



S2 MPC

Level 2A Data Quality Report

Ref. S2-PDGS-MPC-L2ADQR



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1. Scope of the Document

1.1 Introduction

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.

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

- Correction of anomalies #2 and #3
- Introduction of new processing baseline 02.09

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 2.4 and 2.5.3 (toolbox version), and may thus slightly differ from the baseline 02.07 & 02.08 products available on the Copernicus Hub.

The performance assessment will be refined in future issues of the present document.

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 $0.05\rho_{\text{reference}} + 0.005$	TBD
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_{\text{ref}} + 0.2$	97% 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 AOT_{ref} shall be within $ \Delta AOT \leq 0.1 * AOT_{\text{ref}} + 0.03$	39% of retrieved Aerosol optical thickness values at 550 nm are within requirement
Classification accuracy	No requirement defined.	The overall accuracy is 98% for recognition of clear pixels over land and water

Measured performances are detailed in the following sections.

2.2 Performances

2.2.1 Surface reflectance radiometry accuracy

Quantitative assessment of surface reflectance radiometric performance is currently only available for Sen2Cor version 2.4. 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) (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. Both accuracy and uncertainty values show an increasing trend with wavelength (band number). Precision increases up to band 5 and then stays constant. Average accuracy value relative to average surface reflectance reference is below or near to 5% except for bands 5 and 12.

Note, that better performance is expected from version Sen2Cor 2.5 onwards due to largely improved AOT retrieval.

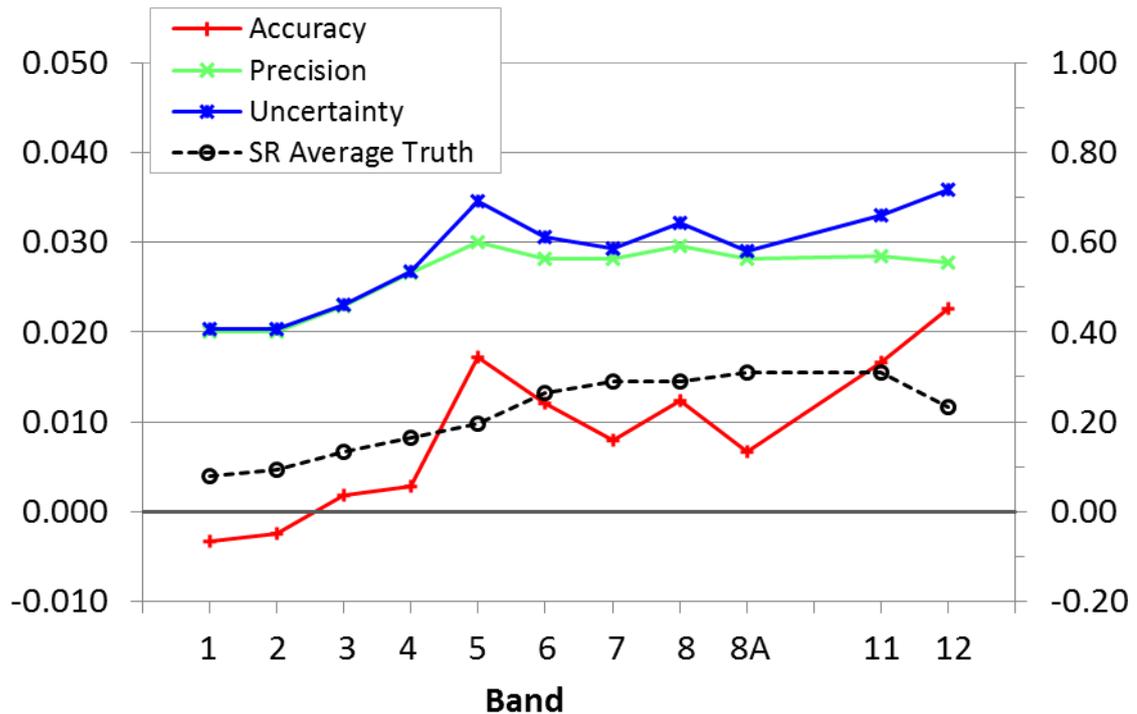


Figure 1: Average accuracy, precision, uncertainty (solid lines, left hand side scale) and surface reflectance reference (dashed line, right hand side scale) per band for Sen2Cor version 2.4 based on the ACIX-dataset.

