TERRASCOPE SENTINEL-2
ALGORITHM THEORETICAL BASE DOCUMENT (ATBD)

S2 – TOC – V220

DOCUMENT CONTROL

Signatures

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Change record

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

ACRONYM	EXPLANATION
ACIX	Atmospheric Correction Inter-comparison Exercise
AOT	Aerosol Optical Thickness
ATBD	Algorithm Theoretical Base Document
CCC	Canopy Chlorophyll Content
CCI	Climate Change Initiative
COG	Cloud-Optimized Geotiff
CWC	Canopy Water Content
DEM	Digital Elevation Model
ESA	European Space Agency
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
FCOVER	Fraction of green vegetation Cover
GeoTIFF	Geospatial Tagged Image File Format
iCOR	Image Correction for atmospheric effects
L1C	Level1C (Top-Of-Atmosphere) product
L2A	Level2A (Top-Of-Canopy) product
LAI	Leaf Area Index
MSI	Multispectral Instrument
NDVI	Normal Difference Vegetation Index
NRT	Near Real Time
OGC	Open Geospatial Consortium
PDGS	Payload Data Ground Segment
PROBA-V	Project for On-Board Autonomy – Vegetation
RAA	Relative Azimuth Angle
RD	Related Document
S2	Sentinel-2
SAA	Sun Azimuth Angle
SAR	Synthetic Aperture RADAR
Sen2Cor	Sentinel-2 Correction
SPOT	Satellite Pour l'Observation de la Terre
SRF	Spectral Response Function
STEP	Science Toolbox Exploitation Platform
SWIR	Short-Wave infrared
SZA	Solar Zenith Angle
TOA	Top-Of-Atmosphere
TOC	Top-Of-Canopy
UTM	Universal Transverse Mercator
VAA	View Azimuth Angle
VITO	Vlaams Instituut voor Technologisch Onderzoek
VNIR	Visible and Near InfraRed

VZA	View Zenith Angle
WGS84	World Geodetic System 1984
WVP	Water Vapour
XML	Extensible Markup Language

1. Introduction

1.1. Terrascope explained

Terrascope is the Belgian platform for accessing Copernicus, PROBA-V, and SPOT-VEGETATION satellite data, products, and services. It offers easy, full, free and open access to all users without restrictions. This enables both specialist and non-specialist users to explore the wealth of available remote sensing information and to develop value-added products and services.

Terrascope currently provides access to the following datasets:

- The full SPOT-VEGETATION archive
- The full PROBA-V archive
- Sentinel-1 SAR data over Belgium and its surroundings
- Sentinel-2 optical data over Europe and Africa
- Sentinel-3 optical Synergy (SYN) – Vegetation (VGT) and thermal Land Surface Temperature (LST) data

In addition to Sentinel-2 surface reflectance (Top-Of-Canopy, TOC) data, Terrascope provides a standard suite of biophysical indicators derived from Sentinel-2—such as Normalized Difference Vegetation Index (NDVI), Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), Fraction of Green Vegetation Cover (FCOVER), Leaf Area Index (LAI), Canopy Chlorophyll Content (CCC), and Canopy Water Content (CWC)—as well as water quality products, including aquatic reflectance (RHOW), Suspended Particulate Matter (SPM), turbidity (TUR), and chlorophyll-a (CHL) concentrations.

Users can generate their own derived information products tailored to specific needs by leveraging the Terrascope processing cluster—available through virtual machines or interactive Notebooks. This approach eliminates the need for local data downloads and storage, as all data are directly accessible within the cluster environment. Integration of Terrascope data and products into external applications is supported through Open Geospatial Consortium (OGC) web services.

Terrascope is user-centred, and we welcome all suggestions for new or improved functionality. For feedback or inquiries, please contact us at info@terrascope.be.

1.2. Scope of Document

This Algorithm Theoretical Base Document (ATBD) describes the origin, processing steps and generation of Sentinel-2 (S2) Level2 Top-Of-Canopy (TOC) products included in the Terrascope Sentinel-2 v220 processing chain.

The document is organised as follows:

- Section 2 provides an overview of the input data used in the processing workflow, including the Sentinel-2 Level-2A input products and ancillary datasets.
- Section 3 describes the data products generated and made available to users.
- Section 4 details the processing methodology, including the generation of an additional cloud mask and the data format conversion applied in Terrascope v220.
- Section 5 summarises the known limitations of the Sentinel-2 Level-2A products and their implications for downstream use.
- Section 6 presents the quality assessment, referring to the operational quality monitoring performed by ESA/Copernicus.

