COPERNICUS SPACE COMPONENT SENTINEL OPTICAL IMAGING

MISSION PERFORMANCE CLUSTER SERVICE

Data Quality Report

Sentinel-2 MSI L2A

October 2022

Ref.: OMPC.CS.DQR.002.09-2022
Issue: 54.0
Date: 11/10/2022
Contract: 4000136252/21/I-BG

Customer:	ESA	**Document Ref.:**	OMPC.CS.DQR.002.09-
Contract No.:	4000136252/21/I-BG	**Date:**	11/10/2022
		Issue:	54.0

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	**Authorized by**	J. Jackson, OPT-MPC S2 Technical Manager
Distribution:	ESA, published in Sentinel Online		
Accepted by ESA	V. Boccia, ESA Deputy TO		S. Dransfeld, ESA TO
Filename	OMPC.CS.DQR.002.09-2022 - i54r0 - MSI L2A DQR October 2022.docx		

Changes Log

Version	Date	Changes
54.0	11/10/2022	First version

List of Changes

Version	Section	Answers to RID	Changes

Table of content

List of Figures

List of Tables

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 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 0034-4257[1].

1.2 Main points for this month

- Nothing to report.

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

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 for surface reflectance, water vapour and aerosol optical thickness reported in this issue of the L2A Data Quality Report have been measured with Sen2cor versions 2.8 (toolbox version), and may thus slightly differ from the performance of the current processing baseline. Cloud masking performance was assessed with Sen2Cor 2.10.

Table 2-1: 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	Uncertainty goal of WV retrieval: $U(WV) \leq (0.1*WV_{ref}+0.2)$ g/cm2	94% of retrieved Water vapour values are within uncertainty goal
Aerosol Optical Thickness at 550 nm	Uncertainty goal of AOT550 retrieval: U(AOT) ≤ 0.1*AOTref+0.03	49% (54%) of Aerosol optical thickness values at 550 nm retrieved with DDV algorithm (with CAMS data as fallback solution) are within uncertainty goal
Classification / Cloud masking	No requirement defined.	Commission of clear pixels ranges from 6% to 19% depending on test site with the higher values mostly due to confusion with transparent clouds. Balanced overall accuracies of clear vs cloud pixels range between 87 – 94%.

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

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. " Evaluation of SEN2COR Surface Reflectance Products over land surface with reference measurements on Ground," in 2022 Ieee 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 $\Delta SR \leq 0.05*SR_{ref} + 0.005$. Systematic uncertainty $U_{sys}(SR) = (0.02 \pm 0.007) * SR + (0.0 \pm 0.002)$ 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.

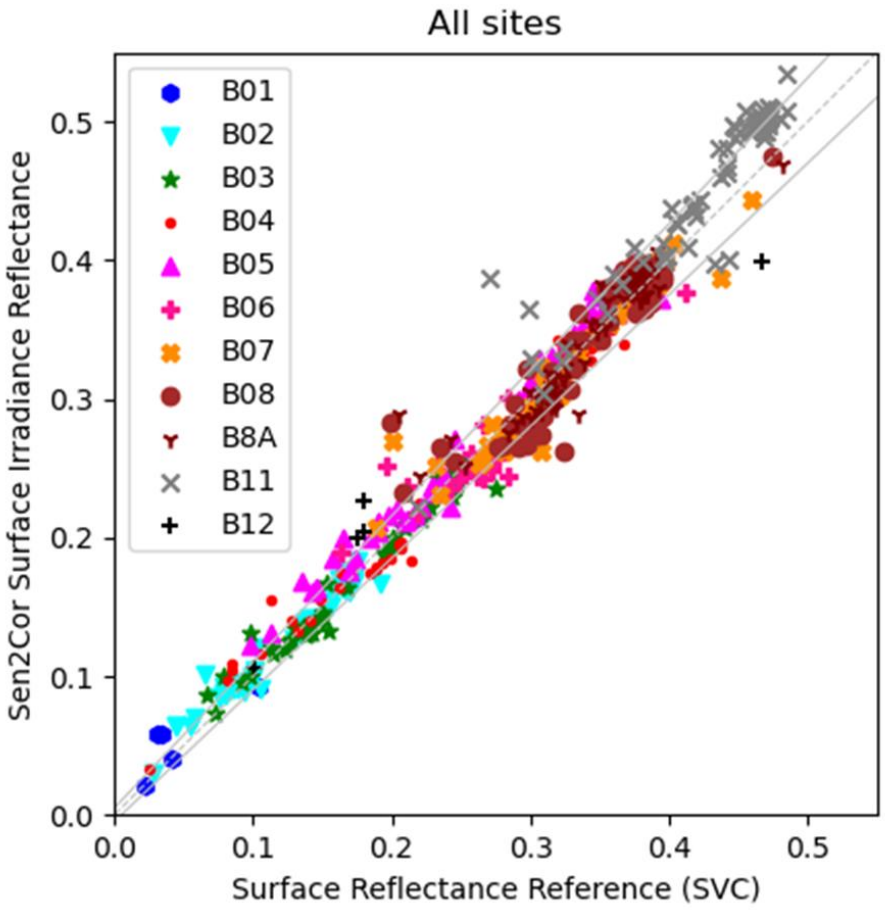


Figure 1: Correlation plot of SR retrieval by Sen2Cor over reference measurements on ground.

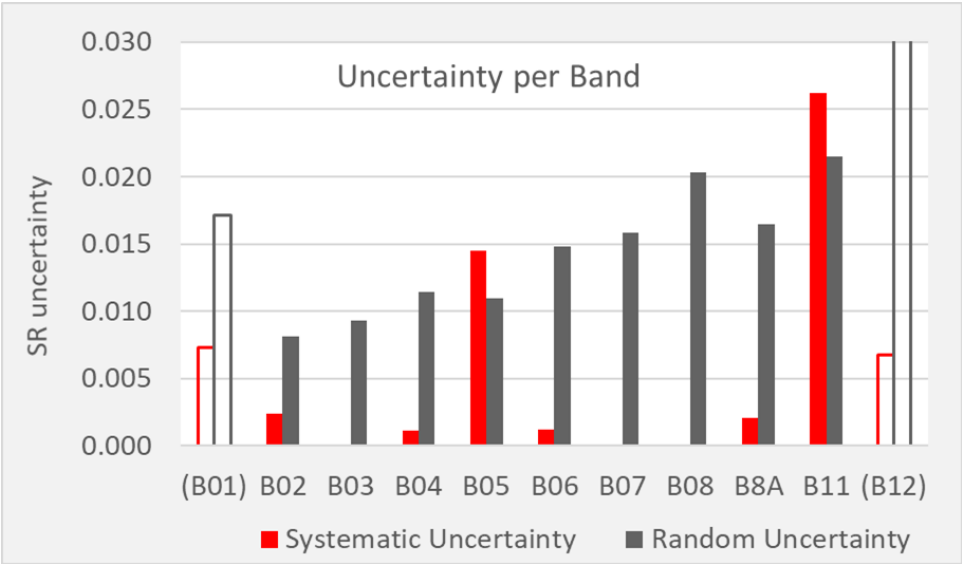


Figure 2: Average SR retrieval performance per band.

