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S2 MPC

Data Quality Report

Ref. S2-PDGS-MPC-DQR

Authors Table

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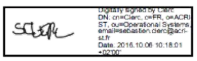
Written by	S. Clerc & MPC Team	ACRI/ARGANS	*Technical Manager*	08/06/2016	
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1. Scope of the Document

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.

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 02.02 for a set of key mission 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).	< 12.36 m at 2σ
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.	< 0.26 pixel at 3σ
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 2.2 in this document)	All bands compliant with > 20% margin

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

Measured performances are detailed in the following sections.

2.2 Geometric Performance

2.2.1 Geometric Calibration Status

An improvement of the yaw pointing bias correction in the processing chain has been identified and will be tested in the short term. The objective is to improve the geolocation performance at the edges of the swath and bring it in line with the performance at the centre of the swath.

Meanwhile the generation of the Global Reference Image is in progress. When completed, the GRI will be used to perform a refinement of the geolocation of L1C product, with an expected improvement of the accuracy to 8.5 m (2 σ) and of the multi-temporal co-registration to 0.3 pixels.

The European GRI has been completed and its accuracy has been analysed, see figure below.

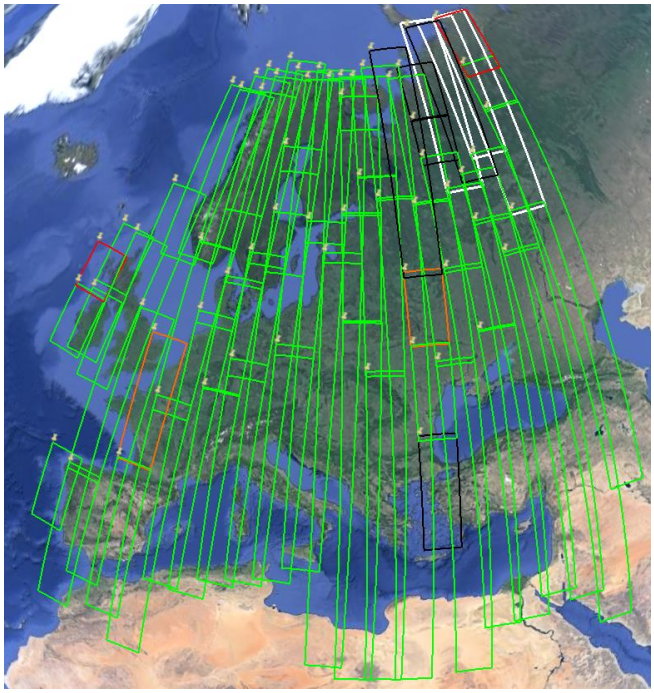

Figure 1: European GRI performance estimation (results courtesy CNES). Green: < 7 m. Orange: < 10 m. Red > 10 m. White: missing GRI data (no cloud-free product). Black: no reference available.

The elaboration of the global GRI is progressing (see figure below) and is expected to cover 70 to 80% of all lands by November 2016.

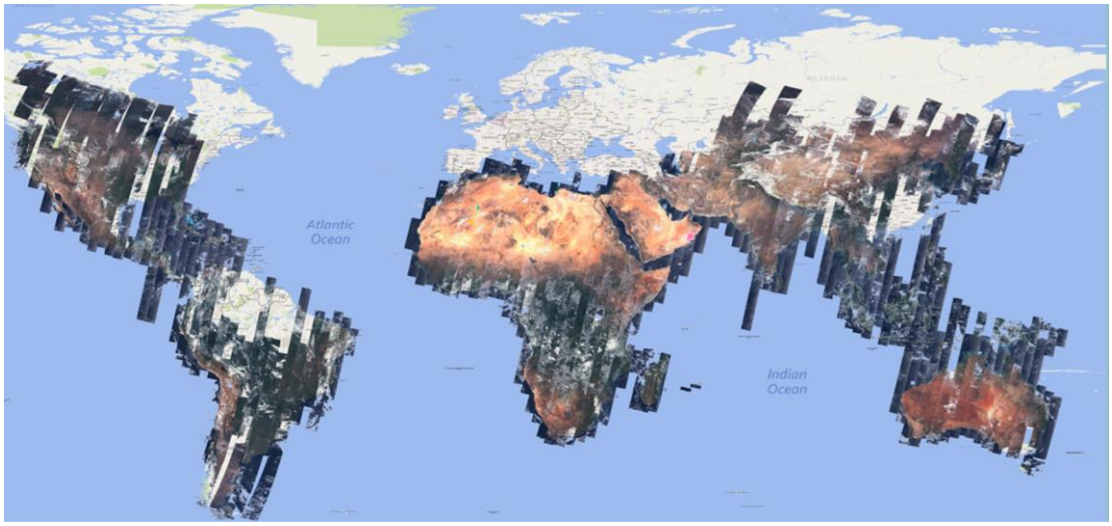

Figure 2: Current coverage of the global GRI.

