PROBA-V

PRODUCTS USER MANUAL

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1.1	07/10/2014	Added text on reprocessing, information on new PDF release	Bart Deronde
1.2	11/03/2015	Additions to PDF release, cloud detection, data support	Bart Deronde

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LIST OF ACRONYMS

Acronym	**Explanation**
AU	Astronomical Unit
CESBIO	Centre d'Études Spatiales de la Biosphère
DN	Digital Number Count
ECMWF	European Centre For Mid-Range Weather Forecasts
ENVI	Environment for Visualizing Images
EOS	Earth Observing System
ESA	European Space Agency
FTP	File Transfer Protocol
FWHM	Full Width at Half Maximum
GeoTIFF	Geographic Tagged Image File Format
GLCF	Global Land Cover Facility
GLSDEM	Global Land Survey Digital Elevation Model
HDF	Hierarchical Data Format
HTTP	HyperText Transfer Protocol
ICP	Instrument Calibration Parameters
IGFOV	Instantaneous Geometric Field Of View
L1C	Radiometrically and geometrically calibrated Level 1 data
Lref	Top-of-Atmosphere Reference Irradiance
LSB	Least Significant Bit
LTDN	Local Time of Descending Node
MSB	Most Significant Bit
MVC	Maximum Value Composite
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NIR	Near-Infrared
NWP	Numerical Weather Prediction
PDF	Product Distribution Facility
PPT	PROBA-V Product Customization Tool
PROBA-V	Project for On-Board Autonomy - Vegetation
RoI	Region of Interest
S1	1-day Synthesis Products
S10	10-day Synthesis Products
SMAC	Simplified Model for Atmospheric Correction
SNR	Signal-To-Noise Ratio
SPIRITS	Software for the Processing and Interpretation of Remotely sensed Image Time Series
SPOT-VGT	Satellite Pour l'Observation de la Terre – Végétation
SRF	Spectral Response Function
SWIR	Short-Wave Infrared
SZA	Solar Zenith Angle
TOA	Top of Atmosphere

TOC	Top of Canopy
TOMS	Total Ozone Monitoring Spectrometer
USGS	United States Geological Survey
VNIR	Visible and Near-InfraRed
VZA	Viewing Zenith Angle
WGS84	World Geodetic System 1984

OBJECTIVES AND REFERENCE DOCUMENTATION

This document describes the PROBA-V product chain, the derived products, and the product portal at which the products are disseminated. The objectives of this document are the following:

- To present an overview of the PROBA-V satellite constellation and the measurement principles
- To provide an overview of the processing chain of the various PROBA-V products
- To give a detailed overview of the various datasets and product file attributes
- To guide the user through the registration and ordering process
- To guide the user in the data viewing and handling

We have attempted to keep the document concise and comprehensible. Interested users on the various PROBA-V topics highlighted in this document are referred to the following scientific papers, see the Reference List for their full citations.

Document name	Major topics covered	Download location
Dierckx, W. et al. (2014). PROBA-V mission for global vegetation monitoring: standard products and image quality. *Int. J. Remote Sens*, **35**, 2589 – 2614.	PROBA-V mission, data quality, data compression, cloud detection, spectral response in relation to SPOT-VGT	http://proba-v.vgt.vito.be/sites/default/files/dierckx_etal_2014.pdf
Sterckx, S., et al. (2014). The PROBA-V mission: image processing and calibration. *Int. J. Remote Sens.*, *35*(7), 2565 – 2588.	PROBA-V mission, detailed processing chain overview, radiometric and geometric calibration, product distribution	http://proba-v.vgt.vito.be/sites/default/files/sterckx_etal_2014.pdf
Francois, M., et al. (2014). The PROBA-V mission: The space segment. *Int. J. Remote Sensing*, **35**, 2548 – 2564, doi:10.1080/01431161.2014.883098.	PROBA-V flight segment, instrument design, technology payloads, geometry and radiometry	http://proba-v.vgt.vito.be/sites/default/files/francois_etal_2014.pdf

1. Introduction

1.1. PROBA-V mission overview

The PROBA-V satellite was launched at 6 May 2013 and was designed to bridge the gap in space-borne vegetation measurements between SPOT-VGT (March 1998 – May 2014) and the upcoming Sentinel-3 satellites, scheduled for launch in 2015/2016. The mission objective is to ensure continuity with the heritage of the SPOT-VGT mission.

The VEGETATION instrument onboard PROBA-V has a volume of just over 0.05 m^3 and weighs only 33 kg. PROBA-V flies at an altitude of 820 km in a sun-synchronous orbit with a local overpass time at launch of 10:45 h. Because the satellite has no onboard propellant, the overpass times are expected to gradually differ from the at-launch value. Figure 1 presents the predicted evolution of the Local Time of Descending Node (LTDN) from launch until mid-2018. The instrument has a Field Of View of 102^o, resulting in a swath width of 2295 km. This swath width ensures a daily near-global coverage (90%), full global coverage is achieved every 2 days. The central camera observes at 100 m nominal resolution, which covers a swath of about 517 km that ensures global coverage every 5 days.

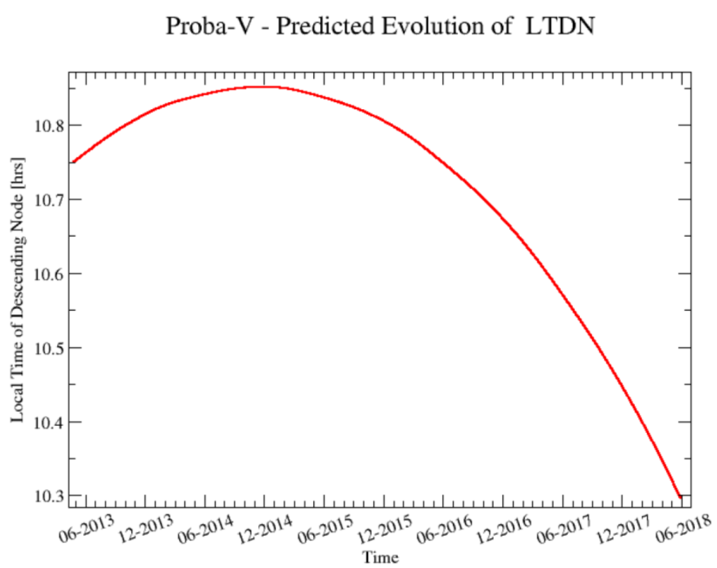

Figure 1: Predicted evolution of the PROBA-V Local Time of Descending Node (LTDN).

PROBA-V registers in four spectral bands: BLUE (centered at 0.463 µm), RED (0.655 µm), NIR (0.845 µm), and SWIR (1.600 µm). Observations are taken at resolutions between 100 and 180 m at nadir up to 350 and 660 m at the swath extremes for the VNIR and SWIR channels, respectively (Francois et al, 2014). Final PROBA-V products are disseminated at 100 m, 300 m and 1 km resolution. The instrument and spectral characteristics will be explained in more detail in Section 1.2. The flight altitude and other characteristics are summarized in Table 1.

Table 1: PROBA-V characteristics.

Altitude [km]	819 - 827
Local overpass time at launch [h]	10:45
Inclination [°]	98.7
Coverage [%]	90 (daily), 100 (every 2 days)
Payload Mass [kg]	33.3
Payload Dimensions [m^3]	0.2 × 0.8 × 0.35
Designed lifetime [yr]	2.5 – 5
Instantaneous geometric field of view (IGFOV) [m]	96.6 for VNIR (BLUE, RED, NIR), 193.8 for SWIR

1.2. Instrument characteristics

The optical design of PROBA-V consists of three cameras. Each camera has two focal planes, one for the short wave infrared (SWIR) and one for the visible and near-infrared (VNIR) bands. The VNIR detector consists of four lines of 5200 pixels. Three spectral bands were implemented, comparable with SPOT-VGT: BLUE, RED, and NIR. The SWIR detector contains the SWIR spectral band and is a linear array composed of three staggered detectors of 1024 pixels. Each used detector line is labelled as a strip. Each camera therefore has 6 strips The instrument plane layout is shown in Figure 2.

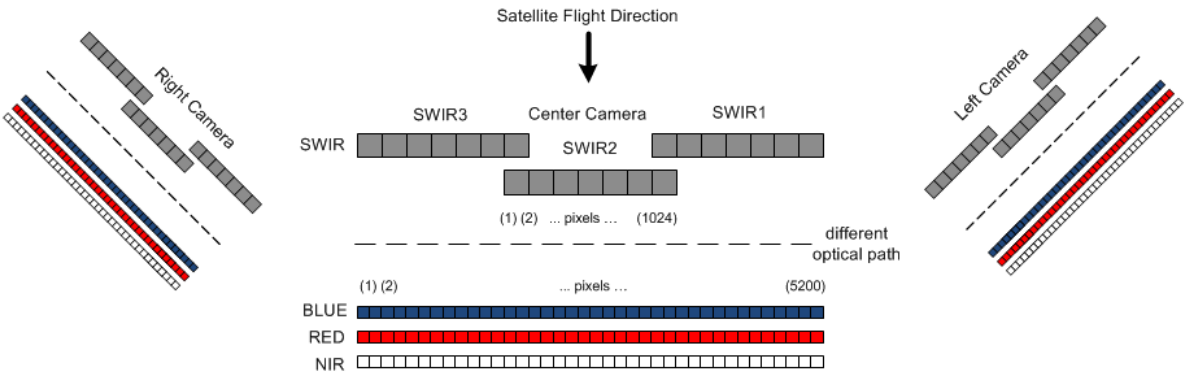

Figure 2: PROBA-V instrument layout.

The instrument has been designed such that the NIR band observes the Earth first, followed by the RED, BLUE, and SWIR bands. As a result, an observation time difference of 12 s exists between the NIR and SWIR bands. This difference is accounted for in ground surface observations, however, it impacts the cloud screening, which will be further discussed in Section 2.2.2.

Table 2 lists the radiometric characteristics of the PROBA-V spectral bands.

Table 2: PROBA-V spectral and radiometric characteristics. L_{ref} refers to the TOA irradiance at the respective spectral band.

Band name	**Centre wavelength (spectral range @FWHM) [µm]**	**Spectral range @FWHM [µm]**	**SNR @L_{ref} [W $m^{-2}sr^{-1}$ μm^{-1}] at 300 m resolution**
BLUE	0.464	0.440 – 0.487	177 @111
RED	0.655	0.614 – 0.696	598 @110
NIR	0.837	0.772 – 0.902	574 @106
SWIR	1.603	1.570 – 1.635	720 @20
Radiometric performance			
Absolute accuracy [%]	< 5		
Inter-channel accuracy [%]	< 3		
Stability [%]	< 3		
Geometric performance			
Geo-location mean accuracy (standard deviation) [m]	BLUE: 55.68 (46.18) RED : 54.98 (45.23) NIR : 57.75 (47.01) SWIR: 58.84 (47.02)		

Figure 3 presents the spectral response functions (SRFs) for the BLUE, RED, NIR, and SWIR channels of PROBA-V, SPOT-VGT1, and -VGT2. It can be seen that differences between the separate band SRFs exist and that these differences are largest for the SWIR band. The differences in spectral response have been thoroughly investigated with respect to observed individual band reflectances and NDVI over various land surfaces. Clouds, snow/ice, and water bodies were excluded from the analysis, because of their minor relevance for the mission.

The inter-sensor differences for the individual band reflectances and NDVI are summarized in Table 3. For the NIR and RED bands, differences between PROBA-V and VGT-1 are of the same order of magnitude as the differences VGT2 – VGT1. This leads to similar NDVI differences, while for the SWIR channel the differences VGT2 – VGT1 are about three times as large.

For the BLUE band, PROBA-V observes systematic higher reflectances than both VGT1 and VGT2, with relative differences of ~2%. However, this translates into an average absolute reflectance difference of < 0.003, i.e., within the mission specification. Further details on the spectral channel analysis can be found in Dierckx et al. (2014). Note that the results presented here are preliminary, and updated set of results will be published on the PROBA-V website soon (http://proba-v.vgt.vito.be).

Table 3: Average relative difference [%] in band reflectance and NDVI between VGT2 and VGT1, PROBA-V and VGT1, and PROBA-V and VGT2.

Relative difference	VGT2 – VGT1	PROBA-V – VGT1	PROBA-V – VGT2
BLUE	-0.13	1.98	2.11
RED	-3.21	-3.91	-0.74
NIR	0.29	-0.47	-0.76
SWIR reflectance difference	-1.37	-4.65	-3.37
NDVI difference	3.68	3.34	-0.33

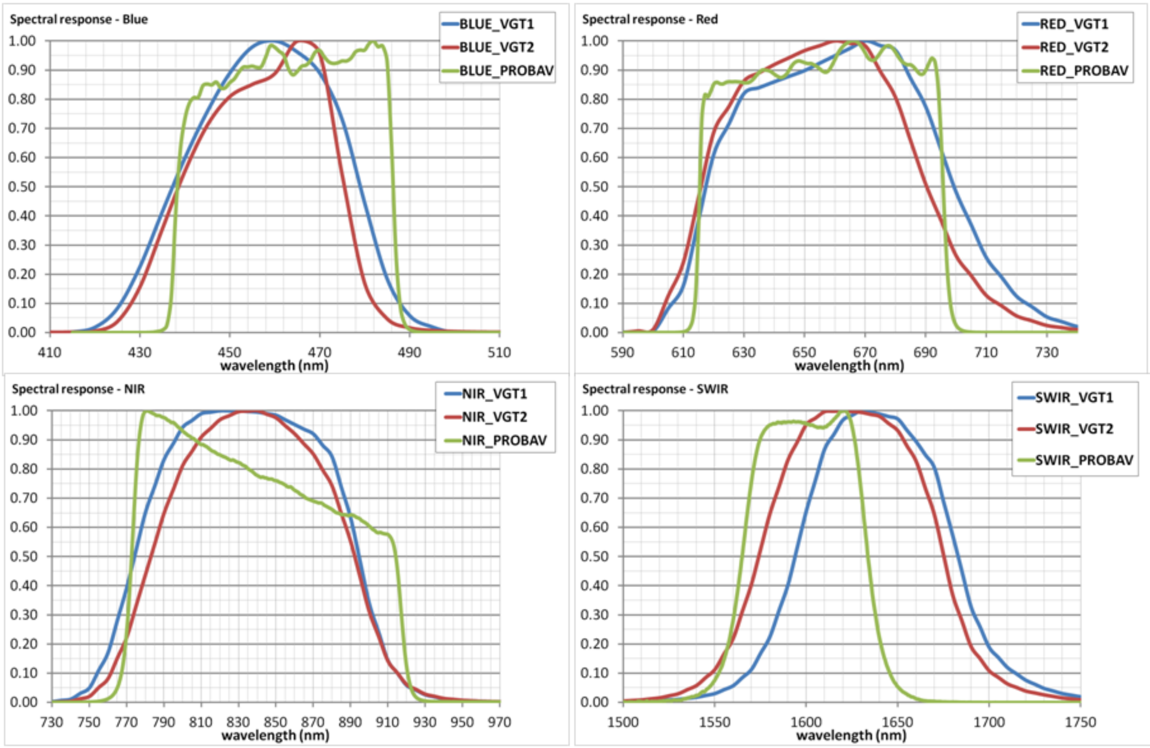

Figure 3: Spectral response functions for SPOT-VGT1, SPOT-VGT2, and PROBA-V for the BLUE, RED, NIR, and SWIR channels.

1.3. PROBA-V products

The PROBA-V products are similar to the ones of SPOT-VEGETATION in terms of file structure and comprise the following elements:

- Segment products (L1C TOA): previously known for SPOT-VGT as P products
- Synthesis products (S1 TOA+TOC and S10 TOC): previously known for SPOT-VGT as S products.

Figure 4 shows the flow chart of the product processing chain. The separate products and algorithms will be further described in Section 2.

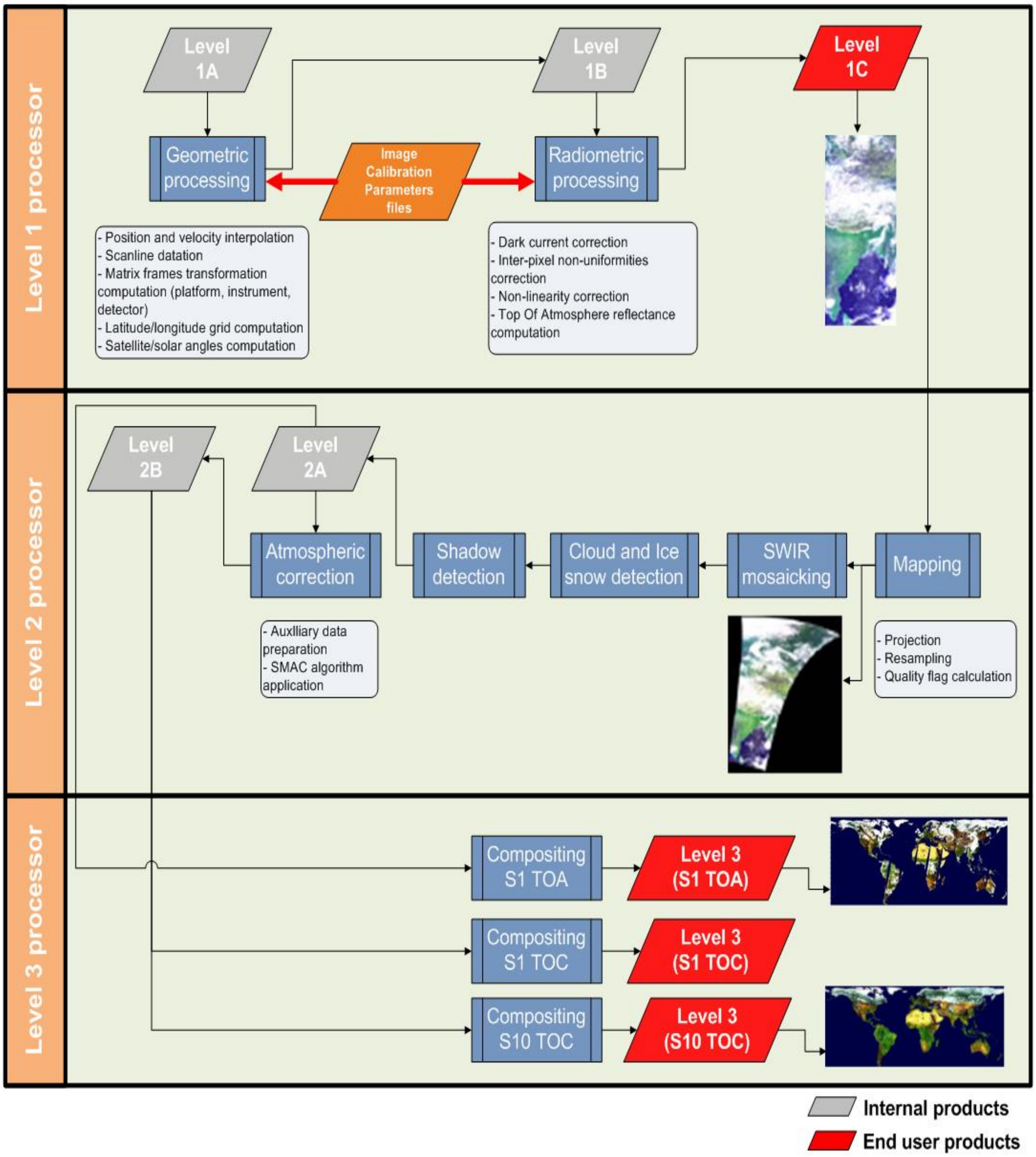

Figure 4: PROBA-V processing chain flow chart.

