

Input/output data specification for the TROPOMI L01b data processor



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Appendix A

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1 Introduction

1.1 Identification

This document, identified by S5P-KNMI-L01B-0012-SD, describes the data format of the TROPOMI Level-1b (L1b) data products. The logic for the L1b data format results from an analysis of different applicable standards and best practices in the Earth Observation (EO) data field. This document is identified in [AD1] as CI-6510-IODS.

1.2 Purpose and objective

The TROPOMI L01b processor developed by KNMI produces L1b data products from L0 input data and auxiliary data products. The TROPOMI L1b data products distinguish radiance, irradiance, calibration and engineering data. Although these products differ in their applicability, the objective is to define a common data format for all TROPOMI L1b products.

This document mainly addresses the output data of the L01b processor (i.e. the L1b data products), providing detailed specifications of the different L1b products. The input data (the Level 0 products and the various auxiliary products) are also identified and summarized in this document. One type of auxiliary data product is the calibration key data. Document [RD10] describes the types of calibration key data files. The L0 products are specified in [AD2].

1.3 Document overview

This document describes the official products that are the result from the Level 0 to Level 1b processing of the data collected by TROPOMI onboard the Sentinel-5 Precursor satellite. For all of the defined data products detailed technical information with respect to their contents and data formats is provided. This allows processing facilities and scientists to develop software for extracting information and in particular to produce higher level (i.e. Level 2) products.

The document is based on the results of discussions with user communities and of studies on data interoperability standards and on the lessons learned from previous missions (i.e. OMI).

After a short introduction of the TROPOMI system, its mission, the geophysical phenomena studied and the parameters measured by the detectors, the L1b products are described. Product specifications are presented in terms of file naming, file format and file structure. Comprehensive descriptions and specifications of all variables contained in the products are presented.

2 Applicable and reference documents

2.1 Applicable documents

- [AD1] Software development plan for TROPOMI L01b data processor. source: KNMI; ref: S5P-KNMI-L01B-0002-PL; issue: 2.0.0; date: 2012-11-14.
- [AD2] Sentinel-5 precursor PDGS L0 product format specification.

source: DLR; ref: S5P-PDGS-DLR-ISP-3011; issue: 1.3; date: 2015-11-30.

[AD3] Software product assurance plan for TROPOMI L01b data processor.

source: KNMI; ref: S5P-KNMI-L01B-0003-PL; issue: 2.0.0; date: 2012-11-14.

[AD4] Software system specification for TROPOMI L01b data processor.

source: KNMI; ref: S5P-KNMI-L01B-0005-RS; issue: 3.0.0; date: 2012-11-21.

- [AD5] Tailoring of the Earth Observation File Format Standard for the Sentinel 5-Precursor Ground Segment. source: ESA; ref: S5P-TN-ESA-GS-106; issue: 2.2; date: 2015-02-20.
- [AD6] Earth Observation Ground Segment File Format Standard. source: ESA; ref: PE-TN-ESA-GS-0001; issue: 2.0; date: 2012-05-03.

2.2 Standard documents

[SD7] Space Engineering - Software.

source: ESA/ECSS; ref: ECSS-E-ST-40C; date: 2009-03-06.

[SD8] Space Product Assurance – Software Product Assurance.

source: ESA/ECSS; ref: ECSS-Q-ST-80C; date: 2009-03-06.

2.3 Reference documents

[RD9] Metadata specification for the TROPOMI L1b products.

source: KNMI; ref: S5P-KNMI-L01B-0014-SD; issue: 5.0.0; date: 2018-04-01.

[RD10] Calibration key data specification for the TROPOMI L01b data processor.

source: KNMI; ref: S5P-KNMI-L01B-0028-SD; issue: 6.0.0; date: 2017-06-01.

[RD11] Terms, definitions and abbreviations for TROPOMI L01b data processor.

source: KNMI; **ref:** S5P-KNMI-L01B-0004-LI; **issue:** 3.0.0; **date:** 2013-11-08.

[RD12] Algorithm theoretical basis document for the TROPOMI L01b data processor.

source: KNMI; **ref:** S5P-KNMI-L01B-0009-SD; **issue:** 8.0.0; **date:** 2017-06-01.

[RD13] NetCDF Climate and Forecast (CF) Metadata Conventions.

source: CFConventions; ref: n/a; issue: 1.6; date: 2011-12-05.

[RD14] INSPIRE Metadata Implementing Rules: Technical Guidelines based on EN ISO 19115 and EN ISO 19119.

source: EC JRC; ref: MD IR and ISO v1 2 20100616; issue: 1.2; date: 2010-06-16.

[RD15] Earth Observation Metadata profile of Observations Measurements.

source: OGC; ref: OGC 10-157r4; issue: 1.0.3-DRAFT; date: 2014-01-10.

[RD16] Command and Telemetry Handbook.

source: Dutch Space; ref: TROP-DS-0000-RP-0579; issue: 4.0; date: 2016-02-09.

2.4 Electronic references

- [ER17] http://www.iers.org.
- [ER18] http://www.unidata.ucar.edu/software/netcdf/docs/.
- $[\mathsf{ER19}]\ \mathtt{http://en.wikipedia.org/wiki/University_Corporation_for_Atmospheric_Research.}$
- [ER20] http://wiki.esipfed.org/index.php/Category:Attribute_Conventions_Dataset_Discovery.
- [ER21] http://www.unidata.ucar.edu/software/thredds/current/tds/.
- [ER22] http://wiki.esipfed.org/index.php/NetCDF,_HDF,_and_ISO_Metadata.

3 Terms, definitions and abbreviated terms

Terms, definitions and abbreviated terms that are used in the development program for the TROPOMI L01b data processor are described in [RD11]. Terms, definitions and abbreviated terms that are specific for this document can be found below.

3.1 Terms and definitions

There are no terms and definitions specific to this document.

3.2 Acronyms and Abbreviations

ACDD Attribute Convention for Dataset Discovery

APID Application Process Identifier

ADN ADEPT/DLESE/NASA

AQA Automated Quality Assurance

AU Astronomical Unit

CCSDS Consultative Committee for Space Data Systems

CF Climate and Forecast
CKDS Calibration Key Data Set
DEM Detector Electronics Module
DIF Data Interchange Format
EC European Commission

EO-FFS Earth Observation Ground Station File Format Standard

EOP Earth Observation Product ESA European Space Agency

ESIP Federation of Earth Science Information Partners

EU European Union

FGDC Federal Geographic Data Committee

GEMET GEneral Multilingual Environmental Thesaurus
GMES Global Monitoring for Environment and Security

HDF Hierarchical Data Format

HMA Heterogeneous Mission Accessibility

IcID Instrument Configuration ID

ID Identifier

IERS International Earth Rotation and Reference Systems Service
INSPIRE Infrastructure for Spatial Information in the European Community

IODS Input/Output Data Specification
ISM Instrument Specific Module
JRC Joint Research Centre
LED Light-Emitting Diode

LTAN Local Solar Time at Ascending Node

NcML NetCDF Markup Language
NetCDF Network Common Data Form

NRT Near Real Time
NUG NetCDF User Guide

OGC Open Geospatial Consortium

QI Quality Indicator

SAA South Atlantic Anomaly

SZA Solar Zenith Angle

THREDDS Thematic Realtime Environmental Distributed Data Services

TOA Top Of Atmosphere

UCAR University Corporation for Atmospheric Research

UML Unified Modeling Language
UTC Coordinated Universal Time
WGS World Geodetic System
WLS White Light Source

XML Extensible Markup Language

4 TROPOMI system overview

4.1 Mission

The Sentinel-5 Precursor (S5p) mission will be implemented as part of the Global Monitoring for Environment and Security (GMES) programme, which is a joint initiative of the European Commission (EC) and of the European Space Agency (ESA). The S5p mission is a single-payload satellite in a low Earth orbit that provides daily global information on concentrations of trace gases and aerosols important for air quality, climate forcing, and the ozone layer. The payload of the mission is the TROPOspheric Monitoring Instrument (TROPOMI), which is jointly developed by The Netherlands and ESA. TROPOMI is a spectrometer with spectral bands in the ultraviolet (UV), the visible (VIS), the near-infrared (NIR) and the shortwave infrared (SWIR). The selected wavelength range for TROPOMI allows observation of key atmospheric constituents, including ozone (O₃), nitrogen dioxide (NO₂), carbon monoxide (CO), sulfur dioxide (SO₂), methane (CH₄), formaldehyde (CH₂O), aerosols and clouds.

4.2 Instrument description

The TROPOMI instrument (TROPOMI) is a space-borne nadir-viewing hyperspectral imager with four separate spectrometers covering non-overlapping and non-contiguous wavelength bands between the ultraviolet and the shortwave infrared. The instrument is the payload on the ESA/GMES Sentinel 5 Precursor mission.

The purpose of TROPOMI is the measurement of atmospheric properties and constituents. The instrument uses passive remote sensing techniques to attain its objective by measuring at the top of the atmosphere the solar radiation reflected by and radiated from the Earth. The instrument operates in a push-broom configuration with a wide swath. Light from the entire swath is recorded simultaneously and dispersed onto two-dimensional imaging detectors: the position along the swath is projected onto one direction of the detectors, and the spectral information for each position is projected on the other direction.

The instrument images a strip of the Earth on a two dimensional detector for a period of approximately 1 second during which the satellite moves by about 7km. This strip has dimensions of approximately 2600 km in the direction across the track of the satellite and 7km in the along-track direction. After the 1 second measurement a new measurement is started thus the instrument scans the Earth as the satellite moves. The two dimensions of the detector are used to detect the different ground pixels in the across track direction and for the different wavelengths. The measurement principle of TROPOMI is shown in Figure 1.

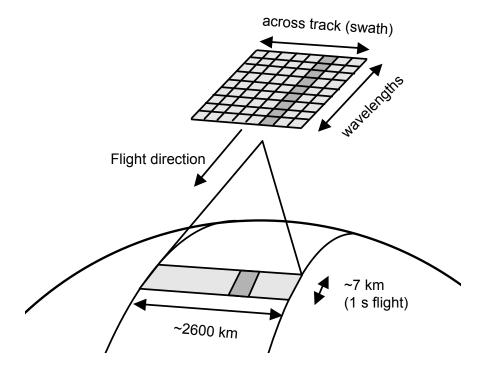


Figure 1: TROPOMI measurement principle

TROPOMI utilizes a single telescope to form an image of the target area onto a rectangular slit that acts as the entrance slit of the spectrometer system. There are four different spectrometers, each with its own optics and detector: medium wave ultraviolet (UV), long wave ultraviolet combined with visual (UVIS), near infrared (NIR), and short wave infrared (SWIR). The spectrometers for UV, UVIS and NIR are jointly referred to as UVN. Table 1 lists the spectral characteristics of the four TROPOMI spectrometers and the definition of the TROPOMI spectral bands with identifiers 1–8.

Instrument module			U\	VN .			SV	VIR
Detector UV			UVIS		NIR		SWIR	
Band ID	1	2	3	4	5	6	7	8
Spectral range [nm]	270–300	300–320	320–405	405–500	675–725	725–775	2305–2345	2345–2385
Spectral resolution [nm]	0.5	0.5	0.5	0.5	0.5	0.5	0.23	0.23
Spectral sam- pling [nm/pixel]	0.065	0.065	0.20	0.20	0.124	0.124	0.084	0.097

Table 1: Main spectral characteristics of the four TROPOMI spectrometers and the definition of the spectral bands with identifiers 1–8. Remark: the figures mentioned for range, resolution and sampling are taken from [RD12]. These figures might change in future releases of [RD12]; this table will be updated accordingly in next issues.

4.3 Instrument operations

For TROPOMI instrument operations, an orbital scheduling approach is used. An orbit is defined from spacecraft midnight to spacecraft midnight. Earth radiance measurements will be performed on the day side of the orbit. At the north side of the orbit, near the day-night terminator, the Sun is visible in the instrument's solar port. Approximately once a day, a solar irradiance measurement is performed. The night side of the orbit is used for calibration and background measurements. The following constraints apply to the calibration measurements:

- 1. Background and calibration measurements can only be performed when the spacecraft is in eclipse.
- 2. No measurements can be taken around spacecraft midnight, in order to facilitate data processing.
- 3. All orbits must contain background measurements in the eclipse part of the orbit that match the radiance measurements on the day side for in-orbit calibration by the L01b Processor.
- 4. Calibration measurements must be performed outside the South Atlantic Anomaly (SAA) area, in order to minimize interference of proton radiation.
- 5. Calibration measurements must have a regular, fixed repetition interval.

In Figure 2 the Sentinel-5p orbit overview is presented. Each S5p orbit has a day (lit) side and a night (dark) side, as illustrated in the figure. On the day side the spacecraft flies from south to north; on the night side it flies from north to south. Spacecraft midnight is defined as the time halfway the nadir day-night terminator and the nadir night-day terminator; spacecraft noon is the time halfway the nadir night-day terminator and the nadir day-night terminator. Both the instrument operations as well as data processing will use the spacecraft midnight as the start and end points of an orbit. Due to seasonal variation, the position of the equator with respect to the spacecraft midnight will change. As a result, spacecraft midnight is not at a fixed latitude.

The S5p reference orbit is a near-polar frozen sun-synchronous orbit, adopted for mission optimization with a mean Local Solar Time at Ascending Node (LTAN) of 13:30 h and a repeat cycle of 17 days or 24155 orbits. More important than this repeat cycle is the operational repeat cycle. To accommodate regular, fixed repetition intervals for the calibration measurements, a scheme of 360 orbits is used. As 360 is divisible by many numbers, it is possible to accommodate many different repetition intervals. For sake of simplicity, the 360 orbits are divided in 24 blocks of 15 orbits, each block corresponding to approximately 25 hours, or roughly to a day. A 'week' is defined to be 6 of these 15-orbit blocks and a 'month' as 4 of these weeks. This allows for easy definition of calibration measurements that have (roughly) daily, weekly, biweekly or monthly repetition cycles.

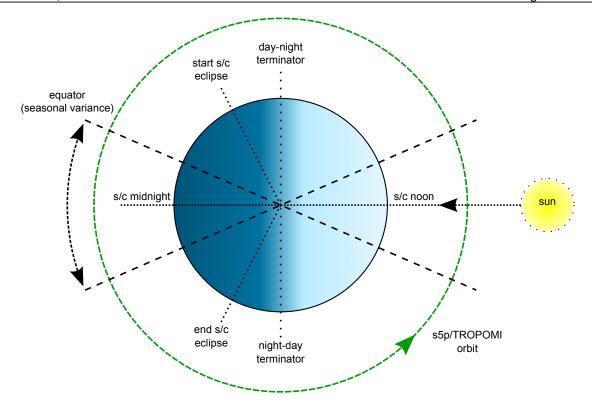


Figure 2: Sentinel-5p orbit overview

4.3.1 Co-addition and small pixels

The signals detected by the spectrometers are digitized in the detector electronics modules (DEMs). The data is saved and co-added in the instrument specific modules (ISMs) in the instrument control unit (ICU). The number of those pixels to be co-added for each detector half (or band) is individually programmable between 0 and 512. It is possible to co-add up to 256 consecutive images. The two halves of one detector can use different co-addition factors.

Information concerning the individual signals of a pixel that contribute (i.e. add up to) to a co-addition is lost, with one exception. One configurable detector pixel, in every row, for both detector output chains, i.e., two columns per detector, is also stored separately for every exposure/co-addition of an image. The data for these 'small-pixel columns' are included in the science data and provide information on a higher spatial resolution than the data for other columns, which may be useful for certain studies.

Clearly, co-addition increases the signal to noise ratio. Pixels in the small pixel columns are excluded from this operation. These pixels provide the only way to get some information about changes in a temporal sense during the co-addition time.

4.3.2 Earth radiance measurements

The Earth radiance measurements form the bulk of the measurements. Apart from the optical properties of the instrument, there is some flexibility in the electronics that determines the Earth radiance ground pixel size. The co-addition period determines the ground pixel size in the along-track direction. Row binning (which is possible for UVN detector modules only) determines the ground pixel size cross-track.

For the Earth radiance measurements, the co-addition period will be set to 1080 ms. This effectively results in a ground pixel size of approximately 7km along-track. For the SWIR-DEM, which contains a CMOS detector, row binning is not supported. This means that, effectively, the binning factor is 1 for the SWIR bands, resulting in a ground pixel size across-track between 7km at the center and 34km at the edges of the across-track field of view.

The binning factors and across-track ground pixel size are summarized in Table 2 (taken from [RD12]).

Band	DEM	Binning factor	Across-track ground pixel size	
1	UV	816	28 68 km	
2	UV	12	3.5 8.5 km	
3	UVIS	12	3.5 8.5 km	
4	UVIS	12	3.5 8.5 km	
5	NIR	12	3.5 8.5 km	
6	NIR	12	3.5 8.5 km	
7	SWIR	n/a	7 34 km	
8	SWIR	n/a	7 34 km	

Table 2: Binning factors and across-track ground pixel sizes for Earth radiance measurements

4.3.3 Solar irradiance measurements

The Sun is visible in TROPOMI's solar irradiance port every orbit for a period of approximately 1.5 minutes around orbit phases 0.75^1 . Every 15 orbits - approximately once every calendar day - TROPOMI will be commanded to perform a solar irradiance measurement. As the main purpose of the solar irradiance measurement is to calculate top-of-atmosphere reflectance, the solar irradiance measurement follows the same binning scheme as the Earth radiance measurements. The remaining parameters will be optimized for the best signal-to-noise ratio. The signal-to-noise ratio is improved even further by averaging the solar irradiance measurements within the L01b Processor.

4.3.4 Background measurements

The background signal for measurements will be calibrated in-orbit. For this to work, every measurement should have accompanying background measurements in the same orbit. These background measurements are performed using the exact same settings as the measurement they accompany. A different IcID for the background measurement ensures that on-ground it is being processed as a background measurement. The background measurements are performed on the eclipse side of the orbit.

4.3.5 Calibration measurements

Calibration measurements will be performed on the night side of the orbit, outside the SAA. The binning scheme that is used for a calibration measurement depends on the objective of that measurement. Calibration measurements that have a strong relation with Earth radiance measurements will use the same binning scheme as Earth radiance measurements. Most calibration measurements however will use a so-called unbinned scheme, that reads out all the pixels of the detector. For these measurements, the co-addition period may be slightly longer than for Earth radiance measurements, to avoid data rate bottlenecks within the instrument or the platform.

Since for instrument operations, the orbits are defined without any seasonal dependency, only a small part of the orbit is guaranteed to be unaffected by the SAA throughout the seasons. This part of the orbit will be used for calibration measurements, while the remainder of the orbit where the spacecraft is in eclipse will be used for background measurements. This is shown in Figure 3. These background measurements are susceptible for proton radiation too, but the L01b Processor will use a filter to avoid background measurements taken in the SAA being used for in-orbit calibration

 $^{^1}$ The orbit phase is defined as $1/(2\pi)$ times the angle in radians traversed by the spacecraft since spacecraft midnight as seen from the center of the Earth. Spacecraft midnight is the point on the night side of the Earth where the spacecraft crosses the orbital plane of the Earth about the Sun. This makes the orbit phase a quantity that runs from 0 to 1, while the spacecraft moves between each spacecraft midnight.

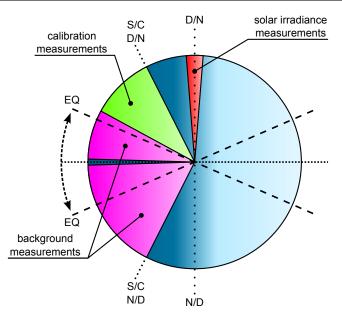


Figure 3: Position of irradiance, calibration and background measurements in the orbit. S/C = spacecraft, EQ = equator, D = day, N = night.

5 Input data products

The main inputs for the L01b are the L0 data products, as described in Table 3. Each of these L0 data products will contain L0 data of a different Application Process Identifier (APID), i.e. 1 APID per product, separate products for each of the APIDs. The L0 product format is specified in [AD2].

Input product	Description
L0ENG_A	L0 Engineering data (X-Band telemetry)
L0ODB_1L0ODB_8	L0 Instrument data for bands 1 through 8
L0SAT_A	L0 Ancillary data (containing S/C ephemeris and attitude)

Table 3: L0 input products

Another important input for the L01b is the Calibration Key Data. It is foreseen that the Calibration Key Data is provided as a set of data products that has a specified validity range (i.e. the set of orbits to which these Calibration Key Data can be applied and as described in metadata). For the production rules, such a Calibration Key Data Set (CKDS) is treated as an auxiliary data product. The frequency at which the CKDS will be updated depends on the performance of the instrument; a first assumption is that daily updates will be made available. The CKDS is described in [RD10]. An overview of all the auxiliary data products that are currently foreseen is provided in Table 4.

Input product	Description
ICM_CKDUVN	Calibration Key Data Set containing dynamic CKD parameters generated by UVN in-flight calibration processor Generated each orbit.
ICM_CKDSIR	Calibration Key Data Set containing dynamic CKD parameters generated by SWIR in-flight calibration processor. Generated each orbit.
AUX_L1_CKD	Calibration Key Data Set containing semi-static CKD parameters delivered by IDAF system. Generated when nescesarry
IERSB	IERS Bulletin B, see [ER17]. The IERS Bulletin B files can be obtained using anonymous FTP from the IERS public FTP server ftp.iers.org in directory ftp://ftp.iers.org/products/eop/bulletinb/format_2009/. These products are generated once per month and are approximately 17kB in size.
IERSC	IERS Bulletin C, see [ER17]. The IERS Bulletin B files can be obtained using anonymous FTP from the IERS public FTP server ftp.iers.org in directory ftp://ftp.iers.org/products/eop/bulletinc/. These products are generated approximately twice per year and are approximately 2kB in size.

Table 4: L0 auxiliary input products

Finally, there are several static input files that determine the run-time configuration of the L01b. These will be delivered with the L01b and are considered part of the run-time environment of the L01b. These files are, for example, used to tailor the L01b for a specific processing mode. This means that for each of the different modes, there will / can be separate deliveries of the L01b. These deliveries could differ in terms of binaries or in term of these static input files or both.

6 TROPOMI L1b product overview

The Level-1b processor output consists of the following data products:

- **Level-1b radiance** The Level-1b radiance products contain the Earth radiance measurements, including annotation data such as geolocation. For each data granule, typically of the size of one orbit, there is a data product for each of the eight bands. The radiance products are the main input for the Level-2 processors.
- Level-1b irradiance The Level-1b irradiance products contain the averaged solar irradiance measurements, including annotation data. For each data granule, there is a data product for each of the two modules, UVN and SWIR. The Level-2 processors will use the irradiance products to calculate reflectance from the Earth radiance data. The irradiance data is used for calibration processing as well. Every 15 orbits approximately once every calendar day TROPOMI will be commanded to perform a solar irradiance measurement. If no solar measurements are available in the data granule being processed, no irradiance product will be generated.
- **Level-1b calibration** The Level-1b calibration products contain the calibration and background measurements, including annotation data, as well as any calibration data that are derived from radiance and irradiance measurements. For each data granule, there is a data product for each of the two modules, UVN and SWIR. The calibration products are the main input for the calibration processors that will use these products for generating updates to the calibration key data and for generating trending and monitoring products.
- Level-1b engineering The Level-1b engineering products contain the instrument's engineering data converted to physical units. For each data granule, there is a single data product. The engineering products are input for the calibration processors who will use these products for generating updates to the calibration key data and for generating trending and monitoring products. The L1b engineering product is only intended for calibration and monitoring purposes. All instrument information needed or relevant for L2 processing will be contained within the radiance and irradiance products. The operational perspective of the L01b processing chain is depicted in Figure 4.

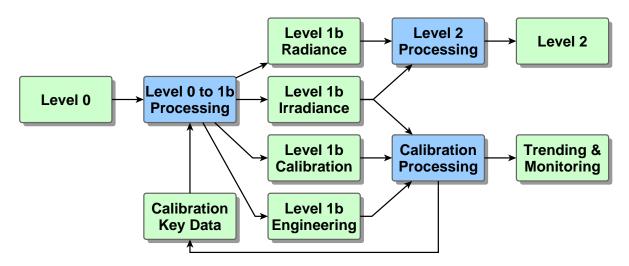


Figure 4: Operational perspective of the L01b processing chain, showing its data products and their position in the processing chain. The blue blocks denote processors; the green blocks denote data products.

The L01b Processor is operationally used in two different modes: **standard product processing** and **near-real-time (NRT) product processing**. The products from standard product processing have the highest quality but less stringent requirements for timeliness. This as opposed to the NRT products, which are required to be available within 2 hours 15 minutes after observation for L1b and 3 hours after observation for L2. To achieve this requirement, speed is favored over quality for the NRT products. The standard products can be distinguished from the NRT products by means of their product or file names and the metadata.