2.2.2 Absolute Geolocation

The geolocation performance has been assessed by measuring the error on a set of ground control points (GCPs) for 107 products during the reporting period.

The analysis confirms the excellent performance of MSI (better than 12.36 m at 95% confidence), with respect to the mission specifications. The final requirement of 12.5 m (2 σ) is already met even before the completion of the GRI and the activation of geometric refinement.

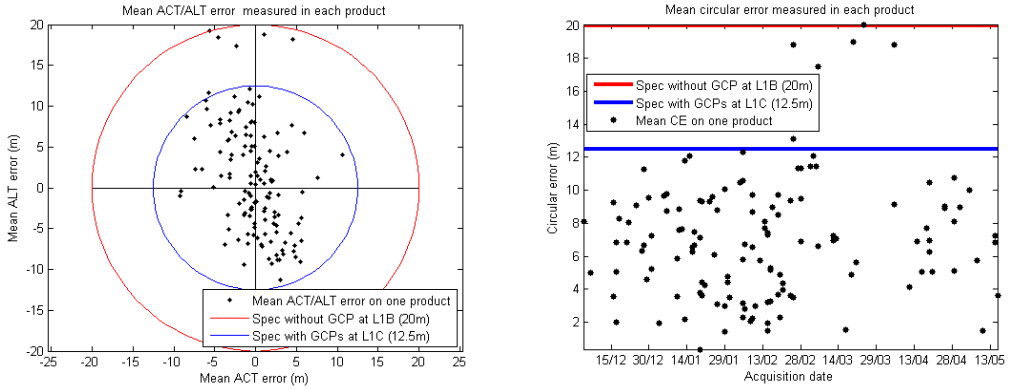

Figure 2-3: Geolocation performance assessment. Left: Statistics of the geolocation error for all Ground Control Points analysed during the reporting period. Right: Evolution of the measured performance. The final performance requirement (blue line) is generally met even before the activation of geometric refinement.

2.2.3 Multi-Spectral Registration

The methodology used to validate multi-spectral co-registration is under consolidation to remove any source of bias introduced by the processing method.

However the first results obtained using a product over Paris indicate that the co-registration requirement (< 0.3 pixel at 99.7% confidence) is met with comfortable margins. The performance is below 0.21 pixel (of the coarser band) for all measured couple of bands, except for the couple B04/B08 (performance 0.26 pixel).

Detailed analysis of the co-registration error has shown no along-track temporal trend, and only a faint across-track trend on one detector.

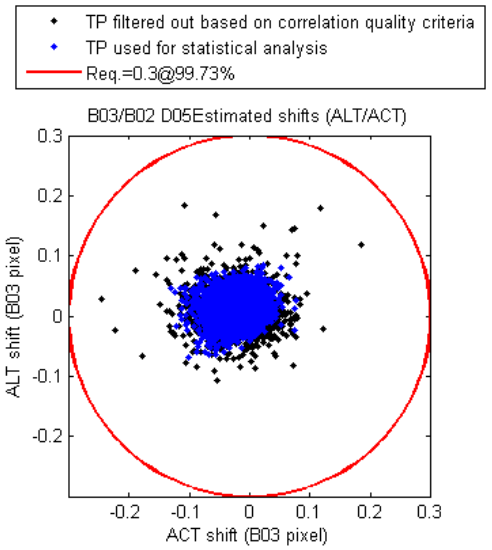

Figure 4: Estimated co-registration errors between visible bands B02 and B03. After filtering for poorly matching tie-points, the estimated performance is better than 0.13 pixel at 99.7% confidence.

2.2.4 Multi-Temporal Registration

A Global Reference Image (GRI) is currently being assembled. This reference image will be used later to improve the geolocation of the Sentinel 2 products. This will in particular improve the multi-temporal registration (registration between two images of the same tile acquired at different time).

