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S2 MPC

Data Quality Report

Ref. S2-PDGS-MPC-DQR

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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 the Level-1C products data quality performances measured on products in Processing Baseline 02.01 and 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 B9: < 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

Geometric calibration coefficients have been updated on 23/02/2016 to reflect a small evolution of the satellite geometry in orbit. This evolution is expected and the correction performed will ensure the stability of product geolocation performance.

Meanwhile the generation of the Global Reference Image is progressing. The European block is nearly completed, and the completion of the Australian and African blocks is well under way. 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.

2.2.2 Absolute Geolocation

The geolocation performance has been assessed by measuring the error on a set of ground control points (GCPs) for 67 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.

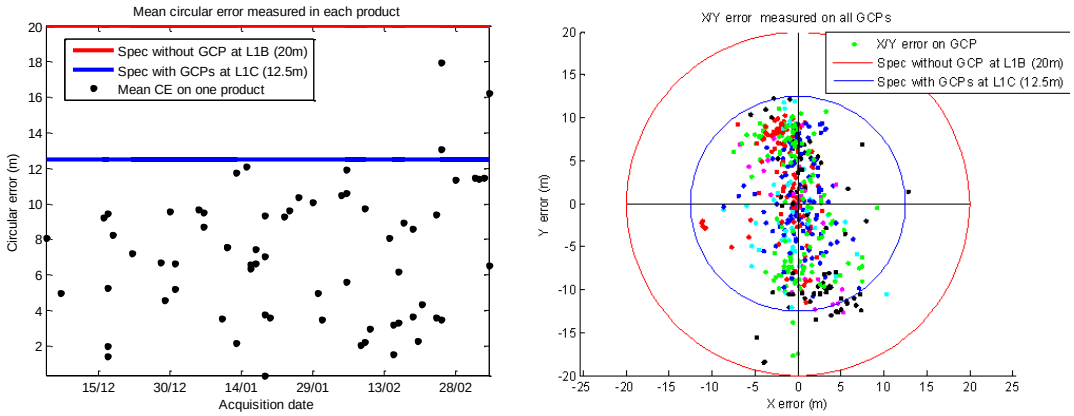

Figure 2-1: Geolocation performance assessment. Left: Evolution of the measured performance. Right: Statistics of the geolocation error for all Ground Control Points analysed during the reporting period. The final performance requirement (blue line) is already met even before the activation of geometric 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.

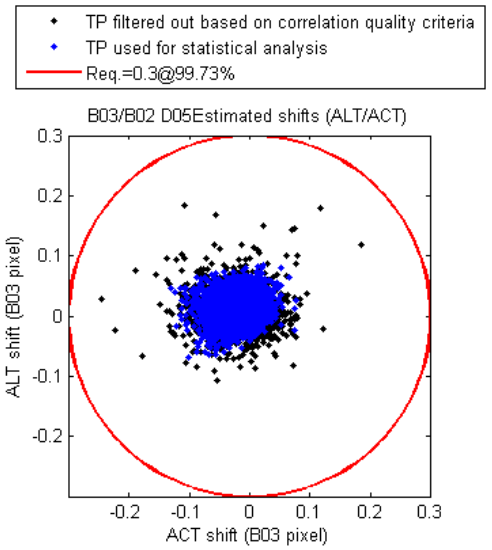

Figure 2: Estimated co-registration errors between visible bands B02 and B03. After filtering for poorly matching tie-points, the estimated performance is better than 0.13 pixel at 99.7% confidence.

2.2.4 Multi-Temporal Registration

The performance requirement (0.3 pixel) will be assessed after activation of the geometric refinement using the Global Reference Images (GRI).

2.3 Radiometric Performance

2.3.1 Radiometric Calibration Status

During the reporting period, radiometric calibration using diffuser images have been performed every 10 days approximately. From April 2016 on, the calibration frequency will be reduced to once per month. A minor evolution of the calibration methodology will also be introduced, starting with April's calibration. This new and more accurate methodology will result in a small increase of the observed Top-Of-Atmosphere (TOA) reflectance for all bands, of the order of 0.2%.

