead to removal of affected products.

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 (TECQA gml files).

4.6 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.

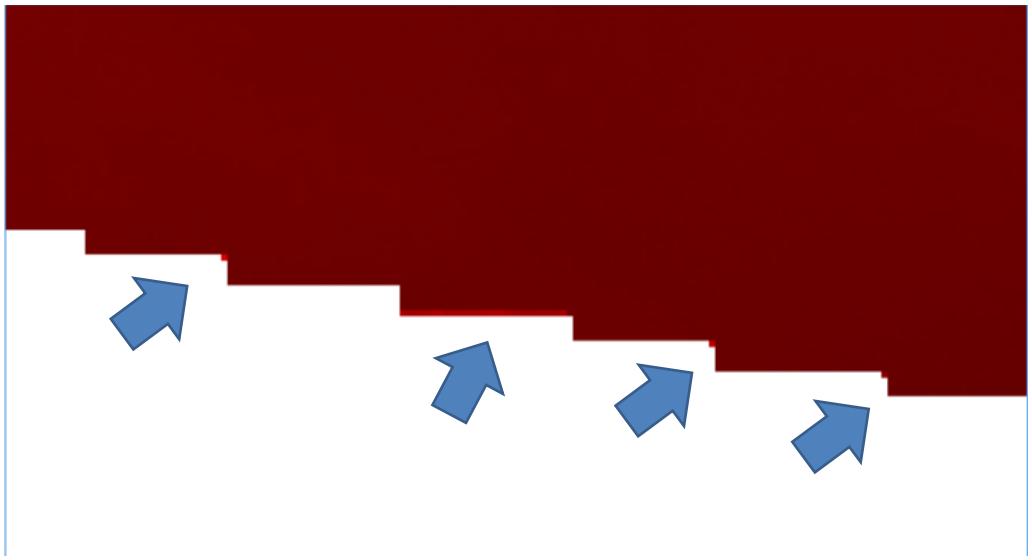


Figure 10: Anomalous pixels on band B4 (anomaly #12).

4.7 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.

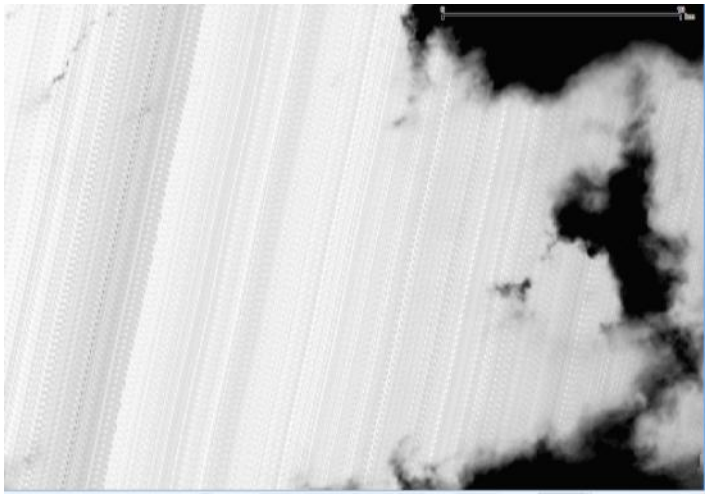


Figure 11: Along-track noise pattern on B10 images over bright clouds (#13).

4.8 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 3rd of April 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.

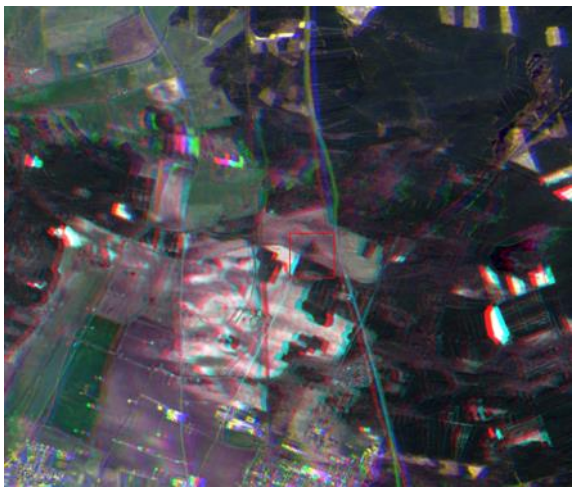


Figure 12: Spectral co-registration error (anomaly #14).

