Royal Netherlands
Meteorological Institute
Ministry of Infrastructure
and Water Management

Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Nitrogendioxide

document number	:	S5P-KNMI-L2-0021-MA
authors	:	Henk Eskes, Jos van Geffen, Folkert Boersma, Kai-Uwe Eichmann, Arnoud Apituley, Mattia Pedergnana, Maarten Sneep, J. Pepijn Veefkind, Diego Loyola
CI identification	:	CI-7570-PUM
issue	:	3.0.0
date	:	2019-03-27
status	:	released

Document approval record

	digital signature
Prepared:	Henk Eskes Digitaal ondertekend door Henk Eskes Datum: 2019.03.27 14:03:27 +01'00'
ATBD Author:	Jos van Geffen Digitally signed by Jos van Geffen Date: 2019.03.27 14:17:40 +01'00'
Checked:	Maarten Sneep Digitally signed by Maarten Sneep Date: 2019.03.27 14:32:15 +01'00'
Approved PM:	Arnoud Apituley Digitally signed by Arnoud Apituley Date: 2019.03.27 14:36:22 +01'00'
Approved PI:	J. Pepijn Veefkind Digitally signed by J. Pepijn Veefkind Date: 2019.03.28 08:30:14 +01'00'

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. 9	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 definition
0.10.0	2016-03-31		Product descriptions updated for 0.10.0 release
0.10.1	2016-07-15		Product descriptions updated for DLR 0.10.1 release
0.11.0	2017-03-01		Updated for release 0.11.0 of the processor software, including new variable names.
0.11.6	2017-06-24		Released
1.0.0	2018-06-13		Prepared for public release of the NO_2 product, include first validation results.
1.0.1	2018-10-29	Sect. 8	Updated for version 1.2.0 of the processor software
2.0.0	2018-10-29		Released
2.0.1	2019-03-25		Updated for version 1.3.0 of the processor software
3.0.0	2019-03-27		Released

Contents

List of Tables

List of Figures

1 Introduction

1.1 Identification

This document, identified as S5P-KNMI-L2-0021-MA, describes the technical characteristics of the S5p/TROPOMI Level 2 products that are needed for efficient and correct use of the data contained. This product user manual is specific for Nitrogendioxide.

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 Nitrogendioxide 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 Nitrogendioxide 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 Nitrogendioxide data. We then continue with a discussion of units and quality assurance parameters. The final chapter contains information about generic metadata and the Appendix lists measurement flags, processing quality flags, and surface classifications.

2 Applicable and reference documents

2.1 Applicable documents

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

2.2 Standard documents

There are no standard documents

2.3 Reference documents

[RD1] J. P. Veefkind, I. Aben, K. McMullan *et al.*; TROPOMI on the ESA Sentinel-5 Precursor: A GMES mission for global observations of the atmospheric composition for climate, air quality and ozone layer applications. *Remote Sens. Environ.*; **120** (2012), 70; 10.1016/j.rse.2011.09.027.

[RD2] Input/output data specification for the TROPOMI L01b data processor. **source:** KNMI; **ref:** S5P-KNMI-L01B-0012-SD; **issue:** 5.0.0; **date:** 2015-09-22.

[RD3] S5P/TROPOMI ATBD Cloud Products. **source:** DLR; **ref:** S5P-DLR-L2-ATBD-400I; **issue:** 1.1.0; **date:** 2016-06-30.

[RD4] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Cloud. **source:** DLR; **ref:** S5P-L2-DLR-PUM-400I; **issue:** 1.0.0; **date:** 2018-04-30.

[RD5] S5P-NPP Cloud Processor ATBD. **source:** RAL Space; **ref:** S5P-NPPC-RAL-ATBD-0001; **issue:** 0.11.0; **date:** 2014-05-15.

[RD6] S5P/TROPOMI HCHO ATBD. **source:** BIRA; **ref:** S5P-BIRA-L2-400F-ATBD; **issue:** 1.0.0; **date:** 2016-02-05.

[RD7] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual HCHO. **source:** DLR; **ref:** S5P-L2-DLR-PUM-400F; **issue:** 1.0.0; **date:** 2018-04-30.

[RD8] S5P/TROPOMI SO_2 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_2. **source:** DLR; **ref:** S5P-L2-DLR-PUM-400E; **issue:** 1.0.0; **date:** 2018-04-30.

[RD10] S5P/TROPOMI Total ozone ATBD. **source:** DLR/BIRA; **ref:** S5P-L2-DLR-ATBD-400A; **issue:** 1.0.0; **date:** 2016-02-01.

[RD11] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Total Ozone Column. **source:** DLR; **ref:** S5P-L2-DLR-PUM-400A; **issue:** 1.0.0; **date:** 2018-04-30.

[RD12] TROPOMI ATBD of tropospheric ozone data products. **source:** DLR/IUP; **ref:** S5P-DLR-IUP-L2-400C; **issue:** 1.0.0; **date:** 2016-02-05.

[RD13] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Ozone Tropospheric Column. **source:** DLR; **ref:** S5P-L2-DLR-PUM-400C; **issue:** 1.0.0; **date:** 2018-04-30.

[RD14] TROPOMI ATBD of the Aerosol Layer Height product. **source:** KNMI; **ref:** S5P-KNMI-L2-0006-RP; **issue:** 1.0.0; **date:** 2016-01-29.

[RD15] 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.

[RD16] TROPOMI ATBD of the UV aerosol index. **source:** KNMI; **ref:** S5P-KNMI-L2-0008-RP; **issue:** 1.0.0; **date:** 2016-02-03.

[RD17] 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.

[RD18] TROPOMI ATBD Ozone profile and tropospheric profile.
source: KNMI; **ref:** S5P-KNMI-L2-0004-RP; **issue:** 0.13.0; **date:** 2015-09-15.

[RD19] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Ozone Profile and Tropospheric Ozone Profile.
source: KNMI; **ref:** S5P-KNMI-L2-0020-MA; **issue:** 0.0.2dr; **date:** 2014-10-16.

[RD20] TROPOMI ATBD of the total and tropospheric NO_2 data products.
source: KNMI; **ref:** S5P-KNMI-L2-0005-RP; **issue:** 1.0.0; **date:** 2016-02-05.

[RD21] Algorithm Theoretical Baseline Document for Sentinel-5 Precursor: Carbon Monoxide Total Column Retrieval.
source: SRON; **ref:** SRON-S5P-LEV2-RP-002; **issue:** 1.0.0; **date:** 2016-02-05.

[RD22] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Carbon Monoxide Column.
source: SRON/KNMI; **ref:** SRON-S5P-LEV2-MA-002; **issue:** 0.0.2dr; **date:** 2014-10-16.

[RD23] Algorithm Theoretical Baseline Document for Sentinel-5 Precursor methane retrieval.
source: SRON; **ref:** SRON-S5P-LEV2-RP-001; **issue:** 1.0.0; **date:** 2016-02-05.

[RD24] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Methane.
source: SRON/KNMI; **ref:** SRON-S5P-LEV2-MA-001; **issue:** 0.0.2dr; **date:** 2014-10-16.

[RD25] Tailoring of the Earth Observation File Format Standard for the Sentinel 5 precursor Ground Segment.
source: ESA/ESTEC; **ref:** S5P-TN-ESA-GS-106; **issue:** 2.2; **date:** 2015-02-20.

[RD26] Algorithm theoretical basis document for the TROPOMI L01b data processor.
source: KNMI; **ref:** S5P-KNMI-L01B-0009-SD; **issue:** 6.0.0; **date:** 2015-09-22.

[RD27] TROPOMI ATBD of the total and tropospheric NO2 data products.
source: KNMI; **ref:** S5P-KNMI-L2-0005-RP; **issue:** 1.0.0; **date:** 2016-02-05.

[RD28] Terms and symbols in the TROPOMI Algorithm Team.
source: KNMI; **ref:** S5P-KNMI-L2-0049-MA; **issue:** 1.0.0; **date:** 2015-07-16.

[RD29] Determine the effective cloud fraction for a specific wavelength.
source: KNMI; **ref:** S5P-KNMI-L2-0115-TN.

[RD30] K. F. Boersma, G. C. M. Vinken and H. J. Eskes; Representativeness errors in comparing chemistry transport and chemistry climate models with satellite UV–Vis tropospheric column retrievals. *Geoscientific Model Development*; **9** (2016) (9), 875; 10.5194/gmd-9-875-2016. URL `https://www.geosci-model-dev.net/9/875/2016/`.

[RD31] H. J. Eskes and K. F. Boersma; Averaging kernels for DOAS total-column satellite retrievals. *Atmospheric Chemistry and Physics*; **3** (2003) (5), 1285; 10.5194/acp-3-1285-2003. URL `http://www.atmos-chem-phys.net/3/1285/2003/`.

[RD32] K. F. Boersma, H. J. Eskes, R. J. Dirksen *et al.*; An improved tropospheric NO_2 column retrieval algorithm for the Ozone Monitoring Instrument. *Atmospheric Measurement Techniques*; **4** (2011) (9), 1905; 10.5194/amt-4-1905-2011. URL `http://www.atmos-meas-tech.net/4/1905/2011/`.

[RD33] Earth Observation – Ground segment file format standard.
source: ESA/ESTEC; **ref:** PE-TN-ESA-GS-0001; **issue:** 2.0; **date:** 2012-05-03.

[RD34] Geographic information – Metadata.
source: ISO; **ref:** ISO 19115:2003(E); **issue:** 1; **date:** 2003-05-01.

[RD35] 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.

[RD36] Geographic information – Data quality.
source: ISO; **ref:** ISO 19157; **issue:** 1; **date:** 2013-10-10.

[RD37] Earth Observation Metadata profile of Observations & Measurements.
source: Open Geospatial Consortium; **ref:** OGC 10-157r3; **issue:** 1.0; **date:** 2012-06-12.

[RD38] Data Standards Requirements for CCI Data Producers.
source: ESA; **ref:** CCI-PRGM-EOPS-TN-13-0009; **issue:** 1.1; **date:** 2013-05-24.

[RD39] Metadata specification for the TROPOMI L1b products.
source: KNMI; **ref:** S5P-KNMI-L01B-0014-SD; **issue:** 2.0.0; **date:** 2014-12-09.

[RD40] 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.

[RD41] Wavelength calibration in the Sentinel 5-precursor Level 2 data processors.
source: KNMI; **ref:** S5P-KNMI-L2-0126-TN; **issue:** 1.0.0; **date:** 2015-09-11.

[RD42] C. D. Rodgers; *Inverse methods for atmospheric sounding. Theory and practice*; volume 2 of *Atmospheric, Oceanic and Planetary Physics* (World Scientific, 2000); ISBN 978-981-02-2740-1. URL `http://www.worldscibooks.com/physics/3171.html`.

[RD43] 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.

[RD44] Geographic information – Metadata – XML schema implementation.
source: ISO; **ref:** ISO 19139:2007(E); **issue:** 1; **date:** 2010-12-13.

[RD45] Observations and Measurements – XML Implementation..
source: Open Geospatial Consortium; **ref:** OGC 10-025r1; **issue:** 2.0; **date:** 2011-03-22.

[RD46] Sentinel 5 precursor/TROPOMI KNMI and SRON level 2 Input Output Data Definition.
source: KNMI; **ref:** S5P-KNMI-L2-0009-SD; **issue:** 5.0.0; **date:** 2016-04-19.

[RD47] Sentinel-5 Precursor Level 2 UPAS Processor Input/Output Definition Document.
source: DLR-IMF; **ref:** S5P-L2-DLR-IODD-3002; **issue:** 3.3.0; **date:** 2017-06-01.

[RD48] S5P-NPP Cloud Processor IODD.
source: RAL; **ref:** S5P-NPPC-RAL-IODD-0001; **issue:** 0.10.0; **date:** 2014-05-28.

[RD49] John Caron; Annotated Schema for NcML (2011). URL `http://www.unidata.ucar.edu/software/netcdf/ncml/v2.2/AnnotatedSchema4.html`.

[RD50] INSPIRE Metadata Regulation, Commission Regulation (EC), No1205/2008.
source: EC; **ref:** Commission Regulation (EC) No 1205/2008; **date:** 2008-12-03.

[RD51] 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.

[RD52] Geographic Information – Observations and Measurements.
source: ISO; **ref:** ISO 19156:2011(E); **date:** 2011-12-20.

[RD53] Observations and Measurements - XML Implementation.
source: OGC; **ref:** OGC 10-025r1; **issue:** 2.0; **date:** 2011-03-22.

2.4 Electronic references

[ER1] Tropomi official website. URL `http://www.tropomi.eu`.

[ER2] S5P official website. URL `https://sentinel.esa.int/web/sentinel/missions/sentinel-5p`.

[ER3] Robert B. Schmunk; Panoply netCDF, HDF and GRIB Data Viewer. URL `http://www.giss.nasa.gov/tools/panoply/`.

[ER4] Infrastructure for Spatial Information in the European Community (INSPIRE) Directive 2007/2/EC. URL http://inspire.jrc.ec.europa.eu/.

[ER5] Brian Eaton, Jonathan Gregory, Bob Drach *et al.*; *NetCDF Climate and Forecast (CF) Metadata Conventions*. Lawrence Livermore National Laboratory (2014). Version 1.7 draft; URL http://cfconventions.org.

[ER6] ESIP; *Attribute Conventions for Dataset Discovery (ACDD)*. 1st edition (2013). URL http://wiki.esipfed.org/index.php/Attribute_Convention_for_Data_Discovery_(ACDD).

[ER7] NetCDF Users Guide (2011). URL http://www.unidata.ucar.edu/software/netcdf/docs/netcdf.html.

[ER8] USGS; Global Land Cover Characteristics Data Base Version 2.0 (2012). Website last visited on March 6, 2017; URL https://lta.cr.usgs.gov/glcc/globdoc2_0.

[ER9] The ECS SDP Toolkit (2012). DEM and land-sea mask data itself is available from ftp://edhs1.gsfc.nasa.gov/edhs/sdptk/DEMdata; URL http://newsroom.gsfc.nasa.gov/sdptoolkit/TKDownload.html.

[ER10] UDUNITS 2 Manual (2011). URL http://www.unidata.ucar.edu/software/udunits/.

[ER11] Cooperative Ocean/Atmosphere Research Data Service; Conventions for the standardization of NetCDF files (1995). URL http://ferret.wrc.noaa.gov/noaa_coop/coop_cdf_profile.html.

3 Terms, definitions and abbreviated terms

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

3.1 Terms and definitions

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

3.2 Acronyms and Abbreviations

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

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

The Sentinel 5 Precursor mission aims at providing information and services on air quality and climate in the timeframe 2017–2023. The S5p mission is part of the Global Monitoring of the European Programme for the establishment of a European capacity for Earth Observation (COPERNICUS). TROPOMI 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]	`L2__CLOUD_`	DLR
NPP-VIIRS Clouds	[RD5]	[RD5]	`L2__NP_BDx`	RAL
HCHO	[RD6]	[RD7]	`L2__HCHO__`	BIRA/DLR
SO_2	[RD8]	[RD9]	`L2__SO2___`	BIRA/DLR
O_3 Total Column	[RD10]	[RD11]	`L2__O3____`	BIRA/DLR
O_3 Tropospheric Column	[RD12]	[RD13]	`L2__O3_TCL`	IUP/DLR
Aerosol layer height	[RD14]	[RD15]	`L2__AER_LH`	KNMI
Ultra violet aerosol index	[RD16]	[RD17]	`L2__AER_AI`	KNMI
O_3 Full Profile	[RD18]	[RD19]	`L2__O3__PR`	KNMI
O_3 Troposheric Profile	[RD18]	[RD19]	`L2__O3_TPR`	KNMI
NO_2	[RD20]	This document	`L2__NO2___`	KNMI
CO	[RD21]	[RD22]	`L2__CO____`	SRON/KNMI
CH_4	[RD23]	[RD24]	`L2__CH4___`	SRON/KNMI

4.1 File name convention

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

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

`S5P_NRTI_L2__NO2____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`**`T`**`HHMMSS`". The "`T`" is a fixed character.
36	51	15	End of the granulein UTC as "`YYYYMMDD`**`T`**`HHMMSS`". The "`T`" is a fixed character.
52	57	5	Orbit number
58	60	2	Collection number
61	67	6	Processor version number as "`MMmmpp`", with "`MM`" the major version number, "`mm`" the minor version number, and "`pp`" the patch level.
68	83	15	The time of processing for this granule in UTC as "`YYYYMMDD`**`T`**`HHMMSS`". The "`T`" is a fixed character.
84	86	2	The file name extension. All Sentinel 5 precursor files are netCDF-4 files and use the extension "`nc`"

5 Data Distribution and Product Support

The TROPOMI Nitrogendioxide product data are available from the Copernicus Open Data Hub https://scihub.copernicus.eu.

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

5.1 Information to supply with a support request

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

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

If generating the header fails, please provide us with the exact original file name of the granule you are trying to read, the exact error message you get and the exact version of the software you are using, including

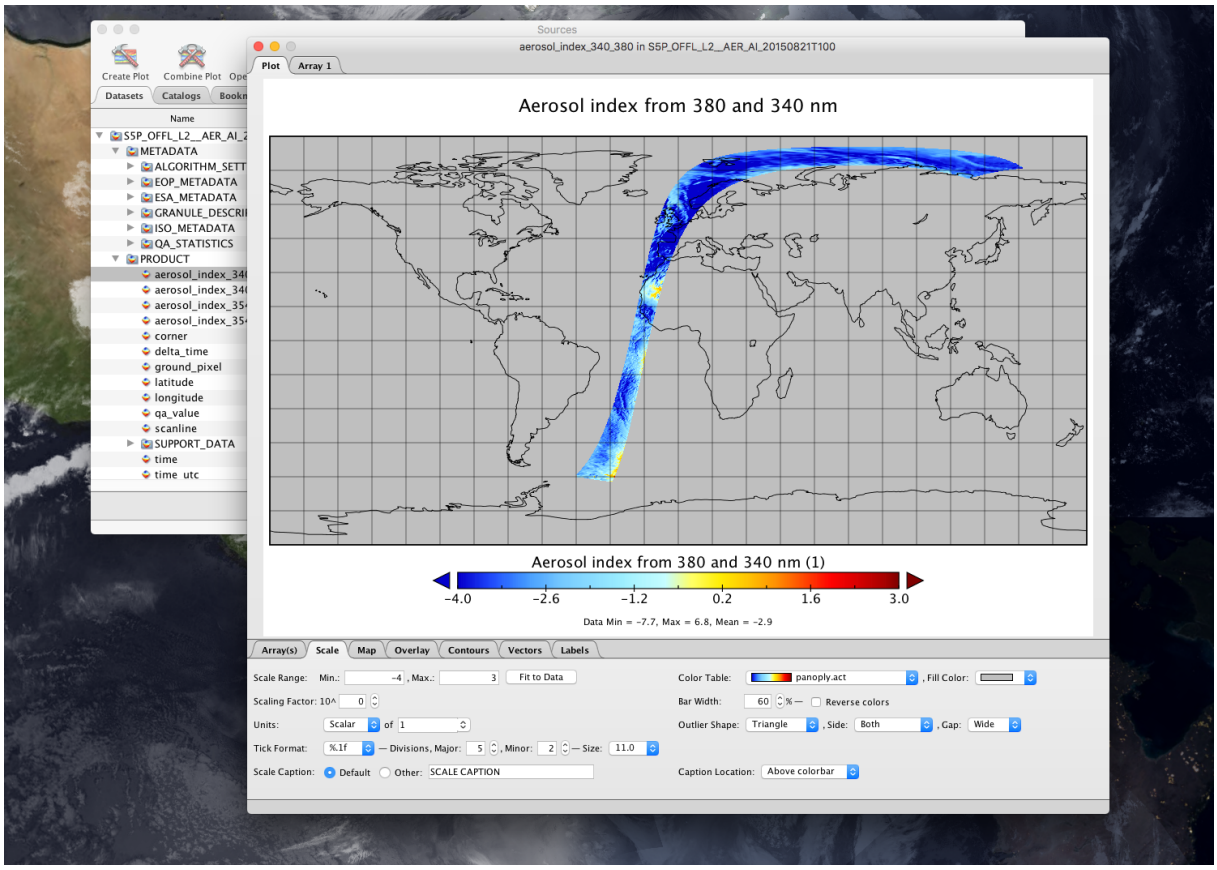

Figure 1: Panoply

the versions of netCDF-4 and HDF-5. Providing us with a checksum to verify file integrity can also speed up our response.

6 General Reader and Visualisation Tools

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

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

7 Instrument description

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

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

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

The instrument images a strip of the Earth on a two dimensional detector for a period of approximately 1 second during which the satellite moves by about 7 km. This strip has dimensions of approximately 2600 km in the direction across the track of the satellite and 7 km in the along-track direction. After the 1 second measurement a new measurement is started thus the instrument scans the Earth as the satellite moves. The two dimensions of the detector are used to detect the different ground pixels in the across track direction and for the different wavelengths. The measurement principle of TROPOMI is shown in figure 2.