The operational perspective of the NRT processing chain differs from the standard L10b processing chain in that it not includes the generation of irradiance products nor that it involves calibration processing. This is show in Figure 5.

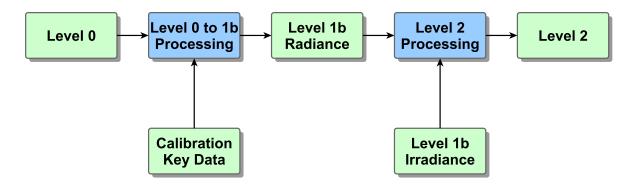


Figure 5: Operational perspective of the NRT processing chain. The blue blocks denote processors; the green blocks denote data products. The irradiance product shown is the result of the standard processing chain.

The data granule (defined as the data time span that is to be processed by the processor) is one orbit for standard product processing. For reasons of efficiency (i.e. data transmission), the volume of one data downlink will be sliced into smaller data volumes. These smaller data volumes form the base of the NRT products, leading approximately to 1 NRT product per data slice.

Table 5 presents an overview of the products: two radiance products will be made for each detector (one for each spectral band). Irradiance and calibration products are instrument module specific.

Instrument module			יט	/N			SV	VIR
Detector	UV		UVIS		NIR		SWIR	
Spectral band	1	2	3	4	5	6	7	8
Radiance product (standard) (# of products/orbit)	1	1	1	1	1	1	1	1
Radiance product (NRT) (# of products/orbit)	10-20	10-20	10-20	10-20	10-20	10-20	10-20	10-20
Irradiance product (# of products/day)	1 (UVN)						1 (SWIR)	
Calibration product (# of products/orbit)			1 (L	IVN)			1 (S)	WIR)
Engineering product (# of products/orbit)	1 (UVN + SWIR)							

Table 5: Overview of L1b products that are generated per day (irradiance product) and per orbit (all other products); The number of NRT products depends on the number of downlink slices and the data volume per slice. The numbers mentions here are indicative.

7 TROPOMI L1b product description

7.1 L1b file structure

The "Earth Observation Ground Station File Format Standard (EO-FFS)" standard [AD04] is relevant to all data files exchanged between ground segment systems within the Earth Observation Missions and as such applicable for the TROPOMI L1b product. This standard provides guidance for data files structures and their encoding, naming and syntax. The EO-FFS standard is used in all recent and upcoming ESA Earth Observations missions, including Sentinel Missions 1, 2 and 3. For the Sentinel 5 Precursor ground segment a tailoring document [AD5] has been made available with a mission specific implementation of the EO-FFS standard.

Within this standard, Earth observation data files are defined as logical files composed of one header and one data block. The logical file can be structured as one physical file or as two physical files separate (i.e. a header file and data block file). The *physical header file* is defined as an XML file containing a fixed part and a variable part of header/metadata information. The header contains configuration control or organizational data. A physical header file has a file name extension ".HDR."

The *data block* can be either an ASCII/XML file or a binary file. In case of a binary file, a self-describing format is preferred. Binary data blocks are always stored as a separate file with file name extension ".DBL". For the TROPOMI L1b products the use of a binary data block is applicable containing one netCDF4 file (see section 7.2 for a discussion on netCDF4). In order to be in conformance with the CF-Metadata conventions [RD13], the tailoring permits to use the file name extension ".nc" for the physical filename instead.

For the TROPOMI L1b products this leads to the following convention with respect to the naming of the physical header and the data block files:

header file: logical_file_name.HDR
data block file: logical_file_name.nc

When these files are distributed the baseline for packaging is "zip", but other formats (i.e. "gzip", "tar" or "tar/gzip") are allowed. However, because of the considerable processing overhead introduced in compressing and decompressing L1b products, it is recommended to use either "zip" without compression or "tar" (uncompressed by definition). In case of packed files the file name extension is ".zip" or ".tar".

7.1.1 L1b logical file name convention

The files shall be named using a fixed set of elements, each of fixed size, separated by underscores "_". The file names are composed of a *Mission ID* (<MMM>), a *File Class* (<CCCC>), a *File Type* (<TTTTTTTTT>) and a *File Instance ID* (<instanceID>):

L1b logical file name: <MMM>_<CCCC>_<TTTTTTTTT>_<instance ID>

The next subsections show how the L1b logical file name will be based on the S5p tailoring defined in [AD5].

7.1.1.1 Mission ID and File Class

The Mission ID and File Class elements for S5p TROPOMI products are listed in Table 6.

Name	Value	Definition
MMM	S5P	Mission identifier (fixed value: "S5P")
CCCC	[TEST, OGCA, GSOV, OPER, NRTI, OFFL, RPRO]	The file class refers to the type of activity for which the file is used. TEST for internal testing OGCA for on-ground calibration GSOV for ground segment overall validation, system level testing OPER for operational processing NRTI for near-real time processing OFFL for offline processing RPRO for reprocessing

Table 6: Mission identifier and file class specification

7.1.1.2 File Type

The File Type element identifies the product and consists of 10 characters, either uppercase letters, digits or underscores "_". For S5p, the File Type can be subdivided into two sub-elements of respectively 4 and 6 characters, as follows:

File Type: <TTTTTTTTT> = <FFFF><DDDDDD>

where:

File Category: <FFFF>

Product Semantic Descriptor: <DDDDDD>

File Category The File Category element consists of 4 characters (3 uppercase letters, digits or underscores "_" + 1 underscore "_").

For the S5p TROPOMI L1b products (science data products) the File Category FFFF = L1B

Product Semantic Descriptor The Product Semantic Descriptor must be unique for a given File Type and be as descriptive as possible. It consists of 6 characters, either uppercase letters, digits or underscores "_".

For S5p L1b data product files (radiance and irradiance data, calibration and engineering products) identified with the File Type element set to "L1B_", the Product Semantic Descriptor is defined as shown in Table 7.

Product Semantic Descriptor	Comment
RA_BD1	Radiance product band 1 (UV detector)
RA_BD2	Radiance product band 2 (UV detector)
RA_BD3	Radiance product band 3 (UVIS detector)
RA_BD4	Radiance product band 4 (UVIS detector)
RA_BD5	Radiance product band 5 (NIR detector)
RA_BD6	Radiance product band 6 (NIR detector)
RA_BD7	Radiance product band 7 (SWIR detector)
RA_BD8	Radiance product band 8 (SWIR detector)
IR_UVN	Irradiance product UVN module
IR_SIR	Irradiance product SWIR module
CA_UVN	Calibration product UVN module
CA_SIR	Calibration product SWIR module
ENG_DB	Engineering product

Table 7: Product Semantic Descriptor for L1b products. See Table 1 for a definition of the bands, modules and detectors.

7.1.1.3 File Instance ID

For science data products (with the File Type "L1B_"), the File Instance ID consists of 63 characters, either uppercase letters, digits or underscores ", with the following shape:

File Instance ID: <yyyymmddThhmmss>_<YYYYMMDDTHHMMSS>_<00000>_<cc>_<ppppppp>_<YYYYMMDDTHHMMSS>

where:

product validity start time: <yyyymmddThhmmss>

product validity stop time: <YYYYMMDDTHHMMSS>

absolute orbit number: <00000>

collection number: <cc>

processor version number: <pppppp>

production (start) time: <YYYYMMDDTHHMMSS>

Notes:

- For standard products the product validity start time is set to spacecraft midnight, which is the start time of the orbit. The product validity stop time is set to the end time of that orbit. For near real-time (NRT) products the validity start and stop times are equal to the start and stop time of the data slice.
- The absolute orbit number starts at 00001 (first ascending node crossing after spacecraft separation).
- The collection number stands for a collection of parameters defining the current product (processor version, auxiliary data, and configuration settings) to ease the interpretation of data products by the end users. The collection number starts at 01.
- The processor version number consists of 6 digits, with the first 2 digits for major updates, the next 2 digits for minor updates and the last 2 digits for new releases, i.e. 010203 for processor version 1.2.3.

7.1.1.4 L1b file name examples

Hereafter (Table 8 and Table 9) some file name examples are provided of the logical file name of the different L1b products. The <instance ID> is not provided for readability.

Radiance products	Irradiance products
(standard and near real time)	
S5P_0PER_L1B_RA_BD1_ <instance id=""></instance>	S5P_OPER_L1B_IR_UVN_ <instance id=""></instance>
S5P_NRTI_L1B_RA_BD1_ <instance id=""></instance>	S5P_OPER_LIB_IR_SIR_ <instance id=""></instance>

Table 8: Logical file name examples for radiance and irradiance products

Calibration products	Engineering product
S5P_OPER_L1B_CA_UVN_ <instance id=""></instance>	S5P_OPER_L1B_ENG_DB_ <instance id=""></instance>
S5P_OPER_L1B_CA_SIR_ <instance id=""></instance>	

Table 9: Logical file name examples for calibration products and engineering products

Here is a full example of the physical file name for an L1b radiance product in netCDF format, containing the radiance measurements of Band 1 (of the UVN module):

 $\tt S5P_OPER_L1B_RA_BD1_20151114T112005_20151114T125934_00140_02_010203_20151204T093045.nc$

7.1.2 L1b header file

The header presents the initial part of a logical file, containing descriptive or configuration control information. The header file (XML) distinguishes a Fixed Header and a Variable Header part. Mandatory elements of the Fixed Header part are defined in EO-FFS and are listed in [RD9].

The Variable Header is specific for each File Type. The EO-FFS suggests some desirable elements that may be included in the variable part, such as a description of the data block type (for L1b: binary), the name of input files used, if any, to generate the file and a reference to a formal document describing the format and contents of the data block. The information on input data sets and the documentation on format and contents of the data is available in the LI_Lineage metadata element of the DQ_DataQuality core element (see: [RD9]) of the ISO 19115-2 metadata specification. The approach is to copy the ISO 19139 XML representation of the LI Lineage element into the Variable Header.

The approach for the TROPOMI L1b products is to include all the required metadata information into the product allowing the automated extraction by dedicated tools of XML formatted metadata records that are fully conformant to the INSPIRE standard [RD14], the OGC standard [RD15], which is adopted by ESA and the ESA standard [AD6]. This means that the metadata are integrated into the product independent of a metadata implementation and that tools are required to produce the standardized metadata representations. The implementation specification, including the header information is provided in section 8.2.

7.2 L1b product data structure

For the TROPOMI L1b products the netCDF-4 enhanced model has been selected as the preferred file format. NetCDF (Network Common Data Form)] [ER18] has been developed by the Unidata Program Center at the University Corporation for Atmospheric Research (UCAR) [ER19] and it is used by many scientists and application developers active in the domains of climatology, meteorology and oceanography. The netCDF-4 format is open standard and has been adopted by the Open Geospatial Consortium (OGC).

NetCDF is a data model for array-oriented scientific data. A freely distributed collection of access libraries implementing support for that data model, and a machine-independent format are available. Together, the interfaces, libraries, and format support the creation, access, and sharing of multi dimensional scientific data. NetCDF is self-documenting, which means it can internally store information used to describe the data. For example, the internal documentation can associate various physical quantities (such as temperature, pressure, and humidity) with spatio-temporal locations (such as points at specific latitudes, longitudes, vertical levels, and times). Three different netCDF formats are supported:

- · netCDF classic model format
- · netCDF 64-bit offset format
- netCDF enhanced data model format (netCDF-4/HDF5 format)

For all netCDF versions (versions 3.x and 4.x) the classic model is the default format. Compared to the classic model, the enhanced model (starting from version 4) offers some important new features such as support for *groups*, (user-defined) *vlen* (variable length) and *compound types* (structures) and *parallel I/O access*.

Although files written using the classic model have the advantage that they may be read by many applications, the use of the enhanced model, supporting groups and structures in particular, offers significant advantages. By the time TROPOMI has been launched, it is expected that many software products will be upgraded in time to support the features of the enhanced data model. Moreover, processing the L1b products to L2 will require dedicated software to be developed using software libraries that are currently available in several languages and already support these features. In view of the above, the enhanced model is used for all L1b products.

In order to support increased interoperability the L1b products shall also comply with the Climate and Forecast (CF) metadata conventions [RD13]. The CF-conventions provide a definitive description of what the data values found in each netCDF variable represent, and of the spatial and temporal properties of the data, including information about grids, such as grid cell bounds and cell averaging methods. This enables users of files from different sources to decide which variables are comparable, and is a basis for building software applications with powerful data extraction, grid remapping, data analysis, and data visualization capabilities.

For data discovery, the metadata of the L1b products shall follow some of the recommendations of the Attribute Convention for Dataset Discovery (ACDD) [ER20]. This convention describes the recommended netCDF attributes for describing a netCDF dataset for use by discovery systems. Tools, such as provided by THREDDS [ER21], will use these attributes for extracting metadata from datasets, and exporting to Dublin

Core, DIF, ADN, FGDC, ISO 19115 etc. metadata formats. In particular, this allows for the export of geospatial metadata in XML according to the ISO 19139 specification, which provides the XML implementation schema for ISO 19115. In the "Metadata specification for the TROPOMI L1b products" [RD9] a comprehensive description of these metadata models and how they are applied to the L1b products are given. Section 8 describes how the metadata is stored in the netCDF file, allowing extraction and exporting to different metadata formats.

NOTE: The L01b products can be read by NetCDF version 4.3.1.1 or higher. It also possible to read the L01b product with HDF5 version 1.8.15-patch1 or higher.

7.2.1 NetCDF File Structure

The file format of the L1b products is structured using groups compliant with the netCDF-4 enhanced model. The group hierarchy is as follows ("/" indicating the root of the groups):

```
/
/global attributes
/MetadataGroup [1]
/MetadataGroup/ISOMetadataGroup [1]
/MetadataGroup/EOPMetadataGroup [1]
/MetadataGroup/ESAMetadataGroup [1]
/ProductGroup [1,*]
/ProductGroup/SensorModeGroup [1,*]
/ProductGroup/SensorModeGroup/ObservationsGroup [1]
/ProductGroup/SensorModeGroup/GeodataGroup [1]
/ProductGroup/SensorModeGroup/InstrumentGroup [1]
/ProcessorGroup [1]
```

In the above schema, for each group is indicated how many occurrences of the particular group are expected/allowed in the parent group ([1,*] meaning 1 or more).

This grouping has several benefits:

- Different metadata groups allow for extraction of metadata into XML documents conforming the different metadata specifications.
- ProductGroups allow the combination of observations made by different sensors into one netCDF file (i.e. Band_1 Radiance, Band_2 Radiance, ...)
- SensorModeGroups allow the combination of observations made by the same sensor operating in different modes (i.e. standard mode, zoom mode, ...)
- The various subgroups of the SensorModeGroup allow grouping of measurement data, location data, instrument data, processor data and other, simplifying the access to the relevant information depending on the intended use.
- Comprehensive information about configuration items (typically, algorithm and processor parameters)
 used in processing the data are stored in a separate ProcessorGroup. This information is not documented
 in detail here, as it is intended to be used only by experts of the L1b processing team.

7.2.2 Naming conventions

7.2.2.1 Groups

Group names are in upper case and consist of alphanumeric characters and underscores. Spaces are not allowed. The group names for the different groups are defined as follows:

MetadataGroup For all products fixed to: METADATA

ISOMetadataGroup For all products fixed to: ISO_METADATA

EOPMetadataGroup For all products fixed to: EOP_METADATA

ESAMetadataGroup For all products fixed to: ESA_METADATA

ProductGroup For radiance products one of the following:

```
BAND1_RADIANCE | BAND2_RADIANCE | BAND3_RADIANCE | BAND4_RADIANCE | BAND5_RADIANCE | BAND5_RADIANCE | BAND7_RADIANCE | BAND8_RADIANCE | For irradiance products one or more of the following:
```

```
BAND1_IRRADIANCE | BAND2_IRRADIANCE | BAND3_IRRADIANCE | BAND4_IRRADIANCE | BAND5_IRRADIANCE | BAND6_IRRADIANCE | BAND7_IRRADIANCE | BAND8_IRRADIANCE
```

SensorModeGroup For all products one of the following:

```
STANDARD_MODE | SPECIAL_MODE_%J
```

where: %J equals to the Instrument Configuration ID modulo 4096 (IcID % 4096); more information on the meaning of the IcID is found in sections 8.39 and 8.40)

There is one STANDARD_MODE group. This means that all measurements taken in the standard mode operation are combined even if the standard operation mode is interleaved with operations of the sensor in a special mode.

ObservationsGroup For all products fixed to: OBSERVATIONS

GeodataGroup For all products fixed to: GEODATA

InstrumentGroup For all products fixed to: INSTRUMENT

ProcessorGroup For all products fixed to: PROCESSOR

7.2.2.2 Variables, attributes and dimensions

All variables and dimensions are written in lower case and consist of alphanumeric characters and underscores. Spaces are not allowed.

Unless specified by CF Conventions or ACDD conventions, attributes are written in lower case and consist of alphanumeric characters and underscores. Spaces are not allowed.

7.2.3 Dimensions and coordinate variables

The spectral radiance measurements are collected as a function of the two dimensions (ground pixels across track and wavelengths) of the detector and of the scans. The corresponding dimensions describing the swath in the netCDF product are named: ground_pixel, spectral_channel and scanline, respectively. For reasons of interoperability the dimension time was added with a fixed size of unity as well as a one-element coordinate variable time(time) indicating the reference time of the measurements. This reference time is yyyy-mm-ddT00:00:00 UTC, where yyyy-mm-dd is the day on which the measurements of a particular data granule start. The delta_time(scanline) variable indicates the time difference with the reference time time(time). Thus combining the information of time(time) and delta_time(scanline) yields the measurement time for each scanline as UTC time.

Following the recommendations of the CF Conventions with respect to the ordering of dimensions having the interpretations of "date or time" (T), "height or depth" (Z), "latitude" (Y) or "longitude" (X), a logical ordering of the dimensions would be (time, spectral_channel, scanline, ground_pixel). However, performance tests have shown that given the preferred way of reading through the data, a relative order of (time, scanline, ground_pixel, spectral_channel) is preferable; this latter dimension ordering is therefore selected for the variables.

In case of a swath-type scanning pattern as used by TROPOMI, the scanline and ground_pixel dimensions cannot be referred to as latitude and longitude because they are on a different grid. However, latitude and longitude information can be stored in auxiliary coordinate variables (here: latitude(time, scanline, ground_pixel)), which are identified by the coordinates attribute. By using this convention, applications will be able to process the latitude and longitudes correctly, allowing, for instance, plotting swath-like measurements on a latitude, longitude grid.

One more dimension is defined in the radiance products: ncorner. The dimension ncorner has a fixed size of 4 and is used for specifying the corner coordinates of the individual ground pixels. The corner coordinates are specified by the latitude_bounds(time, scanline, ground_pixel, ncorner) and longitude_bounds(time, scanline, ground_pixel, ncorner) variables, which represent the boundaries of each pixel.

Because during the irradiance measurements the sensors are not imaging the Earth's surface but are measuring the solar irradiance, pixel is the preferred name for the across-track dimension. Moreover, after correction for the sun elevation the individual irradiance measurements as function of scanline are averaged, which results in just one measurement.

Table 10 lists the typical size of the dimensions for different detectors and bands.

Detector	UV		UVIS		NIR		SWIR	
Band	1	2	3	4	5	6	7	8
time	1	1	1	1	1	1	1	1
spectral_channel	497	497	497	497	497	497	480	480
scanline	3246	3246	3246	3246	3246	3246	3246	3246
<pre>ground_pixel (pixel)</pre>	77	448	450	450	448	448	215	215

Table 10: Typical NetCDF dimension sizes; The scanline dimension varies between orbits and products. A typical value for this size for a radiance product making observations at the day-side of the Earth is 3246. For irradiance products scanline=1. The ground_pixel dimension is only present in radiance products.

7.3 L1b products

7.3.1 Radiance products

The following tables (Table 11 to Table 13) list all variables of the radiance products as they appear in the different groups. There is no difference between standard and near-real time products. A detailed description in CDL is provided in sections 8.4 to 8.132. The netCDF base types are defined in Table 50.

ObservationsGroup	ObservationsGroup				
Variable	Туре	Description			
time	int	Reference time of the measurements. The reference time is set to yyyy-mm-ddT00:00:00 UTC, where yyyy-mm-dd is the day on which the measurements of a particular data granule start.			
spectral_channel	int	Coordinate variable defining the indices in the spectral dimension			
scanline	int	Coordinate variable defining the indices along track			
<pre>ground_pixel</pre>	int	Coordinate variable defining the indices across track			
delta_time	int	Time difference with time for each measurement			
radiance	float	Measured spectral radiance for each spectral pixel			
radiance_error	byte	Estimate of the systematic error (accuracy) of the measured spectral radiance (includes calibration and model errors).			
radiance_noise	byte	Estimate of the statistical error (precision) of the measured spectral radiance (includes shot noise and read noise).			
small_pixel_radiance	float(*)	Measured spectral radiance for the spectral channel dedicated for the small pixel measurements			
quality_level	ubyte	Overall quality assessment information for each (spectral) pixel			
spectral_channel_quality	ubyte	Quality assessment information for each (spectral) pixel			
<pre>detector_row qualification</pre>	ushort	Qualification flag indicating the detector row type or state			
<pre>detector_column qualification</pre>	ushort	Qualification flag indicating column type or state			
measurement_quality	ushort	Overall quality information for a measurement			
<pre>ground_pixel_quality</pre>	ubyte	Quality assessment information for each ground pixel			

Table 11: NetCDF variables in the ObservationGroup for radiance products

GeodataGroup	GeodataGroup				
Variable	Туре	Description			
latitude	float	Latitude of the center of each ground pixel on the WGS84 reference ellipsoid			
latitude_bounds	float	The four latitude boundaries of each ground pixel.			
longitude	float	Longitude of the center of each ground pixel on the WGS84 reference ellipsoid			
longitude_bounds	float	The four longitude boundaries of each ground pixel.			
satellite_orbit_phase	float	Relative offset (0.0 1.0) of the measurement in the orbit			
satellite_altitude	float	The altitude of the spacecraft relative to the WGS84 reference ellipsoid			
satellite_latitude	float	Latitude of the spacecraft sub-satellite point on the WGS84 reference ellipsoid			
satellite_longitude	float	Longitude of the spacecraft sub-satellite point on the WGS84 reference ellipsoid			
viewing_azimuth_angle	float	Azimuth angle of the spacecraft measured from the ground pixel WGS84 reference ellipsoid.			
viewing_zenith_angle	float	Zenith angle of the spacecraft measured from the ground pixel location on the WGS84 reference ellipsoid.			
solar_azimuth_angle	float	Azimuth angle of the sun measured from the ground pixel location on the WGS84 ellipsoid.			
solar_zenith_angle	float	Zenith angle of the sun measured from the ground pixel location on the WGS84 reference ellipsoid.			
earth_sun_distance	float	Distance between the Earth and Sun			

Table 12: NetCDF variables in the GeodataGroup for radiance products. [Note: Because of the nature of the information the variables latitude, longitude, latitude_bounds and longitude_bounds are placed in the GeodataGroup. However, current software applications might have problems to find the auxiliary coordinate variables (in this case latitude and longitude) listed by the coordinates attribute of a variable in the ObservationsGroup.]

InstrumentGroup					
Variable	Туре	Description			
processing_class	short	High level identification of the type of measurement, for example earth / radiance, sun / irradiance, WLS calibration, LED calibration, dark current / background, etc.			
instrument_configuration	compound	Identifier (number) that identifies the (detailed) type of measurement and the configuration of the instrument			
instrument_settings	compound	All fields that determine the instrument configuration and are relevant for data processing, like exposure tme, binning factors, co-addition period, gain settings, status of calibration unit, etc.			
housekeeping_data	compound	Fields that describe scanline dependent instrument characteristics, like detector temperatures, etc.			
binning_table	compound	Contains the binning configuration for all of the instrument configurations used in the group. Not present in SWIR products			
nominal_wavelength	float	The nominal spectral wavelength for each cross track pixel as a function of the spectral channel.			
nominal_wavelength_error	float	The nominal spectral wavelength standard deviation for each cross track pixel as a function of the spectral channel.			

InstrumentGroup (cont'd)				
Variable	Туре	Description		
sample_cycle	int	Index of cycle. During one sample cycle an integer number of scanlines is collected		
sample_cycle_length	int	Length of sample_cycle		
<pre>measurement_to_detector row_table</pre>	compound	Conversion table from measurement row to begin and end row on detector		

Table 13: NetCDF variables in the InstrumentGroup for radiance products

7.3.2 Irradiance products

The following tables (Table 14 to Table16) list all variables of the irradiance products. A detailed description in CDL is provided in sections 8.4 to 8.132. The netCDF base types are defined in Table 50.