4.9 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 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.

4.10 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.

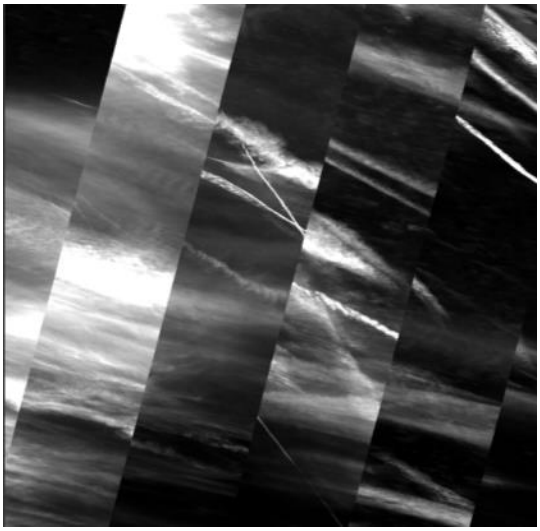


Figure 13: Stretching of 60 m bands (anomaly #16).

4.11 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 the first products for the datastrips (Northern part). It is characterized by a misalignment of the odd and even detectors, as illustrated in the figure below.

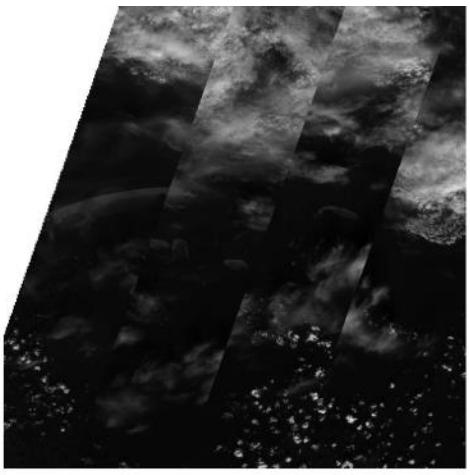


Figure 14: Detector misalignment on band B1 (anomaly #17).

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

4.12 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.

The anomaly is related to the handling of the redundant Star Tracker in the attitude estimation system. A correction of the alignment of the redundant Star Tracker is planned to avoid a re-occurrence of this anomaly.

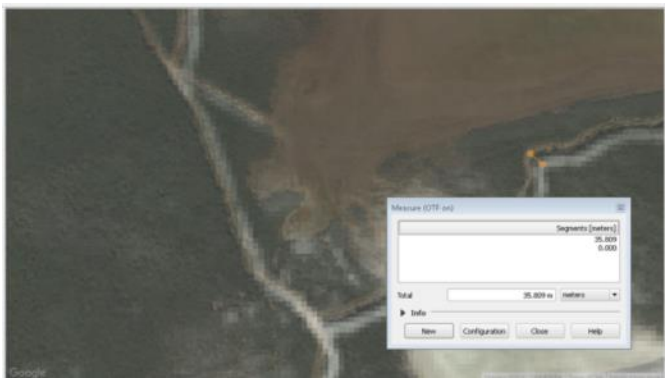


Figure 15: S2 image superimposed with reference map, showing a geolocation error of 35 m (anomaly #18).

4.13 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.

4.14 Degraded AUX files (#23)

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.

4.15 Imprecise technical quality mask (#24)

Since October 2016, technical quality masks (TECQA) 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.

