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Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Carbon Monoxide

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1 Introduction

1.1 Identification

This document, identified as SRON-S5P-LEV2-MA-002, 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 Carbon Monoxide.

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 Carbon Monoxide 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 Carbon Monoxide 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 Carbon Monoxide 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 SO_2 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 SO_2. **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] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Aerosol Layer Height. **source:** KNMI; **ref:** S5P-KNMI-L2-0022-MA; **issue:** 2.4.0; **date:** 2022-07-11.

[RD16] TROPOMI ATBD of the UV aerosol index. **source:** KNMI; **ref:** S5P-KNMI-L2-0008-RP; **issue:** 2.0.0; **date:** 2021-07-05.

[RD17] 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.

[RD18] TROPOMI ATBD Ozone profile and tropospheric profile.
source: KNMI; **ref:** S5P-KNMI-L2-0004-RP; **issue:** 1.0.0; **date:** 2021-10-22.

[RD19] 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.

[RD20] TROPOMI ATBD of the total and tropospheric NO_2 data products.
source: KNMI; **ref:** S5P-KNMI-L2-0005-RP; **issue:** 2.4.0; **date:** 2022-07-11.

[RD21] 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.

[RD22] 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.

[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] T. Borsdorff, O. P. Hasekamp, A. Wassmann *et al.*; Insights into Tikhonov regularization: application to trace gas column retrieval and the efficient calculation of total column averaging kernels. *Atmospheric Measurement Techniques*; **7** (2014) (2), 523; 10.5194/amt-7-523-2014. URL https://doi.org/10.5194/amt-7-523-2014.

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[RD29] T. Borsdorff, J. Aan de Brugh, H. Hu *et al.*; Measuring Carbon Monoxide With TROPOMI: First Results and a Comparison With ECMWF-IFS Analysis Data. *Geophys. Res. Let.*; **45** (2018), 2826; 10.1002/2018GL077045.

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[RD31] T. Borsdorff, A. García Reynoso, G. Maldonado *et al.*; Monitoring CO emissions of the metropolis Mexico City using TROPOMI CO observations. *Atmospheric Chemistry and Physics*; **20** (2020) (24), 15761; 10.5194/acp-20-15761-2020. URL https://acp.copernicus.org/articles/20/15761/2020/.

[RD32] A. Inness, A.-M. Blechschmidt, I. Bouarar *et al.*; Data assimilation of satellite-retrieved ozone, carbon monoxide and nitrogen dioxide with ECMWF's Composition-IFS. *Atmospheric Chemistry and Physics*; **15** (2015) (9), 5275; 10.5194/acp-15-5275-2015. URL https://www.atmos-chem-phys.net/15/5275/2015/.

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[RD34] M. Birk., G. Wagner, J. Loos *et al.*; Methane and water spectroscopic database for TROPOMI Sentinel 5 Precursor in the 2.3μm region. volume 19; (p. 4652) (EGU General Assembly, 2017).

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source: DLR; **ref:** .

[RD36] M. K. Sha, B. Langerock, J.-F. L. Blavier *et al.*; Validation of methane and carbon monoxide from Sentinel-5 Precursor using TCCON and NDACC-IRWG stations. *Atmospheric Measurement Techniques*; **14** (2021) (9), 6249; 10.5194/amt-14-6249-2021. URL https://amt.copernicus.org/articles/14/6249/2021/.

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source: ESA/ESTEC; **ref:** PE-TN-ESA-GS-0001; **issue:** 2.0; **date:** 2012-05-03.

[RD40] Geographic information – Metadata.
source: ISO; **ref:** ISO 19115:2003(E); **issue:** 1; **date:** 2003-05-01.

[RD41] 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.

[RD42] Geographic information – Data quality.
source: ISO; **ref:** ISO 19157; **issue:** 1; **date:** 2013-10-10.

[RD43] Earth Observation Metadata profile of Observations & Measurements.
source: Open Geospatial Consortium; **ref:** OGC 10-157r3; **issue:** 1.0; **date:** 2012-06-12.

[RD44] Data Standards Requirements for CCI Data Producers.
source: ESA; **ref:** CCI-PRGM-EOPS-TN-13-0009; **issue:** 1.1; **date:** 2013-05-24.

[RD45] Metadata specification for the TROPOMI L1b products.
source: KNMI; **ref:** S5P-KNMI-L01B-0014-SD; **issue:** 6.0.0; **date:** 2019-07-19.

[RD46] 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.

[RD47] 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.

[RD48] Geographic information – Metadata – XML schema implementation.
source: ISO; **ref:** ISO 19139:2007(E); **issue:** 1; **date:** 2010-12-13.

[RD49] Observations and Measurements – XML Implementation..
source: Open Geospatial Consortium; **ref:** OGC 10-025r1; **issue:** 2.0; **date:** 2011-03-22.

[RD50] 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.

[RD51] 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.

[RD52] S5P-NPP Cloud Processor IODD.
source: RAL; **ref:** S5P-NPPC-RAL-IODD-0001; **issue:** 0.10.0; **date:** 2014-05-28.

[RD53] John Caron; Annotated Schema for NcML (2011). URL http://www.unidata.ucar.edu/software/netcdf/ncml/v2.2/AnnotatedSchema4.html.

[RD54] INSPIRE Metadata Regulation, Commission Regulation (EC), No1205/2008.
source: EC; **ref:** Commission Regulation (EC) No 1205/2008; **date:** 2008-12-03.

[RD55] 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.

[RD56] Geographic Information – Observations and Measurements.
source: ISO; **ref:** ISO 19156:2011(E); **date:** 2011-12-20.

[RD57] 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 Added
TBC	To be Confirmed
TBD	To be Defined

3.2 Acronyms and Abbreviations

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

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

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

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

Product	**ATBD**	**PUM**	**Identifier**	**Institution**
Cloud	[RD3]	[RD4]	`L2__CLOUD_`	DLR
NPP-VIIRS Clouds	[RD5]	[RD5]	`L2__NP_BDx`	RAL
HCHO	[RD6]	[RD7]	`L2__HCHO__`	BIRA/DLR
SO_2	[RD8]	[RD9]	`L2__SO2___`	BIRA/DLR
O_3 Total Column	[RD10]	[RD11]	`L2__O3____`	BIRA/DLR
O_3 Tropospheric Column	[RD12]	[RD13]	`L2__O3_TCL`	IUP/DLR
Aerosol layer height	[RD14]	[RD15]	`L2__AER_LH`	KNMI
Ultra violet aerosol index	[RD16]	[RD17]	`L2__AER_AI`	KNMI
O_3 Full Profile	[RD18]	[RD19]	`L2__O3__PR`	KNMI
NO_2	[RD20]	[RD21]	`L2__NO2___`	KNMI
CO	[RD22]	This document	`L2__CO____`	SRON/KNMI
CH_4	[RD23]	[RD24]	`L2__CH4___`	SRON/KNMI

4.1 File name convention

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

In the current PUM the Carbon Monoxide product is described and an example of the full real name is as following:

`S5P_NRTI_L2__CO_____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 "`YYYYMMDD`**`T`**`HHMMSS`". The "`T`" is a fixed character.
36	51	15	End of the granule in UTC as "`YYYYMMDD`**`T`**`HHMMSS`". The "`T`" is a fixed character.
52	57	5	Orbit number
58	60	2	Collection number
61	67	6	Processor version number as "`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`**`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 Carbon Monoxide 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.

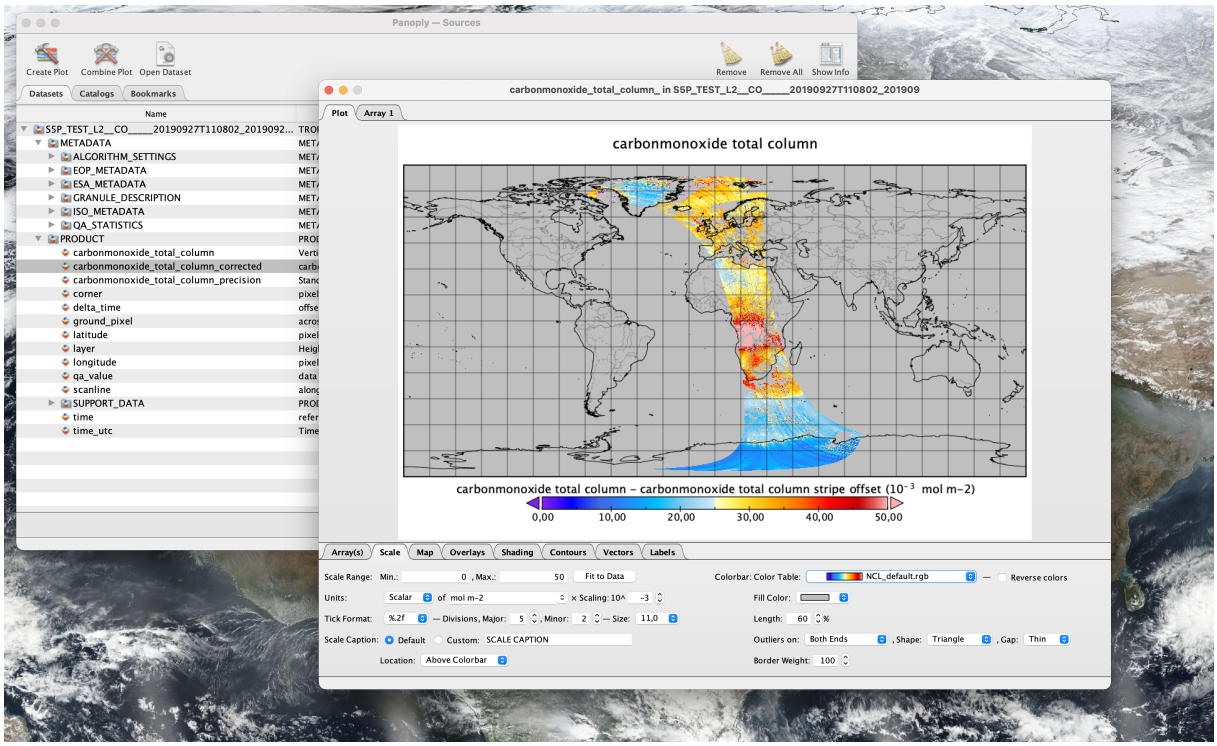

Figure 1: Panoply

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 lon-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.

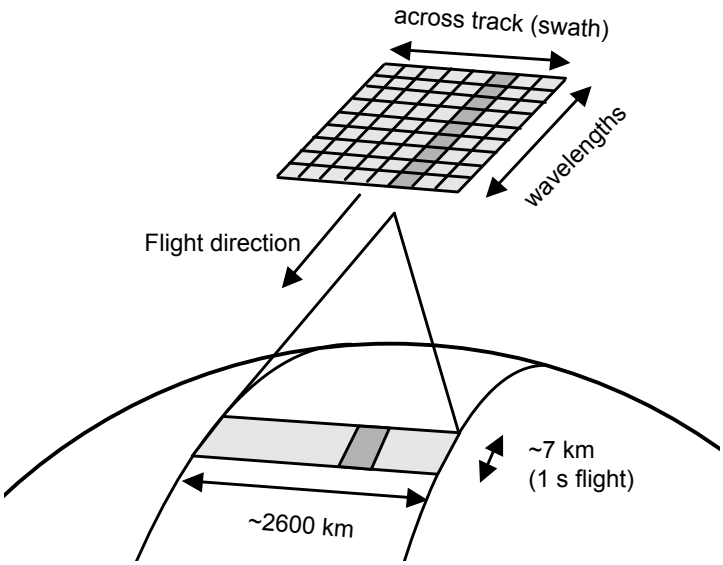

Figure 2: TROPOMI measurement principle.

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 $7.2 \times 3.6\,\mathrm{km}^2$ for bands 2–6, (UVN) $7.2 \times 7.2\,\mathrm{km}^2$ for bands 7 and 8 (SWIR), and $21.6 \times 28.8\,\mathrm{km}^2$ 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 $5.6 \times 3.6\,\mathrm{km}^2$ for bands 2–6, $5.6 \times 7.2\,\mathrm{km}^2$ for bands 7 and 8, and $28 \times 28.8\,\mathrm{km}^2$ 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 Carbon Monoxide Product Description

Carbon monoxide (CO) is an important atmospheric trace gas for our understanding of tropospheric chemistry and in certain urban areas, it is a major atmospheric pollutant. Main sources of CO are combustion of fossil fuels, biomass burning, and atmospheric oxidation of methane (CH_4) and other hydrocarbons. Whereas fossil fuel combustion is the main source of CO at Northern mid-latitudes, the oxidation of isoprenes and biomass burning play an important role in the tropics. Due to the long lifetime of methane, its oxidation provides a close-to uniform background on the global CO distribution. The most important sink of CO is its reaction with the hydroxyl radical OH.

TROPOMI observes the CO global abundance exploiting clear sky and cloudy sky Earth radiance measurements. In the 2.3 μm spectral range of the shortwave infrared (SWIR) part of the solar spectrum, TROPOMI clear sky observations provide CO total columns with sensitivity to the tropospheric boundary layer. For cloudy atmospheres, the column sensitivity changes according to the light path.

8.1 History of product changes

This manual references to the most recent version of the L2 Carbon Monoxide product.

- **L2 ver. 2.4.0** / **L1B data ver. 2.1.0**: The priori profiles of CO are now included in the L2 output. They are not needed for the general usage of the data product [RD27] but their availability is more convenient for data users. The unit of the total column averaging kernel is changed from meters (m) to the unit less representation (1). The previous representation was not common and by those confusing data users. All retrieval parameters are now provided with null-space filling using their priori assumptions. This has no effect on trace gas retrievals like CO that is deploying the profile scaling approach [RD27] but it can improve the quality of the retrieved side parameters (e.g. height_scattering_layer, scattering_optical_-thickness, and the surface_albedo).

- **L2 ver. 2.2.0** / **L1B data ver. 2.0.0**: The spectroscopic database base deployed for the forward calculation of the L2 processor is updated. The HITRAN 2008 database is replaced by the Scientific Exploitation of Operational Missions - Improved Atmospheric Spectroscopy Databases (SEOM-IAS) resulting in a better spectral fit quality and a lower bias with the validation measurements of the TCCON network [RD28]. Furthermore, a posteriori destriping of the L2 data is implemented deploying the Fixed Mask (FD) algorithm [RD28].

- **L2 ver. 1.0.1** / **L1B data ver. 1.0.0.19194**: During the instrument commissioning phase, the CO retrieval software was only marginally adjusted. This software release, includes an improvement of the retrieval convergence for cloudy-sky observations using an estimate of the cloud height from a non-scattering CH_4 retrieval. This did not affected the data quality of the TROPOMI CO product.

Note that the processor version for CO is changing when there is a change to any of the products belonging to the NL-L2 processor suite (NO2, CO, CH4, AI, ALH, O3 PR) even if the change is not affecting the CO product.

8.2 Data Product Examples

After the successful launch of TROPOMI on October 13th, 2017 as the single payload of ESA's Sentinel-5 Precursor (S-5P) satellite, first calibrated SWIR radiance data were received at November 9th, 2017. The data quality was already sufficient to process the CO total column product of the offline data stream with remarkable accuracy [RD29]. Figure 3 shows first results of global CO observations of TROPOMI for the six subsequent days November,13th-17th, and 19th. On November 18th no radiance measurements are available. For our data analysis, we selected only observations with a solar zenith angle (SZA) $< 80^o$ and did not consider the two most westward pixels of the swath, because of a not yet resolved performance issue. Moreover, we selected clear-sky and cloudy sky observations with a cloud height $z_{\mathrm{cld}} < 5000$ m. The TROPOMI data clearly reflects CO enhancements by strong sources like wild fires (e.g. Brazil, Africa, Madagascar, and Australia) as well as anthropogenic air pollution in India and China. The good signal-to-noise ratio of the measurements in combination with the high spatial resolution also permits to detect enhancements by weak regional sources.

Moreover, already in this early phase of the mission TROPOMI demonstrated its capability to detect air pollution above cities, urban and industrial areas on a daily basis, which belongs to the most ambitious objectives of the mission. For example, Fig. 4 shows enhanced CO values over the industrial area near to

Venice as well as pollution above Turin, Milan, and Rome. The daily global coverage of TROPOMI and so the temporal evolution of air pollution on city scales opens up new possibilities to monitor the effect of emission regularization but also requires estimates of the absolute uncertainty of the TROPOMI CO product. The TROPOMI CO data proved useful to estimate emission rates of cities, roads and even can resolve emissions of suburbs within cities [RD30, RD31].

8.3 Product Geophysical Validation

For a first data quality assessment, the TROPOMI CO data product was compared with the near-real-time data analysis of the ECMWF Integrated Forecasting System (IFS) assimilating IASI and MOPITT observations of CO [RD32], which are provided by the Copernicus Atmosphere Monitoring Service (CAMS). For this purpose, Borsdorff et al. 2018a [RD29] collocated the TROPOMI CO retrieval with the 6 hourly CAMS CO fields, interpolating the CAMS data to the time and location of the individual TROPOMI measurement. Subsequently, the integration of the CAMS profile using the column averaging kernel provides the corresponding column density, which takes into account the vertical retrieval sensitivity. This approach allows a one-to-one comparison of CAMS and TROPOMI data, shown in Fig. 5. Overall, the TROPOMI and CAMS CO fields agree well. Figure 6 shows the corresponding histogram of the differences with small mean difference of +3.2 % between the TROPOMI and CAMS CO data with a standard deviation of 5.5 %. Both data sets are strongly correlated with a Pearson correlation coefficient of 0.97. Also interesting is the good agreement of the two data sets over the oceans. Here, data can only be inferred from cloudy observations. In the shortwave infrared spectral range, the ocean surface is very dark (except for glint observation geometry) and so cloud-free measurements generally do not record sufficient light to achieve a meaningful retrieval. The good agreement gives confidence in valuable TROPOMI CO data product for cloudy conditions.

The quality of the TROPOMI CO data product needs to be validated in more detail using independent on-ground reference observations both for clear-sky (filtering data with qa_value=1) and cloudy (filtering data with qa_value=0.7) TROPOMI measurements. To this end, Borsdorff et al., 2018b, [RD33] performed a first validation with CO observations at nine ground-based FTS stations operated by the TCCON network With the limited data available at the time of their study, Borsdorff et al. 2018b [RD33] found good agreement with a small mean bias of TROPOMI CO versus TCCON of 6.0 ppb for clear-sky, 6.2 ppb for cloudy-sky TROPOMI retrievals and 5.8 ppb for the combination of both with a station-to-station deviation of 3.9 ppb for clear-sky, 2.4 ppb for cloudy-sky, and 2.9 ppb for the combination case. Furthermore, the mean standard deviation of the bias is 3.9 ppb for clear-sky, 2.4 ppb for cloud-sky, and 2.9 ppb for the combination. The good agreement between clear-sky and cloudy-sky retrieval underlines the validity of the data retrieval for cloudy scenes, a key aspect of the SICOR algorithm to achieve the data coverage of the TROPOMI CO product. Borsdorff et al. 2019 [RD28] confirmed this findings by validating about 1 year of TROPOMI CO data with measurements of 13 stations operated by the TCCON network. Furthermore, Borsdorff et al. 2019 [RD28] showed that the bias between TROPOMI and TCCON can be further reduced to below 3.6 ppb for clear-sky and cloudy-sky retrievals when replacing the HITRAN 2008 spectroscopic database used in the L2 processor by (SEOM-IAS) which is an ESA Project that revised the line list parameters/absorption cross sections of O_3, CO, CH_4, H_2O, HDO, and SO_2 with the objective to improve the quality of the Sentinel-5P data products (`https://www.wdc.dlr.de/seom-ias/`) [RD34]. of SEOM-IAS were tested by fitting atmospheric spectra recorded by FTIR spectrometry, resulting in significantly improved residuals in spectral sections dominated by CH_4 and H_2O compared to HITRAN 2012 [RD35]. Furthermore, SEOM-IAS achieves the best spectral fit quality (root-mean-squared (rms) differences between simulated and measured TROPOMI SWIR spectra) in comparison with the HITRAN 2008, HITRAN 2012, and HITRAN 2016 spectroscopic databases [RD28]. A full validation of the TROPOMI CO data product covering a period of about 3 years was published by the Belgium Institute for Space Aeronomy (BIRA-IASB) [RD36]. They found that the S5P CO data generally fulfil the missions requirements, with a few exceptions, which are mostly due to co-location mismatches and limited availability of data. The systematic difference between S5P CO total and the TCCON data is on average 9.22 $\pm$ 3.45% (standard TCCON XCO) and 2.45 $\pm$ 3.38% (unscaled TCCON XCO).