ObservationsGroup				
Variable	Туре	Description		
time	int	Reference time of the measurements. The reference time is set to yyyy-mm-ddT00:00:00 UTC, where yyyy-mm-dd is the day on which the measurements of a particular data granule start.		
spectral_channel	int	Coordinate variable defining the indices in the spectral dimension		
scanline	int	Coordinate variable defining the indices along track		
pixel	int	Coordinate variable defining the indices across track		
delta_time	int	Time difference with time for each measurement		
irradiance	float	Measured spectral irradiance for each spectral pixel		
irradiance_error	byte	Estimate of the systematic error (accuracy) of the measured spectral radiance (includes calibration and model errors).		
irradiance_noise	byte	Estimate of the statistical error (precision) of the measured spectral irradiance (includes shot noise and read noise)		
quality_level	ubyte	Overall quality assessment information for each (spectral) pixel		
spectral_channel_quality	ubyte	Quality assessment information for each (spectral) pixel		
<pre>detector_row qualification</pre>	ushort	Qualification flag indicating the detector row type or state		
<pre>detector_column qualification</pre>	ushort	Qualification flag indicating column type or state		
measurement_quality	ushort	Overall quality information for a measurement		

Table 14: NetCDF variables in the ObservationGroup for irradiance products

GeodataGroup				
Variable	Туре	Description		
earth_sun_distance	float	Distance between the Earth and Sun		

Table 15: NetCDF variables in the GeodataGroup for irradiance products

InstrumentGroup				
Variable	Туре	Description		
calibrated_wavelength	float	Calibrated wavelength of each spectral pixel		

InstrumentGroup (cont'd)		
Variable	Туре	Description
calibrated_wavelength	float	Calibrated wavelength error of each spectral pixel
error		
processing_class	short	High level identification of the type of measurement, for example earth / radiance, sun / irradiance, WLS calibration, LED calibration, dark current / background, etc.
instrument_configuration	compound	Identifier (number) that identifies the (detailed) type of measurement and the configuration of the instrument
instrument_settings	compound	All fields that determine the instrument configuration and are relevant for data processing, like exposure tme, binning factors, co-addition period, gain settings, status of calibration unit, etc.
housekeeping_data	compound	Fields that describe scanline dependent instrument characteristics, like detector temperatures, etc.
binning_table	compound	Contains the binning configuration for all of the instrument configurations used in the group. Not present in SWIR products
nominal_wavelength	float	The nominal spectral wavelength for each cross track pixel as a function of the spectral channel.
nominal_wavelength_error	float	The nominal spectral wavelength standard deviation for each cross track pixel as a function of the spectral channel.
sample_cycle	int	Index of cycle. During one sample cycle an integer number of scanlines is collected
sample_cycle_length	int	Length of sample_cycle
<pre>measurement_to_detector row_table</pre>	compound	Conversion table from measurement row to begin and end row on detector

Table 16: NetCDF variables in the InstrumentGroup for irradiance products

7.3.3 Calibration products

7.3.3.1 NetCDF File Structure

The calibration product has a different NetCDF file structure than the file structure for radiance and irradiance products described in section 7.2.1. The file format of the L1b engineering product is structured using groups compliant with the netCDF-4 enhanced model. The group hierarchy is as follows ("/" indicating the root of the groups):

```
/
/global attributes
/MetadataGroup [1]
/MetadataGroup/ISOMetadataGroup [1]
/MetadataGroup/EOPMetadataGroup [1]
/MetadataGroup/ESAMetadataGroup [1]
/ProductGroup [1,*]
/ProductGroup/SensorModeGroup [1,*]
/ProductGroup/SensorModeGroup/ObservationsGroup [1]
/ProductGroup/SensorModeGroup/GeodataGroup [1]
/ProductGroup/SensorModeGroup/InstrumentGroup [1]
/ProductGroup/SensorModeGroup/QualityAssessmentGroup [1]
/ProcessorGroup [1]
```

7.3.3.2 Naming conventions

All naming conventions for the groups described in section 7.2.2 apply, except for the groups specified hereafter.

ProductGroup For calibration products one of the following:

```
BAND1_RADIANCE | BAND2_RADIANCE | BAND3_RADIANCE | BAND4_RADIANCE |
BAND5_RADIANCE | BAND6_RADIANCE | BAND7_RADIANCE | BAND8_RADIANCE |
BAND1_IRRADIANCE | BAND2_IRRADIANCE | BAND3_IRRADIANCE | BAND4_IRRADIANCE |
BAND5_IRRADIANCE | BAND6_IRRADIANCE | BAND7_IRRADIANCE | BAND8_IRRADIANCE |
BAND1_CALIBRATION | BAND2_CALIBRATION | BAND3_CALIBRATION | BAND4_CALIBRATION |
BAND5_CALIBRATION | BAND6_CALIBRATION | BAND7_CALIBRATION | BAND8_CALIBRATION
```

SensorModeGroup For all products the SensorModeGroup name has the format:

%C_MODE_%J

where: %C is the Processing Class Name (in upper case) (see section B);

and %J equals to the Instrument Configuration ID modulo 4096 (IcID % 4096); more information on the meaning of the IcID is found in sections 8.39 and 8.40).

Example: the band 1 calibration product for the white light source measurements is found in the group: /BAND1 CALIBRATION/WLS MODE 1806/OBSERVATIONS.

QualityAssessmentGroup For all products fixed to: QUALITY_ASSESSMENT

7.3.3.3 Radiance calibration groups

ObservationsGroup		
Variable	Туре	Description
time	int	Reference time of the measurements. The reference time is set to yyyy-mm-ddT00:00:00 UTC, where yyyy-mm-dd is the day on which the measurements of a particular data granule start.
delta_time	int	Time difference with time for each measurement
<pre>detector_row qualification</pre>	ushort	Qualification flag indicating the detector row type or state
<pre>detector_column qualification</pre>	ushort	Qualification flag indicating column type or state
measurement_quality	ushort	Overall quality information for a measurement
<pre>ground_pixel_quality</pre>	ubyte	Quality assessment information for each ground pixel
radiance_avg	float	Averaged measured spectral radiance for each spectral pixel of all measurements in the group
radiance_avg_error	float	Average radiance signal error for each spectral pixel of all measurements in the group
radiance_avg_noise	float	Average radiance signal noise for each spectral pixel of all measurements in the group
<pre>radiance_avg_spectral channel_quality</pre>	ubyte	Quality assessment information about a (spectral) pixel in all measurements.
<pre>radiance_avg_quality level</pre>	ubyte	Overall calculated quality assessment information for each (spectral) pixel in the averaged data
radiance_avg_std	float	Average radiance signal standard deviation for each spectral pixel of all measurements in the group
radiance_avg_row	float	Averaged measured spectral radiance value of a single row in a measurement
radiance_avg_col	float	Averaged measured spectral radiance value of a single col- umn in a measurement

ObservationsGroup (cont'd)		
Variable	Туре	Description
radiance_avg_data	float	Averaged measured spectral radiance value of a single measurements
small_pixel_radiance	float(*)	Measured spectral radiance for the spectral channel dedi- cated for the small pixel measurements
scanline	int	Coordinate variable defining the indices along track
ground_pixel	int	Coordinate variable defining the indices across track
spectral_channel	int	Coordinate variable defining the indices in the spectral dimension

 Table 17: NetCDF variables in the ObservationGroup for radiance calibration products

GeodataGroup		
Variable	Туре	Description
satellite_orbit_phase	float	Relative offset (0.0 1.0) of the measurement in the orbit
satellite_altitude	float	The altitude of the spacecraft relative to the WGS84 reference ellipsoid
satellite_latitude	float	Latitude of the spacecraft sub-satellite point on the WGS84 reference ellipsoid
satellite_longitude	float	Longitude of the spacecraft sub-satellite point on the WGS84 reference ellipsoid
solar_azimuth_angle	float	Azimuth angle of the sun measured from the ground pixel location on the WGS84 ellipsoid.
solar_zenith_angle	float	Zenith angle of the sun measured from the ground pixel location on the WGS84 reference ellipsoid.
earth_sun_distance	float	Distance between the Earth and Sun
latitude	float	Latitude of the center of each ground pixel on the WGS84 reference ellipsoid
longitude	float	Longitude of the center of each ground pixel on the WGS84 reference ellipsoid
latitude_bounds	float	The four latitude boundaries of each ground pixel.
longitude_bounds	float	The four longitude boundaries of each ground pixel.
viewing_azimuth_angle	float	Azimuth angle of the spacecraft measured from the ground pixel WGS84 reference ellipsoid.
viewing_zenith_angle	float	Zenith angle of the spacecraft measured from the ground pixel location on the WGS84 reference ellipsoid.

 Table 18: NetCDF variables in the GeodataGroup for radiance calibration products

InstrumentGroup		
Variable	Туре	Description
processing_class	short	High level identification of the type of measurement, for example earth / radiance, sun / irradiance, WLS calibration, LED calibration, dark current / background, etc.
instrument_configuration	compound	Identifier (number) that identifies the (detailed) type of measurement and the configuration of the instrument
instrument_settings	compound	All fields that determine the instrument configuration and are relevant for data processing, like exposure tme, binning factors, co-addition period, gain settings, status of calibration unit, etc.

InstrumentGroup (cont'd)		
Variable	Туре	Description
housekeeping_data	compound	Fields that describe scanline dependent instrument characteristics, like detector temperatures, etc.
nominal_wavelength	float	The nominal spectral wavelength for each cross track pixel as a function of the spectral channel.
nominal_wavelength_error	float	The nominal spectral wavelength standard deviation for each cross track pixel as a function of the spectral channel.
binning_table	compound	Contains the binning configuration for all of the instrument configurations used in the group. Not present in SWIR products
<pre>measurement_to_detector row_table</pre>	compound	Conversion table from measurement row to begin and end row on detector
sample_cycle	int	Index of cycle. During one sample cycle an integer number of scanlines is collected
sample_cycle_length	int	Length of sample_cycle

Table 19: NetCDF variables in the InstrumentGroup for radiance calibration products

QualityAssessmentGroup		
Variable	Туре	Description
detector_pixel_filling histogram	int	Histogram of the detector pixel filling in electrons for each scanline
offset_static_ckd	compound	Detector and electronics offset value, obtained from the calibration key-data
offset_prepostscan pixels	compound	Detector and electronics offset value calculated from the detector's pre- and postscan pixels
offset_readout_register	compound	Detector and electronics offset value calculated from the detector's read-out register
offset_overscan_rows	compound	Detector and electronics offset value calculated from the detector's overscan rows
offset_overscan_columns	compound	Detector and electronics offset value calculated from the detector's overscan columns
monitor_smear_observed	float	Observed detector smear values from the masked regions of the detector, for monitoring purposes
monitor_smear_calculated	float	Calculated detector smear values as used for the detector smear correction, for monitoring purposes
monitor_straylight observed	float	Observed stray light from the stray light areas on the detector, for monitoring purposes
monitor_straylight calculated	float	Calculated stray light, for monitoring purposes
monitor_overscan_rows	float	Signal from the detector's overscan rows, for monitoring purposes
monitor_read_out register	float	Spectral channel signal values as read from the read out register
monitor_radiance wavelength_shift	float	Wavelenght shift for a small wavelength band around the specified wavelength, for monitoring purposes
monitor_radiance	float	Average radiance of a small wavelength band around the specified wavelength, for monitoring purposes.

QualityAssessmentGroup (cont'd)			
Variable	Туре	Description	
monitor_gain_alignment factor	float	Gain alignment factor for the measurement calculated in the GainAlignmentCalculationUVN algorithm. Applied gain alignment factor depends on the settings of this algorithm. Default, the CKD setting of the gain alignment correction factor is used, not the calculated.	
<pre>percentage_spectral channels_missing</pre>	float	Percentage of spectral channels for which the missing flag is set	
<pre>percentage_spectral channels_defective</pre>	float	Percentage of spectral channels for which the defective flag is set	
<pre>percentage_spectral channels_processing</pre>	float	Percentage of spectral channels for which the processing error flag is set	
error			
<pre>percentage_spectral channels_saturated</pre>	float	Percentage of spectral channels for which the saturated flag is set	
<pre>percentage_spectral channels_transient</pre>	float	Percentage of spectral channels for which the transient flag is set	
<pre>percentage_spectral channels_rts</pre>	float	Percentage of spectral channels for which the RTS flag is set	
<pre>percentage_spectral channels_underflow</pre>	float	Percentage of spectral channels for which the underflow flag is set	
<pre>percentage_spectral channels_per_scanline missing</pre>	float	Percentage of spectral channels per scanline for which the missing flag is set	
<pre>percentage_spectral channels_per_scanline defective</pre>	float	Percentage of spectral channels per scanline for which the defective flag is set	
<pre>percentage_spectral channels_per_scanline processing_error</pre>	float	Percentage of spectral channels per scanline for which the processing error flag is set	
<pre>percentage_spectral channels_per_scanline saturated</pre>	float	Percentage of spectral channels per scanline for which the saturated flag is set	
<pre>percentage_spectral channels_per_scanline transient</pre>	float	Percentage of spectral channels per scanline for which the transient flag is set	
<pre>percentage_spectral channels_per_scanline rts</pre>	float	Percentage of spectral channels per scanline for which the RTS flag is set	
<pre>percentage_spectral channels_per_scanline underflow</pre>	float	Percentage of spectral channels per scanline for which the underflow flag is set	
<pre>percentage_scanlines with_processing_steps skipped</pre>	float	Percentage of scanlines for which one or more processing steps were skipped	
percentage_scanlines with_residual correction_skipped	float	Percentage of scanlines for which residual correction was skipped	
percentage_scanlines_in south_atlantic_anomaly	float	Percentage of scanlines in the South Atlantic Anomaly (SAA)	
<pre>percentage_scanlines_in spacecraft_manoeuvre</pre>	float	Percentage of scanlines affected by spacecraft manoeuvres	

QualityAssessmentGroup (cont'd)		
Variable	Туре	Description
percentage_scanlines with_solar_angles_out of_nominal_range	float	Percentage of scanlines for which the solar angles are outside the nominal range
<pre>percentage_ground pixels_descending_side orbit</pre>	float	Percentage of ground pixels on the descending side of the orbit
<pre>percentage_ground pixels_geolocation_error</pre>	float	Percentage of ground pixels with geolocation error
<pre>percentage_ground pixels_geometric boundary_crossing</pre>	float	Percentage of ground pixels that cross a geometric boundary, e.g. dateline crossing
<pre>percentage_ground pixels_night</pre>	float	Percentage of ground pixels for which the night flag is set
<pre>percentage_ground pixels_solar_eclipse</pre>	float	Percentage of ground pixels for which the solar eclipse flag is set
<pre>percentage_ground pixels_sun_glint</pre>	float	Percentage of ground pixels for which the sun glint flag is set
oob_sl_nir_corr_row_avg blu_rad	float	Calculated oob straylight nir correction row average, blue side radiance, for monitoring purposes
oob_sl_nir_dp_factor blu_rad	float	Calculated oob straylight nir dp factor, blue side radiance, for monitoring purposes
oob_sl_nir_corr_row_avg red_rad	float	Calculated oob straylight nir correction row average, red side radiance, for monitoring purposes
oob_sl_nir_dp_factor red_rad	float	Calculated oob straylight nir dp factor, red side radiance, for monitoring purposes
oob_sl_nir_corr_row_avg red_irr	float	Calculated oob straylight nir correction row average, red side irradiance, for monitoring purposes
oob_sl_nir_dp_factor blu_irr	float	Calculated oob straylight nir dp factor, blue side irradiance, for monitoring purposes
oob_sl_nir_dp_factor red_irr	float	Calculated oob straylight nir dp factor, red side irradiance, for monitoring purposes
oob_sl_nir_corr_row_avg blu_irr	float	Calculated oob straylight nir correction row average, blue side radiance, for monitoring purposes

Table 20: NetCDF variables in the QualityAssessmentGroup for radiance calibration products

7.3.3.4 Irradiance calibration groups

ObservationsGroup		
Variable	Туре	Description
time	int	Reference time of the measurements. The reference time is set to yyyy-mm-ddT00:00:00 UTC, where yyyy-mm-dd is the day on which the measurements of a particular data granule start.
spectral_channel	int	Coordinate variable defining the indices in the spectral dimension
scanline	int	Coordinate variable defining the indices along track
pixel	int	Coordinate variable defining the indices across track
delta_time	int	Time difference with time for each measurement
irradiance	float	Measured spectral irradiance for each spectral pixel

ObservationsGroup (cont'd)		
Variable	Туре	Description
irradiance_error	byte	Estimate of the systematic error (accuracy) of the measured spectral radiance (includes calibration and model errors).
irradiance_noise	byte	Estimate of the statistical error (precision) of the measured spectral irradiance (includes shot noise and read noise)
quality_level	ubyte	Overall quality assessment information for each (spectral) pixel
spectral_channel_quality	ubyte	Quality assessment information for each (spectral) pixel
<pre>detector_row qualification</pre>	ushort	Qualification flag indicating the detector row type or state
<pre>detector_column qualification</pre>	ushort	Qualification flag indicating column type or state
measurement_quality	ushort	Overall quality information for a measurement

Table 21: NetCDF variables in the ObservationGroup for irradiance calibration products

GeodataGroup		
Variable	Туре	Description
satellite_orbit_phase	float	Relative offset (0.0 1.0) of the measurement in the orbit
satellite_altitude	float	The altitude of the spacecraft relative to the WGS84 reference ellipsoid
satellite_latitude	float	Latitude of the spacecraft sub-satellite point on the WGS84 reference ellipsoid
satellite_longitude	float	Longitude of the spacecraft sub-satellite point on the WGS84 reference ellipsoid
solar_azimuth_angle	float	Azimuth angle of the sun measured from the instrument
solar_elevation_angle	float	Elevation angle of the sun measured from the instrument.
earth_sun_distance	float	Distance between the Earth and Sun

 Table 22: NetCDF variables in the GeodataGroup for irradiance calibration products

InstrumentGroup		
Variable	Туре	Description
processing_class	short	High level identification of the type of measurement, for example earth / radiance, sun / irradiance, WLS calibration, LED calibration, dark current / background, etc.
instrument_configuration	compound	Identifier (number) that identifies the (detailed) type of measurement and the configuration of the instrument
instrument_settings	compound	All fields that determine the instrument configuration and are relevant for data processing, like exposure tme, binning factors, co-addition period, gain settings, status of calibration unit, etc.
housekeeping_data	compound	Fields that describe scanline dependent instrument characteristics, like detector temperatures, etc.
nominal_wavelength	float	The nominal spectral wavelength for each cross track pixel as a function of the spectral channel.
nominal_wavelength_error	float	The nominal spectral wavelength standard deviation for each cross track pixel as a function of the spectral channel.

InstrumentGroup (cont'd)		
Variable	Туре	Description
binning_table	compound	Contains the binning configuration for all of the instrument configurations used in the group. Not present in SWIR products
calibrated_wavelength	float	Calibrated wavelength of each spectral pixel
<pre>calibrated_wavelength error</pre>	float	Calibrated wavelength error of each spectral pixel
<pre>measurement_to_detector row_table</pre>	compound	Conversion table from measurement row to begin and end row on detector
sample_cycle	int	Index of cycle. During one sample cycle an integer number of scanlines is collected
sample_cycle_length	int	Length of sample_cycle

Table 23: NetCDF variables in the InstrumentGroup for irradiance calibration products

QualityAssessmentGroup		
Variable	Туре	Description
detector_pixel_filling histogram	int	Histogram of the detector pixel filling in electrons for each scanline
offset_static_ckd	compound	Detector and electronics offset value, obtained from the calibration key-data
offset_prepostscan pixels	compound	Detector and electronics offset value calculated from the detector's pre- and postscan pixels
offset_readout_register	compound	Detector and electronics offset value calculated from the detector's read-out register
offset_overscan_rows	compound	Detector and electronics offset value calculated from the detector's overscan rows
offset_overscan_columns	compound	Detector and electronics offset value calculated from the detector's overscan columns
monitor_smear_observed	float	Observed detector smear values from the masked regions of the detector, for monitoring purposes
monitor_smear_calculated	float	Calculated detector smear values as used for the detector smear correction, for monitoring purposes
monitor_straylight observed	float	Observed stray light from the stray light areas on the detector, for monitoring purposes
<pre>monitor_straylight calculated</pre>	float	Calculated stray light, for monitoring purposes
monitor_overscan_rows	float	Signal from the detector's overscan rows, for monitoring purposes
monitor_gain_alignment factor	float	Gain alignment factor for the measurement calculated in the GainAlignmentCalculationUVN algorithm. Applied gain alignment factor depends on the settings of this algorithm. Default, the CKD setting of the gain alignment correction factor is used, not the calculated.
<pre>monitor_read_out register</pre>	float	Spectral channel signal values as read from the read out register
<pre>percentage_spectral channels_missing</pre>	float	Percentage of spectral channels for which the missing flag is set
<pre>percentage_spectral channels_defective</pre>	float	Percentage of spectral channels for which the defective flag is set

QualityAssessmentGroup (cont'd)		
Variable	Туре	Description
percentage_spectral channels_processing error	float	Percentage of spectral channels for which the processing error flag is set
<pre>percentage_spectral channels_saturated</pre>	float	Percentage of spectral channels for which the saturated flag is set
<pre>percentage_spectral channels_transient</pre>	float	Percentage of spectral channels for which the transient flag is set
<pre>percentage_spectral channels_rts</pre>	float	Percentage of spectral channels for which the RTS flag is set
<pre>percentage_spectral channels_underflow</pre>	float	Percentage of spectral channels for which the underflow flag is set
<pre>percentage_spectral channels_per_scanline missing</pre>	float	Percentage of spectral channels per scanline for which the missing flag is set
<pre>percentage_spectral channels_per_scanline defective</pre>	float	Percentage of spectral channels per scanline for which the defective flag is set
<pre>percentage_spectral channels_per_scanline processing_error</pre>	float	Percentage of spectral channels per scanline for which the processing error flag is set
<pre>percentage_spectral channels_per_scanline saturated</pre>	float	Percentage of spectral channels per scanline for which the saturated flag is set
<pre>percentage_spectral channels_per_scanline transient</pre>	float	Percentage of spectral channels per scanline for which the transient flag is set
<pre>percentage_spectral channels_per_scanline rts</pre>	float	Percentage of spectral channels per scanline for which the RTS flag is set
<pre>percentage_spectral channels_per_scanline underflow</pre>	float	Percentage of spectral channels per scanline for which the underflow flag is set
<pre>percentage_scanlines with_processing_steps skipped</pre>	float	Percentage of scanlines for which one or more processing steps were skipped
<pre>percentage_scanlines with_residual correction_skipped</pre>	float	Percentage of scanlines for which residual correction was skipped
<pre>percentage_scanlines_in south_atlantic_anomaly</pre>	float	Percentage of scanlines in the South Atlantic Anomaly (SAA)
percentage_scanlines_in spacecraft_manoeuvre	float	Percentage of scanlines affected by spacecraft manoeuvres
percentage_scanlines with_solar_angles_out of_nominal_range	float	Percentage of scanlines for which the solar angles are outside the nominal range
oob_sl_nir_dp_factor blu_irr	float	Calculated oob straylight nir dp factor, blue side irradiance, for monitoring purposes
<pre>oob_sl_nir_corr_row_avg blu_irr</pre>	float	Calculated oob straylight nir correction row average, blue side radiance, for monitoring purposes
<pre>oob_sl_nir_dp_factor red_irr</pre>	float	Calculated oob straylight nir dp factor, red side irradiance, for monitoring purposes

QualityAssessmentGroup (cont'd)		
Variable	Туре	Description
oob_sl_nir_corr_row_avg red_irr	float	Calculated oob straylight nir correction row average, red side irradiance, for monitoring purposes
oob_sl_nir_dp_factor blu_rad	float	Calculated oob straylight nir dp factor, blue side radiance, for monitoring purposes
oob_sl_nir_dp_factor red_rad	float	Calculated oob straylight nir dp factor, red side radiance, for monitoring purposes
oob_sl_nir_corr_row_avg red_rad	float	Calculated oob straylight nir correction row average, red side radiance, for monitoring purposes
oob_sl_nir_corr_row_avg blu_rad	float	Calculated oob straylight nir correction row average, blue side radiance, for monitoring purposes

 Table 24: NetCDF variables in the QualityAssessmentGroup for irradiance calibration products

