COPERNICUS SPACE COMPONENT SENTINEL OPTICAL IMAGING

MISSION PERFORMANCE CLUSTER SERVICE

# Data Quality Report

# Sentinel-2 MSI L2A

# March 2022


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## Changes Log

| Version | Date | Changes |
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| 47.0 | 09/03/2022 | First version |
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## List of Changes

| Version | Section | Answers to RID | Changes |
|---|---|---|---|
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# 1. Introduction

## 1.1 Scope of the Document

This document provides the status of Sentinel-2 mission Level 2A products data quality. It refers to systematic production from processing baselines 02.07 and higher and complements the Data Quality Report for L1C products.

It documents the measured product performances, the status of Level 2A processing chain, and the list of known anomalies on the production.

Additional performance metrics (in particular geometry) are reported in the companion Level 1C Data Quality Report. Similarly, anomalies affecting L1C products documented in that report also impact L2A products.

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). More information about L2A performance validation can be found in G. Doxani et al., "Atmospheric Correction Inter-Comparison Exercise", Remote Sensing, 10 (352), pp 1-18. DOI: doi:10.3390/rs10020352 ISSN 2072-4292. Please note that a former version of Sen2Cor was used during this inter-comparison exercise (not 02.07) and performance have generally improved since then.

## 1.2 Main points for this month

- The baseline 04.00 was successfully deployed the January 25th 2022 (see section 3.1.3 for more details about the L2A evolutions)
- A patch has been prepared and will be deployed shortly to fix the L2A anomalies described in the sections 4.10, 4.11, and 4.12.

# 2. Measured Product Performances

## 2.1 Performances Overview

The following overview table provides a summary of the Level 2A products data quality performances. Note that the performances reported in this issue of the L2A Data Quality Report have been measured with Sen2cor versions 2.5 (toolbox version), and may thus slightly differ from the performance of the current processing baseline.

***Table 2-1: Summary of Sentinel-2 L2A products measured performances for mission key requirements.***

| Requirement | Description | Measured performance |
|---|---|---|
| **Surface reflectance accuracy** | Uncertainty of Bottom-of-Atmosphere reflectance ρ shall be less than $0.05\rho_{reference} + 0.005$ | Uncertainty (U): all bands outside specification<br>Accuracy: B5 and B12 outside specification for U, all other bands within |
| **Water Vapour accuracy** | The difference ΔWV of retrieved Water vapour to reference from AERONET $WV_{ref}$ shall be within $\|\Delta WV\| \leq 0.1*WV_{ref}+0.2$ | 92% of retrieved Water vapour values are within requirement |
| **Aerosol Optical Depth accuracy** | The difference ΔAOT of retrieved Aerosol optical thickness at 550 nm to reference from AERONET AOTref shall be within $\|\Delta AOT\| \leq 0.1*AOTref+0.03$ | 41% of retrieved Aerosol optical thickness values at 550 nm are within requirement |
| **Classification accuracy** | No requirement defined. | omission and commission classification errors are 15% and 16% for recognition of clear pixels over land and water |

Measured performances are detailed in the following sections.

Starting with Processing Baseline 04.00, Sentinel-2 L2A products are compliant with the CEOS-ARD requirements at the threshold level (see https://ceos.org/ard/).

## 2.2 Performances

### 2.2.1 Surface reflectance radiometry accuracy

Quantitative assessment of surface reflectance radiometric performance is provided for Sen2Cor version 2.5 'user' version. AERONET-corrected surface reflectance data serve as a reference for this analysis. They are computed from the Sentinel-2 L1C data (TOA) using the aerosol properties obtained from AERONET in-situ measurements as input to the 6S radiation transport processor.

The analysis is based on the dataset defined for the Atmospheric Correction Inter-comparison Exercise (ACIX-1) (G. Doxani *et al.*, "Atmospheric Correction Inter-Comparison Exercise", Remote Sensing, 10 (352), pp 1-18. DOI: doi:10.3390/rs10020352 ISSN 2072-4292). Plots were generated for all Sentinel-2 bands showing the average accuracy, precision and uncertainty values (APU) over all images within the validation data set per surface reflectance bin. Accuracy value is equivalent to the mean bias, precision value is equivalent to the repeatability or variation around the mean bias and uncertainty is quadratic sum of Accuracy and Precision.

Average APU per band is shown in Figure 1, while Figure 2 shows the average APU per band relative to the average surface reflectance of the band. Uncertainty is outside specification for all bands due to the large precision value. Less variation of results would remarkably improve the situation because accuracy value is well within the specification except band 5 and band 12. Both uncertainty and accuracy value show an increasing trend with wavelength (band number). Thus, best performance is achieved for VIS bands with lowest accuracy and precision values and lowest uncertainty. Average accuracy value relative to average surface reflectance reference is below or near to 5% except for bands 5 and 12 (Figure 2).

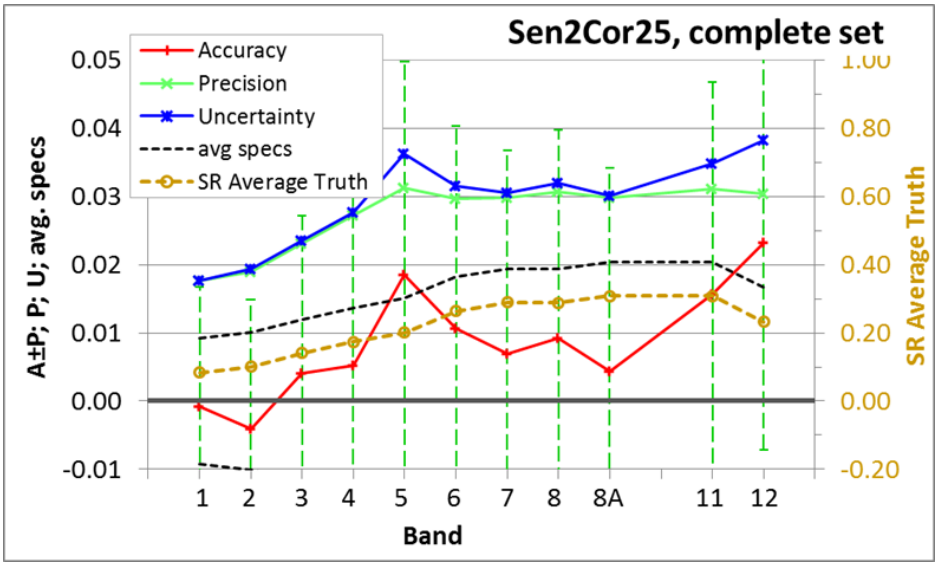


***Figure 1: Average accuracy, precision, uncertainty (solid lines, left hand side scale) and surface reflectance reference (dashed line, right hand side scale) per band for Sen2Cor version 2.5 based on the ACIX-dataset.***

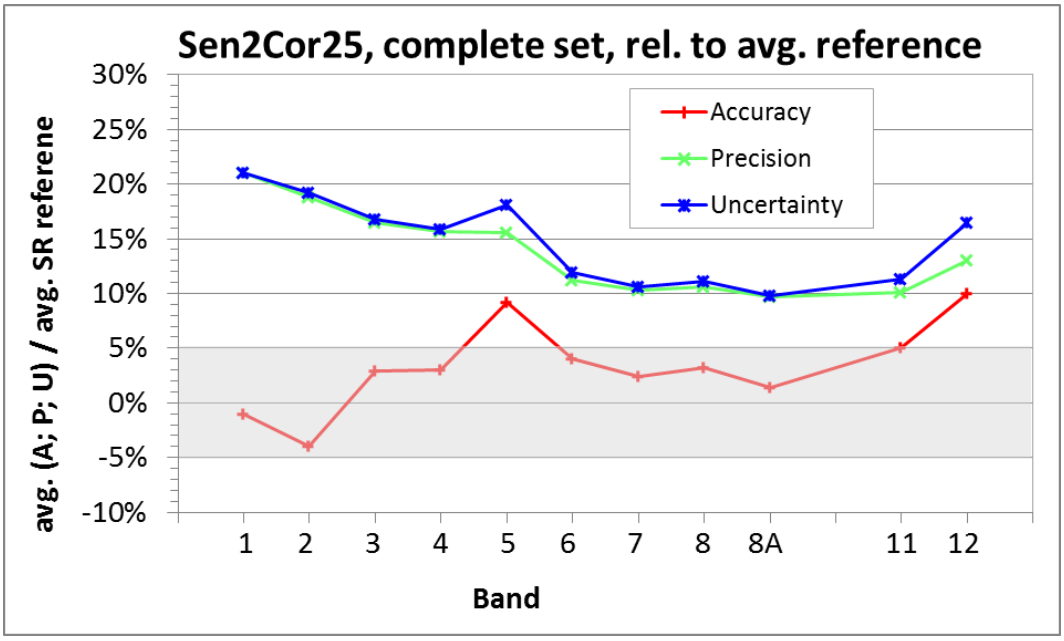


***Figure 2: Average accuracy, precision and uncertainty relative to average surface reflectance reference per band for Sen2Cor version 2.5 based on the ACIX-dataset.***

### 2.2.2 Water Vapour accuracy

Quantitative assessment of water vapour retrieval accuracy is determined by direct comparison of Sen2Cor output averaged over 9 km x 9 km region of interest around Sun photometer with reference value from AERONET Sun photometer.