8.4 A posteriori destriping of the level-2 data

The TROPOMI CO retrievals from single orbits show a striping pattern along the flight path, which is a well-known feature for observations of push-broom spectrometers (e.g. OMI [RD37]). Borsdorff et al 2018b [RD38] reported that the CO stripes can exceed 5 ppb and can hamper, e.g., the detection of small point sources and the estimate of emissions from fire plumes. The origin of the stripy pattern is not yet understood and is changing

with time from orbit to orbit. Borsdorff et al. 2018b [RD38] suggested an empirical destriping approach that is applied on the CO data fields (see left column of Fig 7). This method removes first the background of the CO field by a median smoothing in cross-track direction and then determines per orbit a fixed stripe pattern for correction by a median along the flight path. This method already reduces a major part of the stripes in the CO data and is denoted as fixed mask destriping (FMD). Analyzing TROPOMI CO orbit observation, we found that the stripe patterns changes to some extent also along the flight path, which cannot be captured by this approach. Therefore, we developed an alternative approach that is based on a Fourier filter destriping (FFD) [RD28] (see right column of Fig 7) and already deployed it for scientific studies e.g. [RD30, RD31]. Due to its robustness the FMD destriping approach is implemented for ESA's operational processing of TROPOMI data in the first instance, the FFD approach is planed for a future update of the processor.

8.5 Using the S5p/TROPOMI L2 Carbon Monoxide

The operational S5p level-2 processor employs the SICOR physics-based retrieval algorithm determining CO total column abundances from Earth radiance measurements in the 2.3 μm band [RD22]. The algorithm relies on a profile scaling approach. Simultaneously, the CO total column and several effective parameters are retrieved from the TROPOMI measurements, like the height and optical depth of the scattering layer and the Lambertian surface albedo. For data use, is is sufficient to focus on the CO related output parameters, which are:

1. The retrieved total column of CO.
2. The corresponding column averaging kernel.
3. The statistical noise estimate.

Figure 8 illustrates the CO retrieval product over land for a cloudy atmosphere and a surface albedo $A_s = 0.05$. It shows the difference between the true CO column and retrieved CO column (left panel), the 1-σ estimate of the corresponding retrieval noise (middle panel) and the column averaging kernel (right panel). The left panel shows only small differences ($\leq \pm 1$ %) between the true and the retrieved profile for cloud fractions f_{cld} = 0–1. The differences are due to the description of atmospheric scattering in the retrieval. The shielding of the atmosphere below the cloud does not reduce the retrieved CO column for increasing cloud fraction because the sensitivity of the measurement with respect to the CO abundance above the cloud is used to infer the total CO column by an appropriate scaling of the relative profile. In Figure 8 we have chosen the correct relative profile and so the retrieved column is an estimate of the true CO column. In case that the relative profile differs from the true relative vertical distribution of CO, the column averaging kernel is needed to correctly interpret the retrieval product. Moreover, the retrieval noise on the CO column decreases due to the gain in SNR for increasing cloud coverage. The change of retrieval sensitivity with cloud coverage is clearly illustrated by the column averaging kernels shown in the right panel of Fig. 8. Here, the color of lines indicate the cloud fraction. When the cloud fraction is greater than zero, the column averaging kernel starts to increase above the top of the retrieved cloud height and at the same time the retrieval sensitivity decreases below the cloud such that the net effect on the retrieval CO column nearly cancels out.

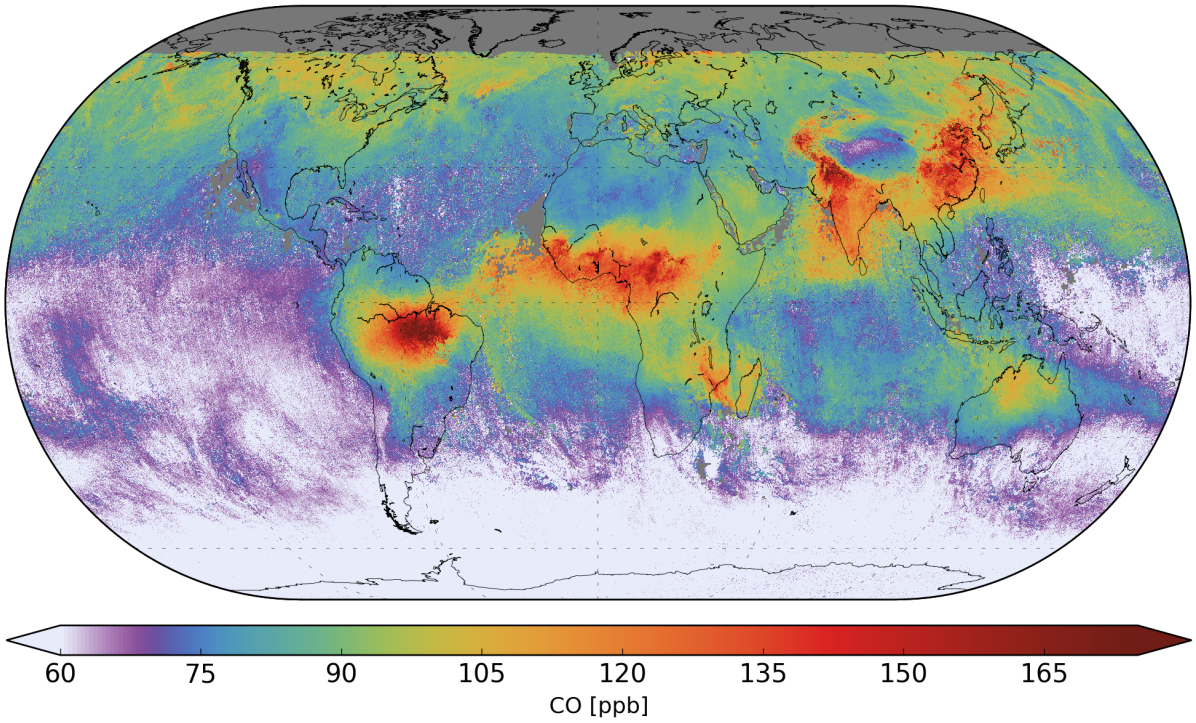

Figure 3: CO total column mixing ratios of TROPOMI averaged from November 13th to 19th, 2017, from [RD29]

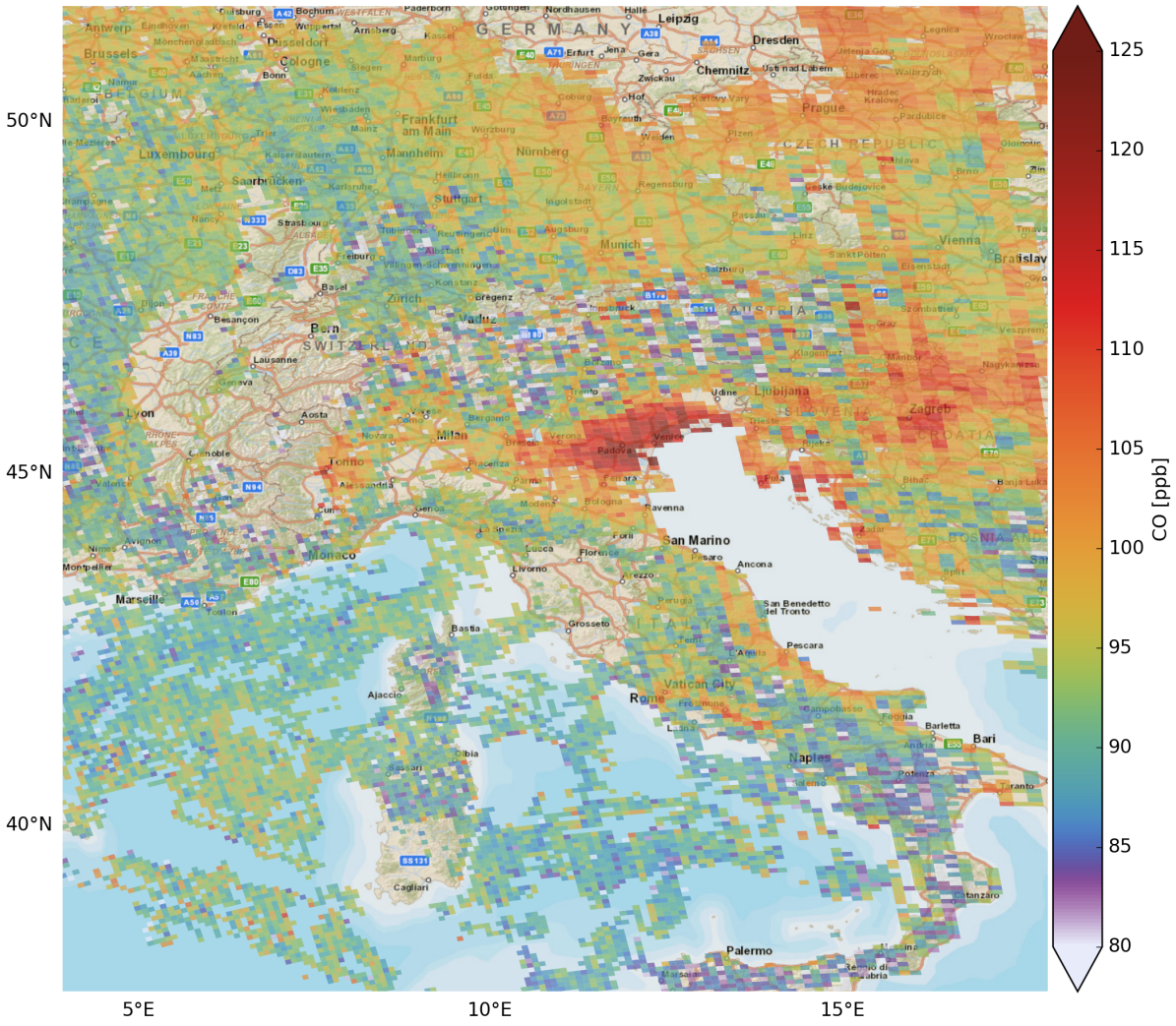

Figure 4: Total column mixing ratio for individual TROPOMI ground pixels for Italy on 25th December 2017, from [RD33]

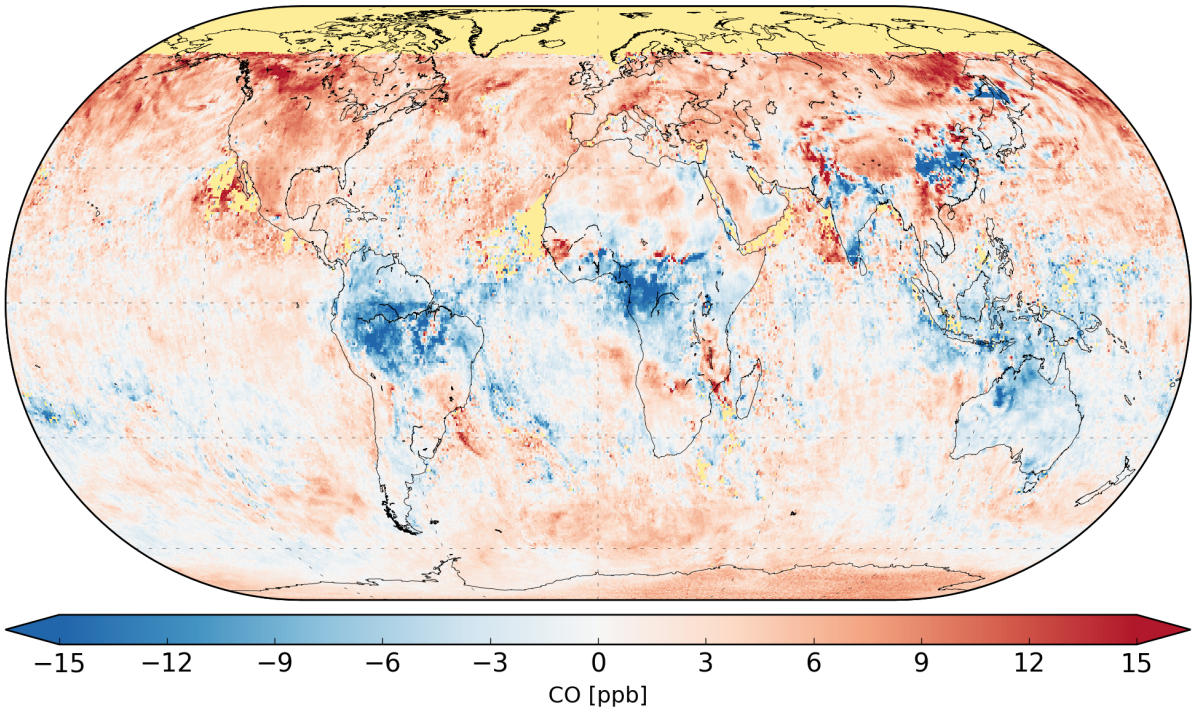

Figure 5: Differences of CO total column mixing ratios (TROPOMI - CAMS) averaged over the same time period as shown in Fig. 3, from [RD29]

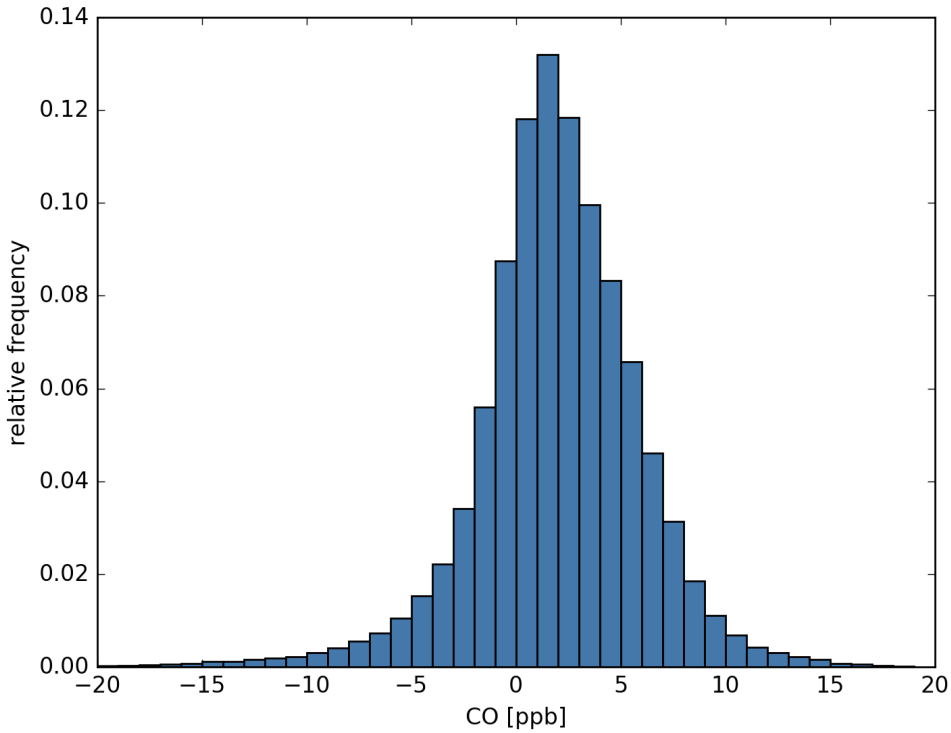

Figure 6: Histogram of the differences shown in Fig. 5, from [RD29]

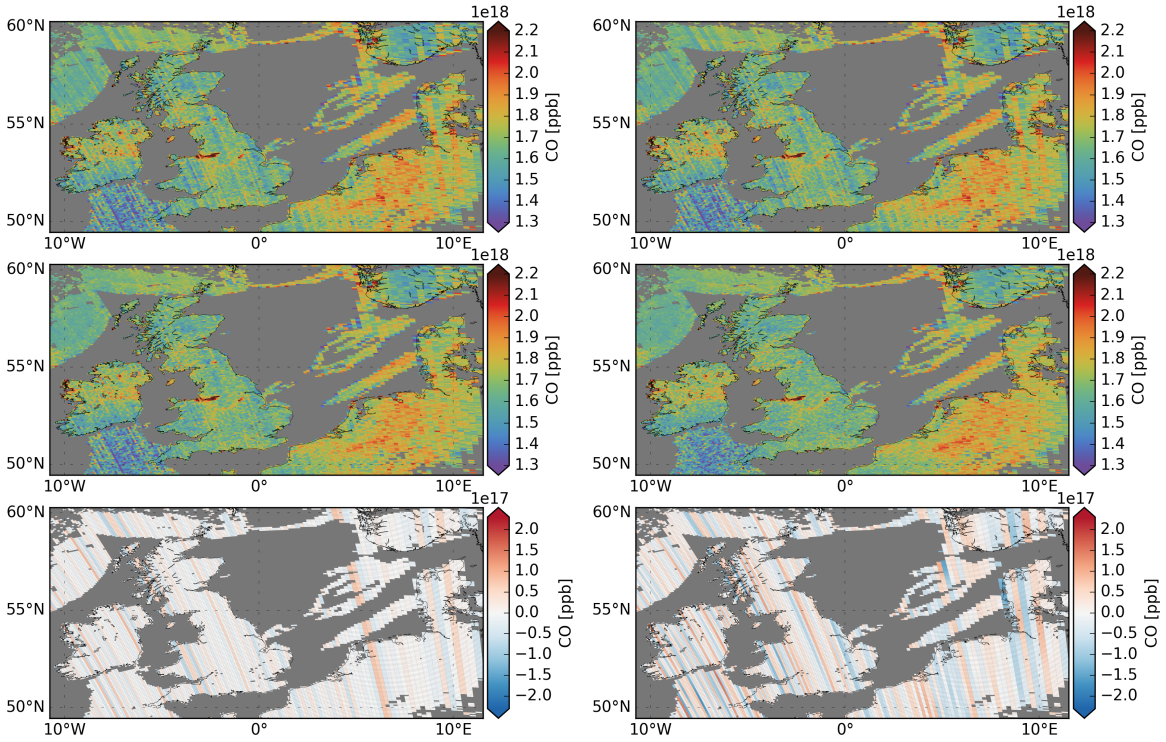

Figure 7: CO retrievals of a TROPOMI orbit granule on 27 June 2018 over the UK. Panels of the first row depict the original data, the second row shows the destriped TROPOMI CO data (FMD method left, FFD method right), and the third row illustrates the destriping mask that was subtracted from the original TROPOMI data, from [RD28]

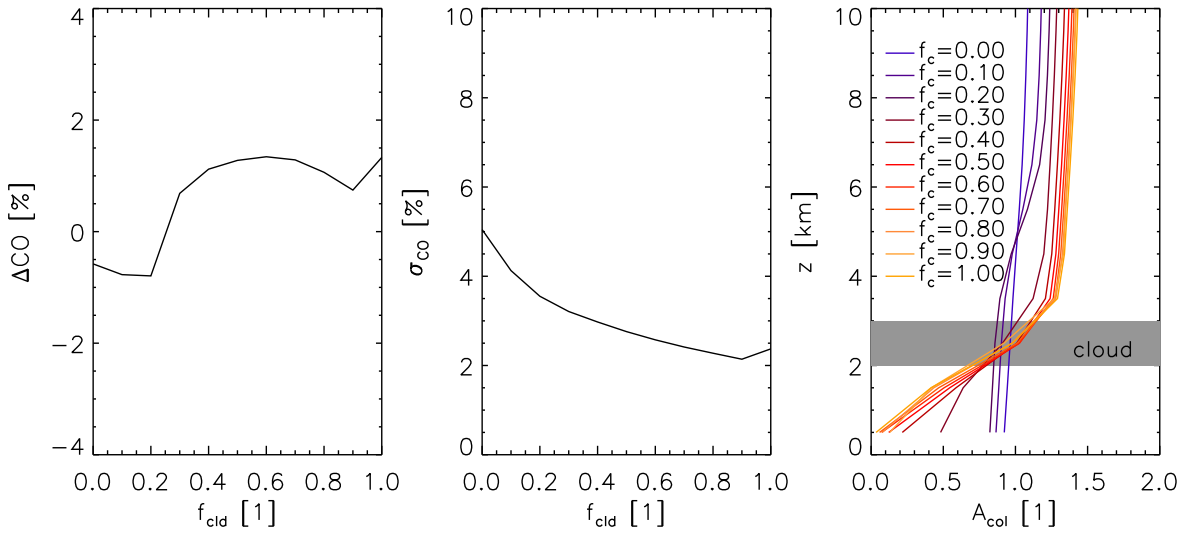

Figure 8: Example of the CO data product, adopted from [RD22]. The SWIR measurements are simulated for a scene partially covered by a water cloud between 2 and 3 km with optical depth $\tau_{\mathrm{cld}} = 30$ and a surface albedo $A_s = 0.05$. Left panel: Difference Δ_{CO} between the true CO column and the retrieved CO column as function of cloud fraction f_{cld} using the true relative CO profile to be scaled by the inversion. Middle panel: 1 σ retrieval noise estimate as function of cloud fraction f_{cld}. Right panel: column averaging kernel as function of altitude for different cloud fractions

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 Carbon Monoxide files is given in section 10. Figure 9 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 values[1].