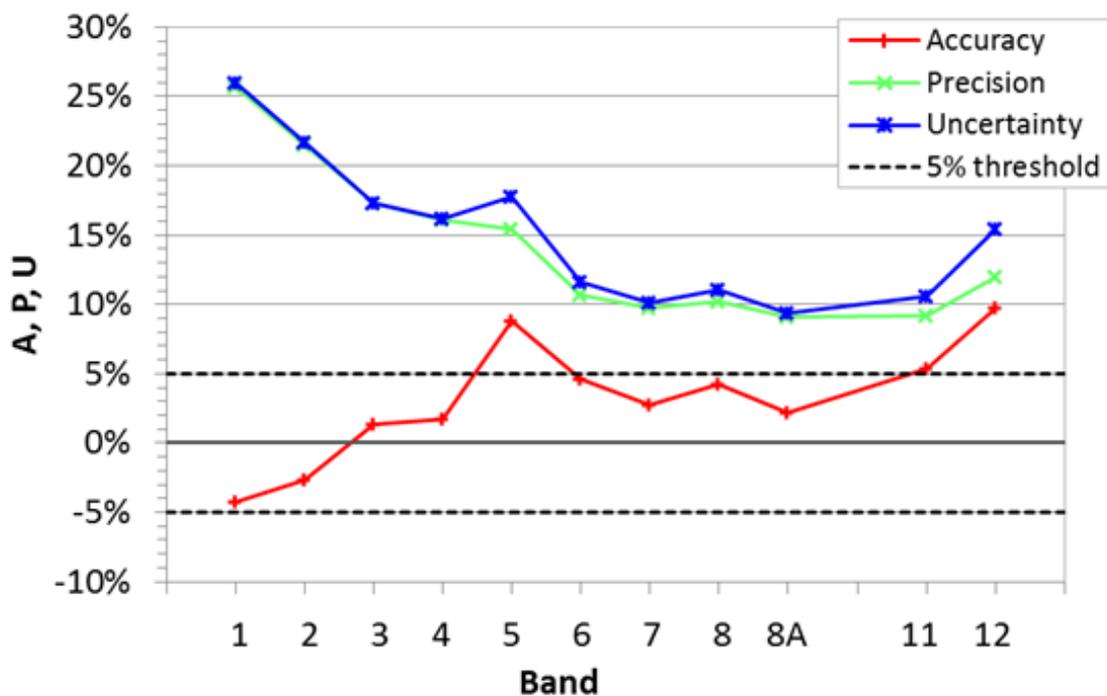


Figure 2: Average accuracy, precision and uncertainty relative to average surface reflectance reference per band for Sen2Cor version 2.4 based on the ACIX-dataset.

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 the ACIX dataset excluding water sites (G. Doxani et al., "Atmospheric Correction Inter-Comparison Exercise", Remote Sensing, 10 (352), pp 1-18. DOI: doi:10.3390/rs10020352 ISSN 2072-4292).

