

Image Processing Tool: Products specifications for Simera Sense xScape product range.

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Sense optical cameras



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I

Ref.IPT: Products specifications

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Ref.IPT: Products specifications

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III

Ref.IPT: Products specifications

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1 INTRODUCTION

Earth observation satellites collect vast amounts of data that can be used for various applications, including environmental monitoring, agriculture, urban planning, and disaster management. The data collected by the satellite's sensors are processed into different product levels (Level 0 and Level 1), with each level offering increasing amounts of data calibration and usability. This document describes the image processing product specifications associated with the Simera Sense optical camera product range, known as xScape.

1.1 Product Levels Overview

- **Level 0:** Raw satellite data without any processing provided by the Satellite operator.
- **Level 1:** Geolocated and radiometrically corrected (i.e., express option) or calibrated data (i.e., advanced option).
 - **Level-1B** processing involves radiometric and geometric corrections or calibration of the raw data captured by the satellite. At this stage, the raw data from the satellite's detectors is corrected or calibrated to account for sensor-specific characteristics and is expressed as Top-of-Atmosphere (TOA) radiance or TOA reflectance. Level-1B data is still in the sensor geometry, meaning it is not yet projected onto a standard Earth coordinate system. This stage focuses primarily on ensuring the accuracy of the raw sensor measurements before further spatial adjustments.
 - **Level-1C** processing takes the data a step further by performing orthorectification. This process projects the imagery into a standard cartographic reference frame, using a Digital Elevation Model (DEM) to account for terrain relief and other geometric factors. The output of Level-1C processing provides orthorectified TOA radiance or reflectance values, meaning that the images are spatially corrected and aligned with geodetic coordinates (latitude, longitude) in the Universal Transverse Mercator (UTM) projection, making them suitable for direct geospatial analysis.

Each product level is tailored to different user needs, from scientific analysis to operational applications.

Two images processing tools are offered: an **express** and an **advanced** option as detailed in the table below. Details on each image processing option is given in the following sections.

Offering	Offered by	Purpose
Advanced Image Processing	Simera Sense (powered by VITO)	This end-to-end solution includes the application of vicarious calibration within the image processing workflow.
Express Image Processing	Simera Sense (powered by VITO)	This software option allows for the rapid processing images to get a first glance of the image characteristics. This software uses the ancillary information obtained from the satellite and camera metadata to geolocate the image. The preflight characterization data is used to perform a basic radiometric correction.

2 EXPRESS IMAGE PROCESSING

2.1 Level 0 (L0) Product

2.1.1 Definition

Level 0 products represent **raw, unprocessed data** directly acquired from the satellite. These are sensor-specific measurements, typically stored in binary format, with minimal post-acquisition processing.

2.1.2 Algorithm Description

At Level 0, the focus is on organizing and packaging **raw satellite data** without making modifications to the measured signals. The key steps in the Level 0 processing algorithm include:

- **Data Decompression (if applicable):** The data received from the satellite are typically compressed to save bandwidth. The first step is to decompress the raw instrument data.
- **Packet Assembly:** The satellite sends down data in packets. The algorithm assembles these packets into full frames or swaths.
- **Time Tagging and Synchronization:** The data is synchronized with a precise time reference (usually based on satellite GPS time and Imaging timer) to track when each data point was captured.
- **Storage in a Standard Format:** The raw data are packaged into a standardized format (GeoTIFF for imagery and JSON file for metadata) for archival.

Level 0 algorithms do not modify the raw data content or apply any corrections. This stage is purely about ensuring the integrity of the transmitted data and preparing it for further processing.

2.1.3 Data Content

- **Unprocessed instrument data:** Includes sensor readings in their original form.
- **Time and location stamps:** Information on when and where the data was captured.

- **Telemetry:** Satellite position, velocity, and attitudes to be further used for the direct geo-referencing process.
- **Auxiliary data:** Metadata required for post-processing, such as sensor settings, timing, configurations.

2.1.4 Use Cases

- **Calibration and validation:** Essential for ground-based researchers or satellite engineers to calibrate instruments and check for sensor performance anomalies. The Level 0 is generally not to be distributed. It can only be used by advanced experts to perform analysis, sanity checks, calibration and debugging.
- **Raw data archival:** For reprocessing data in the future as sensor models or data algorithms improve.

2.2 Level 1 Express Products

2.2.1 Definition

Level 1 express products are **radiometrically and geometrically corrected data** that have been processed from the raw Level 0 data. The express Level 1 processing includes tagging the sensor data with geographical locations and applying radiometric **correction** to convert sensor output into meaningful physical values (TOA radiance/reflectance). The Level 1 products generated by the Express Image Processing tool relies on the **radiometric pre-flight measurements** performed in laboratory. They also use the ancillary information obtained from the satellite and camera metadata to geolocate the image. Please note that there is no in-flight calibration performed to improve the radiometric and geometric absolute performances within the Express Image Processing offer. This in-flight calibration is offered by the Advanced Image Processing tool (see section 3).

Two products are provided by the express option:

- **Level 1B express:** Radiometrically corrected, geo-referenced data (interbands geometric error removed, no absolute location), typically at full resolution in sensor geometry.
- **Level 1C express:** Orthorectified radiometrically corrected and geo-located data based on the information provided by the satellite telemetry.

2.2.2 Data Content

- **Radiometrically corrected data:** Sensor readings converted into physical units (e.g., TOA reflectance, TOA radiance/reflectance).
- **Georeferencing information:** Ensures each pixel is tied to its geographic location based on the ancillary information obtained from the satellite telemetry.
- **Metadata:** Acquisition date, time, sensor-specific information, and corrections applied.

2.2.3 Level 1B Algorithms Description

Level 1B processing applies the following processing steps to the raw data:

- **Interbands geometric correction**

Satellite band misregistration refers to the misalignment of spectral bands in remote sensing imagery, where pixels representing the same ground location in different spectral bands are not perfectly aligned. This problem can occur for several reasons, such as: band displacements in the focal plane, satellite motion, and imaging system optical design. Improper registration affects the quality of multispectral and hyperspectral data analysis and leads to inaccurate results (see Figure 1) for applications such as land cover classification, vegetation monitoring, and change detection. Correcting this misregistration is critical to ensure accurate band matching at the pixel level, enabling more accurate remote sensing analysis and data fusion.

