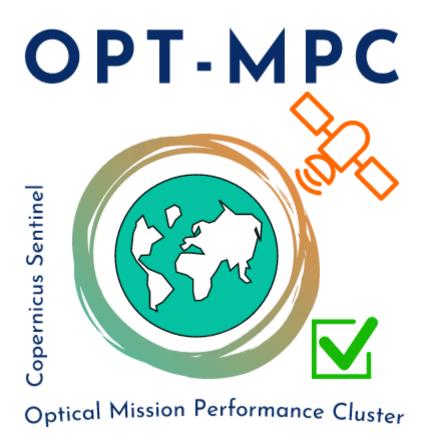
COPERNICUS SPACE COMPONENT SENTINEL OPTICAL IMAGING MISSION PERFORMANCE CLUSTER SERVICE

Data Quality Report Sentinel-2 MSI L2A April 2023



Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0

Date: 12/04/2023

Contract: 4000136252/21/I-BG

Customer: ESA	Document Ref.:	OMPC.CS.DQR.002.03-
Contract No.: 4000136252/21/I-BG	Date:	12/04/2023
	Issue:	60.0

Project:	COPERNICUS SPACE COMPONENT SENTINEL OPTICAL IMAGING MISSION PERFORMANCE CLUSTER SERVICE							
Title:	Data Quality Report - MSI L2A							
Author(s):	S2 MSI ESL team							
Approved by:	S. Enache, OPT-MPC MSI ESL Coordinator S. Clerc, OPT-MPC Optical ESL Coordinator F. Poustomis, OPT-MPC S2 Technical Manager							
Distribution:	ESA, published in Sentinel Onlin	ne						
Accepted by ESA	V. Boccia, ESA Deputy TO S. Dransfeld, ESA TO							
Filename	OMPC.CS.DQR.002.03-2023 - i6	50r0 - MSI L2A DQR A	pril 2023.docx					

Disclaimer

The views expressed herein can in no way be taken to reflect the official opinion of the European Space Agency or the European Union.









Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0

Date: 12/04/2023

Page: iii

Changes Log

Version	Date	Changes
60.0	12/04/2023	First version

List of Changes

Version	Section	Answers to RID	Changes



Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0

Date: 12/04/2023

Page: iv

Table of content

1.	INTE	RODUCTION	1
	1.1	SCOPE OF THE DOCUMENT	1
	1.2	MAIN POINTS FOR THIS MONTH	1
2.	PRO	CESSING BASELINE STATUS	2
	2.1	PROCESSING BASELINE DESCRIPTION	2
	2.2	CONFIGURATION AND DIFFERENCES WITH SEN2COR 'USER' VERSION	3
3.	MEA	SURED PRODUCT PERFORMANCES	4
	3.1	PERFORMANCES OVERVIEW	4
	3.2	Performances	5
	3.2.1	Surface reflectance radiometry	5
	3.2.2	2 Water Vapour accuracy	7
	3.2.3	3 Aerosol Optical Thickness	8
	3.2.4	1 Classification accuracy	9
4.	PRO	DUCT FEATURES	14
5.	PRO	DUCT ANOMALIES	15
	5.1	INTRODUCTION	15
	5.2	VERY LOW NEGATIVE REFLECTANCES NEAR THE EDGE OF THE SWATH (#81)	15
6.	GEN	ERAL INFORMATION ON PRODUCTS	17
	6.1	INSIGHTS INTO THE COPERNICUS COLLECTION-1	17
	6.2	PRODUCT FORMAT	18
	6.3	OFF-LINE PRODUCTS	18
	6.4	Reprocessed products	18

OPT-MPC Paulous Optical Mission Performance Cluster

Optical MPC

Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0 Date: 12/04/2023

Page: v

List of Figures

Figure 1: Correlation plot of SR retrieval by Sen2Cor over reference measurements on ground 6
Figure 2: Average SR retrieval performance per band estimated by comparison with ground measurements. B01 and B12 are shown with empty bars because they result from 4 campaign sample days only. There are no measurements from LaCrau and Gobabeb for B01 and B12 6
Figure 3: Correlation plots of Sen2Cor 2.10 (PBL 4.00) WV retrieval at 20 m resolution over WV reference from AERONET per climate zone on basis of a data set at 76 AERONET sites. The dashed line indicates x=y and the solid lines show the limits of uncertainty goal $U(WV) \le (0.1*WV_{ref}+0.2) \text{ g/cm}^2)$ 8
Figure 4: Correlation plot of Sen2Cor AOT $_{550}$ retrieval at 20 m resolution over AOT $_{550}$ reference from AERONET per climate zone on basis of a data set at 76 AERONET sites. Green triangles are AOT $_{550}$ retrieved with the DDV-algorithm and orange triangles are AOT $_{550}$ resulting from using CAMS data as fall-back solution. The dashed grey line indicates x=y and the solid grey lines show the limits of uncertainty goal $U(AOT_{550}) \le 0.1*AOT_{550ref}+0.03$ 9
Figure 5: Spider plots of the omission and commission errors of clear pixels 13
Figure 6: Spider plots of the omission and commission errors of thin cirrus pixels 13
Figure 7: Spider plots of the omission and commission errors of cloud high probability pixels 13
Figure 8: Illustration of the very low negative reflectances near the edge of the swath observed on the L2A product: S2B_MSIL2A_20220329T105629_N0400_R094_T30SXJ_20220329T134242
List of Tables
Table 3-1: Summary of Sentinel-2 L2A products measured performances for mission key requirements 4
Table 3-2 : Test data selection: AERONET data (level ≥ 1.5) available within ±15 min to overpass time 7
Table 3-3: Selected test sites for Sen2Cor 2.10 validation 10
Table 3-4: Summary of the cloud masking validation results for 4 study areas already analysed. True values are in columns and predicted values are in rows 10
Table 3-5: Summary of the cloud masking validation results for snow covered products. True values are in columns and predicted values are in rows
Table 5-1: Anomaly and processing baseline summary 15