7.3.3.5 Other calibration groups

ObservationsGroup		
Variable	Туре	Description
time	int	Reference time of the measurements. The reference time is set to yyyy-mm-ddT00:00:00 UTC, where yyyy-mm-dd is the day on which the measurements of a particular data granule start.
delta_time	int	Time difference with time for each measurement
small_pixel_signal	float(*)	Measured signal for the spectral channel dedicated for the small pixel measurements
quality_level	ubyte	Overall quality assessment information for each (spectral pixel
spectral_channel_quality	ubyte	Quality assessment information for each (spectral) pixel
<pre>detector_row qualification</pre>	ushort	Qualification flag indicating the detector row type or state
<pre>detector_column qualification</pre>	ushort	Qualification flag indicating column type or state
measurement_quality	ushort	Overall quality information for a measurement
signal	float	Measured signal for the spectral channel
signal_error	byte	Estimate of the systematic error (accuracy) of the measured signal (includes calibration and model errors).
signal_noise	byte	Estimate of the statistical error (precision) of the measured signal (includes shot noise and read noise)
signal_avg	float	Averaged measured spectral signal for each spectral pixel o all measurements in the group
signal_avg_error	float	Average signal error for each spectral pixel of all measure ments in the group
signal_avg_noise	float	Average signal noise for each spectral pixel of all measure ments in the group
signal_avg_spectral channel_quality	ubyte	Quality assessment information about a (spectral) pixel in al measurements.
signal_avg_quality_level	ubyte	Overall calculated quality assessment information for each (spectral) pixel in the averaged data
signal_avg_row	float	Averaged measured spectral signal value of a single row in a measurement

ObservationsGroup (cont'd)		
Variable	Туре	Description
signal_avg_col	float	Averaged measured spectral signal value of a single column in a measurement
signal_avg_data	float	Averaged measured spectral signal value of a single measurement
signal_avg_std	float	Average signal standard deviation for each spectral pixel of all measurements in the group
scanline	int	Coordinate variable defining the indices along track
pixel	int	Coordinate variable defining the indices across track
spectral_channel	int	Coordinate variable defining the indices in the spectral dimension

 Table 25: NetCDF variables in the ObservationGroup for calibration products

GeodataGroup		
Variable	Туре	Description
satellite_orbit_phase	float	Relative offset (0.0 1.0) of the measurement in the orbit
satellite_altitude	float	The altitude of the spacecraft relative to the WGS84 reference ellipsoid
satellite_latitude	float	Latitude of the spacecraft sub-satellite point on the WGS84 reference ellipsoid
satellite_longitude	float	Longitude of the spacecraft sub-satellite point on the WGS84 reference ellipsoid
earth_sun_distance	float	Distance between the Earth and Sun

 Table 26: NetCDF variables in the GeodataGroup for calibration products

InstrumentGroup		
Variable	Туре	Description
processing_class	short	High level identification of the type of measurement, for example earth / radiance, sun / irradiance, WLS calibration, LED calibration, dark current / background, etc.
instrument_configuration	compound	Identifier (number) that identifies the (detailed) type of measurement and the configuration of the instrument
instrument_settings	compound	All fields that determine the instrument configuration and are relevant for data processing, like exposure tme, binning factors, co-addition period, gain settings, status of calibration unit, etc.
housekeeping_data	compound	Fields that describe scanline dependent instrument characteristics, like detector temperatures, etc.
nominal_wavelength	float	The nominal spectral wavelength for each cross track pixel as a function of the spectral channel.
nominal_wavelength_error	float	The nominal spectral wavelength standard deviation for each cross track pixel as a function of the spectral channel.
binning_table	compound	Contains the binning configuration for all of the instrument configurations used in the group. Not present in SWIR products
storage_time	float	The time a row has resided in the storage area of the detector during read-out

InstrumentGroup (cont'd)		
Variable	Туре	Description
<pre>measurement_to_detector row_table</pre>	compound	Conversion table from measurement row to begin and end row on detector
sample_cycle	int	Index of cycle. During one sample cycle an integer number of scanlines is collected
sample_cycle_length	int	Length of sample_cycle

Table 27: NetCDF variables in the InstrumentGroup for calibration products

QualityAssessmentGroup Variable	Туре	Description
	int	<u> </u>
<pre>detector_pixel_filling histogram</pre>	Ш	Histogram of the detector pixel filling in electrons for each scanline
offset_static_ckd	compound	Detector and electronics offset value, obtained from the calibration key-data
offset_prepostscan pixels	compound	Detector and electronics offset value calculated from the detector's pre- and postscan pixels
offset_readout_register	compound	Detector and electronics offset value calculated from the detector's read-out register
offset_overscan_rows	compound	Detector and electronics offset value calculated from the detector's overscan rows
offset_overscan_columns	compound	Detector and electronics offset value calculated from the detector's overscan columns
monitor_smear_observed	float	Observed detector smear values from the masked region of the detector, for monitoring purposes
monitor_smear_calculated	float	Calculated detector smear values as used for the detector smear correction, for monitoring purposes
monitor_straylight observed	float	Observed stray light from the stray light areas on the detecto for monitoring purposes
monitor_straylight calculated	float	Calculated stray light, for monitoring purposes
monitor_overscan_rows	float	Signal from the detector's overscan rows, for monitoring purposes
monitor_radiance wavelength_shift	float	Wavelenght shift for a small wavelength band around the specified wavelength, for monitoring purposes
monitor_read_out register	float	Spectral channel signal values as read from the read our register
monitor_radiance	float	Average radiance of a small wavelength band around the specified wavelength, for monitoring purposes.
<pre>monitor_gain_alignment factor</pre>	float	Gain alignment factor for the measurement calculated in the GainAlignmentCalculationUVN algorithm. Applied gain alignment factor depends on the settings of this algorithm Default, the CKD setting of the gain alignment correction factor is used, not the calculated.
<pre>percentage_spectral channels_missing</pre>	float	Percentage of spectral channels for which the missing flag is set
percentage_spectral channels_defective	float	Percentage of spectral channels for which the defective flag is set
<pre>percentage_spectral channels_processing error</pre>	float	Percentage of spectral channels for which the processing error flag is set

QualityAssessmentGroup (cont'd)		
Variable	Туре	Description
<pre>percentage_spectral channels_saturated</pre>	float	Percentage of spectral channels for which the saturated flag is set
<pre>percentage_spectral channels_transient</pre>	float	Percentage of spectral channels for which the transient flag is set
<pre>percentage_spectral channels_rts</pre>	float	Percentage of spectral channels for which the RTS flag is set
<pre>percentage_spectral channels_underflow</pre>	float	Percentage of spectral channels for which the underflow flag is set
<pre>percentage_spectral channels_per_scanline missing</pre>	float	Percentage of spectral channels per scanline for which the missing flag is set
percentage_spectral channels_per_scanline defective	float	Percentage of spectral channels per scanline for which the defective flag is set
<pre>percentage_spectral channels_per_scanline processing_error</pre>	float	Percentage of spectral channels per scanline for which the processing error flag is set
<pre>percentage_spectral channels_per_scanline saturated</pre>	float	Percentage of spectral channels per scanline for which the saturated flag is set
<pre>percentage_spectral channels_per_scanline transient</pre>	float	Percentage of spectral channels per scanline for which the transient flag is set
<pre>percentage_spectral channels_per_scanline rts</pre>	float	Percentage of spectral channels per scanline for which the RTS flag is set
<pre>percentage_spectral channels_per_scanline underflow</pre>	float	Percentage of spectral channels per scanline for which the underflow flag is set
<pre>percentage_scanlines with_processing_steps skipped</pre>	float	Percentage of scanlines for which one or more processing steps were skipped
<pre>percentage_scanlines with_residual correction_skipped</pre>	float	Percentage of scanlines for which residual correction was skipped
percentage_scanlines_in south_atlantic_anomaly	float	Percentage of scanlines in the South Atlantic Anomaly (SAA)
<pre>percentage_scanlines_in spacecraft_manoeuvre</pre>	float	Percentage of scanlines affected by spacecraft manoeuvres
<pre>percentage_scanlines with_solar_angles_out of_nominal_range</pre>	float	Percentage of scanlines for which the solar angles are outside the nominal range
oob_sl_nir_corr_row_avg blu_irr	float	Calculated oob straylight nir correction row average, blue side radiance, for monitoring purposes
oob_sl_nir_dp_factor blu_rad	float	Calculated oob straylight nir dp factor, blue side radiance, for monitoring purposes
oob_sl_nir_corr_row_avg red_irr	float	Calculated oob straylight nir correction row average, red side irradiance, for monitoring purposes
oob_sl_nir_dp_factor red_rad	float	Calculated oob straylight nir dp factor, red side radiance, for monitoring purposes

QualityAssessmentGroup (cont'd)		
Variable	Туре	Description
oob_sl_nir_dp_factor blu_irr	float	Calculated oob straylight nir dp factor, blue side irradiance, for monitoring purposes
oob_sl_nir_corr_row_avg red_rad	float	Calculated oob straylight nir correction row average, red side radiance, for monitoring purposes
oob_sl_nir_corr_row_avg blu_rad	float	Calculated oob straylight nir correction row average, blue side radiance, for monitoring purposes
oob_sl_nir_dp_factor red_irr	float	Calculated oob straylight nir dp factor, red side irradiance, for monitoring purposes

Table 28: NetCDF variables in the QualityAssessmentGroup for calibration products

7.3.4 Engineering product

The engineering products are input for the calibration processors who will use these products for generating updates to the calibration key data and for generating trending and monitoring products. The L1b engineering product is only intended for calibration and monitoring purposes. All instrument information needed or relevant for L2 processing will be contained within the radiance and irradiance products. As such, the engineering product is expected to be used by experts investigating and troubleshooting instrument performance anomalies. For that reason, only a high level description of the product is provided here. However, this description together with the detailed information contained in the netCDF and the Command and Telemetry Handbook [RD16] will allow expert users to retrieve the relevant engineering data.

7.3.4.1 NetCDF File Structure

The engineering product has a different NetCDF file structure than the file structure for radiance and irradiance products described in section 7.2.1. The file format of the L1b engineering product is structured using groups compliant with the netCDF-4 enhanced model. The group hierarchy is as follows ("/" indicating the root of the groups):

```
/global attributes
/MetadataGroup [1]
/MetadataGroup/ISOMetadataGroup [1]
/MetadataGroup/EOPMetadataGroup [1]
/MetadataGroup/ESAMetadataGroup [1]
/DetectorGroup [4]
/DetectorGroup/BandGroup [2]
/DetectorGroup/DetectorHousekeepingGroup [1]
/MeasurementSetGroup [1]
/NominalHouseKeepingGroup/EventsGroup [1]
/NominalHouseKeepingGroup/MechanismGroup [1]
/NominalHouseKeepingGroup/HeatersGroup [1]
/NominalHouseKeepingGroup/LEDInformationGroup [1]
/NominalHouseKeepingGroup/OBDHGroup [1]
/NominalHouseKeepingGroup/SoftwareConfigurationGroup [1]
/NominalHouseKeepingGroup/TemperaturesGroup [1]
/NominalHouseKeepingGroup/VersionInformationGroup [1]
/NominalHouseKeepingGroup/VoltagesGroup [1]
/ProcessorGroup [1]
/AncillaryDataGroup [1]
/SatelliteInformationGroup[1]
```

All groups in the schema listed above are always present in the netCDF file. The relation between detector type, detector number and bands can be found in Table 10. In the L0 product instrument parameters are available in

engineering data packages. The L01b processor extracts all the parameters from these data packages and groups them in variables which are then stored in the netCDF engineering product. The variables are stored in different groups; the groups and the variables they contain are described in the following sections.

7.3.4.2 Naming conventions

Except for the group names, all naming conventions described in section 7.2.2 apply. Group names are in upper case and consist of alphanumeric characters and underscores. Spaces are not allowed. The group names for the different groups are defined as follows:

DetectorGroup fixed to: DETECTOR1 | DETECTOR2 | DETECTOR3 | DETECTOR4

BandGroup fixed to: BAND1 | BAND2 | BAND3 | BAND4 | BAND5 | BAND6 | BAND7 | BAND8

DetectorHousekeepingGroup fixed to: DETECTOR_HK

MeasurementSetGroup fixed to: MSMTSET

NominalHouseKeepingGroup fixed to: NOMINAL_HK

EventsGroup fixed to: EVENTS

MechanismGroup fixed to: MECHANISMS

HeatersGroup fixed to: HEATERS

LEDInformationGroup fixed to LED_DATA

OBDHGroup fixed to OBDH DATA

SoftwareConfigurationGroup fixed to SW_CFG

TemperaturesGroup fixed to TEMPERATURES

VersionInformationGroup fixed to VERSION_INFO

VoltagesGroup fixed to VOLTAGES

SatelliteInformationGroup fixed to SATELLITE_INFO

AncillaryDataGroup fixed to ANCILLARY_DATA

7.3.4.3 Engineering product groups

The following tables (Table 29 to Table 47) list all variables in the engineering product as they appear in the different groups. A detailed description is outside the scope of this document.

DetectorGroup UVN detecto	DetectorGroup UVN detector		
Variable	Type	Description	
afe_common_config	compound	Extracted AFE setting common for both bands on the detector	
afe_reg_vals	compound	Raw AFE register values from which the AFE parameters are extracted	
clock	compound	Clock information of the detector electronics	
ft_table	compound	Frame Transfer synchronization parameters as stored in the DEM	
heater_cfg	compound	Heater settings for the detector	
misc	compound	Miscellaneous parameters for the detector that don't fit in other groups	
timing	componud	Detector specific timing parameters. Partly extracted from ft_table parameters	

Table 29: NetCDF variables in the DetectorHousekeepingGroup of the engineering product for UVN detectors (detector1 - detector3)

DetectorGroup SWIR detector		
Variable	Туре	Description
ft_table	compound	Frame Transfer synchronization parameters as stored in the DEM
swir_settings	compound	Extracted detector settings which are valid for both bands read from the SWIR Detector
timing	componud	Detector specific timing parameters. Partly extracted from ft_table parameters

Table 30: NetCDF variables in the DetectorGroup of the engineering product for the SWIR detector (detector4)

BandGroup UVN detector		
Variable	Туре	Description
afe_band_cfg	compound	Band specific settings extracted from the AFE registers.
readout_cfg	compound	Read-out settings for the band as used by the ISM.

Table 31: NetCDF variables in the BandGroup for the engineering product for the UVN detectors (detector1-detector3)

BandGroup SWIR detector		
Variable	Туре	Description
readout_cfg	compound	Read-out settings for the band as used by the ISM.

Table 32: NetCDF variables in the BandGroup for the engineering product for the SWIR detector (detector4)

DetectorHousekeepingGroup UVN detector		
Variable	Туре	Description
dem_cntrs	compound	DEM counter values for the detector
power_info	compound	Current and voltage values specific for the detector
spare_info	compound	Spare values in detector Housekeeping data
stat_info	compound	Extracted status values specific for the detector
temperature_info	compound	Temperature values specific for the detector
version_info	compound	DEM firmware version information for the detector

Table 33: NetCDF variables in the DetectorHousekeepingGroup for the engineering product for the UVN detectors (detector1-detector3)

DetectorHousekeepingGroup SWIR detector		
Variable	Туре	Description
adc_info	compound	Extracted current SWIR ADC values
dem_cntrs	compound	DEM counter values for the detector
err_cntrs	compound	SWIR specific error counters
heater_data	compound	Information about SWIR detector internal heater settings
power_info	compound	Current and voltage values specific for the detector
stat_info	compound	Extracted status values specific for the detector
temperature_info	compound	Temperature values specific for the detector
tmtc_info	compound	Extracted TMTC counter values

DetectorHousekeepingGroup SWIR detector (cont'd)		
Variable	Туре	Description
misc	compound	Miscellaneous parameters for the detector that don't fit in other groups

Table 34: NetCDF variables in the DetectorHousekeepingGroup for the engineering product for the SWIR detector (detector4)

MeasurementSetGroup		
Variable	Туре	Description
msmtset	compound	Measurement set information of all engineering data packages, like processing class, instrument configuration and selected DEM and ISM tables

Table 35: NetCDF variables in the MeasurementSetGroup for the engineering product

EventsGroup		
Variable	Туре	Description
events	compound	General event information extracted from the housekeeping data
processing_events	compound	Processing event information extracted from the housekeeping data

 Table 36:
 NetCDF variables in the EventsGroup for the engineering product

MechanismsGroup		
Variable	Туре	Description
fmm	compound	Status information about the folding mirror mechanism on the instrument
difm	compound	Status information about the diffuser mechanism on the instrument

 Table 37: NetCDF variables in the FoldingMirrorsGroup for the engineering product

HeatersGroup		
Variable	Туре	Description
heater_data	compound	Settings and status information about the heaters on the instrument
peltier_info	compound	Settings and status information about the peltier elements on the instrument

Table 38: NetCDF variables in the HeatersGroup for the engineering product

LEDInformationGroup		
Variable	Type	Description
led_data	compound	Status and voltage information about the LEDs on the instrument

Table 39: NetCDF variables in the LEDInformationGroup for the engineering product

OBDHGroup			
Variable	Туре	Description	
obdh_data	compound	Onboard data handling data parameters	

Table 40: NetCDF variables in the OBDHGroup for the engineering product

SoftwareConfigurationGroup		
Variable	Type	Description
params	compound	Software configuration parameters of the instrument.

Table 41: NetCDF variables in the SoftwareConfigurationGroup for the engineering product

TemperaturesGroup		
Variable	Type	Description
hires_temperatures	compound	Calculated temperatures of the high-resolution temperature sensors on the instrument
instr_temperatures	compound	Calculated temperatures of the instrument temperature sensor on the instrument
named_temperatures	compound	Calculated temperatures of named sensors in the engineering data
reference_thermistors	compound	Calculated resistor values of the reference thermistors

 Table 42: NetCDF variables in the TemperaturesGroup for the engineering product

VersionInformationGroup		
Variable	Туре	Description
info	compound	Version information of onboard software of the instrument

Table 43: NetCDF variables in the VersionInformationGroup for the engineering product

VoltagesGroup			
Variable	Туре	Description	
detector1_voltages	compound	Voltages measured for detector1	
detector2_voltages	compound	Voltages measured for detector2	
detector3_voltages	compound	Voltages measured for detector3	
detector4_voltages	compound	Voltages measured for detector4	
instrument_voltages	compound	Instrument voltages	

Table 44: NetCDF variables in the VoltagesGroup for the engineering product

ProcessorGroup		
Variable	Туре	Description
job_configuration	string array	Joborder used for generating this I1b file
algorithm_configuration	string array	Algorithm table used for generating this I1b file

VoltagesGroup (cont'd)		
Variable	Type	Description
processing_configuration	string array	Processing configuration used for generating this I1b file

Table 45: NetCDF variables in the ProcessorGroup for the engineering product

AncillaryDataGroup		
Variable	Туре	Description
aocs_data	compound	AOCS values of the satellite platform
attitude_data	compound	Attitude data in of the satellite platform
gps_satellite_data	compound	GPS satellite data of the satellite platform
navigation_data	compound	Navigation data of the satellite platform
propagated_gps_pos_data	compound	Propagated GPS position of the satellite platform
star_tracker	compound	Star tracker configuration of the satellite platform
configuration		
temperatures	compound	Temperatures measured on the satellite platform

Table 46: NetCDF variables in the AncillaryDataGroup for the engineering product

SatelliteInformationGroup		
Variable	Туре	Description
satellite_pos	compound	Instrument position information calculated by the L1b processor.

 Table 47: NetCDF variables in the ProcessorGroup for the engineering product

8 TROPOMI L1b product specification

8.1 NetCDF4 global attributes

In the "Metadata specification for the TROPOMI L1b products" [RD9] it is discussed how metadata content can be provided by the use of global attributes, thereby facilitating the discovery and understanding of the dataset. The CF-Metadata conventions [RD13] and the Attribute Conventions for Dataset Discovery [ER20] recommend a comprehensive set of attributes to be included as metadata elements. However, for TROPOMI L1b products it was decided to create specific metadata groups in which INSPIRE (ISO), ESA EOP and ESA FFS related metadata information is stored. Many of the metadata attributes proposed by CF-Metadata Conventions and ACDD overlap with the ISO 19115-2 standard and hence the same information can be found in the metadata groups.

In view of the above, only a very limited set of metadata elements is included as global attributes. These attributes provide a convenient way to users of the data products to retrieve quickly some basic information. In Table 48 a list is presented of metadata items included as global attributes in the netCDF product file.

Attribute	ISO mapping	Remark
Conventions		fixed: "CF-1.6"
title	MI_Metadata.identificationInfo. citation.title	
summary	MI_Metadata.identificationInfo. abstract	
institution	MI_Metadata.identificationInfo. pointOfContact.organisationName	
time_coverage_start	MI_Metadata.identificationInfo. extent.temporalElement.beginPosition	UTC time (start of measurements)
time_coverage_end	MI_Metadata.identificationInfo. extent.temporalElement.endPosition	UTC time (end of measurements)
time_reference		UTC time (reference time = "yyyy-mm-ddT00:00:00Z")
orbit		orbit number at which measurements of the data granule start
orbit_begin_icid	First begin trigger icid encountered in L0 data	
orbit_end_icid	Last end trigger icid encountered in L0 data	
orbit_type	(E2) Orbit type	"UNKN" is not known
orbit_type_id	(E2) orbit type id	65535 if not kown
institution		fixed: "KNMI"
processor_version	Version of the L01b processor used for generating product	
library_information	Version information of the libraries used by L01b processor	

Table 48: Global attributes.

Remark 1: UTC times are in expressed in the ISO 8601 format (i.e. YYYY-MM-DDThh:mm:ssZ).

Remark 2: The values of time_coverage_start and time_coverage_end truncated to integer seconds refer to the actual start and end of the measurements, i.e. the measurement time of the first and last scanline, respectively. Therefore, these times do not correspond to the times used in the filename of the product, where the start and end of the orbit (or data slice) are used instead (see section 7.1.1.3).

Remark 3: In case there are no scanlines in the processed orbit the values for time_coverage_start and time_coverage_end are equal to "NULL".

Remark 4: For the definition of the reference time see section 8.4.

8.2 Metadata specification

The netCDF file will have one metadata group (named METADATA) which is a container for specific metadata groups containing metadata information required to produce INSPIRE conformant [RD14], ESA EOP conformant [RD15] and ESA FFS conformant [AD6] XML formatted metadata records. These three specific metadata groups named ISO_METADATA, EOP_METADATA and ESA_METADATA, are structured in subgroups containing only attributes.

The structure of the groups reflects the structure of the particular metadata model, i.e. the groups correspond largely with the major metadata objects of the model. Whenever applicable, the groups contain an attribute with name="objectType" with a value equal to the corresponding object (including namespace) from the metadata model. This approach follows the groups-of-groups approach suggested by [ER22]. In addition, the attributes containing the relevant metadata information are given the same name as the corresponding element of the metadata model.

Details on the metadata can be found in [RD9].

Attribute	Description
ancillary_variables	Attribute to express relationship with other variables; For example, to relate instrument data with associated measures of uncertainty.
bounds	The name of the variable that contains the vertices of the cell boundaries. Used to relate the variable to a coordinate variable.
coordinates	Indicates the spatiotemporal coordinate variables that are needed to geo-locate the data. Contains full path when coordinate variables are not in the same group.
comment	Miscellaneous information about the variable or methods used to produce it
flag_meanings	The flag_meanings attribute is a string whose value is a blank separated list of descriptive words or phrases, one for each flag value.
flag_values	The flag_values attribute is the same type as the variable to which it is attached, and contains a list of the possible flag values
long_name	A long descriptive name describing the content of the variable
standard_name	A standardized name describing the content of the variable
units	A character string that specifies the units used for the variable's data (required for all variables that represent dimensional quantities, except for boundary variables)
valid_max	The maximum valid value for the variable
valid_min	The minimum valid value for the variable
_FillValue	The FillValue attribute specifies the fill value used for missing or undefined data

Table 49: Description of variable attributes

8.3 Fill values

The CF convention recommends to use the _FillValue attribute (or to use the default values) to assign a specific value to NetCDF variables in case of undefined or missing data. The _FillValue depends on the data type of the variable. The following table (Table 50) lists the values used for the various base data types. In the sections hereafter, the _FillValue attribute will only be present in de CDL descriptions if it is different from the default value.

8.4 Variable: time

The variable time(time) is the reference time of the measurements. The reference time is set to yyyy-mm-ddT00:00:00ZUTC, where yyyy-mm-dd is the day on which the measurements of a particular data granule start. The delta_time(scanline) variable (see section 8.5) indicates the time difference with the reference time time(time). Thus combining the information of time(time) and delta_time(scanline) yields the measurement time for each scanline as UTC time. The variable time(time) does (intentionally) not include any leap seconds, to make the conversion from time(time) and delta_time(scanline) to an UTC time easier.

The reference time(time) corresponds to the global attribute $time_reference$ which is an UTC time specified as an ISO 8601 date.