2.3 Radiometric Performance

2.3.1 Radiometric Calibration Status

During the reporting period a calibration has been performed using the improved calibration procedure. As anticipated, this results in a small increase (0.2%) of the radiometry of visible bands.

A decontamination of the instrument is scheduled for early July 2016.

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.
- Comparison with other sensors (Landsat OLI).

The first two methods indicate a radiometry slightly above the reference (typically 3%) for visible bands but still within requirements.

S2A/MSI	Wave length (nm)	Vic. Calib. Coefficient (Best estimate)	Standard deviation
B01	443	1.030	0.028
B02	490	1.020	0.018
B03	560	1.021	0.010
B04	665	1.024	0.013

Table 2-2: Best estimate of the absolute vicarious calibration coefficients and the standard deviation for S2A/MSI from Rayleigh methodology application over four ocean-sites.

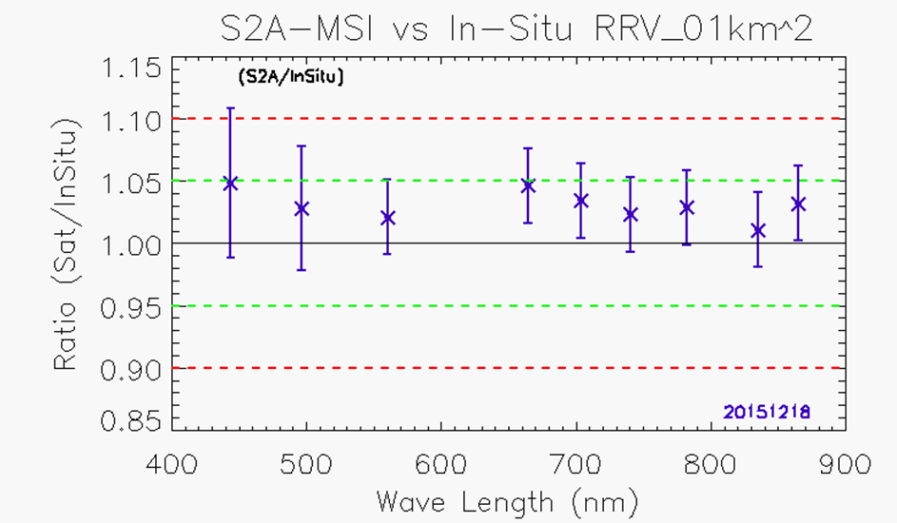

Figure 2-5: Comparison with in-situ measurements over Railroad Valley, USA, on 18th December 2015. In-situ measurements courtesy of USGS.

Comparison with reference models over desert sites are also within the specified 5% with the exception of band B05 which is found above slightly above specifications for two sites.

Comparisons with LANDAST OLI radiometry show remarkable consistency on all sites and during the whole reporting period.

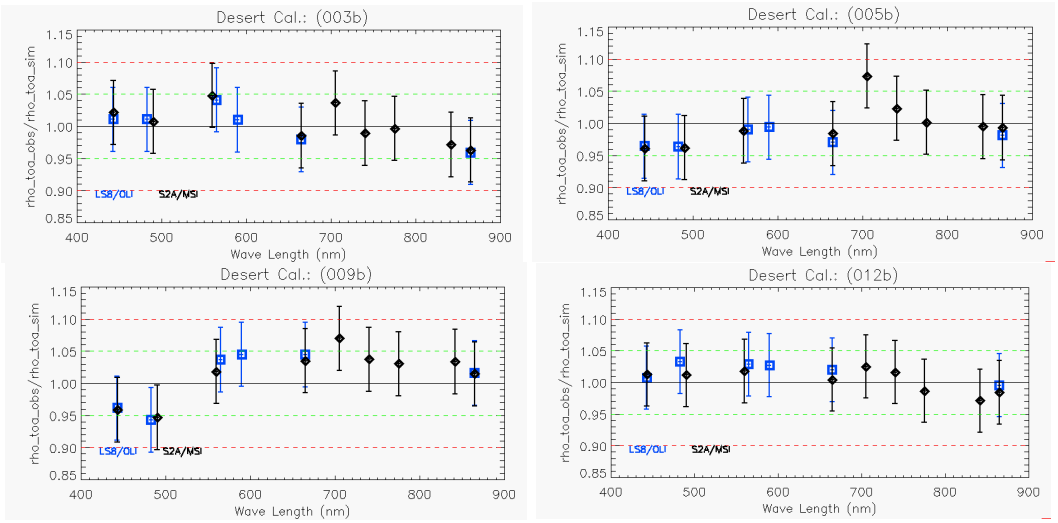

Figure 2-6: Ratio of observed TOA-reflectance to simulated one for each sensor (black) S2A/MSI and (blue) LANDSAT-8/OLI over (Top to bottom) Algeria3 (003b), Algeria5 (005b), Libya1 (009b) and Libya4 (012b) sites as a function of wavelength. Error bars indicate the desert methodology uncertainty.

