



Royal Netherlands
Meteorological Institute
*Ministry of Infrastructure and the
Environment*

Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Aerosol Layer Height



sentinel-5p

document number : S5P-KNMI-L2-0022-MA
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CI identification : CI-7570-PUM
issue : 1.3.2
date : 2019-09-26
status : released

Document approval record

	digital signature
Prepared:	
ATBD Author:	
Checked:	
Approved PM:	
Approved PI:	

Document change record

issue	date	item	comments
0.0.1	2014-05-12	All	Initial version
0.1.0	2014-10-14	All Sect. 4 All All Sec. 9	Document ported to \LaTeX CDR RID #8 solved Reorder of the docs: generic part first and specific sections after. CDR RID #9 solved. One single template is now used for all the PUMs. CDR RID #12 and #13 solved. Added figure explaining geocoordinates order and reference in the text. (CDR RID #5)
0.7.0	2015-03-27	All	Document totally revised: Sections moved and added. Description of the product updated
0.7.1	2015-06-09		Added example figures for a preliminary release (AI only)
0.8.0	2015-09-07		Prepared for preliminary, limited, release
0.9.1	2015-12-15		PUMs updated. File descriptors in line with the last product defini- tion
0.10.0	2016-03-31		Product descriptions updated for 0.10.0 release
0.10.1	2016-07-15		Product descriptions updated for DLR 0.10.1 release
0.11.0	2017-03-01		Updated for release 0.11.0 of the processor software, including new variable names.
0.11.6	2017-06-24		Released
0.11.7	2019-07-05		Update with processor NL L2 v 1.3.1 and ATBD version 1.0.1 (draft 2019-06-24)
1.3.2	2019-09-26		Version number consistent with L2 processor release (1.3.2) Various updates in text to reflect current status.

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1 Introduction

1.1 Identification

This document, identified as S5P-KNMI-L2-0022-MA, describes the technical characteristics of the S5p/TROPOMI Level 2 products that are needed for efficient and correct use of the data contained. This product user manual is specific for Aerosol Layer Height.

1.2 Purpose and objective

The Sentinel-5 Precursor (S5p) mission is a low Earth orbit polar satellite system to provide information and services on air quality, climate and the ozone layer. The S5p mission is part of the Global Monitoring of the Environment and Security (GMES/COPERNICUS) space component programme. The S5p mission consists of a satellite bus, the payload consisting of the TROPOspheric Monitoring Instrument (TROPOMI), and a ground system. A journal paper describing the mission and its objectives can be found in [RD1], while a comprehensive description of the mission can be found in [RD2]. Furthermore, various websites are maintained with S5p/TROPOMI information, e.g. [ER1, ER2].

From the data collected by the TROPOMI instrument, a number of geophysical (L2) products are derived. The algorithms for the raw data treatment (L0 – L1b) and the actual L2 data processing are each described in an algorithm theoretical basis document (ATBD). This Product User Manual (PUM) describes the technical characteristics of the S5p/TROPOMI Level 2 geophysical data products that are needed for efficient and correct use of the data contained.

In the PUM, the common structure of the datafiles and metadata used in all the delivered L2 products as well as a specific section related to the Aerosol Layer Height product are described.

1.3 Document overview

We start with a summary of the S5p L2 products and information needed to obtain and inspect data, as well as how to obtain product support. The Aerosol Layer Height data product is described next, with examples, and information about the use of the data. Format, L2 structure and metadata are addressed in the next chapter, followed by the detailed description of the Aerosol Layer Height data. We then continue with a discussion of units and quality assurance parameters. The final chapter contains information about generic metadata and the Appendix lists measurement flags, processing quality flags, and surface classifications.

2 Applicable and reference documents

2.1 Applicable documents

- [AD1] Tailoring of the Earth Observation File Format Standard for the Sentinel 5 precursor Ground Segment.
source: ESA/ESTEC; **ref:** S5P-TN-ESA-GS-106; **issue:** 2.2; **date:** 2015-02-20.

2.2 Standard documents

There are no standard documents

2.3 Reference documents

- [RD1] J. P. Veefkind, I. Aben, K. McMullan *et al.*; TROPOMI on the ESA Sentinel-5 Precursor: A GMES mission for global observations of the atmospheric composition for climate, air quality and ozone layer applications. *Remote Sens. Environ.*; **120** (2012), 70; 10.1016/j.rse.2011.09.027.
- [RD2] Input/output data specification for the TROPOMI L01b data processor.
source: KNMI; **ref:** S5P-KNMI-L01B-0012-SD; **issue:** 5.0.0; **date:** 2015-09-22.
- [RD3] S5P/TROPOMI ATBD Cloud Products.
source: DLR; **ref:** S5P-DLR-L2-ATBD-400I; **issue:** 1.1.0; **date:** 2016-06-30.
- [RD4] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Cloud.
source: DLR; **ref:** S5P-L2-DLR-PUM-400I; **issue:** 1.0.0; **date:** 2018-04-30.
- [RD5] S5P-NPP Cloud Processor ATBD.
source: RAL Space; **ref:** S5P-NPPC-RAL-ATBD-0001; **issue:** 0.11.0; **date:** 2014-05-15.
- [RD6] S5P/TROPOMI HCHO ATBD.
source: BIRA; **ref:** S5P-BIRA-L2-400F-ATBD; **issue:** 1.0.0; **date:** 2016-02-05.
- [RD7] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual HCHO.
source: DLR; **ref:** S5P-L2-DLR-PUM-400F; **issue:** 1.0.0; **date:** 2018-04-30.
- [RD8] S5P/TROPOMI SO₂ ATBD.
source: BIRA; **ref:** S5P-BIRA-L2-400E-ATBD; **issue:** 1.0.0; **date:** 2016-02-05.
- [RD9] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual SO₂.
source: DLR; **ref:** S5P-L2-DLR-PUM-400E; **issue:** 1.0.0; **date:** 2018-04-30.
- [RD10] S5P/TROPOMI Total ozone ATBD.
source: DLR/BIRA; **ref:** S5P-L2-DLR-ATBD-400A; **issue:** 1.0.0; **date:** 2016-02-01.
- [RD11] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Total Ozone Column.
source: DLR; **ref:** S5P-L2-DLR-PUM-400A; **issue:** 1.0.0; **date:** 2018-04-30.
- [RD12] TROPOMI ATBD of tropospheric ozone data products.
source: DLR/IUP; **ref:** S5P-DLR-IUP-L2-400C; **issue:** 1.0.0; **date:** 2016-02-05.
- [RD13] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Ozone Tropospheric Column.
source: DLR; **ref:** S5P-L2-DLR-PUM-400C; **issue:** 1.0.0; **date:** 2018-04-30.
- [RD14] TROPOMI ATBD of the Aerosol Layer Height product.
source: KNMI; **ref:** S5P-KNMI-L2-0006-RP; **issue:** 1.0.1; **date:** 2019-06-24.
- [RD15] TROPOMI ATBD of the UV aerosol index.
source: KNMI; **ref:** S5P-KNMI-L2-0008-RP; **issue:** 1.0.0; **date:** 2016-02-03.
- [RD16] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Aerosol Index.
source: KNMI; **ref:** S5P-KNMI-L2-0026-MA; **issue:** 0.0.2dr; **date:** 2014-10-16.

- [RD17] TROPOMI ATBD Ozone profile and tropospheric profile.
source: KNMI; **ref:** S5P-KNMI-L2-0004-RP; **issue:** 0.13.0; **date:** 2015-09-15.
- [RD18] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Ozone Profile and Tropospheric Ozone Profile.
source: KNMI; **ref:** S5P-KNMI-L2-0020-MA; **issue:** 0.0.2dr; **date:** 2014-10-16.
- [RD19] TROPOMI ATBD of the total and tropospheric NO₂ data products.
source: KNMI; **ref:** S5P-KNMI-L2-0005-RP; **issue:** 1.0.0; **date:** 2016-02-05.
- [RD20] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Nitrogen Dioxide.
source: KNMI; **ref:** S5P-KNMI-L2-0021-MA; **issue:** 0.0.2dr; **date:** 2014-10-16.
- [RD21] Algorithm Theoretical Baseline Document for Sentinel-5 Precursor: Carbon Monoxide Total Column Retrieval.
source: SRON; **ref:** SRON-S5P-LEV2-RP-002; **issue:** 1.0.0; **date:** 2016-02-05.
- [RD22] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Carbon Monoxide Column.
source: SRON/KNMI; **ref:** SRON-S5P-LEV2-MA-002; **issue:** 0.0.2dr; **date:** 2014-10-16.
- [RD23] Algorithm Theoretical Baseline Document for Sentinel-5 Precursor methane retrieval.
source: SRON; **ref:** SRON-S5P-LEV2-RP-001; **issue:** 1.0.0; **date:** 2016-02-05.
- [RD24] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Methane.
source: SRON/KNMI; **ref:** SRON-S5P-LEV2-MA-001; **issue:** 0.0.2dr; **date:** 2014-10-16.
- [RD25] Tailoring of the Earth Observation File Format Standard for the Sentinel 5 precursor Ground Segment.
source: ESA/ESTEC; **ref:** S5P-TN-ESA-GS-106; **issue:** 2.2; **date:** 2015-02-20.
- [RD26] Algorithm theoretical basis document for the TROPOMI L01b data processor.
source: KNMI; **ref:** S5P-KNMI-L01B-0009-SD; **issue:** 6.0.0; **date:** 2015-09-22.
- [RD27] A. F. J. Sanders, J. F. de Haan, M. Sneep *et al.*; Evaluation of the operational Aerosol Layer Height retrieval algorithm for Sentinel-5 Precursor: application to O₂ A band observations from GOME-2A. *Atmospheric Measurement Techniques*; **8** (2015) (11), 4947; 10.5194/amt-8-4947-2015. URL <https://www.atmos-meas-tech.net/8/4947/2015/>.
- [RD28] S. Nanda, M. de Graaf, J. P. Veefkind *et al.*; A neural network radiative transfer model approach applied to TROPOMI's aerosol height algorithm. *Atmospheric Measurement Techniques Discussions*; **2019** (2019), 1; 10.5194/amt-2019-143. URL <https://www.atmos-meas-tech-discuss.net/amt-2019-143/>.
- [RD29] Earth Observation – Ground segment file format standard.
source: ESA/ESTEC; **ref:** PE-TN-ESA-GS-0001; **issue:** 2.0; **date:** 2012-05-03.
- [RD30] Geographic information – Metadata.
source: ISO; **ref:** ISO 19115:2003(E); **issue:** 1; **date:** 2003-05-01.
- [RD31] Geographic information – Metadata – Part 2: Extensions for imagery and gridded data.
source: ISO; **ref:** ISO 19115-2:2009(E); **issue:** 1; **date:** 2009-02-12.
- [RD32] Geographic information – Data quality.
source: ISO; **ref:** ISO 19157; **issue:** 1; **date:** 2013-10-10.
- [RD33] Earth Observation Metadata profile of Observations & Measurements.
source: Open Geospatial Consortium; **ref:** OGC 10-157r3; **issue:** 1.0; **date:** 2012-06-12.
- [RD34] Data Standards Requirements for CCI Data Producers.
source: ESA; **ref:** CCI-PRGM-EOPS-TN-13-0009; **issue:** 1.1; **date:** 2013-05-24.
- [RD35] Metadata specification for the TROPOMI L1b products.
source: KNMI; **ref:** S5P-KNMI-L01B-0014-SD; **issue:** 2.0.0; **date:** 2014-12-09.

- [RD36] Data elements and interchange formats – Information interchange – Representation of dates and times.
source: ISO; **ref:** ISO 8601:2004(E); **issue:** 3; **date:** 2004-12-01.
- [RD37] Wavelength calibration in the Sentinel 5-precursor Level 2 data processors.
source: KNMI; **ref:** S5P-KNMI-L2-0126-TN; **issue:** 1.0.0; **date:** 2015-09-11.
- [RD38] M.L. Carroll, J.R. Townshend, C.M. DiMiceli *et al.*; A new global raster water mask at 250 m resolution. *International Journal of Digital Earth*; **2** (2009) (4), 291; 10.1080/17538940902951401.
- [RD39] Geographic information – Metadata – XML schema implementation.
source: ISO; **ref:** ISO 19139:2007(E); **issue:** 1; **date:** 2010-12-13.
- [RD40] Observations and Measurements – XML Implementation..
source: Open Geospatial Consortium; **ref:** OGC 10-025r1; **issue:** 2.0; **date:** 2011-03-22.
- [RD41] Sentinel 5 precursor/TROPOMI KNMI and SRON level 2 Input Output Data Definition.
source: KNMI; **ref:** S5P-KNMI-L2-0009-SD; **issue:** 5.0.0; **date:** 2016-04-19.
- [RD42] Sentinel-5 Precursor Level 2 UPAS Processor Input/Output Definition Document.
source: DLR-IMF; **ref:** S5P-L2-DLR-IODD-3002; **issue:** 3.3.0; **date:** 2017-06-01.
- [RD43] S5P-NPP Cloud Processor IODD.
source: RAL; **ref:** S5P-NPPC-RAL-IODD-0001; **issue:** 0.10.0; **date:** 2014-05-28.
- [RD44] John Caron; Annotated Schema for NcML (2011). URL <http://www.unidata.ucar.edu/software/netcdf/ncml/v2.2/AnnotatedSchema4.html>.
- [RD45] INSPIRE Metadata Regulation, Commission Regulation (EC), No1205/2008.
source: EC; **ref:** Commission Regulation (EC) No 1205/2008; **date:** 2008-12-03.
- [RD46] 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.
- [RD47] Geographic Information – Observations and Measurements.
source: ISO; **ref:** ISO 19156:2011(E); **date:** 2011-12-20.
- [RD48] Observations and Measurements - XML Implementation.
source: OGC; **ref:** OGC 10-025r1; **issue:** 2.0; **date:** 2011-03-22.

2.4 Electronic references

- [ER1] Tropomi official website. URL <http://www.tropomi.eu>.
- [ER2] S5P official website. URL <https://sentinel.esa.int/web/sentinel/missions/sentinel-5p>.
- [ER3] Robert B. Schmunk; Panoply netCDF, HDF and GRIB Data Viewer. URL <http://www.giss.nasa.gov/tools/panoply/>.
- [ER4] Infrastructure for Spatial Information in the European Community (INSPIRE) Directive 2007/2/EC. URL <http://inspire.jrc.ec.europa.eu/>.
- [ER5] Brian Eaton, Jonathan Gregory, Bob Drach *et al.*; *NetCDF Climate and Forecast (CF) Metadata Conventions*. Lawrence Livermore National Laboratory (2014). Version 1.7 draft; URL <http://cfconventions.org>.
- [ER6] ESIP; *Attribute Conventions for Dataset Discovery (ACDD)*. 1st edition (2013). URL [http://wiki.esipfed.org/index.php/Attribute_Convention_for_Data_Discovery_\(ACDD\)](http://wiki.esipfed.org/index.php/Attribute_Convention_for_Data_Discovery_(ACDD)).
- [ER7] NetCDF Users Guide (2011). URL <http://www.unidata.ucar.edu/software/netcdf/docs/netcdf.html>.

- [ER8] USGS; Global Land Cover Characteristics Data Base Version 2.0 (2012). Website last visited on March 6, 2017; URL https://lta.cr.usgs.gov/glcc/globdoc2_0.
- [ER9] The ECS SDP Toolkit (2012). DEM and land-sea mask data itself is available from <ftp://edhs1.gsfc.nasa.gov/edhs/sdptk/DEMdata>; URL <http://newsroom.gsfc.nasa.gov/sdptoolkit/TKDownload.html>.
- [ER10] UDUNITS 2 Manual (2011). URL <http://www.unidata.ucar.edu/software/udunits/>.
- [ER11] Cooperative Ocean/Atmosphere Research Data Service; Conventions for the standardization of NetCDF files (1995). URL http://ferret.wrc.noaa.gov/noaa_coop/coop_cdf_profile.html.

3 Terms, definitions and abbreviated terms

Terms, definitions, and abbreviated terms that are specific for this document can be found below.

3.1 Terms and definitions

ATBD	Algorithm Theoretical Basis Document
TBA	To be Added
TBC	To be Confirmed
TBD	To be Defined

3.2 Acronyms and Abbreviations

ATBD	Algorithm Theoretical Basis Document
DLR	Deutsches Zentrum für Luft- und Raumfahrt
ESA	European Space Agency
KNMI	Koninklijk Nederlands Meteorologisch Instituut
IODD	Input Output Data Definition
OCRA	Optical Cloud Recognition Algorithm
PUM	Product User Manual
ROCINN	Retrieval of Cloud Information using Neural Networks
QA	Quality Assurance
UPAS	Universal Processor for UV/VIS Atmospheric Spectrometers

4 Overview of the Sentinel 5 precursor/TROPOMI Level 2 Products

The Sentinel 5 Precursor mission aims at providing information and services on air quality and climate in the timeframe 2017–2023. The S5p mission is part of the Global Monitoring of the European Programme for the establishment of a European capacity for Earth Observation (COPERNICUS). TROPOMI makes daily global observations of key atmospheric constituents, including ozone, nitrogen dioxide, sulfur dioxide, carbon monoxide, methane, formaldehyde as well as cloud and aerosol properties. The list of standard S5p/TROPOMI L2 products is given in table 1. Other products, such as UV index, are under development and will made available at a later date.

Table 1: Standard S5P L2 products with name, identifier, and responsible institutes.

Product	ATBD	PUM	Identifier	Institution
Cloud	[RD3]	[RD4]	L2__CLOUD__	DLR
NPP-VIIRS Clouds	[RD5]	[RD5]	L2__NP_BDx	RAL
HCHO	[RD6]	[RD7]	L2__HCHO__	BIRA/DLR
SO ₂	[RD8]	[RD9]	L2__SO2__	BIRA/DLR
O ₃ Total Column	[RD10]	[RD11]	L2__O3__	BIRA/DLR
O ₃ Tropospheric Column	[RD12]	[RD13]	L2__O3_TCL	IUP/DLR
Aerosol layer height	[RD14]	This document	L2__AER_LH	KNMI
Ultra violet aerosol index	[RD15]	[RD16]	L2__AER_AI	KNMI
O ₃ Full Profile	[RD17]	[RD18]	L2__O3__PR	KNMI
O ₃ Tropospheric Profile	[RD17]	[RD18]	L2__O3_TPR	KNMI
NO ₂	[RD19]	[RD20]	L2__NO2__	KNMI
CO	[RD21]	[RD22]	L2__CO__	SRON/KNMI
CH ₄	[RD23]	[RD24]	L2__CH4__	SRON/KNMI

4.1 File name convention

The table specifies an identifier that is a substring of real name. The complete filename conventions for all the S5p products can be found in [RD25, chapter 4]. Note that intermediate L2 products beside those listed in table 1 may exist within the PDGS framework. For each of the products listed in the table, a PUM is available. Note that product documentation, e.g. ATBDs and PUMs, will be updated with new releases of processors. User documentation is distributed through the tropomi website [ER1]. Information about S5p mission can be found at the official ESA website for the Sentinel 5 precursor mission [ER2].

In the current PUM the Aerosol Layer Height product is described and an example of the full real name is as following:

```
S5P_NRTI_L2_AER_LH_20190920T054303_20190920T054803_10028_01_010302_20190920T062930.nc
```

The components of this file name are given in table 2

Table 2: Components of an S5P product file name. Components are separated by underscores, except for the file extension at the end, which is separated by a period. Character indices start counting at 0, the end-index is a Python style index, it lists the first character not in the block.

Start	End	Length	Meaning
0	3	3	Mission name, always “S5P”
4	8	4	Processing stream, one of “NRTI” (near real-time), “OFFL” (offline) or “RPRO” (reprocessing)
9	19	10	Product identifier, as listed in table 1
20	35	15	Start of granule in UTC as “YYYYMMDDT ^T HHMMSS”. The “T” is a fixed character.
36	51	15	End of the granule in UTC as “YYYYMMDDT ^T HHMMSS”. The “T” is a fixed character.
52	57	5	Orbit number
58	60	2	Collection number
61	67	6	Processor version number as “MM ^{mm} pp”, with “MM” the major version number, “mm” the minor version number, and “pp” the patch level.
68	83	15	The time of processing for this granule in UTC as “YYYYMMDDT ^T HHMMSS”. The “T” is a fixed character.
84	86	2	The file name extension. All Sentinel 5 precursor files are netCDF-4 files and use the extension “.nc”

5 Data Distribution and Product Support

The TROPOMI Aerosol Layer Height product data are available from the Copernicus Open Data Hub <https://scihub.copernicus.eu>.

The access and use of any Copernicus Sentinel data available through the Sentinel Data Hub is governed by the Legal Notice on the use of Copernicus Sentinel Data and Service Information and is given here: https://sentinels.copernicus.eu/documents/247904/690755/Sentinel_Data_Legal_Notice.

5.1 Information to supply with a support request

We have been very careful in the preparation of the processors, the processing system, the data distribution system and all other components that generate the level 2 products for the Sentinel 5 precursor mission. You may encounter problems when reading the level 2 files despite our care, or you may not understand what we have written in the product user manual or the ATBD. You can contact us through the earth observation help desk operated by ESA at EOSupport@copernicus.esa.int. Please clearly indicate that you are requesting support for Sentinel 5 precursor (S5p) / TROPOMI mission.

If you are requesting technical support it is helpful to provide us with details of the file you are trying to read. The easiest way to do this is to provide a “dump” of the header of the file. This can be generated using the “ncdump” tool provided with the netCDF-4 library. Only the header is required, so “ncdump -h FILE.nc > FILE.cd1” will provide us with all metadata in the file and help us pinpoint how the file was produced. Here you replace FILE.nc with the actual file name on the command line.

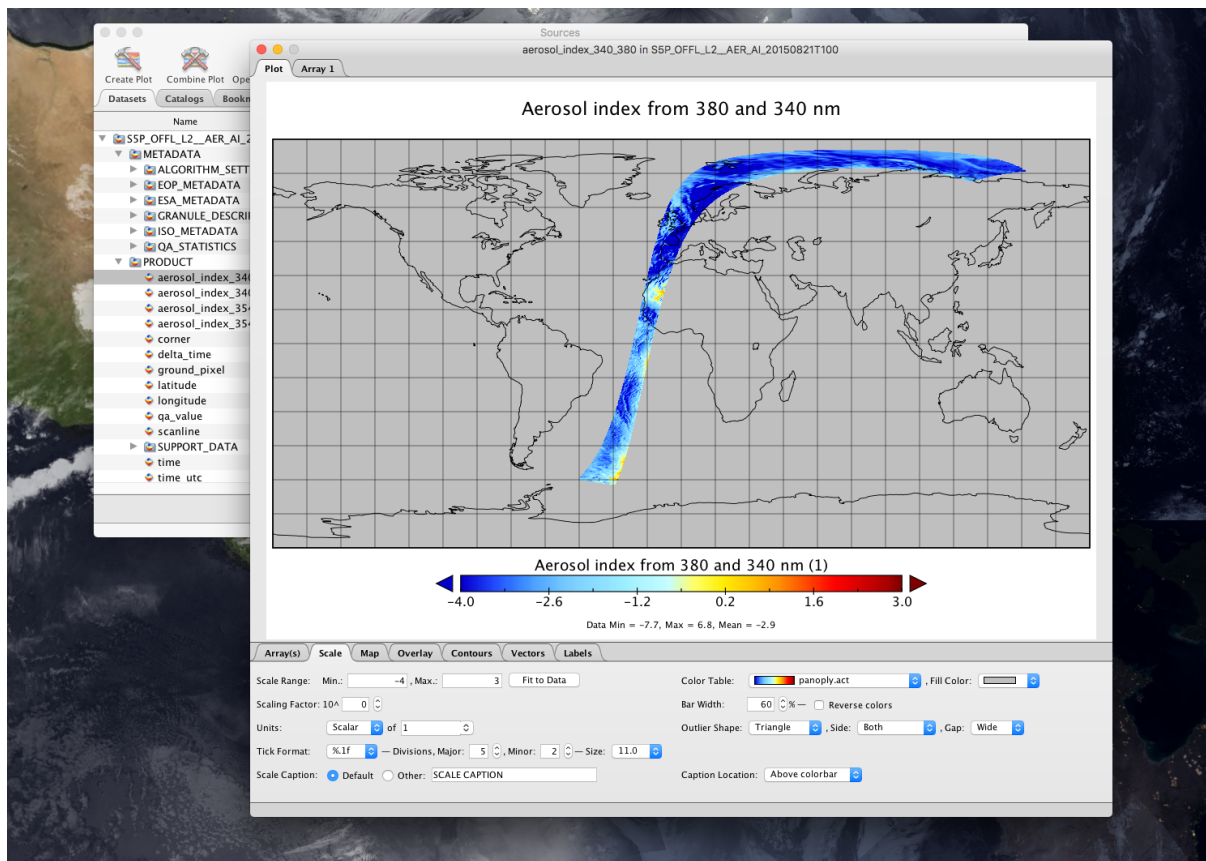


Figure 1: Panoply

If generating the header fails, please provide us with the exact original file name of the granule you are trying to read, the exact error message you get and the exact version of the software you are using, including the versions of netCDF-4 and HDF-5. Providing us with a checksum to verify file integrity can also speed up our response.

6 General Reader and Visualisation Tools

For reading and visualising you may find Panoply [ER3] a useful tool. Panoply is a cross-platform application that plots geo-gridded and other arrays from netCDF, HDF, GRIB, and other datasets, including the Sentinel 5 precursor Level 2 datafiles. With Panoply 4 you can:

- Slice and plot geo-gridded latitude-longitude, latitude-vertical, longitude-vertical, or time-latitude arrays from larger multidimensional variables.
- Slice and plot "generic" 2D arrays from larger multidimensional variables.
- Slice 1D arrays from larger multidimensional variables and create line plots.
- Combine two geo-gridded arrays in one plot by differencing, summing or averaging.
- Plot lon-lat data on a global or regional map using any of over 100 map projections or make a zonal average line plot.
- Overlay continent outlines or masks on lon-lat map plots.
- Use any of numerous color tables for the scale colorbar, or apply your own custom ACT, CPT, or RGB color table.
- Save plots to disk GIF, JPEG, PNG or TIFF bitmap images or as PDF or PostScript graphics files.
- Export lon-lat map plots in KMZ format.
- Export animations as AVI or MOV video or as a collection of individual frame images.

7 Instrument description

On 13 October 2017 the Copernicus Sentinel 5 Precursor (S5P), the first of the European Sentinel satellites dedicated to monitoring of atmospheric composition, was launched. The mission objectives of S5P are to globally monitor air quality, climate and the ozone layer in the time period between 2017 and 2023. The first 6 months of the mission were used for special observations to commission the satellite and the ground processing systems; the operational phase started in April of 2018.

The single payload of the S5P mission is TROPOspheric Monitoring Instrument (TROPOMI), which has been developed by The Netherlands in cooperation with the European Space Agency (ESA). TROPOMI is a nadir viewing shortwave spectrometer that measures in the UV-visible wavelength range (270–500 nm), the near infrared (710–770 nm) and the shortwave infrared (2314–2382 nm).

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 7 km. This strip has dimensions of approximately 2600 km in the direction across the track of the satellite and 7 km 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 2.

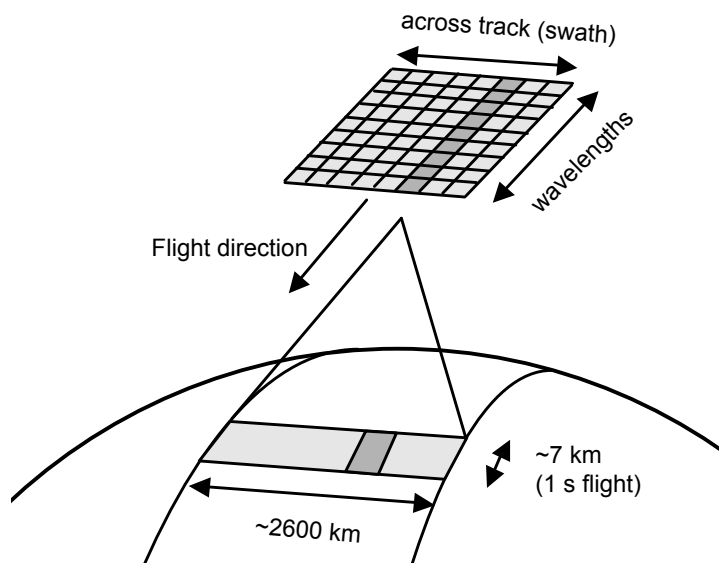


Figure 2: TROPOMI measurement principle.

On August 6th, 2019, the instrument settings of TROPOMI were changed. The nominal integration time was reduced from 1080 ms to 840 ms. Before the change the pixel size is $7.2 \times 3.6 \text{ km}^2$ for bands 2–6, (UVN) $7.2 \times 7.2 \text{ km}^2$ for bands 7 and 8 (SWIR), and $21.6 \times 28.8 \text{ km}^2$ for band 1 (deep UV), after co-addition in the flight direction. After the change in the settings, the pixel dimension in the flight direction is reduced. The new sizes become $5.6 \times 3.6 \text{ km}^2$ for bands 2–6, $5.6 \times 7.2 \text{ km}^2$ for bands 7 and 8, and $28 \times 28.8 \text{ km}^2$ for band 1, after co-addition in the flight direction.

For the UVN spectrometers about 20 million spectra are observed per day. With that resolution TROPOMI is a major step forward compared to its predecessors OMI (Ozone Monitoring Instrument), SCIAMACHY (Scanning Imaging Absorption Spectrometer for Atmospheric Chartography) and GOME-2 (Global Ozone Monitoring Experiment-2). The spatial resolution is combined with a wide swath to allow for daily global coverage. The TROPOMI/S5P geophysical (Level 2) operational data products are listed in section 4.

The S5P will fly in a so-called loose formation with the U.S. Suomi NPP (National Polar-orbiting Partnership) satellite. The primary objective for this formation flying is to use the high spatial resolution cloud observation

capabilities of the VIIRS instrument (Visible Infrared Imager Radiometer Suite). The temporal separation between TROPOMI and VIIRS is less than 5 minutes, both having an equator crossing time near 13:30 local solar time. This formation enables synergistic data products and scientific research potentials.

The spectral range is split over 4 different detectors. By design these detectors do not observe on the same geographic grid. Combining products that were derived from different detectors will require some careful re-mapping to take care of this spatial mismatch.

More details on the TROPOMI instrument and the operational concepts can be found in the Level 0 to 1B ATBD [RD26, parts I–III].

8 S5p/TROPOMI L2 Aerosol Layer Height Product Description

The Tropospheric Monitoring Instrument features a new aerosol product that is dedicated to retrieval of the height of tropospheric aerosols. At present, daily global observations of aerosol height are not available on an operational basis. Aerosol profiles are provided by active sensors, particularly by ground-based lidar systems or by the space-borne Cloud-Aerosol Lidar with Orthogonal Polarisation (CALIOP). These sensors have a high vertical resolution, but they observe at specific locations or in narrow tracks only. However, passive sensors, such as TROPOMI, can cover the entire earth in a single day.

The TROPOMI Aerosol Layer Height product focuses on retrieval of vertically localized aerosol layers in the free troposphere, such as desert dust, biomass burning aerosol, or volcanic ash plumes. The height of such layers is retrieved for cloud-free conditions. Height information for aerosols in the free troposphere is particularly important for aviation safety. Scientific applications include radiative forcing studies, long-range transport modeling and studies of cloud formation processes. Aerosol height information also helps to interpret the UV Aerosol Index (UVAI) in terms of aerosol absorption as the index is strongly height-dependent.

Retrieval of aerosol height is based on absorption by oxygen in the A band. The O₂ A band is located in the near-infrared wavelength range between about 759 and 770 nm. It is a highly structured line absorption spectrum with strongest absorption lines occurring between 760 and 761 nm. The baseline fit window for the Aerosol Layer Height algorithm extends from 758 nm (continuum) to 770 nm. A fit of the reflectance is made using the Optimal Estimation framework.

The ATBD can be found as [RD14]. The algorithm was tested on O₂ A band spectra from GOME-2 and SCIAMACHY [RD27]. Examples of Aerosol Layer Height retrievals and their comparisons with lidar measurements shown here are taken from this reference.

Data from the algorithm has been released. Recent developments have reduced the computation time for the retrieval significantly [RD28], resulting in increased data availability.

Development of the Aerosol Layer Height algorithm will continue in the coming time. User feedback, questions and any other comments or suggestions (big or small) are therefore much appreciated as these help improving the algorithm and product.

8.1 Data Product Examples

The aerosol profile is parameterized by a scattering layer with constant aerosol volume extinction coefficient and constant single scattering albedo. The layer has a fixed pressure thickness (i.e. the difference between the top pressure and the bottom pressure of the layer is held constant) and the reported height parameter is the mid pressure of the aerosol layer (top pressure plus bottom pressure divided by two). See Fig.3. Note that pressure is the independent height variable, which makes sense as the pressure determines the overhead oxygen column.

The state vector contains in any case the aerosol layer's mid pressure and its optical thickness. We emphasise that the retrieved aerosol optical thickness holds for wavelengths of the oxygen A band, as the fit window is confined to this absorption band. The fit window is too small (currently 12 nm) to also provide information about the wavelength dependence of aerosol optical properties. This is the main reason why aerosol mid pressure is the algorithm's target parameter: we aim to do an accurate retrieval of aerosol height in the first place.

Next to aerosol layer mid pressure and aerosol optical thickness, the state vector contains other fit parameters as well. The exact composition of the state vector may change, as algorithm development and real data case studies are continuing. In particular, besides the two aerosol parameters, other fit parameters under consideration are an offset to the a priori ECMWF temperature profile (i.e. the entire temperature profile is shifted by a constant amount), fluorescence emissions for vegetated land, stray light and wavelength shifts.

Fig.4 shows retrieved aerosol layer mid pressure and retrieved aerosol optical thickness for TROPOMI data acquired on 1 August 2018.

8.2 Product Geophysical Validation

Fig.5 shows four examples of lidar measurements compared with retrieved aerosol layer height from GOME-2A. The figures are taken from [RD27]. Retrieved aerosol layer mid height in the baseline retrieval setup is represented by the blue solid horizontal line. We remark that this comparison should not yet be considered a true validation as the spatiotemporal distance between the two measurements was still quite large (for example, differences in overpass times between GOME-2 and CALIPSO can be more than 3 hrs). Still, these figures

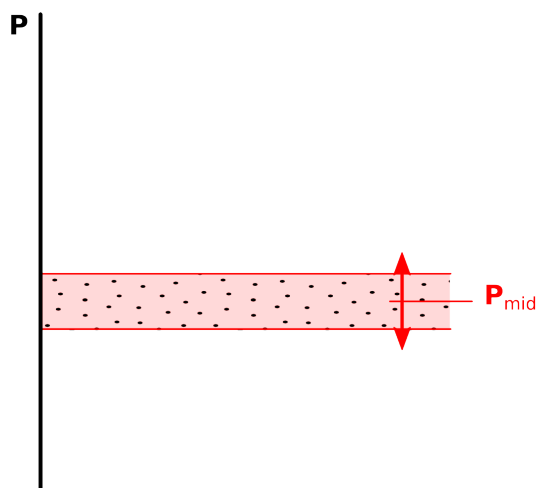


Figure 3: The aerosol profile assumed in retrieval is a uniform scattering layer with fixed pressure thickness. The reported retrieval parameter is the mid pressure of the layer (top pressure plus bottom pressure divided by two).

show aerosol cases which can be considered relatively persistent (e.g. desert dust outbreak) and together with the results from simulation experiments these figures illustrate general findings. One can see that retrieved aerosol layer height captures the aerosol layer and ends up inside the layer such that it represents an average aerosol height.