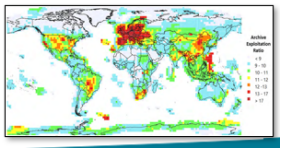
2.2.2 Water Vapour accuracy

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 2397 match-ups in year 2020 at 80 AERONET locations distributed over all continents and all climate zones.

Table 2-2 : Site selection: AERONET data (level ≥ 1.5) available within ±15 min to overpass time. Number of sites selected per continent oriented on data use (2/3 weight) and area of continent (1/3 weight).

climate zone	N-America	S- America	Europe	Africa	Asia	Australia	Antarctica	No. of Sites	No. of Tiles
Polar	2		5		1			**8**	224
Temperate	3		16		3			**22**	758
Midlatitude N	6		10	1	4			**21**	745
Subtropical N	3			2	4			**9**	290
Tropical		3		4	3	1		**11**	189
Subtropical S		2		1		1		**4**	117
Midlatitude S		1		1		2		**4**	60
Aural		1						**1**	14
number of sites	**14**	**7**	**31**	**9**	**15**	**4**	**0**	**80**	**2397**
percentage of sites	**18%**	**9%**	**39%**	**11%**	**19%**	**5%**	**0%**		
⅓ area +⅔ access	17.5%	4.7%	52.8%	7.5%	13.5%	3.9%	3.5%		
data access	17.3%	0.4%	75.5%	0.1%	3.9%	2.8%	0.0%		
area fraction	18%	13%	7%	22%	33%	6%	10%		



The correlation plots of WV retrieval by Sen2Cor 2.8 over AERONET reference are shown in Figure 3. 2020.

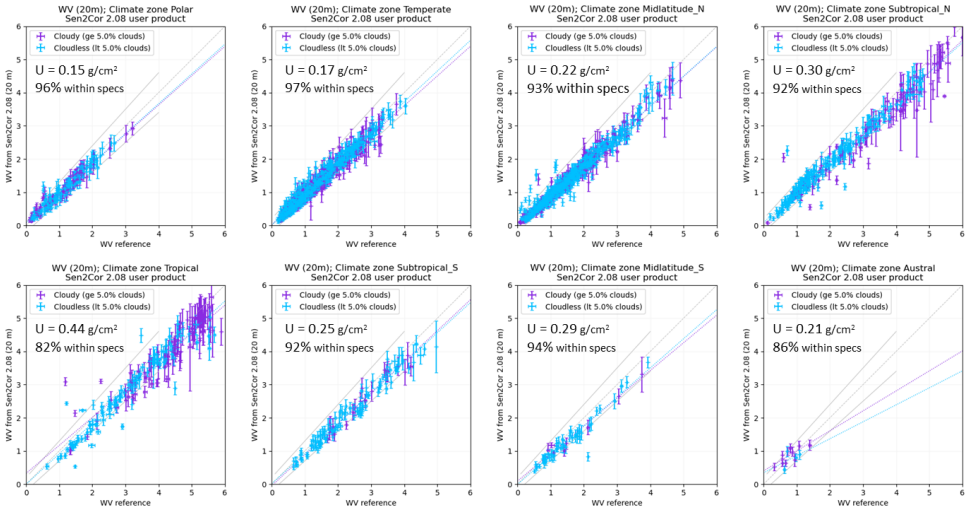


Figure 3: Correlation plots of Sen2Cor 2.8 WV retrieval at 20 m resolution over WV reference from AERONET per climate zone on basis of a data set at 80 AERONET sites. *The dashed line indicates x=y and the solid lines show the limits of uncertainty goal U(WV) ≤ (0.1*WV_{ref}+0.2) g/cm²)*

Water vapour retrieval is very accurate up to really high WV content with 94% of retrievals within the uncertainty goal. Average WV retrieval uncertainty is 0.27 g/cm^2. Validation shows a trend for little underestimation of WV by Sen2Cor confirmed by systematic part of the uncertainty:

$U_{sys}(WV) = (-0.10 \pm 0.004) * WV + (0.03 \pm 0.01)$

2.2.3 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 2397 match-ups in year 2020 at 80 AERONET locations distributed over all continents (see Figure 3 for more details).

The correlation plots of AOT retrieval by Sen2Cor 2.8 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.