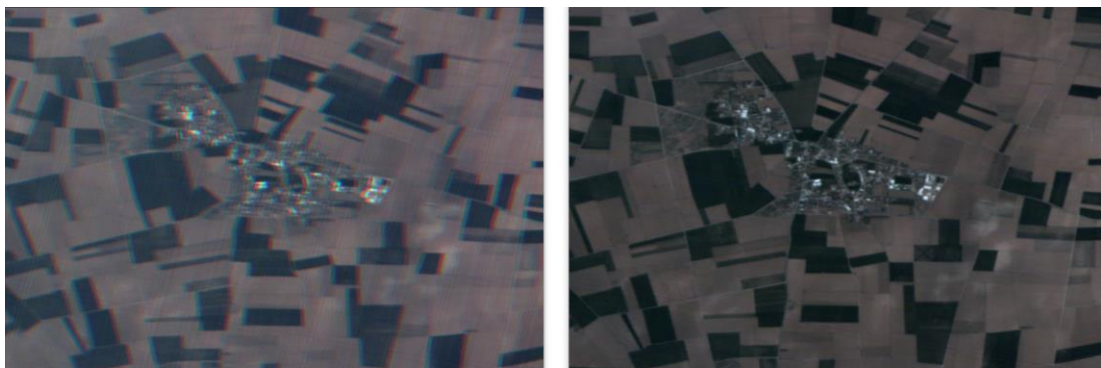


Figure 1: Left RGB image without geometric interbands correction. Right: RGB image with geometric interbands correction applied.

- **Direct georeferencing**

Satellite georeferencing (see Figure 2) is the process of determining the precise geographic coordinates (latitude, longitude, and altitude) of a point on Earth's surface from satellite imagery. The georeferencing step makes use of the satellite telemetry, which provides data on the satellite's position, velocity, and attitude (orientations in space), along with the line-of-sight information from the satellite sensor to the target on Earth. The satellite's position and velocity are obtained from onboard GPS devices, while the attitudes are measured using star trackers. By knowing the satellite's exact location in space and the orientation of its imaging sensor, the line of sight to a specific ground point can be computed and its intersection with the Earth's surface can be determined, yielding the geodetic coordinates (latitude, longitude and height).

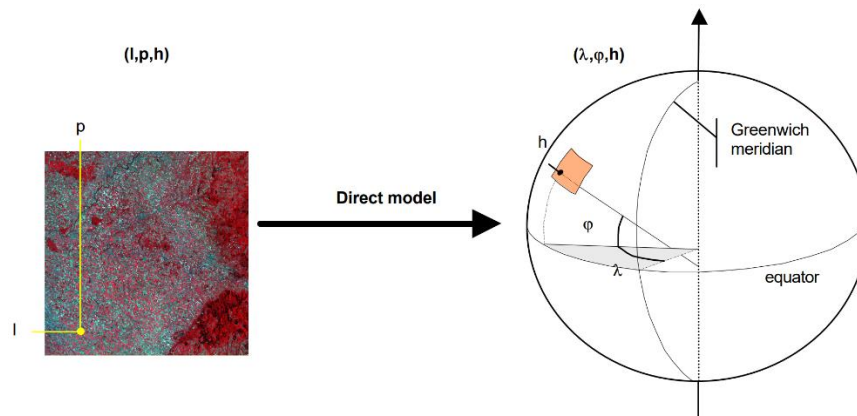


Figure 2: Direct georeferencing processing which locates each pixel and line (p , l) with its corresponding geodetic coordinates longitude, latitude and height (λ , φ , h).

- **Rational Polynomial Coefficients (RPC)**

Rational Polynomial Coefficients (RPCs see section 4.1.2.2) are mathematical parameters used in satellite imagery to approximate the geometric relationship between an image and Earth's surface without needing to know detailed sensor characteristics. By using a rational polynomial function, RPCs model the transformation from image space to ground coordinates through a set of coefficients that describe complex sensor distortions, terrain effects, and perspective. Commonly used in high-resolution satellite images, RPCs simplify georeferencing and orthorectification, allowing users to align images with maps accurately. They offer a flexible, standardized method for satellite data providers to share geometric data, streamlining processing and ensuring compatibility across software tools.

The express Image processing will offer the possibility to generate accurate RPCs coefficients as part of the Level 1B products.

- **Radiometric processing**

This processing corrects for pixel non-uniformities and converts raw Digital Numbers (DNs) into Top of Atmosphere (TOA) radiance values using sensor-specific calibration coefficients. TOA radiance represents the amount of energy that reaches the sensor, expressed in physical units (i.e., $W/m^2 \cdot \mu m \cdot sr$). The IPT tool provides an option for users to output the data in either TOA radiance or TOA reflectance units.

Key steps in the radiometric processing are:

- Per pixel dark signal non-uniformities (DSNU) correction using the lab offset and dark current characterisation data.
- Per pixel gain correction which converts the DN's in TOA radiance units and performs the photo response non-uniformities (PRNU) correction. PRNU is derived from the lab flatfield characterisation data.

Optional steps:

- Vertical destriping : remaining vertical stripes in the image are reduced through a dedicated high frequency equalization algorithm applied in vertical direction.
- Horizontal destriping : remaining horizontal stripes in the image are reduced through a similar high frequency algorithm applied in horizontal direction.
- Conversion to TOA reflectance: The conversion from TOA radiance (L_{TOA}) to TOA reflectance ($\rho_{TOA}^{(OBJ)}$) involves normalizing by the solar irradiance using the following equation:

$$\rho_{TOA}(k) = \frac{\pi \cdot L_{TOA}(k) \cdot d^2}{E_{sun}(k) \cdot \cos SZA}$$

With k the spectral band, d the Sun-Earth distance, SZA the solar zenith angle and E_{sun} is the solar irradiance at wavelength.



Figure 3: Left L0 DN image; Right: L1B image with radiometric correction applied.

- **Quicklook generation:**

No RGB quicklook are created for Level 1B but rather a grayscale quicklook for every spectral band in sensor geometry.

Level 1B products contain Top of Atmosphere (TOA) radiance/reflectance in raw sensor geometry, but every pixel is linked to a geographic location.