The analysis is based on a large dataset of 559 match-ups at 25 AERONET locations distributed over all continents and all climate zones except Midlatitude S.

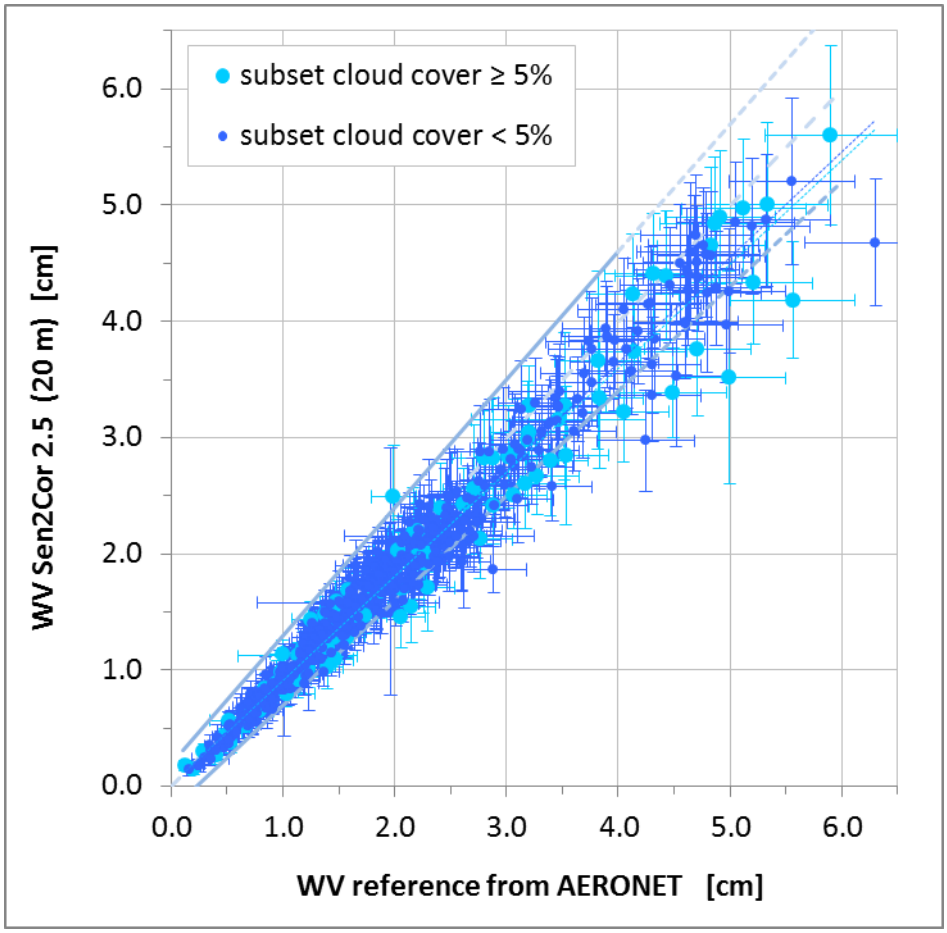


***Figure 3: Correlation plot of Sen2Cor WV retrieval at 20 m resolution over WV reference from AERONET on basis of a data set at 25 AERONET sites.*** *The dashed line indicates x=y and the solid lines show the limits of uncertainty requirement $|\Delta WV| \leq 0.1 * WV_{ref} + 0.2$.*

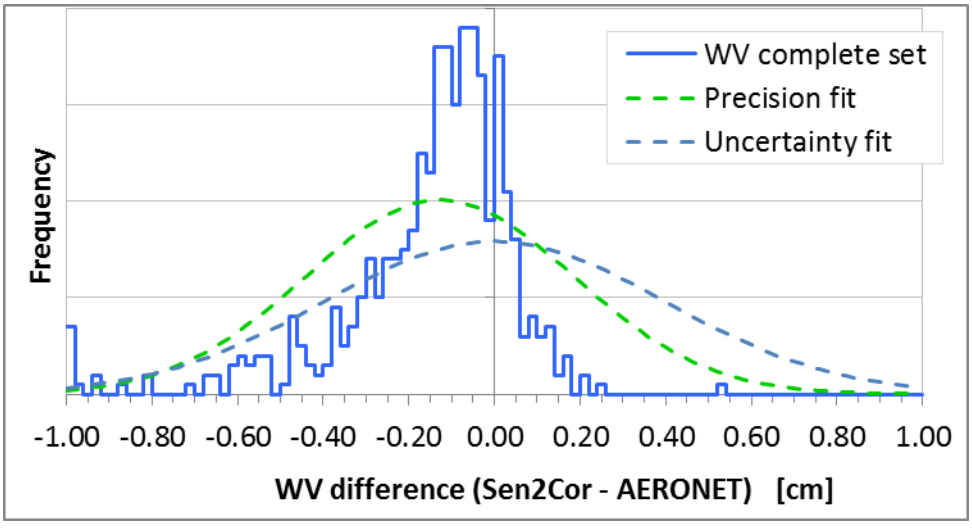


***Figure 4: Histogram plot of WV (at 20 m resolution) retrieval difference to the reference value from AERONET.*** *The green dashed curve gives a normal distribution computed with accuracy as mean value and precision as standard deviation. The blue dashed curve represents a normal distribution around zero with uncertainty as standard deviation.*

***Table 2-2: Statistical numbers reporting on WV-validation for Sen2Cor 2.5 on basis a data set at 25 AERONET sites.***

| WV statistics | |
|---|---|
| Total no. of granules | 559 |
| WV retrievals within requirement | 92% |
| $R^2$ (Coefficient of variation) | 0.97 |
| r (Pearson's corr. coeff.) | 0.98 |
| MA (Median Accuracy value) | -0.13 cm |
| MP (Median Precision value) | 0.22 cm |
| Uncertainty (U) | 0.28 cm |
| Max WV difference | 1.63 cm |

Water vapour retrieval is very accurate with correlations over 0.98 and with 92% of retrievals within the requirement. Validation shows a trend for little underestimation of WV by Sen2Cor. The large maximum difference of WV retrieval occurs at WV reference value above 6 cm, which is an extreme value even for the tropics.

### 2.2.3 Aerosol Optical Depth accuracy

Quantitative assessment of aerosol optical depth retrieval accuracy is determined by direct comparison of Sen2Cor output averaged over 9kmx9km region of interest around Sun photometer with reference value from AERONET Sun photometer. The analysis is based on a large dataset of 559 match-ups at 25 AERONET locations distributed over all continents and all climate zones except Midlatitude S.

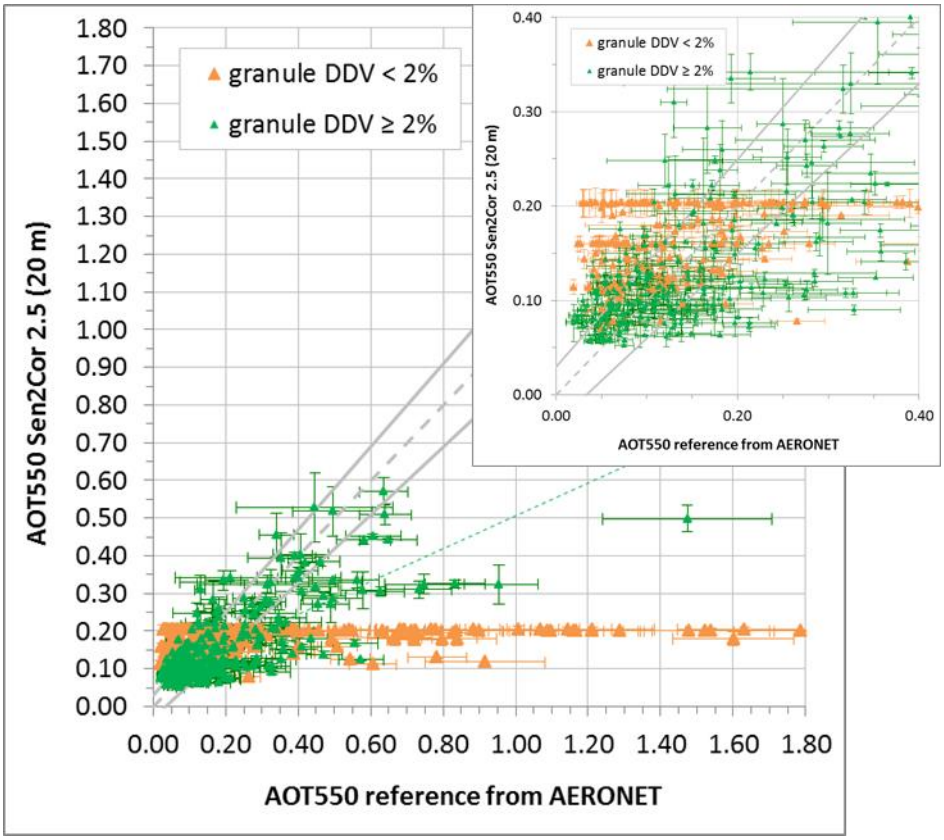


***Figure 5: Correlation plot of Sen2Cor $AOT_{550}$ retrieval at 20 m resolution over $AOT_{550}$ reference from AERONET on basis of a data set at 25 AERONET sites.*** *Green triangles are $AOT_{550}$ retrieved with the DDV-algorithm and orange triangles are $AOT_{550}$ resulting from the present fall-back solution (process with configured start VIS of 40 km). The dashed grey line indicates x=y and the solid grey lines show the limits of uncertainty requirement $|\Delta AOT_{550}| \leq 0.1 * AOT_{550ref} + 0.03$. (Inset: zoom on low AOT values).*