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 [RD39, section 7] and items required by INSPIRE [ER4], ISO 19115 [RD40], ISO 19115-2 [RD41], ISO 19157 [RD42] and OGC 10-157r3 [RD43]. 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 [RD44]. 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.

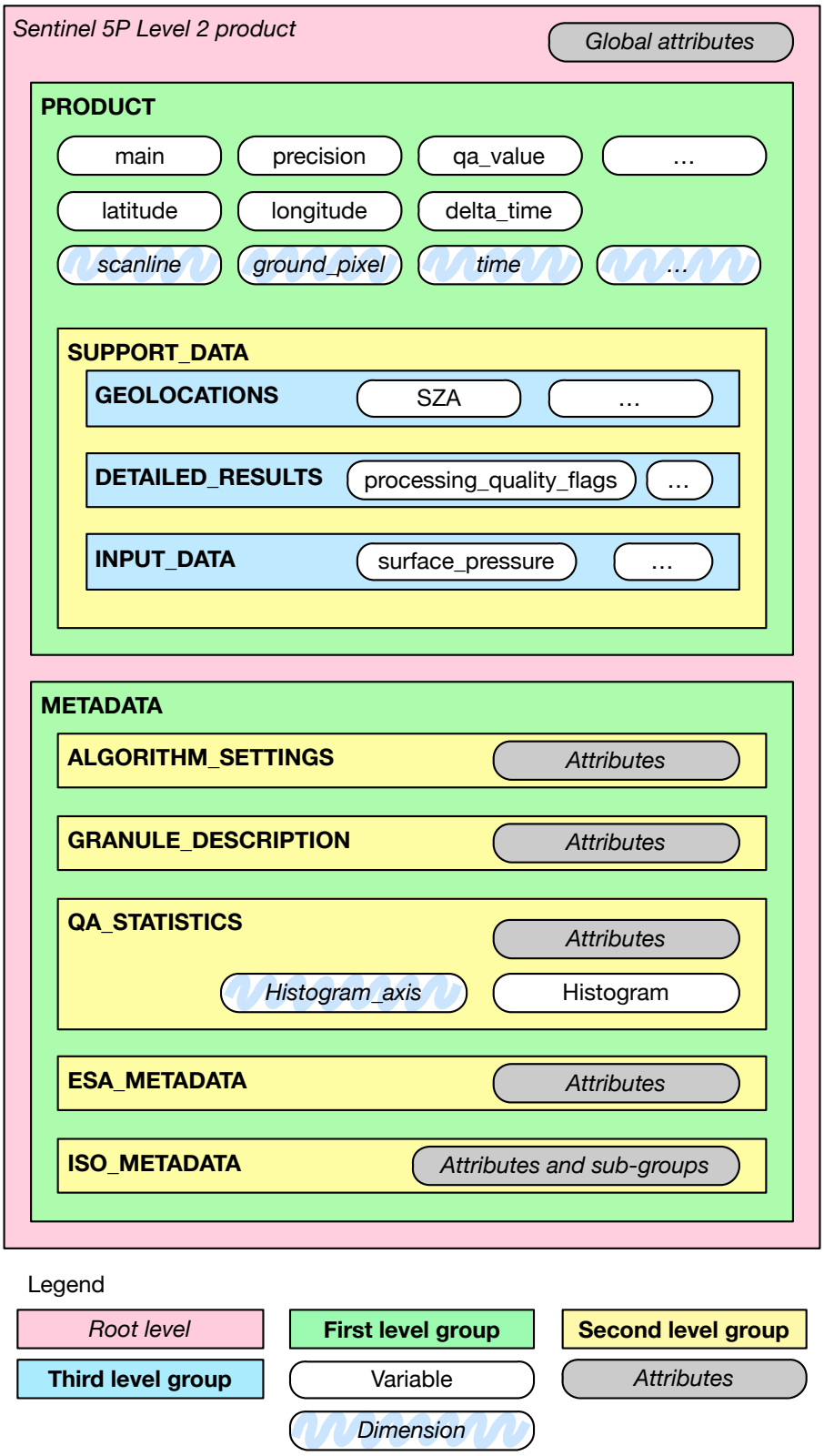

Figure 9: Graphical description of the generic structure of a Level 2 file. The elements labelled as a dimension are coordinate variables. See section 9 for a full description.

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 [RD45] 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 Carbon Monoxide 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 9.

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.

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 memory[2].

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 NO_2 column This variable contains a single value per ground pixel, and the dimensions are (time, scanline, ground_pixel).

O_3 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.

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

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

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 [RD46].

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 [RD46]
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 [RD46], 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 10. 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 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.

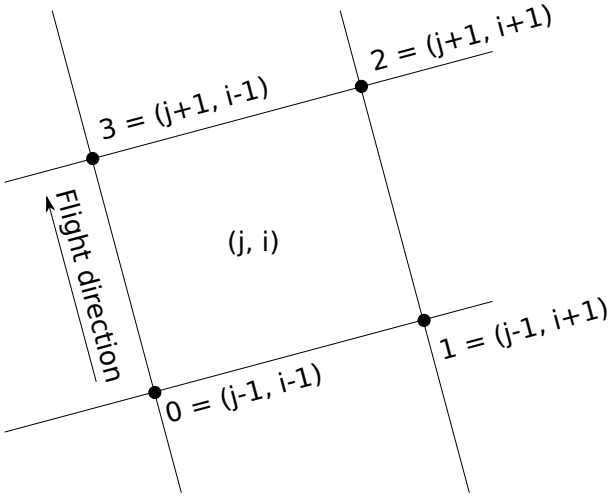

Figure 10: Pixel corner coordinates. The sequence $\{0,1,2,3\}$ refers to the elements in the `corner` dimension.

10 Description of the CO product

Description of the main output file for the CO Column 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 TM5 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_CTM_CO`" or "`Status_CTMCH4`" global attribute.

Global attributes in CO____

Group attributes attached to CO____		
Name	*Value*	*Type*
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 sensing, L2' (dynamic)	NC_STRING
Method of production of the original data. Value includes instrument, generic description of retrieval, product level, and adds a short product name and processor version. This attribute originates from the CF standard.		
history		NC_STRING
Provides an audit trail for modifications to the original data. Well-behaved generic netCDF filters will automatically append their name and the parameters with which they were invoked to the global history attribute of an input netCDF file. Each line shall begin with a timestamp indicating the date and time of day that the program was executed. This attribute originates from the NUG, CF standards.		
summary		NC_STRING
Miscellaneous information about the data or methods used to produce it.		

If processing in a degraded mode 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.

time_reference	'YYYY-MM-DDT00:00:00Z' (dynamic)	NC_STRING

UTC time reference as an ISO 8601 [RD46] string. This corresponds to the UTC value in the `time` dimensional variable. By definition it indicates UTC midnight before the start of the granule.

time_reference_days_since_1950	0 (dynamic)	NC_INT

The reference time expressed as the number of days since 1950-01-01. This is the reference time unit used by both TM5 and ECMWF.

time_reference_julian_day	0.0 (dynamic)	NC_DOUBLE

The reference time expressed as a Julian day number.

time_reference_seconds_since_1970	0 (dynamic)	NC_INT64

The reference time expressed as the number of seconds since 1970-01-01 00:00:00 UTC. This is the reference time unit used by Unix systems.

time_coverage_start	'YYYY-MM-DDTHH:MM:SS.mmmmmmZ' (dynamic)	NC_STRING

Start of the data granule in UTC as an ISO 8601 [RD46] string. See the discussion of the `time_delta` variable on page 32 for details.

time_coverage_end	'YYYY-MM-DDTHH:MM:SS.mmmmmmZ' (dynamic)	NC_STRING

End of the data granule in UTC as an ISO 8601 [RD46] string. See the discussion of the `time_delta` variable on page 32 for details.

time_coverage_duration		NC_STRING

Duration of the data granule as an ISO 8601 [RD46] duration string ("PT%(duration_seconds)sS"). This attribute originates from the CCI standard.

time_coverage_resolution		NC_STRING

Interval between measurements in the data granule as an ISO 8601 [RD46] duration string ("PT%(interval_seconds)fS"). For most products this is 1080 ms in nominal operation, except for "`L2__O3__PR`", which uses 3240 ms due to coaddition. This attribute originates from the CCI standard.

orbit	0 (dynamic)	NC_INT

The absolute orbit number, starting at 1 – first ascending node crossing after spacecraft separation. For pre-launch testing this value should be set to "-1".

references	'%(references)s' (static)	NC_STRING

References that describe the data or methods used to produce it. This attribute originates from the CF standard.

processor_version	'%(version)s' (dynamic)	NC_STRING

The version of the data processor, as string of the form "major.minor.patch".

keywords_vocabulary	'AGU index terms, http://publications.agu.org/author-resource-center/index-terms/' (static)	NC_STRING

The guidelines followed for the keywords attribute. We use the index terms published by the AGU.

keywords	'%(keywords_agu)s' (dynamic)	NC_STRING
Keywords from the "keywords_vocabulary" describing the contents of the file. To be provided by the ATBD authors.		
standard_name_vocabulary	'NetCDF Climate and Forecast Metadata Conventions Standard Name Table (v29, 08 July 2015), http://cfconventions.org/standard-names.html' (static)	NC_STRING
The table followed for the standard_name attributes.		
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
The THREDDS data type appropriate for this dataset, fixed to "Swath" for S5P level 2 products. This attribute originates from the CCI standard.		
date_created	'YYYY-mm-ddTHH:MM:SS.ffffffZ' (dynamic)	NC_STRING
The date on which this file was created. This attribute originates from the CCI standard.		
creator_name	'%(credit)s' (dynamic)	NC_STRING
The name of the creator, equal to the value of the "gmd:credit" attribute. For S5P this attribute is set to "The Sentinel 5 Precursor TROPOMI Level 2 products are developed with funding from the European Space Agency (ESA), the Netherlands Space Office (NSO), the Belgian Science Policy Office, the German Aerospace Center (DLR) and the Bayerisches Staatsministerium für Wirtschaft und Medien, Energie und Technologie (StMWi)." This attribute originates from the CCI standard.		
creator_url	'%(creator_url)s' (dynamic)	NC_STRING
Hyperlink to a location where more information on the product can be found. Set to http://www.tropomi.eu/. This attribute originates from the CCI standard.		
creator_email	'EOSupport@Copernicus.esa.int' (dynamic)	NC_STRING
Point of contact for more information and support for this product. Set to "mailto:EOSupport@Copernicus.esa.int". This attribute originates from the CCI standard.		
project	'Sentinel 5 precursor/TROPOMI' (dynamic)	NC_STRING
The name of the scientific project that created the data. This attribute originates from the CCI standard.		
geospatial_lat_min		NC_FLOAT
Lowest latitude present in the file in decimal degrees. This attribute originates from the CCI standard.		
geospatial_lat_max		NC_FLOAT
Highest latitude present in the file in decimal degrees. This attribute originates from the CCI standard.		
geospatial_lon_min		NC_FLOAT
Lowest longitude present in the file in decimal degrees. This attribute originates from the CCI standard.		
geospatial_lon_max		NC_FLOAT
Highest longitude present in the file in decimal degrees. This attribute originates from the CCI standard.		
license	'No conditions apply' (static)	NC_STRING
describe the restrictions to data access and distribution. For S5P "No conditions apply". This attribute originates from the CCI standard.		
platform	'S5P' (static)	NC_STRING
Name of the satellite, set to "S5P". This attribute originates from the CCI standard.		
sensor	'TROPOMI' (static)	NC_STRING
Name of the sensor, set to "TROPOMI". This attribute originates from the CCI standard.		
spatial_resolution		NC_STRING
Spatial resolution at nadir. For most products this is "$3.5 \times 7\,\mathrm{km}^2$", except for "L2__O3__PR", which uses "$28 \times 21\,\mathrm{km}^2$" and "L2__CO_____" and "L2__CH4____", which both use "$7 \times 7\,\mathrm{km}^2$". This attribute originates from the CCI standard.		
cpp_compiler_version		NC_STRING
The version of the compiler used for the C++ code. The value of this attribute is set via the Makefile.		

cpp_compiler_flags		NC_STRING
The compiler flags passed to the C++ compiler. The value of this attribute is set via the Makefile.		
f90_compiler_version		NC_STRING
The version of the compiler version used for the Fortran code. The value of this attribute is set via the Makefile. Note that not all processors make use of Fortran code.		
f90_compiler_flags		NC_STRING
The compiler flags passed to the Fortran compiler. The value of this attribute is set via the Makefile. Note that not all processors make use of Fortran code.		
build_date		NC_STRING
The date on which the processor was built.		
revision_control_identifier	'%(revision_control_source_identifier)s' (dynamic)	NC_STRING
Revision control system identifier for the source used to build this processor.		
geolocation_grid_from_band		NC_INT
The band from which the geolocation was taken, useful for colocating the level 2 output with other products.		
identifier_product_doi	'%(product_doi)s' (dynamic)	NC_STRING
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 accomodate different release schedules for different products.		
title	'TROPOMI/S5P CO Column %s L2 Swath %sx%skm' (dynamic)	NC_STRING
This is a short description of the product. In near-realtime processing the granule is shorter than 1 orbit, and the attribute must be adapted accordingly. The nominal value is "TROPOMI/S5P CO Column 1-Orbit L2 Swath yx7.0km", 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_CTM_CO		NC_STRING
The status of TM5 CO input, either "Nominal" or "Fallback". Possible values: Nominal, Fallback		
Status_CTMCH4		NC_STRING
The status of TM5 CH_4 input, either "Nominal" or "Fallback". Possible values: Nominal, Fallback		

10.1 Group “PRODUCT” in “CO____”

This is the main group containing the CO 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 CO____/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 31 for details.

size 1 (fixed)

layer The number of layers on which the retrieval is done.

size -1 (dynamic)
source Processor.

Variables in CO____/PRODUCT

scanline in CO____/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*	*Type*
units	‘1’ (static)	NC_STRING
Dimensionless, no physical quantity. This attribute originates from the CF standard.		
axis	‘Y’ (static)	NC_STRING
long_name	‘along-track dimension index’ (static)	NC_STRING
comment	‘This coordinate variable defines the indices along track; index starts at 0’ (static)	NC_STRING

ground_pixel in CO____/PRODUCT

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

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

time in CO____/PRODUCT

Description: The variable `time(time)` is the reference time of the measurements. The reference time is set to YYYY-MM-DDT00:00:00 UTC, midnight UTC before spacecraft midnight, the formal start of the current orbit. The `delta_time(scanline)` variable indicates the time difference of the observations with the reference time. Thus combining the information of `time(time)` and `delta_time(scanline)` yields the measurement time for each scanline as UTC time. The reference `time(time)` corresponds to the global attribute `time_reference` which is specified as a UTC time specified as an ISO 8601 [RD46] date.

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 CO____/PRODUCT

Description: An index for the pixel corners. We follow the CF-Metadata conventions [ER5, section 7.1]. The full coordinate system is right-handed, and the order of the pixel corners is counter-clockwise, starting in the "lower-left" corner (i.e. the smallest value in both latitude and longitude on the ascending part of the orbit, or equivalently for TROPOMI the lowest value for both the `ground_pixel` and `scanline` indices). See figure 10 on page 26 for a graphical depiction of the corners.

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

layer in CO____/PRODUCT

Description: The fixed height grid on which the radiative transfer calculations are done.

Note that height is defined as the (geometric) height above the topographic surface. This differs from the scattering heights defined in other products, which use the geoid as the reference surface. The reason for this difference is that the CO retrieval is performed on a fixed height grid relative to the surface.

Dimensions: layer (coordinate variable).

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'm' (static)	NC_STRING
standard_name	'height' (static)	NC_STRING
long_name	'Height above topographic surface' (static)	NC_STRING
axis	'Z' (static)	NC_STRING

delta_time in CO____/PRODUCT

Description: The `delta_time(scanline)` variable indicates the time difference with the reference time `time(time)` (see page 31). Thus combining the information of `time(time)` and `delta_time(scanline)` yields the start of the measurement time for each scanline as TAI2010 time. Combining the information in the global attribute `time_reference` with `delta_time(scanline)` yields the start of the measurement time in UTC time. The UTC time derived for the first scanline corresponds to the global attribute `time_coverage_start`. However, the UTC time derived for the last scanline does not correspond to global attribute `time_coverage_end`. One scanline measurement is the result of adding independent measurements during one coaddition period. The scanline measurement is given the measurement time of the first sample in this co-addition. It is the measurement time of the last sample in the coaddition period of the last scanline that corresponds to `time_coverage_end`.

This variable gives the time offset in ms accuracy.

Dimensions: time, scanline.

Type: NC_INT.

Source: Processor.

Attributes:

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

time_utc in CO____/PRODUCT

Description: The time of observation expressed as ISO 8601 [RD46] date-time string.

Dimensions: time, scanline.

Type: NC_STRING.

Source: Processor.

Attributes:

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

qa_value in CO____/PRODUCT

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

Dimensions: time, scanline, ground_pixel.