A decontamination of the MSI has been performed on 28th of January 2016. The observed TOA reflectance of SWIR bands B10 and B11 has increased by nearly 1% just after the decontamination. The calibration gains have been adjusted on February 1st. In the interval, users may observe a discontinuity in the radiometry of bands B10 and B11 (still within specifications).

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.

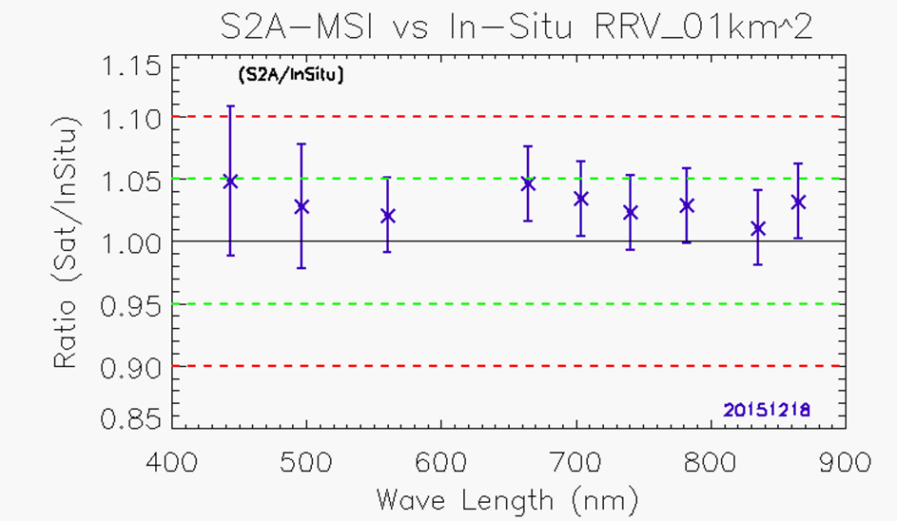

Figure 2-3: Comparison with in-situ measurements over Railroad Valley, USA, on 18th December 2015. In-situ measurements courtesy of USGS.

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. Comparison for SWIR bands is in progress and will be reported in the next Data Quality Report.

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

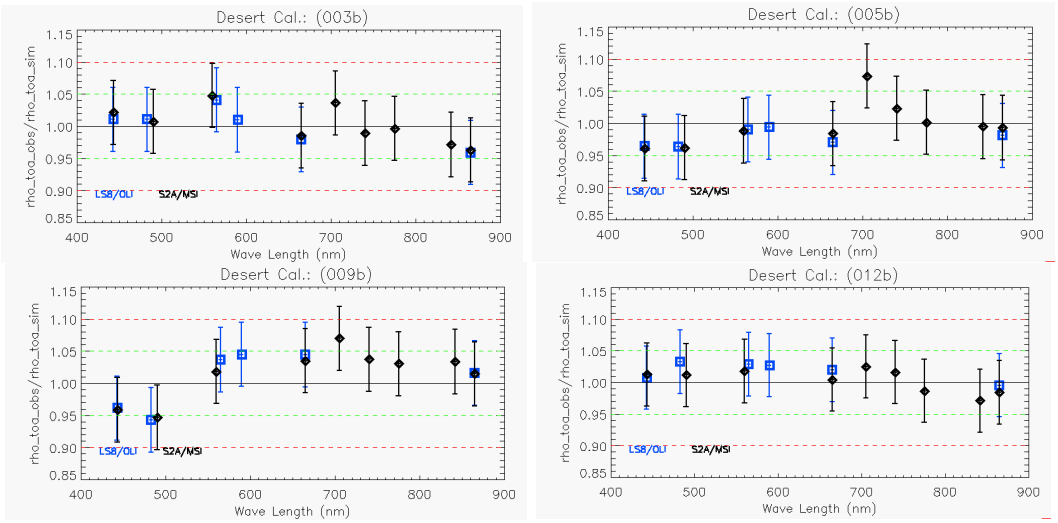

Figure 2-4: Ratio of observed TOA-reflectance to simulated one for each sensor (black) S2A/MSI and (blue) LANDSAT-8/OLI over (Top to bottom) Algeria3 (003b), Algeria5 (005b), Libya1 (009b) and Libya4 (012b) sites as a function of wavelength. Error bars indicate the desert methodology uncertainty.

