



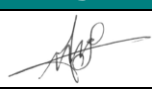


S2 MPC

L2A Product Definition Document

Ref. S2-PDGS-MPC-L2A-PDD-V14.9



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Change Log

Issue	Date	Reason for change	Pages(s)/Section(s)
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1 Draft B	26 Feb 2009	Incorporated refinements as per ESA requirements.	All
1 Draft C	20 Aug 2009	Reorganised to match section structure used for L2B and L3 products. Major rewrite of most sections. Updated table of possible applications for L2A according to latest version of DAP.	All
1	8 Oct 2009	Updates following Review by ESA, Document renamed from S2PAD.TN.001 to S2PAD-VEGA-PD-0001.	All
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Issue	Date	Reason for change	Pages(s)/Section(s)
4.1	29 Aug 2012	Issue after S2PAD Phase 2 CDR. Updated according to ESA comments and discussion on CDR 02/08/2012	All
4.2	21 Mar 2014	Issue for Acceptance Review	All
4.3	16 Jun 2014	Document Change Requests from Sen2Cor Acceptance Review Board report.	All
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4.5	25. Nov 2016	Update to PSD 14.2, delivery of Sen2Cor 2.3.0	2.2.4, 2.4.2, 2.4.3
4.6	23 Jun 2017	Update of Scene Classification class names reformatting of QI description tables	All
4.7	23 Mar 2018	Update to PSD 14.5, delivery of Sen2Cor 2.5.5	All Added Appendix A with DN conversion formulae.
4.8	23 Nov 2020	Update of water vapour units (g.cm-2 or cm) in Table 2-II Added reference to Sentinel-2 L2A Data Quality Reports in section 1.2 Informative Reference Documents and for AOT accuracy reference document. Update to PSD 14.6, delivery of Sen2Cor 2.9.0	Table 2-II Section 1.2 All
4.9	15 Nov 2021	Update to PSD 14.9, delivery of Sen2Cor 2.10: Added band B01 Added reference and description of new L2A_QUALITY report Updated description of L1C QI masks at pixel level Added reference to auxiliary data from Copernicus Atmosphere monitoring service (CAMS) Added new L2A Quality Information parameters in product and tile metadata Update Appendix A with new surface reflectance conversion formula due to the addition of a radiometric offset for L1C and L2A encoding.	2.1.1 2.2 2.4 2.5 Appendix A

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1. Introduction

In the frame of the Copernicus programme jointly implemented by ESA and EC, ESA is developing the Sentinel-2 system, providing globally with systematic acquisition high resolution (10-20 m) optical observations with a high revisit tailored towards the needs of operational land services.

The Sentinel-2 mission will offer an unprecedented combination of the following capabilities: (1) Systematic global coverage of land surfaces: from 56°South to 84°North, coastal waters and all Mediterranean sea; (2) High revisit: every 5 days at equator under the same viewing conditions with two satellites; (3) High spatial resolution: 10 m, 20 m and 60 m; (4) Multi-spectral information with 13 bands in the visible, near infra-red and short wave infra-red part of the spectrum, and (5) Wide field of view: 290 km.

The Level-1C product provides ortho-rectified, i.e. a map projection of the acquired image using a system DEM to correct ground geometric distortions, Top-Of-Atmosphere (TOA) reflectance with a sub-pixel multi-spectral and multi-date registration. This Level-1C product is converted to Bottom-of-Atmosphere (BOA) reflectance and an associated scene classification, which constitutes the Level-2A product.

1.1 Purpose of the document

This document defines the content of the Sentinel-2 Level-2A product. It delivers a collection of the Level-2A related input and output data, covering Scenes, AOT and Water Vapour maps and Quality Indicators. The document has to be considered as a specialisation of the definition provided in [S2-PDD] for the Level-2A product.

The general parts which are common to all products are thus part of the main document [S2-PDD] and will be referred at the corresponding sections.

1.2 Document structure

The document aligns to the structure of products definition given in [S2-PDD]. According to this scheme, the Chapter 2 of this document defines the structure of Level-2A products into six sections:

- Overview, in section 2.1;
- Image data, including preview in section 2.2;
- Metadata, in section 2.3;
- Quality Indicator Data, in section 2.4;

- Auxiliary Data, in section 2.5;
- File Size Estimation, in section 2.6.
- Appendix A: Conversion Formulae

1.3 References

The reference list of all project related documents with their version number and issue date is given in:

[S2-L2A-GLOS] S2PAD Project Glossary S2PAD-VEGA-GLO-0001, version 3.5, 22.05.2015

1.1 Normative Reference Documents

[GS-FFS] Ground Segment File Format Standard
[GS-FFS-TSM] Earth Observation GS File Format Standard - Tailoring for the Sentinel Missions PDGS

1.2 Informative Reference Documents

[CAMS] Copernicus Atmosphere Monitoring Service,
<https://atmosphere.copernicus.eu/catalogue#/product/urn:x-wmo:md:int.ecmwf::copernicus:cams:prod:fc:total-aod:pid094>

[ECMWF] ECMWF Deterministic Atmospheric Model Products
<https://www.ecmwf.int/en/forecasts/datasets/set-i>

[S2-PDD] GMES Space Component – Sentinel-2 Payload Data Ground Segment (PDGS), Product Definition Document

[S2-PSD] Sentinel-2 Products Specification Document

[S2-MRD] Sentinel-2 Mission Requirements Document

[S2-L2A-ATBD] Sentinel-2 Level 2A Algorithm Theoretical Basis Document

[S2-L2A-IODD] Sentinel-2 Level 2A Input Output Data Definition

[S2-L2A-SUM] Sen2Cor User Manual

[S2-L2A-DQR] Sentinel-2 Level 2A Data Quality Report
<https://sentinels.copernicus.eu/web/sentinel/data-product-quality-reports>

1.3 Relation to other Documents

The *Sentinel-2 Level 2A Algorithm Theoretical Basis Document* [S2-L2A-ATBD] defines the algorithms used during Level 2A processing which are labelled as 2A-SC for Level 2A Scene Classification and 2A-AC for Level-2A Atmospheric Correction.