2. Products description

This Section describes the various PROBA-V products. First, the various algorithms that are applied to the raw image data are explained, followed by an explanation of the compositing rules to arrive at the Level 3 synthesis products. Finally, for all product types an overview of the information content is given.

2.1. Segment products (L1C) algorithm

The upper part of Figure 4 (*'Level 1 processor'*) shows the subsequent processing steps which are performed to obtain the Level 1C product. The two main processing steps are:

- Geometric processing
- Radiometric processing

These processing steps are explained in further detail in the following subsections.

2.1.1. Geometric processing

Using the Level1A (raw uncompressed) data, a geo-location step is performed for each satellite position to determine the latitude and longitude of the pixel observed. The satellite position and velocity are interpolated for each scan line using an orbital propagation model. The geo-location accuracy is refined using the geometric Instrument Calibration Parameters (ICP) file (see also Figure 4). The ICP file contains the variation in detector viewing direction relative to the time out of eclipse and the sun beta angle. The geometric processing model additionally calculates the viewing and solar zenith angles (VZA and SZA, respectively), which are required for further processing. The output of the geometric processing is the Level 1B data. The user is referred to Sterckx et al. (2014) for further details on the geometric processing model.

2.1.2. Radiometric processing

The radiometric processing converts the digital number count at a certain spectral band (DN) into physical TOA reflectance values. First, the DN number is corrected for non-linearities, dark currents, and inter-pixel non-uniformities. Second, these numbers are converted to at-sensor radiance *L* [W m^{-2} μm^{-1} sr^{-1}], using the band-specific calibration coefficients derived from the radiometric ICP file. Finally, the TOA radiance *L* is converted into TOA reflectance using:

$$R_{TOA} = \frac{\pi \times d^2 \times L}{E_o \times cos(\theta_s)}$$

With R_{TOA} the obtained TOA reflectance value [-], *d* the Earth – Sun distance [AU], E_o the mean exo-atmospheric irradiance at the specific spectral band [W m^{-2} μm^{-1}], with values from Thuillier et al. (2003). θ_s denotes the solar zenith angle [°]. The output of the radiometric processing is the Level 1C data.

2.2. Synthesis products (S1/S10) algorithm

The L1C data are used as input for further processing in the Level 2 processor, which consists of the following steps:

- Mapping and SWIR mosaicking
- Cloud and cloud shadow detection
- Snow/ice detection
- Atmospheric correction
- Compositing procedure

Please note that the compositing procedure for the 300 m and 1 km products differ in certain steps, this will be explained in more details in Section 2.2.5.

The separate processing steps are explained in the following subsections.

2.2.1. Mapping and SWIR mosaicking

In the mapping procedure, the L1C data are mapped onto a WGS84 geographic lat/lon projection, using a procedure proposed by Riazanoff (2004). An inverse model is used to calculate for a given pixel the original Level 1 *(p, l)* coordinates from the Level 2 *(x, y)* coordinates, with *x* being the longitude, *y* the latitude, *p* the pixel-in-line, and *l* the line number. This mapping is explained in Figure 5.

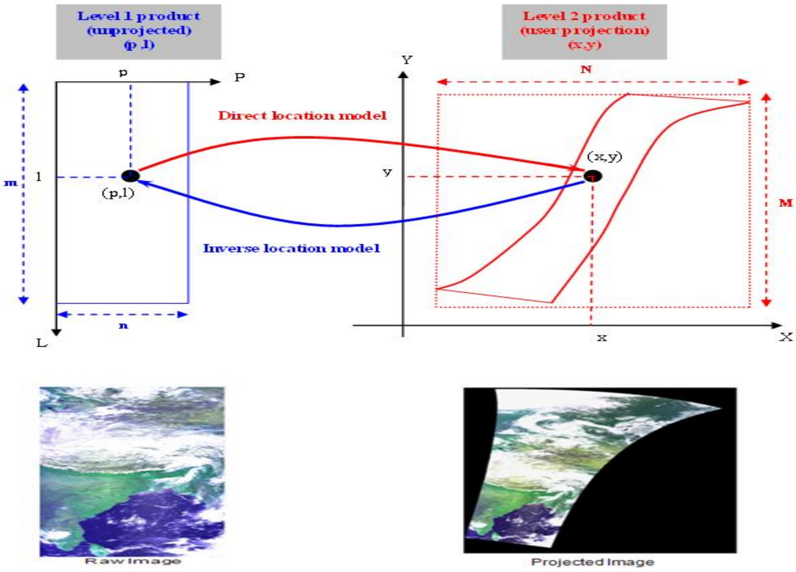

Figure 5: The Level 2 mapping procedure.

The mapping operation is carried out twice, at 0 m and 5000 m above sea level, thereby resulting in two *(p, l)* coordinate sets. The *(p, l)* coordinates at a given altitude are then linearly interpolated from these two datasets. Ortho-rectification is performed using a Digital Elevation Model (DEM) from NASA/USGS (GLSDEM). More information on the GLSDEM can be found at http://glcf.umd.edu/data/glsdem/. GLSDEM data can be downloaded freely from the Global Land Cover Facility (GLCF) ftp site: ftp://ftp.glcf.umd.edu/glcf/GLSDEM/. The data have a resolution of ~90 m and are available in WRS-2 reference format or in degree tiles for the latitudinal range 56°S – 83°N.

In the last step, the Level 2 pixel values are mapped onto the *(x,y)* grid using a stretched bi-cubic interpolation filter (see Dierckx et al., 2014). This interpolation technique was found to be more accurate for PROBA-V compared to the standard bi-cubic interpolation used for SPOT-VGT1 and -VGT2 (Dierckx et al., 2014).

The SWIR detector of each camera consists of three strips (see Figure 2). After the mapping, there are still three separately projected SWIR strips. Therefore a mosaicking step is applied to compose a single SWIR band image. In the overlapping regions the pixel radiometric Status Map is taken into account to select the best pixel (see Figure 6). More information on the Status Map is given in Section 5.

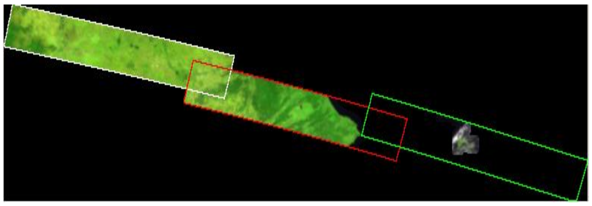

Figure 6: Example of the mosaicking algorithm result on the three SWIR strips.

2.2.2. Snow/ice detection

The snow/ice detection for PROBA-V is similar to the SPOT-VGT mission. The binary snow mask uses five indices based on the TOA reflectance of the four PROBA-V spectral bands:

$$S1 = R_{RED}$$

$$S2 = R_{SWIR}$$

$$S3 = \frac{R_{BLUE} - R_{NIR}}{R_{BLUE} + R_{NIR}}$$

$$S4 = \frac{R_{BLUE} - R_{SWIR}}{R_{BLUE} + R_{SWIR}}$$

$$S5 = \frac{R_{BLUE} + R_{RED}}{2} - R_{SWIR}$$

The decision tree for snow/ice detection is presented in Figure 7, the threshold values for tests S1 – S5 are given in Table 4.

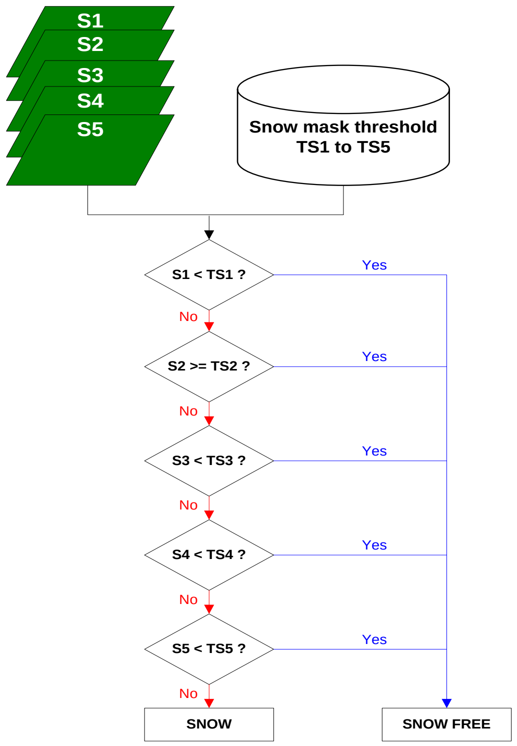

Figure 7: Snow/ice decision tree.

Table 4: Threshold values for the snow/ice detection.

Name	TOA reflectance value [-]
TS1	0.3075
TS2	0.2405
TS3	-0.3865
TS4	0.0435
TS5	0.0385

2.2.3. Cloud and cloud shadow detection

Cloud detection

Clouds obstruct the retrieval of vegetation parameters in satellite observations. Therefore a proper cloud screening is pivotal in the pre-processing of the various value-added products.

The PROBA-V cloud detection algorithm is a modified version of the method applied to the SPOT-VGT BLUE and SWIR observations (Lissens et al., 2000). Using these band reflectances, two separate cloud masks are created. The first (second) mask uses a BLUE (SWIR) band threshold with an additional check at 300 m resolution on the SWIR (BLUE) band. The final cloud mask is a merge of these two masking results. Compared to the SPOT-VGT cloud mask, some modifications were necessary, because the assumption that clouds are observed at the same position in both the BLUE and SWIR bands is no longer valid for PROBA-V, due to the observation time difference. This is further explained below.

As already indicated in Section 1, the PROBA-V instrument design is such that the NIR observes a cloud first, followed by the RED, BLUE, and SWIR bands. The time difference between the NIR and SWIR cloud observations is 12 s. As a result, the NIR and SWIR bands will map clouds onto different positions in the along-track direction, with differences up to ~700 m for clouds at 10 km altitude. Other effects of the observation time difference include viewing angle differences and horizontal cloud shifts. The maximum shift resulting from the latter two effects will not exceed three 300 m pixels along-track and one pixel cross-track on either side.

The cloud detection algorithm accounts for the different observation times as follows.
For the cloud detection based on the BLUE band reflectance, it is checked whether the observed value exceeds the BLUE band reflectance threshold of 0.2465. In addition, it is checked whether the maximum SWIR reflectance value in a 3×3 pixel box (i.e., 1×1 km) above the BLUE pixel in the image exceeds the SWIR band threshold, see the upper panels in Figure 8. If both conditions are satisfied, the BLUE pixel is classified as cloudy. Note that this 3×3-pixel SWIR reflectance test only needs to be applied to the 300 m cloud mask.

Because pixels observed in NIR are mostly observed in front of the BLUE pixel in the image, the pixel below the BLUE pixel is also categorized as cloudy.

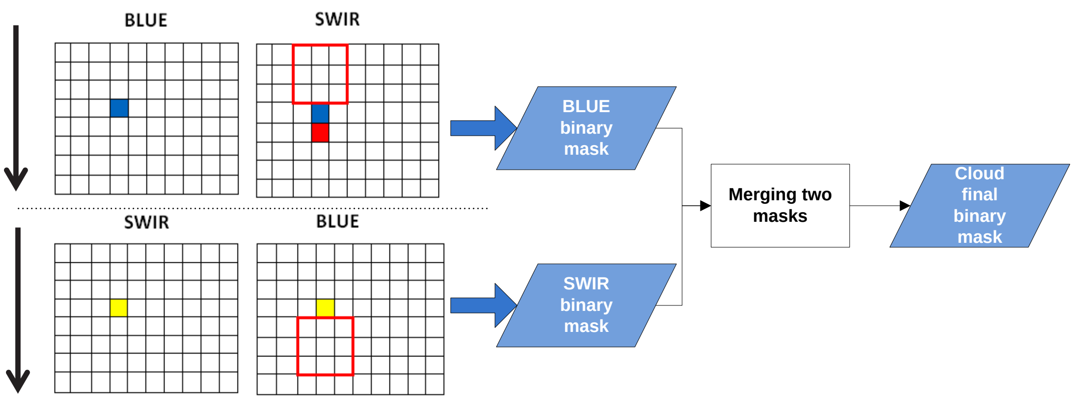

Figure 8: The cloud detection process for the BLUE, SWIR, and final cloud masks. The red pixel denotes the NIR observation. The satellite along-track flight direction is indicated by the black arrows. The 3×3-pixel SWIR reflectance test is only applied for the 300 m cloud mask.

A similar procedure is applied for the SWIR-based cloud mask, but then with an additional forward 3×3 BLUE pixel window (see the lower two panels in Figure 8). The reflectance threshold value for the SWIR band to label a pixel as 'cloudy' is 0.09. The final cloud mask is obtained through merging the BLUE and SWIR masks, with values of 0 and 1 indicating 'clear' and 'cloudy', respectively.

Cloud shadow detection
Cloud shadow detection is also of importance, as the dark areas casted at the Earth surface can lead to erroneous vegetation parameter retrievals. The methodology to screen for cloud shadows

from PROBA-V observations is a hybrid between the radiometric approach (see e.g. Zhu and Woodcock, 2012 and Ackerman et al., 2006) and a geometric approach (see Simpson et al., 2000).

The geometric part of the cloud shadow detection algorithm is presented in Figure 9. A cloud pixel is located at position *p*, with the actual cloud being at height *h* from the tangential plane, i.e., the intersection of the sun beam and the line of sight from the satellite to the cloud pixel. The cloud shadow can then be found as the intersection of the sun beam and the tangential plane at the center. Solar zenith and azimuth angles are assumed to be equal in the cloud and cloud shadow pixels. It follows from Figure 9 that angle φ equals the sum of ϒ and the viewing azimuth angle ϕ_{av}. When φ and the distance between the cloud and associated cloud shadow pixel, *r*, are known, their position can be calculated using geometry, see Sterckx et al (2014) for further details.

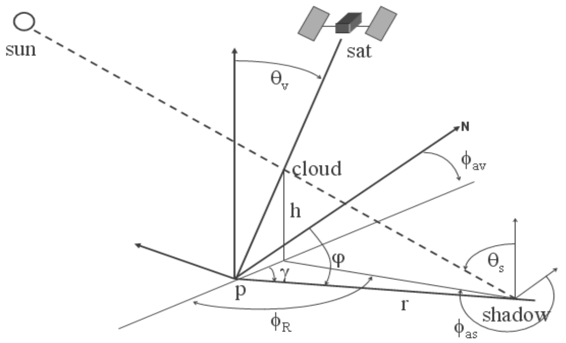

Figure 9: Depiction of solar, satellite, cloud, and cloud shadow geometries.

Cloud heights are estimated using the gradient in NIR reflectance along the projected path from cloud to shadow in the image (Figure 10). In case of a cloud shadow, the NIR reflectance will decrease towards a minimum from cloud to shadow edge. If this change is above a threshold of 20%, a shadow edge is detected. From the locations of the cloud and shadow edge, the cloud height can subsequently be calculated. More details on the cloud shadow detection can be found in Sterckx et al. (2014).

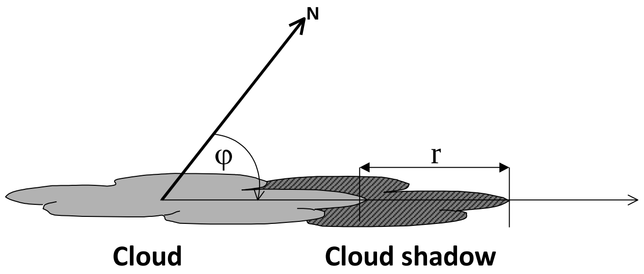

Figure 10: Concept of radiance tracing along the cloud-to-shadow path.

2.2.4. Atmospheric correction

The TOA reflectance observations are the resultant of surface reflectance and scattering, absorption, and multiple reflection within the atmospheric column (clouds, gases, aerosols). In order to obtain the bi-directional surface reflectance values, version 4.2 of the Simplified Model for Atmospheric Correction [SMAC, Rahman et al. (1994)] model is used. This model converts the observed TOA reflectance into TOC reflectance using auxiliary water vapour, ozone, and surface pressure data. Water vapour content is taken from ECMWF NWP model data delivered by MeteoServices (http://www.meteoservices.be), while for ozone a climatology based on Total Ozone Mapping Spectrometer (TOMS) observations prepared by the Centre d'Études Spatiales de la Biosphère (CESBIO) is used. Surface pressure is derived from the Global Land Surface Digital Elevation Model (GLSDEM), using a conversion formula proposed by Plummer et al. (2003). Atmospheric aerosol loads are estimated using an optimization algorithm applied to the BLUE band (Maisongrande et al., 2004).

The SMAC algorithm uses a separate equation for each of the atmospheric interaction processes. Scattering and absorption by atmospheric constituents are parameterized by analytical formulations, whose coefficients are fitted against reference values derived by the 6S radiative transfer model (Vermote et al., 1997).

2.2.5. Compositing procedure

The composition into synthesis images is performed by the Level 3 Processor (see Figure 4). The aim is to optimally combine multiple observations into a single and cloud-free synthesis image. Atmospherically uncorrected (Level2A) or corrected (Level 2B) data are the basis for the TOA and TOC synthesis products, respectively. Cloud coverage is minimized through discarding pixels that were labeled as cloudy. In addition, angular variations are minimized, while global coverage is maximized.

The S10 compositing is applied to avoid spatial coverage gaps resulting from clouds and the non-global daily swath coverage in the tropical areas.

Atmospherically corrected segment files are combined into a global Level 3 synthesis through application of a Maximum Value Composite (MVC) technique (see among others Holben, 1986 and Tarpley et al., 1984). This technique selects pixels with the maximum NDVI value. The following two synthesis products are generated:

- S1 (1-day syntheses): TOA and TOC
- S10 (10-day or dekad syntheses): TOC, with starting days at the 1st, 11th, or 21st day of a month. For months having 28, 29 or 31 days the S10 of the third dekad comprises the remaining days of the month.
- For the 100 m product, also S5 TOA and TOC files are available. PROBA-V 100 m S5 products are comparable with full-coverage 300 m S1 products. Due to the narrow swath of the 100 m camera, there is only overlap in observations for latitudes > ~40^{o}. This means that poleward of this latitude compositing rules can be applied. See Figure 11 for an

indication on the 100 m coverage after 5 days. Please note that S5 data can only be ordered for day 1, 6, …, 21, and 26 of a month.

