

# Sentinel-5 precursor/TROPOMI Level 2 Product User Manual O<sub>3</sub> Tropospheric Column





document number	: S5P-L2-DLR-PUM-400C
authors	: Mattia Pedergnana, Diego Loyola, Arnoud Apituley, Maarten Sneep, J. Pepijn Veefkind
CI identification	: CI-400C-PUM
issue	: 01.01.01
date	: 2018-07-16
status	: released

## Document approval record

	digital signature
Prepared:	
Checked:	
Approved PM:	
Approved QA:	
Approved CM:	

## Contents

Document	t approval record	2
List of Tab	bles	3
List of Fig	jures	3
-	Bx>'s	3
	Introduction	5
	t change record	5
	Identification	6
	Purpose and objective	6
	Document overview	6
2 A	Applicable and reference documents	7
	Applicable documents	7
2.2 5	Standard documents	7
	Reference documents	7
	Electronic references	9
	Terms, definitions and abbreviated terms	10
	Terms and definitions	10
	Acronyms and Abbreviations	10
	Overview of the Sentinel 5 precursor/TROPOMI Level 2 Products	10
	File name convention	11
	Data Distribution	11
6 C	General Reader and Visualisation Tools	11
7 S	S5p/TROPOMI L2 O <sub>3</sub> Tropospheric Column Product Description	13
	Data Product Examples	13
	Product Geophysical Validation	13
	History of product changes	13
	Using the S5p/TROPOMI L2 $O_3$ Tropospheric Column	14
	General structure of S5P/TROPOMI Level 2 files	<b>15</b> 17
	S5p/TROPOMI L2 File Format	17
	Dimensions and dimension ordering	17
	Time information	18
	Vertical coordinates	19
9 L	Units	19
10 C	Quality Assurance parameters	20
	Generic metadata and attributes	29
	The Climate and Forecast conventions	29
	NetCDF User Guide Conventions	30
11.3 0	Global attributes	30
11.4 E	ESA earth observation header	30
	Inspire directive	31
	ISO and OGC standards	31
	Attributes	31
	Common elements in all S5P products	34
	Description of the O <sub>3</sub> Tropospheric Column product	34
	Group "PRODUCT" in "O3_TCL"	35
	Group "SUPPORT_DATA" in "PRODUCT"	40
	Group "METADATA" in "O3_TCL" Group "QA STATISTICS" in "METADATA"	48 49
	Group "ALGORITHM_SETTINGS" in "METADATA"	49 50
	Group "GRANULE DESCRIPTION" in "METADATA"	51
	Flag descriptions	51

## List of Tables

1	Standard S5P L2 products with name, identifier and responsible institutes	10
2	Components of an S5P file name	11
3	History of product changes of O <sub>3</sub> Tropospheric Column	14
4	Reference times available in a S5P L2 file	19
5	Quality assurance parameters	21
6	Abbreviations used in metadata descriptions	29
7	Metadata in the fixed header required by the ESA earth observation file format standard	30
8	Fields in the Validity_Period group	30
9	Fields in the source group	30
10	netCDF-4 type definitions and fill values	32
11	Attributes for variables used in S5p netCDF-4 files	32
12	Processing quality flags, errors, processing failures and filter conditions for S5P Level 2	52
13	Processing quality flags, warnings for S5P Level 2	56
14	Surface classification for S5P Level 2	57

## List of Figures

1	Panoply	12
2	A full day plot of the O <sub>3</sub> Tropospheric Column product acquired on 29th March 2018. Further	
	quicklooks may be found here: https://atmos.eoc.dlr.de/tropomi	14
3	Graphical description of the generic structure of a Level 2 file	16
4	Pixel corner coordinates.	18

## List of <TBx>'s

1	Data Distribution	11
2	Readme document for O <sub>3</sub> Tropospheric Column	13
3	Specific aspects of the O <sub>3</sub> Tropospheric Column product	14
4	Variable units	37

## 1 Introduction

## Document change record

issue	date	item	comments
0.0.1	2014-05-12	All	Initial version
0.1.0	2014-10-14	All	Document ported to LATEX
		Sect. 4	CDR RID #8 solved
		All	Reorder of the docs: generic part first and specific sections after. CDR RID #9 solved.
		All	One single template is now used for all the PUMs. CDR RID #12 and #13 solved.
		Sec. 8	Added figure explaining geocoordinates order and reference in the text. (CDR RID #5)
0.7.0	2015-03-27	All	Document totally revised: Sections moved and added. Description of the product updated
0.7.1	2015-06-09		Added example figures for a preliminary release (AI only)
0.8.0	2015-09-07		Prepared for preliminary, limited, release
0.9.1	2015-12-15		PUMs updated. File descriptors in line with the last product defini- tion
0.10.0	2016-03-31		Product descriptions updated for 0.10.0 release
00.10.01	2016-07-15		Product descriptions updated for DLR 00.10.01 release
00.11.00	2016-11-15	All	Product descriptions updated for DLR 00.11.01 release
		All	Variables names changed in the context of the MPC variables harmonization
01.01.01	2018-07-16	Sec. 7	The chapter containing the specific description of $O_3$ Tropospheric Column has been totally revised and updated with the latest information available
		Sec. 11.7	The file format definition of $O_3$ Tropospheric Column has been aligned with version 1.1.1 of UPAS

### 1.1 Identification

This document, identified as S5P-L2-DLR-PUM-400C, 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  $O_3$  Tropospheric Column.

### 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  $O_3$  Tropospheric Column 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  $O_3$  Tropospheric Column 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  $O_3$  Tropospheric Column 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

There are no applicable documents

### 2.2 Standard documents

There are no standard documents

### 2.3 Reference documents

- [RD1] J. P. Veefkind, I. Aben, K. McMullan *et al.*; TROPOMI on the ESA Sentinel-5 Precursor: A GMES mission for global observations of the atmospheric composition for climate, air quality and ozone layer applications. *Remote Sens. Environ.*; **120** (2012), 70; 10.1016/j.rse.2011.09.027.
- [RD2] Input/output data specification for the TROPOMI L01b data processor. source: KNMI; ref: S5P-KNMI-L01B-0012-SD; issue: 5.0.0; date: 2015-09-22.
- [RD3] S5P/TROPOMI ATBD Cloud Products. source: DLR; ref: S5P-DLR-L2-ATBD-400I; issue: 1.5.0; date: 2018-04-30.
- [RD4] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Cloud. source: DLR; ref: S5P-L2-DLR-PUM-400I; issue: 1.0.0; date: 2018-04-30.
- [RD5] S5P-NPP Cloud Processor ATBD. source: RAL Space; ref: S5P-NPPC-RAL-ATBD-0001; issue: 0.11.0; date: 2014-05-15.
- [RD6] S5P/TROPOMI HCHO ATBD. source: BIRA; ref: S5P-BIRA-L2-400F-ATBD; issue: 1.0.0; date: 2016-02-05.
- [RD7] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual HCHO. source: DLR; ref: S5P-L2-DLR-PUM-400F; issue: 1.0.0; date: 2018-04-30.
- [RD8] S5P/TROPOMI SO<sub>2</sub> ATBD. source: BIRA; ref: S5P-BIRA-L2-400E-ATBD; issue: 1.0.0; date: 2016-02-05.
- [RD9] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual SO<sub>2</sub>. source: DLR; ref: S5P-L2-DLR-PUM-400E; issue: 1.0.0; date: 2018-04-30.
- [RD10] S5P/TROPOMI Total ozone ATBD. source: DLR/BIRA; ref: S5P-L2-DLR-ATBD-400A; issue: 1.0.0; date: 2016-02-01.
- [RD11] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Total Ozone Column. source: DLR; ref: S5P-L2-DLR-PUM-400A; issue: 1.0.0; date: 2018-04-30.
- [RD12] TROPOMI ATBD of tropospheric ozone data products. source: DLR/IUP; ref: S5P-DLR-IUP-L2-400C; issue: 1.5.0; date: 2018-04-30.
- [RD13] TROPOMI ATBD of the Aerosol Layer Height product. source: KNMI; ref: S5P-KNMI-L2-0006-RP; issue: 1.0.0; date: 2016-01-29.
- [RD14] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Aerosol Layer Height. source: KNMI; ref: S5P-KNMI-L2-0022-MA; issue: 0.0.2dr; date: 2014-10-16.
- [RD15] TROPOMI ATBD of the UV aerosol index. source: KNMI; ref: S5P-KNMI-L2-0008-RP; issue: 1.0.0; date: 2016-02-03.
- [RD16] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Aerosol Index. source: KNMI; ref: S5P-KNMI-L2-0026-MA; issue: 0.0.2dr; date: 2014-10-16.
- [RD17] TROPOMI ATBD Ozone profile and tropospheric profile. source: KNMI; ref: S5P-KNMI-L2-0004-RP; issue: 0.13.0; date: 2015-09-15.

[RD18] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Ozone Profile and Tropospheric Ozone Profile.

source: KNMI; ref: S5P-KNMI-L2-0020-MA; issue: 0.0.2dr; date: 2014-10-16.

- [RD19] TROPOMI ATBD of the total and tropospheric NO<sub>2</sub> data products. source: KNMI; ref: S5P-KNMI-L2-0005-RP; issue: 1.0.0; date: 2016-02-05.
- [RD20] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Nitrogen Dioxide. source: KNMI; ref: S5P-KNMI-L2-0021-MA; issue: 0.0.2dr; date: 2014-10-16.
- [RD21] Algorithm Theoretical Baseline Document for Sentinel-5 Precursor: Carbon Monoxide Total Column Retrieval.

source: SRON; ref: SRON-S5P-LEV2-RP-002; issue: 1.0.0; date: 2016-02-05.

- [RD22] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Carbon Monoxide Column. source: SRON/KNMI; ref: SRON-S5P-LEV2-MA-002; issue: 0.0.2dr; date: 2014-10-16.
- [RD23] Algorithm Theoretical Baseline Document for Sentinel-5 Precursor methane retrieval. **source:** SRON; **ref:** SRON-S5P-LEV2-RP-001; **issue:** 1.0.0; **date:** 2016-02-05.
- [RD24] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Methane. source: SRON/KNMI; ref: SRON-S5P-LEV2-MA-001; issue: 0.0.2dr; date: 2014-10-16.
- [RD25] Tailoring of the Earth Observation File Format Standard for the Sentinel 5 precursor Ground Segment. source: ESA/ESTEC; ref: S5P-TN-ESA-GS-106; issue: 2.2; date: 2015-02-20.
- [RD26] Earth Observation Ground segment file format standard. source: ESA/ESTEC; ref: PE-TN-ESA-GS-0001; issue: 2.0; date: 2012-05-03.
- [RD27] Geographic information Metadata. source: ISO; ref: ISO 19115:2003(E); issue: 1; date: 2003-05-01.
- [RD28] 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.
- [RD29] Geographic information Data quality. source: ISO; ref: ISO 19157; issue: 1; date: 2013-10-10.
- [RD30] Earth Observation Metadata profile of Observations & Measurements. source: Open Geospatial Consortium; ref: OGC 10-157r3; issue: 1.0; date: 2012-06-12.
- [RD31] Data Standards Requirements for CCI Data Producers. source: ESA; ref: CCI-PRGM-EOPS-TN-13-0009; issue: 1.1; date: 2013-05-24.
- [RD32] Metadata specification for the TROPOMI L1b products. source: KNMI; ref: S5P-KNMI-L01B-0014-SD; issue: 2.0.0; date: 2014-12-09.
- [RD33] Sentinel-4 UVN Phase B2, C/D and support to phase E1 Level 0 to Level 1b data processing software Input/Output Data Specification (IODS): Level 1b output products and metadata contents and format. source: ESA/ESTEC; ref: S4.ESA.UVN.TN.1206; issue: 1.0; date: 2011-06-23.
- [RD34] Algorithm theoretical basis document for the TROPOMI L01b data processor. source: KNMI; ref: S5P-KNMI-L01B-0009-SD; issue: 6.0.0; date: 2015-09-22.
- [RD35] 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.
- [RD36] John Caron; Annotated Schema for NcML (2011). URL http://www.unidata.ucar.edu/ software/netcdf/ncml/v2.2/AnnotatedSchema4.html.
- [RD37] INSPIRE Metadata Regulation, Commission Regulation (EC), No1205/2008. source: EC; ref: Commission Regulation (EC) No 1205/2008; date: 2008-12-03.

[RD38] 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.

- [RD39] Geographic Information Observations and Measurements. source: ISO; ref: ISO 19156:2011(E); date: 2011-12-20.
- [RD40] Geographic information Metadata XML schema implementation. source: ISO; ref: ISO 19139:2007(E); issue: 1; date: 2010-12-13.
- [RD41] Observations and Measurements XML Implementation. source: OGC; ref: OGC 10-025r1; issue: 2.0; date: 2011-03-22.
- [RD42] 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.

### 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] Unidata; NetCDF library and documentation. URL http://www.unidata.ucar.edu/software/ netcdf/.
- [ER9] UDUNITS 2 Manual (2011). URL http://www.unidata.ucar.edu/software/udunits/.
- [ER10] 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.
- [ER11] 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.
- [ER12] The ECS SDP Toolkit (2012). DEM and land-sea mask data itself is available from ftp:// edhsl.gsfc.nasa.gov/edhs/sdptk/DEMdata; URL http://newsroom.gsfc.nasa.gov/ sdptoolkit/TKDownload.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 will make daily global observations of key atmospheric constituents, including ozone, nitrogen dioxide, sulfur dioxide, carbon monoxide, methane, formaldehyde as well as cloud and aerosol properties. The list of standard S5p/TROPOMI L2 products is given in table 1. Other products, such as UV index, are under development and will made available at a later date.

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

Product	ATBD	PUM	Identifier	Institution
Cloud	[RD3]	[RD4]	L2CLOUD_	DLR
NPP-VIIRS Clouds	[RD5]	[RD5]	L2NP_BDx	RAL
НСНО	[RD6]	[RD7]	L2HCHO	<b>BIRA/DLR</b>
SO <sub>2</sub>	[RD8]	[RD9]	L2S02	<b>BIRA/DLR</b>
O <sub>3</sub> Total Column	[RD10]	[RD11]	L203	<b>BIRA/DLR</b>
O <sub>3</sub> Tropospheric Column	[RD12]	This document	L203_TCL	IUP/DLR
Aerosol layer height	[RD13]	[RD14]	L2AER_LH	KNMI
Ultra violet aerosol index	[RD15]	[RD16]	L2AER_AI	KNMI
O <sub>3</sub> Full Profile	[RD17]	[RD18]	L203PR	KNMI
O <sub>3</sub> Troposheric Profile	[RD17]	[RD18]	L203_TPR	KNMI
Tropospheric NO <sub>2</sub>	[RD19]	[RD20]	L2NO2	KNMI
CO	[RD21]	[RD22]	L2C0	SRON/KNMI
CH <sub>4</sub>	[RD23]	[RD24]	L2CH4	SRON/KNMI

### 4.1 File name convention

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

In the current PUM the  $O_3$  Tropospheric Column product is described and an example of the full real name is as following:

S5P\_NRTI\_L2\_\_03\_TCL\_20140101T000000\_20140102T000000\_00099\_01\_000200\_20141010T173511.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 <b>T</b> HHMMSS". The "T" is a fixed character.
36	51	15	End of the granulein UTC as "YYYYMMDD <b>T</b> 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 <b>T</b> 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

**<TBA #1>** In this chapter, data distribution of TROPOMI  $O_3$  Tropospheric Column will be detailed during Phase *E2*.

## 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.

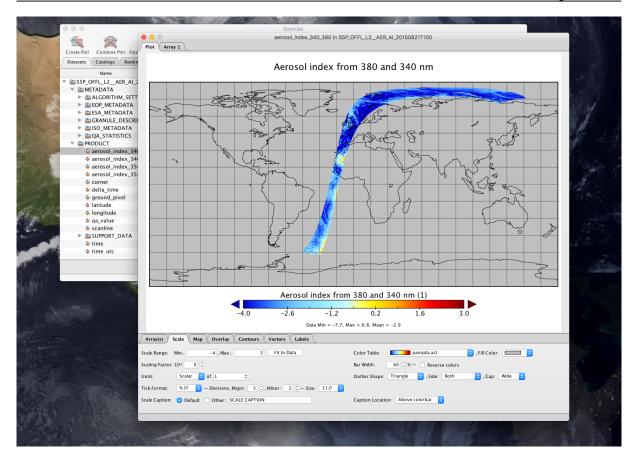


Figure 1: Panoply

- 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 S5p/TROPOMI L2 O<sub>3</sub> Tropospheric Column Product Description

The composition of the atmosphere has undergone dramatic changes in the last decades due to human activities. The quasi-exponential growth in the world population and the industrialization have led to a strong growth in fossil fuel and biomass burning emissions of trace gases such as carbon dioxide ( $CO_2$ ), carbon monoxide (CO), nitrogen oxides ( $NO_x$ ), methane ( $CH_4$ ), and other hydrocarbons. The emissions of nitrogen oxides and hydrocarbons have resulted in an increase of ozone ( $O_3$ ) near the surface and a degradation of air quality on a global scale. Although ozone is a trace gas and constitutes less than 0.001% of the air by volume, it is one of the most important constituents of the atmosphere. The ozone layer in the stratosphere protects the biosphere by absorbing harmful solar ultraviolet (UV) radiation. Downward transport of ozone from the stratosphere contributes to the ozone abundance in the troposphere, but ozone is also produced in the troposphere by sunlight driven chemical reaction cycles, involving  $NO_x$ , CO,  $CH_4$  and other hydrocarbons. This can lead to excessive amounts of ozone near the surface ('summer smog'), which are toxic to ecosystem, animals and men.

Ozone in the tropical troposphere plays various important roles. The intense UV radiation and high humidity in the tropics stimulate the formation of the hydroxyl radical (OH) by the photolysis of  $O_3$ . OH is the most important oxidant in the troposphere because it reacts with virtually all trace gases, such as CO, CH<sub>4</sub> and other hydrocarbons. The *tropopause*, which separates the troposphere from the stratosphere, is higher (17 km) and colder in the tropics, than at mid- and high latitudes. Since the radiative forcing by ozone is directly proportional to the temperature contrast between the radiation absorbed and the radiation emitted, ozone is most efficient as a greenhouse gas in the cold tropical upper troposphere.

The tropics are also characterized by large emissions of  $NO_x$ , CO and hydrocarbons, both from natural and anthropogenic sources. Ozone that is formed over regions where large amounts of these ozone precursors are emitted, can be transported over great distances and affects areas far from the source [RD12].