The *Sentinel-2 Products Specification Document* [S2-PSD] describes Sentinel-2 file naming convention and presents how the Sentinel-2 XSD schemas are organized.

1.4 Definitions of Terms and Conventions

Please refer to section 2.4 of [S2-PDD] for definition of Sentinel-2 mission and terms, e.g. Datatake, Datastrip, MSI Spectral bands, User-product, etc.

2. Level-2A Product Definition

2.1 Overview

Level-2A processing consists in scene classification and atmospheric correction applied to Level-1C orthoimage product.

Level-2A main output is an orthoimage Bottom-Of-Atmosphere (BOA) reflectance product. Additional outputs are Aerosol Optical Thickness (AOT) map, Water Vapour (WV) map, Scene Classification map together with Quality Indicators data.

Level-2A products are resampled as Level-1C products with a constant GSD (Ground Sampling Distance) of 10 m, 20 m and 60 m according to the native resolution of the different spectral bands.

The delivery of 10 m, 20 m or 60 m product is optional. Product content is detailed in section 2.1.2.

2.1.1 Input data of L2A processing

Table 2-I lists the input data of Level-2A processing.

Level-1C TOA (Top-Of-Atmosphere) reflectance is the main input for the Level-2A product generation. Main part of Level-1C metadata will be included in the Level-2A product. The definition of Level-1C product is given in [S2-PDD] and therefore Level-1C metadata would not be further described in this document.

Table 2-I: Input of Level-2A processing

Input of Level-2A processing	Description
From Level-1C	Image Data: Level-1C Top-Of-Atmosphere reflectance values
	Metadata from Level-1C
	Ancillary data from the Level-1C (satellite and ground ancillary data, including solar and incidence angles)
	Quality Indicator files from Level-1C
	Ozone Total Column from ECMWF
	(optional) Aerosol Optical Thickness from at 550 nm from [CAM5]
Auxiliary Data	GIPP: Level-2A processing parameters

Input of Level-2A processing	Description
(see section 2.5)	Digital Elevation Model (provided by user)
	LibRadtran LUTs (internal)
	Snow climatology (internal)
	ESA CCI Land Cover package (Sen2Cor ≥ 2.5) (to be retrieved manually as described in [S2-L2A-SUM])

2.1.2 Product Summary

The geographic coverage of Level-2A products is the same as the Level-1C input products.

One Level-2A product refers always to one Datatake. It may refer to one or several Datastrips from the same Datatake.

The Level-2A product may cover the full Datatake or an extract of the Datatake.

In the case of an extract, the image data are provided to cover the selected extract. In the case of an extract, the ancillary data are always provided through a metadata file on the full Datatake temporal extent.

Level-2A processing is performed on Level-1C products geometrically refined that are identified with a dedicated flag in the Level-1C metadata.

Figure 2-1 gives an overview of the L2A Product Physical Format. Please refer to [S2-PSD] and following sections of this document for more details.

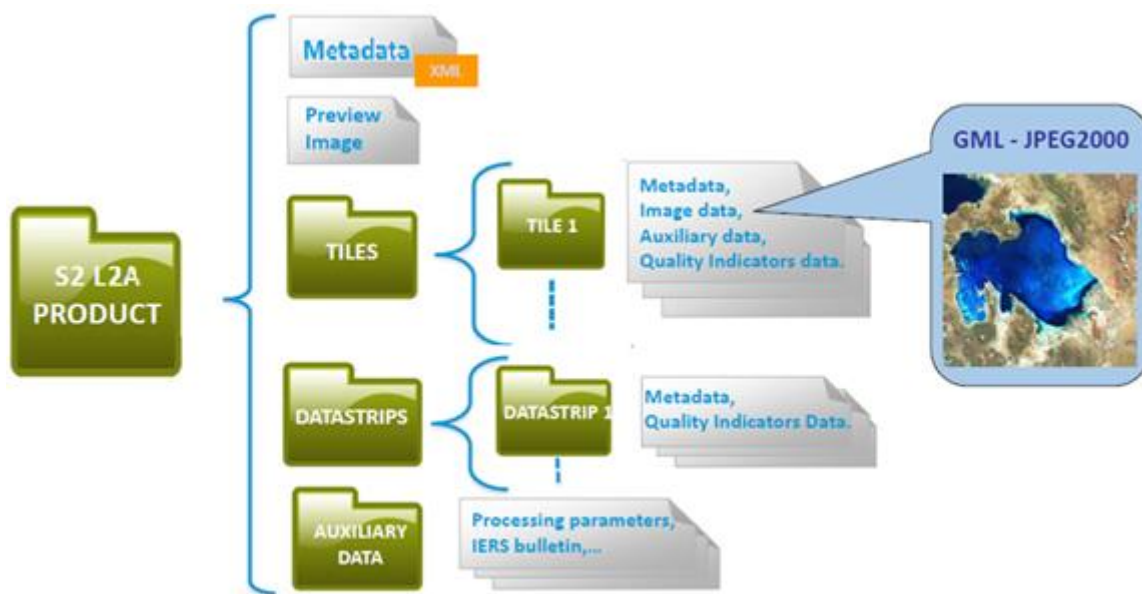


Figure 2-1 Level-2A Product Physical Format

The Level-2A product is characterised by the main following contents, outputs of the scene classification and atmospheric corrections algorithms:

- **Scene classification tiles**

- The Scene Classification (attaching an attribute to each pixel to indicate its type) at 20 m and 60 m resolution [Image Data];
- Statistics on percentage of pixels belonging to each class [QI Data];
- The Quality Indicators for snow and cloud probability (20 m and 60 m) [QI Data].