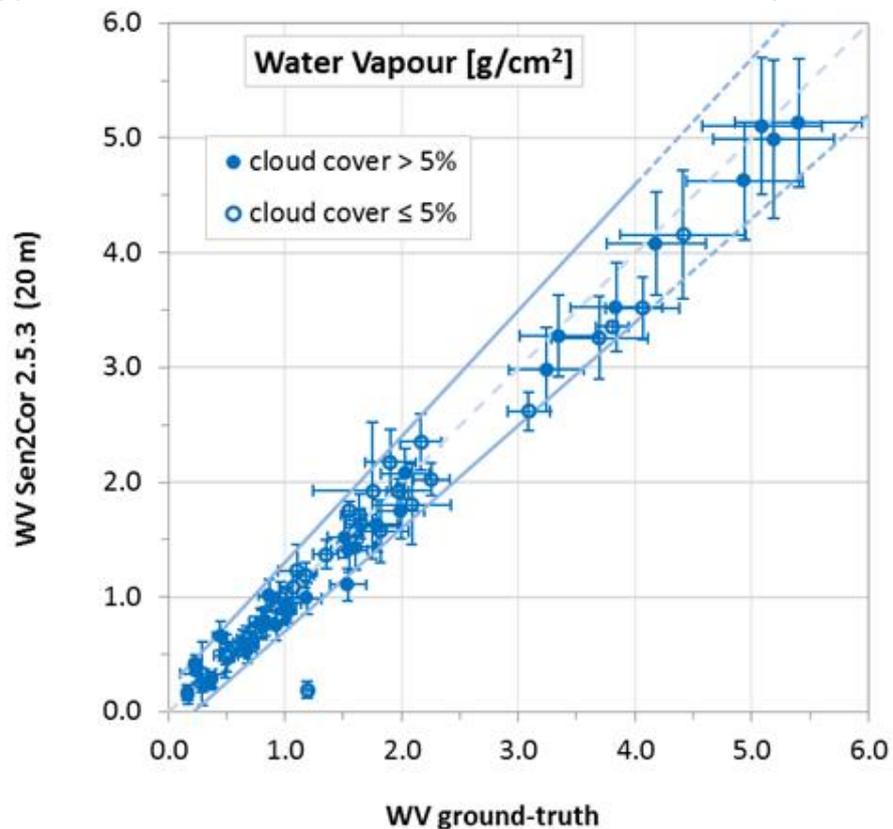


Figure 3: Correlation plot of Sen2Cor WV retrieval at 20 m resolution over WV reference from AERONET on basis of the ACIX data set excluding water sites. The dashed line indicates $x=y$ and the solid lines show the limits of accuracy requirement $|\Delta WV| \leq 0.1 * WV_{ref} + 0.2$.

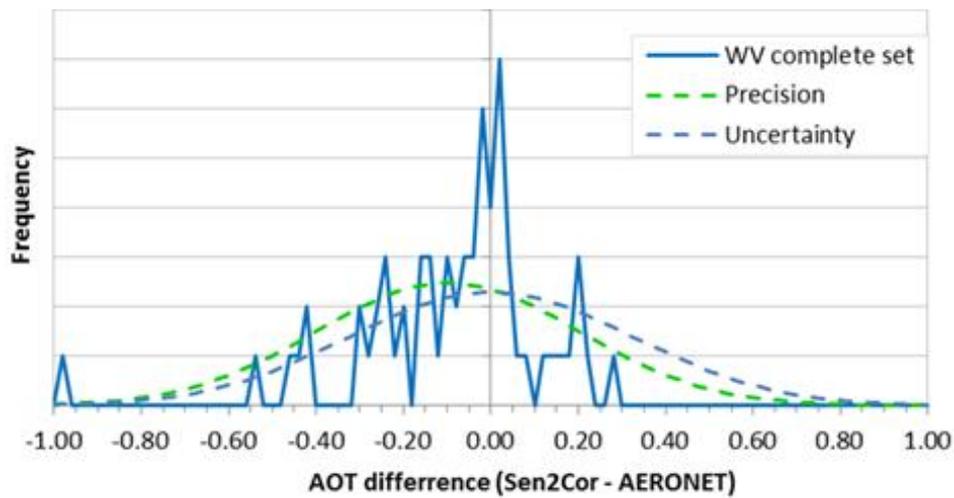


Figure 4: Histogram plot of WV (at 20 m resolution) retrieval difference to the reference value from AERONET. The green dashed curve gives a normal distribution computed with accuracy as mean value and precision as standard deviation. The blue dashed curve represents a normal distribution around zero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

Table 2-2: Statistical numbers reporting on WV-validation for Sen2Cor 2.5 on basis of the ACIX data set excluding water sites.

WV statistics	
Total no. of granules	66
WV retrievals within requirement	97%
R^2 (Coefficient of variation)	0.98
r (Pearson's corr. coeff.)	0.99
MA (Median Accuracy value)	0.16 cm
MP (Median Precision value)	0.17 cm
Uncertainty (U)	0.23 cm
Max WV difference	1.00 cm
95.4% Quantile	0.46 cm
75% Quantile	0.21 cm

Water vapour retrieval is very accurate with correlations over 0.98 and with 97% of retrievals within the requirement. About 95% of water vapour retrievals are less than 0.46 cm different from reference and about 75% deviate less than 0.21 cm from reference.