OPT-MPC Page 10 Per of the Control Mission Performance Cluster Optical Mission Performance Cluster

Optical MPC

Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0 Date: 12/04/2023

Page: 1

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.

Please note that the data quality status before the beginning of 2023 is covered by the <u>Annual Performance Report</u> of 2022. Please refer to this document as well as former Data Quality Reports (DQR) if needed.

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 and performance have generally improved since then. Detailed inter-comparison of cloud masking of Sen2Cor with other processors is published in S. Skakun et al., "Cloud Mask Intercomparison exercise (CMIX): An evaluation of cloud masking algorithms for Landsat 8 and Sentinel-2", Remote Sensing of Environment, Volume 274, 2022, 112990, ISSN 0034-4257¹.

1.2 Main points for this month

- Release of the Sentinel 2 Annual Performance Report (https://sentinels.copernicus.eu/documents/247904/4893455/OMPC.CS.APR.001+-+i1r0+-+52+MSI+Annual+Performance+Report+2022.pdf),
- Availability of the Copernicus Sentinel-2 Collection-1 data (see section 6.1),
- New spider plots of the omission and commission errors for the clear, thin cirrus, and cloud high probability pixels (see section 3.2.4).

_

¹ https://doi.org/10.1016/j.rse.2022.112990

OPT-MPC Paulogo Optical Mission Performance Cluster

Optical MPC

Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0 Date: 12/04/2023

Page: 2

2. Processing Baseline Status

2.1 Processing baseline description

On December 6th, 2022, the **processing baseline 05.09** was deployed. The format of the L1C and L2A products within this new PB remains the same as outlined in the current Product Specification Document (version 14.9).

The operational processor deployed for this processing baseline (version 6.1) is the same used to generate the Copernicus Sentinel-2 Collection-1 (for more details please refer to the section 6.1). The particularity of the current processor is that it can operate with both the Copernicus DEM at 90 meters ground spatial resolution, and/or with its finer defined version at 30 meters resolution. Currently, the 90 m version of the DEM will continue being used for the nominal productions while the 30 m version of the DEM is being used for the historical archive reprocessing.

The Processing Baseline identifier 05.09 tags the operational products generated with the 90 m version of the Copernicus DEM. The Processing Baseline identifier 05.00 tags the Copernicus Sentinel-2 Collection-1 products.

At Level-2A, the following evolutions are included:

- Identification of defective pixels from missing instrument source packets in L2A Scene Classification layer.
- Correction of anomalies #5, #65, #66 and #74 (please refer to https://s2anomalies.acri.fr/anomalies for more details).

In addition to the evolutions included in the processing baseline 05.09, we remind here that a **radiometric offset** on reflectance digital numbers has been introduced with processing baseline 04.00 deployed on January 25th, 2022. Then, the dynamic range is shifted by a band-dependent constant: BOA_ADD_OFFSET. This offset allows encoding negative surface reflectances that may occur over very dark surfaces. **From the user's point of view, the L2A Surface Reflectance (L2A_SR) 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 is:

L2A_SRi = (L2A_DNi + BOA_ADD_OFFSETi) / QUANTIFICATION_VALUEi

The radiometric offset value is reported the field General_Info/Product_Image_Characteristics/BOA_ADD_OFFSET_VALUES_LIST/BOA_ADD_OFFSET of the **Product** Metadata, the field User as well as in Image_Data_Info/Radiometric_Info/BOA_ADD_OFFSET_VALUES_LIST/BOA_ADD_OFFSET of the Datastrip Metadata. It is set to -1000 Digital counts for all spectral bands.

For further information on the former processing baselines, please refer to https://sentinels.copernicus.eu/web/sentinel/technical-guides/sentinel-2-msi/processing-baseline.

OPT-MPC Paulous Deptical Mission Performance Cluster

Optical MPC

Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0 Date: 12/04/2023

Page: 3

2.2 Configuration and differences with Sen2cor 'User' version

The Level-2A operational processor generates, using algorithms of scene classification and atmospheric correction included in Sen2Cor processor, Level-2A (Surface Reflectance) products from Level-1C products. Level-2A can also be generated by the User from the Level-1C product using the standalone version of the Sen2Cor processor: https://step.esa.int/main/snap-supported-plugins/sen2cor/.