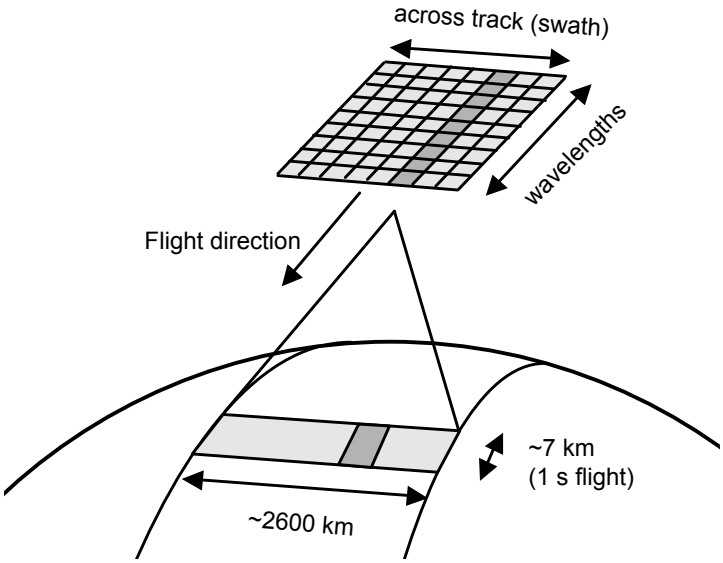

Figure 2: TROPOMI measurement principle.

TROPOMI has a spatial resolution of $7 \times 3.5\,\mathrm{km}^2$ at nadir for bands 2 – 6 (UVN), $7 \times 7\,\mathrm{km}^2$ at nadir for bands 7 and 8 (SWIR), and $21 \times 28\,\mathrm{km}^2$ at nadir for band 1 (deep UV). For the UVN spectrometers about 20 million spectra are observed per day. With that resolution TROPOMI is a major step forward compared to its predecessors OMI (Ozone Monitoring Instrument), SCIAMACHY (Scanning Imaging Absorption Spectrometer for Atmospheric Chartography) and GOME-2 (Global Ozone Monitoring Experiment-2). The spatial resolution is combined with a wide swath to allow for daily global coverage. The TROPOMI/S5P geophysical (Level 2) operational data products are listed in section 4.

The S5P will fly in a so-called loose formation with the U.S. Suomi NPP (National Polar-orbiting Partnership) satellite. The primary objective for this formation flying is to use the high spatial resolution cloud observation capabilities of the VIIRS instrument (Visible Infrared Imager Radiometer Suite). The temporal separation between TROPOMI and VIIRS is less than 5 minutes, both having an equator crossing time near 13:30 local solar time. This formation enables synergistic data products and scientific research potentials.

The spectral range is split over 4 different detectors. By design these detectors do not observe on the

same geographic grid. Combining products that were derived from different detectors will require some careful re-mapping to take care of this spatial mismatch.

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

8 S5P/TROPOMI L2 Nitrogendioxide Product Description

This section describes the main features of the TROPOMI NO_2 data product, gives some examples and lists the history of product changes. A detailed description of the algorithms is provided in the TROPOMI NO_2 ATBD [RD27]. An explanation on how to use the data product is given in Sect. 8.7.

8.1 Terms and definitions

The most important symbols related to the data product described in this document – some of which are not in [RD28] – are the following; see also the data product overview list in Table 3.

N_v	total vertical column density
$N_\mathrm{v}^\mathrm{trop}$	tropospheric vertical column density
$N_\mathrm{v}^\mathrm{strat}$	stratospheric vertical column density
$N_\mathrm{v}^\mathrm{sum}$	sum of tropospheric and stratospheric vertical column density
$\mathbf{A}$	total column averaging kernel
$\mathbf{A}^\mathrm{trop}$	tropospheric column averaging kernel
M	total air-mass factor
M^trop	tropospheric air-mass factor
M^strat	stratospheric air-mass factor
N_s	total slant column density
$N_\mathrm{s}^\mathrm{trop}$	tropospheric slant column density
$N_\mathrm{s}^\mathrm{strat}$	stratospheric slant column density
f_QA	quality assurance value (`qa_value`)

8.2 Acronyms and Abbreviations

AMF	Air-mass factor
CTM	Chemistry Transport Model
DOAS	Differential Optical Absorption Spectroscopy
DOMINO	Dutch OMI NO_2 data products of KNMI for OMI
ECMWF	European Centre for Medium-Range Weather Forecast
FRESCO	Fast Retrieval Scheme for Clouds from the Oxygen A band
NRT	near-real time (i.e. processing within 3 hours of measurement)
OMI	Ozone Monitoring Instrument
TM5	Data assimilation / chemistry transport model (version 5)
TROPOMI	Tropospheric Monitoring Instrument

8.3 Overview of the NO_2 retrieval algorithm

The TROPOMI NO_2 retrieval consists of a three-step procedure, performed on each measured Level-1b spectrum:

1. the retrieval of a total NO_2 slant column density (N_s) from the Level-1b radiance and irradiance spectra measured by TROPOMI using a DOAS (Differential Optical Absorption Spectroscopy) method,
2. the separation of the N_s into a stratospheric ($N_\mathrm{s}^\mathrm{strat}$) and a tropospheric ($N_\mathrm{s}^\mathrm{trop}$) part on the basis of information coming from a data assimilation system, and
3. the conversion of the tropospheric slant column density ($N_\mathrm{s}^\mathrm{trop}$) into a tropospheric vertical column density ($N_\mathrm{v}^\mathrm{trop}$) and the computation of the averaging kernel ($\mathbf{A}$), by applying an appropriate AMF based on a look-up table of altitude-dependent AMFs and actual, daily information on the vertical distribution of NO_2 from the TM5-MP model on a $1^\circ \times 1^\circ$ grid. The altitude-dependent AMF depends on the satellite geometry, terrain eight, cloud fraction and height and surface albedo.

Table 3: Overview of the main data sets for each ground pixel in the final NO_2 data product. Where relevant, the precision of a data set is provided as well. Data sets marked with $*$ are not part of the main data product, but are provided in a separate support data file.

origin of data set	*for each ground pixel*	*symbols*
Level-1b spectrum	measurement time	t
	ground pixel centre and corner coordinates	ϑ_{geo}, δ_{geo}
	viewing geometry data	θ_0, θ, ϕ_0, ϕ
Databases	surface albedo in the NO_2 window	$A_{\text{s,NO}_2}$
	surface albedo used for the cloud retrieval	A_{s}
	surface elevation and pressure	z_{s}, p_{s}
Cloud retrieval	cloud fraction and cloud pressure FRESCO	f_{eff}, p_{c}
	scene pressure and scene albedo FRESCO	p_{sc}, A_{sc}
	cloud fraction in the NO_2 window	$f_{\text{eff,NO}_2}$
	cloud radiance fraction in the NO_2 window	w_{NO_2}
DOAS retrieval	NO_2 slant column	$N_{\text{s,NO}_2}$
	slant columns of secondary trace gases	$N_{\text{s,O}_3}$, $N_{\text{s,H}_2\text{O}_{\text{vap}}}$, $N_{\text{s,}\ldots}$
	Ring effect coefficient	C_{ring}
	polynomial coefficients	$a_m \ \ [m = 0, 1, ..., N_p]$
	wavelength calibration shift and stretch	w_s, w_q
	RMS and χ^2 of the fit	R_{RMS}, χ^2
Data assimilation & AMF calculation	NO_2 tropospheric vertical column	$N_{\text{v}}^{\text{trop}}$
	NO_2 stratospheric vertical column	$N_{\text{v}}^{\text{strat}}$
	NO_2 total vertical columns	$N_{\text{v}} \equiv N_{\text{s}}/M$
		$N_{\text{v}}^{\text{sum}} \equiv N_{\text{v}}^{\text{trop}} + N_{\text{v}}^{\text{strat}}$
	NO_2 slant column stripe amplitude	—
	tropospheric, stratospheric and total AMF	M^{trop}, M^{strat}, M
	averaging kernel	$\mathbf{A}$
	TM5 tropopause layer index	$l_{\text{tp}}^{\text{TM5}}$
	TM5 pressure level coefficients	A_l^{TM5}, B_l^{TM5}
	$*$ NO_2 profile for stratosphere and troposphere	n_{l,NO_2}
	$*$ TM5 temperature profile	T_l^{TM5}
	$*$ TM5 surface elevation and pressure	$z_{\text{s}}^{\text{TM5}}$, $p_{\text{s}}^{\text{TM5}}$
Flags	quality assurance value (`qa_value`)	f_{QA}
	processing quality flags	—
	absorbing aerosol index	—
	snow/ice flag and land/water classification	—

The determination of M^{trop} requires information on the effective cloud fraction and cloud pressure, derived in a separate processing of the Level-1b spectra, the surface albedo, snow-ice information and terrain height. In addition information regarding geolocation and viewing geometry is needed (from the Level-1b spectrum). All these input parameters are also provided in the data product.

Details of the three processing steps and the way they are integrated in the TROPOMI processor are given in the TROPOMI NO_2 ATBD [RD27].

Table 4: Overview of the data set names, units, types and sizes in the main data output product file, listed alphabetically; cf. Table 3. All quantities followed by a $*$ in the "symbol" column consist of the value and the associated precision, where for the latter `_precision` is appended to the data set name; for the vertical column densities the precisions are listed explicitly to clearly show the different types of precisions. In the last column 'PV' denotes the processor version when this variable was introduced.

name/data	*symbol*	*unit*	*data set name*	*data group* †
aerosol absorbing index	—	1	`aerosol_index_354_388`	P/S/I
air-mass factor	M^{trop}	1	`air_mass_factor_troposphere`	P
	M_{clr}^{trop} ⋈	1	`air_mass_factor_clear`	P/S/D
	M_{cld}^{trop} ⋈	1	`air_mass_factor_cloudy`	P/S/D
	M^{strat}	1	`air_mass_factor_stratosphere`	P/S/D
	M	1	`air_mass_factor_total`	P
averaging kernel	$\mathbf{A}$	1	`averaging_kernel`	P
cloud albedo	A_{c}	1	`cloud_albedo_crb`	P/S/I
cloud pressure	p_{c}	hPa	`cloud_pressure_crb`	P/S/I
cloud radiance fraction	w_{NO_2}	1	`cloud_radiance_fraction_nitrogendioxide_window`	P/S/D
DOAS fit results	$N_{\text{s,NO}_2}$ *	mol/m^2	`nitrogendioxide_slant_column_density`	P/S/D
	$N_{\text{s,H}_2\text{O}_{\text{liq}}}$ *	m	`water_liquid_slant_column_density`	P/S/D
	$N_{\text{s,H}_2\text{O}_{\text{vap}}}$ *	mol/m^2	`water_slant_column_density`	P/S/D
	$N_{\text{s,O}_2\text{–O}_2}$ *	mol^2/m^5	`oxygen_oxygen_dimer_slant_column_density`	P/S/D
	$N_{\text{s,O}_3}$ *	mol/m^2	`ozone_slant_column_density`	P/S/D
	C_{ring} *	1	`ring_coefficient`	P/S/D
	χ^2	1	`chi_square`	P/S/D
	N_λ #	1	`number_of_spectral_points_in_retrieval`	P/S/D
	N_i	1	`number_of_iterations`	P/S/D
	a_m *	1	`polynomial_coefficients`	P/S/D
	N_p+1	1	`polynomial_exponents`	P
	R_{RMS}	1	`root_mean_square_error_of_fit`	P/S/D
effective cloud fraction	$f_{\text{eff,NO}_2}$	1	`cloud_fraction_crb_nitrogendioxide_window`	P/S/D
	f_{eff}	1	`cloud_fraction_crb`	P/S/I
ghost column ‡	$N_{\text{v}}^{\text{ghost}}$	mol/m^2	`nitrogendioxide_ghost_column`	P/S/D
ground pixel coordinates	δ_{geo}	°	`latitude`	P
	ϑ_{geo}	°	`longitude`	P
ground pixel corners	δ_{geo}	°	`latitude_bounds`	P/S/G
	ϑ_{geo}	°	`longitude_bounds`	P/S/G
ground pixel index	—	1	`ground_pixel`	P
land/water classification	—	1	`surface_classification`	P/S/I
measurement time §	t	ms	`delta_time`	P
	t	UTC	`time_utc`	P
profile layers	N_l	1	`layer`	P
processing quality flags	—	1	`processing_quality_flags`	P/S/D
quality assuarance value	—	1	`qa_value`	P
satellite coordinates	z_{sat}	m	`satellite_altitude`	P/S/G
	δ_{sat}	°	`satellite_latitude`	P/S/G
	ϑ_{sat}	°	`satellite_longitude`	P/S/G
	φ_{sat}	1	`satellite_orbit_phase`	P/S/G
scanline index	—	1	`scanline`	P
scene albedo	A_{sc}	1	`scene_albedo`	P/S/I
scene pressure	p_{sc}	hPa	`apparent_scene_pressure`	P/S/I
snow-ice flag	—	1	`snow_ice_flag`	P/S/I
stripe amplitude ⊗	—	mol/m^2	`nitrogendioxide_slant_column_density_stripe_amplitude`	P/S/D
surface albedo	$A_{\text{s,NO}_2}$	1	`surface_albedo_nitrogendioxide_window`	P/S/I
	A_{s}	1	`surface_albedo`	P/S/I
surface elevation	z_{s} *	m	`surface_altitude`	P/S/I
surface pressure	p_{s}	hPa	`surface_pressure`	P/S/I
TM5 pressure level coefficients	A_l^{TM5}	Pa	`tm5_constant_a`	P
	B_l^{TM5}	1	`tm5_constant_b`	P
TM5 tropopause layer index	$l_{\text{tp}}^{\text{TM5}}$	1	`tm5_tropopause_layer_index`	P

Table continues on next page

Table 4: — *continued.*

name/data	*symbol*	*unit*	*data set name*	*data group* †
vertical column density	N_{v,NO_2}^{trop}	mol/m^2	nitrogendioxide_tropospheric_column	P
	$\Delta N_{v,NO_2}^{trop}$	mol/m^2	nitrogendioxide_tropospheric_column_precision	P
	$\Delta N_{v,NO_2}^{trop,kernel}$	mol/m^2	nitrogendioxide_tropospheric_column_precision_kernel	P
	N_{v,NO_2}^{strat} *	mol/m^2	nitrogendioxide_stratospheric_column	P/S/D
	N_{v,NO_2}	mol/m^2	nitrogendioxide_total_column	P/S/D
	$\Delta N_{v,NO_2}$	mol/m^2	nitrogendioxide_total_column_precision	P/S/D
	$\Delta N_{v,NO_2}^{kernel}$	mol/m^2	nitrogendioxide_total_column_precision_kernel	P/S/D
	N_{v,NO_2}^{sum} *	mol/m^2	nitrogendioxide_summed_total_column	P/S/D
viewing geometry data	θ_0	°	solar_zenith_angle	P/S/G
	ϕ_0	°	solar_azimuth_angle	P/S/G
	θ	°	viewing_zenith_angle	P/S/G
	ϕ	°	viewing_azimuth_angle	P/S/G
wavelength calibration	w_s *	nm	wavelength_calibration_offset	P/S/D
	w_q *	1	wavelength_calibration_stretch	P/S/D
	χ^2_w	1	wavelength_calibration_chi_square	P/S/D

† Data groups in the output file: P = PRODUCT, P/S/D = PRODUCT/SUPPORT_DATA/DETAILED_RESULTS, P/S/G = PRODUCT/SUPPORT_DATA/GEOLOCATION, P/S/I = PRODUCT/SUPPORT_DATA/INPUT_DATA .
‡ The NO_2 ghost column is the NO_2 profile shape from TM5 integrated from the surface to the cloud pressure level.
§ The measurement time delta_time is the number of milliseconds since the beginning of the current day, while the time_utc gives the absolute measurement time in UTC notation; both have 1 value per scanline.
# The actual number of wavelengths N_λ used in the fit, i.e. after removel of, for example, bad pixels within the fit window.
⊗ Since processor version 1.2 (update October 2018).
⋈ Since processor version 1.3 (update March 2019).

8.4 The NO_2 data product

The main data sets provided in the TROPOMI NO_2 data product are listed in Table 3, consisting of the data sets resulting from the DOAS NO_2 retrieval, the data assimilation step and the AMF calculation. Table 4 provides a list of the names and units of the data sets in the output product file. A more detailed description of each of the data sets can be found in Sect. **??** and further, while Sect. 9 describes the general structure of the TROPOMI output product files.

In order to comply with the SI unit definitions, the TROPOMI NO_2 data product file gives trace gas concentrations in mol/m^2, rather than in the commonly used unit molec/cm^2. The following multiplication factors – also provided as attributes to the data sets – enabling the user to easily make the conversions, if needed:

- The multiplication factor to convert mol/m^2 to molec/cm^2 is 6.02214×10^{19}.
- The multiplication factor to convert mol/m^2 to DU is 2241.15.
- The O_2–O_2 concentration is given in mol^2/m^5; the multiplication factor to convert this to the commenly used unit molec^2/cm^5 is 3.62662×10^{37}.

A cloud product for TROPOMI is retrieved from the O_2 A-band using the FRESCO-S algorithm and the results of this are copied to the NO_2 data product file. Because of the large difference in wavelength between the O_2 A-band and the NO_2 retrieval window, and because of the mismatch in ground footprints, the cloud fraction retrieved in the O_2 A-band will not be exactly representative for the cloud fraction in the NO_2 window. To improve the quality of the NO_2 data product, the cloud fraction f_{eff,NO_2} is also retrieved from the NO_2 spectral window ([RD27], App. C; [RD29]). The NO_2 retrieval makes use of the following cloud quantities:

- The cloud radiance fraction cloud_radiance_fraction_nitrogendioxide_window and cloud fraction cloud_fraction_crb_nitrogendioxide_window (group P/S/D), both derived in the NO_2 spectral window.
- The FRESCO-S cloud pressure cloud_pressure_crb (group P/S/I) derived using the O_2 A-band.
- In case of snow cover or ocean ice, the retrieval switches to using the apparent_scene_pressure and scene_albedo products (group P/S/I) of the FRESCO-S cloud retrieval.

The output for each ground pixel is accompanied by two flags indicating the status of the results of the processing. The "quality assurance value" or qa_value is a continuous variable, ranging from 0 (no output) to

Table 5: Overview of the data set units, types and sizes in the support output product file. This file is also used to store the profiles of HCHO and SO_2, delivered along with the NO_2 profile by the TM5 model, in support of the respective TROPOMI data products. The data is provided on the TM5 grid resolution of $1^\circ \times 1^\circ$ on a half-hourly basis, rather than on TROPOMI pixel basis. The data sets in the main data file are listed in Table 4.

name/data	*symbol*	*unit*	*description*
HCHO profile	$n_{l,\mathrm{HCHO}}$	1	volume mixing ratio
NO_2 profile	$n_{l,\mathrm{NO_2}}$	1	volume mixing ratio
SO_2 profile	$n_{l,\mathrm{SO_2}}$	1	volume mixing ratio
TM5 temperature profile	T_l^{TM5}	K	—
TM5 pressure level coefficients	A_l^{TM5}	Pa	—
	B_l^{TM5}	1	—
TM5 surface elevation ‡	z_s^{TM5}	m	—
TM5 surface pressure	p_s^{TM5}	hPa	—
TM5 tropopause layer index	$l_{\mathrm{tp}}^{\mathrm{TM5}}$	1	—
stripe amplitude ⊗	—	mol/m^2	NO_2 slant column stripe amplitude
date & time	—	1	year, month, day, hour, min, sec
time	d	days	no. of days since 1 Jan. 1950

‡ This data set is provided via a separate static TROPOMI digital elevation map file.
⊗ Since processor version 1.2 (update October 2018).

1 (all is well). Warnings that occur during processing or results of the processing can be reasons to decrease the flag value. This flag provides the main filter for users of the data, see Sect. 8.6. The "processing quality flags" contains the individual event that led to processing failure, or a precise record of the warnings that occurred during processing. The definitions and usage of these flags, described in detail in Appendix A (Tables 15–17), has been harmonised between the Level-2 data products of TROPOMI. The NO_2 data product has the Absorbing Aerosol Index (AAI) as additional information for the NO_2 data users, both in the off-line and the NRT processing mode (not used in the calculation of the `qa_value` at the moment).

8.5 NO_2 data product support file

The data product consists of two files: one with the main retrieval results, detailed above, and a separate file with vertical information on the NO_2 profile and temperature at the $1^\circ \times 1^\circ$ grid of TM5 on a half-hourly basis. Apart from NO_2 fields, the file also contains HCHO fields and SO_2 fields used as a-priori in the TROPOMI retrievals of these species. Most NO_2 data users will not need this additional dataset. In some cases, however, it may be of use to analyse the a-priori model fields. Table 5 provides an overview of the data sets in the support output data product.

8.6 The qa_value field

The output for each ground pixel is accompanied by a flag, the `qa_value`, indicating the status and quality of the retrieval result. The "quality assurance value" (`qa_value` or f_{QA}) is a continuous variable ranging from 0 (error, therefore no output) to 1 (no errors and no warnings). The determination of the `qa_value` is described in detail in the ATBD [RD27]. This is the main flag for pixel selection:

- `qa_value` > 0.75.
  For most users this is the recommended pixel filter. This removes cloud-covered scenes (cloud radiance fraction > 0.5), part of the scenes covered by snow/ice, errors and problematic retrievals.
- `qa_value` > 0.50.
  This adds the good quality retrievals over clouds and over scenes covered by snow/ice. Errors and problematic retrievals are still filtered out. In particular this choice is useful for assimilation and model comparison studies where the averaging kernels are used.