1.3. Description

The S2 TOC reflectance product is a geometrically and atmospherically corrected version of the original COPERNICUS provided data products with additional information on pixel classification, cloud mask, Aerosol Optical Thickness (AOT), water vapour (WVP), and angle information: Sun Zenith Angle (SZA), View Zenith Angle (VZA) and Relative Azimuth Angle (RAA).

S2 Level-2A (L2A) Top-Of-Canopy (TOC) products [RD1] are systematically generated at the ESA ground segment over Europe since March 2018, and production was extended to the entire globe in December 2018. The Terrascope workflow was adapted accordingly and starts with the download of these L2A products. With Sen2Cor [RD2] processing a Scene Classification (SC) step, which generates a classification map called Scene Classification Layer (SCL) which includes four different classes for clouds (including cirrus) and six different classifications for shadows, cloud shadows, vegetation, soils/deserts, water and snow pixels. The output of this workflow encompasses the TOC reflectance for each spectral band, a cloud mask and a scene classification layer, AOT, WVP, SZA, VZA and RAA output layers.

This document applies to the Terrascope S2 v220 processing chain. An overview of the main characteristics of the Terrascope versions up to v220 is provided in Table 1.1. Changes between versions v102 and v200 are described in Table 1.2, while changes between v200 and v220 are summarized in
Table 1.3.

Table 1.1: Summary of main characteristics between different Terrascope versions.

Version	Main characteristics
V101	Input: L1C data Atmospheric correction: iCOR Scene classification : Sen2Cor v2.3 Output: TOC, cloud masks, shadow masks, scene classification
V102	Input: L1C data Atmospheric correction: iCOR with AOT fallback and improved spectral response curves Scene classification: Sen2Cor v2.5.5 Output: TOC, cloud masks, shadow masks, scene classification, AOT
V200	Input: L2A data (NRT) or L1C (historic) Atmospheric correction: Ground Segment Sen2Cor version (NRT) or Sen2Cor v2.8 (historic) Scene classification: Sen2Cor v2.8 with Climate Change Initiative (CCI) auxillary package Output: TOC, scene classification, AOT, WVP, SZA, VZA, RAA
V220	Input: L2A – Copernicus Sentinel-2 Collection 1 (Processing Baseline 05.xx). Output: TOC, cloud mask, scene classification, AOT, WVP, SZA, VZA, RAA

Table 1.2: List of changes between TERRACOPE Sentinel-2 v200 and v102

Adaptations between v200 and V102	Clarification
Scene selection	
Tiles covered with more than 95% clouds are not processed.	To optimise data storage, scenes almost fully covered with clouds will no longer be processed.
Scene classification	
Update of Sen2Cor version (v2.5.5 à v2.8)	On 20.02.2019 a new version of Sen2Cor was released (v2.8).
Atmospheric correction	
Download of Sentinel-2 L2A Near-Real-Time products	Since March 2018, the Payload Data Ground Segment (PDGS) has processed L2A products

Adaptations between v200 and V102	Clarification
	over Europe, and production was extended to global in December 2018. [RD1]
Atmospheric correction with Sen2Cor instead of iCOR.	To be in line with the ESA processing, we switched from iCOR to SEN2COR processing. Both are valid processors and have been included in various inter-comparison exercises (e.g. ACIX-I and ACIX-II).
Output products	
Additional layers at 60 m: - WVP - Angles: RAA, VZA and SZA	Users can use these layers to derive other products or for quality control.
Removal of the: - Cloudmask layers (10m, 20m and 60m) - Shadow mask layers (10m, 20m, 60m)	This information can also be found in the SCENECLASSIFICATION layer.
Update of the INSPIRE Metadata	The metadata xml file has been updated to be compliant with ISO-19115-2 standards.
Values in dense clouds (indicated as high probability clouds in the scene classification layer) of processed tiles (i.e. cloud% < 95%) are masked with a conservative buffer.	Masking of dense clouds allows an optimised data storage.
Data Archive	
Switch from Product Distribution Portal (PDF) to OpenSearch Catalogue for Remote Sensing, with accompanying GeoJSON metadata information.	The new catalogue is easier to maintain.
Change in folder structure on Terrascope cloud processing platform (Virtual machines and Jupyter notebooks)	The folder structure has been revised, made more concise and user-friendly.