The blue upward pointing triangles are retrieved aerosol layer heights from a simulation experiment in which the lidar extinction profiles are used to simulate a spectrum. Thus the only difference between the forward model to simulate the measurement and the forward model used in the retrieval is the aerosol profile: in the retrieval, again the uniform scattering layer is assumed. One can see that retrieved aerosol heights from these retrieval simulations correspond well to retrieved aerosol heights from GOME-2A spectra.

8.3 History of product changes

This manual describes the current version of the L2 Aerosol Layer Height product. A brief description of data product changes is given here. Detailed description of the changes can be found in appropriate versions of the ATBD.

With regard to previous releases of the ALH algorithm, the current implementation, NN-ALH, implements a forward modeling approach using artificial neural networks to speed up the retrieval algorithm. The forward model outputs are trained into a set of neural network models to completely replace line-by-line calculations in the operational processor. With an enhancement of the computational speed by three orders of magnitude, TROPOMI's operational aerosol layer height processor is now able to retrieve aerosol layer heights well within operational capacity [RD28].

8.4 Using the S5p/TROPOMI L2 Aerosol Layer Height

As explained above, the difference between top pressure and bottom pressure of the assumed uniform scattering layer is held constant in the retrieval. The assumed pressure thickness has a value of 50 hPa. Its current value may be found in the output product as an attribute in `aerosol_mid_pressure`.

Without further specification, aerosol layer pressure refers to the mid pressure of the layer because this is the most meaningful height parameter. This is illustrated in Fig.5.

Next to aerosol layer mid pressure (in hPa), also aerosol layer mid altitude (in km) is reported in the group PRODUCT (e.g. the fields `aerosol_mid_pressure` and `aerosol_mid_altitude`).

Altitudes are reported above ground level, where ground level is the average elevation of the TROPOMI ground pixel <TBC>. We calculate altitudes from pressures using the a priori ECMWF profile rather than the

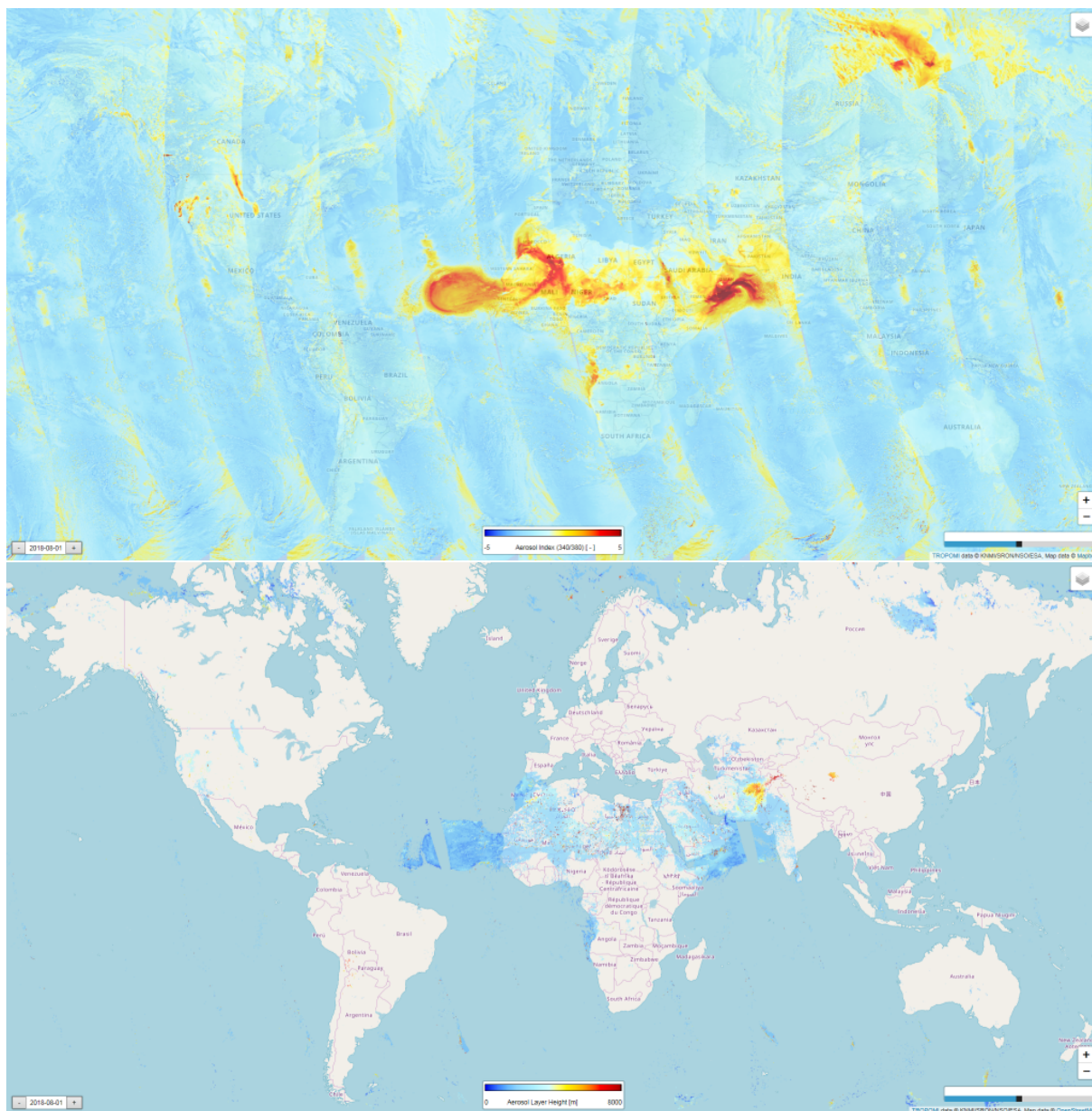


Figure 4: Top panel: TROPOMI UVAI on 1 August 2018 showing a large aerosol (dust) plume over the Atlantic Ocean originating from the Sahara, and several other hotspots of high UVAI from smoke and dust. Bottom panel: TROPOMI ALH-NN retrieval results from an initial test run of the ALH processor with NN implemented in the forward model.

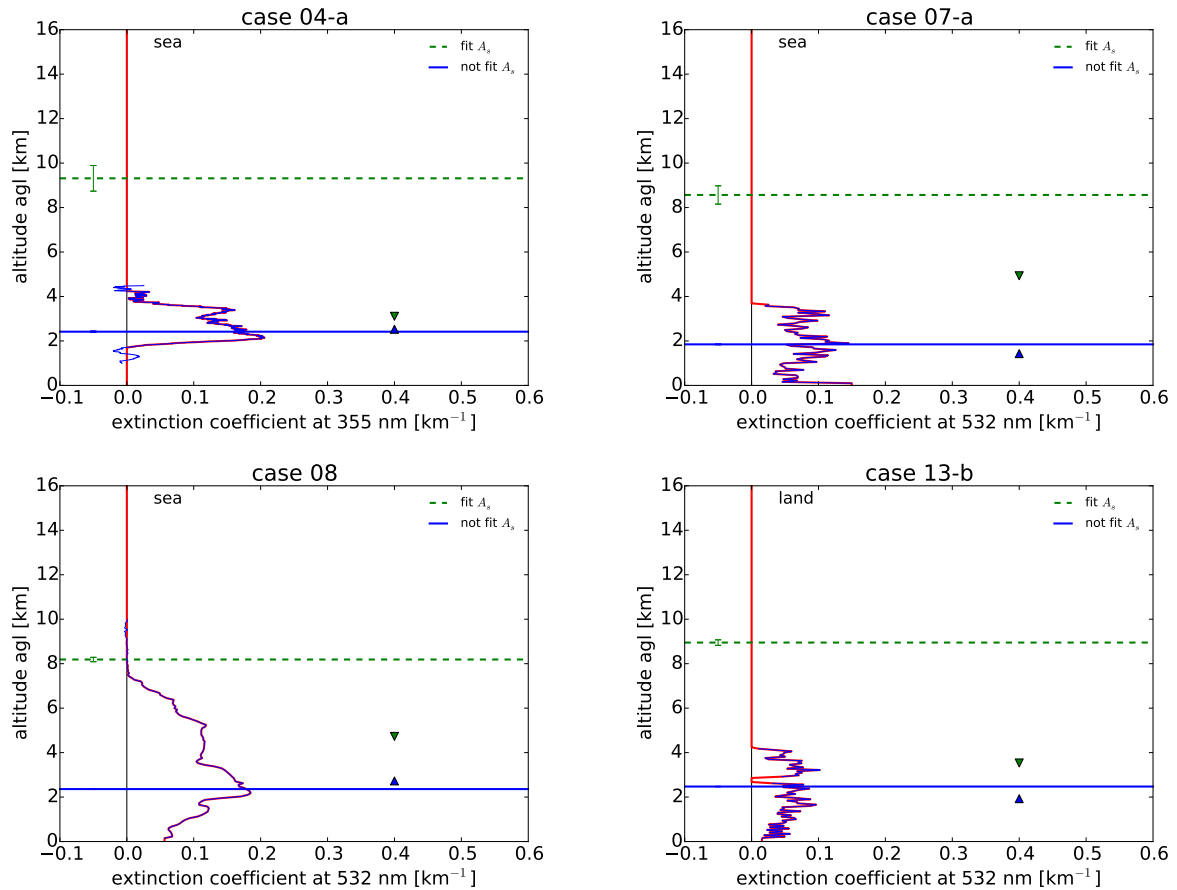


Figure 5: Comparison of retrieved aerosol layer mid pressure with lidar measurements for four representative GOME-2A pixels. Case 07-a and 08 are desert dust over sea, case 13-b is transported dust over land, and case 04-a is transported smoke over land. The blue solid horizontal line is the retrieved aerosol layer height for the baseline retrieval. For details we refer the reader to [RD27].

retrieved temperature profile. The reason for this is the following. We have found that fitting a temperature offset helps to compensate not only for inaccuracies in the a priori ECMWF temperature profile, which are presumably quite small, but also for inaccuracies in the instrument spectral response function (yet unpublished sensitivity experiments with SCIAMACHY spectra, but see also [RD27]). In the latter case, the retrieved temperature offset can become quite large, and the a priori ECMWF temperature profile is more accurately representing the actual temperature than the retrieved temperature profile.

A detailed pixel selection scheme is described in the ATBD ([RD14]). The most important step is selection of cloud-free pixels. Thresholds for cloud-filtering are rather strict, because optically thin clouds can bias the retrieval of aerosols (which are also optically thin). Thus, cloud-filtering will exclude many pixels from retrieval. Furthermore, we will initially use the UV Aerosol Index to select pixels with significant amounts of elevated absorbing aerosols. This will exclude an additional number of pixels. Output fields will therefore typically contain many fill values.

Validation and further sensitivity experiments are needed to understand the relationship between the retrieved height parameter (i.e. the height of the assumed scattering layer) and the actual extinction profile. For the time being, we expect that in the absence of model and instrument errors, the retrieved aerosol layer mid height can be interpreted as an average aerosol height weighted by the extinction coefficient at each height. This is suggested by Fig.5 but needs to be further investigated.

9 General structure of S5P/TROPOMI Level 2 files

This section gives an overview of the basic structure of all Sentinel 5 precursor level 2 files. In subsections 9.1 – 9.3 and sections 11 – 13 some details are provided on the background of the structure of the level 2 files of Sentinel 5 precursor. A complete description of the variables in the Aerosol Layer Height files is given in section 10. Figure 6 gives a graphical representation of the generic structure of a TROPOMI Level 2 file. The outermost layer is the file itself. Within the file different groups are used to organise the data and make it easier to find what you are looking for. Within the file there are two groups: “PRODUCT” and “METADATA”. Both of these groups contain sub-groups. The purpose of each group are discussed below.

PRODUCT The variables in this group will answer the questions *what, when, where* and *how well*. This group stores the main data fields of the product, including the precision of the main parameters, latitude, longitude and variable to determine the observation time and the dimensions needed for the data (a time reference dimension (time), the number of measurements in the granule (scanline), the number of spectra in a measurement (ground_pixel) and depending on the product also a pressure-level dimension, or state-vector dimensions). The “qa_value” parameter summarizes the processing flags into a continuous value, giving a quality percentage: 100 % is the most optimal value, 0 % is a processing failure, in between lies a continuum of values¹.

In the ‘PRODUCT’ group a sub-group ‘SUPPORT_DATA’ can be found:

SUPPORT_DATA Additional data that is not directly needed for using and understanding the main data product is stored in sub-groups of this group.

The data in this group is further split up into the following sub groups:

GEOLOCATIONS Additional geolocation and geometry related fields, including the pixel boundaries (pixel corners), viewing- and solar zenith angles, azimuth angles, and spacecraft location.

DETAILED_RESULTS Additional output, including state-vector elements that are not the main parameter(s), output describing the quality of the retrieval result, such as a χ^2 value, and detailed processing flags.

INPUT_DATA Additional input data, such as meteorological input data, surface albedo values, surface altitude and other data that was used to derive the output. Note that input profile information is not stored here, but is available for download from elsewhere.

METADATA This is a group to collect metadata items, such as the items that appear in the header file [RD29, section 7] and items required by INSPIRE [ER4], ISO 19115 [RD30], ISO 19115-2 [RD31], ISO 19157 [RD32] and OGC 10-157r3 [RD33]. These metadata standards are all meant to facilitate dataset discovery.

The metadata will be stored as attributes, while grouping attributes that belong to a specific standard will be done by using sub-groups in the Metadata group. Some attributes are required to be attached to the global level by convention, such as the CF metadata conventions [ER5], the Attribute Convention for Dataset Discovery [ER6], the NetCDF-4 user guide [ER7] and the ESA CCI project [RD34]. For interoperability reasons the conventions are followed, and the specified global attributes are added to the output files at the root-level.

ALGORITHM_SETTINGS An attribute is added to this group for each key in the configuration file. The exact contents differ for each processor.

GRANULE_DESCRIPTION Parameters describing the granule, such as an outline of the geolocations covered in the granule, the time coverage, and processing facility.

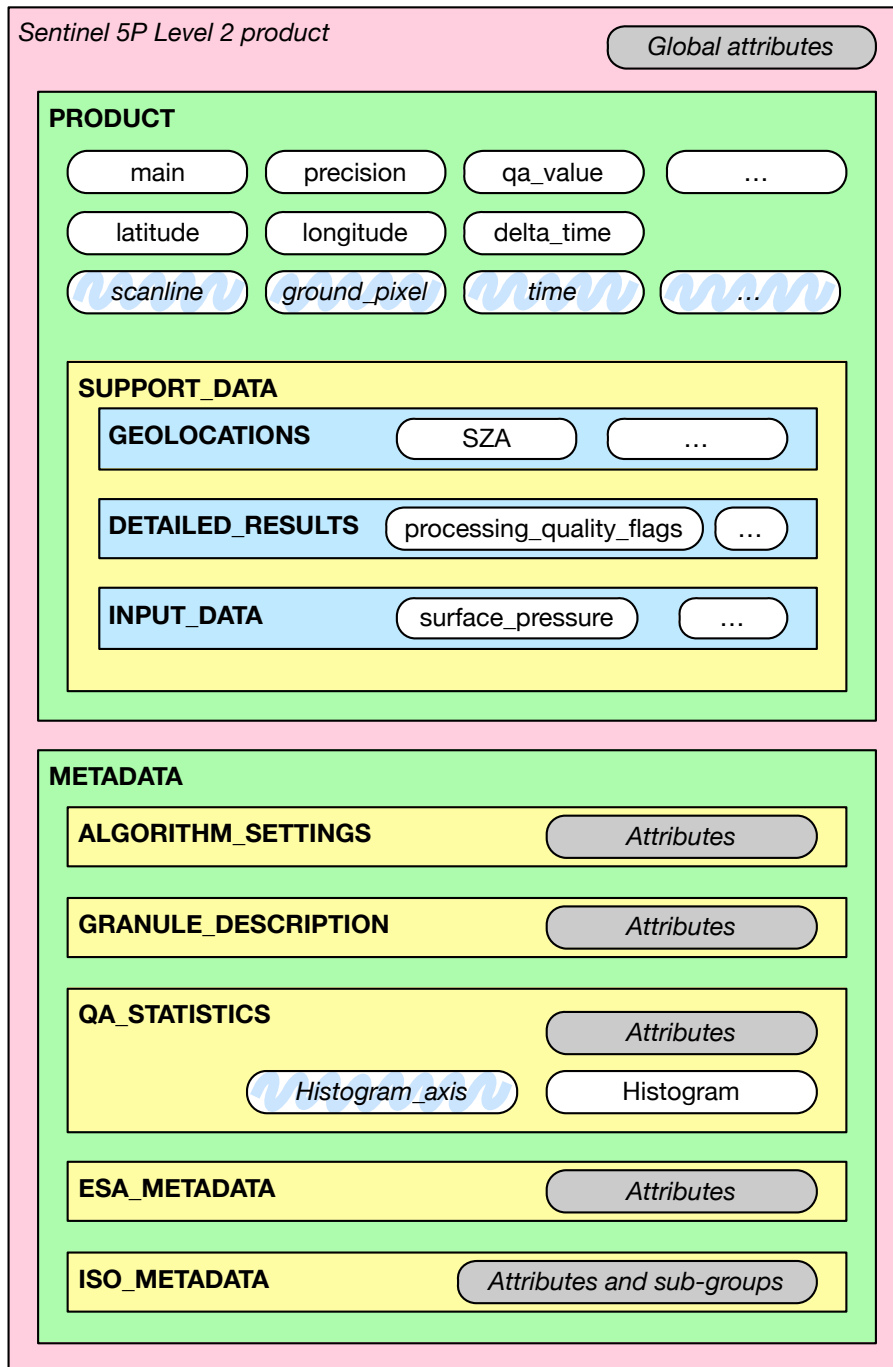
QA_STATISTICS Quality assurance statistics. This group contains two types of data:

1. The total number of pixel matching a certain criterion: number of input pixels, number of pixels successfully processed and the number of pixels that failed for specific reasons. Also part of the pixel counting are the number of warnings that were raised, including those for the south Atlantic anomaly, sun glint and solar eclipse. This is collectively known as ‘event counting’.
2. Histogram(s) of the main parameter(s) in the file. Histograms are additive and allow for easy monitoring of changes over time. This can be a valuable addition for quality monitoring of the science data.

ESA_METADATA The metadata items that are required in the ESA header.

ISO_METADATA The ISO metadata items, organized in subgroups.

¹ More detailed processing flags indicating precisely why the 100 % value isn’t reached, are available elsewhere in the product.



Legend

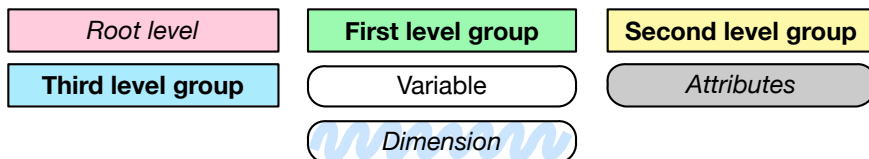


Figure 6: Graphical description of the generic structure of a Level 2 file. The elements labelled as a dimension are coordinate variables. See section 9 for a full description.

EOP_METADATA The EOP metadata items, organized in subgroups.

The work of Level 1B on metadata as described in the metadata specification for TROPOMI L01b data processor [RD35] is used as the basis for the level 2 metadata, in particular for the items in the 'ISO_METADATA' and 'EOP_METADATA' subgroups. The listed metadata standards give a data model and an implementation guideline for producing an XML file with the metadata – as a side-file to the data-file itself. The Level 1B IODS [RD2] describes a method to store the metadata in the NetCDF-4 file, and produce XML side-files as needed. A detailed discussion on metadata as it applies to Level 2 can be found in section 13.

Details of the specific format of the level 2 product file for the Aerosol Layer Height product is given in section 10. Here all variables are described in detail.

9.1 Dimensions and dimension ordering

All variables in a NetCDF-4 file use named and shared dimensions. This explicitly connects variables to dimensions, and to each other. A few of the dimension names were already shown in figure 6.

time A time dimension. The length of this dimension is 1, at least for S5P. The reason this dimension is used are compatibility with Level 1B, and forward compatibility with Sentinel 4 and Level 3 output. Details are provided in sections 9.2.

scanline The dimension that indicates the flight direction.

ground_pixel The dimension perpendicular to the flight direction.

level For profiles this dimension is used for the vertical grid. The levels indicate the interfaces between layers following the CF metadata conventions [ER5, Appendix D].

layer For profiles this dimension is used for the vertical grid. The layers contain the bulk between the levels, a layer has a thickness, a level is at an altitude. This is not fully CF compliant, but saves a lot of memory.

state_vector_length Used when it is appropriate to store a state vector rather than its individual components, for instance in a covariance matrix.

Other dimensions can be added as needed, but these names shall be the default for these roles.

The climate and forecast metadata conventions recommend a specific order for dimensions in a variable [ER5, section 2.4]. Spatiotemporal dimensions should appear in the relative order: “date or time” (T), “height or depth” (Z), “latitude” (Y), and “longitude” (X). Note that the ordering of the dimensions in CDL, our documentation and C/C++ is row-major: the last dimension is stored contiguously in memory².

Using straight latitude and longitude is fine with model parameters, but the S5P/TROPOMI Level 1B/Level 2 observation grid is not a regular grid. Because of the polar orbit, the across track dimension ('ground_pixel') corresponds most closely with the longitude, and therefore is associated with the X -dimension, while the along track dimensions ('scanline') corresponds most directly with latitude, and is therefore labelled as the Y -dimension.

However, in the CF conventions goes on to recommend that additional dimensions are added before the (T, Z, Y, X) axes, that is to have contiguous (T, Z, Y, X) hyperslabs, and spread out the data in other dimensions. We do not follow this recommendation. Instead we recommend to keep units that are likely to be accessed as a unit together in memory, but following the recommended order for (T, Y, X). Note that we do not follow the CF conventions for profiles as they are more likely accessed as complete profiles rather than horizontal slices. A few examples will help:

Tropospheric NO₂ column This variable contains a single value per ground pixel, and the dimensions are (time, scanline, ground_pixel).

O₃ profile This variable provides a column per ground pixel. Since the vertical axis is clearly defined we have the dimensions for this variable as (time, scanline, ground_pixel, level). Note that we do not follow the CF conventions in this case as ozone profiles are more likely accessed as complete profiles rather than horizontal slices.

² Fortran uses column-major order, effectively reversing the dimensions in the code compared to the documentation.

Covariance matrix Here the unit of data that is likely to be accessed as a unit is a complete covariance matrix. The dimensions are therefore (time, scanline, ground_pixel, state_vector_length, state_vector_length).

Covariance matrix for a profile Here the vertical level is used twice for the covariances between the layers. The dimension order in that case becomes (time, scanline, ground_pixel, level, level), as keeping the logical unit of a covariance matrix together in memory is more important than the order recommended by the CF metadata conventions [ER5, section 2.4].

The state_vector_length variable that accompanies the state_vector_length dimension is a string array, giving the names of the state vector elements.

9.2 Time information

Time information is stored in two steps. We have the time dimension, which indicates the reference time. This reference time is defined to be UTC midnight before the start of the orbit, which itself is defined by spacecraft midnight. The time variable contains the reference time in seconds since 2010-01-01, UTC midnight. Alternative representations of the reference time are listed in table 3. The offset of individual measurements within the granule is given in milliseconds with respect to this reference time in the variable delta_time.

The reason for this double reference is to more closely follow the CF conventions. Because the flight direction relates the latitude and the time within the orbit, we have Y and T dimensions that are closely related. By separating these into a time dimension of length 1 and a scanline dimension, we obtain independent Y and T dimensions. The actual observation time of an individual observation must be reconstructed from an offset and a time-delta.

As a service to the users, the time is also stored in the 'time_utc' variable. This variable is a string array, with each observation time stored as an ISO date string [RD36].

Table 3: Reference times available in a S5P L2 file. Types: (A) global attribute, (D) dimensional variable, (V) variable. All reference times ignore leap seconds.

Name	Type	Description
time_reference	(A)	ISO date/time string [RD36]
time_reference_days_since_1950	(A)	The number of days since January first, 1950, UTC midnight, as used in several weather and climate models (ECMWF, TM5).
time_reference_julian_day	(A)	The Julian date of the reference time as used in astronomy. This is the reference time system as used in IDL.
time_reference_seconds_since_1970	(A)	The number of seconds since January first, 1970, UTC midnight. This is also known as the unix epoch. Time functions on many systems will accept this number.
time	(D)	This variable contains the number of seconds since 2010-01-01, UTC midnight.
time_utc	(V)	Array of ISO date/time strings [RD36], one for each observation, i.e. one for each element in the scanline dimension

9.3 Geolocation, pixel corners and angles

The latitude, longitude, pixel corner coordinates and related angles and satellite position in the level 2 files are copied from the level 1B input data [RD26, chapters 26 and 27]. Details about the definitions can be found there. Note that the latitude and longitude have not been corrected for the local surface altitude, but are instead given at the intersection of the line of sight with the WGS84 ellipsoid.

The geo-coordinates of the pixel corners are shown in Figure 7. Note that this choice follows the CF metadata standard [ER5, section 7.1].

The azimuth angles, i.e. the solar azimuth angle ϕ_0 and the viewing azimuth angle ϕ give the angle of the sun and the instrument respectively at the intersection of the line of sight with the WGS84 ellipsoid. Both angles are given as degrees east relative to the local north. This definition is identical to the definition of the azimuth angles in both the OMI and GOME-2 instruments, but requires some care when comparing to a

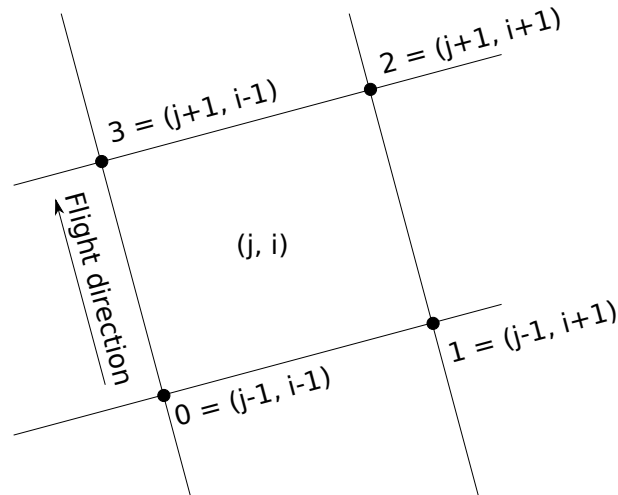


Figure 7: Pixel corner coordinates. The sequence $\{0, 1, 2, 3\}$ refers to the elements in the `corner` dimension.

radiative transfer model. A radiative transfer model will typically use $\varphi - \varphi_0$ which differs by 180° as it follows the path of the light.

9.4 Vertical coordinates

Different ATBD authors have specified different vertical grids for the retrieval, which means that the various Level 2 products are not consistent in this respect. There are several options, depending on the choice made by the authors of the retrieval algorithm. Some authors choose to use a vertical grid on a fixed height scale³, others use a grid that is defined in pressure relative to the surface pressure, similar to the ECMWF vertical grid.

The ECMWF vertical grid is a “atmosphere hybrid sigma pressure coordinate” in CF conventions terminology [ER5, appendix D].

$$p(n, k, j, i) = a_p(k) + b(k)p_s(n, j, i) \quad (1)$$

where $p(n, k, j, i)$ is the pressure at gridpoint (n, k, j, i) on the (T, Z, Y, X) axes; $a_p(k)$ and $b(k)$ the components of the hybrid coordinate at level k and $p_s(n, j, i)$ the surface pressure at coordinate (n, j, i) . As a consequence the surface pressure must be added to the output file, otherwise the pressure levels on which the profiles are reported cannot be reconstructed. In addition the $a_p(k)$ and $b(k)$ coefficients must be added to the output as separate variables.

For the fixed height grid there is no reduced pressure grid available, and similarly calculating a height from the pressure profile requires some assumptions. In some cases the full four-dimensional pressure grid will be given.

³ This is ‘height’ as defined by the CF conventions: distance above the surface; ‘altitude’ is the distance above the geoid or approximate sea level.

10 Description of the aerosol layer height product

Description of the main output file for the aerosol layer height product from the TROPOMI instrument on the Sentinel 5-precursor mission.

These are the file-level attributes.

If the ECMWF dynamic auxiliary data is not available a fallback solution will be used. In this case the Level 2 output file will be flagged using the “`Status_MET_2D`” global attribute.

If the NISE dynamic auxiliary data is not available a fallback solution will be used. In this case the Level 2 output file will be flagged using the “`Status_NISE_`” global attribute.

If the VIIRS dynamic auxiliary data is not available a fallback solution will be used. In this case the Level 2 output file will be flagged using the “`Status_NPP_VIIRS`” global attribute.

Global attributes in AER_LH

Group attributes attached to AER_LH		
<i>Name</i>	<i>Value</i>	<i>Type</i>
Conventions	‘CF-1.7’ (static)	NC_STRING
Name of the conventions followed by the dataset. Note that while we try to follow the climate and forecast metadata conventions, there are some features – notably the use of groups to hierarchically organize the data – that are not part of version 1.6 of the CF metadata conventions. In those cases we try to follow the spirit of the conventions. This attribute originates from the NUG standard.		
institution	‘%(institute)s’ (dynamic)	NC_STRING
The institute where the original data was produced. The actual processing center is given in the <code>ProcessingCenter</code> attribute, here we would like to indicate the responsible parties. The value is a combination from BIRA, DLR, ESA, FMI, IUP, KNMI, MPIC, SRON, The actual value is a combination of the ATBD institute and the institute that developed the processor. This attribute originates from the NUG standard.		
source	‘Sentinel 5 precursor, TROPOMI, space-borne remote sensing, L2’ (dynamic)	NC_STRING
Method of production of the original data. Value includes instrument, generic description of retrieval, product level, and adds a short product name and processor version. This attribute originates from the CF standard.		
history		NC_STRING
Provides an audit trail for modifications to the original data. Well-behaved generic netCDF filters will automatically append their name and the parameters with which they were invoked to the global history attribute of an input netCDF file. Each line shall begin with a timestamp indicating the date and time of day that the program was executed. This attribute originates from the NUG, CF standards.		
summary		NC_STRING
Miscellaneous information about the data or methods used to produce it. If processing in a degraded mode occurred, then a note should be placed in this attribute. A degraded processing mode can occur for several reasons, for instance the use of static backup data for nominally dynamic input or an irradiance product that is older than a few days. A machine-parseable description is available in the “ <code>processing_status</code> ” attribute. This attribute originates from the CF standard.		
tracking_id		NC_STRING
This unique tracking ID is proposed by the Climate Change Initiative – European Space Agency project. This ID is a UUID and allows files to be referenced, and linked up to processing description, input data, documentation, etc. The CCI-ESA project uses version 4 UUIDs (random number based) for consistency with CMIP5. This attribute originates from the CCI standard.		
id	‘%(logical_filename)s’ (dynamic)	NC_STRING
The “ <code>id</code> ” and “ <code>naming_authority</code> ” attributes are intended to provide a globally unique identification for each dataset. The “ <code>id</code> ” value should attempt to uniquely identify the dataset. The naming authority allows a further refinement of the “ <code>id</code> ”. The combination of the two should be globally unique for all time. We use the logical file name for the “ <code>id</code> ” attribute. This attribute originates from the CCI standard.		

time_reference	'YYYY-MM-DDT00:00:00Z' (dynamic)	NC_STRING
UTC time reference as an ISO 8601 [RD36] string. This corresponds to the UTC value in the <code>time</code> dimensional variable. By definition it indicates UTC midnight before the start of the granule.		
time_reference_days_since_1950	0 (dynamic)	NC_INT
The reference time expressed as the number of days since 1950-01-01. This is the reference time unit used by both TM5 and ECMWF.		
time_reference_julian_day	0.0 (dynamic)	NC_DOUBLE
The reference time expressed as a Julian day number.		
time_reference_seconds_since_1970	0 (dynamic)	NC_INT64
The reference time expressed as the number of seconds since 1970-01-01 00:00:00 UTC. This is the reference time unit used by Unix systems.		
time_coverage_start	'YYYY-MM-DDTHH:MM:SS.mmmmmmmZ' (dynamic)	NC_STRING
Start of the data granule in UTC as an ISO 8601 [RD36] string. See the discussion of the <code>time_delta</code> variable on page 31 for details.		
time_coverage_end	'YYYY-MM-DDTHH:MM:SS.mmmmmmmZ' (dynamic)	NC_STRING
End of the data granule in UTC as an ISO 8601 [RD36] string. See the discussion of the <code>time_delta</code> variable on page 31 for details.		
time_coverage_duration		NC_STRING
Duration of the data granule as an ISO 8601 [RD36] duration string ("PT%(duration_seconds)s"). This attribute originates from the CCI standard.		
time_coverage_resolution		NC_STRING
Interval between measurements in the data granule as an ISO 8601 [RD36] duration string ("PT%(interval_seconds)fs"). For most products this is 1080 ms in nominal operation, except for "L2_O3_PR", which uses 3240 ms due to coaddition. This attribute originates from the CCI standard.		
orbit	0 (dynamic)	NC_INT
The absolute orbit number, starting at 1 – first ascending node crossing after spacecraft separation. For pre-launch testing this value should be set to "-1".		
references	'%(references)s' (static)	NC_STRING
References that describe the data or methods used to produce it. This attribute originates from the CF standard.		
processor_version	'%(version)s' (dynamic)	NC_STRING
The version of the data processor, as string of the form "major.minor.patch".		
keywords_vocabulary	'AGU index terms, http://publications.agu.org/author-resource-center/index-terms/ ' (static)	NC_STRING
The guidelines followed for the keywords attribute. We use the index terms published by the AGU.		
keywords	'%(keywords_agu)s' (dynamic)	NC_STRING
Keywords from the " <code>keywords_vocabulary</code> " describing the contents of the file. To be provided by the ATBD authors.		
standard_name_vocabulary	'NetCDF Climate and Forecast Metadata Conventions Standard Name Table (v29, 08 July 2015), http://cfconventions.org/standard-names.html ' (static)	NC_STRING
The table followed for the <code>standard_name</code> attributes.		
naming_authority	'%(naming_authority)s' (dynamic)	NC_STRING
Specify who is giving out the <code>id</code> attribute. This attribute originates from the CCI standard.		
cdm_data_type	'Swath' (static)	NC_STRING
The THREDDS data type appropriate for this dataset, fixed to "Swath" for S5P level 2 products. This attribute originates from the CCI standard.		
date_created	'YYYY-mm-ddTHH:MM:SS.ffffffZ' (dynamic)	NC_STRING

The date on which this file was created. This attribute originates from the CCI standard.

creator_name	'%(credits)' (dynamic)	NC_STRING
The name of the creator, equal to the value of the "gmd:credit" attribute. For S5P this attribute is set to "The Sentinel 5 Precursor TROPOMI Level 2 products are developed with funding from the European Space Agency (ESA), the Netherlands Space Office (NSO), the Belgian Science Policy Office, the German Aerospace Center (DLR) and the Bayerisches Staatsministerium für Wirtschaft und Medien, Energie und Technologie (StMWi)." This attribute originates from the CCI standard.		
creator_url	'%(creator_url)s' (dynamic)	NC_STRING
Hyperlink to a location where more information on the product can be found. Set to http://www.tropomi.eu/ . This attribute originates from the CCI standard.		
creator_email	'EOSupport@Copernicus.esa.int' (dynamic)	NC_STRING
Point of contact for more information and support for this product. Set to "mailto:EOSupport@Copernicus.esa.int". This attribute originates from the CCI standard.		
project	'Sentinel 5 precursor/TROPOMI' (dynamic)	NC_STRING
The name of the scientific project that created the data. This attribute originates from the CCI standard.		
geospatial_lat_min		NC_FLOAT
Lowest latitude present in the file in decimal degrees. This attribute originates from the CCI standard.		
geospatial_lat_max		NC_FLOAT
Highest latitude present in the file in decimal degrees. This attribute originates from the CCI standard.		
geospatial_lon_min		NC_FLOAT
Lowest longitude present in the file in decimal degrees. This attribute originates from the CCI standard.		
geospatial_lon_max		NC_FLOAT
Highest longitude present in the file in decimal degrees. This attribute originates from the CCI standard.		
license	'No conditions apply' (static)	NC_STRING
describe the restrictions to data access and distribution. For S5P "No conditions apply". This attribute originates from the CCI standard.		
platform	'S5P' (static)	NC_STRING
Name of the satellite, set to "S5P". This attribute originates from the CCI standard.		
sensor	'TROPOMI' (static)	NC_STRING
Name of the sensor, set to "TROPOMI". This attribute originates from the CCI standard.		
spatial_resolution		NC_STRING
Spatial resolution at nadir. For most products this is "3.5 × 7 km ² ", except for "L2__O3__PR", which uses "28 × 21 km ² " and "L2__CO____" and "L2__CH4____", which both use "7 × 7 km ² ". This attribute originates from the CCI standard.		
cpp_compiler_version		NC_STRING
The version of the compiler used for the C++ code. The value of this attribute is set via the Makefile.		
cpp_compiler_flags		NC_STRING
The compiler flags passed to the C++ compiler. The value of this attribute is set via the Makefile.		
f90_compiler_version		NC_STRING
The version of the compiler version used for the Fortran code. The value of this attribute is set via the Makefile. Note that not all processors make use of Fortran code.		
f90_compiler_flags		NC_STRING
The compiler flags passed to the Fortran compiler. The value of this attribute is set via the Makefile. Note that not all processors make use of Fortran code.		
build_date		NC_STRING
The date on which the processor was built.		
revision_control_identifier	'%(revision_control_source_identifier)s' (dynamic)	NC_STRING
Revision control system identifier for the source used to build this processor.		
geolocation_grid_from_band		NC_INT

The band from which the geolocation was taken, useful for colocating the level 2 output with other products.

identifier_product_doi	'%(product_doi)s' (dynamic)	NC_STRING
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This is the DOI (“Digital Object Identifier”) of the current product. It allows to easily find download and background information, even if that location is moved after the file has been created.

identifier_product_doi_authority	'http://dx.doi.org/' (static)	NC_STRING
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This attribute defines the authoritative service for use with DOI values in resolving to the URL location.

algorithm_version	'%(algorithm_version)s' (dynamic)	NC_STRING
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The algorithm version, separate from the processor (framework) version, to accomodate different release schedules for different products.

title	'TROPOMI/S5P Aerosol Layer Height %s L2 Swath %sx%skm' (dynamic)	NC_STRING
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This is a short description of the product. In near-realtime processing the granule is shorter than 1 orbit, and the title must be adapted accordingly. The nominal title is “TROPOMI/S5P Aerosol Layer Height 1-Orbit L2 Swath yx3.5km”, with the y dimension adjusted according to the spatial sampling of the input (7.0 or 5.5). This attribute originates from the NUG standard.

product_version	'1.1.0' (dynamic)	NC_STRING
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Included for compatibility with the CCI project, where this item is defined as “the product version of this data file.” We will use the file format version for this attribute following several CCI sub-projects. This attribute originates from the CCI standard.

processing_status	'Nominal' (dynamic)	NC_STRING
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Description the processing status of the granule on a global level, mainly based on the availability of auxiliary input data.