Туре	Storage	_FillValue
byte	8-bit signed integer	-127
ubyte	8-bit unsigned integer	255
short	16-bit signed integer	-32767
ushort	16-bit unsigned integer	65535
int	32-bit signed integer	-2147483647
float	32-bit floating point	9.9692099683868690e+36 (hex: 0x1.ep+122)
double	64-bit floating point	9.9692099683868690e+36 (hex: 0x1.ep+122)
float(*)	32-bit floating point(*)	9.9692099683868690e+36 (hex: 0x1.ep+122)

Table 50: NetCDF type definitions and fill values. Remark 1: The base type for a VLEN type (Variable Length Array) is indicated as type(*), i.e. float(*), short(*), etc. Remark 2: In order to avoid rounding errors, it is recommended to programmers to use the hexadecimal notation when specifying the above fill values for float and double types.

	Variable	Storage type	Units
	time	int	seconds
CDL	<pre>int time(time) ; time:long_name = "referer time:standard_name = "tim time:units = "seconds sin"</pre>	ne";	
	<pre>time:comment = "Reference set to yyyy-mm-ddT00:00:0 measurements of a particular</pre>	00 UTC, where yyyy-mm-dd	•
Remarks		attribute time_reference, w	e UTC time defined by this variable hich is a UTC time specified as an

Table 51: CDL definition time variable

8.5 Variable: delta_time

The delta_time(scanline) variable indicates the time difference with the reference time time(time) (see section 8.4). Thus combining the information of time(time) and delta_time(scanline) yields the measurement time for each scanline as UTC time. The UTC time derived for the first scanline corresponds to the global attribute time_coverage_start. Similarly, the UTC time derived for the last scanline corresponds to global attribute time_coverage_end. One scanline measurement is the result of adding independent measurements during one co-addition period. The time attributed to the scanline measurement is equal to the center time of the co-addition period defined by the first and last sample in this co-addition.

```
    Variable
    Storage type
    Units

    delta_time
    int
    ms

    CDL
    int delta_time(time,scanline);

    delta_time:long_name = "offset from the reference start time of measurement";

    delta_time:units = "ms";

    delta_time:comment = "Time difference with time for each measurement";
```

Table 52: CDL definition delta_time variable

8.6 Variable: ground_pixel

The coordinate variable <code>ground_pixel</code> refers to the across-track dimension of the measurement. The spectral radiance measurements are collected as a function of the two-dimensions (ground pixels across track and wavelengths), of the detector and of the scans. The corresponding dimensions describing the swath in the <code>netCDF</code> product are <code>named</code>: <code>ground_pixel</code>, <code>spectral_channel</code> and <code>scanline</code>, <code>respectively</code>.

	Variable	Storage type	Units
	ground_pixel	int	none
CDL	<pre>int ground_pixel(ground_p ground_pixel:long_name = ground_pixel:units = "1" ground_pixel:comment = "T track; index starts at 0"</pre>	"across track dimension; his dimension variable of	index"; defines the indices across
Remarks	Coordinate variable; The ground corresponds to a higher longitum		west to east, i.e. a higher index g part of the orbit.

Table 53: CDL definition ground_pixel variable

8.7 Variable: pixel

The coordinate variable pixel refers to the across-track dimension of the measurement. Because during the irradiance measurements the sensors are not imaging the Earth's surface but are measuring the solar irradiance, pixel is the preferred name (rather than ground_pixel) for the across-track dimension.

	Variable	Storage type	Units
	pixel	int	none
CDL	pixel:units = "1";	s track dimension index";	
Remarks		to east, i.e. a higher index in co	ound_pixel order in the radiance orresponds to a higher longitude

Table 54: CDL definition pixel variable

8.8 Variable: scanline

The coordinate variable scanline refers to the along-track dimension of the measurement. Scanline numbering starts a 0 for each product. (Thus: the scanline value of 0 is not related to a 'fixed' time but to the first measurement in the product.)

	Variable	Storage type	Units
	scanline	int	none
CDL	<pre>int scanline(scanline); scanline:long_name = "alc scanline:units = "1"; scanline:comment = "This index starts at 0";</pre>		x"; nes the indices along track;
Remarks	Coordinate variable. The scanli before "later" measurements	nes are time-ordered; meaninç	g that "earlier" measurements come

Table 55: CDL definition scanline variable

8.9 Variable: spectral_channel

	Variable	Storage type	Units
	spectral_channel	int	none
CDL	spectral_channel:units =	ne = "wavelength dimension "1" ; = "This dimension variabl	·
Remarks	Coordinate variable; The specindex corresponds to a higher		reasing wavelength, i.e. a higher

Table 56: CDL definition spectral_channel variable

8.10 Variable: radiance

TROPOMI measures the light radiated from and reflected by the Earth's surface and atmosphere in a given direction. The *spectral radiance* is a measure of the rate of the energy received per unit area an per unit of the solid angle as a function of wavelength and is expressed in SI units $W.m^{-2}.nm^{-1}.sr^{-1}$. Because TROPOMI actually measures the rate of photons per unit area and the exact wavelength is not known the *spectral photon radiance* is provided in the L1b product. The spectral photon radiance is expressed with SI units $mol.s^{-1}.m^{-2}.nm^{-1}.sr^{-1}$ using the amount of photons. ² In addition, the spectral photon radiance provided is normalized to the Earth-Sun distance of 1AU. ³ If the Earth spectral radiance is denoted by S_{earth} , the wavelength by λ and the Earth-Sun distance by R, then the Earth spectral radiance normalized at 1AU is given by:

$$S_{\text{earth}}(R_{\text{AU}}, \lambda) = \left(\frac{R}{R_{\text{AU}}}\right)^2 S_{\text{earth}}(R, \lambda) ,$$
 (1)

where $R_{\rm AU}$ is the Earth-Sun distance equal to 1AU. Similarly, the spectral photon radiance is normalized using the factor $\left(\frac{R}{R_{\rm AU}}\right)^2$.

² 1 Mole (unit symbol *mol*) corresponds to Avogadro's number N_A and is equal to 6.02214129.10²³ photons or N_A = 6.02214129.10²³ mol⁻¹.

³ 1 Astronomical Unit (AU) =149,597,870,700 meters

	Variable	Storage type	Units
	radiance	float	$mol.s^{-1}.m^{-2}.nm^{-1}.sr^{-1}$
CDL	spectral_channel_quality	ectral photon radiance" 1.m-2.nm-1.sr-1"; longitude latitude"; bles = "radiance_noise ground_pixel_quality"	; radiance_error quality_level
Remarks	line with the standard_name f	or radiance that has been su	red by sensors on board satellites. In aggested by the cf-satellite user com- ral_photon_radiance is suggested

Table 57: CDL definition radiance variable

8.11 Variable: radiance_noise

The radiance noise (and similarly the error and the irradiance noise and error) is represented as a 10 times the base-10 logarithmic value of the ratio between the radiance and the random error. The representation of the errors in dB is assumed to be accurate and precise. Using a byte type has a considerable contribution as to limiting the final product file size.

	Variable	Storage type	Units
	radiance_noise	byte	none
CDL	byte radiance_noise(time, radiance_noise:long_name deviation"; radiance_noise:units = "1 radiance_noise:coordinate radiance_noise:comment =	scanline,ground_pixel,spectral photon radiar	ectral_channel); nce noise, one standard ; measure for the one
	expressed in decibel (dB)), i.e. 10 times the base	e-10 logarithmic value
	of the ratio between the	radiance and the random e	error.";

Table 58: CDL definition radiance_noise variable

8.12 Variable: radiance_error

	Variable	Storage type	Units
	radiance_error	byte	none
CDL	radiance_error byte none		; measure for the one nce measurement; it is e-10 logarithmic value of

Remarks

Table 59: CDL definition radiance_error variable

8.13 Variable: irradiance

Every 15 orbits - approximately once every calendar day - TROPOMI will be commanded to perform a solar irradiance measurement. Irradiance is a measurement of solar power and is defined as the rate at which solar energy falls onto a surface. Similar to the spectral radiance, the *spectral irradiance* is the irradiance as function of wavelength. The SI units of spectral irradiance are W.m $^{-2}$.nm $^{-1}$. However, like the case of the radiance variable, the L1b product provides the *spectral photon irradiance* with SI units mol.s $^{-1}$.m $^{-2}$.nm $^{-1}$. Also the spectral photon irradiance is normalized to the Earth-Sun distance of 1 AU by applying a factor $\left(\frac{R}{R_{\rm AU}}\right)^2$ (see Equation 1).

	Variable	Storage type	Units
	irradiance	float	$mol.s^{-1}.m^{-2}.nm^{-1}$
CDL	<pre>float irradiance(time,scanline,pixel,spectral irradiance:long_name = "spectral photon irrad irradiance:units = "mol.s-1.m-2.nm-1"; irradiance:ancillary_variables = "irradiance; quality_level spectral_channel_quality"; irradiance:comment = "Measured spectral irrad; ;</pre>		ce"; se irradiance_error
Remarks	satellites. In line with the star	dard_name for radiance that ha	as measured by sensors on board as been suggested by the cf-satellite spectral_photon_irradiance is

Table 60: CDL definition irradiance variable

8.14 Variable: irradiance_noise

	Variable	Storage type	Units
	irradiance_noise	byte	none
CDL	byte irradiance_noise(tim	ne,scanline,pixel,spectral	_channel) ;
	irradiance_noise:long_name = "spectral photon irradiance noise, one		
	standard deviation";		
	<pre>irradiance_noise:units =</pre>	"1" ;	
	irradiance_noise:comment	= "The irradiance_noise i	is a measure for the
	one standard deviation ra	andom error of the irradia	ance measurement; it is
	expressed in decibel (dB)	, i.e. 10 times the base	e-10 logarithmic value of
	the ratio between the irr		

Remarks

Table 61: CDL definition irradiance_noise variable

8.15 Variable: irradiance_error

	Variable	Storage type	Units
	irradiance_error	byte	none
CDL	byte irradiance_error(tim irradiance_error:long_nam deviation"; irradiance_error:units = irradiance_error:comment standard deviation error expressed in decibel (dB) the ratio between the irr	e,scanline,pixel,spectral e = "spectral irradiance "1"; = "The irradiance_error i of the bias of the irradi , i.e. 10 times the base	channel); error, one standard s a measure for the one ance measurement; it is -10 logarithmic value of

Remarks

Table 62: CDL definition irradiance_error variable

8.16 Variable: small_pixel_radiance

One configurable detector pixel, in every row, for both detector output chains, i.e., two columns per detector, is not co-added and is stored separately for every exposure/co-addition of an image. The data for these 'small-pixel columns' are included in the science data and provide information on a higher spatial resolution than the data for other columns, which may be useful for certain studies. Thus for a given wavelength, the small_pixel_radiance is the measurement of the spectral photon radiance expressed with SI units mol.s⁻¹.m⁻².nm⁻¹.sr⁻¹.

The small_pixel_radiance is normalized to the Earth-Sun distance of 1 AU by applying a factor $\left(\frac{R}{R_{\rm AU}}\right)^2$ (see Equation 1).

	Variable	Storage type	Units
	small_pixel_radiance	float(*)	${\sf mol.s^{-1}.m^{-2}.nm^{-1}.sr^{-1}}$
CDL	; small_pixel_radiance:long_ small_pixel_radiance:_Fill_ small_pixel_radiance:coord	<pre>small_pixel_radiance name = "small pixel s = "mol.s-1.m-2.nm-1 .Value = 0x1.ep+122; dinates = "longitude ent = "Measured spect</pre>	.sr-1"; latitude"; ral radiance for the spectral
Remarks small_pixel_type is a netCDF VLEN type There is no standard_name for photon radiance as measured by ser			

user community on the Unidata mailing list, toa_outgoing_spectral_photon_radiance is

Table 63: CDL definition small_pixel_radiance variable

8.17 Variable: spectral_channel_quality

suggested here.

	Variable	Storage type	Units
	spectral_channel_quality	ubyte	none
CDL	ubyte spectral_channel_qual ; spectral_channel_quality:lo spectral_channel_quality:vo spectral_channel_quality:vo spectral_channel_quality:co spectral_channel_quality:fl	Dity(time, scanline, ground ong_name = "spectral chalid_min = 0; alid_max = 254; cordinates = "longitude"	<pre>annel quality flag"; latitude";</pre>
	128UB ; spectral_channel_quality:fl processing_error, saturated spectral_channel_quality:cd (spectral) pixel" ;	d, transient, rts, under	rflow;

Remarks

Table 64: CDL definition spectral_channel_quality variable

8.18 Variable: ground_pixel_quality

	Variable	Storage type	Units
	<pre>ground_pixel_quality</pre>	ubyte	none
CDL	ubyte ground_pixel_quality ground_pixel_quality:long_ ground_pixel_quality:valid ground_pixel_quality:valid ground_pixel_quality:coord ground_pixel_quality:flag_ ground_pixel_quality:flag_ possible, descending, nigh ground_pixel_quality:comme ground_pixel_quality:comme	<pre>name = "ground pixel qmin = 0 ;max = 254 ; .inates = "longitude la values = OUB, 1UB, 2UB meanings = no_error, s .t, geo_boundary_crossi</pre>	uality flag"; titude"; , 4UB, 8UB, 16UB, 128UB; colar_eclipse, sun_glint ng, geolocation_error;

Remarks

Table 65: CDL definition ground_pixel_quality variable

8.19 Variable: quality_level

The L1b variable quality_level is used to provide an overall indication of L1b data quality. Typically, to assign a quality level to a data product, *Quality Indicators (QIs)* are needed, in particular at each stage of the data processing chain - from collection and processing to delivery. A QI should provide sufficient information to allow all users to evaluate a product's suitability for their particular application. These QIs are provided to the users in the variable spectral_channel_quality (covering e.g. transient) and the variable ground_pixel_quality (covering e.g. solar eclipse). A QI is stored in a binary format, representing an on/off mode. Whenever a bit for a specific QI is set, this QI negatively influenced the determination of the quality_level.

The value for the overall quality is obtained by multiplying the quality indicators (ranging from 0 to 1) of the individual algorithms applied in the L01b processing chain. This product is then multiplied by hundred. Thus the maximum quality level is equal to 100; each processing algorithm might introduce a degradation which ultimately can result in the worst quality level equal to 0.

	Variable	Storage type	Units
	quality_level	ubyte	none
CDL	<pre>quality_level:long_name = quality_level:valid_min = quality_level:valid_max = quality_level:coordinate;</pre>	-	al channel";

Table 66: CDL definition quality_level variable

8.20 Variable: measurement_quality

	Variable	Storage type	Units
	measurement_quality	ushort	none
CDL	ushort measurement_quality measurement_quality:long_n measurement_quality:valid measurement_quality:valid measurement_quality:coord: measurement_quality:flag_n 4096US; measurement_quality:flag_n saa, spacecraft_manoeuvre measurement_quality:commen	y(time,scanline); name = "measurement quali _min = 0; _max = 65534; inates = "longitude latit values = OUS, 1US, 2US, 1 meanings = no_error, proc , sub_grp, irr_out_of_ran	ty flag"; dude"; 6US, 32US, 128US, 256US c_skipped, no_residual, uge, sub_group;

Remarks Extended description:

- no_error: No measurement qualification
- proc_skipped: One or more processing steps (algorithms) where skipped
- no residual: No residual correction applied because no correction values where found
- · Measurement was obtained while spacecraft was in South Atlantic Anomaly
- · Measurement was obtained during spacecraft manoeuvre
- · Measurement was flagged as sub-group
- Measurement outside nominal elevation / azimuth range
- Measurement was flagged as sub-group by subgroup algorithm

Table 67: CDL definition measurement_quality variable

8.21 Variable: detector_row_qualification

	Variable	Storage type	Units
	detector_row_qualification	ushort	none
CDL	ushort detector_row_qualification: detector_row_qualification: detector_row_qualification: detector_row_qualification: detector_row_qualification: 256US, 4096US, 8192US; detector_row_qualification: uvn_dump, uvn_covered, uvn_ transistion, gen_non_illumidetector_row_qualification: type or state";	<pre>long_name = "Detector valid_min = 0; valid_max = 65534; flag_values = OUS, 1 flag_meanings = no_cor overscan, uvn_higain nated;</pre>	DOT TOW QUALIFICATION flags"; LUS, 2US, 4US, 8US, 16US, QUALIFICATION, UVN_TOT, n, swir_reference, gen

Remarks Extended description:

- no qualification: No row qualification
- uvn_ror: UVN detector specific, row is read-out register (ROR)
- uvn_dump: UVN detector specific, row is read using dump gate setting
- uvn_covered: UVN detector specific, row is covered on detector
- uvn_overscan: UVN detector specific, over-scan row
- uvn_higain: UVN detector specific, row is read using high gain output
- swir_reference: SWIR detector specific, row is reference line
- Row is transition row on detector
- Row is not illuminated by spectrometer output

Table 68: CDL definition detector_row_qualification variable

8.22 Variable: detector_column_qualification

	Variable	Storage type	Units
	detector_column_qualification	ushort	none
CDL	ushort detector_column_quali detector_column_qualificatio flags"; detector_column_qualificatio detector_column_qualificatio detector_column_qualificatio 256US, 512US, 1024US, 2048US detector_column_qualificatio uvn_odd, uvn_prepost, uvn_ov adc3; detector_column_qualificatio column indicating column typ	n:long_name = "Detection:valid_min = 0; n:valid_max = 65534 n:flag_values = OUS, s; n:flag_meanings = noverscan, swir_adc0, sen:comment = "Qualification".	tor column qualification ; , 1US, 16US, 32US, 64US, p_qualification, skipped, swir_adc1, swir_adc2, swir

Remarks Extended description:

- no_qualification: No column qualification
- · skipped: Column was not read and therefore contains fill values
- uvn_odd: UVN detector specific, pixels in the column took the odd ADC path
- uvn_prepost: UVN detector specific, pixels in the column are pre- or post-scan pixels
- uvn_overscan: UVN detector specific, column is an over-scan column
- swir adc0: SWIR detector specific, pixels in the column used ADC0
- swir adc1: SWIR detector specific, pixels in the column used ADC1
- swir_adc2: SWIR detector specific, pixels in the column used ADC2
- swir_adc3: SWIR detector specific, pixels in the column used ADC3

 $\textbf{Table 69}: \texttt{CDL definition detector_column_qualification variable}$

8.23 Variable: calibrated_wavelength

The nominal_wavelength (section 8.45) provides for each ground pixel the wavelength measured by a spectral channel and is defined by the design parameters of the instrument. The wavelength values as provided by the nominal_wavelength are based on the Calibration Key Data (CKD) which are input to the L01b processing (section 5).

During the measurements the actual measured wavelength will vary from the nominal one and a calibration step is required to correct for this effect. For radiance products this calibration is applied as part of the L2 processing, because it involves atmospheric corrections which are only available at that product level. Therefore, the calibrated_wavelength is not part of the L1b radiance product.

For the L1b irradiance products the calibrated_wavelength is available. As part of the L01b processing the spectral information obtained from the irradiance measurements is compared with a reference solar spectrum. From this comparison a calibrated set of wavelengths is derived which provides a per pixel best estimate for the wavelength actually measured by each individual spectral channel.

	Variable	Storage type	Units
	calibrated_wavelength	float	nm
CDL	<pre>float calibrated_wavelength(time,pixel,spectral_channel) ; calibrated_wavelength:long_name = "spectral channel calibrated wavelength"</pre>		
	; calibrated_wavelength:stan calibrated_wavelength:unit calibrated_wavelength:comm pixel";	s = "nm" ;	
Remarks	The calibrated_wavelength p	·	avelength measured by a spectra ment.

Table 70: CDL definition calibrated_wavelength variable

8.24 Variable: calibrated_wavelength_error

	Variable	Storage type	Units
	calibrated_wavelength_error	float	nm
CDL	float calibrated_wavelength_calibrated_wavelength_error: wavelength error"; calibrated_wavelength_error: error"; calibrated_wavelength_error: calibrated_wavelength_error: wavelength of each spectral	<pre>clong_name = "spectral standard_name = "radi cunits = "nm" ; comment = "Standard d</pre>	channel calibrated ation_wavelength standard
Remark	s The calibrated_wavelength promeasured by a spectral channel ar	•	•

Table 71: CDL definition calibrated_wavelength_error variable

8.25 Variable: latitude

	Variable	Storage type	Units
	latitude	float	degrees north
CDL	float latitude(time,scan	line,ground_pixel);	
	<pre>latitude:long_name = "pi</pre>	xel center latitude";	
	<pre>latitude:standard_name = "latitude";</pre>		
	<pre>latitude:units = "degrees_north" ;</pre>		
	latitude:valid_min = -90	.f ;	
	<pre>latitude:valid_max = 90.</pre>	f ;	
	latitude:bounds = "latit	ude_bounds" ;	
	latitude:comment = "Lati	tude of the center of eac	h ground pixel on the
	WGS84 reference ellipsoi	d" ;	<u> </u>

Remarks Latitude, longitude coordinates for the ground pixel center and the ground pixel corners are calculated at the WGS84 ellipsoid. In principle, the information provided in the GeodataGroup allows to calculate these coordinates at arbitrary altitudes.

Table 72: CDL definition latitude variable

8.26 Variable: longitude

	Variable	Storage type	Units
	longitude	float	degrees east
CDL	float longitude(time,scar	nline,ground_pixel);	
	longitude:long_name = "p:	ixel center longitude";	
	longitude:standard_name = "longitude";		
	<pre>longitude:units = "degrees_east";</pre>		
	<pre>longitude:valid_min = -180.f ;</pre>		
	longitude:valid_max = 180	O.f ;	
	longitude:bounds = "long:	itude_bounds" ;	
	longitude:comment = "Long	gitude of the center of	each ground pixel on the
	WGS84 reference ellipsoid	i" ;	
Remarks			r and the ground pixel corners are
	allows to calculate these coord	•	tion provided in the GeodataGroup

Table 73: CDL definition longitude variable

8.27 Variable: latitude_bounds

The four corner points of the ground pixels are calculated as an interpolation between the centre coordinates (longitude, latitude) of adjacent pixels and lines. The variable latitude_bounds provides the latitude value of these corner points.

	Variable	Storage type	Units
	latitude_bounds	float	degrees north
CDL	<pre>float latitude_bounds(time,scanline,ground_pixel,ncorner) ; latitude_bounds:units = "degrees_north" ; latitude_bounds:comment = "The four latitude boundaries of each ground pixel." ;</pre>		
Remarks CF-Convention: Since a boundary variable is considered to be part of a cometadata, it is not necessary to provide it with attributes such as long_name right-handed coordinate system, the ordering of the bounds is anti-clockwist latitude surface seen from above. Latitude, longitude coordinates for the ground pixel center and the ground		as long_name and units. Using a s anti-clockwise on the longitude-	

calculated at the WGS84 ellipsoid. In principle, the information provided in the GeodataGroup

Table 74: CDL definition latitude_bounds variable

allows to calculate these coordinates at arbitrary altitudes.

8.28 Variable: longitude_bounds

The four corner points of the ground pixels are calculated as an interpolation between the centre coordinates (longitude, latitude) of adjacent pixels and lines. The variable longitude_bounds provides the longitude value of these corner points.

	Variable	Storage type	Units
	longitude_bounds	float	degrees east
CDL	longitude_bounds:units = "	s(time,scanline,ground_pixel,ncorner); s = "degrees_east"; ent = "The four longitude boundaries of each ground	
Remarks		•	be part of a coordinate variable's as long_name and units. Using a

CF-Convention: Since a boundary variable is considered to be part of a coordinate variable's metadata, it is not necessary to provide it with attributes such as long_name and units. Using a right-handed coordinate system, the ordering of the bounds is anti-clockwise on the longitude-latitude surface seen from above.

Latitude, longitude coordinates for the ground pixel center and the ground pixel corners are calculated at the WGS84 ellipsoid. In principle, the information provided in the GeodataGroup allows to calculate these coordinates at arbitrary altitudes.