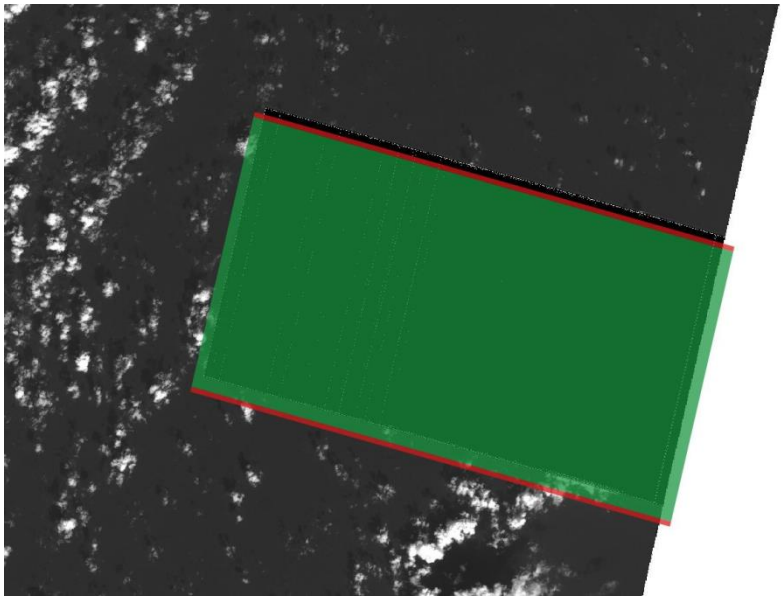


Figure 16: Technical Quality masks (green: lost packets, red: degraded packets) overlayed over an affected imaged. A small gap exists between the mask and the affected area (anomaly #21).

4.16 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.

4.17 Incomplete manifest (#26)

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

4.18 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.

4.19 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.

4.20 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.

4.21 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.

4.22 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.

4.23 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.

4.24 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.

4.25 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 mis-registration 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.

4.26 Missing viewing angles (#37)

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.

4.27 "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.

4.28 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 corrected response functions are now available on the Sentinel on-line website and will be corrected in the product metadata on January 15th 2018.

4.29 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-occurence. In the meantime the products will be removed and replaced with new ones with the correct naming.

4.30 Incorrect Instrument Temperature metadata (#41)

This anomaly affects the Instrument temperature data reported in the "expertise" section of the Datastrip metdata. 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.

4.31 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.

4.32 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.

4.33 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.

A correction has been implemented and will be deployed in the coming weeks.

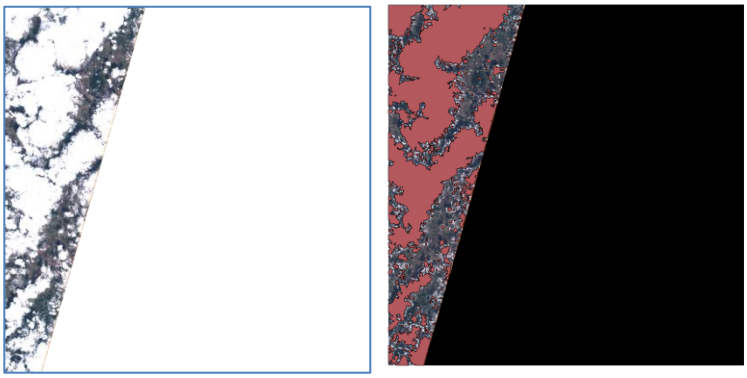


Figure 17: Tile 40UGE acquired on 12/06/2018 by S2B. Left: RGB composite, Right: cloud mask (in red). The cloud coverage percentage is incorrectly reported as 19.3% (anomaly #44).

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. When successful, this operation allows restoring defective pixels to nominal behaviour. After analysis, some S2A SWIR pixels will be switched back to operational status in the coming days.

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	Defective	16/11/2015
B10	10	879	Defective	23/06/2015
B10	10	1174	Defective	23/06/2015
B11	11	24	Defective	26/08/2015
B12	1	440	Defective	26/08/2015
B12	1	703	Defective	06/11/2015
B12	5	174	Defective	07/03/2018

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).

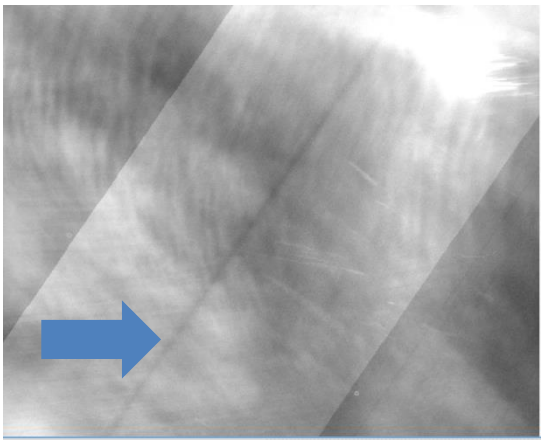


Figure 18: Along-track stripe on B11 image due to a non-linear response on D11 (contrast strongly enhanced).