Sen2cor configuration applied for the Level-2A operational products:

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

Since Baseline 02.11, individual configuration parameters are set as follows and are the same default parameters provided with Sen2cor standalone version:

Log_Level	INFO		
5514	Copernicus DEM at 90 m since baseline03.00		
DEM	Planet-DEM 90 m for previous baselines		
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 operational products generated using the baseline 02.11:

- If the Digital Elevation Model (DEM) is different, this can impact terrain correction results (users have access to SRTM-DEM and Copernicus DEM at 90 m and 30 m whereas L2A operational products uses Planet-DEM for baseline >=02.11 and Copernicus DEM at 90 m for baseline >= 03.00),
- The JP2000 compression library is different, which leads to a slightly different size of the products and a different compression noise.

OPT-MPC Optical Mission Performance Cluster

Optical MPC

Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0 Date: 12/04/2023

Page: 4

3. Measured Product Performances

3.1 Performances Overview

The following overview table provides a summary of the Level 2A products data quality performances. Note that the cloud masking performance and performances for water vapour and aerosol optical thickness reported in this issue of the L2A Data Quality Report have been assessed with Sen2cor versions 2.10 (operational processing, PBL 4.00), and may thus slightly differ from the performance of the current processing baseline. Surface reflectance performance is based on Sen2Cor 2.8.

Table 3-1: Summary of Sentinel-2 L2A products measured performances for mission key requirements.

Requirement on	Description	Measured performance
Surface reflectance	Uncertainty goal of Bottom-of-Atmosphere reflectance retrieval: $U(\rho) \leq 0.05 \rho_{reference} + 0.005$	79% of retrieved SR values are within uncertainty goal
Water Vapour	Water Vapour Uncertainty goal of WV retrieval: $U(WV) \leq (0.1*WV_{ref} + 0.2) \text{ g/cm2}$	
Aerosol Optical Thickness at 550 nm	· Unicertainty goal of AO1550 retrieval.	
Classification / Cloud masking	No requirement defined.	Commission of clear pixels ranges from 0% to 8% depending on test site with the higher values mostly due to confusion with transparent clouds. It is 45% for snow covered winter-season products. Balanced overall accuracies of clear vs cloud pixels range between 92 – 100% and is 77% for snow covered winter-season products

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/).

OPT-MPC Optical Mission Performance Cluster

Optical MPC

Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0 Date: 12/04/2023

Page: 5

3.2 Performances

3.2.1 Surface reflectance radiometry

New quantitative assessment of surface reflectance radiometric retrieval for Sen2Cor 2.8 was done relative to a limited number of surface reflectance reference measurements [B. Pflug, J. Louis, R. de los Reyes, K. Pflug, U. Mueller-Wilm, C. Quang, R.I. Iannone, and P. Reinartz. " <u>Evaluation of SEN2COR Surface Reflectance Products over land surface with reference measurements on Ground</u>," in 2022 leee International Geoscience and Remote Sensing Symposium, (IEEE International Symposium on Geoscience and Remote Sensing IGARSS, 2022, pp.]. Measurements at RadCalNet sites LaCrau and Gobabeb were provided by CNES and RadCalNet-teams and measurements over test sites in Germany were provided by DLR.

The data set used contains 40 sample days from October 2017 to May 2018 for RadCalNet site Gobabeb, 21 sample days from January to September 2018 for RadCalNet site LaCrau, and 4 sample days from May 2018 to October 2021 for different locations in North-Eastern Germany. Reference measurements from RadCalNet sites Gobabeb and LaCrau are reused from Atmospheric Correction Intercomparison eXercise ACIX-2 (G. Doxani *et al.*, "Atmospheric Correction Inter-Comparison Exercise", Remote Sensing, 10 (352), pp 1-18. DOI: doi:10.3390/rs10020352 ISSN 2072-4292). They were provided by CNES for Sentinel-2 bands B02 to B11 in the same angular conditions as Sentinel-2A & 2B observations over the sites.

The site Gobabeb is located in Namibia in a desert environment without vegetation. The site LaCrau is located in the south of France and has sparse vegetation cover. The test areas in Germany represent flat terrain containing meadows and soil in a vegetated environment. Note that this data set is still too small for providing statistically reliable information. It will be extended with availability of new reference measurements.

The quantitative assessment of surface reflectance radiometric performance is provided for Sen2Cor version 2.80 'user' processing with CAMS fall back.

The correlation plot of SR retrieval by Sen2Cor over reference measurements on ground (Figure 1) shows good performance of Sen2Cor SR retrieval for the investigated data set. Results look similar to equivalent plots in the literature. The total uncertainty of SR retrieval with Sen2Cor over all sites is about 0.02 respectively 9% and nearly 80% of SR retrievals are compliant with uncertainty goal Δ SR \leq 0.05*SR_{ref} +0.005. Systematic uncertainty $U_{sys}(SR)=(0.02\pm0.007)*SR+(0.0\pm0.002)$ is well within the uncertainty goal. Figure 2 gives deeper insight into SR retrieval performance by looking to average systematic uncertainties per band. Whereas random uncertainty is little increasing with band number respectively with SR values, we can observe much higher systematic uncertainty for B05 and B11. The origin for that is still not cleared. Current interpretation is that it may be caused by WV absorption which is present in both bands.