Table 1.3: List of changes between TERRACOPE Sentinel-2 v220 and v200

Adaptations between v220 and V200	Clarification
Input data	
L1C is no longer supported as input	Global availability of L2A data

Adaptations between v220 and V200	Clarification
L2A supported from Copernicus Sentinel-2 Collection 1 (Processing Baseline 05.xx)	Ensure consistent time series: v220 includes a full reprocessing of the TERRASCOPE-S2 archive starting from Copernicus Sentinel-2 Collection 1
Output products	
Additional layer at 20 m: - Cloud mask layer	This layer helps users understand why pixels in derived products are masked.
Functionality	
Overview images added to the products	Provides improved viewing functionality and facilitates quick visual inspection of datasets.

1.4. Feature added value/use case

Terrascope v220 provides Sentinel-2 Top-Of-Canopy (TOC) products, derived from Copernicus Sentinel-2 Collection 1 (Processing Baseline 05.xx) onwards, ensuring full temporal homogeneity across the archive. This homogeneity is an essential requirement for reliable time-series analysis, trend detection and quantitative studies. The products are distributed as Cloud-Optimized GeoTIFFs (COGs), which facilitates efficient access, visualization and processing compared with the SAFE/JP2 format used by Copernicus. This format enables fast loading in GIS tools, efficient use in cloud and high-performance computing environments and direct data streaming without the need to download large files. Each TOC product includes user-friendly ancillary layers such as a cloud mask, Scene Classification Layer (SCL), Aerosol Optical Thickness (AOT), Water Vapour (WVP), and viewing geometry parameters (SZA, VZA, RAA). The ancillary layers support quality control and the development of value-added products. Combined with Terrascope's integrated processing environment and web services, these features provide users with analysis-ready Sentinel-2 data optimized for scalable, consistent, and efficient workflows.

1.5. Related documents

Table 1.4 lists the related documents (RD) that are complementary to this ATBD.

Table 1.4: List of related documents

[RD1]	Louis, J., Devignot, O., Pessiot, L. (2017) S2 MPC Level 2A Product Format Specification. Ref. S2-PDGS-MPC-L2A-PFS-V14.2. https://sentinel.esa.int/documents/247904/685211/Sentinel-2-MSI-L2A-Product-Format-Specifications.pdf
[RD2]	Gatti, A., Galoppo, A. Castellani, C., Carriero, F. Sentinel-2 Products Specification Document, REF: S2-PDGS-TAS-DI-PSD issue 14.5,20/03/2018

	https://sentinel.esa.int/documents/247904/685211/Sentinel-2-Products-Specification-Document
[RD3]	Mueller-Wilm, U., Devignot, O., Pessiot, L. (2019) S2 MPC Sen2Cor Software Release Note. Ref. S2-PDGS-MPC-L2A-SRN-V2.8.0. http://step.esa.int/thirdparties/sen2cor/2.8.0/docs/S2-PDGS-MPC-L2A-SRN-V2.8.pdf
[RD4]	Paepen, M., et al. (2019) Terrascope Sentinel-2 Product User Manual V1.1
[RD5]	ESA (2026). Copernicus Sentinel-2 Performance and Data Quality Reports, Copernicus Optical Mission Performance Cluster (OPT-MPC), SentiWiki. Accessed January 2026. https://sentiwiki.copernicus.eu/web/document-library#DocumentLibrary-PerformanceandDataQualityReportsLibrary-S2-Performance-DQR

2. Input data

The Terrascope processing starts from the Sentinel-2 Level-2A (L2A) data products freely available from the Copernicus Data Space Ecosystem (https://dataspace.copernicus.eu/). Sentinel-2 data are delivered in 100 × 100 km² granules (tiles) in UTM/WGS84 projection, with an overlap of approximately 9.8 km. The Sentinel-2 tiling grid is available as a KML file: Sentinel-2 tiling grid.kml. L2A products provide atmospherically corrected Top-Of-Canopy (TOC) reflectance.