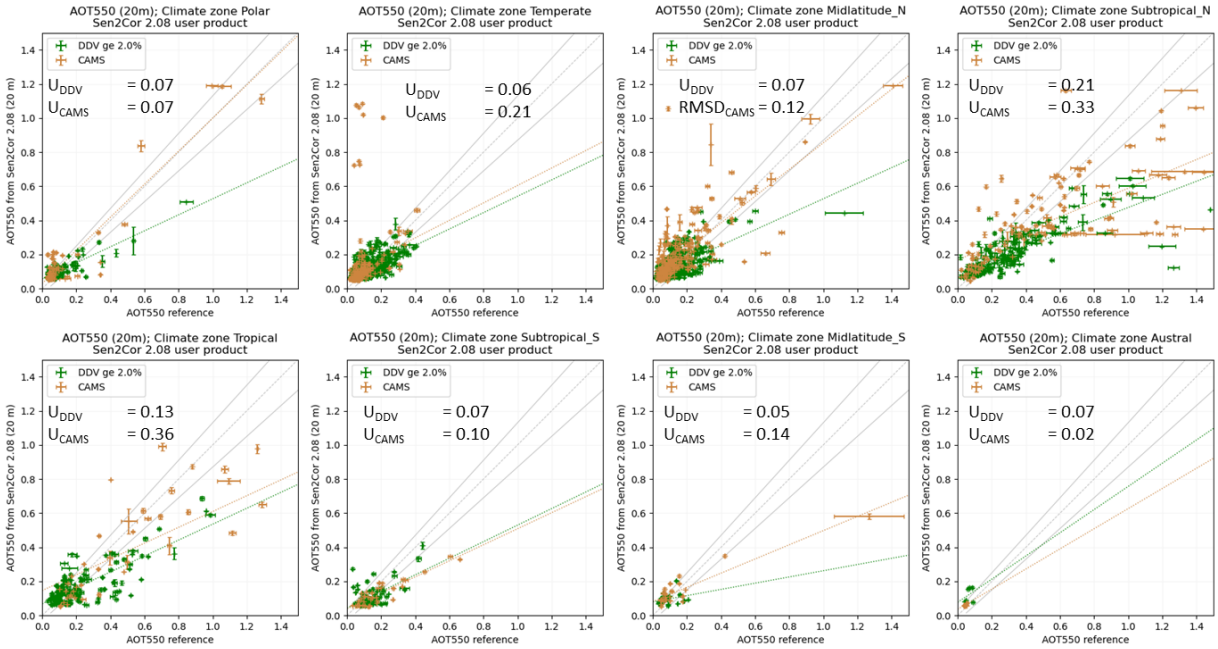


Figure 4: Correlation plot of Sen2Cor AOT$_{550}$ retrieval at 20 m resolution over AOT$_{550}$ reference from AERONET per climate zone on basis of a data set at 80 AERONET sites. *Green triangles are AOT$_{550}$ retrieved with the DDV-algorithm and orange triangles are AOT$_{550}$ resulting from using 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$_{550}$) ≤ 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 49% of values within uncertainty goal with average total uncertainty of 0.10. Validation shows a trend for underestimation of higher AOT by DDV algorithm implemented in Sen2Cor confirmed by systematic part of the uncertainty $U_{sys}^{DDV}(AOT) = (-0.56 \pm 0.01) * AOT + (0.07 \pm 0.002)$. CAMS fall-back solution mostly is activated in arid, non-vegetated regions or during winter time. It gives 54% of values within uncertainty goal, however with larger average uncertainty of 0.29. This larger uncertainty results at least partly from the higher AOT-values present in situations when CAMS data are used. Systematic uncertainty $U_{sys}^{CAMS}(AOT) = (-0.46 \pm 0.02) * AOT + (0.09 \pm 0.006)$ again shows a trend for AOT underestimation relative to AERONET at higher AOT values.

2.2.4 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 19 Sentinel-2 L2A scenes at 4 test sites (Table 2-3).

Table 2-3: Selected test sites for Sen2Cor 2.10 validation

Site	Tile	Date	Cloud cover (%)	No data pixels (%)
Potsdam (Germany)	T33UUU	08-02-20	0.83	34.28
		30-07-20	15.14	0.00
		19-12-20	1.00	33.46
		11-05-21	12.76	0.00
		08-10-21	19.71	0.00
Rimrock (USA)	T11TMM	17-03-20	11.00	8.52
		22-08-20	23.66	1.95
		14-01-21	22.72	1.83
		25-06-21	6.77	4.73
		10-11-21	32.14	2.04
Murcia (Spain)	T30SXH	30-04-20	18.71	0.00
		22-09-20	19.33	0.00
		19-02-21	3.10	0.00

Site	Tile	Date	Cloud cover (%)	No data pixels (%)
		09-07-21	17.80	0.00
		11-12-21	4.66	0.00
Bandung (Indonesia)	T48MZT	16-05-20	19.39	0.55
		08-10-20	45.53	0.78
		14-08-21	19.09	0.83
		21-01-22	27.36	0.90

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

Table 2-4: Summary of the cloud masking validation results for 4 study areas already analysed

Potsdam

	Clear pixels	Clouds	sum	UA	CE	OA
Clear pixels	59%	4%	63%	94%	6%	96%
Clouds	0%	37%	37%	100%	0%	
sum	59%	41%	100%			
						Balanced OA
PA	100%	91%				
OE	0.2%	8.9%				97%

Murcia

	Clear pixels	Clouds	sum	UA	CE	OA
Clear pixels	63%	8%	71%	88%	12%	91%
Clouds	1%	28%	29%	97%	3%	
sum	64%	36%	100%			
						Balanced OA
PA	99%	77%				
OE	1.4%	23.3%				93%

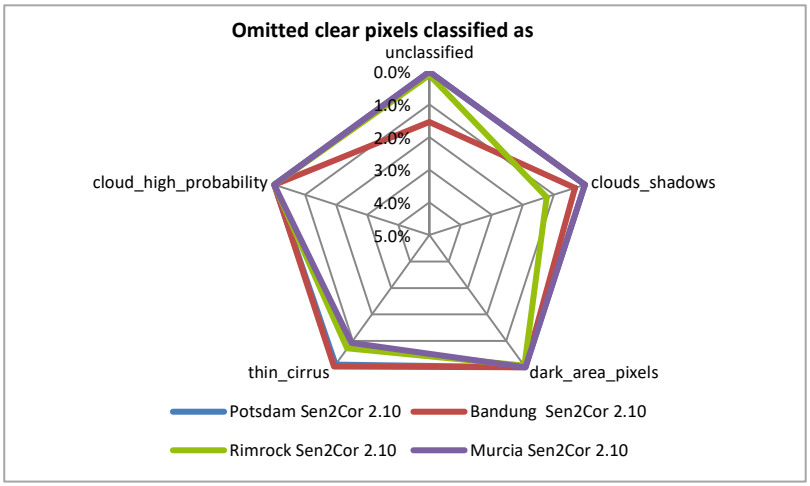
Rimrock

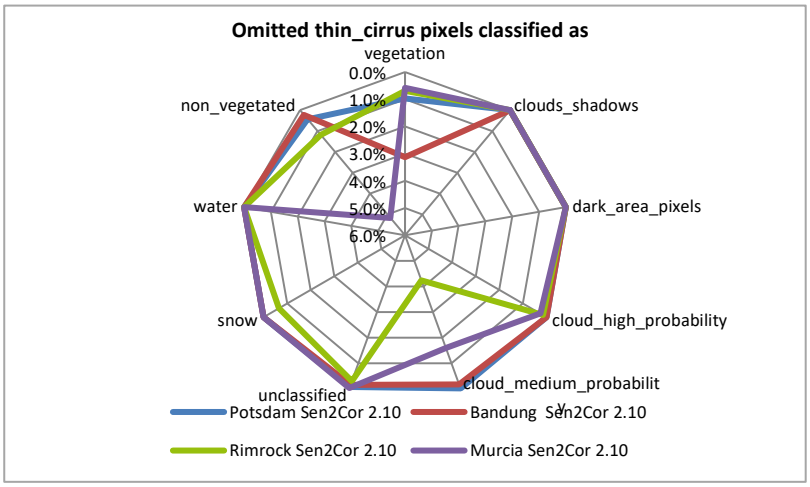
	Clear pixels	Clouds	sum	UA	CE	OA
Clear pixels	46%	11%	57%	81%	19%	87%
Clouds	2%	41%	43%	95%	5%	
sum	48%	52%	100%			
						Balanced OA
PA	96%	80%				
OE	4.2%	20.5%				89%