Type: NC_UBYTE.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'1' (static)	NC_STRING

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

latitude in CO____/PRODUCT

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

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	long_name	'pixel center latitude' (static)	NC_STRING
	units	'degrees_north' (static)	NC_STRING
	standard_name	'latitude' (static)	NC_STRING
	valid_min	-90.0 (static)	NC_FLOAT
	valid_max	90.0 (static)	NC_FLOAT
	bounds	'/PRODUCT/SUPPORT_DATA/GEOLOCATIONS/ latitude_bounds' (static)	NC_STRING
	A link to the boundary coordinates, i.e. the pixel corners. Note that the use of group-names in this attribute is an extension of the climate and forecasting metadata conventions.		

longitude in CO____/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*	*Type*
	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.		

carbonmonoxide_total_column in CO____/PRODUCT

Description: Vertically integrated CO column density

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*

	units	'mol m-2' (static)	NC_STRING
	standard_name	'atmosphere_mole_content_of_carbon_monoxide' (static)	NC_STRING
	long_name	'Vertically integrated CO column' (static)	NC_STRING
	coordinates	'longitude latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		
	ancillary_variables	'carbonmonoxide_total_column_precision' (static)	NC_STRING
	Provide a connection with associated data, in this case the precision of the column. This attribute originates from the NUG, CF standards.		
	multiplication_factor_to_convert_to_molecules_percm2	6.022140857e+19 (static)	NC_FLOAT
	The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.		

carbonmonoxide_total_column_precision in CO____/PRODUCT

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (static)	NC_STRING
	standard_name	'atmosphere_mole_content_of_carbon_monoxide standard_error' (static)	NC_STRING
	long_name	'Standard error of the vertically integrated CO column' (static)	NC_STRING
	coordinates	'longitude latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		
	multiplication_factor_to_convert_to_molecules_percm2	6.022140857e+19 (static)	NC_FLOAT
	The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.		

carbonmonoxide_total_column_corrected in CO____/PRODUCT

Description: Vertically integrated CO column density, with a "destriping" algorithm applied to it. This variable is expected to be empty in near real-time processing.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*

units	'mol m-2' (static)	NC_STRING
standard_name	'atmosphere_mole_content_of_carbon_monoxide' (static)	NC_STRING
long_name	'carbonmonoxide_total_column - carbonmonoxide_total_column_stripe_offset' (static)	NC_STRING
coordinates	'longitude latitude' (static)	NC_STRING
The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		
ancillary_variables	'carbonmonoxide_total_column_precision carbonmonoxide_total_column_stripe_offset' (static)	NC_STRING
Provide a connection with associated data, in this case the precision of the column, and the stripe offset that has been applied. This attribute originates from the NUG, CF standards.		
multiplication_factor_to_convert_to_molecules_percm2	6.022140857e+19 (static)	NC_FLOAT
The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.		

10.1.1 Group "SUPPORT_DATA" in "PRODUCT"

10.1.1.1 Group "GEOLOCATIONS" in "SUPPORT_DATA"

Variables in CO____/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

satellite_latitude in CO____/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*	*Type*
long_name	'sub satellite latitude' (static)	NC_STRING
units	'degrees_north' (static)	NC_STRING
comment	'Latitude of the geodetic sub satellite point on the WGS84 reference ellipsoid' (static)	NC_STRING
valid_min	-90.0 (static)	NC_FLOAT
valid_max	90.0 (static)	NC_FLOAT

satellite_longitude in CO____/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

Description: Longitude of the geodetic sub satellite point on the WGS84 reference ellipsoid.
Dimensions: time, scanline.
Type: NC_FLOAT.
Source: L1B.

Attributes: *Name*	*Value*	*Type*
long_name	'satellite_longitude' (static)	NC_STRING
units	'degrees_east' (static)	NC_STRING

	comment	'Longitude of the geodetic sub satellite point on the WGS84 reference ellipsoid' (static)	NC_STRING
	valid_min	-180.0 (static)	NC_FLOAT
	valid_max	180.0 (static)	NC_FLOAT

satellite_altitude in CO____/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

Description: The altitude of the satellite with respect to the geodetic sub satellite point on the WGS84 reference ellipsoid.

Dimensions: time, scanline.

Type: NC_FLOAT.

Source: L1B.

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

satellite_orbit_phase in CO____/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

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

Dimensions: time, scanline.

Type: NC_FLOAT.

Source: L1B.

Attributes:	*Name*	*Value*	*Type*
	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 CO____/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.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: L1B.

Attributes:	*Name*	*Value*	*Type*
	long_name	'solar zenith angle' (static)	NC_STRING
	standard_name	'solar_zenith_angle' (static)	NC_STRING
	units	'degree' (static)	NC_STRING
	valid_min	0.0 (static)	NC_FLOAT
	valid_max	180.0 (static)	NC_FLOAT
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude are in a different group. How to specify the related geospatial coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].		

	comment	'Solar zenith angle at the ground pixel location on the reference ellipsoid. Angle is measured away from the vertical' (static)	NC_STRING

solar_azimuth_angle in CO____/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

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

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

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: L1B.

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

viewing_zenith_angle in CO____/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

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

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: L1B.

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
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude are in a different group. How to specify the related geospatial coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].		
	comment	'Zenith angle of the satellite at the ground pixel location on the reference ellipsoid. Angle is measured away from the vertical' (static)	NC_STRING

viewing_azimuth_angle in CO____/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 $\varphi - \varphi_0$ it is not sufficient to just subtract `solar_azimuth_angle` from `viewing_azimuth_angle`. The angle needed for radiative transfer calculations is $(180^\circ - (\varphi - \varphi_0)) \bmod 360^\circ$.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: L1B.

Attributes:

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

latitude_bounds in CO____/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 10.

Dimensions: time, scanline, ground_pixel, corner.

Type: NC_FLOAT.

Source: Processor.

longitude_bounds in CO____/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 10.

Dimensions: time, scanline, ground_pixel, corner.

Type: NC_FLOAT.

Source: Processor.

geolocation_flags in CO____/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

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

Dimensions: time, scanline, ground_pixel.

Type: NC_UBYTE.

Source: Processor.

Attributes:

Name	*Value*	*Type*
_FillValue	255 (static)	NC_UBYTE

	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	flag_masks	0, 1, 2, 4, 8, 16, 32, 128 (static)	NC_UBYTE
	flag_meanings	'no_error solar_eclipse sun_glint_possible descending 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"

Variables in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

processing_quality_flags in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS			
Description:	Processing quality flag. This flag indicates processing errors or reasons for not processing a particular pixel (collectively 'errors', leading to a fill value in the output) and warnings that 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, ground_pixel.		
Type:	NC_UINT.		
Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	long_name	'Processing quality flags' (static)	NC_STRING
	comment	'Flags indicating conditions that affect quality of the retrieval.' (static)	NC_STRING

flag_meanings	'success radiance_missing irradiance_missing input_spectrum_missing reflectance_range_error ler_range_error snr_range_error sza_range_error vza_range_error lut_range_error ozone_range_error wavelength_offset_error initialization_error memory_error assertion_error io_error 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 AAI_warning pixel_level_input_data_missing 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_retrieval_warning cloud_inhomogeneity_warning thermal_instability_warning' (static)	NC_STRING

flag_masks	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, 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, 256, 512, 1024, 2048, 4096, 8192, 16384, 32768, 65536, 131072, 262144, 524288, 1048576, 2097152, 4194304, 8388608, 16777216, 33554432, 67108864, 134217728, 268435456, 536870912, 1073741824 (static)	NC_UINT
flag_values	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 256, 512, 1024, 2048, 4096, 8192, 16384, 32768, 65536, 131072, 262144, 524288, 1048576, 2097152, 4194304, 8388608, 16777216, 33554432, 67108864, 134217728, 268435456, 536870912, 1073741824 (static)	NC_UINT
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].

number_of_spectral_points_in_retrieval in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: The number of points in the spectrum that were used in the retrieval.
Dimensions: time, scanline, ground_pixel.
Type: NC_USHORT.
Source: Processor.

Attributes:

Name	*Value*	*Type*
long_name	'Number of spectral points used in the retrieval' (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].

pressure_levels in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Pressure of the layer interfaces of the vertical grid. The pressures indicate the pressure at the *bottom* of each layer. The topmost layer extends to the top of atmosphere.
Dimensions: time, scanline, ground_pixel, layer.
Type: NC_FLOAT.
Source: Processor.

Attributes:

Name	*Value*	*Type*
positive	'down' (static)	NC_STRING
units	'Pa' (static)	NC_STRING
standard_name	'air_pressure' (static)	NC_STRING
long_name	'Pressure at bottom of layer' (static)	NC_STRING

water_total_column in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Water vapour column.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'mol m-2' (static)	NC_STRING
standard_name	'atmosphere_mole_content_of_water_vapor' (static)	NC_STRING
long_name	'Vertically integrated H2O column' (static)	NC_STRING
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
ancillary_variables	'water_total_column_precision' (static)	NC_STRING
multiplication_factor_to_convert_to_molecules_percm2	6.022140857e+19 (static)	NC_FLOAT

The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.

water_total_column_precision in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Precision of the retrieved water vapour column.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'mol m-2' (static)	NC_STRING
standard_name	'atmosphere_mole_content_of_water_vapor standard_error' (static)	NC_STRING

A standard name is currently unavailable for the error on the vertically integrated H_2O vapour column density. A suitable name for inclusion in the standard name list is "`atmosphere_mole_content_of_water_vapor standard_error`", with canonical unit $\mathrm{mol\,m^{-2}}$. This attribute originates from the CF standard.

long_name	'Precision of vertically integrated H2O column' (static)	NC_STRING
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
multiplication_factor_to_convert_to_molecules_percm2	6.022140857e+19 (static)	NC_FLOAT

The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.

semiheavy_water_total_column in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Deuterated water vapour column.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (static)	NC_STRING
	proposed_standard_name	'atmosphere_mole_content_of_water_vapor_containing_2H' (static)	NC_STRING
	A standard name is currently unavailable for the vertically integrated deuterated H_2O vapour column density. A suitable name for inclusion in the standard name list is "`atmosphere_mole_content_of_water_vapor_containing_2H`", with canonical unit $\mathrm{mol\,m^{-2}}$. This naming scheme is proposed as part of CMIP6 by PMIP to the Climate and Forecast Metadata conventions group. This attribute originates from the CF standard.		
	long_name	'Vertically integrated HDO column' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	ancillary_variables	'semiheavy_water_total_column_precision' (static)	NC_STRING
	multiplication_factor_to_convert_to_molecules_percm2	6.022140857e+19 (static)	NC_FLOAT
	The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.		

semiheavy_water_total_column_precision in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description:	Precision of the retrieved deuterated water vapour column.
Dimensions:	time, scanline, ground_pixel.
Type:	NC_FLOAT.
Source:	Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (static)	NC_STRING
	proposed_standard_name	'atmosphere_mole_content_of_water_vapor_containing_2H standard_error' (static)	NC_STRING
	A standard name is currently unavailable for the error of the vertically integrated deuterated H_2O vapour column density. A suitable name for inclusion in the standard name list is "`atmosphere_mole_content_of_deuterated_water_vapor standard_error`", with canonical unit $\mathrm{mol\,m^{-2}}$. This attribute originates from the CF standard.		
	long_name	'Precision of the vertically integrated HDO column' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	multiplication_factor_to_convert_to_molecules_percm2	6.022140857e+19 (static)	NC_FLOAT
	The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.		

scattering_optical_thickness_SWIR in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description:	Scattering optical depth in the SWIR channel.

Dimensions:	time, scanline, ground_pixel.		
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	long_name	'Scattering optical depth at 2330 nm wavelength' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

height_scattering_layer in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description:	Retrieved height of the scattering layer. Note that height is defined as the (geometric) height above the topographic surface. This differs from the scattering heights defined in other products, which use the geoid as the reference surface. The reason for this difference is that the CO retrieval is performed on a fixed height grid relative to the surface.		
Dimensions:	time, scanline, ground_pixel.		
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	units	'm' (static)	NC_STRING
	long_name	'Scattering layer height above the topographic surface' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

surface_albedo_2325 in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description:	Surface albedo at 2325 nm.		
Dimensions:	time, scanline, ground_pixel.		
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	standard_name	'surface_albedo' (static)	NC_STRING
	radiation_wavelength	2325.0 (static)	NC_FLOAT
	The wavelength at which the surface albedo is retrieved.		
	long_name	'Surface albedo at 2325 nm' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

surface_albedo_2335 in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description:	Surface albedo at 2335 nm.		
Dimensions:	time, scanline, ground_pixel.		
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	standard_name	'surface_albedo' (static)	NC_STRING
	radiation_wavelength	2335.0 (static)	NC_FLOAT
	The wavelength at which the surface albedo is retrieved.		
	long_name	'Surface albedo at 2335 nm' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

wavelength_calibration_offset in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Spectral shift of the measurement. To obtain the wavelengths used in the retrieval the value in this variable needs to be added to the wavelengths that are found in Level 1B.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'nm' (static)	NC_STRING
	long_name	'Spectral offset' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

chi_square in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: The χ^2 value for the fit.

$$\chi^2 = \sum_{i=1}^{N} \left[\frac{y_i - f(x_i;\mathbf{a})}{\sigma_i} \right]^2, \quad (1)$$

with $f(x_i;\mathbf{a})$ the modeled result, y_i the observation, σ_i the stated precision of the observation and N the number of observations in the spectrum.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	long_name	'chi squared of fit residuals' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

degrees_of_freedom in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Degrees of freedom for signal for CO

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	long_name	'degrees of freedom for signal' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

number_of_iterations in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: The number of iterations needed to achieve convergence.

Dimensions: time, scanline, ground_pixel.

Type: NC_INT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	long_name	'number of iterations' (static)	NC_STRING
	units	'1' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

column_averaging_kernel in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Averaging kernel for the CO column.

Dimensions: time, scanline, ground_pixel, layer.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*

	units	'1' (static)	NC_STRING
	long_name	'CO column averaging kernel' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		

methane_total_column_prefit in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Total CH_4 column from the pre-fit.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (static)	NC_STRING
	standard_name	'atmosphere_mole_content_of_methane' (static)	NC_STRING
	long_name	'Vertically integrated CH4 column from pre-fit' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	multiplication_factor_to_convert_to_molecules_percm2	6.022140857e+19 (static)	NC_FLOAT
	The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.		

methane_weak_twoband_total_column in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Total CH_4 column from the the weak band of the two-band retrieval.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (static)	NC_STRING
	standard_name	'atmosphere_mole_content_of_methane' (static)	NC_STRING
	long_name	'Vertically integrated CH4 column from weak band' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	multiplication_factor_to_convert_to_molecules_percm2	6.022140857e+19 (static)	NC_FLOAT
	The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.		

methane_strong_twoband_total_column in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Total CH_4 column from the the strong band.

Dimensions: time, scanline, ground_pixel.

Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (static)	NC_STRING
	standard_name	'atmosphere_mole_content_of_methane' (static)	NC_STRING
	long_name	'Vertically integrated CH4 column from strong band' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	multiplication_factor_to_convert_to_molecules_percm2	6.022140857e+19 (static)	NC_FLOAT
	The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.		

water_weak_twoband_total_column in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description:	Total water column from the the weak band of the two-band retrieval.		
Dimensions:	time, scanline, ground_pixel.		
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (static)	NC_STRING
	standard_name	'atmosphere_mole_content_of_water_vapor' (static)	NC_STRING
	long_name	'Vertically integrated H2O column from weak band' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	multiplication_factor_to_convert_to_molecules_percm2	6.022140857e+19 (static)	NC_FLOAT
	The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.		

water_strong_twoband_total_column in CO____/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description:	Total water column from the the strong band.		
Dimensions:	time, scanline, ground_pixel.		
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (static)	NC_STRING
	standard_name	'atmosphere_mole_content_of_water_vapor' (static)	NC_STRING
	A standard name is currently unavailable for the H_2O vapour total vertical column. A suitable name for inclusion in the standard name list is "`atmosphere_mole_content_of_water_vapor`", with canonical unit $\mathrm{mol\,m^{-2}}$. This attribute originates from the CF standard.		

	long_name	'Vertically integrated H2O column from strong band' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	multiplication_-factor_to_convert_to_molecules_percm2	6.022140857e+19 (static)	NC_FLOAT
	The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.		

carbonmonoxide_total_column_stripe_offset in CO____/PRODUCT/SUPPORT_DATA/DETAILED_-RESULTS

Description: The stripe mask that has been applied to the vertically integrated CO column density data and stored in the carbonmonoxide_total_column_corrected variable.

Dimensions: time, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (static)	NC_STRING
	long_name	'Stripe offset as applied to the carbonmonoxide_-total_column_corrected variable' (static)	NC_STRING

10.1.1.3 Group "INPUT_DATA" in "SUPPORT_DATA"

Variables in CO____/PRODUCT/SUPPORT_DATA/INPUT_DATA

surface_altitude in CO____/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 database.

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

surface_altitude_precision in CO____/PRODUCT/SUPPORT_DATA/INPUT_DATA

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

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

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

surface_classification in CO____/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 [RD47].

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

	flag_meanings	'land water some_water coast value_covers_majority_of_pixel water+shallow_ocean water+shallow_inland_water water+ocean_coastline-lake_shoreline water+intermittent_water water+deep_inland_water water+continental_shelf_ocean water+deep_ocean land+urban_and_built-up_land land+dryland_cropland_and_pasture land+irrigated_cropland_and_pasture land+mixed_dryland-irrigated_cropland_and_pasture land+cropland-grassland_mosaic land+cropland-woodland_mosaic land+grassland land+shrubland land+mixed_shrubland-grassland land+savanna land+deciduous_broadleaf_forest land+deciduous_needleleaf_forest land+evergreen_broadleaf_forest land+evergreen_needleleaf_forest land+mixed_forest land+herbaceous_wetland land+wooded_wetland land+barren_or_sparsely_vegetated land+herbaceous_tundra land+wooded_tundra land+mixed_tundra land+bare_ground_tundra land+snow_or_ice' (static)	NC_STRING
	flag_values	0, 1, 2, 3, 4, 9, 17, 25, 33, 41, 49, 57, 8, 16, 24, 32, 40, 48, 56, 64, 72, 80, 88, 96, 104, 112, 120, 128, 136, 144, 152, 160, 168, 176, 184 (static)	NC_UBYTE
	flag_masks	3, 3, 3, 3, 4, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249 (static)	NC_UBYTE
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

instrument_configuration_identifier in CO____/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*	*Type*
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 CO____/PRODUCT/SUPPORT_DATA/INPUT_DATA

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

Dimensions: time, scanline.

Type: NC_SHORT.

Source: L1B.