The O<sub>3</sub> Tropospheric Column files contain two main data sets, one *ozone\_tropospheric\_vertical\_column* gives the tropospheric column between the surface and the 270 hPa pressure level. It is based on the convective cloud differential (ccd) algorithm. The second dataset is based on a different approach the cloud slicing algorithm (csa) and contains the *ozone\_upper\_tropospheric\_mixing\_ratio* between the *cloud\_top\_pressure\_max* and the *cloud\_top\_pressure\_min*.

Refer to the specific ATBD [RD12] documentation for further information about the L2c O<sub>3</sub> Tropospheric Column.

### 7.1 Data Product Examples

Quicklooks are reported in this section as a data product examples of the  $O_3$  Tropospheric Column product (see Figure 2). Further quicklooks may be found here: https://atmos.eoc.dlr.de/tropomi

### 7.2 Product Geophysical Validation

In this chapter, main results from L2 geophysical validation will be presented when it becomes available. Preliminary key validation results were obtained by the Validation data Analysis Facility (VDAF) of the S5P Mission Performance Centre (MPC) and by the S5P Validation Team (S5PVT). The results were reported at the S5P First Public Release Validation Workshop (ESA/ESRIN, June 25th-26th, 2018). Individual contributions to the workshop are archived in http://s5pvt.skytek.com , while up-to-date validation results and consolidated validation reports are available through the MPC VDAF website at http://mpc-vdaf.tropomi.eu. The data are compared to previous satellite missions and to ozone sondes. However only few OFFL  $O_3$  Tropospheric Column data are available up to now and the amount of sonde overpasses is even more limited Therefore no clear conclusion can be drawn at the current state. A reference of the Readme file of  $O_3$  Tropospheric Column will be added as soon as the validation process will start and this document will be issued.

**<TBA #2>** To add references of the Validation Readme document as soon as the validation process for  $O_3$  Tropospheric Column will start.

### 7.3 History of product changes

This manual describes the current version of the L2 O<sub>3</sub> Tropospheric Column product. A brief description of data product changes is given here. Detailed description of the changes can be found in appropriate versions





Min: 1.671298 - Max: 51.30681

Algorithm UPAS-O3TCL-CCD-1.0.1 TROPOMI UPAS2 02.30.73

Sensor

S5P

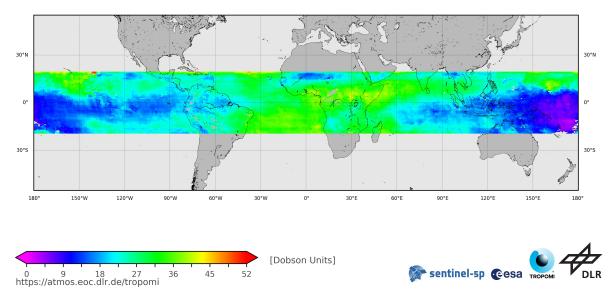


Figure 2: A full day plot of the O<sub>3</sub> Tropospheric Column product acquired on 29th March 2018. Further quicklooks may be found here: https://atmos.eoc.dlr.de/tropomi

of the ATBD.

Table 3: History of product changes of O<sub>3</sub> Tropospheric Column

Version	Description
1.1	The dimensions names have been updated reflecting the algorithm used (CCD or CSA)
0.12	Official version for E2 delivery

#### Using the S5p/TROPOMI L2 O<sub>3</sub> Tropospheric Column 7.4

<TBA #3> Specific aspects of the O<sub>3</sub> Tropospheric Column product to be filled during Phase E2.

## 8 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 8.3 - 8.2 and sections 9 - 11 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  $O_3$  Tropospheric Column files is given in section 13. Figure 3 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<sup>1</sup>.

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  $\chi^2$  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 [RD26, section 7] and items required by INSPIRE [ER4], ISO 19115 [RD27], ISO 19115-2 [RD28], ISO 19157 [RD29] and OGC 10-157r3 [RD30]. 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 [RD31]. 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.

<sup>&</sup>lt;sup>1</sup> More detailed processing flags indicating precisely why the 100 % value isn't reached, are available elsewhere in the product.

Sentinel 5P Level 2 product Global attributes
PRODUCT
main precision qa_value
latitude longitude delta_time
scanline ground_pixel time
SUPPORT_DATA
GEOLOCATIONS SZA
DETAILED_RESULTS (processing_quality_flags)
INPUT_DATA surface_pressure
METADATA
ALGORITHM_SETTINGS Attributes
GRANULE_DESCRIPTION Attributes
QA_STATISTICS Attributes
Histogram_axis Histogram
ESA_METADATA Attributes
ESA_METADATA Attributes
ISO_METADATA Attributes and sub-groups
Legend
Root level         First level group         Second level group
Third level group     Variable     Attributes

**Figure 3**: Graphical description of the generic structure of a Level 2 file. The elements labelled as a dimension are coordinate variables. See section 8 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 [RD32] 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 11.

Details of the specific format of the level 2 product file for the  $O_3$  Tropospheric Column product is given in section 13. Here all variables are described in detail. A dump output of the final structure proposed in Figure 3 shall have a hierarchy as follows:

```
/root/PRODUCT
/root/PRODUCT/SUPPORT_DATA
/root/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS
/root/PRODUCT/SUPPORT_DATA/GEOLOCATION
/root/METADATA
/root/METADATA/ALGORITHM_SETTINGS
/root/METADATA/GRANULE_DESCRIPTION
/root/METADATA/ISO_METADATA
/root/METADATA/ISO_METADATA
/root/METADATA/QA_STATISTICS
```

### Where root is the file itself or the outer level.

The geo-coordinates of the pixel corners are shown in Figure 4. Note that this choice follows the CF metadata standard [ER5, section 7.1].

### 8.1 S5p/TROPOMI L2 File Format

The file format used for all the L2 product is **netCDF-4** [ER8]. This file format is very versatile and flexible and will be used for other Sentinel missions, e.g. S4 mission [RD33], as well as other ESA and NASA missions. The netCDF-4 library is built on top of NetCDF-3 and HDF-5 libraries and it allows a grouping mechanism as well as a wide collection of datatypes and other features tailored from the HDF-5 library. This permits the user to use either the netCDF-4 or HDF-5 APIs in order to read the data. Those APIs are written in many data-analysis packages such as IDL, NCO, Matlab, R, and Mathematica or in general programming languages including Python, Ruby, C, C++, Java and Fortran 90.

### 8.2 Geolocation, pixel corners and angles

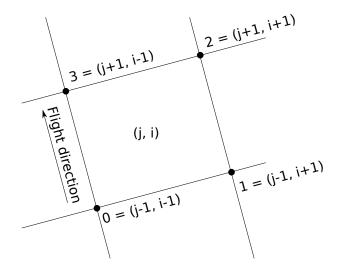
The latitude, longitude, pixel corner coordinates and related angles and satellite position in the level 2 files are copied from the level 1B input data [RD34, chapters 26 and 27]. Details about the definitions can be found there. Note that the latitude and longitude have not been corrected for the local 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 4. Note that this choice follows the CF metadata standard [ER5, section 7.1].

The azimuth angles, i.e. the solar azimuth angle  $\varphi_0$  and the viewing azimuth angle  $\varphi$  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.

### 8.3 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 3.



**Figure 4**: Pixel corner coordinates. The sequence  $\{0, 1, 2, 3\}$  refers to the elements in the corner dimension.

**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 8.4.

scanline The dimension that indicates the flight direction.

ground\_pixel The dimension perpendicular to the flight direction.

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<sup>2</sup>.

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<sub>2</sub> column** This variable contains a single value per ground pixel, and the dimensions are (time, scanline, ground\_pixel).

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

### 8.4 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 4. The offset of individual measurements within the granule is given in milliseconds with respect to this reference time in the variable delta\_time.

<sup>&</sup>lt;sup>2</sup> Fortran uses column-major order, effectively reversing the dimensions in the code compared to the documentation.

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 [RD35].

**Table 4**: Reference times available in a S5P L2 file. Types: (A) global attribute, (D) dimensional variable, (V) variable. All reference times ignore leap seconds.

Name	Туре	Description
time_reference	(A)	ISO date/time string [RD35]
time_reference_days_since_1950	(A)	The number of days since January first, 1950, UTC mid- night, 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 [RD35], one for each obser- vation, i.e. one for each element in the scanline dimension

### 8.5 Vertical coordinates

Different ATBD authors have specified different vertical grids for the retrieval, which means that the various Level 2 products are not consistent in this respect. There are several options, depending on the choice made by the authors of the retrieval algorithm. Some authors choose to use a vertical grid on a fixed height scale<sup>3</sup>, others use a grid that is defined in pressure relative to the surface pressure, similar to the ECMWF vertical grid.

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

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

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

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

### 9 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 [ER9] package to handle units. The CF metadata conventions reinforce this requirement [ER5, sections 1.3 and 3.1].

Making the UDUnits package [ER9] a requirement, and thereby forcing all units to be compliant with formal SI units<sup>4</sup> is a good thing for consistency and will help avoid confusion in the long run. In the short term it will

<sup>&</sup>lt;sup>3</sup> This is 'height' as defined by the CF conventions: distance above the surface; 'altitude' is the distance above the geoid or approximate sea level. <sup>4</sup> And some deeply entrenched non-SI units such as DU.

require adjustments within the earth observation community, as many of the units that the user community is accustomed to are not SI, and are therefore not available within the UDUnits package. The MAG has decided that Sentinel 5 precursor will represent all level 2 output in SI units. In particular, all column amounts will be given in mol  $m^{-2}$ .

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

- multiplication\_factor\_to\_convert\_to\_molecules\_percm2 Multiply the contents of the variable with this scale factor ( $6.02214 \times 10^{+19}$ ) to obtain columns in molecules cm<sup>-2</sup>
- **multiplication\_factor\_to\_convert\_to\_DU** Multiply the contents of the variable with this scale factor (2241.15) to obtain columns in DU.
- multiplication\_factor\_to\_convert\_to\_photons\_persecond\_pernm\_percm2\_persr Multiply the contents of the variable with this scale factor  $(6.02214 \times 10^{+19})$  to obtain a radiance in photons s<sup>-1</sup> nm<sup>-1</sup> cm<sup>-2</sup> sr<sup>-1</sup>.

### **10 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 12 and 13. 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 5.

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:

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

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

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

**Table 5**: 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_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.
<pre>number_of_reflectance_range_error_occurrences</pre>	Number of ground pixels where "any of the reflectances is out of bounds $(R < 0 \text{ or } R > R_{max})$ " 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.
number_of_ozone_range_error_occurrences	Number of ground pixels where "ozone column significantly out of range of profile climatology" occurred.

Name	Description
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" oc- curred.
number_of_cloud_filter_convergence_error_occurrences	Number of ground pixels where "the cloud filter did not converge" occurred.
<pre>number_of_max_iteration_convergence_error_occurrences</pre>	Number of ground pixels where "no convergence because retrieval exceeds maximum number of iterations. Maximum value from configuration" occurred.
<pre>number_of_aot_lower_boundary_convergence_error_occurrences</pre>	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.
number_of_geolocation_error_occurrences	Number of ground pixels where "geolocation out of range" occurred.

Name	Description
number_of_ch4_noscat_zero_error_occurrences	Number of ground pixels where "the CH <sub>4</sub> column retrieved by the non- scattering CO algorithm from the weak band or strong band is 0" occurred.
<pre>number_of_h2o_noscat_zero_error_occurrences</pre>	Number of ground pixels where "the H <sub>2</sub> O column retrieved by the non- scattering CO algorithm from the weak band or strong band is 0" occurred.
number_of_max_optical_thickness_error_occurrences	Number of ground pixels where "maximum optical thickness exceeded during iterations" occurred.
number_of_aerosol_boundary_error_occurrences	Number of ground pixels where "boundary hit of aerosol parameters at last iteration" occurred.
number_of_boundary_hit_error_occurrences	Number of ground pixels where "fatal boundary hit during iterations" occurred.
number_of_chi2_error_occurrences	Number of ground pixels where " $\chi^2$ is not-a-number or larger than $10^{10}$ " occurred.
number_of_svd_error_occurrences	Number of ground pixels where "singular value decomposition failure" oc- curred.
number_of_dfs_error_occurrences	Number of ground pixels where "degree of freedom is not-a-number" occurred.
number_of_radiative_transfer_error_occurrences	Number of ground pixels where "errors occurred during the radiative transfer computations, no processing possible" occurred.
number_of_optimal_estimation_error_occurrences	Number of ground pixels where "errors occurred during the optimal estimation, processing has been terminated" occurred.
number_of_profile_error_occurrences	Number of ground pixels where "flag that indicates if there were any errors during the computation of the ozone profile" occurred.
number_of_cloud_error_occurrences	Number of ground pixels where "no cloud data" occurred.
number_of_model_error_occurrences	Number of ground pixels where "forward model failure" occurred.
<pre>number_of_number_of_input_data_points_too_low_error_occurrences</pre>	Number of ground pixels where "not enough input ozone columns to calculate a tropospheric column" occurred.
number_of_cloud_pressure_spread_too_low_error_occurrences	Number of ground pixels where "cloud pressure variability to low to estimate a tropospheric column" occurred.
number_of_cloud_too_low_level_error_occurrences	Number of ground pixels where "clouds are too low in the atmosphere to assume sufficient shielding" occurred.
number_of_generic_range_error_occurrences	Number of ground pixels where "generic range error" occurred.
number_of_generic_exception_occurrences	Number of ground pixels where "catch all generic error" occurred.

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 calibra- tion 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" oc- curred.
<pre>number_of_vertical_column_density_error_occurrences</pre>	Number of ground pixels where "vertical column density could not be com- puted" occurred.
<pre>number_of_signal_to_noise_ratio_error_occurrences</pre>	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" oc- curred.
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_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.

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.
<pre>number_of_mixed_surface_type_filter_occurrences</pre>	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 ac- cording 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.
<pre>number_of_cloud_fraction_fresco_filter_occurrences</pre>	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.
<pre>number_of_small_pixel_radiance_std_filter_occurrences</pre>	Number of ground pixels where "pixel contains clouds: Standard deviation of radiances in small-pixel column exceeds threshold. Threshold value from ATBD" occurred.
<pre>number_of_cloud_fraction_viirs_filter_occurrences</pre>	Number of ground pixels where "pixel contains clouds: The cloud fraction from VIIRS / NPP exceeds theshold. Threshold value from ATBD" occurred.
<pre>number_of_cirrus_reflectance_viirs_filter_occurrences</pre>	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.

S5P-L2-DLR-PUM-400C Page 25 of 59

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.
<pre>number_of_cf_viirs_nir_ofovc_filter_occurrences</pre>	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 reflect- ance between SWIR and NIR ground pixel exceeds a priori threshold from configuration" occurred.
<pre>number_of_ch4_noscat_ratio_filter_occurrences</pre>	Number of ground pixels where "the ratio between [CH <sub>4</sub> ] <sub>weak</sub> and [CH <sub>4</sub> ] <sub>strong</sub> is below or exceeds a priori thresholds from configuration" occurred.
<pre>number_of_ch4_noscat_ratio_std_filter_occurrences</pre>	Number of ground pixels where "the standard deviation of [CH <sub>4</sub> ] <sub>weak</sub> /[CH <sub>4</sub> ] <sub>strong</sub> within the SWIR pixel and the 8 neighbouring pixels exceeds a priori threshold from configuration" occurred.
<pre>number_of_h2o_noscat_ratio_filter_occurrences</pre>	Number of ground pixels where "the ratio between [H <sub>2</sub> O ] <sub>weak</sub> and [H <sub>2</sub> O ] <sub>strong</sub> is below or exceeds a priori thresholds from configuration" occurred.
<pre>number_of_h2o_noscat_ratio_std_filter_occurrences</pre>	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.

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.
<pre>number_of_pixel_or_scanline_index_filter_occurrences</pre>	Number of ground pixels where "not processed because pixel index does not match general selection criteria" occurred.
<pre>number_of_geographic_region_filter_occurrences</pre>	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 anom- aly 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" occurred.
number_of_AAI_warning_occurrences	Number of ground pixels where "possible aerosol contamination as indicated by the AAI" occurred.
<pre>number_of_pixel_level_input_data_missing_occurrences</pre>	Number of ground pixels where "dynamic auxiliary input data (e.g cloud) is missing for this ground pixel. A fallback option is used" occurred.
number_of_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" occurred.
<pre>number_of_low_cloud_fraction_warning_occurrences</pre>	Number of ground pixels where "low cloud fraction, therefore no cloud pres- sure retrieved" occurred.

Name	Description
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.
<pre>number_of_signal_to_noise_ratio_warning_occurrences</pre>	Number of ground pixels where "signal to noise ratio in SWIR and/or NIR band below threshold from configuration" occurred.
number_of_deconvolution_warning_occurrences	Number of ground pixels where "failed deconvolution irradiance spectrum (not pixel-specific, but row-specific)" occurred.
<pre>number_of_so2_volcanic_origin_likely_warning_occurrences</pre>	Number of ground pixels where "warning for SO <sub>2</sub> BL product, UTLS products: volcanic origin except for heavily polluted sites" occurred.
<pre>number_of_so2_volcanic_origin_certain_warning_occurrences</pre>	Number of ground pixels where "warning for SO <sub>2</sub> 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 caus- ing 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.
<pre>number_of_cloud_retrieval_warning_occurrences</pre>	Number of ground pixels where "warning occurring when the retrieval dia- gnostic indicates a degraded quality of the cloud retrieval" occurred.
<pre>number_of_cloud_inhomogeneity_warning_occurrences</pre>	Number of ground pixels where "the cloud coregistration inhomogeneity para- meter is above a given threshold" occurred.

## 11 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  $O_3$  Tropospheric Column product is given in the file format description, in section 11.7. Here we provide some background on what can be found in which location. The abbreviations listed in table 6 are used in the following part of this document to better identify the nature of the attributes.

**Table 6**: 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 [ER10] conventions	
ISO	ISO standards 19115, 19115-2 and 19157 [RD27, RD28, RD29]	
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 [RD26]	
S5P	Internal use – mostly for retrieval settings, possibly as an extension to ISO 19115 [RD27]	
S	Attribute is a string attribute	
Р	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).	
Т	Attribute is a CCSDS-ASCII time representation ("UTC=" + ISO 8601 [RD35])	

We follow several metadata conventions in the S5P level 2 files, as can be seen in table 6. These include ISO 19115-2 [RD28], OGC 10.157r3 [RD30], the ESA earth observation header [RD26] 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, RD32]. The short version is that the attributes in the data file can be exported as NcML [RD36], 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.

### 11.1 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.

### 11.2 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.

### 11.3 Global attributes

Global attributes that are present at the root level of a S5p L2 product as described in section **??**. These are mostly string attributes.

### 11.4 ESA earth observation header

The ESA earth observations file format guidelines and tailoring for S5P [RD26, 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 **??** for a description the the attributes contained in this part of the header. The fixed header is described in tables 7–9.