Copernicus distributes L2A data in the SENTINEL-SAFE format, containing JPEG2000 image files together with quality indicators, auxiliary data, and metadata. The Multispectral Instrument (MSI) onboard Sentinel-2 acquires reflected solar radiation across 13 spectral bands spanning the Visible (VIS), Near-Infrared (NIR) and Shortwave Infrared (SWIR) region (Figure 2.1):

- 10 m: 4 bands (490, 560, 665, 842 nm)
- 20 m: 6 bands (705, 740, 783, 865, 1610, 2190 nm)
- 60 m: 3 bands for atmospheric correction and cloud/aerosol screening (443, 945, 1375 nm)
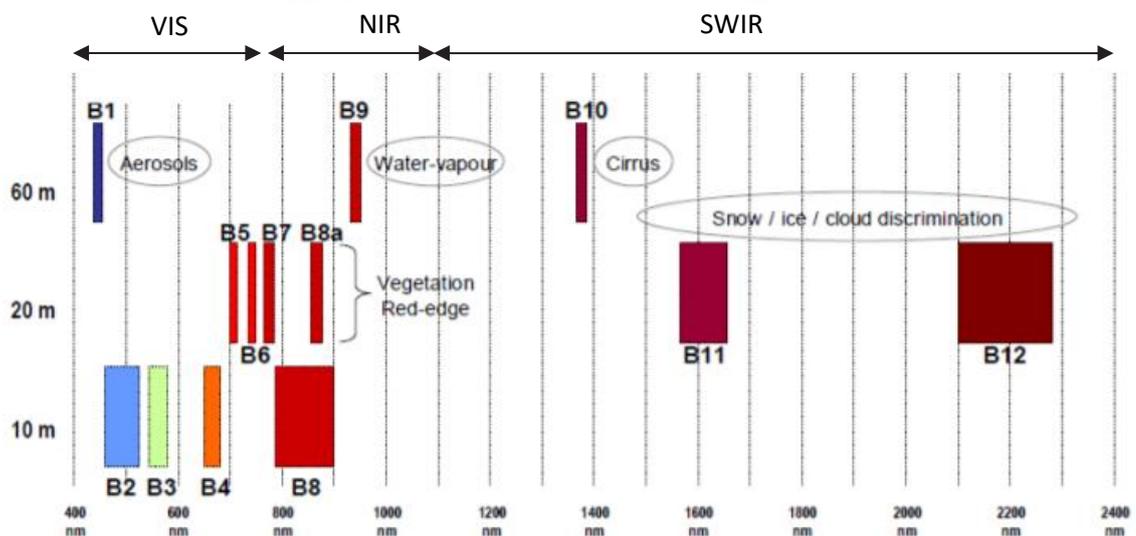

Figure 2.1: S2-MSI Spectral-Bands versus Spatial Resolution Reference [RD3]

More information on the S2 data products and tiling strategy is available on https://sentinel.esa.int/web/sentinel/missions/sentinel-2/data-products. Detailed information on S2 L2A data products can be found in [RD1].

3. Output

3.1. Product layers

The Sentinel-2 TOC products generated and distributed by Terrascope v220 consist of multiple output files. Each file is provided as a single-layer, compressed Cloud-Optimized GeoTIFF (COG). - Figure 3.1 presents the complete list of files included in the S2 TOC product.

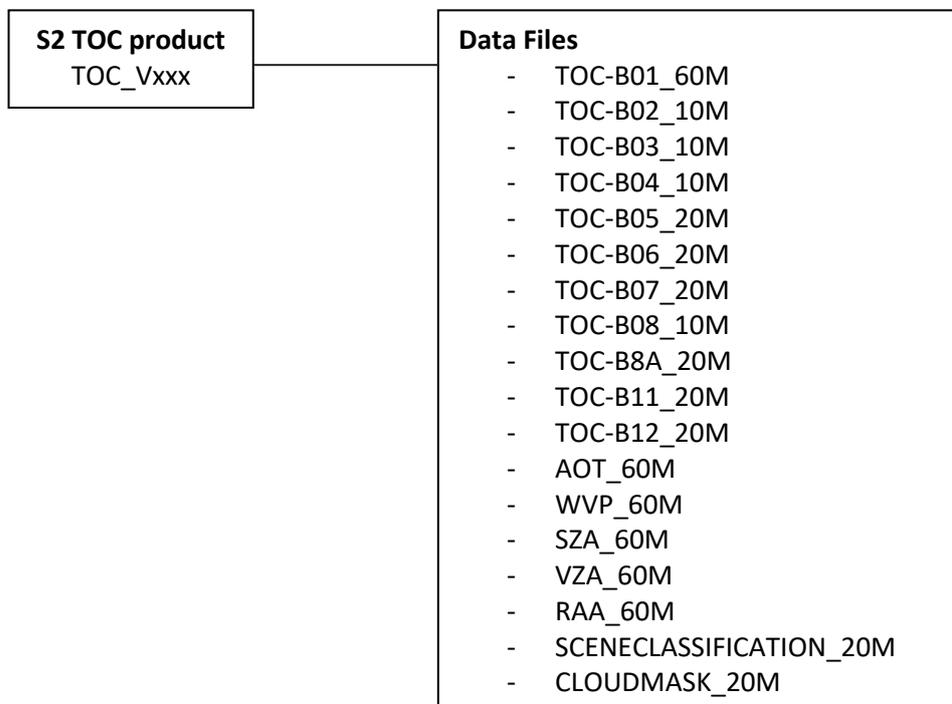| **S2 TOC product** TOC_Vxxx	**Data Files** - TOC-B01_60M - TOC-B02_10M - TOC-B03_10M - TOC-B04_10M - TOC-B05_20M - TOC-B06_20M - TOC-B07_20M - TOC-B08_10M - TOC-B8A_20M - TOC-B11_20M - TOC-B12_20M - AOT_60M - WVP_60M - SZA_60M - VZA_60M - RAA_60M - SCENECLASSIFICATION_20M - CLOUDMASK_20M