- **Atmospheric correction tiles**

- The 60 m resolution product [Image Data];
 - The surface (BOA) reflectance cube with 11 channels (B1, B2, B3, B4, B5, B6, B7, B8a, B9, B11, B12) excluding the 1375 nm cirrus band B10, as it does not contain surface information.
 - The aerosol optical thickness map AOT (550 nm) at 60 m resolution;
 - The water vapour map WV at 60 m resolution;
 - A True Colour Image based on the three channels B2, B3, B4, since PSD V14.2 and above at 60 m resolution;
- The 20 m resolution product [Image Data];
 - The surface (BOA) reflectance cube with 9 channels (B2, B3, B4, B5, B6, B7, B8a, B11, B12), omitting the original 60 m channels (see [RD10] for further details).
 - The aerosol optical thickness map AOT (550 nm) at 20 m resolution;
 - The water vapour map WV at 20 m resolution;
 - A True Colour Image based on the three channels B2, B3, B4, since PSD V14.2 and above at 20 m resolution;

- The 10 m resolution product [Image Data];
 - The surface (BOA) reflectance cube with 4 channels (B2, B3, B4, B8), omitting the original 20 and 60 m channels (see [S2-L2A-ATBD] for further details).
 - The resampled AOT (aerosol optical thickness) map (550 nm) at 10 m resolution;
 - The scene-averaged WV (Water Vapour) map at 10 m resolution;
 - A True Colour Image based on the three channels B2, B3, B4, since PSD V14.2 and above at 10 m resolution;

Note: the user is able to select the output of the L2A processor: 10 m resolution product only, 20 m resolution product only or 60 m resolution product only. By default all resolutions are provided.

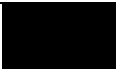











Table 2-II gives an overview of the components of Level-2A product.

Table 2-II: Level-2A Product – Summary Table

Name	Level-2A
Common Characteristics for L2A Products	
Identifier	S2_L2A
Product level	L2A
Description	<p>The L2A product contains the following product components:</p> <ul style="list-style-type: none"> • BOA reflectance images (10 m, 20 m, 60 m); • Aerosol Optical Thickness (AOT) maps (10 m, 20 m, 60 m); • Water Vapour (WV) maps (10 m, 20 m, 60 m); • Scene classification map (on pixel basis) (20 m, 60 m); • True Colour Image (TCI) (10 m, 20 m, 60 m) for PSD V 14.2 and above; • Quality Indicators for Snow and Cloud probability (20 m, 60 m).

Name	Level-2A
Parent Product	L1C
Coverage	Regional
Packaging	Tiles (same size and area coverage as Level 1C input data)
Geo-location accuracy	Identical to the level 1C geo-location performance.
Frequency	Variable upon Level 1C products availability.
Format	SAFE format, see section 1.7 of [S2-PSD].
Size	See section 2.6.
BOA Reflectance [Image Data]	
Algorithm	<p>The surface reflectance is computed using the "Sentinel-2 Atmospheric Correction" (L2A_AtmosCorr) algorithm and is based on reference radiative transfer code. Look Up Tables (LUTs) are based on LibRadtran.</p> <p>The aerosol optical thickness retrieval is based on the dense dark vegetation (DDV) algorithm.</p> <p>The water vapour retrieval over land is performed with the atmospheric pre-corrected differential absorption (APDA) algorithm.</p>
Unit	None
Range	0.0 to 1.0 (Reflectance could be above 1 with anisotropic targets and for certain viewing directions, e.g. specular configuration)
Sampling	16 bits/pixel
Channels and Resolution	<p>B1 (443 nm): 60 m and 20 m staring from PSD 14.9</p> <p>B2 (490 nm): 60 m, 20 m, 10 m</p> <p>B3 (560 nm): 60 m, 20 m, 10 m</p> <p>B4 (665 nm): 60 m, 20 m, 10 m</p> <p>B5 (705 nm): 60 m, 20 m</p> <p>B6 (740 nm): 60 m, 20 m</p>

Name	Level-2A
	<p>B7 (783 nm): 60 m, 20 m B8 (842 nm): 10 m B8a (865 nm): 60 m, 20 m B9 (945 nm): 60 m, 20 m B11 (1610 nm): 60 m, 20 m B12 (2190 nm): 60 m, 20 m</p> <p><u>Note:</u> The MSI of the Sentinel-2 has 13 spectral channels. Channel B10 (Cirrus correction, 1375 nm) which does not contain surface information will be barred. All the other channels will be processed.</p>
Radiometric Accuracy	Mission requirement is 5%
Water Vapour Map [Image Data]	
Algorithm	L2A_AtmosCorr
Unit	[g.cm ⁻²] or [cm]
Range	0.4 – 5.5 [g.cm ⁻²] or [cm]
Sampling	16 bit
Resolution	60 m, 20 m, 10 m
Accuracy	5 – 10 % (Schläpfer 1998, Chylek et al. 2003, Richter and Schläpfer 2008)
Aerosol Optical Thickness (AOT) Map [Image Data]	
Algorithm	L2A_AtmosCorr
Unit	Dimensionless
Range	0 – 1
Sampling	16 bit
Resolution	60 m, 20 m, 10 m
Accuracy	Please refer to L2A Data Quality Report [S2-L2A-DQR]