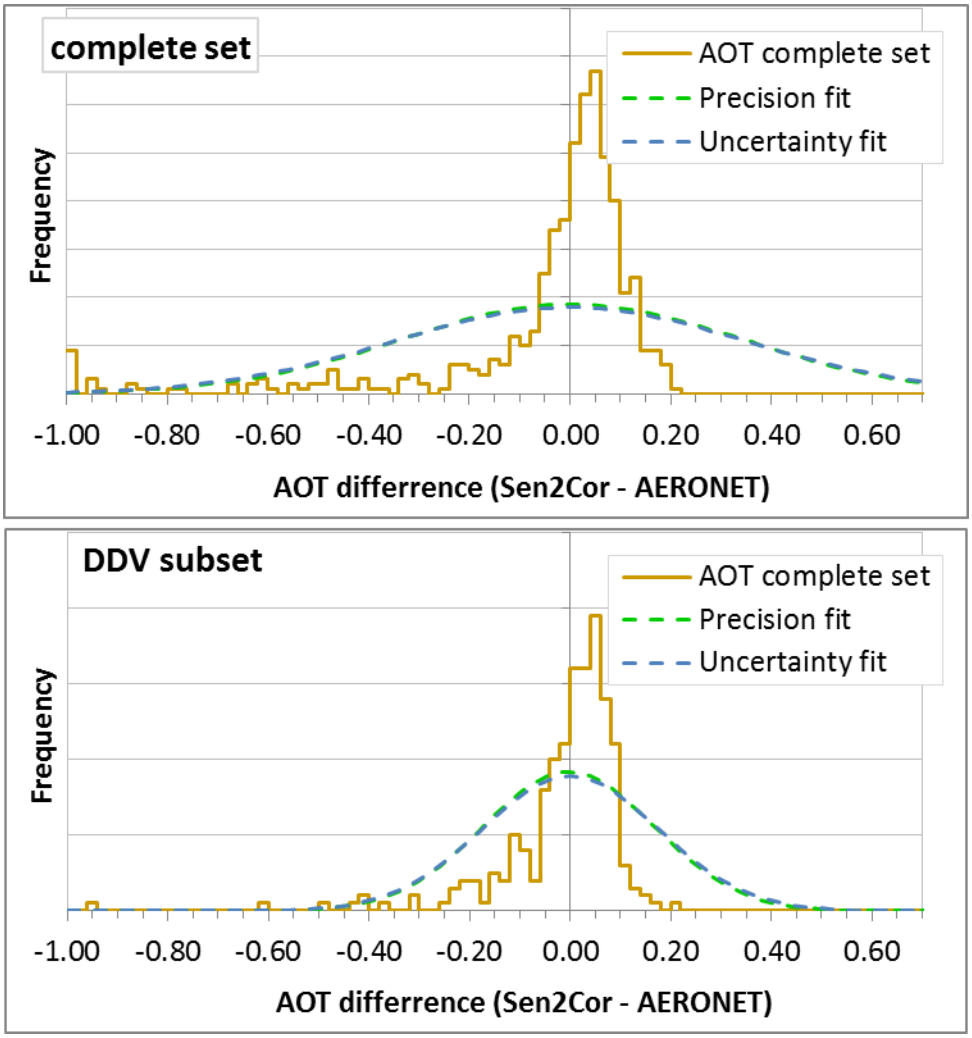


***Figure 6: Histogram plots of $AOT_{550}$ (at 20 m resolution) retrieval difference to the reference value from AERONET.*** *The blue dashed curves give normal distributions around zero with uncertainty as standard deviation. The upper plot shows results for the complete data set and the lower plot for the subset of images containing more than 2% DDV-pixels.*

***Table 2-3: Statistical numbers reporting on $AOT_{550}$-validation for Sen2Cor 2.5 on basis of the ACIX data set excluding water sites.*** *The DDV set is a subset of the complete data set limited to images which contain more than 2% DDV-pixels.*

| AOT statistics | Complete set | DDV set |
|---|---|---|
| Total no. of granules | 559 | 277 |
| Retrievals within requirement | 41% | 48% |
| $R^2$ (Coefficient of variation) | 0.21 | 0.57 |
| r (Pearson's correlation coeff.) | 0.46 | 0.76 |
| MA (Median Accuracy value) | 0.003 | -0.003 |
| MP (Median Precision value) | 0.24 | 0.12 |
| U (Uncertainty) | 0.25 | 0.12 |
| Max $AOT_{550}$ difference | 1.59 | 0.98 |

Aerosol optical depth retrieval results are very different between the complete data set and the dataset limited to images with at least 2% of dense dark vegetation (DDV) pixels. The AOT-retrieval algorithm implemented in Sen2Cor requires DDV-pixels in the image. If there are not enough DDV-pixels present, then the processing is done with a fixed AOT leading to large AOT errors (Figure 5, Figure 6, Table 2-3).

Accuracy ± precision and uncertainty values are 0.00±0.12 and 0.12 for the DDV subset (Table 2-3), which is a very good performance increase since Sen2Cor version 2.4. Correlations are significant higher for the DDV-subset and it contains more retrievals within requirement. Nevertheless, there are only about 50% of retrievals within requirement.

A processor evolution is in development to improve the results for arid regions where no DDV-pixels are present in the image.

### 2.2.4 Classification accuracy

Classification accuracy is evaluated by comparison of the Sen2Cor outputs with reference samples. The reference samples are generated by visual inspection and labelling of a validation data set, which was determined by stratified random sampling.

Current analysis of classification accuracy for Sen2Cor 2.5 using CCI data as auxiliary information is based on 14 Sentinel-2 L2A images over 13 test sites (Table 2-4).

***Table 2-4: Selected test sites for Sen2Cor 2.5 validation***

| Site | Tile | Date (MM/DD/YYYY) | L1C Cloud cover |
|---|---|---|---|
| Antarctic | 21EVK | 2/4/2016 | 9.9 |
| Barrax (Spain) 1 | 30SWH | 5/9/2017 | 17.7 |
| Barrax (Spain) 2 | 30SWH | 5/19/2017 | 1.6 |
| Berlin (Germany) | 33UUU | 5/4/2018 | 0.9 |
| Casleo (Argentina) | 19HDE | 8/12/2016 | 21.7 |
| Dunhuang (China) | 46TFK | 1/22/2018 | 29.4 |
| Manila (Phillipines) | 51PTS | 3/19/2018 | 1.4 |
| Rimrock (USA) | 11TMM | 5/12/2018 | 0.7 |
| Yakutsk (Russia) | 52VEP | 3/8/2016 | 61.5 |
| Etna Volcano (Italy) | 33SVB | 3/9/2017 | 6.9 |
| Kilauea Volcano (USA - Hawaii) | 05QKB | 4/23/2018 | 28.4 |
| Lagos (Portugal) | 29SNB | 8/8/2018 | 0.0 |
| Buenos Aires (Argentina) | 21HUC | 8/27/2018 | 0.0 |
| Tallin (Estonia) | 35VLG | 7/14/2018 | 2.1 |

Beside the Copernicus Sentinel-2 L2A images over core-test sites (defined in Calibration and Validation Plan ROCVP) for the regular validation of scene classification, 6 additional sites – Antarctic, two volcano sites and three coastal sites – were selected. Validation data set represents different atmospheric conditions (e.g. cloud cover), latitudes (various solar angles and seasons), topography (flat, rough and mountainous terrain), and land cover types (agricultural area, forests, water bodies, arid area, urban area, deserts, permanent ice, and active volcanos).

The accuracy assessment per test site is presented in Table 2-5. OA of clear pixels over land and water aggregate results for the Sen2Cor classes vegetation, non-vegetated and water. OA of clouds aggregates results for Sen2Cor classes cloud_medium_probability, cloud_high_probability and thin cirrus. The average overall accuracy for 14 classification products reached 81.1±14.1%. The

recognition of clear pixels over land and water reached OA of 91.5% and a consolidated OA for clouds recognition is 94.8% (Table 2-5).