Table 75: CDL definition longitude_bounds variable

8.29 Variable: solar_zenith_angle

	Variable	Storage type	Units
	solar_zenith_angle	float	degree
CDL	<pre>float solar_zenith_angle(time,scanline,ground_pixel) ; solar_zenith_angle:long_name = "solar zenith angle" ; solar_zenith_angle:standard_name = "solar_zenith_angle" ;</pre>		
	<pre>solar_zenith_angle:units = solar_zenith_angle:valid_m solar_zenith_angle:valid_m solar_zenith_angle:coordin solar_zenith_angle:comment location on the reference vertical. ESA definition</pre>	<pre>din = 0.f ; dax = 180.f ; dates = "longitude latit" date = "Solar zenith angle ellipsoid. Angle is me</pre>	at the ground pixel asured away from the

Remarks

Table 76: CDL definition solar_zenith_angle variable

8.30 Variable: solar_elevation_angle

	Variable	Storage type	Units
	solar_elevation_angle	float	degree
CDL	float solar_elevation_angl	e(time,scanline);	
	<pre>solar_elevation_angle:long_name = "solar elevation angle" ;</pre>		
	solar_elevation_angle:units = "degree";		
	solar_elevation_angle:valid_min = -90.f ;		
	solar_elevation_angle:vali	$d_{max} = +90.f$;	
	solar_elevation_angle:comm	ent = "Solar elevation a	angle measured from the
	Sun port on instrument. A	ngle is measured from th	ne YZ-plane towards the
	X-axis (=nominal Sun LOS)	of the Sun Port reference	ce frame.";

Remarks This variable is only present in the irradiance calibration product

Table 77: CDL definition solar_elevation_angle variable

8.31 Variable: solar_azimuth_angle

Level-2 data processors need information on the lines of sight from the ground pixel position to the spacecraft and to the Sun, in the topocentric reference frame. These are defined by the solar azimuth ϕ_0 and zenith θ_0 angles for the incident sunlight, and spacecraft azimuth ϕ and zenith θ angles for the scattered sunlight With these angles the level-2 data processors can for instance determine the scattering angle Θ . For a complete description see the section on Geometrical algorithms" in [RD12].

	Variable	Storage type	Units
	solar_azimuth_angle	float	degree
CDL	float solar_azimuth_angle(solar_azimuth_angle:long_n solar_azimuth_angle:standa solar_azimuth_angle:units solar_azimuth_angle:valid_ solar_azimuth_angle:coordi solar_azimuth_angle:commen location on the reference North (East = +90, South =	<pre>ame = "solar azimuth ar rd_name = "solar_azimut = "degree"; min = -180.f; max = 180.f; nates = "longitude late t = "Solar azimuth angle ellipsoid. Angle is me</pre>	ngle"; th_angle"; itude"; le at the ground pixel

Remarks

Table 78: CDL definition solar_azimuth_angle variable

8.32 Variable: viewing_zenith_angle

	Variable	Storage type	Units
	viewing_zenith_angle	float	degree
CDL	float viewing_zenith_angle viewing_zenith_angle:long_ viewing_zenith_angle:stand viewing_zenith_angle:units viewing_zenith_angle:valid viewing_zenith_angle:coord viewing_zenith_angle:comme pixel location on the refe vertical.";	<pre>name = "viewing zenith a lard_name = "platform_zen lard_name = "platform_zen lard_name = "largere"; larder = "longitude late larder = "Zenith angle of the</pre>	angle"; nith_angle"; itude"; he satellite at the ground

Table 79: CDL definition viewing_zenith_angle variable

8.33 Variable: viewing_azimuth_angle

	Variable	Storage type	Units
	viewing_azimuth_angle	float	degree
CDL	float viewing_azimuth_angl viewing_azimuth_angle:long viewing_azimuth_angle:stan viewing_azimuth_angle:unit viewing_azimuth_angle:vali viewing_azimuth_angle:coor viewing_azimuth_angle:coom ground pixel location on t clockwise from the North (_name = "viewing azimut dard_name = "platform_a s = "degree"; d_min = -180.f; d_max = 180.f; dinates = "longitude la ent = "Azimuth angle of he reference ellipsoid	ch angle"; azimuth_angle"; atitude"; the satellite at the Angle is measured

Remarks

Table 80: CDL definition viewing_azimuth_angle variable

8.34 Variable: satellite_latitude

	Variable	Storage type	Units
	satellite_latitude	float	degrees north
CDL	float satellite_latitude(time,scanline);	
	<pre>satellite_latitude:long_name = "sub-satellite latitude" ;</pre>		
	satellite_latitude:units	= "degrees_north" ;	
	satellite_latitude:valid_	min = -90.f;	
<pre>satellite_latitude:valid_max = 90.f ;</pre>			
	satellite_latitude:commen	t = "Latitude of the sp	acecraft sub-satellite
	point on the WGS84 refere	nce ellipsoid";	

Remarks

Table 81: CDL definition satellite_latitude variable

8.35 Variable: satellite_longitude

	Variable	Storage type	Units
	satellite_longitude	float	degrees east
CDL	<pre>float satellite_longitude(time,scanline) ;</pre>		
	satellite_longitude:units	= "degrees_east" ;	
	satellite_longitude:valid_	$_{min} = -180.f$;	
	satellite_longitude:valid_	$_{\text{max}} = 180.f$;	
	satellite_longitude:commer	nt = "Longitude of the s	spacecraft sub-satellite
	point on the WGS84 referen	nce ellipsoid" ;	

Table 82: CDL definition satellite_longitude variable

8.36 Variable: satellite_altitude

	Variable	Storage type	Units
	satellite_altitude	float	m
CDL	float satellite_altitude(time,scanline);	
	satellite_altitude:long_n	ame = "satellite altitude	, , , , , , , , , , , , , , , , , , ,
	satellite_altitude:units	= "m" ;	
	satellite_altitude:valid_	min = 700000.f ;	
	satellite_altitude:valid_	max = 900000.f ;	
	satellite_altitude:commen	t = "The altitude of the	spacecraft relative to
	the WGS84 reference ellip	soid" :	•

Remarks

Table 83: CDL definition satellite_altitude variable

8.37 Variable: satellite_orbit_phase

The orbit phase is defined as $1/(2\pi)$ times the angle in radians traversed by the spacecraft since spacecraft midnight as seen from the center of the Earth. Spacecraft midnight is the point on the night side of the Earth where the spacecraft crosses the orbital plane of the Earth about the Sun. This makes the orbit phase a quantity that runs from 0 to 1, while the spacecraft moves between each spacecraft midnight.

	Variable	Storage type	Units
	satellite_orbit_phase	float	none
CDL	float satellite_orbit_phass satellite_orbit_phase:long satellite_orbit_phase:unit satellite_orbit_phase:valisatellite_orbit_phase:valisatellite_orbit_phase:comm measurement in the orbit"	<pre>g_name = "fractional sat cs = "1" ; .d_min = -0.02f ; .d_max = 1.02f ; nent = "Relative offset</pre>	
Remarks	CF-Convention: The conforming "1".	unit for quantities that represe	ent fractions, or parts of a whole, is

Table 84: CDL definition satellite_orbit_phase variable

8.38 Variable: earth_sun_distance

	Variable	Storage type	Units
	earth_sun_distance	float	astronomical unit
CDL	float earth_sun_distance(t earth_sun_distance:long_nate earth_sun_distance:units = earth_sun_distance:valid_nate earth_sun_distance:valid_nate	ame = "distance betweer = "astronomical_unit" ; nin = 0.98f ; nax = 1.02f ;	;

Table 85: CDL definition earth_sun_distance variable

8.39 Variable: processing_class

Different operating modes of the system and the derived L01B products are described by three parameters: the Processing Class, the Instrument Configuration ID (IcID) and Instrument Configuration Version (IcVersion). The concept for these three parameters is taken from the OMI mission:

- The Processing Class defines the type of measurement at a very high level. Contrary to the IcIDs, the set of processing classes is (fairly) static. The advantage of this, is that it is possible to create new IcIDs and as long as these can use an existing processing class, it is not required to update the L01b to support that IcID. Examples of processing classes are Earth_radiance, Sun_irradiance, DLED, WLS, Dark, Background, ... For a complete overview of valid processing classes see Appendix B.
- The Instrument Configuration ID defines the type of measurement and its purposes. The number of Instrument Configuration IDs will increase over the mission as new types of measurements are created / used;
- The Instrument Configuration Version allows to differentiate between multiple versions for a specific IcID.

Each Processing Class and each IcID corresponds to a number. The numbers for Processing Class, IcID and IcVersion are set in the instrument by the instrument operations team for each measurement.

	Variable	Storage type	Units
	processing_class	short	none
CDL	only a limited, fixed set	ne = "processing class"; n = 0; nx = 255; = "The processing_class gh level. Contrary to In to of processing classes i	defines the type of strument Configuration IDs,
Remarks	For a complete overview of val	id processing classes see App	endix B.

Table 86: CDL definition processing_class variable

8.40 Variable: instrument_configuration

The TROPOMI instrument has many configurable parameters. For example, the exposure time, co-addition period, gains and (for UVN-DEMs) the binning factors can be varied. As a result, the instrument can be operated in many different modes or configurations. Each combination of instrument settings is referred to as instrument configuration and is identified by an instrument configuration ID, a number in the range [1,65535]. This instrument configuration ID, or IcID, is primarily used by the instrument, where it identifies an entry in the instrument configuration tables. On ground, the IcID is used to determine the intended purpose of a measurement and is used in the L01b data processing to determine the processing path.

For an IcID, it is possible to have multiple versions, identified by the instrument configuration version or IcVersion. The combination of IcID and IcVersion uniquely identifies the set of configuration settings of the instrument. At a given time, only one IcVersion of an IcID can be active within the instrument. The IcVersion allows to have multiple versions of a measurement with the same purpose, but with different settings. As a result of, for example, instrument degradation, it may be required to change the settings for a measurement. In that case, it is not necessary to create a new IcID, instead the same IcID can be using with a new IcVersion.

<pre>instrument_configuration</pre>	
<pre>int icid ; short ic_version ; } ; instrument_configuration_type instrument_configuration(time,scalinstrument_configuration:long_name = "instrument configuration, IcVersion"; instrument_configuration:comment = "The Instrument Configuration.")</pre>	
Instrument Configuration IDs will increase over the mission as a of measurements are created / used; The Instrument Configuration allows to differentiate between multiple versions for a specific	IcID and n ID f new types n Version

Remarks

Table 87: CDL definition instrument_configuration variable

8.41 Variable: instrument_settings

The instrument_settings variable contains all the instrument settings that are relevant for data processing. Due to the UVN and SWIR modules having different instrument configuration parameters, instrument_settings is defined differently for UVN and SWIR products. The instrument settings are given for each Instrument Configuration ID and version contained in the product.

8.41.1 UVN product: instrument_settings

	Variable	Storage type	Units
	instrument_settings	instrument_settings_type	none
CDL	types:		
	compound instrument_setting	s_type {	
	<pre>int ic_id ;</pre>		
	<pre>short ic_version ;</pre>		
	<pre>short ic_set ;</pre>		
	<pre>short ic_idx ;</pre>		
	<pre>short processing_class ;</pre>		
	<pre>float master_cycle_period ;</pre>		
	<pre>float coaddition_period ;</pre>		
	<pre>float exposure_time ;</pre>		
	<pre>float msmt_mcp_ft_offset ;</pre>		
	float msmt_ft_msmt_start_of	fset ;	
	<pre>float msmt_duration ;</pre>		
	<pre>float flush_duration ;</pre>		
	<pre>short nr_coadditions ;</pre>		
	<pre>short cds_gain ;</pre>		
	<pre>float pga_gain ;</pre>		
	<pre>float dac_offset ;</pre>		
	<pre>int master_cycle_period_us</pre>	;	
	<pre>int coaddition_period_us ;</pre>		
	<pre>int exposure_time_us ;</pre>		
	<pre>int exposure_period_us ;</pre>		
	<pre>short small_pixel_column ;</pre>		
	<pre>short stop_column_read ;</pre>		
	<pre>short start_column_coad ;</pre>		
	<pre>short stop_column_coad ;</pre>		
	short pga_gain_code ;		
	<pre>short dac_offset_code ;</pre>		
	<pre>ubyte clock_mode ;</pre>		
	ubyte clipping ;		
	}; // instrument_settings_t	уре	
	variables:		
	instrument_settings_type in	strument_settings(nsettings);	

Table 88: CDL definition instrument_settings variable

field	type	unit	description
ic_id	int	1	Instrument configuration ID; number that uniquely speci- fies a type of measurement. The combination of the icid and icversion uniquely identifies a specific instrument configuration
ic_version	short	1	Instrument configuration version; version number for the instrument configuration ID. The combination of the icid and icversion uniquely identifies a specific instrument configuration
ic_set	short	1	Instrument configuration set of which the instrument configuration ID is part.
ic_idx	short	1	Index of the instrument configuration ID in the instrument configuration set

field	type	unit	description
processing_class	short	1	The processing_class defines the type of measurement at a very high level. Contrary to Instrument Configuration IDs, only a limited, fixed set of processing classes is identified. Examples of processing classes are Earth_radiance, Sun_irradiance, CLED, WLS, Dark, Background,
master_cycle_period	float	S	Measurement master cycle period in seconds; must be a multiple of the coaddition period.
coaddition_period	float	S	Co-addition period in seconds; the time interval covered by all the co-additions in the measurement. In case no flushing is used, this is equal to the number of co-additions multiplied by the exposure time. In case flushing is used, this is equal to the number of co-additions multiplied by the sum of the exposure time and the flushing time
exposure_time	float	S	The exposure time in seconds for a single (unco-added) frame.
msmt_mcp_ft_offset	float	S	Offset between Master clock pulse and frame trigger starting measurement
msmt_ft_msmt_start_offset	float	s	Offset between FT and start of exposure
msmt_duration	float	S	Delta between start of first exposure in a measurement and end of last exposure in a measurement
flush_duration	float	S	Duration of the flush period of a measurement
nr_coadditions	short	1	The number of co-additions.
cds_gain	short	1	The CDS V/V gain, based on design parameters, either 1x or 2x.
pga_gain	float	1	The AFE PGA V/V gain, based on design parameters.
dac_offset	float	V	The AFE DAC offset in V, based on design parameters.
master_cycle_period_us	int	us	Measurement master cycle period in microseconds; must be a multiple of the coaddition period. Note: Contrary to the master_cycle_period, which is stored as a float, this field is stored as a long and therefore exactly representable and comparable
coaddition_period_us	int	us	Co-addition period in microseconds; the time interval covered by all the co-additions in the measurement. In case no flushing is used, this is equal to the number of co-additions multiplied by the exposure time. In case flushing is used, this is equal to the number of co-additions multiplied by the sum of the exposure time and the flushing time. Note: Contrary to the coaddition_period, which is stored as a float, this field is stored as a long and therefore exactly representable and comparable
exposure_time_us	int	us	The exposure time in microseconds for a single (unco- added) frame. Note: Contrary to the exposure_time, which is stored as a float, this field is stored as a long and therefore exactly representable and comparable.
exposure_period_us	int	us	The interval between two consecutive exposures
small_pixel_column	short	1	Setting (code) for the AFE PGA
stop_column_read	short	1	Setting (code) for the AFE DAC
start_column_coad	short	1	Column for which the data are downlinked for all co- addition

field	type	unit	description
stop_column_coad	short	1	The number of columns from the detector that are read- out
pga_gain_code	short	1	First column that is being co-added
dac_offset_code	short	1	Lastst column that is being co-added
clock_mode	ubyte	1	CCD Clocking mode; 0 = normal, 1 = reverse, 2 = static, 3 = CTE, 4 = invalid
clipping	ubyte	1	Data clipping position

Table 89: Fields in the instrument_settings variable.

8.41.2 SWIR product: instrument_settings

	Variable	Storage type	Units
	instrument_settings	instrument_settings_type	none
CDL	types:		
	compound instrument_setting	gs_type {	
	<pre>int ic_id ;</pre>		
	<pre>short ic_version ;</pre>		
	<pre>short ic_set ;</pre>		
	<pre>short ic_idx ;</pre>		
	<pre>short processing_class ;</pre>		
	float master_cycle_period	;	
	<pre>float coaddition_period ;</pre>		
	<pre>float exposure_time ;</pre>		
	<pre>float msmt_mcp_ft_offset ;</pre>		
	float msmt_ft_msmt_start_or	ffset ;	
	<pre>float msmt_duration ;</pre>		
	<pre>float reset_time ;</pre>		
	<pre>short nr_coadditions ;</pre>		
	<pre>int master_cycle_period_us</pre>	;	
	<pre>int coaddition_period_us ;</pre>		
	<pre>int exposure_time_us ;</pre>		
	<pre>int exposure_period_us ;</pre>		
	<pre>short small_pixel_column ;</pre>		
	<pre>short stop_column_read ;</pre>		
	<pre>short start_column_coad ;</pre>		
	<pre>short stop_column_coad ;</pre>		
	<pre>uint int_hold ;</pre>		
	ushort int_delay ;		
	ubyte clipping;		
	<pre>}; // instrument_settings_t</pre>	суре	
	variables:		
	instrument_settings_type in	nstrument_settings(nsettings);	

Table 90: CDL definition instrument_settings variable

field	type	unit	description
ic_id	int	1	Instrument configuration ID; number that uniquely speci- fies a type of measurement. The combination of the icid and icversion uniquely identifies a specific instrument configuration

field	type	unit	description
ic_version	short	1	Instrument configuration version; version number for the instrument configuration ID. The combination of the icid and icversion uniquely identifies a specific instrument configuration
ic_set	short	1	Instrument configuration set of which the instrument configuration ID is part.
ic_idx	short	1	Index of the instrument configuration ID in the instrument configuration set
processing_class	short	1	The processing_class defines the type of measurement at a very high level. Contrary to Instrument Configuration IDs, only a limited, fixed set of processing classes is identified. Examples of processing classes are Earth_radiance, Sun_irradiance, CLED, WLS, Dark, Background,
master_cycle_period	float	S	Measurement master cycle period in seconds; must be a multiple of the coaddition period.
coaddition_period	float	S	Co-addition period in seconds; the time interval covered by all the co-additions in the measurement. In case no flushing is used, this is equal to the number of co-additions multiplied by the exposure time. In case flushing is used, this is equal to the number of co-additions multiplied by the sum of the exposure time and the flushing time
exposure_time	float	S	The exposure time in seconds for a single (unco-added) frame.
msmt_mcp_ft_offset	float	S	Offset between Master clock pulse and frame trigger starting measurement
msmt_ft_msmt_start_offset	float	s	Offset between FT and start of measurement
msmt_duration	float	S	Delta between start of first exposure in a measurement and end of last exposure in a measurement
reset_time	float	s	Reset time between exposures
nr_coadditions	short	1	The number of co-additions.
master_cycle_period_us	int	us	Measurement master cycle period in microseconds; must be a multiple of the coaddition period. Note: Contrary to the master_cycle_period, which is stored as a float, this field is stored as a long and therefore exactly representable and comparable
coaddition_period_us	int	us	Co-addition period in microseconds; the time interval covered by all the co-additions in the measurement. In case no flushing is used, this is equal to the number of co-additions multiplied by the exposure time. In case flushing is used, this is equal to the number of co-additions multiplied by the sum of the exposure time and the flushing time. Note: Contrary to the coaddition_period, which is stored as a float, this field is stored as a long and therefore exactly representable and comparable
exposure_time_us	int	us	The exposure time in microseconds for a single (uncoadded) frame. Note: Contrary to the exposure_time, which is stored as a float, this field is stored as a long and therefore exactly representable and comparable.
exposure_period_us	int	us	The interval between two consecutive exposures
	1110	u0	and the settles of the conceded to exposures

field	type	unit	description
small_pixel_column	short	1	Column for which the data are downlinked for all coaddition
stop_column_read	short	1	The number of columns from the detector that are read- out
start_column_coad	short	1	First column that is being co-added
stop_column_coad	short	1	Latest column that is being co-added
int_hold	uint	1	INT_HOLD code
int_delay	ushort	1	INT_DELAY code
clipping	ubyte	1	Data clipping position

Table 91: Fields in the instrument_settings variable.

8.42 Variable: binning_table

	Variable	Storage type	Units
	binning_table	binning_table_type	none
CDL	types: compound binning_table_typ short size; short binning_factor; short gain; short detector_start_row; short detector_stop_row; short measurement_start_ro short measurement_stop_row }; // binning_table_type variables:	e { w ;	none
	binning_table_type binning	_table(nsettings, nbinningr	egions);

Table 92: CDL definition binning_table variable

field	type	unit	description
size	short	1	Number of rows in the area before binning / read-out
binning_factor	short	1	Binning factor for the area; 0 if rows are skipped
gain	short	1	CCD output gain for the area $(0 = dump, 1 = 1x, 2 = 2x)$
detector_start_row	short	1	Start row of the binning area on the detector
detector_stop_row	short	1	Stop row of the binning area on the detector; the stop row is exclusive (i.e. up to, but not including)
measurement_start_row	short	1	Start row of the binning area in the measurement. Set to -1 in case the area is skipped. Reflects the rows that are actually written to the output, in case a subset of the data is written.
measurement_stop_row	short	1	Stop row of the binning area in the measurement; the stop row is exclusive (i.e. up to, but not including). Set to -1 in case the area is skipped. Reflects the rows that are actually written to the output, in case a subset of the data is written.

Table 93: Fields in the binning_table variable.

8.43 Variable: housekeeping_data

	Variable	Storage type	Units
	housekeeping_data	housekeeping_data_type	none
DL	types:		
	compound housekeeping_data_t	type {	
	<pre>float temp_det1 ;</pre>		
	<pre>float temp_det2 ;</pre>		
	<pre>float temp_det3 ;</pre>		
	<pre>float temp_det4 ;</pre>		
	<pre>float data_offset_s ;</pre>		
	<pre>float temp_tss_up_neg_x ;</pre>		
	<pre>float temp_tss_up_neg_y ;</pre>		
	<pre>float temp_tss_up_pos_x ;</pre>		
	<pre>float temp_tss_up_pos_y ;</pre>		
	<pre>float temp_tss_up_mid ;</pre>		
	<pre>float temp_tss_low_mid ;</pre>		
	<pre>float temp_low_uvn_obm ;</pre>		
	<pre>float temp_up_uvn_obm ;</pre>		
	<pre>float temp_obm_swir ;</pre>		
	<pre>float temp_obm_solar_baffle</pre>	;	
	<pre>float temp_cu_sls_stim ;</pre>		
	<pre>float temp_obm_swir_grating</pre>	;	
	<pre>float temp_obm_swir_if ;</pre>		
	<pre>float temp_pelt_cu_sls1 ;</pre>		
	<pre>float temp_pelt_cu_sls2 ;</pre>		
	<pre>float temp_pelt_cu_sls3 ;</pre>		
	<pre>float temp_pelt_cu_sls4 ;</pre>		
	<pre>float temp_pelt_cu_sls5 ;</pre>		
	ubyte difm_status ;		
	ubyte fmm_status ;		
	ubyte det1_led_status ;		
	ubyte det2_led_status ;		
	<pre>ubyte det3_led_status ;</pre>		
	ubyte det4_led_status ;		
	ubyte common_led_status ;		
	ubyte sls1_status ;		
	ubyte sls2_status ;		
	ubyte sls3_status ;		
	ubyte sls4_status ;		
	ubyte sls5_status ;		
	ubyte wls_status ;		
	<pre>ubyte filler_char1 ;</pre>		
	<pre>float swir_vdet_bias ;</pre>		
	}; // housekeeping_data_type		
	variables:		
	housekeeping_data_type house	ekeeping_data(time, scanline)	;

 Table 94: CDL definition housekeeping_data variable

field	type	unit	description	
temp_det1	float	K	Temperature of the detector 1	
temp_det2	float	K	Temperature of the detector 2	

field	type	unit	description
temp_det3	float	K	Temperature of the detector 3
temp_det4	float	K	Temperature of the detector 4
data_offset_s	float	s	Offset time to measurement time of housekeeping data
temp_tss_up_neg_x	float	K	TSS Upper surface Mid -X side temperature
temp_tss_up_neg_y	float	K	TSS Upper surface Mid -Y side temperature
temp_tss_up_pos_x	float	K	TSS Upper surface Mid +X side temperature
temp_tss_up_pos_y	float	K	TSS Upper surface Mid +Y side temperature
temp_tss_up_mid	float	K	TSS Upper surface middle temperature
temp_tss_low_mid	float	K	TSS lower surface middle temperature
temp_low_uvn_obm	float	K	Temperature of the lower UVN OBM
temp_up_uvn_obm	float	K	Temperature of the upper UVN OBM
temp_obm_swir	float	K	Temperature of the SWIR OBM
temp_obm_solar_baffle	float	K	Temperature of the OBM Solar baffle
temp_cu_sls_stim	float	K	Temperature of the OBM CU SLS stimuli
temp_obm_swir_grating	float	K	Temperature of the SWIR grating
temp_obm_swir_if	float	K	Temperature of the OBM at SWIR interface
temp_pelt_cu_sls1	float	K	Temperature of the Peltier Control Calibration unit for SLS1
temp_pelt_cu_sls2	float	K	Temperature of the Peltier Control Calibration unit for SLS2
temp_pelt_cu_sls3	float	K	Temperature of the Peltier Control Calibration unit for SLS3
temp_pelt_cu_sls4	float	K	Temperature of the Peltier Control Calibration unit for SLS4
temp_pelt_cu_sls5	float	K	Temperature of the Peltier Control Calibration unit for SLS5
difm_status	ubyte	1	DIFM status; 0 UNKNOWN, 1 WLS, CLED_QVD2 2, SUN_QVD2 3, SLS 4, CLED_QVD2 5, SUN_QVD1 6, OSCILATING 7
fmm_status	ubyte	1	FMM status; UNKNOWN 0, NADIR_VIEW 1, CALIBRATION 2
det1_led_status	ubyte	1	Led of detector 1 on (1) or off (0)
det2_led_status	ubyte	1	Led of detector 2 on (1) or off (0)
det3_led_status	ubyte	1	Led of detector 3 on (1) or off (0)
det4_led_status	ubyte	1	Led of detector 1 on (1) or off (0)
common_led_status	ubyte	1	Common led on (1) or off (0)
sls1_status	ubyte	1	Led SLS1 on (1) or off (0)
sls2_status	ubyte	1	Led SLS2 on (1) or off (0)
sls3_status	ubyte	1	Led SLS3 on (1) or off (0)
sls4_status	ubyte	1	Led SLS4 on (1) or off (0)
sls5_status	ubyte	1	Led SLS5 on (1) or off (0)
wls_status	ubyte	1	Led WLS on (1) or off (0)
filler_char1	ubyte	1	Filler byte for alignment
swir_vdet_bias	float	V	Bias voltage of SWIR detector

 Table 95: Fields in the housekeeping_data variable.