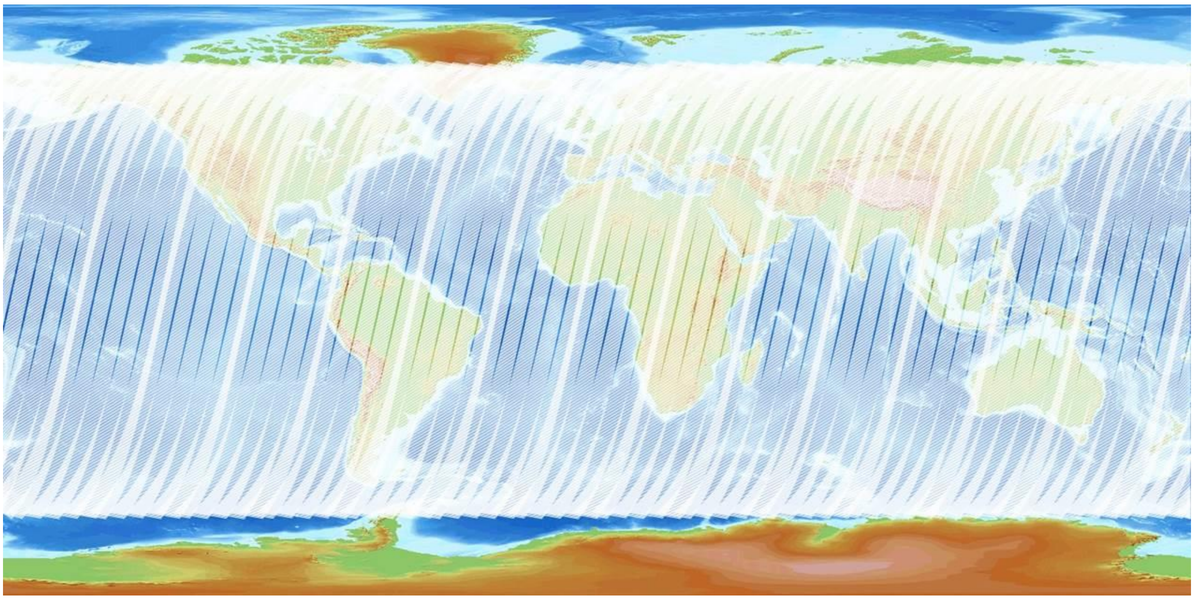

Figure 11: Overview of the 100 m coverage after 5 days. The brighter white areas indicate overlapping observations.

In order to preserve continuity between the PROBA-V 1 km products and the SPOT-VGT era, the compositing rules for the 1 km resolution differ from the 300 m resolution. For the sake of clarity, below the compositing rules for both resolutions are listed.

The compositing rules **for the 300 m and 100 m** synthesis are as follows:

- Observations covered by all spectral bands are preferred over observations covered by only a few spectral bands.
- Observations with a good pixel quality indicator for all bands are preferred over observations of less quality.
- Cloud-free observations are preferred over ice/snow observations, which in turn are preferred over cloud observations.
- In case two observations satisfy the rules above, the VZA and SZA are used to distinguish optimal from less optimal observations. The larger the VZA and/or SZA, the larger the (two-way) optical path length. Using the thresholds presented in Table 5, observations are categorized as ‘good’, ‘acceptable’, and ‘bad’. Logically, the selection order is ‘good’ > ‘acceptable’ > ‘bad’. See Figure 12 for the decision tree.
- In case two or more observations are still of equal quality, the observation yielding the maximum NDVI value is preferred.

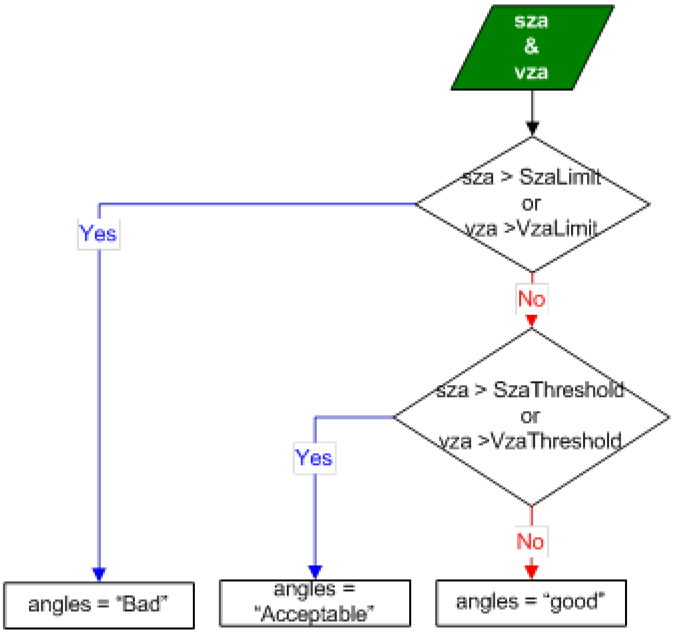

Figure 12: Procedure to determine the observation quality based on SZA and VZA in the synthesis processing. Note that in the 1 km processing only the SZA rule is applied.

Table 5: SZA and VZA threshold values in the synthesis processing. Note that in the 1 km processing only the SZA rule is applied.

Rule	Limit	Threshold
Solar Zenith Angle	90°	60°
Viewing Zenith Angle	75°	40°

The compositing rules **for the 1 km** synthesis are as follows:

- Observations covered by all spectral bands are preferred over observations covered by only a few spectral bands.
- Observations with a good pixel quality indicator for the BLUE, NIR, and RED bands are preferred over observations of less quality. This differs from the 300 m compositing rule in that SWIR observations with lower than ‘good’ radiometric quality are allowed.
- Cloud-free observations are preferred over ice/snow observations, which in turn are preferred over cloud observations.
- In case two observations satisfy the rules above, the SZA is used to distinguish optimal from less optimal observations. Using the SZA threshold presented in Table 5, observations are categorized as ‘good’, ‘acceptable’, and ‘bad’. Logically, the selection order is ‘good’ > ‘acceptable’ > ‘bad’.
- In case two or more observations are still of equal quality, the observation yielding the maximum NDVI value is preferred.

As a result of these compositing rules, the 1 km synthesis products will sometimes contain pixels with a ‘bad’ SWIR status, while being cloud-free and having a ‘clear and good’ status for the other bands. These pixels can be identified in the synthesis status map by a status value of 232 instead of 248 (see Section 5.2).

Such pixels have been flagged because they have an unusually high dark current value compared to other SWIR pixels. In most cases the pixels involved are still reliable, and are handled by the radiometric correction as part of Level1 processing. However, these pixels are considered by the PROBA-V Calibration team to have a substandard pixel quality and should be treated as such by the user.

3. Product data access

3.1. PROBA-V Product Distribution Facility (PDF)

PROBA-V products can be ordered and downloaded using the PROBA-V Product Distribution Facility, which can be approached via http://www.vito-eodata.be/. Figure 13 shows the main page of the distribution portal.

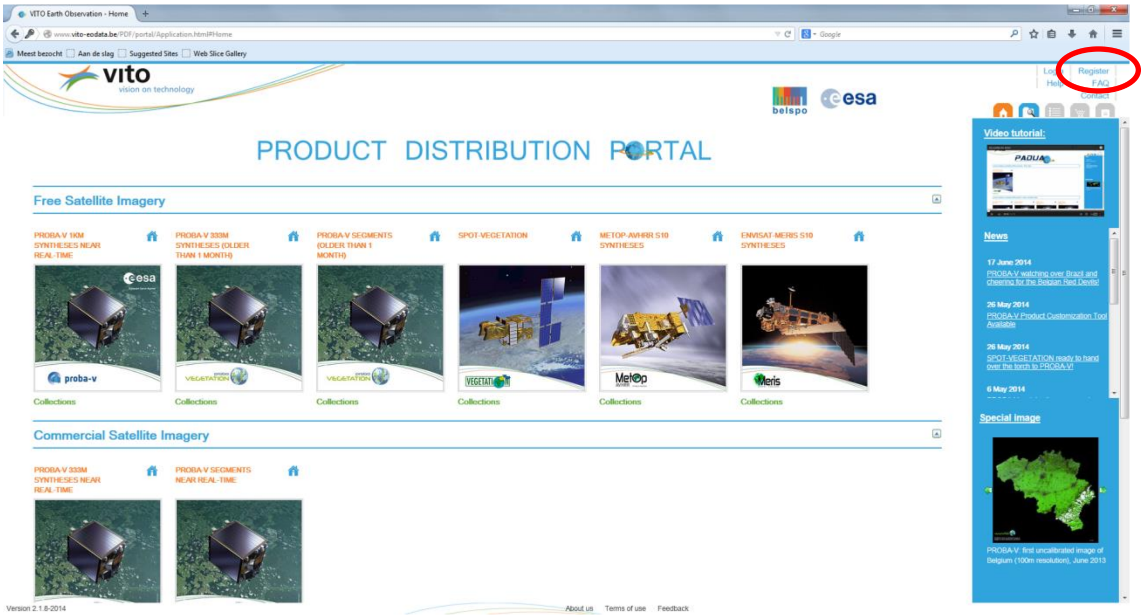

Figure 13: Main page of the PROBA-V Product Distribution Facility. The registration link is highlighted by the red oval shape.

3.2. Registration to the PDF

To order PROBA-V data, registration to the PDF is required. Registration can proceed after clicking the 'Register' link in the portal main page's upper-right corner. See Figure 13 for the link location.

After clicking the link, a form to be filled out by the user appears on top of the portal's main page, see Figure 14. The user is requested to provide additional information and to accept the Terms and Conditions. After clicking the 'Register' button, an e-mail with an activation link is sent to the user and registration is completed. It is noted that in some occasions, the activation mail ends up in the junk e-mail folder.

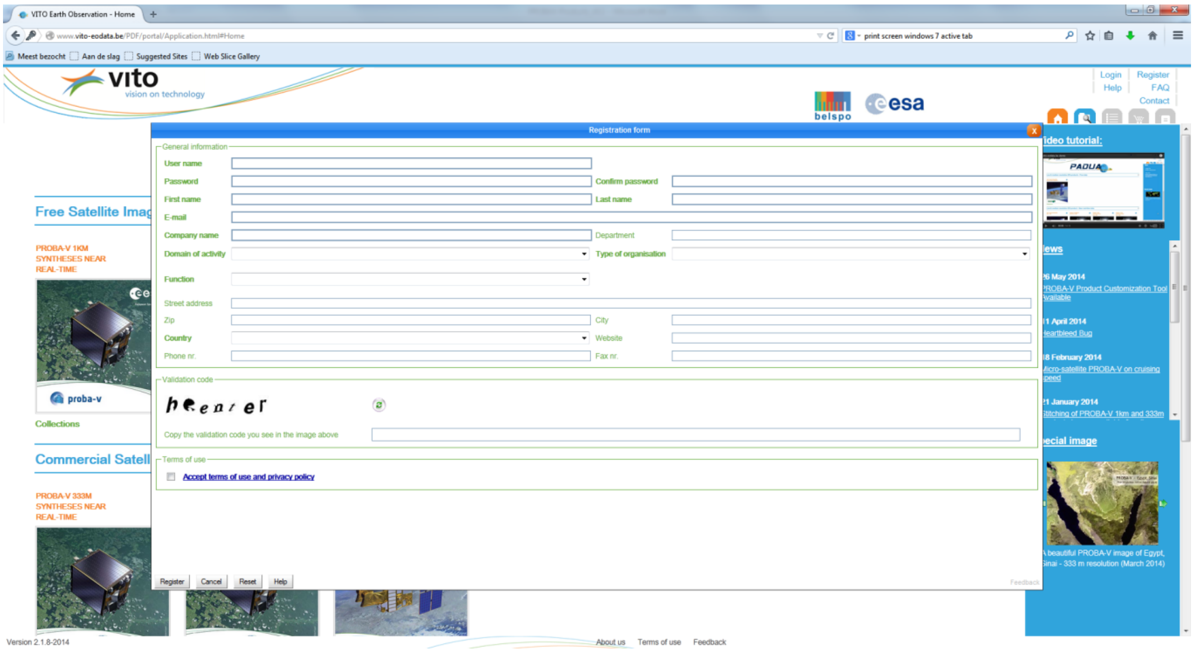

Figure 14: User registration form.

3.3. Product catalogue and ordering

PROBA-V data can be searched in the catalogue. From the main portal page, the user can select one of the image tiles that are linked to the various PROBA-V collections:

- Segment Products – older than 1 month
- Segment Products – younger than 1 month
- 1 km Synthesis Products
- 300 m Synthesis Products – older than 1 month
- 300 m Synthesis Products – younger than 1 month
- 100 m Synthesis Products – older than 1 month
- 100 m Synthesis Products – younger than 1 month

Note that the 300 m and 100 m Segment and Synthesis products are commercial data for the Near Real Time (<1 month). Upon product type selection, a new screen is opened, with a world map to the left and a catalogue search criteria window to the right (see Figure 15). In this example, the PROBA-V 300 m S1 product has been selected and data for the period of 1 – 31 January 2014 are requested.

After selection of one or more products, the user has the following options:

1. Back to search: go back and refine the search

2. Prepare order: proceed with the selected product(s), see Figure 16. The user can further specify details (e.g. choose the delivery method: FTP pull, FTP push, HTTP download) and refine the dataset selection. Further, the user has the option to have multiple product tiles stitched into a single product output file. Further product customization options (reformat, select bands, etc) can be available. Please contact the Helpdesk for further information and conditions.
3. Fast order by ftp: by clicking this button, all selected products are ordered non-customised and delivered via FTP pull.
4. For the 1 km products, additional registration at the ESA Earthnet Online Portal is required. A detailed description of this registration procedure is available from: http://www.vito-eodata.be/PDF/image/faq_help/Manual_PROBA-V1km_data.pdf

To download large areas, an option exists to stitch the data into a single file. The stitching can be enabled by selecting ‘Stitching’ in the ‘Prepare Order’ form (see Figure 16).

After order preparation, the user needs to confirm the order by clicking the ‘submit’ button. The user will receive an e-mail with download information once the ordered data have been produced by the PDF.

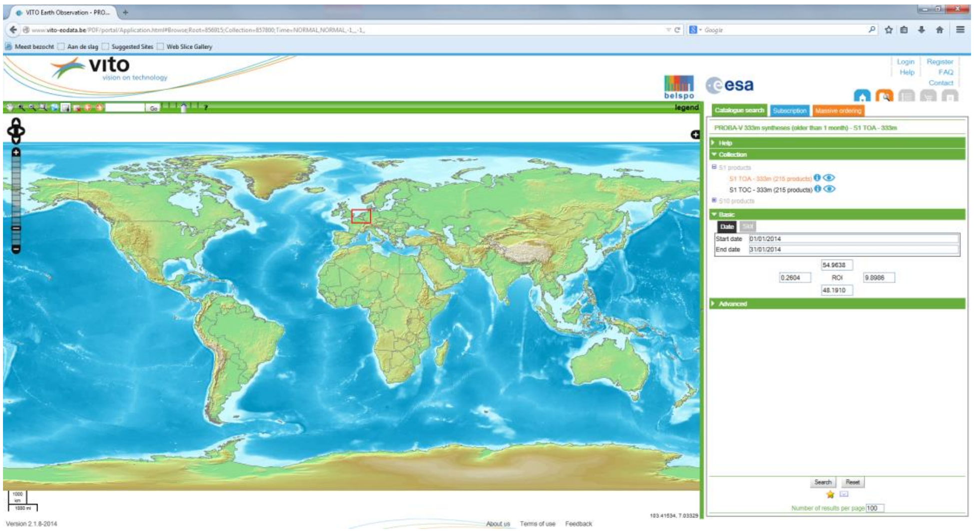

Figure 15: World map with a defined Region of Interest (RoI), the selected product suite (S1, 300 m) and the selected date range (1 – 31 January 2014).

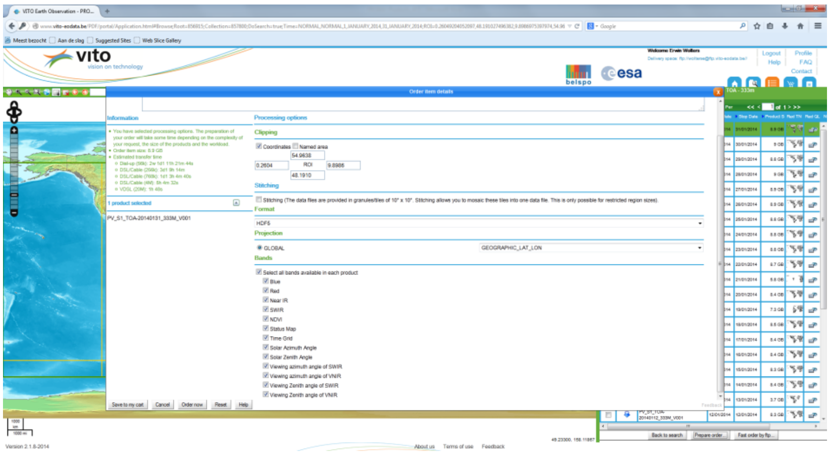

Figure 16: the 'Prepare Order' form.

Since the PDF release of November 2014, users have the option to download bulk data for a given region, time period, or a combination of both. This facility is called 'Fast HTTP Access' (see Figure 17)and a short User Manual, which also contains explanations on how to use `wget`, is available at http://www.vito-eodata.be/PDF/image/Data_pool_manual.pdf.

Further, from April 2015 onwards all products will also be available in GeoTiff format.