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 the ACIX dataset excluding water sites (G. Doxani et al., "Atmospheric Correction Inter-Comparison Exercise", Remote Sensing, 10 (352), pp 1-18. DOI: doi:10.3390/rs10020352 ISSN 2072-4292).

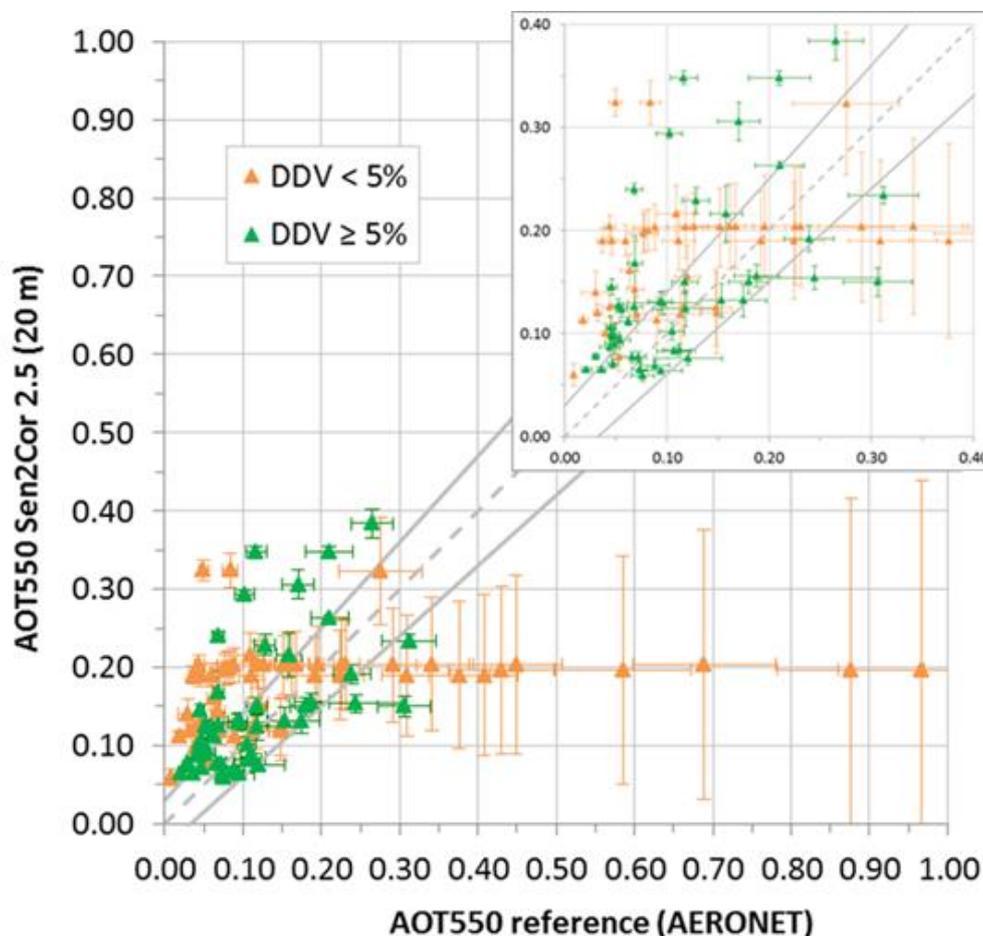


Figure 5: Correlation plot of Sen2Cor AOT₅₅₀ retrieval at 20 m resolution over AOT₅₅₀ reference from AERONET on basis of the ACIX data set excluding water sites. Green triangles are AOT₅₅₀ retrieved with the DDV-algorithm and orange triangles are AOT₅₅₀ resulting from the present fall-back solution (process with configured start VIS of 40 km). The dashed grey line indicates x=y and the solid grey lines show the limits of accuracy requirement $|\Delta AOT_{550}| \leq 0.1 * AOT_{550ref} + 0.03$. (Inset: zoom on low AOT values).