2.2.4 Level1C Algorithms Description

- **Orthorectification and projection to UTM projection**

Level 1C processing introduces **orthorectification and projection to UTM projection**. The output of Level 1C processing is georeferenced, radiometrically corrected images. Similarly, to Level 1B, quicklooks are also generated.

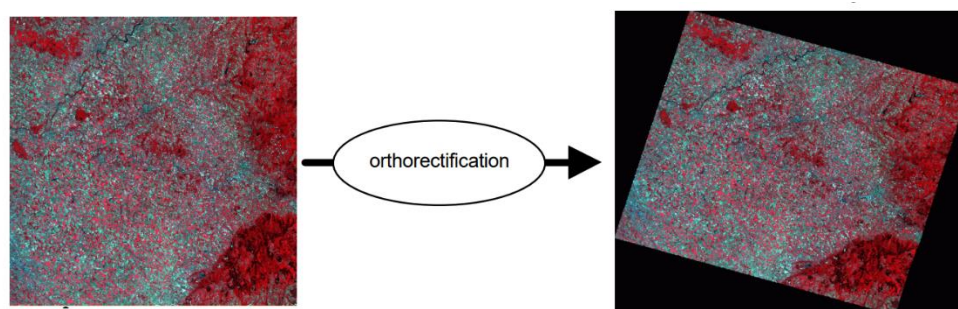


Figure 4: Orthorectification processing.

- **Quicklook generation**

Each band of a multi-spectral or hyper-spectral image can be displayed as a combination of three channels (i.e. the red, green and blue channel) as a colour composite image. Depending on the combination of these three channels, a true colour composite, i.e. using the RGB bands of the instrument, or false colour composite image, i.e. any combination other than using visible red, green and blue as the red, green and blue channel of the colour composite, can be made. Quicklooks provide users with a visual summary of the full-resolution dataset for rapid inspection and assessment.

3 ADVANCED IMAGE PROCESSING

3.1 LEVEL 0 Product

See section 2.1

3.2 Level 1 Advanced Products

3.2.1 Definition

Level 1 advanced products are **radiometrically and geometrically calibrated data** that have been processed from the raw L0 data. The advanced Level 1 processing includes tagging the sensor data with geographical locations and applying in-flight radiometric **calibrations** to convert sensor output into calibrated radiance values. **Vicarious in-flight calibration** is performed to calibrate the instrument after launch providing a new set of calibration coefficients. These calibration coefficients are used to enhance the radiometric and geometric absolute performances offering a high accurate product suitable for downstream application (e.g land cover, change detection, urban planning, etc...). The Advanced Image Processing product including absolute, interbands geometric correction and in-flight radiometric

calibration, delivers high quality standard products (Level 1B, Level 1C) validated using similar assessment methodology as developed in ESA Earthnet Data Assessment Project (EDAP+).

- **Level 1B advanced data:** Calibrated, geo-referenced data, typically at full resolution in sensor geometry.
- **Level 1C advanced data:** Orthorectified Calibrated and absolutely geo-located data, ready for scientific and operational use.

3.2.2 Data Content

See section 2.2.2

3.2.3 Level 1B Algorithms Description

In addition to steps described in the section 2.2.3, in-flight vicarious calibration is applied offline. It aims at estimating a refined set of radiometric and geometric calibration coefficients to be used by the Image Processing Tool (IPT) to enhance the absolute radiometric and geometric performances.

- **Advanced radiometric processing – Vicarious calibration**

In the advanced radiometric processing, vicarious calibration methods are employed to refine the calibration coefficients in-flight, enhancing the radiometric accuracy of the data.

This includes updates to dark current values and verification of the absolute radiometric calibration:

- **Dark Current Update:** The magnitude of the dark current is expected to increase with time due to space radiation. Images taken during the night-time portion of the orbit of dark ocean sites are used to periodically recalibrate the dark current values to maintain accuracy over time.
- **Absolute Radiometric Calibration:** verification and update of the absolute radiometric calibration through various methods:
 - **Desert:** The absolute radiometric accuracy is assessed using acquisition over the Libya-4 and, Niger-2 desert sites
 - **RadCalNet:** Data from the Radiometric Calibration Network (RadCalNet) serve as an additional source for assessing radiometric accuracy.
 - **Comparison with Sentinel-2:** Radiometric calibration is further verified by comparing against data from well-calibrated Sentinel-2A and 2B sensors

- **Advanced geometric processing**

Geometric calibration is required to ensure accurate absolute geolocation accuracy. The interior (focal plane distortions) and exterior orientations (boresight angles and satellite attitudes) are calibrated using bundle adjustment and set of accurate Ground Control Points (GCPs). A set of correction parameters will be derived and used in the direct georeferencing to generate accurate RPCs coefficients per sensors to be provided as part of Level 1B.

Note:

For platforms with stable multitemporal attitude data (variations below 2 pixels) one shot of geometric calibration may be sufficient to get optimal geolocation. For platforms with a **less stable** geo-pointing performance, a systematic correction should be considered **for every scene**.

3.2.4 Level 1C Algorithm Description

See section 2.2.4.

3.2.5 Use Cases

- **Data users and researchers:** Most scientific and commercial users interested in Earth observation will rely on Level 1C products as they contain calibrated, usable data.
- **Operational monitoring:** Useful for environmental monitoring, urban planning, and land use classification.
- **Preparation for higher-level processing:** Level 1 data serve as input for the generation of Level 2 and higher-level products. Level 2 data are atmospherically corrected Top of Canopy (TOC) products. On request, a tool to apply atmospheric correction can be provided (see reference link to ICOR tool <https://remotesensing.vito.be/services/icor>).

4 DATA FORMATS

Satellite products are delivered in the following formats:

- **Level 0:** Raw binary format specific to the satellite's onboard instruments.
- **Level 1:** delivered in standard Cloud Optimized GeoTIFF (COG) format for ease of use across different GIS and scientific platforms. Refer to sections 4.1 and 4.2 for further details on the data format of Level 1B and Level 1C products.

4.1 Level 1B Product Data Format

As detailed in section 3.2.3, a Level 1B product contains the radiometrically and geometrically processed, geo-referenced TOA (Top of Atmosphere) data, usually at full resolution in sensor geometry.

