

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





document number : S5P-KNMI-L2-0022-MA

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CI identification : CI-7570-PUM

issue : 2.4.0
applicable to processor release : 2.4.0
date : 2022-07-11
status : released

Document approval record

This document was prepared by Arnoud Apituley, Mattia Pedergnana, Maarten Sneep, J. Pepijn Veefkind, Diego Loyola, Bram Sanders, Martin de Graaf.

Document change record

issue	date	item	comments	
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.	
2.0.0	2021-06-24		Released with L2 processor update July 2021	
2.0.1	2021-11-15		Updated for processor release 2.3.1	
2.4.0	2022-07-11		Updated for processor release 2.4.0	

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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: 10.0.0; date: 2019-07-19.
- [RD3] S5P/TROPOMI ATBD Cloud Products. source: DLR; ref: S5P-DLR-L2-ATBD-400I; issue: 2.3.0; date: 2021-06-25.
- [RD4] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Cloud. source: DLR; ref: S5P-L2-DLR-PUM-400I; issue: 2.4.0; date: 2022-07-11.
- [RD5] S5P-NPP Cloud Processor ATBD.
 source: RAL Space; ref: S5P-NPPC-RAL-ATBD-0001; issue: 1.0.0; date: 2016-02-12.
- [RD6] S5P/TROPOMI HCHO ATBD. source: BIRA; ref: S5P-BIRA-L2-400F-ATBD; issue: 2.4.1; date: 2022-06-22.
- [RD7] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual HCHO. source: DLR; ref: S5P-L2-DLR-PUM-400F; issue: 2.4.0; date: 2022-07-11.
- [RD8] S5P/TROPOMI SO₂ ATBD. source: BIRA; ref: S5P-BIRA-L2-400E-ATBD; issue: 2.4.0; date: 2022-06-22.
- [RD9] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual SO₂. **source:** DLR; **ref:** S5P-L2-DLR-PUM-400E; **issue:** 2.4.0; **date:** 2022-07-11.
- [RD10] S5P/TROPOMI Total ozone ATBD. source: DLR; ref: S5P-L2-DLR-ATBD-400A; issue: 2.3.0; date: 2021-06-04.
- [RD11] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Total Ozone Column. source: DLR; ref: S5P-L2-DLR-PUM-400A; issue: 2.4.0; date: 2022-07-11.
- [RD12] TROPOMI/S5P ATBD of tropospheric ozone data products. source: DLR/IUP; ref: S5P-DLR-IUP-L2-400C; issue: 2.3.0; date: 2021-06-04.
- [RD13] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Ozone Tropospheric Column. source: DLR; ref: S5P-L2-DLR-PUM-400C; issue: 2.3.0; date: 2021-06-04.
- [RD14] TROPOMI ATBD of the Aerosol Layer Height product. source: KNMI; ref: S5P-KNMI-L2-0006-RP; issue: 2.4.0; date: 2022-04-08.
- [RD15] TROPOMI ATBD of the UV aerosol index. source: KNMI; ref: S5P-KNMI-L2-0008-RP; issue: 2.0.0; date: 2021-07-05.
- [RD16] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Aerosol Index. source: KNMI; ref: S5P-KNMI-L2-0026-MA; issue: 2.4.0; date: 2022-07-11.

- [RD17] TROPOMI ATBD Ozone profile and tropospheric profile. source: KNMI; ref: S5P-KNMI-L2-0004-RP; issue: 1.0.0; date: 2021-10-22.
- [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: 2.4.0; date: 2022-07-11.
- [RD19] TROPOMI ATBD of the total and tropospheric NO₂ data products. **source:** KNMI; **ref:** S5P-KNMI-L2-0005-RP; **issue:** 2.4.0; **date:** 2022-07-11.
- [RD20] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Nitrogen Dioxide. source: KNMI; ref: S5P-KNMI-L2-0021-MA; issue: 2.4.0; date: 2022-07-11.
- [RD21] Algorithm Theoretical Baseline Document for Sentinel-5 Precursor: Carbon Monoxide Total Column Retrieval.
 source: SRON; ref: SRON-S5P-LEV2-RP-002; issue: 2.4.0; date: 2022-07-12.
- [RD22] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Carbon Monoxide Column. source: SRON/KNMI; ref: SRON-S5P-LEV2-MA-002; issue: 2.4.0; date: 2022-07.11.
- [RD23] Algorithm Theoretical Baseline Document for Sentinel-5 Precursor methane retrieval. source: SRON; ref: SRON-S5P-LEV2-RP-001; issue: 2.4.0; date: 2022-05-30.
- [RD24] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Methane. source: SRON/KNMI; ref: SRON-S5P-LEV2-MA-001; issue: 2.4.0; date: 2022-07-11.
- [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: 9.0.0; date: 2019-07-19.
- [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*; **12** (2019), 6610; 10.5194/amt-12-6619-2019. URL https://amt.copernicus.org/articles/12/6619/2019/.
- [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: 6.0.0; date: 2019-07-19.
- [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: 15.0; date: 2021-08-05.
- [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).
- [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 AddedTBC To be ConfirmedTBD 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]	L2CLOUD_	DLR
NPP-VIIRS Clouds	[RD5]	[RD5]	L2NP_BDx	RAL
HCHO	[RD6]	[RD7]	L2HCHO	BIRA/DLR
SO ₂	[RD8]	[RD9]	L2S02	BIRA/DLR
O ₃ Total Column	[RD10]	[RD11]	L203	BIRA/DLR
O ₃ Tropospheric Column	[RD12]	[RD13]	L203_TCL	IUP/DLR
Aerosol layer height	[RD14]	This document	L2AER_LH	KNMI
Ultra violet aerosol index	[RD15]	[RD16]	L2AER_AI	KNMI
O ₃ Full Profile	[RD17]	[RD18]	L203PR	KNMI
NO_2	[RD19]	[RD20]	L2NO2	KNMI
CO	[RD21]	[RD22]	L2CO	SRON/KNMI
CH ₄	[RD23]	[RD24]	L2CH4	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:

 $\tt S5P_NRTI_L2_AER_LH_20190920T054303_20190920T054803_10028_01_010302_20190920T062930.nc$ 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 "YYYYMMDDTHHMMSS". The "T" is a fixed character.
36	51	15	End of the granule in UTC as "YYYYMMDDTHHMMSS". The "T" is a fixed character.
52	57	5	Orbit number
58	60	2	Collection number
61	67	6	Processor version number as "MMmmpp", 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 "YYYYMMDD ${f T}$ 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.cdl" 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.

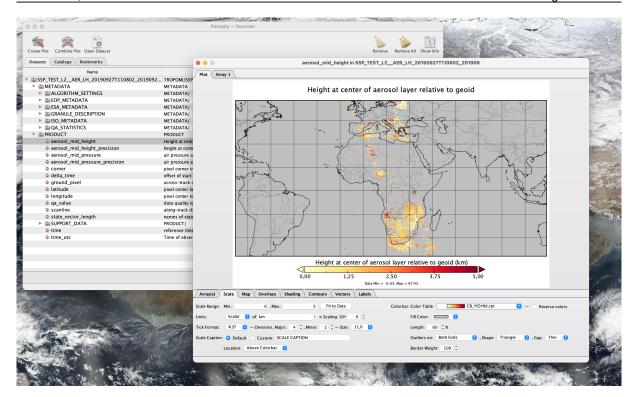


Figure 1: Panoply

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 Ion-lat map plots in KMZ format.
- Export animations as AVI or MOV video or as a collection of invididual 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.

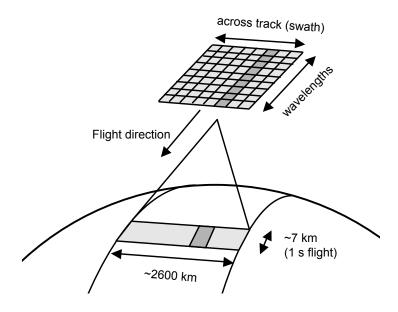


Figure 2: TROPOMI measurement principle.

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 O_2 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 O_2 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

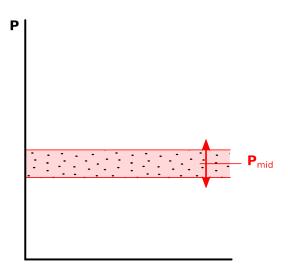


Figure 3: The aerosol profile assumed in retrieval is a uniform scattering layer with fixed pressure thickness. The reported retrieval parameter is the mid pressure of the layer (top pressure plus bottom pressure divided by two).

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 <code>aerosol_mid_pressure</code>.

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

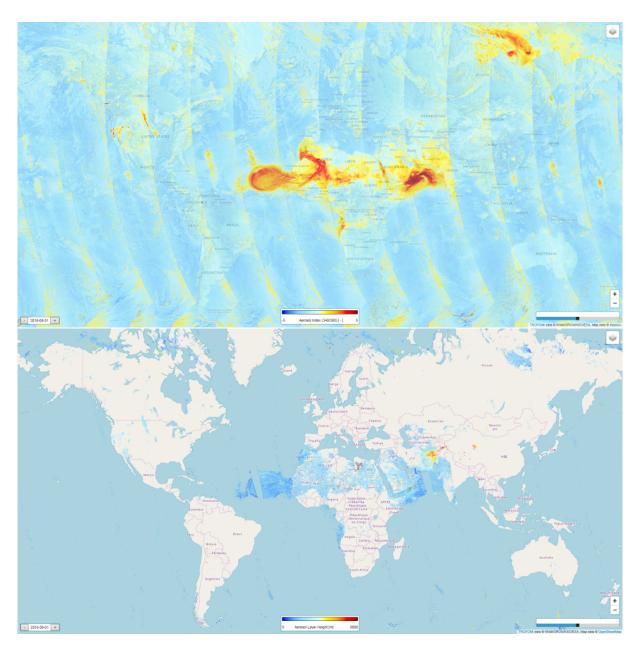


Figure 4: Top panel: TROPOMI UVAI on 1 August 2018 showing a large aerosol (dust) plume over the Atlantic Ocean originating from the Sahara, and several other hotspots of high UVAI from smoke and dust. Bottom panel: TROPOMI ALH-NN retrieval results from an initial test run of the ALH processor with NN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

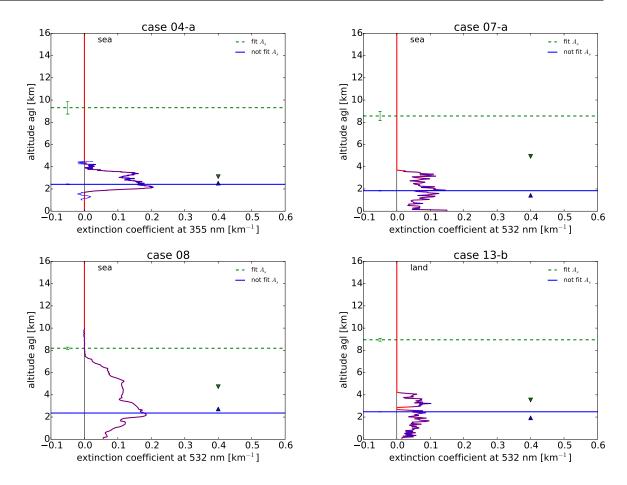


Figure 5: Comparison of retrieved aerosol layer mid pressure with lidar measurements for four representative GOME-2A pixels. Case 07-a and 08 are desert dust over sea, case 13-b is transported dust over land, and case 04-a is transported smoke over land. The blue solid horizontal line is the retrieved 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.

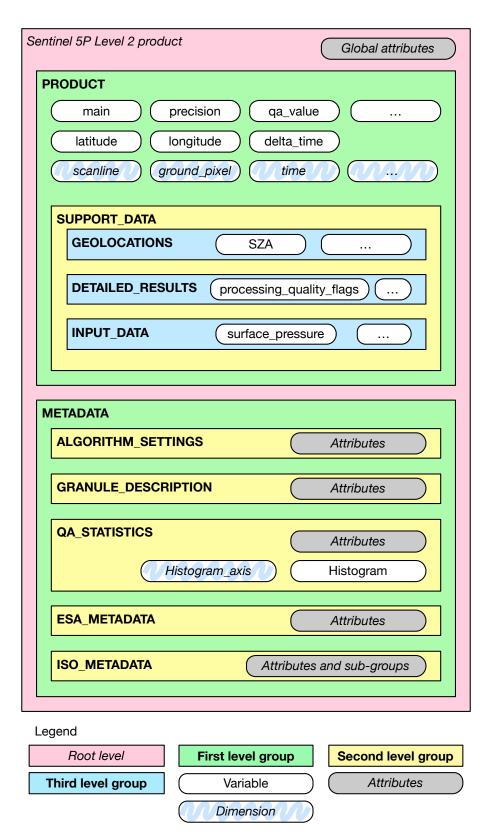


Figure 6: Graphical description of the generic structure of a Level 2 file. The elements labelled as a dimension are coordinate variables. See section 9 for a full description.

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

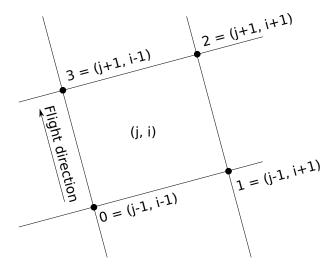


Figure 7: Pixel corner coordinates. The sequence $\{0,1,2,3\}$ refers to the elements in the corner dimension.

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].

$$p(n,k,j,i) = a_{p}(k) + b(k)p_{s}(n,j,i)$$
(1)

where p(n,k,j,i) is the pressure at gridpoint (n,k,j,i) on the (T,Z,Y,X) axes; $a_{\rm p}(k)$ and b(k) the components of the hybrid coordinate at level k and $p_{\rm s}(n,j,i)$ 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 $a_{\rm p}(k)$ 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 attach	ned to AER_LH	
Name	Value	Туре
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 hierarchicaly 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 ProcessingCenter 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 NC_STRING sensing, L2' (dynamic)

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 occured, 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 "processing_status" 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 "id" and "naming_authority" attributes are intended to provide a globally unique identification for each dataset. The "id" value should attempt to uniquely identify the dataset. The naming authority allows a further refinement of the "id". The combination of the two should be globally unique for all time. We use the logical file name for the "id" attribute. This attribute originates from the CCI standard.