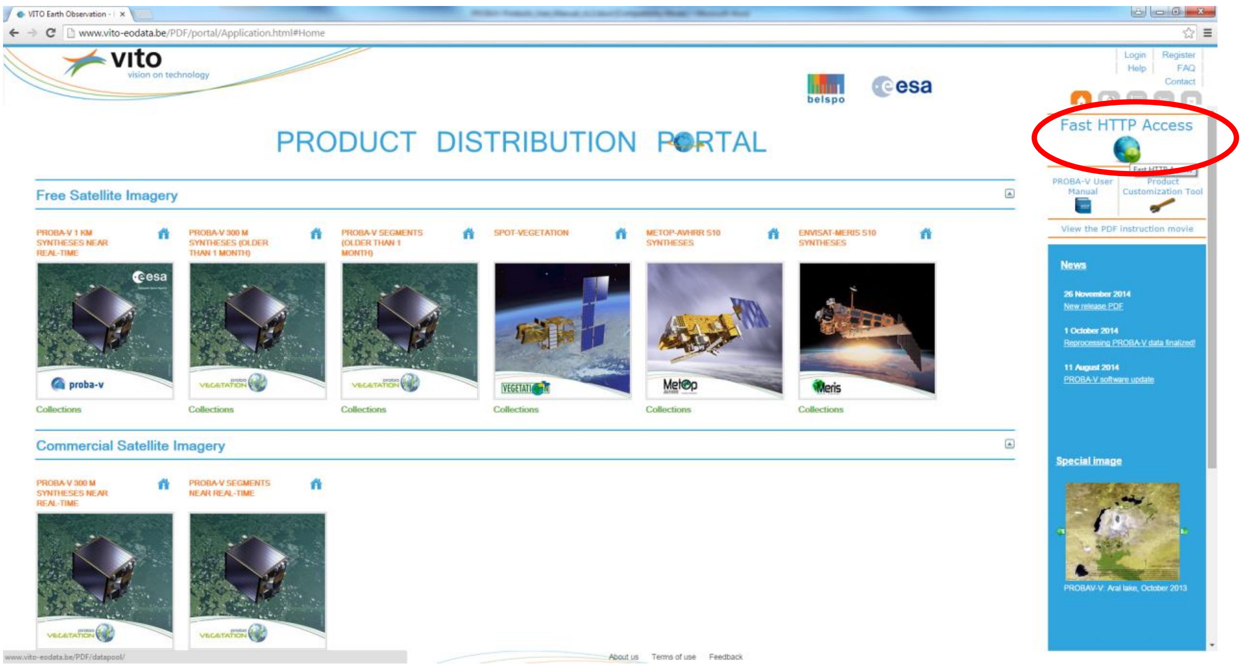

Figure 17: Location of the 'Fast HTTP Access' facility at the portal's main page.

3.4. Further information

New users can consult a video tutorial, available at http://www.vito-eodata.be/PDF/image/movie/pdf_instruction_movie.html.

3.5. User contact

User questions can be addressed to the PROBA-V Helpdesk and can be inserted using the 'Contact' link in the upper-right corner of the portal's main page (see Figure 13). Alternatively, the Helpdesk can be contacted directly through the following e-mail address:

helpdeskticket@vgt.vito.be

4. Data File Format

4.1. HDF5 EOS File Format

The PROBA-V data products are disseminated as HDF5 files (Hierarchical Data Format, Version 5, for more information see http://www.hdfgroup.org/HDF5/), which comprises a set of file formats and libraries designed to store and organize large amounts of numerical data. The structure within an HDF5 file has mainly two major object types:

- Datasets, which are multi-dimensional arrays of homogeneous type
- Groups, which are container structures that can contain other datasets and groups

The HDF5 file format is hierarchical and is built up like a file system. See for example Figure 18, which shows the various Datasets and Groups for a PROBA-V L1C file, as well as the BLUE and RED bands opened as images. In HDF5, attributes with additional information are attached to the Datasets and Groups.

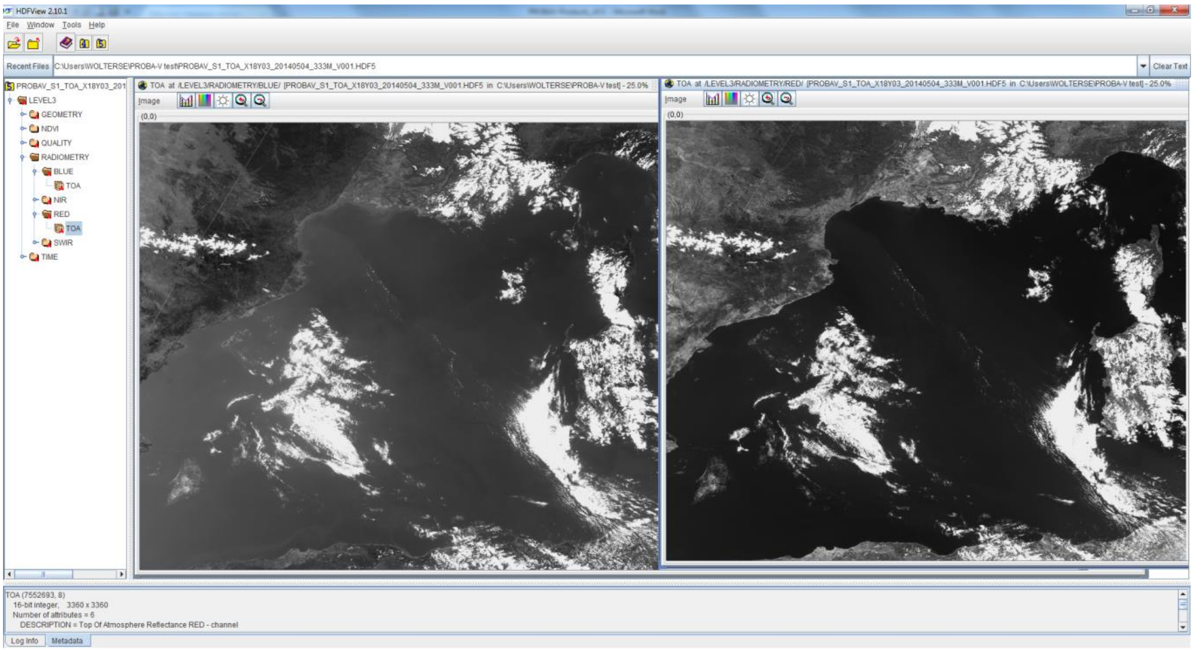

Figure 18: Overview of the Datasets, Groups, and images of the BLUE and RED spectral bands within a PROBA-V L1C HDF5 file.

4.1.1. SZIP compression

The HDF5 files are produced using the SZIP (de)compression software. SZIP is a stand-alone software library that ensures lossless compression of scientific data and is superior in both compression rate and (de)compression times during I/O as compared to e.g. GZIP.

Most software packages that can read HDF5 files have the SZIP library included. However, users are referred to the following links to obtain more detailed information on the SZIP performance and to download the SZIP library pre-compiled source code:

http://www.hdfgroup.org/doc_resource/SZIP/
http://www.hdfgroup.org/ftp/lib-external/szip/2.1/src/

4.1.2. Customization tool

Upon various user requests for extended PROBA-V data tools, VITO developed the PROBA-V Product Customization Tool (PPT).
The PPT software facilitates the use of PROBA-V products by providing following customization operations:

- File format conversion (HDF5 → HDF4 / GeoTIFF)
- Map projections
  - Albers Equal Area
  - Lambert Equal Area
  - Equi-rectangular
  - Geographic
  - Hammer
  - Sinusoidal
  - Goode Homolosine
  - Interrupted Goode Homolosine
  - Lambert Azimuthal
  - Lambert Conformal Conic
  - Mercator
  - Mollweide
  - Polar Stereographic
  - Stereographic
  - Transverse Mercator
  - Universal Transverse Mercator
- Mosaicking
- Band extraction
- Clipping

The PPT software is compiled for use on multiple operating systems (Unix and Windows) for both 32- and 64-bit systems.

An extensive PPT User Manual is included in the download package, available from the PPT download page (http://www.vito-eodata.be/PDF/image/news/PROBA-V_Product_Customization_Tool.html)

4.2. File Versioning Information

The PROBA-V products have been produced with various algorithms throughout the processing chain. Table 6 presents these algorithms, while Table 7 contains information on the algorithms' version numbers as per July 2014. The latter information is found in the Level3 Group attributes.

Table 6: Definition of the various PROBA-V processing algorithms.

Meta data Field	Description
PROCESSINGINFO_GEOMODELLING	Identifier for the algorithm and version of the geometric processing step.
PROCESSINGINFO_RADIOMODELLING	Identifier for the algorithm and version of the radiometric processing step.
PROCESSINGINFO_MAPPING	Identifier for the algorithm and version of the projection step.
PROCESSINGINFO_MOSAIC	Identifier for the algorithm and version of the mosaic processing step.
PROCESSINGINFO_ CLOUDICESNOWDETECTION	Identifier for the algorithm and version of the cloud/snow/ice detection processing step.
PROCESSINGINFO_ SHADOWDETECTION	Identifier for the algorithm and version of the shadow detection processing step.
PROCESSINGINFO_ATMOSPHERIC_ CORRECTION	Identifier for the algorithm and version of the atmospheric correction processing step.
PROCESSINGINFO_COMPOSITING	Identifier for the algorithm and version of the compositing processing step.

Table 7: Currently supported algorithm versions.

Meta data Field	Value	Description
PROCESSINGINFO_GEOMODELLING	PROBAV_GEOMODELLING_V1.0	Initial version of the geometric modelling algorithm
PROCESSINGINFO_ RADIOMODELLING	PROBAV_RADIOMODELLING_V1.0	Initial version of the radiometric modelling algorithm
PROCESSINGINFO_MAPPING	PROBAV_MAPPING_V1.0	Initial version of the Geometric modelling algorithm
PROCESSINGINFO_MOSAIC	PROBAV_MOSAIC_V1.0	Initial version of the mosaicking algorithm
PROCESSINGINFO_ CLOUDICESNOWDETECTION	PROBAV_ CLOUDICESNOWDETECTION_V1.0	Initial version of the cloud and snow/ice detection algorithm
PROCESSINGINFO_ SHADOWDETECTION	PROBAV_ SHADOWDETECTION_V1.0	Initial version of the shadow detection algorithm
PROCESSINGINFO_ATMOSPHERIC_ CORRECTION	PROBAV_ATMCORR_ SMAC_V1.0	Initial version of the atmospheric correction algorithm
PROCESSINGINFO_COMPOSITING	PROBAV_COMPOSITING_MVC_V1.0 PROBAV_COMPOSITING_MVC_V2.0	Initial version of the NVC compositing algorithm Same as PROBAV_COMPOSITING_MVC_V1.0, but with the following changes

		for the 1 km compositing: • No pixel selection based on viewing zenith angle (VZA) thresholds • Disabled checking on validity of SWIR quality This version was applicable for all 1 km synthesis products processed from 13/06/2014 – 15/07/2014.
	PROBAV_COMPOSITING_MVC_V2.1	Same as PROBAV_COMPOSITING_MVC_V2.0, but with the following changes: • Fixed time grid (minutes since start of the synthesis)

The time lines in Figure 19 show when the various algorithm versions were implemented.

The first operational PROBA-V data were disseminated at 16 October 2013 as V1. During the first few weeks, it was found that a radiometric correction was necessary, which was implemented at 27 November 2013. All operational data were then reprocessed and data from 16 October – 26 November 2013 was renamed to V2. In June 2014, changes in the synthesis compositing rules were implemented for both the 300 m and 1 km products. These changes comprised the following:

- The VZA angle rule was switched off for the 1 km compositing. This was decided for consistency reasons with respect to the SPOT-VGT era.
- The Bad SWIR rule was switched off for the 1 km compositing: initially, a 'good' radiometric quality for all the bands was required. However, for consistency reasons with respect to SPOT-VGT, especially for the NDVI product, it was decided to exclude the SWIR channel from these requirements.
- The time grid resolution was changed from days into minutes for both the 300 m and 1 km compositing. This change enables users to perform a proper atmospheric correction.

The above-mentioned changes were implemented at 13 June 2014 and reprocessing was finalized by September 2014. Product files from 27 November 2013 onwards were renamed from V1 to V2, while product files from 16 October – 26 November 2013 were renamed from V2 to V3, see the solid blue arrows in the lower part of Figure 19.

It is important to notice that the explanation above only refers to the product file versioning. Information on the used versions of the various algorithms (as presented in Table 6 and Table 7) can be found in the product file meta data attributes (Level3 Group). The location of these attributes can be found in the Appendices.

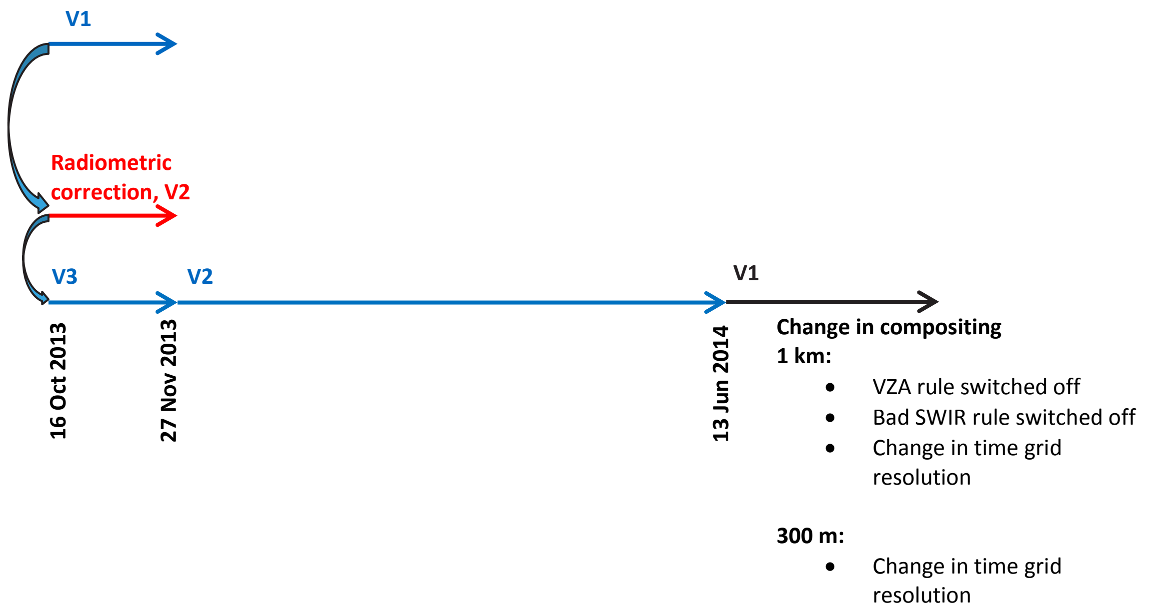

Figure 19: Schematic representation of the PROBA-V file name versioning.

4.3. PROBA-V File Format Description

4.3.1. Segment Product File Naming Convention

The file format for the segment (L1C) products is as follows:

PROBAV_L1C_*<DATE>***_***<TIME>***_***<CAMERA>***_V***<VERSION>***.hdf5**

In which:

<DATE> start date of the segment identifier (format: YYYYMMDD).
<TIME> start time (UTC) of the segment (format: hhmmss).
<CAMERA> camera identifier
1: left camera (descending orbit, east)
2: central camera
3: right camera (descending orbit, west)
<VERSION> version identifier, three digits starting from “001”

Example: the filename *PROBAV_L1C_20140517_121832_1_V001.hdf5* represents the data that was observed from 17 May 2014 12:18:32 UTC onwards with the left camera.

The segment files contain the following dataset structure:

- **LEVEL 1A**
  This group contains the raw uncompressed digital value for each pixel. It also contains the **Platform** information provided by the spacecraft.

- **LEVEL 1B**
  This group gives the output of the geometric processing. It contains the geographical coordinates (latitude, longitude) for each pixel at heights of 0 and 5000 m above sea level. It contains as well the viewing and illumination geometry for each pixel.

- **LEVEL 1C**
  Contains the radiometrically corrected Top-Of-Atmosphere reflectance value for each pixel. It also contains a quality indicator, which gives information per pixel on the reliability of the value.

The above Levels have the following datasets:

- BLUE
- NIR
- RED
- SWIR1
- SWIR2
- SWIR3

The respective datasets contain the Digital Number counts for the respective spectral bands, with attributes providing information on the scale and offset values required to convert the DN to physical reflectance values.

Figure 20 displays the dataset structure of an L1C file.

Further, each of the Levels contain additional HDF5 Attribute Tables in which detailed information on geolocation, processing, etc. is stored. Detailed explanations of the entire dataset structure for the L1C files is given in Appendix A1.

Figure 20: Dataset structure of a segment product file.

4.3.2. Synthesis Product File Naming Convention

The file format for the synthesis products is as follows:

PROBAV__<TYPE>_ **_**_<TILE-ID>_**_**_<DATE>_**_**_<GRID>_**_V**_<VERSION>_**.hdf5**

In which:

<TYPE>	product type (‘S1_TOA’, ‘S1_TOC’ or ‘S10_TOC’)
<TILE-ID>	tile identifier. ‘X00Y00’ is the identifier for the top-left tile, numbering increases in eastward and southward direction for X and Y, respectively. See Figure 21 for the tile numbering.
<DATE>	start date of the synthesis (YYYYMMDD)
<GRID>	spatial resolution (300 m or 1 km)
<VERSION>	version identifier, three digits starting from ‘001’

Example : The top-left tile of the third 1 km S10 of September 2013 has filename:
PROBAV_S10_TOC_X00Y00_20130921_1KM_V001.hdf5.

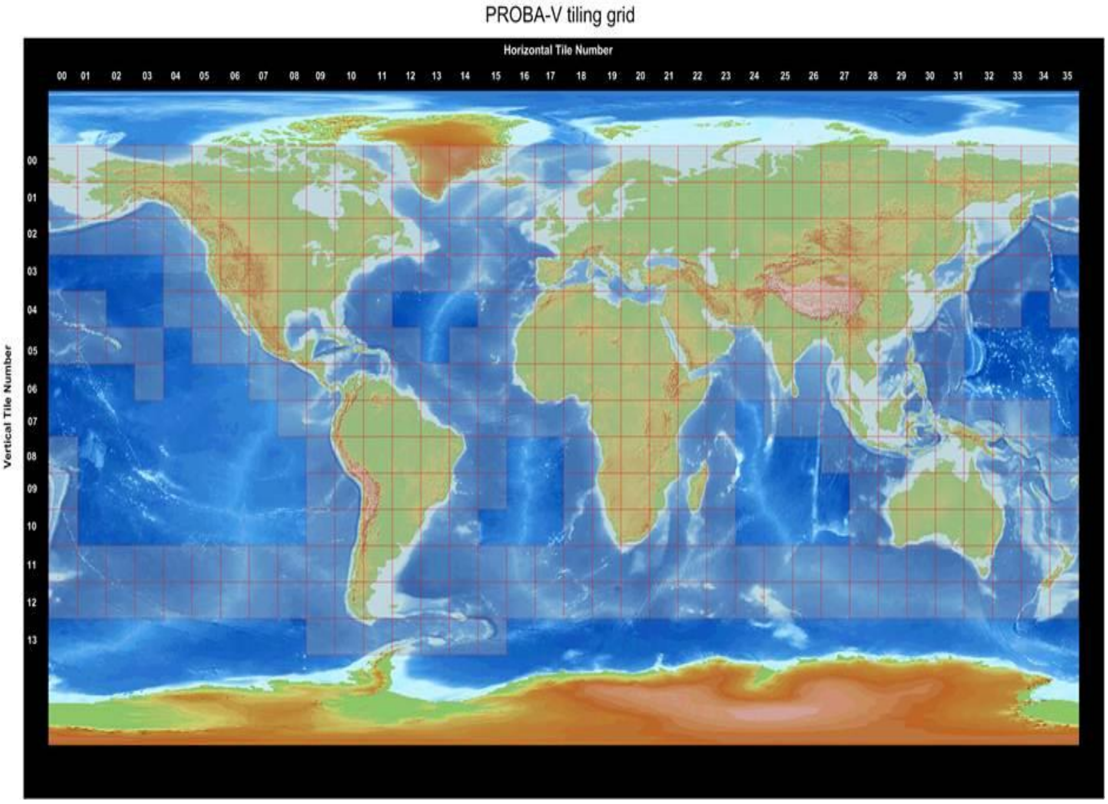

Figure 21: PROBA-V tile numbering.