Table 7: Metadata in the fixed header required by the ESA earth observation file format standard. The data	ł
types refer to the short list in table 6.	

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 _O <sub>3</sub> Tropospheric Column". It is redundant with the File Type element embedded in the File Name.
Validity_Period	Group, see table 8	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 9	Information about the ground segment facility where the product was generated.

Table 8: Fields in the Validity\_Period group. The data types refer to the short list in table 6.

Name	Data type	Definition
Validity_Start	Т	This is the UTC Validity Start Time, the same as the Validity Start Time in the File Name and the time_coverage_start global attribute.
Validity_Stop	Т	This is the UTC Validity Stop Time, the same as the Validity Stop Time in the File Name and the time_coverage_end global attribute.

 Table 9: Fields in the source group. The data types refer to the short list in table 6.

Name	Data type	Definition
System	S	Name of the Ground Segment element creating the file.

Name	Data type	Definition
Creator	S	Name of the facility or tool, within the Ground Segment element, creating the file.
Creator_Version	S	Version of the tool.
Creation_Date	Т	This is the UTC Creation Date. This field also appears in the file name and in the date_created global attribute.

Table 9: Fields in the source group (continued).

### **11.5** 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 [RD37] 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 [RD38] define how the Regulation can be implemented using ISO 19115. As also reported in [RD32], 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.

### 11.6 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 [RD28] and ISO 19156 [RD39], 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 [RD40]
- 2. OGC 10-025C [RD41]
- 3. OGC 10-157 [RD30]

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 [RD32].

### 11.7 Attributes

In Table 11 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 6. The NetCDF attribute \_FillValue which represents missing or undefined data can assume the default values listed in Table 10.

**Table 10**: netCDF-4 type definitions and fill values. In order to avoid rounding errors, it is recommended to use the hexadecimal notation when specifying fill values for float and double types. Note that these are the netCDF-4 default fill values, there should be no need to specify these values explicitly. In some cases the fill value for float or double variables may fall within the valid range of a variable. For those cases an explicit fill value must be set, the value  $-9.9692099683868690 \times 10^{36}$  (hex:  $-0 \times 1.ep+122$ ) is recommended for these cases.

Туре	Description	Fill value
byte	8-bit signed integer	-127
ubyte	8-bit unsigned integer	255
short	16-bit signed integer	-32767
ushort	16-bit unsigned integer	65535
int	32-bit signed integer	-2147483647
uint	32-bit unsigned integer	4294967295
float	32-bit floating point	$9.9692099683868690 \times 10^{36}$ (hex: 0x1.ep+122)
double	64-bit floating point	$9.9692099683868690 \times 10^{36}$ (hex: 0x1.ep+122)

Table 11: Attributes for variables used in S5p netCDF-4 files. The data types refer to the short list in table 6.

Name	Туре	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 <sup>2</sup> to data-fields.
comment	S	CF	Miscellaneous information about the data or methods used to produce it.
coordinates	S	CF	Identifies auxiliary coordinate variables, providing a connection between data and geolocation, time.
_FillValue	Р	NUG	Value to represent missing or undefined data. Recommended (default) values are given in table 10.
flag_masks	Р	CF	Provides a list of bit fields expressing Boolean or enumerated flags.
flag_meanings	S	CF	Use in conjunction with flag_values to provide descriptive words or phrases for each flag value.
flag_values	Р	CF	Provides a list of the flag values. Use in conjunction with flag_meanings.
formula	S	CF	Formula to calculate the values for an adaptive grid, for in- stance 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.

Name	Туре	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 9 for a detailed discussion.
valid_max	Р	NUG	Largest valid value of a variable.
valid_min	Р	NUG	Smallest valid value of a variable.
valid_range	P[2]	NUG	Smallest and largest valid values of a variable. This attribute should not be combined with either valid_min or valid_max

 Table 11: Attributes for variables used in S5p netCDF-4 files (continued).

## 12 Common elements in all S5P products

This section describes the elements that are common to all S5P/TROPOMI products. The product specific descriptions include references to this section. References to standards follow the abbreviations given in table 6.

## **13** Description of the O<sub>3</sub> Tropospheric Column product

Description of the main output file for the Ozone Tropospheric Column product from the TROPOMI instrument on the Sentinel 5-precursor mission.

### Global attributes in O3\_TCL

Group attributes attached to	O3_TCL	
Name	Value	Туре
Conventions	'CF-1.7' (static)	NC_STRING
metadata conventions, there data – that are not part of ve	lowed by the dataset. Note that while we try to follow the clime are some features – notably the use of groups to hierarchic ersion 1.7 of the CF metadata conventions. In those cases we s attribute originates from the NUG standard.	aly organize the
institution	'DLR-IUP' (dynamic)	NC_STRING
ProcessingCenter attribu combination from BIRA, DL that were agreed upon in the	iginal data was produced. The actual processing center ute, here we would like to indicate the responsible parties. R, ESA, FMI, IUP, KNMI, MPIC, SRON, Use the same CCI project. The actual value is a combination of the ATBD processor. This attribute originates from the NUG standard.	The value is a institute names
title	'TROPOMI/S5P Ozone Tropospheric Column' (dy- namic)	NC_STRING
This is a short description of	the product. This attribute originates from the NUG standard	J.
references	'https://atmos.eoc.dlr.de/tropomi' (static)	NC_STRING
	he data or methods used to produce it. A URI to the ATBD his attribute originates from the CF standard.	seems to be an
time_reference	'YYYY-MM-DDT00:00:00Z' (dynamic)	NC_STRING
	ISO 8601 [RD35] string. This corresponds to the UTC va inition it indicates UTC midnight before the start of the granu	
time_coverage_start	'YYYY-MM-DDTHH:MM:SS.mmmmmmZ' (dynamic)	NC_STRING
Start of the data granule in L	JTC as an ISO 8601 [RD35] string.	
time_coverage_end	'YYYY-MM-DDTHH:MM:SS.mmmmmmZ' (dynamic)	NC_STRING
	TC as an ISO 8601 [RD35] string.	
processor_version	'version' (static)	NC_STRING
Version of the processor use	d	
algorithm_version		NC_STRING
The algorithm version, separe schedules for different produ	rate from the processor (framework) version, to accomodate licts.	different release
product_version	'0.0.0' (dynamic)	NC_STRING
The product version, separate	te from the processor (framework) and algorithm version.	
keywords_vocabulary	'AGU index terms, http://publications.agu.org/author- resource-center/index-terms/' (static)	NC_STRING
The guidelines followed for the	he keywords attribute. We use the index terms published by t	the AGU.

keywords	'0345 Pollution, Urban and regional; 0365 Troposphe Composition and chemistry; 0368 Troposphere, C stituent Transport and Chemistry; 3360 Remote se ing' (static)	on-
Keywords from the " ${\tt keywords}$ ATBD authors.	ords_vocabulary" <b>describing the contents of the file.</b> T	o be provided by the
identifier_product_doi		NC_STRING
· •	bject Identifier") of the current product. It allows to easil ven if that location is moved after the file has been created	•
identifier_product_doi_a thority	u- 'http://dx.doi.org/' (static)	NC_STRING
This attribute defines the a	uthoritative service for use with DOI values in resolving to	the URL location.
id	'%(logical_filename)s' (dynamic)	NC_STRING
dataset. The "id" value sho refinement of the "id". The	nority" attributes are intended to provide a globally unique i uld attempt to uniquely identify the dataset. The naming aut combination of the two should be globally unique for all tim ute. This attribute originates from the CCI standard.	hority allows a further

### 13.1 Group "PRODUCT" in "O3\_TCL"

This is the main group containing the Ozone Tropospheric Column product. At this level the dimensions are defined, the actual data can be found one level deeper.

### Dimensions in O3\_TCL/PRODUCT

time size 1 (fixed) source Processor. mode Present in all modes. latitude\_ccd size 80 (fixed) source Processor. mode Present in all modes. longitude\_ccd size 360 (fixed) source Processor. mode Present in all modes. latitude\_csa size 8 (fixed) source Processor. mode Present in all modes. longitude\_csa size 18 (fixed) source Processor. mode Present in all modes.

### Variables in O3\_TCL/PRODUCT

time in O3_T	CL/PRODUCT		
Description:	The variable time	(time) is the reference time of the measurement.	
Dimensions:	time (coordinate va	riable).	
Туре:	NC_INT.		
Source:	Processor.		
Mode:	Present in all mode	S.	
Attributes:	Name	Value	Туре
	units	'seconds' (static)	NC_STRING
	standard_name	'time' (static)	NC_STRING
	long_name	'time of the measurements' (static)	NC_STRING

latitude_ccd	in O3_TCL/PRODUC	т	
Description:	The latitude of the	pixel centers of the grid cell in the data data for t	tropospheric column
	Latitude, longitude o	coordinates for the grid cell centre are calculated at	the WGS84 ellipsoid.
Dimensions:	latitude_ccd (coord	inate variable).	
Туре:	NC_FLOAT.		
Source:	Processor.		
Mode:	Present in all mode	S.	
Attributes:	Name	Value	Туре
	long_name	'pixel center latitude for CCD data' (static)	NC_STRING
	units	'degrees_north' (static)	NC_STRING
	standard_name	'latitude' (static)	NC_STRING
	valid_min	-20.0 (static)	NC_FLOAT
	valid_max	20.0 (static)	NC_FLOAT
longitude_cc	d in O3_TCL/PRODU	JCT	
Description:		e pixel centers of the grid cell in the data for troposples for the grid cell centre are calculated at the WG	
Dimensions:	longitude_ccd (cool	-	1
Туре:	NC FLOAT.	· ,	
Source:	Processor.		
Mode:	Present in all mode	S.	
Attributes:	Name	Value	Туре
	long_name	'pixel center longitude for CCD data' (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
latitude csa	in O3 TCL/PRODUC		
Description:	—		
Beeenptient	The latitude of the n	lixel centers of the grid cell in the data for lipper from	ospheric mixing ratio
		vixel centers of the grid cell in the data for upper trop coordinates for the grid cell centre are calculated at	
Dimensions:	Latitude, longitude o	coordinates for the grid cell centre are calculated at	
	Latitude, longitude o latitude_csa (coord	coordinates for the grid cell centre are calculated at	
Туре:	Latitude, longitude o	coordinates for the grid cell centre are calculated at	
Type: Source:	Latitude, longitude of latitude_csa (coord NC_FLOAT.	coordinates for the grid cell centre are calculated at inate variable).	
Type: Source: Mode:	Latitude, longitude of latitude_csa (coord NC_FLOAT. Processor.	coordinates for the grid cell centre are calculated at inate variable).	the WGS84 ellipsoid.
Type: Source: Mode:	Latitude, longitude of latitude_csa (coord NC_FLOAT. Processor. Present in all mode Name	coordinates for the grid cell centre are calculated at inate variable).	the WGS84 ellipsoid.
Type: Source: Mode:	Latitude, longitude of latitude_csa (coord NC_FLOAT. Processor. Present in all mode	coordinates for the grid cell centre are calculated at inate variable).	the WGS84 ellipsoid.
Type: Source: Mode:	Latitude, longitude of latitude_csa (coord NC_FLOAT. Processor. Present in all mode Name long_name	coordinates for the grid cell centre are calculated at inate variable). s. <u>Value</u> 'latitude center for CSA data' (static)	the WGS84 ellipsoid
Dimensions: Type: Source: Mode: Attributes:	Latitude, longitude of latitude_csa (coord NC_FLOAT. Processor. Present in all mode Name long_name units standard_name	coordinates for the grid cell centre are calculated at inate variable). s. <u>Value</u> 'latitude center for CSA data' (static) 'degrees_north' (static) 'latitude' (static)	the WGS84 ellipsoid <i>Type</i> NC_STRING NC_STRING NC_STRING
Type: Source: Mode:	Latitude, longitude of latitude_csa (coord NC_FLOAT. Processor. Present in all mode <i>Name</i> long_name units standard_name valid_min	coordinates for the grid cell centre are calculated at inate variable). s. <u>Value</u> 'latitude center for CSA data' (static) 'degrees_north' (static) 'latitude' (static) -20.0 (static)	the WGS84 ellipsoid <i>Type</i> NC_STRING NC_STRING NC_STRING NC_FLOAT
Type: Source: Mode: Attributes:	Latitude, longitude of latitude_csa (coord NC_FLOAT. Processor. Present in all mode <i>Name</i> long_name units standard_name valid_min valid_max	coordinates for the grid cell centre are calculated at inate variable). s. Value 'latitude center for CSA data' (static) 'degrees_north' (static) 'latitude' (static) -20.0 (static) 20.0 (static)	the WGS84 ellipsoid <i>Type</i> NC_STRING NC_STRING NC_STRING
Type: Source: Mode: Attributes:	Latitude, longitude of latitude_csa (coord NC_FLOAT. Processor. Present in all mode <i>Name</i> long_name units standard_name valid_min valid_max a in O3_TCL/PRODU The longitude of the	coordinates for the grid cell centre are calculated at inate variable). s. Value 'latitude center for CSA data' (static) 'degrees_north' (static) 'latitude' (static) -20.0 (static) 20.0 (static) JCT e pixel centers of the grid cell in the data for upper	the WGS84 ellipsoid <i>Type</i> NC_STRING NC_STRING NC_STRING NC_FLOAT NC_FLOAT
Type: Source: Mode: Attributes: Attributes:	Latitude, longitude of latitude_csa (coord NC_FLOAT. Processor. Present in all mode <i>Name</i> long_name units standard_name valid_min valid_max a in O3_TCL/PRODU The longitude of the ratio. Latitude, long	coordinates for the grid cell centre are calculated at inate variable). s. Value 'latitude center for CSA data' (static) 'degrees_north' (static) 'latitude' (static) -20.0 (static) 20.0 (static) JCT e pixel centers of the grid cell in the data for upper itude coordinates for the grid cell centre	the WGS84 ellipsoid <i>Type</i> NC_STRING NC_STRING NC_STRING NC_FLOAT NC_FLOAT
Type: Source: Mode: Attributes: Iongitude_cs Description: Dimensions:	Latitude, longitude of latitude_csa (coord NC_FLOAT. Processor. Present in all mode <i>Name</i> long_name units standard_name valid_max a in O3_TCL/PRODU The longitude of the ratio. Latitude, long longitude_csa (coord)	coordinates for the grid cell centre are calculated at inate variable). s. Value 'latitude center for CSA data' (static) 'degrees_north' (static) 'latitude' (static) -20.0 (static) 20.0 (static) JCT e pixel centers of the grid cell in the data for upper itude coordinates for the grid cell centre	the WGS84 ellipsoid <i>Type</i> NC_STRING NC_STRING NC_STRING NC_FLOAT NC_FLOAT
Type: Source: Mode: Attributes: Iongitude_cs Description: Dimensions: Type:	Latitude, longitude of latitude_csa (coord NC_FLOAT. Processor. Present in all mode Name long_name units standard_name valid_min valid_max a in O3_TCL/PRODU The longitude of the ratio. Latitude, long longitude_csa (coord) NC_FLOAT.	coordinates for the grid cell centre are calculated at inate variable). s. Value 'latitude center for CSA data' (static) 'degrees_north' (static) 'latitude' (static) -20.0 (static) 20.0 (static) JCT e pixel centers of the grid cell in the data for upper itude coordinates for the grid cell centre	the WGS84 ellipsoid <i>Type</i> NC_STRING NC_STRING NC_STRING NC_FLOAT NC_FLOAT
Type: Source: Mode: Attributes: Iongitude_cs Description: Dimensions: Type: Source:	Latitude, longitude of latitude_csa (coord NC_FLOAT. Processor. Present in all mode <i>Name</i> long_name units standard_name valid_max a in O3_TCL/PRODU The longitude of the ratio. Latitude, long longitude_csa (coord) NC_FLOAT. Processor.	coordinates for the grid cell centre are calculated at inate variable). s. Value 'latitude center for CSA data' (static) 'degrees_north' (static) 'latitude' (static) -20.0 (static) 20.0 (static) JCT e pixel centers of the grid cell in the data for upper itude coordinates for the grid cell centre rdinate variable).	the WGS84 ellipsoid <i>Type</i> NC_STRING NC_STRING NC_STRING NC_FLOAT NC_FLOAT
Type: Source: Mode: Attributes: Attributes: Description: Dimensions: Type: Source: Mode:	Latitude, longitude of latitude_csa (coord NC_FLOAT. Processor. Present in all mode <i>Name</i> long_name units standard_name valid_max a in O3_TCL/PRODU The longitude of the ratio. Latitude, long longitude_csa (coord NC_FLOAT. Processor. Present in all mode	coordinates for the grid cell centre are calculated at inate variable). s. Value 'latitude center for CSA data' (static) 'degrees_north' (static) 'latitude' (static) -20.0 (static) 20.0 (static) JCT e pixel centers of the grid cell in the data for upper itude coordinates for the grid cell centre rdinate variable).	the WGS84 ellipsoid
Type: Source: Mode: Attributes:	Latitude, longitude of latitude_csa (coord NC_FLOAT. Processor. Present in all mode <i>Name</i> long_name units standard_name valid_max a in O3_TCL/PRODU The longitude of the ratio. Latitude, long longitude_csa (coord) NC_FLOAT. Processor.	coordinates for the grid cell centre are calculated at inate variable). s. Value 'latitude center for CSA data' (static) 'degrees_north' (static) 'latitude' (static) -20.0 (static) 20.0 (static) JCT e pixel centers of the grid cell in the data for upper itude coordinates for the grid cell centre rdinate variable).	the WGS84 ellipsoid <i>Type</i> NC_STRING NC_STRING NC_STRING NC_FLOAT NC_FLOAT