	2000/INA PRT20 00 0071//	NO OTRINO
time_reference	'YYYY-MM-DDT00:00:00Z' (dynamic)	NC_STRING
dimensional variable. By definiti	D 8601 [RD36] string. This corresponds to the UTC value on it indicates UTC midnight before the start of the granue	lle.
time_reference_days since_1950	0 (dynamic)	NC_INT
The reference time expressed as by both TM5 and ECMWF.	s the number of days since 1950-01-01. This is the referen	ce time unit used
time_reference_julian_day	0.0 (dynamic)	NC_DOUBLE
The reference time expressed a	s a Julian day number.	
time_reference_seconds since_1970	0 (dynamic)	NC_INT64
The reference time expressed reference time unit used by Unix	as the number of seconds since 1970-01-01 00:00:00 x systems.	UTC. This is the
time_coverage_start	'YYYY-MM-DDTHH:MM:SS.mmmmmmZ' (dynamic)	NC_STRING
Start of the data granule in UTO variable on page 31 for details.	C as an ISO 8601 [RD36] string. See the discussion of t	the time_delta
time_coverage_end	'YYYY-MM-DDTHH:MM:SS.mmmmmmZ' (dynamic)	NC_STRING
End of the data granule in UTC variable on page 31 for details.	as an ISO 8601 [RD36] string. See the discussion of t	he time_delta
time_coverage_duration		NC_STRING
Duration of the data granule as attribute originates from the CC	an ISO 8601 [RD36] duration string ("PT%(duration_se I standard.	conds)sS"). This
time_coverage_resolution		NC_STRING
seconds)fS"). For most product	in the data granule as an ISO 8601 [RD36] duration string ts this is 1080 ms in nominal operation, except for "L2	
orbit	0 (dynamic)	NC_INT
The absolute orbit number, star pre-launch testing this value sho	rting at 1 – first ascending node crossing after spacecraft buld be set to " -1 ".	
references	'%(references)s' (static)	NC_STRING
References that describe the d standard.	ata or methods used to produce it. This attribute original	ates from the CF
processor_version	'%(version)s' (dynamic)	NC_STRING
The version of the data process	or, 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 k	keywords attribute. We use the index terms published by	the AGU.
keywords	'%(keywords_agu)s' (dynamic)	NC_STRING
Keywords from the "keywords ATBD authors.	_vocabulary" describing the contents of the file. To be	provided by the
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 standard		
naming_authority	'%(naming_authority)s' (dynamic)	NC_STRING
Specify who is giving out the id	attribute. This attribute originates from the CCI standard	
cdm_data_type	'Swath' (static)	NC_STRING
attribute originates from the CC		
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 '%(credit)s' (dynamic)	NC_STRING
The name of the creator, equal to the value of the "gmd:credit" attribute. For S5P this to "The Sentinel 5 Precursor TROPOMI Level 2 products are developed with funding from Space Agency (ESA), the Netherlands Space Office (NSO), the Belgian Science Policy Of Aerospace Center (DLR) and the Bayerisches Staatsministerium für Wirtschaft und Mec Technologie (StMWi)." This attribute originates from the CCI standard.	om the European ffice, the German
creator_url '%(creator_url)s' (dynamic)	NC_STRING
Hyperlink to a location where more information on the product can be found. Set to $http:/eu/$. This attribute originates from the CCI standard.	/www.tropomi.
creator_email 'EOSupport@Copernicus.esa.int' (dynamic)	NC_STRING
Point of contact for more information and support for this product "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 C	CI standard.
geospatial_lat_max	NC_FLOAT
Highest latitude present in the file in decimal degrees. This attribute originates from the 0	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 originates from the CCI standard.	y". This attribute
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 " $3.5 \times 7 \mathrm{km^2}$ ", except for " $\mathrm{L2}$ $\mathrm{O3}$ _ " $28 \times 21 \mathrm{km^2}$ " and " $\mathrm{L2}$ CO " and " $\mathrm{L2}$ $\mathrm{CH4}$ ", which both use " $7 \times 7 \mathrm{km^2}$ ". This at from the CCI standard.	_PR", which uses tribute originates
cpp_compiler_version	NC_STRING
The version of the compiler used for the C++ code. The value of this attribute is set via the	ne Makefile.
cpp_compiler_flags	NC_STRING
The compiler flags passed to the C++ compiler. The value of this attribute is set via the N	1akefile.
f90_compiler_version	NC_STRING
The version of the compiler version used for the Fortran code. The value of this attrib Makefile. Note that not all processors make use of Fortran code.	ute is set via the
f90_compiler_flags	NC_STRING
The compiler flags passed to the Fortran compiler. The value of this attribute is set via that not all processors make use of Fortran code.	e Makefile. Note
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.	
	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

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

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

The algorithm version, separate from the processor (framework) version, to accommodate different release schedules for different products.

title

'TROPOMI/S5P Aerosol Layer Height %s L2 Swath NC_STRING

%sx%skm' (dynamic)

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

'1.4.0' (dynamic)

NC_STRING

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

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

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

Possible values: Nominal, Fallback

Status NISE

NC STRING

The status of NISE input, either "Nominal", "ECMWF" or "Static_Fallback". The nominal behaviour is to use ECMWF snow/ice information in preference to NISE data.

Possible values: Nominal, ECMWF, Static Fallback

Status_NPP_VIIRS

NC STRING

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.

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.

corner The number of corners for a pixel.

size 4 (fixed)

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

size 1 (fixed)

albedo Number of surface albedo inputs.

size -1 (dynamic)
source Processor.

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.

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.

Attributes:

Name	Value	Туре
units	'1' (static)	NC_STRING
Dimensionless, no p	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 <code>ground_pixel</code> refers to the across-track dimension of the measurement. The <code>ground_pixel</code> 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: Processo

Attributes:

Processor.				
Name	Value	Туре		
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		

WGS84 ellipsoid.

	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:	time is set to YYYY formal start of the codifference of the old of time (time) are scanline as UTC time.	(time) is the reference time of the measurements -MM-DDT00:00:00 UTC, midnight UTC before spaced urrent orbit. The delta_time(scanline) variable observations with the reference time. Thus combining delta_time(scanline) yields the measurement. The reference time(time) corresponds to the which is specified as a UTC time specified as an ISO 8	craft midnight, the indicates the time g the information ent time for each e global attribute	
Dimensions:	time (coordinate variable).			
Type:	NC_INT.			
Source:	Processor.			
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 time_reference global attribute' (static)	NC_STRING	
corner in AEF	R_LH/PRODUCT			
Dimensions:	longitude on the asc		ne lowest value for	
Type:	NC_INT.			
Source:	Processor.			
Attributes:	Name	Value	Туре	
Attributes.	units	'1' (static)	NC STRING	
		physical quantity. This attribute originates from the CF	_	
	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/F	PRODUCT		
Description:	Names of the state	vector elements, as variable length character strings.		
Dimensions:	state_vector_length	(coordinate variable).		
Type:	NC_STRING.			
Source:	Processor.			
Attributes:	Name	Value	Type	
	units	'1' (static)	NC_STRING	
	long_name	'names of state vector elements' (static)	NC_STRING	
latitude in AE Description:		pixel centers of the ground pixels in the data. Laground pixel center and the ground pixel corners are		

Dimensions:	time, scanline, grou	nd_pixel.	
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	Name	Value	Туре
	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 bounds	ary coordinates, i.e. the pixel corners. Note that the us	e of aroun-names

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.

Iongitude 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.

Attributes:

Name	Value	Туре
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 TAl2010 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.

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

	units	'milliseconds' (static)	NC_STRING	
time_utc in A	ER_LH/PRODUCT			
Description:	The time of observa	tion expressed as ISO 8601 [RD36] date-time string.		
Dimensions:	time, scanline.			
Type:	NC_STRING.			
Source:	Processor.			
Attributes:	Name	Value	Туре	
	long_name	'Time of observation as ISO 8601 date-time string' (static)	NC_STRING	
qa_value in A	ER_LH/PRODUCT			
Description:	A continuous quality	descriptor, varying between 0 (no data) and 1 (full of	quality data). The	
		sed on observation conditions and retrieval flags. Det		
		processing_quality_flags elsewhere in the pro	duct.	
Dimensions:	time, scanline, grour	nd_pixel.		
Type:	NC_UBYTE.			
Source:	Processor.			
Attributes:	Name	Value	Туре	
	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	NC_STRING	
		(no data) and 1 (full quality data). Recommend to ignore data with qa_value < 0.5' (static)		
	coordinates	'longitude latitude' (static)	NC_STRING	
aerosol_mid_	_pressure in AER_LH	H/PRODUCT		
Description:	•	aerosol layer with an assumed pressure thickness of	• ,	
	and a constant aerosol volume extinction coefficient and single scattering albedo. Mid			
	pressure is equal to top pressure plus bottom pressure divided by two. This pressure is limited to the surface pressure, regardless of the exact retrieval result.			
Dimensions:	time, scanline, grour			
	NC FLOAT.	iu_pixei.		
Type: Source:	Processor.			
Attributes:	Name	Value	Timo	
Allibules.			Type	
	units	'Pa' (static)	NC_STRING	
	long_name	'air_pressure_at_center_of_aerosol_layer, never higher than surface pressure' (static)	NC_STRING	
	coordinates	'longitude latitude' (static)	NC_STRING	
	assumed_layer	5000.0 (static)	NC FLOAT	
	pressure_thick- ness_Pa	ooo.o (statio)	110_1 20/11	
	Assumed thickness of the aerosol layer in the retrieval. This is a fixed but configurable parameter.			
aeroeol mid	_height in AER_LH/P	RODUCT		
Description:			mid altitudo (a)	
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, grour	-		
2	o, ocariirio, groui	10_pmon		

Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	Name	Value	Туре
	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_precisior	n in AER_LH/PRODUCT	
Description:	A measure for the posteriori) distribution	recision of p_{mid} is the standard deviation (sigma) of the on.	e fit parameter's (a
Dimensions:	time, scanline, grou	nd_pixel.	
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	Name	Value	Туре
	units	'Pa' (static)	NC_STRING
	long_name	'air_pressure_at_center_of_aerosol_layer stand- ard_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, grou	nd_pixel.	
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	Name	Value	Туре
	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.			
Attributes:	Name	Value	Туре	
	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_long	gitude in AER_LH/P	PRODUCT/SUPPORT_DATA/GEOLOCATIONS	
Description:	Longitude of the geodetic sub satellite point on the WGS84 reference ellipsoid.		
Dimensions:	time, scanline.		
Туре:	NC_FLOAT.		
Source:	L1B.		
Attributes:	Name	Value	Туре
	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_altit	ude in AER_LH/PR	ODUCT/SUPPORT_DATA/GEOLOCATIONS	
Description: Dimensions:	The altitude of the reference ellipsoid time, scanline. NC FLOAT.	e satellite with respect to the geodetic sub satellite poi	nt on the WGS8
Type: Source:	L1B.		
Attributes:	Name	Value	Tuno
Allibules.			Type
	long_name units	'satellite altitude' (static) 'm' (static)	NC_STRING 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 orbi	-	H/PRODUCT/SUPPORT_DATA/GEOLOCATIONS	
Description:	_ -	$[0,\ldots,1.0]$ of the measurement in the orbit.	
Dimensions:	time, scanline.	, , ,	
Type:	NC_FLOAT.		
Source:	L1B.		
Attributes:	Name	Value	Туре
	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/F	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 $\vartheta_0 \leq \vartheta_0^{\text{max}}$ with $80^\circ \leq \vartheta_0^{\text{max}} \leq 88^\circ$, depending on the algorithm. The actual value for ϑ_0^{max} can be found in the algorithm metadata settings.		
	time, scanline, gro	und pixel.	
		—	
Dimensions: Type: Source:	NC_FLOAT.	_	

coordinates

Attributes:	Name	Value	Туре
	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 lo	ngitude are in a different group. How to specify the case is not specified in the climate and forecast	related geospatial
	comment	'Solar zenith angle at the ground pixel location on the reference ellipsoid. Angle is measured away from the vertical' (static)	NC_STRING
solar_azimut	h_angle in AER_LH/	PRODUCT/SUPPORT_DATA/GEOLOCATIONS	
Description:	measured clockwise This is the same de	angle at the ground pixel location on the reference ellipse from the North (North = 0° , East = 90° , South = ± 18 elimition that is use in both OMI and GOME-2 level 1B	80° , West = -90°). files.
		e viewing_azimuth_angle on the calculation of the diative transfer calculations.	e relative azimutri
Dimensions:	time, scanline, grou	ınd_pixel.	
Type:	NC_FLOAT.		
Source:	L1B.		
Attributes:	Name	Value	Туре
	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
		ngitude are in a different group. How to specify the case is not specified in the climate and forecast	
	comment	'Solar azimuth angle at the ground pixel location on the reference ellipsoid. Angle is measured clock- wise from the North (East = 90, South = +/-180, West = -90)' (static)	NC_STRING
viewing_zeni	th_angle in AER_LH	I/PRODUCT/SUPPORT_DATA/GEOLOCATIONS	
Description:	Zenith angle of the is measured away f	satellite ϑ at the ground pixel location on the reference from the vertical.	ce ellipsoid. Angle
Dimensions:	time, scanline, grou	nd_pixel.	
Type:	NC_FLOAT.		
Source:	L1B.	Valua	Tuno
Attributes:	Name	Value	Type
	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

'/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].

'Zenith angle of the satellite at the ground pixel location on the reference ellipsoid. Angle is measured away from the vertical' (static)

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 = $\pm 180^{\circ}$, West = -90°). This is the same definition that is use in both OMI and GOME-2 level 1B files.

To calculate the azimuth difference $\phi-\phi_0$ it is not sufficient to just subtract <code>solar_-azimuth_angle</code> from <code>viewing_azimuth_angle</code>. The angle needed for radiative transfer calculations is $(180^\circ-(\phi-\phi_0)) \mod 360^\circ$.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: L1B.