Figure 21 explains the tile numbering (tiles have 10° × 10° dimensions). The top-left tile is numbered ‘X00Y00’ (having top-left coordinates 180° E, 75° N), with the X and Y tile numbering increasing eastward and southward, respectively.

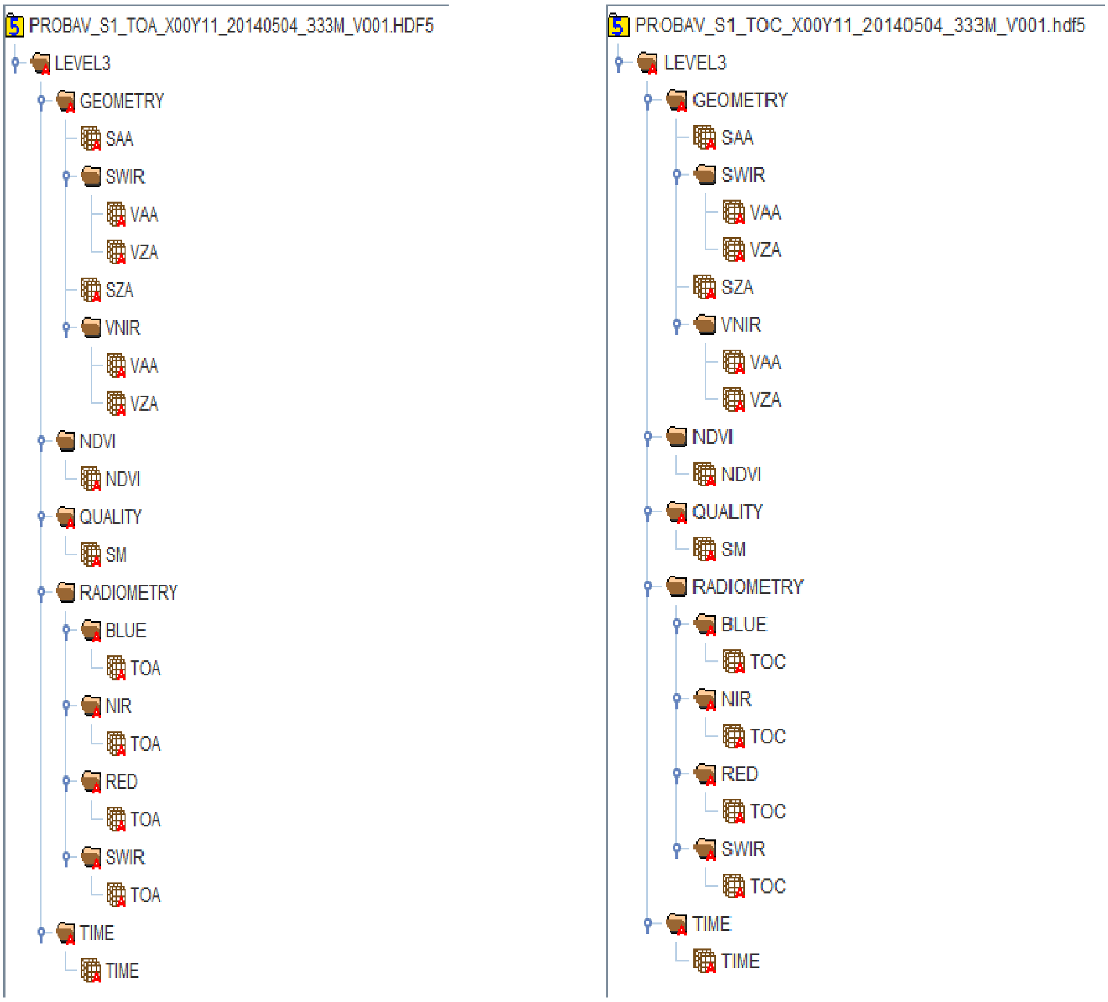

Figure 22: Dataset structure of S1 TOA (left) and TOC (right) product files.

The dataset structure is built around the Level 3 Main Group. Within this Main Group, the following Groups can be distinguished:

- **GEOMETRY**
  Contains the viewing and illumination geometry for each product pixel.

- **NDVI**
  Contains the Normalized Difference Vegetation Index (NDVI) for each product pixel.

- **QUALITY**
  Contains a quality state indicator for each product pixel, consisting of an observation indicator (clear, cloud, ice, shadow, undefined), a land/sea flag and a radiometric quality indicator.

- **RADIOMETRY**
  Contains the reflectance value for each product pixel, in Top of Atmosphere (TOA) or Top of Canopy (TOC) format.

- **TIME**
  Contains the date and time of observation, expressed as the number of minutes since the beginning of the synthesis period.

Figure 22 presents the entire dataset structure for the TOA and TOC Synthesis products. Detailed information on the Groups, Attributes, and Datasets is given in Appendix A2.

4.4. Data viewing and handling

The HDF5 file format is readable for most data interpretation languages, such as IDL, R, and Python. Further, applications exist to quickly view the data as images and to perform basic calculations on the data. Examples of such applications are HDFView and Quantum GIS.

4.4.1. DN value scaling

The reflectances that are provided in the L1C, S1, and S10 data files are presented as Digital Count Numbers (DN). This means that these numbers need to be converted in order to obtain reflectance values. The general formula to arrive at the Physical Value (PV) is:

$$PV = (DN - OFFSET) / SCALE$$

The SCALE and OFFSET parameters can be found in the BLUE, RED, NIR, and SWIR dataset attributes in the L1C, S1, and S10 files. Note that for the L1C files the SWIR channel data contains the observations for each of the three strips.

4.4.2. Opening HDF5 S1 and S10 in ENVI 5.2

From ENVI 5.2 onwards, PROBA-V HDF5 files are supported. Opening of the HDF5 files is done as follows:

- Click ‘File’ → ‘Open As’ → ‘PROBA-V’ → ‘Synthesis (S1 & S10)’, see Figure 23.
- The VNIR bands (RED, NIR, BLUE) of the PROBA-V HDF5 file are opened.

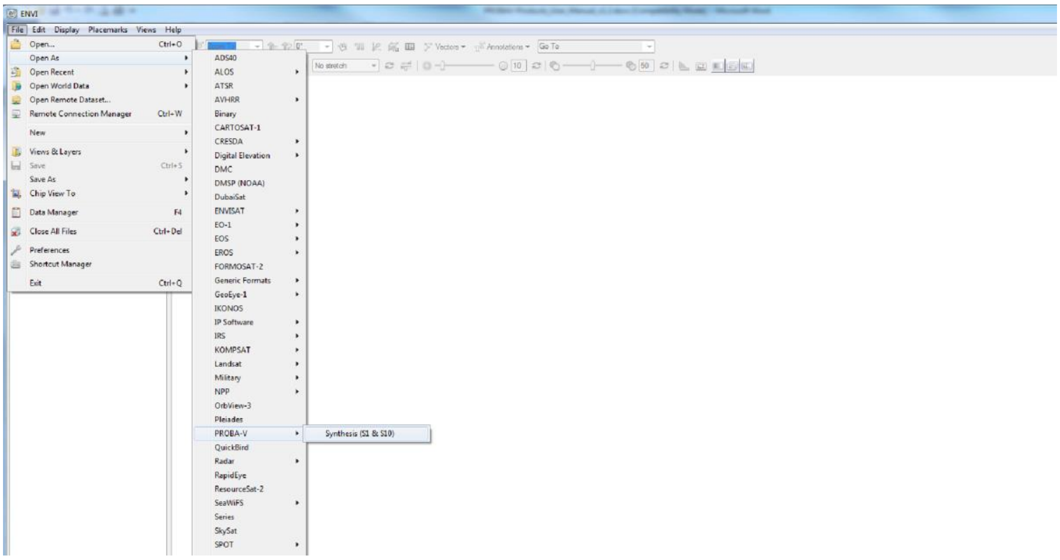

Figure 23: Opening a PROBA-V HDF5 file.

For further details on the image processing using ENVI 5.2, please consult the ENVI documentation.

4.4.3. Opening HDF5 in IDL

The example program below shows how to open a PROBA-V S1 synthesis HDF5 file in IDL and how to read the data.

```
PRO read_hdf5
    ;Open the HDF5 file.
    file = 'PROBAV_S1_TOA_X11Y07_20140607_300 m_V001.hdf5'
    file_id = H5F_OPEN(file)

    ;Open the image dataset within the file.
    dataset_id1 = H5D_OPEN(file_id, '/RADIOMETRY/BLUE/TOA')

    ;Read in the actual image data.
    image = H5D_READ(dataset_id1)

    H5D_CLOSE, dataset_id1
    H5F_CLOSE, file_id
end
```

4.4.4. Opening HDF5 in R

The example program below shows how to open a PROBA-V S10 synthesis HDF5 file and how to read the data in R, using the `h5r` package. Note that some alternative packages (such as `rhdf5`) exist, the syntax to open and read the HDF5 file will be slightly different.

```
read_hdf5 <-function(){
```

```
    require(h5r)

    filename <- "PROBAV_S1_TOA_X11Y07_20140607_300 m_V001.hdf5"

    #extract the HDF5 dataset
    h5 <- H5File(filename,'r')
    dblu  <- getH5Dataset(h5, "/LEVEL3/RADIOMETRY/BLUE/TOA")

    #get the image values and store into 3360 x 3360 matrix
    blue  <- array(readH5Data(dblu), c(3360, 3360))
}
```

4.4.5. Opening HDF5 in Python

The example program below shows how to open a PROBA-V S1 synthesis HDF5 file in Python, using the h5py and numpy packages.

```
#Import h5py library
Import h5py

#Open HDF5 file with h5py, read-write mode
h5f=h5py.File ('PROBAV_S1_TOA_X11Y07_20140607_300 m_V001.hdf5','r+')

#Use Python dictionary syntax to explore the HDF5 structure
h5f.keys()

#Get dimensions
h5f['/LEVEL3/RADIOMETRY/BLUE/TOA'].shape

#Get data type
h5f['/LEVEL3/RADIOMETRY/BLUE/TOA'].dtype

#Get value array
h5f['/LEVEL3/RADIOMETRY/BLUE/TOA'].value
```

4.4.6. Opening HDF5 in HDFView

The example below show how to open a PROBA-V S1 synthesis HDF5 file in HDFView (v2.10). After starting up HDFView, select a file, see Figure 24.

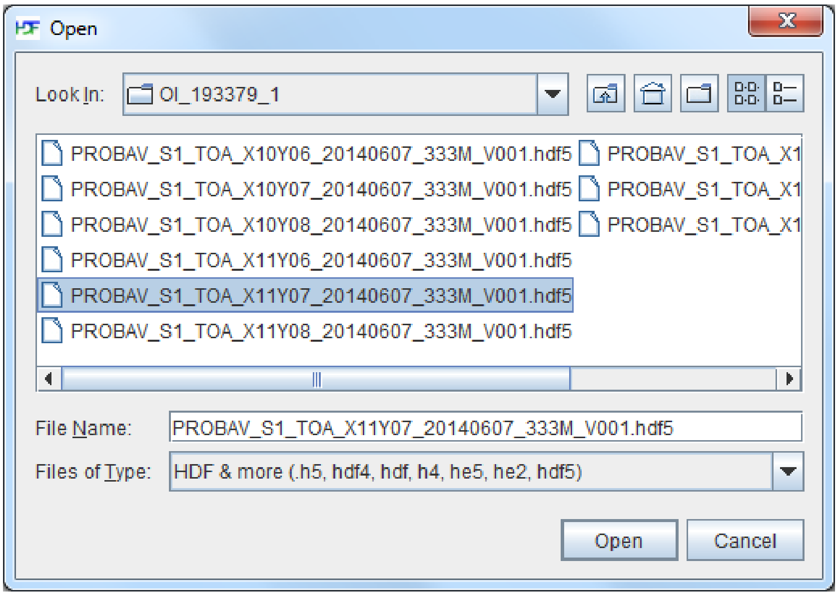

Figure 24: Dialog box for opening an HDF5 file in HDFView.

Upon opening the HDF5 file, the selected band data (in this case the BLUE band) can be viewed through right-clicking the band. Select ‘Open As’ (see Figure 25), which gives 2 options: open the data as a spreadsheet or view the data as an image

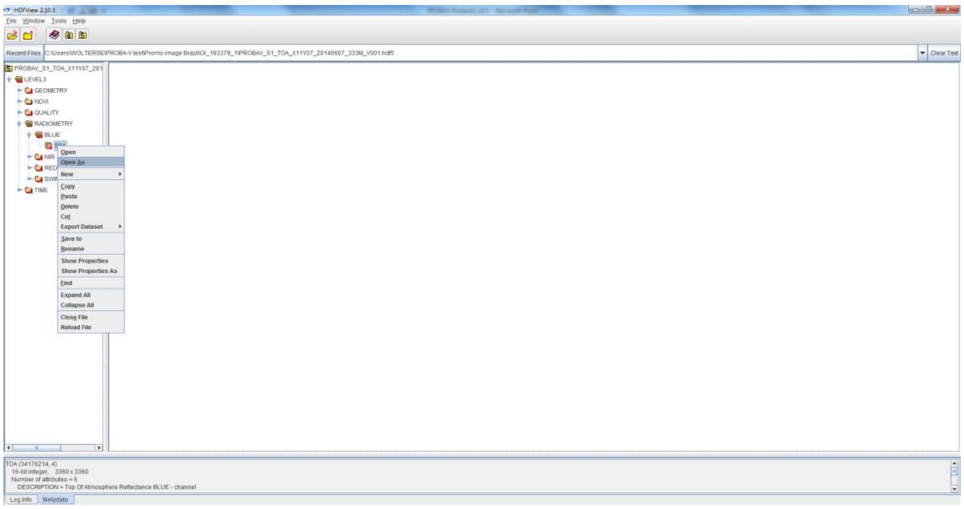

Figure 25: Band selection to open the dataset as either spreadsheet or image.

When selecting ‘Open As Image’, the user has to choose a color palette, see Figure 26. After clicking ‘OK’, the dataset is loaded and presented as an image. For further options and basic statistics to be calculated within HDFView, reference is made to the HDFView User Guide:

http://www.hdfgroup.org/products/java/hdfview/UsersGuide/

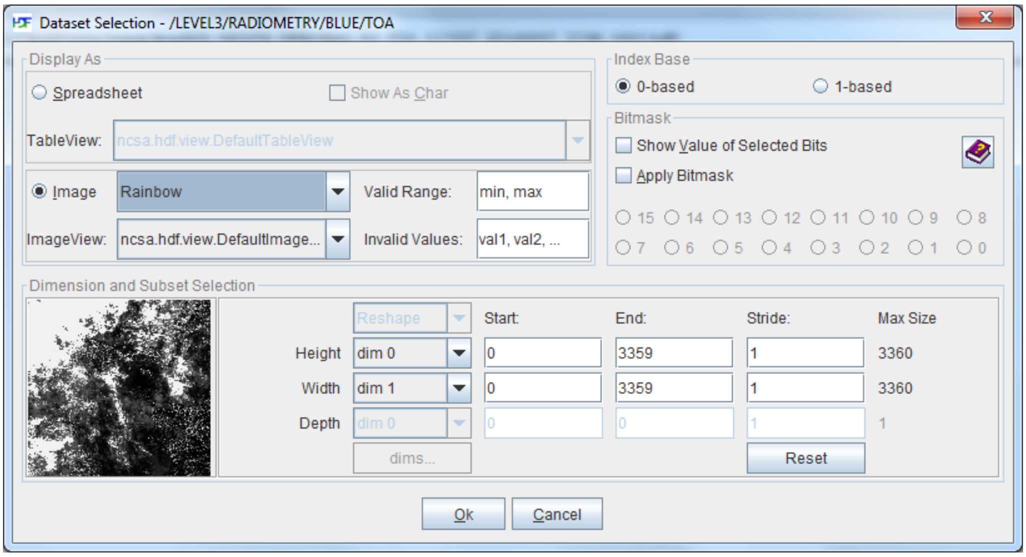

Figure 26: Selection of the color palette for image viewing.

4.4.7. Opening HDF5 in Quantum GIS

Below a short description on how to open a PROBA-V HDF5 file in Quantum GIS (version 2.2 Valmiera) is given.

In the Quantum GIS main screen, select the 'Open Raster' icon. A dialog box to select the raster file is opened, see Figure 27. Once the HDF5 file is opened, another dialog box for selecting one or more bands is opened, see Figure 28. In this example the BLUE band is selected for further viewing. After band selection, the proper coordinate reference system needs to be chosen, which is presented in Figure 29. Once these three steps have been completed, the band image is loaded and further actions can be performed.

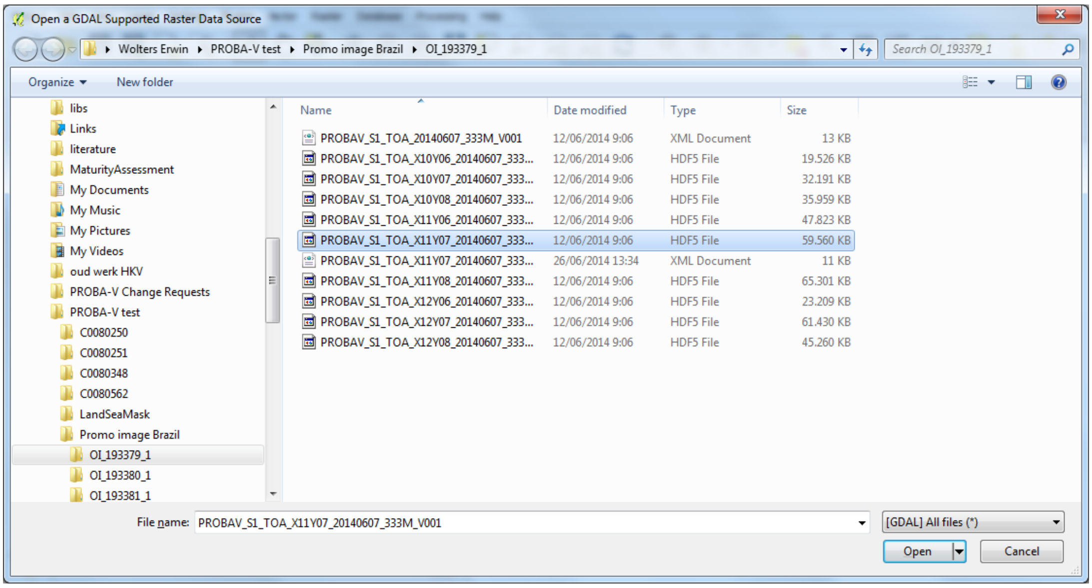

Figure 27: Dialog box for opening a raster file.