Units

8.44 Variable: measurement_to_detector_row_table in engineering product

	Variable	Storage type	Units
mea	surement_to_detector_row_table	msmt_to_det_row_table_type	none
CDL	<pre>types: compound msmt_to_det_row_table short det_start_row ; short det_end_row ; }; // msmt_to_det_row_table_ty variables:</pre>		o(timo scanlino
	ground_pixel);	asurement_to_detector_row_table	e(time, scaniine,

Remarks

Table 96: CDL definition measurement_to_detector_row_table variable

field	type	unit	description	
det_start_row	short	1	Detector start row for measurement row	
det_end_row	short	1	Detector end row for measurement row	

Table 97: Fields in the measurement_to_detector_row_table variable.

8.45 Variable: nominal_wavelength

Variable

The nominal_wavelength provides for each ground pixel the wavelength measured by a spectral channel and is defined by the design parameters of the instrument. The wavelength values as provided by the nominal_wavelength are based on the Calibration Key Data (CKD) which are input to the L01b processing (section 5). See also the discussion on calibrated_wavelength in section 8.23.

Storage type

	nominal_wavelength	float	nm
CDL	float nominal_wavelength(ti nominal_wavelength:long_nam nominal_wavelength:standard nominal_wavelength:units = nominal_wavelength:comment cross track pixel as a func	<pre>e = "spectral channe _name = "radiation_w "nm" ; = "The nominal spect</pre>	<pre>l nominal wavelength"; avelength"; ral wavelength for each</pre>
Remarks	The nominal_wavelength provious channel and is defined by the des	•	vavelength measured by a spectral trument.

The values mentioned for valid_min and valid_max apply to the Band1 product and serve as an example. The valid values for all products are listed in Table 1 in section 4.2

Table 98: CDL definition nominal_wavelength variable

8.46 Variable: nominal_wavelength_error

	Variable	Storage type	Units
	nominal_wavelength_error	float	nm
CDL	float nominal_wavelength_error(time,ground_pixel,spectral_channel); nominal_wavelength_error:long_name = "spectral channel nominal wavele error"; nominal_wavelength_error:standard_name = "radiation_wavelength standa error"; nominal_wavelength_error:units = "nm"; nominal_wavelength_error:comment = "The nominal spectral wavelength for each cross track pixel as a function of the spectral channel.";		hannel nominal wavelength ion_wavelength standard spectral wavelength error
Remarks	measured by a spectral channel a	and is defined by the design id_min and valid_max and vali	apply to the Band1 product and

Table 99: CDL definition nominal_wavelength_error variable

8.47 Variable: sample_cycle

The concept of "sample cycle" has been introduced to allow for comparison of the different radiance products (i.e. bands). In principle, the eight products all can have different co-addition periods, i.e. the time period in which independent measurements are added in order to reduce the data rate as well as to increase the signal—to-noise ratio. The number of independent measurements is depending on the integration time which differs for each band, but is fixed for a specific instrument configuration.

For all bands measurements start at the same time but because the co-addition time may be different the scanlines may have a different time stamp. However, after a period of length sample_cycle_length the measurement cycle is repeated and again the measurements start at the same time. Thus, within the sample_cycle a fixed number (for a certain instrument configuration) of scanlines is collected, which differ for each radiance product. However, the sample_cycle index is the same for all these products.

	Variable	Storage type	Units
	sample_cycle	int	none
CDL	<pre>int sample_cycle(time,sca sample_cycle:long_name = sample_cycle:units = "1" sample_cycle:comment = "s scanline; index starts at</pre>	<pre>"sample cycle"; ; ample_cycle provides a sa</pre>	ample_cycle index for each
Remarks	One unique set of sample_cy originating from the same orbit.		Il radiance products (i.e. bands)

Table 100: CDL definition sample_cycle variable

8.48 Variable: sample_cycle_length

	Variable	Storage type	Units	
	sample_cycle_length	int	ms	
CDL	<pre>int sample_cycle_length(ti sample_cycle_length:long_r sample_cycle_length:units sample_cycle_length:commer</pre>	name = "length of sample = "ms" ;	•	

Remarks

Table 101: CDL definition sample_cycle_length variable

8.49 Variable: monitor_straylight_observed

	Variable	Storage type	Units
	monitor_straylight_observed	float	electron.s-1
CDL	<pre>float monitor_straylight_obs ; monitor_straylight_observed: monitor_straylight_observed: light areas on the detector;</pre>	units = "electron.s	s-1"; l stray light from the stray

Remarks

Table 102: CDL definition monitor_straylight_observed variable

8.50 Variable: offset_readout_register

	Variable	Storage type	Units	
	offset_readout_register	n/a	none	
CDL	types: datapoint_type {			
	double value ;			
	double error ;			
	}			
	offset_readout_register(time,scanline,ccd_gain,parity);			
	offset_readout_register:comment = "Detector and electronics offset value			
	calculated from the detector's read-out register";			

Remarks Only available for UVN bands

Table 103: CDL definition offset_readout_register variable

8.51 Variable: irradiance_avg

	Variable	Storage type	Units
	irradiance_avg	float	$mol.s^{-1}.m^{-2}.nm^{-1}$
CDL	<pre>float irradiance_avg(time irradiance_avg:units = "m irradiance_avg:ancillary_ error"; irradiance_avg:comment = spectral pixel of all mea</pre>	nol.s-1.m-2.nm-1"; variables = "irradiance" "Averaged measured spec	e_avg_noise irradiance_avgctral irradiance for each

Remarks

Table 104: CDL definition irradiance_avg variable

8.52 Variable: irradiance_avg_noise

	Variable	Storage type	Units
	irradiance_avg_noise	float	none
CDL	float irradiance_avg_noise irradiance_avg_noise:comme spectral pixel of all meas	nt = "Average irradiance	e signal noise for each

Remarks

Table 105: CDL definition irradiance_avg_noise variable

8.53 Variable: irradiance_avg_error

	Variable	Storage type	Units
	irradiance_avg_error	float	none
CDL	float irradiance_avg_error irradiance_avg_error:comme spectral pixel of all meas	nt = "Average irradiance	e signal error for each

Remarks

Table 106: CDL definition irradiance_avg_error variable

8.54 Variable: irradiance_avg_quality_level

	Variable	Storage type	Units
	irradiance_avg_quality_level	ubyte	none
CDL	ubyte irradiance_avg_quality	-	=
	<pre>irradiance_avg_quality_level ;</pre>	l:long_name = "quali	y level of spectral channel"
	irradiance_avg_quality_level		
	irradiance_avg_quality_level		
	irradiance_avg_quality_lever assessment information for e		± v

Remarks

Table 107: CDL definition irradiance_avg_quality_level variable

8.55 Variable: irradiance_avg_std

	Variable	Storage type	Units
	irradiance_avg_std	float	none
CDL	float irradiance_avg_std(time,pixel,spectral_channel);		
	<pre>irradiance_avg_std:comment = "Average irradiance signal standard deviation</pre>		
	for each spectral pixel of	f all measurements in th	e group" ;

Remarks

Table 108: CDL definition irradiance_avg_std variable

8.56 Variable: irradiance_avg_spectral_channel_quality

	Variable	Storage type	Units
irrad	liance_avg_spectral_channel quality	ubyte	none
CDL	ubyte irradiance_avg_spectral; irradiance_avg_spectral_channe quality flag"; irradiance_avg_spectral_channe irradiance_avg_spectral_channe irradiance_avg_spectral_channe 16UB, 32UB, 64UB, 128UB; irradiance_avg_spectral_channe bad_pixel, processing_error, s irradiance_avg_spectral_channe information about a (spectral)	el_quality:long_nel_quality:valid_el_quality:valid_el_quality:flag_nel_quality:flag_nel_quality:flag_nel_quality:commenel_qua	name = "spectral channel _min = 0 ; _max = 254 ; values = 0UB, 1UB, 2UB, 8UB, meanings = no_error, missing, ient, rts, underflow ; nt = "Quality assessment
Remarks	Flags of measurements ignored by the	ne averaging algorith	nms are present.

Table 109: CDL definition irradiance_avg_spectral_channel_quality variable

Units

8.57 Variable: irradiance_avg_col

	Variable	Storage type	Units
	irradiance_avg_col	float	none
CDL	float irradiance avg col(time.scanline.pixel) :	

Remarks

Table 110: CDL definition irradiance_avg_col variable

Variable

8.58 Variable: radiance_avg

		5 71		
	radiance_avg	float	$mol.s^{-1}.m^{-2}.nm^{-1}.sr^{-1}$	
CDL	<pre>float radiance_avg(time,g radiance_avg:units = "mol radiance_avg:coordinates radiance_avg:ancillary_va; ; radiance_avg:comment = "A spectral pixel of all mea</pre>	i.s-1.m-2.nm-1.sr-1"; = "longitude latitude" ariables = "radiance_av	; yg_noise radiance_avg_error" cral radiance for each	
Remarks	satellites. In line with the stand	ard_name for radiance that	e as measured by sensors on boathas been suggested by the cf-satell ng_spectral_photon_radiance	lite

Storage type

Table 111: CDL definition radiance_avg variable

8.59 Variable: radiance_avg_error

	Variable	Storage type	Units
	radiance_avg_error	float	none
CDL	float radiance_avg_error(radiance_avg_error:coordin radiance_avg_error:commen spectral pixel of all mean	nates = "longitude latit t = "Average radiance si	ude"; gnal error for each

Table 112: CDL definition radiance_avg_error variable

8.60 Variable: radiance_avg_noise

	Variable	Storage type	Units
	radiance_avg_noise	float	none
CDL	float radiance_avg_noise(fradiance_avg_noise:coordingradiance_avg_noise:commenfradiance_avg_noise:commenfradiance_avg_noise)	nates = "longitude latit t = "Average radiance si	ude"; gnal noise for each

Remarks

Table 113: CDL definition radiance_avg_noise variable

8.61 Variable: radiance_avg_quality_level

	Variable	Storage type	Units
	radiance_avg_quality_level	ubyte	none
CDL	<pre>radiance_avg_quality_level: radiance_avg_quality_level: radiance_avg_quality_level:</pre>	<pre>long_name = "quality of valid_min = 0; valid_max = 100; coordinates = "longist comment = "Overall ca</pre>	level of spectral channel"; tude latitude"; alculated quality assessment

Remarks

Table 114: CDL definition radiance_avg_quality_level variable

8.62 Variable: radiance_avg_spectral_channel_quality

	Variable	Storage type	Units
radianc	e_avg_spectral_channel_quality	ubyte	none
CDL	ubyte radiance_avg_spectral_channel_channel); radiance_avg_spectral_channel_flag"; radiance_avg_spectral_channel_radiance_avg_spectral_channel_radiance_avg_spectral_channel_radiance_avg_spectral_channel_flags, 32UB, 64UB, 128UB; radiance_avg_spectral_channel_bad_pixel, processing_error, stadiance_avg_spectral_channel_information about a (spectral)	_quality:long_nam _quality:valid_mi _quality:valid_ma _quality:coordina _quality:flag_val _quality:flag_mea _saturated, transi _quality:comment	ne = "spectral channel quality in = 0; ax = 254; ates = "longitude latitude"; lues = OUB, 1UB, 2UB, 8UB, anings = no_error, missing, ient, rts, underflow; = "Quality assessment
Remarks	Flags of measurements ignored by the	ne averaging algorith	ims are present.

Table 115: CDL definition radiance_avg_spectral_channel_quality variable

8.63 Variable: radiance_avg_std

	Variable	Storage type	Units
	radiance_avg_std	float	none
CDL	<pre>float radiance_avg_std(time,ground_pixel,spectral_channel) ; radiance_avg_std:coordinates = "longitude latitude" ;</pre>		
	<pre>radiance_avg_std:comment each spectral pixel of al</pre>	0 0	

Remarks

Table 116: CDL definition radiance_avg_std variable

8.64 Variable: radiance_avg_row

	Variable	Storage type	Units
	radiance_avg_row	float	none
CDL	float radiance_avg_row(ti radiance_avg_row:comment single row in a measureme	= "Averaged measured spe	-

Remarks

Table 117: CDL definition radiance_avg_row variable

8.65 Variable: radiance_avg_data

	Variable	Storage type	Units
	radiance_avg_data	float	none
CDL	<pre>float radiance_avg_data(t radiance_avg_data:comment single measurements";</pre>		spectral radiance value of a

Remarks

Remarks

Table 118: CDL definition radiance_avg_data variable

8.66 Variable: percentage_ground_pixels_geolocation_error

	Variable	Storage type	Units
percer	tage_ground_pixels_geolocation error	float	none
CDL	float percentage_ground_pixels_percentage_ground_pixels_geolog pixels with geologation error"	cation_error:co	

Table 119: CDL definition percentage_ground_pixels_geolocation_error variable

8.67 Variable: percentage_spectral_channels_rts

	Variable	Storage type	Units	
	percentage_spectral_channels_rts	float	none	
CDL	float percentage_spectral_cha	annels_rts(time);		

percentage_spectral_channels_rts:comment = "Percentage of spectral channels for which the RTS flag is set";

Remarks

Table 120: CDL definition percentage_spectral_channels_rts variable

8.68 Variable: percentage_spectral_channels_per_scanline_transient

	Variable	Storage type	Units
per	centage_spectral_channels_per scanline_transient	float	none
CDL	float percentage_spectral_char percentage_spectral_channels_p of spectral channels per scan	er_scanline_trans	ient:comment = "Percentage

Remarks

Table 121: CDL definition percentage_spectral_channels_per_scanline_transient variable

8.69 Variable: oob_sl_nir_corr_row_avg_blu_irr

	Variable	Storage type	Units
	oob_sl_nir_corr_row_avg_blu_irr	float	electron.s-1
CDL	<pre>float oob_sl_nir_corr_row_avg channel); oob_sl_nir_corr_row_avg_blu_i: oob_sl_nir_corr_row_avg_blu_i: correction row average, blue s</pre>	rr:units = "elec rr:comment = "Ca	tron.s-1"; llculated oob straylight nir

Remarks

Table 122: CDL definition oob_sl_nir_corr_row_avg_blu_irr variable

8.70 Variable: oob_sl_nir_dp_factor_blu_irr

	Variable	Storage type	Units
	oob_sl_nir_dp_factor_blu_irr	float	electron.s-1.nm-1
CDL	float oob_sl_nir_dp_factor_blu_irr(time,scanline,fiber); oob_sl_nir_dp_factor_blu_irr:units = "electron.s-1.nm-1"; oob_sl_nir_dp_factor_blu_irr:comment = "Calculated oob straylight nir		
	factor, blue side irradiance	, for monitoring pu	ırposes" ;

8.71 Variable: oob_sl_nir_corr_row_avg_red_irr

	Variable	Storage type	Units
·	oob_sl_nir_corr_row_avg_red_irr	float	electron.s-1
CDL	float oob_sl_nir_corr_row_avg channel); oob_sl_nir_corr_row_avg_red_i oob_sl_nir_corr_row_avg_red_i correction row average, red s	rr:units = "elect rr:comment = "Cal	ron.s-1"; culated oob straylight nir

Remarks

Table 124: CDL definition oob_sl_nir_corr_row_avg_red_irr variable

8.72 Variable: oob_sl_nir_dp_factor_red_irr

	Variable	Storage type	Units
	oob_sl_nir_dp_factor_red_irr	float	electron.s-1.nm-1
CDL	float oob_sl_nir_dp_factor_red_irr(time,scanline,fiber); oob_sl_nir_dp_factor_red_irr:units = "electron.s-1.nm-1";		
	<pre>oob_sl_nir_dp_factor_red_irr factor, red side irradiance,</pre>		, ,

Remarks

Table 125: CDL definition oob_sl_nir_dp_factor_red_irr variable

8.73 Variable: oob_sl_nir_corr_row_avg_blu_rad

	Variable	Storage type	Units
	oob_sl_nir_corr_row_avg_blu_rad	float	electron.s-1
CDL	float oob_sl_nir_corr_row_avg channel); oob_sl_nir_corr_row_avg_blu_r oob_sl_nir_corr_row_avg_blu_r correction row average, blue	ad:units = "elect ad:comment = "Cal	ron.s-1" ; culated oob straylight nir

Table 126: CDL definition oob_sl_nir_corr_row_avg_blu_rad variable

8.74 Variable: oob_sl_nir_dp_factor_blu_rad

	Variable	Storage type	Units
	oob_sl_nir_dp_factor_blu_rad	float	electron.s-1.nm-1
CDL	<pre>float oob_sl_nir_dp_factor_blu_rad(time,scanline,fiber) ;</pre>		
	<pre>oob_sl_nir_dp_factor_blu_rad:units = "electron.s-1.nm-1" ; oob_sl_nir_dp_factor_blu_rad:comment = "Calculated oob straylight nir dp factor, blue side radiance, for monitoring purposes" ;</pre>		

Remarks

Table 127: CDL definition oob_sl_nir_dp_factor_blu_rad variable

8.75 Variable: oob_sl_nir_corr_row_avg_red_rad

	Variable	Storage type	Units
	oob_sl_nir_corr_row_avg_red_rad	float	electron.s-1
CDL	float oob_sl_nir_corr_row_avg channel); oob_sl_nir_corr_row_avg_red_r oob_sl_nir_corr_row_avg_red_r correction row average, red s	rad:units = "elect rad:comment = "Cal	ron.s-1"; culated oob straylight nir

Remarks

Table 128: CDL definition oob_sl_nir_corr_row_avg_red_rad variable

8.76 Variable: oob_sl_nir_dp_factor_red_rad

	Variable	Storage type	Units
	oob_sl_nir_dp_factor_red_rad	float	electron.s-1.nm-1
CDL	<pre>float oob_sl_nir_dp_factor_re oob_sl_nir_dp_factor_red_rad oob_sl_nir_dp_factor_red_rad factor, red side radiance, for</pre>	units = "electron. comment = "Calcula":	s-1.nm-1"; ted oob straylight nir dp

Remarks

Table 129: CDL definition oob_sl_nir_dp_factor_red_rad variable

8.77 Variable: solar_azimuth_angle_irr_cal

	Variable	Storage type	Units
	solar_azimuth_angle	float	degree
CDL	float solar_azimuth_angle	(time,scanline);	
	<pre>solar_azimuth_angle:long_name = "solar azimuth angle" ;</pre>		
	<pre>solar_azimuth_angle:standard_name = "solar_azimuth_angle" ;</pre>		
	solar_azimuth_angle:units	= "degree" ;	
	solar_azimuth_angle:valid_	$_{min} = -180.f$;	
	solar_azimuth_angle:valid_	$\max = 180.f$;	
	solar_azimuth_angle:commer	nt = "Azimuth angle of th	ne sun measured from the
	instrument";		

Remarks

Table 130: CDL definition solar_azimuth_angle variable

8.78 Variable: irradiance_avg_data

	Variable	Storage type	Units
	irradiance_avg_data	float	none
CDL	<pre>float irradiance_avg_data(time,scanline) ;</pre>		
	irradiance_avg_data:commer	nt = "Averaged measured	spectral irradiance value
	of a single measurements"	;	

Remarks

Table 131: CDL definition irradiance_avg_data variable

8.79 Variable: solar_azimuth_angle_rad_cal

	Variable	Storage type	Units
	solar_azimuth_angle	float	degree
CDL	float solar_azimuth_angle(solar_azimuth_angle:long_r solar_azimuth_angle:standa solar_azimuth_angle:units solar_azimuth_angle:valid_ solar_azimuth_angle:valid_ solar_azimuth_angle:coordi solar_azimuth_angle:commer location on the reference North (East = +90, South =	<pre>mame = "solar azimuth ang ard_name = "solar_azimuth = "degree"; min = -180.f; max = 180.f; mates = "longitude latit at = "Solar azimuth angle ellipsoid. Angle is mean</pre>	gle"; n_angle"; sude"; e at the ground pixel

Table 132: CDL definition solar_azimuth_angle variable

8.80 Variable: signal_avg

	Variable	Storage type	Units
	signal_avg	float	none
CDL		iables = "signal_avg_noise eraged measured spectral s	

Remarks Unit differs between groups

Table 133: CDL definition signal_avg variable

8.81 Variable: signal_avg_error

	Variable	Storage type	Units
	signal_avg_error	float	none
CDL	float signal_avg_error(time,pixel,spectral_channel); signal_avg_error:comment = "Average signal error for each spectral pixel all measurements in the group";		-
Remarks	Unit differs between groups		

Table 134: CDL definition signal_avg_error variable

8.82 Variable: signal_avg_noise

	Variable	Storage type	Units
	signal_avg_noise	float	none
CDL	3 3	0 0); for each spectral pixel of
Remarks	Unit differs between groups		

Table 135: CDL definition signal_avg_noise variable

8.83 Variable: signal_avg_quality_level

	Variable	Storage type	Units
	signal_avg_quality_level	ubyte	none
CDL	ubyte signal_avg_quality_le signal_avg_quality_level:lo signal_avg_quality_level:va signal_avg_quality_level:va signal_avg_quality_level:co information for each (spect	<pre>ng_name = "qualiy le' lid_min = 0 ; lid_max = 100 ; mment = "Overall cal</pre>	vel of spectral channel"; culated quality assessment

8.84 Variable: signal_avg_spectral_channel_quality

	Variable	Storage type	Units
signal	_avg_spectral_channel_quality	ubyte	none
CDL	ubyte signal_avg_spectral_chansignal_avg_spectral_channel_quflag"; signal_avg_spectral_channel_qusignal_avg_spectral_channel_qusignal_avg_spectral_channel_qusignal_avg_spectral_channel_qusignal_avg_spectral_channel_qupixel, processing_error, satursignal_avg_spectral_channel_quinformation about a (spectral)	nality:long_name nality:valid_min nality:valid_max nality:flag_value nality:flag_meani rated, transient, nality:comment =	= "spectral channel quality = 0; = 254; = 0UB, 1UB, 2UB, 8UB, 16UB, ngs = no_error, missing, bad rts, underflow; "Quality assessment
Remarks	Flags of measurements ignored by th	ne averaging algorith	ms are present.