Bandung

	Clear pixels	Clouds	sum	UA	CE	OA
Clear pixels	44%	5%	49%	90%	10%	94%
Clouds	1%	50%	51%	99%	1%	
sum	44%	56%	100%			
						Balanced OA
PA	99%	91%				
OE	1.2%	9.2%				94%

The accuracy assessment for cloud masking per test site is presented in Table 2-4. Sen2Cor classes cloud medium probability, cloud high probability and thin cirrus are aggregated to clouds and 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 87 – 94%. In terms of commission errors of the clear pixel the range is between 6-19% with the lower values at sites Potsdam and Bandung and the higher for Murcia and Rimrock which show also a 20% omission of clouds. This high omission of clouds is due to confusion with thin cirrus clouds visible in the spider plots (Figure 5). Other remarkable omission in the spider plot is between different cloud classes of Sen2Cor and thus not important. Also the omission of clear pixels for Bandung which are classified as 'unclassified' is not critical.


Omitted clear pixels classified as
unclassified
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
clouds_shadows
dark_area_pixels
thin_cirrus
cloud_high_probability
Potsdam Sen2Cor 2.10
Bandung Sen2Cor 2.10
Rimrock Sen2Cor 2.10
Murcia Sen2Cor 2.10


Omitted thin_cirrus pixels classified as
vegetation
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
clouds_shadows
dark_area_pixels
cloud_high_probability
cloud_medium_probabilit
y
unclassified
snow
water
non_vegetated
Potsdam Sen2Cor 2.10
Bandung Sen2Cor 2.10
Rimrock Sen2Cor 2.10
Murcia Sen2Cor 2.10

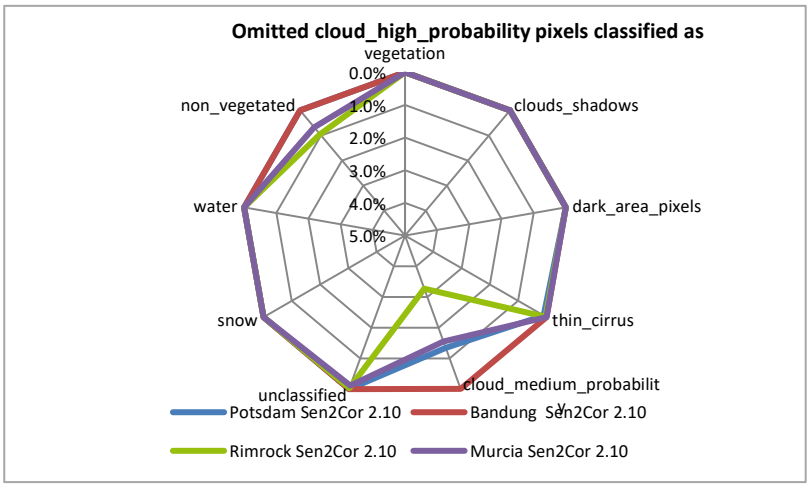

Omitted cloud_high_probability pixels classified as
vegetation
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
clouds_shadows
dark_area_pixels
thin_cirrus
cloud_medium_probabilit
y
unclassified
snow
water
non_vegetated
Potsdam Sen2Cor 2.10
Bandung Sen2Cor 2.10
Rimrock Sen2Cor 2.10
Murcia Sen2Cor 2.10

Figure 5 : Summarized results of omission and commission classification errors for clear pixels, thin cirrus pixels and clouds detection for the 4 analysed sites.

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.

For more details on the evolutions of the Sentinel-2 L2A products tagged by different processing baselines please refer to the following webpage:

https://sentinels.copernicus.eu/web/sentinel/technical-guides/sentinel-2-msi/processing-baseline.

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 Copernicus DEM since baseline 03.00
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 for baseline >=02.11 and Copernicus DEM 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,
- 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 03.00

On March 30th, 2021 a new processing baseline 03.00 has been introduced. The topographic correction and scene classification are improved thanks to the use of the Copernicus 90 m DEM.

3.1.3 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.

3.1.4 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 6:

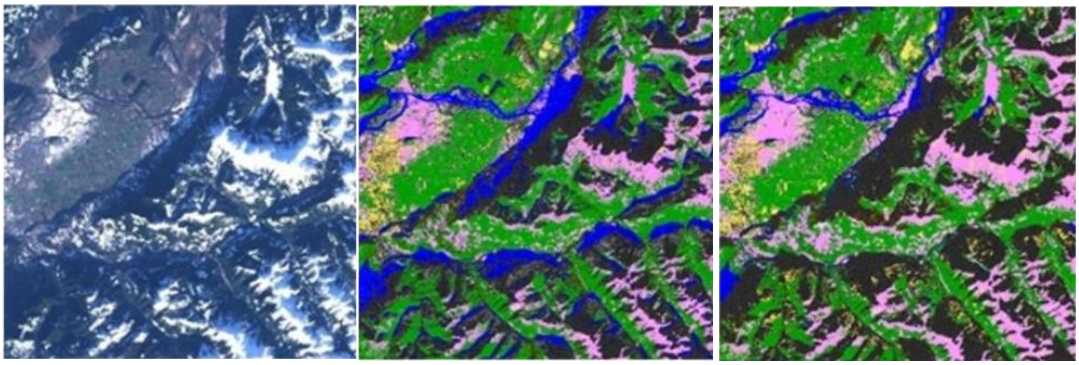


Figure 6: Improvement of topographic shadow classification. Left: L1C True Colour image. Middle: Scene Classification Layer PB 03.00 with false water detections in topographic shadows. Right: Scene Classification Layer for PB 04.04 with correctly classified topographic shadows.

- 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 7: 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.