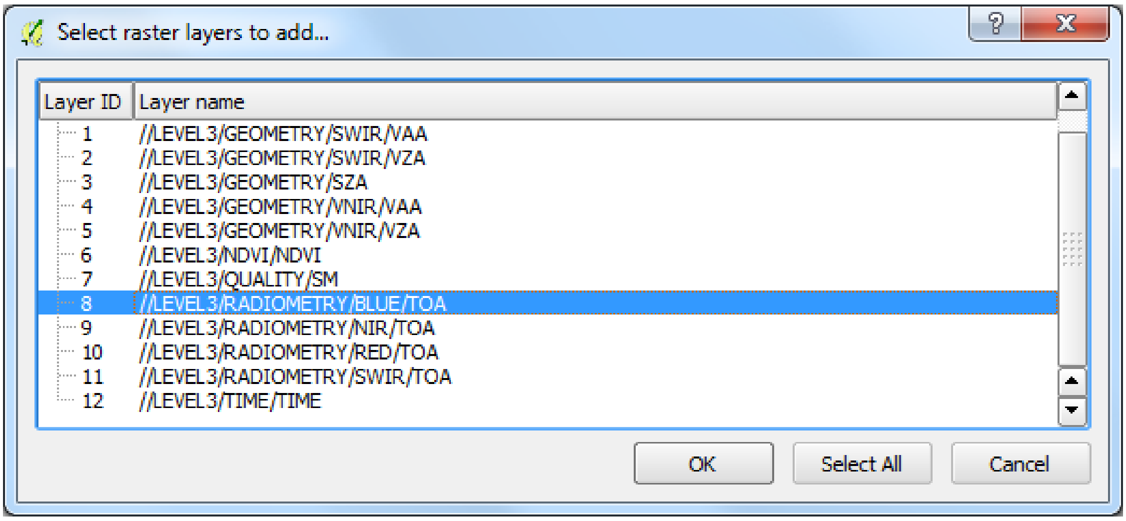

Figure 28: Selection of the BLUE band TOA data.

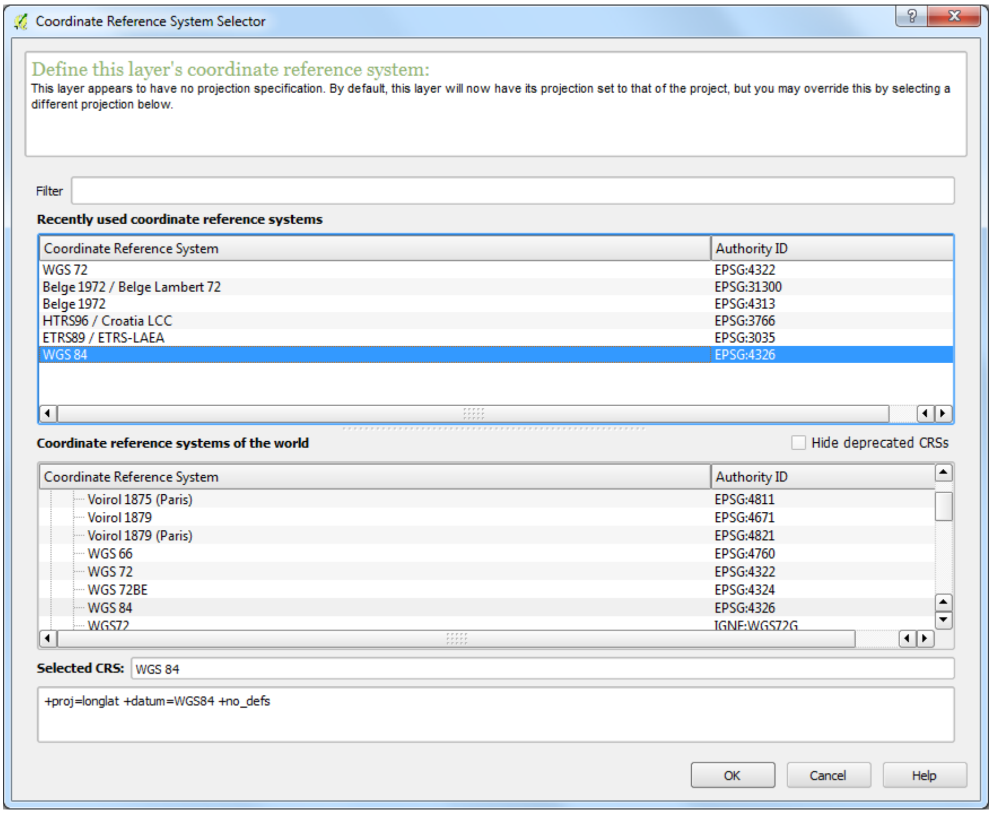

Figure 29: Selection of the WGS84 Coordinate Reference System.

It is noted that, although a CRS is selected, a discrepancy between the QGIS and HDF5 Geotie point definitions exists. This will result in the HDF5 image being displayed with image coordinates, rather than with the WGS84 lat/lon coordinates. In order to obtain proper overlays with e.g. vector files, the user is advised to download PROBA-V images in GeoTiff format or to open the HDF5 in GIS programs that are compliant with the HDF5 Geotie point definition (e.g. ENVI 5.2).

4.4.8. Opening HDF5 in SPIRITS

The 'Software for the Processing and Interpretation
of Remotely sensed Image Time Series' (SPIRITS) package (Eerens and Haesen, 2014) was developed at VITO and is a Windows-based software tool aiming at the analysis of remotely sensed earth observation data. Although it includes a wide range of general purpose functionalities, the focus is put on the processing of image time series, derived from various low- and medium-resolution sensors.

SPIRITS enables conversion of the PROBA-V HDF5 file format into the ENVI file format upon further viewing and processing. More details on the conversion and the SPIRITS software can be found in the SPIRITS Manual:

http://spirits.jrc.ec.europa.eu/files/SpiritsManual.pdf

5. Quality assurance

Both the Segment and Synthesis product files are delivered with quality indicators. Below, these indicators are shortly explained. Reference is made to Appendices A1 and A2 for the Segment and Synthesis files, respectively, for more detailed information.

5.1. Segment product files

For the Segment product (L1C files), the quality is indicated by the Q Dataset, which is located in the L1C STRIP Group (see Appendix A1 for more details). The pixel quality for the L1C data is decoded as 8-bit unsigned integers, the values and their meaning are given in Table 8.

Table 8: Explanation of the quality indicators in the Segment Product.

Status	Explanation
0	'Correct': no quality issues encountered
1	'Missing': the pixel value is missing due to a bad detector
2	'WasSaturated': the DN value of the pixel is equal to 4095 (coded in 12 bits =2^12-1)
3	'BecameSaturated': during the calculation of the TOA reflectance the value became higher than 4095
4	'BecameNegative': during the calculation of the TOA reflectance the value became lower than 0
5	'Interpolated': the value of the pixel radiance was interpolated using the neighbouring pixels
6	'BorderCompressed': the pixel quality is uncertain due to on-board compression artefacts

5.2. Synthesis product files

In the S1 and S10 product files, the quality indicator is located in the SM (Status Map) Dataset within the QUALITY Group. The SM Dataset contains a quality state indicator for each pixel, consisting of an observation indicator (clear, cloud, ice, shadow, undefined), a land/sea flag and a radiometric quality indicator. Table 9 lists the various quality values.

Table 9: Explanation of the quality indicators in the Status Map Dataset.

Bit (LSB to MSB)	Description	Value	Key
0-2	Cloud/Ice Snow/Shadow Flag	000 001 010 011 100	Clear Shadow Undefined Cloud Ice
3	Land/Sea	0 1	Sea Land
4	Radiometric quality SWIR flag	0 1	Bad Good
5	Radiometric quality NIR flag	0 1	Bad Good
6	Radiometric quality RED flag	0 1	Bad Good
7	Radiometric quality BLUE flag	0 1	Bad Good

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APPENDICES

Appendix A1: Detailed Segment Product file description

Below a detailed description of the Segment Product (L1C) files is given. Reference is made to Figure 20, which presents the dataset structure of the file.

Table 10: HDF5 structure of L1C product file.

Type	Name	Description	Data type
HDF5 Group	LEVEL1A	HDF5 group containing the Level1A data and meta data. The structure and content of this group is elaborated in Table 11.	See Table 11
HDF5 Group	LEVEL1B	HDF5 group containing the Level1B data and meta data. The structure and content of this group is elaborated in Table 12.	See Table 12
HDF5 Group	LEVEL1C	HDF5 group containing the Level1C data and meta data. The structure and content of this group is elaborated in Table 13.	See Table 13
HDF5 Attribute	ACQUISITION_STATION	Identifier for the data reception station (i.e., Kiruna or Fairbanks).	String
HDF5 Attribute	BOTTOM_LEFT_LATITUDE	The latitude of the bottom-left point of the bounding box [^{o}].	32-bit floating-point
HDF5 Attribute	BOTTOM_LEFT_LONGITUDE	The longitude of the bottom-left point of the bounding box [^{o}].	32-bit floating-point
HDF5 Attribute	BOTTOM_RIGHT_LATITUDE	The latitude of the bottom-right point of the bounding box [^{o}].	32-bit floating-point

HDF5 Attribute	BOTTOM_RIGHT_LONGITUDE	The longitude of the bottom-right point of the bounding box [°].	32-bit floating-point
HDF5 Attribute	CAMERA	Camera identifier. Possible values are: “LEFT” for the left camera (camera 1), “CENTER” for the center camera (camera 2), “RIGHT” for the right camera (camera 3)	String
HDF5 Attribute	DATELINE_CROSSING	Flag indicating whether or not the segment is crossing the dateline (180° border).	String
HDF5 Attribute	DAY_NIGHT_FLAG	Indicating whether or not the segment is a day segment or taken at night.	String
HDF5 Attribute	DEFECT_PIXELMAP_ID	Field identifying the defect pixel map.	32-bit integer
HDF5 Attribute	DESCRIPTION	Short description of the file content, i.e. “PROBA-V Level1C product”.	String
HDF5 Attribute	INSTRUMENT	Short name for the instrument, i.e. VEGETATION.	String
HDF5 Attribute	NORTHPOLE_INDICATOR	Flag indicating whether or not the segment is covering the north pole.	String
HDF5 Attribute	NUMBER_OF_STRIPS	The number of strips this product contains. This value is typically set to 6.	32-bit integer
HDF5 Attribute	OBSERVATION_END_DATE	The observation end date (UTC) of the segment. The format is: YYYY-MM-DD.	String
HDF5 Attribute	OBSERVATION_END_TIME	The observation end time (UTC) of the segment. The format is: hh:mm:ss.μμμμμμ.	String
HDF5 Attribute	OBSERVATION_START_DATE	The observation start date (UTC) of the segment. The format is: YYYY-MM-DD.	String
HDF5 Attribute	OBSERVATION_START_TIME	The observation start time (UTC) of the segment. The format is: hh:mm:ss.μμμμμμ.	String

HDF5 Attribute	OVERPASS_NUMBER	The overpass number.	32-bit integer
HDF5 Attribute	PLATFORM	Short name for the platform and its serial number, i.e. PROBA-1.	String
HDF5 Attribute	PROCESSING_DATE	The date the product was generated. The format is: YYYY-MM-DD.	String
HDF5 Attribute	PROCESSING_DATE	The time the product was generated. The format is: hh:mm:ss.μμμμμμ.	String
HDF5 Attribute	PRODUCT_REFERENCE	A unique textual reference to the product (type: string). This string has following syntax: RawSegment_PROBAV#<CAMERA>_<YYYYMMDD><hhmmss>_L1C_V<VERSION> Where: <CAMERA>: identifier for the camera (1, 2 or 3) <YYYYMMDD>: the observation start date <hhmmss>: the start observation start time <VERSION>: the version identifier (three digits)	String
HDF5 Attribute	ROI_IDENTIFIER	Identifier for the Region Of Interest. If the Level1C product is a full swath product, it contains the value "FULL_SWATH".	String
HDF5 Attribute	SOUTHPOLE_INDICATOR	Flag indicating whether or not the segment is covering the south pole.	String
HDF5 Attribute	TOP_LEFT_LATITUDE	The latitude of the top-left point of the bounding box [°].	32-bit floating-point
HDF5 Attribute	TOP_LEFT_LONGITUDE	The longitude of the top-left point of the bounding box [°].	32-bit floating-point
HDF5 Attribute	TOP_RIGHT_LATITUDE	The latitude of the top-right point of the bounding box [°].	32-bit floating-point
HDF5 Attribute	TOP_RIGHT_LONGITUDE	The longitude of the top-right point of the bounding box [°].	32-bit floating-point

Table 11: HDF5 structure of LEVEL1A Group.

Type	Name	Description
HDF5 Group	PLATFORM	HDF5 group containing the platform data and ancillary data that is applicable for this segment. The content and structure of this group is elaborated in Table 12.
HDF5 Group	BLUE	HDF5 group containing the instrument data and meta data for the BLUE strip.The structure and content of this group is elaborated in Table 13.
HDF5 Group	NIR	HDF5 group containing the instrument data and meta data for the NIR strip. The structure and content of this group is elaborated in Table 13.
HDF5 Group	RED	HDF5 group containing the instrument data and meta data for the RED strip. The structure and content of this group is elaborated in Table 13.
HDF5 Group	SWIR1	HDF5 group containing the instrument data and meta data for the SWIR1 strip. The structure and content of this group is elaborated in Table 13.
HDF5 Group	SWIR2	HDF5 group containing the instrument data and meta data for the SWIR2 strip. The structure and content of this group is elaborated in Table 13.
HDF5 Group	SWIR3	HDF5 group containing the instrument data and meta data for the SWIR3 strip. The structure and content of this group is elaborated in Table 13.

Table 12: HDF5 structure of PLATFORM Group

Type	Name	Description
HDF5 Table	ATT	Table containing the attitude-related data with a frequency of 4 Hz. The table consists of the following fields: • MJD: the Modified Julian Date in TAI (Temps Atomique International, data type: 64-bit floating-point). • QW: the first quaternion (BodyFixed frame (BOF) to Celestial frame (CEL), data type: 64-bit floating-point). • QX: the second quaternion (BodyFixed frame (BOF) to Celestial frame (CEL), data type: 64-bit floating-point). • QY: the third quaternion (BodyFixed frame (BOF) to Celestial frame (CEL), data type: 64-bit floating point). • QZ: the fourth quaternion (BodyFixed frame (BOF) to Celestial frame (CEL), data type: 64-bit floating-point). The table contains following attributes: • FREQUENCY: the frequency [Hz] at which the ATT data is generated (data type: 32-bit floating-point). • VERSION: the version number (data type: string). Every field of the table contains following attributes: • DESCRIPTION: short description of the field content (data type: string) • NAME: the name of the field (data type: string) • UNITS: the units or "-" in case no units are available (data type: string).
HDF5 Table	OBET_ GPS	Table containing the time correlation data between OBET and GPS with a frequency of 1 Hz. The table consists of following fields: • OBET: the OBET time [s] (data type: 64-bit floating-point) • GPS_WEEK: the GPS week time (data type: 16-bit integer) • GPS_SECONDS: the GPS second time [s] (data type: 64-bit floating point) The table contains the following attributes: • FREQUENCY: the frequency [Hz] at which the time correlation related data is generated (data type: 32-bit floating-point). • VERSION: the version number (data type: string). Every field of the table contains the following attributes: • DESCRIPTION: short description of the field content (data type: string) • NAME: the name of the field (data type: string) • UNITS: the units or "-" in case no units are available (data type: string).
HDF5 Table	OBET_ VI	Table containing the time correlation data between OBET and VI (Vegetation Instrument) with a frequency of 1 Hz. The table consists of following fields: • OBET: the OBET time [s] (data type: 64-bit floating-point). • VI: the VI time [s] (data type: 64-bit floating-point). The table contains following attributes: • FREQUENCY: the frequency [Hz] at which the time correlation related data is generated (data type: 32-bit floating-point).

		Every field of the table contains following attributes: • DESCRIPTION: short description of the field content (data type: string) • NAME: the name of the field (data type: string) • UNITS: the units or "-" in case no units are available (data type: string).
HDF5 Table	PRM	Table including any housekeeping telemetry generated by the Vegetation Instrument. The data has a frequency of 1 Hz. The table consists of following fields: • MJD: the Modified Julian Date in TAI [d] (Temps Atomique International, data type: 64-bit floating-point). • TIME_OUT_ECLIPSE: the time since out of eclipse (delta) [s] (data type: 32-bit integer). The special value 0 means in eclipse and the value -1 means NO VALUE. • VI_1 : VI Temperature TMA of left spectral imager (data type: 32-bit unsigned integer). • VI_2 : VI Temperature TMA of central spectral imager (data type: 32-bit unsigned integer) • VI_3 : VI Temperature TMA of right spectral imager (data type: 32-bit unsigned integer) • VI_4 : VI parameter 4 TBD (data type: 32-bit unsigned integer) • VI_5: VI parameter 5 TBD (data type: 32-bit unsigned integer) • VI_6: VI parameter 6 TBD (data type: 32-bit unsigned integer) • VI_7: VI parameter 7 Temperature: Optical bench near star tracker (data type: 32-bit unsigned integer) • VI_8: VI parameter 8 Temperature: Left SWIR detector (data type: 32-bit unsigned integer) • VI_9: VI parameter 9 Temperature: Central SWIR detector (data type: 32-bit unsigned integer) • VI_10: VI parameter 10 Temperature: Right SWIR detector (data type: 32-bit unsigned integer) • VI_11: VI parameter 11 Temperature: Left VNIR detector (data type: 32-bit unsigned integer) • VI_12: VI parameter 12 Temperature: Central VNIR detector (data type: 32-bit unsigned integer) • VI_13: VI parameter 13 Temperature: Right VNIR detector (data type: 32-bit unsigned integer) • VI_14: VI parameter 14 Temperature: Left flexure (data type: 32-bit unsigned integer) • VI_15: VI parameter 15 Temperature: Central flexure (data type: 32-bit unsigned integer) • VI_16:VI parameter 16 Temperature: Right flexure (data type: 32-bit unsigned integer) • SPARE_1: spare parameter TBD (data type: 32-bit unsigned integer) • SPARE_2: spare parameter TBD (data type: 32-bit unsigned integer) • SPARE_3: spare parameter TBD (data type: 32-bit unsigned integer) • SPARE_4: spare parameter TBD (data type: 32-bit unsigned integer) • SPARE_5: spare parameter TBD (data type: 32-bit unsigned integer) • SPARE_6: spare parameter TBD (data type: 32-bit unsigned integer) • SPARE_7: spare parameter TBD (data type: 32-bit unsigned integer)

		• SPARE_8: spare parameter TBD (data type: 32-bit unsigned integer) • SPARE_9: spare parameter TBD (data type: 64-bit unsigned integer) • SPARE_10: spare parameter TBD (data type: 64-bit unsigned integer) • SPARE_11: spare parameter TBD (data type: 64-bit unsigned integer) • SPARE_12: spare parameter TBD (data type: 64-bit unsigned integer) • SPARE_13: spare parameter TBD (data type: 64-bit unsigned integer) • SPARE_14: spare parameter TBD (data type: 64-bit unsigned integer) • SPARE_15: spare parameter TBD (data type: 64-bit unsigned integer) • SPARE_16: spare parameter TBD (data type: 64-bit unsigned integer) The table contains following attributes: • FREQUENCY: the frequency [Hz] (data type: 32-bit floating-point). • PACKET_EDITION: the packet edition (data type: 32-bit integer) • VERSION: the current version (data type:string) Every field of the table contains following attributes: • DESCRIPTION: short description of the field content (type: string) • NAME: the name of the field (type: string) • UNITS: the units (type: string)
HDF5 Table	PV	Table containing the position and velocity related data with a frequency of 1 Hz. The table consists of the following fields: • MJD: the Modified Julian Date in TAI (Temps Atomique International, data type: 64-bit floating-point) • PX: the position in the X direction in the Terrestrial frame (TER) [m] (data type: 64-bit floating-point). • PY: the position in the Y direction in the Terrestrial frame (TER) [m] (data type: 64-bit floating-point). • PZ: the position in the Z direction in the Terrestrial frame (TER) [m] (data type: 64-bit floating-point). • VX: the velocity in the X direction in the Terrestrial frame (TER) [m s^{-1}] (data type: 64-bit floating-point). • VY: the velocity in the Y direction in the Terrestrial frame (TER) [m s^{-1}] (data type: 64-bit floating-point). • VZ: the velocity in the Z direction in the Terrestrial frame (TER) [m s^{-1}] (data type: 64-bit floating-point). The table contains following attributes: • FREQUENCY: the frequency [Hz] at which the PV data is generated (data type: 32-bit floating-point). • VERSION: the version number (data type: string). Every field of the table contains following attributes: • DESCRIPTION: short description of the field content (data type: string) • NAME: the name of the field (data type: string) • UNITS: the units (data type: string)

Table 13: HDF5 structure of LEVEL1A STRIP (BLUE, RED, NIR, SWIR1, SWIR2, and SWIR3) Groups.