Attributes:

Name	*Value*	*Type*
long_name	'IcVersion' (static)	NC_STRING
comment	'Version of the instrument_configuration_identifier' (static)	NC_STRING

scaled_small_pixel_variance in CO____/PRODUCT/SUPPORT_DATA/INPUT_DATA

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

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

$$V(t,r,c) = \frac{1}{N_{\text{small pixels}}} \sum_{i=0}^{N_{\text{small pixels}}-1} \left(R(t,r,c,i) - \langle R(t,r,c)\rangle\right)^2 \quad (3)$$

$$V_{\text{scaled}}(t,r,c) = \frac{V(t,r,c)}{\langle R(t,r,c)\rangle^2} \quad (4)$$

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

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

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

eastward_wind in CO____/PRODUCT/SUPPORT_DATA/INPUT_DATA

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

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	standard_name	'eastward_wind' (static)	NC_STRING
	long_name	'Eastward wind from ECMWF at 10 meter height level' (static)	NC_STRING
	units	'm s-1' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	ancillary_variables	'northward_wind' (static)	NC_STRING

northward_wind in CO____/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description:	The horizontal component of the wind at 10 meter height in the northward direction. This is the 10V parameter from ECMWF (grib variable 166).		
Dimensions:	time, scanline, ground_pixel.		
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	standard_name	'northward_wind' (static)	NC_STRING
	long_name	'Northward wind from ECMWF at 10 meter height level' (static)	NC_STRING
	units	'm s-1' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	ancillary_variables	'eastward_wind' (static)	NC_STRING

surface_pressure in CO____/PRODUCT/SUPPORT_DATA/INPUT_DATA

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

carbonmonoxide_profile_apriori in CO____/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description:	A priori CO profile.		
Dimensions:	time, scanline, ground_pixel, layer.		
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (static)	NC_STRING
	long_name	'CO a priori profile' (static)	NC_STRING
	standard_name	'mole_fraction_of_carbon_monoxide_in_air' (static)	NC_STRING

coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		

10.2 Group "METADATA" in "CO____"

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 CO____/METADATA/QA_STATISTICS

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

number_of_irradiance_missing_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “the number of spectral pixels in the irradiance due to flagging is too small to perform the fitting” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “2”.

number_of_input_spectrum_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_range_error_occurrences	0 (static)	NC_INT

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

number_of_ler_range_error_occurrences	0 (static)	NC_INT

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

number_of_snr_range_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “too low signal to noise to perform retrieval” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “6”.

number_of_sza_range_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “solar zenith angle out of range, maximum value from configuration” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “7”.

number_of_vza_range_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “viewing zenith angle out of range, maximum value from configuration” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “8”.

number_of_lut_range_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “extrapolation in lookup table (airmass factor, cloud radiances)” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “9”.

number_of_ozone_range_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “ozone column significantly out of range of profile climatology” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “10”.

number_of_wavelength_offset_error_occurrences	0 (static)	NC_INT

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

number_of_initialization_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “an error occurred during the processing of the pixel, no output was generated. The following errors raise this flag: Mismatch between irradiance and radiance wavelengths; The on-ground distance between band 1 and band 2 ground pixels exceeds a threshold set in the configuration. Derived a-priori information does not validate, no processing is possible” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “12”.

number_of_memory_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “memory allocation or deallocation error” occurred, i.e. where the lower 8 bits of the `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_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “error detected during transfer of data between algorithm and framework” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “15”.

number_of_numerical_error_occurrences	0 (static)	NC_INT

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

number_of_lut_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “error in accessing the lookup table” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “17”.

number_of_ISRF_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “error detected in the input instrument spectral response function input data” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “18”.

number_of_convergence_error_occurrences	0 (static)	NC_INT

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

number_of_cloud_filter_convergence_error_occurrences	0 (static)	NC_INT

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

number_of_max_iteration_convergence_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “no convergence because retrieval exceeds maximum number of iterations. Maximum value from configuration” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “21”.

number_of_aot_lower_boundary_convergence_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “no convergence because the aerosol optical thickness crosses lower boundary twice in succession” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “22”.

number_of_other_boundary_convergence_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “no convergence because a state vector element crosses boundary twice in succession. Note that a separate failure flag is defined for non-convergence due to crossing of lower AOT boundary” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “23”.

number_of_geolocation_error_occurrences	0 (static)	NC_INT

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

number_of_ch4_noscat_zero_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “the CH_4 column retrieved by the non-scattering CO algorithm from the weak band or strong band is 0” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “25”.

number_of_h2o_noscat_zero_error_occurrences	0 (static)	NC_INT

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_thickness_error_occurrences	0 (static)	NC_INT

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

number_of_aerosol_boundary_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “boundary hit of aerosol parameters at last iteration” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “28”.

number_of_boundary_hit_error_occurrences	0 (static)	NC_INT

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

number_of_chi2_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “χ^2 is not-a-number or larger than 10^{10}” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “30”.

number_of_svd_error_occurrences	0 (static)	NC_INT

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

number_of_dfs_error_occurrences	0 (static)	NC_INT

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

number_of_radiative_transfer_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “errors occurred during the radiative transfer computations, no processing possible” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “33”.

number_of_optimal_estimation_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “errors occurred during the optimal estimation, processing has been terminated” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “34”.

number_of_profile_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “flag that indicates if there were any errors during the computation of the ozone profile” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “35”.

number_of_cloud_error_occurrences	0 (static)	NC_INT

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

number_of_model_error_occurrences	0 (static)	NC_INT

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_input_data_points_too_low_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “not enough input ozone columns to calculate a tropospheric column” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “38”.

number_of_cloud_pressure_spread_too_low_error_occurrences	0 (static)	NC_INT

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_level_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “clouds are too low in the atmosphere to assume sufficient shielding” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “40”.

number_of_generic_range_error_occurrences	0 (static)	NC_INT

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

number_of_generic_exception_occurrences	0 (static)	NC_INT

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

number_of_input_spectrum_alignment_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “input radiance and irradiance spectra are not aligned correctly” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “43”.

number_of_abort_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “not processed because processor aborted prematurely (time out or user abort” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “44”.

number_of_wrong_input_type_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “wrong input type error, mismatch between expectation and received data” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “45”.

number_of_wavelength_calibration_error_occurrences	0 (static)	NC_INT

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_error_occurrences	0 (static)	NC_INT

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_density_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “slant column fit returned error, no values can be compute” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “48”.

number_of_airmass_factor_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “airmass factor could not be compute” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “49”.

number_of_vertical_column_density_error_occurrences	0 (static)	NC_INT

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

number_of_signal_to_noise_ratio_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “the signal to noise ratio for this spectrum is too low for processin” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “51”.

number_of_configuration_error_occurrences	0 (static)	NC_INT

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

number_of_key_error_occurrences	0 (static)	NC_INT

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

number_of_saturation_error_occurrences	0 (static)	NC_INT

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

number_of_max_num_outlier_exceeded_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “the number of outliers detected in the DOAS fit exceeds a maximum set for healthy spectra.” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “55”.

number_of_solar_eclipse_filter_occurrences	0 (static)	NC_INT

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

number_of_cloud_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “the cloud filter triggered causing the pixel to be skipped” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “65”.

number_of_altitude_consistency_filter_occurrences 0 (static) NC_INT

Number of ground pixels where input filter “too large difference between ECMWF altitude and DEM altitude value” occurred, i.e. where the lower 8 bits of the `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_occurrences 0 (static) 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_type_filter_occurrences 0 (static) NC_INT

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_occurrences 0 (static) 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_occurrences 0 (static) NC_INT

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_fresco_filter_occurrences 0 (static) NC_INT

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”.

number_of_aai_scene_albedo_filter_occurrences 0 (static) NC_INT

Number of ground pixels where input filter “pixel contains clouds: The difference between scene albedo at 380 nm from AAI calculation and the climatologcal 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_radiance_std_filter_occurrences 0 (static) 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_viirs_filter_occurrences 0 (static) NC_INT

Number of ground pixels where input filter “pixel contains clouds: The cloud fraction from VIIRS / NPP exceeds theshold. 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_occurrences 0 (static) NC_INT

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_ifov_filter_occurrences	0 (static)	NC_INT

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_ofova_filter_occurrences	0 (static)	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_ofovb_filter_occurrences	0 (static)	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_ofovc_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “fraction of cloudy VIIRS pixels wihtin 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_ifov_filter_occurrences	0 (static)	NC_INT

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 wihtin 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_ofovc_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “fraction of cloudy VIIRS pixels wihtin 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_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “average VIIRS cirrus reflectance within SWIR ground pixel exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the `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_viirs_filter_occurrences 0 (static) NC_INT

Number of ground pixels where input filter “difference in VIIRS average cirrus reflectance between SWIR and NIR ground pixel exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “87”.

number_of_ch4_noscat_ratio_filter_occurrences 0 (static) NC_INT

Number of ground pixels where input filter “the ratio between $[CH_4]_{weak}$ and $[CH_4]_{strong}$ is below or exceeds a priori thresholds from configuration” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “88”.

number_of_ch4_noscat_ratio_std_filter_occurrences 0 (static) NC_INT

Number of ground pixels where input filter “the standard deviation of $[CH_4]_{weak}/[CH_4]_{strong}$ within the SWIR pixel and the 8 neighbouring pixels exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “89”.

number_of_h2o_noscat_ratio_filter_occurrences 0 (static) NC_INT

Number of ground pixels where input filter “the ratio between $[H_2O]_{weak}$ and $[H_2O]_{strong}$ is below or exceeds a priori thresholds from configuration” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “90”.

number_of_h2o_noscat_ratio_std_filter_occurrences 0 (static) NC_INT

Number of ground pixels where input filter “the standard deviation of $[H_2O]_{weak}/[H_2O]_{strong}$ within the SWIR pixel and the 8 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_occurrences 0 (static) NC_INT

Number of ground pixels where input filter “difference between the FRESCO apparent surface pressure and the ECMWF surface pressure exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “92”.

number_of_psurf_fresco_stdv_filter_occurrences 0 (static) NC_INT

Number of ground pixels where input filter “the standard deviation of the FRESCO apparent surface pressure in the NIR pixel and the 8 surrounding pixels exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “93”.

number_of_ocean_filter_occurrences 0 (static) NC_INT

Number of ground pixels where input filter “the ground pixel is over ocean (and ocean glint retrievals are not switched on)” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “94”.

number_of_time_range_filter_occurrences 0 (static) NC_INT

Number of ground pixels where input filter “time is out of the range that is to be processed” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “95”.

number_of_pixel_or_scanline_index_filter_occurrences 0 (static) NC_INT

Number of ground pixels where input filter “not processed because pixel index does not match general selection criteria” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “96”.

number_of_geographic_region_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “pixel falls outside the specified regions of interest” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “97”.

number_of_input_spectrum_warning_occurrences	0 (static)	NC_INT

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

number_of_wavelength_calibration_warning_occurrences	0 (static)	NC_INT

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

number_of_extrapolation_warning_occurrences	0 (static)	NC_INT

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

number_of_sun_glint_warning_occurrences	0 (static)	NC_INT

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_anomaly_warning_occurrences	0 (static)	NC_INT

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

number_of_sun_glint_correction_occurrences	0 (static)	NC_INT

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

number_of_snow_ice_warning_occurrences	0 (static)	NC_INT

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

number_of_cloud_warning_occurrences	0 (static)	NC_INT

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_occurrences	0 (static)	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_input_data_missing_occurrences	0 (static)	NC_INT

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_fraction_warning_occurrences 0 (static) NC_INT

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

number_of_altitude_consistency_warning_occurrences 0 (static) NC_INT

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

number_of_signal_to_noise_ratio_warning_occurrences 0 (static) NC_INT

Number of ground pixels where processing warning “signal to noise ratio in SWIR and/or NIR band below threshold from configuration. For the 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_warning_occurrences 0 (static) NC_INT

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

number_of_so2_volcanic_origin_likely_warning_occurrences 0 (static) NC_INT

Number of ground pixels where processing warning “warning for 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_origin_certain_warning_occurrences 0 (static) NC_INT

Number of ground pixels where processing warning “warning for SO_2 BL product, UTLS products: volcanic origin certain” occurred, i.e. where bit 24 in the `processing_quality_flags` is set to “1”.

number_of_interpolation_warning_occurrences 0 (static) NC_INT

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

number_of_saturation_warning_occurrences 0 (static) NC_INT

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

number_of_high_sza_warning_occurrences	0 (static)	NC_INT
Number of ground pixels where processing warning “warning for high solar zenith angle. In this case, the processing can be performed with less final quality” occurred, i.e. where bit 27 in the `processing_quality_flags` is set to “1”.		
number_of_cloud_retrieval_warning_occurrences	0 (static)	NC_INT
Number of ground pixels where processing warning “warning occurring when the retrieval diagnostic indicates a degraded quality of the cloud retrieval” occurred, i.e. where bit 28 in the `processing_quality_flags` is set to “1”.		
number_of_cloud_inhomogeneity_warning_occurrences	0 (static)	NC_INT
Number of ground pixels where processing warning “the cloud coregistration inhomogeneity parameter is above a given threshold. 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”.		
number_of_thermal_instability_warning_occurrences	0 (static)	NC_INT
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_warnings	‘None’ (static)	NC_STRING
All warning messages, separated by newlines, with duplicates removed.		
time_for_algorithm_initialization	-1.0 (static)	NC_DOUBLE
Time in seconds needed for initialization.		
time_for_processing	-1.0 (static)	NC_DOUBLE
Time in seconds needed for processing.		
time_per_pixel	-1.0 (static)	NC_DOUBLE
Time per pixel in seconds needed for processing.		
time_standard_deviation_per_pixel	-1.0 (static)	NC_DOUBLE
Standard deviation of the time per pixel in seconds needed for processing.		

Dimensions in CO____/METADATA/QA_STATISTICS

vertices For the histogram boundaries.

size 2 (fixed)

CO_total_vertical_column_histogram_axis Histogram axis.

size 100 (fixed)

CO_total_vertical_column_pdf_axis Probability density function axis.

size 400 (fixed)

Variables in CO____/METADATA/QA_STATISTICS

carbonmonoxide_total_column_histogram_axis in CO____/METADATA/QA_STATISTICS	
Description:	Horizontal axis for the histograms of the CO total vertical column.
Dimensions:	CO_total_vertical_column_histogram_axis.
Type:	NC_FLOAT.
Source:	Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'1' (dynamic)	NC_STRING
	Same unit as the main parameter. This attribute originates from the CF standard.		
	comment	'Histogram axis of CO total vertical column' (static)	NC_STRING
	long_name	'Histogram of the CO total vertical column' (static)	NC_STRING
	bounds	'CO_total_vertical_column_histogram_bounds' (static)	NC_STRING

carbonmonoxide_total_column_pdf_axis in CO____/METADATA/QA_STATISTICS

Description: Horizontal axis for the probability distribution functions of the CO total vertical column.

Dimensions: CO_total_vertical_column_pdf_axis.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (dynamic)	NC_STRING
	Same unit as the main parameter. This attribute originates from the CF standard.		
	comment	'Probability density function of CO total vertical column' (static)	NC_STRING
	long_name	'Probability density function of CO total vertical column' (static)	NC_STRING
	bounds	'CO_total_vertical_column_pdf_bounds' (static)	NC_STRING

carbonmonoxide_total_column_histogram_bounds in CO____/METADATA/QA_STATISTICS

Dimensions: CO_total_vertical_column_histogram_axis, vertices.

Type: NC_FLOAT.

Source: Processor.

carbonmonoxide_total_column_pdf_bounds in CO____/METADATA/QA_STATISTICS

Dimensions: CO_total_vertical_column_pdf_axis, vertices.

Type: NC_FLOAT.

Source: Processor.

carbonmonoxide_total_column_histogram in CO____/METADATA/QA_STATISTICS

Description: Histogram of the CO column in the current granule.

Dimensions: CO_total_vertical_column_histogram_axis.

Type: NC_INT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	comment	'Histogram of the CO column in the current granule' (static)	NC_STRING
	number_of_overflow_values	0 (dynamic)	NC_INT
	The number of encountered values that are larger than the top of the histogram.		
	number_of_underflow_values	0 (dynamic)	NC_INT
	The number of encountered values that are smaller than the base of the histogram.		

carbonmonoxide_total_column_pdf in CO____/METADATA/QA_STATISTICS

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

Dimensions: CO_total_vertical_column_pdf_axis.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	comment	'Probability density function of the CO column 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 CO____/METADATA/ALGORITHM_SETTINGS

configuration.version.framework 1.2.0
Allow the framework to verify that the configuration file is up to date.
configuration.version.algorithm 1.5.0
Allow the processor to verify that the configuration file is up to date.
processing.algorithm CO____
Define the algorithm that is to be loaded.
processing.writelog 2
Write log in FORTRAN code.
processing.threadStackSize 1000000000
Minimum threadStackSize = 10000000 (10 MB). A lower threadStackSize will cause a segmentation fault during the execution.
input.count 2
Define the number of input files.
input.1.type L1B_RA_BD7
Define the input type (band) for the first input (radiance band 7). This key is needed to read from the JobOrder input file.
input.1.irrType L1B_IR_SIR
Define which irradiance accompanies the first input.
input.1.band 7
Which band is this (for selecting the irradiance and coregistration to output).
input.2.type L1B_RA_BD8
Define the input type (band) for the second input (radiance band 8). This key is needed to read from the JobOrder input file.
input.2.irrType L1B_IR_SIR
Define which irradiance accompanies the second input.
input.2.band 8
Which band is this (for selecting the irradiance and coregistration to output).
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__CO____
Output product short name. This key is needed to read from the JobOrder input file.
output.1.band 7
Geolocation in output follows this band.
output.1.config product.CO____.xml
Output product specification.

output.histogram.carbonmonoxide_total_column.range 0.03, 0.05
Range for the histogram of the CO column.
processing.perform_destriping true
Enable destriping as a post-processing step in offline processing.
processing.destripe_min_fraction_valid 0.6
Minimum fraction of a scanline that has valid data before scanline is included in destriping algorithm.
processing.destripe_fillvalue_is_contageous true
Fill values contaminate the whole window when smoothing.
processing.vzaMin 0.0
processing.vzaMax 75.0
Maximum viewing zenith angle (full swath)
processing.szaMin 0.0
processing.szaMax 85.0
Maximum solar zenith angle.
processing.groupDem DEM_RADIUS_05000
Which DEM to use.
processing.correct_surface_pressure_for_altitude false
Flag to control the correction of the surface pressure for local orography. Default is true, set to false because SRON code does not expect us to modify this value.
qa_value.cloud_warning 100.0
he qa_value multiplication factor (in percent) for when the cloud_warning flag is raised.
qa_value.data_range_warning 0.0
he qa_value multiplication factor (in percent) for when the data_range_warning flag is raised.
qa_value.deconvolution_warning 0.0
he qa_value multiplication factor (in percent) for when the deconvolution_warning flag is raised.
qa_value.extrapolation_warning 0.0
he qa_value multiplication factor (in percent) for when extrapolation was used in the retrieval.
qa_value.input_spectrum_warning 0.0
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 0.0
he qa_value multiplication factor (in percent) for when the wavelength calibration offset is larger than a configured threshold.
qa_value.sun_glint_warning 100.0
he qa_value multiplication factor (in percent) for when the pixel is potentially affected by sun glint.
qa_value.south_atlantic_anomaly_warning 100.0
he qa_value multiplication factor (in percent) for when the instrument was flying through the South Atlantic Anomaly while taking this measurement.
qa_value.sun_glint_correction 100.0
he qa_value multiplication factor (in percent) for when the cloud fraction was corrected for sun glint.
qa_value.snow_ice_warning 100.0
he qa_value multiplication factor (in percent) for when the snow_ice_warning flag is raised.
qa_value.AAI_warning 100.0
he qa_value multiplication factor (in percent) for when the AAI_warning flag is raised.
qa_value.pixel_level_input_data_missing 100.0
he qa_value multiplication factor (in percent) for when the pixel_level_input_data_missing flag is raised.
qa_value.low_cloud_fraction_warning 100.0
he qa_value multiplication factor (in percent) for when the low_cloud_fraction_warning flag is raised.
qa_value.altitude_consistency_warning 100.0
he qa_value multiplication factor (in percent) for when the altitude_consistency_warning flag is raised.
qa_value.signal_to_noise_ratio_warning 100.0
he qa_value multiplication factor (in percent) for when the signal_to_noise_ratio_warning flag is raised.
qa_value.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.saturation_warning 100.0
he qa_value multiplication factor (in percent) for when the saturation_warning is raised.
qa_value.sza_threshold 80.0
pper limit for the solar zenith angle. Higher solar zenith angles will be assigned 'qa_value.sza_modification_percent'.
qa_value.sza_modification_percent 0.0
he qa_value multiplication factor (in percent) for when solar zenith angle is larger than the upper limit in 'qa_value.sza_threshold'.
qa_value.bad_rows 0, 1
List of bad rows.
qa_value.bad_rows_modification_percent 0.0
he qa_value multiplication factor (in percent) for bad rows.
qa_value.scattering_optical_thickness_swir_limit 0.5
Upper limit to the aerosol optical thickness derived from the SWIR before the "uncivilized cloudy" scenario kicks in.
qa_value.cloud_height_cloud_free_upper_limit 500.0
pper limit for the cloud height to classify a scene as cloud free, in combination with 'qa_value.scattering_optical_thickness_swir_limit'.
qa_value.cloud_height_civilized_cloudy_upper_limit 5000.0
pper limit for the cloud height to classify a scene as 'civilized cloudy', in combination with 'qa_value.scattering_optical_thickness_swir_limit'.
qa_value.cloud_free_modification_percent 100.0
he qa_value multiplication factor (in percent) for cloud free scenes.
qa_value.civilized_cloudy_modification_percent 70.0
he qa_value multiplication factor (in percent) for civilized cloudy scenes.
qa_value.uncivilized_cloudy_modification_percent 40.0
he qa_value multiplication factor (in percent) for uncivilized cloudy scenes.
qa_value.thermal_instability_warning 40.0
he qa_value multiplication factor (in percent) for when the thermal_instability_warning flag is raised.
quality_control.qa_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 succesfully 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 CO____/METADATA/GRANULE_DESCRIPTION

Group attributes attached to GRANULE_DESCRIPTION		
Name	*Value*	*Type*
GranuleStart		NC_STRING
Start of the granule as ISO date/time string in UTC: *YYYY***-***MM***-***DD***T***HH***:***MM***:***SS***.***mmmmmm***Z**. The formal definition of ISO date/time strings is given in [RD46].		
GranuleEnd		NC_STRING
End of the granule as ISO date/time string in UTC: *YYYY***-***MM***-***DD***T***HH***:***MM***:***SS***.***mmmmmm***Z**. The formal definition of ISO date/time strings is given in [RD46].		
InstrumentName	'TROPOMI' (static)	NC_STRING
The name of the instrument, fixed to "TROPOMI".		