Attributes:

Name	Value	Туре
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].

'Satellite azimuth angle at the ground pixel location on the reference ellipsoid. Angle is measured clockwise from the North (East = 90, South = +/-180, West = -90)' (static)

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.

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.

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, grou	nd_pixel.		
Type:	NC_UBYTE.			
Source:	Processor.			
Attributes:	Name	Value	Туре	
	_FillValue	255 (static)	NC_UBYTE	
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING	
	flag_masks	0, 1, 2, 4, 8, 16, 32, 128 (static)	NC_UBYTE	
	flag_meanings	'no_error solar_eclipse sun_glint_possible des- cending night geo_boundary_crossing spacecraft manoeuvre geolocation_error' (static)	NC_STRING	
	flag_values	0, 1, 2, 4, 8, 16, 32, 128 (static)	NC_UBYTE	
	long_name	'geolocation flags' (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"

$\label{thm:condition} \textbf{Variables in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS}$

processing_o	quality_flags in Al	ER_LH/PRODUCT/SUPPORT_DATA/DETAILED_RESU	JLTS		
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 occured 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, gr	time, scanline, ground_pixel.			
Type:	NC_UINT.	NC_UINT.			
Source:	Processor.				
Attributes:	Name	Value	Туре		
	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 numerical_error lut_error ISRF_error convergence_error cloud_filter_convergence_error max_iteration_convergence error aot lower boundary convergence_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 transfer_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 error 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_radiance_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 pixel level input data missing AAI warning data range warning low cloud fraction warning 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_recloud inhomogeneity warning trieval warning

thermal instability warning' (static)

NC STRING

	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
		• • •	
	units	'1' (static)	NC STRING
	long_name	'number of iterations' (static)	NC_STRING
Attributes:	Name	Value	Туре
Source:	Processor.		
Туре:	NC_INT.	→	
Dimensions:	time, scanline, gro	· ·	
Description:	_	rations needed to achieve convergence.	
number of i		H/PRODUCT/SUPPORT DATA/DETAILED RESULTS	
		ongitude are in a different group. How to specify the r s case is not specified in the climate and forecast r	• .
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	long_name	'Number of spectral points used in the retrieval' (static)	NC_STRING
Attributes:	Name	Value	Type
Source:	Processor.		
Type:	NC_USHORT.		
Dimensions:	time, scanline, gro	ound_pixel.	
Description:	•	ints in the spectrum that were used in the retrieval.	
	spectral_points_in_	retrieval in AER_LH/PRODUCT/SUPPORT_DATA/DET	AILED_RESULT
		s case is not specified in the climate and forecast r	
		ongitude are in a different group. How to specify the r	_
	coordinates	536870912, 1073741824 (static) '/PRODUCT/longitude /PRODUCT/latitude' (static)	NC STRING
		33554432, 67108864, 134217728, 268435456,	
		1048576, 2097152, 4194304, 8388608, 16777216,	
		16384, 32768, 65536, 131072, 262144, 524288,	
		94, 95, 96, 97, 256, 512, 1024, 2048, 4096, 8192,	
		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,	
		44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 64, 65,	
		31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43,	
	nay_values	17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30,	140_01141
	flag_values	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16,	NC_UINT
		33554432, 67108864, 134217728, 268435456, 536870912, 1073741824 (static)	
		1048576, 2097152, 4194304, 8388608, 16777216,	
		16384, 32768, 65536, 131072, 262144, 524288,	
		255, 255, 256, 512, 1024, 2048, 4096, 8192,	
		255, 255, 255, 255, 255, 255, 255, 255,	
		255, 255, 255, 255, 255, 255, 255, 255,	
		255, 255, 255, 255, 255, 255, 255, 255,	
		255, 255, 255, 255, 255, 255, 255, 255,	
		255, 255, 255, 255, 255, 255, 255, 255,	
		255, 255, 255, 255, 255, 255, 255, 255,	
		255, 255, 255, 255, 255, 255, 255, 255,	

Mid pressure of an aerosol layer with an assumed pressure thickness of (currently) 50 hPa Description:

> and a constant aerosol volume extinction coefficient and single scattering albedo. Mid pressure is equal to top pressure plus bottom pressure divided by two. This pressure is the original retrieval result, and may contain pressures higher than the reported surface

pressure.

Dimensions: time, scanline, ground_pixel.

NC FLOAT. Type: Source: Processor.

Attributes:

Name	Value	Туре
units	'Pa' (static)	NC_STRING
long_name	'air_pressure_at_center_of_aerosol_layer, can be higher than surface pressure' (static)	NC_STRING
coordinates	'longitude latitude' (static)	NC_STRING
assumed_layer pressure_thick- ness_Pa	5000.0 (static)	NC_FLOAT

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

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

758 nm, and is used to achieve radiance closure in the retrieval.

Dimensions: time, scanline, ground pixel.

Type: NC FLOAT. Source: Processor.

Attributes:

Name	Value	Туре
units	'1' (static)	NC_STRING
standard_name	'atmosphere_optical_thickness_due_to_ambient_aerosol_particles' (static)	NC_STRING
long_name	'aerosol_optical_thickness' (static)	NC_STRING
comment	'This parameter is used to achieve radiance closure at 758 nm, it is not intended to be a 'Sentinel 5p aerosol optical thickness'.' (static)	NC_STRING
radiation wavelength	758.0 (static)	NC_FLOAT
coordinates	'longitude latitude' (static)	NC_STRING

surface albedo in AER LH/PRODUCT/SUPPORT DATA/DETAILED RESULTS

Surface albedo at two wavelength nodes. Polynomial interpolation is used to determine the Description:

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.

NC FLOAT. Type: Source: Processor.

Attributes:

Name	Value	Туре
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 units attribute.

time, scanline, ground pixel, state vector length, state vector length. Dimensions:

Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	Name	Value	Туре
	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_opti	cal_thickness_prec	ision in AER_LH/PRODUCT/SUPPORT_DATA/DETA	ILED_RESULTS
Description:	A measure for the posteriori) distributi	precision of $ au$ is the standard deviation (sigma) of the ion.	fit parameter's (
Dimensions:	time, scanline, grou	und_pixel.	
Туре:	NC_FLOAT.		
Source:	Processor.		
Attributes:	Name	Value	Туре
	units	'1' (static)	NC_STRING
	standard_name	'atmosphere_optical_thickness_due_to_ambient_aerosol_particles standard_error' (static)	NC_STRING
	long_name	'aerosol_optical_thickness standard_error' (static)	NC_STRING
	coordinates	'longitude latitude' (static)	NC_STRING
root_mean_s	quare_error_of_fit	in AER_LH/PRODUCT/SUPPORT_DATA/DETAILED_	RESULTS
Description:	Root mean square	error	
Dimensions:	time, scanline, grou	und pixel.	
Type:	NC FLOAT.		
• .	_		
Source:	Processor.		
	Processor. Name	Value	Туре
		Value '1' (static)	Type NC STRING
	Name units	'1' (static)	NC_STRING
	Name	'1' (static) 'root_mean_square_error' (static)	NC_STRING NC_STRING
Attributes:	Name units long_name coordinates	'1' (static) 'root_mean_square_error' (static) 'longitude latitude' (static)	NC_STRING
Attributes: chi_square ir	Name units long_name coordinates	'1' (static) 'root_mean_square_error' (static)	NC_STRING NC_STRING
Attributes: chi_square in Description:	Name units long_name coordinates AER_LH/PRODUC Chi squared	'1' (static) 'root_mean_square_error' (static) 'longitude latitude' (static) T/SUPPORT_DATA/DETAILED_RESULTS	NC_STRING NC_STRING
Attributes: chi_square in Description: Dimensions:	Name units long_name coordinates AER_LH/PRODUC Chi squared time, scanline, grou	'1' (static) 'root_mean_square_error' (static) 'longitude latitude' (static) T/SUPPORT_DATA/DETAILED_RESULTS	NC_STRING NC_STRING
Attributes: chi_square in Description: Dimensions: Type:	Name units long_name coordinates AER_LH/PRODUC Chi squared time, scanline, ground NC_FLOAT.	'1' (static) 'root_mean_square_error' (static) 'longitude latitude' (static) T/SUPPORT_DATA/DETAILED_RESULTS	NC_STRING NC_STRING
Attributes: chi_square in Description: Dimensions: Type: Source:	Name units long_name coordinates AER_LH/PRODUC Chi squared time, scanline, grou NC_FLOAT. Processor.	'1' (static) 'root_mean_square_error' (static) 'longitude latitude' (static) T/SUPPORT_DATA/DETAILED_RESULTS und_pixel.	NC_STRING NC_STRING NC_STRING
Attributes: chi_square in Description: Dimensions: Type: Source:	Name units long_name coordinates AER_LH/PRODUC Chi squared time, scanline, grou NC_FLOAT. Processor. Name	'1' (static) 'root_mean_square_error' (static) 'longitude latitude' (static) T/SUPPORT_DATA/DETAILED_RESULTS und_pixel. Value	NC_STRING NC_STRING NC_STRING Type
Chi_square in Description: Dimensions: Type: Source:	Name units long_name coordinates AER_LH/PRODUC Chi squared time, scanline, groun NC_FLOAT. Processor. Name units	'1' (static) 'root_mean_square_error' (static) 'longitude latitude' (static) T/SUPPORT_DATA/DETAILED_RESULTS und_pixel. Value '1' (static)	NC_STRING NC_STRING NC_STRING Type NC_STRING
Chi_square in Description: Dimensions: Type: Source:	Name units long_name coordinates AER_LH/PRODUC Chi squared time, scanline, grou NC_FLOAT. Processor. Name units long_name	'1' (static) 'root_mean_square_error' (static) 'longitude latitude' (static) T/SUPPORT_DATA/DETAILED_RESULTS und_pixel. Value '1' (static) 'chi_squared' (static)	NC_STRING NC_STRING NC_STRING Type NC_STRING NC_STRING
Chi_square in Description: Dimensions: Type: Source: Attributes:	Name units long_name coordinates AER_LH/PRODUC Chi squared time, scanline, grou NC_FLOAT. Processor. Name units long_name coordinates	'1' (static) 'root_mean_square_error' (static) 'longitude latitude' (static) T/SUPPORT_DATA/DETAILED_RESULTS und_pixel. Value '1' (static) 'chi_squared' (static) 'longitude latitude' (static)	NC_STRING NC_STRING NC_STRING Type NC_STRING
chi_square in Description: Dimensions: Type: Source: Attributes:	Name units long_name coordinates AER_LH/PRODUCT Chi squared time, scanline, groun NC_FLOAT. Processor. Name units long_name coordinates freedom in AER_LH/	'1' (static) 'root_mean_square_error' (static) 'longitude latitude' (static) T/SUPPORT_DATA/DETAILED_RESULTS und_pixel. Value '1' (static) 'chi_squared' (static) 'longitude latitude' (static) /PRODUCT/SUPPORT_DATA/DETAILED_RESULTS	NC_STRING NC_STRING NC_STRING Type NC_STRING NC_STRING
Chi_square in Description: Dimensions: Type: Source: Attributes: degrees_of_f Description:	Name units long_name coordinates AER_LH/PRODUC Chi squared time, scanline, grou NC_FLOAT. Processor. Name units long_name coordinates freedom in AER_LH/ Degrees of freedon	'1' (static) 'root_mean_square_error' (static) 'longitude latitude' (static) T/SUPPORT_DATA/DETAILED_RESULTS und_pixel. Value '1' (static) 'chi_squared' (static) 'longitude latitude' (static) /PRODUCT/SUPPORT_DATA/DETAILED_RESULTS	NC_STRING NC_STRING NC_STRING Type NC_STRING NC_STRING
Chi_square in Description: Dimensions: Type: Source: Attributes: degrees_of_t Description: Dimensions:	Name units long_name coordinates n AER_LH/PRODUC Chi squared time, scanline, groun NC_FLOAT. Processor. Name units long_name coordinates freedom in AER_LH/ Degrees of freedom time, scanline, groun time, scanline, groun	'1' (static) 'root_mean_square_error' (static) 'longitude latitude' (static) T/SUPPORT_DATA/DETAILED_RESULTS und_pixel. Value '1' (static) 'chi_squared' (static) 'longitude latitude' (static) /PRODUCT/SUPPORT_DATA/DETAILED_RESULTS	NC_STRING NC_STRING NC_STRING Type NC_STRING NC_STRING
chi_square in Description: Dimensions: Type: Source: Attributes: degrees_of_f Description: Dimensions: Type:	Name units long_name coordinates AER_LH/PRODUCT Chi squared time, scanline, groun NC_FLOAT. Processor. Name units long_name coordinates freedom in AER_LH/ Degrees of freedom time, scanline, groun NC_FLOAT.	'1' (static) 'root_mean_square_error' (static) 'longitude latitude' (static) T/SUPPORT_DATA/DETAILED_RESULTS und_pixel. Value '1' (static) 'chi_squared' (static) 'longitude latitude' (static) /PRODUCT/SUPPORT_DATA/DETAILED_RESULTS	NC_STRING NC_STRING NC_STRING Type NC_STRING NC_STRING
Chi_square in Description: Dimensions: Type: Source: Attributes: degrees_of_f Description: Dimensions: Type: Source: Source:	Name units long_name coordinates AER_LH/PRODUC Chi squared time, scanline, groun NC_FLOAT. Processor. Name units long_name coordinates freedom in AER_LH/ Degrees of freedom time, scanline, groun NC_FLOAT. Processor.	'1' (static) 'root_mean_square_error' (static) 'longitude latitude' (static) T/SUPPORT_DATA/DETAILED_RESULTS und_pixel. Value '1' (static) 'chi_squared' (static) 'longitude latitude' (static) //PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nund_pixel.	NC_STRING NC_STRING NC_STRING Type NC_STRING NC_STRING NC_STRING NC_STRING
Chi_square in Description: Dimensions: Type: Source: Attributes: degrees_of_f Description: Dimensions: Type: Source: Source:	Name units long_name coordinates AER_LH/PRODUCT Chi squared time, scanline, groun NC_FLOAT. Processor. Name units long_name coordinates freedom in AER_LH/ Degrees of freedom time, scanline, groun NC_FLOAT. Processor. NC_FLOAT. Processor. Name	'1' (static) 'root_mean_square_error' (static) 'longitude latitude' (static) T/SUPPORT_DATA/DETAILED_RESULTS und_pixel. Value '1' (static) 'chi_squared' (static) 'longitude latitude' (static) /PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nund_pixel. Value	NC_STRING NC_STRING NC_STRING NC_STRING NC_STRING NC_STRING NC_STRING NC_STRING
Chi_square in Description: Dimensions: Type: Source: Attributes: degrees_of_f Description: Dimensions: Type: Source: Source:	Name units long_name coordinates AER_LH/PRODUC Chi squared time, scanline, grou NC_FLOAT. Processor. Name units long_name coordinates freedom in AER_LH/ Degrees of freedom time, scanline, grou NC_FLOAT. Processor. NC_FLOAT. Processor. Name units	'1' (static) 'root_mean_square_error' (static) 'longitude latitude' (static) T/SUPPORT_DATA/DETAILED_RESULTS und_pixel. Value '1' (static) 'chi_squared' (static) 'longitude latitude' (static) /PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nund_pixel. Value '1' (static)	NC_STRING NC_STRING NC_STRING NC_STRING NC_STRING NC_STRING NC_STRING NC_STRING NC_STRING
Description: Dimensions: Type: Source: Attributes:	Name units long_name coordinates AER_LH/PRODUCT Chi squared time, scanline, groun NC_FLOAT. Processor. Name units long_name coordinates freedom in AER_LH/ Degrees of freedom time, scanline, groun NC_FLOAT. Processor. NC_FLOAT. Processor. Name	'1' (static) 'root_mean_square_error' (static) 'longitude latitude' (static) T/SUPPORT_DATA/DETAILED_RESULTS und_pixel. Value '1' (static) 'chi_squared' (static) 'longitude latitude' (static) /PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nund_pixel. Value	NC_STRING NC_STRING NC_STRING Type NC_STRING NC_STRING NC_STRING 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.