	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
ozone_tropos	spheric_vertical_co	lumn in O3_TCL/PRODUCT	
Description:		$O_3$ Tropospheric column. s and other attributes still have to be added.	
Dimensions:	time, latitude_ccd, l	ongitude_ccd.	
Туре:	NC_FLOAT.		
Source:	Processor.		
Mode:	Present in all mode	S.	
Attributes:	Name	Value	Туре
	units	'mol m-2' (static)	NC_STRING
	standard_name	'troposphere_mole_content_of_ozone' (static)	NC_STRING
	long_name	'average tropospheric ozone column based on CCD algorithm' (static)	NC_STRING
	valid_min	0 (static)	NC_FLOAT
	multiplication factor_to_con- vert to DU	2241.15 (static)	NC_FLOAT
	value this means th "DU" or Dobson Un	entinel 5 precursor files are given in SI units. For an i sat the unit is $mol m^{-2}$ . Traditionally the unit for an interity. This attribute provides the multiplication factor to	egrated column i calculate the tota
	value this means th "DU" or Dobson Un column in DU from have tools that work	at the unit is $mol m^{-2}$ . Traditionally the unit for an interits. This attribute provides the multiplication factor to the value in $mol m^{-2}$ . This is provided as a convenied in DU.	egrated column is calculate the tota nce to users who
	value this means th "DU" or Dobson Un column in DU from	at the unit is $mol m^{-2}$ . Traditionally the unit for an interits. This attribute provides the multiplication factor to the value in $mol m^{-2}$ . This is provided as a convenie	egrated column is calculate the tota
	value this means th "DU" or Dobson Un column in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Se value this means th is "molecules cm <sup>-2</sup> " column in molecules	at the unit is $mol m^{-2}$ . Traditionally the unit for an interits. This attribute provides the multiplication factor to the value in $mol m^{-2}$ . This is provided as a convenied in DU.	egrated column is calculate the tota nce to users who NC_FLOAT ntegrated column calculate the tota
	value this means th "DU" or Dobson Un column in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Se value this means th is "molecules cm <sup>-2</sup> " column in molecules	the unit is $mol m^{-2}$ . Traditionally the unit for an interior to the value in $mol m^{-2}$ . This is provided as a convenie of $mol m^{-2}$ . This is provided as a convenie of $m$ DU. 6.02214e+19 (static) entinel 5 precursor files are given in SI units. For an interior the unit is $mol m^{-2}$ . Traditionally the unit for an interior to constant the unit is $mol m^{-2}$ . Traditionally the unit for an interior to constant the value in $mol m^{-2}$ . This is provided as a convenient to constant the unit is $mol m^{-2}$ . Traditionally the unit for an interior to constant the value in $mol m^{-2}$ . This is provided as a convenient to constant the unit is $mol m^{-2}$ . This is provided as a convenient to constant the unit is $mol m^{-2}$ . This is provided as a convenient to constant the unit is $mol m^{-2}$ . This is provided as a convenient to constant the unit is $mol m^{-2}$ . This is provided as a convenient to constant the unit is $mol m^{-2}$ . This is provided as a convenient to constant the unit is $mol m^{-2}$ . This is provided as a convenient to constant the unit is $mol m^{-2}$ . This is provided as a convenient to constant the unit is $mol m^{-2}$ . This is provided as a convenient to constant the unit is $mol m^{-2}$ . This is provided as a convenient to constant the unit is $mol m^{-2}$ .	egrated column is calculate the tota nce to users who NC_FLOAT ntegrated column tegrated column calculate the tota a convenience to
ozone_tropo	value this means th "DU" or Dobson Un column in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Se value this means th is "molecules cm <sup>-2</sup> " column in molecules users who have too coordinates	the unit is $mol m^{-2}$ . Traditionally the unit for an interior to the value in $mol m^{-2}$ . This is provided as a convenience in DU. 6.02214e+19 (static) entinel 5 precursor files are given in SI units. For an interior to the unit is $mol m^{-2}$ . Traditionally the unit for an interior and the unit is $mol m^{-2}$ . Traditionally the unit for an interior and the unit is $mol m^{-2}$ . Traditionally the unit for an interior and the unit is $mol m^{-2}$ . This is provided as a convenience of the unit is $mol m^{-2}$ . Traditionally the unit for an interior and the unit is $mol m^{-2}$ . This is provided as a convenience of the unit is $mol m^{-2}$ . This is provided as a convenience of the unit is $mol m^{-2}$ . This is provided as a convenience of the unit is $mol m^{-2}$ . This is provided as a convenience of the unit is $mol m^{-2}$ . This is provided as a convenience of the unit is $mol m^{-2}$ . This is provided as a convenience of the unit is $mol m^{-2}$ . This is provided as a convenience of the unit is $mol m^{-2}$ . This is provided as a convenience of the unit is $mol m^{-2}$ . This is provided as a convenience of the unit is $mol m^{-2}$ . This is provided as a convenience of the unit is $mol m^{-2}$ . This is provided as a convenience of the unit is $mol m^{-2}$ .	egrated column is calculate the tota nce to users who NC_FLOAT ntegrated column tegrated column calculate the tota a convenience to
ozone_tropo: Description:	value this means th "DU" or Dobson Un column in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Se value this means th is "molecules cm <sup>-2</sup> " column in molecules users who have too coordinates	the unit is $mol m^{-2}$ . Traditionally the unit for an interior to a the value in $mol m^{-2}$ . This is provided as a convenient the value in $mol m^{-2}$ . This is provided as a convenient in DU. 6.02214e+19 (static) entinel 5 precursor files are given in SI units. For an interior the unit is $mol m^{-2}$ . Traditionally the unit for an interior to a scm <sup>-2</sup> from the value in $mol m^{-2}$ . This is provided as a converse is that work in molecules cm <sup>-2</sup> . '/PRODUCT/longitude_ccd /PRODUCT/latitudeccd' (static)	egrated column is calculate the tota nce to users who NC_FLOAT ntegrated column tegrated column calculate the tota a convenience to
	value this means th "DU" or Dobson Un column in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Se value this means th is "molecules cm <sup>-2</sup> " column in molecules users who have too coordinates	<ul> <li>at the unit is mol m<sup>-2</sup>. Traditionally the unit for an interits. This attribute provides the multiplication factor to the value in mol m<sup>-2</sup>. This is provided as a convenient of the value in mol m<sup>-2</sup>. This is provided as a convenient of the value in mol m<sup>-2</sup>. This is provided as a convenient of the value in mol m<sup>-2</sup>. This is provided as a convenient of the unit is mol m<sup>-2</sup>. Traditionally the unit for an international the unit is mol m<sup>-2</sup>. Traditionally the unit for an international the unit is mol m<sup>-2</sup>. Traditionally the unit for an international the unit is mol m<sup>-2</sup>. Traditionally the unit for an international the unit is mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in</li></ul>	egrated column is calculate the tota nce to users who NC_FLOAT ntegrated column tegrated column calculate the tota a convenience to
Description:	value this means th "DU" or Dobson Un column in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Se value this means th is "molecules cm <sup>-2</sup> " column in molecules users who have too coordinates spheric_vertical_coo Random error of Og	<ul> <li>at the unit is mol m<sup>-2</sup>. Traditionally the unit for an interits. This attribute provides the multiplication factor to the value in mol m<sup>-2</sup>. This is provided as a convenient of the value in mol m<sup>-2</sup>. This is provided as a convenient of the value in mol m<sup>-2</sup>. This is provided as a convenient of the value in mol m<sup>-2</sup>. This is provided as a convenient of the unit is mol m<sup>-2</sup>. Traditionally the unit for an international the unit is mol m<sup>-2</sup>. Traditionally the unit for an international the unit is mol m<sup>-2</sup>. Traditionally the unit for an international the unit is mol m<sup>-2</sup>. Traditionally the unit for an international the unit is mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in</li></ul>	egrated column is calculate the tota nce to users who NC_FLOAT ntegrated column tegrated column calculate the tota a convenience to
Description: Dimensions:	value this means th "DU" or Dobson Un column in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Se value this means th is "molecules cm <sup>-2</sup> " column in molecules users who have too coordinates spheric_vertical_coo Random error of Og time, latitude_ccd, I	<ul> <li>at the unit is mol m<sup>-2</sup>. Traditionally the unit for an interits. This attribute provides the multiplication factor to the value in mol m<sup>-2</sup>. This is provided as a convenient of the value in mol m<sup>-2</sup>. This is provided as a convenient of the value in mol m<sup>-2</sup>. This is provided as a convenient of the value in mol m<sup>-2</sup>. This is provided as a convenient of the unit is mol m<sup>-2</sup>. Traditionally the unit for an international the unit is mol m<sup>-2</sup>. Traditionally the unit for an international the unit is mol m<sup>-2</sup>. Traditionally the unit for an international the unit is mol m<sup>-2</sup>. Traditionally the unit for an international the unit is mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This is provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in mol m<sup>-2</sup>. This provided as a score from the value in</li></ul>	egrated column is calculate the tota nce to users who NC_FLOAT ntegrated column tegrated column calculate the tota a convenience to
Description: Dimensions: Type:	value this means th "DU" or Dobson Un column in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Se value this means th is "molecules cm <sup>-2</sup> " column in molecules users who have too coordinates spheric_vertical_coo Random error of Og time, latitude_ccd, I NC_FLOAT.	at the unit is mol m <sup>-2</sup> . Traditionally the unit for an interits. This attribute provides the multiplication factor to the value in mol m <sup>-2</sup> . This is provided as a convenient in DU. 6.02214e+19 (static) entinel 5 precursor files are given in SI units. For an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . This is provided as ls that work in molecules cm <sup>-2</sup> . '/PRODUCT/longitude_ccd /PRODUCT/latitudeccd' (static) lumn_precision in O3_TCL/PRODUCT a Tropospheric column. ongitude_ccd.	egrated column is calculate the tota nce to users who NC_FLOAT ntegrated column tegrated column calculate the tota a convenience to
Description: Dimensions: Type: Source:	value this means th "DU" or Dobson Un column in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Se value this means th is "molecules cm <sup>-2</sup> " column in molecules users who have too coordinates spheric_vertical_coo Random error of Os time, latitude_ccd, I NC_FLOAT. Processor.	at the unit is mol m <sup>-2</sup> . Traditionally the unit for an interits. This attribute provides the multiplication factor to the value in mol m <sup>-2</sup> . This is provided as a convenient in DU. 6.02214e+19 (static) entinel 5 precursor files are given in SI units. For an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . This is provided as ls that work in molecules cm <sup>-2</sup> . '/PRODUCT/longitude_ccd /PRODUCT/latitudeccd' (static) lumn_precision in O3_TCL/PRODUCT a Tropospheric column. ongitude_ccd.	agrated column is         calculate the tota         nce to users who         NC_FLOAT         ntegrated column         ntegrated column         calculate the tota         a convenience to         NC_STRING
Description: Dimensions: Type: Source: Mode:	value this means th "DU" or Dobson Un column in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Se value this means th is "molecules cm <sup>-2</sup> " column in molecules users who have too coordinates spheric_vertical_co Random error of Oa time, latitude_ccd, I NC_FLOAT. Processor. Present in all mode	at the unit is mol m <sup>-2</sup> . Traditionally the unit for an interits. This attribute provides the multiplication factor to the value in mol m <sup>-2</sup> . This is provided as a convenie of n DU. 6.02214e+19 (static) entinel 5 precursor files are given in SI units. For an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . This is provided as ls that work in molecules cm <sup>-2</sup> . '/PRODUCT/longitude_ccd /PRODUCT/latitudeccd' (static) lumn_precision in O3_TCL/PRODUCT a Tropospheric column. ongitude_ccd.	egrated column is calculate the tota nce to users who NC_FLOAT ntegrated column talculate the tota a convenience to NC_STRING
Description: Dimensions: Type: Source: Mode:	value this means th "DU" or Dobson Un column in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Se value this means th is "molecules cm <sup>-2</sup> " column in molecules users who have too coordinates spheric_vertical_co Random error of Oa time, latitude_ccd, I NC_FLOAT. Processor. Present in all mode Name	at the unit is $mol m^{-2}$ . Traditionally the unit for an interite. This attribute provides the multiplication factor to the value in $mol m^{-2}$ . This is provided as a convenie of $n$ DU. 6.02214e+19 (static) entinel 5 precursor files are given in SI units. For an interit the unit is $mol m^{-2}$ . Traditionally the unit for an interit the unit is $mol m^{-2}$ . Traditionally the unit for an interit the unit is $mol m^{-2}$ . Traditionally the unit for an interit the unit is $mol m^{-2}$ . This is provided as ls that work in $molecules cm^{-2}$ . '/PRODUCT/longitude_ccd /PRODUCT/latitudeccd' (static) lumn_precision in O3_TCL/PRODUCT a Tropospheric column. ongitude_ccd.	agrated column is         calculate the tota         nce to users who         NC_FLOAT         ntegrated column         ntegrated column         calculate the tota         a convenience to         NC_STRING
Description: Dimensions: Type: Source: Mode:	value this means th "DU" or Dobson Un column in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Se value this means th is "molecules cm <sup>-2</sup> " column in molecules users who have too coordinates spheric_vertical_co Random error of Og time, latitude_ccd, I NC_FLOAT. Processor. Present in all mode Name units	at the unit is mol m <sup>-2</sup> . Traditionally the unit for an interits. This attribute provides the multiplication factor to the value in mol m <sup>-2</sup> . This is provided as a convenie of in DU. 6.02214e+19 (static) entinel 5 precursor files are given in SI units. For an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . Traditionally the unit for an interit the unit is mol m <sup>-2</sup> . This is provided as ls that work in molecules cm <sup>-2</sup> . '/PRODUCT/longitude_ccd /PRODUCT/latitudeccd' (static) lumn_precision in O3_TCL/PRODUCT a Tropospheric column. ongitude_ccd. s. <u>Value</u> 'mol m-2' (static) 'troposphere_mole_content_of_ozone standard	agrated column is         calculate the tota         nce to users who         NC_FLOAT         Integrated column         ntegrated column         calculate the tota         a convenience to         NC_STRING         Type         NC_STRING

	multiplication factor_to_con- vert_to_DU	2241.15 (static)	NC_FLOAT
	The quantities in Se value this means th "DU" or Dobson Uni	entinel 5 precursor files are given in SI units. For an i at the unit is $mol m^{-2}$ . Traditionally the unit for an inte- its. This attribute provides the multiplication factor to o the value in $mol m^{-2}$ . This is provided as a convenie of in DU.	egrated column is calculate the total
	multiplication factor_to_con- vert_to_mo- lecules_percm2	6.02214e+19 (static)	NC_FLOAT
	value this means the is "molecules $cm^{-2}$ ".	entinel 5 precursor files are given in SI units. For an interact the unit is $mol m^{-2}$ . Traditionally the unit for an interact the unit is mol m^{-2}. Traditionally the unit for an interact the scm <sup>-2</sup> from the value in $mol m^{-2}$ . This is provided as ls that work in molecules cm <sup>-2</sup> .	ntegrated column alculate the total
	coordinates	<pre>'/PRODUCT/longitude_ccd /PRODUCT/latitude ccd' (static)</pre>	NC_STRING
ozone_tropos	spheric_mixing_rati	o in O3_TCL/PRODUCT	
Description:	Average O <sub>3</sub> Tropos	bheric mixing rtaio in ppb.	
Dimensions:	time, latitude_ccd, l		
Туре:	NC FLOAT.	· _	
Source:	Processor.		
Mode:	Present in all mode	S	
Attributes:	Name	Value	Туре
, an ibutob.	units	'1' (static)	NC STRING
	scale_factor	1e-9 (static)	NC FLOAT
	standard_name	'troposphere_mole_fraction_of_ozone_in_air' (static)	NC_STRING
	long_name	'average tropospheric ozone mixing ratio based on CCD algorithm' (static)	NC_STRING
	valid_min	0 (static)	NC_FLOAT
	vertical_range bottom	'surface' (static)	NC_STRING
	vertical_range top	'10_km' (static)	NC_STRING
	coordinates	<pre>'/PRODUCT/longitude_ccd /PRODUCT/latitude ccd' (static)</pre>	NC_STRING
ozone_tropo	spheric_mixing_rati	o_precision in O3_TCL/PRODUCT	
Description:	Random error of O <sub>3</sub>	Tropospheric mixing ratio in ppb.	
Dimensions:	time, latitude_ccd, le	ongitude_ccd.	
Туре:	NC_FLOAT.		
Source:	Processor.		
Mode:	Present in all mode	S.	
Attributes:	Name	Value	Туре
	units	'1' (static)	NC_STRING
	scale_factor	1e-9 (static)	NC_FLOAT
	standard_name	'troposphere_mole_fraction_of_ozone_in_air standard_error' (static)	 NC_STRING