The `qa_value` indicates whether the footprint is cloud covered or not, and whether there is snow or ice on the surface. It is set to 0 if anywhere in the processing an error occured, as indicated by the `processing_quality_flags`. Warnings related to the South Atlantic Anomaly, sun glint, or missing non-critical input

data lower the `qa_value`. Apart from warnings and errors, the `qa_value` depends on the solar zenith angle, tropospheric air-mass factor, quality of the DOAS fit, and filters unrealistic albedo values.

Since the processor version 1.2 data product additional retrievals over snow-ice get a `qa_value` > 0.75, namely when the cloud pressure is close to the surface pressure, indicating that there is no cloud. This significantly improves the coverage for high latitudes.

8.7 Using the S5P/TROPOMI L2 product

The NO_2 L2 files are extended and can be used for many different purposes, including data assimilation, model validation, comparison with surface remote sensing observations or in-situ profile observations with aircraft, both for the troposphere or stratosphere. Furthermore the data may be used directly to visualise the day-to-day variations in NO_2. The fields that users will read from the L2 file will depend on their specific application. Table 6 provides a list of six main classes of possible NO_2 applications and the data sets that the corrresponding users will need for their purpose. Usage of the NO_2 data product is also discussed in a recent paper, see [RD30].

8.8 Using the averaging kernel

For each retrieved NO_2 column, the TROPOMI data product provides the corresponding averaging kernel, and the information needed to apply this kernel. The averaging kernel for DOAS retrievals is computed as the altitude-dependent AMF ratioed (decoupled from the NO_2 vertical distribution) by the total air-mass factor

Table 6: Overview of different user applications of NO_2 data and the data sets (and their precision σ) the users will need for this purpose. In addition most users will need pixel related data, such as measurement time and geolocation.

	user application	*data sets needed*
# 1	Tropospheric chemistry / air quality model evaluation and data assimilation Validation with tropospheric NO_2 profile measurements (aircraft, balloon, MAX-DOAS)	$N_\mathrm{v}^\mathrm{trop}$, $\sigma\left(N_\mathrm{v}^\mathrm{trop}\right)$ M^trop, M, $\mathbf{A}$ † A_l^TM5, B_l^TM5, $l_\mathrm{tp}^\mathrm{TM5}$, p_s f_QA
# 2	Tropospheric column comparisons, e.g. with other NO_2 column retrievals	$N_\mathrm{v}^\mathrm{trop}$, $\sigma\left(N_\mathrm{v}^\mathrm{trop}\right)$ f_QA
# 3	Stratospheric chemistry model evaluation and data assimilation Validation with stratospheric NO_2 profile measurements (limb/occultation satellite observations)	$N_\mathrm{v}^\mathrm{strat}$, $\sigma\left(N_\mathrm{v}^\mathrm{strat}\right)$ M^strat, M, $\mathbf{A}$ ‡ A_l^TM5, B_l^TM5, $l_\mathrm{tp}^\mathrm{TM5}$, p_s f_QA
# 4	Stratospheric column comparisons, e.g. with ground-based remote sensors (SAOZ)	$N_\mathrm{v}^\mathrm{strat}$, $\sigma\left(N_\mathrm{v}^\mathrm{strat}\right)$ f_QA
# 5	Whole atmosphere (troposphere + stratosphere) data assimilation systems	N_v, $\sigma\left(N_\mathrm{v}\right)$ § $\mathbf{A}$, f_QA A_l^TM5, B_l^TM5, $l_\mathrm{tp}^\mathrm{TM5}$, p_s
# 6	Whole atmosphere column comparisons e.g. with PANDORA instruments	$N_\mathrm{v}^\mathrm{sum}$, $\sigma\left(N_\mathrm{v}^\mathrm{sum}\right)$ § f_QA
# 7	Visualisation of the NO_2 product	$N_\mathrm{v}^\mathrm{trop}$, $N_\mathrm{v}^\mathrm{strat}$, $N_\mathrm{v}^\mathrm{sum}$, f_QA §

† The tropospheric kernel $\mathbf{A}^\mathrm{trop}$ is derived from the total kernel $\mathbf{A}$ and the air-mass factors M and M^trop.
‡ The stratospheric kernel $\mathbf{A}^\mathrm{strat}$ is derived from the total kernel $\mathbf{A}$ and the air-mass factors M and M^strat.
§ Note that the total NO_2 vertical column $N_\mathrm{v} \equiv N_\mathrm{s}/M$ is *not* the same as the sum $N_\mathrm{v}^\mathrm{sum} \equiv N_\mathrm{v}^\mathrm{trop} + N_\mathrm{v}^\mathrm{strat}$

[RD31].

The tropospheric column averaging kernel has to be computed from the total column kernel provided in the datafile. This is done by multiplying the total averaging kernel **A** by M/M^{trop} (see [RD32]) and setting all elements of the kernel to zero above the tropopause layer,

$$\begin{aligned} \mathbf{A}^{\text{trop}} &= \frac{M}{M^{\text{trop}}}\mathbf{A} \quad , l <= l_{\text{tp}}^{\text{TM5}} \\ \mathbf{A}^{\text{trop}} &= 0 \quad , l > l_{\text{tp}}^{\text{TM5}} \end{aligned} \tag{1}$$

A model simulated satellite NO_2 column is obtained by multiplying the model partial column profile with the averaging kernel, or

$$N_{\text{v}}^{\text{trop,model}} = \sum_l A_l^{\text{trop}} x_{m,l} \tag{2}$$

where $x_{m,l}$ is the model partial column in layer l. This can then be compared with the satellite tropospheric NO_2 column retrieved ($N_{\text{v}}^{\text{trop}}$). Note that this application of the kernel requires a vertical interpolation (integration) between the model grid and the data product grid. There will also be a mismatch between the surface pressures in the model and in the data product, and it is advised to simply modify one of the pressures to match the other.

Using the averaging kernel is important for data users who wish to minimise the discrepancies between the assumptions in the TROPOMI retrieval and their application of interest, for example for validation, data assimilation, or comparison to a model. Such comparisons become independent of the a-priori profile shapes of the TM5-MP model when the kernels are used.

An important additional feature of the averaging kernel **A** is that it also allows users to replace the a-priori profile used in the retrieval by their own a-priori, e.g. from a high-resolution regional air-quality chemistry-transport model. The vertical column $N_{\text{v}}{}'$ derived from the new NO_2 a-priori profile is achieved by using the following equations:

$$\begin{aligned} N_{\text{v}}^{'} &= \frac{M}{M^{'}} N_{\text{v}} \\ \mathbf{A}^{'} &= \frac{M}{M^{'}} \mathbf{A} \\ M^{'}(\mathbf{x}_m) &= M(\mathbf{x}_a) \sum_l A_l^{trop} x_{m,l} / \sum_l x_{m,l} \end{aligned}$$

Here $M(x_a)$ is the air-mass factor provided in the data file, depending on the TM5-MP a-priori profile $\mathbf{x}_a$, and $M^{'}(\mathbf{x}_m)$ is a new air-mass factor computed with the alternative a-priori model profile $\mathbf{x}_m$.

8.9 Data Product Example

An example of the TROPOMI NO_2 dataset is given in figure 3. The images were created with the NASA-GISS Panoply software, `https://www.giss.nasa.gov/tools/panoply/` which is a recommended tool to visualise the TROPOMI L2 files.

8.10 Product Geophysical Validation

Validation results for the TROPOMI L2 products are generated by the S5P Mission Performance Centre (MPC, `http://www.tropomi.eu/data-products/mission-performance-centre`) and by the S5P Validation Team (S5PVT) members. The MPC provides routine validation results for the TROPOMI L2 products in the form of up-to-date validation results and consolidated validation reports. These are made available through the MPC Validation Data Analysis Facility (VDAF), hosted by BIRA-IASB, `http://mpc-vdaf.tropomi.eu`. This routine activity started 13 July 2018.

Preliminary validation results for the v1.0 NO_2 product were reported at the S5P First Public Release Validation Workshop (ESA/ESRIN, June 25-26, 2018). Individual contributions to the workshop are available in `https://nikal.eventsair.com/QuickEventWebsitePortal/sentinel-5p-first-product-release-workshop/sentinel-5p`.

Initial validation results for the period up to September 2018 are available on the MPC-VDAF server at `http://mpc-vdaf.tropomi.eu/index.php/nitrogen-dioxide` in the form of a so-called Validation Web Article. After this initial phase, the validation results are reported in a series of quarterly validation reports, the first one covering the period July-October 2018. The validation activity as described in the first web article contains the following components:

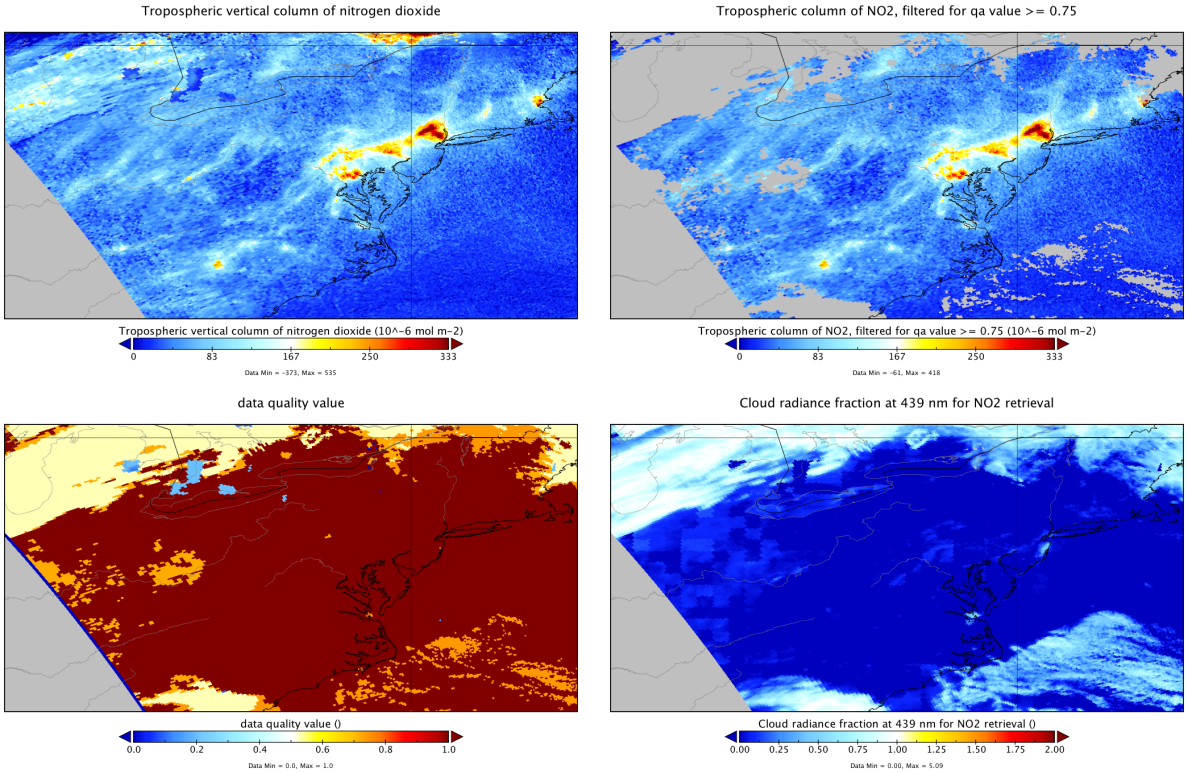

Figure 3: Example of the TROPOMI NO_2 data product, orbit 657, 28 November 2017, view over the Eastern USA. The top-left panel shows the NO_2 tropospheric column as provided in the file (unit μmol/m^2). The top-right shows the same NO_2 tropospheric column, but now the pixels are filtered with `qa_value` > 0.75. The lower-left panel shows the `qa_value`, which is for a large part determined by the cloud radiance fraction (lower right).

- TROPOMI NO_2 stratospheric column data are compared to UV-Vis zenith-scattered-light twilight DOAS (ZSL-DOAS) measurements collected from the Network for the Detection of Atmospheric Composition Change (NDACC).
- TROPOMI NO_2 tropospheric column data are compared to NDACC UV-Vis Multi-Axis DOAS (MAXDOAS) measurements processed in Rapid-Delivery mode.
- The S5PVT AO project NIDFORVAL (NItrogen Dioxide and FORmaldehyde Validation) contributes NO2 data from UV-Vis MAXDOAS instruments, compared with tropospheric NO_2 retrievals from S5P.
- The NIDFORVAL project also contributes measurements from Pandora direct Sun instruments, compared with total column NO_2 retrievals.

Other validation and verification activities are:

- The TROPOMI DOAS NO_2 slant column retrievals have been verified with independent DOAS retrieval software, in particular, the slant column verification software of IUP-Bremen.
- TROPOMI NO_2 slant columns and tropospheric columns have been compared with OMI slant column retrievals (with QDOAS, QA4ECV settings, and with the NASA OMI retrievals) for the same day and location. An example is shown in Fig. 4.

8.11 History of product changes

This product user manual describes the current version of the Level-2 NO_2 data product, v1.2.0. A brief description of data product changes is given here. Detailed description of the algorithms can be found in the NO_2 ATBD.

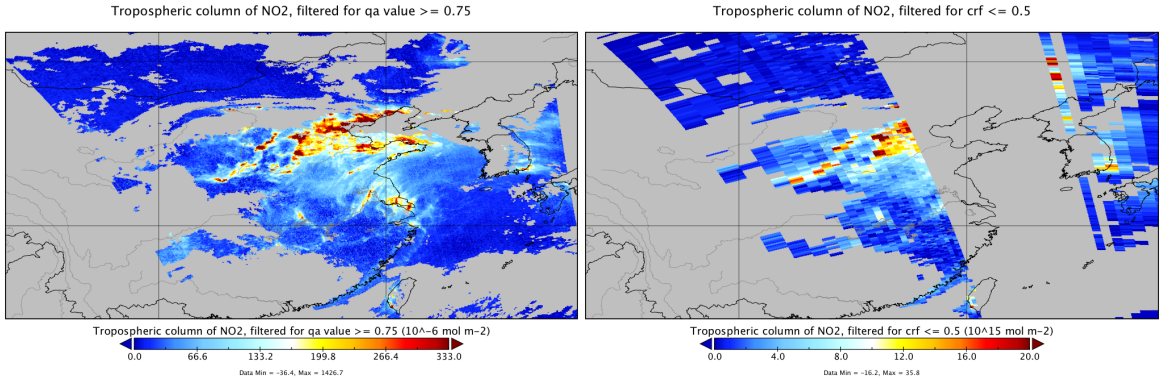

Figure 4: Tropospheric NO_2 vertical column values retrieved from TROPOMI observations (left panel) on 23 February 2018 (unit μmol/m^2) from the reprocessing dataset with the v1 processor, compared with the corresponding OMI NO_2 tropospheric column observations for the same day (right panel) (unit 10^{15} molec/cm^2; 10μmol/m$^2 \approx 6 \times 10^{15}$ molec/cm^2) derived with the QA4ECV OMI NO_2 retrieval software. The scales have been chosen to allow a quantitative comparison. Note that the OMI data has been stripe corrected, while no stripe correction was applied to TROPOMI.

8.11.1 Version 1.3.0

On 27 March 2019 the NO_2 processor was upgraded from version 1.2.2 to 1.3.0. The main changes can be summarised as follows:

- The FRESCO-S cloud retrieval has been updated. The surface albedo is now adjusted to match the top of atmosphere reflectance if the top of atmosphere reflectance is lower than expected using the prescribed surface albedo and cloud fraction 0. In this way negative cloud fractions are avoided. Similar changes were implemented for fully cloud covered scenes. In the (relatively rare) case that the cloud fraction from the NO_2 spectral window is larger than zero, but the old FRESCO-S implementation (v1.0.1-v1.2.1) retrieves a negative cloud fraction with unrealistic cloud pressures, this was resulting in high, noisy NO2 spots. With the new FRESCO-S implementation the retrievals in these cases produce realistic values consistent with nearby retrievals.

- The rules determining the `qa_value` have been adjusted. In particular the lower limit on the tropospheric air-mass factor was reduced, which increases the number of valid pixels somewhat.

- The fully clear-sky and fully cloudy tropospheric air-mass factors are now written to the output file. Also, the wind speed at 10m altitude was added for interpretation of the observations (to identify the direction of the pollution plumes).

8.11.2 Version 1.2.0 / 1.2.2

In the last week of October 2018 the NO_2 processor was upgraded from version 1.1.0 to 1.2.0. The main changes can be summarised as follows:

- A "destriping" algorithm is used to remove across-track biases between the individual viewing angles (450 in total for TROPOMI). A stripe amplitude is computed on a daily basis over the (clean) tropical Pacific Ocean, and is defined as a difference between the TROPOMI NO_2 slant column and the TM5-MP predicted slant column. These differences are averaged over a 30 degree latitude region and over a period of 7 days, and are de-biased by removing the mean. The slant columns are corrected by subtracting these averaged stripe amplitudes. The array of stripe amplitudes is provided in the L2 files, and also in the product support file (the NRT processor obtains the de-striping information from this file).

- The retrievals for the high solar zenith angles (SZA) and polar regions has improved through a series of changes. In the TM5-MP model the photolysis for SZA > 85 degree was improved, impacting in particular the stratospheric columns at high latitudes. The assimilation of NO_2 observations is now restricted to the ascending part of the orbit, removing the impact of the high SZA less reliable and redundant observations on the stratospheric NO_2 column analysis.

- Good retrievals over snow-ice, with a scene pressure close to the surface pressure, now have a `qa_value` > 0.75. The cloud retrieval can not distinguish clouds from snow/ice, but the near equivalence of the scene pressure and surface pressure indicates that the scene is nearly cloud-free.
- The computation of the thermal tropopause level now uses a more advanced algorithm, resulting in smaller jumps and more realistic mean values.
- Measurements during Solar eclipse are now labelled as low quality, `qa_value` < 0.5.

8.11.3 Version 1.0.2 / 1.1.0

Since the launch of Sentinel-5P, the NO_2 processor has been improved considerably. The main developments in the first half-year of 2018, up to the first release of the NO_2 v1.0.2 data in early July, can be summarised as follows:

- KNMI has developed its own new DOAS solver to replace the old inflexible OMNO2A OMI software. The DOAS equation (see ATBD) is solved with a non-linear intensity fit based on optimal estimation, with χ^2 optimisation, which compares well with OMI and QDOAS processor applied to TROPOMI.
- The FRESCO+ cloud (pressure) retrieval has been re-coded to account for the high spectral resolution of TROPOMI in the O2-A band. The new code is called FRESCO-S.
- The NRT retrieval code (implemented in the PDGS) has been updated. It now contains the latest developments resulting from the developments in the QA4ECV project, and is consistent with TM5-MP-domino offline code, run at KNMI. As a result, we expect relatively minor differences between the NRT and off-line products.
- The filtering of the NO_2 observations has been improved to better deal with saturated pixels, or observations close to saturated pixels. These occur over very bright scenes, mainly high clouds in the tropics. The SCD uncertainty from the DOAS fit is a sensitive parameter to detect effects of saturation.
- The modelling of stratospheric chemistry in the TM5-MP model (NO_2 profile shapes) has been improved by improving the interpolation to the ODIN HNO_3 and HALOE NO_2 climatologies.
- The routine to compute the tropopause level has been replaced, leading to a smoother and more physical tropopause pressure.
- Anomalies over ice near Antarctica have been removed by a better use of the snow-ice information from NISE.
- A detailed recipe for computing the `qa_value` was developed and implemented.
- The TM5-MP-domino processing at KNMI (chemistry-transport model run, computation of the stratospheric NO_2 column, NO_2 profile shapes and AMF retrievals) originally needed about 5 hours to process one day of TROPOMI NO_2 data. The AMF retrieval module in TM5-MP-domino has been made MPI-parallel. The runtime is now about 1 hour for 1 day of TROPOMI NO_2 (15 orbits).

9 General structure of S5P/TROPOMI Level 2 files

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

PRODUCT The variables in this group will answer the questions *what*, *when*, *where* and *how well*. This group stores the main data fields of the product, including the precision of the main parameters, latitude, longitude and variable to determine the observation time and the dimensions needed for the data (a time reference dimension (time), the number of measurements in the granule (scanline), the number of spectra in a measurement (ground_pixel) and depending on the product also a pressure-level dimension, or state-vector dimensions). The "qa_value" parameter summarizes the processing flags into a continuous value, giving a quality percentage: 100 % is the most optimal value, 0 % is a processing failure, in between lies a continuum of values[1].

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

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

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

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

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

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

METADATA This is a group to collect metadata items, such as the items that appear in the header file [RD33, section 7] and items required by INSPIRE [ER4], ISO 19115 [RD34], ISO 19115-2 [RD35], ISO 19157 [RD36] and OGC 10-157r3 [RD37]. 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 [RD38]. For interoperability reasons the conventions are followed, and the specified global attributes are added to the output files at the root-level.

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

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

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

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

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

ISO_METADATA The ISO metadata items, organized in subgroups.