Name	Level-2A		
Scene Classification [Image Data]			
Algorithm	L2A_SceneClass		
Unit	None		
Range	0	No Data (Missing data) (black)	
	1	Saturated or defective pixel (red)	
	2	Cast Shadows (very dark grey)	
	3	Cloud shadows (dark brown)	
	4	Vegetation (green)	
	5	Not-vegetated (dark yellow)	
	6	Water (dark and bright) (blue)	
	7	Unclassified (dark grey)	
	8	Cloud medium probability (grey)	
	9	Cloud high probability (white)	
	10	Thin cirrus (very bright blue)	
	11	Snow or ice (very bright pink)	
	Note: Scene Classification pixels are set to 1 (Saturated or defective pixel) if at least one band involved in the L2A_SC is affected by Level-1C quality masks. See section 0 for details.		
Sampling	n/a (binary parameter)		
Resolution	60 m		
Accuracy	Overall 80 - 95% Please refer to L2A Data Quality Report [S2-L2A-DQR]		
Cloud Probability [QI Data]			

Name	Level-2A
Algorithm	L2A_SceneClass
Unit	Dimensionless
Range	0 - 100
Sampling	8 bit/sample
Resolution	60 m, 20 m
Accuracy	See Cloud Confidence Table 2-X
Snow Probability [QI Data]	
Algorithm	L2A_SceneClass
Unit	Dimensionless
Range	0 – 100
Sampling	8 bit/sample
Resolution	60 m, 20 m
Accuracy	See Snow Confidence Table 2-X

2.2 Image Data

The Level-2 A image data is composed of BOA reflectance images, Aerosol Optical Thickness (AOT) maps, Water Vapour (WV) maps and Scene classification map (SCL).

The Level-2A image data product uses the same tiling, encoding and filling structure as Level-1C as described in detail in section 8.2.1 and 8.2.2 of [S2-PDD].

*Physical tiles (ex. set of JPEG2000 files)
Each tile is geo-referenced (UTM projection)*

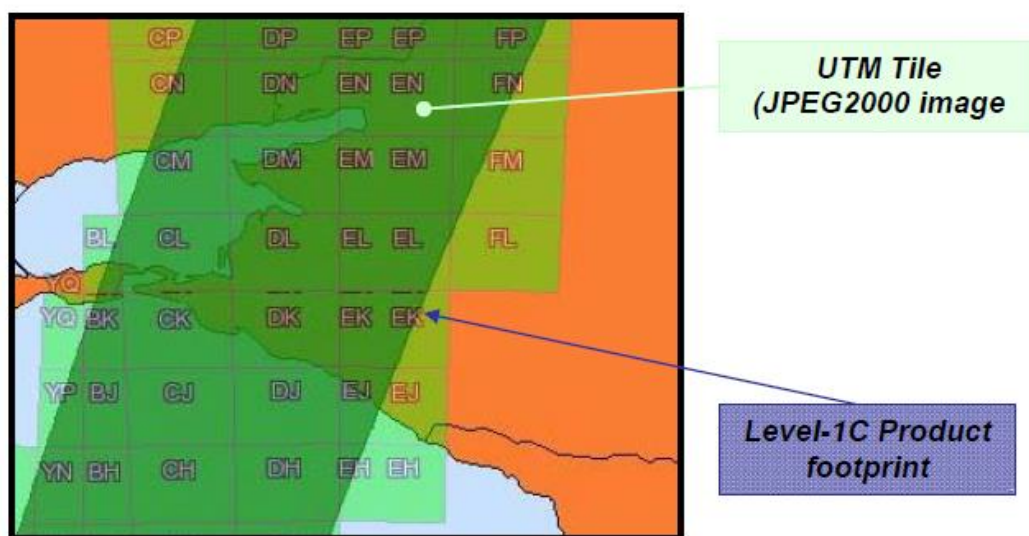


Figure 2-2: Example of Level-2A product tiled in several files

2.2.1 Atmospheric correction images

For BOA Reflectance images, pixel value is encoded on 16 useful bits and is directly proportional to Bottom-Of-Atmosphere reflectance values.

Table 2-III below lists the data type, the encoding, data size and resolution of the Atmospheric correction image data generated by the Level-2A processing.

Table 2-III: Atmospheric correction Image Data

Name	Data Type	Image Size (width, height)	Resolution	Description
60 m product				
BOA Reflectance				
B1 channel	JPEG 2000, 16bit	1830 x 1830	60 m	Image

Name	Data Type	Image Size (width, height)	Resolution	Description
B2 channel	JPEG 2000, 16bit	1830 x 1830	60 m	Image
B3 channel	JPEG 2000, 16bit	1830 x 1830	60 m	Image
B4 channel	JPEG 2000, 16bit	1830 x 1830	60 m	Image
B5 channel	JPEG 2000, 16bit	1830 x 1830	60 m	Image
B6 channel	JPEG 2000, 16bit	1830 x 1830	60 m	Image
B7 channel	JPEG 2000, 16bit	1830 x 1830	60 m	Image
B8a channel	JPEG 2000, 16bit	1830 x 1830	60 m	Image
B9 channel	JPEG 2000, 16bit	1830 x 1830	60 m	Image
B11 channel	JPEG 2000, 16bit	1830 x 1830	60 m	Image
B12 channel	JPEG 2000, 16bit	1830 x 1830	60 m	Image
Water Vapour Map				
WV map	JPEG 2000, 16 bit	1830 x 1830	60 m	Image
Aerosol Optical Thickness Map				
AOT map	JPEG 2000, 16 bit	1830 x 1830	60 m	Image