	long_name	'standard deviation of tropospheric ozone mixing ratio based on CCD algorithm' (static)	NC_STRING
	valid_min	'0' (static)	NC_STRING
	vertical_range bottom	'surface' (static)	NC_STRING
	vertical_range top	'10_km' (static)	NC_STRING
ozone_upper	_tropospheric_mixi	ng_ratio in O3_TCL/PRODUCT	
Description:	Average O <sub>3</sub> Troposp	pheric mixing rtaio in ppb.	
Dimensions:	time, latitude_csa, lo	ongitude_csa.	
Туре:	NC_FLOAT.		
Source:	Processor.		
Mode:	Present in all modes	5.	
Attributes:	Name	Value	Туре
	units	'1' (static)	NC_STRING
	long_name	'upper tropospheric ozone mixing ratio' (static)	NC_STRING
	scale_factor	1e-9 (static)	NC_FLOAT
	standard_name	'troposphere_mole_fraction_of_ozone_in_air' (static)	NC_STRING
	long_name	'upper tropospheric ozone mixing ratio based on	NC_STRING
	long_name	CSA algorithm' (static)	
	valid_min		NC_FLOAT
		CSA algorithm' (static)	NC_FLOAT NC_STRING
- • •	valid_min coordinates _tropospheric_mixin	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_precision in O3_TCL/PRODUCT	—
Description:	valid_min coordinates tropospheric_mixin Random error of O <sub>3</sub>	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_precision in O3_TCL/PRODUCT upper Tropospheric mixing ratio in ppb.	—
Description: Dimensions:	valid_min coordinates tropospheric_mixin Random error of O <sub>3</sub> time, latitude_csa, lo	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_precision in O3_TCL/PRODUCT upper Tropospheric mixing ratio in ppb.	—
Description: Dimensions: Type:	valid_min coordinates tropospheric_mixin Random error of O <sub>3</sub> time, latitude_csa, lo NC_FLOAT.	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_precision in O3_TCL/PRODUCT upper Tropospheric mixing ratio in ppb.	—
Description: Dimensions: Type: Source:	valid_min coordinates tropospheric_mixin Random error of O <sub>3</sub> time, latitude_csa, lo NC_FLOAT. Processor.	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_precision in O3_TCL/PRODUCT upper Tropospheric mixing ratio in ppb. ongitude_csa.	—
Description: Dimensions: Type:	valid_min coordinates tropospheric_mixin Random error of O <sub>3</sub> time, latitude_csa, lo NC_FLOAT.	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_precision in O3_TCL/PRODUCT upper Tropospheric mixing ratio in ppb. ongitude_csa.	—
Description: Dimensions: Type: Source:	valid_min coordinates tropospheric_mixin Random error of O <sub>3</sub> time, latitude_csa, lo NC_FLOAT. Processor. Present in all modes <i>Name</i>	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_precision in O3_TCL/PRODUCT upper Tropospheric mixing ratio in ppb. ongitude_csa. S. Value	NC_STRING
Description: Dimensions: Type: Source: Mode:	valid_min coordinates <u>-tropospheric_mixin</u> Random error of O <sub>3</sub> time, latitude_csa, lo NC_FLOAT. Processor. Present in all modes <u>Name</u> units	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_precision in O3_TCL/PRODUCT upper Tropospheric mixing ratio in ppb. ongitude_csa. S. Value '1' (static)	NC_STRING
Description: Dimensions: Type: Source: Mode:	valid_min coordinates _tropospheric_mixin Random error of O <sub>3</sub> time, latitude_csa, lo NC_FLOAT. Processor. Present in all modes Name units scale_factor	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_precision in O3_TCL/PRODUCT upper Tropospheric mixing ratio in ppb. ongitude_csa. S. Value '1' (static) 1e-9 (static)	NC_STRING <i>Type</i> NC_STRING NC_FLOAT
Description: Dimensions: Type: Source: Mode:	valid_min coordinates <u>-tropospheric_mixin</u> Random error of O <sub>3</sub> time, latitude_csa, lo NC_FLOAT. Processor. Present in all modes <u>Name</u> units	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_precision in O3_TCL/PRODUCT upper Tropospheric mixing ratio in ppb. ongitude_csa. S. Value '1' (static)	NC_STRING <i>Type</i> NC_STRING NC_FLOAT
Description: Dimensions: Type: Source: Mode:	valid_min coordinates _tropospheric_mixin Random error of O <sub>3</sub> time, latitude_csa, lo NC_FLOAT. Processor. Present in all modes Name units scale_factor	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_precision in O3_TCL/PRODUCT upper Tropospheric mixing ratio in ppb. ongitude_csa. s. Value '1' (static) 1e-9 (static) 'troposphere_mole_fraction_of_ozone_in_air	NC_STRING <i>Type</i> NC_STRING NC_FLOAT NC_STRING
Description: Dimensions: Type: Source: Mode:	valid_min coordinates -tropospheric_mixin Random error of O <sub>3</sub> time, latitude_csa, lo NC_FLOAT. Processor. Present in all modes Name units scale_factor standard_name	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_precision in O3_TCL/PRODUCT upper Tropospheric mixing ratio in ppb. ongitude_csa. S. Value '1' (static) 1e-9 (static) 'troposphere_mole_fraction_of_ozone_in_air standard_error' (static) 'standard deviation of upper tropospheric ozone	NC_STRING <i>Type</i> NC_STRING NC_FLOAT NC_STRING NC_STRING
Description: Dimensions: Type: Source: Mode:	valid_min coordinates -tropospheric_mixin Random error of O <sub>3</sub> time, latitude_csa, lo NC_FLOAT. Processor. Present in all modes Name units scale_factor standard_name long_name	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_precision in O3_TCL/PRODUCT upper Tropospheric mixing ratio in ppb. ongitude_csa. s. Value '1' (static) 1e-9 (static) 'troposphere_mole_fraction_of_ozone_in_air standard_error' (static) 'standard deviation of upper tropospheric ozone mixing ratio based on CSA algorithm' (static)	Type NC_STRING NC_STRING NC_FLOAT NC_STRING
Description: Dimensions: Type: Source: Mode: Attributes:	valid_min         coordinates         '_tropospheric_mixin         Random error of O3         time, latitude_csa, lo         NC_FLOAT.         Processor.         Present in all modes         Name         units         scale_factor         standard_name         long_name         valid_min         coordinates	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_precision in O3_TCL/PRODUCT upper Tropospheric mixing ratio in ppb. ongitude_csa. S. Value '1' (static) 1e-9 (static) 'troposphere_mole_fraction_of_ozone_in_air standard_error' (static) 'standard deviation of upper tropospheric ozone mixing ratio based on CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude	NC_STRING Type NC_STRING NC_FLOAT NC_STRING NC_STRING
Description: Dimensions: Type: Source: Mode: Attributes: Attributes: ozone_upper Description:	valid_min         coordinates         '_tropospheric_mixin         Random error of O3         time, latitude_csa, lo         NC_FLOAT.         Processor.         Present in all modes         Name         units         scale_factor         standard_name         long_name         valid_min         coordinates	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_precision in O3_TCL/PRODUCT upper Tropospheric mixing ratio in ppb. ongitude_csa. S. Value '1' (static) 1e-9 (static) 'troposphere_mole_fraction_of_ozone_in_air standard_error' (static) 'standard deviation of upper tropospheric ozone mixing ratio based on CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_flag in O3_TCL/PRODUCT	NC_STRING <i>Type</i> NC_STRING NC_FLOAT NC_STRING NC_STRING
Description: Dimensions: Type: Source: Mode: Attributes: Attributes:	valid_min coordinates tropospheric_mixin Random error of O <sub>3</sub> time, latitude_csa, lo NC_FLOAT. Processor. Present in all modes Name units scale_factor standard_name long_name valid_min coordinates	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) mg_ratio_precision in O3_TCL/PRODUCT upper Tropospheric mixing ratio in ppb. ongitude_csa. S. Value '1' (static) 1e-9 (static) 'troposphere_mole_fraction_of_ozone_in_air standard_error' (static) 'standard deviation of upper tropospheric ozone mixing ratio based on CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) mg_ratio_flag in O3_TCL/PRODUCT r tropospheric O <sub>3</sub> .	NC_STRING Type NC_STRING NC_FLOAT NC_STRING NC_STRING
Description: Dimensions: Type: Source: Mode: Attributes: Attributes: ozone_upper Description:	valid_min         coordinates         *_tropospheric_mixin         Random error of O3         time, latitude_csa, lo         NC_FLOAT.         Processor.         Present in all modes         Name         units         scale_factor         standard_name         long_name         valid_min         coordinates	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) mg_ratio_precision in O3_TCL/PRODUCT upper Tropospheric mixing ratio in ppb. ongitude_csa. S. Value '1' (static) 1e-9 (static) 'troposphere_mole_fraction_of_ozone_in_air standard_error' (static) 'standard deviation of upper tropospheric ozone mixing ratio based on CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) mg_ratio_flag in O3_TCL/PRODUCT r tropospheric O <sub>3</sub> .	NC_STRING Type NC_STRING NC_FLOAT NC_STRING NC_STRING
Description: Dimensions: Type: Source: Mode: Attributes: Attributes: <b>ozone_upper</b> Description: Dimensions:	valid_min         coordinates         *_tropospheric_mixin         Random error of O3         time, latitude_csa, lo         NC_FLOAT.         Processor.         Present in all modes         Name         units         scale_factor         standard_name         long_name         valid_min         coordinates         *_tropospheric_mixin         Quality flag of upper         time, latitude_csa, lo	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) mg_ratio_precision in O3_TCL/PRODUCT upper Tropospheric mixing ratio in ppb. ongitude_csa. S. Value '1' (static) 1e-9 (static) 'troposphere_mole_fraction_of_ozone_in_air standard_error' (static) 'standard deviation of upper tropospheric ozone mixing ratio based on CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) mg_ratio_flag in O3_TCL/PRODUCT r tropospheric O <sub>3</sub> .	NC_STRING Type NC_STRING NC_FLOAT NC_STRING NC_STRING
Description: Dimensions: Type: Source: Mode: Attributes: Attributes: <b>ozone_upper</b> Description: Dimensions: Type:	valid_min         coordinates         *_tropospheric_mixin         Random error of O3         time, latitude_csa, lo         NC_FLOAT.         Processor.         Present in all modes         Name         units         scale_factor         standard_name         long_name         valid_min         coordinates         *_tropospheric_mixin         Quality flag of upper         time, latitude_csa, lo         NC_INT.	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_precision in O3_TCL/PRODUCT upper Tropospheric mixing ratio in ppb. ongitude_csa. S. Value '1' (static) 1e-9 (static) 'troposphere_mole_fraction_of_ozone_in_air standard_error' (static) 'standard deviation of upper tropospheric ozone mixing ratio based on CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_flag in O3_TCL/PRODUCT r tropospheric O <sub>3</sub> . ongitude_csa.	NC_STRING <i>Type</i> NC_STRING NC_FLOAT NC_STRING NC_STRING
Description: Dimensions: Type: Source: Mode: Attributes: Attributes: <b>ozone_upper</b> Description: Dimensions: Type: Source:	valid_min         coordinates         *_tropospheric_mixin         Random error of O3         time, latitude_csa, lo         NC_FLOAT.         Processor.         Present in all modes         Name         units         scale_factor         standard_name         long_name         valid_min         coordinates         *_tropospheric_mixin         Quality flag of upper         time, latitude_csa, lo         NC_INT.         Processor.	CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_precision in O3_TCL/PRODUCT upper Tropospheric mixing ratio in ppb. ongitude_csa. S. Value '1' (static) 1e-9 (static) 'troposphere_mole_fraction_of_ozone_in_air standard_error' (static) 'standard deviation of upper tropospheric ozone mixing ratio based on CSA algorithm' (static) 0 (static) '/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static) ng_ratio_flag in O3_TCL/PRODUCT r tropospheric O <sub>3</sub> . ongitude_csa.	NC_STRING <i>Type</i> NC_STRING NC_FLOAT NC_STRING NC_STRING

	standard_name	<pre>'troposphere_mole_fraction_of_ozone_in_air status_flag' (static)</pre>	NC_STRING
	long_name	'quality flag to upper tropospheric mixing ratio based on CSA algorithm' (static)	NC_STRING
	valid_min	0 (static)	NC_FLOAT
	flag_values	'0, 1, 2, 4, 8' (static)	NC_STRING
	flag_meanings	'good_quality not_enough_datapoints pressure difference_too_small highest_clouds_too_low neg- ative_mixingratio_retrieved' (static)	NC_STRING
	coordinates	<pre>'/PRODUCT/longitude_csa /PRODUCT/latitude csa' (static)</pre>	NC_STRING
qa_value in C	D3_TCL/PRODUCT		
Description:	value will change ba	y descriptor, varying between 0 (no data) and 1 (full ased on observation conditions and retrieval flags. De processing_quality_flags elsewhere in the pro	tailed quality flag
Dimensions:	time, latitude_ccd, l	ongitude_ccd.	
Туре:	NC_UBYTE.		
Source:	Processor.		
Mode:	Present in all mode	S.	
Attributes:	Name	Value	Туре
	units	'1' (static)	NC_STRING
	scale_factor	0.01 (static)	NC_FLOAT
	add_offset	0 (static)	NC_FLOAT
	valid_min	0 (static)	NC_UBYTE
	valid_max	100 (static)	NC_UBYTE
	long_name	'data quality value for the CCD algorithm' (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	<pre>'/PRODUCT/longitude_ccd /PRODUCT/latitude ccd' (static)</pre>	NC_STRING

#### 13.1.1 Group "SUPPORT\_DATA" in "PRODUCT"

# 13.1.1.1 Group "DETAILED\_RESULTS" in "SUPPORT\_DATA"

# Variables in O3\_TCL/PRODUCT/SUPPORT\_DATA/DETAILED\_RESULTS

ozone_strato	spheric_vertical_c	olumn in O3_TCL/PRODUCT/SUPPORT_DATA/DB	ETAILED_RESULTS	
Description:	Average stratospheric $O_3$ column (for cloudy conditions)			
Dimensions:	time, latitude_ccd,	longitude_ccd.		
Туре:	NC_FLOAT.			
Source:	Processor.			
Mode:	Present in all mode	9S.		
Attributes:	Name	Value	Туре	
	units	'mol m-2' (static)	NC_STRING	
	standard_name	'stratosphere_mole_content_of_ozone' (static)	NC_STRING	

	long_name	'average stratospheric ozone column based on the CCD algorithm' (static)	NC_STRING
	vertical_range bottom	'10_km' (static)	NC_STRING
	vertical_range top	'80_km' (static)	NC_STRING
	multiplication factor_to_con- vert_to_DU	2241.15 (static)	NC_FLOAT
	value this means th "DU" or Dobson Uni	entinel 5 precursor files are given in SI units. For an i at the unit is $mol m^{-2}$ . Traditionally the unit for an interits. This attribute provides the multiplication factor to the value in $mol m^{-2}$ . This is provided as a convenient of $mol m^{-2}$ .	egrated column is calculate the total
	multiplication factor_to_con- vert_to_mo- lecules_percm2	6.02214e+19 (static)	NC_FLOAT
	value this means the second s	entinel 5 precursor files are given in SI units. For an i nat the unit is $mol m^{-2}$ . Traditionally the unit for an in This attribute provides the multiplication factor to $c s cm^{-2}$ from the value in $mol m^{-2}$ . This is provided as Is that work in molecules $cm^{-2}$ .	ntegrated column calculate the total
ozone_strato	ospheric_vertical_co	olumn_precision in O3_TCL/PRODUCT/SUPPORT_I	DATA/DETAILED
Description: Dimensions: Type:	time, latitude_ccd, lo NC_FLOAT.	$D_3$ column (for cloudy conditions) ongitude_ccd.	
Source: Mode:	Processor. Present in all modes	-	
Attributes:	Name	Value	Туре
, an barbor	units	'mol m-2' (static)	NC STRING
	standard_name	'stratosphere_mole_content_of_ozone error' (static)	NC_STRING
	long_name	'standard deviation of stratospheric ozone column based on the CCD algorithm' (static)	NC_STRING
	vertical_range bottom	'10_km' (static)	NC_STRING
	vertical_range top	'80_km' (static)	NC_STRING
	multiplication factor_to_con- vert_to_DU	2241.15 (static)	NC_FLOAT
	The quantities in Se value this means th "DU" or Dobson Uni	entinel 5 precursor files are given in SI units. For an i at the unit is $mol m^{-2}$ . Traditionally the unit for an interits. This attribute provides the multiplication factor to the value in $mol m^{-2}$ . This is provided as a convenies in DU.	egrated column is calculate the tota
	multiplication factor_to_con- vert to mo-	6.02214e+19 (static)	NC_FLOAT

	value this means th is "molecules $cm^{-2}$ ". column in molecules	entinel 5 precursor files are given in SI units. For an i nat the unit is $mol m^{-2}$ . Traditionally the unit for an in This attribute provides the multiplication factor to $c c c m^{-2}$ from the value in $mol m^{-2}$ . This is provided as Is that work in molecules $cm^{-2}$ .	ntegrated column calculate the total
ozone_strato	ospheric_vertical_co ESULTS	lumn_reference in O3_TCL/PRODUCT/S	SUPPORT_DATA/
Description:	Average stratospher	ric $O_3$ column in the reference area (for each latitude	band)
Dimensions:	time, latitude_ccd.		
Туре:	NC_FLOAT.		
Source:	Processor.		
Mode:	Present in all modes	5.	
Attributes:	Name	Value	Туре
	units	'mol m-2' (static)	NC_STRING
	standard_name	'stratosphere_mole_content_of_ozone' (static)	NC_STRING
	long_name	'averaged stratospheric ozone column in the refer- ence are based on the CCD algorithm' (static)	NC_STRING
	vertical_range bottom	'10_km' (static)	NC_STRING
	vertical_range top	'80_km' (static)	NC_STRING
	multiplication factor_to_con- vert to DU	2241.15 (static)	NC_FLOAT
	value this means th "DU" or Dobson Uni	entinel 5 precursor files are given in SI units. For an i at the unit is $mol m^{-2}$ . Traditionally the unit for an interts. This attribute provides the multiplication factor to the value in $mol m^{-2}$ . This is provided as a convenie to DU.	egrated column is calculate the total
	multiplication factor_to_con- vert_to_mo- lecules_percm2	6.02214e+19 (static)	NC_FLOAT
	value this means th is "molecules $cm^{-2}$ ". column in molecules	entinel 5 precursor files are given in SI units. For an i bat the unit is $mol m^{-2}$ . Traditionally the unit for an in This attribute provides the multiplication factor to $c c c m^{-2}$ from the value in $mol m^{-2}$ . This is provided as Is that work in molecules cm <sup>-2</sup> .	ntegrated column calculate the total
ozone_strato	spheric_vertical_co	lumn_reference_precision in O3_TCL/PRODUCT/S	SUPPORT_DATA/
Description:		ric $O_3$ column in the reference area (for each latitude	band)
Dimensions:	time, latitude_ccd.		
Туре:	NC FLOAT.		
Source:	Processor.		
Mode:	Present in all modes	5.	
Attributes:	Name	Value	Туре
	units	'mol m-2' (static)	NC_STRING