Comparison for SWIR bands have been performed recently with a different methodology. While the previous methodology relies on the use of MERIS as reference sensor, this one relies on direct comparison of measurements acquired in similar viewing conditions. The comparison confirms the good agreement for VNIR bands and indicates similar if not better agreement on SWIR bands (better than 2.5%).

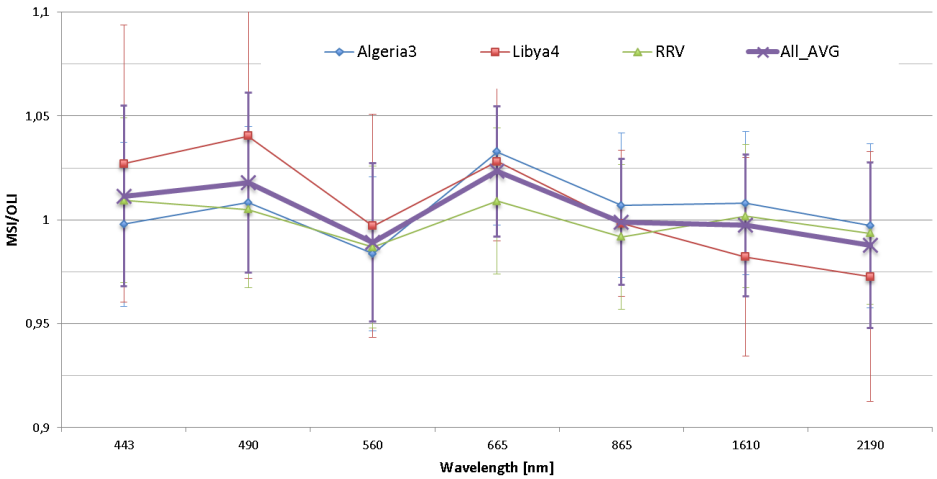

Figure 7: Ratio of S2 MSI to LANDSAT OLI TOA reflectances acquired in similar viewing conditions. Sites Algeria3, Lybia4, Railroad Valley and average value. Error bars indicate the uncertainty of the methodology.

2.3.3 Noise

The characterisation of the noise has been refined since the end of the commissioning using various estimation methods. In spite of differences on some spectral bands, they all confirm the large margins with respect to specifications, see figure below.

The Signal-to-Noise Ratio (SNR) for RBG bands is higher than 210, and nearly 40% above specifications. The smallest margin is obtained for band B8 (27% above specification), while the smallest SNR occurs for band B11 (SNR = 159, 59% above specification).

The noise characteristics are very stable over time.

Table 2-3: Estimated SNR performance 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	74.5	68	67	103	52.5	9	6	4	1.5
Measured	1142	214	249	230	253	220	227	221	161	185	316	159	217
Requirement	129	154	168	142	117	89	105	174	72	114	50	100	100