Name	Data Type	Image Size (width, height)	Resolution	Description
20 m product				
BOA Reflectance				
B1 channel	JPEG 2000, 16bit	5490 x 5490	20 m	Image
B2 channel	JPEG 2000, 16bit	5490 x 5490	20 m	Image
B3 channel	JPEG 2000, 16bit	5490 x 5490	20 m	Image
B4 channel	JPEG 2000, 16bit	5490 x 5490	20 m	Image
B5 channel	JPEG 2000, 16bit	5490 x 5490	20 m	Image
B6 channel	JPEG 2000, 16bit	5490 x 5490	20 m	Image
B7 channel	JPEG 2000, 16bit	5490 x 5490	20 m	Image
B8a channel	JPEG 2000, 16bit	5490 x 5490	20 m	Image
B11 channel	JPEG 2000, 16bit	5490 x 5490	20 m	Image
B12 channel	JPEG 2000, 16bit	5490 x 5490	20 m	Image
Water Vapor Map				
WV map	16 bit	5490 x 5490	20 m	Image
Aerosol Optical Thickness Map				
AOT map	16 bit	5490 x 5490	20 m	Image

Name	Data Type	Image Size (width, height)	Resolution	Description
10 m product				
BOA Reflectance				
B2 channel	JPEG 2000, 16bit	10980 x 10980	10 m	Image
B3 channel	JPEG 2000, 16bit	10980 x 10980	10 m	Image
B4 channel	JPEG 2000, 16bit	10980 x 10980	10 m	Image
B8 channel	JPEG 2000, 16bit	10980 x 10980	10 m	Image
Water Vapour Map				
WV map	JPEG2000, 16 bit	10980 x 10980	10 m	Image
Aerosol Optical Thickness Map				
AOT map	JPEG2000, 16 bit	10980 x 10980	10 m	Image

2.2.2 Scene Classification image

Table 2-IV below lists the data type, the encoding, data size and resolution of the scene classification Image data as generated by the Level-2A processing. JPEG2000 is very efficient for this type of dataset with only 12 available values with a compression rate of the order of 10.

Table 2-IV: Scene Classification Image data

Name	Data Type	Image Size (width, height)	Resolution	Description
Scene Classification				

Name	Data Type	Image Size (width, height)	Resolution	Description
SCL map 60 m	JPEG 2000, 8bit	1830 x 1830	60 m	Array covering all picture columns/rows at 60 m spatial resolution.
SCL map 20 m	JPEG 2000, 8bit	5490 x 5490	20 m	Array covering all picture columns/rows at 20 m spatial resolution.

2.2.3 Digital Elevation Map (DEM)

Table 2-IV below lists the data type, the encoding, data size and resolution of an optional Digital Elevation Map as generated by the Level-2A processing. OpenJPEG is only able to store unsigned integer values, thus an offset of +10.000 has been applied in order to allow negative heights. The scale of the DEM is thus (meter – 10.000).

Table 2-V: Digital Elevation Map

Name	Data Type	Image Size (width, height)	Resolution	Description
Digital Elevation Map				
DEM (optional)	JPEG 2000, 16bit	60 m: 1830 x 1830 20 m: 5490 x 5490 10 m: 10980 x 10980	60 m 20 m 10 m	Array covering the digital elevation map in m + offset of 10.000, to allow negative height.

2.2.4 True Colour Image (TCI, since PSD V.14.2)

Table 2-VII below lists the data type, the encoding, data size and resolution of the true colour image data as generated by the Level-2A processing.

Table 2-VI TCI Data

Name	Data Type	Image Size (width, height)	Resolution	Description
True Colour Image for BOA Reflectance				
TCI Image	JPEG2000, 8bit	60 m: 1830 x 1830 20 m: 5490 x 5490 10 m: 10980 x 10980	60 m 20 m 10 m	RGB (3 channels: RED = B4; GREEN = B3; BLUE = B2). Preview dynamic is stretched (min = 0.0, max = 0.250, scale =255.0)

2.2.5 Preview Data

Table 2-VII below lists the data type, the encoding, data size and resolution of the preview and browse image data as generated by the Level-2A processing.

Table 2-VII Preview Data

Name	Data Type	Data Size (MBytes)	Resolution	Description
Preview Image (Quick Look) for BOA Reflectance				
Preview Image	JPEG2000, 8bit	<0.3	320 m	RGB (3 channels: RED = B4; GREEN = B3; BLUE = B2). Preview dynamic is stretched (min = 0.0, max = 0.250, scale =255.0)

2.3 Metadata

This section describes the metadata provided with the Level-2A product.

Metadata provided by Level-2A processing is indicated **in bold** in following sections.

2.3.1 Product Level Metadata

The following information is applicable to the whole product.

2.3.1.1 Brief Metadata

The following information is provided in the Level-2A "brief" metadata:

- Product level information:
 - Datatake information (inherited from Level-0 metadata, see [S2-PDD]):
 - Datatake unique identifier;
 - Spacecraft name (Sentinel-2A/B/...);
 - Datatake type (MSI Operation Mode: Nominal, Dark Signal, etc.);
 - Imaging start time;
 - Imaging orbit number;
 - Imaging orbit direction.
 - **Processing Level (Level-2A);**
 - List of Level-2A tiles composing the product and the dimensions of each tile;
 - Tiles aggregation flag (Boolean);
 - **Image format and pointer to the image data files;**
 - Spectral bands (relation between product image channels and on-board spectral bands);
 - **Reflectance quantification value (in order to convert digit count into reflectance) and unit;**
 - **Special values encoding (e.g. NODATA, SATURATION).**
- Datastrip level information (repeatable for each Datastrip composing the product):

- Datastrip unique identifier;
- Preview data information:
 - **Pointer to preview image files (see section 2.2.5);**
- **Product level quality indicators (see section 2.4.1).**

2.3.1.2 Standard Metadata

The following information is provided in the standard metadata structure:

- Brief metadata, as in section 2.3.1.1.
- Following information repeatable for each Datastrip:
 - Auxiliary data information:
 - Auxiliary data from Level-1C;
 - **Identification of OGCD/GIPP used for Level-2A (identifier and version), including Meteorological, Atmospheric data and ESA CCI data listed in section 2.5.**

2.3.1.3 Expertise Metadata

The following information is provided in the expertise metadata structure:

- Brief metadata, as in section 2.3.1.1;
- Standard metadata, as in section 2.3.1.2;
- Following information repeatable for each Datastrip:
 - **Datastrip generation information (Level-2A generation date, software version,...);**
 - Level-1C expertise metadata.