Figure 3.1: S2 TOC product file list

The S2 TOC spectral bands cover the VIS to SWIR ranges at multiple spatial resolutions. The spatial and spectral characteristics of the delivered bands are summarized in Table 3.1. Bands B09 and B10 are not included as they correspond to the water vapor and cirrus absorption bands respectively.

Table 3.1: Spatial and spectral characteristics of the S2 TOC products.

Layer	Spatial res. [m]	S2A		S2B		S2C	
		Central wavelength [nm]	Bandwidth [nm]	Central wavelength [nm]	Bandwidth [nm]	Central wavelength [nm]	Bandwidth [nm]
TOC-B01_60M	60	443.9	27	442.3	45	444.2	21
TOC-B02_10M	10	496.6	98	492.1	98	489.0	65
TOC-B03_10M	10	560.0	45	559.0	46	560.6	36
TOC-B04_10M	10	664.5	38	665.0	39	666.5	30
TOC-B05_20M	20	703.9	19	703.8	20	707.1	15
TOC-B06_20M	20	740.2	18	739.1	18	741.1	15
TOC-B07_20M	20	782.5	28	779.7	28	784.7	21
TOC-B08_10M	10	835.1	145	833.0	133	834.6	114
TOC-B8A_20M	20	864.8	33	864.0	32	865.6	20
TOC-B11_20M	20	1613.7	143	1610.4	141	1612.0	89
TOC-B12_20M	20	2202.4	242	2185.7	238	2191.3	182

The AOT, WVP, SZA, VZA and RAA are provided in the native 60 m resolution.

The physical pixel values in the S2 TOC files are converted from floating point values into integers, mainly to reduce the file sizes. Table 3.2 lists the technical information of the S2 TOC product, with information necessary to calculate the Physical Values (PV) from the Digital Numbers (DN) available in the files. The physical number can be defined by using the following formula:

Physical Value = Scaling * Digital Number + Offset.

Table 3.2: Technical information on the S2 TOC, AOT, WVP, SZA, VZA, RAA values

	TOC [-]	AOT [-]	WVP [g cm^{-2}]	SZA [°]	VZA [°]	RAA [°]
Physical min	-1.0	0.00	1	0	0	0
Physical max	2.0	2.5	3.5	80	12	180
Digital number min	-10000	0	100	0	0	0
Digital number max	20000	2500	350	8000	1200	18000
Scaling	0.0001	0.001	0.01	0.01	0.01	0.01
Offset	0.0	0.0	0.0	0.0	0.0	0.0

The Scene Classification layer is provided at 20m spatial resolution, with class values defined in Table 3.3. [RD2]. The cloud mask layer is also delivered at 20m resolution.