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

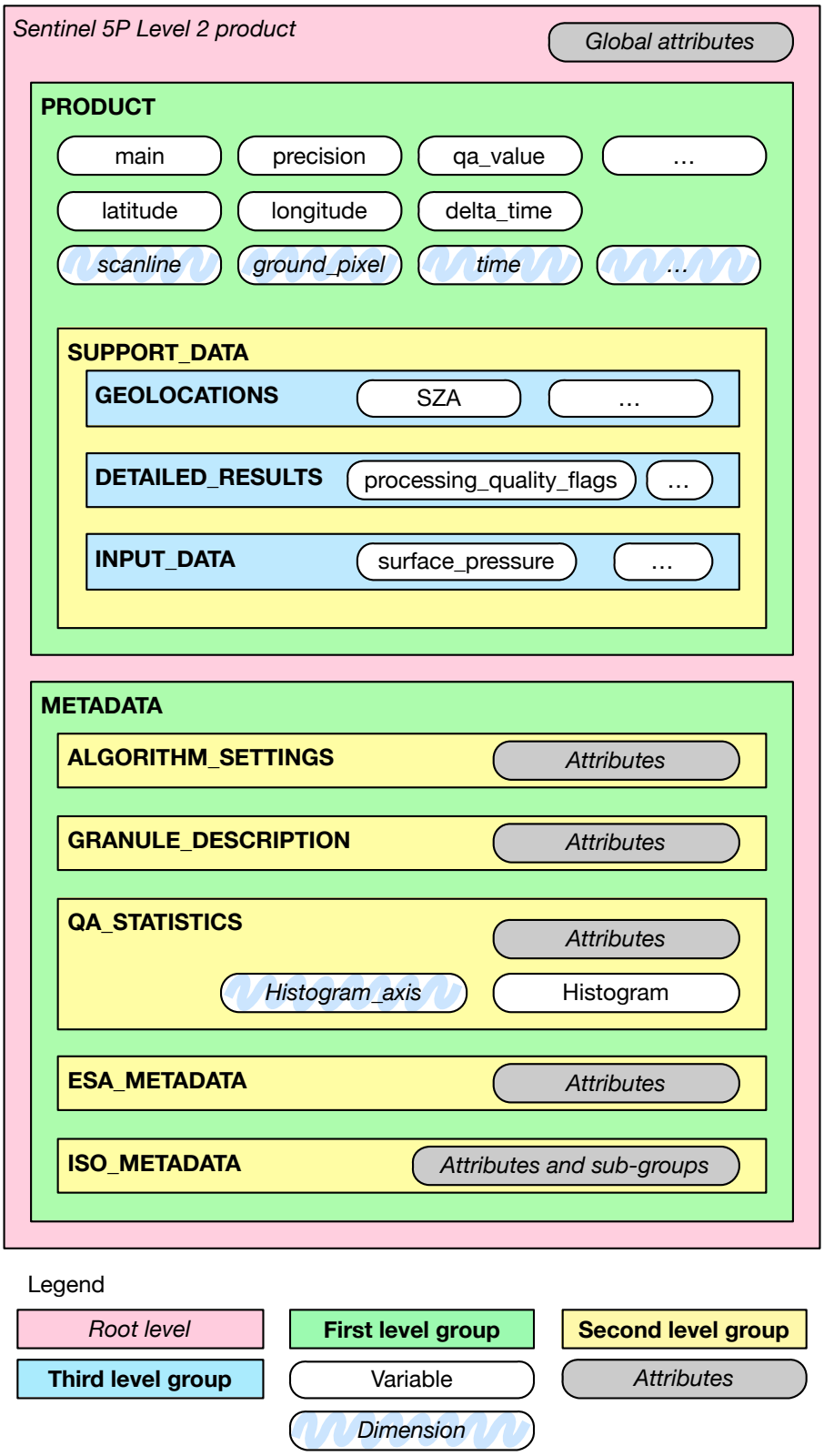

Figure 5: Graphical description of the generic structure of a Level 2 file. The elements labelled as a dimension are coordinate variables. See section 9 for a full description.

EOP_METADATA The EOP metadata items, organized in subgroups.

The work of Level 1B on metadata as described in the metadata specification for TROPOMI L01b data processor [RD39] is used as the basis for the level 2 metadata, in particular for the items in the 'ISO_METADATA' and 'EOP_METADATA' subgroups. The listed metadata standards give a data model and an implementation guideline for producing an XML file with the metadata – as a side-file to the data-file itself. The Level 1B IODS [RD2] describes a method to store the metadata in the NetCDF-4 file, and produce XML side-files as needed. A detailed discussion on metadata as it applies to Level 2 can be found in section 13.

Details of the specific format of the level 2 product file for the Nitrogendioxide product is given in section **??**. Here all variables are described in detail.

9.1 Dimensions and dimension ordering

All variables in a NetCDF-4 file use named and shared dimensions. This explicitly connects variables to dimensions, and to each other. A few of the dimension names were already shown in figure 5.

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

scanline The dimension that indicates the flight direction.

ground_pixel The dimension perpendicular to the flight direction.

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

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

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

The climate and forecast metadata conventions recommend a specific order for dimensions in a variable [ER5, section 2.4]. Spatiotemporal dimensions should appear in the relative order: "date or time" (T), "height or depth" (Z), "latitude" (Y), and "longitude" (X). Note that the ordering of the dimensions in CDL, our documentation and C/C++ is row-major: the last dimension is stored contiguously in memory[2].

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

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

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

O_3 profile This variable provides a column per ground pixel. Since the vertical axis is clearly defined we have the dimensions for this variable as (time, scanline, ground_pixel, level). Note that we do not follow the CF conventions in this case as ozone profiles are more likely accessed as complete profiles rather than horizontal slices.

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

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

9.2 Time information

Time information is stored in two steps. We have the time dimension, which indicates the reference time. This reference time is defined to be UTC midnight before the start of the orbit, which itself is defined by spacecraft midnight. The `time` variable contains the reference time in seconds since 2010-01-01, UTC midnight. Alternative representations of the reference time are listed in table 7. The offset of individual measurements within the granule is given in milliseconds with respect to this reference time in the variable `delta_time`.

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

As a service to the users, the time is also stored in the '`time_utc`' variable. This variable is a string array, with each observation time stored as an ISO date string [RD40].

Table 7: Reference times available in a S5P L2 file. Types: (A) global attribute, (D) dimensional variable, (V) variable. All reference times ignore leap seconds.

Name	Type	Description
time_reference	(A)	ISO date/time string [RD40]
time_reference_days_since_1950	(A)	The number of days since January first, 1950, UTC midnight, as used in several weather and climate models (ECMWF, TM5).
time_reference_julian_day	(A)	The Julian date of the reference time as used in astronomy. This is the reference time system as used in IDL.
time_reference_seconds_since_1970	(A)	The number of seconds since January first, 1970, UTC midnight. This is also known as the unix epoch. Time functions on many systems will accept this number.
time	(D)	This variable contains the number of seconds since 2010-01-01, UTC midnight.
time_utc	(V)	Array of ISO date/time strings [RD40], one for each observation, i.e. one for each element in the scanline dimension

9.3 Geolocation, pixel corners and angles

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

The geo-coordinates of the pixel corners are shown in Figure 6. Note that this choice follows the CF metadata standard [ER5, section 7.1].

The azimuth angles, i.e. the solar azimuth angle φ_0 and the viewing azimuth angle φ give the angle of the sun and the instrument respectively at the intersection of the line of sight with the WGS84 ellipsoid. Both angles are given as degrees east relative to the local north. This definition is identical to the definition of the azimuth angles in both the OMI and GOME-2 instruments, but requires some care when comparing to a radiative transfer model. A radiative transfer model will typically use $\varphi - \varphi_0$ which differs by 180° as it follows the path of the light.

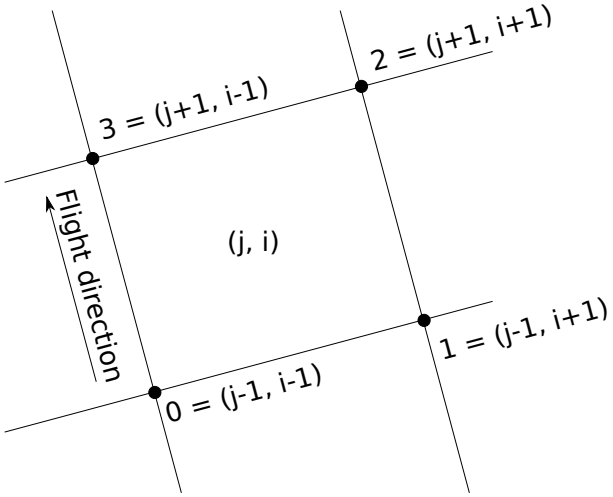

Figure 6: Pixel corner coordinates. The sequence $\{0, 1, 2, 3\}$ refers to the elements in the `corner` dimension.

10 Description of the nitrogen dioxide product

Description of the output file for the NO_2 product from the TROPOMI instrument on the Sentinel 5-precursor mission.

These are the file-level attributes.

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

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

Global attributes in NO2

Group attributes attached to NO2		
Name	*Value*	*Type*
Conventions	'CF-1.7' (static)	NC_STRING
Name of the conventions followed by the dataset. Note that while we try to follow the climate and forecast metadata conventions, there are some features – notably the use of groups to hierarchicaly organize the data – that are not part of version 1.6 of the CF metadata conventions. In those cases we try to follow the spirit of the conventions. This attribute originates from the NUG standard.		
institution	'%(institute)s' (dynamic)	NC_STRING
The institute where the original data was produced. The actual processing center is given in the `ProcessingCenter` attribute, here we would like to indicate the responsible parties. The value is a combination from BIRA, DLR, ESA, FMI, IUP, KNMI, MPIC, SRON, ... The actual value is a combination of the ATBD institute and the institute that developed the processor. This attribute originates from the NUG standard.		
source	'Sentinel 5 precursor, TROPOMI, space-borne remote sensing, L2' (dynamic)	NC_STRING
Method of production of the original data. Value includes instrument, generic description of retrieval, product level, and adds a short product name and processor version. This attribute originates from the CF standard.		
history		NC_STRING
Provides an audit trail for modifications to the original data. Well-behaved generic netCDF filters will automatically append their name and the parameters with which they were invoked to the global history attribute of an input netCDF file. Each line shall begin with a timestamp indicating the date and time of day that the program was executed. This attribute originates from the NUG, CF standards.		
summary		NC_STRING
Miscellaneous information about the data or methods used to produce it.		

If processing in a degraded mode occured, then a note should be placed in this attribute. A degraded processing mode can occur for several reasons, for instance the use of static backup data for nominally dynamic input or an irradiance product that is older than a few days. A machine-parseable description is available in the "`processing_status`" attribute. This attribute originates from the CF standard.

tracking_id		NC_STRING

This unique tracking ID is proposed by the Climate Change Initiative – European Space Agency project. This ID is a UUID and allows files to be referenced, and linked up to processing description, input data, documentation, etc. The CCI-ESA project uses version 4 UUIDs (random number based) for consistency with CMIP5. This attribute originates from the CCI standard.

id	'%(logical_filename)s' (dynamic)	NC_STRING

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

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

UTC time reference as an ISO 8601 [RD40] string. This corresponds to the UTC value in the `time` dimensional variable. By definition it indicates UTC midnight before the start of the granule.

time_reference_days_since_1950	0 (dynamic)	NC_INT

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

time_reference_julian_day	0.0 (dynamic)	NC_DOUBLE

The reference time expressed as a Julian day number.

time_reference_seconds_since_1970	0 (dynamic)	NC_INT64

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

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

Start of the data granule in UTC as an ISO 8601 [RD40] string. See the discussion of the `time_delta` variable on page 38 for details.

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

End of the data granule in UTC as an ISO 8601 [RD40] string. See the discussion of the `time_delta` variable on page 38 for details.

time_coverage_duration		NC_STRING

Duration of the data granule as an ISO 8601 [RD40] duration string ("PT%(duration_seconds)sS"). This attribute originates from the CCI standard.

time_coverage_resolution		NC_STRING

Interval between measurements in the data granule as an ISO 8601 [RD40] duration string ("PT%(interval_seconds)fS"). For most products this is 1080 ms in nominal operation, except for "`L2__O3__PR`", which uses 3240 ms due to coaddition. This attribute originates from the CCI standard.

orbit	0 (dynamic)	NC_INT

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

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

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

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

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

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

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

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

cpp_compiler_flags		NC_STRING
The compiler flags passed to the C++ compiler. The value of this attribute is set via the Makefile.		
f90_compiler_version		NC_STRING
The version of the compiler version used for the Fortran code. The value of this attribute is set via the Makefile. Note that not all processors make use of Fortran code.		
f90_compiler_flags		NC_STRING
The compiler flags passed to the Fortran compiler. The value of this attribute is set via the Makefile. Note that not all processors make use of Fortran code.		
build_date		NC_STRING
The date on which the processor was built.		
revision_control_identifier	'%(revision_control_source_identifier)s' (dynamic)	NC_STRING
Revision control system identifier for the source used to build this processor.		
geolocation_grid_from_band		NC_INT
The band from which the geolocation was taken, useful for colocating the level 2 output with other products.		
identifier_product_doi	'%(product_doi)s' (dynamic)	NC_STRING
This is the DOI ("Digital Object Identifier") of the current product. It allows to easily find download and background information, even if that location is moved after the file has been created.		
identifier_product_doi_authority	'http://dx.doi.org/' (static)	NC_STRING
This attribute defines the authoritative service for use with DOI values in resolving to the URL location.		
algorithm_version	'%(algorithm_version)s' (dynamic)	NC_STRING
The algorithm version, separate from the processor (framework) version, to accomodate different release schedules for different products.		
title	'TROPOMI/S5P NO2 1-Orbit L2 Swath 7x3.5km' (dynamic)	NC_STRING
This is a short description of the product. For the full NO_2 vertical column product the title is "TROPOMI/S5P NO2 1-Orbit L2 Swath 7x3.5km". In near-realtime processing the granule is shorter than 1 orbit, and the title must be adapted accordingly. This attribute originates from the NUG standard.		
processing_status		NC_STRING
This attribute indicates how the data is produced. The possible values are indicated. For near real time processing forecast profiles produced by TM5 at KNMI will be used. For offline processing the nominal data stream is processed at KNMI where assimilation is used to produce optimal quality data. However, as a backup the forecast NO_2 profile shapes from the NRT data stream can be used. This backup product is of sub-optimal quality, but can be used to meet delivery requirements. This attribute indicates the status of the product. Note that both the NRT product and the backup product need to be sent to KNMI for processing. The backup product replaces the slant column product that was mentioned in earlier releases of the IODD. Possible values: NRTI-processing product, OFFL-processing backup product/slant column product, OFFL-processing nominal product		
product_version	'1.1.0' (dynamic)	NC_STRING
Included for compatibility with the CCI project, where this item is defined as "the product version of this data file." We will use the file format version for this attribute following several CCI sub-projects. This attribute originates from the CCI standard.		
Status_MET_2D		NC_STRING
The status of ECMWF input, either "Nominal" or "Fallback". Note that the "MET_2D" auxiliary input is used as an achor point for *all* meteorological data (where applicable). Possible values: Nominal, Fallback		
Status_NISE__		NC_STRING
The status of NISE input, either "Nominal", "ECMWF_Fallback" or "Static_Fallback".		

Possible values: Nominal, ECMWF_Fallback, Static_Fallback

Status_CTMFCT NC_STRING

The status of TM5 forecast input, either “Nominal”, “Fallback” or “Not applicable”. The latter is for nominal offline products.

Possible values: Nominal, Fallback, Not applicable

10.1 Group “PRODUCT” in “NO2”

This is the main group containing the NO_2 vertical column product. At this level the dimensions and the main data fields are defined. Support data can be found in the “SUPPORT_DATA” group.

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

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

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

Dimensions in NO2/PRODUCT

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

size Unlimited.

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

size -1 (dynamic)
source L1B.

corner The number of corners for a pixel.

size 4 (fixed)

time The time dimension. See the discussion of the associated dimensional variable on page 35 for details.

size 1 (fixed)

polynomial_exponents The number of polynomial coefficients in the DOAS fit: $N_p + 1$, with N_p the degree of the polynomial.

size -1 (dynamic)
source Processor.

intensity_offset_polynomial_exponents The number of polynomial coefficients in the background offset correction in the DOAS fit: $N_{\text{off}} + 1$, with N_{off} the degree of the background offset correction polynomial.

size -1 (dynamic)
source Processor.

layer Number of layers, N_l, in the TM5 model for the NO_2 profile and AMF calculations.

size -1 (dynamic)
source Processor.

vertices Dimension to indicate layer boundaries.

size 2 (fixed)

Variables in NO2/PRODUCT

scanline in NO2/PRODUCT

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

Dimensions: scanline (coordinate variable).
Type: NC_INT.
Source: Processor.

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

ground_pixel in NO2/PRODUCT

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

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

time in NO2/PRODUCT

Description: The variable `time(time)` is the reference time of the measurements. The reference time is set to YYYY-MM-DDT00:00:00 UTC, midnight UTC before spacecraft midnight, the formal start of the current orbit. The `delta_time(scanline)` variable indicates the time difference of the observations with the reference time. Thus combining the information of `time(time)` and `delta_time(scanline)` yields the measurement time for each scanline as UTC time. The reference `time(time)` corresponds to the global attribute `time_reference` which is specified as a UTC time specified as an ISO 8601 [RD40] date.
Dimensions: time (coordinate variable).
Type: NC_INT.
Source: Processor.

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

corner in NO2/PRODUCT

Description: An index for the pixel corners. We follow the CF-Metadata conventions [ER5, section 7.1]. The full coordinate system is right-handed, and the order of the pixel corners is counter-clockwise, starting in the "lower-left" corner (i.e. the smallest value in both latitude and longitude on the ascending part of the orbit, or equivalently for TROPOMI the lowest value for both the `ground_pixel` and `scanline` indices). See figure 6 on page 30 for a graphical depiction of the corners.

Dimensions: corner (coordinate variable).

Type: NC_INT.

Source: Processor.

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

polynomial_exponents in NO2/PRODUCT

Description: The coordinate variable `polynomial_exponents` contains the exponents for the polynomial in the DOAS fit: $0, 1, \ldots, N_p$, with N_p the degree of the polynomial.

Dimensions: polynomial_exponents (coordinate variable).

Type: NC_INT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	Dimensionless, no physical quanity. This attribute originates from the CF standard.		
	long_name	'Polynomial exponents for background polynomial' (static)	NC_STRING
	ancillary_variables	'/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/polynomial_coefficients' (static)	NC_STRING

intensity_offset_polynomial_exponents in NO2/PRODUCT

Description: The coordinate variable `intensity_offset_polynomial_exponents` contains the exponents for the intensity offset polynomial in the DOAS fit: $0, 1, \ldots, N_p$, with N_{off} the degree of the polynomial.

Dimensions: intensity_offset_polynomial_exponents (coordinate variable).

Type: NC_INT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	Dimensionless, no physical quanity. This attribute originates from the CF standard.		
	long_name	'Polynomial exponents for intensity offset' (static)	NC_STRING
	ancillary_variables	'/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/polynomial_coefficients' (static)	NC_STRING

layer in NO2/PRODUCT

Description: The coordinate variable `layer` contains the numbers of the atmospheric layers in the TM5 model: N_l. The `tm5_tropopause_layer_index` is given in terms of this coordinate.

With the `tm5_constant_a` as a, `tm5_constant_b` as b and `surface_pressure` as p_s the pressure at the interfaces between these layers can be calculated using

$$p(t,k,j,i,l) = a(k,l) + b(k,l) * p_s(t,j,i) \quad (3)$$

The indices in equation 3 have the folowing meanings: t is time (always 0 in TROPOMI), k is the layer index, starting at the surface, j the scanline (flight direction), i the ground-pixel (across track) and l indicates bottom ($l = 0$, highest pressure) or top ($l = 1$, lowest pressure) of the layer.

Dimensions: layer (coordinate variable).

Type: NC_INT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	standard_name	'atmosphere_hybrid_sigma_pressure_coordinate' (static)	NC_STRING
	units	'1' (static)	NC_STRING
	Dimensionless, no physical quanity. This attribute originates from the CF standard.		
	long_name	'TM5 atmospheric layer numbers' (static)	NC_STRING
	positive	'down' (static)	NC_STRING
	Give the ordering of the layers in the TM5 model. This attribute originates from the CF standard.		
	axis	'Z' (static)	NC_STRING
	formula_terms	'ap: tm5_constant_a b: tm5_constant_b ps: /PRODUCT/SUPPORT_DATA/INPUT_DATA/ surface_pressure' (static)	NC_STRING
	comment	'p(t, k, j, i, l) = ap(k, l) + b(k, l)*ps(t, j, i); k from surface to top of atmosphere; l=0 for base of layer, l=1 for top of layer.' (static)	NC_STRING

vertices in NO2/PRODUCT

Description: The coordinate variable `vertices` is is used to indicate boundaries for vertical layers, it is short for *number of vertices*.

Dimensions: vertices (coordinate variable).