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
	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
	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).

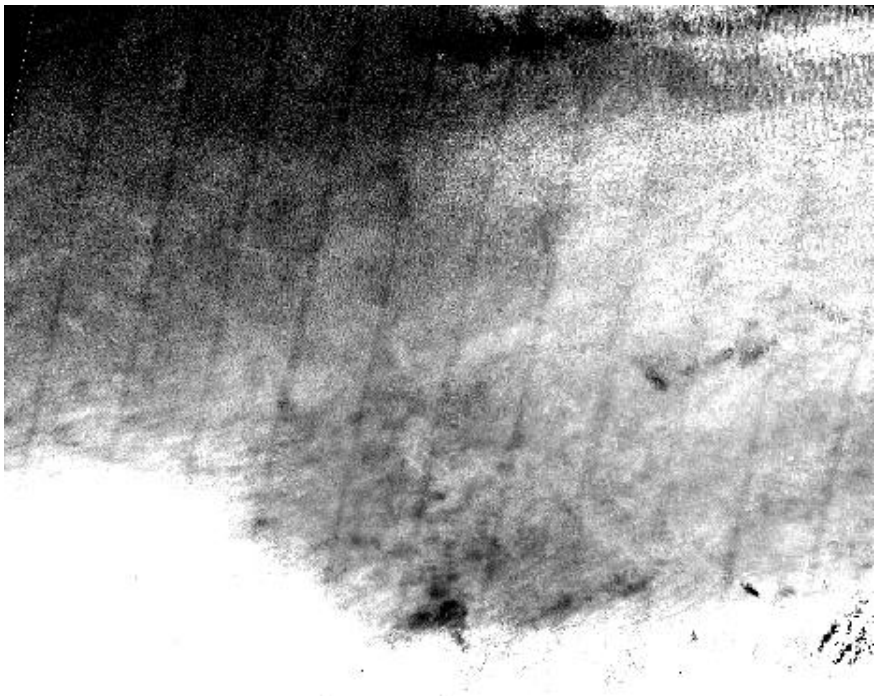


Figure 19: Along-track stripes resulting from spectral response non-uniformity (band B03).

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).

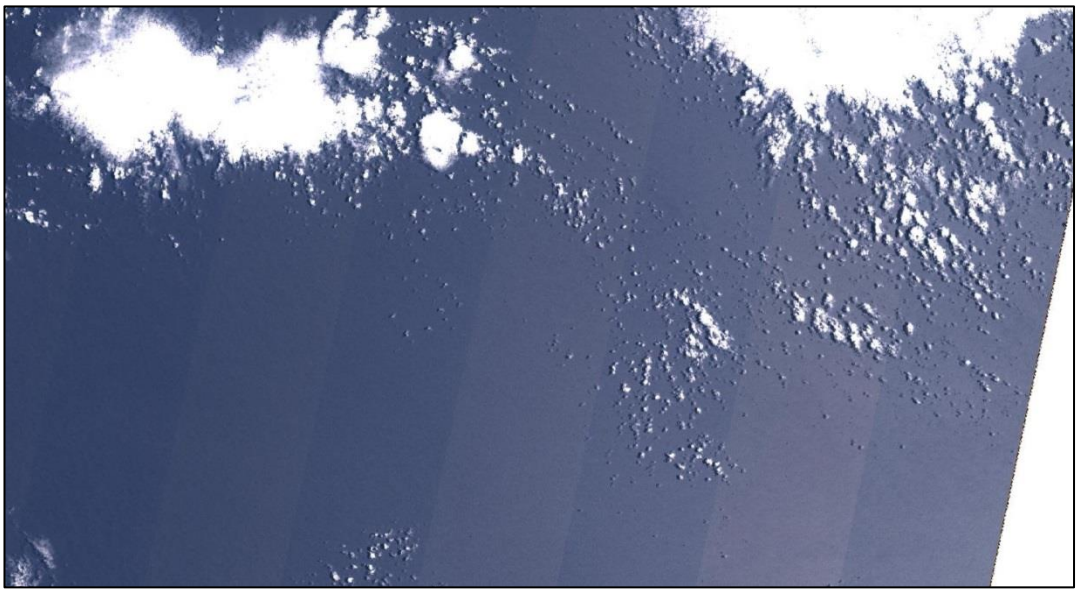


Figure 20: Stripe pattern over sea surface, due to the observation parallax effect between odd and even detectors.