Table 3.3: Explanation of pixel classification values

Layer	Value	Classification
SCENE CLASSIFICATION	0	NO_DATA
	1	SATURATED_OR_DEFECTIVE
	2	CAST_SHADOW
	3	CLOUD_SHADOWS
	4	VEGETATION
	5	BARE_SOIL
	6	WATER
	7	UNCLASSIFIED
	8	CLOUD_MEDIUM_PROBABILITY
	9	CLOUD_HIGH_PROBABILITY
	10	THIN_CIRRUS
	11	SNOW

The folder structure used on the Terrascope platform is:
1. Product and version - *e.g. TOC_V2*
2. Year - *e.g. 2019*
3. Month - *e.g. April*
4. Day - *e.g. 04*
5. Tile_ID - *e.g. S2B_20190504T105629_31UDS_TOC_V220*

In some cases, the same Sentinel-2 product may appear multiple times in the Copernicus Data Space Ecosystem (CDSE). For example, the following Sentinel-2 Level-2A products correspond to the same acquisition but differ in their delivery (processing) timestamps:

a) S2A_MSIL2A_20241005T094031_N0511_R036_T35WNM_**20241005T125814**

b) S2A_MSIL2A_20241005T094031_N0511_R036_T35WNM_**20241005T105949**

The processing timestamp embedded in the filename (highlighted in bold), allows redelivered products to be distinguished. To obtain a spatially complete tile, Terrascope mosaics both products in a single, fully filled product.

3.2. Product version

Terrascope products are produced in a controlled way. Every product has a version indicator, consistent with the Semantic Versioning 2.0.0 protocols (https://semver.org/). The version indicator has three digits: XYZ.

- X is 0 during prototyping and pre-operational use. X is 1 for the first operational setup, and increments when if its results are no longer backward compatible (i.e. any further processing will have to be adapted to deal with e.g. format changes, value scaling, etc.).

- Y is reset to 0 with an X increment. Y increments when functionality is added, but backward compatibility is guaranteed (e.g. when a different approach is taken for atmospheric or geometric correction).

- Z is reset to 0 when Y increments. Z increments when the software is patched (bug fixed) without any functional changes.

The current Terrascope Sentinel2 workflow version is v220.

Whenever X or Y changes, the impact of the updates will be reported and the new and previous versions of the workflow will be run in parallel, for a 3-4 month period. This allows users to implement changes to their subsequent processing. Users are informed about version changes through the Terrascope newsletter (to subscribe: https://terrascope.be/en/stay-informed).

3.3. Product data access

The Terrascope S2 data products can be accessed through:

- Terrascope viewer: https://viewer.terrascope.be/en
  For viewing, discovery and data access. The viewer provides fast access to satellite data including Sentinel. You can easily search, view and compare various data layers. Via the 'Export' tab you can even download png images, GIF timelapses or the original data in just a few clicks. Would you like to implement your own processing? In that case, you can also directly retrieve the satellite data. You can do so through our data portal.

- Web services: Web Map Service (WMS) and Web Map Tile Service (WMTS):
  https://bit.ly/TerrascopeFAQ_WMTS
  Protocols for downloading images and integrating them into GIS software

- Notebooks (login required): https://notebooks.terrascope.be/hub/login
  Programming environment to quickly access and edit data

- Virtual Machines (VM) (login required): https://forum.terrascope.be/en/request-vm
  External computer used to view data and process it in the cloud

The details of each of these access points are described on https://terrascope.be/en/services.

4. Methodology

4.1. Introduction

Previous Terrascope processing versions included atmospheric correction and scene classification to compensate for periods when these products were not yet available from Copernicus. In Terrascope v220, these processing steps are no longer required, as the processing chain starts from Sentinel-2 Level-2A products (Processing Baseline 05.xx), for which atmospheric correction and scene classification are already performed by Copernicus.

Consequently, only two additional processing steps are applied in Terrascope v220: the generation of an additional cloud mask and a data format conversion step. The cloud mask is subsequently used in the derivation of higher-level land products, including LAI, NDVI, FAPAR, FCOVER, CCC and CWC.Cloud mask

4.1.1. Justification

A large proportion of Sentinel-2 acquisitions is affected by cloud cover, which limits their usability for quantitative land surface analysis. Although cloud information is already available in the Sentinel-2 Level-2A products through the scene classification layer (SCL), an additional cloud mask is implemented in the Terrascope v220 processing chain to improve flexibility and efficiency in downstream applications.

The refined cloud mask, derived from the SCL, allows cloud-contaminated pixels to be identified and, where appropriate, excluded from further processing, thereby reducing storage and computational costs associated with pixels that do not contribute to value-added products. The cloud mask is intentionally eroded along cloud boundaries, so that users retain the option to include or exclude pixels located at cloud edges depending on the requirements of their application. This approach provides greater control over the trade-off between data coverage and cloud contamination in the derived land products.