OPT-MPC Paulous regiments of the control of the co

Optical MPC

Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0 Date: 12/04/2023

Page: 6

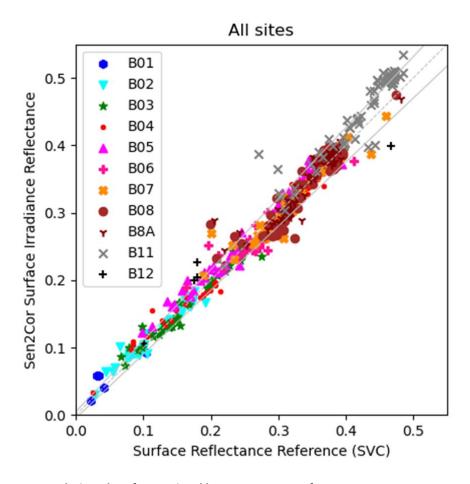


Figure 1: Correlation plot of SR retrieval by Sen2Cor over reference measurements on ground.

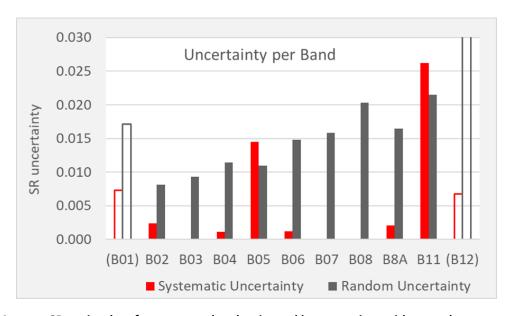


Figure 2: Average SR retrieval performance per band estimated by comparison with ground measurements. B01 and B12 are shown with empty bars because they result from 4 campaign sample days only. There are no measurements from LaCrau and Gobabeb for B01 and B12.

OPT-MPC

Optical MPC

Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0 Date: 12/04/2023

Page: 7

3.2.2 Water Vapour accuracy

Quantitative assessment of water vapour retrieval uncertainty is determined by direct comparison of Sen2Cor output averaged over 9 km x 9 km region of interest around Sun photometer location with ± 15 min time average reference value from AERONET Sun photometer.

The analysis is based on a large dataset of 1989 match-ups in year 2022 at 76 AERONET locations distributed over all continents and all climate zones.

Table 3-2 : Test data selection: AERONET data (level ≥ 1.5) available within ±15 min to overpass time.

Number of tiles used for analysis per continent.

Data selection oriented on data use (1/3 weight) and area of continent (2/3 weight).

climate zone	N-America	S- America	Europe	Africa	Asia	Australia	No. of Sites	No. of Tiles
Polar	72		154				7	226
Temperate	159		242				14	401
Midlatitude N	248		191	45	213		21	697
Subtropical N	85			101	116		13	302
Tropical		78		78	39	19	13	214
Subtropical S		9		61		11	5	81
Midlatitude S		23		0		34	4	57
Aural		11					1	11
number of Tiles	564	121	587	285	368	64	76	1989
percentage of Tiles	28%	6%	30%	14%	19%	3%	A WAY	For St.
²/₃ area +¹/₃ access	18%	9%	30%	15%	23%	5%	. E	
data access	17%	0.4%	76%	0.1%	4%	3%	· 🦻	We ZO
area fraction	18%	13%	8%	22%	33%	6%		-

The correlation plots of WV retrieval by Sen2Cor 2.10 (PBL 4.00) over AERONET reference are shown in Figure 3.

Water vapour retrieval is very accurate up to really high WV content with 96% of retrievals within the uncertainty goal. Average WV retrieval uncertainty is 0.23 g/cm². Validation shows a trend for little underestimation of WV by Sen2Cor confirmed by systematic part of the uncertainty:

 $U_{svs}(WV) = (-0.08 \pm 0.003) *WV + (0.01 \pm 0.006)$



Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0

Date: 12/04/2023

Page: 8

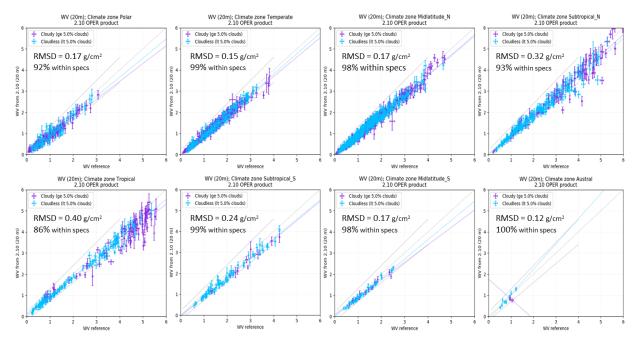


Figure 3: Correlation plots of Sen2Cor 2.10 (PBL 4.00) WV retrieval at 20 m resolution over WV reference from **AERONET per climate zone on basis of a data set at 76 AERONET sites.** The dashed line indicates x=y and the solid lines show the limits of uncertainty goal $U(WV) \le (0.1*WV_{ref}+0.2) \text{ g/cm}^2$)

3.2.3 Aerosol Optical Thickness

Quantitative assessment of aerosol optical thickness retrieval uncertainty is determined by direct comparison of Sen2Cor output averaged over 9kmx9km region of interest around Sun photometer with ±15 min time average reference value from AERONET Sun photometer. The analysis is based on a large dataset of 1989 match-ups in year 2022 at 76 AERONET locations distributed over all continents (see Figure 3 for more details).