6.2.2 Misregistration of High Altitude Objects

The processing algorithm ensures the coregistration 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 coregistered. 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 21~~Figure 21~~ below.

Figure 21: Spectral misregistration and detector misalignment for object at high altitude (plane and contrail). This feature is not an anomaly.

6.3 Across-Track noise

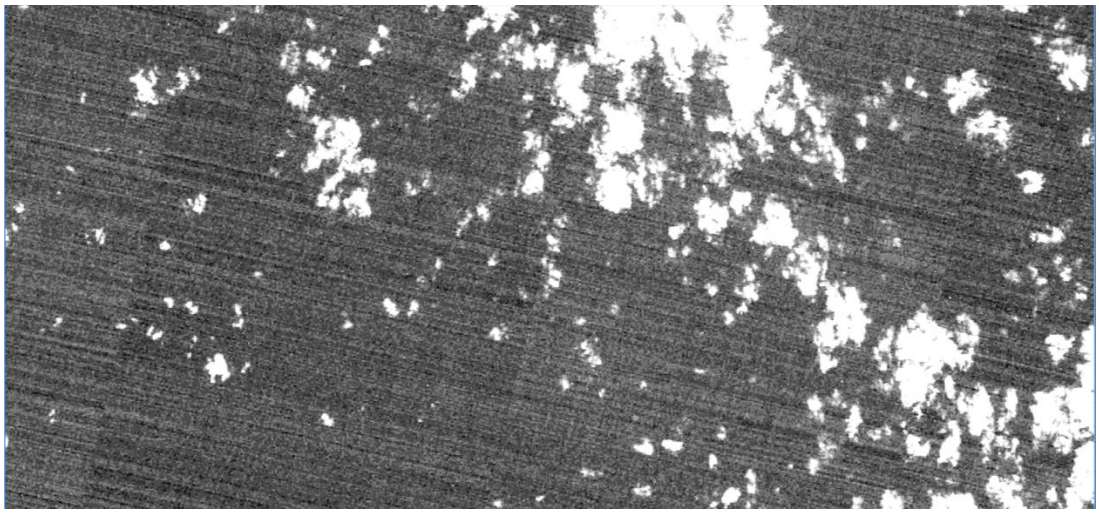


Figure 22: Across-Track intra-detector noise pattern

This feature can be observed in very dark images (typically on B10 or B12 over the sea). It is characterized by across-track lines covering a whole detector. The typical range of this noise pattern is a few digital counts, and therefore within the requirements of the mission.

This phenomenon is induced by the compression noise on "blind" pixels used for dark signal correction. Thanks to an improved filtering, this noise will be reduced with production baseline 02.07.