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

See [RD37] for details about the wavelength fit.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT. Source: Processor.

Attributes:

Name	Value	Туре
long_name	'wavelength offset' (static)	NC_STRING
units	'nm' (static)	NC_STRING
wavelength fit -	0.0 (static)	NC FLOAT

window start

The start wavelength of the wavelength fit window.

wavelength_fit_- 0.0 (static) NC_FLOAT window end

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 conven-

coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].

ancillary_vari- ables	'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.

1/-1...

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.
Source: Processor.

Source: Processor
Attributes: Name

iname	value	iype
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.

$$\lambda_{\mathsf{true}} = \lambda_{\mathsf{nominal}} + \delta\lambda + q\lambda^*$$
 (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.

Attributes: Name Value Type

	long_name	'wavelength stretch' (static)	NC_STRING
	units	'1' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	coordinates in this tions [ER5].	ngitude are in a different group. How to specify the case is not specified in the climate and forecast	metadata conven
	ancillary_vari- ables	'wavelength_calibration_stretch_precision' (static)	NC_STRING
	comment	'True wavelength = nominal wavelength + wavelength offset + wavelength stretch * scaled wavelength' (static)	NC_STRING
wavelength_ ULTS	calibration_stretch_	_precision in AER_LH/PRODUCT/SUPPORT_DATA	/DETAILED_RES
Description:	A posteriori precision	on of the fitted wavelength stretch.	
Dimensions:	time, scanline, grou	und_pixel.	
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	Name	Value	Туре
	long_name	'wavelength stretch precision' (static)	NC_STRING
	units	'1' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC STRING
wavelength_	tions [ER5].	uare in AER_LH/PRODUCT/SUPPORT_DATA/DETAII	
Description:			LED_RESULIS
•	The χ^2 from the wa	avelength calibration pre-fit in the Level 2 processor.	LED_RESULIS
Dimensions:	The χ^2 from the watime, scanline, ground	avelength calibration pre-fit in the Level 2 processor.	LED_RESULIS
Dimensions: Type:	The χ^2 from the watime, scanline, ground NC_FLOAT.	avelength calibration pre-fit in the Level 2 processor.	LED_RESULIS
Dimensions: Type: Source:	The χ^2 from the watime, scanline, ground NC_FLOAT. Processor.	avelength calibration pre-fit in the Level 2 processor. und_pixel.	
Dimensions: Type: Source:	The χ^2 from the watime, scanline, ground NC_FLOAT. Processor. Name	avelength calibration pre-fit in the Level 2 processor. und_pixel. Value	Туре
Dimensions: Type: Source:	The χ^2 from the watime, scanline, ground NC_FLOAT. Processor. Name long_name	avelength calibration pre-fit in the Level 2 processor. und_pixel. Value 'wavelength calibration chi square' (static)	<i>Type</i> NC_STRING
Description: Dimensions: Type: Source: Attributes:	The χ^2 from the watime, scanline, ground NC_FLOAT. Processor. Name long_name units	avelength calibration pre-fit in the Level 2 processor. und_pixel. Value 'wavelength calibration chi square' (static) '1' (static)	Type NC_STRING NC_STRING
Dimensions: Type: Source:	The χ^2 from the watime, scanline, ground NC_FLOAT. Processor. Name long_name units coordinates The latitude and lo	avelength calibration pre-fit in the Level 2 processor. und_pixel. Value 'wavelength calibration chi square' (static)	Type NC_STRING NC_STRING NC_STRING related geospatia
Dimensions: Type: Source: Attributes:	The χ^2 from the watime, scanline, ground NC_FLOAT. Processor. Name long_name units coordinates The latitude and lo coordinates in this tions [ER5].	welength calibration pre-fit in the Level 2 processor. und_pixel. Value 'wavelength calibration chi square' (static) '1' (static) '/PRODUCT/longitude /PRODUCT/latitude' (static) ngitude are in a different group. How to specify the	Type NC_STRING NC_STRING NC_STRING related geospatia metadata conven
Dimensions: Type: Source: Attributes: wavelength_ ULTS	The χ^2 from the watime, scanline, ground NC_FLOAT. Processor. Name long_name units coordinates The latitude and lo coordinates in this tions [ER5]. calibration_irradian	Value 'wavelength calibration pre-fit in the Level 2 processor. und_pixel. Value 'wavelength calibration chi square' (static) '1' (static) '/PRODUCT/longitude /PRODUCT/latitude' (static) ngitude are in a different group. How to specify the is case is not specified in the climate and forecast in the cli	Type NC_STRING NC_STRING NC_STRING related geospatia metadata conven /DETAILED_RES
Dimensions: Type: Source: Attributes: wavelength_ ULTS	The χ^2 from the watime, scanline, ground NC_FLOAT. Processor. Name long_name units coordinates The latitude and lote coordinates in this tions [ER5]. calibration_irradian Fitted wavelength is processor.	avelength calibration pre-fit in the Level 2 processor. and_pixel.	Type NC_STRING NC_STRING NC_STRING related geospatia metadata conver /DETAILED_RES
Dimensions: Type: Source: Attributes: wavelength_ ULTS	The χ^2 from the watime, scanline, ground NC_FLOAT. Processor. Name long_name units coordinates The latitude and lote coordinates in this tions [ER5]. calibration_irradian Fitted wavelength is processor.	Value 'wavelength calibration pre-fit in the Level 2 processor. und_pixel. Value 'wavelength calibration chi square' (static) '1' (static) '/PRODUCT/longitude /PRODUCT/latitude' (static) ngitude are in a different group. How to specify the is case is not specified in the climate and forecast in the cli	Type NC_STRING NC_STRING NC_STRING related geospatia metadata conver /DETAILED_RES
Dimensions: Type: Source: Attributes: wavelength_ ULTS Description:	The χ^2 from the watime, scanline, ground NC_FLOAT. Processor. Name long_name units coordinates The latitude and lote coordinates in this tions [ER5]. calibration_irradian Fitted wavelength is processor.	avelength calibration pre-fit in the Level 2 processor. and_pixel.	Type NC_STRING NC_STRING NC_STRING related geospatia metadata conver /DETAILED_RES
Dimensions: Type: Source: Attributes: wavelength_ ULTS Description: Dimensions: Type:	The χ^2 from the watime, scanline, ground NC_FLOAT. Processor. Name long_name units coordinates The latitude and locoordinates in this tions [ER5]. calibration_irradian Fitted wavelength oprocessor. See [RD37] for detail	avelength calibration pre-fit in the Level 2 processor. and_pixel.	Type NC_STRING NC_STRING NC_STRING related geospatia metadata conver /DETAILED_RES
Dimensions: Type: Source: Attributes: wavelength_ ULTS Description: Dimensions: Type:	The χ^2 from the watime, scanline, ground NC_FLOAT. Processor. Name long_name units coordinates The latitude and lote coordinates in this tions [ER5]. calibration_irradian Fitted wavelength oprocessor. See [RD37] for detatime, ground_pixel.	avelength calibration pre-fit in the Level 2 processor. and_pixel.	Type NC_STRING NC_STRING NC_STRING related geospatia metadata conver /DETAILED_RES
Dimensions: Type: Source: Attributes: wavelength_ ULTS Description: Dimensions: Type: Source:	The χ^2 from the watime, scanline, ground NC_FLOAT. Processor. Name long_name units coordinates The latitude and locoordinates in this tions [ER5]. calibration_irradian Fitted wavelength oprocessor. See [RD37] for detatime, ground_pixel. NC_FLOAT.	avelength calibration pre-fit in the Level 2 processor. and_pixel.	Type NC_STRING NC_STRING NC_STRING related geospatia metadata conver /DETAILED_RES
Dimensions: Type: Source: Attributes:	The χ^2 from the watime, scanline, ground NC_FLOAT. Processor. Name long_name units coordinates The latitude and lote coordinates in this tions [ER5]. calibration_irradian Fitted wavelength oprocessor. See [RD37] for detatime, ground_pixel. NC_FLOAT. Processor.	welength calibration pre-fit in the Level 2 processor. and_pixel.	Type NC_STRING NC_STRING NC_STRING related geospatia metadata conver /DETAILED_RES e-fit in hte Level 2

	wavelength_fit window_start	0.0 (static)	NC_FLOAT
	The start wavelengt	h 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_vari- ables	'wavelength_calibration_irradiance_offset_precision' (static)	NC_STRING
	comment	'True wavelength = nominal wavelength + wavelength offset + wavelength stretch * scaled wavelength' (static)	NC_STRING
wavelength_ DETAILED_R	_	ce_offset_precision in AER_LH/PRODUCT/S	SUPPORT_DATA/
Description:	A posteriori precisio	n of the fitted wavelength offset for the irradiance spe	ectrum.
Dimensions:	time, ground_pixel.		
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	Name	Value	Туре
	long_name	'irradiance wavelength offset precision' (static)	NC_STRING
	units	'nm' (static)	NC_STRING
wavelength_ RESULTS	calibration_irradiand	ce_chi_square in AER_LH/PRODUCT/SUPPORT_D	DATA/DETAILED
Description:	The χ^2 from the irra	diance wavelength calibration pre-fit in the Level 2 pr	ocessor.
Dimensions:	time, ground_pixel.		
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	Name	Value	Туре
	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_altit	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.				
Dimensions:	time, scanline, ground_pixel.				
Type:	NC_FLOAT.				
Source:	surface elevation da	atabase.			
Attributes:	Name	Value	Туре		
	long_name	'Surface altitude' (static)	NC_STRING		
	standard_name	'surface_altitude' (static)	NC_STRING		
	units	units 'm' (static) NC_STRING			
	coordinates	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_altitu	ude_precision in AEI	R_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 surfacealtitude variable for details.		
Dimensions:	time, scanline, grou	nd_pixel.	
Type:	NC_FLOAT.		
Source:	surface elevation da	tabase.	
Attributes:	Name	Value	Туре
	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 cal- culating 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 convensions. 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).

Attributes:	Name	Value	Туре
	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_broadleaf_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, 4, 249, 249, 249, 249, 249, 249, 249,	NC_UBYTE
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
instrument configuration identify	fier in AER LH/PRODUCT/SUPPORT DATA/INPUT	DATA

instrument_configuration_identifier in AER_LH/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description:

The IcID 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 IcID, is primarily used by the instrument, where it identifies an entry in the instrument configuration tables. On ground, the IcID is used to determine the intended purpose of a measurement and is used in the L0 to 1b data processing to determine the processing path.

Dimensions: time, scanline.

Type: NC_INT. Source: L1B.

Attributes:

Name	Value	Туре
long_name	'IcID' (static)	NC_STRING
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

For an IcID (see the instrument configuration identifier above), it is possible Description:

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

Dimensions: time, scanline. NC SHORT. Type:

L1B. Source:

Value Attributes: Mama

name	value	rype
long_name	'IcVersion' (static)	NC_STRING
comment	'Version of the instrument_configuration_identifier'	NC_STRING
	(static)	

scaled small pixel variance in AER LH/PRODUCT/SUPPORT DATA/INPUT DATA

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

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

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

$$V_{\text{scaled}}(t,r,c) = \frac{V(t,r,c)}{\langle R(t,r,c) \rangle^{2}}$$
(5)

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

$$V_{\text{scaled}}(t,r,c) = \frac{V(t,r,c)}{\langle R(t,r,c) \rangle^2}$$
 (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 $i = [0, \dots, N_{\mathsf{small \; pixels}} - 1]$ 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.

NC FLOAT. Type: Source: Processor.

Attributes:

Name	Value	lype
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	NC_STRING
	small pixels' (static)	

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

The horizontal component of the wind at 10 meter height in the eastward direction. This is Description:

the 10U parameter from ECMWF (grib variable 165).

Dimensions: time, scanline, ground pixel.