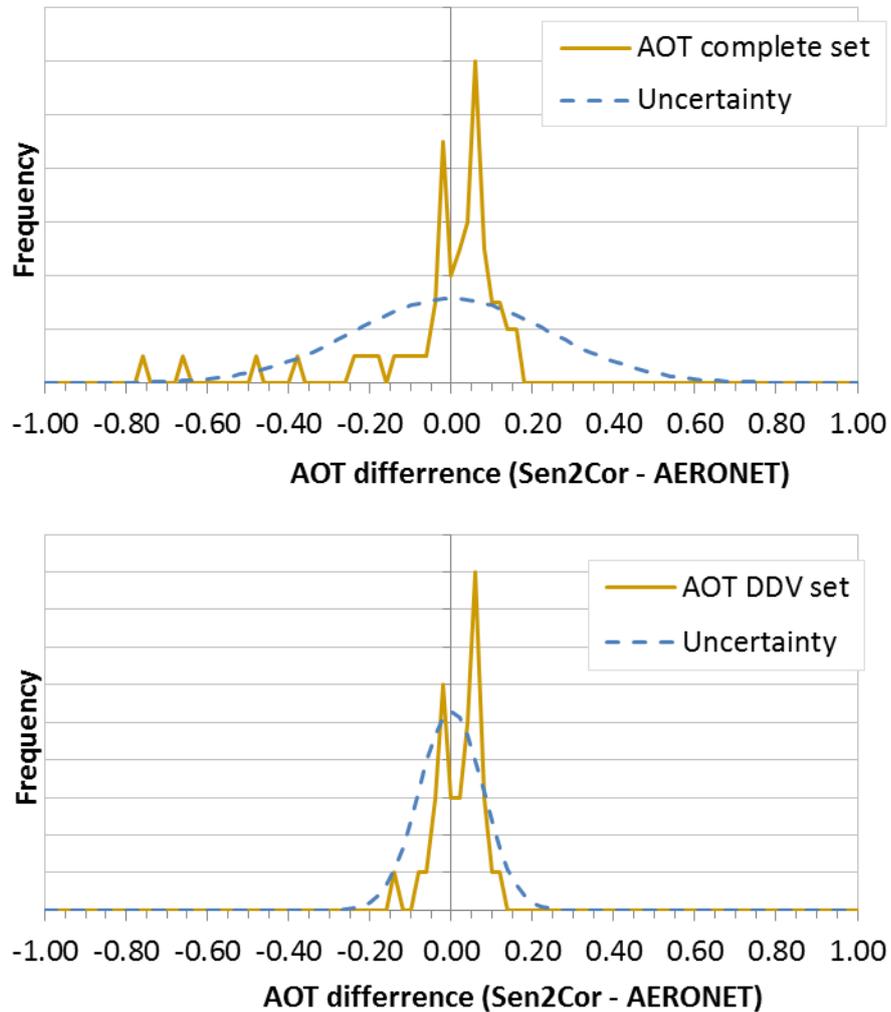


Figure 6: Histogram plots of AOT₅₅₀ (at 20 m resolution) retrieval difference to the reference value from AERONET. The blue dashed curves give normal distributions around zero with uncertainty as standard deviation. The upper plot shows results for the complete data set and the lower plot for the subset of images containing more than 5% DDV-pixels.

Table 2-3: Statistical numbers reporting on AOT₅₅₀-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 5% DDV-pixels.

AOT statistics	Complete set	DDV set
Total no. of granules	67	37
Retrievals within requirement	39%	49%
R ² (Coefficient of variation)	0.27	0.47
r (Pearson's correlation coeff.)	0.52	0.69
MA (Median Accuracy value)	0.05	0.04
MP (Median Precision value)	0.15	0.03
U (Uncertainty)	0.17	0.06
Max AOT ₅₅₀ difference	0.77	0.16
95.4% Quantile	0.38	0.10
75% Quantile	0.10	0.06