2.3.2 Tile Level Metadata

The following metadata are provided on tile level:

2.3.2.1 Brief Metadata

The following information is provided in the Level-2A "brief" metadata for each Level-2A tile:

- Tile identifier, as referenced by Level-1C data;
- Tile geocoding:
 - o Upper-left coordinates (ULX, ULY) of the tile (in meters);
 - o Pixel dimensions (XDIM, YDIM) within the tile (in meters and depending on band GSD);
 - o Tile size in number of lines/columns.

2.3.2.2 Standard Metadata

For each tile of the Level-2A product, the following information is provided in the standard metadata:

- Brief metadata
- Tile identification and reference to a given Datastrip;
- Grid of sun angles (zenith and azimuth) and the correction which takes into account earth-sun distance variation and for each band sun equivalent irradiance
- Mean sun angle;
- Grid of incidence angles (zenith and azimuth) (per bands and detectors);
- Mean incidence angle;
- **Tile level quality indicators as listed in section 2.4.2;**
- **Pixel level quality indicators (as a pointer to the QI files) as listed in section 0.**

2.3.2.3 Expertise Metadata

At tile level, the expertise metadata is composed by the same information as in the standard metadata structure (see section 2.3.2.2).

2.4 Quality Indicator Data

The following quality indicators (QI) are provided with Level-2A products.
Some QIs provided in Level-2A products are inherited from Level-1C QIs.

2.4.1 Product Level Quality Indicators

The following Level-2A QIs are provided on product level and refer to one Datatake. They are provided through the metadata file.

Table 2-VIII: Product Level Quality Indicators

Name	Data Type	Description
Level-2A Quality Indicators (Product level)		
% of no data pixels (missing data on projected tiles)	Float formatted in String	This information is derived from the scene classification image based on Level-1C radiometric information.
% of saturated or defective pixels	"	This information is derived from the scene classification image based on Level-1C radiometric quality masks.
% of pixels classified as dark features /shadows	"	For Level-2A products the classification of cloud, vegetation, water, etc. pixel is based on radiometry (and geometry for cloud shadow). Ranging from 0 for 0% to 100 for 100%.
% of pixels classified as cloud shadow	"	"
% of pixels classified as vegetation	"	"
% of pixels classified not-vegetated	"	"
% of pixels classified as water	"	"

Name	Data Type	Description
% of pixels classified as unclassified	"	"
% of pixels classified as medium probability cloud	"	"
% of pixels classified as high probability cloud	"	"
% of pixels classified as cirrus	"	"
% of pixels classified as snow or ice	"	"
% of pixels classified as cloud coverage	"	This is a combination of the three following classes: medium probability + high probability clouds + cirrus. Ranging from 0 for 0% to 100 for 100%. (This QI field is present in PSD Version 14.2 and above)
% of pixels classified as cloudy pixel over land	"	This is QI is the cloud coverage above land pixels within the tile. Ranging from 0 for 0% to 100 for 100%. (This QI field is present in PSD Version 14.9 and above)
Declared accuracy of the radiative transfer model	"	LibRadtran code achieves a relative accuracy of 5% - 10% http://www.bmayer.de/index.html?radtran.html&1
Water vapour retrieval accuracy	"	APDA (Atmospherically Pre-corrected Differential Absorption) method achieves a typical relative accuracy of 5 - 10% except over very dark surfaces.

Name	Data Type	Description
		(Schläpfer 1998, Chylek et al. 2003, Richter and Schläpfer 2008)
AOT_RETRIEVAL_METHOD	String	Either SEN2COR_DDV, CAMS, DEFAULT
GRANULE_MEAN_AOT	Float formatted in String	Mean value of Aerosol optical thickness at 550 nm over the tile [unitless]
GRANULE_MEAN_WV	Float formatted in String	Mean value of Water vapour over the tile [g.cm-2]
OZONE_SOURCE	String	Either AUX_ECMWFT, CONFIG
OZONE_VALUE	Float formatted in String	Mean value of Total Column Ozone over the tile [Dobson unit]
Embedded Level-1C Quality Indicators (Product level)		
Geometric Quality indicators	Float formatted in String	Orbit level quality indicators from Level-0: Absolute location, Planimetric stability, and ephemeris and ancillary data quality. See section 5.5.1 of [S2-PDD] for details. Orbit level quality indicators from Level-1B: Geometric refining quality, average, mean quadratic residuals, histograms of spatio-triangulation residuals on ground for each axis (X, Y, Z) and in image reference frame for each axis (row, col). See section 7.4.1 of [S2-PDD] for details.

Name	Data Type	Description
% of degraded MSI and ancillary data over the product	"	Level-1C Quality Indicator

2.4.2 Tile Level Quality Indicators

The following Level-2A Quality Indicators are provided on tile level in the tile metadata.