MissionName	'Sentinel-5 precursor' (static)	NC_STRING
The name of the mission, fixed to "Sentinel-5 precursor".		
MissionShortName	'S5P' (static)	NC_STRING
The short name of the mission, fixed to "S5P".		
ProcessLevel	'2' (static)	NC_STRING
This is a level 2 product.		
ProcessingCenter	'%(processingcenter)s' (dynamic)	NC_STRING
Where was the processor run? The source is the probably the joborder, the most likely value for operational use is "DLR/Oberpfaffenhofen".		
ProcessingNode		NC_STRING
The name of the machine that processed the data. This may aid in diagnosing failures in the processing.		
ProcessorVersion	'%(version)s' (dynamic)	NC_STRING
The version number of the processor used to produce the file. This is a string formatted as "major.minor.bugfix".		
ProductFormatVersion	1 (static)	NC_INT
The version of the format of the product file. This should be incremented whenever a datafield is added to the files.		
ProcessingMode		NC_STRING
This attribute indicates the mode of the processor.		
Possible values: Near-realtime, Offline, Reprocessing, Test, SyntheticTest		
LongitudeOfDaysideNadirEquatorCrossing		NC_FLOAT
The longitude of the nadir-point at the day-side equator crossing. This gives a rough indication where the orbit is located. The value is calculated using an orbit propagator before the observation, so that a consisten value is used for all processing stages.		
CollectionIdentifier	'%(collection_identifier)s' (dynamic)	NC_STRING
Identification of the processing collection, i.e. the group of products that can be used together as a consistent data set.		
ProductShortName	'L2__CO____' (static)	NC_STRING
The short product name. For the CO product this is fixed to "L2__CO____".		

10.2.3.1 Group "ISO_METADATA" in "iso_metadata"

Metadata that is structured following the ISO metadata standards [RD40, RD48], 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 [RD45].

All "`objectType`" attributes indicate the XML object when generating an ISO 19139 [RD48] 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 CO____/METADATA/ISO_METADATA

Group attributes attached to ISO_METADATA		
Name	*Value*	*Type*
gmd:dateStamp	'2015-10-16' (static)	NC_STRING
Date of creation of the metadata, as ISO 8601 [RD46] string specifying year, month and day.		
gmd:fileIdentifier	'urn:ogc:def:EOP:ESA:SENTINEL.S5P_TROP_-%(shortname)s' (dynamic)	NC_STRING
Unique identifier for metadata file, see the Level 1B metadata specification [RD45, table 5] for a discussion of the value.		
Replace %(...)s with the "`ProductShortName`" value from the Level 2 "`/METADATA/GRANULE_-DESCRIPTION`" metadata group.		

gmd:hierarchyLevelName	'EO Product Collection' (static)	NC_STRING
Name of the hierarchy levels for which the metadata is provided.		
gmd:metadataStandardName	'ISO 19115-2 Geographic Information - Metadata Part 2 Extensions for imagery and gridded data' (static)	NC_STRING
Name of the metadata standard.		
gmd:metadataStandardVersion	'ISO 19115-2:2009(E), S5P profile' (static)	NC_STRING
Version (profile) of the metadata standard used.		
objectType	'gmi:MI_Metadata' (static)	NC_STRING
Name of the metadata class [RD45, table 5].		

10.2.3.2 Group "gmd:language" in "ISO_METADATA"

Language used for the metadata, fixed to English.

Attributes in CO____/METADATA/ISO_METADATA/gmd:language

Group attributes attached to gmd:language		
Name	*Value*	*Type*
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 CO____/METADATA/ISO_METADATA/gmd:characterSet

Group attributes attached to gmd:characterSet		
Name	*Value*	*Type*
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.

Attributes in CO____/METADATA/ISO_METADATA/gmd:hierarchyLevel

Group attributes attached to gmd:hierarchyLevel		
Name	*Value*	*Type*
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 CO____/METADATA/ISO_METADATA/gmd:contact

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

10.2.3.6 Group "gmd:contactInfo" in "gmd:contact"

The detailed contact information.

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

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

10.2.3.7 Group "gmd:address" in "gmd:contactInfo"

The actual email address.

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

Group attributes attached to gmd:address		
Name	*Value*	*Type*
gmd:electronicMailAddress	'EOSupport@copernicus.esa.int' (static)	NC_STRING
objectType	'gmd:CI_Address' (static)	NC_STRING

10.2.3.8 Group "gmd:role" in "gmd:contact"

The role of the adress provided in this group.

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

Group attributes attached to gmd:role		
Name	*Value*	*Type*
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 CO____/METADATA/ISO_METADATA/gmd:identificationInfo

Group attributes attached to gmd:identificationInfo		
Name	*Value*	*Type*
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 $30 \times 30\,\mathrm{km}^2$ for the "small" pixels, and $35 \times 30\,\mathrm{km}^2$ for the "large" pixels.

L2__AER_AI (KNMI) Aerosol index 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

L2__AER_LH (KNMI) Altitude of elevated aerosol layer for cloud-free observations 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

L2__NO2___ (KNMI) Nitrogen dioxide tropospheric column 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

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 $5.5 \times 7\,\mathrm{km}^2$ observed at about 13:30 local solar time from spectra measured by TROPOMI

L2__CO____ (SRON) Carbon monoxide column with a spatial resolution of $5.5 \times 7\,\mathrm{km}^2$ 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 $5.5 \times 3.5\,\mathrm{km}^2$ observed at about 13:30 local solar time from spectra measured by TROPOMI (KNMI FRESCO cloud support product)

L2__O22CLD (KNMI) O_2–O_2 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 O_2–O_2 cloud support product)

gmd:credit	'%(credit)s' (static)	NC_STRING
Recognition of those who contributed to the resource(s).		
gmd:language	'eng' (static)	NC_STRING
gmd:topicCategory	'climatologyMeteorologyAtmosphere' (static)	NC_STRING
Main theme(s) of the dataset.		
objectType	'gmd:MD_DataIdentification' (static)	NC_STRING
Name of the metadata class [RD45, table 10].		

10.2.3.10 Group "gmd:citation" in "gmd:identificationInfo"

Citation data for the resource.

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

Group attributes attached to gmd:citation		
Name	*Value*	*Type*
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 [RD45, table 11].		

10.2.3.11 Group "gmd:date" in "gmd:citation"

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

Group attributes attached to gmd:date		
Name	*Value*	*Type*
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 CO____/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:citation/gmd:date/gmd:dateType

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

10.2.3.13 Group "gmd:identifier" in "gmd:citation"

Unique identifier for metadata file, see the Level 1B metadata specification [RD45, table 5] for a discussion of the value.

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

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

10.2.3.14 Group "gmd:pointOfContact" in "gmd:identificationInfo"

See description of the "`gmd:contact`" attribute above.

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

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

10.2.3.15 Group "gmd:contactInfo" in "gmd:pointOfContact"

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

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

10.2.3.16 Group "gmd:address" in "gmd:contactInfo"

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

Group attributes attached to gmd:address		
Name	*Value*	*Type*
gmd:electronicMailAddress	'EOSupport@copernicus.esa.int' (static)	NC_STRING
objectType	'gmd:CI_Address' (static)	NC_STRING

10.2.3.17 Group "gmd:role" in "gmd:pointOfContact"

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

Group attributes attached to gmd:role		
Name	*Value*	*Type*
codeList	'http://www.isotc211.org/2005/resources/Codelist/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 CO____/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 CO____/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#1/gmd:type

Group attributes attached to gmd:type		
Name	*Value*	*Type*
codeList	'http://www.isotc211.org/2005/resources/Codelist/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 CO____/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#1/gmd:thesaurusName

Group attributes attached to gmd:thesaurusName		
Name	*Value*	*Type*
gmd:title	'GEMET - INSPIRE themes, version 1.0' (static)	NC_STRING
objectType	'gmd:CI_Citation' (static)	NC_STRING

10.2.3.21 Group "gmd:date" in "gmd:thesaurusName"

Reference date for the cited resource.

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

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

10.2.3.22 Group "gmd:dateType" in "gmd:date"

What date is used for the reference date.

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

Group attributes attached to gmd:dateType		
Name	*Value*	*Type*
codeList	'http://www.isotc211.org/2005/resources/Codelist/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 CO____/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#2

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

10.2.3.24 Group "gmd:thesaurusName" in "gmd:descriptiveKeywords#2"

Name by which the cited resource is known.

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

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

10.2.3.25 Group "gmd:date" in "gmd:thesaurusName"

Reference date for the cited resource.

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

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

10.2.3.26 Group "gmd:dateType" in "gmd:date"

What date is used for the reference date.

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

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

10.2.3.27 Group "gmd:resourceConstraints" in "gmd:identificationInfo"

Provides information about constraints which apply to the resource.

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

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

10.2.3.28 Group "gmd:accessConstraints" in "gmd:resourceConstraints"

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

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

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

10.2.3.29 Group "gmd:spatialRepresentationType" in "gmd:identificationInfo"

Method used to spatially represent geographic information.

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

Group attributes attached to gmd:spatialRepresentationType		
Name	*Value*	*Type*
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 CO____/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:characterSet

Group attributes attached to gmd:characterSet		
Name	*Value*	*Type*
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 CO____/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:extent

Group attributes attached to gmd:extent		
Name	*Value*	*Type*
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 CO____/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:extent/gmd:geographicElement

Group attributes attached to gmd:geographicElement		
Name	*Value*	*Type*
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 *inclusion*.		
objectType	'gmd:EX_GeographicBoundingBox' (static)	NC_STRING

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

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

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

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

Time period covered by the content of the dataset.

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

Group attributes attached to gmd:extent		
Name	*Value*	*Type*
gml:beginPosition	'2014-11-14T19:58:00' (dynamic)	NC_STRING
Time of the start of the granule, expressed as ISO 8601 [RD46] date-time string.		
gml:endPosition	'2014-11-14T20:08:00' (dynamic)	NC_STRING
Time of the end of the granule, expressed as ISO 8601 [RD46] 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 80) 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 CO____/METADATA/ISO_METADATA/gmd:dataQualityInfo

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

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

The specific data to which the data quality information applies.

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

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

10.2.3.37 Group "gmd:level" in "gmd:scope"

Hierarchical level of the data specified by the scope.

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

Group attributes attached to gmd:level		
Name	*Value*	*Type*
codeList	'http://www.isotc211.org/2005/resources/Codelist/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 CO____/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:report

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

10.2.3.39 Group "gmd:result" in "gmd:report"

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

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

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

10.2.3.40 Group "gmd:specification" in "gmd:result"

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

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

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

10.2.3.41 Group "gmd:date" in "gmd:specification"

Reference date for the cited resource.

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

Group attributes attached to gmd:date		
Name	*Value*	*Type*
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 CO____/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:report/gmd:result/gmd:specification/gmd:date/gmd:dateType

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

10.2.3.43 Group "gmd:lineage" in "gmd:dataQualityInfo"

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

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

Group attributes attached to gmd:lineage		
Name	*Value*	*Type*
objectType	'gmd:LI_Lineage' (static)	NC_STRING
gmd:statement	'L2 %(product)s dataset produced by %(processingcenter)s from the S5P/TROPOMI L1B product' (dynamic)	NC_STRING
General explanation of the data producer's knowledge about the lineage of a dataset. Insert short description of the actual Level 2 product in this string (at the %(. . .)s).		

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

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

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

Group attributes attached to gmd:processStep		
Name	*Value*	*Type*
objectType	'gmi:LE_ProcessStep' (static)	NC_STRING

gmd:description	'Processing of L1b to L2 %(product)s data for orbit %(orbit)d using the %(institute)s processor version %(version)s' (dynamic)	NC_STRING
Description of the event, including related parameters or tolerances. Insert short description of the actual Level 2 product, the orbit number, the name of the 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 CO____/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:output

Group attributes attached to gmi: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

10.2.3.46 Group "gmd:sourceCitation" in "gmi:output"

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

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

Group attributes attached to gmd:sourceCitation		
Name	*Value*	*Type*
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 CO____/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 CO____/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*	*Type*

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

10.2.3.49 Group "gmd:identifier" in "gmd:sourceCitation"

Identification of the output product.

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

Group attributes attached to gmd:identifier		
Name	*Value*	*Type*
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 CO____/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:output/gmi:processedLevel

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

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

Description of the processor in more detail.

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

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

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

Identification of the processor.

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

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

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

Reference to document describing processing software.

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

Group attributes attached to gmi:softwareReference		
Name	*Value*	*Type*
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 CO____/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:softwareReference/gmd:date

Group attributes attached to gmd:date		
Name	*Value*	*Type*
gmd:date	'%(processor_release_date)s' (dynamic)	NC_STRING
Release date of the processor expressed as an ISO 8601 date string [RD46].		
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 CO____/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:softwareReference/gmd:date/gmd:dateType

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

10.2.3.56 Group "gmi:documentation#1" in "gmi:processingInformation"

Reference to the ATBD of the product.

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

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

10.2.3.57 Group "gmd:date" in "gmi:documentation#1"

Release date of the ATBD.

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

Group attributes attached to gmd:date		
Name	*Value*	*Type*
gmd:date	'%(date_atbd)s' (dynamic)	NC_STRING
Release date of the ATBD expressed as an ISO 8601 date string [RD46].		
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 CO____/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:documentation#1/gmd:date/gmd:dateType

Group attributes attached to gmd:dateType		
Name	*Value*	*Type*
codeList	'http://www.isotc211.org/2005/resources/Codelist/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 CO____/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:documentation#2

Group attributes attached to gmi:documentation#2		
Name	*Value*	*Type*
objectType	'gmd:CI_Citation' (static)	NC_STRING
gmd:title	'%(title_pum)s' (dynamic)	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 CO____/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:documentation#2/gmd:date

Group attributes attached to gmd:date		
Name	*Value*	*Type*
gmd:date	'%(date_pum)s' (dynamic)	NC_STRING
Release date of the PUM expressed as an ISO 8601 date string [RD46].		
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 CO____/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:documentation#2/gmd:date/gmd:dateType

Group attributes attached to gmd:dateType		
Name	*Value*	*Type*
codeList	'http://www.isotc211.org/2005/resources/Codelist/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 CO____/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:report

Group attributes attached to gmi:report		
Name	*Value*	*Type*
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 CO____/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmd:source#1

Group attributes attached to gmd:source#1		
Name	*Value*	*Type*
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 CO____/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmd:source#1/gmi:processedLevel

Group attributes attached to gmi:processedLevel		
Name	*Value*	*Type*
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 CO____/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmd:source#1/gmd:sourceCitation

Group attributes attached to gmd:sourceCitation		
Name	*Value*	*Type*
objectType	'gmd:CI_Citation' (static)	NC_STRING

10.2.3.66 Group "gmd:date" in "gmd:sourceCitation"

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

Group attributes attached to gmd:date		
Name	*Value*	*Type*
gmd:date		NC_STRING
Production date and time of the input file(s) in this group expressed as an ISO 8601 date-time string [RD46]. 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 CO____/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmd:source#1/gmd:sourceCitation/gmd:date/gmd:dateType

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

10.2.3.68 Group "gmd:title" in "gmd:sourceCitation"

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

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

10.2.3.69 Group "gmd:alternateTitle#1" in "gmd:sourceCitation"

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

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

gmd:source#1/gmd:sourceCitation/gmd:alternateTitle#1

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

10.2.3.70 Group "gmi:acquisitionInformation" in "ISO_METADATA"

Metadata regarding the acquisition of the original data.

Attributes in CO____/METADATA/ISO_METADATA/gmi:acquisitionInformation

Group attributes attached to gmi:acquisitionInformation		
Name	*Value*	*Type*
objectType	'gmi:MI_AcquisitionInformation' (static)	NC_STRING

10.2.3.71 Group "gmi:platform" in "gmi:acquisitionInformation"

The platform we are on.

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

Group attributes attached to gmi:platform		
Name	*Value*	*Type*
gmi:description	'Sentinel 5 Precursor' (static)	NC_STRING
objectType	'gmi:MI_Platform' (static)	NC_STRING

10.2.3.72 Group "gmi:identifier" in "gmi:platform"

Short identifier of the platform.

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

Group attributes attached to gmi:identifier		
Name	*Value*	*Type*
gmd:code	'S5P' (static)	NC_STRING
gmd:codeSpace	'http://www.esa.int/' (static)	NC_STRING
objectType	'gmd:RS_Identifier' (static)	NC_STRING

10.2.3.73 Group "gmi:instrument" in "gmi:platform"

The instrument used for the observations.

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

Group attributes attached to gmi:instrument		
Name	*Value*	*Type*
objectType	'gmi:MI_Instrument' (static)	NC_STRING
gmi:type	'UV-VIS-NIR-SWIR imaging spectrometer' (static)	NC_STRING
Type of the instrument.		

10.2.3.74 Group "gmi:identifier" in "gmi:instrument"

Unique identifier for the instrument.

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

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

10.2.3.75 Group "EOP_METADATA" in "EOP_metadata"

Based on the OGC 10-025 standard for Observations & Measurements [RD49], 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 CO____/METADATA/EOP_METADATA

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

10.2.3.76 Group "om:phenomenonTime" in "EOP_METADATA"

Time coverage of the granule.

Attributes in CO____/METADATA/EOP_METADATA/om:phenomenonTime

Group attributes attached to om:phenomenonTime		
Name	*Value*	*Type*
gml:beginPosition		NC_STRING
Start of time coverage of the data in the granule expressed as an ISO 8601 date-time string [RD46].		
gml:endPosition		NC_STRING
End of time coverage of the data in the granule expressed as an ISO 8601 date-time string [RD46].		
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 CO____/METADATA/EOP_METADATA/om:procedure

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

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

Platform name and orbit type.

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

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

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

Instrument descriptor.

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

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

10.2.3.80 Group "eop:sensor" in "om:procedure"

Sensor description.

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

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

10.2.3.81 Group "eop:acquisitionParameters" in "om:procedure"

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

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

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

10.2.3.82 Group "om:observedProperty" in "EOP_METADATA"

An xlink to the observed property definition.

Attributes in CO____/METADATA/EOP_METADATA/om:observedProperty

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

10.2.3.83 Group "om:featureOfInterest" in "EOP_METADATA"

Attributes in CO____/METADATA/EOP_METADATA/om:featureOfInterest

Group attributes attached to om:featureOfInterest		
Name	*Value*	*Type*
objectType	'eop:FootPrint' (static)	NC_STRING

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

10.2.3.84 Group "eop:multiExtentOf" in "om:featureOfInterest"

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

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

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

10.2.3.85 Group "gml:surfaceMembers" in "eop:multiExtentOf"

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

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

10.2.3.86 Group "gml:exterior" in "gml:surfaceMembers"

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

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

10.2.3.87 Group "eop:metaDataProperty" in "EOP_METADATA"

This group contains all the metadata relative to the 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 CO____/METADATA/EOP_METADATA/eop:metaDataProperty

Group attributes attached to eop:metaDataProperty		
Name	*Value*	*Type*
objectType	'eop:EarthObservationMetaData' (static)	NC_STRING
eop:acquisitionType	'NOMINAL' (dynamic)	NC_STRING
Used to distinguish at a high level the appropriateness of the acquisition for "general" use, whether the product is a nominal acquisition, special calibration product or other. Copy from L1b. For Level 2 this should *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 the product (see `http://www.datacite.org` for DOIs for datasets).		
eop:parentIdentifier	'urn:ogc:def:EOP:ESA:SENTINEL.S5P_TROP_-%(shortname)s' (dynamic)	NC_STRING
Unique collection identifier for metadata file, see the Level 1B metadata specification [RD45, table 5] for a discussion of the value. This is a copy of the "gmd:fileIdentifier" attribute in the "/METADATA/ISO_METADATA" group.		
eop:productType	'S5P_%(mode)s_%(product)s' (dynamic)	NC_STRING
Product type identifier. Replace %(mode)s with the operational mode the processor is running in ('NRTI', 'OFFL' or 'RPRO', as per [RD25]) and %(product)s with the 10 character output file name semantic descriptors as given in [RD50, RD51, RD52].		
eop:status	'ACQUIRED' (dynamic)	NC_STRING
Refers to product status. Values listed in the standard: 'ARCHIVED', 'ACQUIRED', 'CANCELLED', 'FAILED', 'PLANNED', 'POTENTIAL', 'REJECTED', 'QUALITY-DEGRADED'. Copied from L1B.		
eop:productQualityStatus	'NOMINAL' (dynamic)	NC_STRING
Indicator that specifies whether the product quality is degraded or not. Allowed values: 'DEGRADED', 'NOMINAL'.		
eop:productQualityDegradationTag	'NOT APPLICABLE' (dynamic)	NC_STRING
Contains further textual information concerning the quality degradation. According to the metadata standards it shall be provided *only* if "eop:productQualityStatus" value is set to 'DEGRADED'. Because the way we generate out output files, this attribute will always be present, even when "eop:productQualityStatus" value is 'NOMINAL'. In those cases the value shall be set to "NOT APPLICABLE". Possible values are "MISSING AUXILIARY INPUT" and "NOT APPLICABLE". Note that Level 1B does not set this value, so only problems detectable in the processor are covered.		