Possible values: Nominal, Degraded

Status_MET_2D		NC_STRING
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The status of ECMWF input, either “Nominal” or “Fallback”. Note that the “MET_2D” auxiliary input is used as an anchor point for *all* meteorological data (where applicable).

Possible values: Nominal, Fallback

Status_NISE		NC_STRING
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The status of NISE input, either “Nominal”, “ECMWF_Fallback” or “Static_Fallback”.

Possible values: Nominal, ECMWF_Fallback, Static_Fallback

Status_NPP_VIIRS		NC_STRING
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The status of NPP-VIIRS input, either “NRTI”, “Nominal” or “Fallback”. In NRTI mode, this auxiliary input is expected to be missing.

Possible values: NRTI, Nominal, Fallback

10.1 Group “PRODUCT” in “AER_LH”

This is the main group containing the aerosol layer height product. At this level the dimensions and the main data fields are defined. Support data can be found in the “SUPPORT_DATA” group.

The dimensions that are common to all products. These are all located in the “PRODUCT” group, and can be accessed from that group and all sub-groups of the “PRODUCT” group, that is everywhere except the “METADATA” group.

All dimensions have an associated variable. These variables give a meaning to the dimension, spanning the axis of other variables.

The latitude and longitude. Used in all products, placed in the “PRODUCT” group.

Dimensions in AER_LH/PRODUCT

scanline The number of measurements along the swath, in the flight-direction.

size Unlimited.

mode Present in all modes.

ground_pixel The number of ground pixels across track. This depends on the product and will follow the dimension found in the main input Level 1B product.

size -1 (dynamic)
source L1B.
mode Present in all modes.

corner The number of corners for a pixel.

size 4 (fixed)
mode Present in all modes.

time The time dimension. See the discussion of the associated dimensional variable on page 30 for details.

size 1 (fixed)
mode Present in all modes.

albedo Number of surface albedo inputs.

size -1 (dynamic)
source Processor.
mode Present in all modes.

state_vector_length Number of state vector elements. $2 + wvl_node_sa + wvl_node_fluorescence$ elements: {aerosol_mid_pressure, aerosol_tau, surface_albedo[wvl_node_sa], fluorescence_emission[wvl_node_fluorescence]}.

size 2 (dynamic)
source Processor.
mode Present in all modes.

Variables in AER_LH/PRODUCT

scanline in AER_LH/PRODUCT

Description: The coordinate variable `scanline` refers to the along-track dimension of the measurement. The scanlines are time-ordered, meaning that “earlier” measurements have a lower index than “later” measurements. This variable merely contains an index to ensure that when indicating a pixel in a file the same index is used. This avoids the off-by-one confusion that frequently occurred in OMI discussions.

Dimensions: scanline (coordinate variable).

Type: NC_INT.

Source: Processor.

Mode: Present in all modes.

Attributes:	Name	Value	Type
	units	'1' (static)	NC_STRING
		Dimensionless, no physical quantity. This attribute originates from the CF standard.	
	axis	'Y' (static)	NC_STRING
	long_name	'along-track dimension index' (static)	NC_STRING
	comment	'This coordinate variable defines the indices along track; index starts at 0' (static)	NC_STRING

ground_pixel in AER_LH/PRODUCT

Description: The coordinate variable `ground_pixel` refers to the across-track dimension of the measurement. The `ground_pixel` ordering is from left to right with respect to the flight direction. For the Sentinel 5 precursor orbit this corresponds to west to east during the ascending part of the orbit, i.e. a higher index corresponds to a higher longitude. This variable merely contains an index to ensure that when indicating a pixel in a file the same index is used. This avoids the off-by-one confusion that frequently occurred in OMI discussions.

Dimensions: ground_pixel (coordinate variable).

Type: NC_INT.

Source: Processor.

Mode: Present in all modes.

Attributes:	Name	Value	Type
	units	'1' (static)	NC_STRING
		Dimensionless, no physical quantity. This attribute originates from the CF standard.	
	axis	'X' (static)	NC_STRING
	long_name	'across-track dimension index' (static)	NC_STRING
	comment	'This coordinate variable defines the indices across track, from west to east; index starts at 0' (static)	NC_STRING

time in AER_LH/PRODUCT

Description: The variable `time(time)` is the reference time of the measurements. The reference time is set to YYYY-MM-DDT00:00:00 UTC, midnight UTC before spacecraft midnight, the formal start of the current orbit. The `delta_time(scanline)` variable indicates the time difference of the observations with the reference time. Thus combining the information of `time(time)` and `delta_time(scanline)` yields the measurement time for each scanline as UTC time. The reference `time(time)` corresponds to the global attribute `time_reference` which is specified as a UTC time specified as an ISO 8601 [RD36] date.

Dimensions: time (coordinate variable).

Type: NC_INT.

Source: Processor.

Mode: Present in all modes.

Attributes:	Name	Value	Type
	units	'seconds since 2010-01-01 00:00:00' (dynamic)	NC_STRING
	standard_name	'time' (static)	NC_STRING
	axis	'T' (static)	NC_STRING
	long_name	'reference time for the measurements' (static)	NC_STRING
	comment	'The time in this variable corresponds to the time in the <code>time_reference</code> global attribute' (static)	NC_STRING

corner in AER_LH/PRODUCT

Description: An index for the pixel corners. We follow the CF-Metadata conventions [ER5, section 7.1]. The full coordinate system is right-handed, and the order of the pixel corners is counter-clockwise, starting in the "lower-left" corner (i.e. the smallest value in both latitude and longitude on the ascending part of the orbit, or equivalently for TROPOMI the lowest value for both the `ground_pixel` and `scanline` indices). See figure 7 on page 24 for a graphical depiction of the corners.

Dimensions: corner (coordinate variable).

Type: NC_INT.

Source: Processor.

Mode: Present in all modes.

Attributes:	Name	Value	Type
	units	'1' (static)	NC_STRING
		Dimensionless, no physical quantity. This attribute originates from the CF standard.	
	long_name	'pixel corner index' (static)	NC_STRING
	comment	'This coordinate variable defines the indices for the pixel corners; index starts at 0 (counter-clockwise, starting from south-western corner of the pixel in ascending part of the orbit)' (static)	NC_STRING

state_vector_length in AER_LH/PRODUCT

Description: Names of the state vector elements, as variable length character strings.

Dimensions: `state_vector_length` (coordinate variable).

Type: NC_STRING.

Source: Processor.

Mode:	Present in all modes.		
Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	units	'1' (static)	NC_STRING
	long_name	'names of state vector elements' (static)	NC_STRING

latitude in AER_LH/PRODUCT

Description: The latitude of the pixel centers of the ground pixels in the data. Latitude, longitude coordinates for the ground pixel center and the ground pixel corners are calculated at the WGS84 ellipsoid.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Mode: Present in all modes.

Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	long_name	'pixel center latitude' (static)	NC_STRING
	units	'degrees_north' (static)	NC_STRING
	standard_name	'latitude' (static)	NC_STRING
	valid_min	-90.0 (static)	NC_FLOAT
	valid_max	90.0 (static)	NC_FLOAT
	bounds	'/PRODUCT/SUPPORT_DATA/GEOLOCATIONS/ latitude_bounds' (static)	NC_STRING

A link to the boundary coordinates, i.e. the pixel corners. Note that the use of group-names in this attribute is an extension of the climate and forecasting metadata conventions.

longitude in AER_LH/PRODUCT

Description: The longitude of the pixel centers of the ground pixels in the data. Latitude, longitude coordinates for the ground pixel center and the ground pixel corners are calculated at the WGS84 ellipsoid.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Mode: Present in all modes.

Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	long_name	'pixel center longitude' (static)	NC_STRING
	units	'degrees_east' (static)	NC_STRING
	standard_name	'longitude' (static)	NC_STRING
	valid_min	-180.0 (static)	NC_FLOAT
	valid_max	180.0 (static)	NC_FLOAT
	bounds	'/PRODUCT/SUPPORT_DATA/GEOLOCATIONS/ longitude_bounds' (static)	NC_STRING

A link to the boundary coordinates, i.e. the pixel corners. Note that the use of group-names in this attribute is an extension of the climate and forecasting metadata conventions.

delta_time in AER_LH/PRODUCT

Description: The `delta_time(scanline)` variable indicates the time difference with the reference time `time(time)` (see page 30). Thus combining the information of `time(time)` and `delta_time(scanline)` yields the start of the measurement time for each scanline as TAI2010 time. Combining the information in the global attribute `time_reference` with `delta_time(scanline)` yields the start of the measurement time in UTC time. The UTC time derived for the first scanline corresponds to the global attribute `time_coverage_start`. However, the UTC time derived for the last scanline does not correspond to global attribute `time_coverage_end`. One scanline measurement is the result of adding independent measurements during one coaddition period. The scanline measurement is given the measurement time of the first sample in this co-addition. It is the measurement time of the last sample in the coaddition period of the last scanline that corresponds to `time_coverage_end`.

This variable gives the time offset in ms accuracy.

Dimensions: time, scanline.
Type: NC_INT.
Source: Processor.
Mode: Present in all modes.

Attributes:	Name	Value	Type
	long_name	'offset of start time of measurement relative to time_reference' (static)	NC_STRING
	units	'milliseconds' (static)	NC_STRING

time_utc in AER_LH/PRODUCT

Description: The time of observation expressed as ISO 8601 [RD36] date-time string.

Dimensions: time, scanline.
Type: NC_STRING.
Source: Processor.
Mode: Present in all modes.

Attributes:	Name	Value	Type
	long_name	'Time of observation as ISO 8601 date-time string' (static)	NC_STRING

qa_value in AER_LH/PRODUCT

Description: A continuous quality descriptor, varying between 0 (no data) and 1 (full quality data). The value will change based on observation conditions and retrieval flags. Detailed quality flags are provided in the `processing_quality_flags` elsewhere in the product.

Dimensions: time, scanline, ground_pixel.
Type: NC_UBYTE.
Source: Processor.
Mode: Present in all modes.

Attributes:	Name	Value	Type
	units	'1' (static)	NC_STRING
	scale_factor	0.01 (static)	NC_FLOAT
	add_offset	0 (static)	NC_FLOAT
	valid_min	0 (static)	NC_UBYTE
	valid_max	100 (static)	NC_UBYTE
	long_name	'data quality value' (static)	NC_STRING
	comment	'A continuous quality descriptor, varying between 0 (no data) and 1 (full quality data). Recommend to ignore data with qa_value < 0.5' (static)	NC_STRING
	coordinates	'longitude latitude' (static)	NC_STRING

aerosol_mid_pressure in AER_LH/PRODUCT

Description: Mid pressure of an aerosol layer with an assumed pressure thickness of (currently) 50 hPa and a constant aerosol volume extinction coefficient and single scattering albedo. Mid pressure is equal to top pressure plus bottom pressure divided by two.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Mode: Present in all modes.

Attributes:

<i>Name</i>	<i>Value</i>	<i>Type</i>
units	'Pa' (static)	NC_STRING
long_name	'air_pressure_at_center_of_aerosol_layer' (static)	NC_STRING
coordinates	'longitude latitude' (static)	NC_STRING
assumed_layer_pressure_thickness_Pa	5000.0 (static)	NC_FLOAT

Assumed thickness of the aerosol layer in the retrieval. This is a fixed but configurable parameter.

aerosol_mid_height in AER_LH/PRODUCT

Description: The aerosol layer mid pressure (p_{mid}) is converted into an aerosol layer mid altitude (z_{mid}) using an appropriate temperature profile, i.e. the temperature profile used in the retrieval. The value is given relative to the geoid.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Mode: Present in all modes.

Attributes:

<i>Name</i>	<i>Value</i>	<i>Type</i>
units	'm' (static)	NC_STRING
long_name	'Height at center of aerosol layer relative to geoid' (static)	NC_STRING
coordinates	'longitude latitude' (static)	NC_STRING

aerosol_mid_pressure_precision in AER_LH/PRODUCT

Description: A measure for the precision of p_{mid} is the standard deviation (sigma) of the fit parameter's (a posteriori) distribution.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Mode: Present in all modes.

Attributes:

<i>Name</i>	<i>Value</i>	<i>Type</i>
units	'Pa' (static)	NC_STRING
long_name	'air_pressure_at_center_of_aerosol_layer_standard_error' (static)	NC_STRING
coordinates	'longitude latitude' (static)	NC_STRING

aerosol_mid_height_precision in AER_LH/PRODUCT

Description: A measure for the precision is the standard deviation (sigma) of the fit parameter's (a posteriori) distribution, converted from mid pressure to mid altitude using an appropriate temperature profile.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Mode: Present in all modes.

Attributes:	Name	Value	Type
	units	'm' (static)	NC_STRING
	long_name	'height_at_center_of_aerosol_layer standard_error' (static)	NC_STRING
	coordinates	'longitude latitude' (static)	NC_STRING

10.1.1 Group "SUPPORT_DATA" in "PRODUCT"

10.1.1.1 Group "GEOLOCATIONS" in "SUPPORT_DATA"

Variables in AER_LH/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

satellite_latitude in AER_LH/PRODUCT/SUPPORT_DATA/GEOLOCATIONS			
Description:	Latitude of the geodetic sub satellite point on the WGS84 reference ellipsoid.		
Dimensions:	time, scanline.		
Type:	NC_FLOAT.		
Source:	L1B.		
Mode:	Present in all modes.		
Attributes:	Name	Value	Type
	long_name	'sub satellite latitude' (static)	NC_STRING
	units	'degrees_north' (static)	NC_STRING
	comment	'Latitude of the geodetic sub satellite point on the WGS84 reference ellipsoid' (static)	NC_STRING
	valid_min	-90.0 (static)	NC_FLOAT
	valid_max	90.0 (static)	NC_FLOAT
satellite_longitude in AER_LH/PRODUCT/SUPPORT_DATA/GEOLOCATIONS			
Description:	Longitude of the geodetic sub satellite point on the WGS84 reference ellipsoid.		
Dimensions:	time, scanline.		
Type:	NC_FLOAT.		
Source:	L1B.		
Mode:	Present in all modes.		
Attributes:	Name	Value	Type
	long_name	'satellite_longitude' (static)	NC_STRING
	units	'degrees_east' (static)	NC_STRING
	comment	'Longitude of the geodetic sub satellite point on the WGS84 reference ellipsoid' (static)	NC_STRING
	valid_min	-180.0 (static)	NC_FLOAT
	valid_max	180.0 (static)	NC_FLOAT
satellite_altitude in AER_LH/PRODUCT/SUPPORT_DATA/GEOLOCATIONS			
Description:	The altitude of the satellite with respect to the geodetic sub satellite point on the WGS84 reference ellipsoid.		
Dimensions:	time, scanline.		
Type:	NC_FLOAT.		
Source:	L1B.		
Mode:	Present in all modes.		
Attributes:	Name	Value	Type
	long_name	'satellite altitude' (static)	NC_STRING

units	'm' (static)	NC_STRING
comment	'The altitude of the satellite with respect to the geodetic sub satellite point on the WGS84 reference ellipsoid' (static)	NC_STRING
valid_min	700000.0 (static)	NC_FLOAT
valid_max	900000.0 (static)	NC_FLOAT

satellite_orbit_phase in AER_LH/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

Description: Relative offset [0.0, ..., 1.0] of the measurement in the orbit.

Dimensions: time, scanline.

Type: NC_FLOAT.

Source: L1B.

Mode: Present in all modes.

Attributes:

<i>Name</i>	<i>Value</i>	<i>Type</i>
long_name	'fractional satellite orbit phase' (static)	NC_STRING
units	'1' (static)	NC_STRING
comment	'Relative offset [0.0, ..., 1.0] of the measurement in the orbit' (static)	NC_STRING
valid_min	-0.02 (static)	NC_FLOAT
valid_max	1.02 (static)	NC_FLOAT

solar_zenith_angle in AER_LH/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

Description: Solar zenith angle ϑ_0 at the ground pixel location on the reference ellipsoid. Angle is measured away from the vertical. ESA definition of day side: $\vartheta_0 < 92^\circ$. Pixels are processed when $\vartheta_0 \leq \vartheta_0^{\max}$ with $80^\circ \leq \vartheta_0^{\max} \leq 88^\circ$, depending on the algorithm. The actual value for ϑ_0^{\max} can be found in the algorithm metadata settings.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: L1B.

Mode: Present in all modes.

Attributes:

<i>Name</i>	<i>Value</i>	<i>Type</i>
long_name	'solar zenith angle' (static)	NC_STRING
standard_name	'solar_zenith_angle' (static)	NC_STRING
units	'degree' (static)	NC_STRING
valid_min	0.0 (static)	NC_FLOAT
valid_max	180.0 (static)	NC_FLOAT
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude are in a different group. How to specify the related geospatial coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].	
comment	'Solar zenith angle at the ground pixel location on the reference ellipsoid. Angle is measured away from the vertical' (static)	NC_STRING

solar_azimuth_angle in AER_LH/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

Description: The solar azimuth angle at the ground pixel location on the reference ellipsoid. The angle is measured clockwise from the North (North = 0°, East = 90°, South = 180°, West = 270°). This is the same definition that is use in both OMI and GOME-2 level 1B files.

See the note on the `viewing_azimuth_angle` on the calculation of the relative azimuth angle as used in radiative transfer calculations.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source:	L1B.		
Mode:	Present in all modes.		
Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	long_name	'solar azimuth angle' (static)	NC_STRING
	standard_name	'solar_azimuth_angle' (static)	NC_STRING
	units	'degree' (static)	NC_STRING
	valid_min	-180.0 (static)	NC_FLOAT
	valid_max	180.0 (static)	NC_FLOAT
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude are in a different group. How to specify the related geospatial coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].		
	comment	'Solar azimuth angle at the ground pixel location on the reference ellipsoid. Angle is measured clockwise from the North (East = 90, South = 180, West = 270)' (static)	NC_STRING

viewing_zenith_angle in AER_LH/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

Description: Zenith angle of the satellite ϑ at the ground pixel location on the reference ellipsoid. Angle is measured away from the vertical.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: L1B.

Mode: Present in all modes.

Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	long_name	'viewing zenith angle' (static)	NC_STRING
	standard_name	'viewing_zenith_angle' (static)	NC_STRING
	units	'degree' (static)	NC_STRING
	valid_min	0.0 (static)	NC_FLOAT
	valid_max	180.0 (static)	NC_FLOAT
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude are in a different group. How to specify the related geospatial coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].		
	comment	'Zenith angle of the satellite at the ground pixel location on the reference ellipsoid. Angle is measured away from the vertical' (static)	NC_STRING

viewing_azimuth_angle in AER_LH/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

Description: The satellite azimuth angle at the ground pixel location on the reference ellipsoid. The angle is measured clockwise from the North (North = 0°, East = 90°, South = 180°, West = 270°). This is the same definition that is use in both OMI and GOME-2 level 1B files.

To calculate the azimuth difference $\varphi - \varphi_0$ it is not sufficient to just subtract `solar_azimuth_angle` from `viewing_azimuth_angle`. The angle needed for radiative transfer calculations is $(180^\circ - (\varphi - \varphi_0)) \bmod 360^\circ$.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: L1B.

Mode: Present in all modes.

Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	long_name	'viewing azimuth angle' (static)	NC_STRING
	standard_name	'viewing_azimuth_angle' (static)	NC_STRING

units	'degree' (static)	NC_STRING
valid_min	-180.0 (static)	NC_FLOAT
valid_max	180.0 (static)	NC_FLOAT
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude are in a different group. How to specify the related geospatial coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].	
comment	'Satellite azimuth angle at the ground pixel location on the reference ellipsoid. Angle is measured clockwise from the North (East = 90, South = 180, West = 270)' (static)	NC_STRING

latitude_bounds in AER_LH/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

Description: The latitude of the pixel corners of the ground pixels in the data. Latitude, longitude coordinates for the ground pixel center and the ground pixel corners are calculated at the WGS84 ellipsoid.

The order of the pixel corners follows the CF-metadata conventions [ER5, section 7.1], i.e. the ordering is counter-clockwise when viewed from above. A graphical representation is given in figure 7.

Dimensions: time, scanline, ground_pixel, corner.

Type: NC_FLOAT.

Source: Processor.

Mode: Present in all modes.

longitude_bounds in AER_LH/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

Description: The longitude of the pixel corners of the ground pixels in the data. Latitude, longitude coordinates for the ground pixel center and the ground pixel corners are calculated at the WGS84 ellipsoid.

The order of the pixel corners follows the CF-metadata conventions [ER5, section 7.1], i.e. the ordering is counter-clockwise when viewed from above. A graphical representation is given in figure 7.

Dimensions: time, scanline, ground_pixel, corner.

Type: NC_FLOAT.

Source: Processor.

Mode: Present in all modes.

geolocation_flags in AER_LH/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

Description: Additional flags describing the ground pixel, including the influence of a solar eclipse, the possibility of sun glint, whether we are in the descending part of the orbit, whether we are on the night side of the orbit, whether the pixel crosses the dateline (useful for plotting), or if there was some geolocation error.

Dimensions: time, scanline, ground_pixel.

Type: NC_UBYTE.

Source: Processor.

Mode: Present in all modes.

Attributes:	Name	Value	Type
	_FillValue	255 (static)	NC_UBYTE
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	flag_masks	0, 1, 2, 4, 8, 16, 128 (static)	NC_UBYTE
	flag_meanings	'no_error solar_eclipse sun_glint_possible descending night geo_boundary_crossing geolocation_error' (static)	NC_STRING
	flag_values	0, 1, 2, 4, 8, 16, 128 (static)	NC_UBYTE

long_name	'ground pixel quality flag' (static)	NC_STRING
max_val	254 (static)	NC_UBYTE
min_val	0 (static)	NC_UBYTE
units	'1' (static)	NC_STRING

10.1.1.2 Group "DETAILED_RESULTS" in "SUPPORT_DATA"

Variables in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

processing_quality_flags in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Processing quality flag. This flag indicates processing errors or reasons for not processing a particular pixel (collectively 'errors', leading to a fill value in the output) and warnings that occurred while processing this pixel (warnings which may affect the quality of the retrieval result). A detailed description is provided in appendix A.

Dimensions: time, scanline, ground_pixel.

Type: NC_UINT.

Source: Processor.

Mode: Present in all modes.

Attributes:	Name	Value	Type
	long_name	'Processing quality flags' (static)	NC_STRING
	comment	'Flags indicating conditions that affect quality of the retrieval.' (static)	NC_STRING

flag_meanings	'success radiance_missing irradiance_missing input_spectrum_missing reflectance_range_error ler_range_error snr_range_error sza_range_error vza_range_error lut_range_error ozone_range_ error wavelength_offset_error initialization_error memory_error assertion_error io_error numer- ical_error lut_error ISRF_error convergence_error cloud_filter_convergence_error max_iteration_ convergence_error aot_lower_boundary_conver- gence_error other_boundary_convergence_error geolocation_error ch4_noscat_zero_error h2o_ noscat_zero_error max_optical_thickness_error aerosol_boundary_error boundary_hit_error chi2_error svd_error dfs_error radiative_trans- fer_error optimal_estimation_error profile_error cloud_error model_error number_of_input_ data_points_too_low_error cloud_pressure_ spread_too_low_error cloud_too_low_level_error generic_range_error generic_exception input_ spectrum_alignment_error abort_error wrong_ input_type_error wavelength_calibration_error coregistration_error slant_column_density_error airmass_factor_error vertical_column_density_er- ror signal_to_noise_ratio_error configuration_error key_error saturation_error max_num_outlier_ exceeded_error solar_eclipse_filter cloud_filter altitude_consistency_filter altitude_roughness_ filter sun_glint_filter mixed_surface_type_filter snow_ice_filter aai_filter cloud_fraction_fresco_ filter aai_scene_albedo_filter small_pixel_radi- ance_std_filter cloud_fraction_viirs_filter cirrus_ reflectance_viirs_filter cf_viirs_swir_ifov_filter cf_viirs_swir_ofova_filter cf_viirs_swir_ofovb_filter cf_viirs_swir_ofovc_filter cf_viirs_nir_ifov_filter cf_viirs_nir_ofova_filter cf_viirs_nir_ofovb_filter cf_viirs_nir_ofovc_filter refl_cirrus_viirs_swir_filter refl_cirrus_viirs_nir_filter diff_refl_cirrus_viirs_filter ch4_noscat_ratio_filter ch4_noscat_ratio_std_filter h2o_noscat_ratio_filter h2o_noscat_ratio_std_filter diff_psurf_fresco_ecmwf_filter psurf_fresco_ stdv_filter ocean_filter time_range_filter pixel_ or_scanline_index_filter geographic_region_filter input_spectrum_warning wavelength_calibration_ warning extrapolation_warning sun_glint_warning south_atlantic_anomaly_warning sun_glint_ correction snow_ice_warning cloud_warning AAI_warning pixel_level_input_data_missing data_range_warning low_cloud_fraction_warn- ing altitude_consistency_warning signal_to_ noise_ratio_warning deconvolution_warning so2_volcanic_origin_likely_warning so2_volcanic_ origin_certain_warning interpolation_warning saturation_warning high_sza_warning cloud_re- trieval_warning cloud_inhomogeneity_warning' (static)	NC_STRING
----------------------	---	-----------

flag_masks	255, 256, 512, 1024, 2048, 4096, 8192, 16384, 32768, 65536, 131072, 262144, 524288, 1048576, 2097152, 4194304, 8388608, 16777216, 33554432, 67108864, 134217728, 268435456, 536870912 (static)	NC_UINT
flag_values	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 256, 512, 1024, 2048, 4096, 8192, 16384, 32768, 65536, 131072, 262144, 524288, 1048576, 2097152, 4194304, 8388608, 16777216, 33554432, 67108864, 134217728, 268435456, 536870912 (static)	NC_UINT
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static) The latitude and longitude are in a different group. How to specify the related geospatial coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].	NC_STRING
number_of_spectral_points_in_retrieval in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS		
Description: The number of points in the spectrum that were used in the retrieval.		
Dimensions: time, scanline, ground_pixel.		
Type: NC_USHORT.		
Source: Processor.		
Mode: Present in all modes.		
Attributes:	<i>Name</i>	<i>Value</i>
	long_name	'Number of spectral points used in the retrieval' (static)
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static) The latitude and longitude are in a different group. How to specify the related geospatial coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].
number_of_iterations in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS		
Description: The number of iterations needed to achieve convergence.		
Dimensions: time, scanline, ground_pixel.		
Type: NC_INT.		
Source: Processor.		
Mode: Present in all modes.		
Attributes:	<i>Name</i>	<i>Value</i>
	long_name	'number of iterations' (static)
	units	'1' (static)

	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
aerosol_optical_thickness in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS			
Description:	Aerosol optical thickness τ of the assumed aerosol layer. The optical thickness holds for 760 nm.		
Dimensions:	time, scanline, ground_pixel.		
Type:	NC_FLOAT.		
Source:	Processor.		
Mode:	Present in all modes.		
Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	units	'1' (static)	NC_STRING
	proposed_standard_name	'vertical_atmosphere_optical_thickness_due_to_ambient_aerosol_particles' (static)	NC_STRING
	long_name	'aerosol_optical_thickness' (static)	NC_STRING
	coordinates	'longitude latitude' (static)	NC_STRING
surface_albedo in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS			
Description:	Surface albedo at two wavelength nodes. Polynomial interpolation is used to determine the surface albedo at other wavelengths. The current version of the ALH algorithm does not fit the surface albedo but keeps it fixed in retrieval at climatological values.		
Dimensions:	time, scanline, ground_pixel.		
Type:	NC_FLOAT.		
Source:	Processor.		
Mode:	Present in all modes.		
Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	units	'1' (static)	NC_STRING
	standard_name	'surface_albedo' (static)	NC_STRING
	coordinates	'longitude latitude' (static)	NC_STRING
covariance_matrix in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS			
Description:	The matrix is by definition symmetric, a VLEN data-type might be in order. Note that each element has a different unit, so no <code>units</code> attribute.		
Dimensions:	time, scanline, ground_pixel, state_vector_length, state_vector_length.		
Type:	NC_FLOAT.		
Source:	Processor.		
Mode:	Present in all modes.		
Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	comment	'Covariance matrix of the retrieved parameters. The names of the state vector elements can be found in the state_vector_length variable. Note that each element has another unit, so no explicit unit has been defined for this variable.' (static)	NC_STRING
	long_name	'Covariance matrix' (static)	NC_STRING
aerosol_optical_thickness_precision in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS			
Description:	A measure for the precision of τ is the standard deviation (sigma) of the fit parameter's (a posteriori) distribution.		
Dimensions:	time, scanline, ground_pixel.		
Type:	NC_FLOAT.		
Source:	Processor.		
Mode:	Present in all modes.		
Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	units	'1' (static)	NC_STRING

long_name	'aerosol_optical_thickness_standard_error' (static)	NC_STRING
coordinates	'longitude latitude' (static)	NC_STRING

root_mean_square_error_of_fit in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Root mean square error
 Dimensions: time, scanline, ground_pixel.
 Type: NC_FLOAT.
 Source: Processor.
 Mode: Present in all modes.

Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	units	'1' (static)	NC_STRING
	long_name	'root_mean_square_error' (static)	NC_STRING
	coordinates	'longitude latitude' (static)	NC_STRING

chi_square in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Chi squared
 Dimensions: time, scanline, ground_pixel.
 Type: NC_FLOAT.
 Source: Processor.
 Mode: Present in all modes.

Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	units	'1' (static)	NC_STRING
	long_name	'chi_squared' (static)	NC_STRING
	coordinates	'longitude latitude' (static)	NC_STRING

degrees_of_freedom in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Degrees of freedom
 Dimensions: time, scanline, ground_pixel.
 Type: NC_FLOAT.
 Source: Processor.
 Mode: Present in all modes.

Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	units	'1' (static)	NC_STRING
	long_name	'degrees_of_freedom' (static)	NC_STRING
	coordinates	'longitude latitude' (static)	NC_STRING

wavelength_calibration_offset in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Fitted wavelength offset from the wavelength calibration pre-fit in the Level 2 processor.

$$\lambda_{\text{true}} = \lambda_{\text{nominal}} + \delta\lambda \quad (2)$$

See [RD37] for details about the wavelength fit.

Dimensions: time, scanline, ground_pixel.
 Type: NC_FLOAT.
 Source: Processor.
 Mode: Present in all modes.

Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	long_name	'wavelength_offset' (static)	NC_STRING
	units	'nm' (static)	NC_STRING
	wavelength_fit_-window_start	0.0 (static)	NC_FLOAT

The start wavelength of the wavelength fit window.

wavelength_fit_-window_end	0.0 (static)	NC_FLOAT
The end wavelength of the wavelength fit window.		
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
The latitude and longitude are in a different group. How to specify the related geospatial coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].		
ancillary_variables	'wavelength_calibration_offset_precision' (static)	NC_STRING
comment	'True wavelength = nominal wavelength + wavelength offset + wavelength stretch * scaled wavelength' (static)	NC_STRING

wavelength_calibration_offset_precision in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: A posteriori precision of the fitted wavelength offset.
 Dimensions: time, scanline, ground_pixel.
 Type: NC_FLOAT.
 Source: Processor.
 Mode: Present in all modes.

Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	long_name	'wavelength offset precision' (static)	NC_STRING
	units	'nm' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
The latitude and longitude are in a different group. How to specify the related geospatial coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].			

wavelength_calibration_stretch in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Fitted wavelength stretch q from the wavelength calibration pre-fit in the Level 2 processor.

$$\lambda_{\text{true}} = \lambda_{\text{nominal}} + \delta\lambda + q\lambda^* \quad (3)$$

with λ^* a scaled wavelength to the range $[-1, 1]$ over the full fit window. This is an optional fit parameter.

Dimensions: time, scanline, ground_pixel.
 Type: NC_FLOAT.
 Source: Processor.
 Mode: Present in all modes.

Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	long_name	'wavelength stretch' (static)	NC_STRING
	units	'1' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
The latitude and longitude are in a different group. How to specify the related geospatial coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].			
	ancillary_variables	'wavelength_calibration_stretch_precision' (static)	NC_STRING
	comment	'True wavelength = nominal wavelength + wavelength offset + wavelength stretch * scaled wavelength' (static)	NC_STRING

wavelength_calibration_stretch_precision in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description:	A posteriori precision of the fitted wavelength stretch.		
Dimensions:	time, scanline, ground_pixel.		
Type:	NC_FLOAT.		
Source:	Processor.		
Mode:	Present in all modes.		
Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	long_name	'wavelength stretch precision' (static)	NC_STRING
	units	'1' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude are in a different group. How to specify the related geospatial coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].		
wavelength_calibration_chi_square in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS			
Description:	The χ^2 from the wavelength calibration pre-fit in the Level 2 processor.		
Dimensions:	time, scanline, ground_pixel.		
Type:	NC_FLOAT.		
Source:	Processor.		
Mode:	Present in all modes.		
Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	long_name	'wavelength calibration chi square' (static)	NC_STRING
	units	'1' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude are in a different group. How to specify the related geospatial coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].		
wavelength_calibration_irradiance_offset in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS			
Description:	Fitted wavelength offset from the irradiance wavelength calibration pre-fit in the Level 2 processor.		
	$\lambda_{\text{true}} = \lambda_{\text{nominal}} + \delta\lambda \quad (4)$		
	See [RD37] for details about the wavelength fit.		
Dimensions:	time, ground_pixel.		
Type:	NC_FLOAT.		
Source:	Processor.		
Mode:	Present in all modes.		
Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	long_name	'wavelength offset' (static)	NC_STRING
	units	'nm' (static)	NC_STRING
	wavelength_fit_-window_start	0.0 (static)	NC_FLOAT
	The start wavelength of the irradiance wavelength fit window.		
	wavelength_fit_-window_end	0.0 (static)	NC_FLOAT
	The end wavelength of the irradiance wavelength fit window.		
	ancillary_variables	'wavelength_calibration_offset_precision' (static)	NC_STRING
	comment	'True wavelength = nominal wavelength + wavelength offset + wavelength stretch * scaled wavelength' (static)	NC_STRING

wavelength_calibration_irradiance_offset_precision in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: A posteriori precision of the fitted wavelength offset for the irradiance spectrum.
 Dimensions: time, ground_pixel.
 Type: NC_FLOAT.
 Source: Processor.
 Mode: Present in all modes.

Attributes:	Name	Value	Type
	long_name	'irradiance wavelength offset precision' (static)	NC_STRING
	units	'nm' (static)	NC_STRING

wavelength_calibration_irradiance_chi_square in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: The χ^2 from the irradiance wavelength calibration pre-fit in the Level 2 processor.
 Dimensions: time, ground_pixel.
 Type: NC_FLOAT.
 Source: Processor.
 Mode: Present in all modes.

Attributes:	Name	Value	Type
	long_name	'wavelength calibration irradiance chi squared' (static)	NC_STRING
	units	'1' (static)	NC_STRING

10.1.1.3 Group "INPUT_DATA" in "SUPPORT_DATA"

Variables in AER_LH/PRODUCT/SUPPORT_DATA/INPUT_DATA

surface_altitude in AER_LH/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description: The mean of the sub-pixels of the surface altitude within the approximate field of view, based on the GMTED2010 surface elevation database. The surface altitude is referenced to the Earth Gravitational Model 1996 (EGM96) geoid. The WGS84 ellipsoid is the best fitting ellipsoid to the EGM96 geoid model, but the altitude presented here is the orthometric height not an ellipsoid height.
 Dimensions: time, scanline, ground_pixel.
 Type: NC_FLOAT.
 Source: surface elevation database.
 Mode: Present in all modes.

Attributes:	Name	Value	Type
	long_name	'Surface altitude' (static)	NC_STRING
	standard_name	'surface_altitude' (static)	NC_STRING
	units	'm' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	source	'http://topotools.cr.usgs.gov/gmted_viewer/' (static)	NC_STRING
	comment	'The mean of the sub-pixels of the surface altitude within the approximate field of view, based on the GMTED2010 surface elevation database' (static)	NC_STRING

surface_altitude_precision in AER_LH/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description: The standard deviation of sub-pixels used in calculating the mean surface altitude, based on the GMTED2010 surface elevation database. See the description of the `surface_altitude` variable for details.

Dimensions: time, scanline, ground_pixel.
 Type: NC_FLOAT.
 Source: surface elevation database.
 Mode: Present in all modes.

Attributes:	Name	Value	Type
	long_name	'surface altitude precision' (static)	NC_STRING
	standard_name	'surface_altitude standard_error' (static)	NC_STRING
	units	'm' (static)	NC_STRING
	standard_error_- multiplier	1.0 (static)	NC_FLOAT
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	source	'http://topotools.cr.usgs.gov/gmted_viewer/' (static)	NC_STRING
	comment	'The standard deviation of sub-pixels used in calculating the mean surface altitude, based on the GMTED2010 surface elevation database' (static)	NC_STRING

surface_classification in AER_LH/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description: This is a combined land/water mask and surface classification data field. For land the "Global Land Cover Characteristics Data Base Version 2.0" is used [ER8], specifically the "USGS Land Use/Land Cover System (Modified Level 2)" classification. Over water the classification from the NASA SDP toolkit [ER9], which is based on [RD38].

The structure of this variable is indicated with the flag_meanings, flag_values and flag_masks, following the CF-metadata conventions. Bits 0 and 1 indicate the land-water mask at two levels, bit 2 gives a rough statistic on the coverage of the pixel, and the remainder of the byte indicates the surface classification in more detail. Note that these values are static and based on the databases indicated above.

Dimensions: time, scanline, ground_pixel.
 Type: NC_UBYTE.
 Source: surface elevation database (including flag attributes).
 Mode: Present in all modes.

Attributes:	Name	Value	Type
	long_name	'Land-water mask and surface classification based on a static database' (static)	NC_STRING
	comment	'Flag indicating land/water and further surface classifications for the ground pixel' (static)	NC_STRING
	source	'USGS (https://lta.cr.usgs.gov/GLCC) and NASA SDP toolkit (http://newsroom.gsfc.nasa.gov/sdptoolkit/toolkit.html)' (static)	NC_STRING

flag_meanings	'land water some_water coast value_covers_majority_of_pixel water+shallow_ocean water+shallow_inland_water water+ocean_-coastline-lake_shoreline water+intermittent_water water+deep_inland_water water+continental_shelf_ocean water+deep_ocean land+urban_-and_built-up_land land+dryland_cropland_-and_pasture land+irrigated_cropland_and_pasture land+mixed_dryland-irrigated_cropland_-and_pasture land+cropland-grassland_mosaic land+cropland-woodland_mosaic land+grassland land+shrubland land+mixed_shrubland-grassland land+savanna land+deciduous_broadleaf_forest land+deciduous_needleleaf_forest land+evergreen_broadleaf_forest land+evergreen_needleleaf_forest land+mixed_forest land+herbaceous_wetland land+wooded_wetland land+barren_or_sparsely_vegetated land+herbaceous_tundra land+wooded_tundra land+mixed_tundra land+bare_ground_tundra land+snow_or_ice' (static)	NC_STRING
flag_values	0, 1, 2, 3, 4, 9, 17, 25, 33, 41, 49, 57, 8, 16, 24, 32, 40, 48, 56, 64, 72, 80, 88, 96, 104, 112, 120, 128, 136, 144, 152, 160, 168, 176, 184 (static)	NC_UBYTE
flag_masks	3, 3, 3, 3, 4, 249 (static)	NC_UBYTE
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
instrument_configuration_identifier in AER_LH/PRODUCT/SUPPORT_DATA/INPUT_DATA		
Description:	The lclID from the instrument configuration in the Level 1B data product. 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 an instrument configuration and is identified by an instrument configuration ID, a number in the range [1,65535]. This instrument configuration ID, or lclID, is primarily used by the instrument, where it identifies an entry in the instrument configuration tables. On ground, the lclID is used to determine the intended purpose of a measurement and is used in the L0 to 1b data processing to determine the processing path.	
Dimensions:	time, scanline.	
Type:	NC_INT.	
Source:	L1B.	
Mode:	Present in all modes.	
Attributes:	<i>Name</i>	<i>Value</i>
	long_name	'lclID' (static)
	comment	'The Instrument Configuration ID defines the type of measurement and its purpose. The number of instrument configuration IDs will increase over the mission as new types of measurements are created and used' (static)
		NC_STRING
instrument_configuration_version in AER_LH/PRODUCT/SUPPORT_DATA/INPUT_DATA		

Description: For an lcID (see the `instrument_configuration_identifier` above), it is possible to have multiple versions, identified by the instrument configuration version or lcVersion. The combination of lcID and lcVersion uniquely identifies the set of configuration settings of the instrument. At a given time, only one lcVersion of an lcID can be active within the instrument. The lcVersion 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 lcID, instead the same lcID can be using with a new lcVersion.

Dimensions: time, scanline.
Type: NC_SHORT.
Source: L1B.
Mode: Present in all modes.

Attributes:	Name	Value	Type
	long_name	'lcVersion' (static)	NC_STRING
	comment	'Version of the instrument_configuration_identifier' (static)	NC_STRING

scaled_small_pixel_variance in AER_LH/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description: The scaled variance of the small pixel values for each ground pixel.

$$\langle R(t, r, c) \rangle = \frac{1}{N_{\text{small pixels}}} \sum_{i=0}^{N_{\text{small pixels}}-1} R(t, r, c, i) \quad (5)$$

$$V(t, r, c) = \frac{1}{N_{\text{small pixels}}} \sum_{i=0}^{N_{\text{small pixels}}-1} (R(t, r, c, i) - \langle R(t, r, c) \rangle)^2 \quad (6)$$

$$V_{\text{scaled}}(t, r, c) = \frac{V(t, r, c)}{\langle R(t, r, c) \rangle^2} \quad (7)$$

with $\langle R(t, r, c) \rangle$ the mean reflectance for small pixels of ground pixel (t, r, c) , $V(t, r, c)$ the variance of the small pixels, $V_{\text{scaled}}(t, r, c)$ the scaled small pixel variance, and $R(t, r, c, i)$ with $i = [0, \dots, N_{\text{small pixels}} - 1]$ the small pixel reflectance of ground pixel (t, r, c) . The reflectance R is calculated as $R = (\pi I) / (\mu_0 E_0)$, with I the radiance, E_0 the irradiance and $\mu_0 = \cos(\vartheta_0)$, where ϑ_0 is the solar zenith angle.

Dimensions: time, scanline, ground_pixel.
Type: NC_FLOAT.
Source: Processor.
Mode: Present in all modes.

Attributes:	Name	Value	Type
	long_name	'scaled small pixel variance' (static)	NC_STRING
	units	'1' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
		The latitude and longitude are in a different group. How to specify the related geospatial coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].	
	comment	'The scaled variance of the reflectances of the small pixels' (static)	NC_STRING
	radiation_wavelength		NC_FLOAT
		The approximate wavelength of the small pixel column in nm. Note that due to the spectral smile this wavelength will depend on the ground_pixel index.	

eastward_wind in AER_LH/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description: The horizontal component of the wind at 10 meter height in the eastward direction. This is the 10U parameter from ECMWF (grib variable 165).

Dimensions: time, scanline, ground_pixel.
 Type: NC_FLOAT.
 Source: Processor.
 Mode: Present in all modes.

Attributes:

<i>Name</i>	<i>Value</i>	<i>Type</i>
standard_name	'eastward_wind' (static)	NC_STRING
long_name	'Eastward wind from ECMWF at 10 meter height level' (static)	NC_STRING
units	'm s-1' (static)	NC_STRING
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
ancillary_variables	'northward_wind' (static)	NC_STRING

northward_wind in AER_LH/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description: The horizontal component of the wind at 10 meter height in the northward direction. This is the 10V parameter from ECMWF (grib variable 166).

Dimensions: time, scanline, ground_pixel.
 Type: NC_FLOAT.
 Source: Processor.
 Mode: Present in all modes.

Attributes:

<i>Name</i>	<i>Value</i>	<i>Type</i>
standard_name	'northward_wind' (static)	NC_STRING
long_name	'Northward wind from ECMWF at 10 meter height level' (static)	NC_STRING
units	'm s-1' (static)	NC_STRING
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
ancillary_variables	'eastward_wind' (static)	NC_STRING

aerosol_index_354_388 in AER_LH/PRODUCT/SUPPORT_DATA/INPUT_DATA

Dimensions: time, scanline, ground_pixel.
 Type: NC_FLOAT.
 Source: AER_AI.
 Mode: Present in all modes.

Attributes:

<i>Name</i>	<i>Value</i>	<i>Type</i>
units	'1' (static)	NC_STRING
comment	'Aerosol index from 388 and 354 nm' (static)	NC_STRING
long_name	'Aerosol index from 388 and 354 nm' (static)	NC_STRING
radiation_wavelength	354.0, 388.0 (static)	NC_FLOAT
The wavelengths used for the determination of the aerosol index.		
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

cloud_fraction in AER_LH/PRODUCT/SUPPORT_DATA/INPUT_DATA

Dimensions: time, scanline, ground_pixel.
 Type: NC_FLOAT.
 Source: FRESCO.
 Mode: Present in all modes.

Attributes:

<i>Name</i>	<i>Value</i>	<i>Type</i>
units	'1' (static)	NC_STRING

comment	'Cloud fraction from the cloud product, normally FRESCO' (static)	NC_STRING
long_name	'Cloud fraction from the cloud product' (static)	NC_STRING
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

viirs_cloud_mask in AER_LH/PRODUCT/SUPPORT_DATA/INPUT_DATA

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: NP_BD6.

Mode: Present in all modes.

Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	units	'1' (static)	NC_STRING
	comment	'Cloud mask from the VIIRS instrument on the Suomi NPP satellite' (static)	NC_STRING
	long_name	'Cloud mask from the VIIRS instrument on the Suomi NPP satellite' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

viirs_cirrus_reflectance in AER_LH/PRODUCT/SUPPORT_DATA/INPUT_DATA

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: NP_BD6.

Mode: Present in all modes.

Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	units	'1' (static)	NC_STRING
	comment	'Cirrus reflectance from the VIIRS instrument on the Suomi NPP satellite' (static)	NC_STRING
	long_name	'Cirrus reflectance from the VIIRS instrument on the Suomi NPP satellite' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

diff_albedo_380 in AER_LH/PRODUCT/SUPPORT_DATA/INPUT_DATA

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Mode: Present in all modes.

Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	units	'1' (static)	NC_STRING
	comment	'Difference between scene and surface albedo at 380 nm' (static)	NC_STRING
	long_name	'Difference between scene and surface albedo at 380 nm' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

small_pixel_precision in AER_LH/PRODUCT/SUPPORT_DATA/INPUT_DATA

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Mode: Present in all modes.

Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	units	'1' (static)	NC_STRING
	comment	'Standard deviation of small pixel radiance' (static)	NC_STRING

long_name	'Standard deviation of small pixel radiance' (static)	NC_STRING
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

surface_pressure in AER_LH/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description: Surface pressure.
 Dimensions: time, scanline, ground_pixel.
 Type: NC_FLOAT.
 Source: Processor.
 Mode: Present in all modes.

Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	units	'Pa' (static)	NC_STRING
	standard_name	'surface_air_pressure' (static)	NC_STRING
	long_name	'surface_air_pressure' (static)	NC_STRING
	source		NC_STRING
	Possible values: ECMWF, Using DEM and assuming fixed sea-level pressure of 1013 hPa and scale height of 8.3 km		
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude are in a different group. How to specify the related geospatial coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].		

snow_ice_flag in AER_LH/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description: This is a snow/ice classification data field.
 Dimensions: time, scanline, ground_pixel.
 Type: NC_UBYTE.
 Source: Processor.
 Mode: Present in all modes.

Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	long_name	'Snow-ice mask' (static)	NC_STRING
	_FillValue	254 (static)	NC_UBYTE
	comment	'Flag indicating snow/ice at center of ground pixel' (static)	NC_STRING
	source		NC_STRING
	Possible values: NSIDC/NISE, ECMWF		

flag_meanings	'snow-free_land sea_ice_1_percent sea_ice_2_percent sea_ice_3_percent sea_ice_4_percent sea_ice_5_percent sea_ice_6_percent sea_ice_7_percent sea_ice_8_percent sea_ice_9_percent sea_ice_10_percent sea_ice_11_percent sea_ice_12_percent sea_ice_13_percent sea_ice_14_percent sea_ice_15_percent sea_ice_16_percent sea_ice_17_percent sea_ice_18_percent sea_ice_19_percent sea_ice_20_percent sea_ice_21_percent sea_ice_22_percent sea_ice_23_percent sea_ice_24_percent sea_ice_25_percent sea_ice_26_percent sea_ice_27_percent sea_ice_28_percent sea_ice_29_percent sea_ice_30_percent sea_ice_31_percent sea_ice_32_percent sea_ice_33_percent sea_ice_34_percent sea_ice_35_percent sea_ice_36_percent sea_ice_37_percent sea_ice_38_percent sea_ice_39_percent sea_ice_40_percent sea_ice_41_percent sea_ice_42_percent sea_ice_43_percent sea_ice_44_percent sea_ice_45_percent sea_ice_46_percent sea_ice_47_percent sea_ice_48_percent sea_ice_49_percent sea_ice_50_percent sea_ice_51_percent sea_ice_52_percent sea_ice_53_percent sea_ice_54_percent sea_ice_55_percent sea_ice_56_percent sea_ice_57_percent sea_ice_58_percent sea_ice_59_percent sea_ice_60_percent sea_ice_61_percent sea_ice_62_percent sea_ice_63_percent sea_ice_64_percent sea_ice_65_percent sea_ice_66_percent sea_ice_67_percent sea_ice_68_percent sea_ice_69_percent sea_ice_70_percent sea_ice_71_percent sea_ice_72_percent sea_ice_73_percent sea_ice_74_percent sea_ice_75_percent sea_ice_76_percent sea_ice_77_percent sea_ice_78_percent sea_ice_79_percent sea_ice_80_percent sea_ice_81_percent sea_ice_82_percent sea_ice_83_percent sea_ice_84_percent sea_ice_85_percent sea_ice_86_percent sea_ice_87_percent sea_ice_88_percent sea_ice_89_percent sea_ice_90_percent sea_ice_91_percent sea_ice_92_percent sea_ice_93_percent sea_ice_94_percent sea_ice_95_percent sea_ice_96_percent sea_ice_97_percent sea_ice_98_percent sea_ice_99_percent sea_ice_100_percent permanent_ice snow mixed_pixels_at_coastlines suspect_ice_value corners ocean' (static)	NC_STRING
flag_values	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 103, 252, 253, 254, 255 (static)	NC_UBYTE
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

10.2 Group “METADATA” in “AER_LH”

This is a group to collect metadata items, such as the items that also appear in the header file and items required by Inspire [ER4]. Most metadata will be stored as attributes. Grouping attributes that belong to a specific standard is done by using sub-groups in the Metadata group. Included in this group are the granule description, algorithm settings and quality assurance parameters. Note that some metadata attributes are required to be attached to the global level by convention, such as the CF-Metadata convention [ER5] and the NetCDF user guide [ER7].

10.2.1 Group “QA_STATISTICS” in “METADATA”

Quality assurance statistics are gathered in variables located in this group. These can include histograms of the main parameters and event occurrence statistics. The contents of this group is under discussion. Note that the QA statistics may be stored as scalar variables rather than attributes. The former allow attributes to be attached to them, providing a more meaningful description than just the name.

Attributes in AER_LH/METADATA/QA_STATISTICS

Group attributes attached to QA_STATISTICS		
<i>Name</i>	<i>Value</i>	<i>Type</i>
number_of_groundpixels	0 (static)	NC_INT
Number of ground pixels in the file.		
number_of_processed_ - pixels	0 (static)	NC_INT
Number of ground pixels where a retrieval was attempted. This is the <code>number_of_groundpixels</code> minus the pixels that were rejected based on time or configuration (range and step-size in scanline or ground_pixel index).		
number_of_successfully_ - processed_pixels	0 (static)	NC_INT
Number of ground pixels where a retrieval was successful.		
number_of_rejected_pixels_ - not_enough_spectrum	0 (static)	NC_INT
Number of pixels where processing was not attempted because after filtering for bad and missing pixels there were not enough spectral pixels left in either the radiance, irradiance or after calculating the reflectance.		
number_of_failed_retrievals	0 (static)	NC_INT
Number of pixels where processing failed for whatever reason.		
number_of_ground_pixels_ - with_warnings	0 (static)	NC_INT
Number of pixels with one or more warnings.		
number_of_missing_scan- lines	0 (static)	NC_INT
Number of scanlines that are missing from the input.		
number_of_radiance_miss- ing_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “the number of spectral pixels in the radiance due to flagging is too small to perform the fitting” occurred, i.e. where the lower 8 bits of the <code>processing_ quality_flags</code> have the value “1”.		
number_of_irradiance_miss- ing_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “the number of spectral pixels in the irradiance due to flagging is too small to perform the fitting” occurred, i.e. where the lower 8 bits of the <code>processing_ quality_flags</code> have the value “2”.		
number_of_input_spec- trum_missing_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “the reflectance spectrum does not contain enough points to perform the retrieval. This is different from (ir)radiance_missing in that the missing points may not be aligned” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “3”.		
number_of_reflectance_range_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “any of the reflectances is out of bounds ($R < 0$ or $R > R_{max}$)” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “4”.		
number_of_ler_range_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “lambert-equivalent reflectivity out of range error” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “5”.		
number_of_snr_range_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “too low signal to noise to perform retrieval” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “6”.		
number_of_sza_range_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “solar zenith angle out of range, maximum value from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “7”.		
number_of_vza_range_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “viewing zenith angle out of range, maximum value from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “8”.		
number_of_lut_range_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “extrapolation in lookup table (airmass factor, cloud radiances)” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “9”.		
number_of_ozone_range_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “ozone column significantly out of range of profile climatology” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “10”.		
number_of_wavelength_offset_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “wavelength offset exceeds maximum from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “11”.		
number_of_initialization_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “an error occurred during the processing of the pixel, no output was generated. The following errors raise this flag: Mismatch between irradiance and radiance wavelengths; The on-ground distance between band 1 and band 2 ground pixels exceeds a threshold set in the configuration. Derived a-priori information does not validate, no processing is possible” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “12”.		
number_of_memory_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “memory allocation or deallocation error” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “13”.		
number_of_assertion_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “error in algorithm detected during assertion” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “14”.		
number_of_io_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “error detected during transfer of data between algorithm and framework” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “15”.		
number_of_numerical_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “general fatal numerical error occurred during inversion” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “16”.		
number_of_lut_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “error in accessing the lookup table” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “17”.		
number_of_ISRF_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “error detected in the input instrument spectral response function input data” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “18”.		
number_of_convergence_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “the main algorithm did not converge” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “19”.		
number_of_cloud_filter_convergence_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “the cloud filter did not converge” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “20”.		
number_of_max_iteration_convergence_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “no convergence because retrieval exceeds maximum number of iterations. Maximum value from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “21”.		
number_of_aot_lower_boundary_convergence_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “no convergence because the aerosol optical thickness crosses lower boundary twice in succession” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “22”.		
number_of_other_boundary_convergence_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “no convergence because a state vector element crosses boundary twice in succession. Note that a separate failure flag is defined for non-convergence due to crossing of lower AOT boundary” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “23”.		
number_of_geolocation_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “geolocation out of range” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “24”.		

number_of_ch4_noscat_zero_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “the CH ₄ column retrieved by the non-scattering CO algorithm from the weak band or strong band is 0” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “25”.		
number_of_h2o_noscat_zero_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “the H ₂ O column retrieved by the non-scattering CO algorithm from the weak band or strong band is 0” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “26”.		
number_of_max_optical_thickness_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “maximum optical thickness exceeded during iterations” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “27”.		
number_of_aerosol_boundary_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “boundary hit of aerosol parameters at last iteration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “28”.		
number_of_boundary_hit_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “fatal boundary hit during iterations” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “29”.		
number_of_chi2_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “ χ^2 is not-a-number or larger than 10^{10} ” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “30”.		
number_of_svd_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “singular value decomposition failure” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “31”.		
number_of_dfs_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “degree of freedom is not-a-number” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “32”.		
number_of_radiative_transfer_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “errors occurred during the radiative transfer computations, no processing possible” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “33”.		
number_of_optimal_estimation_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “errors occurred during the optimal estimation, processing has been terminated” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “34”.		
number_of_profile_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “flag that indicates if there were any errors during the computation of the ozone profile” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “35”.		
number_of_cloud_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “no cloud data” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “36”.		
number_of_model_error_oc- currences	0 (static)	NC_INT
Number of ground pixels where processing error “forward model failure” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “37”.		
number_of_number_of_in- put_data_points_too_low_- error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “not enough input ozone columns to calculate a tropospheric column” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “38”.		
number_of_cloud_pres- sure_spread_too_low_er- ror_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “cloud pressure variability too low to estimate a tropospheric column” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “39”.		
number_of_cloud_too_low_- level_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “clouds are too low in the atmosphere to assume sufficient shielding” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “40”.		
number_of_generic_range_- error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “generic range error” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “41”.		
number_of_generic_excep- tion_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “catch all generic error” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “42”.		
number_of_input_spec- trum_alignment_error_oc- currences	0 (static)	NC_INT
Number of ground pixels where processing error “input radiance and irradiance spectra are not aligned correctly” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “43”.		
number_of_abort_error_oc- currences	0 (static)	NC_INT
Number of ground pixels where processing error “not processed because processor aborted prematurely (time out or user abort)” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “44”.		
number_of_wrong_input_- type_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “wrong input type error, mismatch between expectation and received data” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “45”.		
number_of_wavelength_cal- ibration_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “an error occurred in the wavelength calibration of this pixel” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “46”.		
number_of_coregistration_- error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “no colocated pixels found in a supporting band” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “47”.		

number_of_slant_column_density_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “slant column fit returned error, no values can be compute” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “48”.		
number_of_airmass_factor_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “airmass factor could not be compute” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “49”.		
number_of_vertical_column_density_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “vertical column density could not be compute” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “50”.		
number_of_signal_to_noise_ratio_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “the signal to noise ratio for this spectrum is too low for processin” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “51”.		
number_of_configuration_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “error while parsing the configuratio” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “52”.		
number_of_key_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “key does not exis” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “53”.		
number_of_saturation_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “saturation in input spectru” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “54”.		
number_of_max_num_outlier_exceeded_error_occurrences	0 (static)	NC_INT
Number of ground pixels where processing error “the number of outliers detected in the DOAS fit exceeds a maximum set for healthy spectra.” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “55”.		
number_of_solar_eclipse_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “solar eclipse” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “64”.		
number_of_cloud_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “the cloud filter triggered causing the pixel to be skipped” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “65”.		
number_of_altitude_consistency_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “too large difference between ECMWF altitude and DEM altitude value” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “66”.		
number_of_altitude_roughness_filter_occurrences	0 (static)	NC_INT

<p>Number of ground pixels where input filter “too large standard deviation of altitude in DEM” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “67”.</p>		
number_of_sun_glint_filter_ - occurrences	0 (static)	NC_INT
<p>Number of ground pixels where input filter “for pixels over water, viewing direction inside sun glint region. Definition of sun glint angle and threshold value from ATBD” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “68”.</p>		
number_of_mixed_surface_ - type_filter_occurrences	0 (static)	NC_INT
<p>Number of ground pixels where input filter “pixel contains land and water areas (e.g. coastal pixel)” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “69”.</p>		
number_of_snow_ice_filter_ - occurrences	0 (static)	NC_INT
<p>Number of ground pixels where input filter “pixel contains snow/ice: Snow/ice flag according to dynamic input OR climatological surface albedo at VIS wavelength is larger than 0.5” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “70”.</p>		
number_of_aai_filter_ - occurrences	0 (static)	NC_INT
<p>Number of ground pixels where input filter “aAI smaller than 2.0” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “71”.</p>		
number_of_cloud_fraction_ - fresco_filter_occurrences	0 (static)	NC_INT
<p>Number of ground pixels where input filter “pixel contains clouds: The FRESCO effective cloud fraction is larger than threshold. Threshold value from ATBD” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “72”.</p>		
number_of_aai_scene_albedo_filter_ - occurrences	0 (static)	NC_INT
<p>Number of ground pixels where input filter “pixel contains clouds: The difference between scene albedo at 380 nm from AAI calculation and the climatological surface albedo exceeds threshold. Threshold value from ATBD. This test filters out clouds” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “73”.</p>		
number_of_small_pixel_radiance_std_filter_ - occurrences	0 (static)	NC_INT
<p>Number of ground pixels where input filter “pixel contains clouds: Standard deviation of radiances in small-pixel column exceeds threshold. Threshold value from ATBD” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “74”.</p>		
number_of_cloud_fraction_ - viirs_filter_occurrences	0 (static)	NC_INT
<p>Number of ground pixels where input filter “pixel contains clouds: The cloud fraction from VIIRS / NPP exceeds threshold. Threshold value from ATBD” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “75”.</p>		
number_of_cirrus_reflectance_viirs_filter_ - occurrences	0 (static)	NC_INT
<p>Number of ground pixels where input filter “pixel contains clouds: Cirrus reflectance from VIIRS / NPP exceeds threshold. Threshold value from ATBD” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “76”.</p>		
number_of_cf_viirs_swir_ - ifov_filter_occurrences	0 (static)	NC_INT
<p>Number of ground pixels where input filter “fraction of cloudy VIIRS pixels within S5P SWIR ground pixel exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “77”.</p>		

number_of_cf_viirs_swir_ofova_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “fraction of cloudy VIIRS pixels within S5P SWIR OFOVa exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “78”.		
number_of_cf_viirs_swir_ofovb_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “fraction of cloudy VIIRS pixels within S5P SWIR OFOVb exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “79”.		
number_of_cf_viirs_swir_ofovc_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “fraction of cloudy VIIRS pixels within S5P SWIR OFOVc exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “80”.		
number_of_cf_viirs_nir_ifov_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “fraction of cloudy VIIRS pixels within S5P NIR ground pixel exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “81”.		
number_of_cf_viirs_nir_ofova_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “fraction of cloudy VIIRS pixels within S5P NIR OFOVa exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “82”.		
number_of_cf_viirs_nir_ofovb_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “fraction of cloudy VIIRS pixels within S5P NIR OFOVb exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “83”.		
number_of_cf_viirs_nir_ofovc_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “fraction of cloudy VIIRS pixels within S5P NIR OFOVc exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “84”.		
number_of_refl_cirrus_viirs_swir_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “average VIIRS cirrus reflectance within SWIR ground pixel exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “85”.		
number_of_refl_cirrus_viirs_nir_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “average VIIRS cirrus reflectance within NIR ground pixel exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “86”.		
number_of_diff_refl_cirrus_viirs_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “difference in VIIRS average cirrus reflectance between SWIR and NIR ground pixel exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “87”.		

number_of_ch4_noscat_ratio_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “the ratio between $[CH_4]_{weak}$ and $[CH_4]_{strong}$ is below or exceeds a priori thresholds from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “88”.		
number_of_ch4_noscat_ratio_std_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “the standard deviation of $[CH_4]_{weak}/[CH_4]_{strong}$ within the SWIR pixel and the 8 neighbouring pixels exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “89”.		
number_of_h2o_noscat_ratio_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “the ratio between $[H_2O]_{weak}$ and $[H_2O]_{strong}$ is below or exceeds a priori thresholds from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “90”.		
number_of_h2o_noscat_ratio_std_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “the standard deviation of $[H_2O]_{weak}/[H_2O]_{strong}$ within the SWIR pixel and the 8 neighbouring pixels exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “91”.		
number_of_diff_psurf_fresco_ecmwf_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “difference between the FRESCO apparent surface pressure and the ECMWF surface pressure exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “92”.		
number_of_psurf_fresco_stdv_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “the standard deviation of the FRESCO apparent surface pressure in the NIR pixel and the 8 surrounding pixels exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “93”.		
number_of_ocean_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “the ground pixel is over ocean (and ocean glint retrievals are not switched on)” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “94”.		
number_of_time_range_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “time is out of the range that is to be processed” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “95”.		
number_of_pixel_or_scan_line_index_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “not processed because pixel index does not match general selection criteria” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “96”.		
number_of_geographic_region_filter_occurrences	0 (static)	NC_INT
Number of ground pixels where input filter “pixel falls outside the specified regions of interest” occurred, i.e. where the lower 8 bits of the <code>processing_quality_flags</code> have the value “97”.		
number_of_input_spectrum_warning_occurrences	0 (static)	NC_INT

Number of ground pixels where processing warning “number of good pixels in radiance, irradiance or calculated reflectance below threshold from configuration” occurred, i.e. where bit 8 in the `processing_quality_flags` is set to “1”.

number_of_wavelength_calibration_warning_occurrences	0 (static)	NC_INT
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Number of ground pixels where processing warning “offset from wavelength fit is larger than limit set in configuration” occurred, i.e. where bit 9 in the `processing_quality_flags` is set to “1”.

number_of_extrapolation_warning_occurrences	0 (static)	NC_INT
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Number of ground pixels where processing warning “pressure or temperature outside cross section LUT range, other lookup table extrapolation” occurred, i.e. where bit 10 in the `processing_quality_flags` is set to “1”.

number_of_sun_glint_warning_occurrences	0 (static)	NC_INT
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Number of ground pixels where processing warning “sun glint possibility warning” occurred, i.e. where bit 11 in the `processing_quality_flags` is set to “1”.

number_of_south_atlantic_anomaly_warning_occurrences	0 (static)	NC_INT
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Number of ground pixels where processing warning “tROPOMI is inside the south Atlantic anomaly while taking these measurements” occurred, i.e. where bit 12 in the `processing_quality_flags` is set to “1”.

number_of_sun_glint_correction_occurrences	0 (static)	NC_INT
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Number of ground pixels where processing warning “a sun glint correction has been applied” occurred, i.e. where bit 13 in the `processing_quality_flags` is set to “1”.

number_of_snow_ice_warning_occurrences	0 (static)	NC_INT
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Number of ground pixels where processing warning “snow/ice flag is set, i.e. using scene data from the cloud support product” occurred, i.e. where bit 14 in the `processing_quality_flags` is set to “1”.

number_of_cloud_warning_occurrences	0 (static)	NC_INT
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Number of ground pixels where processing warning “cloud filter based on FRESCO apparent surface pressure (VIIRS not available), cloud fraction above threshold or cloud pressure adjusted to force cloud above surface. In case of Cloud product this flag indicates the possibility of ice-clouds” occurred, i.e. where bit 15 in the `processing_quality_flags` is set to “1”.

number_of_AAI_warning_occurrences	0 (static)	NC_INT
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Number of ground pixels where processing warning “possible aerosol contamination as either indicated by the AAI (O₃ profile) or other criteria (Cloud)” occurred, i.e. where bit 16 in the `processing_quality_flags` is set to “1”.

number_of_pixel_level_input_data_missing_occurrences	0 (static)	NC_INT
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Number of ground pixels where processing warning “dynamic auxiliary input data (e.g.. cloud) is missing for this ground pixel. A fallback option is used” occurred, i.e. where bit 17 in the `processing_quality_flags` is set to “1”.

number_of_data_range_warning_occurrences	0 (static)	NC_INT
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Number of ground pixels where processing warning “carbon monoxide column tends to negative values; Water column tends to negative values; Heavy water (HDO) column tends to negative values; others. In case of the O₃ product this flag indicates VCD or effective albedo values outside a valid range. In case of the SO₂ or the HCHO product this flag indicates AMF values outside a valid range” occurred, i.e. where bit 18 in the `processing_quality_flags` is set to “1”.

number_of_low_cloud_fraction_warning_occurrences 0 (static) NC_INT

Number of ground pixels where processing warning “low cloud fraction, therefore no cloud pressure retrieved” occurred, i.e. where bit 19 in the `processing_quality_flags` is set to “1”.

number_of_altitude_consistency_warning_occurrences 0 (static) NC_INT

Number of ground pixels where processing warning “difference between ECMWF surface elevation and high-resolution surface elevation exceeds threshold from configuration” occurred, i.e. where bit 20 in the `processing_quality_flags` is set to “1”.

number_of_signal_to_noise_ratio_warning_occurrences 0 (static) NC_INT

Number of ground pixels where processing warning “signal to noise ratio in SWIR and/or NIR band below threshold from configuration. For the O₃ and HCHO products this flag indicates an RMS above a certain threshold” occurred, i.e. where bit 21 in the `processing_quality_flags` is set to “1”.

number_of_deconvolution_warning_occurrences 0 (static) NC_INT

Number of ground pixels where processing warning “failed deconvolution irradiance spectrum (not pixel-specific, but row-specific)” occurred, i.e. where bit 22 in the `processing_quality_flags` is set to “1”.

number_of_so2_volcanic_origin_likely_warning_occurrences 0 (static) NC_INT

Number of ground pixels where processing warning “warning for SO₂ BL product, UTLS products: volcanic origin except for heavily polluted sites” occurred, i.e. where bit 23 in the `processing_quality_flags` is set to “1”.

number_of_so2_volcanic_origin_certain_warning_occurrences 0 (static) NC_INT

Number of ground pixels where processing warning “warning for SO₂ BL product, UTLS products: volcanic origin certain” occurred, i.e. where bit 24 in the `processing_quality_flags` is set to “1”.

number_of_interpolation_warning_occurrences 0 (static) NC_INT

Number of ground pixels where processing warning “warning for interpolation on partially missing data. In this case the valid available data is used, potentially leading to a bias” occurred, i.e. where bit 25 in the `processing_quality_flags` is set to “1”.

number_of_saturation_warning_occurrences 0 (static) NC_INT

Number of ground pixels where processing warning “saturation occurred spectrum, possibly causing biases in the retrieval” occurred, i.e. where bit 26 in the `processing_quality_flags` is set to “1”.

number_of_high_sza_warning_occurrences 0 (static) NC_INT

Number of ground pixels where processing warning “warning for high solar zenith angle. In this case, the processing can be performed with less final quality” occurred, i.e. where bit 27 in the `processing_quality_flags` is set to “1”.

number_of_cloud_retrieval_warning_occurrences 0 (static) NC_INT

Number of ground pixels where processing warning “warning occurring when the retrieval diagnostic indicates a degraded quality of the cloud retrieval” occurred, i.e. where bit 28 in the `processing_quality_flags` is set to “1”.

number_of_cloud_inhomogeneity_warning_occurrences	0 (static)	NC_INT
Number of ground pixels where processing warning “the cloud coregistration inhomogeneity parameter is above a given threshold” occurred, i.e. where bit 29 in the <code>processing_quality_flags</code> is set to “1”.		
global_processing_warnings	‘None’ (static)	NC_STRING
All warning messages, separated by newlines, with duplicates removed.		
time_for_algorithm_initialization	-1.0 (static)	NC_DOUBLE
Time in seconds needed for initialization.		
time_for_processing	-1.0 (static)	NC_DOUBLE
Time in seconds needed for processing.		
time_per_pixel	-1.0 (static)	NC_DOUBLE
Time per pixel in seconds needed for processing.		
time_standard_deviation_per_pixel	-1.0 (static)	NC_DOUBLE
Standard deviation of the time per pixel in seconds needed for processing.		