***Table 2-5: Accuracy assessment per test site for SCL product with 11 classes, and for clear land and water pixels, and clouds separation.***

| Site | | OA | OA clear pixels | OA clouds | Pixel validated |
|---|---|---|---|---|---|
| Antarctic | | 94.7 | 96.8 | 98.8 | 527803 |
| Barrax (Spain) -1 | | 64.6 | 96.9 | 98.7 | 141546 |
| Barrax (Spain) -2 | | 90.5 | 98.7 | 99.5 | 104799 |
| Berlin (Germany) | | 93.4 | 96.5 | no clouds | 51964 |
| Casleo (Argentina) | | 63.8 | 86.1 | 98.1 | 186238 |
| Dunhuang (China) | | 57.3 | 66.2 | no clouds | 105454 |
| Manila (Phillipines) | | 82.1 | 90.0 | 91.6 | 106263 |
| Rimrock (USA) | | 90.2 | 98.2 | 99.2 | 103394 |
| Yakutsk (Russia) | | 69.9 | 93.8 | 92.9 | 177983 |
| Etna Volcano (Italy) | | 95.8 | 97.9 | 99.4 | 132340 |
| Kilauea Volcano (USA - Hawaii) | | 60.4 | 75.4 | 74.2 | 118357 |
| Lagos (Portugal) | | 96.8 | 97.3 | no clouds | 69753 |
| Buenos Aires (Argentina) | | 91.8 | 97.3 | no clouds | 31841 |
| Tallin (Estonia) | | 84.3 | 90.4 | 95.6 | 71773 |
| | | | | | |
| | Average | 81.1 | 91.5 | 94.8 | 137822 |
| | Stdev | 14.1 | 9.4 | 7.4 | |

Commission and omission errors (corresponding to user's and producer's accuracies respectively) are presented in Table 2-6. Commission for recognition of clear pixels over land and water reached about 16% and omission error was 15%. Commission for recognition of clouds reached 25% while omission error was 11%. In total 1,929,508 pixels were validated.

***Table 2-6: Summarized results of omission and commission classification errors for clear pixels and clouds detection for 14 Sentinel-2 images.***

| **Clear pixels over land and water** | | | | |
|---|---|---|---|---|
| | Clear pixels Land-Water | Others | Sum | **Commission** |
| Clear pixels Land-Water | 733113 | 78587 | 811700 | 16.136 |
| Others | 72526 | 1045282 | 1117808 | 26.874 |
| Sum | 805639 | 1123869 | 1929508 | |
| **Omission** | 15.011 | 18.818 | | |
| **All clouds** | | | | |
| | Clouds | Others | Sum | **Commission** |
| Clouds | 491769 | 30212 | 521981 | 25.013 |
| Others | 54967 | 1352560 | 1407527 | 5.082 |
| Sum | 546736 | 1382772 | 1929508 | |
| **Omission** | 10.788 | 2.642 | | |

# 3. Processing Chain Status

## 3.1 Processing baseline

Note that ESA-L2A core products which can be downloaded from SciHub have not all been processed with the same Sen2Cor processor version. There is no reprocessing of the archive after a new Sen2Cor release.

### 3.1.1 Configuration and differences with Sen2cor 'User' version

Sen2cor configuration applied for ESA-L2A core production

- has Terrain correction activated
- uses CCI AUX data to support scene classification

since Baseline 02.11. Individual configuration parameters are set as follows:

| | |
|---|---|
| Log_Level | INFO |
| DEM | Planet-DEM |
| Generate_DEM_Output | FALSE |
| Generate_TCI_Output | TRUE |
| Generate_DDV_Output | FALSE |
| Downsample_20_to_60 | TRUE |
| Aerosol_Type | RURAL |
| Mid_Latitude | SUMMER |
| Ozone_Content | get the best approximation from metadata |
| WV_Correction | 1: only 940 nm bands |
| VIS_Update_Mode | 1: variable visibility |
| WV_Watermask | 1: land-average |
| Cirrus_Correction | FALSE |
| DEM_Terrain_Correction | TRUE |
| BRDF_Correction | 0: no BRDF correction |
| Adj_Km | 1.000 |
| Visibility km | 40.0 |
| Smooth_WV_Map | 100.0 |
| WV_Threshold_Cirrus | 0.25 |

Some differences can be found between L2A products generated by users with current Sen2cor version and the ESA-L2A core products from the 02.11 baseline:

- The Digital Elevation Model (DEM) is different, which can impact terrain correction results (users have access to SRTM-DEM whereas ESA-L2A core production uses Planet-DEM),
- The JP2000 compression library is different, which leads to a slightly different size of the products and a different compression noise,
- Anomaly #4 is corrected in baseline 02.11, while this anomaly will be corrected in a future version of the toolbox version.

### 3.1.2 New processing baseline 03.01

On June 30th 2021, a new processing baseline 03.01 has been introduced. The checksum algorithm has been changed from md5 to SHA3.

### 3.1.3 Major evolution: processing baseline 04.00

Processing Baseline 04.00 will be activated on January 25th, 2022. This major evolution will lead to a modification of the L2A products format.

The new L2A products will inherit the modifications of the L1C processing baseline 04.00, described in the L1C Data Quality Report, in particular the provision of quality masks in raster (JP2) format.

- Provision of negative radiometric values (implementing an offset): The dynamic range will be shifted by a band-dependent constant: BOA_ADD_OFFSET. This offset will allow encoding negative surface reflectances that may occur over very dark surfaces. From the user's point of view, the L2A Bottom of Atmosphere (BOA) reflectance (L2A_BOA) shall be retrieved from the output radiometry as follows:
  - Digital Number DN=0 remains the "NO_DATA" value
  - For a given DN in [1; 1;2^15-1], the L2A BOA reflectance value will be: L2A_BOAi = (L2A_DNi + BOA_ADD_OFFSETi) / QUANTIFICATION_VALUEi

  The radiometric offset value will be reported in a new field in the General_Info/Product_Image_Characteristics section of the Datastrip and User Product Metadata. It will be initially set to -1000 Digital counts for all bands.
- It is also noted that the percentage of negative surface reflectance pixels per band will be also reported in the L2A_QUALITY report in the QI_DATA folder of the tile.
- Provision of Band 01 at 20 m spatial resolution: Band 01 will be added with 20m resolution (in the 20 m resolution image folder) in addition to the native 60 m resolution.
- Addition of Level-2A Quality Indicators (new fields in the tile metadata and additional xml L2A_QI_report in the QI_DATA folder): New Quality Indicators CLOUDY_PIXEL_OVER_LAND_PERCENTAGE, AOT_RETRIEVAL_METHOD, GRANULE_MEAN_AOT, GRANULE_MEAN_WV, OZONE_SOURCE, and OZONE_VALUE, will be added in the Level-2A tile metadata in the Quality_Indicators_Info section. In addition, Quality Indicators providing

information on the Scene Classification, Atmospheric Correction and Auxiliary Data will be reported in a new L2A_QUALITY.xml report in the QI_DATA folder of the tile.

- Aerosol correction using CAMS auxiliary data: The Level-2A processor will use the CAMS Total Aerosol Optical Depth (AOD) at 550nm when Dark Dense Vegetation (DDV) pixels are missing in the image. This improvement will mitigate the chess-board effect that is sometimes visible between tiles. The list of additional CAMS parameters is detailed in the table below.

***Table 3-1: Correspondence table between CAMS variable name and physical parameter name.***

| Band number | GRIB parameter ID | Physical parameter name and units if applicable |
|---|---|---|
| 1 | Z | Geopotential (at the surface = orography) [m^2/s^2] |
| 2 | var213 | Total Aerosol Optical Depth at 469nm (aod469) |
| 3 | var207 | Total Aerosol Optical Depth at 550nm (aod550) |
| 4 | var214 | Total Aerosol Optical Depth at 670nm (aod670) |
| 5 | var215 | Total Aerosol Optical Depth at 865nm (aod865) |
| 6 | var216 | Total Aerosol Optical Depth at 1240nm (aod1240) |
| 7 | var211 | Black Carbon Aerosol Optical Depth at 550nm (bcaod550) |
| 8 | var209 | Dust Aerosol Optical Depth at 550nm (duaod550) |
| 9 | var210 | Organic Matter Aerosol Optical Depth at 550nm (omaod550) |
| 10 | var208 | Sea Salt Aerosol Optical Depth at 550nm (ssaod550) |
| 11 | var212 | Sulphate Aerosol Optical Depth at 550nm (suaod550) |

- Improvement of the bright target classification over coastal areas: The cloud detection over coastal areas of bright targets (e.g. buildings and bright sand) is improved to mitigate against false detections.
- Topographic and cast shadows
  - Improvement of the Topographic and cast shadows classification as shown in Figure 7:

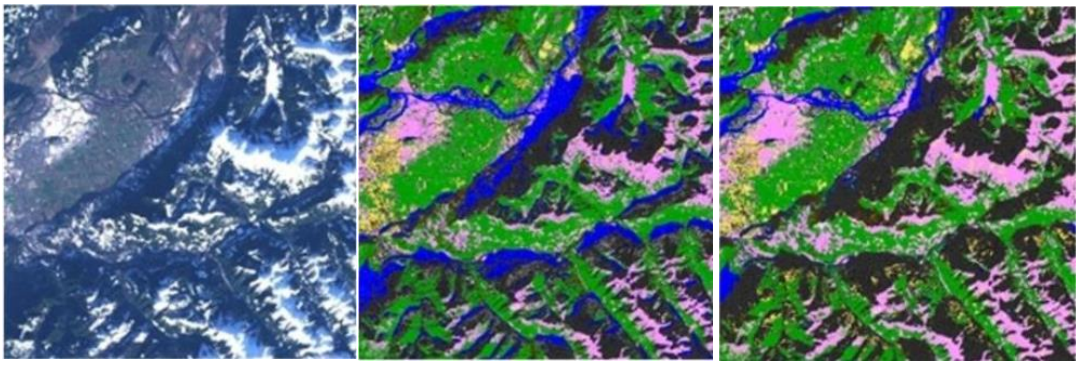

***Figure 7: Improvement of topographic shadow classification. Left: L1C True Colour image. Middle: Scene Classification Layer PB 03.00 with false water detections in topographic shadows. Right: Scene Classification Layer for PB 04.04 with correctly classified topographic shadows.***

- The label "dark features and shadows" (SCL = 2) is replaced by "topographic and cast shadows" (keeping code SCL = 2).

| Label | Classification |
|---|---|
| 0 | NO_DATA |
| 1 | SATURATED_OR_DEFECTIVE |
| 2 | CAST_SHADOWS |
| 3 | CLOUD_SHADOWS |
| 4 | VEGETATION |
| 5 | NOT_VEGETATED |
| 6 | WATER |
| 7 | UNCLASSIFIED |
| 8 | CLOUD_MEDIUM_PROBABILITY |
| 9 | CLOUD_HIGH_PROBABILITY |
| 10 | THIN_CIRRUS |
| 11 | SNOW |

***Figure 8: Scene Classification Map (SCL)***

- Improvement of clouds and cloud shadows detection: Thanks to the use of the Sentinel-2 MSI parallax properties between bands B08 (resampled at 20m) and B8A (20m native resolution), the accuracy of the cloud detection algorithm has been improved, reducing the false clouds detection of bright targets - especially in urban areas - as well as reducing the snow false detection in high altitude clouds. Also, the cloud shadow algorithm benefits from using the parallax properties, by retrieving an estimate of the cloud top-height to improve the localization of clouds shadows on ground.

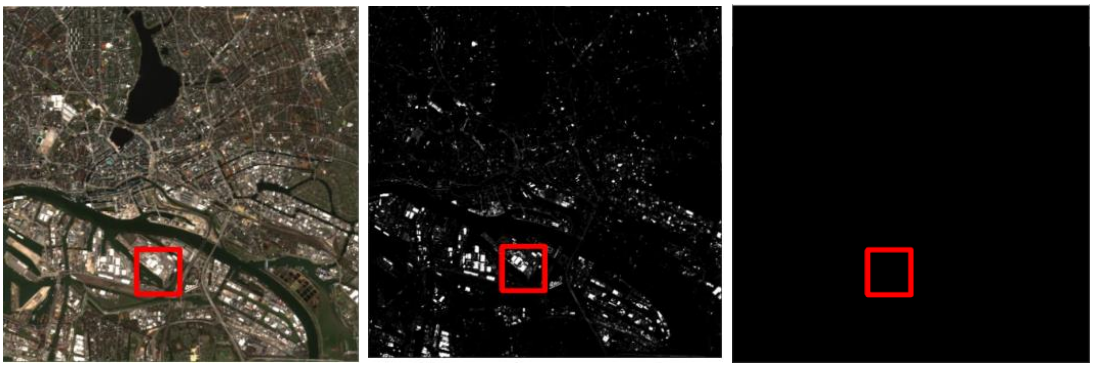

***Figure 9: Improvement of the cloud detection. Left: L2A true colour image. Middle: Cloud Probability Layer of PB 03.00 product showing false cloud detections on bright targets. Right: Cloud Probability layer for PB 04.00 without false detections.***

- Addition of the DOI (Digital Object Identifier) in the Level-2A metadata: Similarly to Level-1C product, a DOI will be reported in a new field in the General_Info section of the Datastrip and User Product Metadata.

## 3.2 Status of Processing Baselines and Known Processing Anomalies

The following table provides the status of known L2A processing anomalies. Note that some L1C anomalies directly affect the quality of the L2A products.

***Table 3-2: Anomaly and processing baseline summary.***

| Anomaly ID | Baseline number | 02.07 | 02.08 | 02.09 | 02.10 | 02.11 | 02.12, 02.13, 02.14 |
|---|---|---|---|---|---|---|---|
| | Deployment date | 26/03/2018 | 23/05/2018 | 08/09/2018 | 06/11/2018 | 21/112018 | 06/05/2019 |
| | Anomaly title | | | | | | |
| 55 | Wrong tile ID metadata | All products until 05/04/2018 | | | | | |
| 56 | Incorrect No Data mask | Limited occurrences for pixels near the edge of the swath (Until 19/09/2018) | | | | | |
| 59 | Encoding of Quality Bands | Until 19/09/2018 | | | | | |
| 60 | Terrain Correction over clouds | A few products | | | | | |
| 61 | Naming of quality mask files | | | A few products | | | |
| 62 | Cloud Probability mask | Some products | | | | | |
| 63 | Products processed without DEM | | | | | | Until 09/05/19 |
| 65 | Incorrect SCL at high Sun Zenith Angle | High SZA | | | | | |

# 4. Product Anomalies

## 4.1 Introduction

This chapter describes anomalies observed on the L2A production. Note that some L1C anomalies affect also the quality of L2A products. Whenever this is the case, any reprocessing to correct an anomaly will include level 2 products.

An on-line version of the anomaly register is available on-line at this url:
https://sentinels.copernicus.eu/web/sentinel/user-guides/sentinel-2-msi/sentinel-2-anomalies/home/

This register includes all anomalies (L1C and L2A). Note that in previous issues of the L2A DQR (prior to November 2019), L2A anomalies were numbered separately.

Two recent L1C anomalies are also affecting L2A products:

- Anomaly 70: products with zero solar irradiance
- Strong geolocation error on orbit S2A orbits 31188 and 32722

More details about these anomalies can be found in the L1C Data Quality Report.

## 4.2 Incorrect Tile ID metadata (#55)

This minor anomaly affects the L1C_TILE_ID field of the tile metadata. The processing baseline of the source L1C product is incorrectly reported as 02.07 instead of 02.06. The issue has been corrected on 05/04/2018.

## 4.3 Incorrect No Data mask (#56)

In the Scene Classification mask (SCL) some pixels near the edge of the swath may be incorrectly flagged as “water” instead of “No Data”. The issue has been fixed on 19/09/2018.

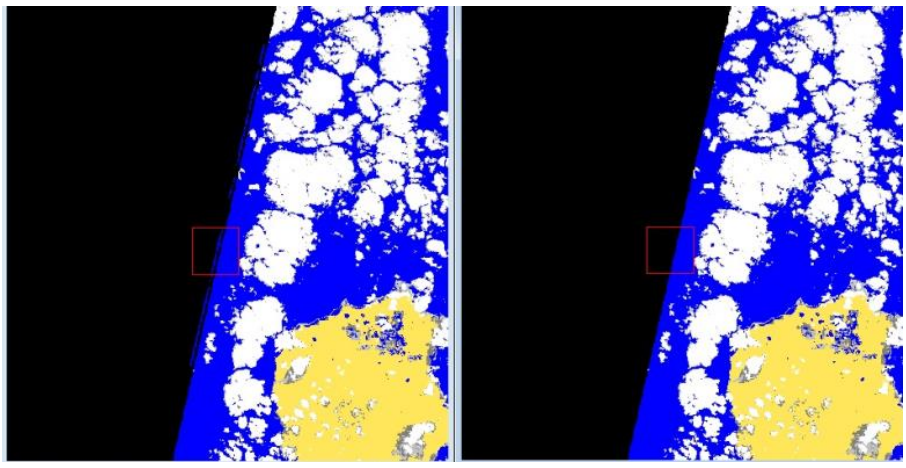

***Figure 10: Incorrect No Data Mask (anomaly #2)****. Left: pixels incorrectly flagged as water (blue) near the swath edge. Right: same image after correction.*

## 4.4 Encoding of Quality Bands (#59)

In products from processing baselines 02.07 and 02.08, the quality bands are coded over 16 bits instead of 8 bits as specified in the Product Definition Document (PDD). This minor anomaly affects the following bands: SCL, CLD, SNW, PVI, TCI. The correction has been deployed on 19/09/2018.