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 evolution of the SNR has been monitored during the reporting period and shows no significant evolution.

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

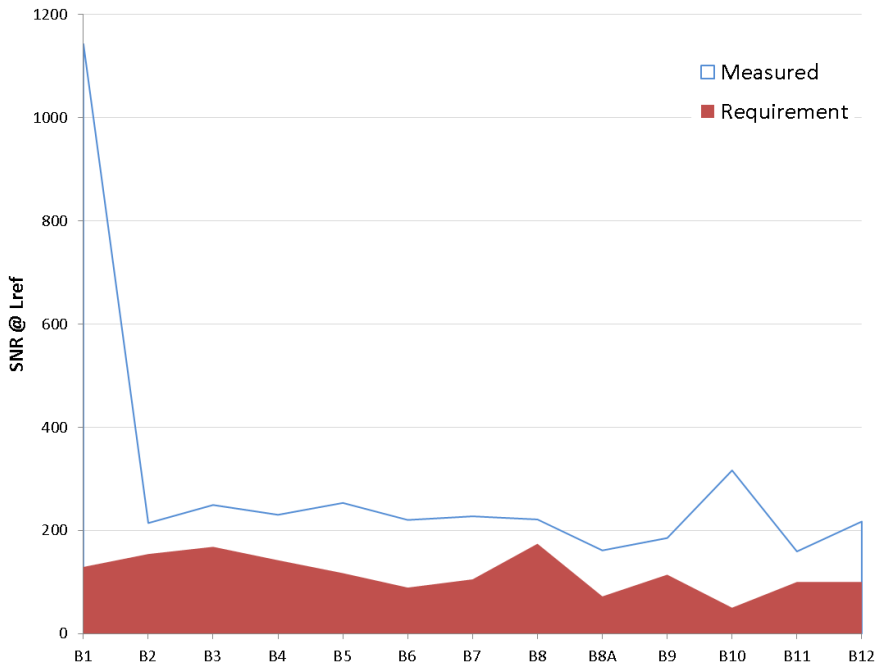

Figure 2-5: SNR performance estimation (blue) and specification (red).

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. Product Anomalies

3.1 Introduction

In this chapter we report on anomalies identified on L1C products during the reporting period. The list of all known anomalies is summarized in the table below and is detailed in the following sections. All anomalies are minor except anomaly 10 (striping of VIS images). Images affected by anomaly 10 have been removed from the public archive.

Table 3-1: Summary of identified anomalies

ID	Element affected	Summary	Start date	End date	Status
3	Product format	Incorrect tile numbering	Launch	16/12/2015	Corrected with baseline 02.01
4	Product MTD	Instrument Measurement Time error	Launch	On-going	Corrected, to be deployed
5	Images	Minimum Reflectance "0"	Launch	23/03/2016	Corrected with IPF v2.20
6	Granule MTD	Detector Footprint at equator	Launch	23/03/2016	Corrected with IPF v2.20
7	Product MTD	Missing Physical Gains MTD	Launch	23/03/2016	Corrected with IPF v2.20
8	B12 and B11 images	Shifted pixel	25/11/2015	21/01/2016	Corrected
10	VIS band images	Striping of VIS bands	21/02/2016	29/02/2016	Not systematic Correction in progress
11	Granule MTD	Missing Viewing Angles MTD	Launch	23/03/2016	Not systematic Corrected with IPF v2.20

3.2 Format Anomalies

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).

3.3 Metadata Anomalies

3.3.1 Cloud percentage anomaly

The cloud percentage metadata at granule level was incorrectly computed for partially covered tiles (tiles with No Data values). This issue has been fixed with processing baseline 02.01 on 27/01/2016.