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

Processing information.

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

Group attributes attached to eop:processing		
Name	*Value*	*Type*
objectType	'eop:ProcessingInformation' (static)	NC_STRING
eop:processingCenter	'%(processingcenter)s' (dynamic)	NC_STRING
The processing center, taken from the "`Processing_Station`" key in the joborder.		
eop:processingDate	'YYYY-mm-ddTHH:MM:SSZ' (dynamic)	NC_STRING
The processing date, as an ISO 8601 date-time string [RD46].		
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, "`tropnll2dp.exe`" for KNMI and "`upas-l2`" 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
Processing mode taken from mission specific code list. For S5P we use the *File Class* identifiers [RD25, section 4.1.2]: 'TEST', 'OGCA', 'GSOV', 'OPER', 'NRTI', 'OFFL', 'RPRO'.		

10.2.3.89 Group "ESA_METADATA" in "ESA_metadata"

Metadata defined in the ESA file format standard [RD39].

10.2.3.90 Group "earth_explorer_header" in "ESA_METADATA"

Attributes in CO____/METADATA/ESA_METADATA/earth_explorer_header

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

10.2.3.91 Group "fixed_header" in "earth_explorer_header"

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

Attributes in CO____/METADATA/ESA_METADATA/earth_explorer_header/fixed_header

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

10.2.3.92 Group "validity_period" in "fixed_header"

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

Group attributes attached to validity_period		
Name	*Value*	*Type*
objectType	'Validity_Period' (static)	NC_STRING
Validity_Start		NC_STRING
The value is the string "`UTC=`" concatenated with the `time_coverage_start` global attribute. This attribute corresponds to the "Validity_Start" element in the "Validity_Period" XML structure in the header file.		
Validity_Stop		NC_STRING
The value is the string "`UTC=`" concatenated with the `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 CO____/METADATA/ESA_METADATA/earth_explorer_header/fixed_header/source

Group attributes attached to source		
Name	*Value*	*Type*
objectType	‘Source’ (static)	NC_STRING
System	‘%(processingcenter)s’ (dynamic)	NC_STRING
Name of the Ground Segment element creating the file. For Level 2 files, this is the PDGS, but for testing a different value may be used. This attribute corresponds to the “System” element in the “Source” XML structure in the header file.		
Creator	‘%(processor_name)s’ (dynamic)	NC_STRING
Name of the facility or tool, within the Ground Segment element, creating the file. This attribute corresponds to the “Creator” element in the “Source” XML structure in the header file.		
Creator_Version	‘%(version)s’ (dynamic)	NC_STRING
Version number of the tool that created the file. This attribute corresponds to the “Creator_Version” element in the “Source” XML structure in the header file.		
Creation_Date		NC_STRING
The start date and time of processing, as a string: “`UTC=YYYY-MM-DDThh:mm:ss`”. This attribute corresponds to the “Creator_Date” element in the “Source” XML structure in the header file.		

10.2.3.94 Group “variable_header” in “earth_explorer_header”

Attributes in CO____/METADATA/ESA_METADATA/earth_explorer_header/variable_header

Group attributes attached to variable_header		
Name	*Value*	*Type*
objectType	‘Variable_Header’ (static)	NC_STRING

10.2.3.95 Group “gmd:lineage” in “variable_header”

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

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

Group attributes attached to gmd:lineage		
Name	*Value*	*Type*
objectType	‘gmd:LI_Lineage’ (static)	NC_STRING
gmd:statement	‘L2 %(product)s dataset produced by %(processingcenter)s from the S5P/TROPOMI L1B product’ (dynamic)	NC_STRING
General explanation of the data producer’s knowledge about the lineage of a dataset. Insert short description of the actual Level 2 product in this string (at the %(. . .)s).		

10.2.3.96 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 CO____/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep

Group attributes attached to gmd:processStep		
Name	*Value*	*Type*
objectType	'gmi:LE_ProcessStep' (static)	NC_STRING
gmd:description	'Processing of L1b to L2 %(product)s data for orbit %(orbit)d using the %(institute)s processor version %(version)s' (dynamic)	NC_STRING
Description of the event, including related parameters or tolerances. Insert short description of the actual Level 2 product, the orbit number, the name of the 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 CO____/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:output

Group attributes attached to gmi: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 CO____/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:output/gmd:sourceCitation

Group attributes attached to gmd:sourceCitation		
Name	*Value*	*Type*
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 CO____/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*	*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

10.2.3.100 Group "gmd:dateType" in "gmd:date"

Meaning of the reference date for the cited resource.

Attributes in CO____/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*	*Type*
codeList	'http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode' (static)	NC_STRING
codeListValue	'creation' (static)	NC_STRING
objectType	'gmd:CI_DateTypeCode' (static)	NC_STRING

10.2.3.101 Group "gmd:identifier" in "gmd:sourceCitation"

Identification of the output product.

Attributes in CO____/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*	*Type*
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 CO____/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:output/gmi:processedLevel

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

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

Description of the processor in more detail.

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

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

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

Identification of the processor.

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

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

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

Reference to document describing processing software.

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

Group attributes attached to gmi:softwareReference		
Name	*Value*	*Type*
gmd:title	'%(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 CO____/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:softwareReference/gmd:date

Group attributes attached to gmd:date		
Name	*Value*	*Type*
gmd:date	'%(processor_release_date)s' (dynamic)	NC_STRING
Release date of the processor expressed as an ISO 8601 date string [RD46].		
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 CO____/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:softwareReference/gmd:date/gmd:dateType

Group attributes attached to gmd:dateType		
Name	*Value*	*Type*
codeList	'http://www.isotc211.org/2005/resources/Codelist/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 CO____/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:documentation#1

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

10.2.3.109 Group "gmd:date" in "gmi:documentation#1"

Release date of the ATBD.

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

Group attributes attached to gmd:date		
Name	*Value*	*Type*
gmd:date	'%(date_atbd)s' (dynamic)	NC_STRING
Release date of the ATBD expressed as an ISO 8601 date string [RD46].		
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 CO____/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*	*Type*
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 CO____/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*	*Type*
objectType	'gmd:CI_Citation' (static)	NC_STRING
gmd:title	'%(title_pum)s' (dynamic)	NC_STRING
Specification of the current release of the PUM of the product.		

10.2.3.112 Group "gmd:date" in "gmi:documentation#2"

Release date of the PUM.

Attributes in CO____/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*	*Type*
gmd:date	'%(date_pum)s' (dynamic)	NC_STRING
Release date of the PUM expressed as an ISO 8601 date string [RD46].		
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 CO____/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:processingInformation/gmi:documentation#2/gmd:date/gmd:dateType

Group attributes attached to gmd:dateType		
Name	*Value*	*Type*
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 CO____/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:report

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

10.2.3.115 Group "gmd:source#1" in "gmd:processStep"

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

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

Group attributes attached to gmd:source#1		
Name	*Value*	*Type*
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 CO____/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*	*Type*
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 CO____/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmd:source#1/gmd:sourceCitation

Group attributes attached to gmd:sourceCitation		
Name	*Value*	*Type*
objectType	'gmd:CI_Citation' (static)	NC_STRING

10.2.3.118 Group "gmd:date" in "gmd:sourceCitation"

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

Group attributes attached to gmd:date		
Name	*Value*	*Type*
gmd:date		NC_STRING
Production date and time of the input file(s) in this group expressed as an ISO 8601 date-time string [RD46]. 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 CO____/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmd:source#1/gmd:sourceCitation/gmd:date/gmd:dateType

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

10.2.3.120 Group "gmd:title" in "gmd:sourceCitation"

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

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

10.2.3.121 Group "gmd:alternateTitle#1" in "gmd:sourceCitation"

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

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

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

11 Units

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

Making the UDUnits package [ER10] a requirement, and thereby forcing all units to be compliant with formal SI units[3] 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 $\mathrm{mol\,m^{-2}}$.

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 $\mathrm{molecules\,cm^{-2}}$

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 $\mathrm{s^{-1}\,nm^{-1}\,cm^{-2}\,sr^{-1}}$.

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:

$$f_{\mathrm{pdf}}(x_j) = \frac{1}{N}\sum_{i=0}^{N}\frac{\cos\left(\delta_{\mathrm{geo},i}\right)}{\sigma_i\sqrt{2\pi}}\exp\left[\frac{(x_j - x_i)^2}{2\sigma_i^2}\right] \tag{5}$$

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 $\cos\left(\delta_{\mathrm{geo},i}\right)$ 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.

[3] 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 ($R < 0$ 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	Description
number_of_ozone_range_error_occurrences	Number of ground pixels where “ozone column significantly out of range of profile climatology” occurred.
number_of_wavelength_offset_error_occurrences	Number of ground pixels where “wavelength offset exceeds maximum from configuration” occurred.
number_of_initialization_error_occurrences	Number of ground pixels where “an error occurred during the processing of the pixel, no output was generated. The following errors raise this flag: Mismatch between irradiance and radiance wavelengths; The on-ground distance between band 1 and band 2 ground pixels exceeds a threshold set in the configuration. Derived a-priori information does not validate, no processing is possible” occurred.
number_of_memory_error_occurrences	Number of ground pixels where “memory allocation or deallocation error” occurred.
number_of_assertion_error_occurrences	Number of ground pixels where “error in algorithm detected during assertion” occurred.
number_of_io_error_occurrences	Number of ground pixels where “error detected during transfer of data between algorithm and framework” occurred.
number_of_numerical_error_occurrences	Number of ground pixels where “general fatal numerical error occurred during inversion” occurred.
number_of_lut_error_occurrences	Number of ground pixels where “error in accessing the lookup table” occurred.
number_of_ISRF_error_occurrences	Number of ground pixels where “error detected in the input instrument spectral response function input data” occurred.
number_of_convergence_error_occurrences	Number of ground pixels where “the main algorithm did not converge” occurred.
number_of_cloud_filter_convergence_error_occurrences	Number of ground pixels where “the cloud filter did not converge” occurred.
number_of_max_iteration_convergence_error_occurrences	Number of ground pixels where “no convergence because retrieval exceeds maximum number of iterations. Maximum value from configuration” occurred.
number_of_aot_lower_boundary_convergence_error_occurrences	Number of ground pixels where “no convergence because the aerosol optical thickness crosses lower boundary twice in succession” occurred.
number_of_other_boundary_convergence_error_occurrences	Number of ground pixels where “no convergence because a state vector element crosses boundary twice in succession. Note that a separate failure flag is defined for non-convergence due to crossing of lower AOT boundary” occurred.

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

Name	Description
number_of_geolocation_error_occurrences	Number of ground pixels where “geolocation out of range” occurred.
number_of_ch4_noscat_zero_error_occurrences	Number of ground pixels where “the CH_4 column retrieved by the non-scattering CO algorithm from the weak band or strong band is 0” occurred.
number_of_h2o_noscat_zero_error_occurrences	Number of ground pixels where “the H_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.
number_of_number_of_input_data_points_too_low_error_occurrences	Number of ground pixels where “not enough input ozone columns to calculate a tropospheric column” occurred.
number_of_cloud_pressure_spread_too_low_error_occurrences	Number of ground pixels where “cloud pressure variability to low to estimate a tropospheric column” occurred.
number_of_cloud_too_low_level_error_occurrences	Number of ground pixels where “clouds are too low in the atmosphere to assume sufficient shielding” occurred.
number_of_generic_range_error_occurrences	Number of ground pixels where “generic range error” occurred.
number_of_generic_exception_occurrences	Number of ground pixels where “catch all generic error” occurred.

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

Name	Description
number_of_input_spectrum_alignment_error_occurrences	Number of ground pixels where “input radiance and irradiance spectra are not aligned correctly” occurred.
number_of_abort_error_occurrences	Number of ground pixels where “not processed because processor aborted prematurely (time out or user abort)” occurred.
number_of_wrong_input_type_error_occurrences	Number of ground pixels where “wrong input type error, mismatch between expectation and received data” occurred.
number_of_wavelength_calibration_error_occurrences	Number of ground pixels where “an error occurred in the wavelength calibration of this pixel” occurred.
number_of_coregistration_error_occurrences	Number of ground pixels where “no colocated pixels found in a supporting band” occurred.
number_of_slant_column_density_error_occurrences	Number of ground pixels where “slant column fit returned error, no values can be computed” occurred.
number_of_airmass_factor_error_occurrences	Number of ground pixels where “airmass factor could not be computed” occurred.
number_of_vertical_column_density_error_occurrences	Number of ground pixels where “vertical column density could not be computed” occurred.
number_of_signal_to_noise_ratio_error_occurrences	Number of ground pixels where “the signal to noise ratio for this spectrum is too low for processing” occurred.
number_of_configuration_error_occurrences	Number of ground pixels where “error while parsing the configuration” occurred.
number_of_key_error_occurrences	Number of ground pixels where “key does not exist” occurred.
number_of_saturation_error_occurrences	Number of ground pixels where “saturation in input spectrum” occurred.
number_of_max_num_outlier_exceeded_error_occurrences	Number of ground pixels where “the number of outliers detected in the DOAS fit exceeds a maximum set for healthy spectra. ” occurred.
number_of_solar_eclipse_filter_occurrences	Number of ground pixels where “solar eclipse” occurred.
number_of_cloud_filter_occurrences	Number of ground pixels where “the cloud filter triggered causing the pixel to be skipped” occurred.
number_of_altitude_consistency_filter_occurrences	Number of ground pixels where “too large difference between ECMWF altitude and DEM altitude value” occurred.
number_of_altitude_roughness_filter_occurrences	Number of ground pixels where “too large standard deviation of altitude in DEM” occurred.

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

Name	Description
number_of_sun_glint_filter_occurrences	Number of ground pixels where “for pixels over water, viewing direction inside sun glint region. Definition of sun glint angle and threshold value from ATBD” occurred.
number_of_mixed_surface_type_filter_occurrences	Number of ground pixels where “pixel contains land and water areas (e.g. coastal pixel)” occurred.
number_of_snow_ice_filter_occurrences	Number of ground pixels where “pixel contains snow/ice: Snow/ice flag according to dynamic input OR climatological surface albedo at VIS wavelength is larger than 0.5” occurred.
number_of_aai_filter_occurrences	Number of ground pixels where “AAI smaller than 2.0” occurred.
number_of_cloud_fraction_fresco_filter_occurrences	Number of ground pixels where “pixel contains clouds: The FRESCO effective cloud fraction is larger than threshold. Threshold value from ATBD” occurred.
number_of_aai_scene_albedo_filter_occurrences	Number of ground pixels where “pixel contains clouds: The difference between scene albedo at 380 nm from AAI calculation and the climatologcal surface albedo exceeds threshold. Threshold value from ATBD. This test filters out clouds” occurred.
number_of_small_pixel_radiance_std_filter_occurrences	Number of ground pixels where “pixel contains clouds: Standard deviation of radiances in small-pixel column exceeds threshold. Threshold value from ATBD” occurred.
number_of_cloud_fraction_viirs_filter_occurrences	Number of ground pixels where “pixel contains clouds: The cloud fraction from VIIRS / NPP exceeds theshold. Threshold value from ATBD” occurred.
number_of_cirrus_reflectance_viirs_filter_occurrences	Number of ground pixels where “pixel contains clouds: Cirrus reflectance from VIIRS / NPP exceeds threshold. Threshold value from ATBD” occurred.
number_of_cf_viirs_swir_ifov_filter_occurrences	Number of ground pixels where “fraction of cloudy VIIRS pixels wihtin S5P SWIR ground pixel exceeds a priori threshold from configuration” occurred.
number_of_cf_viirs_swir_ofova_filter_occurrences	Number of ground pixels where “fraction of cloudy VIIRS pixels wihtin S5P SWIR OFOVa exceeds a priori threshold from configuration” occurred.
number_of_cf_viirs_swir_ofovb_filter_occurrences	Number of ground pixels where “fraction of cloudy VIIRS pixels wihtin S5P SWIR OFOVb exceeds a priori threshold from configuration” occurred.
number_of_cf_viirs_swir_ofovc_filter_occurrences	Number of ground pixels where “fraction of cloudy VIIRS pixels wihtin S5P SWIR OFOVc exceeds a priori threshold from configuration” occurred.
number_of_cf_viirs_nir_ifov_filter_occurrences	Number of ground pixels where “fraction of cloudy VIIRS pixels wihtin S5P NIR ground pixel exceeds a priori threshold from configuration” occurred.

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

Name	Description
number_of_cf_viirs_nir_ofova_filter_occurrences	Number of ground pixels where “fraction of cloudy VIIRS pixels wihtin S5P NIR OFOVa exceeds a priori threshold from configuration” occurred.
number_of_cf_viirs_nir_ofovb_filter_occurrences	Number of ground pixels where “fraction of cloudy VIIRS pixels wihtin S5P NIR OFOVb exceeds a priori threshold from configuration” occurred.
number_of_cf_viirs_nir_ofovc_filter_occurrences	Number of ground pixels where “fraction of cloudy VIIRS pixels wihtin S5P NIR OFOVc exceeds a priori threshold from configuration” occurred.
number_of_refl_cirrus_viirs_swir_filter_occurrences	Number of ground pixels where “average VIIRS cirrus reflectance within SWIR ground pixel exceeds a priori threshold from configuration” occurred.
number_of_refl_cirrus_viirs_nir_filter_occurrences	Number of ground pixels where “average VIIRS cirrus reflectance within NIR ground pixel exceeds a priori threshold from configuration” occurred.
number_of_diff_refl_cirrus_viirs_filter_occurrences	Number of ground pixels where “difference in VIIRS average cirrus reflectance between SWIR and NIR ground pixel exceeds a priori threshold from configuration” occurred.
number_of_ch4_noscat_ratio_filter_occurrences	Number of ground pixels where “the ratio between $[CH_4]_{weak}$ and $[CH_4]_{strong}$ is below or exceeds a priori thresholds from configuration” occurred.
number_of_ch4_noscat_ratio_std_filter_occurrences	Number of ground pixels where “the standard deviation of $[CH_4]_{weak}/[CH_4]_{strong}$ within the SWIR pixel and the 8 neighbouring pixels exceeds a priori threshold from configuration” occurred.
number_of_h2o_noscat_ratio_filter_occurrences	Number of ground pixels where “the ratio between $[H_2O]_{weak}$ and $[H_2O]_{strong}$ is below or exceeds a priori thresholds from configuration” occurred.
number_of_h2o_noscat_ratio_std_filter_occurrences	Number of ground pixels where “the standard deviation of $[H_2O]_{weak}/[H_2O]_{strong}$ within the SWIR pixel and the 8 neigbouring pixels exceeds a priori threshold from configuration” occurred.
number_of_diff_psurf_fresco_ecmwf_filter_occurrences	Number of ground pixels where “difference between the FRESCO apparent surface pressure and the ECMWF surface pressure exceeds a priori threshold from configuration” occurred.
number_of_psurf_fresco_stdv_filter_occurrences	Number of ground pixels where “the standard deviation of the FRESCO apparent surface pressure in the NIR pixel and the 8 surrounding pixels exceeds a priori threshold from configuration” occurred.
number_of_ocean_filter_occurrences	Number of ground pixels where “the ground pixel is over ocean (and ocean glint retrievals are not switched on)” occurred.