NC FLOAT. Type:

Source:	Processor.		
Attributes:	Name	Value	Туре
	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_vari- ables	'northward_wind' (static)	NC_STRING
northward_w	rind in AER_LH/PRC	DDUCT/SUPPORT_DATA/INPUT_DATA	
Description:		ponent of the wind at 10 meter height in the northward from ECMWF (grib variable 166).	d direction. This is
Dimensions:	time, scanline, grou	und_pixel.	
Туре:	NC_FLOAT.		
Source:	Processor.		
Attributes:	Name	Value	Туре
	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_vari- ables	'eastward_wind' (static)	NC_STRING
aerosol_inde	x_354_388 in AER_	LH/PRODUCT/SUPPORT_DATA/INPUT_DATA	
Dimensions:	time, scanline, grou	und_pixel.	
Type:	NC_FLOAT.		
Source:	AER_AI.		
Attributes:	Name	Value	Туре
	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 u	sed for the determination of the aerosol index.	
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
cloud_fractio	n in AER_LH/PROD	OUCT/SUPPORT_DATA/INPUT_DATA	
Dimensions:	time, scanline, grou	und_pixel.	
Type:	NC_FLOAT.		
Source:	FRESCO.		
Attributes:	Name	Value	Туре
	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 r	nask in AER LH/PR	RODUCT/SUPPORT_DATA/INPUT_DATA	
Dimensions:	time, scanline, grou		
Type:	NC FLOAT.	_	
71: -			

Source:	NP_BD6.		
Attributes:	Name	Value	Туре
	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_ı	reflectance in AER_	LH/PRODUCT/SUPPORT_DATA/INPUT_DATA	
Dimensions:	time, scanline, grou	ınd_pixel.	
Type:	NC_FLOAT.		
Source:	NP_BD6.		
Attributes:	Name	Value	Туре
	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_3	380 in AER_LH/PRO	DUCT/SUPPORT_DATA/INPUT_DATA	
Dimensions:	time, scanline, grou	ınd_pixel.	
Туре:	NC_FLOAT.		
Source:	Processor.		
Attributes:	Name	Value	Туре
	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_ _l	precision in AER_LH	H/PRODUCT/SUPPORT_DATA/INPUT_DATA	
Dimensions:	time, scanline, grou	ınd_pixel.	
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	Name	Value	Туре
	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_pres	sure in AER_LH/PR	ODUCT/SUPPORT_DATA/INPUT_DATA	
Description:	Surface pressure.		
Dimensions:	time, scanline, grou	ınd_pixel.	
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	Name	Value	Туре
	units	'Pa' (static)	NC_STRING
	standard_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.

Attributes: Name

Name	Value	Туре
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

NC STRING

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)

flag values

0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, N 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)

coordinates

'/PRODUCT/longitude /PRODUCT/latitude' (static)

NC_STRING

NC UBYTE

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	
Name	Value	Туре
number_of_groundpixels	0 (static)	NC_INT
Number of ground pixels in the f	ile.	
number_of_processed	0 (static)	NC_INT
pixels		
	a retrieval was attempted. This is the numbed on time or configuration (range and step	
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
	ng was not attempted because after filtering left in either the radiance, irradiance or af	
number_of_failed_retrievals	0 (static)	NC_INT
Number of pixels where process	sing failed for whatever reason.	
number_of_ground_pixels with_warnings	0 (static)	NC_INT
Number of pixels with one or mo	ore warnings.	
number_of_missing_scan- ines	0 (static)	NC_INT
Number of scanlines that are mi	ssing from the input.	
number_of_radiance_miss- ng_occurrences	0 (static)	NC_INT
• .	e processing error "the number of spectra the fitting" occurred, i.e. where the low e "1".	•
number_of_irradiance_miss-	0 (static)	NC_INT
ng_occurrences		
	e processing error "the number of spectra the fitting" occurred, i.e. where the low	
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 processing_quality_flags have the value "3".

number_of_reflectance_-

0 (static)

NC INT

range_error_occurrences

Number of ground pixels where processing error "any of the reflectances is out of bounds (R < 0 or $R > R_{\text{max}}$)" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "4".

number_of_ler_range_er-

0 (static)

NC INT

ror occurrences

Number of ground pixels where processing error "lambert-equivalent reflectivity out of range error" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "5".

number_of_snr_range_er-

0 (static)

NC_INT

ror_occurrences

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 processing_quality_flags have the value "6".

number_of_sza_range_er-

0 (static)

NC INT

ror occurrences

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 processing_quality_flags have the value "7".

number_of_vza_range_er-

0 (static)

NC INT

ror_occurrences

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 processing_quality_flags have the value "8".

number_of_lut_range_er-

0 (static)

NC INT

ror_occurrences

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 processing_quality_flags have the value "9".

number_of_ozone_range_er- 0 (static)

NC INT

ror_occurrences

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 processing_quality_flags have the value "10".

number_of_wavelength_off- 0 (static)

NC INT

set error occurrences

Number of ground pixels where processing error "wavelength offset exceeds maximum from configuration" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "11".

number_of_initialization_er- 0 (station_

NC INT

ror_occurrences

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 processing_quality_flags have the value "12".

number_of_memory_error_- 0 (static)

NC INT

occurrences

Number of ground pixels where processing error "memory allocation or deallocation error" occurred, i.e. where the lower 8 bits of the processing_quality_flags 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 processing_quality_flags have the value "14".

number of io error occur-0 (static) NC INT

rences

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 processing_quality_flags have the value "15".

number of numerical er-

0 (static)

NC INT

ror occurrences

Number of ground pixels where processing error "general fatal numerical error occurred during inversion" occurred, i.e. where the lower 8 bits of the processing quality_flags have the value "16".

number of lut error occur-0 (static) rences

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 processing_quality_flags have the value "17".

number of ISRF error oc-0 (static) NC INT

currences

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 processing_quality_flags have the value "18".

number of convergence er- 0 (static)

NC INT

ror occurrences

Number of ground pixels where processing error "the main algorithm did not converge" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "19".

number of cloud filter -

0 (static)

NC INT

convergence error occur-

rences

Number of ground pixels where processing error "the cloud filter did not converge" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "20".

number of max iteration -0 (static) NC INT

convergence error occur-

rences

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 processing_quality_flags have the value "21".

number of aot lower -

0 (static)

NC INT

boundary convergence er-

ror occurrences

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 processing_quality_flags have the value "22".

number of other boundary convergence error oc0 (static)

NC INT

currences

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 processing_quality_flags have the value "23".

number of geolocation er-0 (static) NC INT

ror occurrences

Number of ground pixels where processing error "geolocation out of range" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "24".

number_of_ch4_noscat_- 0 (static) zero error occurrences

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 processing_quality_flags have the value "25".

number_of_h2o_noscat_-

0 (static)

NC_INT

zero_error_occurrences

Number of ground pixels where processing error "the H_2O 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 processing_quality_flags have the value "26".

number_of_max_optical_-

0 (static)

NC INT

thickness error occur-

rences

Number of ground pixels where processing error "maximum optical thickness exceeded during iterations" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "27".

${\color{red}\textbf{number_of_aerosol_bound-}} \quad 0 \; (\text{static})$

NC_INT

ary error occurrences

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 processing_quality_flags have the value "28".

number_of_boundary_hit_- 0 (static)

NC_INT

error_occurrences

Number of ground pixels where processing error "fatal boundary hit during iterations" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "29".

number_of_chi2_error_oc- 0 (static)

NC_INT

currences

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 processing_quality_flags have the value "30".

number_of_svd_error_oc- 0 (static)

NC INT

currences

Number of ground pixels where processing error "singular value decomposition failure" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "31".

${\color{red}\textbf{number_of_dfs_error_occur-}} \quad \textbf{0 (static)}$

NC INT

rences

Number of ground pixels where processing error "degree of freedom is not-a-number" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "32".

number_of_radiative_trans- 0 (static)

NC INT

fer_error_occurrences

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 processing_quality_flags have the value "33".

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 processing_quality_flags have the value "24"

number_of_profile_error_oc- 0 (static)

NC INT

currences

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 processing_quality_-flags have the value "35".

number_of_cloud_error_oc- 0 (static) currences

NC INT

Number of ground pixels where processing error "no cloud data" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "36".

number_of_model_error_oc-0 (static) NC INT

currences

Number of ground pixels where processing error "forward model failure" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "37".

number of number of in-

NC INT

put data points too low -

error occurrences

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 processing quality flags have the value "38".

number of cloud pres-

0 (static)

0 (static)

NC_INT

sure_spread_too_low_er-

ror_occurrences

Number of ground pixels where processing error "cloud pressure variability to low to estimate a tropospheric column" occurred, i.e. where the lower 8 bits of the processing quality_flags have the value "39".

number of cloud too low - 0 (static)

NC INT

level error occurrences

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 processing_quality_flags have the value "40".

number of generic range -0 (static) NC INT

error occurrences

Number of ground pixels where processing error "generic range error" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "41".

number of generic excep-

NC INT

tion_occurrences

Number of ground pixels where processing error "catch all generic error" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "42".

number of input spec-

0 (static)

0 (static)

NC INT

trum alignment error oc-

currences

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 processing_quality_flags have the value "43".

number of abort error oc-0 (static)

currences

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 processing_quality_flags have the value "44".

number_of_wrong_input_-

0 (static)

NC INT

type error occurrences

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 processing quality_flags have the value "45".

number_of_wavelength_cal-0 (static) NC INT

ibration_error_occurrences

Number of ground pixels where processing error "an error occurred in the wavelength calibration of this pixe" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "46".

number of coregistration -0 (static) NC_INT

error_occurrences

Number of ground pixels where processing error "no colocated pixels found in a supporting ban" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "47".

number_of_slant_column_- 0 (static)
density error occurrences

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 processing_quality_flags have the value "48".

number_of_airmass_factor_- 0 (static)
error occurrences

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 processing_quality_flags have the value "49".

number_of_vertical_-

0 (static)

NC INT

column density error -

occurrences

Number of ground pixels where processing error "vertical column density could not be compute" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "50".

number_of_signal_to_-

0 (static)

NC INT

noise_ratio_error_occur-

rences

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 processing_quality_flags have the value "51".

number_of_configuration_- 0 (static)

NC_INT

error_occurrences

Number of ground pixels where processing error "error while parsing the configuratio" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "52".

number_of_key_error_oc-

0 (static)

NC INT

currences

Number of ground pixels where processing error "key does not exis" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "53".

number_of_saturation_er-

0 (static)

NC INT

ror_occurrences

Number of ground pixels where processing error "saturation in input spectru" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "54".

number_of_max_num_out-

0 (static)

NC INT

lier_exceeded_error_occur-

rences

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 processing_quality_-flags have the value "55".

number_of_solar_eclipse_fil- 0 (static)

NC INT

ter occurrences

Number of ground pixels where input filter "solar eclipse" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "64".

number_of_cloud_filter_oc- 0 (state
currences

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 processing_quality_flags have the value "65".

number_of_altitude_consist- 0 (static) ency filter occurrences

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 processing_quality_flags have the value "66".

number_of_altitude_roughness filter occurrences 0 (static)

NC INT

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 processing_quality_flags have the value "67".

number of sun glint filter - 0 (static) occurrences

NC INT

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 processing_quality_flags have the value "68".

number of mixed surface - 0 (static)

NC INT

type filter occurrences

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 processing_quality_flags have the value "69".

number of snow ice filter - 0 (static) occurrences

NC INT

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 processing_quality_flags have the value "70".

number of aai filter occur-0 (static)

NC INT

rences

Number of ground pixels where input filter "aAI smaller than 2.0" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "71".

number of cloud fraction - 0 (static)

NC INT

fresco_filter_occurrences

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 processing_quality_flags have the value "72".

0 (static)

0 (static)

0 (static)

number of aai scene al-

NC INT

bedo_filter_occurrences

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 processing_quality_flags have the value "73".

number of small pixel radi- 0 (static) ance std filter occurrences

NC INT

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 processing_quality_flags have the value "74".

number of cloud fraction - 0 (static)

NC INT

viirs filter occurrences

Number of ground pixels where input filter "pixel contains clouds: The cloud fraction from VIIRS / NPP exceeds the shold. Threshold value from ATBD" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "75".

number of cirrus reflectance viirs filter occur-

NC INT

rences

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 processing_quality_flags have the value "76".

number of_cf_viirs_swir_-

NC INT

ifov filter occurrences

Number of ground pixels where input filter "fraction of cloudy VIIRS pixels wihtin S5P SWIR ground pixel exceeds a priori threshold from configuration" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "77".

number_of_cf_viirs_swir_- 0 (static)
ofova filter occurrences

NC INT

Number of ground pixels where input filter "fraction of cloudy VIIRS pixels wihtin S5P SWIR OFOVa exceeds a priori threshold from configuration" occurred, i.e. where the lower 8 bits of the processing_quality_-flags have the value "78".

number_of_cf_viirs_swir_- 0 (static)
ofovb filter occurrences

NC INT

Number of ground pixels where input filter "fraction of cloudy VIIRS pixels wihtin S5P SWIR OFOVb exceeds a priori threshold from configuration" occurred, i.e. where the lower 8 bits of the processing_quality_-flags have the value "79".

number_of_cf_viirs_swir_- 0 (static)
ofovc filter occurrences

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 processing_quality_-flags have the value "80".

number_of_cf_viirs_nir_- 0 (static)

NC_INT

ifov_filter_occurrences

Number of ground pixels where input filter "fraction of cloudy VIIRS pixels wihtin S5P NIR ground pixel exceeds a priori threshold from configuration" occurred, i.e. where the lower 8 bits of the processing_quality_flags 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 wihtin S5P NIR OFOVa exceeds a priori threshold from configuration" occurred, i.e. where the lower 8 bits of the processing_quality_-flags 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 processing_quality_-flags have the value "83".

number_of_cf_viirs_nir_- 0 (static)

NC INT

ofovc_filter_occurrences

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 processing_quality_-flags have the value "84".

number_of_refl_cirrus_-viirs_swir_filter_occur-

0 (static)

NC INT

rences

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 processing_quality_flags 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 processing_quality_-flags have the value "86".

number_of_diff_refl_cirrus_- 0 (static)

NC_INT

viirs_filter_occurrences

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 processing_quality_flags have the value "87".

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 processing_quality_-flags have the value "88".

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 $processing_quality_flags$ have the value "89".

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 processing_quality_-flags have the value "90".