Type: NC_INT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	Dimensionless, no physical quanity. This attribute originates from the CF standard.		
	long_name	'TM5 atmospheric layer upper and lower bound indices' (static)	NC_STRING

latitude in NO2/PRODUCT

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

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	long_name	'pixel center latitude' (static)	NC_STRING
	units	'degrees_north' (static)	NC_STRING
	standard_name	'latitude' (static)	NC_STRING
	valid_min	-90.0 (static)	NC_FLOAT

	valid_max	90.0 (static)	NC_FLOAT
	bounds	'/PRODUCT/SUPPORT_DATA/GEOLOCATIONS/ latitude_bounds' (static)	NC_STRING
	A link to the boundary coordinates, i.e. the pixel corners. Note that the use of group-names in this attribute is an extension of the climate and forecasting metadata conventions.		

longitude in NO2/PRODUCT

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

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	long_name	'pixel center longitude' (static)	NC_STRING
	units	'degrees_east' (static)	NC_STRING
	standard_name	'longitude' (static)	NC_STRING
	valid_min	-180.0 (static)	NC_FLOAT
	valid_max	180.0 (static)	NC_FLOAT
	bounds	'/PRODUCT/SUPPORT_DATA/GEOLOCATIONS/ longitude_bounds' (static)	NC_STRING
	A link to the boundary coordinates, i.e. the pixel corners. Note that the use of group-names in this attribute is an extension of the climate and forecasting metadata conventions.		

delta_time in NO2/PRODUCT

Description: The `delta_time(scanline)` variable indicates the time difference with the reference time `time(time)` (see page 35). Thus combining the information of `time(time)` and `delta_time(scanline)` yields the start of the measurement time for each scanline as TAI2010 time. Combining the information in the global attribute `time_reference` with `delta_time(scanline)` yields the start of the measurement time in UTC time. The UTC time derived for the first scanline corresponds to the global attribute `time_coverage_start`. However, the UTC time derived for the last scanline does not correspond to global attribute `time_coverage_end`. One scanline measurement is the result of adding independent measurements during one coaddition period. The scanline measurement is given the measurement time of the first sample in this co-addition. It is the measurement time of the last sample in the coaddition period of the last scanline that corresponds to `time_coverage_end`.

This variable gives the time offset in ms accuracy.

Dimensions: time, scanline.

Type: NC_INT.

Source: Processor.

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

time_utc in NO2/PRODUCT

Description: The time of observation expressed as ISO 8601 [RD40] date-time string.

Dimensions: time, scanline.

Type: NC_STRING.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*

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

qa_value in NO2/PRODUCT

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

Dimensions: time, scanline, ground_pixel.

Type: NC_UBYTE.

Source: Processor.

Attributes:

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

nitrogendioxide_tropospheric_column in NO2/PRODUCT

Description: Tropospheric vertical column of NO_2, $N_V^{trop}(NO_2)$.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'mol m-2' (static)	NC_STRING
standard_name	'troposphere_mole_content_of_nitrogen_dioxide' (static)	NC_STRING
long_name	'Tropospheric vertical column of nitrogen dioxide' (static)	NC_STRING
coordinates	'longitude latitude' (static)	NC_STRING
ancillary_variables	'nitrogendioxide_tropospheric_column_precision air_mass_factor_troposphere air_mass_factor_total averaging_kernel' (static)	NC_STRING
	Provide a connection with associated data. This attribute originates from the NUG, CF standards.	
multiplication_factor_to_convert_to_molecules_percm2	6.02214e+19 (static)	NC_FLOAT
	The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.	

nitrogendioxide_tropospheric_column_precision in NO2/PRODUCT

Description: Precision of the tropospheric vertical column of NO_2.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (static)	NC_STRING
	standard_name	'troposphere_mole_content_of_nitrogen_dioxide standard_error' (static)	NC_STRING
	long_name	'Precision of the tropospheric vertical column of nitrogen dioxide' (static)	NC_STRING
	coordinates	'longitude latitude' (static)	NC_STRING
	multiplication_factor_to_convert_to_molecules_percm2	6.022140857e+19 (static)	NC_FLOAT
	The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.		
nitrogendioxide_tropospheric_column_precision_kernel in NO2/PRODUCT			
Description:	Precision of the tropospheric vertical column of NO_2 when the averaging kernel is applied.		
Dimensions:	time, scanline, ground_pixel.		
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (static)	NC_STRING
	standard_name	'troposphere_mole_content_of_nitrogen_dioxide standard_error' (static)	NC_STRING
	long_name	'Precision of the tropospheric vertical column of nitrogen dioxide when applying the averaging kernel' (static)	NC_STRING
	coordinates	'longitude latitude' (static)	NC_STRING
	multiplication_factor_to_convert_to_molecules_percm2	6.022140857e+19 (static)	NC_FLOAT
	The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.		
averaging_kernel in NO2/PRODUCT			
Description:	Averaging kernel **A** for in the air mass factor correction, describing the NO_2 profile sensitivity of the vertical column density. This is dimensionless, and the profile is given as subcolumn per layer.		
Dimensions:	time, scanline, ground_pixel, layer.		
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	long_name	'Averaging kernel' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

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

ancillary_variables	'tm5_constant_a tm5_constant_b tm5_tropopause_layer_index /PRODUCT/SUPPORT_DATA/INPUT_DATA/surface_pressure' (static)	NC_STRING

Provide a connection with associated data. This attribute originates from the NUG, CF standards.

air_mass_factor_troposphere in NO2/PRODUCT

Description: Tropospheric air mass factor, M^{trop}, computed by integrating the altitude dependent air mass factor over the atmospheric layers from the surface up to and including the layer with the tropopause, i.e. over atmospheric layers $l = 1, 2, \ldots, l_{\text{tp}}$, with l_{tp} given in `tm5_tropopause_layer_index`.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'1' (static)	NC_STRING
long_name	'Tropospheric air mass factor' (static)	NC_STRING
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

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

ancillary_variables	'tm5_tropopause_layer_index' (static)	NC_STRING

Provide a connection with associated data. This attribute originates from the NUG, CF standards.

air_mass_factor_total in NO2/PRODUCT

Description: Total air mass factor, M, computed by integrating the altitude dependent air mass factor over the atmospheric layers from the surface to top-of-atmosphere, i.e. over atmospheric layers $l = 1, 2, \ldots, N_l$, with N_l given by the dimension `profile_layers`.

The total air mass factor is used to compute the total vertical column `no2_total_vertical` from the total slant column `nitrogendioxide_slant_column_density`.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'1' (static)	NC_STRING
long_name	'Total air mass factor' (static)	NC_STRING
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

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

tm5_tropopause_layer_index in NO2/PRODUCT

Description: Index of the highest layer in TM5 which is completely inside the troposphere, in terms of the `layer` coordinate. See variable `layer` on page 36 for details.

Dimensions: time, scanline, ground_pixel.

Type: NC_INT.

Source: Processor.

Attributes:

Name	*Value*	*Type*

	units	'1' (static)	NC_STRING
	long_name	'TM5 layer index of the highest layer in the tropopause' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	ancillary_variables	'tm5_constant_a tm5_constant_b /PRODUCT/SUPPORT_DATA/INPUT_DATA/surface_pressure' (static)	NC_STRING
	Provide a connection with associated data. This attribute originates from the NUG, CF standards.		

tm5_constant_a in NO2/PRODUCT

Description:	Hybrid A coefficient at the TM5 pressure levels. See variable `layer` on page 36 for details.		
Dimensions:	layer, vertices.		
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	units	'Pa' (static)	NC_STRING
	long_name	'TM5 hybrid A coefficient at upper and lower interface levels' (static)	NC_STRING

tm5_constant_b in NO2/PRODUCT

Description:	Hybrid B coefficient at the TM5 pressure levels. See variable `layer` on page 36 for details.		
Dimensions:	layer, vertices.		
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	long_name	'TM5 hybrid B coefficient at upper and lower interface levels' (static)	NC_STRING

10.1.1 Group "SUPPORT_DATA" in "PRODUCT"

10.1.1.1 Group "GEOLOCATIONS" in "SUPPORT_DATA"

Variables in NO2/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

satellite_latitude in NO2/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

Description:	Latitude of the geodetic sub satellite point on the WGS84 reference ellipsoid.		
Dimensions:	time, scanline.		
Type:	NC_FLOAT.		
Source:	L1B.		
Attributes:	*Name*	*Value*	*Type*
	long_name	'sub satellite latitude' (static)	NC_STRING
	units	'degrees_north' (static)	NC_STRING
	comment	'Latitude of the geodetic sub satellite point on the WGS84 reference ellipsoid' (static)	NC_STRING
	valid_min	-90.0 (static)	NC_FLOAT
	valid_max	90.0 (static)	NC_FLOAT

satellite_longitude in NO2/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

Description:	Longitude of the geodetic sub satellite point on the WGS84 reference ellipsoid.

Dimensions:	time, scanline.		
Type:	NC_FLOAT.		
Source:	L1B.		
Attributes:	*Name*	*Value*	*Type*
	long_name	'satellite_longitude' (static)	NC_STRING
	units	'degrees_east' (static)	NC_STRING
	comment	'Longitude of the geodetic sub satellite point on the WGS84 reference ellipsoid' (static)	NC_STRING
	valid_min	-180.0 (static)	NC_FLOAT
	valid_max	180.0 (static)	NC_FLOAT

satellite_altitude in NO2/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

Description:	The altitude of the satellite with respect to the geodetic sub satellite point on the WGS84 reference ellipsoid.		
Dimensions:	time, scanline.		
Type:	NC_FLOAT.		
Source:	L1B.		
Attributes:	*Name*	*Value*	*Type*
	long_name	'satellite altitude' (static)	NC_STRING
	units	'm' (static)	NC_STRING
	comment	'The altitude of the satellite with respect to the geodetic sub satellite point on the WGS84 reference ellipsoid' (static)	NC_STRING
	valid_min	700000.0 (static)	NC_FLOAT
	valid_max	900000.0 (static)	NC_FLOAT

satellite_orbit_phase in NO2/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

Description:	Relative offset $[0.0, \ldots, 1.0]$ of the measurement in the orbit.		
Dimensions:	time, scanline.		
Type:	NC_FLOAT.		
Source:	L1B.		
Attributes:	*Name*	*Value*	*Type*
	long_name	'fractional satellite orbit phase' (static)	NC_STRING
	units	'1' (static)	NC_STRING
	comment	'Relative offset [0.0, ..., 1.0] of the measurement in the orbit' (static)	NC_STRING
	valid_min	-0.02 (static)	NC_FLOAT
	valid_max	1.02 (static)	NC_FLOAT

solar_zenith_angle in NO2/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

Description:	Solar zenith angle ϑ_0 at the ground pixel location on the reference ellipsoid. Angle is measured away from the vertical. ESA definition of day side: $\vartheta_0 < 92^\circ$. Pixels are processed when $\vartheta_0 \leq \vartheta_0^{\text{max}}$ with $80^\circ \leq \vartheta_0^{\text{max}} \leq 88^\circ$, depending on the algorithm. The actual value for ϑ_0^{max} can be found in the algorithm metadata settings.		
Dimensions:	time, scanline, ground_pixel.		
Type:	NC_FLOAT.		
Source:	L1B.		
Attributes:	*Name*	*Value*	*Type*
	long_name	'solar zenith angle' (static)	NC_STRING
	standard_name	'solar_zenith_angle' (static)	NC_STRING
	units	'degree' (static)	NC_STRING

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

solar_azimuth_angle in NO2/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

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

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

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: L1B.

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

viewing_zenith_angle in NO2/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

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

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: L1B.

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

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

viewing_azimuth_angle in NO2/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

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

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

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: L1B.

Attributes:

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

latitude_bounds in NO2/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

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

The order of the pixel corners follows the CF-metadata conventions [ER5, section 7.1], i.e. the ordering is counter-clockwise when viewed from above. A graphical representation is given in figure 6.

Dimensions: time, scanline, ground_pixel, corner.

Type: NC_FLOAT.

Source: Processor.

longitude_bounds in NO2/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

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

The order of the pixel corners follows the CF-metadata conventions [ER5, section 7.1], i.e. the ordering is counter-clockwise when viewed from above. A graphical representation is given in figure 6.

Dimensions: time, scanline, ground_pixel, corner.

Type: NC_FLOAT.

Source: Processor.

geolocation_flags in NO2/PRODUCT/SUPPORT_DATA/GEOLOCATIONS

Description:	Additional flags describing the ground pixel, including the influence of a solar eclipse, the possibility of sun glint, whether we are in the descending part of the orbit, whether we are on the night side of the orbit, whether the pixel crosses the dateline (useful for plotting), or if there was some geolocation error.		
Dimensions:	time, scanline, ground_pixel.		
Type:	NC_UBYTE.		
Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	_FillValue	255 (static)	NC_UBYTE
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	flag_masks	0, 1, 2, 4, 8, 16, 128 (static)	NC_UBYTE
	flag_meanings	'no_error solar_eclipse sun_glint_possible descending night geo_boundary_crossing geolocation_error' (static)	NC_STRING
	flag_values	0, 1, 2, 4, 8, 16, 128 (static)	NC_UBYTE
	long_name	'ground pixel quality flag' (static)	NC_STRING
	max_val	254 (static)	NC_UBYTE
	min_val	0 (static)	NC_UBYTE
	units	'1' (static)	NC_STRING

10.1.1.2 Group "DETAILED_RESULTS" in "SUPPORT_DATA"

Variables in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

processing_quality_flags in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS			
Description:	Processing quality flag. This flag indicates processing errors or reasons for not processing a particular pixel (collectively 'errors', leading to a fill value in the output) and warnings that occured while processing this pixel (warnings which may affect the quality of the retrieval result). A detailed description is provided in appendix A.		
Dimensions:	time, scanline, ground_pixel.		
Type:	NC_UINT.		
Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	long_name	'Processing quality flags' (static)	NC_STRING
	comment	'Flags indicating conditions that affect quality of the retrieval.' (static)	NC_STRING

flag_meanings	‘success radiance_missing irradiance_missing input_spectrum_missing reflectance_range_error ler_range_error snr_range_error sza_range_error vza_range_error lut_range_error ozone_range_error wavelength_offset_error initialization_error memory_error assertion_error io_error numerical_error lut_error ISRF_error convergence_error cloud_filter_convergence_error max_iteration_convergence_error aot_lower_boundary_convergence_error other_boundary_convergence_error geolocation_error ch4_noscat_zero_error h2o_noscat_zero_error max_optical_thickness_error aerosol_boundary_error boundary_hit_error chi2_error svd_error dfs_error radiative_transfer_error optimal_estimation_error profile_error cloud_error model_error number_of_input_data_points_too_low_error cloud_pressure_spread_too_low_error cloud_too_low_level_error generic_range_error generic_exception input_spectrum_alignment_error abort_error wrong_input_type_error wavelength_calibration_error coregistration_error slant_column_density_error airmass_factor_error vertical_column_density_error signal_to_noise_ratio_error configuration_error key_error saturation_error solar_eclipse_filter cloud_filter altitude_consistency_filter altitude_roughness_filter sun_glint_filter mixed_surface_type_filter snow_ice_filter aai_filter cloud_fraction_fresco_filter aai_scene_albedo_filter small_pixel_radiance_std_filter cloud_fraction_viirs_filter cirrus_reflectance_viirs_filter cf_viirs_swir_ifov_filter cf_viirs_swir_ofova_filter cf_viirs_swir_ofovb_filter cf_viirs_swir_ofovc_filter cf_viirs_nir_ifov_filter cf_viirs_nir_ofova_filter cf_viirs_nir_ofovb_filter cf_viirs_nir_ofovc_filter refl_cirrus_viirs_swir_filter refl_cirrus_viirs_nir_filter diff_refl_cirrus_viirs_filter ch4_noscat_ratio_filter ch4_noscat_ratio_std_filter h2o_noscat_ratio_filter h2o_noscat_ratio_std_filter diff_psurf_fresco_ecmwf_filter psurf_fresco_stdv_filter ocean_filter time_range_filter pixel_or_scanline_index_filter geographic_region_filter input_spectrum_warning wavelength_calibration_warning extrapolation_warning sun_glint_warning south_atlantic_anomaly_warning sun_glint_correction snow_ice_warning cloud_warning AAI_warning pixel_level_input_data_missing data_range_warning low_cloud_fraction_warning altitude_consistency_warning signal_to_noise_ratio_warning deconvolution_warning so2_volcanic_origin_likely_warning so2_volcanic_origin_certain_warning interpolation_warning saturation_warning high_sza_warning cloud_retrieval_warning cloud_inhomogeneity_warning’ (static)	NC_STRING

	flag_masks	255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 255, 256, 512, 1024, 2048, 4096, 8192, 16384, 32768, 65536, 131072, 262144, 524288, 1048576, 2097152, 4194304, 8388608, 16777216, 33554432, 67108864, 134217728, 268435456, 536870912 (static)	NC_UINT
	flag_values	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 256, 512, 1024, 2048, 4096, 8192, 16384, 32768, 65536, 131072, 262144, 524288, 1048576, 2097152, 4194304, 8388608, 16777216, 33554432, 67108864, 134217728, 268435456, 536870912 (static)	NC_UINT
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude are in a different group. How to specify the related geospatial coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].		

number_of_spectral_points_in_retrieval in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

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

Attributes:	*Name*	*Value*	*Type*
	long_name	'Number of spectral points used in the retrieval' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude are in a different group. How to specify the related geospatial coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].		

number_of_iterations in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: The number of iterations needed to achieve convergence.
Dimensions: time, scanline, ground_pixel.
Type: NC_INT.
Source: Processor.

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

wavelength_calibration_offset in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

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

$$\lambda_{\text{true}} = \lambda_{\text{nominal}} + \delta\lambda \tag{4}$$

See [RD41] for details about the wavelength fit.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

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

wavelength_calibration_offset_precision in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: A posteriori precision of the fitted wavelength offset.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

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

wavelength_calibration_stretch in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

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

$$\lambda_{\text{true}} = \lambda_{\text{nominal}} + \delta\lambda + q\lambda^{*} \tag{5}$$

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

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
long_name	'wavelength stretch' (static)	NC_STRING
units	'1' (static)	NC_STRING

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

wavelength_calibration_stretch_precision in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: A posteriori precision of the fitted wavelength stretch.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	long_name	'wavelength stretch precision' (static)	NC_STRING
	units	'1' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude are in a different group. How to specify the related geospatial coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].		

wavelength_calibration_chi_square in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: The χ^2 from the wavelength calibration pre-fit in the Level 2 processor.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	long_name	'wavelength calibration chi square' (static)	NC_STRING
	units	'1' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude are in a different group. How to specify the related geospatial coordinates in this case is not specified in the climate and forecast metadata conventions [ER5].		

wavelength_calibration_irradiance_offset in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

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

$$\lambda_{\text{true}} = \lambda_{\text{nominal}} + \delta\lambda \tag{6}$$

See [RD41] for details about the wavelength fit.

Dimensions: time, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	long_name	'wavelength offset' (static)	NC_STRING
	units	'nm' (static)	NC_STRING
	wavelength_fit_window_start	0.0 (static)	NC_FLOAT
	The start wavelength of the irradiance wavelength fit window.		
	wavelength_fit_window_end	0.0 (static)	NC_FLOAT

	The end wavelength of the irradiance wavelength fit window.		
	ancillary_variables	'wavelength_calibration_offset_precision' (static)	NC_STRING
	comment	'True wavelength = nominal wavelength + wavelength offset + wavelength stretch * scaled wavelength' (static)	NC_STRING

wavelength_calibration_irradiance_offset_precision in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

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

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

wavelength_calibration_irradiance_chi_square in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

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

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

nitrogendioxide_stratospheric_column in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Stratospheric vertical column of NO_2, $N_V^{strat}(NO_2)$.
Dimensions: time, scanline, ground_pixel.
Type: NC_FLOAT.
Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (static)	NC_STRING
	standard_name	'stratosphere_mole_content_of_nitrogen_dioxide' (static)	NC_STRING
	long_name	'Stratospheric vertical column of nitrogen dioxide, derived from the TM5-MP vertical profiles' (static)	NC_STRING
	coordinates	'longitude latitude' (static)	NC_STRING
	ancillary_variables	'nitrogendioxide_stratospheric_column_precision air_mass_factor_stratosphere /PRODUCT/air_mass_factor_total /PRODUCT/averaging_kernel' (static)	NC_STRING
	Provide a connection with associated data. This attribute originates from the NUG, CF standards.		
	multiplication_factor_to_convert_to_molecules_percm2	6.02214e+19 (static)	NC_FLOAT

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

nitrogendioxide_stratospheric_column_precision in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Precision of the stratospheric vertical column of NO_2.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'mol m-2' (static)	NC_STRING
standard_name	'stratosphere_mole_content_of_nitrogen_dioxide standard_error' (static)	NC_STRING
long_name	'Precision of stratospheric vertical column of nitrogen dioxide' (static)	NC_STRING
coordinates	'longitude latitude' (static)	NC_STRING
multiplication_factor_to_convert_to_molecules_percm2	6.02214e+19 (static)	NC_FLOAT

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

nitrogendioxide_total_column in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Total vertical column of NO_2, defined by the ratio of the slant column density of NO_2 and the total air mass factor: $N_V(NO_2) = N_S(NO_2)/M$.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'mol m-2' (static)	NC_STRING
proposed_standard_name	'atmosphere_mole_content_of_nitrogen_dioxide' (static)	NC_STRING
long_name	'Total vertical column of nitrogen dioxide derived from the total slant column and TM5 profile in stratosphere and troposphere' (static)	NC_STRING
coordinates	'longitude latitude' (static)	NC_STRING
ancillary_variables	'nitrogendioxide_total_column_precision / PRODUCT/averaging_kernel' (static)	NC_STRING

Provide a connection with associated data. This attribute originates from the NUG, CF standards.

multiplication_factor_to_convert_to_molecules_percm2	6.02214e+19 (static)	NC_FLOAT

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

nitrogendioxide_total_column_precision in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Precision of the total vertical column of NO_2 given in the variable `no2_total_vertical`

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'mol m-2' (static)	NC_STRING
proposed_standard_name	'atmosphere_mole_content_of_nitrogen_dioxide standard_error' (static)	NC_STRING
long_name	'Precision of the total vertical column of nitrogen dioxide derived from the total slant column and TM5 profile in stratosphere and troposphere' (static)	NC_STRING
coordinates	'longitude latitude' (static)	NC_STRING
multiplication_factor_to_convert_to_molecules_percm2	6.02214e+19 (static)	NC_FLOAT

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

nitrogendioxide_total_column_precision_kernel in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Precision of the total vertical column of NO_2 given in the variable `no2_total_vertical`, when the averaging kernel is applied.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'mol m-2' (static)	NC_STRING
proposed_standard_name	'atmosphere_mole_content_of_nitrogen_dioxide standard_error' (static)	NC_STRING
long_name	'Precision of the total vertical column of nitrogen dioxide derived from the total slant column and TM5 profile in stratosphere and troposphere, when the averaging kernel is applied' (static)	NC_STRING
coordinates	'longitude latitude' (static)	NC_STRING
multiplication_factor_to_convert_to_molecules_percm2	6.02214e+19 (static)	NC_FLOAT

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

nitrogendioxide_summed_total_column in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Total vertical column of NO_2, defined by the sum of the vertical tropospheric NO_2 column and the vertical stratospheric NO_2 column: $N_V^{\mathrm{sum}}(NO_2) = N_V^{\mathrm{trop}}(NO_2) + N_V^{\mathrm{strat}}(NO_2)$.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'mol m-2' (static)	NC_STRING
proposed_standard_name	'atmosphere_mole_content_of_nitrogen_dioxide' (static)	NC_STRING
long_name	'Sum of the tropospheric and stratospheric vertical columns' (static)	NC_STRING
coordinates	'longitude latitude' (static)	NC_STRING
ancillary_variables	'nitrogendioxide_summed_total_column_precision' (static)	NC_STRING
Provide a connection with associated data. This attribute originates from the NUG, CF standards.		
multiplication_factor_to_convert_to_molecules_percm2	6.02214e+19 (static)	NC_FLOAT
The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.		

nitrogendioxide_summed_total_column_precision in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Precision of the total vertical column of NO_2 given in the variable `no2_sum_vertical` ($N_V^{\mathrm{sum}}(NO_2)$).