The correlation plots of AOT retrieval by Sen2Cor 2.10 (PBL 4.00) over AERONET reference are shown in Figure 4 The data were processed with DDV algorithm respectively using AOT from the Copernicus Atmosphere Monitoring Service (CAMS) as fall back-solution for AOT-retrieval when there are less than 2% Dense Dark Vegetation (DDV) pixels in the image.

OPT-MPC Particul Mission Performance Cluster Ontical Mission Performance Cluster

Optical MPC

Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0

Date: 12/04/2023

Page: 9

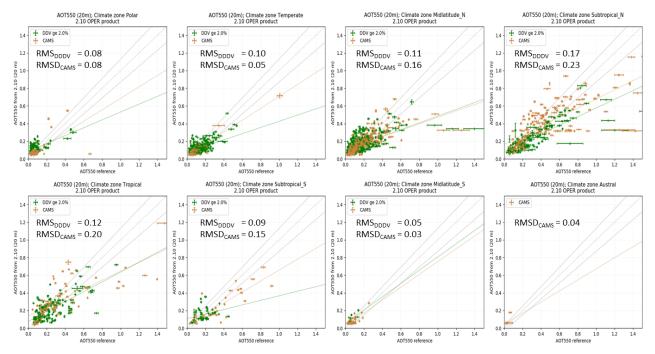


Figure 4: Correlation plot of Sen2Cor AOT₅₅₀ retrieval at 20 m resolution over AOT₅₅₀ reference from AERONET per climate zone on basis of a data set at 76 AERONET sites. Green triangles are AOT₅₅₀ retrieved with the DDV-algorithm and orange triangles are AOT₅₅₀ resulting from using CAMS data as fall-back solution. The dashed grey line indicates x=y and the solid grey lines show the limits of uncertainty goal $U(AOT_{550}) \le 0.1*AOT_{550ref}+0.03$.

The AOT-retrieval algorithm implemented in Sen2Cor requires DDV-pixels in the image. If there are not enough DDV-pixels present, then the auxiliary CAMS files embedded in the L2A products are used as fall-back solution. Therefore, aerosol optical thickness retrieval results are analysed separately for the DDV algorithm and the CAMS-fall-back solution. The DDV algorithm gives 25% to 63% of values within uncertainty goal dependent on climate zone (average 48%) with average total uncertainty of 0.11. Validation shows a trend for underestimation of higher AOT by DDV algorithm implemented in Sen2Cor confirmed by systematic part of the uncertainty $U_{sys}^{DDV}(AOT) = (-0.54 \pm 0.01) *AOT + (0.08 \pm 0.003)$. CAMS fall-back solution mostly is activated in arid, non-vegetated regions or during winter time. It gives 34% to 80% of values within uncertainty goal dependent on climate zone (average 57%), however with larger average uncertainty of 0.16. This larger uncertainty results at least partly from the higher AOT-values present in situations when CAMS data are used. Systematic uncertainty $U_{sys}^{CAMS}(AOT) = (-0.42 \pm 0.01) *AOT + (0.08 \pm 0.005)$ again shows a trend for AOT underestimation relative to AERONET at higher AOT values.

3.2.4 Classification accuracy

Classification performance is evaluated by comparison of the Sen2Cor outputs with reference samples. The reference samples were labelled visually based on the RGB and false-RGB composites, cirrus band layer, and the spectral profiles.

Current analysis of classification accuracy for Sen2Cor 2.10 SCL products were evaluated on a set of 10 Sentinel-2 L2A scenes at 4 test sites (Table 3-3) for non-snow covered products and on a set of 4 Sentinel-2 L2A scenes for test site Yakutsk with snow coverage. Results for snow covered products are reported separately.

OPT-MPC Paulor Sulpara Charles Optical Mission Performance Claster

Optical MPC

Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0 Date: 12/04/2023

Page: 10

Table 3-3: Selected test sites for Sen2Cor 2.10 validation

Site	Tile	Date	Cloud cover (%)	No data pixels (%)
Potsdam	T221111	22-03-2022	6.07	0.00
(Germany)	T33UUU	04.08.2022	18.58	0.00
Rimrock	T11TNANA	24-04-2022	7.27	1.79
(USA)	T11TMM	16-09-2022	28.12	2.00
Murcia	T30SXH	15-05-2022	24.01	0.00
(Spain)		07-10-2022	11.00	0.00
Bandung	T40147T	10-06-2022	26.48	6.48
(Indonesia)	T48MZT	22-11-2022	96	0.86
Yakutsk (Russia)	TEQVED	10-02-2022	12.76	0.00
	T52VEP	28-07-2022	12.84	0.00

Validation sites are distributed over several continents, covering different climate zones, and including various seasons, and environments.