4.1.1 Product Content and Structure

A Level 1B product is composed of a magnitude of files (i.e. image data and meta-data) that are stored in a parent directory with a name that uniquely identifies the Level 1B product. Following naming convention is used for the base directory:

```
<PREFIX>_LEVEL1B_<START_ACQUISITION_TIME>
```

Where:

- **<PREFIX>**: free-form prefix that is added to name of the Level 1B product. Typically, it contains information like the name of the satellite mission, the identifier for the instrument, the name of the customer, etc...
- **<START_ACQUISITION_TIME>**: the start acquisition date and time of the scene in the format "YYYYMMDDThhmmssZ".

A Level 1B product is composed of following files and directories:

Name	Type	Description
<PRODUCTID>_CONTOUR.kml	File	KML (Keyhole Markup Language) vector file containing the footprint (i.e. contour) of the product. The figure below gives an example file opened in Google Earth:

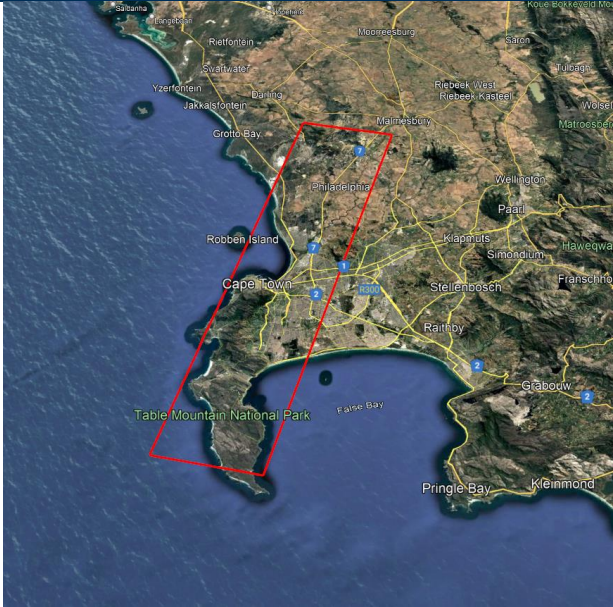
		
<PRODUCTID>_META.ini	File	<p>Meta-data file in the INI – format. The file is a plain text meta-data file with a structure and syntax comprising key-value pairs organized in sections.</p> <p>Refer to section 5 for further details on the content of the meta-data file.</p>
Band<BAND>	Directory	<p>Subdirectory containing the band-specific data files for spectral band <BAND>, where <BAND> is the one-based spectral band identifier. For example:</p> <ul style="list-style-type: none"> • Band1: subdirectory containing data files for the first spectral band • Band2: subdirectory containing data files for the second spectral band • Band3: subdirectory containing data files for the third spectral band • Etc.

Table 1: Content and structure of a Level 1B product directory.

As detailed in the table above, the spectral band-specific data files are grouped into the “Band<BAND>” subdirectory, where <BAND> is the one-based identifier for the spectral band. Each file has a unique suffix that identifies the type of data contained:

Suffix name	Data type	Units	No data	Description
LTOA#<BAND>	Float64	W/m ² .µm.sr	-9999	TOA radiance data of spectral band <BAND>. Refer to section 4.1.2.1 for further details on the file format specifications.
RTOA#<BAND>	Float64	-	-9999	TOA reflectance data of spectral band <BAND>. Refer to section 4.1.2.1 for further details on the file format specifications.

Q#<BAND>	Uint8	-	1	Radiometric quality grid. Refer to Table 10 for further details on the possible values. Refer to section 4.1.2.1 for further details on the file format specifications.
QLK#<BAND>	Uint8	-	0	Colour stretched grayscale quicklook file of the radiometric dataset (i.e. TOA radiance or TOA reflectance) of spectral band <BAND>. Refer to section 4.1.2.1 for further details on the file format specifications.
VAA#<BAND>	Float32	Degrees	-9999	Satellite viewing azimuth angles of spectral band <BAND>. Refer to section 4.1.2.1 for further details on the file format specifications.
VZA#<BAND>	Float32	Degrees	-9999	Satellite viewing zenith angles of spectral band <BAND>. Refer to section 4.1.2.1 for further details on the file format specifications.
SAA#<BAND>	Float32	Degrees	-9999	Solar azimuth angles of spectral band <BAND>. Refer to section 4.1.2.1 for further details on the file format specifications.
SZA#<BAND>	Float32	Degrees	-9999	Solar zenith angles data of spectral band <BAND>. Refer to section 4.1.2.1 for further details on the file format specifications.
LN#<BAND>	Float64	Degrees	-9999	Ortho-rectified longitude data of spectral band <BAND>. Refer to section 4.1.2.1 for further details on the file format specifications.
LN1#<BAND>	Float64	Degrees	-9999	Longitude data at height 0m for spectral band <BAND>
LN2#<BAND>	Float64	Degrees	-9999	Longitude data at height 5000m for spectral band <BAND>. Refer to section 4.1.2.1 for further details on the file format specifications.
LT#<BAND>	Float64	Degrees	-9999	Ortho-rectified latitude data of spectral band <BAND>
LT1#<BAND>	Float64	Degrees	-9999	Latitude data at height 0m for spectral band <BAND>. Refer to section 4.1.2.1 for further details on the file format specifications.
LT2#<BAND>	Float64	Degrees	-9999	Latitude data at height 5000m for spectral band <BAND>. Refer to section 4.1.2.1 for further details on the file format specifications.
HEIGHT#<BAND>	Float32	Meters	-9999	Altitude data for spectral band <BAND>. Refer to section 4.1.2.1 for further details on the file format specifications.
RPC#<BAND>	-	-	-	Rational Polynomial Coefficients (RPC) file for spectral band <BAND>. Refer to section

				4.1.2.2 for further details on the file format specifications.
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Table 2: Image files of a Level 1B product.

4.1.2 File Format Specifications

4.1.2.1 Image Files

The spectral band-specific image files listed in Table 2 are each single-band files saved in the Cloud Optimized GeoTIFF (COG) file format (<http://cogeo.org/>). A COG file is a regular (Geo)TIFF file, but with an internal organization that enables efficient data access; the pixel data are stored at full resolution and additionally, multiple downsampled (i.e. with coarser resolution) overviews are added to the file, that are mainly used for fast display in zooming out operations in a GIS application.