Table 2-IX: Level-2A Tile Level Quality Indicators

Name	Data Type	Description
Level-2A Quality Indicators (Tile level)		
% of no data pixels (missing data on projected tiles)	Float formatted in String	This information is derived from the scene classification image based on Level-1C radiometric information.
% of saturated or defective pixels	"	This information is derived from the scene classification image based on Level-1C radiometric quality masks.
% of pixels classified as dark features /shadows	"	This information is derived from the scene classification image based on Level-1C radiometry. Ranging from 0 for 0% to 100 for 100%.
% of pixels classified as cloud shadow	"	"
% of pixels classified as vegetation	"	"
% of pixels classified not-vegetated	"	"

Name	Data Type	Description
% of pixels classified as water	"	"
% of pixels classified as unclassified	"	"
% of pixels classified as medium probability cloud	"	"
% of pixels classified as high probability cloud	"	"
% of pixels classified as cirrus	"	"
% of pixels classified as snow or ice	"	"
% of pixels classified as cloud coverage	"	This is a combination of the three following classes: medium probability + high probability clouds + cirrus. Ranging from 0 for 0% to 100 for 100%. (This QI field is present in PSD Version 14.2 and above)
% of pixels classified as cloudy pixel over land	"	This is QI is the cloud coverage above land pixels within the tile. Ranging from 0 for 0% to 100 for 100%. (This QI field is present in PSD Version 14.9 and above)
AOT_RETRIEVAL_METHOD	String	Either SEN2COR_DD, CAMS, DEFAULT
GRANULE_MEAN_AOT	Float formatted in String	Mean value of Aerosol optical thickness at 550 nm over the tile [unitless]

Name	Data Type	Description
GRANULE_MEAN_WV	Float formatted in String	Mean value of Water vapour over the tile [g.cm-2]
OZONE_SOURCE	String	Either AUX_ECMWFT, CONFIG
OZONE_VALUE	Float formatted in String	Mean value of Total Column Ozone over the tile [Dobson unit]
Embedded Level-1C Quality Indicators (Tile level)		
% of degraded MSI and ancillary data over the tile	Float formatted in String	Level-1C Quality Indicator

2.4.2.1 L2A_QUALITY report

Starting with PSD version 14.9, a new L2A_QUALITY.xml file is available at tile level in the QI_DATA folder. The L2A_QUALITY report provides L2A quality information derived during the L2A processing.

The L2A Quality Indicators reported in the L2A_QUALITY report are separated in three main groups:

- -Scene Class quality indicators;
- - Atmospheric Correction quality indicators;
- - Auxiliary Data quality indicators.

For further details on the quality indicators reported in the L2A_QUALITY report please refer to Sentinel-2 Data Quality Report S2-PDGS-MPC-L2ADQR.

2.4.3 Pixel Level Quality Indicators

These quality indicators are provided at tile level through dedicated quality masks that provide quality information at pixel level.

Please note that high-level radiometric quality information is also available at pixel level through the scene classification image (2 classes: no data pixels and defective/saturated pixels).

QIs provided by Level-2A processing are provided at 60 m and 20 m resolution as raster masks, the same resolution as the Pixel Classification. Users may resample this to lower or higher resolution, if required.

The following Level-2A QIs are provided on pixel level.

Table 2-X: Level-2A Pixel Level Quality Indicators

Name	Data Type	Data Size (Byte)	Resolution	Description
Cloud Confidence	Unsigned Integer	1	60 m / 20 m	Ranging from 0 for high confidence clear sky to 100 for high confidence cloudy.
Snow or Ice Confidence	Unsigned Integer	1	60 m / 20 m	Ranging from 0 for high confidence no snow/ice to 100 for high confidence snow/ice.
Embedded Level-1C Quality Indicators (Pixel level) PSD 14.9				
L1C quality masks (MSK_QUALIT)	raster file	N/A	native resolution of the band	MSK_QUALIT gathers the following masks: MSK_CLOLOW (Coarse cloud mask files) MSK_TECQUA (Technical quality mask) MSK_DEFECT (Radiometric quality mask) MSK_SATURA (Radiometric Saturation mask) MSK_NODATA (Radiometric No Data mask)

Name	Data Type	Data Size (Byte)	Resolution	Description
L1C classification mask	raster file	N/A	60 m	MSK_CLASSI gathers the following masks: MSK_CLOUDS (Finer cloud mask file) MSK_SNOWICE (Coarse snow/ice mask file)
Detector footprint masks	raster file	N/A	native resolution of the band	MSK_DETFOO gathers the following masks: MSK_DETFOO (Detector footprint mask)

Note: QIs inherited from Level-1C products are provided as vector files; one for each type of mask and each tile. Each vector mask file consists of a set of polygons defined in ground geometry: (X, Y) in the projected frame.

2.5 Auxiliary Data

All Auxiliary Data used for Level-2A processing are referenced in the Level-2A Metadata whereas Level-1C meteorological datasets are provided within Level-2A product.

Please refer to [S2-L2A-ATBD] for details on auxiliary data.

2.5.1 Provided Auxiliary Data

The following auxiliary data is provided in the Level-2A product structure:

- Level-1C inherited Auxiliary Data which consists in an elementary set of meteorological datasets extracted and resampled from ECMWF forecast output (cf. [ECMWF]);
- Level-1C inherited Auxiliary Data which consists in an elementary set of atmospherical datasets extracted and resampled from CAMS forecast output (cf. [CAMS]).

2.5.2 Referenced Auxiliary Data

The following auxiliary data is referenced in the Level-2A metadata:

- The Digital Elevation Model (provided by user) used for the Level-2A processing is (optionally) provided in the AUX data subfolder on the GRANULE level, labelled by resolution.
- The LibRadtran LUTs used for the Level-2A processing are not provided within the product but only as a reference to the data used.
- The Snow climatology used for the Level-2A processing is not provided itself within the product but only as a reference to the data used.
- The ESA CCI LC datasets used for the Level-2A processing are not provided within the product but only as a reference (Land Cover map, water bodies v4 and snow products).