NC_INT

Number of ground pixels where input filts

Number of ground pixels where input filter "the standard deviation of [H₂O]_{weak}/[H₂O]_{strong} within the SWIR pixel and the 8 neigbouring pixels exceeds a priori threshold from configuration" occurred, i.e. where the lower 8 bits of the processing_quality_flags have the value "91".

number_of_diff_psurf_fresco ecmwf filter occurNC_INT

fresco_ecmwf_filter_occurrences

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 processing_quality_flags have the value "92".

number_of_psurf_fresco_- 0 (static) stdv filter occurrences

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 processing_quality_flags have the value "93".

number_of_ocean_filter_oc- 0 (static currences

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 processing_quality_flags have the value "94"

number_of_time_range_fil- 0 (static)

NC_INT

ter_occurrences

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 processing_quality_flags have the value "95".

number_of_pixel_or_scan-

0 (static)

0 (static)

NC INT

line_index_filter_occur-

rences

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 processing_quality_flags have the value "96".

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 processing_quality_flags have the value "97".

number_of_input_spec-trum_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_-

0 (static)

NC INT

calibration_warning_occurrences

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_- 0 (static)
warning_occurrences

NC INT

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_warn- 0 (static)

NC_INT

ing_occurrences

Number of ground pixels where processing warning "sun glint posibility warning" occurred, i.e. where bit 11 in the processing_quality_flags is set to "1".

number_of_south_atlantic_- 0 (static)

NC_INT

anomaly_warning_occur-

rences

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_cor- 0 (static)

NC_INT

rection_occurrences

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_warn- 0 (static)

NC INT

ing_occurrences

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_- 0 (static)
occurrences

NC INT

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 possiblity of ice-clouds" occurred, i.e. where bit 15 in the processing_quality_flags is set to "1".

number_of_AAI_warning_- 0 (static)
occurrences

NC INT

Number of ground pixels where processing warning "possible aerosol contamination as either indicated by the AAI (O_3 profile)" occurred, i.e. where bit 16 in the processing_quality_flags is set to "1".

number_of_pixel_level_in- 0 (static)

NC INT

put_data_missing_occur-

rences

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

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 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. For O_3 profile this warning indicates an out of range cost function, or an out of range RMS difference between retrieval and a priori" occurred, i.e. where bit 18 in the processing_quality_flags is set to "1".

number_of_low_cloud_frac- 0 (static tion warning occurrences

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_consist- 0 (static) ency_warning_occurrences

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_-

0 (static)

NC INT

noise_ratio_warning_occur-

rences

Number of ground pixels where processing 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" occurred, i.e. where bit 21 in the processing_quality_flags is set to "1".

number_of_deconvolution_- 0 (static) warning_occurrences

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_- 0 (static)

NC_INT

origin_likely_warning_occur-

rences

Number of ground pixels where processing warning "warning for SO_2 BL product, UTLS products: volcanic origin except for heavily polluted sites. For O_3 profile this warning is issued in case of a large SO_2 column which has an impact on the O_3 profile retrieval" occurred, i.e. where bit 23 in the processing_quality_flags is set to "1".

number_of_so2_volcanic_- 0 (static)

NC INT

origin_certain_warning_oc-

currences

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_- 0 (static)
warning_occurrences

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_warn- 0 (static)
ing_occurrences

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_warn- 0 (static)
ing occurrences

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_- 0 (static) warning occurrences

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_inhomo-

0 (static)

NC INT

geneity_warning_occur-

rences

Number of ground pixels where processing warning "the cloud coregistration inhomogeneity parameter is above a given threshold. This warning is also set when the coregistration weight sums are less than 1" occurred, i.e. where bit 29 in the processing_quality_flags is set to "1".

${\color{red}\textbf{number_of_thermal_instabil-}} \quad 0 \; (\text{static})$

NC INT

ity warning occurrences

Number of ground pixels where processing warning "input spectra have been labeled with a thermal instability warning flag" occurred, i.e. where bit 30 in the processing_quality_flags is set to "1".

global_processing_warn-

'None' (static)

NC_STRING

ings

All warning messages, separated by newlines, with duplicates removed.

time_for_algorithm_initialization NC_DOUBLE

Time in seconds needed for initialization.

time_for_processing

-1.0 (static)

-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_-

-1.0 (static)

NC DOUBLE

per_pixel

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)

aerosol_mid_height_histogram_axis Histogram axis.

size 100 (fixed)

aerosol_mid_height_pdf_axis Probability density function axis.

size 400 (fixed)

aerosol_mid_pressure_histogram_axis Histogram axis.

size 100 (fixed)

aerosol_mid_pressure_pdf_axis Probability density function axis.

size 400 (fixed)

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.

Attributes:	Name	Value	Туре	
	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.			
Attributes:	Name	Value	Туре	
	units	'Pa' (dynamic)	NC_STRING	
	Same unit as the m	ain parameter. This attribute originates from the CF s		
	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_histogra	m_bounds in AER_LH/METADATA/QA_STATISTICS		
Dimensions:	aerosol_mid_pressure_histogram_axis, vertices.			
Type:	NC_FLOAT.			
Source:	Processor.			
aerosol_mid_	_pressure_pdf_boui	nds in AER_LH/METADATA/QA_STATISTICS		
Dimensions:	aerosol_mid_pressure_pdf_axis, vertices.			
Type:	NC_FLOAT.			
Source:	Processor.			
		axis in AER_LH/METADATA/QA_STATISTICS		
Description:	Horizontal axis for the histograms of the aerosol mid altitude.			
Dimensions:		t_histogram_axis (coordinate variable).		
Type:	NC_FLOAT.			
Source:	Processor.			
Attributes:	Name	Value	Туре	
	units	'm' (dynamic)	NC_STRING	
		ain parameter. This attribute originates from the CF s		
	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_		AER_LH/METADATA/QA_STATISTICS	1.1.	
	Horizontal axis for t	he probability distribution functions of the aerosol mid	altitude.	
Description:		•		
Dimensions:	aerosol_mid_height	t_pdf_axis (coordinate variable).		
Dimensions: Type:	aerosol_mid_height	•		
Dimensions: Type: Source:	aerosol_mid_height NC_FLOAT. Processor.	t_pdf_axis (coordinate variable).		
Dimensions: Type:	aerosol_mid_height NC_FLOAT. Processor. Name	t_pdf_axis (coordinate variable). Value	Туре	
Dimensions: Type: Source:	aerosol_mid_height NC_FLOAT. Processor. Name units	t_pdf_axis (coordinate variable). Value 'm' (dynamic)	Type NC_STRING	
Dimensions: Type: Source:	aerosol_mid_height NC_FLOAT. Processor. Name units	t_pdf_axis (coordinate variable). Value	Type 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.		
aerosol_mid	_height_pdf_bounds	in AER_LH/METADATA/QA_STATISTICS	
Dimensions:	aerosol_mid_height	_pdf_axis, vertices.	
Туре:	NC_FLOAT.		
Source:	Processor.		
aerosol_mid	_height_histogram i	1 AER_LH/METADATA/QA_STATISTICS	
Description:	Histogram of the ae	rosol mid altitude in the current granule.	
Dimensions:	aerosol_mid_height	_histogram_axis.	
Туре:	NC_INT.		
Source:	Processor.		
Attributes:	Name	Value	Туре
	comment	'Histogram of the aerosol mid altitude in the current granule' (static)	NC_STRING
	number_of_over- flow_values	0 (dynamic)	NC_INT
	The number of enco	ountered values that are larger than the top of the hist	ogram.
	number_of_un- derflow_values	0 (dynamic)	NC_INT
	The number of enco	ountered values that are smaller than the base of the	histogram.
aerosol_mid	_pressure_histograr	n in AER_LH/METADATA/QA_STATISTICS	
Description:	Histogram of the ae	rosol mid pressure in the current granule.	
Dimensions:	aerosol_mid_pressu	ure_histogram_axis.	
Туре:	NC_INT.		
Source:	Processor.		
Attributes:	Name	Value	Туре
	comment	'Histogram of the aerosol mid pressure in the current granule' (static)	NC_STRING
	number_of_over-	0 (dynamic)	NC_INT
	flow_values		
		ountered values that are larger than the top of the hist	
	number_of_un- derflow_values	0 (dynamic)	NC_INT
		ountered values that are smaller than the base of the	histogram.
		LH/METADATA/QA_STATISTICS	
Description:		unction of the aerosol mid altitude in the current granul $_{ m geo})$ and spread out using the error estimate.	e. The values ar
Dimensions:	aerosol_mid_height	_pdf_axis.	
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	Name	Value	Туре
	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 AE	ER_LH/METADATA/QA_STATISTICS	
Description:	Probability density function of the aerosol mid pressure in the current granule. The values are weighted with $\cos(\delta_{\rm geo})$ and spread out using the error estimate.		
Dimensions:	aerosol_mid_pressure_pdf_axis.		
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	Name	Value	Туре
	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 2.2.0

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

processing.szaMax 75.0

Maximum solar zenith angle (degrees). See section 5.1.5-1 in the aerosol layer height ATBD.

processing.filterSunGlint true

Filter pixels with possible sun glint. See section 5.1.5-2 in the aerosol layer height ATBD.

processing.filterMixedSurface true

Filter pixels that contain both land and water. See section 5.1.5-4 in the aerosol layer height ATBD.

processing.sgaLimit 18.0

For pixels over water, sun glint angle must be larger than this angle (degrees). See section 5.1.5-2 in the aerosol layer height ATBD.

processing.aerosolIndexMin 1.0

Low aerosol index filter threshold. See section 5.1.5-6 and 5.1.5-7 in the aerosol layer height ATBD.

processing.surfaceAltitudePrecisionWarning 300.0

High standard deviation of altitude warning threshold. See section 5.1.5-3 in the aerosol layer height ATBD.

processing.surfaceAltitudePrecisionMax 300.0

High standard deviation of altitude filter threshold. See section 5.1.5-3 in the aerosol layer height ATBD. **processing.cloudFractionWarning** 0.02

High cloud (FRESCO, NRTI)) fraction warning threshold. See section 5.1.5-6 in the aerosol layer height ATBD.

processing.cloudFractionMax 0.04

High cloud fraction (FRESCO, NRTI) filter threshold. See section 5.1.5-6 in the aerosol layer height ATRD

processing.cloudFractionNPPWarning 0.01

High NPP/VIIRS cloud fraction warning threshold. See section 5.1.5-7 in the aerosol layer height ATBD. **processing.cloudFractionNPPMax** 0.02

High NPP/VIIRS cloud fraction filter threshold. See section 5.1.5-7 in the aerosol layer height ATBD.

processing.avgCirrusReflWarning 0.02

High cirrus reflectance warning threshold. See section 5.1.5-8 in the aerosol layer height ATBD.

processing.avgCirrusReflMax 0.4

High cirrus reflectance filter threshold. See section 5.1.5-8 in the aerosol layer height ATBD.

processing.albedo380diffWarning 0.05

processing.albedo380diffMax 0.1

processing.albedoRelMin 0.25

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 comression (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, 772.0

Use this wavelength from the surface albedo database

processing.groupDem DEM RADIUS 05000

Which DEM to use.

processing.dler.useDLER false

Use the DLER if true, use the LER otherwise. Note that the descending part of the orbit will always use the traditional LER value.

processing.dler.spatial_interpolation true

Use spatial interpolation is true, use nearest neighbour sampling otherwise. Note that the interpolation algorithm does not take coastlines into account, spatial interpolation may mix land and water pixels.

processing.dler.fractional_snice false

Mix data from the clear and snow/ice databases using the fractional ice coverage. Not implemented, set to false or leave out. Currently the settings for the NISE conversion from ECMWF input is used.

processing.dler.ice_max_threshold 1

This is the maximum threshold (in percent) that is allowed for the sea ice fraction before switching to the snow/ice data.

processing.dler.snow max threshold 10

This is the maximum threshold (in percent) that is allowed for the snow fraction before the NISE snow value is set. Note that in the current setup this value is controlled using the processing.snowCoverFractionLimit key.

processing.dler.wavelengths 380, 758, 772

The wavelengths at which the surface albedo is needed in the Aerosol Layer Height algorithm.

