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## Change Log

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<th>Reason for change</th>
<th>Pages(s)/Section(s)</th>
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<td>01</td>
<td>2015-11-30</td>
<td>Version for data access opening</td>
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1. Scope of the Document

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

This first version released on 30 November 2015, provides the status at the moment of opening of the data access for all users through website https://scihub.esa.int/.

This document covers Level-1C products generated with Processing Baseline 02.00.

As the quality of the Sentinel-2 products will gradually improve during mission ramp-up, the document will be updated regularly and keep trace of the quality of all products available in the archive.

The document also includes a brief description of some specific Level-1C product features that should be understood when using Sentinel-2 images.
2. Level-1C Data Quality Status

2.1 Overview

The following overview table provides a summary of the Level-1C products' data quality (with processing baseline 02.00) for a set of key mission requirements.

Measured performances are detailed in the following sections, together with identified limitations of the products.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
<th>Measured performance</th>
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<tr>
<td>Absolute geolocation (without ground control points)</td>
<td>The geo-location uncertainty shall be better than 20 m at 2σ confidence level (without Ground Control Points).</td>
<td>&lt; 10 m at 2σ</td>
</tr>
<tr>
<td>Multi-spectral registration</td>
<td>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.</td>
<td>&lt; 0.23 m at 3σ</td>
</tr>
<tr>
<td>Absolute radiometric uncertainty</td>
<td>The absolute radiometric uncertainty shall be better than 5% (goal 3%) for the set of bands specified in [SSRD] over the reduced dynamic range.</td>
<td>B1, B2, B3, B4: &lt; 2% ± 2%</td>
</tr>
<tr>
<td>SNR</td>
<td>The Signal-to-Noise Ratio (SNR) shall be higher than the values specified in [SSRD].</td>
<td>All bands compliant with &gt; 20% margin</td>
</tr>
</tbody>
</table>

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

2.2 Geometric Performances

2.2.1 Absolute Geolocation

Geometric characterisation and calibration have been performed during commissioning in order to reach the required geolocation accuracy. The instrument line of sight is stable across the focal plane and in time.

The intrinsic geolocation performance of the L1C product is excellent. The geolocation error is below one pixel. The figure below shows a typical performance for visible band images (B04).
Figure 2-1: Measured geolocation error: mean value for each product analysed.

In the medium-term, geometric refinement using the Global Reference Image (GRI) will further increase the geometric quality of the Sentinel-2 products.

2.2.2 Multi-Spectral Registration

Spectral co-registration performance is also excellent, as shown in the figure below. The performance at 99.73% is 0.23 pixel, well below the requirement of 0.3.

Figure 2-2: Co-registration error between bands B02 and B03.
2.2.3 Noise

The characterisation of the noise has shown a very good performance, see figure below.

![Figure 2-3: The signal-to-noise ratio (SNR) is better than required values for all bands, with a particularly good behaviour for band B1.](image)

Pixel characterization performed using long “dark signal” acquisitions confirmed existence of a temporally evolving noise on SWIR pixels (known as Random Telegraph Signal or RTS). This effect was expected since tests performed on-ground. A monitoring procedure for this effect has been validated and will continue during operations. Mitigations measures to cope with defective or anomalous pixels have demonstrated their effectiveness.

2.3 Radiometric Performances

2.3.1 Radiometric Calibration

The in-flight radiometric mechanism and the associated on-ground processing are fully operational. Calibration operations will be performed relatively frequently during the first year of operations to handle the effect of residual post-flight contamination. This effect will decrease thanks to decontamination operations and the radiometry will stabilize.

2.3.2 Radiometric Uncertainty

The radiometric validation is in progress. As it is based on statistical analysis of a long time series, a precise assessment of the radiometric uncertainty is not yet available. However preliminary results obtained are consistent with the 5% uncertainty requirement, see below.
Figure 2-4: Radiometric accuracy estimated by the Rayleigh method over ocean surface: ratio of measured over predicted reflectance for spectral bands B1, B2, B3, B4. The preliminary results indicate a performance better than 5%.