## 4.5 Terrain correction over clouds (#60)

This anomaly creates spurious topographic correction over cloudy pixels. Please note the impact of this anomaly is limited to the visual appearance of the images. Cloudy pixels are flagged in the scene classification mask and shall not be used for quantitative remote sensing.

Terrain correction has been de-activated for cloudy pixels with processing baseline 02.10.

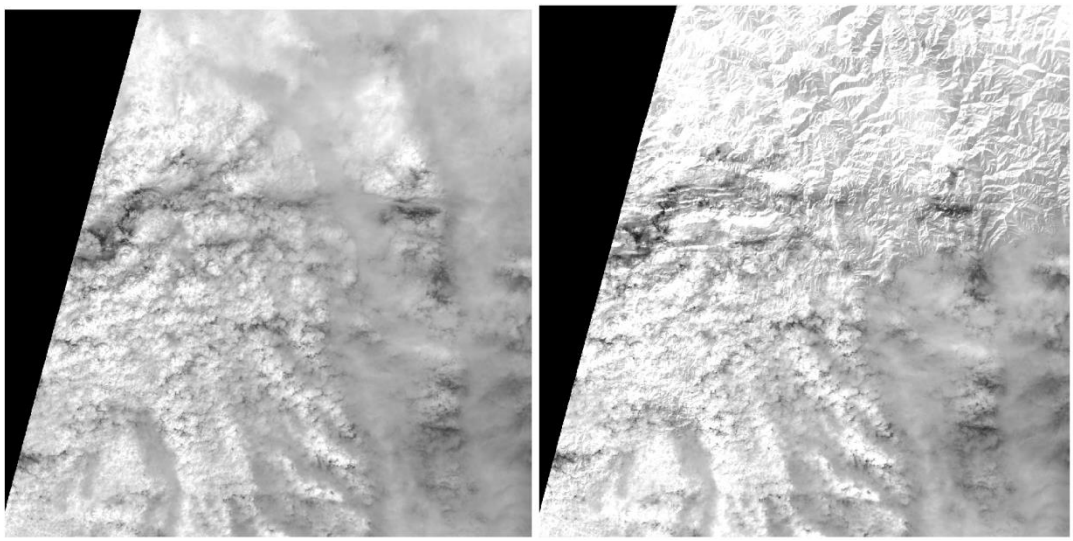

***Figure 11: Band B04, Tile 32TLP from orbit S2B 7098.*** *Left: L1C image; Right: L2A image. The topography seems to be visible through the opaque clouds. (Anomaly #4)*

## 4.6 Naming of quality masks files (#61)

This anomaly affects the naming of the quality mask files in the QI_DATA folder. The “long name” convention (e.g. S2A_OPER_MSK…) is used instead of the “short name” convention (MSK_DEFECT…). This anomaly has been found on L2A products of orbit S2B 8458 only. It is currently under investigation.

## 4.7 Incorrect cloud probability near the boundary of the swath (#62)

This issue affects the computation of the cloud probability (CLDPRB mask) near the boundary of the swath. The mask extends outside the area of valid data. Users are advised to disregard the cloud probability values for pixels which are flagged as No Data in the spectral band images. This issue is fixed with PB 03.00.

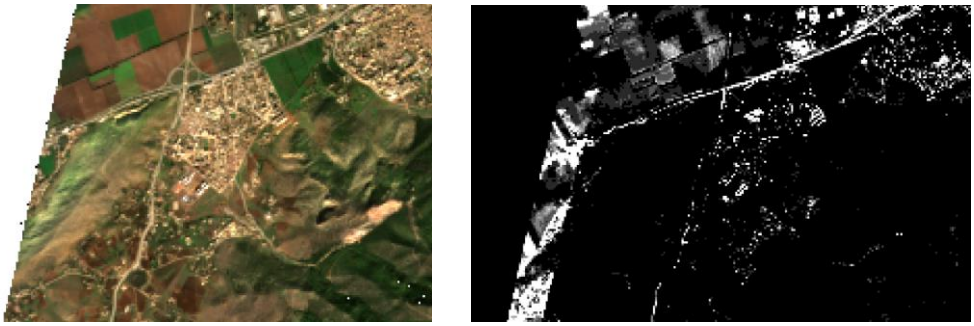

***Figure 12: Incorrect values of the cloud probability mask (CLDPRB) near the boundary of the swath. Left: L2A true colour image, Right: CLDPRB mask.***

## 4.8 Products processed without DEM (#63)

Due to a ground segment anomaly, some L2A products with sensing time between 00:46:48 UTC on 6 May and 10:06:28 UTC on 9 May have been processed without DEM and ESA CCI data package.

The main impacts on product quality are as follows:

- The quality of the cloud screening and scene classification is reduced (lower accuracy for water detection and cloud discrimination)
- Surface reflectances are less accurate due to a processing with a default altitude
- Terrain correction is not applied. This effect is clearly visible in the next figure.

***Figure 13: Left: affected product processed without DEM.***
***Right: corrected product processed with DEM (anomaly #7).***

The affected products have been replaced by reprocessed products.

## 4.9 Scene classification at high Sun-Zenith Angle (#65)

This anomaly affects products acquired at high Sun-Zenith Angle (SZA). Due to a processing anomaly, the scene classification contains pixels incorrectly classified as “Dark Features”. A fix has been identified and will be deployed in the next processing baseline.

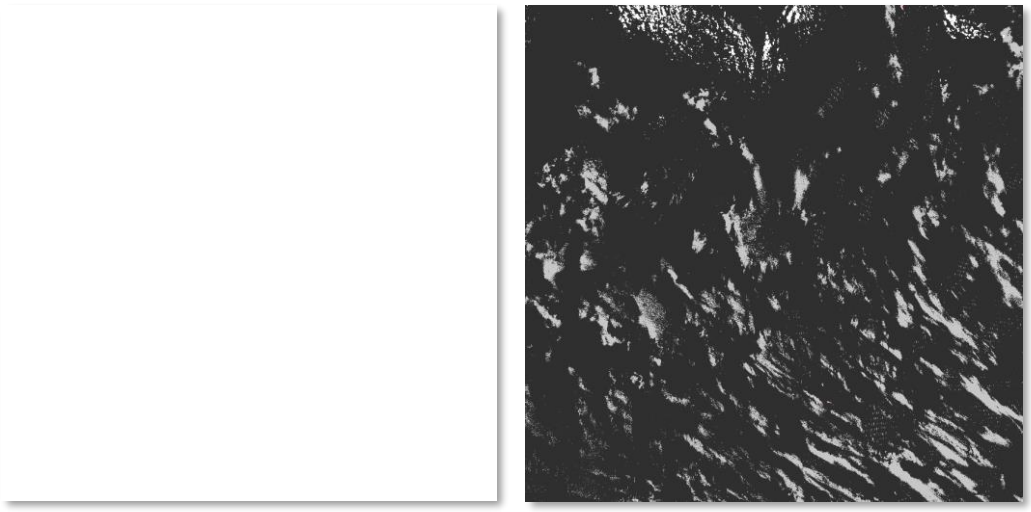

***Figure 14: Incorrect Scene Classification for products at high Sun-Zenith Angle***
***Left: True Colour Image (Snow and clouds).***
***Right: Scene Classification. Black pixels are incorrectly classified as "Dark Features".***
*Ref: (S2B_MSIL2A_20191105T022549_N0213_R017_T46DEH_20191105T064747, Australian Antarctic Territory).*

## 4.10 Halo near image boundaries (#66)

A light halo can sometimes be observed along image boundaries, either edge of the swath or end of data-strips. The issue is fixed with PB >= 03.00 for most of the cases. A fix has been prepared to cover all the possible cases.

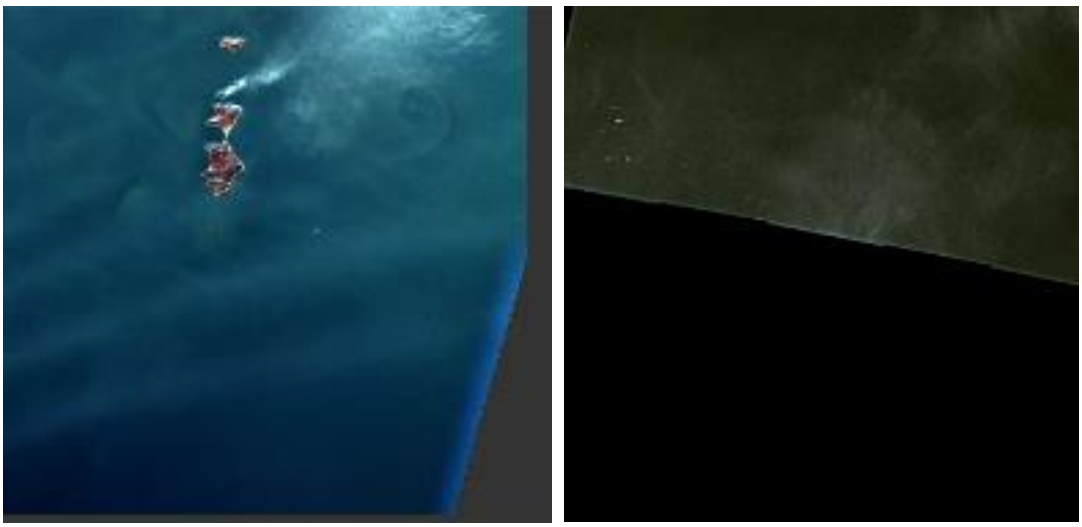

***Figure 15: Halo near a swath edge (left) or data-strip end (right). Anomaly #66.***

## 4.11 No data pixels identified in the swath

Some no data pixels were identified in one L2A product since the deployment of the baseline 04.00 (reoccurrence of anomaly #5, but affecting only L2A products).