Each image file is compressed using the lossless DEFLATE compression algorithm, with a block size of 512x512 pixels.

Following meta-data tags are set in each COG image file:

Meta-data tag	Description
NoData	The “no data” value of the dataset, as detailed in Table 2.
Description	A short textual description of the dataset.
Unit Type	The units of the dataset (e.g. “degrees”, “meters”, etc.). If set to “-“, the dataset is unitless.

Table 3: Meta-data tags of Level1B product.

4.1.2.2 Rational Polynomial Coefficients (RPC) File

The RPC file is an ASCII file containing the Rational Polynomial Coefficients applicable for a given spectral band. RPC coefficients are required for the rational function expansion to convert ground coordinates into sensor coordinates (and vice versa).

The content of the RPC file is described below:

Name	Description	Value Range	Units
ERR_BIAS	The RMS bias error in meters per horizontal axis of all points in the image (-1.0 if unknown)	>= 0	meters
ERR_RAND	RMS random error in meters per horizontal axis of each point in the image (-1.0 if unknown)	>= 0	meters
LINE_OFF	Line Offset	>= 0	pixels
SAMP_OFF	Sample Offset	>= 0	pixels
LAT_OFF	Geodetic Latitude Offset	-90 to +90	degrees
LONG_OFF	Geodetic Longitude Offset	-180 to +180	degrees
HEIGHT_OFF	Geodetic Height Offset	unlimited	meters
LINE_SCALE	Line Scale	> 0	pixels

SAMP_SCALE	Sample Scale	> 0	pixels
LAT_SCALE	Geodetic Latitude Scale	0 < LAT_SCALE <= 90	degrees
LONG_SCALE	Geodetic Longitude Scale	0 < LONG_SCALE <= 180	degrees
HEIGHT_SCALE	Geodetic Height Scale	HEIGHT_SCALE > 0	meters
LINE_NUM_COEFF (1-20)	Line Numerator Coefficients. Twenty coefficients for the polynomial in the Numerator of the r_n equation (*).	unlimited	-
LINE_DEN_COEFF (1-20)	Line Denominator Coefficients. Twenty coefficients for the polynomial in the Denominator of the r_n equation (*).	unlimited	-
SAMP_NUM_COEFF (1-20)	Sample Numerator Coefficients. Twenty coefficients for the polynomial in the Numerator of the c_n equation (*).	unlimited	-
SAMP_DEN_COEFF (1-20)	Sample Denominator Coefficients. Twenty coefficients for the polynomial in the Denominator of the c_n equation (*).	unlimited	-

Table 4: RPC file content.

(*) The rational function polynomial equation numerators and denominators each are 20-term cubic polynomial functions of the form:

$$\sum_{i=1}^{20} C_i \cdot \rho_i(P, L, H) =$$

$$\begin{array}{llll} C_1 & + C_6 \cdot L \cdot H & + C_{11} \cdot P \cdot L \cdot H & + C_{16} \cdot P^3 \\ + C_2 \cdot L & + C_7 \cdot P \cdot H & + C_{12} \cdot L^3 & + C_{17} \cdot P \cdot H^2 \\ + C_3 \cdot P & + C_8 \cdot L^2 & + C_{13} \cdot L \cdot P^2 & + C_{18} \cdot L^2 \cdot H \\ + C_4 \cdot H & + C_9 \cdot P^2 & + C_{14} \cdot L \cdot H^2 & + C_{19} \cdot P^2 \cdot H \\ + C_5 \cdot L \cdot P & + C_{10} \cdot H^2 & + C_{15} \cdot L^2 \cdot P & + C_{20} \cdot H^3 \end{array}$$

Where:

P = (Latitude - LAT_OFF) / LAT_SCALE
L = (Longitude - LONG_OFF) / LONG_SCALE
H = (Height - HEIGHT_OFF) / HEIGHT_SCALE
 r_n = (Row - LINE_OFF) / LINE_SCALE
 c_n = (Column - SAMP_OFF) / SAMP_SCALE

4.2 Level 1C Product Data Format

As detailed in section 2.2.4, a Level 1C product contains the ortho-rectified radiometrically and geometrically calibrated, geo-located TOA (Top Of Atmosphere) data. The data is projected to a uniform and fixed grid in the Geographic Lat/Lon or UTM/WGS84 coordinate reference system.

4.2.1 Product Content and Structure


A Level 1C product is composed of a magnitude of files (i.e. image data and meta-data) that are stored in a parent directory with a name that uniquely identifies the Level 1C product. Following naming convention is used for the base directory:

```
<PREFIX>_LEVEL1C_<START_ACQUISITION_TIME>
```

Where:

- <PREFIX> : free-form prefix that is added to name of the Level 1C product. Typically, it contains information like the name of the satellite mission, the identifier for the instrument, the name of the customer, etc...
- <START_ACQUISITION_TIME>: the start acquisition date and time of the scene in the format “YYYYMMDDThhmmssZ”.

A Level 1C product is composed of following files and directories:

Name	Type	Description
<PRODUCTID>_CONTOUR.kml	File	KML (Keyhole Markup Language) vector file containing the footprint (i.e. contour) of the product and the embedded RGB quicklook. The figure below gives an example file opened in Google Earth: <div style="text-align: center;">  </div>
<PRODUCTID>_META.ini	File	Meta-data file in the INI – format. The file is a plain text meta-data file with a structure and syntax comprising key-value pairs organized in sections. Refer to section 5 for further details on the content of the meta-data file.
<PRODUCTID>_RGB.tiff	File	False-colour RGB quicklook file of the product. Refer to section 4.2.2.2 for further details on the format of the file.

<PRODUCTID>_RGB_PREVIEW.jpeg	File	False-colour RGB thumbnail file of the product. Refer to section 4.2.2.3 for further details on the format of the file.
Band<BAND>	Directory	Subdirectory containing the image data files for the spectral band <BAND>, where <BAND> is the one-based spectral band identifier. For example: <ul style="list-style-type: none"> • Band1: subdirectory containing image files for the first spectral band • Band2: subdirectory containing image files for the second spectral band • Band3: subdirectory containing image files for the third spectral band • Etc.