	long_name	'standard deviation of stratospheric ozone column in the reference area based on the CCD algorithm' (static)	NC_STRING
	vertical_range bottom	'10_km' (static)	NC_STRING
	vertical_range top	'80_km' (static)	NC_STRING
	• – –	lumn_reference_flag in O3_TCL/PRODUCT/S	SUPPORT_DATA/
DETAILED_R			
Description:	•	ric $O_3$ column in the reference area (for each latitude	band)
Dimensions:	time, latitude_ccd.		
Туре:	NC_INT.		
Source:	Processor.		
Mode:	Present in all modes	5.	
Attributes:	Name	Value	Туре
	units	'1' (static)	NC_STRING
	standard_name	<pre>'stratosphere_mole_content_of_ozone status_flag' (static)</pre>	NC_STRING
	long_name	'quality flag of stratospheric ozone column in the reference area based on the CCD algorithm' (static)	NC_STRING
	flag_values	'0, 1, 2, 4, 8' (static)	NC_STRING
	flag_meanings	'good_quality stratospheric_ozone_too_low not enough_datapoints error_too_large difference_to	NC_STRING
		neighbours_too_large' (static)	
	multiplication factor_to_con- vert_to_DU	neighbours_too_large' (static) 2241.15 (static)	NC_FLOAT
	factor_to_con- vert_to_DU The quantities in Se value this means the "DU" or Dobson Uni	2241.15 (static) entinel 5 precursor files are given in SI units. For an i at the unit is $mol m^{-2}$ . Traditionally the unit for an inte ts. This attribute provides the multiplication factor to the value in $mol m^{-2}$ . This is provided as a convenie	ntegrated column egrated column is calculate the tota
	factor_to_con- vert_to_DU The quantities in Se value this means the "DU" or Dobson Uni column in DU from	2241.15 (static) entinel 5 precursor files are given in SI units. For an i at the unit is $mol m^{-2}$ . Traditionally the unit for an inte ts. This attribute provides the multiplication factor to the value in $mol m^{-2}$ . This is provided as a convenie	ntegrated column egrated column is calculate the tota
	factor_to_con- vert_to_DU The quantities in Sevalue this means the "DU" or Dobson Unicolumn in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Sevalue this means the is "molecules cm <sup>-2</sup> ". column in molecules users who have tool	2241.15 (static) entinel 5 precursor files are given in SI units. For an i at the unit is mol m <sup>-2</sup> . Traditionally the unit for an inter ts. This attribute provides the multiplication factor to o the value in mol m <sup>-2</sup> . This is provided as a convenie in DU. 6.02214e+19 (static) entinel 5 precursor files are given in SI units. For an i that the unit is mol m <sup>-2</sup> . Traditionally the unit for an in This attribute provides the multiplication factor to o form <sup>-2</sup> from the value in mol m <sup>-2</sup> . This is provided as ls that work in molecules cm <sup>-2</sup> .	ntegrated column egrated column is calculate the total nce to users who NC_FLOAT ntegrated column ntegrated column calculate the total a convenience to
ozone_total_	factor_to_con- vert_to_DU The quantities in Se value this means the "DU" or Dobson Uni column in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Se value this means th is "molecules cm <sup>-2</sup> ". column in molecules users who have tool vertical_column in C	2241.15 (static) entinel 5 precursor files are given in SI units. For an i at the unit is mol m <sup>-2</sup> . Traditionally the unit for an inter ts. This attribute provides the multiplication factor to the value in mol m <sup>-2</sup> . This is provided as a convenie in DU. 6.02214e+19 (static) entinel 5 precursor files are given in SI units. For an i tat the unit is mol m <sup>-2</sup> . Traditionally the unit for an in This attribute provides the multiplication factor to c scm <sup>-2</sup> from the value in mol m <sup>-2</sup> . This is provided as a stat work in molecules cm <sup>-2</sup> .	ntegrated column egrated column is calculate the tota nce to users who NC_FLOAT ntegrated column ntegrated column calculate the tota a convenience to
	factor_to_con- vert_to_DU The quantities in Se value this means the "DU" or Dobson Uni column in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Se value this means th is "molecules cm <sup>-2</sup> ". column in molecules users who have tool vertical_column in C	2241.15 (static) entinel 5 precursor files are given in SI units. For an i at the unit is mol m <sup>-2</sup> . Traditionally the unit for an inter ts. This attribute provides the multiplication factor to o the value in mol m <sup>-2</sup> . This is provided as a convenie in DU. 6.02214e+19 (static) entinel 5 precursor files are given in SI units. For an i that the unit is mol m <sup>-2</sup> . Traditionally the unit for an in This attribute provides the multiplication factor to o form <sup>-2</sup> from the value in mol m <sup>-2</sup> . This is provided as ls that work in molecules cm <sup>-2</sup> .	ntegrated column egrated column is calculate the tota nce to users who NC_FLOAT ntegrated column ntegrated column calculate the tota a convenience to
Description: Dimensions:	factor_to_con- vert_to_DU The quantities in Sevalue this means the "DU" or Dobson Unicolumn in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Sevalue this means the is "molecules cm <sup>-2</sup> ". column in molecules users who have tool vertical_column in C Average total O <sub>3</sub> colutime, latitude_ccd, lot	2241.15 (static) entinel 5 precursor files are given in SI units. For an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the value in mol m <sup>-2</sup> . This is provided as a convenie of the value in mol m <sup>-2</sup> . This is provided as a convenie of nDU. 6.02214e+19 (static) entinel 5 precursor files are given in SI units. For an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the unit is mol m <sup>-2</sup> . This is provided as a set that work in molecules cm <sup>-2</sup> . D3_TCL/PRODUCT/SUPPORT_DATA/DETAILED_RE lumn for cloud free pixels	ntegrated column egrated column is calculate the tota nce to users who NC_FLOAT ntegrated column ntegrated column calculate the tota a convenience to
Description: Dimensions:	factor_to_con- vert_to_DU The quantities in Sevalue this means the "DU" or Dobson Unicolumn in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Sevalue this means the is "molecules cm <sup>-2</sup> ". column in molecules users who have tool vertical_column in Context and the seven se	2241.15 (static) entinel 5 precursor files are given in SI units. For an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the value in mol m <sup>-2</sup> . This is provided as a convenie of the value in mol m <sup>-2</sup> . This is provided as a convenie of nDU. 6.02214e+19 (static) entinel 5 precursor files are given in SI units. For an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the unit is mol m <sup>-2</sup> . This is provided as a set that work in molecules cm <sup>-2</sup> . D3_TCL/PRODUCT/SUPPORT_DATA/DETAILED_RE lumn for cloud free pixels	ntegrated column egrated column is calculate the tota nce to users who NC_FLOAT ntegrated column ntegrated column calculate the tota a convenience to
Description:	factor_to_con- vert_to_DU The quantities in Sevalue this means the "DU" or Dobson Unicolumn in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Sevalue this means the is "molecules cm <sup>-2</sup> ". column in molecules users who have tool vertical_column in C Average total O <sub>3</sub> colutime, latitude_ccd, lot	2241.15 (static) entinel 5 precursor files are given in SI units. For an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the value in mol m <sup>-2</sup> . This is provided as a convenie of the value in mol m <sup>-2</sup> . This is provided as a convenie of nDU. 6.02214e+19 (static) entinel 5 precursor files are given in SI units. For an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the unit is mol m <sup>-2</sup> . Traditionally the unit for an interact the unit is mol m <sup>-2</sup> . This is provided as a set that work in molecules cm <sup>-2</sup> . D3_TCL/PRODUCT/SUPPORT_DATA/DETAILED_RE lumn for cloud free pixels	ntegrated column egrated column is calculate the tota nce to users who NC_FLOAT ntegrated column ntegrated column calculate the tota a convenience to
Description: Dimensions: Type:	factor_to_con- vert_to_DU The quantities in Se value this means the "DU" or Dobson Uni column in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Se value this means th is "molecules cm <sup>-2</sup> ". column in molecules users who have tool vertical_column in C Average total O <sub>3</sub> col time, latitude_ccd, lo	2241.15 (static) entinel 5 precursor files are given in SI units. For an i at the unit is mol m <sup>-2</sup> . Traditionally the unit for an inte ts. This attribute provides the multiplication factor to o the value in mol m <sup>-2</sup> . This is provided as a convenie in DU. 6.02214e+19 (static) entinel 5 precursor files are given in SI units. For an i bat the unit is mol m <sup>-2</sup> . Traditionally the unit for an in This attribute provides the multiplication factor to c from the value in mol m <sup>-2</sup> . This is provided as ls that work in molecules cm <sup>-2</sup> . D3_TCL/PRODUCT/SUPPORT_DATA/DETAILED_RE lumn for cloud free pixels ongitude_ccd.	ntegrated column egrated column is calculate the tota nce to users who NC_FLOAT ntegrated column ntegrated column calculate the tota a convenience to
Description: Dimensions: Type: Source:	factor_to_con- vert_to_DU The quantities in Sevalue this means the "DU" or Dobson Unicolumn in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Sevalue this means the is "molecules cm <sup>-2</sup> ". column in molecules users who have tool vertical_column in C Average total O <sub>3</sub> colume, latitude_ccd, lo NC_FLOAT. Processor.	2241.15 (static) entinel 5 precursor files are given in SI units. For an i at the unit is mol m <sup>-2</sup> . Traditionally the unit for an inte ts. This attribute provides the multiplication factor to o the value in mol m <sup>-2</sup> . This is provided as a convenie in DU. 6.02214e+19 (static) entinel 5 precursor files are given in SI units. For an i bat the unit is mol m <sup>-2</sup> . Traditionally the unit for an in This attribute provides the multiplication factor to c from the value in mol m <sup>-2</sup> . This is provided as ls that work in molecules cm <sup>-2</sup> . D3_TCL/PRODUCT/SUPPORT_DATA/DETAILED_RE lumn for cloud free pixels ongitude_ccd.	ntegrated column egrated column is calculate the tota nce to users who NC_FLOAT ntegrated column ntegrated column calculate the tota a convenience to
Description: Dimensions: Type: Source: Mode:	factor_to_con- vert_to_DU The quantities in Se value this means the "DU" or Dobson Uni column in DU from have tools that work multiplication factor_to_con- vert_to_mo- lecules_percm2 The quantities in Se value this means th is "molecules cm <sup>-2</sup> ". column in molecules users who have tool vertical_column in C Average total O <sub>3</sub> col time, latitude_ccd, le NC_FLOAT. Processor.	2241.15 (static) entinel 5 precursor files are given in SI units. For an i at the unit is mol m <sup>-2</sup> . Traditionally the unit for an inter- ts. This attribute provides the multiplication factor to o the value in mol m <sup>-2</sup> . This is provided as a convenie in DU. 6.02214e+19 (static) entinel 5 precursor files are given in SI units. For an i that the unit is mol m <sup>-2</sup> . Traditionally the unit for an in This attribute provides the multiplication factor to c form <sup>-2</sup> from the value in mol m <sup>-2</sup> . This is provided as is that work in molecules cm <sup>-2</sup> . D3_TCL/PRODUCT/SUPPORT_DATA/DETAILED_RE lumn for cloud free pixels ongitude_ccd.	ntegrated column egrated column is calculate the tota nce to users who NC_FLOAT ntegrated column calculate the tota a convenience to

	long_name	'averaged total ozone column based on the CCD algorithm' (static)	NC_STRING
	vertical_range bottom	'surface' (static)	NC_STRING
	vertical_range top	'80_km' (static)	NC_STRING
	multiplication factor_to_con- vert to DU	2241.15 (static)	NC_FLOAT
	The quantities in Se value this means th "DU" or Dobson Uni	entinel 5 precursor files are given in SI units. For an in at the unit is $mol m^{-2}$ . Traditionally the unit for an inter- ts. This attribute provides the multiplication factor to a the value in $mol m^{-2}$ . This is provided as a convenie is in DU.	egrated column i calculate the tota
	multiplication factor_to_con- vert_to_mo- lecules_percm2	6.02214e+19 (static)	NC_FLOAT
	value this means th is "molecules $cm^{-2}$ ". column in molecules	entinel 5 precursor files are given in SI units. For an in nat the unit is $mol m^{-2}$ . Traditionally the unit for an in This attribute provides the multiplication factor to c $scm^{-2}$ from the value in $mol m^{-2}$ . This is provided as is that work in molecules cm <sup>-2</sup> .	ntegrated colum alculate the tota
	users who have loo		
	terations_ozone_up	per_tropospheric_mixing_ratio in O3_TCL/PRODU	JCT/SUPPORT_
		per_tropospheric_mixing_ratio in O3_TCL/PRODU	JCT/SUPPORT_
DATA/DETAIL Dimensions:	terations_ozone_up ED_RESULTS time, latitude_csa, lo	per_tropospheric_mixing_ratio in O3_TCL/PRODU	JCT/SUPPORT_
DATA/DETAIL	terations_ozone_up ED_RESULTS	per_tropospheric_mixing_ratio in O3_TCL/PRODU	JCT/SUPPORT_
DATA/DETAIL Dimensions: Type: Source:	terations_ozone_up ED_RESULTS time, latitude_csa, lo NC_INT.	per_tropospheric_mixing_ratio in O3_TCL/PRODU	JCT/SUPPORT_
DATA/DETAIL Dimensions: Type: Source: Mode:	terations_ozone_up ED_RESULTS time, latitude_csa, lo NC_INT. Processor.	per_tropospheric_mixing_ratio in O3_TCL/PRODU	JCT/SUPPORT_
DATA/DETAIL Dimensions: Type:	terations_ozone_up ED_RESULTS time, latitude_csa, lo NC_INT. Processor. Present in all modes	per_tropospheric_mixing_ratio in O3_TCL/PRODU ongitude_csa. s.	
DATA/DETAIL Dimensions: Type: Source: Mode:	terations_ozone_up ED_RESULTS time, latitude_csa, lo NC_INT. Processor. Present in all modes Name	per_tropospheric_mixing_ratio in O3_TCL/PRODU ongitude_csa. s. <u>Value</u> 'number of iterations in the upper tropospheric mix- ing ratio retrieval based on the CSA algorithm'	Туре
DATA/DETAIL Dimensions: Type: Source: Mode: Attributes: ozone_total_	terations_ozone_up ED_RESULTS time, latitude_csa, lo NC_INT. Processor. Present in all modes Name Iong_name units	per_tropospheric_mixing_ratio in O3_TCL/PRODU ongitude_csa. s. <u>Value</u> 'number of iterations in the upper tropospheric mix- ing ratio retrieval based on the CSA algorithm' (static)	<i>Type</i> NC_STRING NC_STRING
DATA/DETAIL Dimensions: Type: Source: Mode: Attributes: ozone_total_ ULTS	terations_ozone_up ED_RESULTS time, latitude_csa, lo NC_INT. Processor. Present in all modes Name long_name units vertical_column_press	per_tropospheric_mixing_ratio in O3_TCL/PRODU ongitude_csa. s. <u>Value</u> 'number of iterations in the upper tropospheric mix- ing ratio retrieval based on the CSA algorithm' (static) '1' (static)	<i>Type</i> NC_STRING NC_STRING
DATA/DETAIL Dimensions: Type: Source: Mode: Attributes: Attributes: <b>ozone_total_</b> ULTS Description:	terations_ozone_up ED_RESULTS time, latitude_csa, lo NC_INT. Processor. Present in all modes Name long_name units vertical_column_press	per_tropospheric_mixing_ratio in O3_TCL/PRODU ongitude_csa. s. <u>Value</u> 'number of iterations in the upper tropospheric mix- ing ratio retrieval based on the CSA algorithm' (static) '1' (static) ecision in O3_TCL/PRODUCT/SUPPORT_DATA/ of the total O <sub>3</sub> column for cloud free pixels	<i>Type</i> NC_STRING NC_STRING
DATA/DETAIL Dimensions: Type: Source: Mode: Attributes:	terations_ozone_up ED_RESULTS time, latitude_csa, lo NC_INT. Processor. Present in all modes Name Iong_name units vertical_column_press	per_tropospheric_mixing_ratio in O3_TCL/PRODU ongitude_csa. s. <u>Value</u> 'number of iterations in the upper tropospheric mix- ing ratio retrieval based on the CSA algorithm' (static) '1' (static) ecision in O3_TCL/PRODUCT/SUPPORT_DATA/ of the total O <sub>3</sub> column for cloud free pixels	<i>Type</i> NC_STRING NC_STRING
DATA/DETAIL Dimensions: Type: Source: Mode: Attributes: Attributes: <b>ozone_total_</b> ULTS Description: Dimensions:	terations_ozone_up ED_RESULTS time, latitude_csa, lo NC_INT. Processor. Present in all modes Name long_name units vertical_column_pro Standard deviation of time, latitude_ccd, lo	per_tropospheric_mixing_ratio in O3_TCL/PRODU ongitude_csa. s. <u>Value</u> 'number of iterations in the upper tropospheric mix- ing ratio retrieval based on the CSA algorithm' (static) '1' (static) ecision in O3_TCL/PRODUCT/SUPPORT_DATA/ of the total O <sub>3</sub> column for cloud free pixels	<i>Type</i> NC_STRING NC_STRING
DATA/DETAIL Dimensions: Type: Source: Mode: Attributes: Attributes: <b>ozone_total_</b> ULTS Description: Dimensions: Type:	terations_ozone_up ED_RESULTS time, latitude_csa, lo NC_INT. Processor. Present in all modes Name long_name units vertical_column_pro Standard deviation of time, latitude_ccd, lo NC_FLOAT.	per_tropospheric_mixing_ratio in O3_TCL/PRODU ongitude_csa. s. <u>Value</u> 'number of iterations in the upper tropospheric mix- ing ratio retrieval based on the CSA algorithm' (static) '1' (static) ecision in O3_TCL/PRODUCT/SUPPORT_DATA/ of the total O <sub>3</sub> column for cloud free pixels ongitude_ccd.	<i>Type</i> NC_STRING NC_STRING
DATA/DETAIL Dimensions: Type: Source: Mode: Attributes: Attributes: <b>ozone_total_</b> ULTS Description: Dimensions: Type: Source:	terations_ozone_up ED_RESULTS time, latitude_csa, lo NC_INT. Processor. Present in all modes Name Iong_name units vertical_column_pro Standard deviation o time, latitude_ccd, lo NC_FLOAT. Processor.	per_tropospheric_mixing_ratio in O3_TCL/PRODU ongitude_csa. s. <u>Value</u> 'number of iterations in the upper tropospheric mix- ing ratio retrieval based on the CSA algorithm' (static) '1' (static) ecision in O3_TCL/PRODUCT/SUPPORT_DATA/ of the total O <sub>3</sub> column for cloud free pixels ongitude_ccd.	<i>Type</i> NC_STRING NC_STRING
DATA/DETAIL Dimensions: Type: Source: Mode: Attributes: <b>ozone_total_</b> ULTS Description: Dimensions: Type: Source: Mode:	terations_ozone_up ED_RESULTS time, latitude_csa, lo NC_INT. Processor. Present in all modes Name Iong_name units vertical_column_pro Standard deviation of time, latitude_ccd, lo NC_FLOAT. Processor. Present in all modes	per_tropospheric_mixing_ratio in O3_TCL/PRODU ongitude_csa. <u>S.</u> <u>Value</u> 'number of iterations in the upper tropospheric mix- ing ratio retrieval based on the CSA algorithm' (static) '1' (static) ecision in O3_TCL/PRODUCT/SUPPORT_DATA/ of the total O <sub>3</sub> column for cloud free pixels ongitude_ccd. S.	<i>Type</i> NC_STRING NC_STRING DETAILED_RES
DATA/DETAIL Dimensions: Type: Source: Mode: Attributes: <b>ozone_total_</b> ULTS Description: Dimensions: Type: Source: Mode:	terations_ozone_up ED_RESULTS time, latitude_csa, lo NC_INT. Processor. Present in all modes Name Iong_name units vertical_column_pro Standard deviation of time, latitude_ccd, lo NC_FLOAT. Processor. Present in all modes Name	per_tropospheric_mixing_ratio in O3_TCL/PRODU ongitude_csa. <u>Value</u> 'number of iterations in the upper tropospheric mix- ing ratio retrieval based on the CSA algorithm' (static) '1' (static) ecision in O3_TCL/PRODUCT/SUPPORT_DATA/ of the total O <sub>3</sub> column for cloud free pixels ongitude_ccd. s. <u>Value</u>	<i>Type</i> NC_STRING NC_STRING DETAILED_RES
DATA/DETAIL Dimensions: Type: Source: Mode: Attributes: <b>ozone_total_</b> ULTS Description: Dimensions: Type: Source: Mode:	terations_ozone_up ED_RESULTS time, latitude_csa, lo NC_INT. Processor. Present in all modes Name Iong_name units vertical_column_pro Standard deviation of time, latitude_ccd, lo NC_FLOAT. Processor. Present in all modes Name units	per_tropospheric_mixing_ratio in O3_TCL/PRODU ongitude_csa. <u>S.</u> <u>Value</u> 'number of iterations in the upper tropospheric mix- ing ratio retrieval based on the CSA algorithm' (static) '1' (static) ecision in O3_TCL/PRODUCT/SUPPORT_DATA/ of the total O <sub>3</sub> column for cloud free pixels ongitude_ccd. <u>S.</u> <u>Value</u> 'mol m-2' (static) 'atmosphere_mole_content_of_ozone standard	<i>Type</i> NC_STRING NC_STRING DETAILED_RES <i>Type</i> NC_STRING
DATA/DETAIL Dimensions: Type: Source: Mode: Attributes: <b>ozone_total_</b> ULTS Description: Dimensions: Type: Source: Mode:	terations_ozone_up ED_RESULTS time, latitude_csa, lo NC_INT. Processor. Present in all modes Name Iong_name units vertical_column_pro Standard deviation of time, latitude_ccd, lo NC_FLOAT. Processor. Present in all modes Name units standard_name	per_tropospheric_mixing_ratio in O3_TCL/PRODU ongitude_csa. s. <u>Value</u> 'number of iterations in the upper tropospheric mix- ing ratio retrieval based on the CSA algorithm' (static) '1' (static) ecision in O3_TCL/PRODUCT/SUPPORT_DATA/ of the total O <sub>3</sub> column for cloud free pixels ongitude_ccd. s. <u>Value</u> 'mol m-2' (static) 'atmosphere_mole_content_of_ozone standard error' (static) 'standard deviation of total ozone column based on	<i>Type</i> NC_STRING NC_STRING DETAILED_RES <i>Type</i> NC_STRING NC_STRING