Aerosol optical depth retrieval results are very different between the complete data set and the dataset limited to images with at least 5% 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 0.04±0.03 and 0.06 for the DDV subset (Table 2-3), which is a very good performance increase since Sen2Cor version 2.4. Accuracy ± precision and uncertainty values for Sen2Cor version 2.4 are 0.11±0.07 and 0.14 for the DDV subset. About 95% of AOT retrievals with Sen2Cor 2.5 are less than 0.10 different from reference value. 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 2 images over test site Barrax in Spain. The average overall accuracy over both images is 98% for recognition of clear pixels over land and water and 99% for recognition of clouds. Detailed results for one of these images are shown in Table 2-4. Users (resp. producers) accuracy for recognition of clear pixels over land and water correspond to commission error of 0.09 (resp. omission error of 0.02). Users (resp. producers) accuracy for recognition of clouds corresponds to commission error of 0.01 (resp. omission error of 0.01).

Table 2-4: Classification accuracy for recognition of clear pixels and for detection of clouds for an example image over Barrax (Spain) acquired on 09.05.2017. "Clear pixels over land and water" aggregate the Sen2Cor classes vegetation, non-vegetated and water. "All clouds" aggregate Sen2Cor classes cloud_medium_probability, cloud_high_probability and thin cirrus.

Clear pixels over land and water				
	Land-Water	Others	Sum	users accuracy
Land-Water	36297	3387	39684	0.915
Others	937	100925	101862	0.991
Sum	37234	104312	141546	
producers accuracy	0.975	0.968	OA	0.969
All clouds				
	Clouds	Others	Sum	users accuracy
Clouds	70310	851	71161	0.988
Others	939	69446	70385	0.987
Sum	71249	70297	141546	
producers accuracy	0.987	0.988	OA	0.987

3. Processing Chain Status

3.1 Processing baseline

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

The Processing Baseline 02.08 has been introduced on 23/05/2018. It uses Sen2Cor version 2.6.3, while the "Toolbox" version publicly available is version 2.5.5. Also note that the Ground Segment uses a different configuration. In particular PlanetDEM is used for the Digital Elevation Model (DEM), while the public version uses Shuttle Radar Topography Mission (STRM). Cirrus and BRDF corrections are not activated for ground segment production.

A minor evolution was introduced on 19th September 2018 to correct anomalies #2 and #3.

Processing Baseline 02.09 will be deployed on 8th October 2018. This Baseline will introduce the use of auxiliary data from the Land Cover CCI. This will be used to support the scene classification, which will improve the accuracy of the mask. Some illustrations of this improvement are presented on Figure 7 and Figure 8 below. The product format remains unchanged.