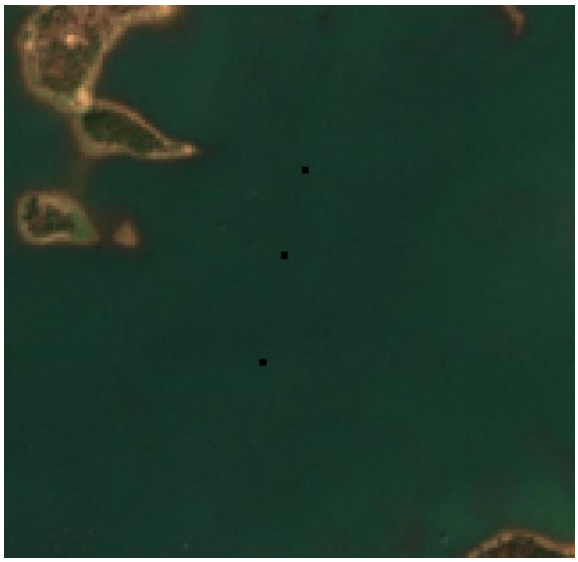

***Figure 16: No data pixels identified in the swath [band B12]***
*Product: S2A_MSIL2A_20220125T032021_N0400_R118_T48PWC_20220125T060655.SAFE*

The issue rises in Sen2Cor when reading the L1C JP2000 image using the offset of 1000 DN (PB >=04.00). This leads to those L1C pixels with a value of exactly DN = 1000, being converted to a TOA reflectance of 0.0, which is interpreted by Sen2Cor processor as NoData. A fix has been prepared to correctly handle those pixels.

## 4.12 L2A surface reflectance overflow > 32768 (#74)

Some occurrences of yellow pixels over extra bright clouds have been identified when looking at the True Colour Image (TCI) visualization in EOBrowser since the deployment of the baseline 04.00. These pixels seem related to an overflow (or rollover) of the integer 16-bit, DN > 32768, when surface reflectance data is converted from float to 16-bit signed integer. It corresponds to a “surface” reflectance higher than 318%.

Please note that these yellow pixels are correctly flagged as clouds in the Scene Classification Map (SCL).

After further investigation, it turns out that the issue is not related to Sen2Cor processing but to the JPEG2000 encoding. A temporary fix in Sen2Cor processing has been prepared by clipping data to a value of 32767 DN.

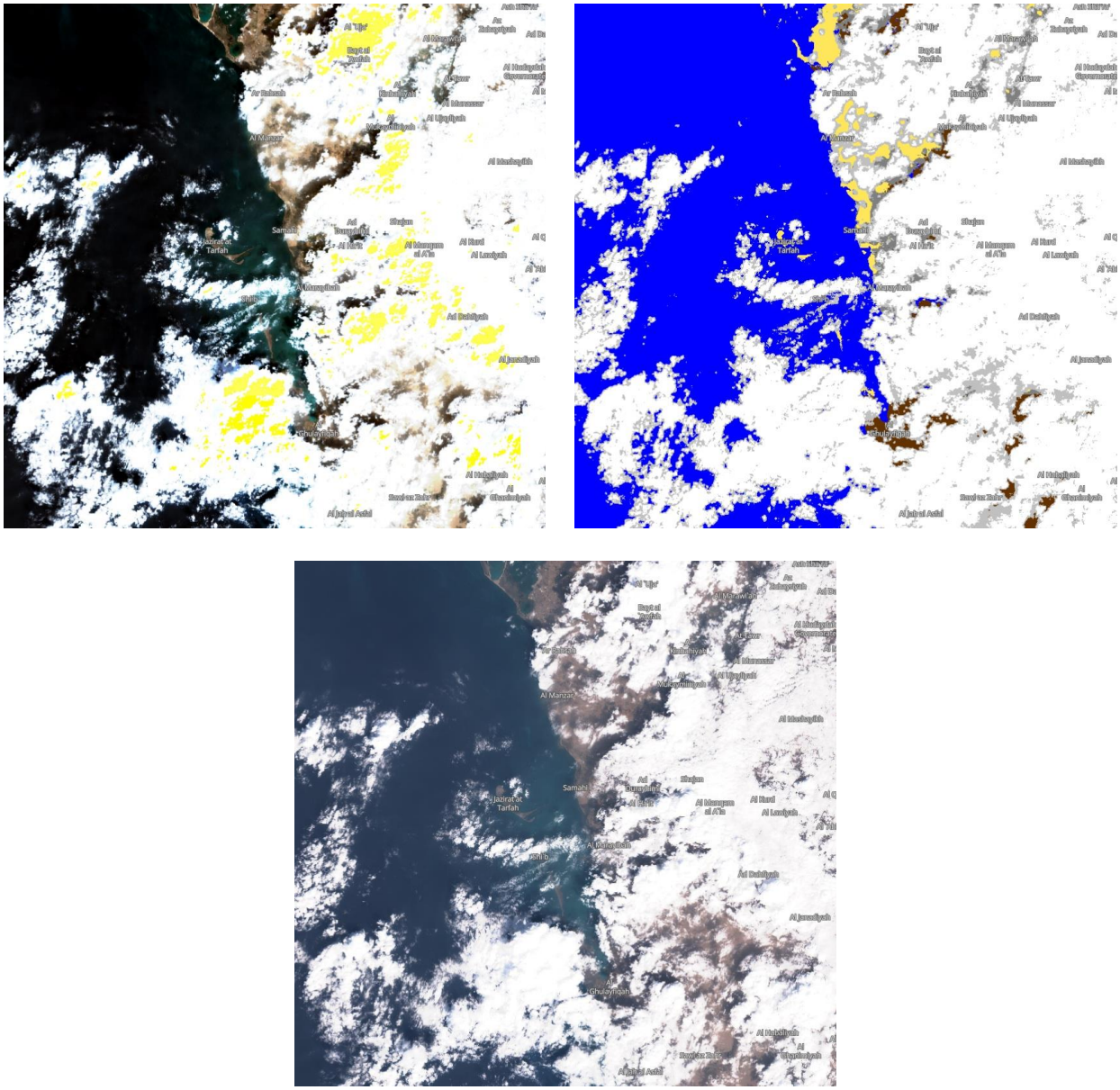

***Figure 17: Illustration of the L2A surface reflectance overflow > 32768 in the L2A TCI image (top left). The L2A SCL image (top right) and the associated L1C (bottom middle) are also shown.***

*L1C product: S2B_MSIL1C_20220125T073109_N0400_R049_T38PKB_20220125T093037.SAFE*
*L2A product: S2B_MSIL2A_20220125T073109_N0400_R049_T38PKB_20220125T102321.SAFE*

# 5. Product features

## 5.1 Scene classification

The current scene classification algorithm has some known limitations:

- Over-detection of clouds over bright targets,
- Under-detection of semi-transparent clouds or cloud edges,
- Cloud pixels miss-classified as snow (shaded parts of the clouds),
- Dark areas miss-classified as cloud shadows. This can occur in particular when bright objects are incorrectly classified as clouds,
- Topographic shadows may be miss-classified as water,
- Open fires can be miss-classified as cirrus.
- Degraded pixels from data loss at L1C are currently not supported by the L2A processor. Users are advised to check the TECQUA mask to identify affected pixels.

As mentioned in section 3.1, these problems have been significantly reduced starting with baseline 02.09.

Starting with baseline 02.10, terrain correction is no longer applied for pixels identified as cloudy. This can lead to visual artefacts at the edges of semi-transparent clouds, see figure below.