6.4 Gradient cross-talk

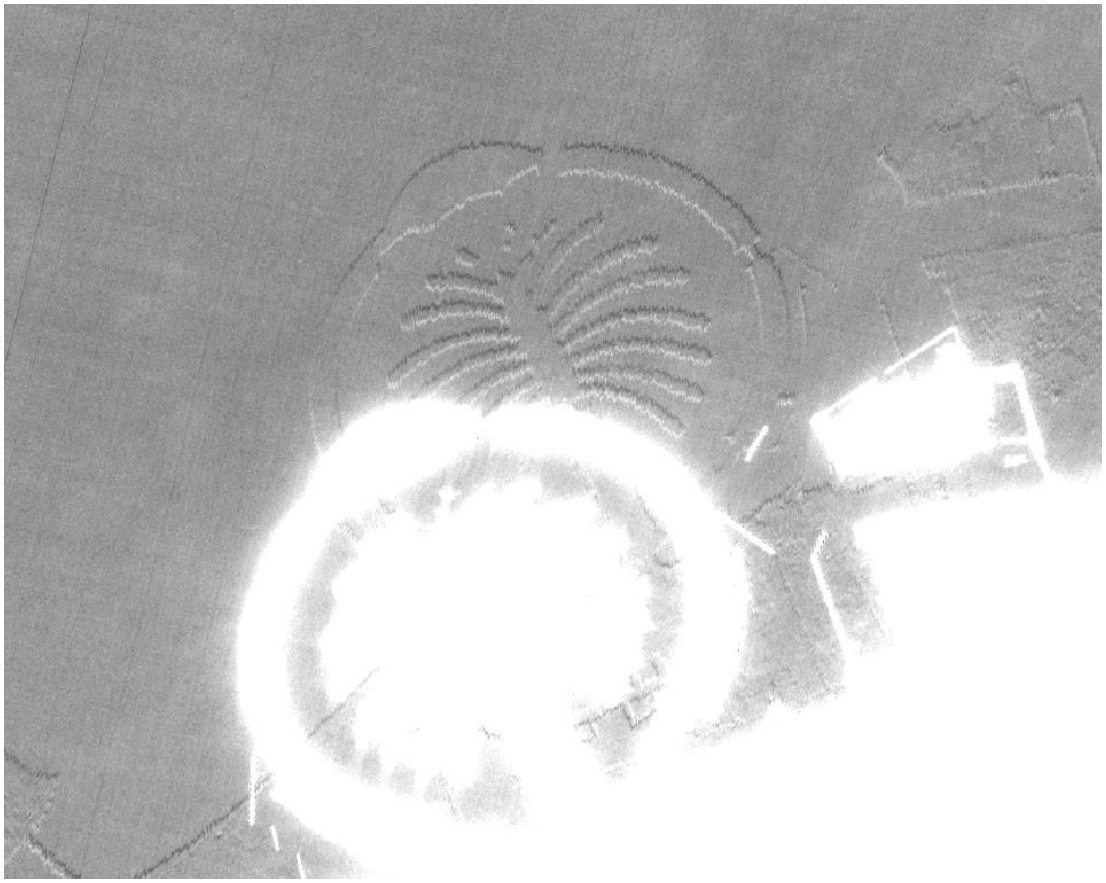
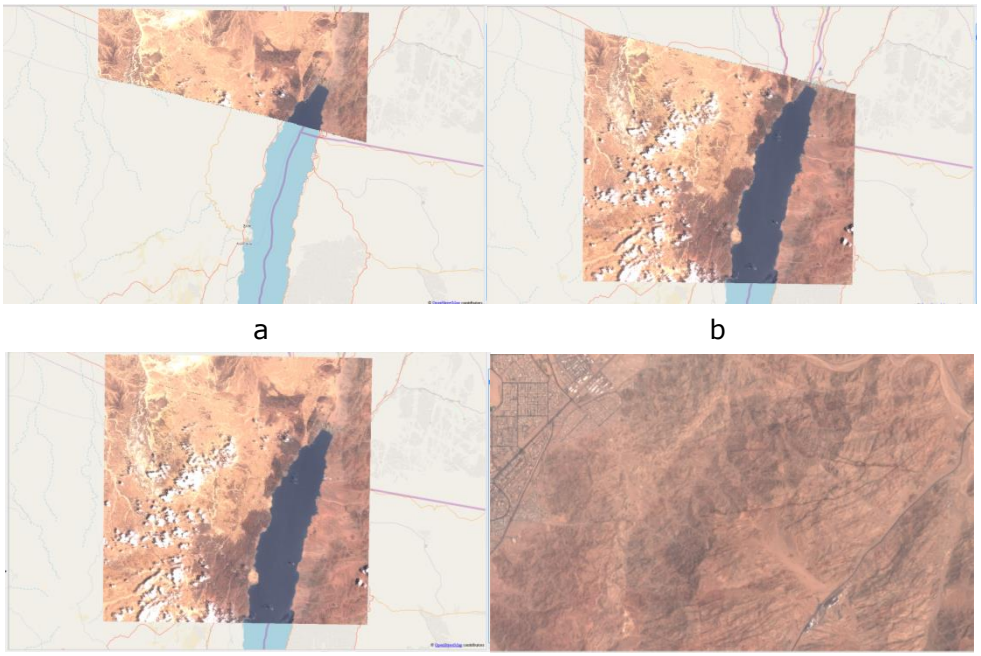


Figure 23: Gradient cross-talk on band B12 (highly enhanced contrast).

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.

6.5 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 will be generated for level 1C tiles located at the interface between the data-strips. Images from the two products can be merged seamlessly.



a b

c d

Figure 24: 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.

End of document