4.1.2. Implementation

Pixels corresponding to predefined cloud-related SCL classe 9, i.e. CLOUD_HIGH_PROBABILITY (see Table 3.3) are initially flagged as cloudy, while all other classes are considered valid observations. Pixels flagged as no-data in the SCL layer are consistently propagated through the masking process.

To improve the spatial coherence and robustness of the cloud mask, a sequence of morphological operations is applied. First, small gaps within cloud regions are filled using a binary closing operation to reduce noise and fragmentation. Subsequently, isolated small cloud-like features that are likely false detections are removed by applying a closing operation on the inverted mask, effectively

suppressing small cloud objects below a defined spatial threshold. A final erosion step using a circular structuring element is then applied to slightly contract cloud boundaries, reducing cloud edge contamination while preserving contiguous cloud structures.

The resulting mask provides a spatially consistent and conservative delineation of cloudy and cloud-free pixels, and is used as input for the generation of higher-level land products.

4.2. Data conversion

4.2.1. Justification

Sentinel-2 Level-2A products are originally distributed in the SAFE format, which consists of multiple files organised in a complex directory structure. While this format is well suited for archiving and standardised dissemination, it is less efficient for large-scale data access and processing. Therefore, a data conversion step is implemented in the Terrascope processing chain to convert the input Sentinel-2 Level-2A products into Cloud-Optimized GeoTIFF (COG) format.

The use of COGs enables efficient, on-demand access to raster data through internal tiling and overviews, supporting partial reads and direct streaming over standard web protocols. This significantly improves performance in GIS applications, cloud-based environments, and high-performance computing workflows. In addition, storing the data as COGs reduces data handling overhead and facilitates scalable processing, while preserving the original spatial resolution and radiometric information of the Sentinel-2 products.

4.2.2. Implementation

As part of the Terrascope v220 processing chain, raster layers are converted into Cloud-Optimized GeoTIFF (COG) format following a digitisation step. The input raster data are provided as floating-point GeoTIFFs and are transformed into integer-based representations using predefined scale and offset parameters. This digitisation preserves the physical meaning of the data while reducing file size and improving computational efficiency.

During the conversion, physical validity ranges and saturation thresholds can be applied to ensure that values outside the expected physical domain are handled consistently. Invalid or undefined values are propagated as no-data values in the output product. Optional masking can be applied to explicitly flag pixels affected by clouds or other exclusion criteria, either by assigning a no-data value or a user-defined digital number.

The output products are written as tiled GeoTIFFs with internal compression and include band-level metadata such as scale factors, offsets, units, descriptions, and auxiliary metadata where applicable. Image overviews are generated at multiple resolution levels using nearest-neighbour resampling to

preserve the discrete nature of the digitised values. The resulting Cloud-Optimized GeoTIFFs enable efficient access patterns, partial reads, and scalable processing in cloud-based, high-performance, and web-based environments.

4.3. Outlook

In future updates, the Terrascope processing chain will remain compliant with the evolving Copernicus Sentinel-2 processing baselines and product specifications. Changes introduced in new Sentinel-2 processing versions will be carefully assessed and, where relevant, consistently integrated into the Terrascope processing framework to ensure long-term temporal consistency, traceability, and compatibility of the derived products.

5. Limitations

Sentinel-2 Level-2A Top-Of-Canopy (TOC) products are primarily designed for land surface applications. Users interested in water reflectance products are referred to the Terrascope RHOW products, which are specifically optimised for aquatic environments.

Several limitations and anomalies affecting Sentinel-2 Level-2A products have been identified and documented by Copernicus. Many of these issues have been mitigated or resolved through successive processing baselines. However, some residual effects may still occur and should be considered in downstream analyses. The following sections summarise the known limitations, based on information extracted from the Copernicus Sentinel-2 documentation (https://sentiwiki.copernicus.eu/web/s2-products#S2Products-Productanomaliesandfeatures)

Scene classification limitations

The Scene Classification Layer (SCL) is subject to known limitations. Earlier processing baselines suffered from cloud over-detection over bright targets, under-detection of semi-transparent clouds and cloud edges, confusion between clouds and snow, and misclassification of topographic shadows as water. These issues have largely been corrected since Processing Baseline (PB) 04.00. Remaining limitations include the misclassification of open fires as cirrus clouds, occasional misclassification of dark surfaces as cloud shadows (particularly during winter with high solar zenith angles), and the omission of very low-altitude clouds or fog, which may be classified as non-vegetated surfaces. In addition, visual artefacts can occur at the edges of semi-transparent clouds, as terrain correction is not applied to pixels classified as cloudy.