Table 3-4: Summary of the cloud masking validation results for 4 study areas already analysed. True values are in columns and predicted values are in rows.

Potsdam (T33UUU)

	Clear	Cloud	sum	UA	CE	OA
Clear	76 %	2%	78%	97%	3%	91%
Cloud	7%	15%	22%	69%	31%	
sum	82%	18%	100%			
PA	92%	87%				Balanced OA
OE	8.4%	12.6%				94%



Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0

Date: 12/04/2023

Page: 11

Rimrock (T11TMM)

	Clear	Cloud	sum	UA	CE	OA
Clear	52 %	1%	54%	97%	3%	92%
Cloud	6%	40%	46%	87%	13%	
sum	58%	42%	100%			
PA	90%	96%				Balanced OA
OE	10.3%	3.5%				93%

Murcia (T30SXH)

	Clear	Cloud	sum	UA	CE	OA
Clear	52 %	5%	56%	92%	8%	90%
Cloud	5%	39%	44%	89%	11%	
sum	56%	44%	100%			
PA	91%	89%				Balanced OA
OE	8.5%	10.8%				92%

Bandung (T48MZT)

	Clear	Cloud	sum	UA	CE	OA
Clear	42 %	0%	42%	100%	0%	92%
Cloud	8%	50%	58%	87%	13%	
sum	50%	50%	100%			
PA	85%	100%				Balanced OA
OE	15.4%	0.2%				92%

Yakutsk (T52VEP, summer – no snow cover)

	Clear	Cloud	sum	UA	CE	OA
Clear	75 %	0%	75%	100%	0%	100%
Cloud	0%	25%	25%	99%	1%	
sum	75%	25%	100%			
PA	100%	99%				Balanced OA
OE	0.2%	0.7%				100%

OPT-MPC Parties of the control of t

Optical MPC

Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0 Date: 12/04/2023

Page: 12

The accuracy assessment for cloud masking per test site is presented in Table 3-4 for products without snow cover. Sen2Cor classes cloud medium probability, cloud high probability and thin cirrus are aggregated to clouds, whereas Sen2Cor classes water, vegetated, non-vegetated and snow are aggregated to clear pixels. Commission and omission errors correspond to user's (UA) and producer's (PA) accuracies respectively. Balanced overall accuracy (OA) is the average of omission (OE) and commission (CE) errors. Results show good cloud masking performance with balanced overall accuracies of clear vs cloud pixels ranging between 92-100%. In terms of commission errors of the clear pixel the range is between 0-8% with the lower values at sites Bandung and Yakutsk and the higher for Murcia which show also a 11% omission of clouds.

Table 3-5: Summary of the cloud masking validation results for snow covered products. True values are in columns and predicted values are in rows.

Yakutsk (T52VEP, winter - with snow cover)

	Clear	Cloud	sum	UA	CE	OA
Clear	45 %	36%	81%	55%	45%	63%
Cloud	1%	18%	19%	95%	5%	
sum	46%	54%	100%			
PA	98%	33%				Balanced OA
OE	1.9%	66.8%				77%

The accuracy assessment for cloud masking on snow covered products (so far only test site Yakutsk) is presented in Table 3-5. Results show worse cloud masking performance compared to products without snow cover, with balanced overall accuracy of clear vs cloud pixels of 77%. Commission errors of the clear pixel is 45%. It is important to consider that labelling the snow-covered product is more challenging than products without snow cover, which leads to higher uncertainties in the labelled masking references. There are more (longer) shadows in winter due to the low sun elevation, which are difficult to recognize over bright snow surface.

Figure 5 to Figure 7 show the misclassification of the clear, thin cirrus, and cloud high probability pixels in more details in the form of spider plots. Figure 5 shows the misclassification of omitted clear pixels and the real classes of the committed clear pixels. In Bandung scenes, there are 17% clear pixels misclassified as thin cirrus. In Yakutsk winter scene, there are 16% of cloud shadow and 20% thin cirrus pixels misclassified as clear pixels. Figure 6 shows the misclassification of omitted thin cirrus pixels and the real classes of the committed thin cirrus pixels. In Yakutsk winter scene, there are 20% omitted thin cirrus pixels misclassified as snow pixels. Figure 7 shows the misclassification of omitted cloud high probability pixels and the real classes of the committed cloud high probability pixels. Both the omission and commission errors of cloud high probability pixels are relatively low. This shows that misclassification between thin cirrus and clear pixels often occurs in scenes from tropical climate such as Bandung, and in scenes with snow covers, cloud high probability pixels are correctly classified but thin cirrus and cloud shadow pixels are often misclassified as clear pixels.