 $\textbf{Table 137}: \texttt{CDL definition signal_avg_spectral_channel_quality variable}$

8.85 Variable: signal_avg_std

	Variable	Storage type	Units
	signal_avg_std	float	none
CDL	<pre>float signal_avg_std(time signal_avg_std:comment = spectral pixel of all mea</pre>	"Average signal standard	deviation for each
Remarks	Unit differs between groups		

Table 138: CDL definition signal_avg_std variable

8.86 Variable: signal_avg_data

	Variable	Storage type	Units
	signal_avg_data	float	none
CDL	<pre>float signal_avg_data(tim signal_avg_data:comment = single measurement";</pre>		ectral signal value of a

Table 139: CDL definition signal_avg_data variable

8.87 Variable: signal_avg_row

	Variable	Storage type	Units
	signal_avg_row	float	none
CDL	<pre>float signal_avg_row(time,scanline,spectral_channel) ; signal_avg_row:comment = "Averaged measured spectral signal value of a</pre>		
	single row in a measureme	ent";	

Remarks

Table 140: CDL definition signal_avg_row variable

8.88 Variable: signal_avg_col

	Variable	Storage type	Units
	signal_avg_col	float	none
CDL	<pre>float signal_avg_col(tim signal_avg_col:comment = single column in a measu</pre>	"Averaged measured spects	ral signal value of a

Remarks

Table 141: CDL definition signal_avg_col variable

8.89 Variable: small_pixel_signal

	Variable	Storage type	Units
	small_pixel_signal	float(*)	none
CDL	<pre>types: float(*) small_pi</pre>	0 01	
	small_pixel_signal_type s	mall_pixel_signal(time,so	canline,pixel) ;
<pre>small_pixel_signal:long_name = "small pixel photon signal";</pre>			n signal" ;
	<pre>small_pixel_signal:_FillValue = 0x1.ep+122 ;</pre>		
small_pixel_signal:comment = "Measured signal for the spectral			the spectral channel
	dedicated for the small p	ixel measurements";	-

Remarks

Table 142: CDL definition small_pixel_signal variable

8.90 Variable: percentage-spectral_channels_per_scanline_rts

	Variable	Storage type	Units
per	centage_spectral_channels_per scanline_rts	float	none
CDL	float percentage_spectral_chan percentage_spectral_channels_p spectral channels per scanline	er_scanline_rts	:comment = "Percentage of

Table 143: CDL definition percentage_spectral_channels_per_scanline_rts variable

8.91 Variable: percentage-scanlines_with_processing_steps_skipped

	Variable	Storage type	Units
percer	ntage_scanlines_with_processing	float	none
	steps_skipped		
ODI	67		1. 1/

float percentage_scanlines_with_processing_steps_skipped(time);

percentage_scanlines_with_processing_steps_skipped:comment = "Percentage of scanlines for which one or more processing steps were skipped";

Remarks

Table 144: CDL definition percentage_scanlines_with_processing_steps_skipped variable

8.92 Variable: percentage_scanlines_with_residual_correction_skipped

Variable	Storage type	Units
percentage_scanlines_with_residual	float	none
correction_skipped		

CDL

float percentage_scanlines_with_residual_correction_skipped(time) ;
percentage_scanlines_with_residual_correction_skipped:comment = "Percentage
of scanlines for which residual correction was skipped" ;

Remarks

Table 145: CDL definition percentage_scanlines_with_residual_correction_skipped variable

8.93 Variable: percentage_ground_pixels_descending_side_orbit

Variable	Storage type	Units
percentage_ground_pixels_descending	float	none
side_orbit		

CDL

float percentage_ground_pixels_descending_side_orbit(time) ;
percentage_ground_pixels_descending_side_orbit:comment = "Percentage of
ground pixels on the descending side of the orbit" ;

Remarks

Table 146: CDL definition percentage_ground_pixels_descending_side_orbit variable

8.94 Variable: percentage_spectral_channels_per_scanline_defective

	Variable	Storage type	Units
per	centage_spectral_channels_per scanline_defective	float	none
CDL	float percentage spectral char	nels per scanline	defective(time.scanline) :

float percentage_spectral_channels_per_scanline_defective(time,scanline) ;
percentage_spectral_channels_per_scanline_defective:comment = "Percentage
 of spectral channels per scanline for which the defective flag is set";

Remarks

Table 147: CDL definition percentage_spectral_channels_per_scanline_defective variable

8.95 Variable: percentage_scanlines_in_spacecraft_manoeuvre

	Variable	Storage type	Units
perc	entage_scanlines_in_spacecraft	float	none
	manoeuvre		
CDL	float percentage_scanlines_in	_spacecraft_manoeuvre	e(time) ;
	percentage_scanlines_in_space	craft_manoeuvre:comm	ent = "Percentage of
	scanlines affected by spacecra	aft manoeuvres" :	

Remarks

Table 148: CDL definition percentage_scanlines_in_spacecraft_manoeuvre variable

8.96 Variable: monitor_straylight_calculated

	Variable	Storage type	Units
	monitor_straylight_calculated	float	electron.s-1
CDL	<pre>float monitor_straylight_cal ; monitor_straylight_calculate monitor_straylight_calculate monitoring purposes";</pre>	d:units = "electron	

Remarks

Table 149: CDL definition monitor_straylight_calculated variable

8.97 Variable: monitor_radiance_wavelength_shift

	Variable	Storage type	Units
monit	or_radiance_wavelength_shift	float	none
CDL	float monitor_radiance_waveler monitor_radiance_wavelength_sl wavelength band around the spe	nift:comment = "Way	velenght shift for a small
Remarks	The name of the variable in the output xxxx is the center wavelength value. wavelength can be found in the variable	The center wavelength	and the bandwidth around the center

Table 150: CDL definition monitor_radiance_wavelength_shift variable

8.98 Variable: monitor_gain_alignment_factor

	Variable	Storage type	Units
	monitor_gain_alignment_factor	float	none
CDL	float monitor_gain_alignment monitor_gain_alignment_facto measurement calculated in th Applied gain alignment facto Default, the CKD setting of not the calculated.";	r:comment = "Gain ala e GainAlignmentCalcul r depends on the sett	ignment factor for the lationUVN algorithm.

Remarks

Table 151: CDL definition monitor_gain_alignment_factor variable

8.99 Variable: measurement_to_detector_row_table

	Variable	Storage type	Units
meas	surement_to_detector_row_table	n/a	none
CDL	<pre>types: msmt_to_det_row_table short detector_start_row; short detector_end_row; } measurement_to_detector_row_t measurement_to_detector_row_t measurement row to begin and</pre>	able(time,scanline,g able:comment = "Convo	ersion table from

Remarks

 Table 152:
 CDL definition measurement_to_detector_row_table variable

8.100 Variable: signal

	Variable	Storage type	Units
	signal	float	none
CDL	<pre>signal:long_name = "spec signal:ancillary_variabl spectral_channel_quality</pre>	es = "signal_noise signal_	error quality_level

Table 153 : CDL definition signal variable

8.101 Variable: signal_error

	Variable	Storage type	Units
	signal_error	byte	none
CDL	byte signal_error(time,sc signal_error:long_name = signal_error:units = "1" signal_error:comment = "T deviation error of the bi decibel (dB), i.e. 10 ti between the signal and th	"spectral photon signal; he signal_error is a mea as of the measurement si mes the base-10 logarith	error"; sure for the one standard gnal; it is expressed in

Remarks

Table 154: CDL definition signal_error variable

8.102 Variable: signal_noise

	Variable	Storage type	Units
	signal_noise	byte	none
CDL	<pre>byte signal_noise(time,scanline,pixel,spectral_channel) ; signal_noise:long_name = "spectral photon signal noise, one standard</pre>		
	<pre>deviation" ; signal_noise:units = "1"</pre>		iorgo, one goanaara
	signal_noise:comment = "	The signal_noise is a measure the measurement signal;	
	decibel (dB), i.e. 10 t between the signal and t	imes the base-10 logarithment random error.";	nic value of the ratio

Remarks

Table 155: CDL definition signal_noise variable

8.103 Variable: percentage_ground_pixels_night

	Variable	Storage type	Units
	percentage_ground_pixels_night	float	none
CDL	DL float percentage_ground_pixels_night(time);		
	<pre>percentage_ground_pixels_night:comment = "Percentage of ground pixels for</pre>		
	which the night flag is set"	;	

Table 156: CDL definition percentage_ground_pixels_night variable

8.104 Variable: percentage_spectral_channels_transient

	Variable	Storage type	Units
	<pre>percentage_spectral_channels</pre>	float	none
CDL	float percentage_spectral_cha percentage_spectral_channels_ channels for which the transi	transient:comment	= "Percentage of spectral

Remarks

Table 157: CDL definition percentage_spectral_channels_transient variable

8.105 Variable: offset_prepostscan_pixels

	Variable	Storage type	Units
	offset_prepostscan_pixels	n/a	none
CDL	<pre>types: datapoint_type { double value ; double error ; } offset_prepostscan_pixels(t) offset_prepostscan_pixels:cc calculated from the detector</pre>	omment = "Detector and	electronics offset value
Remarks	Only available for UVN bands		

Table 158: CDL definition offset_prepostscan_pixels variable

8.106 Variable: percentage_spectral_channels_per_scanline_saturated

	Variable	Storage type	Units
per	centage_spectral_channels_per scanline_saturated	float	none
CDL	float percentage_spectral_char percentage_spectral_channels_p of spectral channels per scanl	er_scanline_satu	rated:comment = "Percentage

Remarks

 $\textbf{Table 159}: \texttt{CDL definition percentage_spectral_channels_per_scanline_saturated \ variable}$

8.107 Variable: monitor_smear_calculated

	Variable	Storage type	Units
	monitor_smear_calculated	float	electron
CDL	float monitor_smear_calcula monitor_smear_calculated:un monitor_smear_calculated:co used for the detector smear	its = "electron" ; mment = "Calculated de	etector smear values as
Remarks	Only available for UVN bands		

 Table 160: CDL definition monitor_smear_calculated variable

8.108 Variable: radiance_avg_col

	Variable	Storage type	Units
	radiance_avg_col	float	none
CDL	<pre>float radiance_avg_col(ti radiance_avg_col:comment single column in a measur</pre>	= "Averaged measured spec	

Remarks

Table 161: CDL definition radiance_avg_col variable

8.109 Variable: offset_overscan_rows

	Variable	Storage type	Units
	offset_overscan_rows	n/a	none
CDL	<pre>types: datapoint_type { double value ; double error ; } offset_overscan_rows(time, offset_overscan_rows:comment calculated from the detect</pre>	nt = "Detector and elec	-
Remarks	Only available for UVN bands		

Table 162: CDL definition offset_overscan_rows variable

8.110 Variable: percentage_spectral_channels_per_scanline_underflow

	Variable	Storage type	Units
perd	centage_spectral_channels_per scanline_underflow	float	none
CDL	<pre>float percentage_spectral_char percentage_spectral_channels_p of spectral channels per scanl</pre>	er_scanline_underf	flow:comment = "Percentage

Remarks

Remarks

Table 163: CDL definition percentage_spectral_channels_per_scanline_underflow variable

8.111 Variable: offset_overscan_columns

	Variable	Storage type	Units
	offset_overscan_columns	n/a	none
CDL	<pre>types: datapoint_type { double value ; double error ; } offset_overscan_columns(tim offset_overscan_columns:com calculated from the detector</pre>	ment = "Detector and el	ectronics offset value
Remarks	Only available for UVN bands		

Table 164: CDL definition offset_overscan_columns variable

8.112 Variable: percentage_scanlines_with_solar_angles_out_of_nominal_range

	Variable	Storage type	Units
-	rcentage_scanlines_with_solar angles_out_of_nominal_range	float	none
CDL	<pre>float percentage_scanlines_wit percentage_scanlines_with_sola "Percentage of scanlines for a range";</pre>	ar_angles_out_of_n	ominal_range:comment =

Table 165: CDL definition percentage_scanlines_with_solar_angles_out_of_nominal_range variable

8.113 Variable: small_pixel_irradiance

Variable	Storage type	Units
small_pixel_irradiance	float(*)	none
<pre>types: float(*) small_pix</pre>	el_irradiance_type ;	
<pre>small_pixel_irradiance_type small_pixel_irradiance(time,scanline,pixel) ;</pre>		
small_pixel_irradiance:long	$g_name = "small pixel pl$	hoton signal";
<pre>small_pixel_irradiance:_Fi</pre>	11Value = 0x1.ep+122;	
		for the spectral channel
dedicated for the small pi	xel measurements" :	-
	small_pixel_irradiance types: float(*) small_pix small_pixel_irradiance:typ small_pixel_irradiance:_Fi small_pixel_irradiance:com	<pre>small_pixel_irradiance float(*) types: float(*) small_pixel_irradiance_type;</pre>

Remarks

Table 166: CDL definition small_pixel_irradiance variable

8.114 Variable: monitor_overscan_rows

	Variable	Storage type	Units
	monitor_overscan_rows	float	none
CDL	<pre>float monitor_overscan_row monitor_overscan_rows:comm for monitoring purposes" ;</pre>	ent = "Signal from the d	

Remarks

Table 167: CDL definition monitor_overscan_rows variable

8.115 Variable: detector_pixel_filling_histogram

	Variable	Storage type	Units
dete	ctor_pixel_filling_histogram	int	none
CDL	<pre>int detector_pixel_filling_his detector_pixel_filling_histog filling in electrons for each</pre>	ram:comment = "]	anline,nbins); Histogram of the detector pixel
Remarks	Only available for UVN bands		

Table 168: CDL definition detector_pixel_filling_histogram variable

8.116 Variable: offset_static_ckd

	Variable	Storage type	Units
	offset_static_ckd	n/a	none
CDL	<pre>types: datapoint_type { double value ; double error ;</pre>		
	<pre>} offset_static_ckd(time,sc offset_static_ckd:comment obtained from the calibra</pre>	= "Detector and electron	
Remarks	Only available for LIVN hands		

Remarks Only available for UVN bands

Table 169: CDL definition offset_static_ckd variable

8.117 Variable: percentage_spectral_channels_defective

	Variable	Storage type	Units
	percentage_spectral_channels	float	none
	defective		
CDL	DL float percentage_spectral_channels_defective(time);		
	<pre>percentage_spectral_channels_defective:comment = "Flags of measurements</pre>		
	ignored by the averaging algo	orithms are present.'	;

Remarks

Table 170: CDL definition percentage_spectral_channels_defective variable

8.118 Variable: percentage_spectral_channels_missing

Variable	Storage type	Units
percentage_spectral_channels_missing	float	none
float percentage_spectral_chan percentage_spectral_channels_m channels for which the missing	nissing:comment	

Table 171: CDL definition percentage_spectral_channels_missing variable

8.119 Variable: percentage_scanlines_in_south_atlantic_anomaly

	Variable	Storage type	Units
	<pre>percentage_scanlines_in_south atlantic_anomaly</pre>	float	none
CDL	float percentage_scanlines_ir percentage_scanlines_in_south scanlines in the South Atlant	n_atlantic_anomaly:	comment = "Percentage of

Remarks

Table 172: CDL definition percentage_scanlines_in_south_atlantic_anomaly variable

8.120 Variable: storage_time

	Variable	Storage type	Units
	storage_time	float	S
CDL	<pre>float storage_time(nsetti storage_time:long_name = storage_time:units = "s" storage_time:comment = "T the detector during read-</pre>	"Storage time";; ; The time a row has resided	d in the storage area of

Remarks

Remarks

Table 173: CDL definition storage_time variable

8.121 Variable: percentage_spectral_channels_per_scanline_processing_error

	Variable	Storage type	Units
pe	rcentage_spectral_channels_per scanline_processing_error	float	none
CDL	<pre>float percentage_spectral_char error(time,scanline) ; percentage_spectral_channels_p "Percentage of spectral channe error flag is set" ;</pre>	per_scanline_process	ing_error:comment =

 $\textbf{Table 174}: \texttt{CDL definition percentage_spectral_channels_per_scanline_processing_error\ variable}$

8.122 Variable: percentage_spectral_channels_saturated

	Variable	Storage type	Units
	percentage_spectral_channels saturated	float	none
CDL	float percentage_spectral_cha	annels_saturated(ti	me) ;
	<pre>percentage_spectral_channels_saturated:comment = "Percentage of spectral"</pre>		
	channels for which the satura	ated flag is set";	

Remarks

Table 175: CDL definition percentage_spectral_channels_saturated variable

8.123 Variable: irradiance_avg_row

	Variable	Storage type	Units
	irradiance_avg_row	float	none
CDL	<pre>float irradiance_avg_row(time,scanline,spectral_channel);</pre>		
	irradiance_avg_row:commen of a single row in a meas		ectral irradiance value

Remarks

Table 176: CDL definition irradiance_avg_row variable

8.124 Variable: percentage_spectral_channels_processing_error

	Variable	Storage type	Units
	<pre>percentage_spectral_channels processing_error</pre>	float	none
CDL	float percentage_spectral_chapercentage_spectral_channels_spectral channels for which t	_processing_error:com	mment = "Percentage of

Remarks

Table 177: CDL definition percentage_spectral_channels_processing_error variable

8.125 Variable: percentage_spectral_channels_underflow

able	Storage type	Units
tral_channels	float	none
flow		
float percentage_spectral_channels_underflow(time);		
percentage_spectral_channels_underflow:comment = "Percentage of spectral		
or which the underf	low flag is set"	;
	_spectral_channels_	ctral_channels float rflow entage_spectral_channels_underflow(t

Table 178: CDL definition percentage_spectral_channels_underflow variable

8.126 Variable: monitor_read_out_register

	Variable	Storage type	Units
m	nonitor_read_out_register	float	none
CDL	float monitor_read_out_regis monitor_read_out_register:co from the read out register"	omment = "Spectral	<pre>spectral_channel) ; channel signal values as read</pre>
Remarks	Only available for UVN bands		

Table 179: CDL definition monitor_read_out_register variable

8.127 Variable: percentage_ground_pixels_sun_glint

	Variable	Storage type	Units
perce	entage_ground_pixels_sun_glint	float	none
CDL	float percentage_ground_pixels percentage_ground_pixels_sun_g for which the sun glint flag i	glint:comment =	

Remarks

Table 180: CDL definition percentage_ground_pixels_sun_glint variable

8.128 Variable: monitor_radiance

	Variable	Storage type	Units	
	monitor_radiance	float	none	
CDL	<pre>float monitor_radiance(time,scanline,pixel) ; monitor_radiance:comment = "Average radiance of a small wavelength band around the specified wavelength, for monitoring purposes." ;</pre>			
Remarks	The name of the variable in the output file is monitor_radiance_xxxxnm whe wavelength value. The center wavelength and the bandwidth around the cebe found in the variable attributes center wavelength and wavelength band		round the center wavelength can	

Table 181: CDL definition monitor_radiance variable

8.129 Variable: percentage_ground_pixels_geometric_boundary_crossing

	Variable	Storage type	Units
perc	entage_ground_pixels_geometric boundary_crossing	float	none
CDL	<pre>float percentage_ground_pixels percentage_ground_pixels_geome of ground pixels that cross a { ;</pre>	tric_boundary_cr	cossing:comment = "Percentage

8.130 Variable: monitor_smear_observed

	Variable	Storage type	Units	
	monitor_smear_observed	float	electron	
CDL	<pre>float monitor_smear_observed(time,scanline,dual_dim,spectral_channel) ; monitor_smear_observed:units = "electron" ; monitor_smear_observed:comment = "Observed detector smear values from the masked regions of the detector, for monitoring purposes" ;</pre>			
Remarks	Only available for UVN bands			

Table 183: CDL definition monitor_smear_observed variable

8.131 Variable: percentage_spectral_channels_per_scanline_missing

	Variable	Storage type	Units
percentage_spectral_channels_per		float	none
	scanline_missing		
CDL	float percentage_spectral_char	nnels_per_scanlin	e_missing(time,scanline);
	percentage_spectral_channels_	per_scanline_miss	ing:comment = "Percentage of
	spectral channels per scanline	e for which the m	issing flag is set";

Remarks

Table 184: CDL definition percentage_spectral_channels_per_scanline_missing variable

8.132 Variable: percentage_ground_pixels_solar_eclipse

	Variable	Storage type	Units
percentage_ground_pixels_solar		float	none
	eclipse		
CDI	float percentage_ground_pixels_solar_eclipse(time);		
	<pre>percentage_ground_pixels_solar_eclipse:comment = "Percentage of ground</pre>		
	pixels for which the solar ed	clipse flag is set	;

Table 185: CDL definition percentage_ground_pixels_solar_eclipse variable

Appendix A Estimated product size

Table 186 lists the estimated product sizes for the eight different standard radiance products. This estimation is based on the netCDF product definition as presented in this document, No compression has been applied. The baseline for the granule size of the standard products is one orbit; no sliced products, i.e. products covering a part of the orbit are foreseen.

Near-real time products (NRT) cover approximately one data slice of one total data downlink volume (see chapter 6) rather than one orbit. Because the standard products and NRT products are based on the same netCDF product definition, the product sizes of these slices can be estimated from Table 186 taking into account that the file size is proportional to the number of scanlines.

Detector	UV		UVIS		NIR		SWIR	
Band	1	2	3	4	5	6	7	8
spectral_channel	497	497	497	497	497	497	480	480
scanline	3246	3246	3246	3246	3246	3246	3246	3246
ground_pixel	77	448	450	450	448	448	215	215
Product size (GByte)	1.0	5.6	5.7	5.7	5.7	5.7	2.6	2.6

Table 186: Estimated product size of radiance products; these sizes largely depend on the size of the dimensions spectral_channel, scanline and ground_pixel.

Estimated product sizes for the irradiance, calibration and engineering products are presented in the table below (Table 187). For all products both the average data volumes and typical product size are presented. Especially for irradiance products there is a substantial difference between these, as the irradiance products are only generated for a selection of orbits.

Product	Average Product size (GByte)	Typical Product size (GByte)
Irradiance UVN	0.003	0.030
Irradiance SWIR	0.0006	0.006
Calibration UVN	19.59	17.52
Calibration SWIR	3.42	3.07
Engineering	0.06	0.06

Table 187: Estimated product size irradiance, calibration and engineering products

Appendix B Processing classes

Class	Name	Definition
		Undefined
0	Undefined	Value to indicate that a processing class was explicitly not set
		Nominal modes
1	Earth_radiance	Nominal earth radiance measurement
2	Earth_radiance_special	Earth radiance special mode. Can be used for special radiance measurements that have a special purpose (e.g. specific campaigns, geolocation validation) or require special handling (e.g. zoom modes)
3	Solar_irradiance	Nominal solar irradiance measurement
4	Solar_irradiance_special	Solar Irradiance special mode. Can be used for special irradiance measurements that have a special purpose (e.g. back-up diffuser) or require special handling (e.g. zoom modes)
5-15	-	Reserved for future use
	li	n-flight calibration modes
16	DLED	Detector LED measurement
17	CLED	Common LED measurement
18	WLS	White Light Source measurement
19	SLS	Spectral Line Source measurement
20	Dark	Dark current measurement
21	Background	Background measurement
22	CTE	UVN CTE measurement (using ClkDrvAb = 1)
23	No_clock	UVN no clocking measurement (using ClkDrvAll = 1)
24	Reverse_clock	UVN reverse clocking measurement (using reverse clocking timing for RiseR* and FallR*)
25	Storage	UVN CCD Storage section characterization measurement
26	Flush	Detector flush mode
27	Orbit_identification	Special IcID used for identification of the different orbit types.
28	RTS	Measurement for identification of pixels that have Random Telegraph Signal (RTS) behaviour
29	-	Reserved for future use
30	-	Reserved for future use
31	Background_radiance	Background measurement for an earth radiance measurement
32	Background_radiance_special	Background measurement for an earth radiance special measurement
33	Background_irradiance	Background measurement for a solar irradiance measurement
34	Background_irradiance_special	Background measurement for a solar irradiance special measurement
35-39	-	Reserved for future use
40	Electronics_cal_offset	Measurement for calibration of the electronics offset
41	Electronics_cal_gain	Measurement for calibration of the electronics gain
42	Electronics_cal_linearity	Measurement for calibration of the electronics (non-)linearity
43-63	-	Reserved for future use
		Test modes
64	ICU_test	ICU test mode
65	DEM_test	DEM test mode
66	Functional_test	Instrument functional test

67 68 69-95	Processor_test Auto_optimization	Data processor software test
	Auto ontimization	
69-95	/lato_optimization	Automated optimization measurement
	-	Reserved for future use
	ı	Modes for specific processing
96	Discard	Discard / ignore data
97	Process_BU	Process data up-to binary units (i.e. no processing)
98	Process_electrons	Process data up-to electrons
99	Process_electron_flux	Process data up-to electrons per second
100	Process_photon_flux	Process data up-to photons per second (similar to Earth radiance)
101	Process_upto_binning	Process data up-to binning factor correction
102-127	-	Reserved for future use
		On-ground calibration modes
128	OCAL	Generic on-ground calibration processing, nominal mode
129	OCAL special	Generic on-ground calibration processing, special mode
130-200		Reserved for future use
201	OCAL radiance	Nominal on-ground calibration radiance measurement
202	OCAL_radiance_special	On-ground calibration radiance special mode
203	OCAL_irradiance	Nominal on-ground calibration irradiance measurement
204	OCAL_irradiance_special	On-ground calibration irradiance special mode
205-215	-	Reserved for future use
216	OCAL_DLED	On-ground calibration detector LED measurement
217	OCAL_CLED	On-ground calibration common LED measurement
218	OCAL_WLS	On-ground calibration White Light Source measurement
219	OCAL_SLS	On-ground calibration Spectral Line Source measurement
220	OCAL_Dark	On-ground calibration dark current measurement
221	OCAL_Background	On-ground calibration background measurement
222	OCAL_CTE	On-ground calibration UVN CTE measurement (using ClkDrvAb = 1)
223	OCAL_No_clock	On-ground calibration UVN no clocking measurement (using ClkDrvAll = 1)
224	OCAL_Reverse_clock	On-ground calibration UVN reverse clocking measurement (using reverse clocking timing for RiseR* and FallR*)
225	OCAL_Storage	On-ground calibration UVN CCD Storage section characterization measurement
226	OCAL_Flush	On-ground calibration detector flush mode
227-255	-	Reserved for future use
		Unused

Values 256 through 32767 are not used.

Table 188: Processing classes