2.6 File Size Estimation (single tile)

The total size of Image data and QI Data output can be calculated based on sections 2.2 and 2.4. The data size has been calculated for a single tile assuming an image size of 110km * 110km and lossless JPEG2000 compression, with a mean compression rate of 2.0 for surface reflectance bands and higher compression rate for AOT, WVP, DEM and Scene Classification

The following data have been neglected in the file size estimation, due to their relatively small size:

- Product Metadata
- Quality Indicators provided in Metadata
- Preview Images
- Embedded Level-1C Quality indicators

Table 2-XI: Total File Size (110x110km² tile)

Name	Data Format	Resolution	MBytes	Description
60 m Image Data				
60 m Product BOA Reflectance	JPEG2000 , 16bit	60 m	35.2	Primary Output, Image Data (BOA) for spectral channels B1, B2, B3, B4, B5, B6, B7, B8a, B9, B11, B12. One JP2 file per band.

Name	Data Format	Resolution	MBytes	Description
60 m WV map	JPEG2000 , 16 bit	60 m	~3.3	Water Vapour map at 60 m resolution
60 m AOT map	JPEG2000 , 16 bit	60 m	~3.3	Aerosol Optical Thickness map
60 m Scene Classification	JPEG2000 , 8 bit	60 m	~1.0	Category of the pixel, e.g. land, water, cloud, cloud shadow, snow or ice
60 m TCI image	JPEG2000 , 8 bit x 3	60 m	~5.0	True Colour Image Data (BOA) for spectral channels B2, B3, B4
60 m DEM (optional)	JPEG2000 , 16 bit	60 m	~3.3	Digital Elevation Map (optional)
Total (60 m)	~53.0			MBytes
20 m Image Data				
20 m Product BOA Reflectance	JPEG2000 , 16bit	20 m	259.2	Primary Output, Image Data (BOA) for spectral channels B2, B3, B4, B5, B6, B7, B8a, B11, B12. One JP2 file per band.
20 m WV map	JPEG2000 , 16 bit	20 m	~20.0	20 m Water Vapour map
20 m AOT map	JPEG2000 , 16 bit	20 m	~1.0	20 m Aerosol Optical Thickness map
20 m Scene Classification	JPEG2000 , 8 bit	20 m	~5.0	Category of the pixel, e.g. land, water, cloud, cloud shadow, snow or ice
20 m TCI image	JPEG2000 , 8 bit x 3	20 m	~50	True Colour Image Data (BOA) for spectral channels B2, B3, B4

Name	Data Format	Resolution	MBytes	Description
20 m DEM (optional)	JPEG2000 , 16 bit	20 m	~20.0	Digital Elevation Map (optional)
Total (20 m)	~355.0			MBytes
10 m Image Data				
10 m Product BOA Reflectance	JPEG2000 , 16 bit	10 m	461.6	Primary Output, Image Data (BOA) for spectral channels B2, B3, B4, B8. One JP2 file per band.
10 m WV map	JPEG2000 , 16 bit	10 m	~50.0	20 m Water Vapour map
10 m AOT map	JPEG2000 , 16 bit	10 m	~2.0	20 m Aerosol Optical Thickness map
10 m TCI image	JPEG2000 , 8 bit x 3	10 m	~150	True Colour Image Data (BOA) for spectral channels B2, B3, B4
10 m DEM (optional)	JPEG2000 , 16 bit	10 m	~50.0	Digital Elevation Map (optional)
Total (10 m)	~710.0			MBytes
Quality Indicators Data				
60 m /20 m Cloud Confidence	JPEG2000 , 8 bit	60 m 20 m	~1.0 ~5.0	Q.I. for cloud, ranging from 0 for high confidence clear sky to 100 for high confidence cloudy.
60 m /20 m Snow or Ice Confidence	JPEG2000 , 8 bit	60 m 20 m	~1.0 ~5.0	Q.I. for snow, ranging from 0 for high confidence no snow to 100 for high confidence snow.
Total			~850.0	MBytes

Appendix A Conversion Formulae

The table below lists the conversion formulae to apply to image **digital numbers (DN)** to obtain physical values starting with PSD 14.9

Image Type	Conversion formula	Physical Units	Comments
Surface_reflectance	<p>PSD >= 14.9:</p> $SR = (DN - 1000) / 10000.$ <p>PSD < 14.9:</p> $SR = DN / 10000.$	Unit less	<p>Surface Reflectance values lies usually between 0.0 and 1.0.</p> <p>Specular effects on surface or clouds could lead to values higher than 1.0.</p> <p>The L2A Quantification and radiometric offset values are aligned with the L1C Quantification and radiometric offset values of the L1C product from which the L2A product is generated.</p>
Resampled_AOT	$AOT = DN / 1000.$	Unit less	<p>The aerosol optical thickness (τ) is defined as the integrated extinction coefficient over a vertical column of atmosphere of unit cross section. Extinction coefficient is the fractional depletion of radiance per unit path length (also called attenuation for radar frequencies). Example in formula:</p> $I = I_0(e^{-\tau})$
Water_Vapour	$WVP = DN / 1000.$	g.cm ⁻² (or cm)	<p>Typical ranges of water vapour columns are (sea-level-to space):</p> <p>tropical conditions: wvp = 3-5 g.cm⁻² midlatitude summer: wvp = 2-3 g.cm⁻² dry summer, spring, fall: wvp = 1-1.5 g.cm⁻² dry desert or winter: wvp = 0.3-0.8 g.cm⁻²</p>
Digital_Elevation_Map	$DEM = DN - 10000$	m	<p>OpenJPEG is only able to store unsigned integer values, thus an offset of +10.000 is applied in order to allow negative heights. The scale of the DEM is thus (meter - 10.000).</p>