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

Name	Description
number_of_time_range_filter_occurrences	Number of ground pixels where “time is out of the range that is to be processed” occurred.
number_of_pixel_or_scanline_index_filter_occurrences	Number of ground pixels where “not processed because pixel index does not match general selection criteria” occurred.
number_of_geographic_region_filter_occurrences	Number of ground pixels where “pixel falls outside the specified regions of interest” occurred.
number_of_input_spectrum_warning_occurrences	Number of ground pixels where “number of good pixels in radiance, irradiance or calculated reflectance below threshold from configuration” occurred.
number_of_wavelength_calibration_warning_occurrences	Number of ground pixels where “offset from wavelength fit is larger than limit set in configuration” occurred.
number_of_extrapolation_warning_occurrences	Number of ground pixels where “pressure or temperature outside cross section LUT range, other lookup table extrapolation” occurred.
number_of_sun_glint_warning_occurrences	Number of ground pixels where “sun glint 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.
number_of_pixel_level_input_data_missing_occurrences	Number of ground pixels where “dynamic auxiliary input data (e.g.. cloud) is missing for this ground pixel. A fallback option is used” occurred.

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

Name	Description
number_of_data_range_warning_occurrences	Number of ground pixels where “carbon monoxide column tends to negative values; Water column tends to negative values; Heavy water (HDO) column tends to negative values; others. In case of the O_3 product this flag indicates VCD or effective albedo values outside a valid range. In case of the SO_2 or the HCHO product this flag indicates AMF values outside a valid range. 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.
number_of_altitude_consistency_warning_occurrences	Number of ground pixels where “difference between ECMWF surface elevation and high-resolution surface elevation exceeds threshold from configuration” occurred.
number_of_signal_to_noise_ratio_warning_occurrences	Number of ground pixels where “signal to noise ratio in SWIR and/or NIR band below threshold from configuration. For the O_3 and HCHO products this flag indicates an RMS above a certain threshold” occurred.
number_of_deconvolution_warning_occurrences	Number of ground pixels where “failed deconvolution irradiance spectrum (not pixel-specific, but row-specific)” occurred.
number_of_so2_volcanic_origin_likely_warning_occurrences	Number of ground pixels where “warning for SO_2 BL product, UTLS products: volcanic origin except for heavily polluted sites. 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.
number_of_cloud_retrieval_warning_occurrences	Number of ground pixels where “warning occurring when the retrieval diagnostic indicates a degraded quality of the cloud retrieval” occurred.

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 Carbon Monoxide 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 [RD40, RD41, RD42]
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 [RD39]
S5P	Internal use – mostly for retrieval settings, possibly as an extension to ISO 19115 [RD40]
S	Attribute is a string attribute
P	Attribute has the data-type of the variable with which it is associated (‘parent’ data type).
I	Attribute is an integer value
F	Attribute is a floating point value (either 32-bit or 64-bit).
T	Attribute is a CCSDS-ASCII time representation (“`UTC=`” + ISO 8601 [RD46])

We follow several metadata conventions in the S5P level 2 files, as can be seen in table 5. These include ISO 19115-2 [RD41], OGC 10.157r3 [RD43], the ESA earth observation header [RD39] 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, RD45]. The short version is that the attributes in the data file can be exported as NcML [RD53], 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 [RD39, RD25] specify the creation of a header file with a basic description of the contents of an output file. This header file consists of a fixed part and a customizable variable part. The variable part contains the lineage of the product is repeated, see section 10.2.3.43 for a description the the attributes contained in this part of the header. The fixed header is described in tables 6 – 8.

Table 6: Metadata in the fixed header required by the ESA earth observation file format standard. The data types refer to the short list in table 5.

Name	Data type	Definition
File_Name	S	File name of the product without extension.
File_Description	S	Description of the file type.
Notes	S	Any type of notes/comments (multi-lines).
Mission	S	Description of the mission (Fixed to “S5P”)
File_Class	S	Description of the file class. It is redundant with the File Class element embedded in the File Name.(e.g., “NRTI”)
File_Type	S	Description of the file type, for the current product it is set to “L2_-_Carbon Monoxide”. It is redundant with the File Type element embedded in the File Name.
Validity_Period	Group, see table 7	Time coverage of the data.
File_Version	I	It is redundant with the File Version element embedded in the File Name.
Source	Group, see table 8	Information about the ground segment facility where the product was generated.

Table 7: Fields in the Validity_Period group. The data types refer to the short list in table 5.

Name	Data type	Definition
Validity_Start	T	This is the UTC Validity Start Time, the same as the Validity Start Time in the File Name and the time_coverage_start global attribute.
Validity_Stop	T	This is the UTC Validity Stop Time, the same as the Validity Stop Time in the File Name and the 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	T	This is the UTC Creation Date. This field also appears in the file name and in the date_created global attribute.

13.5 Inspire directive

INSPIRE is based on the infrastructures for spatial information established and operated by the 27 Member States of the European Union. The INSPIRE directive came into force on 15 May 2007 and will be developed in several stages until a complete release with due date set in 2019. The INSPIRE directive aims to create a European Union (EU) spatial data infrastructure. This will enable the sharing of environmental spatial information among public sector organizations and better facilitate public access to spatial information across Europe. The European Commission issued a Metadata Regulation [RD54] 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 [RD55] define how the Regulation can be implemented using ISO 19115. As also reported in [RD45], 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 [RD41] and ISO 19156 [RD56], 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 [RD48]
2. OGC 10-025C [RD57]
3. OGC 10-157 [RD43]

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 [RD45].

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: `-0x1.ep+122`) is recommended for these cases.

Type	Description	Fill value
byte	8-bit signed integer	-127
ubyte	8-bit unsigned integer	255
short	16-bit signed integer	-32767
ushort	16-bit unsigned integer	65535
int	32-bit signed integer	-2147483647
uint	32-bit unsigned integer	4294967295
float	32-bit floating point	$9.9692099683868690 \times 10^{36}$ (hex: `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 km^2 to data-fields.
comment	S	CF	Miscellaneous information about the data or methods used to produce it.
coordinates	S	CF	Identifies auxiliary coordinate variables, providing a connection between data and geolocation, time.
_FillValue	P	NUG	Value to represent missing or undefined data. Recommended (default) values are given in table 9.
flag_masks	P	CF	Provides a list of bit fields expressing Boolean or enumerated flags.
flag_meanings	S	CF	Use in conjunction with flag_values to provide descriptive words or phrases for each flag value.
flag_values	P	CF	Provides a list of the flag values. Use in conjunction with flag_meanings.
formula	S	CF	Formula to calculate the values for an adaptive grid, for instance for a dimensionless vertical coordinate. Example: "`hyam hybm (mlev=hyam+hybm*aps)`".
formula_terms	S	CF	Identifies variables that correspond to the terms in a formula, for instance for a dimensionless vertical coordinate. Example: "`ap: hyam b: hybm ps: aps`"
institution	S	CF	Specifies where the original data was produced.
long_name	S	CF	A descriptive name that indicates a variable's content. This name is not standardized.
positive	S	CF	Direction of increasing vertical coordinate value ('up' for z in m or 'down' for p in hPa).
references	S	CF	References that describe the data or methods used to produce it.
source	S	CF	Method of production of the original data.

Table 10: Attributes for variables used in S5p netCDF-4 files (continued).

Name	Type	Std.	Description
standard_error_multiplier	F	CF	If a data variable with a standard_name modifier of standard_error has this attribute, it indicates that the values are the stated multiple of one standard error. The only allowed value for S5p files is 1, used only to disambiguate.
standard_name	S	CF	A standard name that references a description of a variable's content in the standard name table.
units	S	CF	Units of a variable's content. See section 11 for a detailed discussion.
valid_max	P	NUG	Largest valid value of a variable.
valid_min	P	NUG	Smallest valid value of a variable.
valid_range	P[2]	NUG	Smallest and largest valid values of a variable. This attribute should not be combined with either valid_min or valid_max

A Flag descriptions

The following tables describe the Measurement flags, Processing quality flags (processing failures and filter conditions, errors and warnings) and surface classifications.

Table 11: Processing quality flags, errors, processing failures and filter conditions for S5P Level 2. Warnings are listed in table 12. The value in the first column is the result of a bitwise 'and' of 255 (0xFF) and the value in the "processing_quality_flags" variable.

#	Short name	Description	Algorithm
0	success	No failures, output contains value. Warnings still possible.	All
1	radiance_missing	The number of spectral pixels in the radiance due to flagging is too small to perform the fitting.	All
2	irradiance_missing	The number of spectral pixels in the irradiance due to flagging is too small to perform the fitting.	All
3	input_spectrum_missing	The reflectance spectrum does not contain enough points to perform the retrieval. This is different from (ir)radiance_missing in that the missing points may not be aligned.	All
4	reflectance_range_error	Any of the reflectances is out of bounds ($R < 0$ or $R > R_{\text{max}}$).	FRESCO
5	ler_range_error	Lambert-equivalent reflectivity out of range error.	CO, CH_4
6	snr_range_error	Too low signal to noise to perform retrieval.	CO
7	sza_range_error	Solar zenith angle out of range, maximum value from configuration.	All
8	vza_range_error	Viewing zenith angle out of range, maximum value from configuration.	Development phase only
9	lut_range_error	Extrapolation in lookup table (airmass factor, cloud radiances).	NO_2
10	ozone_range_error	Ozone column significantly out of range of profile climatology.	Total O_3 column
11	wavelength_offset_error	Wavelength offset exceeds maximum from configuration.	FRESCO, NO_2
12	initialization_error	An error occurred during the processing of the pixel, no output was generated. The following errors raise this flag: Mismatch between irradiance and radiance wavelengths; The on-ground distance between band 1 and band 2 ground pixels exceeds a threshold set in the configuration. Derived a-priori information does not validate, no processing is possible.	All
13	memory_error	Memory allocation or deallocation error.	CO, CH_4
14	assertion_error	Error in algorithm detected during assertion.	CO
15	io_error	Error detected during transfer of data between algorithm and framework.	CO, ALH, CH_4, O_3 profile
16	numerical_error	General fatal numerical error occurred during inversion.	CO, FRESCO
17	lut_error	Error in accessing the lookup table.	CH_4
18	ISRF_error	Error detected in the input instrument spectral response function input data.	CH_4
19	convergence_error	The main algorithm did not converge.	All
20	cloud_filter_convergence_error	The cloud filter did not converge.	CO

Table 11: Processing quality flags, errors, processing failures and filter conditions for S5P Level 2 (continued).

#	Short name	Description	Algorithm
21	max_iteration_convergence_error	No convergence because retrieval exceeds maximum number of iterations. Maximum value from configuration.	ALH
22	aot_lower_boundary_convergence_error	No convergence because the aerosol optical thickness crosses lower boundary twice in succession.	ALH
23	other_boundary_convergence_error	No convergence because a state vector element crosses boundary twice in succession. Note that a separate failure flag is defined for non-convergence due to crossing of lower AOT boundary.	ALH
25	ch4_noscat_zero_error	The CH_4 column retrieved by the non-scattering CO algorithm from the weak band or strong band is 0.	CH_4
26	h2o_noscat_zero_error	The H_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.	CH_4
29	boundary_hit_error	Fatal boundary hit during iterations.	CH_4
30	chi2_error	χ^2 is not-a-number or larger than 10^{10}.	CH_4
31	svd_error	Singular value decomposition failure.	CH_4
32	dfs_error	Degree of freedom is not-a-number.	CH_4
33	radiative_transfer_error	Errors occurred during the radiative transfer computations, no processing possible.	O_3 profile
34	optimal_estimation_error	Errors occurred during the optimal estimation, processing has been terminated.	O_3 profile
35	profile_error	Flag that indicates if there were any errors during the computation of the ozone profile.	O_3 profile
36	cloud_error	No cloud data.	Cloud
37	model_error	Forward model failure.	Cloud, Total O_3 column
38	number_of_input_data_points_too_low_error	Not enough input ozone columns to calculate a tropospheric column.	Tropospheric O_3 column
39	cloud_pressure_spread_too_low_error	Cloud pressure variability 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 climatologcal surface albedo exceeds threshold. Threshold value from ATBD. This test filters out clouds.	ALH
74	small_pixel_radiance_std_filter	Pixel contains clouds: Standard deviation of radiances in small-pixel column exceeds threshold. Threshold value from ATBD.	ALH, CH_4
75	cloud_fraction_viirs_filter	Pixel contains clouds: The cloud fraction from VIIRS / NPP exceeds theshold. 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 wihtin 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 wihtin 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 wihtin S5P NIR OFOVc exceeds a priori threshold from configuration.	CH_4
85	refl_cirrus_viirs_swir_filter	Average VIIRS cirrus reflectance within SWIR ground pixel exceeds a priori threshold from configuration.	CH_4
86	refl_cirrus_viirs_nir_filter	Average VIIRS cirrus reflectance within NIR ground pixel exceeds a priori threshold from configuration.	CH_4
87	diff_refl_cirrus_viirs_filter	Difference in VIIRS average cirrus reflectance between SWIR and NIR ground pixel exceeds a priori threshold from configuration.	CH_4
88	ch4_noscat_ratio_filter	The ratio between $[CH_4]_{weak}$ and $[CH_4]_{strong}$ is below or exceeds a priori thresholds from configuration.	CH_4
89	ch4_noscat_ratio_std_filter	The standard deviation of $[CH_4]_{weak}/[CH_4]_{strong}$ within the SWIR pixel and the 8 neighbouring pixels exceeds a priori threshold from configuration.	CH_4
90	h2o_noscat_ratio_filter	The ratio between $[H_2O]_{weak}$ 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.	CH_4
93	psurf_fresco_stdv_filter	The standard deviation of the FRESCO apparent surface pressure in the NIR pixel and the 8 surrounding pixels exceeds a priori threshold from configuration.	CH_4
94	ocean_filter	The ground pixel is over ocean (and ocean glint retrievals are not switched on).	CH_4
95	time_range_filter	Time is out of the range that is to be processed.	All
96	pixel_or_scanline_index_filter	Not processed because pixel index does not match general selection criteria.	All
97	geographic_region_filter	Pixel falls outside the specified regions of interest.	All

Table 12: Processing quality flags, warnings for S5P Level 2. Errors, processing failures and filter conditions are listed in table 11. If a bitwise 'and' of the mask value and the value in the "processing_quality_flags" variable is not zero, then the warning applies to the specific retrieval.

Bit #	Mask (hex)	Short name	Description	Algorithm
0–7	0x000000FF	error	If non-zero an error has occurred when processing the pixel, see table 11 for details.	All
8	0x00000100	input_spectrum_warning	Number of good pixels in radiance, irradiance or calculated reflectance below threshold from configuration.	All
9	0x00000200	wavelength_calibration_warning	Offset from wavelength fit is larger than limit set in configuration.	Most
10	0x00000400	extrapolation_warning	Pressure or temperature outside cross section LUT range, other lookup table extrapolation.	CO, CH_4
11	0x00000800	sun_glint_warning	Sun glint 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
14	0x00004000	snow_ice_warning	Snow/ice flag is set, i.e. using scene data from the cloud support product.	NO_2, Cloud
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
16	0x00010000	AAI_warning	Possible aerosol contamination as either indicated by the AAI (O_3 profile).	O_3 profile

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

Bit #	Mask (hex)	Short name	Description	Algorithm
17	0x00020000	pixel_level_input_data_missing	Dynamic auxiliary input data (e.g.. cloud) is missing for this ground pixel. A fallback option is used.	All
18	0x00040000	data_range_warning	Carbon monoxide column tends to negative values; Water column tends to negative values; Heavy water (HDO) column tends to negative values; others. In case of the O_3 product this flag indicates VCD or effective albedo values outside a valid range. In case of the SO_2 or the HCHO product this flag indicates AMF values outside a valid range. 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.	CO, CH_4, O_3, SO_2, HCHO, O_3 profile
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
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 [RD47].

Bit #	Mask (hex)	Short name	Description
0	0x03	Land	The pixel is over land, for more than 50 %
1	0x03	Water	The pixel is over water, for more than 50 %
2	0x03	some_water	Pixel contains water (however small the fraction), i.e. at least one of the 15×15 arcsecond subpixels in the SDP dataset is classified as water
3	0x03	coastline	Pixel is water, but contains land (coastline)
0	0x04	mixed_surface	Pixel has a mixed surface type. Classification is result of highest bin, not overwhelming majority, i.e. type covers less than 50 % of pixel surface
4	0x04	value_covers_majority_of_pixel	Pixel is dominated by surface type, i.e. type covers more than 50 % of pixel surface
9	0xF9	Water+Shallow_Ocean	Water, shallow ocean
17	0xF9	Water+Shallow_Inland_Water	Water, shallow inland water (lake)
25	0xF9	Water+Ocean_Coastline-Lake_Shoreline	Water, mixed with land; coastline
33	0xF9	Water+Intermittent_Water	Intermittent water, for instance the Wadden Sea
41	0xF9	Water+Deep_Inland_Water	Deep inland water
49	0xF9	Water+Continental_Shelf_Ocean	Water, continental shelf ocean
57	0xF9	Water+Deep_Ocean	Water, deep ocean
8	0xF9	Land+Urban_And_Built-up_Land	Land, urban areas
16	0xF9	Land+Dryland_Cropland_And_Pasture	Land, Dryland Cropland and Pasture
24	0xF9	Land+Irrigated_Cropland_And_Pasture	Land, Irrigated Cropland and Pasture
32	0xF9	Land+Mixed_Dryland-irrigated_Cropland_And_Pasture	Land, Mixed Dryland/Irrigated Cropland and Pasture
40	0xF9	Land+Cropland-grassland_Mosaic	Land, Cropland/Grassland Mosaic
48	0xF9	Land+Cropland-woodland_Mosaic	Land, Cropland/Woodland Mosaic
56	0xF9	Land+Grassland	Land, Grassland
64	0xF9	Land+Shrubland	Land, Shrubland
72	0xF9	Land+Mixed_Shrubland-grassland	Land, Mixed Shrubland/Grassland
80	0xF9	Land+Savanna	Land, Savanna
88	0xF9	Land+Deciduous_Broadleaf_Forest	Land, Deciduous Broadleaf Forest

Table 13: Surface classification for S5P Level 2 (continued).

Bit #	Mask (hex)	Short name	Description
96	0xF9	Land+Deciduous_Needleleaf_Forest	Land, Deciduous Needleleaf Forest
104	0xF9	Land+Evergreen_Broadleaf_Forest	Land, Evergreen Broadleaf Forest
112	0xF9	Land+Evergreen_Needleleaf_Forest	Land, Evergreen Needleleaf Forest
120	0xF9	Land+Mixed_Forest	Land, Mixed Forest
128	0xF9	Land+Herbaceous_Wetland	Land, Herbaceous Wetland
136	0xF9	Land+Wooded_Wetland	Land, Wooded Wetland
144	0xF9	Land+Barren_Or_Sparsely_Vegetated	Land, Barren or Sparsely Vegetated
152	0xF9	Land+Herbaceous_Tundra	Land, Herbaceous Tundra
160	0xF9	Land+Wooded_Tundra	Land, Wooded Tundra
168	0xF9	Land+Mixed_Tundra	Land, Mixed Tundra
176	0xF9	Land+Bare_Ground_Tundra	Land, Bare Ground Tundra
184	0xF9	Land+Snow_Or_Ice	Land, Snow or Ice