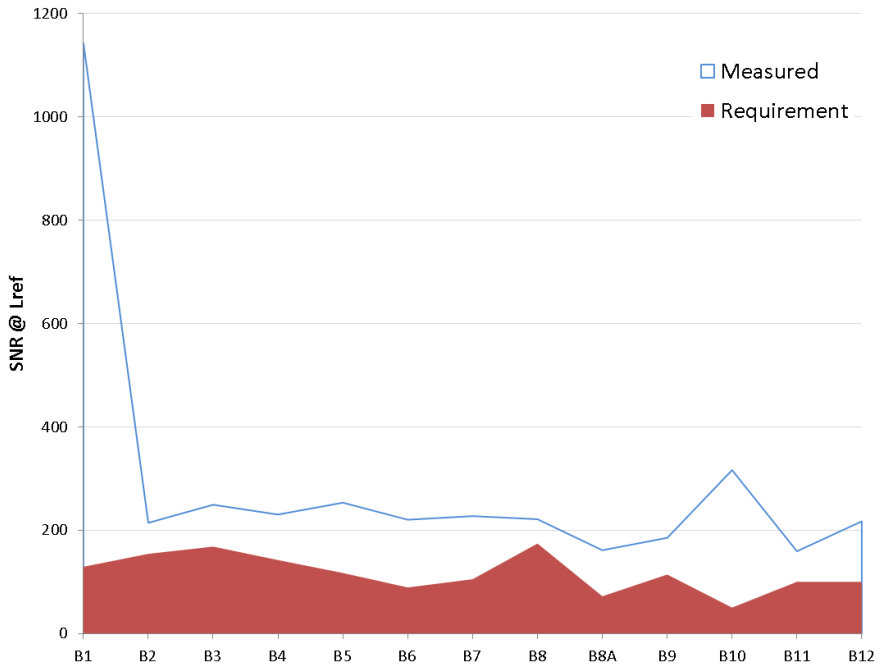

Figure 2-8: SNR performance estimation (blue) and specification (red).

2.3.4 Modulation Transfer Function

The Modulation Transfer Function has been estimated by analysing images with sharp edges. The estimated performance is close to requirements for all measurements, and slightly better than expected from ground measurements.

Table 2-4: Preliminary MTF performance assessment.

Spectral Band	Measured ACT	Measured ALT	Requirement
B2	0.31±0.06	0.33±0.17	0.15 < MTF < 0.30
B3	0.30±0.07	0.37±0.11	0.15 < MTF < 0.30
B4	0.24±0.04	0.30±0.11	0.15 < MTF < 0.30
B8	0.17±0.07	0.34±0.11	0.15 < MTF < 0.30

3. Processing Chain Status

3.1 Status of processing baselines and known processing anomalies

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

Table 3-1: Summary of identified processing anomalies and associated processing baselines

	Baseline number	02.00	02.01		02.02
	Deployment date	23/11/2015	27/01/2016	31/03/2016	03/05/2016
Anomaly ID	Anomaly title				
3	Incorrect tile numbering	yes			
4	Instrument Measurement Time MTD	yes	yes	yes	yes
5	Minimum Reflectance "0"	yes	yes		
6	Detector Footprint at Equator	yes	yes		
7	Missing Physical Gains MTD	yes	yes	yes	yes
8	Shifted Pixel	yes, until 25/01/2016			
11	Missing Viewing Angles MTD	yes, not systematic	yes, not systematic		
12	Anomalous Pixels			yes, few products impacted	

3.2 Archive Reprocessing

A reprocessing campaign of images acquired during the commissioning period (from launch till 30/11/2015) is in progress and products are progressively introduced in the public archive. This reprocessing uses baseline number 02.01 and 02.02.

3.3 Outlook

A new processing baseline 02.03 will be introduced in the coming days. This new baseline will not impact Level 1c products.

4. Product Anomalies

4.1 Introduction

This section describes all known product anomalies. Each anomaly is tagged with a code #N" allowing to link 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.

Table 4-1: Anomalies not related to processing

Anomaly ID	Anomaly title	Classification	Affected products	Product status
9	Striping of SWIR bands	Minor	A few orbits, not systematic	Not released
10	Striping of Visible bands	Major	A few orbits, not systematic	Removed from archive
13	B10 noise	Minor	Products with high reflectances	Available
14	Geolocation error	Major	Orbits 3218, 4080 and 4081	Removed from archive

4.2 Incorrect Tile Numbering (#3)

Some tiles in the Southern hemisphere were incorrectly labelled in products of baseline 02.00. This problem has been corrected on baseline 02.01, and the kml file documenting the grid of tiles has been corrected (see https://sentinel.esa.int/documents/247904/1955685/S2A_OPER_GIP_TILPAR_MPC__20151209T095117_V20150622T000000_21000101T000000_B00.kml/ec05e22c-a2bc-4a13-9e84-02d5257b09a8).

4.3 Instrument Measurement Time MTD (#4)

Within the satellite ancillary metadata, the value of Instrument Measurement Time (IMT) is not represented correctly due to a formatting error.

4.4 Minimum Reflectance "0" (#5)

Valid pixels with zero reflectance could not be distinguished from "no data" pixels (coded with value 0). Zero reflectance pixels could be observed on the water vapour absorption band B10 or on SWIR band B12 over water surfaces.