Type	Name	Description	Data type
HDF5 Table	BLOCKDATA	Table containing the block related data. The table consists of following fields: • MJD: the Modified Julian Date in TAI (Temps Atomique International), [d] (data type: 64-bit floating-point). • INTEGRATION_TIME: the integration time [s] (data type: 32-bit floating point) • TEMPERATURE: the temperature • [° C] (data type: 32-bit floating-point) • DARK_PIXEL_1: the dark pixel value for pixel 3 (data type: 16-bit integer) • DARK_PIXEL_2: the dark pixel value for pixel 4 (data type: 16-bit integer) • DARK_PIXEL_3: the dark pixel value for pixel 5997 (data type: 16-bit integer) • DARK_PIXEL_4: the dark pixel value for pixel 5998 (data type: 16-bit integer) Each field contains following attributes: • DESCRIPTION: short description of the field content (data type: string) • NAME: the name of the field (data type: string) • UNITS: the units (data type: string) **Note:** there are no BLOCKDATA dataset for the SWIR strips (SWIR1, SWIR2, SWIR3)	See Description
HDF5 Table	LINEDATA	Table containing the line related data. The table consists of the following fields: • MJD: the Modified Julian Date in TAI (Temps Atomique International) [d] associated with the centre of the integration period (data type: 64-bit floating-point). • LINE_QUALITY: line flag (data type: 32-bit integer) indicating whether a	See Description

Type	Name	Description	Data type
		line is : - good (flag = 0) - bad (flag = 1) - missing (flag = 2) • INTEGRATION_TIME: the integration time [s] (data type: 32-bit floating-point) • TIME_OUT_ECLIPSE: the time since out of eclipse (delta) [s] (data type: 32-bit integer). The special value "0" means in eclipse and the value "-9999" means NO_DATA. • TEMPERATURE: the temperature • [^{o} C] (data type: 32-bit floating-point) (NO_DATA = -9999) Further, every field of the table contains following attributes: • DESCRIPTION: short description of the field content (data type: string) • NAME: the name of the field (data type: string) • NO_DATA: the "no data" value (type: 32-bit floating-point or 32-bit integer). This attribute is optional in case no "no data" value is applicable for the field. • UNITS: the used units (type: string)	
HDF5 Dataset	DN	Dataset containing the digital numbers (extracted from the raw data). Table 14 lists the meta data items attached to this dataset.	16-bit integer
HDF5 Attribute	COMPRESSION_RATIO	The used compression ratio.	32-bit floating-point
HDF5 Attribute	DETECTOR	Identifier for the detector. Possible values are: VNIR, SWIR	String
HDF5 Attribute	GAIN_FACTOR	The gain factor.	32-bit floating-point
HDF5 Attribute	LINE_END	The end line of the bottom-right pixel value in the image.	32-bit integer
HDF5 Attribute	LINE_START	The start line of the top-left pixel value (0, 0) in the image. In case the image contains the full swatch, this value is set to 0.	32-bit integer
HDF5 Attribute	OBSERVATION_END_DATE	The observation end date (UTC), i.e. the date of the last line of the strip. The format is: YYYY-MM-DD.	String

Type	Name	Description	Data type
HDF5 Attribute	OBSERVATION_END_ TIME	The observation end time (UTC), i.e., the time of the last line of the strip. The format is: hh:mm:ss.µµµµµµ.	String
HDF5 Attribute	OBSERVATION_START_ DATE	The observation start date (UTC), i.e., the date of the first line of the strip. The format is: YYYY-MM-DD.	String
HDF5 Attribute	OBSERVATION_START_ TIME	The observation start time (UTC), i.e., the time of the first line of the strip. The format is: hh:mm:ss.µµµµµµ.	String
HDF5 Attribute	PIXEL_END	The end index of the bottom-right pixel value in the image. In case the image contains the full swath, this value is set to: 5199 for the VNIR strips 1023 for the SWIR strips	32-bit integer
HDF5 Attribute	PIXEL_START	The start index of the top-left pixel value (0, 0) in the image. In case the image contains the full swatch, this value is set to 0.	32-bit integer
HDF5 Attribute	STRIP	Identifier for the strip. Possible values are: BLUE, RED, NIR, SWIR1 (left SWIR strip), SWIR2 (center SWIR strip), SWIR3 (right SWIR strip)	String

Table 14: HDF5 metadata items for DN datasets.

Type	Name	Description	Data type
HDF5 Attribute	DESCRIPTION	Description of the DN dataset name.	String
HDF5 Attribute	MAPPING	The mapping information, consisting of following values: • **<proj_id>**: the projection ID (e.g. "Geographic Lat/Lon") • **<x_m>**: A value indicating whether the map X coordinates refer to the top-left corner (0.0) or center (0.5) of the pixel. • **<y_m>**: A value indicating whether the map Y coordinates refer to the top-left corner (0.0) or center (0.5) of the pixel. • **<x_start>**: the X coordinate of the upper-left pixel. • **<y_start>**: the Y coordinate of the upper-left pixel. • **<x_res>**: the spatial resolution in the X direction. • **<y_res>**: the spatial resolution in the Y direction. • **<datum>**: the projection's datum (in case of unprojected image, the value is '-'). • **<units>**: the projection 's unit (in case of an unprojected image, the value is '-'). Note that his is an optional attribute. If not provided, it is assumed that no geographical information is attached to the dataset.	String
HDF5 Attribute	NO_DATA	Indicates the "no data" value of the dataset. This value has been set to "-1".	32-bit floating-point
HDF5 Attribute	OFFSET	OFFSET values (see SCALE attribute)	32-bit floating-point
HDF5 Attribute	SCALE	The coding information, indicating that the pixels have been scaled with a given scale and offset according to following formula: OUT = OFFSET + IN * SCALE • The scale factor • The offset factor The physical value is determined as IN = (OUT-OFFSET)/SCALE.	32-bit floating-point

Table 15: HDF5 structure of LEVEL1B group.

Type	Name	Description	Data type
HDF5 Table	CONTOUR	Table containing the contour points of the segment. The table contains two fields: • The longitude values of the segment's contour. • The latitude values of the segment's contour. This contour is the contour that encloses all the strip contours.	32-bit floating point
HDF5 Group	BLUE	HDF5 group containing the instrument data and metadata for the BLUE strip. The structure and content of this group is elaborated in Table 16.	See Table 16
HDF5 Group	NIR	HDF5 group containing the instrument data and metadata for the NIR strip. The structure and content of this group is elaborated in Table 16.	See Table 16
HDF5 Group	RED	HDF5 group containing the instrument data and metadata for the RED strip. The structure and content of this group is elaborated in Table 16.	See Table 16
HDF5 Group	SWIR1	HDF5 group containing the instrument data and metadata for the SWIR1 strip. The structure and content of this group is elaborated in Table 16.	See Table 16
HDF5 Group	SWIR2	HDF5 group containing the instrument data and metadata for the SWIR2 strip. The structure and content of this group is elaborated in Table 16.	See Table 16
HDF5 Group	SWIR3	HDF5 group containing the instrument data and metadata for the SWIR3 strip. The structure and content of this group is elaborated in Table 16.	See Table 16
HDF5 Attribute	ICP_REFERENCE	Reference to the used geometric ICP file. This string has the following syntax: PROBAV_ICP_GEOMETRIC#{LEFT|RIGHT|CENTER}_<StartDate>_V<Revision>	String
HDF5 Attribute	LEAPSECONDS	Leap second =TAI-UTC [s].	32-bit floating point
HDF5 Attribute	POLARMOTION_DELTA_UT1	The difference between UT1 and UTC (UT1-UTC), [s].	32-bit floating point

HDF5 Attribute	POLARMOTION_X	X: The X position of the Celestial Intermediate Pole (CIP) and the Celestial/Terrestrial Ephemeris Origins (CEO, TEO) in the Geocentric Celestial Reference System (GCRS) and International Terrestrial Reference System (ITRS) [sec].	32-bit floating point
HDF5 Attribute	POLARMOTION_Y	Y: The Y position of the Celestial Intermediate Pole (CIP) and the Celestial/Terrestrial Ephemeris Origins (CEO, TEO) in the Geocentric Celestial Reference System (GCRS) and International Terrestrial Reference System (ITRS) [sec].	32-bit floating point
HDF5 Attribute	PROCESSINGINFO_ GEOMODELLING	Reference to the used geo-modelling tool, e.g. “GEOMODELLING V1.0”.	String
HDF5 Attribute	SUN_BETA_ANGLE	The sun beta angle [^{o}].	32-bit floating point

Table 16: HDF5 structure of LEVEL1B STRIP (BLUE, NIR, RED, SWIR1, SWIR2, and SWIR3) Groups.

Type	Name	Description	Data type
HDF5 Table	CONTOUR	Table containing the contour points of the strip. The table contains: • Longitude, the longitude values of the segment's contour • Latitude, the latitude values of the segment's contour	32-bit floating point
HDF5 Dataset	LN1	Dataset containing the longitude at 0 m altitude. Table 17 lists the meta data items specific for this dataset.	32-bit floating-point
HDF5 Dataset	LN2	Dataset containing the longitude at 5000 m altitude. Table 17 lists the meta data items specific for this dataset.	32-bit floating-point
HDF5 Dataset	LT1	Dataset containing the latitude at 0 m altitude. Table 17 lists the meta data items specific for this dataset.	32-bit floating-point
HDF5 Dataset	LT2	Dataset containing the latitude at 5000 m altitude. Table 17 lists the meta data items specific for this dataset.	32-bit floating-point
HDF5 Dataset	SAA	Dataset containing the solar azimuth angles. Table 17 lists the meta data items specific for this dataset.	8-bit unsigned integer
HDF5 Dataset	SZA	Dataset containing the solar SZA. Table 17 lists the meta data items specific for this dataset.	8-bit unsigned integer
HDF5 Dataset	VAA	Dataset containing the viewing azimuth angles. Table 17 lists the meta data items specific for this dataset.	8-bit unsigned integer
HDF5 Dataset	VZA	Dataset containing the VZA. Table 17 lists the meta data items specific for this dataset.	8-bit unsigned integer
HDF5 Attribute	BOTTOM_LEFT_CORNER_LATITUDE	The latitude of the bottom-left corner point of the strip [^{o}].	32-bit floating-point
HDF5 Attribute	BOTTOM_LEFT_CORNER_LONGITUDE	The longitude of the bottom-left corner point of the strip [^{o}].	32-bit floating-point
HDF5 Attribute	BOTTOM_LEFT_CORNER_X	The X position of the bottom-left corner point of the strip.	32-bit floating-point
HDF5 Attribute	BOTTOM_LEFT_CORNER_Y	The Y position of the bottom-left corner point of the strip.	32-bit floating-point
HDF5 Attribute	BOTTOM_RIGHT_CORNER_LATITUDE	The latitude of the bottom-right corner point of the strip [^{o}].	32-bit floating-point

HDF5 Attribute	BOTTOM_RIGHT_CORNER_LONGITUDE	The longitude of the bottom-right corner point of the strip [°].	32-bit floating-point
HDF5 Attribute	BOTTOM_RIGHT_CORNER_X	The X position of the bottom-right corner point of the strip.	32-bit floating-point
HDF5 Attribute	BOTTOM_RIGHT_CORNER_Y	The Y position of the bottom-right corner point of the strip.	32-bit floating-point
HDF5 Attribute	CENTER_LATITUDE	The latitude of the center point of the strip [°].	32-bit floating-point
HDF5 Attribute	CENTER_LONGITUDE	The longitude of the center point of the strip [°].	32-bit floating-point
HDF5 Attribute	CENTER_X	The X position of the center point of the strip.	32-bit floating-point
HDF5 Attribute	CENTER_Y	The Y position of the center point of the strip.	32-bit floating-point
HDF5 Attribute	DETECTOR	Identifier for the detector. Possible values are: VNIR, SWIR	String
HDF5 Attribute	OBSERVATION_END_DATE	The observation end date (UTC), i.e., the date of the last line of the strip. The format is: YYYY-MM-DD.	String
HDF5 Attribute	OBSERVATION_END_TIME	The observation end time (UTC), i.e. the time of the last line of the strip. The format is: hh:mm:ss.μμμμμμ.	String
HDF5 Attribute	OBSERVATION_START_DATE	The observation start date (UTC), i.e., the date of the first line of the strip. The format is: YYYY-MM-DD.	String
HDF5 Attribute	OBSERVATION_START_TIME	The observation start time (UTC), i.e., the time of the first line of the strip. The format is: hh:mm:ss.μμμμμμ.	String
HDF5 Attribute	STRIP	Identifier for the strip. Possible values are: BLUE, RED, NIR, SWIR1 (left SWIR strip), SWIR2 (center SWIR strip), SWIR3 (right SWIR strip).	String
HDF5 Attribute	TOP_LEFT_CORNER_LATITUDE	The latitude of the top-left corner point of the strip [°].	32-bit floating-point
HDF5 Attribute	TOP_LEFT_CORNER_LONGITUDE	The longitude of the top-left corner point of the strip [°].	32-bit floating-point
HDF5 Attribute	TOP_LEFT_CORNER_X	The X position of the top-left corner point of the strip.	32-bit floating-point
HDF5 Attribute	TOP_LEFT_CORNER_Y	The Y position of the top-left corner point of the strip.	32-bit floating-point
HDF5 Attribute	TOP_RIGHT_CORNER_LATITUDE	The latitude of the top -right corner point of the strip [°].	32-bit floating-point
HDF5 Attribute	TOP_RIGHT_CORNER_LONGITUDE	The longitude of the top-right corner point of the strip [°].	32-bit floating-point
HDF5 Attribute	TOP_RIGHT_CORNER_X	The X position of the top-right corner point of the strip.	32-bit floating-point

HDF5 Attribute	TOP_RIGHT_CORNER_Y	The Y position of the top-right corner point of the strip.	32-bit floating-point

Table 17: HDF5 meta data items for L1B datasets.

Type	Name	Description	Data type
HDF5 Attribute	DESCRIPTION	Description of the dataset.	String
HDF5 Attribute	MAPPING	The mapping information, consisting of following values: • **<proj_id>**: the projection ID (e.g. “Geographic Lat/Lon”) • **<x_m>**: A value indicating whether the map X coordinates refer to the top-left corner (0.0) or center (0.5) of the pixel. • **<y_m>**: A value indicating whether the map Y coordinates refer to the top-left corner (0.0) or center (0.5) of the pixel. • **<x_start>**: the X coordinate of the upper-left pixel. • **<y_start>**: the Y coordinate of the upper-left pixel. • **<x_res>**: the spatial resolution in the X direction. • **<y_res>**: the spatial resolution in the Y direction. • **<datum>**: the projection‘s datum (in case of unprojected image, the value is ‘-’). • **<units>**: the projection ‘s unit (in case of unprojected image, the value is ‘-’). Note that his is an optional attribute. If not provided, it is assumed that no geographical information is attached to the dataset.	String
HDF5 Attribute	NO_DATA	Indicates the “no data” value of the dataset. Typically, this value is set to “-9999”. This attribute is optional, meaning that in case the attribute is not present, no “no data” value is applicable for the dataset.	String
HDF5 Attribute	OFFSET	OFFSET values (see SCALE attribute)	32-bit floating-point

HDF5 Attribute	SCALE	The coding information, indicating that the pixels have been scaled with a given scale and offset according to following formula: OUT = OFFSET + IN * SCALE • The scale factor • The offset factor The physical value is determined as IN = (OUT-OFFSET)/SCALE.	32-bit floating-point
HDF5 Attribute	UNIT	Unit type of the dataset (if not applicable the values '-' is used)	String

Table 18: HDF5 structure of LEVEL1C group.

Type	Name	Description	Data type
HDF5 Group	BLUE	HDF5 group containing the instrument data and metadata for the BLUE strip. The structure and content of this group is elaborated in Table 19.	See Table 19
HDF5 Group	NIR	HDF5 group containing the instrument data and metadata for the NIR strip. The structure and content of this group is elaborated in Table 19.	See Table 19
HDF5 Group	RED	HDF5 group containing the instrument data and metadata for the RED strip. The structure and content of this group is elaborated in Table 19.	See Table 19
HDF5 Group	SWIR1	HDF5 group containing the instrument data and metadata for the SWIR1 strip. The structure and content of this group is elaborated in Table 19.	See Table 19
HDF5 Group	SWIR2	HDF5 group containing the instrument data and metadata for the SWIR2 strip. The structure and content of this group is elaborated in Table 19.	See Table 19
HDF5 Group	SWIR3	HDF5 group containing the instrument data and metadata for the SWIR3 strip. The structure and content of this group is elaborated in Table 19.	See Table 19
HDF5 Attribute	ICP_REFERENCE	Reference to the used radiometric ICP file. This string has following syntax: PROBAV_ICP_RADIOMETRIC#{LEFT|RIGHT|CENTER}_<StartDate>_V<Revision>	String
HDF5 Attribute	PROCESSINGINFO_RADIOMODELLING	Reference to the used radio modelling tool.	String

Table 19: HDF5 structure of LEVEL1C STRIP (BLUE, NIR, RED, SWIR1, SWIR2, and SWIR3) Groups.