Tile overlap inconsistencies

Level-2A products are processed independently at tile level. As a result, minor inconsistencies may occur in overlap areas between adjacent tiles. These can include small differences in scene classification, aerosol optical depth (AOD), and surface reflectance values. While generally limited, such discrepancies should be considered when mosaicking or performing spatially continuous analyses.

Terrain correction artefacts

Inaccuracies in the Digital Elevation Model (DEM) may lead to over-correction in fully or partially shaded terrain. This can result in unrealistic bluish colours in reflectance composites and reduced accuracy of surface reflectance values, particularly in mountainous or complex terrain.

High solar zenith angle effects

For acquisitions with a mean Sun-Zenith Angle (SZA) exceeding 70°, the L2A processor applies a clipped SZA value of 70°. This leads to an under-correction of atmospheric effects and may result in

bluish artefacts in the surface reflectance. Such products are not recommended for quantitative or scientific analysis. Since Processing Baseline 02.14, these cases are flagged by a warning in the quality reports.

Terrain correction discontinuities in flat areas

In very flat regions observed under high solar zenith angles, subtle contour-like artefacts may appear in L2A products. These artefacts arise from the vertical quantisation of the DEM used in terrain correction.

6. Quality assessment

The quality of Sentinel-2 Level-2A (L2A) products is routinely assessed and monitored by ESA within the framework of the Copernicus Optical Mission Performance Cluster (OPT-MPC), with results documented in the Sentinel-2 Performance and Data Quality Reports [RD5]. The OPT-MPC Data Quality Reports provide an independent and systematic evaluation of L2A product performance, including surface reflectance accuracy, atmospheric parameter retrievals, and scene classification quality. These assessments are based on comparisons with in situ reference measurements (e.g. RadCalNet and AERONET), multi-year global datasets, and well-defined validation protocols. The Terrascope v220 processing chain builds upon these validated Copernicus L2A products and therefore inherits their documented quality characteristics and limitations, as described in the latest Sentinel-2 MSI L2A Data Quality Report (January 2026)

Summary of the latest Sentinel-2 L2A quality assessment (January 2026)

According to the most recent OPT-MPC Data Quality Report, Sentinel-2 L2A products demonstrate a high and stable level of performance for land surface applications

- **Surface reflectance**
  The Bottom-Of-Atmosphere (BOA) surface reflectance meets mission uncertainty requirements for the majority of observations. Validation against RadCalNet sites shows that more than 90% of retrieved reflectance values fall within the specified uncertainty bounds under favourable illumination conditions (SZA < 50°), with consistent performance between Sentinel-2A and Sentinel-2B.

- **Water vapour retrieval**
  Total column water vapour estimates derived by Sen2Cor exhibit very good agreement with AERONET measurements. Approximately 95% of retrievals fall within the defined uncertainty goal, with an average uncertainty of about 0.15 g·cm^{-2} and only a small systematic underestimation at higher water vapour contents.

- **Aerosol optical thickness (AOT)**
  Aerosol optical thickness at 550 nm is retrieved using either the Dense Dark Vegetation (DDV) algorithm or a CAMS-based fallback solution when DDV pixels are insufficient. The CAMS fallback generally provides more stable performance across climate zones. Overall, between roughly 40% and 65% of AOT retrievals fall within the uncertainty goal, with a tendency toward underestimation at higher aerosol loads.

- **Scene classification and cloud masking**
  The scene classification shows good overall performance, with balanced accuracies for clear versus cloud pixels typically ranging between about 80% and 98% for snow-free scenes. Performance degrades in snow-covered and desert environments, where cloud shadows and

bright surfaces are more difficult to discriminate, leading to higher omission and commission errors.

- **Known artefacts and anomalies**
  The report confirms the presence of known product features and anomalies, including tile-overlap inconsistencies, terrain over-correction in shaded areas, artefacts at high solar zenith angles, and rare cases of very low negative reflectances near swath edges. These effects are documented, tracked, and, where possible, mitigated through successive processing baselines.

Overall, the January 2026 assessment confirms that Sentinel-2 L2A products generated with recent processing baselines are compliant with CEOS Analysis Ready Data for Land (CARD4L) requirements at the threshold level and are suitable for quantitative land surface applications, provided that documented limitations are taken into account