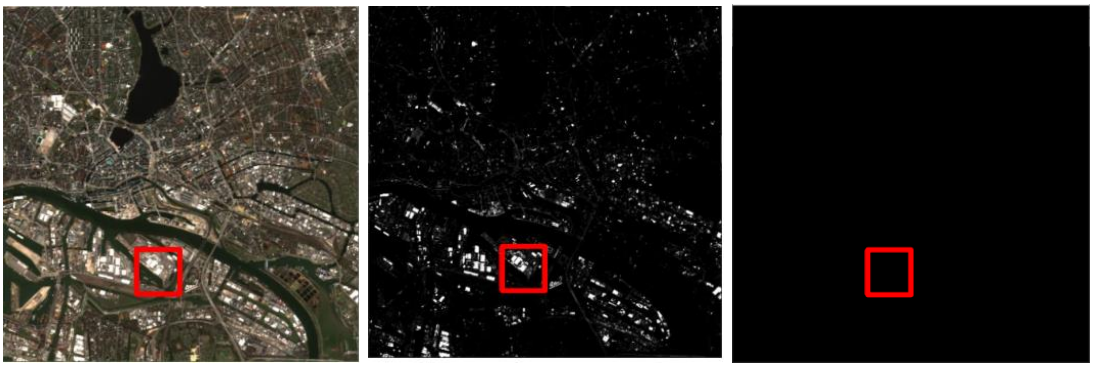


Figure 8: Improvement of the cloud detection. Left: L2A true colour image. Middle: Cloud Probability Layer of PB 03.00 product showing false cloud detections on bright targets. Right: Cloud Probability layer for PB 04.00 without false detections.

- 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://s2anomalies.acri.fr/

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.

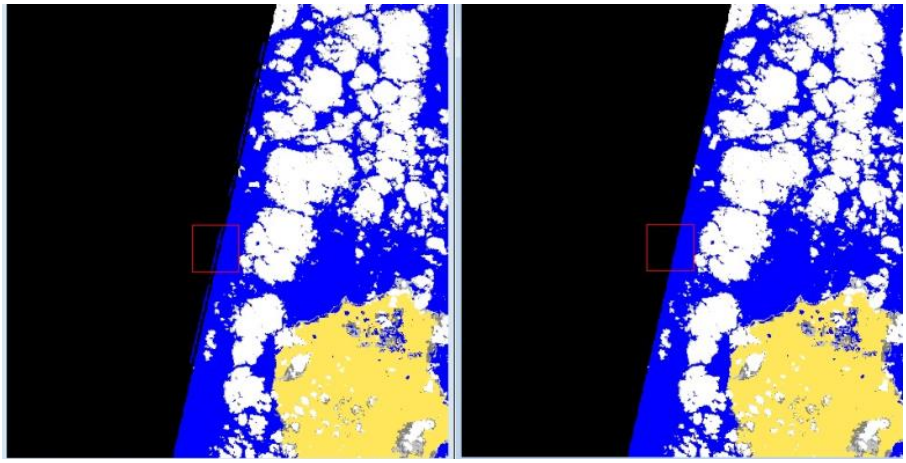


***Figure 9: Incorrect No Data Mask (anomaly #2)**. Left: pixels incorrectly flagged as water (blue) near the swath edge. Right: same image after correction.*

4.4 Encoding of Quality Bands (#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.

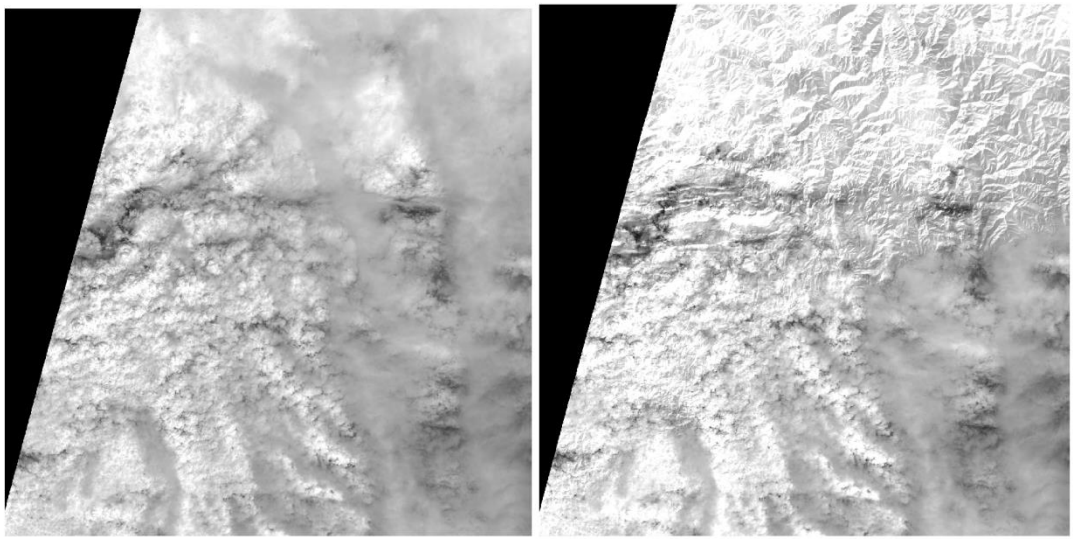


Figure 10: Band B04, Tile 32TLP from orbit S2B 7098. *Left: L1C image; Right: L2A image. The topography seems to be visible through the opaque clouds. (Anomaly #4)*

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.

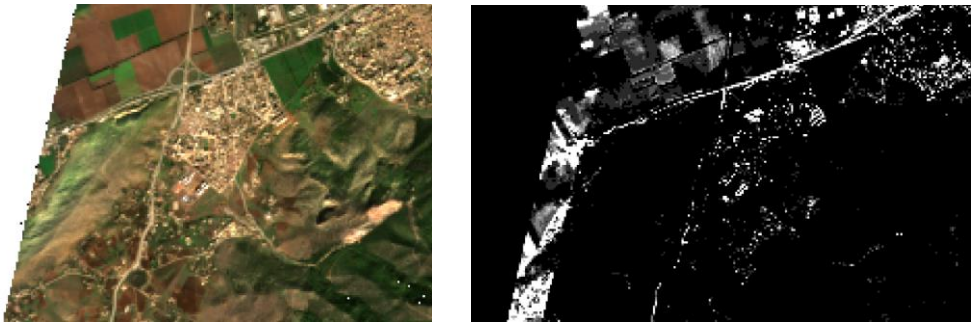


Figure 11: Incorrect values of the cloud probability mask (CLDPRB) near the boundary of the swath. Left: L2A true colour image, Right: CLDPRB mask.

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 12: 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.