Type	Name	Description	Data type
HDF5 Dataset	Q	Dataset containing the quality indicator values. Every pixel is decoded in an 8-bit integer value. • status = 1 ‘Missing’ : the pixel value is missing due to a bad detector • status = 2 ‘WasSaturated’ : the value DN of the pixel is equal to 4095 (coded in 12 bits =2^12) • status = 3 ‘BecameSaturated’ : during the calculation of the TOA reflectance, the value becomes higher than 4095 • status = 4 ‘BecameNegative’ : during the calculation of the TOA reflectance, the value becomes lower than 0 • status = 5 ‘Interpolated’ : the value of the radiance of the pixel is interpolated using the neighbour pixels • status = 6 ‘BorderCompressed: the quality of theses pixels of a strip are uncertain due to on-board compression artefacts. • status = 0 ‘Correct’ : if none of these qualities is assigned to the pixel Table 20 lists the meta data items specific for this dataset.	See Table 20
HDF5 Dataset	TOA	Dataset containing the Top Of Atmosphere (TOA) reflectance values. Every pixel is decoded as a 16-bit integer value. Table 20 lists the meta data items specific for this dataset.	See Table 20
HDF5 Attribute	DETECTOR	Identifier for the detector. Possible values are: VNIR, SWIR	String

HDF5 Attribute	OBSERVATION_END_DATE	The observation end date (UTC), i.e. the date of the last line of the strip. The format is: YYYY-MM-DD.	String
HDF5 Attribute	OBSERVATION_END_TIME	The observation end time (UTC), i.e. the time of the last line of the strip. The format is: hh:mm:ss.µµµµµµ.	String
HDF5 Attribute	OBSERVATION_START_DATE	The observation start date (UTC), i.e. the date of the first line of the strip. The format is: YYYY-MM-DD.	String
HDF5 Attribute	OBSERVATION_START_TIME	The observation start time (UTC), i.e. the time of the first line of the strip. The format is: hh:mm:ss.µµµµµµ.	String
HDF5 Attribute	SOLAR_IRRADIANCE	The solar Top-Of-Atmosphere irradiance.	32-bit floating point
HDF5 Attribute	STRIP	Identifier for the strip (type: string). Possible values are: BUE, RED, NIR, SWIR1 (left SWIR strip), SWIR2 (center SWIR strip), SWIR3 (right SWIR strip)	String

Table 20: HDF5 meta data items for the L1C attributes.

Type	Name	Description	Data type
HDF5 Attribute	DESCRIPTION	Short description of the dataset.	String
HDF5 Attribute	MAPPING	The mapping information, consisting of following values: • **<proj_id>**: the projection ID (e.g. "Geographic Lat/Lon") • **<x_m>**: A value indicating whether the map X coordinates refer to the top-left corner (0.0) or center (0.5) of the pixel. • **<y_m>**: A value indicating whether the map Y coordinates refer to the top-left corner (0.0) or center (0.5) of the pixel. • **<x_start>**: the X coordinate of the upper-left pixel. • **<y_start>**: the Y coordinate of the upper-left pixel. • **<x_res>**: the spatial resolution in the X direction. • **<y_res>**: the spatial resolution in the Y direction. • **<datum>**: the projection's datum (in case of unprojected image, the value is '-'). • **<units>**: the projection 's unit (in case of unprojected image, the value is '-'). Note that his is an optional attribute. If not provided, it is assumed that no geographical information is attached to the dataset.	String
HDF5 Attribute	NO_DATA	The no data value.	32-bit floating-point
HDF5 Attribute	OFFSET	The offset factor. The physical value (PV) is calculated as PV = (DN-offset)/scale (DN digital number)	32-bit floating-point
HDF5 Attribute	SCALE	The scale factor. The physical value (PV) is calculated as PV = (DN-offset)/scale (DN digital number)	32-bit floating-point
HDF5 Attribute	UNITS	The units.	String

Appendix A2: Detailed Synthesis (S1/S10) Product file description

Below follows the detailed description of the various Groups, Datasets, and Attributes of the Synthesis product files. Reference is made to Figure 22, in which the HDF5 dataset structure is visualized.

Table 21: HDF5 structure of Synthesis file.

Type	Name	Description	Data type
HDF5 Group	LEVEL3	HDF5 “root” group containing the Level3 TOA/TOC data and meta data. The structure and content of this group is elaborated in Table 22.	-
HDF5 Attribute	DESCRIPTION	Short description of the file content, e.g. PROBA-V Level3 S1 Top Of Atmosphere product at 1km	-
HDF5 Attribute	INSTRUMENT	Short name for the instrument, i.e., VEGETATION.	-
HDF5 Attribute	MAP_PROJECTION_ FAMILY	The family to which the projection belongs.	String
HDF5 Attribute	MAP_PROJECTION_ NAME	The full name of the projection.	String
HDF5 Attribute	MAP_PROJECTION_ REFERENCE	A unique reference (EPSG code) of the projection. An example is EPSG:4326.	String
HDF5 Attribute	MAP_PROJECTION_ UNITS	The units of the projection. Possible values are: DEGREES, METERS	String
HDF5 Attribute	MAP_PROJECTION_ WKT	The projection string.	String
HDF5 Attribute	PLATFORM	Short name for the platform and its serial number, i.e. PROBA-1.	String
HDF5 Attribute	PROCESSING_DATE	The date the product was generated. The format is: YYYY-MM-DD.	String
HDF5 Attribute	PROCESSING_TIME	The time the product was generated. The format is: hh:mm:ss.μμμμμμ.	String
HDF5 Attribute	PRODUCT_ REFERENCE	A unique textual reference to the product. This string has following syntax: Synthesis_PROBAV_<YYYYMMDD>_<LEVEL> _ <GRID>_V<VERSION> Where: <YYYYMMDD> is the start observation date; <LEVEL> is ‘S1_TOA’, ‘S1_TOC’ or ‘S10_TOC’; <GRID> is the spatial resolution; <VERSION> is the version identifier (three digits)	String

HDF5 Attribute	VERSION	Denotes the product version	32-bit integer
HDF5 Attribute	SYNTHESIS_PERIOD	The synthesis period. Following values are possible: 1: for a daily synthesis, 10: for a ten-daily synthesis	32-bit integer

Table 22: HDF5 structure of LEVEL3 Root Group.

Type	Name	Description	Data type
HDF5 Group	GEOMETRY	HDF5 group containing the geometry data for the synthesis. The structure and content of this group is elaborated in Table 23.	-
HDF5 Group	NDVI	HDF5 group containing the NDVI (Normalized Difference Vegetation Index) data for the synthesis. The structure and content of this group is elaborated in Table 24.	-
HDF5 Group	QUALITY	HDF5 group containing the quality data for the synthesis. The structure and content of this group is elaborated in Table 25.	-
HDF5 Group	RADIOMETRY	HDF5 group containing the radiometry data for the synthesis. The structure and content of this group is elaborated in Table 26.	-
HDF5 Group	TIME	HDF5 group containing the timing data for the synthesis. The structure and content of this group is elaborated in Table 28.	-
HDF5 Attribute	PROCESSINGINFO_CLOUDICESNOW_DETECTION	Reference to the used cloud, snow and ice detection algorithm version.	String
HDF5 Attribute	PROCESSINGINFO_COMPOSITING	Reference to the used compositing algorithm version.	String
HDF5 Attribute	PROCESSINGINFO_GEOMODELLING	Reference to the used geo modelling algorithm version.	String
HDF5 Attribute	PROCESSINGINFO_MAPPING	Reference to the used mapping algorithm version.	String
HDF5 Attribute	PROCESSINGINFO_MOSAIC	Reference to the used mosaicking algorithm version.	String
HDF5 Attribute	PROCESSINGINFO_RADIOMODELLING	Reference to the used radio modelling algorithm version.	String
HDF5 Attribute	PROCESSINGINFO_SHADOWDETECTION	Reference to the used shadow detection algorithm version.	String

Table 23: HDF5 structure of GEOMETRY group.

Type	Name	Description	Data type
HDF5 Group	SWIR	HDF5 group containing the data and meta data for the SWIR – detector. This group contains two datasets: • **VAA**: dataset containing the viewing azimuth angles. Every pixel is decoded in an 8-bit unsigned integer value. • **VZA**: dataset containing the viewing zenith angles. Every pixel is decoded in an 8-bit unsigned integer value. Table 29 lists the meta data items specific for this dataset.	-
HDF5 Group	VNIR	HDF5 group containing the data and meta data for the VNIR detector. This group contains two datasets: • **VAA**: dataset containing the viewing azimuth angles. Every pixel is decoded in an 8-bit unsigned integer value. • **VZA**: dataset containing the viewing zenith angles. Every pixel is decoded in an 8-bit unsigned integer value. Table 29 lists the meta data items specific for this dataset	-
HDF5 Dataset	SAA	Dataset containing the solar azimuth angles. Every pixel is decoded as an 8-bit unsigned integer value. Table 29 lists the meta data items specific for this dataset.	-
HDF5 Dataset	SZA	HDF5 dataset containing the SZA. Every pixel is decoded as an 8-bit unsigned integer value. Table 29 lists the meta data items specific for this dataset.	-
HDF5 Attribute	BOTTOM_LEFT_LATITUDE	The latitude of the bottom-left point of the synthesis.	32-bit floating-point

HDF5 Attribute	BOTTOM_LEFT_LONGITUDE	The longitude of the bottom-left point of the synthesis.	32-bit floating-point
HDF5 Attribute	BOTTOM_LEFT_X	The X coordinate of the bottom-left point of the cartographic bounding box of the synthesis.	32-bit floating-point
HDF5 Attribute	BOTTOM_LEFT_Y	The Y coordinate of the bottom-left point of the cartographic bounding box of the synthesis.	32-bit floating-point
HDF5 Attribute	BOTTOM_RIGHT_LATITUDE	The latitude of the bottom-right point of the synthesis.	32-bit floating-point
HDF5 Attribute	BOTTOM_RIGHT_LONGITUDE	The longitude of the bottom-right point of the synthesis.	32-bit floating-point
HDF5 Attribute	BOTTOM_RIGHT_X	The X coordinate of the bottom-right point of the cartographic bounding box of the synthesis.	32-bit floating-point
HDF5 Attribute	BOTTOM_RIGHT_Y	The Y coordinate of the bottom-right point of the cartographic bounding box of the synthesis.	32-bit floating-point
HDF5 Attribute	CENTER_LATITUDE	The latitude of the center point of the geographic bounding box of the synthesis.	32-bit floating-point
HDF5 Attribute	CENTER_LONGITUDE	The longitude of the center point of the geographic bounding box of the synthesis.	32-bit floating-point
HDF5 Attribute	CENTER_X	The center point in X direction of the cartographic bounding box of the synthesis.	32-bit floating-point
HDF5 Attribute	CENTER_Y	The center point in Y direction of the cartographic bounding box of the synthesis.	32-bit floating-point
HDF5 Attribute	TOP_LEFT_LATITUDE	The latitude of the top-left point of the synthesis.	32-bit floating-point
HDF5 Attribute	TOP_LEFT_LONGITUDE	The longitude of the top-left point of the synthesis.	32-bit floating-point
HDF5 Attribute	TOP_LEFT_X	The X - coordinate of the top-left point of the cartographic bounding box of the synthesis.	32-bit floating-point
HDF5 Attribute	TOP_LEFT_Y	The Y - coordinate of the top-left point of the cartographic bounding box of the synthesis.	32-bit floating-point
HDF5 Attribute	TOP_RIGHT_LATITUDE	The latitude of the top-right point of the synthesis.	32-bit floating-point
HDF5 Attribute	TOP_RIGHT_LONGITUDE	The longitude of the top-right point of the synthesis.	32-bit floating-point
HDF5 Attribute	TOP_RIGHT_X	The X - coordinate of the top-right point of the cartographic bounding box of the synthesis.	32-bit floating-point
HDF5 Attribute	TOP_RIGHT_Y	The Y - coordinate of the top-right point of the cartographic bounding box of the synthesis.	32-bit floating-point

Table 24: HDF5 structure of NDVI Group.

Type	Name	Description	Data type
HDF5 Dataset	NDVI	Dataset containing the NDVI (Normalized Difference Vegetation Index). Table 29 lists the meta data items specific for this dataset.	8-bit unsigned integer

Table 25: HDF5 structure of QUALITY Group.

<table>
<tr><th>Type</th><th>Name</th><th>Description</th><th>Data type</th></tr>
<tr><td>HDF5 Dataset</td><td>SM</td><td>Dataset containing the quality flags and status pixels.
<table>
<tr><th>Bit (LSB to MSB)</th><th>Description</th><th>Value</th><th>Key</th></tr>
<tr><td>0-2</td><td>Cloud/Ice Snow/Shadow Flag</td><td>000
001
010
011
100</td><td>Clear
Shadow
Undefined
Cloud
Ice</td></tr>
<tr><td>3</td><td>Land/Sea</td><td>0
1</td><td>Sea
Land</td></tr>
<tr><td>4</td><td>Radiometric quality SWIR flag</td><td>0
1</td><td>Bad
Good</td></tr>
<tr><td>5</td><td>Radiometric quality NIR flag</td><td>0
1</td><td>Bad
Good</td></tr>
<tr><td>6</td><td>Radiometric quality RED flag</td><td>0
1</td><td>Bad
Good</td></tr>
<tr><td>7</td><td>Radiometric quality BLUE flag</td><td>0
1</td><td>Bad
Good</td></tr>
</table>
Table 29 lists the meta data items specific for this dataset.</td><td>8-bit unsigned integer</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>HDF5 Attribute</td><td>PERCENTAGE_ CLOUD</td><td>The percentage cloud.</td><td>32-bit floating-point</td></tr>
<tr><td>HDF5 Attribute</td><td>PERCENTAGE_ SNOW</td><td>The percentage snow.</td><td>32-bit floating-point</td></tr>
<tr><td>HDF5 Attribute</td><td>PERCENTAGE_ LAND</td><td>The percentage land.</td><td>32-bit floating-point</td></tr>
<tr><td>HDF5 Attribute</td><td>PERCENTAGE_ MISSING_ DATA</td><td>The percentage missing data.</td><td>32-bit floating-point</td></tr>
</table>

Table 26: HDF5 structure of RADIOMETRY Group.

Type	Name	Description
HDF5 Group	BLUE	HDF5 group containing the radiometry data for BLUE band of the synthesis. The structure and content of this group is explained in Table 27.
HDF5 Group	NIR	HDF5 group containing the radiometry data for NIR band of the synthesis. The structure and content of this group is explained in Table 27.
HDF5 Group	RED	HDF5 group containing the radiometry data for RED band of the synthesis. The structure and content of this group is explained in Table 27.
HDF5 Group	SWIR	HDF5 group containing the radiometry data for SWIR band of the synthesis. The structure and content of this group is explained in Table 27.

Table 27: HDF5 structure of band groups in the RADIOMETRY Group.

Type	Name	Description	Data type
HDF5 Dataset	TOA or TOC	Dataset containing the Top Of Atmosphere reflectance values (TOA) or Top Of Canopy reflectance values (TOC). Table 29 lists the meta data items specific for this dataset.	16-bit integer
HDF5 Attribute	DETECTOR	Identifier for the detector (type: string). Possible values are: VNIR, SWIR	String
HDF5 Attribute	GAIN_FACTOR	The gain factor (type: float).	32-bit floating-point
HDF5 Attribute	OBSERVATION_END_DATE	The observation end date (UTC), i.e. the date of the last line of the band (type: string). The format is: YYYY-MM-DD.	String
HDF5 Attribute	OBSERVATION_END_TIME	The observation end time (UTC), i.e. the time of the last line of the band (type: string). The format is: hh:mm:ss.µµµµµµ .	String

HDF5 Attribute	OBSERVATION_START_DATE	The observation start date (UTC), i.e. the date of the first line of the band (type: string). The format is: YYYY-MM-DD.	String
HDF5 Attribute	OBSERVATION_START_TIME	The observation start time (UTC), i.e. the time of the first line of the band (type: string). The format is: hh:mm:ss.µµµµµµ.	String
HDF5 Attribute	SOLAR_IRRADIANCE	The solar irradiance at TOA.	32-bit floating-point

Table 28: HDF5 structure of TIME Group.

Type	**Name**	**Description**	**Data type**
HDF5 Dataset	TIME	Dataset containing the start acquisition time of the selected segment, expressed in minutes since the beginning of the synthesis period. Table 29 lists the meta data items specific for this dataset.	16-bit unsigned integer
HDF5 Attribute	OBSERVATION_END_DATE	The observation end date (UTC) of the synthesis. The format is: YYYY-MM-DD.	String
HDF5 Attribute	OBSERVATION_END_TIME	The observation end time (UTC) of the synthesis. The format is: hh:mm:ss.	String
HDF5 Attribute	OBSERVATION_START_DATE	The observation start date (UTC) of the synthesis. The format is: YYYY-MM-DD.	String
HDF5 Attribute	OBSERVATION_START_TIME	The observation start time (UTC) of the synthesis. The format is: hh:mm:ss.	String

Table 29: HDF5 meta data items for the datasets.

Type	Name	Description	Data type
HDF5 Attribute	DESCRIPTION	Short description of the dataset.	String
HDF5 Attribute	MAPPING	The mapping information, consisting of following values: • **<proj_id>**: the projection ID (e.g. “Geographic Lat/Lon”) • **<x_m>**: A value indicating whether the map X coordinates refer to the top-left corner (0.0) or center (0.5) of the pixel. • **<y_m>**: A value indicating whether the map Y coordinates refer to the top-left corner (0.0) or center (0.5) of the pixel. • **<x_start>**: the X coordinate of the upper-left pixel. • **<y_start>**: the Y coordinate of the upper-left pixel. • **<x_res>**: the spatial resolution in the X direction. • **<y_res>**: the spatial resolution in the Y direction. • **<datum>**: the projection‘s datum (in case of unprojected image, the value is ‘-’). • **<units>**: the projection ‘s unit (in case of unprojected image, the value is ‘-’). Note that his is an optional attribute. If not provided, it is assumed that no geographical information is attached to the dataset.	String
HDF5 Attribute	NO_DATA	The no data value.	64-bit floating-point
HDF5 Attribute	OFFSET	The scale factor. The physical value (PV) is calculated as PV = (DN-offset)/scale (DN = Digital Number Count)	32-bit floating-point
HDF5 Attribute	SCALE	The scale factor. The physical value (PV) is calculated as PV = (DN-offset)/scale (DN = Digital Number Count)	32-bit floating-point
HDF5 Attribute	UNITS	The units of the dataset.	String