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'mol m-2' (static)	NC_STRING
proposed_standard_name	'atmosphere_mole_content_of_nitrogen_dioxide standard_error' (static)	NC_STRING
long_name	'Precision of the sum of the tropospheric and stratospheric vertical columns' (static)	NC_STRING
coordinates	'longitude latitude' (static)	NC_STRING
multiplication_factor_to_convert_to_molecules_percm2	6.02214e+19 (static)	NC_FLOAT

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

nitrogendioxide_slant_column_density in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: NO_2 slant column density, $N_S(NO_2)$.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'mol m-2' (static)	NC_STRING
long_name	'NO2 slant column density' (static)	NC_STRING
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
ancillary_variables	'nitrogendioxide_slant_column_density_precision' (static)	NC_STRING

Provide a connection with associated data. This attribute originates from the NUG, CF standards.

multiplication_factor_to_convert_to_molecules_percm2	6.02214e+19 (static)	NC_FLOAT

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

nitrogendioxide_slant_column_density_precision in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: NO_2 slant column density precision.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'mol m-2' (static)	NC_STRING
long_name	'NO2 slant column density precision' (static)	NC_STRING
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
multiplication_factor_to_convert_to_molecules_percm2	6.02214e+19 (static)	NC_FLOAT

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

nitrogendioxide_slant_column_density_stripe_amplitude in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: The stripe amplitude is subtracted from the NO_2 slant column density before the vertical column is computed. The stripe amplitude is determined at the last output time step in the TM5 system, using a 7-day running mean for data over the Pacific Ocean.

Dimensions:	time, ground_pixel.		
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (static)	NC_STRING
	long_name	'Across-track NO2 slant column stripe offset, 7-day mean, determined over the Pacific Ocean' (static)	NC_STRING
	comment	'The stripe amplitude is subtracted from the NO2 slant column before the vertical columns are computed' (static)	NC_STRING
	multiplication_factor_to_convert_to_molecules_percm2	6.02214e+19 (static)	NC_FLOAT
	The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.		

ozone_slant_column_density in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description:	O_3 slant column density as part of the NO_2 slant column fit, $N_S(O_3)$.		
Dimensions:	time, scanline, ground_pixel.		
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (static)	NC_STRING
	long_name	'O3 slant column density' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	ancillary_variables	'ozone_slant_column_density_precision' (static)	NC_STRING
	Provide a connection with associated data. This attribute originates from the NUG, CF standards.		
	multiplication_factor_to_convert_to_molecules_percm2	6.02214e+19 (static)	NC_FLOAT
	The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.		
	multiplication_factor_to_convert_to_DU	2241.15 (static)	NC_FLOAT
	The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "DU" or Dobson Units. This attribute provides the multiplication factor to calculate the total column in DU from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in DU.		

ozone_slant_column_density_precision in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description:	O_3 slant column density precision as part of the NO_2 slant column fit.

Dimensions: time, scanline, ground_pixel.
Type: NC_FLOAT.
Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'mol m-2' (static)	NC_STRING
long_name	'O3 slant column density precision' (static)	NC_STRING
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
multiplication_factor_to_convert_to_molecules_percm2	6.02214e+19 (static)	NC_FLOAT

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

multiplication_factor_to_convert_to_DU	2241.15 (static)	NC_FLOAT

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

oxygen_oxygen_dimer_slant_column_density in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: O_2–O_2 slant column density as part of the NO_2 slant column fit, $N_S(O_2\text{–}O_2)$.
Dimensions: time, scanline, ground_pixel.
Type: NC_FLOAT.
Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'mol2 m-5' (static)	NC_STRING
long_name	'Slant column density of oxygen collision induced absorption' (static)	NC_STRING
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
ancillary_variables	'oxygen_oxygen_dimer_slant_column_density_precision' (static)	NC_STRING

Provide a connection with associated data. This attribute originates from the NUG, CF standards.

multiplication_factor_to_convert_to_molecules2_percm5	3.62662e+37 (static)	NC_DOUBLE

The quantities in Sentinel 5 precursor files are given in SI units. For the integrated column value of O_2–O_2 this means that the unit is $\mathrm{mol^2\,m^{-5}}$. Traditionally the unit for O_2–O_2 column is "$\mathrm{molecules^2\,cm^{-5}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules^2\,cm^{-5}}$ from the value in $\mathrm{mol^2\,m^{-5}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules^2\,cm^{-5}}$.

oxygen_oxygen_dimer_slant_column_density_precision in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: O_2–O_2 slant column density precision as part of the NO_2 slant column fit.

Dimensions: time, scanline, ground_pixel.
Type: NC_FLOAT.
Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'mol2 m-5' (static)	NC_STRING
	long_name	'Precision of the slant column density of oxygen collision induced absorption' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	multiplication_factor_to_convert_to_molecules2_percm5	3.62662e+37 (static)	NC_DOUBLE

The quantities in Sentinel 5 precursor files are given in SI units. For the integrated column value of O_2–O_2 this means that the unit is $\mathrm{mol}^2\,\mathrm{m}^{-5}$. Traditionally the unit for O_2–O_2 column is "$\mathrm{molecules}^2\,\mathrm{cm}^{-5}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules}^2\,\mathrm{cm}^{-5}$ from the value in $\mathrm{mol}^2\,\mathrm{m}^{-5}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules}^2\,\mathrm{cm}^{-5}$.

water_slant_column_density in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: H_2O vapor slant column density as derived as part of the NO_2 slant column fit, $N_S(H_2O_{vap})$.
Dimensions: time, scanline, ground_pixel.
Type: NC_FLOAT.
Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (static)	NC_STRING
	long_name	'Water vapor slant column density' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	ancillary_variables	'water_slant_column_density_precision' (static)	NC_STRING

Provide a connection with associated data. This attribute originates from the NUG, CF standards.

	multiplication_factor_to_convert_to_molecules_percm2	6.02214e+19 (static)	NC_FLOAT

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

water_slant_column_density_precision in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: H_2O vapor slant column density precision as derived as part of the NO_2 slant column fit.
Dimensions: time, scanline, ground_pixel.
Type: NC_FLOAT.
Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (static)	NC_STRING
	long_name	'Precision of water vapor slant column density' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

	multiplication_factor_to_convert_to_molecules_percm2	6.02214e+19 (static)	NC_FLOAT
	The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.		

water_liquid_slant_column_density in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Liquid H_2O column density as part of the NO_2 slant column fit, $N_S(H_2O_{liq})$.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'm' (static)	NC_STRING
	long_name	'Liquid water column' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		
	ancillary_variables	'water_liquid_slant_column_density_precision' (static)	NC_STRING
	Provide a connection with associated data. This attribute originates from the NUG, CF standards.		

water_liquid_slant_column_density_precision in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Liquid H_2O column density precison as part of the NO_2 slant column fit.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'm' (static)	NC_STRING
	long_name	'Precision of liquid water column' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		

ring_coefficient in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Fit coefficient of the Ring effect, C_{ring}.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	long_name	'Fit coefficient of the Ring effect' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		

	ancillary_variables	'ring_coefficient_precision' (static)	NC_STRING
	Provide a connection with associated data. This attribute originates from the NUG, CF standards.		

ring_coefficient_precision in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Fit coefficient of the Ring effect precision

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	long_name	'Precision of fit coefficient of the Ring effect' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		

polynomial_coefficients in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: The polynomial coefficients of the DOAS fit. The wavelengths in the polynomial have been scaled from -1 to $+1$ over the fit window. The fit window is given in the "ALGORITHM_SETTINGS" in the metadata.

Dimensions: time, scanline, ground_pixel, polynomial_exponents.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	long_name	'Polynomial coefficients of the DOAS fit' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		
	ancillary_variables	'polynomial_coefficients_precision' (static)	NC_STRING
	Provide a connection with associated data. This attribute originates from the NUG, CF standards.		

polynomial_coefficients_precision in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Precision of the polynomial coefficients of the DOAS fit.

Dimensions: time, scanline, ground_pixel, polynomial_exponents.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	long_name	'Precision of the polynomial coefficients of the DOAS fit' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		

intensity_offset_coefficients in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: The polynomial coefficients of the background offset correction in the DOAS fit. The wavelengths in the polynomial have been scaled from -1 to $+1$ over the fit window. The fit window is given in the "ALGORITHM_SETTINGS" in the metadata.

Dimensions: time, scanline, ground_pixel, intensity_offset_polynomial_exponents.

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'1' (static)	NC_STRING
long_name	'Polynomial coefficients of the DOAS fit' (static)	NC_STRING
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.	
ancillary_variables	'polynomial_coefficients_precision' (static)	NC_STRING
	Provide a connection with associated data. This attribute originates from the NUG, CF standards.	

intensity_offset_coefficients_precision in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Precision of the polynomial coefficients of the background offset correction in DOAS fit.

Dimensions: time, scanline, ground_pixel, intensity_offset_polynomial_exponents.

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'1' (static)	NC_STRING
long_name	'Precision of the polynomial coefficients of the DOAS fit' (static)	NC_STRING
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.	

cloud_fraction_crb_nitrogendioxide_window in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: The effective cloud fraction for the scene. Note that the NO_2 retrieval derives its own cloud fraction at the wavelength where the air mass factor calculation is done, 440 nm, with the cloud albedo fixed at 0.8, and the cloud pressure taken from the O_2 A-band retrieval.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
proposed_standard_name	'effective_cloud_area_fraction_assuming_fixed_cloud_albedo' (static)	NC_STRING
units	'1' (static)	NC_STRING
long_name	'Cloud fraction at 440 nm for NO2 retrieval' (static)	NC_STRING
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.	
radiation_wavelength	440.0 (static)	NC_FLOAT
	The wavelengths used for the determination of the cloud fraction.	

	assumed_-cloud_albedo	0.8 (static)	NC_FLOAT
	The cloud albedo assumed in the cloud fraction retrieval.		
	ancillary_variables	'cloud_radiance_fraction_nitrogendioxide_window /PRODUCT/SUPPORT_DATA/INPUT_DATA/ cloud_pressure_crb' (static)	NC_STRING
	Provide a connection with associated data. This attribute originates from the NUG, CF standards.		

cloud_radiance_fraction_nitrogendioxide_window in NO2/PRODUCT/SUPPORT_DATA/DETAILED_-RESULTS

Description: The cloud radiance fraction for the scene.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	long_name	'Cloud radiance fraction at 440 nm for NO2 retrieval' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		
	radiation_-wavelength	440.0 (static)	NC_FLOAT
	The wavelengths used for the determination of the cloud fraction.		
	assumed_-cloud_albedo	0.8 (static)	NC_FLOAT
	The cloud albedo assumed in the cloud fraction retrieval.		
	ancillary_variables	'cloud_fraction_crb_nitrogendioxide_window /PRODUCT/SUPPORT_DATA/INPUT_DATA/ cloud_pressure_crb' (static)	NC_STRING
	Provide a connection with associated data. This attribute originates from the NUG, CF standards.		

chi_square in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: The χ^2 value of the fit.

$$\chi^2 = \sum_{i=1}^{N_\lambda} \left[\frac{R_{\text{meas}}(\lambda_i) - R_{\text{mod}}(\lambda_i)}{\Delta R_{\text{meas}}(\lambda_i)} \right]^2 \tag{7}$$

with $R_{\text{meas}}(\lambda)$ the measured reflectance spectrum, $R_{\text{mod}}(\lambda)$ the modelled reflectance spectrum, and N_λ the number of spectral pixels in the fit window.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	long_name	'Chi squared of fit' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		

	ancillary_variables	'number_of_spectral_points_in_retrieval degrees_of_freedom' (static)	NC_STRING
	Provide a connection with the number of data points in the fit and the degrees of freedom, required to properly interpret the χ^2 values. This attribute originates from the NUG, CF standards.		

root_mean_square_error_of_fit in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Root mean square residual of the fit.

$$R_{\text{RMS}} = \sqrt{\frac{1}{N_\lambda}\sum_{i=1}^{N_\lambda}\left[R_{\text{meas}}(\lambda_i) - R_{\text{mod}}(\lambda_i)\right]^2} \tag{8}$$

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	long_name	'Root mean square residual of the fit' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		
	ancillary_variables	'number_of_spectral_points_in_retrieval' (static)	NC_STRING
	Provide a connection with associated data. This attribute originates from the NUG, CF standards.		

degrees_of_freedom in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Number of degrees of freedom for the DOAS fit. The method used for the fit is an optimal estimation based routine, for the definition of degrees of freedom see Rodgers [RD42].

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	long_name	'Degrees of freedom from slant column fit' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	ancillary_variables	'number_of_spectral_points_in_retrieval' (static)	NC_STRING
	Provide a connection with associated data. This attribute originates from the NUG, CF standards.		

air_mass_factor_stratosphere in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Stratospheric air mass factor, M^{strat}, computed by integrating the altitude dependent air mass factor over the atmospheric layers above the layer with the tropopause to top-of-atmosphere, i.e. over atmospheric layers $l = l_{\text{tp}}+1,\ldots,N_l$, with N_l given by the dimension `profile_layers` and l_{tp} given by the variable `tm5_tropopause_layer_index`.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

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

	long_name	'Stratospheric air mass factor' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		
	ancillary_variables	'/PRODUCT/tm5_tropopause_layer_index' (static)	NC_STRING
	Provide a connection with associated data. This attribute originates from the NUG, CF standards.		

air_mass_factor_cloudy in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Tropospheric air mass factor for the cloud-covered part of the satellite footprint, computed by integrating the altitude dependent cloud-covered air mass factor over the atmospheric layers from the cloud pressure up to and including the layer with the tropopause, i.e. over atmospheric layers $l = 1, 2, \ldots, l_{\text{tp}}$, with l_{tp} given in `tm5_tropopause_layer_index`.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'1' (static)	NC_STRING
long_name	'Air mass factor for the cloud-covered part of the scene' (static)	NC_STRING
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		
ancillary_variables	'tm5_tropopause_layer_index' (static)	NC_STRING

air_mass_factor_clear in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: Tropospheric air mass factor for the cloud-free part of the satellite footprint, computed by integrating the altitude dependent clear-sky air mass factor over the atmospheric layers from the surface up to and including the layer with the tropopause, i.e. over atmospheric layers $l = 1, 2, \ldots, l_{\text{tp}}$, with l_{tp} given in `tm5_tropopause_layer_index`.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'1' (static)	NC_STRING
long_name	'Air mass factor for the cloud-free part of the scene' (static)	NC_STRING
coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		
ancillary_variables	'tm5_tropopause_layer_index' (static)	NC_STRING

nitrogendioxide_ghost_column in NO2/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS

Description: The ghost column is the NO_2 profile shape from TM5 integrated over the model layers from the surface to the cloud pressure level. (The ghost column does not have a associated precision estimate.)

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (static)	NC_STRING
	long_name	'Ghost column NO2: modelled NO2 column below the cloud top' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	ancillary_variables	'/PRODUCT/SUPPORT_DATA/INPUT_DATA/cloud_pressure_crb' (static)	NC_STRING
	Provide a connection with associated data. This attribute originates from the NUG, CF standards.		
	multiplication_factor_to_convert_to_molecules_percm2	6.02214e+19 (static)	NC_FLOAT
	The quantities in Sentinel 5 precursor files are given in SI units. For an integrated column value this means that the unit is $\mathrm{mol\,m^{-2}}$. Traditionally the unit for an integrated column is "$\mathrm{molecules\,cm^{-2}}$". This attribute provides the multiplication factor to calculate the total column in $\mathrm{molecules\,cm^{-2}}$ from the value in $\mathrm{mol\,m^{-2}}$. This is provided as a convenience to users who have tools that work in $\mathrm{molecules\,cm^{-2}}$.		

10.1.1.3 Group "INPUT_DATA" in "SUPPORT_DATA"

Variables in NO2/PRODUCT/SUPPORT_DATA/INPUT_DATA

surface_altitude in NO2/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description:	The mean of the sub-pixels of the surface altitude within the approximate field of view, based on the GMTED2010 surface elevation database. The surface altitude is referenced to the Earth Gravitational Model 1996 (EGM96) geoid. The WGS84 ellipsoid is the best fitting ellipsoid to the EGM96 geoid model, but the altitude presented here is the orthometric height not an ellipsoid height.		
Dimensions:	time, scanline, ground_pixel.		
Type:	NC_FLOAT.		
Source:	surface elevation database.		
Attributes:	*Name*	*Value*	*Type*
	long_name	'Surface altitude' (static)	NC_STRING
	standard_name	'surface_altitude' (static)	NC_STRING
	units	'm' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	source	'http://topotools.cr.usgs.gov/gmted_viewer/' (static)	NC_STRING
	comment	'The mean of the sub-pixels of the surface altitude-within the approximate field of view, based on the GMTED2010 surface elevation database' (static)	NC_STRING

surface_altitude_precision in NO2/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description:	The standard deviation of sub-pixels used in calculating the mean surface altitude, based on the GMTED2010 surface elevation database. See the description of the `surface_altitude` variable for details.		
Dimensions:	time, scanline, ground_pixel.		
Type:	NC_FLOAT.		
Source:	surface elevation database.		
Attributes:	*Name*	*Value*	*Type*

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

surface_classification in NO2/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description: This is a combined land/water mask and surface classification data field. For land the "Global Land Cover Characteristics Data Base Version 2.0" is used [ER8], specifically the "USGS Land Use/Land Cover System (Modified Level 2)" classification. Over water the classification from the NASA SDP toolkit [ER9], which is based on [RD43].

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

Dimensions: time, scanline, ground_pixel.

Type: NC_UBYTE.

Source: surface elevation database (including flag attributes).

Attributes:	*Name*	*Value*	*Type*
	long_name	'Land-water mask and surface classification based on a static database' (static)	NC_STRING
	comment	'Flag indicating land/water and further surface classifications for the ground pixel' (static)	NC_STRING
	source	'USGS (https://lta.cr.usgs.gov/GLCC) and NASA SDP toolkit (http://newsroom.gsfc.nasa.gov/sdptoolkit/toolkit.html)' (static)	NC_STRING
	flag_meanings	'land water some_water coast value_covers_majority_of_pixel water+shallow_ocean water+shallow_inland_water water+ocean_coastline-lake_shoreline water+intermittent_water water+deep_inland_water water+continental_shelf_ocean water+deep_ocean land+urban_and_built-up_land land+dryland_cropland_and_pasture land+irrigated_cropland_and_pasture land+mixed_dryland-irrigated_cropland_and_pasture land+cropland-grassland_mosaic land+cropland-woodland_mosaic land+grassland land+shrubland land+mixed_shrubland-grassland land+savanna land+deciduous_broadleaf_forest land+deciduous_needleleaf_forest land+evergreen_broadleaf_forest land+evergreen_needleleaf_forest land+mixed_forest land+herbaceous_wetland land+wooded_wetland land+barren_or_sparsely_vegetated land+herbaceous_tundra land+wooded_tundra land+mixed_tundra land+bare_ground_tundra land+snow_or_ice' (static)	NC_STRING

	flag_values	0, 1, 2, 3, 4, 9, 17, 25, 33, 41, 49, 57, 8, 16, 24, 32, 40, 48, 56, 64, 72, 80, 88, 96, 104, 112, 120, 128, 136, 144, 152, 160, 168, 176, 184 (static)	NC_UBYTE
	flag_masks	3, 3, 3, 3, 4, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249, 249 (static)	NC_UBYTE
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

instrument_configuration_identifier in NO2/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description: The IcID from the instrument configuration in the Level 1B data product. The TROPOMI instrument has many configurable parameters. For example, the exposure time, co-addition period, gains and (for UVN-DEMs) the binning factors can be varied. As a result, the instrument can be operated in many different modes or configurations. Each combination of instrument settings is referred to as an instrument configuration and is identified by an instrument configuration ID, a number in the range $[1, 65535]$. This instrument configuration ID, or IcID, is primarily used by the instrument, where it identifies an entry in the instrument configuration tables. On ground, the IcID is used to determine the intended purpose of a measurement and is used in the L0 to 1b data processing to determine the processing path.