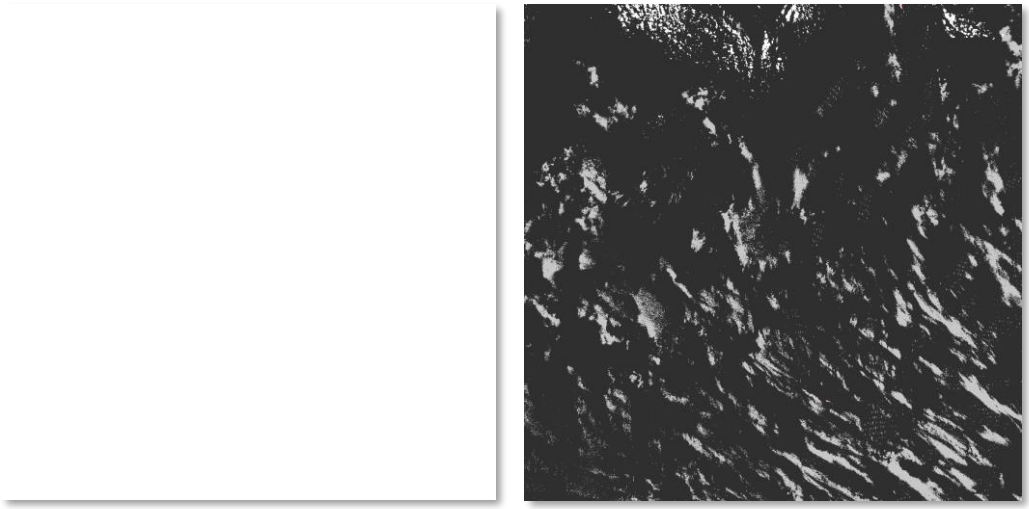


Figure 13: Incorrect Scene Classification for products at high Sun-Zenith Angle
Left: True Colour Image (Snow and clouds).
Right: Scene Classification. Black pixels are incorrectly classified as “Dark Features”.
Ref: (S2B_MSIL2A_20191105T022549_N0213_R017_T46DEH_20191105T064747, Australian Antarctic 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.

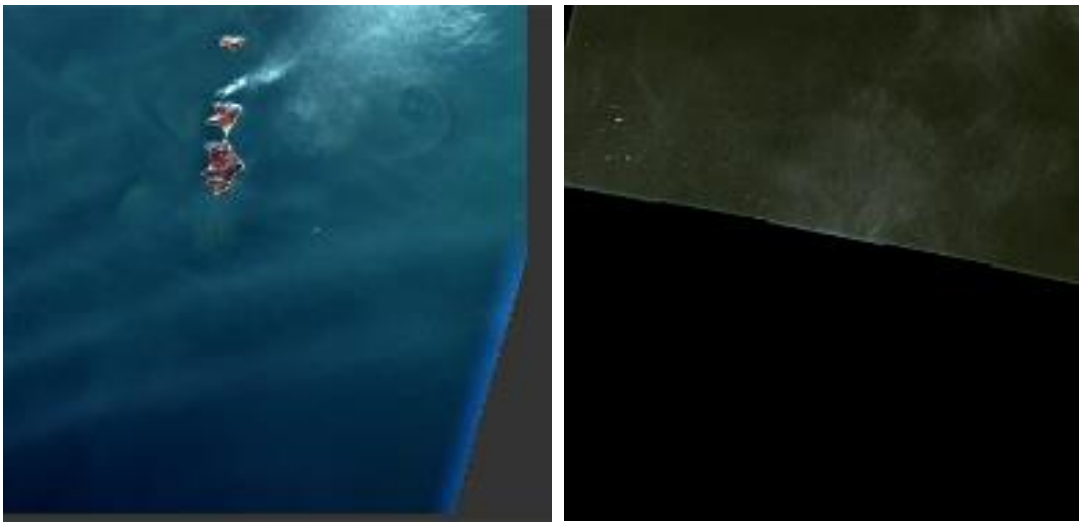


Figure 14: Halo near a swath edge (left) or data-strip end (right). Anomaly #66.

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).

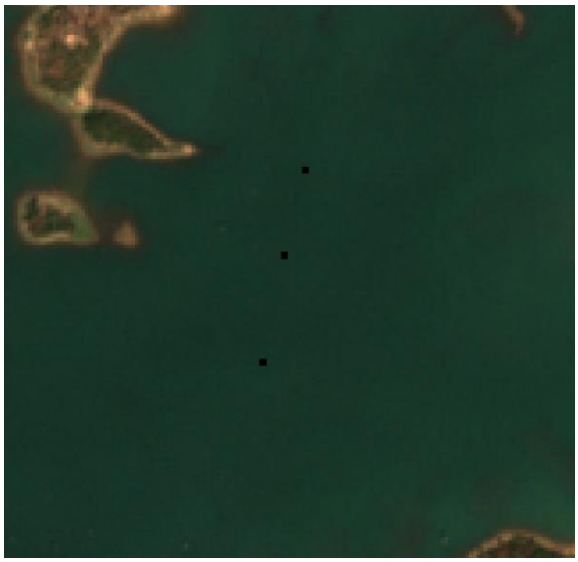


Figure 15: No data pixels identified in the swath [band B12]
Product: S2A_MSIL2A_20220125T032021_N0400_R118_T48PWC_20220125T060655.SAFE

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.