	multiplication factor_to_con- vert_to_DU	2241.15 (static)	NC_FLOAT
	The quantities in Se value this means th "DU" or Dobson Un	entinel 5 precursor files are given in SI units. For an i bat the unit is $mol m^{-2}$ . Traditionally the unit for an interits. This attribute provides the multiplication factor to the value in $mol m^{-2}$ . This is provided as a convenie $\kappa$ in DU.	egrated column is calculate the total
	multiplication	6.02214e+19 (static)	NC_FLOAT
	factor_to_con-		
	vert_to_mo-		
	lecules_percm2	antinal E progurage filos are given in Clumita. For en i	nto grated a aluma
	value this means the is "molecules $cm^{-2}$ " column in molecules	entinel 5 precursor files are given in SI units. For an i nat the unit is $mol m^{-2}$ . Traditionally the unit for an in . This attribute provides the multiplication factor to $c s cm^{-2}$ from the value in $mol m^{-2}$ . This is provided as Is that work in molecules $cm^{-2}$ .	ntegrated column calculate the total
cloud_top_pr	essure_min in O3_	TCL/PRODUCT/SUPPORT_DATA/DETAILED_RESU	LTS
Description:		pressure for the calcualtion of upper tropospheric mix	king ratio
Dimensions:	time, latitude_csa, l	ongitude_csa.	
Туре:	NC_FLOAT.		
Source:	Processor.		
Mode:	Present in all mode	S.	
Attributes:	Name	Value	Туре
	units	'Pa' (static)	NC_STRING
-	standard_name	'TBD' (static)	NC_STRING
	long_name	'minimum cloud top pressure minimum based on the CSA algorithm' (static)	NC_STRING
cloud_top_pr	essure_max in O3_	TCL/PRODUCT/SUPPORT_DATA/DETAILED_RESU	LTS
Description:	maximum cloud top	pressure for the calcualtion of upper tropospheric mi	xing ratio.
Dimensions:	time, latitude_csa, l	ongitude_csa.	
Туре:	NC_FLOAT.		
Source:	Processor.		
Mode:	Present in all mode	S.	
Attributes:	Name	Value	Туре
	units	'Pa' (static)	NC_STRING
	units standard_name	'Pa' (static) 'TBD' (static)	NC_STRING NC_STRING
surface_albe	standard_name long_name	'TBD' (static)	NC_STRING
surface_albe	standard_name long_name do in O3_TCL/PROE	'TBD' (static) 'maximum cloud top pressure' (static)	NC_STRING
_	standard_name long_name do in O3_TCL/PROE	'TBD' (static) 'maximum cloud top pressure' (static) DUCT/SUPPORT_DATA/DETAILED_RESULTS bedo for the cloud free observations.	NC_STRING
Description:	standard_name long_name do in O3_TCL/PROE Average surface alt	'TBD' (static) 'maximum cloud top pressure' (static) DUCT/SUPPORT_DATA/DETAILED_RESULTS bedo for the cloud free observations.	NC_STRING
Description: Dimensions: Type: Source:	standard_name long_name do in O3_TCL/PROE Average surface alk time, latitude_ccd, I NC_FLOAT. Processor.	'TBD' (static) 'maximum cloud top pressure' (static) DUCT/SUPPORT_DATA/DETAILED_RESULTS bedo for the cloud free observations. ongitude_ccd.	NC_STRING
Description: Dimensions: Type:	standard_name long_name do in O3_TCL/PROE Average surface alk time, latitude_ccd, I NC_FLOAT.	'TBD' (static) 'maximum cloud top pressure' (static) DUCT/SUPPORT_DATA/DETAILED_RESULTS bedo for the cloud free observations. ongitude_ccd.	NC_STRING
Description: Dimensions: Type: Source:	standard_name long_name do in O3_TCL/PROE Average surface all time, latitude_ccd, I NC_FLOAT. Processor. Present in all mode Name	'TBD' (static) 'maximum cloud top pressure' (static) DUCT/SUPPORT_DATA/DETAILED_RESULTS bedo for the cloud free observations. ongitude_ccd. s. Value	NC_STRING NC_STRING <i>Type</i>
Description: Dimensions: Type: Source: Mode:	standard_name long_name do in O3_TCL/PROE Average surface alk time, latitude_ccd, I NC_FLOAT. Processor. Present in all mode Name units	'TBD' (static) 'maximum cloud top pressure' (static) DUCT/SUPPORT_DATA/DETAILED_RESULTS bedo for the cloud free observations. ongitude_ccd. s. <u>Value</u> '1' (static)	NC_STRING NC_STRING <i>Type</i> NC_STRING
Description: Dimensions: Type: Source: Mode:	standard_name long_name do in O3_TCL/PROE Average surface all time, latitude_ccd, I NC_FLOAT. Processor. Present in all mode Name units standard_name	<pre>'TBD' (static) 'maximum cloud top pressure' (static) DUCT/SUPPORT_DATA/DETAILED_RESULTS bedo for the cloud free observations. ongitude_ccd. s. Value '1' (static) 'surface_albedo' (static)</pre>	NC_STRING NC_STRING <i>Type</i> NC_STRING NC_STRING
Description: Dimensions: Type: Source: Mode:	standard_name long_name do in O3_TCL/PROE Average surface alk time, latitude_ccd, I NC_FLOAT. Processor. Present in all mode Name units	'TBD' (static) 'maximum cloud top pressure' (static) DUCT/SUPPORT_DATA/DETAILED_RESULTS bedo for the cloud free observations. ongitude_ccd. s. <u>Value</u> '1' (static)	NC_STRING NC_STRING <i>Type</i> NC_STRING

	valid_max	1 (static)	NC_FLOAT
surface_altitu	ude in O3_TCL/PRO	DUCT/SUPPORT_DATA/DETAILED_RESULTS	
Description:		b-pixels of the surface altitude above the reference geoi Id of view, based on the GMTED2010 surface elevatio	
Dimensions:	time, latitude_ccd, l	ongitude_ccd.	
Туре:	NC_FLOAT.		
Source:	surface elevation da	atabase.	
Mode:	Present in all mode	S.	
Attributes:	Name	Value	Туре
	long_name	'surface altitude based on the CCD algorithm' (static)	NC_STRING
	standard_name	'surface_altitude' (static)	NC_STRING
	units	'm' (static)	NC_STRING
	coordinates	<pre>'/PRODUCT/longitude_ccd /PRODUCT/latitude ccd' (static)</pre>	NC_STRING
		ngitude are in a different group. How to specify the r case is not specified in the climate and forecast n	
	source	'http://topotools.cr.usgs.gov/gmted_viewer/' (static)	NC_STRING
	comment	'The mean of the sub-pixels of the surface altitude above the reference geoid (WGS84) within the ap- proximate field of view, based on the GMTED2010	NC_STRING
		surface elevation database' (static)	
surface class	sification in O3 TCI	surface elevation database' (static) /PRODUCT/SUPPORT_DATA/DETAILED_RESULTS	
_		/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS	
Description:	Average surface co	/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nditon flag for cloud free observations.	,
Description: Dimensions:	Average surface co time, latitude_ccd, l	/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nditon flag for cloud free observations.	
Description: Dimensions: Type:	Average surface co	/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nditon flag for cloud free observations.	
Description: Dimensions: Type: Source:	Average surface co time, latitude_ccd, l NC_INT.	/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nditon flag for cloud free observations. longitude_ccd.	
Description: Dimensions: Type: Source: Mode:	Average surface co time, latitude_ccd, l NC_INT. Processor.	/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nditon flag for cloud free observations. longitude_ccd.	
Description: Dimensions: Type: Source: Mode:	Average surface co time, latitude_ccd, l NC_INT. Processor. Present in all mode	/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nditon flag for cloud free observations. ongitude_ccd.	Туре
Description: Dimensions: Type: Source: Mode:	Average surface co time, latitude_ccd, l NC_INT. Processor. Present in all mode Name	/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nditon flag for cloud free observations. ongitude_ccd. s. <u>Value</u> '1' (static)	
surface_class Description: Dimensions: Type: Source: Mode: Attributes:	Average surface co time, latitude_ccd, l NC_INT. Processor. Present in all mode Name units	/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nditon flag for cloud free observations. longitude_ccd. s. Value	<i>Type</i> NC_STRING
Description: Dimensions: Type: Source: Mode:	Average surface co time, latitude_ccd, l NC_INT. Processor. Present in all mode Name units standard_name	/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nditon flag for cloud free observations. ongitude_ccd. s. Value '1' (static) 'TBD' (static) 'averaged land-water mask based on the CCD al-	<i>Type</i> NC_STRING NC_STRING
Description: Dimensions: Type: Source: Mode:	Average surface co time, latitude_ccd, l NC_INT. Processor. Present in all mode Name units standard_name long_name flag_values	/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nditon flag for cloud free observations. ongitude_ccd. s. <u>Value</u> '1' (static) 'TBD' (static) 'averaged land-water mask based on the CCD al- gorithm' (static) '0, 1, 2' (static)	<i>Type</i> NC_STRING NC_STRING NC_STRING NC_STRING
Description: Dimensions: Type: Source: Mode: Attributes: Attributes:	Average surface co time, latitude_ccd, l NC_INT. Processor. Present in all mode Name units standard_name long_name flag_values flag_meanings	/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nditon flag for cloud free observations. ongitude_ccd. s. Value '1' (static) 'TBD' (static) 'averaged land-water mask based on the CCD al- gorithm' (static)	<i>Type</i> NC_STRING NC_STRING NC_STRING NC_STRING NC_STRING
Description: Dimensions: Type: Source: Mode: Attributes: Attributes:	Average surface co time, latitude_ccd, l NC_INT. Processor. Present in all mode Name units standard_name long_name flag_values flag_meanings observations_ozone ED_RESULTS	/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nditon flag for cloud free observations. ongitude_ccd. s. <i>Value</i> '1' (static) 'TBD' (static) 'averaged land-water mask based on the CCD al- gorithm' (static) '0, 1, 2' (static) 'land coast water' (static)	<i>Type</i> NC_STRING NC_STRING NC_STRING NC_STRING NC_STRING
Description: Dimensions: Type: Source: Mode: Attributes: Attributes: <b>number_of_o</b> DATA/DETAIL Description:	Average surface co time, latitude_ccd, l NC_INT. Processor. Present in all mode Name units standard_name long_name flag_values flag_meanings observations_ozone ED_RESULTS	/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nditon flag for cloud free observations. ongitude_ccd. s. Value '1' (static) 'TBD' (static) 'averaged land-water mask based on the CCD al- gorithm' (static) '0, 1, 2' (static) 'land coast water' (static) e_stratospheric_vertical_column in O3_TCL/PRODU veraged for stratospheric O <sub>3</sub> column	<i>Type</i> NC_STRING NC_STRING NC_STRING NC_STRING NC_STRING
Description: Dimensions: Type: Source: Mode: Attributes: Attributes: Data/DETAIL Description: Dimensions:	Average surface co time, latitude_ccd, l NC_INT. Processor. Present in all mode Name units standard_name long_name flag_values flag_meanings observations_ozone ED_RESULTS Number of pixels av	/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nditon flag for cloud free observations. ongitude_ccd. s. Value '1' (static) 'TBD' (static) 'averaged land-water mask based on the CCD al- gorithm' (static) '0, 1, 2' (static) 'land coast water' (static) e_stratospheric_vertical_column in O3_TCL/PRODU veraged for stratospheric O <sub>3</sub> column	<i>Type</i> NC_STRING NC_STRING NC_STRING NC_STRING NC_STRING
Description: Dimensions: Type: Source: Mode: Attributes: Attributes: DATA/DETAIL Description: Dimensions: Type:	Average surface co time, latitude_ccd, l NC_INT. Processor. Present in all mode Name units standard_name long_name flag_values flag_meanings observations_ozone ED_RESULTS Number of pixels av time, latitude_ccd, l	/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nditon flag for cloud free observations. ongitude_ccd. s. Value '1' (static) 'TBD' (static) 'averaged land-water mask based on the CCD al- gorithm' (static) '0, 1, 2' (static) 'land coast water' (static) e_stratospheric_vertical_column in O3_TCL/PRODU veraged for stratospheric O <sub>3</sub> column	<i>Type</i> NC_STRING NC_STRING NC_STRING NC_STRING NC_STRING
Description: Dimensions: Type: Source: Mode: Attributes: Attributes: Datta/DETAIL Description: Dimensions: Type: Source:	Average surface co time, latitude_ccd, l NC_INT. Processor. Present in all mode Name units standard_name Iong_name flag_values flag_meanings observations_ozone ED_RESULTS Number of pixels av time, latitude_ccd, l	/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nditon flag for cloud free observations. longitude_ccd. s. Value '1' (static) 'TBD' (static) 'averaged land-water mask based on the CCD al- gorithm' (static) '0, 1, 2' (static) 'land coast water' (static) e_stratospheric_vertical_column in O3_TCL/PRODU veraged for stratospheric O <sub>3</sub> column longitude_ccd.	<i>Type</i> NC_STRING NC_STRING NC_STRING NC_STRING NC_STRING
Description: Dimensions: Type: Source: Mode: Attributes: Attributes: DATA/DETAIL Description: Dimensions: Type: Source: Mode:	Average surface co time, latitude_ccd, l NC_INT. Processor. Present in all mode Name units standard_name long_name flag_values flag_meanings observations_ozone ED_RESULTS Number of pixels av time, latitude_ccd, l NC_INT. Processor.	/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nditon flag for cloud free observations. longitude_ccd. s. Value '1' (static) 'TBD' (static) 'averaged land-water mask based on the CCD al- gorithm' (static) '0, 1, 2' (static) 'land coast water' (static) e_stratospheric_vertical_column in O3_TCL/PRODU veraged for stratospheric O <sub>3</sub> column longitude_ccd.	<i>Type</i> NC_STRING NC_STRING NC_STRING NC_STRING NC_STRING
Description: Dimensions: Type: Source: Mode: Attributes: Attributes:	Average surface co time, latitude_ccd, l NC_INT. Processor. Present in all mode Name units standard_name Iong_name flag_values flag_meanings bbservations_ozone ED_RESULTS Number of pixels av time, latitude_ccd, l NC_INT. Processor. Present in all mode	/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nditon flag for cloud free observations. longitude_ccd. s. Value '1' (static) 'TBD' (static) 'averaged land-water mask based on the CCD al- gorithm' (static) '0, 1, 2' (static) 'land coast water' (static) p_stratospheric_vertical_column in O3_TCL/PRODU veraged for stratospheric O <sub>3</sub> column longitude_ccd. s. Value	Type NC_STRING NC_STRING NC_STRING NC_STRING UCT/SUPPORT Type
Description: Dimensions: Type: Source: Mode: Attributes: Attributes: DATA/DETAIL Description: Dimensions: Type: Source: Mode:	Average surface co time, latitude_ccd, l NC_INT. Processor. Present in all mode Name units standard_name long_name flag_values flag_meanings observations_ozone ED_RESULTS Number of pixels av time, latitude_ccd, l NC_INT. Processor. Present in all mode Name	/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS nditon flag for cloud free observations. longitude_ccd. IS. Value '1' (static) 'TBD' (static) 'averaged land-water mask based on the CCD al- gorithm' (static) '0, 1, 2' (static) 'land coast water' (static) e_stratospheric_vertical_column in O3_TCL/PRODU veraged for stratospheric O <sub>3</sub> column longitude_ccd. IS.	<i>Type</i> NC_STRING NC_STRING NC_STRING NC_STRING UCT/SUPPORT

	valid_min	0 (static)	NC_FLOAT
	bservations_ozone ATA/DETAILED_RES	e_stratospheric_vertical_column_reference in O3_ SULTS	_TCL/PRODUCT
Description:	Number of pixels a	veraged for stratospheric $O_3$ column in the reference a	area.
Dimensions:	time, latitude_ccd.		
Туре:	NC_INT.		
Source:	Processor.		
Mode:	Present in all mode	2S.	
Attributes:	Name	Value	Туре
	units	'1' (static)	NC_STRING
	standard_name	'TBD' (static)	NC_STRING
	long_name	'number of data averaged for stratospheric refer- ence ozone column based on the CCD algorithm' (static)	NC_STRING
	valid_min	0 (static)	NC_FLOAT
	bservations_ozone	e_tropospheric_vertical_column in O3_TCL/PRODU	JCT/SUPPORT_
Description:	_	els averaged for O3 tropospheric column in a grid cell.	
Dimensions:	time, latitude_ccd,		
Гуре:	NC INT.	<b>·</b> –	
Source:	Processor.		
Mode:	Present in all mode	9S.	
Attributes:	Name	Value	Туре
	units	'1' (static)	NC_STRING
	standard_name	'troposphere_mole_content_of_ozone number_of observations' (static)	NC_STRING
	long_name	'number of data averaged for tropospheric ozone column based on the CCD algorithm' (static)	NC_STRING
	valid_min	0 (static)	NC_FLOAT
number_of_c RESULTS	observations_ozone	e_total_column in O3_TCL/PRODUCT/SUPPORT_D	ATA/DETAILED_
Description:	Number of S5P pix	els averaged for $O_3$ total column in a grid cell.	
Dimensions:	time, latitude_ccd,	longitude_ccd.	
Туре:	NC_INT.		
Source:	Processor.		
Mode:	Present in all mode	9S.	
Attributes:	Name	Value	Туре
	units	'1' (static)	NC_STRING
	standard_name	'atmosphere_mole_content_of_ozone number_of observations' (static)	NC_STRING
	long_name	'number of data averaged for total ozone column based on the CCD algorithm' (static)	NC_STRING
	valid_min	0 (static)	NC_FLOAT
	bservations_ozone		TCL/PRODUCT
	ATA/DETAILED_RES	SULIS	
	_	SULTS else for uppertroposheric $O_3$ retrieval.	
SUPPORT_D	_	els used for uppertroposheric $O_3$ retrieval.	
SUPPORT_D Description:	Number of S5P pix	els used for uppertroposheric $O_3$ retrieval.	