Dimensions in AER_LH/METADATA/QA_STATISTICS

vertices For the histogram boundaries.

- size** 2 (fixed)
- mode** Present in all modes.

aerosol_mid_height_histogram_axis Histogram axis.

- size** 100 (fixed)
- mode** Present in all modes.

aerosol_mid_height_pdf_axis Probability density function axis.

- size** 400 (fixed)
- mode** Present in all modes.

aerosol_mid_pressure_histogram_axis Histogram axis.

- size** 100 (fixed)
- mode** Present in all modes.

aerosol_mid_pressure_pdf_axis Probability density function axis.

- size** 400 (fixed)
- mode** Present in all modes.

Variables in AER_LH/METADATA/QA_STATISTICS

aerosol_mid_pressure_histogram_axis in AER_LH/METADATA/QA_STATISTICS

Description: Horizontal axis for the histograms of the aerosol mid pressure.

Dimensions: aerosol_mid_pressure_histogram_axis (coordinate variable).

Type: NC_FLOAT.

Source: Processor.

Mode: Present in all modes.

Attributes:	Name	Value	Type
	units	'Pa' (dynamic)	NC_STRING
	Same unit as the main parameter. This attribute originates from the CF standard.		
	comment	'Histogram of aerosol mid altitude' (static)	NC_STRING
	long_name	'Histogram of aerosol mid altitude' (static)	NC_STRING
	bounds	'aerosol_mid_pressure_histogram_bounds' (static)	NC_STRING

aerosol_mid_pressure_pdf_axis in AER_LH/METADATA/QA_STATISTICS

Description: Horizontal axis for the probability distribution functions of the aerosol mid pressure.
 Dimensions: aerosol_mid_pressure_pdf_axis (coordinate variable).
 Type: NC_FLOAT.
 Source: Processor.
 Mode: Present in all modes.

Attributes:	Name	Value	Type
	units	'Pa' (dynamic)	NC_STRING
	Same unit as the main parameter. This attribute originates from the CF standard.		
	comment	'Probability density function of aerosol mid altitude' (static)	NC_STRING
	long_name	'Probability density function of aerosol mid altitude' (static)	NC_STRING
	bounds	'aerosol_mid_pressure_pdf_bounds' (static)	NC_STRING

aerosol_mid_pressure_histogram_bounds in AER_LH/METADATA/QA_STATISTICS

Dimensions: aerosol_mid_pressure_histogram_axis, vertices.
 Type: NC_FLOAT.
 Source: Processor.
 Mode: Present in all modes.

aerosol_mid_pressure_pdf_bounds in AER_LH/METADATA/QA_STATISTICS

Dimensions: aerosol_mid_pressure_pdf_axis, vertices.
 Type: NC_FLOAT.
 Source: Processor.
 Mode: Present in all modes.

aerosol_mid_height_histogram_axis in AER_LH/METADATA/QA_STATISTICS

Description: Horizontal axis for the histograms of the aerosol mid altitude.
 Dimensions: aerosol_mid_height_histogram_axis (coordinate variable).
 Type: NC_FLOAT.
 Source: Processor.
 Mode: Present in all modes.

Attributes:	Name	Value	Type
	units	'm' (dynamic)	NC_STRING
	Same unit as the main parameter. This attribute originates from the CF standard.		
	comment	'Histogram of aerosol mid altitude' (static)	NC_STRING
	long_name	'Histogram of aerosol mid altitude' (static)	NC_STRING
	bounds	'aerosol_mid_height_histogram_bounds' (static)	NC_STRING

aerosol_mid_height_pdf_axis in AER_LH/METADATA/QA_STATISTICS

Description: Horizontal axis for the probability distribution functions of the aerosol mid altitude.
 Dimensions: aerosol_mid_height_pdf_axis (coordinate variable).
 Type: NC_FLOAT.
 Source: Processor.

Mode:	Present in all modes.		
Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	units	'm' (dynamic) Same unit as the main parameter. This attribute originates from the CF standard.	NC_STRING
	comment	'Probability density function of aerosol mid altitude' (static)	NC_STRING
	long_name	'Probability density function of aerosol mid altitude' (static)	NC_STRING
	bounds	'aerosol_mid_height_pdf_bounds' (static)	NC_STRING
aerosol_mid_height_histogram_bounds in AER_LH/METADATA/QA_STATISTICS			
Dimensions:	aerosol_mid_height_histogram_axis, vertices.		
Type:	NC_FLOAT.		
Source:	Processor.		
Mode:	Present in all modes.		
aerosol_mid_height_pdf_bounds in AER_LH/METADATA/QA_STATISTICS			
Dimensions:	aerosol_mid_height_pdf_axis, vertices.		
Type:	NC_FLOAT.		
Source:	Processor.		
Mode:	Present in all modes.		
aerosol_mid_height_histogram in AER_LH/METADATA/QA_STATISTICS			
Description:	Histogram of the aerosol mid altitude in the current granule.		
Dimensions:	aerosol_mid_height_histogram_axis.		
Type:	NC_INT.		
Source:	Processor.		
Mode:	Present in all modes.		
Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	comment	'Histogram of the aerosol mid altitude in the current granule' (static)	NC_STRING
	number_of_overflow_values	0 (dynamic) The number of encountered values that are larger than the top of the histogram.	NC_INT
	number_of_underflow_values	0 (dynamic) The number of encountered values that are smaller than the base of the histogram.	NC_INT
aerosol_mid_pressure_histogram in AER_LH/METADATA/QA_STATISTICS			
Description:	Histogram of the aerosol mid pressure in the current granule.		
Dimensions:	aerosol_mid_pressure_histogram_axis.		
Type:	NC_INT.		
Source:	Processor.		
Mode:	Present in all modes.		
Attributes:	<i>Name</i>	<i>Value</i>	<i>Type</i>
	comment	'Histogram of the aerosol mid pressure in the current granule' (static)	NC_STRING
	number_of_overflow_values	0 (dynamic) The number of encountered values that are larger than the top of the histogram.	NC_INT
	number_of_underflow_values	0 (dynamic)	NC_INT

The number of encountered values that are smaller than the base of the histogram.

aerosol_mid_height_pdf in AER_LH/METADATA/QA_STATISTICS

Description: Probability density function of the aerosol mid altitude in the current granule. The values are weighted with $\cos(\delta_{geo})$ and spread out using the error estimate.

Dimensions: aerosol_mid_height_pdf_axis.

Type: NC_FLOAT.

Source: Processor.

Mode: Present in all modes.

Attributes:	Name	Value	Type
	comment	'Probability density function of the aerosol mid altitude in the current granule' (static)	NC_STRING
	geolocation_sampling_total	0 (static)	NC_FLOAT

The sum of cosine values of latitudes from the pixels that were used in the pdf.

aerosol_mid_pressure_pdf in AER_LH/METADATA/QA_STATISTICS

Description: Probability density function of the aerosol mid pressure in the current granule. The values are weighted with $\cos(\delta_{geo})$ and spread out using the error estimate.

Dimensions: aerosol_mid_pressure_pdf_axis.

Type: NC_FLOAT.

Source: Processor.

Mode: Present in all modes.

Attributes:	Name	Value	Type
	comment	'Probability density function of the aerosol mid pressure in the current granule' (static)	NC_STRING
	geolocation_sampling_total	0 (static)	NC_FLOAT

The sum of cosine values of latitudes from the pixels that were used in the pdf.

10.2.2 Group "ALGORITHM_SETTINGS" in "METADATA"

The algorithm settings are attached as attributes to this group. The current settings are listed here, each item in the list is a string attribute.

Configurations in AER_LH/METADATA/ALGORITHM_SETTINGS

processing.algorithm AER_LH

Define the algorithm that is to be loaded.

configuration.version.framework 1.2.0

Allow the framework to verify that the configuration file is up to date.

configuration.version.algorithm 2.0.0

Allow the processor to verify that the configuration file is up to date.

processing.szaMax 75.0

Maximum solar zenith angle (degrees).

processing.filterSunGlint false

Filter pixels with possible sun glint

processing.filterMixedSurface false

Filter pixels that contain both land and water

processing.sgaLimit 18.0

For pixels over water, sun glint angle must be larger than this angle (degrees).

processing.aerosolIndexWarning 1.0

Low aerosol index warning threshold

processing.aerosolIndexMin 0.0

Low aerosol index filter threshold

processing.surfaceAltitudePrecisionWarning 300.0
High standard deviation of altitude warning threshold.

processing.surfaceAltitudePrecisionMax 1000.0
High standard deviation of altitude filter threshold

processing.cloudFractionWarning 0.6
High cloud fraction warning threshold

processing.cloudFractionMax 0.6
High cloud fraction filter threshold

processing.cloudFractionNPPWarning 1.1
High NPP/VIIRS cloud fraction warning threshold

processing.cloudFractionNPPMax 1.1
High NPP/VIIRS cloud fraction filter threshold

processing.avgCirrusRefWarning 0.01
High cirrus reflectance warning threshold

processing.avgCirrusRefMax 0.4
High cirrus reflectance filter threshold

processing.albedo380diffWarning 0.2

processing.albedo380diffMax 0.4

processing.albedoReMin 0.0

processing.smallPixelStdDevMax 1.0e-07
Standard deviation of the small pixels should be smaller than this limit, to filter out inhomogeneous scenes.

processing.loadSavedModel false
load the NN model from the tensorflow SavedModel

processing.modelDirectory v0_20181026
relative location of the tensorflow SavedModel

processing.saveModelAsNetcdf false
ave the model as netCDF to the location specified by the LUT_ALH_NN key

processing.applyDynamicScaling false
apply dynamic scaling

processing.dynamicScalingThreshold 15.0
dynamic scaling threshold

processing.albedoFactorsWater 0.7, 0.85, 1.0, 1.15, 1.3
albedo factors above water (only relevant if output.1.level == 1)

processing.albedoFactorsLand -0.5, -0.25, 0.0, 0.25, 0.5
albedo factors above land (only relevant if output.1.level == 1)

processing.aotLowerBound 0.0
Minimum value in the training data set for the aerosol optical thickness. A retrieved value below this limit means that the network extrapolated. A warning will be set for that pixel.

processing.aotUpperBound 5.0
Maximum value in the training data set for the aerosol optical thickness. A retrieved value above this limit means that the network extrapolated. A warning will be set for that pixel.

processing.deadline.handling information
When deadline time is passed write message with this log level

input.count 5
Define the number of input files.

input.1.type L1B_RA_BD6
Define the input type (band) for the second input (radiance band 6). This key is needed to read from the JobOrder input file.

input.1.irrType L1B_IR_UVN
Define which irradiance accompanies the second input.

input.1.band 6
Which band is this (for selecting the irradiance and coregistration to output).

input.2.type L2__FRESCO
Define the input type for the fourth input (FRESCO clouds, L2 product). This key is needed to read from the JobOrder input file.

input.2.band 6
On which band is this (for coregistration to output).

input.2.required false

input.3.type L2__AER_AI
Define the input type for the fifth input (aerosol index, L2 product). This key is needed to read from the JobOrder input file.

input.3.band 3
On which band is this (for coregistration to output).

input.4.type L2__NP_BD6
Define the input type for the sixth input (NPP/VIIRS clouds on band 6, L2 product, optional). This key is needed to read from the JobOrder input file.

input.4.band 6
On which band is this (for coregistration to output).

input.4.required false
Input is required

input.5.type L2__CLOUD_
Define the input type for the second input (DLR clouds, L2 product). This key is needed to read from the JobOrder input file.

input.5.band 3
On which band is this (for coregistration to output).

input.5.required false
DLR clouds is not required, just one of the two cloud products.

output.count 1
Define the number of output products (should be 1).

output.useFletcher32 true
Boolean to indicate status of Fletcher32 filter (default is on).

output.useCompression true
Boolean to set status of compression (default is on).

output.useShuffleFilter true
Boolean to set status of shuffle filter (default is on).

output.compressionLevel 3
Integer value to set compression level, default is 3.

output.1.type L2__AER_LH
Output product short name. This key is needed to read from the JobOrder input file.

output.1.config product.AER_LH.xml
Output product specification.

output.1.band 6
Geolocation in output follows this band.

output.1.level 0
Output level: 0 = nominal; 1 = extended

processing.nprogress 50000
Determines after how many processed pixels a progress message is written to the log

processing.nPasses 1
number of passes; this algorithm can work in both 1 and 2 passes.

output.histogram.aerosol_mid_pressure.range 1050.0, 150.0
Range for the histogram of the aerosol layer height mid pressure.

output.histogram.aerosol_mid_height.range 0, 10000
Range for the histogram of the aerosol layer height mid altitude.

processing.fitWindowBegin 758.0
Start of fit window for aerosol layer height

processing.fitWindowEnd 770.0
End of fit window for aerosol layer height

processing.surfaceAlbedoWav 758.0, 770.0
Use this wavelength from the (GOME2 based) surface albedo database

processing.groupDem DEM_RADIUS_05000
Which DEM to use.

processing.groupLer GOME2
Which LER database to use.

processing.band.count 1
Number of spectrum bands for processing

processing.band.1.begin 738.0
Begin of spectral band to be read from L1b data

processing.band.1.end 780.0
End of spectral band to be read from L1b data

processing.band.1.step 1
Step of spectral pixels

processing.band.1.input 1
Corresponding input number

processing.timeFinalize 60.0
Time needed to finalize and close the output file.

processing.signal_to_noise.test yes
lag pixels when signal to noise ratio is below threshold. Default no testing, unless processing.signal_to_noise.window.range is set.

processing.signal_to_noise.window.range 740.0, 745.0
avelength pixel range for testing signal to noise ratio. Default range is all wavelngts, but only if processing.signal_to_noise.test is set

processing.signal_to_noise.threshold 12
Threshold value for signal to noise ratio, in decibel. Ground-pixel is flagged when majority wavelength pixels has signal to noise below threshold. Default is 12.

processing.radianceFractionMinError 0.90
inum fraction of valid spectral pixels required in band 2 for processing ground-pixel. With less pixels a PQF_E_INPUT_SPECTRUM_MISSING is generated.

processing.radianceFractionMinWarning 0.98
ith less valid spectral pixels in band 2 a PQF_W_INPUT_SPECTRUM_WARNING is generated. The ground-pixel can still be processed.

wavelength_calibration.perform_wavelength_fit yes
Master switch for the wavelength calibration.

wavelength_calibration.polynomial_order 2
The wavelength calibration fit uses a background polynomial. This is the order for this polynomial, 2 for aerosol layer heigh, as the window is short.

wavelength_calibration.include_stretch no
For aerosol layer height we do not include a stretch/squeeze parameter as we extrapolate the result.

wavelength_calibration.include_ring no
Ring effect is insignificant in the NIR.

wavelength_calibration.initial_guess.a0 1.0
Initial guess for the parameters of the polynomial in the wavelength fit. 1, 0.1, 0.01, 0.01, ... for a0, a1, a2, a3, ... as appropriate.

wavelength_calibration.initial_guess.a1 0.1

wavelength_calibration.initial_guess.a2 0.01

wavelength_calibration.sigma.a0 1.0
a priori precision of the polynomial coefficients. 1, 0.1, 0.1, 0.1, ... for a0, a1, a2, a3, ... as appropriate.

wavelength_calibration.sigma.a1 0.1

wavelength_calibration.sigma.shift 0.045
a priori precision of the wavelength shift. Set to the spectral sampling for band 6 divided by 3.

wavelength_calibration.initial_guess.shift 0.0
Initial guess for the wavelength shift.

wavelength_calibration.window 738.0, 757.0
The wavelength calibration window. This window excludes the oxygen A band itself.

wavelength_calibration.max_iterations 8
The maximum number of iterations for hte wavelength fit.

wavelength_calibration.convergence_threshold 1.0
Convergence criterium (auto scaled).

qa_value.input_spectrum_warning 50.0
he qa_value multiplication factor (in percent) for when the number of pixels in the input spectrum is below nominal.

qa_value.wavelength_calibration_warning 100.0
he qa_value multiplication factor (in percent) for when the wavelength calibration offset is larger than a configured threshold.

- qa_value.extrapolation_warning** 70.0
 he qa_value multiplication factor (in percent) for when extrapolation was used in the retrieval.
- qa_value.sun_glint_warning** 50.0
 he qa_value multiplication factor (in percent) for when the pixel is potentially affected by sun glint.
- qa_value.south_atlantic_anomaly_warning** 50.0
 he qa_value multiplication factor (in percent) for when the instrument was flying through the South Atlantic Anomaly while taking this measurement.
- qa_value.sun_glint_correction** 100.0
 he qa_value multiplication factor (in percent) for when the cloud fraction was corrected for sun glint.
- qa_value.snow_ice_warning** 100.0
 he qa_value multiplication factor (in percent) for when the snow_ice_warning flag is raised.
- qa_value.cloud_warning** 50.0
 he qa_value multiplication factor (in percent) for when the cloud_warning flag is raised.
- qa_value.aai_warning** 50.0
 he qa_value multiplication factor (in percent) for when the aai_warning flag is raised.
- qa_value.pixel_level_input_data_missing** 50.0
 he qa_value multiplication factor (in percent) for when the pixel_level_input_data_missing flag is raised.
- qa_value.data_range_warning** 50.0
 he qa_value multiplication factor (in percent) for when the data_range_warning flag is raised.
- qa_value.low_cloud_fraction_warning** 100.0
 he qa_value multiplication factor (in percent) for when the low_cloud_fraction_warning flag is raised.
- qa_value.altitude_consistency_warning** 100.0
 he qa_value multiplication factor (in percent) for when the altitude_consistency_warning flag is raised.
- qa_value.signal_to_noise_ratio_warning** 100.0
 he qa_value multiplication factor (in percent) for when the signal_to_noise_ratio_warning flag is raised.
- qa_value.deconvolution_warning** 100.0
 he qa_value multiplication factor (in percent) for when the deconvolution_warning flag is raised.
- qa_value.so2_volcanic_origin_likely_warning** 100.0
 he qa_value multiplication factor (in percent) for when the so2_volcanic_origin_likely_warning flag is raised.
- qa_value.so2_volcanic_origin_certain_warning** 100.0
 he qa_value multiplication factor (in percent) for when the so2_volcanic_origin_certain_warning flag is raised.
- qa_value.interpolation_warning** 100.0
 he qa_value multiplication factor (in percent) for when the interpolation_warning flag is raised.
- qa_value.sza_threshold** 60.0, 75.0
 lower and upper limits of the solar zenith angle where the qa_value is modified from 1 to 'qa_value.sza_modification_percent'.
- qa_value.sza_modification_percent** 80.0
 qa_value multiplication factor (in percent) for values where $\vartheta_0 > \vartheta_{0,max}$.
- qa_value.vza_threshold** 60.0, 75.0
 lower and upper limits of the viewing zenith angle where the qa_value is modified from 1 to 'qa_value.vza_modification_percent'.
- qa_value.vza_modification_percent** 80.0
 qa_value multiplication factor (in percent) for values where $\vartheta > \vartheta_{max}$.

10.2.3 Group “GRANULE_DESCRIPTION” in “METADATA”

Common granule level metadata.

Attributes in AER_LH/METADATA/GRANULE_DESCRIPTION

Group attributes attached to GRANULE_DESCRIPTION		
Name	Value	Type
GranuleStart		NC_STRING
Start of the granule as ISO date/time string in UTC: YYYY-MM-DDTHH:MM:SS.mmmmmmmZ. The formal definition of ISO date/time strings is given in [RD36].		

GranuleEnd		NC_STRING
End of the granule as ISO date/time string in UTC: YYYY-MM-DDTHH:MM:SS.mmmmmmmZ. The formal definition of ISO date/time strings is given in [RD36].		
InstrumentName	'TROPOMI' (static)	NC_STRING
The name of the instrument, fixed to "TROPOMI".		
MissionName	'Sentinel-5 precursor' (static)	NC_STRING
The name of the mission, fixed to "Sentinel-5 precursor".		
MissionShortName	'S5P' (static)	NC_STRING
The short name of the mission, fixed to "S5P".		
ProcessLevel	'2' (static)	NC_STRING
This is a level 2 product.		
ProcessingCenter	'%(processingcenter)s' (dynamic)	NC_STRING
Where was the processor run? The source is the probably the joborder, the most likely value for operational use is "DLR/Oberpfaffenhofen".		
ProcessingNode		NC_STRING
The name of the machine that processed the data. This may aid in diagnosing failures in the processing.		
ProcessorVersion	'%(version)s' (dynamic)	NC_STRING
The version number of the processor used to produce the file. This is a string formatted as "major.minor.bugfix".		
ProductFormatVersion	1 (static)	NC_INT
The version of the format of the product file. This should be incremented whenever a datafield is added to the files.		
ProcessingMode		NC_STRING
This attribute indicates the mode of the processor. Possible values: Near-realtime, Offline, Reprocessing, Test, SyntheticTest		
LongitudeOfDaysideNadirEquatorCrossing		NC_FLOAT
The longitude of the nadir-point at the day-side equator crossing. This gives a rough indication where the orbit is located. The value is calculated using an orbit propagator before the observation, so that a consistent value is used for all processing stages.		
ProductShortName	'L2_AER_LH' (static)	NC_STRING
The short product name. For the aerosol layer height product this is fixed to "L2_AER_LH".		

10.2.3.1 Group "ISO_METADATA" in "iso_metadata"

Metadata that is structured following the ISO metadata standards [RD30, RD39], especially part 2. The metadata in this group is structured using the methods from Level 1B, which is described in the Level 1B metadata specification [RD35].

All "objectType" attributes indicate the XML object when generating an ISO 19139 [RD39] compliant XML metadata file.

Note that this group is meant to be treated as a 'black box'. The information is collected here so that it can be extracted into XML side-files for ingestion into data search tools and metadata collections.

Attributes in AER_LH/METADATA/ISO_METADATA

Group attributes attached to ISO_METADATA		
Name	Value	Type
gmd:dateStamp	'2015-10-16' (static)	NC_STRING
Date of creation of the metadata, as ISO 8601 [RD36] string specifying year, month and day.		
gmd:fileIdentifier	'urn:ogc:def:EOP:ESA:SENTINEL.S5P_TROP_- %(shortname)s' (dynamic)	NC_STRING
Unique identifier for metadata file, see the Level 1B metadata specification [RD35, table 5] for a discussion of the value.		

Replace %(...s with the “ProductShortName” value from the Level 2 “/METADATA/GRANULE_DESCRIPTION” metadata group.

gmd:hierarchyLevelName	‘EO Product Collection’ (static)	NC_STRING
Name of the hierarchy levels for which the metadata is provided.		
gmd:metadataStandardName	‘ISO 19115-2 Geographic Information - Metadata Part 2 Extensions for imagery and gridded data’ (static)	NC_STRING
Name of the metadata standard.		
gmd:metadataStandardVersion	‘ISO 19115-2:2009(E), S5P profile’ (static)	NC_STRING
Version (profile) of the metadata standard used.		
objectType	‘gmi:MI_Metadata’ (static)	NC_STRING
Name of the metadata class [RD35, table 5].		

10.2.3.2 Group “gmd:language” in “ISO_METADATA”

Language used for the metadata, fixed to English.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:language

Group attributes attached to gmd:language		
<i>Name</i>	<i>Value</i>	<i>Type</i>
codeList	‘http://www.loc.gov/standards/iso639-2/’ (static)	NC_STRING
codeListValue	‘eng’ (static)	NC_STRING
objectType	‘gmd:LanguageCode’ (static)	NC_STRING

10.2.3.3 Group “gmd:characterSet” in “ISO_METADATA”

The character encoding used for the metadata. This is fixed to UTF-8, but the climate and forecasting conventions, version 1.6 limits this further to 7-bit ASCII (which is a subset of UTF-8).

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:characterSet

Group attributes attached to gmd:characterSet		
<i>Name</i>	<i>Value</i>	<i>Type</i>
codeList	‘http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MD_CharacterSetCode’ (static)	NC_STRING
codeListValue	‘utf8’ (static)	NC_STRING
objectType	‘gmd:MD_CharacterSetCode’ (static)	NC_STRING

10.2.3.4 Group “gmd:hierarchyLevel” in “ISO_METADATA”

Scope to which metadata applies.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:hierarchyLevel

Group attributes attached to gmd:hierarchyLevel		
<i>Name</i>	<i>Value</i>	<i>Type</i>
codeList	‘http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MD_ScopeCode’ (static)	NC_STRING
codeListValue	‘series’ (static)	NC_STRING
objectType	‘gmd:MD_ScopeCode’ (static)	NC_STRING

10.2.3.5 Group “gmd:contact” in “ISO_METADATA”

Contact information for the product.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:contact

Group attributes attached to gmd:contact

<i>Name</i>	<i>Value</i>	<i>Type</i>
gmd:organisationName	'Copernicus Space Component Data Access System, ESA, Services Coordinated Interface' (static)	NC_STRING
objectType	'gmd:CI_ResponsibleParty' (static)	NC_STRING

10.2.3.6 Group “gmd:contactInfo” in “gmd:contact”

The detailed contact information.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:contact/gmd:contactInfo

Group attributes attached to gmd:contactInfo

<i>Name</i>	<i>Value</i>	<i>Type</i>
objectType	'gmd:CI_Contact' (static)	NC_STRING

10.2.3.7 Group “gmd:address” in “gmd:contactInfo”

The actual email address.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:contact/gmd:contactInfo/gmd:address

Group attributes attached to gmd:address

<i>Name</i>	<i>Value</i>	<i>Type</i>
gmd:electronicMailAddress	'EOSupport@copernicus.esa.int' (static)	NC_STRING
objectType	'gmd:CI_Address' (static)	NC_STRING

10.2.3.8 Group “gmd:role” in “gmd:contact”

The role of the address provided in this group.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:contact/gmd:role

Group attributes attached to gmd:role

<i>Name</i>	<i>Value</i>	<i>Type</i>
codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_RoleCode' (static)	NC_STRING
codeListValue	'pointOfContact' (static)	NC_STRING
objectType	'gmd:CI_RoleCode' (static)	NC_STRING

10.2.3.9 Group “gmd:identificationInfo” in “ISO_METADATA”

Identification information contains information to uniquely identify the data. Identification information includes information about the citation for the resource, an abstract, the purpose, credit, the status and points of contact. The MD_Identification entity is mandatory. The MD_Identification entity is specified (subclassed) as MD_DataIdentification because in this case it is used to identify data.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo

Group attributes attached to gmd:identificationInfo

<i>Name</i>	<i>Value</i>	<i>Type</i>
gmd:abstract		NC_STRING

Brief narrative summary of the content of the resource. This is product specific.

L2__AER_AI (KNMI) Aerosol index with a spatial resolution of $7 \times 7 \text{ km}^2$ observed at about 13:30 local solar time from spectra measured by TROPOMI

L2__AER_LH (KNMI) Altitude of elevated aerosol layer for cloud-free observations with a spatial resolution of $7 \times 7 \text{ km}^2$ observed at about 13:30 local solar time from spectra measured by TROPOMI

L2__NO2__ (KNMI) Nitrogen dioxide tropospheric column with a spatial resolution of $7 \times 7 \text{ km}^2$ observed at about 13:30 local solar time from spectra measured by TROPOMI

L2__O3__PR (KNMI) Ozone profile with a vertical resolution of 6 km and a horizontal resolution of $28 \times 21 \text{ km}^2$ observed at about 13:30 local solar time from spectra measured by TROPOMI

L2__O3__TPR (KNMI) Tropospheric ozone profile with a vertical resolution of 6 km and a horizontal resolution of $7 \times 7 \text{ km}^2$ observed at about 13:30 local solar time from spectra measured by TROPOMI

L2__CH4__ (SRON) Dry-air mixing ratio of methane for cloud-free observations with a spatial resolution of $7 \times 7 \text{ km}^2$ observed at about 13:30 local solar time from spectra measured by TROPOMI

L2__CO__ (SRON) Carbon monoxide column with a spatial resolution of $7 \times 7 \text{ km}^2$ observed at about 13:30 local solar time from spectra measured by TROPOMI

L2__FRESCO (KNMI) Cloud fraction and cloud pressure with a spatial resolution of $3.5 \times 7 \text{ km}^2$ observed at about 13:30 local solar time from spectra measured by TROPOMI (KNMI cloud support product)

gmd:credit	'%(credit)s' (static)	NC_STRING
Recognition of those who contributed to the resource(s).		
gmd:language	'eng' (static)	NC_STRING
gmd:topicCategory	'climatologyMeteorologyAtmosphere' (static)	NC_STRING
Main theme(s) of the dataset.		
objectType	'gmd:MD_DataIdentification' (static)	NC_STRING
Name of the metadata class [RD35, table 10].		

10.2.3.10 Group “gmd:citation” in “gmd:identificationInfo”

Citation data for the resource.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:citation

Group attributes attached to gmd:citation		
<i>Name</i>	<i>Value</i>	<i>Type</i>
gmd:title		NC_STRING
Name by which the cited resource is known. This is the same as the global “title” attribute.		
objectType	'gmd:CI_Citation' (static)	NC_STRING
Name of the metadata class [RD35, table 11].		