OPT-MPC

Optical MPC

Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0

Date: 12/04/2023

Page: 13

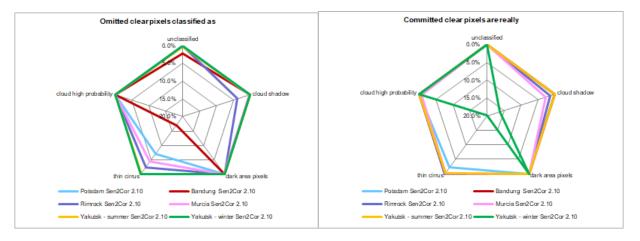


Figure 5: Spider plots of the omission and commission errors of clear pixels

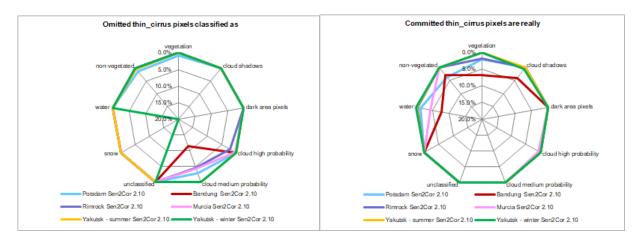


Figure 6: Spider plots of the omission and commission errors of thin cirrus pixels

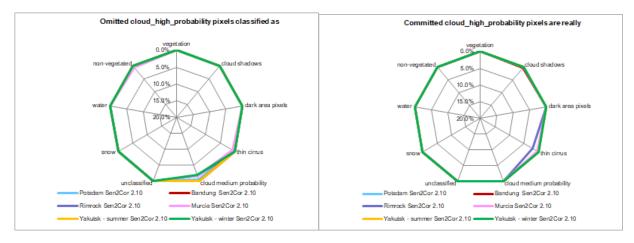


Figure 7: Spider plots of the omission and commission errors of cloud high probability pixels



Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0 Date: 12/04/2023

Page: 14

4. Product features

Some known product features are visible on Sentinel 2 Level-2A products.

These features are generated by:

- the current scene classification algorithm which has some known limitations,
- the overlap area between adjacent tiles,
- terrain over-correction on shaded areas due to inaccuracies of the Digital Elevation Model,
- products with a Sun-Zenith Angle (SZA) higher than 70°,
- corrupted pixels affected by missing or degraded instrument source packets,
- discontinuities visible in Terrain Correction on very flat areas,
- artefacts at the edge of the swath due to L2A NoData mask.

Please refer to https://sentinels.copernicus.eu/web/sentinel/technical-guides/sentinel-2-msi/data-guality-reports/product-features for more details and examples of the known Sentinel 2 product features, as well as to the https://sentinels.copernicus.eu/web/sentinel/technical-guides/sentinel-2-msi/data-guality-reports/product-features for more details and examples of the known Sentinel 2 product features, as well as to the https://sentinels.copernicus.eu/web/sentinel/technical-guides/sentinel-2-msi/data-guality-reports/product-features for more details and examples of the known Sentinel 2 product features, as well as to the <a href="https://sentinels.copernicus.eu/web/sentinel/technical-guides/sentinel/technical-gu



Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0 Date: 12/04/2023

Page: 15

5. Product anomalies

5.1 Introduction

This section describes the L2A product anomalies that occurred in 2023. Please refer to the APR 2022 or to the on-line Sentinel-2 anomaly database https://s2anomalies.acri.fr/anomalies to have the full list of anomalies.

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.

Each anomaly is tagged with a code "#N" allowing linking it to a given processing baseline through the three tables provided in the sub-sections below.

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

	Baseline number	05.09	
Anomaly ID	Deployment date	06/12/2022	
	Anomaly title		
81	Very low negative reflectances near	Some products	

Table 5-1: Anomaly and processing baseline summary.

5.2 Very low negative reflectances near the edge of the swath (#81)

A new anomaly consisting in a dark area with very low negative reflectances near the edge of the swath was observed by the S2GM team on the product:

S2B_MSIL2A_20220329T105629_N0400_R094_T30SXJ_20220329T134242.

This anomaly is particularly visible on the B02 band. This radiometry "distortion" defect is not present in the L1C image. This defect is the result of an overcorrection of the adjacency correction algorithm for the case when the radiometry of the pixels near the swath border is noticeably different from the average radiometry of the scene. The blue bands are the spectral bands which are affected the most. An evolution is in preparation to improve the quality of the adjacency correction for the pixels near the swath border. Users are advised to pay particular attention to the swath border area for the cases mentioned above (very heterogeneous radiometry of the scene). The effect can be visible up to 1 km from the swath border. An evolution is in preparation to improve the quality of the adjacency correction for the pixels near the swath border for these particular cases.



Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0

Date: 12/04/2023

Page: 16

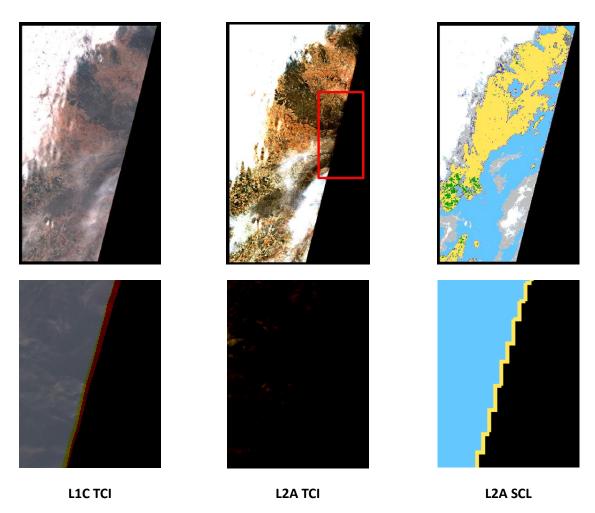


Figure 8 : Illustration of the very low negative reflectances near the edge of the swath observed on the L2A product: S2B_MSIL2A_20220329T105629_N0400_R094_T30SXJ_20220329T134242.

An illustration of the corresponding L1C product (first column) is also shown

OPT-MPC Paragraphy of The Control Musican Performance Cluster Optical Musican Performance Cluster

Optical MPC

Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0 Date: 12/04/2023

Page: 17

6. General information on products

6.1 Insights into the Copernicus Collection-1

The Collection-1 reprocessing will provide consistent Sentinel 2A and Sentinel 2B time series with a uniform processing baseline (PB 05.00) and optimized calibration.

The L2A surface reflectance product will be compliant with the CEOS Analysis Ready Data for Land (CARD4L) standard from 2015 to the present.

The improvements introduced in recent baselines will be generalized to the whole time series:

- Geometric refining using the high-quality Copernicus Digital Elevation Model (introduced in PB 03.00),
- Harmonized radiometry after alignment of S2B on S2A (introduced with PB 04.00),
- Most recent product format for L1C and L2A with radiometric offset, quality masks in raster format, L2A quality indicators, DOI (introduced in PB 04.00),
- Improved L2A processing algorithms for scene classification and surface reflectance (aligned with PB 04.00).

In addition, the PB 05.00 will provide some specific improvements over the current 04.00 baseline:

- Optimization of the applicability of successive radiometric and geometric calibrations,
- Reliable quality mask for radiometric saturation,
- Identification of defective pixels from missing instrument source packets in L2A Scene Classification layer,
- Use of the Copernicus Digital Elevation Model at 30 m resolution.

Collection-1 products are distributed via three different platforms:

- https://creodias.eu.: the data catalogue is accessible at https://finder.creodias.eu/. To query only Collection-1 products, a filter on the sensing date (i.e. before January 2022 for Collection-1 products) and on the publication date can be used, as the dissemination of these products started in January 2023.
- https://www.onda-dias.eu: the data catalogue is accessible at https://catalogue.onda-dias.eu/catalogue/. To query only Collection-1 products (PB 05.00), you can write "*_N0500_*" in the research bar of the catalogue.
- https://mundiwebservices.com: L1C Collection-1 products can be found at https://mundiwebservices.com/geodata/S2R MSI L1C, and L2A Collection-1 products at https://mundiwebservices.com/geodata/S2R MSI L2A.

In March 2023, Collection-1 products of August to December 2021 are available. The dissemination of older products is ongoing.

Additional information regarding the status and accessibility of Collection 1 reprocessed data can be found on: https://sentinels.copernicus.eu/web/sentinel/technical-guides/sentinel-2-msi/copernicus-sentinel-2-collection-1-availability-status.

OPT-MPC Paragraphy of The Control Musican Performance Cluster Optical Musican Performance Cluster

Optical MPC

Data Quality Report – Sentinel-2 MSI L2A April 2023

Ref.: OMPC.CS.DQR.002.03-2023

Issue: 60.0 Date: 12/04/2023

Page: 18

6.2 Product Format

On December 6th 2016, a new naming convention has been introduced (Product Specification Document version 14). The new convention leads to shorter product paths with less redundancy of information. The product name now includes the acquisition date and a "product discriminator" which is related to the acquisition date but can be different in some instances.

A reformatting of the Data Hub product archive to the single-tile, short name format is currently in progress. The JP2000 images are not affected by the reformatting.

Note that the product footprint for all products generated before July 20th 2016 include areas of No Data, while for the later product the footprint outlines valid pixels only.

6.3 Off-line products

Beginning 23rd September 2019, Sentinel-2 products older than one year will not be available on-line in the Copernicus data hubs. Instead, they will be retrieved on demand from the Long-Term Archive (LTA). Products retrieved from the LTA will be different from the original ones delivered in Near Real Time production:

- The product discriminator (the second date in the product) will be different. However, the zip file provided with the delivery will keep the name of the original product.
- The product will be restored using the latest applicable format (currently compact, single tile format, PSD v14.2).
- The GENERATION_TIME field in the User Product metadata will also reflect the date of the retrieval from the LTA.

See https://scihub.copernicus.eu/userguide/LongTermArchive for more details.

6.4 Reprocessed products

Two situations can lead to a recovery reprocessing and update of the SciHub archive:

- Products affected by major anomalies tracked in the Sentinel-2 anomaly database
- Datastrips with missing L1C tiles. In this case the products are not tracked in the anomaly database.

In both cases, the original products are removed and replaced by products with a more recent generation time. However, in the latter case, the original products can still be considered as valid.

End of document