It has been decided to truncate reflectance values to digital number 1 (i.e. reflectance 0.0001) to solve this issue, only "no data" pixels will be marked with value 0.

4.5 Detector Footprint at Equator (#6)

An error was found in the detector footprint gml file for tiles immediately North of the equator (systematic error). This error is corrected with baseline 02.01 after end of March 2016.

4.6 Missing Physical Gains MTD (#7)

Band 12 is missing in the "physical gains" metadata.

4.7 Shifted Pixels (#8)

Two pixels on detector 10 of band 12 and 11 appear shifted along-track on images acquired between 25/11/2015 and 21/01/2016. This minor defect is due to an operation error during a pixel on-board reselection, which has been corrected after identification of the root cause.

4.8 Striping of Visible Bands (#10)

A major anomaly affecting VIS band images occurred on 21/02/2016 after a restart of the Sentinel-2A mass memory unit (MMFU).

The data of even detectors of visible bands were missing from products acquired at the beginning of a datastrip. This results in discoloured stripes along-track in RGB images. Anomalous products have been rapidly removed from the catalogue. The anomaly can be corrected by reprocessing the instrument source packets after filtering. Therefore, the missing products for the corresponding period should be available in the future.

The anomaly was traced back an incorrect handling of instrument source packets by the MMFU after the reboot of the unit. A procedure to handle this problem in case of a potential re-occurrence has been established.

4.9 Missing Viewing Angles MTD (#11)

For some products, the mean viewing angles in the tile metadata were missing for some bands in some products (not systematic). This anomaly is solved with baseline 02.01 after end of March 2016.

4.10 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.

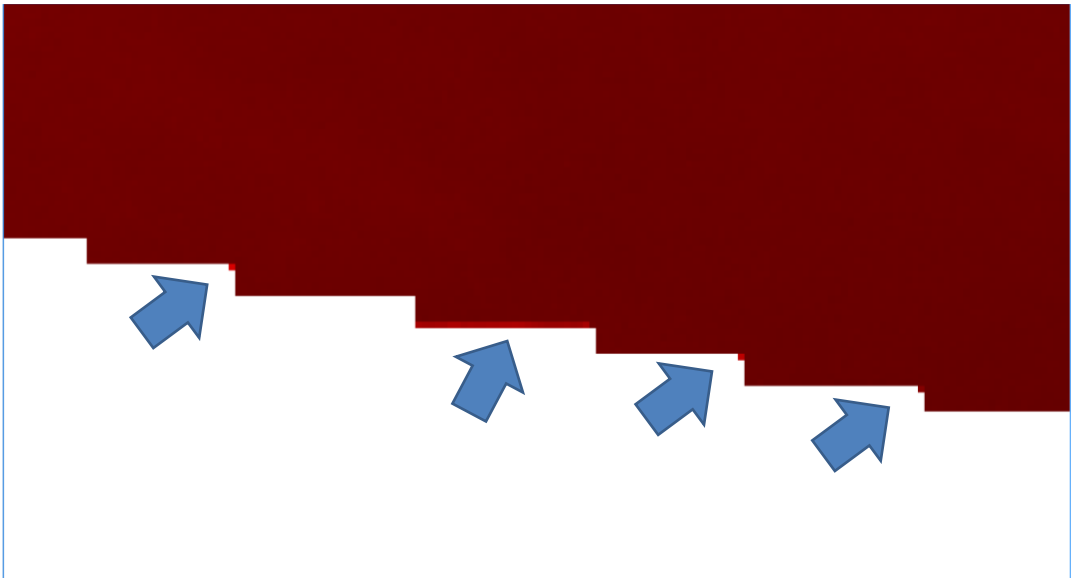

Figure 9: Anomalous pixels on band B4 (anomaly #12).

4.11 Noise on Band 10 Images (#13)

This anomaly concerns Band 10 images with high reflectances (above 5000 digital counts), which occur on thick high altitude clouds. This anomaly is characterized by an along-track repetitive noise pattern and non-uniformity of the reflectance.

This anomaly is still under investigation. The current understanding is that it is not linked to processing. Note that this does not affect the use of B10 as an indicator of high-altitude cirrus clouds.