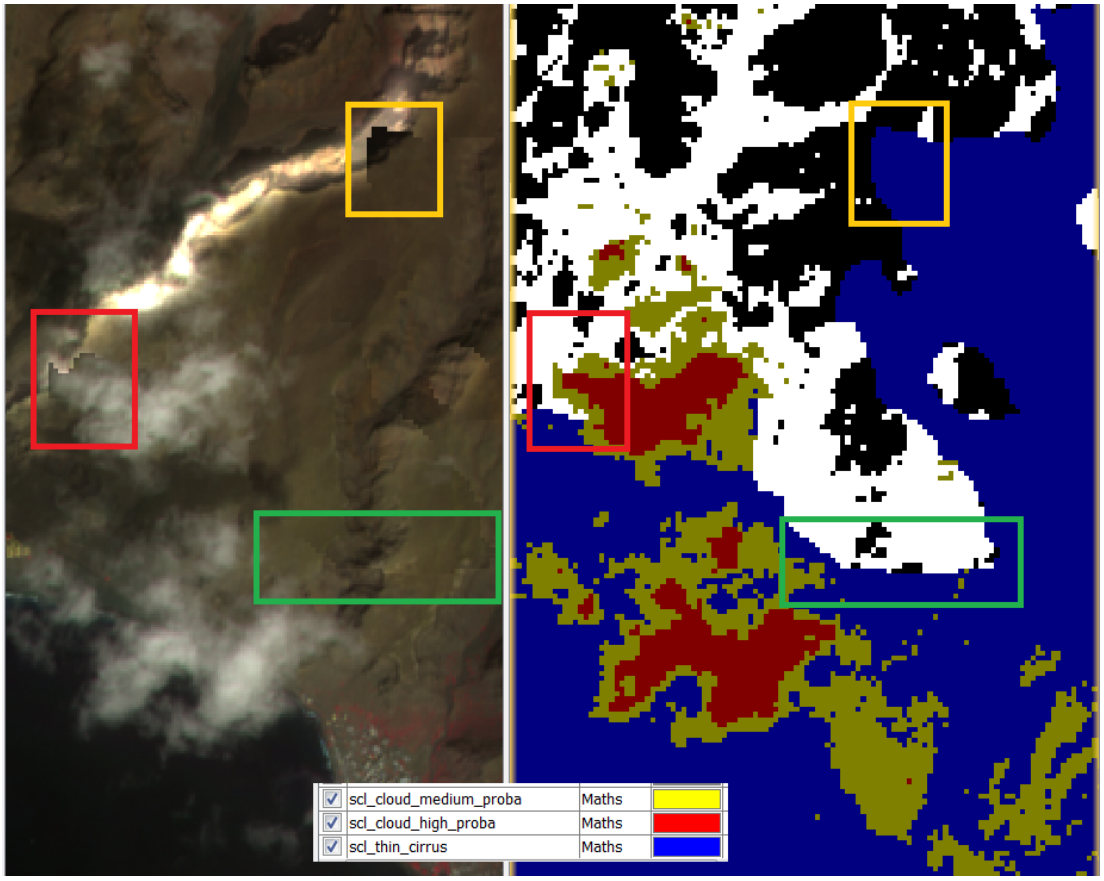


***Figure 18: Visual artefacts at the edges of semi-transparent clouds.***

Another known issue concerns the occurrence of blocky patterns on the Scene Classification mask, as illustrated in the figure below. This issue is due to the coarser resolution of the CCI auxiliary data used to improve the scene classification. In some cases (as on Figure 19 – Left) it can lead to a local over-detection of clouds.

***Figure 19: Blocky patterns on the scene classification layer (SCL).***
***Left: near the coastline. Right: near city boundaries.***

## 5.2 Overlap between tiles

The L2A products are processed at tile level and some differences can occur in the overlap area between adjacent tiles:

- The scene classification may be different for a few pixels

- The AOD and surface reflectances are generally different, although the difference should be small.

## 5.3 Terrain over-correction on shaded areas

Due to inaccuracies of the Digital Elevation Model, a strong terrain correction may be applied in totally or partially shaded areas. This results in a bluish colour in colour composite and inaccuracy in the surface reflectance.

***Figure 20: Terrain over-correction on shaded areas.***
***Left: Level 1C true colour image, right: L2A true colour image.***

## 5.4 Maximal Sun-Zenith Angle

Users are advised that products with a Sun-Zenith Angle (SZA) higher than 70° are processed with a clipped SZA value of 70°. This results in an under-correction of the atmospheric signal, which results in a bluish colour on the L2A products. The surface reflectance of products with SZA > 70° should not be used for quantitative/scientific analysis. The value of the SZA can be obtained from the GRANULE metadata (MTD_TL.xml, field Mean_Sun_Angle/ZENITH_ANGLE). In the coming period, a warning message will also be introduced in the GENERAL_QUALITY report to identify these products.

***Figure 21: L2A True Colour Image of tile 30VVH;***
***left: 10/10/2018, SZA = 62°; right: 24/12/208, SZA = 80°. The radiometric quality for surface reflectance is not ensured for SZA > 70°.***

## 5.5 Missing packets

In the current version of L2A products, corrupted pixels affected by missing or degraded instrument source packets are not reported in the Scene Classification Layer. Users are advised to check the TECQUA mask to identify affected areas where the SCL is not reliable.

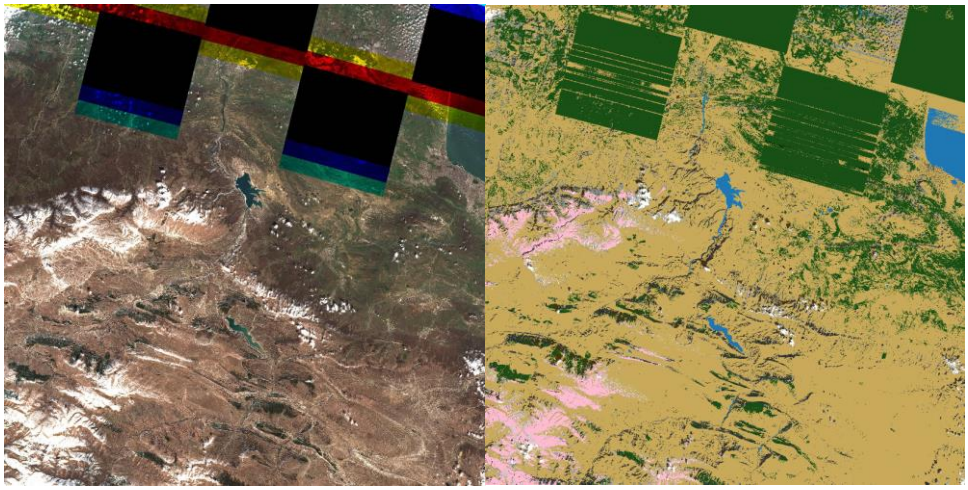

***Figure 22: Left: TCI image of a product affected by missing packets. Right: Scene Classification Layer.***

Note that missing packets in atmospheric correction input bands (B10 and B09) can affect surface reflectance of other spectral bands.

## 5.6 Discontinuities visible in Terrain Correction on very flat areas

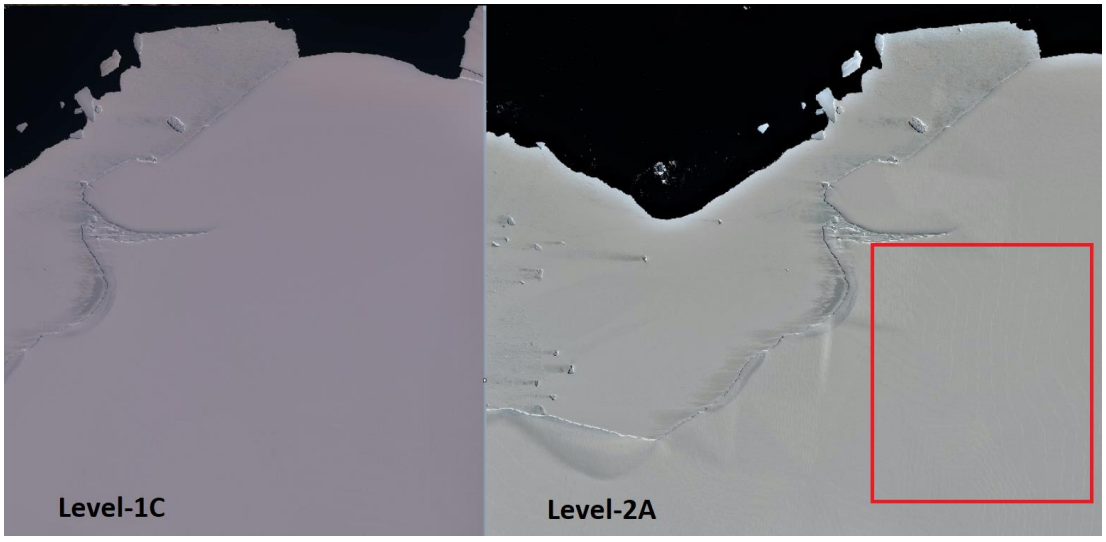


***Figure 23: Contour-like line features (red box – right) visible in L2A products over Antarctica***

This apparent contouring in L2A products arises on images over very flat area with high Sun-Zenith angles. This artifact comes from the impact of the vertical quantization of the Digital Elevation Map (1 metre steps in the current production) on topographic correction.

***End of document***