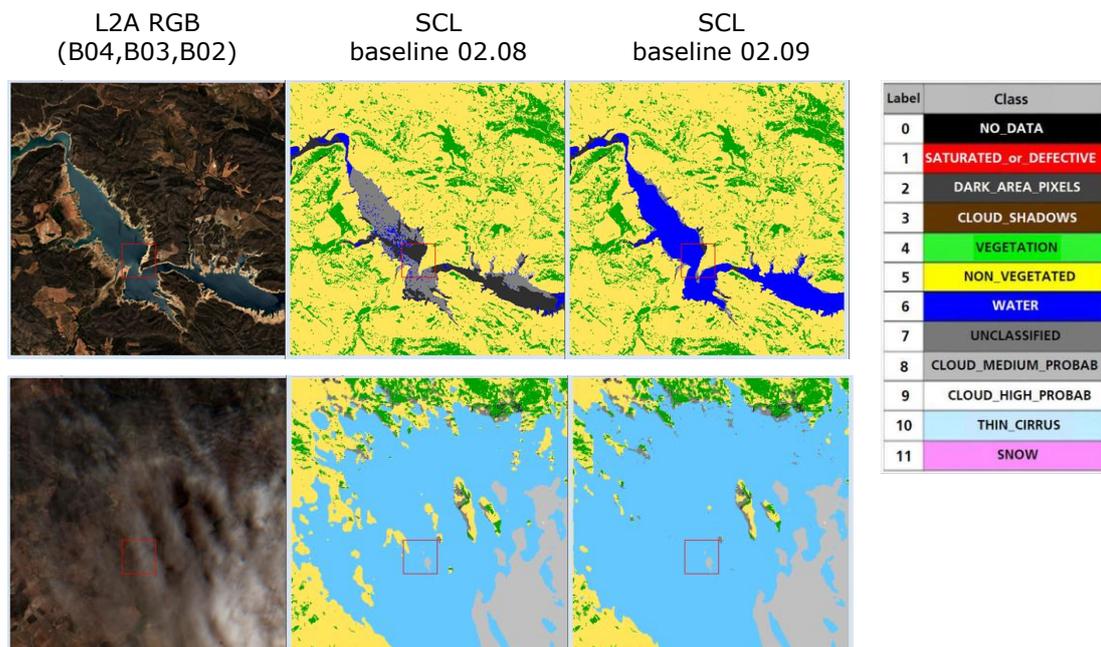


Figure 7: Example of evolution of the scene classification. Left: Level 2A RGB image, Middle: processing baseline 02.08, Right: processing baseline 02.09. The new processing baseline improves water and cirrus /semi-transparent clouds classifications.

L2A RGB

SCL

SCL

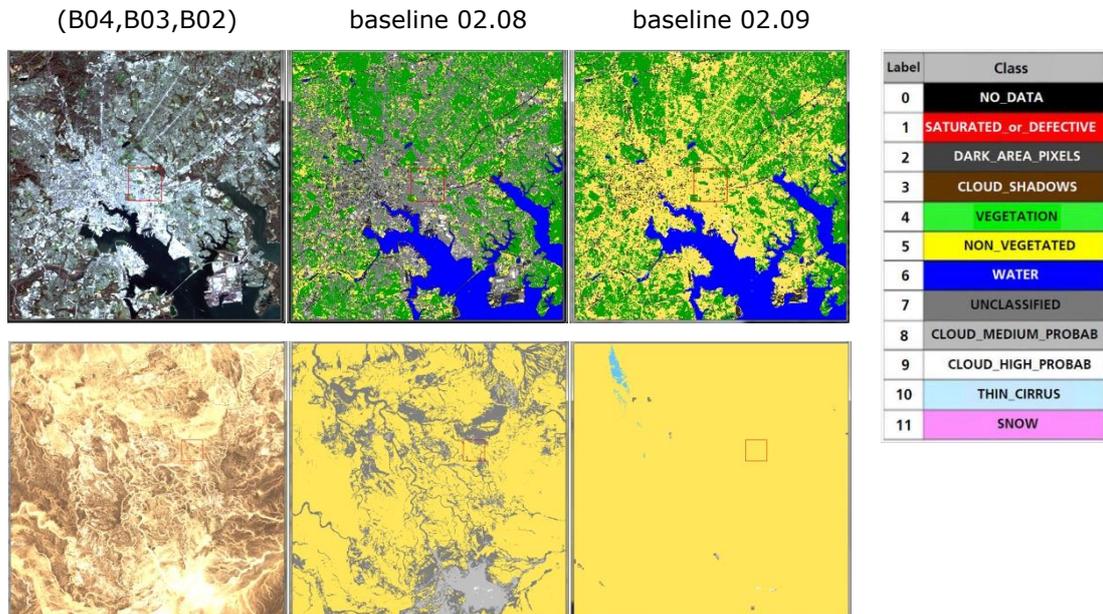


Figure 8: Example of evolution of the scene classification. Left: Level 2A RGB image, Middle: processing baseline 02.08, Right: processing baseline 02.09. The new processing baseline improves urban and arid sites classifications.

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. Users are invited to refer to the L1C Data Quality Report for a complete status.

Table 3-1: Anomaly and processing baseline summary.

Anomaly ID	Baseline number	02.07	02.08
	Deployment date	26/03/2018	23/05/2018
	Anomaly title	Affected products	Affected products
1	Wrong tile ID metadata	All products until 05/04/2018	
2	Incorrect No Data mask	Limited occurrences for pixels near the edge of the swath (Until 19/09/2018)	
3	Encoding of Quality Bands	Until 19/09/2018	
4	Terrain Correction over clouds	A few products	

4. Product Anomalies

4.1 Introduction

This chapter describes anomalies observed on the L2A production.