Mode:	Present in all mode	PS.	
Attributes:	Name	Value	Туре
	units	'1' (static)	NC_STRING
	standard_name	'TBD' (static)	NC_STRING
	long_name	'number of data used in the upper tropospheric mixing ratio retrieval' (static)	NC_STRING
number_of_skipped_observations_ozone_upper_tropospheric_mixing_ratio in O3_TCL/PRODUC SUPPORT_DATA/DETAILED_RESULTS			
Description:	Number of S5P pixe	els skipped during uppertropospheric $O_3$ retrieval.	
Dimensions:	time, latitude_csa, l	longitude_csa.	
Туре:	NC_INT.		
Source:	Processor.		
Mode:	Present in all mode	S.	
Attributes:	Name	Value	Туре
	units	'1' (static)	NC_STRING
	standard_name	'TBD' (static)	NC_STRING
	long_name	'number of data skipped in the upper tropospheric mixing ratio retrieval based on the CSA algorithm' (static)	NC_STRING

# 13.2 Group "METADATA" in "O3\_TCL"

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 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].

#### Attributes in O3\_TCL/METADATA

Group attributes attached to METADATA				
Name	Value	Туре		
input_orbits	'list' (dynamic)	NC_STRING		
List of L2 orbits data that v	vere used to produce the tropospheric $O_3$ prod	uct		
processor_version	'version' (dynamic)	NC_STRING		
Version of the processor u	sed			
algorithm_version		NC_STRING		
The algorithm version, separate from the processor (framework) version, to accomodate different relea schedules for different products.				
input_files	'list' (dynamic)	NC_STRING		
Absolute path of L2 proc	ducts which were used to produce the troposph	neric O <sub>3</sub> product		
processingMode		NC_STRING		
Processor MODE (NRTI, C	DFFL, RPRO, OPER or TEST)			
days_for_tropospheric_c	column	NC_INT		
This attributes indicates ho	This attributes indicates how many days of Ozone Total Column were ingested as input to the tropospheric			
processors.				
dates_for_tropospheric_	column	NC_STRING		
This attributes indicates w processors.	which days of Ozone Total Column were inges	ted as input to the tropospheric		

#### 13.2.1 Group "QA\_STATISTICS" in "METADATA"

# Dimensions in O3\_TCL/METADATA/QA\_STATISTICS

#### histogram\_axis\_upper\_tropospheric\_ozone

size 100 (fixed) source Processor. mode Present in all modes.

#### histogram\_axis\_tropospheric\_ozone

size 100 (fixed) source Processor. mode Present in all modes.

#### Variables in O3\_TCL/METADATA/QA\_STATISTICS

histogram_a	xis_upper_troposph	neric_ozone in O3_TCL/METADATA/QA_STATISTICS	6		
Description:	Histogram axis for the tropospheric_o3 column, int type				
Dimensions:	histogram_axis_up	histogram_axis_upper_tropospheric_ozone (coordinate variable).			
Туре:	NC_INT.				
Source:	Processor.				
Mode:	Present in all mode	S.			
Attributes:	Name	Value	Туре		
	units	'1' (static)	NC_STRING		
histogram_a	xis_tropospheric_o	zone in O3_TCL/METADATA/QA_STATISTICS			
Description:	Histogram axis for t	he tropospheric_o3 column, float type			
Dimensions:	histogram_axis_tro	pospheric_ozone (coordinate variable).			
Туре:	NC_FLOAT.				
Source:	Processor.				
Mode:	Present in all mode	S.			
Attributes:	Name	Value	Туре		
	units	'1' (static)	NC_STRING		
ozone_upper	_troposheric_mixin	g_ratio_histogram in O3_TCL/METADATA/QA_STA	FISTICS		
Description:	Histogram of upper	tropospheric ozone mixing ratios in the current granu	le.		
Dimensions:	histogram_axis_up	per_tropospheric_ozone.			
Туре:	NC_INT.				
Source:	Processor.				
Mode:	Present in all mode	·S.			
Attributes:	Name	Value	Туре		
	units	'1' (static)	NC_STRING		
	standard_name	'TBD' (static)	NC_STRING		
	long_name	'histogram of upper tropospheric ozone mixing ra- tios' (static)	NC_STRING		
	comment	'Histogram of upper tropospheric ozone mixing ra- tios in the current granule' (static)	NC_STRING		
ozone_tropo	spheric_vertical_co	lumn_histogram in O3_TCL/METADATA/QA_STATIS	STICS		
Description:	Histogram of upper	tropospheric ozone mixing ratios in the current granu	le.		
•	Histogram of upper histogram_axis_tro		le.		
Dimensions:	• • • •		le.		
Description: Dimensions: Type: Source:	histogram_axis_tro		le.		

Attributes:	Name	Value	Туре
	units	'1' (static)	NC_STRING
	standard_name	'TBD' (static)	NC_STRING
	long_name	'histogram of tropospheric ozone columns' (static)	NC_STRING
	comment	'Histogram of tropospheric ozone columns in the current granule' (static)	NC_STRING

# 13.2.2 Group "ALGORITHM\_SETTINGS" in "METADATA"

#### Attributes in O3\_TCL/METADATA/ALGORITHM\_SETTINGS

Group attributes attached to ALGORITHM_SETTINGS				
Name	Value	Туре		
stratospheric_o3_cloud minimum_fraction	'0.8' (static)	NC_STRING		
stratospheric_o3_cloud minimum_height	'8.5' (static)	NC_STRING		
stratospheric_o3_cloud maximum_height	'14.9' (static)	NC_STRING		
stratospheric_o3_cloud topheight	'10' (static)	NC_STRING		
stratospheric_o3_ref_min- imum	'200' (static)	NC_STRING		
stratospheric_o3_ref_min- imum_number	'8' (static)	NC_STRING		
stratospheric_o3_ref_max- imum_deviation	'10' (static)	NC_STRING		
stratospheric_o3_ref_max- imum_delta	'4.2' (static)	NC_STRING		
tropospheric_o3_cloud maximum_fraction	'0.1' (static)	NC_STRING		
upper_tropospheric_o3_min- imum_start	'15' (static)	NC_STRING		
upper_tropospheric_o3_min- imum_continue	'5' (static)	NC_STRING		
upper_tropospheric_o3_min- imum_iterations	'2' (static)	NC_STRING		
upper_tropospheric_o3 maximum_iterations	'10' (static)	NC_STRING		
upper_tropospheric_o3 cloud_maximum_height	'17' (static)	NC_STRING		
upper_tropospheric_o3 cloud_minimum_height	'5' (static)	NC_STRING		
upper_tropospheric_o3 pressure_minimum_differ- ence	'100' (static)	NC_STRING		
upper_tropospheric_o3 pressure_minimum	'400' (static)	NC_STRING		

#### 13.2.3 Group "GRANULE\_DESCRIPTION" in "METADATA"

### Attributes in O3\_TCL/METADATA/GRANULE\_DESCRIPTION

Group attributes attached t	o GRANULE_DESCRIPTION	
Name	Value	Туре
ProductShortName	'L2_O3_TCL' (static)	NC_STRING
The short product name. F	or the $O_3$ Tropospheric Column product this is fixe	ed to "L2 O3_TCL".
GranuleStart		NC_STRING
Start of the granule as ISO definition of ISO date/time s	date/time string in UTC: YYYY-MM-DDTHH:MM: strings is given in [RD35].	SS.mmmmmm <b>Z</b> . The forma
GranuleEnd		NC_STRING
End of the granule as ISO definition of ISO date/times	date/time string in UTC: YYYY-MM-DDTHH:MM: strings is given in [RD35].	SS.mmmmmmmZ. The forma
InstrumentName	'TROPOMI' (static)	NC_STRING
The name of the instrumen	t, fixed to "TROPOMI".	
MissionName	'Sentinel-5 precursor' (static)	NC_STRING
The name of the mission, fi	xed to "Sentinel-5 precursor".	
MissionShortName	'S5P' (static)	NC_STRING
The short name of the miss	sion, fixed to "S5P".	
ProcessLevel	'2c' (static)	NC_STRING
This is a level 2c product.		
ProcessorVersion	'%(version)s' (dynamic)	NC_STRING
The version number of th jor.minor.bugfix".	e processor used to produce the file. This is	a string formatted as "ma
ProductFormatVersion		NC_STRING
The version of the format o	f the product file. This should be incremented whe	enever a datafield is added to

the files.

# A Flag descriptions

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

Please be aware that this section is work in progress and the flags are not included in the product yet. The aim of this section is for review only.

**Table 12**: Processing quality flags, errors, processing failures and filter conditions for S5P Level 2. Warnings are listed in table 13. The value in the first column is the result of a bitwise 'and' of 255 (0xFF) and the value in the "processing\_quality\_flags" variable.

#	Short name	Description	Algorithm
0	success	No failures, output contains value. Warnings still possible.	All
1	radiance_missing	The number of spectral pixels in the radiance due to flagging is too small to perform the fitting.	All
2	irradiance_missing	The number of spectral pixels in the irradiance due to flagging is too small to perform the fitting.	All
3	input_spectrum_missing	The reflectance spectrum does not contain enough points to perform the retrieval. This is different from (ir)radiance_missing in that the missing points may not be aligned.	All
4	reflectance_range_error	Any of the reflectances is out of bounds ( $R < 0$ or $R > R_{max}$ ).	FRESCO
5	ler_range_error	Lambert-equivalent reflectivity out of range error.	CO, CH <sub>4</sub>
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 <sub>2</sub>
10	ozone_range_error	Ozone column significantly out of range of profile climatology.	Total O <sub>3</sub> column
11	wavelength_offset_error	Wavelength offset exceeds maximum from configuration.	FRESCO, NO <sub>2</sub>
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 <sub>4</sub>
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 <sub>4</sub> , O <sub>3</sub> profile
16	numerical_error	General fatal numerical error occurred during inversion.	CO, FRESCO
17	lut_error	Error in accessing the lookup table.	CH <sub>4</sub>
18	ISRF_error	Error detected in the input instrument spectral response function input data.	CH <sub>4</sub>
19	convergence_error	The main algorithm did not converge.	All
20	cloud_filter_convergence_error	The cloud filter did not converge.	CO

#	Short name	Description	Algorithm
21	max_iteration_convergence_error	No convergence because retrieval exceeds maximum number of iterations. Max- imum 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 suc- cession. Note that a separate failure flag is defined for non-convergence due to crossing of lower AOT boundary.	ALH
24	geolocation_error	Geolocation out of range.	
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 <sub>4</sub>
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 <sub>4</sub>
27	max_optical_thickness_error	Maximum optical thickness exceeded during iterations.	CH <sub>4</sub>
28	aerosol_boundary_error	Boundary hit of aerosol parameters at last iteration.	CH <sub>4</sub>
29	boundary_hit_error	Fatal boundary hit during iterations.	CH <sub>4</sub>
30	chi2_error	$\chi^2$ is not-a-number or larger than $10^{10}$ .	CH <sub>4</sub>
31	svd_error	Singular value decomposition failure.	CH <sub>4</sub>
32	dfs_error	Degree of freedom is not-a-number.	CH <sub>4</sub>
33	radiative_transfer_error	Errors occurred during the radiative transfer computations, no processing possible.	O <sub>3</sub> profile
34	optimal_estimation_error	Errors occurred during the optimal estimation, processing has been terminated.	O <sub>3</sub> profile
35	profile_error	Flag that indicates if there were any errors during the computation of the ozone profile.	O <sub>3</sub> profile
36	cloud_error	No cloud data.	Cloud
37	model_error	Forward model failure.	Cloud, Total O <sub>3</sub> column
38	number_of_input_data_points_too_low_error	Not enough input ozone columns to calculate a tropospheric column.	Tropospheric O3 column
39	cloud_pressure_spread_too_low_error	Cloud pressure variability to low to estimate a tropospheric column.	Tropospheric O3 column
40	cloud_too_low_level_error	Clouds are too low in the atmosphere to assume sufficient shielding.	Tropospheric O3 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

#	Short name	Description	Algorithm
44	abort_error	Not processed because processor aborted prematurely (time out or user abort)	All
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
48	slant_column_density_error	Slant column fit returned error, no values can be computed	
49	airmass_factor_error	Airmass factor could not be computed	
50	vertical_column_density_error	vertical column density could not be computed	
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
64	solar_eclipse_filter	Solar eclipse.	All
65	cloud_filter	The cloud filter triggered causing the pixel to be skipped.	CO, ALH, CH <sub>4</sub>
66	altitude_consistency_filter	Too large difference between ECMWF altitude and DEM altitude value.	CO, CH <sub>4</sub>
67	altitude_roughness_filter	Too large standard deviation of altitude in DEM.	CO, ALH, CH <sub>4</sub>
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 ex- ceeds threshold. Threshold value from ATBD.	ALH, CH <sub>4</sub>
75	cloud_fraction_viirs_filter	Pixel contains clouds: The cloud fraction from VIIRS / NPP exceeds theshold. Threshold value from ATBD.	ALH

#	Short name	Description	Algorithm
76	cirrus_reflectance_viirs_filter	Pixel contains clouds: Cirrus reflectance from VIIRS / NPP exceeds threshold. Threshold value from ATBD.	ALH
77	cf_viirs_swir_ifov_filter	Fraction of cloudy VIIRS pixels wihtin S5P SWIR ground pixel exceeds a priori threshold from configuration.	CH <sub>4</sub>
78	cf_viirs_swir_ofova_filter	Fraction of cloudy VIIRS pixels wihtin S5P SWIR OFOVa exceeds a priori threshold from configuration.	CH <sub>4</sub>
79	cf_viirs_swir_ofovb_filter	Fraction of cloudy VIIRS pixels wihtin S5P SWIR OFOVb exceeds a priori threshold from configuration.	CH <sub>4</sub>
80	cf_viirs_swir_ofovc_filter	Fraction of cloudy VIIRS pixels wihtin S5P SWIR OFOVc exceeds a priori threshold from configuration.	CH <sub>4</sub>
81	cf_viirs_nir_ifov_filter	Fraction of cloudy VIIRS pixels wihtin S5P NIR ground pixel exceeds a priori threshold from configuration.	CH <sub>4</sub>
82	cf_viirs_nir_ofova_filter	Fraction of cloudy VIIRS pixels wihtin S5P NIR OFOVa exceeds a priori threshold from configuration.	CH <sub>4</sub>
83	cf_viirs_nir_ofovb_filter	Fraction of cloudy VIIRS pixels wihtin S5P NIR OFOVb exceeds a priori threshold from configuration.	CH <sub>4</sub>
84	cf_viirs_nir_ofovc_filter	Fraction of cloudy VIIRS pixels wihtin S5P NIR OFOVc exceeds a priori threshold from configuration.	CH <sub>4</sub>
85	refl_cirrus_viirs_swir_filter	Average VIIRS cirrus reflectance within SWIR ground pixel exceeds a priori threshold from configuration.	CH <sub>4</sub>
86	refl_cirrus_viirs_nir_filter	Average VIIRS cirrus reflectance within NIR ground pixel exceeds a priori threshold from configuration.	CH <sub>4</sub>
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 <sub>4</sub>
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 <sub>4</sub>
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 <sub>4</sub>
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 <sub>4</sub>

#	Short name	Description	Algorithm
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 <sub>4</sub>
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 <sub>4</sub>
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 <sub>4</sub>
94	ocean_filter	The ground pixel is over ocean (and ocean glint retrievals are not switched on).	CH <sub>4</sub>
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 13**: Processing quality flags, warnings for S5P Level 2. Errors, processing failures and filter conditions are listed in table 12. 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 12 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 <sub>4</sub>
11	0x0000800	sun_glint_warning	Sun glint posibility warning.	All
12	0x00001000	south_atlantic_anomaly_warning	TROPOMI is inside the south Atlantic anomaly while taking these measure- ments.	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 <sub>2</sub>
15	0x00008000	cloud_warning	Cloud filter based on FRESCO apparent surface pressure (VIIRS not avail- able), cloud fraction above threshold or cloud pressure adjusted to force cloud above surface.	$CH_4$ , $O_3$ profile

Table 13: Processing quality flags, warnings for S5P Level 2 (continued).

Bit #	Mask (hex)	Short name	Description	Algorithm
16	0x00010000	AAI_warning	Possible aerosol contamination as indicated by the AAI.	O <sub>3</sub> profile
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.	CO, CH <sub>4</sub>
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 <sub>4</sub>
21	0x00200000	signal_to_noise_ratio_warning	Signal to noise ratio in SWIR and/or NIR band below threshold from configur- ation.	CH <sub>4</sub>
22	0x00400000	deconvolution_warning	Failed deconvolution irradiance spectrum (not pixel-specific, but row-specific).	CO, CH <sub>4</sub>
23	0x00800000	so2_volcanic_origin_likely_warning	Warning for SO <sub>2</sub> BL product, UTLS products: volcanic origin except for heavily polluted sites.	SO <sub>2</sub>
24	0x01000000	so2_volcanic_origin_certain_warning	Warning for SO <sub>2</sub> BL product, UTLS products: volcanic origin certain.	SO <sub>2</sub>
25	0x02000000	interpolation_warning	Warning for interpolation on partially missing data. In this case the valid available data is used, potentially leading to a bias.	All
26	0x04000000	saturation_warning	Saturation occurred spectrum, possibly causing biases in the retrieval	All
27	0x08000000	high_sza_warning	Warning for high solar zenith angle. In this case, the processing can be performed with less final quality.	All
28	0x10000000	cloud_retrieval_warning	Warning occurring when the retrieval diagnostic indicates a degraded quality of the cloud retrieval.	Cloud
29	0x20000000	cloud_inhomogeneity_warning	The cloud coregistration inhomogeneity parameter is above a given threshold	Cloud
30	0x40000000		Reserved for future use	

Table 14: 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 [ER11], specifically the "USGS Land Use/Land Cover System (Modified Level 2)" classification. Over water the classification from the NASA SDP toolkit [ER12], which is based on [RD42].

Bit #	Mask (hex)	Short name	Description
0	0x03	Land	The pixel is over land, for more than 50 %

Table 14: Surface classification for S5P Level 2 (continued).

Bit #	Mask (hex)	Short name	Description
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 $15 \times 15$ 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
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

 Table 14:
 Surface classification for S5P Level 2 (continued).

Bit #	Mask (hex)	Short name	Description
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