2.3.3 Non-linearity

A group of pixels in the middle of detector 11 of band 11 are affected by a defect which creates a non-linear radiometric response. A specific calibration has been performed for those pixels in order to minimize the defect. However a slight defect (darker band in the middle of the detector footprint) can still be seen on low radiance scenes (e.g. at high latitudes or over the ocean).

Figure 2-5: L1b image of Band 11 Detector 11 over a dark area. Left: original defect. Right: after ad-hoc calibration. The defect (darker line in the middle of the image) is still visible but much reduced.
2.4 Product Format

2.4.1 Content

The product content is fully compliant with the Product Specification Document (PSD) version 13.1 available online at http://sentinels.copernicus.eu.

2.4.2 Masks

Cloud and cirrus masks are included in the products in vector format (gml). No land masks are currently provided, but this evolution is planned.

The performance of the cloud and cirrus detection algorithms can be evaluated in terms of over-detections and under-detections.

Both cloud and cirrus masks are currently adjusted to minimize under-detections, which leads on the other hand to over-detections:

- Snowy surfaces at high altitudes (typically above 1 000 m) are wrongly identified as cirrus clouds
- Bright surfaces (sand, white buildings) are sometimes identified as clouds.

Some fine-tuning of the detection algorithms is in progress in order to find the optimal balance between over- and under-detections.

2.4.3 Quantification and Coding

The L1C product quantization value has been set to 10 000: a Digital Number of 10 000 corresponds to a reflectance of 1, while a Digital Number of 1 represents a minimal value of the reflectance (0.001). The Digital Number 0 is a fill value (No Data), used for L1C pixels outside of the instrument observation swath.

Currently no offset is applied when coding the reflectance in Digital Numbers. For dark Band 10 images, instrument noise can lead to negative reflectance measurements in the end product. When converted into Digital Numbers, these negative reflectances appear as “NoData” values in the image. The figure below presents such an example for B10.
Figure 2-6: Band 10 image over an area without high-altitude clouds. The white dots are created by instrument noise which is incorrectly coded as “NoData” value.

An offset enabling a small range of negative reflectances values - and thereby enable a more faithful representation of the instrument noise for low reflectance scenes - is currently being assessed.

Another potential line of investigation is an optimization of the quantization value in order to reduce the size of the products, while keeping an accurate representation of the radiometry.

2.5 Product Features

2.5.1 Introduction

The purpose of this chapter is to describe product features that are induced by the design of the S2 mission and instrument. These features are not anomalies, but they need to be taken into account when interpreting Multispectral Imager (MSI) images.

These features arise from the measurement principle of the MSI. The focal plane is composed of a series of multispectral detectors which are placed in a staggered configuration (see figure below).
As a result:

- Each spectral band sees a given point on the ground at a slightly different time and under a slightly different angle.
- A similar but larger difference exists between odd and even detectors.

### 2.5.2 Striping Effect on Sea Surfaces

The reflection of sunlight over sea surface waves creates a characteristic effect known as sun-glint. The effect is highly dependent on the observation geometry. The consequence is that even and odd MSI detectors are affected differently by sun-glint, which results in “stripe” patterns over ocean surfaces. This intensity of this effect is variable (in particular seasonally) as it is highly dependent on illumination conditions and sea surface conditions.

![Stripe pattern over sea surface.](image)

### 2.5.3 Multi-spectral Registration for Moving Objects and Clouds

Fast moving objects (planes especially) are observed at different times by each spectral band. As a result, the same object appears several times with different colours.
The differences in view angles are correctly handled by the processing chain thanks to a numerical terrain model. However this processing cannot accurately cross-register images of clouds at high altitude. As a result, the spectral bands are slightly shifted, which can give a “rainbow” appearance to the cloud.

![Figure 2-9: Examples of spectral misregistration effects. Left: high-altitude clouds. Right: airplane.](image)

### 2.5.4 Geolocation of High-altitude Clouds

Similarly, the correction performed to adjust images of even and odd detectors is efficient for objects close to the surface. Discontinuities can be seen on clouds at the boundaries of detectors.
Figure 2-10: Screenshot of the visibility changes in geometry between neighbouring detectors (one looking forward and the other backward) on high clouds.

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