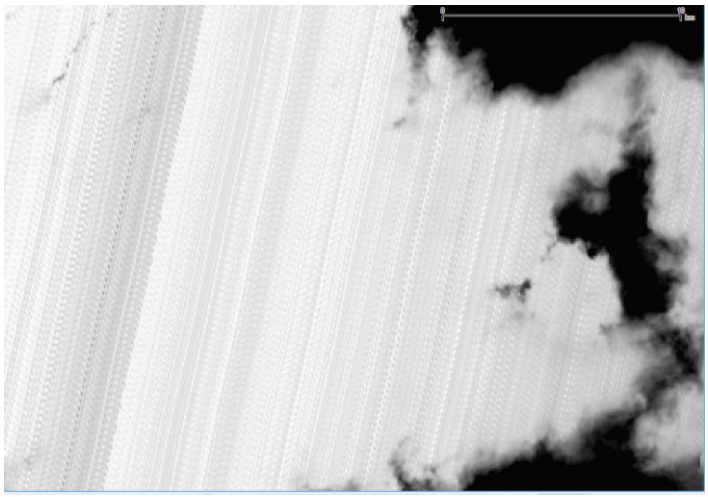

Figure 10: Along-track noise pattern on B10 images over bright clouds (#13).

4.12 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 (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.

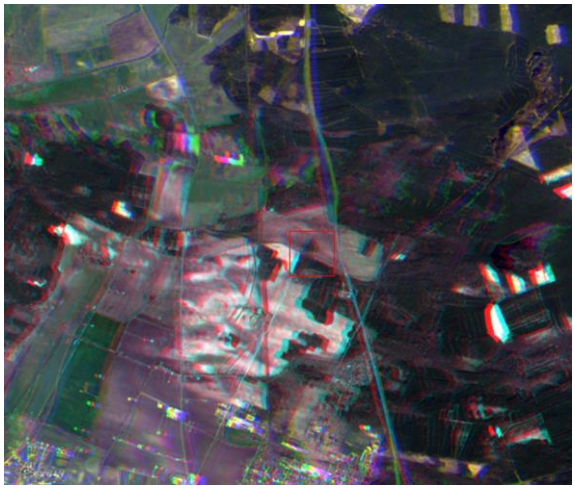

Figure 11: Spectral co-registration error (anomaly #14).

5. Pixels Status

In the following tables are listed all the identified defective and noisy pixels:

- Defective pixels which currently replaced by an interpolation of neighbouring pixels. Defective pixels are interpolated.
- Noisy pixels: pixels operational but with a high noise level. These pixels are being monitored and could be declared defective in the future.

Pixel 640 on band 12 detector 10 was successfully reconfigured on the 23rd of February 2016 and is no longer defective.

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

Table 5-1: Defective pixels on Band 10

Band B11			Current status & R2DEPI defective pixels	
Band	**Detector**	**Pixel number (from 0)**	**Current status**	**Last updated**
B11	2	471	Noisy	
B11	8	61	Noisy	
B11	8	999	Noisy	
B11	11	1271	Noisy	

Table 5-2: Defective pixels on Band 11

Band B12			Current status & R2DEPI defective pixels	
Band	**Detector**	**Pixel number (from 0)**	**Current status**	**Last updated**
B12	1	185	Noisy	
B12	1	213	Noisy	

B12	1	440	Defective	26/08/2015
B12	1	488	Noisy	
B12	1	592	Noisy	
B12	1	603	Noisy	
B12	1	703	Defective	06/11/2015
B12	1	727	Noisy	
B12	1	855	Noisy	
B12	1	1045	Noisy	
B12	3	1089	Noisy	
B12	4	25	Noisy	
B12	4	32	Noisy	
B12	4	73	Noisy	
B12	4	126	Noisy	
B12	4	444	Noisy	
B12	4	682	Noisy	
B12	4	716	Noisy	
B12	4	726	Noisy	
B12	4	799	Noisy	
B12	4	803	Noisy	
B12	4	806	Noisy	
B12	4	880	Noisy	
B12	4	1075	Noisy	
B12	4	1110	Noisy	
B12	4	1245	Noisy	
B12	5	303	Noisy	
B12	5	661	Noisy	
B12	5	1121	Noisy	
B12	5	1122	Noisy	
B12	6	90	Noisy	
B12	6	773	Noisy	
B12	8	805	Noisy	
B12	8	965	Noisy	
B12	9	176	Noisy	
B12	10	640	OK	23/02/2016

Table 5-3: Defective pixels on band 12

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