Table 5: Content and structure of a Level 1C product directory.

As detailed in Table 1, the spectral band-specific image files are grouped into the “Band<BAND>” subdirectory, where <BAND> is the one-based identifier for the spectral band. Each image file has a unique suffix that identifies the type of data contained:

Suffix name	Data type	Units	No data	Description
LTOA#<BAND>	Float64	W/m ² .µm.sr	-9999	TOA radiance data of spectral band <BAND>
RTOA#<BAND>	Float64	-	-9999	TOA reflectance data of spectral band <BAND>
Q#<BAND>	Uint8	-	1	Radiometric quality grid. Radiometric quality grid. Refer to Table 10 for further details on the possible values.
VAA#<BAND>	Float32	Degrees	-9999	Satellite viewing azimuth angles of spectral band <BAND>
VZA#<BAND>	Float32	Degrees	-9999	Satellite viewing zenith angles of spectral band <BAND>
SAA#<BAND>	Float32	Degrees	-9999	Solar azimuth angles of spectral band <BAND>
SZA#<BAND>	Float32	Degrees	-9999	Solar zenith angles data of spectral band <BAND>
HEIGHT#<BAND>	Float32	Meters	-9999	Altitude data for spectral band <BAND>

Table 6: Image files of a Level 1C product.

4.2.2 File Format Specifications

4.2.2.1 Image Files

Each band-specific image file listed in Table 6 is a single-band file saved in the Cloud Optimized GeoTIFF (COG) file format (<http://cogeo.org/>). It contains the pixel data stored at full resolution and additionally, multiple down sampled (i.e. with coarser resolution) overviews are added to the file, that are mainly used for fast display in zooming out operations in a GIS application.

The image files are saved in one of following CRS (Coordinate Reference System):

- Geographic Lat/Lon as defined in [EPSG:4326](#)
- UTM/WGS84 (Universal Transverse Mercator) as defined in EPSG:326xx (UTM northern hemisphere) and EPSG:327xx (UTM southern hemisphere), where xx indicates the UTM zone number ranging from 00 to 36.

Cubic convolution (bi-cubic) is used by default to do the resampling. Each image file is compressed using the lossless DEFLATE compression algorithm, with a block size of 512x512 pixels.

Following meta-data tags are set in each COG image file:

Meta-data tag	Description
NoData	The “no data” value of the dataset, as detailed in Table 6.
Description	A short textual description of the dataset.
Unit Type	The units of the dataset (e.g. “degrees”, “meters”, etc.). If set to “-“, the dataset is unitless.

Table 7: Meta-data tags of Level1C product.

4.2.2.2 RGB Quicklook File

The RGB quicklook file is a false-color image in the COG file format that is composed of four spectral bands each decoded as 8-bit unsigned integer values, where:

- The first three bands represent the red, green and blue colour channels. A colour enhancement algorithm has been applied on these bands to make the colours more vivid for visual use.
- The fourth layer represents the transparency (i.e. alpha) layer. All pixels for which the red, green or blue channel is equal to “no data” are made transparent. All other pixels are opaque.

The RGB quicklook file is in the same CRS as the image files. The RGB quicklook file is compressed using the lossy JPEG compression algorithm, with a block size of 512x512 pixels.

An example is given in the figure below:



Figure 5: Example RGB quicklook file.

4.2.2.3 RGB-Thumbnail File

The RGB thumbnail file is a false-color image in the JPEG file format. It is a file at sub-sampled (i.e. with coarser resolution) that is typically intended for fast visualization and visual inspection of the product.

The RGB thumbnail file is compressed using the lossy JPEG compression algorithm, with a block size of 512x512 pixels. No CRS is assigned to the RGB thumbnail file.

4.3 Summary

The table below lists the key features and differences between a Level 1B and Level 1C product:

	Level 1B product	Level 1C product
Product components & format	<ul style="list-style-type: none"> • Image files (COG format) • Meta-data file (INI format) • Contour file (KML format) • RPC file (text file) 	<ul style="list-style-type: none"> • Image files (COG format) • Meta-data file (INI format) • Contour file (KML format) • Quicklook file (COG format) • Thumbnail file (JPEG format)

Product framing	Scene based	Scene based
Spectral bands	Instrument dependent	Instrument dependent
Radiometric corrections	<ul style="list-style-type: none"> • Conversion to absolute radiometric values (TOA radiance or TOA reflectance) based on calibration coefficients • Generated with on-ground (or in-flight updated) calibration coefficients • High-frequency equalization correction (optional) 	<ul style="list-style-type: none"> • Conversion to absolute radiometric values (TOA radiance or TOA reflectance) based on calibration coefficients • Generated with on-ground or in-flight updated calibration coefficients • High-frequency equalization correction (optional)
Geometric corrections	<ul style="list-style-type: none"> • Relative inter-band correction (bands are co-registered) • Generated with on-ground (Express) or in-flight updated calibration coefficients (Advanced) • Rational Polynomial Coefficients (RPC) 	<ul style="list-style-type: none"> • Relative inter-band correction (bands are co-registered) • Generated with on-ground (Express) or in-flight updated calibration coefficients (Advanced)
Map projection (CRS)	N/A (sensor geometry)	<ul style="list-style-type: none"> • Geographic Lat/Lon • UTM/WGS84
Ground Sampling Distance	The native GSD of the image acquisition.	Projected and resampled to a fixed grid at a spatial resolution of the image acquisition.

Table 8: Key specifications of Level 1B and Level 1C products.

5 METADATA AND QUALITY INFORMATION

Metadata for each product level includes following information:

- **Acquisition date and time**
- **Satellite and sensor details**
- **Processing level (L0, L1B or L1C)**
- **Geographical coverage:** bounding box, footprint and center coordinate
- **Quality flags:** Indicating issues like radiometric quality of each pixel.
- **Processing history:** Including algorithms used, calibration data applied, and any corrections.

5.1 Product Meta-data

The meta-data of a product is delivered in the INI file format. The meta-data file is a plain text file with a structure and syntax comprising key-value pairs organized in sections. The content of the file is detailed below.