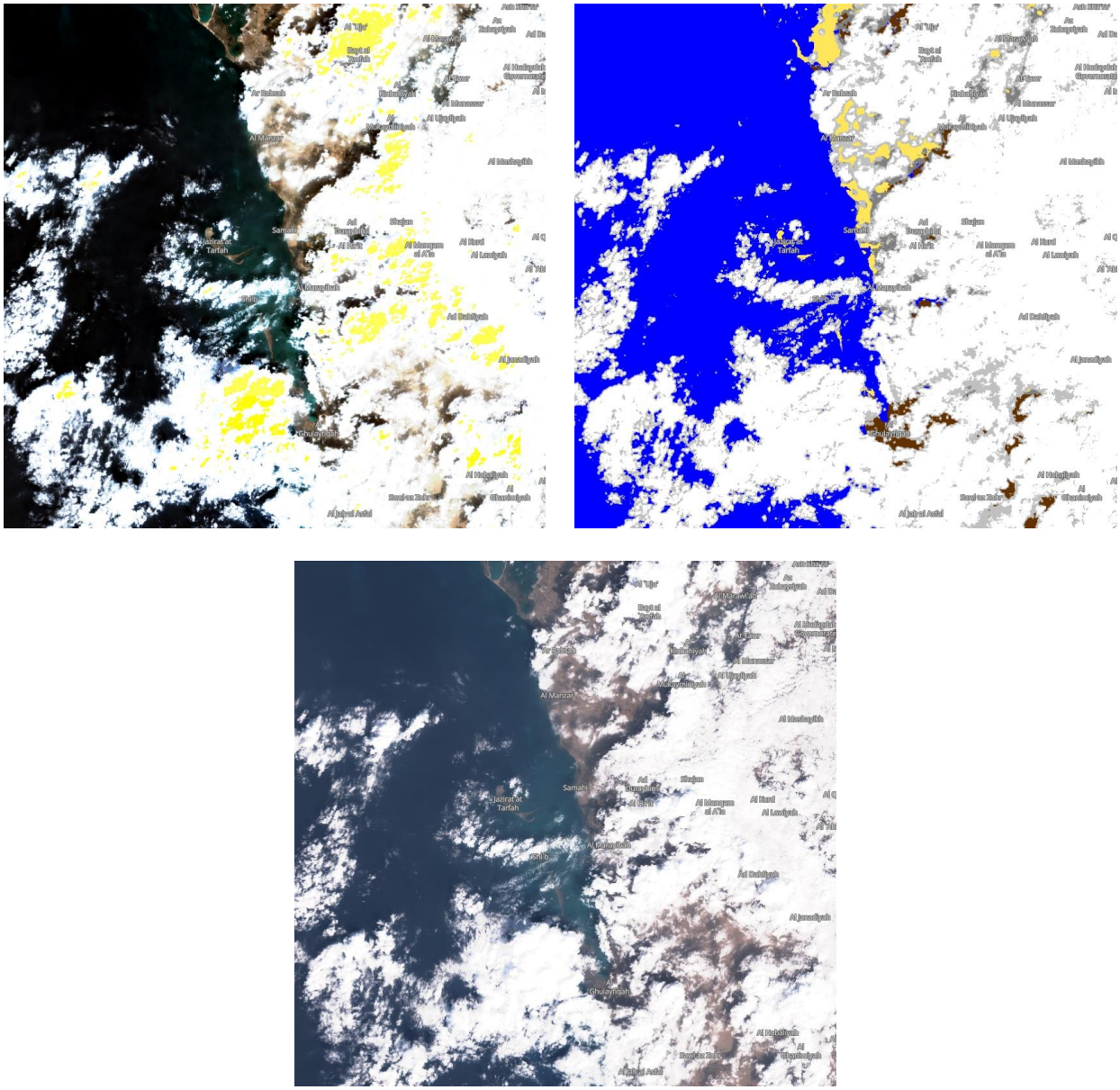


Figure 16: Illustration of the L2A surface reflectance overflow > 32768 in the L2A TCI image (top left). The L2A SCL image (top right) and the associated L1C (bottom middle) are also shown.

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

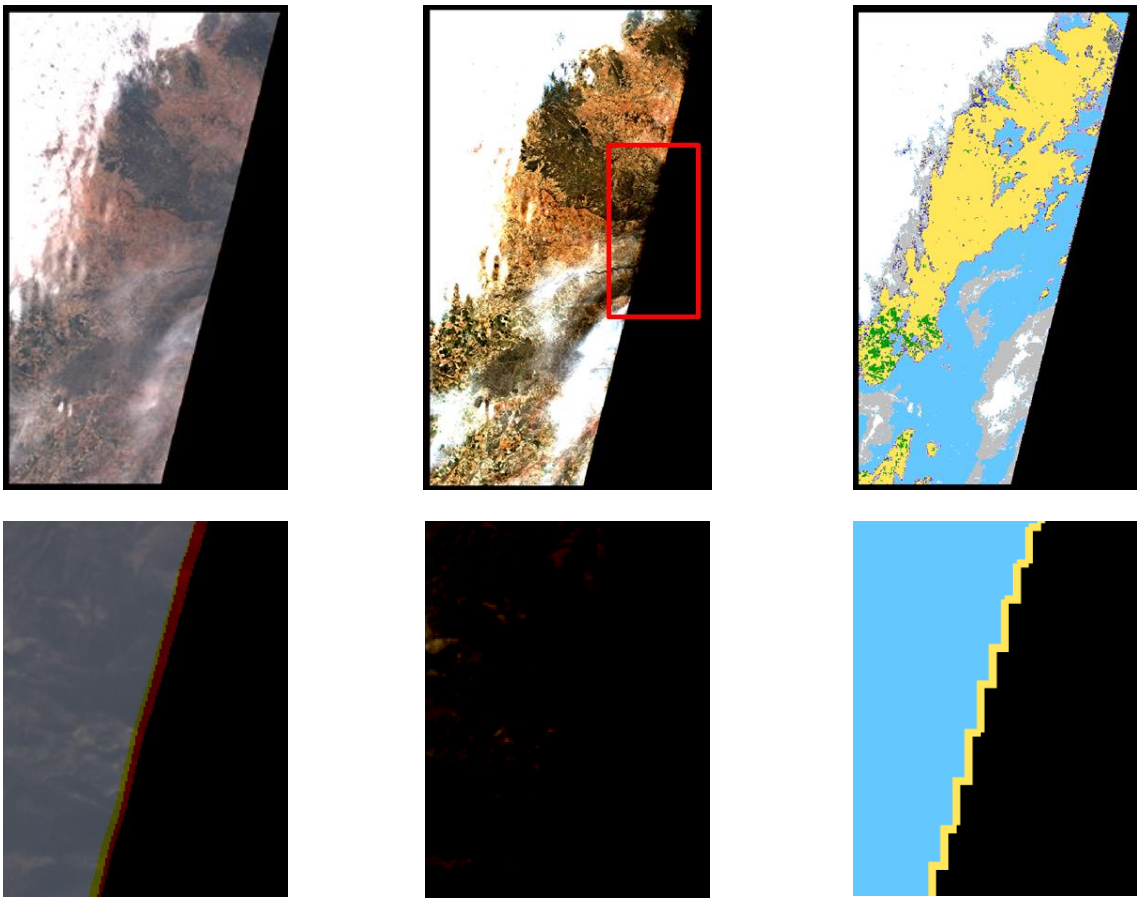
4.13 Very low negative reflectances near the edge of the swath

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.



L1C TCI **L2A TCI** **L2A SCL**

Figure 17 : 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

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.