Dimensions: time, scanline.

Type: NC_INT.

Source: L1B.

Attributes:	*Name*	*Value*	*Type*
	long_name	'IcID' (static)	NC_STRING
	comment	'The Instrument Configuration ID defines the type of measurement and its purpose. The number of instrument configuration IDs will increase over the mission as new types of measurements are created and used' (static)	NC_STRING

instrument_configuration_version in NO2/PRODUCT/SUPPORT_DATA/INPUT_DATA

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

Dimensions: time, scanline.

Type: NC_SHORT.

Source: L1B.

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

scaled_small_pixel_variance in NO2/PRODUCT/SUPPORT_DATA/INPUT_DATA

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

$$\langle R(t,r,c)\rangle = \frac{1}{N_{\text{small pixels}}} \sum_{i=0}^{N_{\text{small pixels}}-1} R(t,r,c,i) \quad (9)$$

$$V(t,r,c) = \frac{1}{N_{\text{small pixels}}} \sum_{i=0}^{N_{\text{small pixels}}-1} \left(R(t,r,c,i) - \langle R(t,r,c)\rangle\right)^2 \quad (10)$$

$$V_{\text{scaled}}(t,r,c) = \frac{V(t,r,c)}{\langle R(t,r,c)\rangle^2} \quad (11)$$

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

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

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

eastward_wind in NO2/PRODUCT/SUPPORT_DATA/INPUT_DATA

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

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:

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

northward_wind in NO2/PRODUCT/SUPPORT_DATA/INPUT_DATA

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

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes: *Name* *Value* *Type*

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

surface_pressure in NO2/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description: Surface pressure.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'Pa' (static)	NC_STRING
	standard_name	'surface_air_pressure' (static)	NC_STRING
	long_name	'Surface pressure' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		

surface_albedo_nitrogendioxide_window in NO2/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description: Surface albedo in the NO_2 fit window.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	standard_name	'surface_albedo' (static)	NC_STRING
	long_name	'Surface albedo in the NO2 fit window' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		
	radiation_wavelength	440.0 (static)	NC_FLOAT
	The wavelength at which the surface albedo is determined. The CF-conventions propose to use a coordinate variable for this, but this seems more appropriate.		

surface_albedo in NO2/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description: Surface albedo in the cloud product.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	standard_name	'surface_albedo' (static)	NC_STRING
	long_name	'Surface albedo in the cloud product' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		
	radiation_-wavelength	758.0 (static)	NC_FLOAT
	The wavelength at which the surface albedo is determined. The CF-conventions propose to use a coordinate variable for this, but this seems more appropriate.		

cloud_pressure_crb in NO2/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description: Cloud pressure from the cloud product.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'Pa' (static)	NC_STRING
	proposed_stand-ard_name	'air_pressure_at_cloud_optical_centroid' (static)	NC_STRING
	There is no standard name for this parameter. This attribute originates from the CF standard.		
	source		NC_STRING
	The short name of the cloud product ingested for producing this granule. Default is 'FRESCO'. This attribute originates from the CF standard.		
	long_name	'Cloud optical centroid pressure' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		

cloud_fraction_crb in NO2/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description: The effective cloud fraction from the cloud product.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	proposed_stand-ard_name	'effective_cloud_area_fraction_assuming_fixed_-cloud_albedo' (static)	NC_STRING
	There is no standard name for this parameter. This attribute originates from the CF standard.		
	source		NC_STRING
	The short name of the cloud product ingested for producing this granule. Default is 'FRESCO'. This attribute originates from the CF standard.		
	long_name	'Effective cloud fraction from the cloud product' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		

cloud_albedo_crb in NO2/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description: Cloud albedo used in the retrieval.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	standard_name	'cloud_albedo' (static)	NC_STRING
	source		NC_STRING
	The short name of the cloud product ingested for producing this granule. Default is 'FRESCO'. This attribute originates from the CF standard.		
	long_name	'Cloud albedo in the cloud product' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		

scene_albedo in NO2/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description: Scene albedo in the cloud product.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	proposed_standard_name	'cloud_albedo_assuming_completely_cloudy_sky' (static)	NC_STRING
	source		NC_STRING
	The short name of the cloud product ingested for producing this granule. Default is 'FRESCO'. This attribute originates from the CF standard.		
	long_name	'Scene albedo in the cloud product' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		
	radiation_wavelength	758.0 (static)	NC_FLOAT
	The wavelength at which the surface albedo is determined. The CF-conventions propose to use a coordinate variable for this, but this seems more appropriate.		

apparent_scene_pressure in NO2/PRODUCT/SUPPORT_DATA/INPUT_DATA

Description: Scene pressure from the cloud product.

Dimensions: time, scanline, ground_pixel.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'Pa' (static)	NC_STRING
	proposed_standard_name	'air_pressure_at_cloud_optical_centroid_assuming_completely_cloudy_sky' (static)	NC_STRING
	There is no standard name for this parameter. This attribute originates from the CF standard.		
	source		NC_STRING
	The short name of the cloud product ingested for producing this granule. Default is 'FRESCO'. This attribute originates from the CF standard.		
	long_name	'Scene pressure from the cloud product' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING

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

snow_ice_flag in NO2/PRODUCT/SUPPORT_DATA/INPUT_DATA

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

Attributes:

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

	flag_meanings	'snow-free_land sea_ice_1_percent sea_ice_2_percent sea_ice_3_percent sea_ice_4_percent sea_ice_5_percent sea_ice_6_percent sea_ice_7_percent sea_ice_8_percent sea_ice_9_percent sea_ice_10_percent sea_ice_11_percent sea_ice_12_percent sea_ice_13_percent sea_ice_14_percent sea_ice_15_percent sea_ice_16_percent sea_ice_17_percent sea_ice_18_percent sea_ice_19_percent sea_ice_20_percent sea_ice_21_percent sea_ice_22_percent sea_ice_23_percent sea_ice_24_percent sea_ice_25_percent sea_ice_26_percent sea_ice_27_percent sea_ice_28_percent sea_ice_29_percent sea_ice_30_percent sea_ice_31_percent sea_ice_32_percent sea_ice_33_percent sea_ice_34_percent sea_ice_35_percent sea_ice_36_percent sea_ice_37_percent sea_ice_38_percent sea_ice_39_percent sea_ice_40_percent sea_ice_41_percent sea_ice_42_percent sea_ice_43_percent sea_ice_44_percent sea_ice_45_percent sea_ice_46_percent sea_ice_47_percent sea_ice_48_percent sea_ice_49_percent sea_ice_50_percent sea_ice_51_percent sea_ice_52_percent sea_ice_53_percent sea_ice_54_percent sea_ice_55_percent sea_ice_56_percent sea_ice_57_percent sea_ice_58_percent sea_ice_59_percent sea_ice_60_percent sea_ice_61_percent sea_ice_62_percent sea_ice_63_percent sea_ice_64_percent sea_ice_65_percent sea_ice_66_percent sea_ice_67_percent sea_ice_68_percent sea_ice_69_percent sea_ice_70_percent sea_ice_71_percent sea_ice_72_percent sea_ice_73_percent sea_ice_74_percent sea_ice_75_percent sea_ice_76_percent sea_ice_77_percent sea_ice_78_percent sea_ice_79_percent sea_ice_80_percent sea_ice_81_percent sea_ice_82_percent sea_ice_83_percent sea_ice_84_percent sea_ice_85_percent sea_ice_86_percent sea_ice_87_percent sea_ice_88_percent sea_ice_89_percent sea_ice_90_percent sea_ice_91_percent sea_ice_92_percent sea_ice_93_percent sea_ice_94_percent sea_ice_95_percent sea_ice_96_percent sea_ice_97_percent sea_ice_98_percent sea_ice_99_percent sea_ice_100_percent permanent_ice snow mixed_pixels_at_coastlines suspect_ice_value corners ocean' (static)	NC_STRING
	flag_values	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 103, 252, 253, 254, 255 (static)	NC_UBYTE
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
aerosol_index_354_388 in NO2/PRODUCT/SUPPORT_DATA/INPUT_DATA			

Description:	Absorbing aerosol index from the AAI product (AER_AI).		
Dimensions:	time, scanline, ground_pixel.		
Type:	NC_FLOAT.		
Source:	Processor.		
Attributes:	*Name*	*Value*	*Type*
	units	'1' (static)	NC_STRING
	long_name	'Absorbing aerosol index from the TROPOMI AAI product' (static)	NC_STRING
	coordinates	'/PRODUCT/longitude /PRODUCT/latitude' (static)	NC_STRING
	The latitude and longitude coordinates of the TROPOMI swath is not defined as a Cartesian product of latitude and longitude axes. Following [ER5, section 5.2] we use this attribute to connect the data with the geolocation. This attribute originates from the CF standard.		

10.2 Group "METADATA" in "NO2"

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

10.2.1 Group "QA_STATISTICS" in "METADATA"

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

Attributes in NO2/METADATA/QA_STATISTICS

Group attributes attached to QA_STATISTICS		
Name	*Value*	*Type*
number_of_groundpixels	0 (static)	NC_INT
Number of ground pixels in the file.		
number_of_processed_-pixels	0 (static)	NC_INT
Number of ground pixels where a retrieval was attempted. This is the `number_of_groundpixels` minus the pixels that were rejected based on time or configuration (range and step-size in scanline or ground_pixel index).		
number_of_successfully_-processed_pixels	0 (static)	NC_INT
Number of ground pixels where a retrieval was successful.		
number_of_rejected_pixels_-not_enough_spectrum	0 (static)	NC_INT
Number of pixels where processing was not attempted because after filtering for bad and missing pixels there were not enough spectral pixels left in either the radiance, irradiance or after calculating the reflectance.		
number_of_failed_retrievals	0 (static)	NC_INT
Number of pixels where processing failed for whatever reason.		
number_of_ground_pixels_-with_warnings	0 (static)	NC_INT
Number of pixels with one or more warnings.		

number_of_radiance_missing_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error "the number of spectral pixels in the radiance due to flagging is too small to perform the fitting" occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value "1".

number_of_irradiance_missing_occurrences	0 (static)	NC_INT

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

number_of_input_spectrum_missing_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error "the reflectance spectrum does not contain enough points to perform the retrieval. This is different from (ir)radiance_missing in that the missing points may not be aligned" occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value "3".

number_of_reflectance_range_error_occurrences	0 (static)	NC_INT

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

number_of_ler_range_error_occurrences	0 (static)	NC_INT

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

number_of_snr_range_error_occurrences	0 (static)	NC_INT

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

number_of_sza_range_error_occurrences	0 (static)	NC_INT

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

number_of_vza_range_error_occurrences	0 (static)	NC_INT

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

number_of_lut_range_error_occurrences	0 (static)	NC_INT

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

number_of_ozone_range_error_occurrences	0 (static)	NC_INT

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

number_of_wavelength_offset_error_occurrences	0 (static)	NC_INT

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

number_of_initialization_error_occurrences	0 (static)	NC_INT

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

number_of_memory_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “memory allocation or deallocation error” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “13”.

number_of_assertion_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error “error in algorithm detected during assertion” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “14”.

number_of_io_error_occurrences	0 (static)	NC_INT

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

number_of_numerical_error_occurrences	0 (static)	NC_INT

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

number_of_lut_error_occurrences	0 (static)	NC_INT

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

number_of_ISRF_error_occurrences	0 (static)	NC_INT

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

number_of_convergence_error_occurrences	0 (static)	NC_INT

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

number_of_cloud_filter_convergence_error_occurrences	0 (static)	NC_INT

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

number_of_max_iteration_convergence_error_occurrences	0 (static)	NC_INT

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

number_of_aot_lower_boundary_convergence_error_occurrences	0 (static)	NC_INT

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

number_of_other_boundary_convergence_error_occurrences	0 (static)	NC_INT

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

number_of_geolocation_error_occurrences	0 (static)	NC_INT

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

number_of_ch4_noscat_zero_error_occurrences	0 (static)	NC_INT

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

number_of_h2o_noscat_zero_error_occurrences	0 (static)	NC_INT

Number of ground pixels where processing error "the H_2O column retrieved by the non-scattering CO algorithm from the weak band or strong band is 0" occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value "26".

number_of_max_optical_thickness_error_occurrences	0 (static)	NC_INT

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

number_of_aerosol_boundary_error_occurrences	0 (static)	NC_INT

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

number_of_boundary_hit_error_occurrences	0 (static)	NC_INT

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

number_of_chi2_error_occurrences	0 (static)	NC_INT

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

number_of_svd_error_occurrences	0 (static)	NC_INT

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

number_of_dfs_error_occurrences	0 (static)	NC_INT

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

number_of_radiative_transfer_error_occurrences	0 (static)	NC_INT

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

number_of_optimal_estimation_error_occurrences	0 (static)	NC_INT

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

number_of_profile_error_occurrences	0 (static)	NC_INT

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

number_of_cloud_error_occurrences	0 (static)	NC_INT

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

number_of_model_error_occurrences	0 (static)	NC_INT

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

number_of_number_of_input_data_points_too_low_error_occurrences	0 (static)	NC_INT

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

number_of_cloud_pressure_spread_too_low_error_occurrences	0 (static)	NC_INT

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

number_of_cloud_too_low_level_error_occurrences	0 (static)	NC_INT

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

number_of_generic_range_error_occurrences	0 (static)	NC_INT

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

number_of_generic_exception_occurrences	0 (static)	NC_INT

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

number_of_input_spectrum_alignment_error_occurrences	0 (static)	NC_INT

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

number_of_abort_error_occurrences	0 (static)	NC_INT

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

number_of_wrong_input_type_error_occurrences	0 (static)	NC_INT

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

number_of_wavelength_calibration_error_occurrences	0 (static)	NC_INT

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

number_of_coregistration_error_occurrences	0 (static)	NC_INT

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

number_of_slant_column_density_error_occurrences	0 (static)	NC_INT

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

number_of_airmass_factor_error_occurrences	0 (static)	NC_INT

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

number_of_vertical_column_density_error_occurrences	0 (static)	NC_INT

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

number_of_signal_to_noise_ratio_error_occurrences	0 (static)	NC_INT

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

number_of_configuration_error_occurrences	0 (static)	NC_INT

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

number_of_key_error_occurrences	0 (static)	NC_INT

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

number_of_saturation_error_occurrences	0 (static)	NC_INT

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

number_of_solar_eclipse_filter_occurrences	0 (static)	NC_INT

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

number_of_cloud_filter_occurrences	0 (static)	NC_INT

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

number_of_altitude_consistency_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “too large difference between ECMWF altitude and DEM altitude value” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “66”.

number_of_altitude_roughness_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “too large standard deviation of altitude in DEM” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “67”.

number_of_sun_glint_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “for pixels over water, viewing direction inside sun glint region. Definition of sun glint angle and threshold value from ATBD” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “68”.

number_of_mixed_surface_type_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “pixel contains land and water areas (e.g. coastal pixel)” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “69”.

number_of_snow_ice_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “pixel contains snow/ice: Snow/ice flag according to dynamic input OR climatological surface albedo at VIS wavelength is larger than 0.5” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “70”.

number_of_aai_filter_occurrences	0 (static)	NC_INT

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

number_of_cloud_fraction_fresco_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “pixel contains clouds: The FRESCO effective cloud fraction is larger than threshold. Threshold value from ATBD” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “72”.

number_of_aai_scene_albedo_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “pixel contains clouds: The difference between scene albedo at 380 nm from AAI calculation and the climatologcal surface albedo exceeds threshold. Threshold value from ATBD. This test filters out clouds” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “73”.

number_of_small_pixel_radiance_std_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “pixel contains clouds: Standard deviation of radiances in small-pixel column exceeds threshold. Threshold value from ATBD” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “74”.

number_of_cloud_fraction_viirs_filter_occurrences	0 (static)	NC_INT

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

number_of_cirrus_reflectance_viirs_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “pixel contains clouds: Cirrus reflectance from VIIRS / NPP exceeds threshold. Threshold value from ATBD” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “76”.

number_of_cf_viirs_swir_ifov_filter_occurrences	0 (static)	NC_INT

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

number_of_cf_viirs_swir_ofova_filter_occurrences	0 (static)	NC_INT

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

number_of_cf_viirs_swir_ofovb_filter_occurrences	0 (static)	NC_INT

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

number_of_cf_viirs_swir_ofovc_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “fraction of cloudy VIIRS pixels wihtin S5P SWIR OFOVc exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “80”.

number_of_cf_viirs_nir_ifov_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “fraction of cloudy VIIRS pixels wihtin S5P NIR ground pixel exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “81”.

number_of_cf_viirs_nir_ofova_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “fraction of cloudy VIIRS pixels wihtin S5P NIR OFOVa exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “82”.

number_of_cf_viirs_nir_ofovb_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “fraction of cloudy VIIRS pixels wihtin S5P NIR OFOVb exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “83”.

number_of_cf_viirs_nir_ofovc_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “fraction of cloudy VIIRS pixels wihtin S5P NIR OFOVc exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “84”.

number_of_refl_cirrus_viirs_swir_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “average VIIRS cirrus reflectance within SWIR ground pixel exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “85”.

number_of_refl_cirrus_viirs_nir_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “average VIIRS cirrus reflectance within NIR ground pixel exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “86”.

number_of_diff_refl_cirrus_viirs_filter_occurrences	0 (static)	NC_INT

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

number_of_ch4_noscat_ratio_filter_occurrences	0 (static)	NC_INT

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

number_of_ch4_noscat_ratio_std_filter_occurrences	0 (static)	NC_INT

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

number_of_h2o_noscat_ratio_filter_occurrences	0 (static)	NC_INT

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

number_of_h2o_noscat_ratio_std_filter_occurrences	0 (static)	NC_INT

Number of ground pixels where input filter “the standard deviation of $[H_2O]_{weak}/[H_2O]_{strong}$ within the SWIR pixel and the 8 neigbouring pixels exceeds a priori threshold from configuration” occurred, i.e. where the lower 8 bits of the `processing_quality_flags` have the value “91”.

number_of_diff_psurf_fresco_ecmwf_filter_occurrences	0 (static)	NC_INT

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

number_of_psurf_fresco_stdv_filter_occurrences	0 (static)	NC_INT

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

number_of_ocean_filter_occurrences	0 (static)	NC_INT

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

number_of_time_range_filter_occurrences	0 (static)	NC_INT

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

number_of_pixel_or_scanline_index_filter_occurrences	0 (static)	NC_INT

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

number_of_geographic_region_filter_occurrences	0 (static)	NC_INT

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

number_of_input_spectrum_warning_occurrences	0 (static)	NC_INT

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

number_of_wavelength_calibration_warning_occurrences	0 (static)	NC_INT

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

number_of_extrapolation_warning_occurrences	0 (static)	NC_INT

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

number_of_sun_glint_warning_occurrences	0 (static)	NC_INT

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

number_of_south_atlantic_anomaly_warning_occurrences	0 (static)	NC_INT

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

number_of_sun_glint_correction_occurrences	0 (static)	NC_INT

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

number_of_snow_ice_warning_occurrences	0 (static)	NC_INT

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

number_of_cloud_warning_occurrences	0 (static)	NC_INT

Number of ground pixels where processing warning “cloud filter based on FRESCO apparent surface pressure (VIIRS not available), cloud fraction above threshold or cloud pressure adjusted to force cloud above surface” occurred, i.e. where bit 15 in the `processing_quality_flags` is set to “1”.

number_of_AAI_warning_occurrences	0 (static)	NC_INT

Number of ground pixels where processing warning “possible aerosol contamination as indicated by the AAI” occurred, i.e. where bit 16 in the `processing_quality_flags` is set to “1”.

number_of_pixel_level_input_data_missing_occurrences	0 (static)	NC_INT

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

number_of_data_range_warning_occurrences	0 (static)	NC_INT

Number of ground pixels where processing warning “carbon monoxide column tends to negative values; Water column tends to negative values; Heavy water (HDO) column tends to negative values; others” occurred, i.e. where bit 18 in the `processing_quality_flags` is set to “1”.

number_of_low_cloud_fraction_warning_occurrences	0 (static)	NC_INT

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

number_of_altitude_consistency_warning_occurrences	0 (static)	NC_INT

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

number_of_signal_to_noise_ratio_warning_occurrences	0 (static)	NC_INT

Number of ground pixels where processing warning “signal to noise ratio in SWIR and/or NIR band below threshold from configuration” occurred, i.e. where bit 21 in the `processing_quality_flags` is set to “1”.

number_of_deconvolution_warning_occurrences	0 (static)	NC_INT

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

number_of_so2_volcanic_origin_likely_warning_occurrences	0 (static)	NC_INT

Number of ground pixels where processing warning “warning for SO_2 BL product, UTLS products: volcanic origin except for heavily polluted sites” occurred, i.e. where bit 23 in the `processing_quality_flags` is set to “1”.

number_of_so2_volcanic_origin_certain_warning_occurrences	0 (static)	NC_INT

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

number_of_interpolation_warning_occurrences	0 (static)	NC_INT

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

number_of_saturation_warning_occurrences	0 (static)	NC_INT

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

number_of_high_sza_warning_occurrences	0 (static)	NC_INT

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

number_of_cloud_retrieval_warning_occurrences	0 (static)	NC_INT
Number of ground pixels where processing warning “warning occurring when the retrieval diagnostic indicates a degraded quality of the cloud retrieval” occurred, i.e. where bit 28 in the `processing_quality_flags` is set to “1”.		
number_of_cloud_inhomogeneity_warning_occurrences	0 (static)	NC_INT
Number of ground pixels where processing warning “the cloud coregistration inhomogeneity parameter is above a given threshold” occurred, i.e. where bit 29 in the `processing_quality_flags` is set to “1”.		
global_processing_warnings	‘None’ (static)	NC_STRING
All warning messages, separated by newlines, with duplicates removed.		
time_for_algorithm_initialization	-1.0 (static)	NC_DOUBLE
Time in seconds needed for initialization.		
time_for_processing	-1.0 (static)	NC_DOUBLE
Time in seconds needed for processing.		
time_per_pixel	-1.0 (static)	NC_DOUBLE
Time per pixel in seconds needed for processing.		
time_standard_deviation_per_pixel	-1.0 (static)	NC_DOUBLE
Standard deviation of the time per pixel in seconds needed for processing.		