10.2.3.11 Group “gmd:date” in “gmd:citation”

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:citation/gmd:date

Group attributes attached to gmd:date		
<i>Name</i>	<i>Value</i>	<i>Type</i>
gmd:date	'%(processor_release_date)s' (static)	NC_STRING
objectType	'gmd:CI_Date' (static)	NC_STRING

10.2.3.12 Group “gmd:dateType” in “gmd:date”

Event used for reference date.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:citation/gmd:date/gmd:dateType

Group attributes attached to gmd:dateType		
Name	Value	Type
codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode' (static)	NC_STRING
codeListValue	'creation' (static)	NC_STRING
objectType	'gmd:CI_DateTypeCode' (static)	NC_STRING

10.2.3.13 Group “gmd:identifier” in “gmd:citation”

Unique identifier for metadata file, see the Level 1B metadata specification [RD35, table 5] for a discussion of the value.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:citation/gmd:identifier

Group attributes attached to gmd:identifier		
Name	Value	Type
gmd:code	'urn:ogc:def:EOP:ESA:SENTINEL.S5P_TROP_-%(shortname)s' (dynamic)	NC_STRING
Replace “%(shortname)s” with the “ProductShortName” value from the Level 2 “/METADATA/GRANULE_-DESCRIPTION” metadata group.		
objectType	'gmd:MD_Identifier' (static)	NC_STRING

10.2.3.14 Group “gmd:pointOfContact” in “gmd:identificationInfo”

See description of the “gmd:contact” attribute above.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:pointOfContact

Group attributes attached to gmd:pointOfContact		
Name	Value	Type
gmd:organisationName	'Copernicus Space Component Data Access System, ESA, Services Coordinated Interface' (static)	NC_STRING
objectType	'gmd:CI_ResponsibleParty' (static)	NC_STRING

10.2.3.15 Group “gmd:contactInfo” in “gmd:pointOfContact”

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:pointOfContact/gmd:contactInfo

Group attributes attached to gmd:contactInfo		
Name	Value	Type
objectType	'gmd:CI_Contact' (static)	NC_STRING

10.2.3.16 Group “gmd:address” in “gmd:contactInfo”

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:pointOfContact/gmd:contactInfo/gmd:address

Group attributes attached to gmd:address

Name	Value	Type
gmd:electronicMailAddress	'EOSupport@copernicus.esa.int' (static)	NC_STRING
objectType	'gmd:CI_Address' (static)	NC_STRING

10.2.3.17 Group “gmd:role” in “gmd:pointOfContact”

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:pointOfContact/gmd:role

Group attributes attached to gmd:role

Name	Value	Type
codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodestats.xml#CI_RoleCode' (static)	NC_STRING
codeListValue	'distributor' (static)	NC_STRING
objectType	'gmd:CI_RoleCode' (static)	NC_STRING

10.2.3.18 Group “gmd:descriptiveKeywords#1” in “gmd:identificationInfo”

Provides category keywords, their type, and reference source. Within the framework of GEMET the choice of keywords is very limited. More meaningful keywords can be derived from the Climate and Forecast metadata conventions' standard name list, see “gmd:descriptiveKeywords#2” below.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#1

Group attributes attached to gmd:descriptiveKeywords#1

Name	Value	Type
gmd:keyword#1	'Atmospheric conditions' (static)	NC_STRING
objectType	'gmd:MD_Keywords' (static)	NC_STRING

10.2.3.19 Group “gmd:type” in “gmd:descriptiveKeywords#1”

Subject matter used to group similar keywords.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#1/gmd:type

Group attributes attached to gmd:type

Name	Value	Type
codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodestats.xml#MD_KeywordTypeCode' (static)	NC_STRING
codeListValue	'theme' (static)	NC_STRING
objectType	'gmd:MD_KeywordTypeCode' (static)	NC_STRING

10.2.3.20 Group “gmd:thesaurusName” in “gmd:descriptiveKeywords#1”

Name by which the cited resource is known.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#1/gmd:thesaurusName

Group attributes attached to gmd:thesaurusName

Name	Value	Type
gmd:title	'GEMET - INSPIRE themes, version 1.0' (static)	NC_STRING
objectType	'gmd:CI_Citation' (static)	NC_STRING

10.2.3.21 Group “gmd:date” in “gmd:thesaurusName”

Reference date for the cited resource.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#1/gmd:thesaurusName/gmd:date

Group attributes attached to gmd:date		
Name	Value	Type
gmd:date	'2008-06-01' (static)	NC_STRING
objectType	'gmd:CI_Date' (static)	NC_STRING

10.2.3.22 Group “gmd:dateType” in “gmd:date”

What date is used for the reference date.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#1/gmd:thesaurusName/gmd:date/gmd:dateType

Group attributes attached to gmd:dateType		
Name	Value	Type
codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodetables.xml#CI_DateTypeCode' (static)	NC_STRING
codeListValue	'publication' (static)	NC_STRING
objectType	'gmd:CI_DateTypeCode' (static)	NC_STRING

10.2.3.23 Group “gmd:descriptiveKeywords#2” in “gmd:identificationInfo”

Provides category keywords, their type, and reference source. These keywords are taken from the Climate and Forecast metadata conventions' standard name list [ER5]. The keywords listed below identify the most important parameters in the product.

L2_AER_AI (KNMI) ultraviolet_aerosol_index

L2_AER_LH (KNMI) height_of_elevated_aerosol_layer

L2_NO2__ (KNMI) troposphere_mole_content_of_nitrogen_dioxide, stratosphere_mole_content_of_nitrogen_dioxide, atmosphere_mole_content_of_nitrogen_dioxide

L2_O3_PR (KNMI) mole_fraction_of_ozone_in_air

L2_O3_TPR (KNMI) mole_fraction_of_ozone_in_air

L2_CH4__ (SRON) atmosphere_mole_fraction_of_methane_in_dry_air

L2_CO__ (SRON) atmosphere_mole_content_of_carbon_monoxide

L2_FRESCO (KNMI) air_pressure_at_cloud_optical_centroid, effective_cloud_area_fraction_assuming_fixed_cloud_albedo, cloud_albedo_assuming_completely_cloudy_sky, air_pressure_at_cloud_optical_centroid_assuming_completely_cloudy_sky

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#2

Group attributes attached to gmd:descriptiveKeywords#2		
Name	Value	Type
gmd:keyword#1		NC_STRING
objectType	'gmd:MD_Keywords' (static)	NC_STRING

10.2.3.24 Group “gmd:thesaurusName” in “gmd:descriptiveKeywords#2”

Name by which the cited resource is known.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#2/gmd:thesaurusName

Group attributes attached to gmd:thesaurusName		
Name	Value	Type
gmd:title	'CF Standard Name Table v65' (static)	NC_STRING
xlink:href	'http://cfconventions.org/standard-names.html' (dynamic)	NC_STRING
objectType	'gmd:CI_Citation' (static)	NC_STRING

10.2.3.25 Group “gmd:date” in “gmd:thesaurusName”

Reference date for the cited resource.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#2/gmd:thesaurusName/gmd:date

Group attributes attached to gmd:date		
Name	Value	Type
gmd:date	'2019-04-09' (static)	NC_STRING
objectType	'gmd:CI_Date' (static)	NC_STRING

10.2.3.26 Group “gmd:dateType” in “gmd:date”

What date is used for the reference date.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#2/gmd:thesaurusName/gmd:date/gmd:dateType

Group attributes attached to gmd:dateType		
Name	Value	Type
codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode' (static)	NC_STRING
codeListValue	'publication' (static)	NC_STRING
objectType	'gmd:CI_DateTypeCode' (static)	NC_STRING

10.2.3.27 Group “gmd:resourceConstraints” in “gmd:identificationInfo”

Provides information about constraints which apply to the resource.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:resourceConstraints

Group attributes attached to gmd:resourceConstraints		
Name	Value	Type
gmd:useLimitation	'no conditions apply' (static)	NC_STRING
Limitation affecting the fitness for use of the resource or metadata.		
objectType	'gmd:MD_LegalConstraints' (static)	NC_STRING

10.2.3.28 Group “gmd:accessConstraints” in “gmd:resourceConstraints”

Access constraints applied to assure the protection of privacy or intellectual property, and any special restrictions or limitations on obtaining the resource or metadata.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:resourceConstraints/gmd:accessConstraints

Group attributes attached to gmd:accessConstraints		
Name	Value	Type

codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MD_RestrictionCode' (static)	NC_STRING
codeListValue	'copyright' (static)	NC_STRING
objectType	'gmd:MD_RestrictionCode' (static)	NC_STRING

10.2.3.29 Group “gmd:spatialRepresentationType” in “gmd:identificationInfo”

Method used to spatially represent geographic information.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:spatialRepresentationType

Group attributes attached to gmd:spatialRepresentationType		
<i>Name</i>	<i>Value</i>	<i>Type</i>
codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MD_SpatialRepresentation-TypeCode' (static)	NC_STRING
codeListValue	'grid' (static)	NC_STRING
objectType	'gmd:MD_SpatialRepresentationTypeCode' (static)	NC_STRING

10.2.3.30 Group “gmd:characterSet” in “gmd:identificationInfo”

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:characterSet

Group attributes attached to gmd:characterSet		
<i>Name</i>	<i>Value</i>	<i>Type</i>
codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MD_CharacterSetCode' (static)	NC_STRING
codeListValue	'utf8' (static)	NC_STRING
objectType	'gmd:MD_CharacterSetCode' (static)	NC_STRING

10.2.3.31 Group “gmd:extent” in “gmd:identificationInfo”

Extent information including the bounding box, bounding polygon, vertical, and temporal extent of the dataset.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:extent

Group attributes attached to gmd:extent		
<i>Name</i>	<i>Value</i>	<i>Type</i>
objectType	'gmd:EX_Extent' (static)	NC_STRING

10.2.3.32 Group “gmd:geographicElement” in “gmd:extent”

Geographic position of the granule. This is only an approximate reference so specifying the coordinate reference system is unnecessary. The usual limitations apply: $-180^\circ \leq \vartheta \leq 180^\circ$ and $-90^\circ \leq \delta \leq 90^\circ$. Note that for full orbits these values provide little information as at least one pole will be present in the data, ensuring full longitudinal coverage.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:extent/gmd:geographicElement

Group attributes attached to gmd:geographicElement		
<i>Name</i>	<i>Value</i>	<i>Type</i>
gmd:eastBoundLongitude	180.0 (dynamic)	NC_FLOAT
gmd:northBoundLatitude	90.0 (dynamic)	NC_FLOAT
gmd:southBoundLatitude	-90.0 (dynamic)	NC_FLOAT
gmd:westBoundLongitude	-180.0 (dynamic)	NC_FLOAT

gmd:extentTypeCode	'true' (static)	NC_STRING
Indication of whether the bounding polygon encompasses an area covered by the data or an area where data is not present. The value "true" indicates <i>inclusion</i> .		
objectType	'gmd:EX_GeographicBoundingBox' (static)	NC_STRING

10.2.3.33 Group "gmd:temporalElement" in "gmd:extent"

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:extent/gmd:temporalElement

Group attributes attached to gmd:temporalElement		
Name	Value	Type
objectType	'gmd:EX_TemporalExtent' (static)	NC_STRING

10.2.3.34 Group "gmd:extent" in "gmd:temporalElement"

Time period covered by the content of the dataset.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:extent/gmd:temporalElement/gmd:extent

Group attributes attached to gmd:extent		
Name	Value	Type
gml:beginPosition	'2014-11-14T19:58:00' (dynamic)	NC_STRING
Time of the start of the granule, expressed as ISO 8601 [RD36] date-time string.		
gml:endPosition	'2014-11-14T20:08:00' (dynamic)	NC_STRING
Time of the end of the granule, expressed as ISO 8601 [RD36] date-time string.		
objectType	'gml:TimePeriod' (static)	NC_STRING

10.2.3.35 Group "gmd:dataQualityInfo" in "ISO_METADATA"

This group contains a general assessment of the quality of the dataset. In addition, the package contains information about the sources and production processes used in producing a dataset, which is of particular importance for imagery and gridded data.

For the TROPOMI level 2 products the use of the contained class LI_Lineage (group "gmd:lineage", section 10.2.3.43 on page 83) is important for describing the sources which are either used or produced (output) in a series of process steps. The sources refer to the various L1b data products used as inputs (and the L0 products used in producing *those* products) and the auxiliary data (static and especially dynamic) when producing the L2 products.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo

Group attributes attached to gmd:dataQualityInfo		
Name	Value	Type
objectType	'gmd:DQ_DataQuality' (static)	NC_STRING

10.2.3.36 Group "gmd:scope" in "gmd:dataQualityInfo"

The specific data to which the data quality information applies.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:scope

Group attributes attached to gmd:scope		
Name	Value	Type
objectType	'gmd:DQ_Scope' (static)	NC_STRING

10.2.3.37 Group “gmd:level” in “gmd:scope”

Hierarchical level of the data specified by the scope.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:scope/gmd:level

Group attributes attached to gmd:level		
Name	Value	Type
codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodetlists.xml#MD_ScopeCode' (static)	NC_STRING
codeListValue	'dataset' (static)	NC_STRING
objectType	'gmd:MD_ScopeCode' (static)	NC_STRING

10.2.3.38 Group “gmd:report” in “gmd:dataQualityInfo”

Value (or set of values) obtained from applying a data quality measure or the outcome of evaluating the obtained value (or set of values) against a specified acceptable conformance quality level.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:report

Group attributes attached to gmd:report		
Name	Value	Type
objectType	'gmd:DQ_DomainConsistency' (static)	NC_STRING

10.2.3.39 Group “gmd:result” in “gmd:report”

Value (or set of values) obtained from applying a data quality measure or the outcome of evaluating the obtained value (or set of values) against a specified acceptable conformance quality level.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:report/gmd:result

Group attributes attached to gmd:result		
Name	Value	Type
objectType	'gmd:DQ_ConformanceResult' (static)	NC_STRING
gmd:pass	'true' (static)	NC_STRING
Indication of conformance result. The value “true” indicates “pass”.		
gmd:explanation	'INSPIRE Data specification for orthoimagery is not yet officially published so conformity has not yet been evaluated' (static)	NC_STRING
Explanation of the meaning of conformance for this result. Within the context of INSPIRE conformance can currently not be determined.		

10.2.3.40 Group “gmd:specification” in “gmd:result”

Citation of product specification or user requirement against which data is being evaluated.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:report/gmd:result/gmd:specification

Group attributes attached to gmd:specification		
Name	Value	Type
objectType	'gmd:CI_Citation' (static)	NC_STRING
gmd:title	'INSPIRE Data Specification on Orthoimagery - Guidelines, version 3.0rc3' (static)	NC_STRING

10.2.3.41 Group “gmd:date” in “gmd:specification”

Reference date for the cited resource.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:report/gmd:result/gmd:specification/

gmd:date

Group attributes attached to gmd:date		
<i>Name</i>	<i>Value</i>	<i>Type</i>
gmd:date	'2013-02-04' (static)	NC_STRING
objectType	'gmd:CI_Date' (static)	NC_STRING

10.2.3.42 Group “gmd:dateType” in “gmd:date”

Meaning of the reference date for the cited resource.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:report/gmd:result/gmd:specification/gmd:date/gmd:dateType

Group attributes attached to gmd:dateType		
<i>Name</i>	<i>Value</i>	<i>Type</i>
codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodetables.xml#CI_DateTypeCode' (static)	NC_STRING
codeListValue	'publication' (static)	NC_STRING
objectType	'gmd:CI_DateTypeCode' (static)	NC_STRING

10.2.3.43 Group “gmd:lineage” in “gmd:dataQualityInfo”

Non-quantitative quality information about the lineage of the data specified by the scope.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage

Group attributes attached to gmd:lineage		
<i>Name</i>	<i>Value</i>	<i>Type</i>
objectType	'gmd:LI_Lineage' (static)	NC_STRING
gmd:statement	'L2 %(product)s dataset produced by %(processingcenter)s from the S5P/TROPOMI L1B product' (dynamic)	NC_STRING

General explanation of the data producer’s knowledge about the lineage of a dataset. Insert short description of the actual Level 2 product in this string (at the %(...)s).

10.2.3.44 Group “gmd:processStep” in “gmd:lineage”

Information about an event or transformation in the life of the dataset including details of the algorithm and software used for processing.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep

Group attributes attached to gmd:processStep		
<i>Name</i>	<i>Value</i>	<i>Type</i>
objectType	'gmi:LE_ProcessStep' (static)	NC_STRING
gmd:description	'Processing of L1b to L2 %(product)s data for orbit %(orbit)d using the %(institute)s processor version %(version)s' (dynamic)	NC_STRING

Description of the event, including related parameters or tolerances. Insert short description of the actual Level 2 product, the orbit number, the name of the institute responsible for the CFI and the software version in this string (at the respective %(...)s and %(...)d).

10.2.3.45 Group “gmi:output” in “gmd:processStep”

Description of the output.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:output

Group attributes attached to gmi:output

<i>Name</i>	<i>Value</i>	<i>Type</i>
gmd:description		NC_STRING
Short description of the output, a copy of the global 'title' attribute.		
objectType	'gmi:LE_Source' (static)	NC_STRING

10.2.3.46 Group “gmd:sourceCitation” in “gmi:output”

Reference to the actual filename of the output data and production date and time.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:output/gmd:sourceCitation

Group attributes attached to gmd:sourceCitation

<i>Name</i>	<i>Value</i>	<i>Type</i>
gmd:title	'%(logical_filename)s' (dynamic)	NC_STRING
Output file name without extension.		
objectType	'gmd:CI_Citation' (static)	NC_STRING

10.2.3.47 Group “gmd:date” in “gmd:sourceCitation”

Production date and time of the output file.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:output/gmd:sourceCitation/gmd:date

Group attributes attached to gmd:date

<i>Name</i>	<i>Value</i>	<i>Type</i>
gmd:date		NC_STRING
Production date and time of the output file. Note that the definition in the XML schema appears to allow the use of a “CI_DateTime” instead of a “CI_Date”.		
objectType	'gmd:CI_DateTime' (static)	NC_STRING

10.2.3.48 Group “gmd:dateType” in “gmd:date”

Meaning of the reference date for the cited resource.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:output/gmd:sourceCitation/gmd:date/gmd:dateType

Group attributes attached to gmd:dateType

<i>Name</i>	<i>Value</i>	<i>Type</i>
codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode' (static)	NC_STRING
codeListValue	'creation' (static)	NC_STRING
objectType	'gmd:CI_DateTypeCode' (static)	NC_STRING

10.2.3.49 Group “gmd:identifier” in “gmd:sourceCitation”

Identification of the output product.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:output/gmd:sourceCitation/gmd:identifier

Group attributes attached to gmd:identifier

<i>Name</i>	<i>Value</i>	<i>Type</i>
gmd:code	'%(shortname)s' (dynamic)	NC_STRING

The product short name, a copy of the 'ProductShortName' attribute in '/METADATA/GRANULE_DESCRIPTION'.

objectType	'gmd:MD_Identifier' (static)	NC_STRING
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10.2.3.50 Group "gmi:processedLevel" in "gmi:output"

Process level of the output file.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:output/gmi:processedLevel

Group attributes attached to gmi:processedLevel		
Name	Value	Type
gmd:code	'L2' (static)	NC_STRING
objectType	'gmd:MD_Identifier' (static)	NC_STRING

10.2.3.51 Group "gmi:processingInformation" in "gmd:processStep"

Description of the processor in more detail.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInformation

Group attributes attached to gmi:processingInformation		
Name	Value	Type
objectType	'gmi:LE_Processing' (static)	NC_STRING

10.2.3.52 Group "gmi:identifier" in "gmi:processingInformation"

Identification of the processor.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:identifier

Group attributes attached to gmi:identifier		
Name	Value	Type
gmd:code	'%(institute)s L2 %(product)s processor, version %(version)s' (dynamic)	NC_STRING
Descriptive name of the processor, with the %(...)s placeholders replaced with the responsible institute's name, product name and software release version.		
objectType	'gmd:MD_Identifier' (static)	NC_STRING

10.2.3.53 Group "gmi:softwareReference" in "gmi:processingInformation"

Reference to document describing processing software.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:softwareReference

Group attributes attached to gmi:softwareReference		
Name	Value	Type
gmd:title	'L2 %(product)s processor description' (dynamic)	NC_STRING
Title of processor description.		
objectType	'gmd:CI_Citation' (static)	NC_STRING

10.2.3.54 Group "gmd:date" in "gmi:softwareReference"

Release date (compile date) of the processor.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:softwareReference/gmd:date

Group attributes attached to gmd:date		
Name	Value	Type
gmd:date		NC_STRING
	Release date of the processor expressed as an ISO 8601 date string [RD36].	
objectType	'gmd:CI_DateTime' (static)	NC_STRING

10.2.3.55 Group “gmd:dateType” in “gmd:date”

Confirm that this is the release date of the processor.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:softwareReference/gmd:date/gmd:dateType

Group attributes attached to gmd:dateType		
Name	Value	Type
codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodeLists.xml#CI_DateTypeCode' (static)	NC_STRING
codeListValue	'creation' (static)	NC_STRING
objectType	'gmd:CI_DateTypeCode' (static)	NC_STRING

10.2.3.56 Group “gmi:documentation#1” in “gmi:processingInformation”

Reference to the ATBD of the product.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:documentation#1

Group attributes attached to gmi:documentation#1		
Name	Value	Type
objectType	'gmd:CI_Citation' (static)	NC_STRING
gmd:title	'%(title_atbd)s' (dynamic)	NC_STRING
	Specification of the current release of the ATBD of the product.	
doi	'%(atbd_doi)s' (dynamic)	NC_STRING
	DOI for the algorithm theoretical basis document.	

10.2.3.57 Group “gmd:date” in “gmi:documentation#1”

Release date of the ATBD.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:documentation#1/gmd:date

Group attributes attached to gmd:date		
Name	Value	Type
gmd:date	'%(date_atbd)s' (dynamic)	NC_STRING
	Release date of the ATBD expressed as an ISO 8601 date string [RD36].	
objectType	'gmd:CI_Date' (static)	NC_STRING

10.2.3.58 Group “gmd:dateType” in “gmd:date”

Specify the type of the date of the ATBD (revision of publication).

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:documentation#1/gmd:date/gmd:dateType

Group attributes attached to gmd:dateType		
Name	Value	Type
codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodetlists.xml#CI_DateTypeCode' (static)	NC_STRING
codeListValue	'revision' (static)	NC_STRING
objectType	'gmd:CI_DateTypeCode' (static)	NC_STRING

10.2.3.59 Group “gmi:documentation#2” in “gmi:processingInformation”

Reference to the PUM of the product.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:documentation#2

Group attributes attached to gmi:documentation#2		
Name	Value	Type
objectType	'gmd:CI_Citation' (static)	NC_STRING
gmd:title	'%(title_pum)s' (dynamic) Specification of the current release of the PUM of the product.	NC_STRING
doi	'%(pum_doi)s' (dynamic) DOI for the product user manual.	NC_STRING

10.2.3.60 Group “gmd:date” in “gmi:documentation#2”

Release date of the PUM.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:documentation#2/gmd:date

Group attributes attached to gmd:date		
Name	Value	Type
gmd:date	'%(date_pum)s' (dynamic) Release date of the PUM expressed as an ISO 8601 date string [RD36].	NC_STRING
objectType	'gmd:CI_Date' (static)	NC_STRING

10.2.3.61 Group “gmd:dateType” in “gmd:date”

Specify the type of the date of the PUM (revision of publication).

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:documentation#2/gmd:date/gmd:dateType

Group attributes attached to gmd:dateType		
Name	Value	Type
codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodetlists.xml#CI_DateTypeCode' (static)	NC_STRING
codeListValue	'revision' (static)	NC_STRING
objectType	'gmd:CI_DateTypeCode' (static)	NC_STRING

10.2.3.62 Group “gmi:report” in “gmd:processStep”

Short report of what occurred during the process step.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:report

Group attributes attached to gmi:report

<i>Name</i>	<i>Value</i>	<i>Type</i>
gmi:description	'Sentinel 5-precursor TROPOMI L1b processed to L2 data using the %(institute)s L2 %(product)s processor' (dynamic)	NC_STRING
Textual description of what occurred during the process step. Replace %(. . .)s as indicated.		
gmi:fileType	'netCDF-4' (static)	NC_STRING
Type of file that contains the processing report, in our case the processing report is contained in the main output file.		
gmi:name	'%(logical_filename)s.nc' (dynamic)	NC_STRING
objectType	'gmi:LE_ProcessStepReport' (dynamic)	NC_STRING

10.2.3.63 Group “gmd:source#1” in “gmd:processStep”

Information about the source data used in creating the data specified by the scope. Repeat group as needed, incrementing the number of the source (after the # mark).

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmd:source#1

Group attributes attached to gmd:source#1

<i>Name</i>	<i>Value</i>	<i>Type</i>
objectType	'gmi:LE_Source' (static)	NC_STRING
gmd:description		NC_STRING
Description of the input data, including L1B, L2, dynamic auxiliary input data and semi-static auxiliary input data. Base strings are “TROPOMI L1B %s radiance product”, “TROPOMI L1B %s irradiance product”, “TROPOMI L2 %s product”, “Auxiliary ECMWF %s Meteorological forecast data”, “Processor %s configuration file”, “Auxiliary %s reference data”, “Auxiliary %s algorithm lookup table”, “Auxiliary CTM %s model input data”, “Auxiliary snow and ice input data” and “Auxiliary NPP/VIIRS cloud screening input data”. The %s to be replaced with specific descriptors.		

10.2.3.64 Group “gmi:processedLevel” in “gmd:source#1”

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmd:source#1/gmi:processedLevel

Group attributes attached to gmi:processedLevel

<i>Name</i>	<i>Value</i>	<i>Type</i>
gmd:code	<i>Empty!</i>	NC_STRING
objectType	'gmd:MD_Identifier' (static)	NC_STRING

10.2.3.65 Group “gmd:sourceCitation” in “gmd:source#1”

Reference to the actual filename of the input data.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmd:source#1/gmd:sourceCitation

Group attributes attached to gmd:sourceCitation

<i>Name</i>	<i>Value</i>	<i>Type</i>
objectType	'gmd:CI_Citation' (static)	NC_STRING

10.2.3.66 Group “gmd:date” in “gmd:sourceCitation”

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmd:source#1/gmd:sourceCitation/gmd:date

Group attributes attached to gmd:date		
Name	Value	Type
gmd:date		NC_STRING
Production date and time of the input file(s) in this group expressed as an ISO 8601 date-time string [RD36]. Note that the definition in the XML schema appears to allow the use of a “CI_DateTime” instead of a “CI_Date”.		
objectType	‘gmd:CI_Date’ (static)	NC_STRING

10.2.3.67 Group “gmd:dateType” in “gmd:date”

Meaning of the reference date for the cited resource.

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmd:source#1/gmd:sourceCitation/gmd:date/gmd:dateType

Group attributes attached to gmd:dateType		
Name	Value	Type
codeList	‘http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode’ (static)	NC_STRING
codeListValue	‘creation’ (static)	NC_STRING
objectType	‘gmd:CI_DateTypeCode’ (static)	NC_STRING

10.2.3.68 Group “gmd:title” in “gmd:sourceCitation”

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmd:source#1/gmd:sourceCitation/gmd:title

Group attributes attached to gmd:title		
Name	Value	Type
gco:characterString		NC_STRING
Textual description of the input file group (same as the “gmd:description” attribute in the “gmi:LE_Source” object).		

10.2.3.69 Group “gmd:alternateTitle#1” in “gmd:sourceCitation”

All filenames in this group, in case more files of a particular file type are delivered, for instance for meteorological or model input. Repeat group as needed, incrementing the number of the input file (after the # mark).

Attributes in AER_LH/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmd:source#1/gmd:sourceCitation/gmd:alternateTitle#1

Group attributes attached to gmd:alternateTitle#1		
Name	Value	Type
gmx:FileName	Empty!	NC_STRING
The basename of the input file.		

10.2.3.70 Group “gmi:acquisitionInformation” in “ISO_METADATA”

Metadata regarding the acquisition of the original data.

Attributes in AER_LH/METADATA/ISO_METADATA/gmi:acquisitionInformation

Group attributes attached to gmi:acquisitionInformation

Name	Value	Type
objectType	'gmi:MI_AcquisitionInformation' (static)	NC_STRING

10.2.3.71 Group “gmi:platform” in “gmi:acquisitionInformation”

The platform we are on.

Attributes in AER_LH/METADATA/ISO_METADATA/gmi:acquisitionInformation/gmi:platform

Group attributes attached to gmi:platform

Name	Value	Type
gmi:description	'Sentinel 5 Precursor' (static)	NC_STRING
objectType	'gmi:MI_Platform' (static)	NC_STRING

10.2.3.72 Group “gmi:identifier” in “gmi:platform”

Short identifier of the platform.

Attributes in AER_LH/METADATA/ISO_METADATA/gmi:acquisitionInformation/gmi:platform/gmi:identifier

Group attributes attached to gmi:identifier

Name	Value	Type
gmd:code	'S5P' (static)	NC_STRING
gmd:codeSpace	'http://www.esa.int/' (static)	NC_STRING
objectType	'gmd:RS_Identifier' (static)	NC_STRING

10.2.3.73 Group “gmi:instrument” in “gmi:platform”

The instrument used for the observations.

Attributes in AER_LH/METADATA/ISO_METADATA/gmi:acquisitionInformation/gmi:platform/gmi:instrument

Group attributes attached to gmi:instrument

Name	Value	Type
objectType	'gmi:MI_Instrument' (static)	NC_STRING
gmi:type	'UV-VIS-NIR-SWIR imaging spectrometer' (static)	NC_STRING

Type of the instrument.

10.2.3.74 Group “gmi:identifier” in “gmi:instrument”

Unique identifier for the instrument.

Attributes in AER_LH/METADATA/ISO_METADATA/gmi:acquisitionInformation/gmi:platform/gmi:instrument/gmi:identifier

Group attributes attached to gmi:identifier

Name	Value	Type
gmd:code	'TROPOMI' (static)	NC_STRING
The actual identifier.		
gmd:codeSpace	'http://www.esa.int/' (static)	NC_STRING
Name or identifier of the organization responsible for the namespace.		
objectType	'gmd:RS_Identifier' (static)	NC_STRING

10.2.3.75 Group “EOP_METADATA” in “EOP_metadata”

Based on the OGC 10-025 standard for Observations & Measurements [RD40], an Earth Observation Product (EOP) schema was developed which refines an observation into the feature type earth observation. This

schema was then extended with sensor-specific thematic schemas.

Attributes in AER_LH/METADATA/EOP_METADATA

Group attributes attached to EOP_METADATA		
Name	Value	Type
gml:id	'%(logical_filename)s.ID' (dynamic)	NC_STRING
Unique ID for this "atm:EarthObservation" object. Constructed from the logical output filename and the extension "ID" separated by a dot.		
objectType	'atm:EarthObservation' (static)	NC_STRING

10.2.3.76 Group "om:phenomenonTime" in "EOP_METADATA"

Time coverage of the granule.

Attributes in AER_LH/METADATA/EOP_METADATA/om:phenomenonTime

Group attributes attached to om:phenomenonTime		
Name	Value	Type
gml:beginPosition		NC_STRING
Start of time coverage of the data in the granule expressed as an ISO 8601 date-time string [RD36].		
gml:endPosition		NC_STRING
End of time coverage of the data in the granule expressed as an ISO 8601 date-time string [RD36].		
objectType	'gml:TimePeriod' (static)	NC_STRING

10.2.3.77 Group "om:procedure" in "EOP_METADATA"

Platform, instrument and sensor used for the acquisition and the acquisition parameters.

Attributes in AER_LH/METADATA/EOP_METADATA/om:procedure

Group attributes attached to om:procedure		
Name	Value	Type
gml:id	'%(logical_filename)s.EOE' (dynamic)	NC_STRING
Unique ID for this "eop:EarthObservationEquipment" object. Constructed from the logical output filename and the extension "EOE" separated by a dot.		
objectType	'eop:EarthObservationEquipment' (static)	NC_STRING

10.2.3.78 Group "eop:platform" in "om:procedure"

Platform name and orbit type.

Attributes in AER_LH/METADATA/EOP_METADATA/om:procedure/eop:platform

Group attributes attached to eop:platform		
Name	Value	Type
eop:shortName	'Sentinel-5p' (static)	NC_STRING
objectType	'eop:Platform' (static)	NC_STRING

10.2.3.79 Group "eop:instrument" in "om:procedure"

Instrument descriptor.

Attributes in AER_LH/METADATA/EOP_METADATA/om:procedure/eop:instrument

Group attributes attached to eop:instrument		
Name	Value	Type
eop:shortName	'TROPOMI' (static)	NC_STRING

objectType	'eop:Instrument' (static)	NC_STRING
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10.2.3.80 Group “eop:sensor” in “om:procedure”

Sensor description.

Attributes in AER_LH/METADATA/EOP_METADATA/om:procedure/eop:sensor

Group attributes attached to eop:sensor		
Name	Value	Type
eop:sensorType	'ATMOSPHERIC' (static)	NC_STRING
objectType	'eop:Sensor' (static)	NC_STRING

10.2.3.81 Group “eop:acquisitionParameters” in “om:procedure”

Additional parameters describing the data acquisition. Only an orbit number is used here.

Attributes in AER_LH/METADATA/EOP_METADATA/om:procedure/eop:acquisitionParameters

Group attributes attached to eop:acquisitionParameters		
Name	Value	Type
eop:orbitNumber	0 (dynamic)	NC_INT
objectType	'eop:Acquisition' (static)	NC_STRING

10.2.3.82 Group “om:observedProperty” in “EOP_METADATA”

An xlink to the observed property definition.

Attributes in AER_LH/METADATA/EOP_METADATA/om:observedProperty

Group attributes attached to om:observedProperty		
Name	Value	Type
nilReason	'inapplicable' (dynamic)	NC_STRING
This element should use the attribute 'nilReason="inapplicable"'. 		

10.2.3.83 Group “om:featureOfInterest” in “EOP_METADATA”

Attributes in AER_LH/METADATA/EOP_METADATA/om:featureOfInterest

Group attributes attached to om:featureOfInterest		
Name	Value	Type
objectType	'eop:FootPrint' (static)	NC_STRING
gml:id	'%(logical_filename)s.FP' (dynamic)	NC_STRING
Unique ID for this “eop:FootPrint” object. Constructed from the logical output filename and the extension “FP” separated by a dot.		

10.2.3.84 Group “eop:multiExtentOf” in “om:featureOfInterest”

Acquisition footprint coordinates, described by a closed polygon – the last point is equal to the first point, using latitude, longitude pairs. The expected structure is “gml:Polygon/gml:exterior/gml:LinearRing/gml:posList”.

Attributes in AER_LH/METADATA/EOP_METADATA/om:featureOfInterest/eop:multiExtentOf

Group attributes attached to eop:multiExtentOf		
Name	Value	Type
objectType	'gml:MultiSurface' (static)	NC_STRING

10.2.3.85 Group “gml:surfaceMembers” in “eop:multiExtentOf”

Attributes in AER_LH/METADATA/EOP_METADATA/om:featureOfInterest/eop:multiExtentOf/gml:surfaceMembers

Group attributes attached to gml:surfaceMembers		
Name	Value	Type
objectType	'gml:Polygon' (static)	NC_STRING

10.2.3.86 Group “gml:exterior” in “gml:surfaceMembers”

Attributes in AER_LH/METADATA/EOP_METADATA/om:featureOfInterest/eop:multiExtentOf/gml:surfaceMembers/gml:exterior

Group attributes attached to gml:exterior		
Name	Value	Type
gml:posList		NC_STRING
The Polygon geometry shall be encoded in the EPSG:4326 geographic coordinate reference system (WGS-84) and the coordinate pairs shall be ordered as latitude/longitude. Polygons enclose areas with points listed in counter-clockwise direction.		
objectType	'gml:LinearRing' (static)	NC_STRING

10.2.3.87 Group “eop:metaDataProperty” in “EOP_METADATA”

This group contains all the metadata relative to the Earth observation product that do not fit inside one of the other groups, i.e. metadata that do not describe the time, the mechanism, the location or the result of the observation.

These metadata are mainly the EarthObservation identifier, the acquisition type and information relative to the downlink and archiving centers.