4.2 Incorrect Tile ID metadata (#1)

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 (#2)

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 and has been deployed on 19/09/2018.

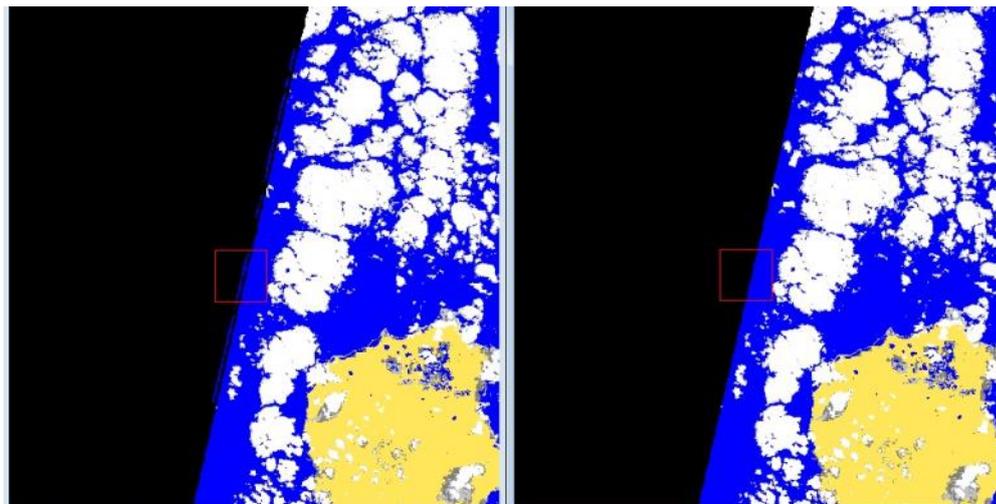


Figure 9: Incorrect No Data Mask (anomaly #2). Left: pixels incorrectly flagged as water (blue) near the swath edge. Right: same image after correction.

4.4 Encoding of Quality Bands (#3)

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 (#4)

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.

A correction has been implemented and is currently under validation. It should be deployed in the next period.

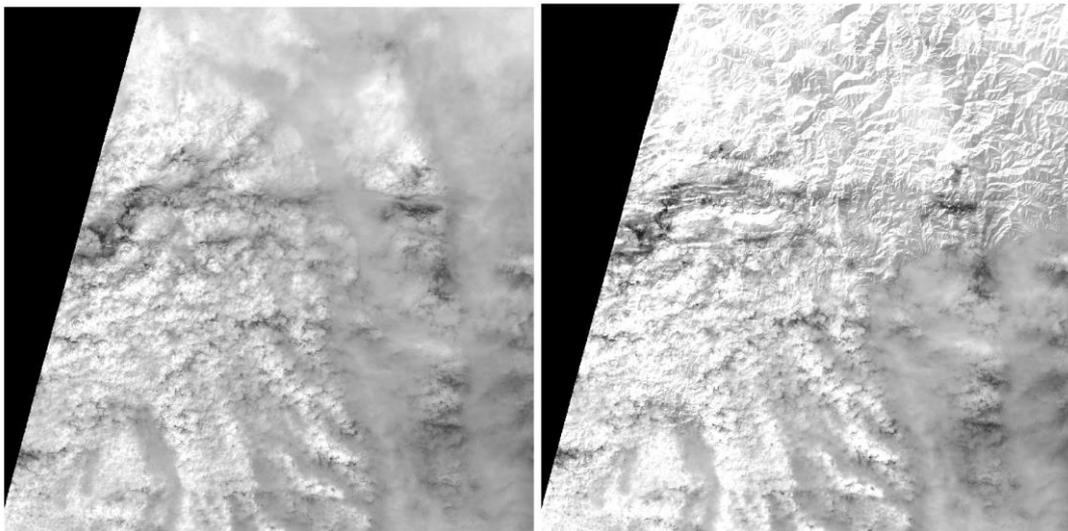


Figure 10: Band B04, Tile 32TLP from orbit S2B 7098. Left: L1C image; Right: L2A image. The topography seems to be visible through the opaque clouds. (Anomaly #4)

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