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 wavelengts, 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

inumum 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, \dots for a0, a1, a2, a3, \dots 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.

ga value.extrapolation warning 70.0

he ga value multiplication factor (in percent) for when extrapolation was used in the retrieval.

ga 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 ga value multiplication factor (in percent) for when the snow ice warning flag is raised.

qa_value.cloud_warning 50.0

he ga value multiplication factor (in percent) for when the cloud warning flag is raised.

qa value.aai warning 50.0

he ga 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 ga 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 ga value multiplication factor (in percent) for when the signal to noise ratio warning flag is raised.

ga value.deconvolution warning 100.0

he ga 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.thermal instability warning 100.0

he qa_value multiplication factor (in percent) for when the thermal_instability_warning flag is raised.

ga value.sza threshold 60.0, 75.0

ower 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

a_value multiplication factor (in percent) for values where $\vartheta_0 > \vartheta_0$, max.

ga value.vza threshold 60.0, 75.0

ower 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

a_value multiplication factor (in percent) for values where $\vartheta > \vartheta$ _max.

quality control.ga value.limit 0.5

f the maximum qa_value in the granule is smaller than this limit, then a warning shall be issued. Default = 0.5

quality control.missing input.max fraction 0.25

If the fraction of successfully processed pixels that has a pixel level input data missing warning attached it exceeds this fraction, then a warning will be issued. Default = 0.5

quality control.success.min fraction 0.001

If the fraction of successfully processed pixels is smaller than this limit, then a warning will be issued. Default = 0.001

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	Туре
GranuleStart		NC_STRING
Start of the granule as ISO of definition of ISO date/time s	date/time string in UTC: YYYY-MM-DDTHH:MM:Satrings is given in [RD36].	S.mmmmmm Z . The formal
GranuleEnd		NC_STRING
End of the granule as ISO d definition of ISO date/time s	late/time string in UTC: YYYY-MM-DDTHH:MM:Strings is given in [RD36].	S.mmmmm Z . The formal
InstrumentName	'TROPOMI' (static)	NC_STRING
The name of the instrument	r, fixed to "TROPOMI".	
MissionName	'Sentinel-5 precursor' (static)	NC_STRING
The name of the mission, fix	xed to "Sentinel-5 precursor".	
MissionShortName	'S5P' (static)	NC_STRING
The short name of the missi	ion, fixed to "S5P".	
ProcessLevel	'2' (static)	NC_STRING
This is a level 2 product.		
ProcessingCenter	'%(processingcenter)s' (dynamic)	NC_STRING
Where was the processor ru use is "DLR/Oberpfaffenhofe	n? The source is the probably the joborder, the mosen".	t likely value for operational
ProcessingNode		NC_STRING
The name of the machine th	nat processed the data. This may aid in diagnosing	failures in the processing.
ProcessorVersion	'%(version)s' (dynamic)	NC_STRING
The version number of the jor.minor.bugfix".	e processor used to produce the file. This is a	string formatted as "ma-
ProductFormatVersion	1 (static)	NC_INT
The version of the format of the files.	the product file. This should be incremented whene	ever a datafield is added to
ProcessingMode		NC_STRING
This attribute indicates the r	mode of the processor.	
Possible values: Near-realting	me, Offline, Reprocessing, Test, SyntheticTest	
LongitudeOfDaysideNadir	EquatorCrossing	NC_FLOAT
	oint at the day-side equator crossing. This gives a calculated using an orbit propagator before the obseing stages.	_
CollectionIdentifier	'%(collection_identifier)s' (dynamic)	NC_STRING
Identification of the proces consistent data set.	sing collection, i.e. the group of products that ca	an be used together as a
ProductShortName	'L2AER_LH' (static)	NC_STRING

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	Туре	
gmd:dateStamp	'2015-10-16' (static)	NC_STRING	
Date of creation of the metadata	, as ISO 8601 [RD36] string specifying year, month and o	day.	
gmd:fileIdentifier	'urn:ogc:def:EOP:ESA:SENTINEL.S5P_TROP %(shortname)s' (dynamic)	NC_STRING	
Unique identifier for metadata file of the value.	e, see the Level 1B metadata specification [RD35, table 5]] for a discussion	
Replace %()s with the "ProductShortName" value from the Level 2 "/METADATA/GRANULEDESCRIPTION" 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			
Name	Value	Туре	
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			
Name	Value	Туре	
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 wich metadata applies.

${\bf Attributes\ in\ AER_LH/METADATA/ISO_METADATA/gmd:} hierarchy Level$

Group attributes at	tached to gmd:hierarchyLevel	
Name	Value	Туре

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			
Name	Value	Туре	
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		
Name	Value	Туре
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			
Name	Value	Туре	
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 adress provided in this group.

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

Group attributes attached to gmd:role		
Name	Value	Туре
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		
Name	Value	Туре
gmd:abstract		NC_STRING

Brief narrative summary of the content of the resource. This is product specific, with modifications for timeliness and and pixel size. The pixel size listed below are the "small" pixels, with a length of 5.5 km in the flight direction for the main bands. For observations before August 6, 2019, the length in the flight direction is 7 km. Ozone profile adds several pixels in the flight direction, and has an approximate pixel size of $30 \times 30 \, \text{km}^2$ for the "small" pixels, and $35 \times 30 \, \text{km}^2$ for the "large" pixels.

- **L2_AER_AI (KNMI)** Aerosol index with a spatial resolution of $5.5 \times 3.5 \, \text{km}^2$ 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 $5.5 \times 3.5 \, \text{km}^2$ 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 $5.5 \times 3.5 \, \text{km}^2$ 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 $30 \times 30 \,\mathrm{km^2}$ 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 $5.5 \times 7 \, \text{km}^2$ observed at about 13:30 local solar time from spectra measured by TROPOMI
- **L2_CO___(SRON)** Carbon monoxide column with a spatial resolution of $5.5 \times 7 \, \text{km}^2$ 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 $5.5 \times 3.5 \, \text{km}^2$ observed at about 13:30 local solar time from spectra measured by TROPOMI (KNMI FRESCO cloud support product)
- **L2_O22CLD (KNMI)** O₂–O₂ cloud retrieval with a spatial resolution of $5.5 \times 3.5 \,\mathrm{km^2}$ observed at about 13:30 local solar time from spectra measured by TROPOMI (KNMI O₂–O₂ cloud support product)

gmd:credit	'%(credit)s' (static)	NC_STRING		
Recognition of those who con	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			
Name	Value	Туре	
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			
Name	Value	Туре	
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	Туре	
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	I to gmd:identifier	
Name	Value	Туре
gmd:code	'urn:ogc:def:EOP:ESA:SENTINEL.S5P_TROP %(shortname)s' (dynamic)	NC_STRING
Replace "%(shortname)s" DESCRIPTION" metadata	with the "ProductShortName" value from the Level 2 "/META a group.	DATA/GRANULE
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	Туре	
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	Туре	
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	Туре	
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	Туре	
codeList	'http://www.isotc211.org/2005/resources/Codelist/ gmxCodelists.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 choise of keywords is very limited. More meaningful keywords can be derived from the Climate and Forecast metadada 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	Туре	
codeList	'http://www.isotc211.org/2005/resources/Codelist/ gmxCodelists.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	Туре	
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	Туре	
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	Туре	
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	

10.2.3.23 Group "gmd:descriptiveKeywords#2" in "gmd:identificationInfo"

Provides category keywords, their type, and reference source. These keywords are taken from the Climate and Forecast metadada 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_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

L2_O22CLD (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	Туре		
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		Туре
gmd:title	'CF Standard Name Table v65' (static)		NC_STRING
xlink:href	'http://cfconventions.org/standard-names.html' namic)	(dy-	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	Туре	
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	Туре	
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	Туре	
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	Туре	
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	
Name	Value	Туре
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"

$Attributes\ in\ AER_LH/METADATA/ISO_METADATA/gmd: identification Info/gmd: character Set$

Group attributes attached to gmd:characterSet			
Name	Value	Туре	
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			
Name	Value	Туре	
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 lease 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			
Name	Value	Туре	
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	Туре	
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 attach	ed to gmd:extent	
Name	Value	Туре
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 82) 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	Туре	
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	Туре
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	Туре
codeList	'http://www.isotc211.org/2005/resources/Codelist/ gmxCodelists.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	Туре	
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 t	o gmd:result	
Name	Value	Туре
objectType	'gmd:DQ_ConformanceResult' (static)	NC_STRING
gmd:pass	'true' (static)	NC_STRING
Indication of confomance re	esult. 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 currently not be determined	of conformance for this result. Within the context of INSPIRE ${f c}$ d.	conformance can

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	Туре
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		
Name	Value	Туре
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		
Name	Value	Туре
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

10.2.3.43 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	
Name	Value	Туре
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

10.2.3.44 Group "gmd:processStep" in "gmd:lineage"

of the actual Level 2 product in this string (at the %(...)s).

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		
Name	Value	Туре
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 institude 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		
Name	Value	Туре
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		
Name	Value	Туре
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			
Name	Value	Type	
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		
Name	Value	Туре
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		
Name	Value	Туре
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

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 attach	ned to gmi:processedLevel	
Name	Value	Туре
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	Туре	
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	Туре	
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	Туре	
gmd:title	'%(processor_name)s processor' (dynamic)	NC_STRING	
Name of the processor.			
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	Туре
gmd:date	'%(processor_release_date)s' (dynamic)	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"

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	Туре	
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	Туре	
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	Туре	
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	Туре	
codeList	'http://www.isotc211.org/2005/resources/Codelist/ gmxCodelists.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	Туре	
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.			
doi	'%(pum_doi)s' (dynamic)	NC_STRING	
DOI for the product user manual.			

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	Туре	
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	

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	Туре	
codeList	'http://www.isotc211.org/2005/resources/Codelist/ gmxCodelists.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			
Name	Value	Туре	
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 attach	ned to gmd:source#1	
Name	Value	Туре
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 attac	hed to gmi:processedLevel	
Name	Value	Туре
gmd:code	Empty!	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 attac	hed to gmd:sourceCitation	
Name	Value	Туре
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 atta	ched to gmd:date	
Name	Value	Туре
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	Туре	
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 a	ttached to gmd:title	
Name	Value	Туре
gco:characterStr	ing	NC_STRING
Textual description Source" object).	n of the input file group (same as the "gmo	d:description" attribute in the "gmi:LE

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	d to gmd:alternateTitle#1	
Name	Value	Туре
gmx:FileName	Empty!	NC_STRING
The basename of the inp	out 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 attacl	ned to gmi:acquisitionInformation	
Name	Value	Туре
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	Туре
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	Туре
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.

$Attributes \ in \ AER_LH/METADATA/ISO_METADATA/gmi: acquisition Information/gmi: platform/gmi: instrument acquisition of the property of the$

Group attributes attached to	gmi:instrument	
Name	Value	Туре
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	Туре	
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 attac	hed to EOP_METADATA	
Name	Value	Туре
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 atta	ached to om:phenomenonTime	
Name	Value	Туре
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	Туре	
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	Туре	
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	d to eop:instrument	
Name	Value	Туре
eop:shortName	'TROPOMI' (static)	NC_STRING
objectType	'eop:Instrument' (static)	NC_STRING

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	Туре	
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	Туре
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 attack	hed to om:observedProperty	
Name	Value	Туре
nilReason	'inapplicable' (dynamic)	NC_STRING
This element should u	se 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	Туре
objectType	'eop:FootPrint' (static)	NC_STRING

gml:id	'%(logical_filename)s.FP' (dynamic)	NC_STRING
Unique ID for this "eop:FootPrir "FP" separated by a dot.	nt" object. Constructed from the logical output file	ename and the extension

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 attac	hed to eop:multiExtentOf	
Name	Value	Туре
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 attac	hed to gml:surfaceMembers	
Name	Value	Туре
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 at	tached to gml:exterior	
Name	Value	Туре
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 Eath 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	Туре
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 *always* 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	g the product (see $http://www.datacite.org$ for DC	Ols for datasets).		
eop:parentldentifier	'urn:ogc:def:EOP:ESA:SENTINEL.S5P_TROP %(shortname)s' (dynamic)	NC_STRING		
Unique collection identifier for me discussion of the value.	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:fileIde	ntifier" attribute in the "/METADATA/ISO_METADATA" gro	oup.		
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	s: 'DEGRADED',		

eop:productQualityDegradationTal@T 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.

'NOMINAL'.

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

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

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	Туре
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 attributos attache	ad to fixed header	
Group attributes attache	_	
Name	Value	Туре
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 glo	bal "title" attribute.	
Notes		NC_STRING
This is a copy of the glo	bal "comment" attribute.	
Mission	'S5P' (static)	NC_STRING
The mission identifier for	or the Sentinel 5-precursor mission is "S5P".	
File_Class		NC_STRING
The file class of the outposection 4.1.2].	out. Values are taken from the tailoring of the EO file for	mat tailoring for S5P [RD25,
File_Type	'%(shortname)s' (dynamic)	NC_STRING
Following the EO file for	rmat tailoring for S5P [RD25, sections 4.1.3.1 and 4.1.3	3.2].
File_Version	0 (dynamic)	NC_INT
	tion is not part of the file name conventions for S5P. If a re, then it has to be provided by the PDGS via the job ided 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 atta	ached to validity_period	
Name	Value	Туре
objectType	'Validity_Period' (static)	NC_STRING
Validity_Start		NC_STRING
	ring "UTC=" concatenated with the time_coverage_s to the "Validity_Start" element in the "Validity_Period" X	•
Validity_Stop		NC_STRING
The value is the string "UTC=" concatenated with the time_coverage_end 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 attache	ed to source	
Name	Value	Туре
objectType	'Source' (static)	NC_STRING
System	'%(processingcenter)s' (dynamic)	NC_STRING
	gment element creating the file. For Level 2 files, this a used. This attribute corresponds to the "System" e ile.	
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 to in the "Source" XML stru	ol that created the file. This attribute corresponds to thucture in the header file.	ne "Creator_Version" element
Creation_Date		NC_STRING
The start date and time	of processing, as a string: "UTC=YYYY-MM-DDThh: m	nm:ss". This attribute corres-

10.2.3.94 Group "variable_header" in "earth_explorer_header"

Attributes in AER_LH/METADATA/ESA_METADATA/earth_explorer_header/variable_header

ponds to the "Creator_Date" element in the "Source" XML structure in the header file.