Attributes in AER_LH/METADATA/EOP_METADATA/eop:metaDataProperty

Group attributes attached to eop:metaDataProperty		
Name	Value	Type
objectType	'eop:EarthObservationMetaData' (static)	NC_STRING
eop:acquisitionType	'NOMINAL' (dynamic)	NC_STRING
Used to distinguish at a high level the appropriateness of the acquisition for “general” use, whether the product is a nominal acquisition, special calibration product or other. Copy from L1b. For Level 2 this should <i>always</i> be 'NOMINAL'.		
eop:identifier	'%(logical_filename)s' (dynamic)	NC_STRING
Logical file name.		
eop:doi	'%(product_doi)s' (dynamic)	NC_STRING
Digital Object Identifier identifying the product (see http://www.datacite.org for DOIs for datasets).		
eop:parentIdentifier	'urn:ogc:def:EOP:ESA:SENTINEL.S5P_TROP_ - %(shortname)s' (dynamic)	NC_STRING
Unique collection identifier for metadata file, see the Level 1B metadata specification [RD35, table 5] for a discussion of the value.		
This is a copy of the “gmd:fileIdentifier” attribute in the “/METADATA/ISO_METADATA” group.		
eop:productType	'S5P_%(mode)s_%(product)s' (dynamic)	NC_STRING
Product type identifier. Replace %(mode)s with the operational mode the processor is running in ('NRTI', 'OFFL' or 'RPRO', as per [RD25]) and %(product)s with the 10 character output file name semantic descriptors as given in [RD41, RD42, RD43].		
eop:status	'ACQUIRED' (dynamic)	NC_STRING

Refers to product status. Values listed in the standard: 'ARCHIVED', 'ACQUIRED', 'CANCELLED', 'FAILED', 'PLANNED', 'POTENTIAL', 'REJECTED', 'QUALITY-DEGRADED'. Copied from L1B.

eop:productQualityStatus 'NOMINAL' (dynamic) NC_STRING
 Indicator that specifies whether the product quality is degraded or not. Allowed values: 'DEGRADED', 'NOMINAL'.

eop:productQualityDegradation 'NOT APPLICABLE' (dynamic) NC_STRING
 Contains further textual information concerning the quality degradation. According to the metadata standards it shall be provided *only* if "eop:productQualityStatus" value is set to 'DEGRADED'. Because the way we generate out output files, this attribute will always be present, even when "eop:productQualityStatus" value is 'NOMINAL'. In those cases the value shall be set to "NOT APPLICABLE".
 Possible values are "MISSING AUXILIARY INPUT" and "NOT APPLICABLE". Note that Level 1B does not set this value, so only problems detectable in the processor are covered.

10.2.3.88 Group "eop:processing" in "eop:metaDataProperty"

Processing information.

Attributes in AER_LH/METADATA/EOP_METADATA/eop:metaDataProperty/eop:processing

Group attributes attached to eop:processing		
Name	Value	Type
objectType	'eop:ProcessingInformation' (static)	NC_STRING
eop:processingCenter	'%(processingcenter)s' (dynamic) The processing center, taken from the "Processing_Station" key in the joborder.	NC_STRING
eop:processingDate	'YYYY-mm-ddTHH:MM:SSZ' (dynamic) The processing date, as an ISO 8601 date-time string [RD36].	NC_STRING
eop:processingLevel	'L2' (static) These are all Level 2 products.	NC_STRING
eop:processorName	'%(processor_name)s' (static) The name of the processor, "tropn112dp.exe" for KNMI and "upas-12" for DLR.	NC_STRING
eop:processorVersion	'%(version)s' (dynamic) Version of the processor, as "major.minor.bugfix".	NC_STRING
eop:nativeProductFormat	'netCDF-4' (static) Native product format.	NC_STRING
eop:processingMode	'%(mode)s' (dynamic) Processing mode taken from mission specific code list. For S5P we use the <i>File Class</i> identifiers [RD25, section 4.1.2]: 'TEST', 'OGCA', 'GSOV', 'OPER', 'NRTI', 'OFFL', 'RPRO'.	NC_STRING

10.2.3.89 Group "ESA_METADATA" in "ESA_metadata"

Metadata defined in the ESA file format standard [RD29].

10.2.3.90 Group "earth_explorer_header" in "ESA_METADATA"

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header

Group attributes attached to earth_explorer_header		
Name	Value	Type
objectType	'Earth_Explorer_Header' (static)	NC_STRING

10.2.3.91 Group "fixed_header" in "earth_explorer_header"

The fixed header. We do not use a variable header, so only the fixed header is present.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/fixed_header

Group attributes attached to fixed_header		
Name	Value	Type
objectType	'Fixed_Header' (static)	NC_STRING
File_Name	'%(logical_filename)s' (dynamic)	NC_STRING
The <i>logical</i> file name, i.e. the file name without extension.		
File_Description		NC_STRING
This is a copy of the global "title" attribute.		
Notes		NC_STRING
This is a copy of the global "comment" attribute.		
Mission	'S5P' (static)	NC_STRING
The mission identifier for the Sentinel 5-precursor mission is "S5P".		
File_Class	'%(mode)s' (dynamic)	NC_STRING
The file class of the output. Values are taken from the tailoring of the EO file format tailoring for S5P [RD25, section 4.1.2].		
File_Type	'%(shortname)s' (dynamic)	NC_STRING
Following the EO file format tailoring for S5P [RD25, sections 4.1.3.1 and 4.1.3.2].		
File_Version	0 (dynamic)	NC_INT
The file version information is not part of the file name conventions for S5P. If a file version number is to be recorded in this attribute, then it has to be provided by the PDGS via the job order. If provided, then the value is ≥ 1 . If not provided the fill value is 0.		

10.2.3.92 Group "validity_period" in "fixed_header"

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/fixed_header/validity_period

Group attributes attached to validity_period		
Name	Value	Type
objectType	'Validity_Period' (static)	NC_STRING
Validity_Start		NC_STRING
The value is the string "UTC=" concatenated with the <code>time_coverage_start</code> global attribute. This attribute corresponds to the "Validity_Start" element in the "Validity_Period" XML structure in the header file.		
Validity_Stop		NC_STRING
The value is the string "UTC=" concatenated with the <code>time_coverage_end</code> global attribute. This attribute corresponds to the "Validity_Stop" element in the "Validity_Period" XML structure in the header file.		

10.2.3.93 Group "source" in "fixed_header"

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/fixed_header/source

Group attributes attached to source		
Name	Value	Type
objectType	'Source' (static)	NC_STRING
System	'%(processingcenter)s' (dynamic)	NC_STRING
Name of the Ground Segment element creating the file. For Level 2 files, this is the PDGS, but for testing a different value may be used. This attribute corresponds to the "System" element in the "Source" XML structure in the header file.		
Creator	'%(processor_name)s' (dynamic)	NC_STRING

Name of the facility or tool, within the Ground Segment element, creating the file. This attribute corresponds to the “Creator” element in the “Source” XML structure in the header file.

Creator_Version	‘%(version)s’ (dynamic)	NC_STRING
Version number of the tool that created the file. This attribute corresponds to the “Creator_Version” element in the “Source” XML structure in the header file.		

Creation_Date		NC_STRING
The start date and time of processing, as a string: “UTC=YYYY-MM-DDThh:mm:ss”. This attribute corresponds to the “Creation_Date” element in the “Source” XML structure in the header file.		

10.2.3.94 Group “variable_header” in “earth_explorer_header”

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header

Group attributes attached to variable_header

Name	Value	Type
objectType	‘Variable_Header’ (static)	NC_STRING

10.2.3.95 Group “gmd:lineage” in “variable_header”

Non-quantitative quality information about the lineage of the data specified by the scope.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage

Group attributes attached to gmd:lineage

Name	Value	Type
objectType	‘gmd:L1_Lineage’ (static)	NC_STRING
gmd:statement	‘L2 %(product)s dataset produced by %(processingcenter)s from the S5P/TROPOMI L1B product’ (dynamic)	NC_STRING

General explanation of the data producer’s knowledge about the lineage of a dataset. Insert short description of the actual Level 2 product in this string (at the %(...)s).

10.2.3.96 Group “gmd:processStep” in “gmd:lineage”

Information about an event or transformation in the life of the dataset including details of the algorithm and software used for processing.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep

Group attributes attached to gmd:processStep

Name	Value	Type
objectType	‘gmi:LE_ProcessStep’ (static)	NC_STRING
gmd:description	‘Processing of L1b to L2 %(product)s data for orbit %(orbit)d using the %(institute)s processor version %(version)s’ (dynamic)	NC_STRING

Description of the event, including related parameters or tolerances. Insert short description of the actual Level 2 product, the orbit number, the name of the institute responsible for the CFI and the software version in this string (at the respective %(...)s and %(...)d).

10.2.3.97 Group “gmi:output” in “gmd:processStep”

Description of the output.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:output

Group attributes attached to gmi:output

<i>Name</i>	<i>Value</i>	<i>Type</i>
gmd:description		NC_STRING
Short description of the output, a copy of the global 'title' attribute.		
objectType	'gmi:LE_Source' (static)	NC_STRING

10.2.3.98 Group “gmd:sourceCitation” in “gmi:output”

Reference to the actual filename of the output data and production date and time.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:output/gmd:sourceCitation

Group attributes attached to gmd:sourceCitation

<i>Name</i>	<i>Value</i>	<i>Type</i>
gmd:title	'%(logical_filename)s' (dynamic)	NC_STRING
Output file name without extension.		
objectType	'gmd:CI_Citation' (static)	NC_STRING

10.2.3.99 Group “gmd:date” in “gmd:sourceCitation”

Production date and time of the output file.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:output/gmd:sourceCitation/gmd:date

Group attributes attached to gmd:date

<i>Name</i>	<i>Value</i>	<i>Type</i>
gmd:date		NC_STRING
Production date and time of the output file. Note that the definition in the XML schema appears to allow the use of a “CI_DateTime” instead of a “CI_Date”.		
objectType	'gmd:CI_DateTime' (static)	NC_STRING

10.2.3.100 Group “gmd:dateType” in “gmd:date”

Meaning of the reference date for the cited resource.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:output/gmd:sourceCitation/gmd:date/gmd:dateType

Group attributes attached to gmd:dateType

<i>Name</i>	<i>Value</i>	<i>Type</i>
codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodetlists.xml#CI_DateTypeCode' (static)	NC_STRING
codeListValue	'creation' (static)	NC_STRING
objectType	'gmd:CI_DateTypeCode' (static)	NC_STRING

10.2.3.101 Group “gmd:identifier” in “gmd:sourceCitation”

Identification of the output product.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:output/gmd:sourceCitation/gmd:identifier

Group attributes attached to gmd:identifier

<i>Name</i>	<i>Value</i>	<i>Type</i>
gmd:code	'%(shortname)s' (dynamic)	NC_STRING

The product short name, a copy of the 'ProductShortName' attribute in '/METADATA/GRANULE_DESCRIPTION'.

objectType	'gmd:MD_Identifier' (static)	NC_STRING
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10.2.3.102 Group "gmi:processedLevel" in "gmi:output"

Process level of the output file.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:output/gmi:processedLevel

Group attributes attached to gmi:processedLevel		
Name	Value	Type
gmd:code	'L2' (static)	NC_STRING
objectType	'gmd:MD_Identifier' (static)	NC_STRING

10.2.3.103 Group "gmi:processingInformation" in "gmd:processStep"

Description of the processor in more detail.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:processingInformation

Group attributes attached to gmi:processingInformation		
Name	Value	Type
objectType	'gmi:LE_Processing' (static)	NC_STRING

10.2.3.104 Group "gmi:identifier" in "gmi:processingInformation"

Identification of the processor.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:identifier

Group attributes attached to gmi:identifier		
Name	Value	Type
gmd:code	'%(institute)s L2 %(product)s processor, version %(version)s' (dynamic)	NC_STRING
Descriptive name of the processor, with the %(...)s placeholders replaced with the responsible institute's name, product name and software release version.		
objectType	'gmd:MD_Identifier' (static)	NC_STRING

10.2.3.105 Group "gmi:softwareReference" in "gmi:processingInformation"

Reference to document describing processing software.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:softwareReference

Group attributes attached to gmi:softwareReference		
Name	Value	Type
gmd:title	'L2 %(product)s processor description' (dynamic)	NC_STRING
Title of processor description.		
objectType	'gmd:CI_Citation' (static)	NC_STRING

10.2.3.106 Group "gmd:date" in "gmi:softwareReference"

Release date (compile date) of the processor.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:softwareReference/gmd:date

Group attributes attached to gmd:date		
Name	Value	Type
gmd:date		NC_STRING
	Release date of the processor expressed as an ISO 8601 date string [RD36].	
objectType	'gmd:CI_DateTime' (static)	NC_STRING

10.2.3.107 Group “gmd:dateType” in “gmd:date”

Confirm that this is the release date of the processor.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:softwareReference/gmd:date/gmd:dateType

Group attributes attached to gmd:dateType		
Name	Value	Type
codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodetlists.xml#CI_DateTypeCode' (static)	NC_STRING
codeListValue	'creation' (static)	NC_STRING
objectType	'gmd:CI_DateTypeCode' (static)	NC_STRING

10.2.3.108 Group “gmi:documentation#1” in “gmi:processingInformation”

Reference to the ATBD of the product.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:documentation#1

Group attributes attached to gmi:documentation#1		
Name	Value	Type
objectType	'gmd:CI_Citation' (static)	NC_STRING
gmd:title	'%(title_atbd)s' (dynamic)	NC_STRING
	Specification of the current release of the ATBD of the product.	

10.2.3.109 Group “gmd:date” in “gmi:documentation#1”

Release date of the ATBD.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:documentation#1/gmd:date

Group attributes attached to gmd:date		
Name	Value	Type
gmd:date	'%(date_atbd)s' (dynamic)	NC_STRING
	Release date of the ATBD expressed as an ISO 8601 date string [RD36].	
objectType	'gmd:CI_Date' (static)	NC_STRING

10.2.3.110 Group “gmd:dateType” in “gmd:date”

Specify the type of the date of the ATBD (revision of publication).

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:documentation#1/gmd:date/gmd:dateType

Group attributes attached to gmd:dateType

<i>Name</i>	<i>Value</i>	<i>Type</i>
codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodetlists.xml#CI_DateTypeCode' (static)	NC_STRING
codeListValue	'revision' (static)	NC_STRING
objectType	'gmd:CI_DateTypeCode' (static)	NC_STRING

10.2.3.111 Group “gmi:documentation#2” in “gmi:processingInformation”

Reference to the PUM of the product.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:documentation#2

Group attributes attached to gmi:documentation#2

<i>Name</i>	<i>Value</i>	<i>Type</i>
objectType	'gmd:CI_Citation' (static)	NC_STRING
gmd:title	'%(title_pum)s' (dynamic)	NC_STRING

Specification of the current release of the PUM of the product.

10.2.3.112 Group “gmd:date” in “gmi:documentation#2”

Release date of the PUM.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:documentation#2/gmd:date

Group attributes attached to gmd:date

<i>Name</i>	<i>Value</i>	<i>Type</i>
gmd:date	'%(date_pum)s' (dynamic)	NC_STRING

Release date of the PUM expressed as an ISO 8601 date string [RD36].

objectType	'gmd:CI_Date' (static)	NC_STRING
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10.2.3.113 Group “gmd:dateType” in “gmd:date”

Specify the type of the date of the PUM (revision of publication).

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:documentation#2/gmd:date/gmd:dateType

Group attributes attached to gmd:dateType

<i>Name</i>	<i>Value</i>	<i>Type</i>
codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodetlists.xml#CI_DateTypeCode' (static)	NC_STRING
codeListValue	'revision' (static)	NC_STRING
objectType	'gmd:CI_DateTypeCode' (static)	NC_STRING

10.2.3.114 Group “gmi:report” in “gmd:processStep”

Short report of what occurred during the process step.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:report

Group attributes attached to gmi:report

<i>Name</i>	<i>Value</i>	<i>Type</i>
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gmi:description	'Sentinel 5-precursor TROPOMI L1b processed to L2 data using the %(institute)s L2 %(product)s processor' (dynamic)	NC_STRING
Textual description of what occurred during the process step. Replace %(...)s as indicated.		
gmi:fileType	'netCDF-4' (static)	NC_STRING
Type of file that contains the processing report, in our case the processing report is contained in the main output file.		
gmi:name	'%(logical_filename)s.nc' (dynamic)	NC_STRING
objectType	'gmi:LE_ProcessStepReport' (dynamic)	NC_STRING

10.2.3.115 Group “gmd:source#1” in “gmd:processStep”

Information about the source data used in creating the data specified by the scope. Repeat group as needed, incrementing the number of the source (after the # mark).

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmd:source#1

Group attributes attached to gmd:source#1		
<i>Name</i>	<i>Value</i>	<i>Type</i>
objectType	'gmi:LE_Source' (static)	NC_STRING
gmd:description	NC_STRING	
Description of the input data, including L1B, L2, dynamic auxiliary input data and semi-static auxiliary input data. Base strings are “TROPOMI L1B %s radiance product”, “TROPOMI L1B %s irradiance product”, “TROPOMI L2 %s product”, “Auxiliary ECMWF %s Meteorological forecast data”, “Processor %s configuration file”, “Auxiliary %s reference data”, “Auxiliary %s algorithm lookup table”, “Auxiliary CTM %s model input data”, “Auxiliary snow and ice input data” and “Auxiliary NPP/VIIRS cloud screening input data”. The %s to be replaced with specific descriptors.		

10.2.3.116 Group “gmi:processedLevel” in “gmd:source#1”

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmd:source#1/gmi:processedLevel

Group attributes attached to gmi:processedLevel		
<i>Name</i>	<i>Value</i>	<i>Type</i>
gmd:code	<i>Empty!</i>	NC_STRING
objectType	'gmd:MD_Identifier' (static)	NC_STRING

10.2.3.117 Group “gmd:sourceCitation” in “gmd:source#1”

Reference to the actual filename of the input data.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmd:source#1/gmd:sourceCitation

Group attributes attached to gmd:sourceCitation		
<i>Name</i>	<i>Value</i>	<i>Type</i>
objectType	'gmd:CI_Citation' (static)	NC_STRING

10.2.3.118 Group “gmd:date” in “gmd:sourceCitation”

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/

gmd:processStep/gmd:source#1/gmd:sourceCitation/gmd:date

Group attributes attached to gmd:date		
Name	Value	Type
gmd:date		NC_STRING
Production date and time of the input file(s) in this group expressed as an ISO 8601 date-time string [RD36]. Note that the definition in the XML schema appears to allow the use of a “CI_DateTime” instead of a “CI_Date”.		
objectType	‘gmd:CI_Date’ (static)	NC_STRING

10.2.3.119 Group “gmd:dateType” in “gmd:date”

Meaning of the reference date for the cited resource.

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmd:source#1/gmd:sourceCitation/gmd:date/gmd:dateType

Group attributes attached to gmd:dateType		
Name	Value	Type
codeList	‘http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode’ (static)	NC_STRING
codeListValue	‘creation’ (static)	NC_STRING
objectType	‘gmd:CI_DateTypeCode’ (static)	NC_STRING

10.2.3.120 Group “gmd:title” in “gmd:sourceCitation”

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmd:source#1/gmd:sourceCitation/gmd:title

Group attributes attached to gmd:title		
Name	Value	Type
gco:characterString		NC_STRING
Textual description of the input file group (same as the “gmd:description” attribute in the “gmi:LE_Source” object).		

10.2.3.121 Group “gmd:alternateTitle#1” in “gmd:sourceCitation”

All filenames in this group, in case more files of a particular file type are delivered, for instance for meteorological or model input. Repeat group as needed, incrementing the number of the input file (after the # mark).

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmd:source#1/gmd:sourceCitation/gmd:alternateTitle#1

Group attributes attached to gmd:alternateTitle#1		
Name	Value	Type
gmx:FileName	Empty!	NC_STRING
The basename of the input file.		

11 Units

The `units` attribute originates from the NetCDF-4 users guide [ER7]. This means that the use of this attribute is integral to the use of NetCDF-4 itself, and that the use of the `units` attribute in the NetCDF-4 users guide is a hard requirement. The NetCDF-4 users guide [ER7] strongly suggests to use the UDUnits [ER10] package to handle units. The CF metadata conventions reinforce this requirement [ER5, sections 1.3 and 3.1].

Making the UDUnits package [ER10] a requirement, and thereby forcing all units to be compliant with formal SI units⁴ is a good thing for consistency and will help avoid confusion in the long run. In the short term it will require adjustments within the earth observation community, as many of the units that the user community is accustomed to are not SI, and are therefore not available within the UDUnits package. The MAG has decided that Sentinel 5 precursor will represent all level 2 output in SI units. In particular, all column amounts will be given in mol m⁻².

To make it easier for end-users to adjust to these ‘new’ units, conversion factors are attached to the appropriate variables.

multiplication_factor_to_convert_to_molecules_perkm2 Multiply the contents of the variable with this scale factor ($6.02214 \times 10^{+19}$) to obtain columns in molecules cm⁻²

multiplication_factor_to_convert_to_DU Multiply the contents of the variable with this scale factor (2241.15) to obtain columns in DU.

multiplication_factor_to_convert_to_photons_persecond_pernm_perkm2_persr Multiply the contents of the variable with this scale factor ($6.02214 \times 10^{+19}$) to obtain a radiance in photons s⁻¹ nm⁻¹ cm⁻² sr⁻¹.

12 Quality Assurance parameters

The Level 2 output will include automated quality assurance parameters. These include ‘event counters’ for each of the flags defined in the processing quality flags, see tables 11 and 12. These processing quality flags are made uniform across all products, and include flags that may not be applicable to a particular algorithm. We still count all flags, so this list is the same for all products, a list is provided in table 4.

In addition to these ‘event counters’, we also store a histogram of the main parameters. Storing a histogram of retrieved values is easy during processing, and allows for continuous statistical quality monitoring of the retrieval. It also makes it easy to collect histograms of S5P/TROPOMI data for longer periods. The bins for the histogram depend on the parameter in the Level 2 product, and are defined in the configuration file.

In addition to the histogram an approximation of a probability density function can be created:

$$f_{\text{pdf}}(x_j) = \frac{1}{N} \sum_{i=0}^N \frac{\cos(\delta_{\text{geo},i})}{\sigma_i \sqrt{2\pi}} \exp \left[-\frac{(x_j - x_i)^2}{2\sigma_i^2} \right] \quad (8)$$

This is a discrete approximation of a continuous probability density function, for discrete values x_j for all successful retrievals $i = 1, \dots, N$. The value of $\cos(\delta_{\text{geo},i})$ is used to make the result less sensitive to the relative oversampling of S5P at high latitude.

The mission performance center for Sentinel 5 precursor maintains a record of quality control/quality assurance parameters for monitoring purposes.

⁴ And some deeply entrenched non-SI units such as DU.

Table 4: Common quality assurance parameters. The actual integer values of incident occurrences are stored. Using percentages stored as integers will hide potential issues, especially given the total number of pixels in a S5P/TROPOMI granule.

Name	Description
<code>number_of_groundpixels</code>	Number of ground pixels in the file.
<code>number_of_processed_pixels</code>	Number of ground pixels where a retrieval was attempted. This is the <code>number_of_groundpixels</code> minus the pixels that were rejected on trivial grounds, such as the solar zenith angle.
<code>number_of_successfully_processed_pixels</code>	Number of ground pixels where a retrieval was successful.
<code>number_of_rejected_pixels_not_enough_spectrum</code>	Number of ground pixels where a retrieval was not attempted because too many spectral pixels were flagged as bad.
<code>number_of_failed_retrievals</code>	Number of pixels that were attempted but failed.
<code>number_of_ground_pixels_with_warnings</code>	Number of pixels with one or more warnings.
<code>number_of_missing_scanlines</code>	Number of scanlines that are missing from the input, presumably transmission errors.
<code>number_of_radiance_missing_occurrences</code>	Number of ground pixels where “the number of spectral pixels in the radiance due to flagging is too small to perform the fitting” occurred.
<code>number_of_irradiance_missing_occurrences</code>	Number of ground pixels where “the number of spectral pixels in the irradiance due to flagging is too small to perform the fitting” occurred.
<code>number_of_input_spectrum_missing_occurrences</code>	Number of ground pixels where “the reflectance spectrum does not contain enough points to perform the retrieval. This is different from (ir)radiance_ missing in that the missing points may not be aligned” occurred.
<code>number_of_reflectance_range_error_occurrences</code>	Number of ground pixels where “any of the reflectances is out of bounds ($R < 0$ or $R > R_{max}$)” occurred.
<code>number_of_ler_range_error_occurrences</code>	Number of ground pixels where “lambert-equivalent reflectivity out of range error” occurred.
<code>number_of_snr_range_error_occurrences</code>	Number of ground pixels where “too low signal to noise to perform retrieval” occurred.
<code>number_of_sza_range_error_occurrences</code>	Number of ground pixels where “solar zenith angle out of range, maximum value from configuration” occurred.
<code>number_of_vza_range_error_occurrences</code>	Number of ground pixels where “viewing zenith angle out of range, maximum value from configuration” occurred.
<code>number_of_lut_range_error_occurrences</code>	Number of ground pixels where “extrapolation in lookup table (airmass factor, cloud radiances)” occurred.

Table 4: Common quality assurance parameters. (continued).

Name	Description
number_of_ozone_range_error_occurrences	Number of ground pixels where “ozone column significantly out of range of profile climatology” occurred.
number_of_wavelength_offset_error_occurrences	Number of ground pixels where “wavelength offset exceeds maximum from configuration” occurred.
number_of_initialization_error_occurrences	Number of ground pixels where “an error occurred during the processing of the pixel, no output was generated. The following errors raise this flag: Mismatch between irradiance and radiance wavelengths; The on-ground distance between band 1 and band 2 ground pixels exceeds a threshold set in the configuration. Derived a-priori information does not validate, no processing is possible” occurred.
number_of_memory_error_occurrences	Number of ground pixels where “memory allocation or deallocation error” occurred.
number_of_assertion_error_occurrences	Number of ground pixels where “error in algorithm detected during assertion” occurred.
number_of_io_error_occurrences	Number of ground pixels where “error detected during transfer of data between algorithm and framework” occurred.
number_of_numerical_error_occurrences	Number of ground pixels where “general fatal numerical error occurred during inversion” occurred.
number_of_lut_error_occurrences	Number of ground pixels where “error in accessing the lookup table” occurred.
number_of_ISRF_error_occurrences	Number of ground pixels where “error detected in the input instrument spectral response function input data” occurred.
number_of_convergence_error_occurrences	Number of ground pixels where “the main algorithm did not converge” occurred.
number_of_cloud_filter_convergence_error_occurrences	Number of ground pixels where “the cloud filter did not converge” occurred.
number_of_max_iteration_convergence_error_occurrences	Number of ground pixels where “no convergence because retrieval exceeds maximum number of iterations. Maximum value from configuration” occurred.
number_of_aot_lower_boundary_convergence_error_occurrences	Number of ground pixels where “no convergence because the aerosol optical thickness crosses lower boundary twice in succession” occurred.
number_of_other_boundary_convergence_error_occurrences	Number of ground pixels where “no convergence because a state vector element crosses boundary twice in succession. Note that a separate failure flag is defined for non-convergence due to crossing of lower AOT boundary” occurred.

Table 4: Common quality assurance parameters. (continued).

Name	Description
number_of_geolocation_error_occurrences	Number of ground pixels where “geolocation out of range” occurred.
number_of_ch4_noscat_zero_error_occurrences	Number of ground pixels where “the CH ₄ column retrieved by the non-scattering CO algorithm from the weak band or strong band is 0” occurred.
number_of_h2o_noscat_zero_error_occurrences	Number of ground pixels where “the H ₂ O column retrieved by the non-scattering CO algorithm from the weak band or strong band is 0” occurred.
number_of_max_optical_thickness_error_occurrences	Number of ground pixels where “maximum optical thickness exceeded during iterations” occurred.
number_of_aerosol_boundary_error_occurrences	Number of ground pixels where “boundary hit of aerosol parameters at last iteration” occurred.
number_of_boundary_hit_error_occurrences	Number of ground pixels where “fatal boundary hit during iterations” occurred.
number_of_chi2_error_occurrences	Number of ground pixels where “ χ^2 is not-a-number or larger than 10 ¹⁰ ” occurred.
number_of_svd_error_occurrences	Number of ground pixels where “singular value decomposition failure” occurred.
number_of_dfs_error_occurrences	Number of ground pixels where “degree of freedom is not-a-number” occurred.
number_of_radiative_transfer_error_occurrences	Number of ground pixels where “errors occurred during the radiative transfer computations, no processing possible” occurred.
number_of_optimal_estimation_error_occurrences	Number of ground pixels where “errors occurred during the optimal estimation, processing has been terminated” occurred.
number_of_profile_error_occurrences	Number of ground pixels where “flag that indicates if there were any errors during the computation of the ozone profile” occurred.
number_of_cloud_error_occurrences	Number of ground pixels where “no cloud data” occurred.
number_of_model_error_occurrences	Number of ground pixels where “forward model failure” occurred.
number_of_number_of_input_data_points_too_low_error_occurrences	Number of ground pixels where “not enough input ozone columns to calculate a tropospheric column” occurred.
number_of_cloud_pressure_spread_too_low_error_occurrences	Number of ground pixels where “cloud pressure variability to low to estimate a tropospheric column” occurred.
number_of_cloud_too_low_level_error_occurrences	Number of ground pixels where “clouds are too low in the atmosphere to assume sufficient shielding” occurred.
number_of_generic_range_error_occurrences	Number of ground pixels where “generic range error” occurred.
number_of_generic_exception_occurrences	Number of ground pixels where “catch all generic error” occurred.

Table 4: Common quality assurance parameters. (continued).

Name	Description
number_of_input_spectrum_alignment_error_occurrences	Number of ground pixels where “input radiance and irradiance spectra are not aligned correctly” occurred.
number_of_abort_error_occurrences	Number of ground pixels where “not processed because processor aborted prematurely (time out or user abort)” occurred.
number_of_wrong_input_type_error_occurrences	Number of ground pixels where “wrong input type error, mismatch between expectation and received data” occurred.
number_of_wavelength_calibration_error_occurrences	Number of ground pixels where “an error occurred in the wavelength calibration of this pixel” occurred.
number_of_coregistration_error_occurrences	Number of ground pixels where “no colocated pixels found in a supporting band” occurred.
number_of_slant_column_density_error_occurrences	Number of ground pixels where “slant column fit returned error, no values can be computed” occurred.
number_of_airmass_factor_error_occurrences	Number of ground pixels where “airmass factor could not be computed” occurred.
number_of_vertical_column_density_error_occurrences	Number of ground pixels where “vertical column density could not be computed” occurred.
number_of_signal_to_noise_ratio_error_occurrences	Number of ground pixels where “the signal to noise ratio for this spectrum is too low for processing” occurred.
number_of_configuration_error_occurrences	Number of ground pixels where “error while parsing the configuration” occurred.
number_of_key_error_occurrences	Number of ground pixels where “key does not exist” occurred.
number_of_saturation_error_occurrences	Number of ground pixels where “saturation in input spectrum” occurred.
number_of_max_num_outlier_exceeded_error_occurrences	Number of ground pixels where “the number of outliers detected in the DOAS fit exceeds a maximum set for healthy spectra. ” occurred.
number_of_solar_eclipse_filter_occurrences	Number of ground pixels where “solar eclipse” occurred.
number_of_cloud_filter_occurrences	Number of ground pixels where “the cloud filter triggered causing the pixel to be skipped” occurred.
number_of_altitude_consistency_filter_occurrences	Number of ground pixels where “too large difference between ECMWF altitude and DEM altitude value” occurred.
number_of_altitude_roughness_filter_occurrences	Number of ground pixels where “too large standard deviation of altitude in DEM” occurred.

Table 4: Common quality assurance parameters. (continued).

Name	Description
number_of_sun_glint_filter_occurrences	Number of ground pixels where “for pixels over water, viewing direction inside sun glint region. Definition of sun glint angle and threshold value from ATBD” occurred.
number_of_mixed_surface_type_filter_occurrences	Number of ground pixels where “pixel contains land and water areas (e.g. coastal pixel)” occurred.
number_of_snow_ice_filter_occurrences	Number of ground pixels where “pixel contains snow/ice: Snow/ice flag according to dynamic input OR climatological surface albedo at VIS wavelength is larger than 0.5” occurred.
number_of_aai_filter_occurrences	Number of ground pixels where “AAI smaller than 2.0” occurred.
number_of_cloud_fraction_fresco_filter_occurrences	Number of ground pixels where “pixel contains clouds: The FRESCO effective cloud fraction is larger than threshold. Threshold value from ATBD” occurred.
number_of_aai_scene_albedo_filter_occurrences	Number of ground pixels where “pixel contains clouds: The difference between scene albedo at 380 nm from AAI calculation and the climatological surface albedo exceeds threshold. Threshold value from ATBD. This test filters out clouds” occurred.
number_of_small_pixel_radiance_std_filter_occurrences	Number of ground pixels where “pixel contains clouds: Standard deviation of radiances in small-pixel column exceeds threshold. Threshold value from ATBD” occurred.
number_of_cloud_fraction_viirs_filter_occurrences	Number of ground pixels where “pixel contains clouds: The cloud fraction from VIIRS / NPP exceeds threshold. Threshold value from ATBD” occurred.
number_of_cirrus_reflectance_viirs_filter_occurrences	Number of ground pixels where “pixel contains clouds: Cirrus reflectance from VIIRS / NPP exceeds threshold. Threshold value from ATBD” occurred.
number_of_cf_viirs_swir_ifov_filter_occurrences	Number of ground pixels where “fraction of cloudy VIIRS pixels within S5P SWIR ground pixel exceeds a priori threshold from configuration” occurred.
number_of_cf_viirs_swir_ofova_filter_occurrences	Number of ground pixels where “fraction of cloudy VIIRS pixels within S5P SWIR OFOVa exceeds a priori threshold from configuration” occurred.
number_of_cf_viirs_swir_ofovb_filter_occurrences	Number of ground pixels where “fraction of cloudy VIIRS pixels within S5P SWIR OFOVb exceeds a priori threshold from configuration” occurred.
number_of_cf_viirs_swir_ofovc_filter_occurrences	Number of ground pixels where “fraction of cloudy VIIRS pixels within S5P SWIR OFOVc exceeds a priori threshold from configuration” occurred.
number_of_cf_viirs_nir_ifov_filter_occurrences	Number of ground pixels where “fraction of cloudy VIIRS pixels within S5P NIR ground pixel exceeds a priori threshold from configuration” occurred.

Table 4: Common quality assurance parameters. (continued).

Name	Description
number_of_cf_viirs_nir_ofova_filter_occurrences	Number of ground pixels where “fraction of cloudy VIIRS pixels within S5P NIR OFOVa exceeds a priori threshold from configuration” occurred.
number_of_cf_viirs_nir_ofovb_filter_occurrences	Number of ground pixels where “fraction of cloudy VIIRS pixels within S5P NIR OFOVb exceeds a priori threshold from configuration” occurred.
number_of_cf_viirs_nir_ofovc_filter_occurrences	Number of ground pixels where “fraction of cloudy VIIRS pixels within S5P NIR OFOVc exceeds a priori threshold from configuration” occurred.
number_of_refl_cirrus_viirs_swir_filter_occurrences	Number of ground pixels where “average VIIRS cirrus reflectance within SWIR ground pixel exceeds a priori threshold from configuration” occurred.
number_of_refl_cirrus_viirs_nir_filter_occurrences	Number of ground pixels where “average VIIRS cirrus reflectance within NIR ground pixel exceeds a priori threshold from configuration” occurred.
number_of_diff_refl_cirrus_viirs_filter_occurrences	Number of ground pixels where “difference in VIIRS average cirrus reflectance between SWIR and NIR ground pixel exceeds a priori threshold from configuration” occurred.
number_of_ch4_noscat_ratio_filter_occurrences	Number of ground pixels where “the ratio between $[CH_4]_{weak}$ and $[CH_4]_{strong}$ is below or exceeds a priori thresholds from configuration” occurred.
number_of_ch4_noscat_ratio_std_filter_occurrences	Number of ground pixels where “the standard deviation of $[CH_4]_{weak}/[CH_4]_{strong}$ within the SWIR pixel and the 8 neighbouring pixels exceeds a priori threshold from configuration” occurred.
number_of_h2o_noscat_ratio_filter_occurrences	Number of ground pixels where “the ratio between $[H_2O]_{weak}$ and $[H_2O]_{strong}$ is below or exceeds a priori thresholds from configuration” occurred.
number_of_h2o_noscat_ratio_std_filter_occurrences	Number of ground pixels where “the standard deviation of $[H_2O]_{weak}/[H_2O]_{strong}$ within the SWIR pixel and the 8 neighbouring pixels exceeds a priori threshold from configuration” occurred.
number_of_diff_psurf_fresco_ecmwf_filter_occurrences	Number of ground pixels where “difference between the FRESCO apparent surface pressure and the ECMWF surface pressure exceeds a priori threshold from configuration” occurred.
number_of_psurf_fresco_stdv_filter_occurrences	Number of ground pixels where “the standard deviation of the FRESCO apparent surface pressure in the NIR pixel and the 8 surrounding pixels exceeds a priori threshold from configuration” occurred.
number_of_ocean_filter_occurrences	Number of ground pixels where “the ground pixel is over ocean (and ocean glint retrievals are not switched on)” occurred.