3.3.2 Anomalies corrected on March 23rd 2016

An error was found in the detector footprint gml file for tiles immediately North of the equator (systematic error).

Some bands were absent from the list physical gains in the user product metadata.

For some products, the mean viewing angles in the tile medata were missing for some bands in some products (not systematic).

All these anomalies have been corrected on March 23rd 2016.

3.4 Images Anomalies

3.4.1 Zero Reflectance

As reported in the last Data Quality Report, 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. The fix has been implemented on March 23rd 2016. From that point on, only "no data" pixels will be marked with value 0.

3.4.2 Shifted Pixel

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.

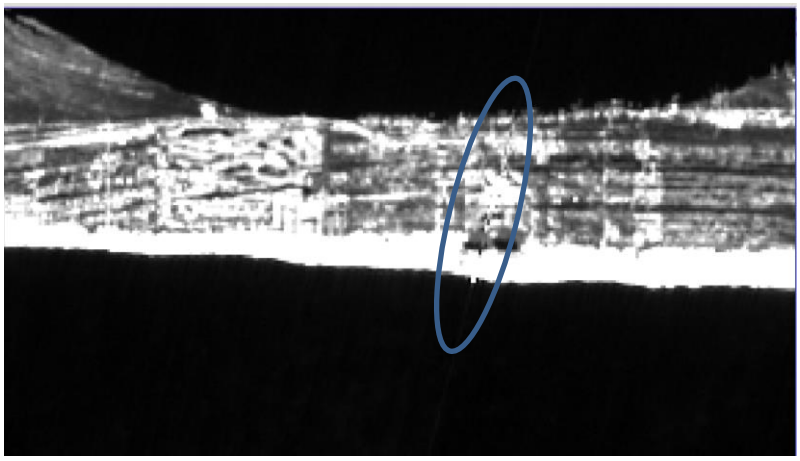

Figure 6: shifted pixel on band B12 image.

3.4.3 Striping of Visible Bands

A serious 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. Defective Pixels

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

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

Band B10			Current status & R2DEPI defective pixels	
Band	**Detector**	**Pixel number (from 0)**	**Current status**	**Date of declaration in case of defect**
B10	4	1104	Defective	16/11/2015
B10	10	879	Defective	23/06/2015
B10	10	1174	Defective	23/06/2015

Table 4-1: Defective pixels on Band 10

Band B11			Current status & R2DEPI defective pixels	
Band	**Detector**	**Pixel number (from 0)**	**Current status**	**Date of declaration in case of defect**
B11	2	471	Noisy	
B11	8	61	Noisy	
B11	8	999	Noisy	
B11	11	1271	Noisy	

Table 4-2: Defective pixels on Band 11

Band B12			Current status & R2DEPI defective pixels	
Band	**Detector**	**Pixel number (from 0)**	**Current status**	**Date of declaration in case of defect**
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	Defective	28/01/2016

Table 4-3: Defective pixels on band 12

5. Processing Chain Status

5.1 Processing Baselines and Processor Versions

The table below summarizes the evolutions of the processing baseline and Instrument Processing Facility (IPF) versions.

Table 5-1: Processing baselines

Processing Baseline	IPF Version	Date of change	Reason for change
02.00	2.16	23/11/2015	• Reference version at opening of the data access to users.
02.01	2.17	27/01/2015	• Fixed tile naming convention (cf. 3.2). • Fixed cloud percentage metadata (cf. 3.3.1).
	2.20	24/03/2016 to 31/03/2016	• Correction of detector footprint anomaly (cf. 3.3). • Correction of viewing angles Metadata anomaly (cf. 3.3). • Correction of zero reflectance value anomaly (cf. 3.4.1).

5.2 Archive Reprocessing

A reprocessing campaign of images acquired during the commissioning period (from launch till 30/11/2015) is in progress.

This reprocessing uses baseline number 02.01. Products generated with IPF v2.17 will however retain the minor defects corrected with v2.20 (in particular detector footprint anomaly).

End of document