Group attributes attached to variable_header		
Name	Value	Туре
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 Name	Value	Туре
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
•	e data producer's knowledge about the lineage of a dataset. Insert duct in this string (at the $%()$ s).	short description

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	Туре
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 institude 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		
Croup attributes att	acried to grin.output	
Name	Value	Type
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 attac	hed to gmd:sourceCitation	
Name	Value	Туре
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			
Name	Value	Туре	
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			
Name	Value	Туре	
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	

10.2.3.101 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			
Name	Value	Туре	
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	

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 attach	ed to gmi:processedLevel	
Name	Value	Туре
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 attac	hed to gmi:processingInformation	
Name	Value	Туре
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 attach	ned to gmi:identifier	
Name	Value	Туре
gmd:code	'%(institute)s L2 %(product)s processor, version %(version)s' (dynamic)	NC_STRING
•	e processor, with the $\%(\dots)$ s placeholders replaced with the respond software release version.	onsible institute's
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	Туре
gmd:title	'%(processor_name)s processor' (dynamic)	NC_STRING
Name of the processor.		
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 attac	hed to gmd:date	
Name	Value	Туре
gmd:date	'%(processor_release_date)s' (dynamic)	NC_STRING
Release date of the p	rocessor 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"

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	Туре
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

10.2.3.108 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 attach	ned to gmi:documentation#1	
Name	Value	Туре
objectType	'gmd:CI_Citation' (static)	NC_STRING
gmd:title	'%(title_atbd)s' (dynamic)	NC_STRING
Specification of the cur	rent 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 atta	ched to gmd:date	
Name	Value	Туре
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		
Name	Value	Туре
codeList	'http://www.isotc211.org/2005/resources/Codelist/ gmxCodelists.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		
Name	Value	Туре
objectType	'gmd:CI_Citation' (static)	NC_STRING
gmd:title	'%(title_pum)s' (dynamic)	NC_STRING
Specification of the cur	rent 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		
Name	Value	Туре
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

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 gm	d:dateType	
Name	Value	Туре
codeList	'http://www.isotc211.org/2005/resources/Codelist/ gmxCodelists.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			
Name	Value	Туре	
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 or	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 attache	ed to gmd:source#1	
Name	Value	Туре
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			
Name	Value	Туре	
gmd:code	Empty!	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 attac	hed to gmd:sourceCitation	
Name	Value	Туре
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	Туре	
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	Туре
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 at	ttached to gmd:title	
Name	Value	Туре
gco:characterStri	ing	NC_STRING
Textual description Source" object).	n of the input file group (same as the "gm	d:description" attribute in the "gmi:LE

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	Туре	
gmx:FileName	Empty!	NC_STRING	
The basename of the inp	out 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 units 4 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_percm2 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_percm2_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:

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

This is a discrete approximation of a continuous probability density function, for discrete values x_j for all successful retrievals $i=1,\ldots,N$. The value of $\cos\left(\delta_{\text{geo},i}\right)$ 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
number_of_groundpixels	Number of ground pixels in the file.
number_of_processed_pixels	Number of ground pixels where a retrieval was attempted. This is the number_of_groundpixels minus the pixels that were rejected on trivial grounds, such as the solar zenith angle.
number_of_successfully_processed_pixels	Number of ground pixels where a retrieval was successful.
number_of_rejected_pixels_not_enough_spectrum	Number of ground pixels where a retrieval was not attempted because too many spectral pixels were flagged as bad.
number_of_failed_retrievals	Number of pixels that were attempted but failed.
number_of_ground_pixels_with_warnings	Number of pixels with one or more warnings.
number_of_missing_scanlines	Number of scanlines that are missing from the input, presumably transmission errors.
number_of_radiance_missing_occurrences	Number of ground pixels where "the number of spectral pixels in the radiance due to flagging is too small to perform the fitting" occurred.
number_of_irradiance_missing_occurrences	Number of ground pixels where "the number of spectral pixels in the irradiance due to flagging is too small to perform the fitting" occurred.
number_of_input_spectrum_missing_occurrences	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.
number_of_reflectance_range_error_occurrences	Number of ground pixels where "any of the reflectances is out of bounds $(R < 0 \text{ or } R > R_{\text{max}})$ " occurred.
number_of_ler_range_error_occurrences	Number of ground pixels where "lambert-equivalent reflectivity out of range error" occurred.
number_of_snr_range_error_occurrences	Number of ground pixels where "too low signal to noise to perform retrieval" occurred.
number_of_sza_range_error_occurrences	Number of ground pixels where "solar zenith angle out of range, maximum value from configuration" occurred.
number_of_vza_range_error_occurrences	Number of ground pixels where "viewing zenith angle out of range, maximum value from configuration" occurred.
number_of_lut_range_error_occurrences	Number of ground pixels where "extrapolation in lookup table (airmass factor,

cloud radiances)" occurred.

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

Name
number_of_ozone_range_error_occurrences
number_of_wavelength_offset_error_occurrences
number_of_initialization_error_occurrences
number_of_memory_error_occurrences
number_of_assertion_error_occurrences
number_of_io_error_occurrences
number_of_numerical_error_occurrences
number_of_lut_error_occurrences
number_of_ISRF_error_occurrences
number_of_convergence_error_occurrences
number_of_cloud_filter_convergence_error_occurrences
number_of_max_iteration_convergence_error_occurrences
number_of_aot_lower_boundary_convergence_error_occurrences

number_of_other_boundary_convergence_error_occurrences

Description

Number of ground pixels where "ozone column significantly out of range of profile climatology" occurred.

Number of ground pixels where "wavelength offset exceeds maximum from configuration" occurred.

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 ground pixels where "memory allocation or deallocation error" occurred.

Number of ground pixels where "error in algorithm detected during assertion" occurred.

Number of ground pixels where "error detected during transfer of data between algorithm and framework" occurred.

Number of ground pixels where "general fatal numerical error occurred during inversion" occurred.

Number of ground pixels where "error in accessing the lookup table" occurred.

Number of ground pixels where "error detected in the input instrument spectral response function input data" occurred.

Number of ground pixels where "the main algorithm did not converge" occurred.

Number of ground pixels where "the cloud filter did not converge" occurred.

Number of ground pixels where "no convergence because retrieval exceeds maximum number of iterations. Maximum value from configuration" occurred.

Number of ground pixels where "no convergence because the aerosol optical thickness crosses lower boundary twice in succession" occurred.

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_2O 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.	
<pre>number_of_number_of_input_data_points_too_low_error_occurrences</pre>	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
number_of_sun_glint_filter_occurrences
number_of_mixed_surface_type_filter_occurrences
number_of_snow_ice_filter_occurrences
number_of_aai_filter_occurrences
number_of_cloud_fraction_fresco_filter_occurrences
number_of_aai_scene_albedo_filter_occurrences
number_of_small_pixel_radiance_std_filter_occurrences
number_of_cloud_fraction_viirs_filter_occurrences
number_of_cirrus_reflectance_viirs_filter_occurrences
number_of_cf_viirs_swir_ifov_filter_occurrences
number_of_cf_viirs_swir_ofova_filter_occurrences

number of cf viirs swir ofovb filter occurrences

number of cf viirs swir ofovc filter occurrences

number of cf viirs nir ifov filter occurrences

Description

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 ground pixels where "pixel contains land and water areas (e.g. coastal pixel)" occurred.

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 ground pixels where "AAI smaller than 2.0" occurred.

Number of ground pixels where "pixel contains clouds: The FRESCO effective cloud fraction is larger than threshold. Threshold value from ATBD" occurred.

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 ground pixels where "pixel contains clouds: Standard deviation of radiances in small-pixel column exceeds threshold. Threshold value from ATBD" occurred.

Number of ground pixels where "pixel contains clouds: The cloud fraction from VIIRS / NPP exceeds the shold. Threshold value from ATBD" occurred.

Number of ground pixels where "pixel contains clouds: Cirrus reflectance from VIIRS / NPP exceeds threshold. Threshold value from ATBD" occurred.

Number of ground pixels where "fraction of cloudy VIIRS pixels wihtin S5P SWIR ground pixel exceeds a priori threshold from configuration" occurred.

Number of ground pixels where "fraction of cloudy VIIRS pixels within S5P SWIR OFOVa exceeds a priori threshold from configuration" occurred.

Number of ground pixels where "fraction of cloudy VIIRS pixels wihtin S5P SWIR OFOVb exceeds a priori threshold from configuration" occurred.

Number of ground pixels where "fraction of cloudy VIIRS pixels wihtin S5P SWIR OFOVc exceeds a priori threshold from configuration" occurred.

Number of ground pixels where "fraction of cloudy VIIRS pixels wihtin S5P NIR ground pixel exceeds a priori threshold from configuration" occurred.

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

N	la	m	Δ	

number of cf viirs nir ofova filter occurrences number of cf viirs nir ofovb filter occurrences number of cf viirs nir ofovc filter occurrences number of refl cirrus viirs swir filter occurrences number of refl_cirrus_viirs_nir_filter_occurrences number of diff refl cirrus viirs filter occurrences number of ch4 noscat ratio filter occurrences number of ch4 noscat ratio std filter occurrences number of h2o noscat ratio filter occurrences number of h2o noscat ratio std filter occurrences number of diff psurf fresco_ecmwf filter occurrences number_of_psurf_fresco_stdv_filter_occurrences number_of_ocean_filter_occurrences

Description

Number of ground pixels where "fraction of cloudy VIIRS pixels within S5P NIR OFOVa exceeds a priori threshold from configuration" occurred.

Number of ground pixels where "fraction of cloudy VIIRS pixels within S5P NIR OFOVb exceeds a priori threshold from configuration" occurred.

Number of ground pixels where "fraction of cloudy VIIRS pixels within S5P NIR OFOVc exceeds a priori threshold from configuration" occurred.

Number of ground pixels where "average VIIRS cirrus reflectance within SWIR ground pixel exceeds a priori threshold from configuration" occurred.

Number of ground pixels where "average VIIRS cirrus reflectance within NIR ground pixel exceeds a priori threshold from configuration" occurred.

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 ground pixels where "the ratio between [CH₄]_{weak} and [CH₄]_{strong} is below or exceeds a priori thresholds from configuration" occurred.

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 ground pixels where "the ratio between [H₂O] $_{weak}$ and [H₂O] $_{strong}$ is below or exceeds a priori thresholds from configuration" occurred.

Number of ground pixels where "the standard deviation of $[H_2O]_{weak}/[H_2O]_{strong}$ within the SWIR pixel and the 8 neigbouring pixels exceeds a priori threshold from configuration" occurred.

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 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 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 posibility 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 possiblity 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)" occurred.
<pre>number_of_pixel_level_input_data_missing_occurrences</pre>	Number of ground pixels where "dynamic auxiliary input data (e.g cloud) is missing for this ground pixel. A fallback option is used" occurred.

Number of ground pixels where "warning occurring when the retrieval dia-

gnostic indicates a degraded quality of the cloud retrieval" occurred.

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

number_of_cloud_retrieval_warning_occurrences

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. For O ₃ profile this warning indicates an out of range cost function, or an out of range RMS difference between retrieval and a priori" occurred.
number_of_low_cloud_fraction_warning_occurrences	Number of ground pixels where "low cloud fraction, therefore no cloud pressure retrieved" occurred.
<pre>number_of_altitude_consistency_warning_occurrences</pre>	Number of ground pixels where "difference between ECMWF surface elevation and high-resolution surface elevation exceeds threshold from configuration" occurred.
<pre>number_of_signal_to_noise_ratio_warning_occurrences</pre>	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.
<pre>number_of_so2_volcanic_origin_likely_warning_occurrences</pre>	Number of ground pixels where "warning for SO_2 BL product, UTLS products: volcanic origin except for heavily polluted sites. For O_3 profile this warning is issued in case of a large SO_2 column which has an impact on the O_3 profile retrieval" 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.

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

Name	Description
number_of_cloud_inhomogeneity_warning_occurrences	Number of ground pixels where "the cloud coregistration inhomogeneity parameter is above a given threshold. This warning is also set when the coregistration weight sums are less than 1" occurred.
number_of_thermal_instability_warning_occurrences	Number of ground pixels where "input spectra have been labeled with a thermal instability warning flag" 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
Р	Attribute has the data-type of the variable with which it is associated ('parent' data type).
1	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 en 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 "L2Aerosol 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	Т	This is the UTC Validity Start Time, the same as the Validity Start Time in the File Name and the time_coverage_start global attribute.
Validity_Stop	Т	This is the UTC Validity Stop Time, the same as the Validity Stop Time in the File Name and the time_coverage_end 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.
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	Т	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 evelopment 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.

Туре	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: $0x1.ep+122$)
double	64-bit floating point	$9.9692099683868690 \times 10^{36}$ (hex: 0x1.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 $\mathrm{km^2}$ 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	Р	NUG	Value to represent missing or undefined data. Recommended (default) values are given in table 9.
flag_masks	Р	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	Р	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 standarderror 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	Р	NUG	Largest valid value of a variable.
valid_min	Р	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.	CH₄
26	h2o_noscat_zero_error	The $\rm H_2O$ 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.	CH₄
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 to 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, CH₄
75	cloud_fraction_viirs_filter	Pixel contains clouds: The cloud fraction from VIIRS / NPP exceeds the shold. 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 wihtin S5P SWIR OFOVa exceeds a priori threshold from configuration.	CH ₄
79	cf_viirs_swir_ofovb_filter	Fraction of cloudy VIIRS pixels wihtin 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 wihtin S5P NIR ground pixel exceeds a priori threshold from configuration.	CH ₄
82	cf_viirs_nir_ofova_filter	Fraction of cloudy VIIRS pixels wihtin S5P NIR OFOVa exceeds a priori threshold from configuration.	CH ₄
83	cf_viirs_nir_ofovb_filter	Fraction of cloudy VIIRS pixels wihtin 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.	CH₄
85	refl_cirrus_viirs_swir_filter	Average VIIRS cirrus reflectance within SWIR ground pixel exceeds a priori threshold from configuration.	CH₄
86	refl_cirrus_viirs_nir_filter	Average VIIRS cirrus reflectance within NIR ground pixel exceeds a priori threshold from configuration.	CH₄
87	diff_refl_cirrus_viirs_filter	Difference in VIIRS average cirrus reflectance between SWIR and NIR ground pixel exceeds a priori threshold from configuration.	CH₄
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 $[H_2O]_{weak}$ and $[H_2O]_{strong}$ is below or exceeds a priori thresholds from configuration.	CH ₄
91	h2o_noscat_ratio_std_filter	The standard deviation of $[H_2O]_{weak}/[H_2O]_{strong}$ within the SWIR pixel and the 8 neigbouring 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.	CH₄
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.	CH₄
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, CH₄	
11	0x00000800	sun_glint_warning	Sun glint posibility 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	ម៉
14	0x00004000	snow_ice_warning	Snow/ice flag is set, i.e. using scene data from the cloud support product.	NO ₂ , Cloud	5
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 possiblity of ice-clouds.	CH ₄ , O ₃ profile, Cloud	Page 121 of 124
16	0x00010000	AAI_warning	Possible aerosol contamination as either indicated by the AAI (O ₃ profile).	O ₃ profile	124

Table 12: Processing quality flags, warnings for S5P Level 2 (continued).

it#	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. For O_3 profile this warning indicates an out of range cost function, or an out of range RMS difference between retrieval and a priori.	All CO, CH ₄ , O ₃ , SO ₂ , HCHC
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. For O_3 profile this warning is issued in case of a large SO_2 column which has an impact on the O_3 profile retrieval.	SO ₂ , O ₃ profile
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. This warning is also set when the coregistration weight sums are less than 1.	Cloud Cloud All
30	0x40000000	thermal_instability_warning	Input spectra have been labeled with a thermal instability warning flag.	All

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 $15\times15\mathrm{arcsecond}$ 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