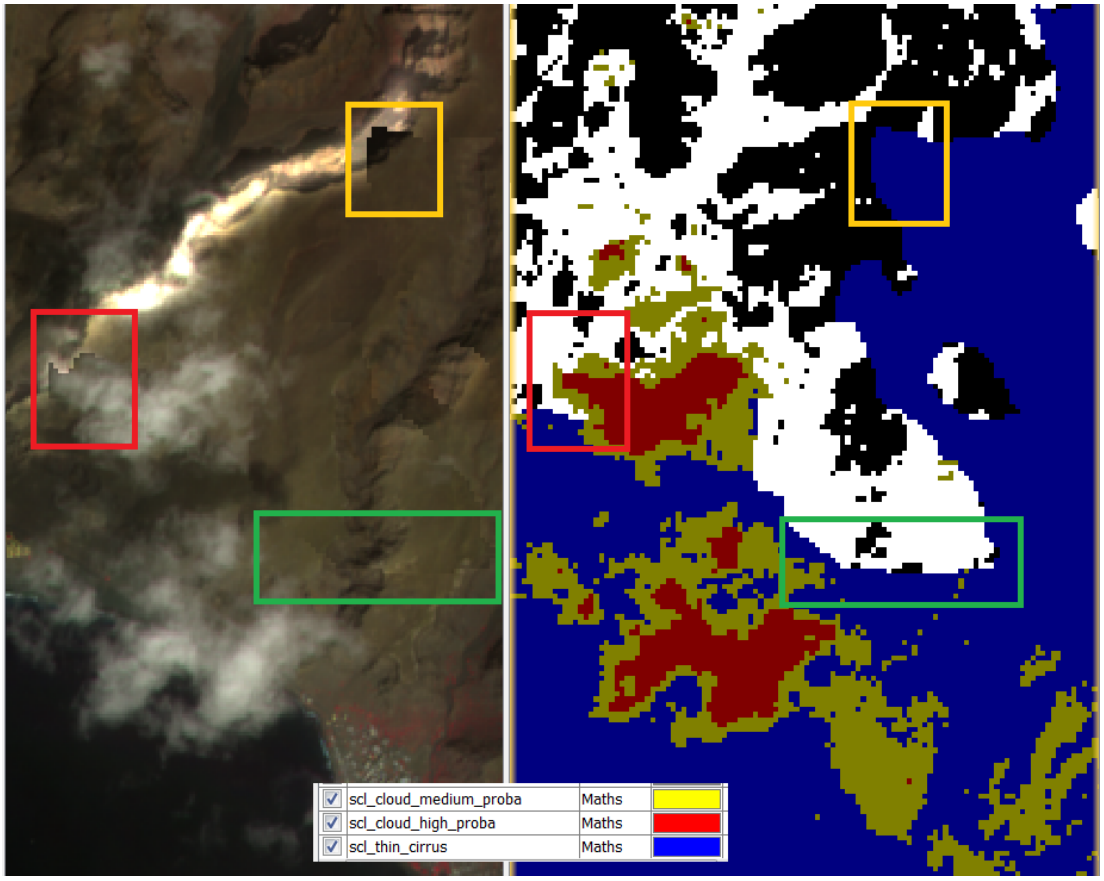


Figure 18: Visual artefacts at the edges of semi-transparent clouds.

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.

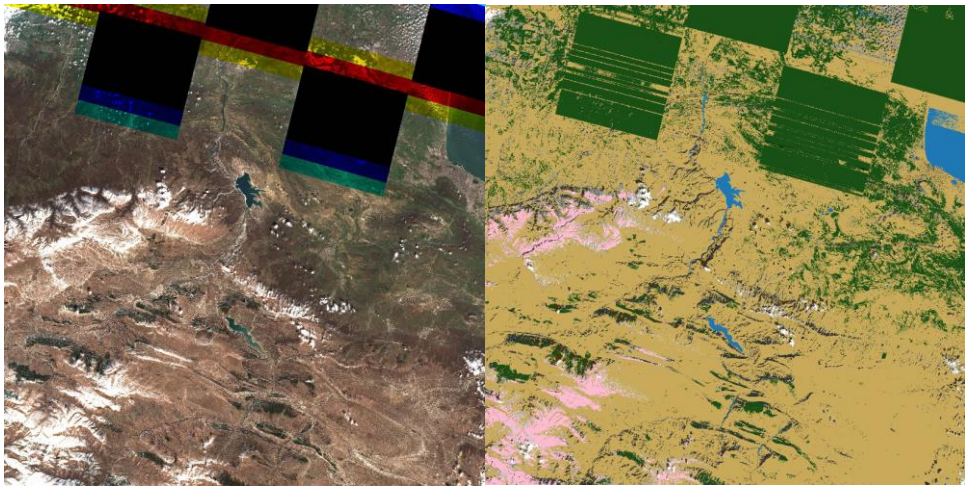


Figure 22: Left: TCI image of a product affected by missing packets. Right: Scene Classification Layer.

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

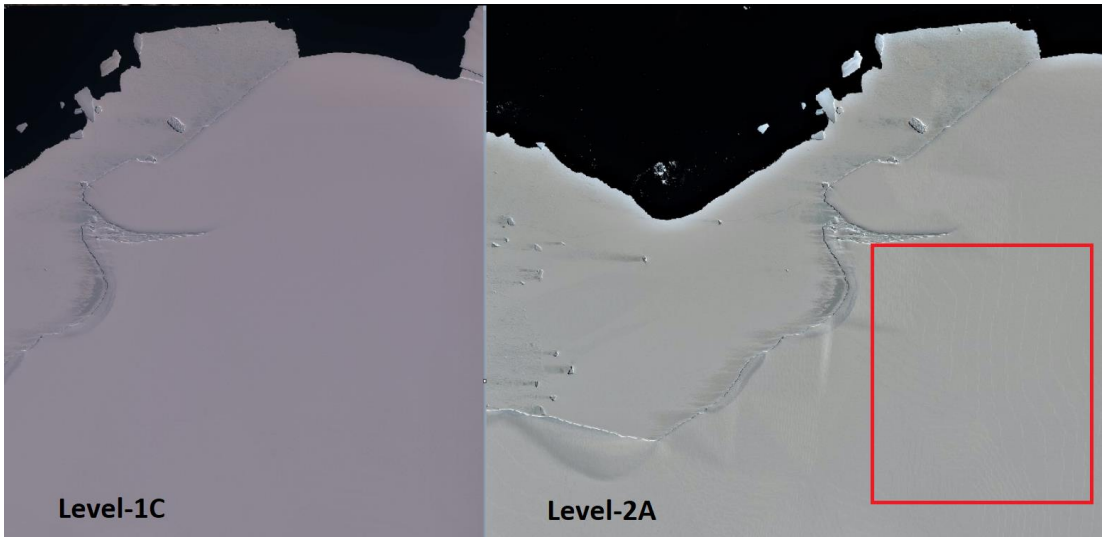


Figure 23: Contour-like line features (red box – right) visible in L2A products over Antarctica

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 meter steps in the current production) on topographic correction.

End of document