Section "General"		
Meta-data	Type	Description
LEVEL0_PRODUCT_REFERENCE	String	Unique textual reference of the input Level0 product.
LEVEL1_PRODUCT_REFERENCE	String	Unique textual reference of the output Level1B/C product.
PROCESSING_LEVEL	String	Processing level (LEVEL1B or LEVEL1C).
START_ACQUISITION_TIME	String	Start acquisition date and time in the format "YYYYMMDDThhmmssZ".
STOP_ACQUISITION_TIME	String	Stop acquisition date and time in the format "YYYYMMDDThhmmssZ".
IPT_VERSION	String	Version identifier for the IPT that generated the product.
PROCESSING_TIME	String	Date and time at which the Level1B/C product was generated in the format "YYYYMMDDThhmmssZ".
Section "Geolocation"		
Meta-data	Type	Description
FOOTPRINT_WKT	String	Contour points of the Level1B/C product as a WKT (Well Known Text) string. The contour points are provided as (lon, lat) coordinates.
FOOTPRINT_GEOJSON	String	Contour points of the Level1B/C product as a GeoJSON string. The contour points are provided as (lon, lat) coordinates.
BBOX_MINX	Float	Minimum X-coordinate of the image bounding box expressed in the same map projection units of the Level1 product. In case the product is still in sensor geometry (i.e. Level1B product), it represents the first pixel index (i.e. 0).
BBOX_MINY	Float	Minimum Y-coordinate of the image bounding box expressed in the same map projection units of the Level1 product. In case the product is still in sensor geometry (i.e. Level1B product), it represents the first line index (i.e. 0).
BBOX_MAXX	Float	Maximum X-coordinate of the image bounding box expressed in the same map projection units of the Level1

		product. In case the product is still in sensor geometry (i.e. Level1B product), it represents the last pixel index.
BBOX_MAXY	Float	Maximum Y-coordinate of the image bounding box expressed in the same map projection units of the Level1 product. In case the product is still in sensor geometry (i.e. Level1B product), it represents the last line index.
BBOX_MINLON	Float	Minimum longitude coordinate of the image bounding box.
BBOX_MINLAT	Float	Minimum latitude coordinate of the image bounding box.
BBOX_MAXLON	Float	Maximum longitude coordinate of the image bounding box.
BBOX_MAXLAT	Float	Maximum latitude coordinate of the image bounding box.
CENTER_X	Float	Center X-coordinate of the product expressed in the same map projection units of the Level1 product. In case the product is still in sensor geometry (i.e. Level1B product), it represents the center pixel index.
CENTER_Y	Float	Center Y-coordinate of the product expressed in the same map projection units of the Level1 product. In case the product is still in sensor geometry (i.e. Level1B product), it represents the center line index.
CENTER_LON	Float	Center longitude coordinate of the product.
CENTER_LAT	Float	Center latitude coordinate of the product.
SAA	String	Minimum and maximum solar azimuth angle of the scene. The value is a string in the following syntax: Min : xxx degrees / Max : yyy degrees Example: Min : 157.63 degrees / Max : 158.26 degrees
SZA	String	Minimum and maximum solar zenith angle of the scene. The value is a string in the following syntax: Min : xxx degrees / Max : yyy degrees Example: Min : 37.16 degrees / Max : 37.49 degrees
VAA	String	Minimum and maximum viewing azimuth angle of the scene. The value is a string in the following syntax: Min : xxx degrees / Max : yyy degrees Example: Min : 113.32 degrees / Max : 255.49 degrees
VZA	String	Minimum and maximum viewing zenith angle of the scene. The value is a string in the following syntax: Min : xxx degrees / Max : yyy degrees Example:

		Min : 2.26 degrees / Max : 3.49 degrees
Section "CRS"		
Meta-data	Type	Description
CRS_PROJ4	String	CRS provided as a PROJ4 – string. Example: <code>+proj=utm +zone=10 +south +datum=WGS84 +units=m +no_defs +type=crs</code>
CRS_WKT	String	CRS provided as a WKT string. Example: <pre>PROJCS["WGS 84 / UTM zone 10S", GEOGCS["WGS 84", DATUM["WGS_1984", SPHEROID["WGS 84", 6378137, 298.257223563, AUTHORITY["EPSG", "7030"]], AUTHORITY["EPSG", "6326"]], PRIMEM["Greenwich", 0, AUTHORITY["EPSG", "8901"]], UNIT["degree", 0.0174532925199433, AUTHORITY["EPSG", "9122"]], AUTHORITY["EPSG", "4326"]], PROJECTION["Transverse_Mercator"], PARAMETER["latitude_of_origin", 0], PARAMETER["central_meridian", -123], PARAMETER["scale_factor", 0.9996], PARAMETER["false_easting", 500000], PARAMETER["false_northing", 10000000], UNIT["metre", 1, AUTHORITY["EPSG", "9001"]], AXIS["Easting", EAST], AXIS["Northing", NORTH], AUTHORITY["EPSG", "32710"]]</pre>
CRS_EPSG	Integer	CRS EPSG code, as defined in https://spatialreference.org/
GSD	String	Ground Sampling Distance (i.e. spatial resolution) of the product. The value is a string in the following format: <code><gsd> meters</code> Where: <ul style="list-style-type: none">• <gsd>: grounds ampling distance (units: meters) Example: <code>5.00 meters</code>
Section "Instrument_Configuration"		
Meta-data	Type	Description
TDI	String	TDI (Time Delay Integration) applied for each spectral band. The value is a comma-separated string in the format: <code>Band<band_id> : <tdi></code> Where:

		<ul style="list-style-type: none"> • <band_id>: one-based band identifier for the spectral band • <tdi>: TDI stage applied for the spectral band <band_id>. <p>Example:</p> <p>Band1 : 4 , Band4 : 2 , Band8 : 3 , Band16 : 4</p>
BINNING	Integer	Binning factor (1 indicates no binning has been applied).
MODE	Integer	Imager acquisition mode: <ul style="list-style-type: none"> • 0: snapshot mode • 1: line scan mode • 5: high accuracy hyperspectral mode
Section "Calibration"		
Meta-data	Type	Description
ICP_GEOMETRIC	String	Reference to the used geometric ICP (Instrument Calibration Parameters) file.
ICP_RADIOMETRIC	String	Reference to the used radiometric ICP (Instrument Calibration Parameters) file.
BORESIGHT_ANGLE	Float	Boresight X, Y and Z angle value.
PL2BOF_ANGLE	Float	X, Y and Z angle value for the conversion from payload to body-fixed frame.
LEAP_SECONDS	Integer	Leap seconds value (units: seconds).
POLARMOTION_BULLETINB	String	Reference to the used polar motion Bulletin-B file.
POLARMOTION_DELTA_UT1	Float	Delta UT1 of the polar motion data (units: seconds).
POLARMOTION_X	Float	Polar motion X-coordinate (units: arc-seconds)
POLARMOTION_Y	Float	Polar motion Y-coordinate (units: arc-seconds)
Section "Processing Steps"		
Meta-data	Type	Description
GEOMETRIC_CORRECTION_INTERBAND	String	Flag indicating whether geometric inter-band correction has been applied ("Yes") or not ("No")
GEOMETRIC_CORRECTION_ABSOLUTE	String	Flag indicating whether absolute geometric correction has been applied ("Yes") or not ("No")
RADIOMETRIC_PROCESSING	String	<p>The absolute radiometric values type (TOA radiance or TOA reflectance) and corresponding units. The value is a string in the format:</p> <p><RADIOMETRIC_TYPE> (units: <RADIOMETRIC_UNITS>)</p> <p>Where:</p> <ul style="list-style-type: none"> • <RADIOMETRIC_TYPE>: TOA_RADIANCE or TOA_REFLECTANCE • <RADIOMETRIC_UNITS>: "W / m² . μm . sr" for TOA radiance and "-" for TOA reflectance <p>Example:</p> <p>TOA_RADIANCE (units = W / m² . μm . sr)</p>

RADIOMETRIC_CORRECTION_HF_EQUALIZATION_ACT	String	Flag indicating whether high-frequency equalization in across-track (ACT) direction has been applied (“Yes”) or not (“No”).
RADIOMETRIC_CORRECTION_HF_EQUALIZATION_ALT	String	Flag indicating whether high-frequency equalization in along-track (ALT) direction has been applied (“Yes”) or not (“No”).
Section “Radiometric_Quality”		
Meta-data	Type	Description
CORRECT	String	<p>The percentage of pixels (for each spectral band) that have a good radiometric quality status. The value is a comma-separated string in the format:</p> <p><code>Band<band_id> : <value>%</code></p> <p>Where:</p> <ul style="list-style-type: none"> • <band_id>: one-based band identifier for the spectral band • <value>: percentage of pixels that are correct <p>Example:</p> <p><code>Band1 : 100.00% , Band4 : 99.99% , Band8 : 94.84%</code></p>
INTERPOLATED		<p>The percentage of pixels (for each spectral band) that during the conversion from DN to TOA radiance were interpolated using the nearest neighbour. The value is a comma-separated string in the format:</p> <p><code>Band<band_id> : <value>%</code></p> <p>Where:</p> <ul style="list-style-type: none"> • <band_id>: one-based band identifier for the spectral band • <value>: percentage of pixels that are interpolated <p>Example:</p> <p><code>Band1 : 0.00% , Band4 : 0.001% , Band8 : 0.00%</code></p>
MISSING		<p>The percentage of pixels (for each spectral band) that are missing (i.e. set to “no data”). The value is a comma-separated string in the format:</p> <p><code>Band<band_id> : <value>%</code></p> <p>Where:</p> <ul style="list-style-type: none"> • <band_id>: one-based band identifier for the spectral band • <value>: percentage of pixels that are missing <p>Example:</p>

<p>NEGATIVE</p>	<p>Band1 : 0.00% , Band4 : 0.00% , Band8 : 0.07%</p> <p>The percentage of pixels (for each spectral band) that during the conversion from DN to TOA radiance became negative. The value is a comma-separated string in the format:</p> <p>Band<band_id> : <value>%</p> <p>Where:</p> <ul style="list-style-type: none"> • <band_id>: one-based band identifier for the spectral band • <value>: percentage of pixels that are negative <p>Example:</p> <p>Band1 : 0.00% , Band4 : 0.001% , Band8 : 0.00%</p>
<p>SATURATED</p>	<p>Band1 : 0.00% , Band4 : 0.001% , Band8 : 0.00%</p> <p>The percentage of pixels (for each spectral band) of which the input DN was saturated or that during the conversion from DN to TOA radiance became larger than a threshold value. The value is a comma-separated string in the format:</p> <p>Band<band_id> : <value>%</p> <p>Where:</p> <ul style="list-style-type: none"> • <band_id>: one-based band identifier for the spectral band • <value>: percentage of pixels that are saturated <p>Example:</p> <p>Band1 : 0.00% , Band4 : 0.001% , Band8 : 0.00%</p>

Table 9: Description of meta-data fields.

5.2 Quality Information

Quality information is essential for ensuring that users understand the limitations and potential issues in the dataset before performing analysis. As described in sections 4.1 and 4.2, each spectral band of a Level 1B (resp. Level 1C) product has a radiometric quality dataset (i.e. Q – grid) identifying the per-pixel radiometric quality status.

Each pixel value can be one of following values:

Value	Description
0	The pixel is considered good.
1	The pixel is missing.
2	The value DN of the pixel was saturated.
3	During the radiometric conversion from DN to TOA, the value became saturated (i.e. higher than a specific threshold).

4	During the radiometric conversion from DN to TOA, the value became negative.
5	The value of the TOA radiance of the pixel is interpolated using the neighbour pixels.

Table 10: Radiometric quality status values.

Additionally, following radiometric quality statistics will be added to the product meta-data (for each spectral band). Refer to the “Radiometric_Quality” section inside the meta-data file (Table 9) for further details.

- Percentage of radiometric pixels that have a good quality status.
- Percentage of radiometric pixels that are missing.
- Percentage of radiometric pixels of which the input DN was saturated or that became saturated during the conversion from DN to TOA radiance.
- Percentage of radiometric pixels that were interpolated using the nearest neighbour during the conversion from DN to TOA radiance.
- Percentage of radiometric pixels that became negative during the conversion from DN to TOA radiance.

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