Table 4: Common quality assurance parameters. (continued).

Name	Description
number_of_time_range_filter_occurrences	Number of ground pixels where “time is out of the range that is to be processed” occurred.
number_of_pixel_or_scanline_index_filter_occurrences	Number of ground pixels where “not processed because pixel index does not match general selection criteria” occurred.
number_of_geographic_region_filter_occurrences	Number of ground pixels where “pixel falls outside the specified regions of interest” occurred.
number_of_input_spectrum_warning_occurrences	Number of ground pixels where “number of good pixels in radiance, irradiance or calculated reflectance below threshold from configuration” occurred.
number_of_wavelength_calibration_warning_occurrences	Number of ground pixels where “offset from wavelength fit is larger than limit set in configuration” occurred.
number_of_extrapolation_warning_occurrences	Number of ground pixels where “pressure or temperature outside cross section LUT range, other lookup table extrapolation” occurred.
number_of_sun_glint_warning_occurrences	Number of ground pixels where “sun glint possibility warning” occurred.
number_of_south_atlantic_anomaly_warning_occurrences	Number of ground pixels where “TROPOMI is inside the south Atlantic anomaly while taking these measurements” occurred.
number_of_sun_glint_correction_occurrences	Number of ground pixels where “A sun glint correction has been applied” occurred.
number_of_snow_ice_warning_occurrences	Number of ground pixels where “snow/ice flag is set, i.e. using scene data from the cloud support product” occurred.
number_of_cloud_warning_occurrences	Number of ground pixels where “cloud filter based on FRESCO apparent surface pressure (VIIRS not available), cloud fraction above threshold or cloud pressure adjusted to force cloud above surface. In case of Cloud product this flag indicates the possibility of ice-clouds” occurred.
number_of_AAI_warning_occurrences	Number of ground pixels where “possible aerosol contamination as either indicated by the AAI (O ₃ profile) or other criteria (Cloud)” occurred.
number_of_pixel_level_input_data_missing_occurrences	Number of ground pixels where “dynamic auxiliary input data (e.g.. cloud) is missing for this ground pixel. A fallback option is used” occurred.

Table 4: Common quality assurance parameters. (continued).

Name	Description
number_of_data_range_warning_occurrences	Number of ground pixels where “carbon monoxide column tends to negative values; Water column tends to negative values; Heavy water (HDO) column tends to negative values; others. In case of the O ₃ product this flag indicates VCD or effective albedo values outside a valid range. In case of the SO ₂ or the HCHO product this flag indicates AMF values outside a valid range” occurred.
number_of_low_cloud_fraction_warning_occurrences	Number of ground pixels where “low cloud fraction, therefore no cloud pressure retrieved” occurred.
number_of_altitude_consistency_warning_occurrences	Number of ground pixels where “difference between ECMWF surface elevation and high-resolution surface elevation exceeds threshold from configuration” occurred.
number_of_signal_to_noise_ratio_warning_occurrences	Number of ground pixels where “signal to noise ratio in SWIR and/or NIR band below threshold from configuration. For the O ₃ and HCHO products this flag indicates an RMS above a certain threshold” occurred.
number_of_deconvolution_warning_occurrences	Number of ground pixels where “failed deconvolution irradiance spectrum (not pixel-specific, but row-specific)” occurred.
number_of_so2_volcanic_origin_likely_warning_occurrences	Number of ground pixels where “warning for SO ₂ BL product, UTLS products: volcanic origin except for heavily polluted sites” occurred.
number_of_so2_volcanic_origin_certain_warning_occurrences	Number of ground pixels where “warning for SO ₂ BL product, UTLS products: volcanic origin certain” occurred.
number_of_interpolation_warning_occurrences	Number of ground pixels where “warning for interpolation on partially missing data. In this case the valid available data is used, potentially leading to a bias” occurred.
number_of_saturation_warning_occurrences	Number of ground pixels where “saturation occurred spectrum, possibly causing biases in the retrieval” occurred.
number_of_high_sza_warning_occurrences	Number of ground pixels where “warning for high solar zenith angle. In this case, the processing can be performed with less final quality” occurred.
number_of_cloud_retrieval_warning_occurrences	Number of ground pixels where “warning occurring when the retrieval diagnostic indicates a degraded quality of the cloud retrieval” occurred.
number_of_cloud_inhomogeneity_warning_occurrences	Number of ground pixels where “the cloud coregistration inhomogeneity parameter is above a given threshold” occurred.

13 Generic metadata and attributes

Metadata gives information about the satellite, algorithms, configuration as well as other parameters useful for the interpretation of the processed data and tracing the production process of the level 2 files. The Sentinel 5 precursor product files, both for level 1B and level 2 contain a rich amount of metadata, both at the variable level and at the granule level. The full description of the metadata in the files for the Aerosol Layer Height product is given in the file format description, in section 10.2. Here we provide some background on what can be found in which location. The abbreviations listed in table 5 are used in the following part of this document to better identify the nature of the attributes.

Table 5: The abbreviations used in metadata descriptions to indicate the origin of a specific attribute, and the abbreviations used to indicate the type of an attribute.

Abbreviation	Description
NUG	netCDF-4 Users Guide [ER7]
CF	Climate and Forecast metadata conventions [ER5], which includes the COARDS [ER11] conventions
ISO	ISO standards 19115, 19115-2 and 19157 [RD30, RD31, RD32]
Inspire	Inspire directive [ER4]
ACDD	ESIP-ACDD Attribute convention for dataset discovery [ER6]
CCI	Attributes requested by the ESA climate change initiative project. These largely overlap with the ACDD attributes.
ESA	Fixed ESA Header [RD29]
S5P	Internal use – mostly for retrieval settings, possibly as an extension to ISO 19115 [RD30]
S	Attribute is a string attribute
P	Attribute has the data-type of the variable with which it is associated ('parent' data type).
I	Attribute is an integer value
F	Attribute is a floating point value (either 32-bit or 64-bit).
T	Attribute is a CCSDS-ASCII time representation ("UTC=" + ISO 8601 [RD36])

We follow several metadata conventions in the S5P level 2 files, as can be seen in table 5. These include ISO 19115-2 [RD31], OGC 10.157r3 [RD33], the ESA earth observation header [RD29] and the Climate and Forecast metadata conventions [ER5]. Following ISO 19115-2 also ensures compliance with the Inspire directive, with the provision that a few items that are optional in the ISO standard are required by Inspire. These metadata standards prescribe the generation of XML files as side-files to the main product file. These metadata standards are mostly intended for data discovery and data dissemination. This means that the metadata must be ingested by a server so that it can be stored in a database. This database will end users help to find the data they need. Ingestion of this metadata is facilitated by storing the metadata in a predefined XML format. While it is possible to store the required XML directly in a NetCDF variable or attribute, it is hard to use these directly to extract metadata. Using attributes for the individual metadata fields makes it far easier for users to read the metadata from their programs, as the interface becomes uniform: just netCDF-4.

The then question becomes how to store the metadata for the ISO 19115-2, OGC 10.157r3 and the ESA earth observation header in the NetCDF datafile, in a way that facilitates automated creation of the XML side files for ingestion into the database for dissemination and discovery. Fortunately this problem has already been solved by the S5P L1B team, and a description can be found in the L1B input/output data specification and the metadata specification [RD2, RD35]. The short version is that the attributes in the data file can be exported as NcML [RD44], which can be translated into the desired output using an XSLT transformation. Support attributes are added to the data file to facilitate this. Creating such a transformation script has been declared out of scope for the level 1B and level 2 processor CFI providers.

13.1 The Climate and Forecast conventions

The CF metadata conventions [ER5] provide guidelines for attributes for variables so that the link between data and its geolocation and time of observation can be made automatically. Applying the CF-metadata conventions to the output products already limits the number of choices we will have to make. Units and other attributes are

already defined and some structure is provided by the CF-conventions, for instance in linking data fields with geolocation.

13.2 NetCDF User Guide Conventions

A full description of the conventions might be found in the NetCDF user manual [ER7]]. In general, names starting with underscore character are always reserved for use by the NetCDF library. NUG conventions are a subset of the CF-conventions.

13.3 Global attributes

Global attributes that are present at the `root` level of a S5p L2 product as described in section 10. These are mostly `string` attributes.

13.4 ESA earth observation header

The ESA earth observations file format guidelines and tailoring for S5P [RD29, RD25] specify the creation of a header file with a basic description of the contents of an output file. This header file consists of a fixed part and a customizable variable part. The variable part contains the lineage of the product is repeated, see section 10.2.3.43 for a description the the attributes contained in this part of the header. The fixed header is described in tables 6–8.

Table 6: Metadata in the fixed header required by the ESA earth observation file format standard. The data types refer to the short list in table 5.

Name	Data type	Definition
File_Name	S	File name of the product without extension.
File_Description	S	Description of the file type.
Notes	S	Any type of notes/comments (multi-lines).
Mission	S	Description of the mission (Fixed to “S5P”)
File_Class	S	Description of the file class. It is redundant with the File Class element embedded in the File Name.(e.g., “NRTI”)
File_Type	S	Description of the file type, for the current product it is set to “L2__-Aerosol Layer Height”. It is redundant with the File Type element embedded in the File Name.
Validity_Period	Group, see table 7	Time coverage of the data.
File_Version	I	It is redundant with the File Version element embedded in the File Name.
Source	Group, see table 8	Information about the ground segment facility where the product was generated.

Table 7: Fields in the Validity_Period group. The data types refer to the short list in table 5.

Name	Data type	Definition
Validity_Start	T	This is the UTC Validity Start Time, the same as the Validity Start Time in the File Name and the <code>time_coverage_start</code> global attribute.
Validity_Stop	T	This is the UTC Validity Stop Time, the same as the Validity Stop Time in the File Name and the <code>time_coverage_end</code> global attribute.

Table 8: Fields in the source group. The data types refer to the short list in table 5.

Name	Data type	Definition
System	S	Name of the Ground Segment element creating the file.

Table 8: Fields in the source group (continued).

Name	Data type	Definition
Creator	S	Name of the facility or tool, within the Ground Segment element, creating the file.
Creator_Version	S	Version of the tool.
Creation_Date	T	This is the UTC Creation Date. This field also appears in the file name and in the date_created global attribute.

13.5 Inspire directive

INSPIRE is based on the infrastructures for spatial information established and operated by the 27 Member States of the European Union. The INSPIRE directive came into force on 15 May 2007 and will be developed in several stages until a complete release with due date set in 2019. The INSPIRE directive aims to create a European Union (EU) spatial data infrastructure. This will enable the sharing of environmental spatial information among public sector organizations and better facilitate public access to spatial information across Europe. The European Commission issued a Metadata Regulation [RD45] which aims at setting the requirements for the creation and maintenance of metadata for spatial data sets, spatial data set series and spatial data services corresponding to the themes listed in the annexes of the regulation.

Since many different standard are involved, collisions may occur. The INSPIRE Metadata Implementing Rules [RD46] define how the Regulation can be implemented using ISO 19115. As also reported in [RD35], the conclusion of the study pointed out the following:

1. The conformance of an ISO 19115 metadata set to the ISO 19115 Core does not guarantee the conformance to INSPIRE.
2. The use of these guidelines to create INSPIRE metadata ensures that the metadata is not in conflict with ISO 19115. However, full conformance to ISO 19115 implies the provision of additional metadata elements which are not required by INSPIRE.

13.6 ISO and OGC standards

Two ISOs standards useful for the description of collection of Earth Observation products and to the description of individual EO products are ISO 19115-2 [RD31] and ISO 19156 [RD47], respectively. However, these two ISOs do not provide any encoding syntax but they are merely conceptual models. On the other hand, standards that provide encoding and XML schema for describing, validating and exchanging metadata about geographic datasets and for observations and measurements are:

1. ISO 19139 [RD39]
2. OGC 10-025C [RD48]
3. OGC 10-157 [RD33]

Full description of all above mentioned standard is not part of this document. The S5p L01B development team have addressed and analyzed the complex structure of the application of all those ISOs and OGC standard in the S5P L01B metadata specification [RD35].

13.7 Attributes

In Table 10 a list of attributes that can be appended to variables in S5p products. Not all of these attributes will be used on all variables, but for each variables an appropriate selection is made. The different types with their respective abbreviations are shown in Table 5. The NetCDF attribute `_FillValue` which represents missing or undefined data can assume the default values listed in Table 9.

Table 9: netCDF-4 type definitions and fill values. In order to avoid rounding errors, it is recommended to use the hexadecimal notation when specifying fill values for float and double types. Note that these are the netCDF-4 default fill values, there should be no need to specify these values explicitly. In some cases the fill value for float or double variables may fall within the valid range of a variable. For those cases an explicit fill value must be set, the value $-9.9692099683868690 \times 10^{36}$ (hex: $-0 \times 1 . ep + 122$) is recommended for these cases.

Type	Description	Fill value
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
uint	32-bit unsigned integer	4294967295
float	32-bit floating point	$9.9692099683868690 \times 10^{36}$ (hex: $0 \times 1 . ep + 122$)
double	64-bit floating point	$9.9692099683868690 \times 10^{36}$ (hex: $0 \times 1 . ep + 122$)

Table 10: Attributes for variables used in S5p netCDF-4 files. The data types refer to the short list in table 5.

Name	Type	Std.	Description
ancillary_variables	S	CF	Identifies a variable that contains closely associated data, e.g. the measurement uncertainties of instrument data.
bounds	S	CF	Connects a boundary variable to a coordinate variable.
cell_measures	S	CF	Identifies variables that contain cell areas or volumes. This can be used to connect approximate ground pixel coverage in km ² to data-fields.
comment	S	CF	Miscellaneous information about the data or methods used to produce it.
coordinates	S	CF	Identifies auxiliary coordinate variables, providing a connection between data and geolocation, time.
_FillValue	P	NUG	Value to represent missing or undefined data. Recommended (default) values are given in table 9.
flag_masks	P	CF	Provides a list of bit fields expressing Boolean or enumerated flags.
flag_meanings	S	CF	Use in conjunction with flag_values to provide descriptive words or phrases for each flag value.
flag_values	P	CF	Provides a list of the flag values. Use in conjunction with flag_meanings.
formula	S	CF	Formula to calculate the values for an adaptive grid, for instance for a dimensionless vertical coordinate. Example: "hyam hybm (mlev=hyam+hybm*aps)".
formula_terms	S	CF	Identifies variables that correspond to the terms in a formula, for instance for a dimensionless vertical coordinate. Example: "ap: hyam b: hybm ps: aps"
institution	S	CF	Specifies where the original data was produced.
long_name	S	CF	A descriptive name that indicates a variable's content. This name is not standardized.
positive	S	CF	Direction of increasing vertical coordinate value ('up' for z in m or 'down' for p in hPa).
references	S	CF	References that describe the data or methods used to produce it.
source	S	CF	Method of production of the original data.

Table 10: Attributes for variables used in S5p netCDF-4 files (continued).

Name	Type	Std.	Description
standard_error_multiplier	F	CF	If a data variable with a standard_name modifier of standard_error has this attribute, it indicates that the values are the stated multiple of one standard error. The only allowed value for S5p files is 1, used only to disambiguate.
standard_name	S	CF	A standard name that references a description of a variable's content in the standard name table.
units	S	CF	Units of a variable's content. See section 11 for a detailed discussion.
valid_max	P	NUG	Largest valid value of a variable.
valid_min	P	NUG	Smallest valid value of a variable.
valid_range	P[2]	NUG	Smallest and largest valid values of a variable. This attribute should not be combined with either valid_min or valid_max

A Flag descriptions

The following tables describe the Measurement flags, Processing quality flags (processing failures and filter conditions, errors and warnings) and surface classifications.

Table 11: Processing quality flags, errors, processing failures and filter conditions for S5P Level 2. Warnings are listed in table 12. The value in the first column is the result of a bitwise ‘and’ of 255 (0xFF) and the value in the “processing_quality_flags” variable.

#	Short name	Description	Algorithm
0	success	No failures, output contains value. Warnings still possible.	All
1	radiance_missing	The number of spectral pixels in the radiance due to flagging is too small to perform the fitting.	All
2	irradiance_missing	The number of spectral pixels in the irradiance due to flagging is too small to perform the fitting.	All
3	input_spectrum_missing	The reflectance spectrum does not contain enough points to perform the retrieval. This is different from (ir)radiance_missing in that the missing points may not be aligned.	All
4	reflectance_range_error	Any of the reflectances is out of bounds ($R < 0$ or $R > R_{\max}$).	FRESCO
5	ler_range_error	Lambert-equivalent reflectivity out of range error.	CO, CH ₄
6	snr_range_error	Too low signal to noise to perform retrieval.	CO
7	sza_range_error	Solar zenith angle out of range, maximum value from configuration.	All
8	vza_range_error	Viewing zenith angle out of range, maximum value from configuration.	Development phase only
9	lut_range_error	Extrapolation in lookup table (airmass factor, cloud radiances).	NO ₂
10	ozone_range_error	Ozone column significantly out of range of profile climatology.	Total O ₃ column
11	wavelength_offset_error	Wavelength offset exceeds maximum from configuration.	FRESCO, NO ₂
12	initialization_error	An error occurred during the processing of the pixel, no output was generated. The following errors raise this flag: Mismatch between irradiance and radiance wavelengths; The on-ground distance between band 1 and band 2 ground pixels exceeds a threshold set in the configuration. Derived a-priori information does not validate, no processing is possible.	All
13	memory_error	Memory allocation or deallocation error.	CO, CH ₄
14	assertion_error	Error in algorithm detected during assertion.	CO
15	io_error	Error detected during transfer of data between algorithm and framework.	CO, ALH, CH ₄ , O ₃ profile
16	numerical_error	General fatal numerical error occurred during inversion.	CO, FRESCO
17	lut_error	Error in accessing the lookup table.	CH ₄
18	ISRF_error	Error detected in the input instrument spectral response function input data.	CH ₄
19	convergence_error	The main algorithm did not converge.	All
20	cloud_filter_convergence_error	The cloud filter did not converge.	CO

Table 11: Processing quality flags, errors, processing failures and filter conditions for S5P Level 2 (continued).

#	Short name	Description	Algorithm
21	max_iteration_convergence_error	No convergence because retrieval exceeds maximum number of iterations. Maximum value from configuration.	ALH
22	aot_lower_boundary_convergence_error	No convergence because the aerosol optical thickness crosses lower boundary twice in succession.	ALH
23	other_boundary_convergence_error	No convergence because a state vector element crosses boundary twice in succession. Note that a separate failure flag is defined for non-convergence due to crossing of lower AOT boundary.	ALH
25	ch4_noscat_zero_error	The CH ₄ column retrieved by the non-scattering CO algorithm from the weak band or strong band is 0.	CH ₄
26	h2o_noscat_zero_error	The H ₂ O column retrieved by the non-scattering CO algorithm from the weak band or strong band is 0.	CH ₄
27	max_optical_thickness_error	Maximum optical thickness exceeded during iterations.	CH ₄
28	aerosol_boundary_error	Boundary hit of aerosol parameters at last iteration.	CH ₄
29	boundary_hit_error	Fatal boundary hit during iterations.	CH ₄
30	chi2_error	χ^2 is not-a-number or larger than 10 ¹⁰ .	CH ₄
31	svd_error	Singular value decomposition failure.	CH ₄
32	dfs_error	Degree of freedom is not-a-number.	CH ₄
33	radiative_transfer_error	Errors occurred during the radiative transfer computations, no processing possible.	O ₃ profile
34	optimal_estimation_error	Errors occurred during the optimal estimation, processing has been terminated.	O ₃ profile
35	profile_error	Flag that indicates if there were any errors during the computation of the ozone profile.	O ₃ profile
36	cloud_error	No cloud data.	Cloud
37	model_error	Forward model failure.	Cloud, Total O ₃ column
38	number_of_input_data_points_too_low_error	Not enough input ozone columns to calculate a tropospheric column.	Tropospheric O ₃ column
39	cloud_pressure_spread_too_low_error	Cloud pressure variability too low to estimate a tropospheric column.	Tropospheric O ₃ column
40	cloud_too_low_level_error	Clouds are too low in the atmosphere to assume sufficient shielding.	Tropospheric O ₃ column
41	generic_range_error	Generic range error.	All
42	generic_exception	Catch all generic error.	All
43	input_spectrum_alignment_error	Input radiance and irradiance spectra are not aligned correctly.	All
44	abort_error	Not processed because processor aborted prematurely (time out or user abort)	All

Table 11: Processing quality flags, errors, processing failures and filter conditions for S5P Level 2 (continued).

#	Short name	Description	Algorithm
45	wrong_input_type_error	Wrong input type error, mismatch between expectation and received data.	All
46	wavelength_calibration_error	An error occurred in the wavelength calibration of this pixel	All
47	coregistration_error	No colocated pixels found in a supporting band	All
51	signal_to_noise_ratio_error	The signal to noise ratio for this spectrum is too low for processing	All
52	configuration_error	Error while parsing the configuration	All
53	key_error	Key does not exist	All
54	saturation_error	Saturation in input spectrum	All
55	max_num_outlier_exceeded_error	The number of outliers detected in the DOAS fit exceeds a maximum set for healthy spectra.	NO ₂
64	solar_eclipse_filter	Solar eclipse.	All
65	cloud_filter	The cloud filter triggered causing the pixel to be skipped.	CO, ALH, CH ₄
66	altitude_consistency_filter	Too large difference between ECMWF altitude and DEM altitude value.	CO, CH ₄
67	altitude_roughness_filter	Too large standard deviation of altitude in DEM.	CO, ALH, CH ₄
68	sun_glint_filter	For pixels over water, viewing direction inside sun glint region. Definition of sun glint angle and threshold value from ATBD.	ALH
69	mixed_surface_type_filter	Pixel contains land and water areas (e.g. coastal pixel).	ALH
70	snow_ice_filter	Pixel contains snow/ice: Snow/ice flag according to dynamic input OR climatological surface albedo at VIS wavelength is larger than 0.5.	ALH
71	aai_filter	AAI smaller than 2.0.	ALH
72	cloud_fraction_fresco_filter	Pixel contains clouds: The FRESCO effective cloud fraction is larger than threshold. Threshold value from ATBD.	ALH
73	aai_scene_albedo_filter	Pixel contains clouds: The difference between scene albedo at 380 nm from AAI calculation and the climatological surface albedo exceeds threshold. Threshold value from ATBD. This test filters out clouds.	ALH
74	small_pixel_radiance_std_filter	Pixel contains clouds: Standard deviation of radiances in small-pixel column exceeds threshold. Threshold value from ATBD.	ALH, CH ₄
75	cloud_fraction_viirs_filter	Pixel contains clouds: The cloud fraction from VIIRS / NPP exceeds threshold. Threshold value from ATBD.	ALH
76	cirrus_reflectance_viirs_filter	Pixel contains clouds: Cirrus reflectance from VIIRS / NPP exceeds threshold. Threshold value from ATBD.	ALH

Table 11: Processing quality flags, errors, processing failures and filter conditions for S5P Level 2 (continued).

#	Short name	Description	Algorithm
77	cf_viirs_swir_ifov_filter	Fraction of cloudy VIIRS pixels within S5P SWIR ground pixel exceeds a priori threshold from configuration.	CH ₄
78	cf_viirs_swir_ofova_filter	Fraction of cloudy VIIRS pixels within S5P SWIR OFOVa exceeds a priori threshold from configuration.	CH ₄
79	cf_viirs_swir_ofovb_filter	Fraction of cloudy VIIRS pixels within S5P SWIR OFOVb exceeds a priori threshold from configuration.	CH ₄
80	cf_viirs_swir_ofovc_filter	Fraction of cloudy VIIRS pixels within S5P SWIR OFOVc exceeds a priori threshold from configuration.	CH ₄
81	cf_viirs_nir_ifov_filter	Fraction of cloudy VIIRS pixels within S5P NIR ground pixel exceeds a priori threshold from configuration.	CH ₄
82	cf_viirs_nir_ofova_filter	Fraction of cloudy VIIRS pixels within S5P NIR OFOVa exceeds a priori threshold from configuration.	CH ₄
83	cf_viirs_nir_ofovb_filter	Fraction of cloudy VIIRS pixels within S5P NIR OFOVb exceeds a priori threshold from configuration.	CH ₄
84	cf_viirs_nir_ofovc_filter	Fraction of cloudy VIIRS pixels within S5P NIR OFOVc exceeds a priori threshold from configuration.	CH ₄
85	refl_cirrus_viirs_swir_filter	Average VIIRS cirrus reflectance within SWIR ground pixel exceeds a priori threshold from configuration.	CH ₄
86	refl_cirrus_viirs_nir_filter	Average VIIRS cirrus reflectance within NIR ground pixel exceeds a priori threshold from configuration.	CH ₄
87	diff_refl_cirrus_viirs_filter	Difference in VIIRS average cirrus reflectance between SWIR and NIR ground pixel exceeds a priori threshold from configuration.	CH ₄
88	ch4_noscat_ratio_filter	The ratio between [CH ₄] _{weak} and [CH ₄] _{strong} is below or exceeds a priori thresholds from configuration.	CH ₄
89	ch4_noscat_ratio_std_filter	The standard deviation of [CH ₄] _{weak} /[CH ₄] _{strong} within the SWIR pixel and the 8 neighbouring pixels exceeds a priori threshold from configuration.	CH ₄
90	h2o_noscat_ratio_filter	The ratio between [H ₂ O] _{weak} and [H ₂ O] _{strong} is below or exceeds a priori thresholds from configuration.	CH ₄
91	h2o_noscat_ratio_std_filter	The standard deviation of [H ₂ O] _{weak} /[H ₂ O] _{strong} within the SWIR pixel and the 8 neighbouring pixels exceeds a priori threshold from configuration.	CH ₄

Table 11: Processing quality flags, errors, processing failures and filter conditions for S5P Level 2 (continued).

#	Short name	Description	Algorithm
92	diff_psurf_fresco_ecmwf_filter	Difference between the FRESCO apparent surface pressure and the ECMWF surface pressure exceeds a priori threshold from configuration.	CH ₄
93	psurf_fresco_stdv_filter	The standard deviation of the FRESCO apparent surface pressure in the NIR pixel and the 8 surrounding pixels exceeds a priori threshold from configuration.	CH ₄
94	ocean_filter	The ground pixel is over ocean (and ocean glint retrievals are not switched on).	CH ₄
95	time_range_filter	Time is out of the range that is to be processed.	All
96	pixel_or_scanline_index_filter	Not processed because pixel index does not match general selection criteria.	All
97	geographic_region_filter	Pixel falls outside the specified regions of interest.	All

Table 12: Processing quality flags, warnings for S5P Level 2. Errors, processing failures and filter conditions are listed in table 11. If a bitwise ‘and’ of the mask value and the value in the “processing_quality_flags” variable is not zero, then the warning applies to the specific retrieval.

Bit #	Mask (hex)	Short name	Description	Algorithm
0–7	0x000000FF	error	If non-zero an error has occurred when processing the pixel, see table 11 for details.	All
8	0x00000100	input_spectrum_warning	Number of good pixels in radiance, irradiance or calculated reflectance below threshold from configuration.	All
9	0x00000200	wavelength_calibration_warning	Offset from wavelength fit is larger than limit set in configuration.	Most
10	0x00000400	extrapolation_warning	Pressure or temperature outside cross section LUT range, other lookup table extrapolation.	CO, CH ₄
11	0x00000800	sun_glint_warning	Sun glint possibility warning.	All
12	0x00001000	south_atlantic_anomaly_warning	TROPOMI is inside the south Atlantic anomaly while taking these measurements.	All
13	0x00002000	sun_glint_correction	A sun glint correction has been applied.	Cloud
14	0x00004000	snow_ice_warning	Snow/ice flag is set, i.e. using scene data from the cloud support product.	NO ₂
15	0x00008000	cloud_warning	Cloud filter based on FRESCO apparent surface pressure (VIIRS not available), cloud fraction above threshold or cloud pressure adjusted to force cloud above surface. In case of Cloud product this flag indicates the possibility of ice-clouds.	CH ₄ , O ₃ profile, Cloud
16	0x00010000	AAI_warning	Possible aerosol contamination as either indicated by the AAI (O ₃ profile) or other criteria (Cloud).	O ₃ profile, Cloud

Table 12: Processing quality flags, warnings for S5P Level 2 (continued).

Bit #	Mask (hex)	Short name	Description	Algorithm
17	0x00020000	pixel_level_input_data_missing	Dynamic auxiliary input data (e.g.. cloud) is missing for this ground pixel. A fallback option is used.	All
18	0x00040000	data_range_warning	Carbon monoxide column tends to negative values; Water column tends to negative values; Heavy water (HDO) column tends to negative values; others. In case of the O ₃ product this flag indicates VCD or effective albedo values outside a valid range. In case of the SO ₂ or the HCHO product this flag indicates AMF values outside a valid range.	CO, CH ₄ , O ₃ , SO ₂ , HCHO
19	0x00080000	low_cloud_fraction_warning	Low cloud fraction, therefore no cloud pressure retrieved.	Cloud
20	0x00100000	altitude_consistency_warning	Difference between ECMWF surface elevation and high-resolution surface elevation exceeds threshold from configuration.	CH ₄
21	0x00200000	signal_to_noise_ratio_warning	Signal to noise ratio in SWIR and/or NIR band below threshold from configuration. For the O ₃ and HCHO products this flag indicates an RMS above a certain threshold.	CH ₄ , O ₃ , HCHO
22	0x00400000	deconvolution_warning	Failed deconvolution irradiance spectrum (not pixel-specific, but row-specific).	CO, CH ₄
23	0x00800000	so2_volcanic_origin_likely_warning	Warning for SO ₂ BL product, UTLS products: volcanic origin except for heavily polluted sites.	SO ₂
24	0x01000000	so2_volcanic_origin_certain_warning	Warning for SO ₂ BL product, UTLS products: volcanic origin certain.	SO ₂
25	0x02000000	interpolation_warning	Warning for interpolation on partially missing data. In this case the valid available data is used, potentially leading to a bias.	All
26	0x04000000	saturation_warning	Saturation occurred spectrum, possibly causing biases in the retrieval	All
27	0x08000000	high_sza_warning	Warning for high solar zenith angle. In this case, the processing can be performed with less final quality.	All
28	0x10000000	cloud_retrieval_warning	Warning occurring when the retrieval diagnostic indicates a degraded quality of the cloud retrieval.	Cloud
29	0x20000000	cloud_inhomogeneity_warning	The cloud coregistration inhomogeneity parameter is above a given threshold	Cloud

Table 13: Surface classification for S5P Level 2. This is a combined land/water mask and surface classification data field. For land the “Global Land Cover Characteristics Data Base Version 2.0” is used [ER8], specifically the “USGS Land Use/Land Cover System (Modified Level 2)” classification. Over water the classification from the NASA SDP toolkit [ER9], which is based on [RD38].

Bit #	Mask (hex)	Short name	Description
0	0x03	Land	The pixel is over land, for more than 50 %
1	0x03	Water	The pixel is over water, for more than 50 %
2	0x03	some_water	Pixel contains water (however small the fraction), i.e. at least one of the 15 × 15 arcsecond subpixels in the SDP dataset is classified as water
3	0x03	coastline	Pixel is water, but contains land (coastline)
0	0x04	mixed_surface	Pixel has a mixed surface type. Classification is result of highest bin, not overwhelming majority, i.e. type covers less than 50 % of pixel surface
4	0x04	value_covers_majority_of_pixel	Pixel is dominated by surface type, i.e. type covers more than 50 % of pixel surface
9	0xF9	Water+Shallow_Ocean	Water, shallow ocean
17	0xF9	Water+Shallow_Inland_Water	Water, shallow inland water (lake)
25	0xF9	Water+Ocean_Coastline-Lake_Shoreline	Water, mixed with land; coastline
33	0xF9	Water+Intermittent_Water	Intermittent water, for instance the Wadden Sea
41	0xF9	Water+Deep_Inland_Water	Deep inland water
49	0xF9	Water+Continental_Shelf_Ocean	Water, continental shelf ocean
57	0xF9	Water+Deep_Ocean	Water, deep ocean
8	0xF9	Land+Urban_And_Built-up_Land	Land, urban areas
16	0xF9	Land+Dryland_Cropland_And_Pasture	Land, Dryland Cropland and Pasture
24	0xF9	Land+Irrigated_Cropland_And_Pasture	Land, Irrigated Cropland and Pasture
32	0xF9	Land+Mixed_Dryland-irrigated_Cropland_And_Pasture	Land, Mixed Dryland/Irrigated Cropland and Pasture
40	0xF9	Land+Cropland-grassland_Mosaic	Land, Cropland/Grassland Mosaic
48	0xF9	Land+Cropland-woodland_Mosaic	Land, Cropland/Woodland Mosaic
56	0xF9	Land+Grassland	Land, Grassland
64	0xF9	Land+Shrubland	Land, Shrubland
72	0xF9	Land+Mixed_Shrubland-grassland	Land, Mixed Shrubland/Grassland
80	0xF9	Land+Savanna	Land, Savanna
88	0xF9	Land+Deciduous_Broadleaf_Forest	Land, Deciduous Broadleaf Forest

Table 13: Surface classification for S5P Level 2 (continued).

Bit #	Mask (hex)	Short name	Description
96	0xF9	Land+Deciduous_Needleleaf_Forest	Land, Deciduous Needleleaf Forest
104	0xF9	Land+Evergreen_Broadleaf_Forest	Land, Evergreen Broadleaf Forest
112	0xF9	Land+Evergreen_Needleleaf_Forest	Land, Evergreen Needleleaf Forest
120	0xF9	Land+Mixed_Forest	Land, Mixed Forest
128	0xF9	Land+Herbaceous_Wetland	Land, Herbaceous Wetland
136	0xF9	Land+Wooded_Wetland	Land, Wooded Wetland
144	0xF9	Land+Barren_Or_Sparsely_Vegetated	Land, Barren or Sparsely Vegetated
152	0xF9	Land+Herbaceous_Tundra	Land, Herbaceous Tundra
160	0xF9	Land+Wooded_Tundra	Land, Wooded Tundra
168	0xF9	Land+Mixed_Tundra	Land, Mixed Tundra
176	0xF9	Land+Bare_Ground_Tundra	Land, Bare Ground Tundra
184	0xF9	Land+Snow_Or_Ice	Land, Snow or Ice