Dimensions in NO2/METADATA/QA_STATISTICS

vertices For the histogram boundaries.

size 2 (fixed)

nitrogendioxide_tropospheric_column_histogram_axis Histogram axis for the tropospheric NO_2 column.

size 100 (fixed)

nitrogendioxide_tropospheric_column_pdf_axis Probability density function axis for the tropospheric NO_2 column.

size 400 (fixed)

nitrogendioxide_stratospheric_column_histogram_axis Histogram axis for the stratospheric NO_2 column.

size 100 (fixed)

nitrogendioxide_stratospheric_column_pdf_axis Probability density function axis for the stratospheric NO_2 column.

size 400 (fixed)

nitrogendioxide_total_column_histogram_axis Histogram axis for the total NO_2 column.

size 100 (fixed)

nitrogendioxide_total_column_pdf_axis Probability density function axis for the total NO_2 column.

size 400 (fixed)

Variables in NO2/METADATA/QA_STATISTICS

nitrogendioxide_stratospheric_column_histogram_axis in NO2/METADATA/QA_STATISTICS

Description: Horizontal axis for the histogram of the stratospheric NO_2 vertical column.

Dimensions: nitrogendioxide_stratospheric_column_histogram_axis (coordinate variable).

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'mol m-2' (dynamic)	NC_STRING
Same unit as the main parameter. This attribute originates from the CF standard.		
comment	'Histogram of the stratospheric NO2 vertical column' (static)	NC_STRING
long_name	'Histogram of the stratospheric NO2 vertical column' (static)	NC_STRING
bounds	'nitrogendioxide_stratospheric_column_histogram_bounds' (static)	NC_STRING

nitrogendioxide_stratospheric_column_pdf_axis in NO2/METADATA/QA_STATISTICS

Description: Horizontal axis for the probability distribution function of the stratospheric NO_2 vertical column.

Dimensions: nitrogendioxide_stratospheric_column_pdf_axis (coordinate variable).

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'mol m-2' (dynamic)	NC_STRING
Same unit as the main parameter. This attribute originates from the CF standard.		
comment	'Probability density function of the stratospheric NO2 vertical column' (static)	NC_STRING
long_name	'Probability density function of the stratospheric NO2 vertical column' (static)	NC_STRING
bounds	'aerosol_nitrogendioxide_stratospheric_column_pdf_bounds' (static)	NC_STRING

nitrogendioxide_stratospheric_column_histogram_bounds in NO2/METADATA/QA_STATISTICS

Dimensions: nitrogendioxide_stratospheric_column_histogram_axis, vertices.

Type: NC_FLOAT.

Source: Processor.

nitrogendioxide_stratospheric_column_pdf_bounds in NO2/METADATA/QA_STATISTICS

Dimensions: nitrogendioxide_stratospheric_column_pdf_axis, vertices.

Type: NC_FLOAT.

Source: Processor.

nitrogendioxide_tropospheric_column_histogram_axis in NO2/METADATA/QA_STATISTICS

Description: Horizontal axis for the histograms of the tropospheric NO_2 vertical column.

Dimensions: nitrogendioxide_tropospheric_column_histogram_axis (coordinate variable).

Type: NC_FLOAT.

Source: Processor.

Attributes:

Name	*Value*	*Type*
units	'mol m-2' (dynamic)	NC_STRING
Same unit as the main parameter. This attribute originates from the CF standard.		
comment	'Histogram of the tropospheric NO2 vertical column' (static)	NC_STRING
long_name	'Histogram of the tropospheric NO2 vertical column' (static)	NC_STRING

	bounds	'nitrogendioxide_tropospheric_column_histogram_bounds' (static)	NC_STRING

nitrogendioxide_tropospheric_column_pdf_axis in NO2/METADATA/QA_STATISTICS

Description: Horizontal axis for the probability distribution functions of the tropospheric NO_2 vertical column.

Dimensions: nitrogendioxide_tropospheric_column_pdf_axis (coordinate variable).

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (dynamic)	NC_STRING
	Same unit as the main parameter. This attribute originates from the CF standard.		
	comment	'Probability density function of the tropospheric NO2 vertical column' (static)	NC_STRING
	long_name	'Probability density function of the tropospheric NO2 vertical column' (static)	NC_STRING
	bounds	'nitrogendioxide_tropospheric_column_pdf_bounds' (static)	NC_STRING

nitrogendioxide_tropospheric_column_histogram_bounds in NO2/METADATA/QA_STATISTICS

Dimensions: nitrogendioxide_tropospheric_column_histogram_axis, vertices.

Type: NC_FLOAT.

Source: Processor.

nitrogendioxide_tropospheric_column_pdf_bounds in NO2/METADATA/QA_STATISTICS

Dimensions: nitrogendioxide_tropospheric_column_pdf_axis, vertices.

Type: NC_FLOAT.

Source: Processor.

nitrogendioxide_total_column_histogram_axis in NO2/METADATA/QA_STATISTICS

Description: Horizontal axis for the histograms of the total NO_2 vertical column.

Dimensions: nitrogendioxide_total_column_histogram_axis (coordinate variable).

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (dynamic)	NC_STRING
	Same unit as the main parameter. This attribute originates from the CF standard.		
	comment	'Histogram of the total NO2 vertical column' (static)	NC_STRING
	long_name	'Histogram of the total NO2 vertical column' (static)	NC_STRING
	bounds	'nitrogendioxide_total_column_histogram_bounds' (static)	NC_STRING

nitrogendioxide_total_column_pdf_axis in NO2/METADATA/QA_STATISTICS

Description: Horizontal axis for the probability distribution functions of the total NO_2 vertical column.

Dimensions: nitrogendioxide_total_column_pdf_axis (coordinate variable).

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	units	'mol m-2' (dynamic)	NC_STRING
	Same unit as the main parameter. This attribute originates from the CF standard.		
	comment	'Probability density function of the total NO2 vertical column' (static)	NC_STRING
	long_name	'Probability density function of the total NO2 vertical column' (static)	NC_STRING

	bounds	'nitrogendioxide_total_column_pdf_bounds' (static)	NC_STRING

nitrogendioxide_total_column_histogram_bounds in NO2/METADATA/QA_STATISTICS

Dimensions: nitrogendioxide_total_column_histogram_axis, vertices.
Type: NC_FLOAT.
Source: Processor.

nitrogendioxide_total_column_pdf_bounds in NO2/METADATA/QA_STATISTICS

Dimensions: nitrogendioxide_total_column_pdf_axis, vertices.
Type: NC_FLOAT.
Source: Processor.

nitrogendioxide_tropospheric_column_histogram in NO2/METADATA/QA_STATISTICS

Description: Histogram of the tropospheric NO_2 vertical column in the current granule.
Dimensions: nitrogendioxide_tropospheric_column_histogram_axis.
Type: NC_INT.
Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	comment	'Histogram of the tropospheric NO2 vertical column in the current granule' (static)	NC_STRING
	number_of_overflow_values	0 (dynamic)	NC_INT
	The number of encountered values that are larger than the top of the histogram.		
	number_of_underflow_values	0 (dynamic)	NC_INT
	The number of encountered values that are smaller than the base of the histogram.		

nitrogendioxide_stratospheric_column_histogram in NO2/METADATA/QA_STATISTICS

Description: Histogram of the stratospheric NO_2 vertical column in the current granule.
Dimensions: nitrogendioxide_stratospheric_column_histogram_axis.
Type: NC_INT.
Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	comment	'Histogram of the stratospheric NO2 vertical column in the current granule' (static)	NC_STRING
	number_of_overflow_values	0 (dynamic)	NC_INT
	The number of encountered values that are larger than the top of the histogram.		
	number_of_underflow_values	0 (dynamic)	NC_INT
	The number of encountered values that are smaller than the base of the histogram.		

nitrogendioxide_total_column_histogram in NO2/METADATA/QA_STATISTICS

Description: Histogram of the total NO_2 vertical column in the current granule.
Dimensions: nitrogendioxide_total_column_histogram_axis.
Type: NC_INT.
Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	comment	'Histogram of the total NO2 vertical column in the current granule' (static)	NC_STRING
	number_of_overflow_values	0 (dynamic)	NC_INT
	The number of encountered values that are larger than the top of the histogram.		

	number_of_underflow_values	0 (dynamic)	NC_INT
	The number of encountered values that are smaller than the base of the histogram.		

nitrogendioxide_tropospheric_column_pdf in NO2/METADATA/QA_STATISTICS

Description: Probability density function of tropospheric NO_2 vertical column in the current granule. The values are weighted with $\cos(\delta_{\text{geo}})$ and spread out using the error estimate.

Dimensions: nitrogendioxide_tropospheric_column_pdf_axis.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	comment	'Probability density function of the tropospheric NO2 vertical column in the current granule' (static)	NC_STRING
	geolocation_sampling_total	0 (static)	NC_FLOAT
	The sum of cosine values of latitudes from the pixels that were used in the pdf.		

nitrogendioxide_stratospheric_column_pdf in NO2/METADATA/QA_STATISTICS

Description: Probability density function of the stratospheric NO_2 vertical column in the current granule. The values are weighted with $\cos(\delta_{\text{geo}})$ and spread out using the error estimate.

Dimensions: nitrogendioxide_stratospheric_column_pdf_axis.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	comment	'Probability density function of the stratospheric NO2 vertical column in the current granule' (static)	NC_STRING
	geolocation_sampling_total	0 (static)	NC_FLOAT
	The sum of cosine values of latitudes from the pixels that were used in the pdf.		

nitrogendioxide_total_column_pdf in NO2/METADATA/QA_STATISTICS

Description: Probability density function of tropospheric NO_2 vertical column in the current granule. The values are weighted with $\cos(\delta_{\text{geo}})$ and spread out using the error estimate.

Dimensions: nitrogendioxide_total_column_pdf_axis.

Type: NC_FLOAT.

Source: Processor.

Attributes:	*Name*	*Value*	*Type*
	comment	'Probability density function of the total NO2 vertical column in the current granule' (static)	NC_STRING
	geolocation_sampling_total	0 (static)	NC_FLOAT
	The sum of cosine values of latitudes from the pixels that were used in the pdf.		

10.2.2 Group "ALGORITHM_SETTINGS" in "METADATA"

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

Configurations in NO2/METADATA/ALGORITHM_SETTINGS

configuration.version.framework 1.2.0
Allow the framework to verify that the configuration file is up to date.
configuration.version.algorithm 1.3.0
Allow the processor to verify that the configuration file is up to date.
processing.algorithm NO2___

Define the algorithm that is to be loaded.

input.count 5
Define the number of input files.

input.1.type L1B_RA_BD4
Define the input type (band) for the first input (radiance band 4). This key is needed to read from the JobOrder input file.

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

input.1.band 4
Which band is this (for selecting the irradiance and coregistration to output).

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

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

input.2.required false
FRESCO is not required, just one of the two cloud products. O22CLD is not required, just one of the three cloud products.

input.3.type L2__AER_AI
efine the input type for the third input (AER_AI, L2 product). This key is needed to read from the JobOrder input file.

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

input.4.type L2__CLOUD_
Define the input type for the second input (DLR clouds, L2 product). This key is needed to read from the JobOrder input file.

input.4.band 3
On which band is this (for coregistration to output).

input.4.required false
DLR clouds is not required, just one of the two cloud products.

input.5.type L2__O22CLD
Define the input type for the second input (O22CLD clouds, L2 product). This key is needed to read from the JobOrder input file.

input.5.band 4
On which band is this (for coregistration to output).

input.5.required false

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

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

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

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

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

output.1.type L2__NO2___
Output product short name. This key is needed to read from the JobOrder input file.

output.1.config product.NO2___.xml
Output product specification.

output.1.band 4
Geolocation in output follows this band.

output.1.level 0
Output level, 0 = nominal.

processing.vzaMin 0.0

processing.vzaMax 75.0
Maximum viewing zenith angle (full swath)

processing.szaMin 0.0

processing.szaMax 88.0
Maximum solar zenith angle.
processing.saturationMaxFraction 0.01
Maximum fraction of the radiance spectrum that is allowed to be flagged as saturated.
processing.correct_surface_pressure_for_altitude true
Flag to control the correction of the surface pressure for local orography. Default is true.
processing.NO2_scd_limit -20.0e-6
NO_2 slant column values smaller than this limit will be treated as an error.
processing.reflectance_noise_floor 2500.0
This is the maximum signal to noise ratio allowed on the reflectance. The noise will be adjusted upwards when this is exceeded.
processing.use_error_in_l1b false
Use both noise an error when calculating the error on the reflectance. Default is to use the noise only.
NO2DOAS.species NO2, O3, O2O2, H2O_vapor, H2O_liquid
omma separated list of trace gases to be included in the DOAS fit. Use names as they appear in the REF_XS_NO2 file.
NO2DOAS.NO2.output.name nitrogendioxide
Name of the NO_2 trace gas as it appears in the output file.
NO2DOAS.O3.output.name ozone
Name of the O_3 trace gas as it appears in the output file.
NO2DOAS.O2O2.output.name oxygen_oxygen_dimer
Name of the O_2–O_2 trace gas as it appears in the output file.
NO2DOAS.H2O_vapor.output.name water
Name of the water vapour absorber as it appears in the output file.
NO2DOAS.H2O_liquid.output.name water_liquid
Name of the liquid water absorber as it appears in the output file.
NO2DOAS.include_ring true
Include the ring spectrum in the fit.
NO2DOAS.include_offset false
Include an intensity offset term in the DOAS fit.
NO2DOAS.wavelength_start 405.0
Begin of the DOAS fit window.
NO2DOAS.wavelength_end 465.0
End of the DOAS fit window.
NO2DOAS.max_iterations 20
Maximum number of iterations for the DOAS fit
NO2DOAS.convergence_threshold 0.99
Convergence threshold criterion.
NO2DOAS.scale_precision_with_chisq true
Scale the reported precision with the reduced χ^2. Default is false.
NO2DOAS.polynomial_order 5
Order of the background polynomial.
NO2DOAS.background_offset.polynomial_order 1
When fitting an intensity offset: the order for that polynomial
NO2DOAS.intensity_offset_scalefactor 1.0
When fitting an intensity offset: the scale factor.
processing.radianceFractionMinError 0.4
Minimum fraction of the spectrum that must be valid when fitting.
processing.radianceFractionMinWarning 0.8
Minimum fraction of the spectrum that must be valid before generating a warning.
NO2DOAS.initial_guess.a0 1.0
Initial guess for the first polynomial coefficient.
NO2DOAS.initial_guess.a1 0.125
Initial guess for the second polynomial coefficient (etc.).
NO2DOAS.initial_guess.a2 0.015625
NO2DOAS.initial_guess.a3 0.015625
NO2DOAS.initial_guess.a4 0.015625
NO2DOAS.initial_guess.a5 0.015625

NO2DOAS.initial_guess.c0 1.0
Initial guess for the first polynomial coefficient of the intensity offset (when included in the fit).
NO2DOAS.initial_guess.c1 0.125
Initial guess for the second polynomial coefficient of the intensity offset (etc.).
NO2DOAS.initial_guess.c2 0.015625
NO2DOAS.initial_guess.c3 0.015625
NO2DOAS.initial_guess.NO2 1.2e-5
Initial guess for the NO_2 slant column.
NO2DOAS.initial_guess.O3 3.6e-1
Initial guess for the O_3 slant column.
NO2DOAS.initial_guess.O2O2 8.0e+5
Initial guess for the O_2–O_2 slant column.
NO2DOAS.initial_guess.H2O_vapor 1.5e+3
Initial guess for the water vapour slant column.
NO2DOAS.initial_guess.H2O_liquid 0.0
Initial guess for the liquid water column.
NO2DOAS.initial_guess.ring 0.06
Initial guess for the Ring coefficient.
NO2DOAS.sigma.a0 1.0
A priori error of the first polynomial coefficient. A priori error of the second polynomial coefficient (etc.).
NO2DOAS.sigma.a1 0.125
NO2DOAS.sigma.a2 0.015625
NO2DOAS.sigma.a3 0.015625
NO2DOAS.sigma.a4 0.015625
NO2DOAS.sigma.a5 0.015625
NO2DOAS.sigma.c0 1.0
A priori error of the first polynomial coefficient of the intensity offset. A priori error of the second polynomial coefficient of the intensity offset (etc.).
NO2DOAS.sigma.c1 0.125
NO2DOAS.sigma.c2 0.015625
NO2DOAS.sigma.c3 0.015625
NO2DOAS.sigma.NO2 1.0e-2
A priori error on the NO_2 slant column. Should be wide enough to capture all cases.
NO2DOAS.sigma.O3 5.0e0
A priori error on the O_3 slant column. Should be wide enough to capture all cases.
NO2DOAS.sigma.O2O2 2.0e+6
A priori error on the O_2–O_2 slant column. Should be wide enough to capture all cases.
NO2DOAS.sigma.H2O_vapor 1.0e+4
A priori error on the water vapour slant column. Should be wide enough to capture all cases.
NO2DOAS.sigma.H2O_liquid 20.0
A priori error on the liquid water column. Should be wide enough to capture all cases.
NO2DOAS.sigma.ring 0.2
A priori error on the Ring coefficient
processing.irradFluxVarName irradiance_flux_cf
ame of the variable containing the irradiance spectrum in the REF_SOLAR_ file.
processing.radRingFluxVarName radiance_ring_flux_cf
ame of the variable containing the radiance Ring spectrum in the REF_SOLAR_ file.
NO2DOAS.reference_cross_sections_key REF_XS_NO2
Key in the job order file that points to the file containing the reference spectra.
NO2DOAS.NO2.reference_temperature -1.0
NO2DOAS.O3.reference_temperature -1.0
wavelength_calibration.perform_wavelength_fit yes
Master switch for the wavelength calibration.
wavelength_calibration.polynomial_order 2
The wavelength calibration fit uses a background polynomial. This is the order for this polynomial, 2 for NO_2.
wavelength_calibration.include_stretch no
For aerosol layer height we do not include a stretch/squeeze parameter as we extrapolate the result.

wavelength_calibration.include_ring yes
Ring effect is significant in the VIS.
wavelength_calibration.irr.include_ring no
wavelength_calibration.initial_guess.a0 1.0
Initial guess for the parameters of the polynomial in the wavelength fit. 1, 0.1, 0.01, 0.01, . . . for a0, a1, a2, a3, . . . as appropriate.
wavelength_calibration.initial_guess.a1 0.1
wavelength_calibration.initial_guess.a2 0.01
wavelength_calibration.sigma.a0 1.0
a priori precision of the polynomial coefficients. 1, 0.1, 0.1, 0.1, . . . for a0, a1, a2, a3, . . . as appropriate.
wavelength_calibration.sigma.a1 0.1
wavelength_calibration.sigma.a2 0.01
wavelength_calibration.sigma.shift 0.07
a priori precision of the wavelength shift. Set to the spectral sampling for band 4 divided by 3.
wavelength_calibration.sigma.ring 0.06
a priori precision of the Ring coefficient.
wavelength_calibration.sigma.stretch 0.07
a priori precision of the strech parameter. Due to scaling equal to pixel size scaling at end of window.
wavelength_calibration.initial_guess.shift 0.0
Initial guess for the wavelength shift.
wavelength_calibration.initial_guess.ring 0.06
Initial guess for the Ring coefficient.
wavelength_calibration.initial_guess.stretch 0.0
Initial guess for the wavelength stretch.
wavelength_calibration.window 405.0, 465.0
The wavelength calibration window (i.e. the whole fit window, this is different from OMI).
wavelength_calibration.max_iterations 12
The maximum number of iterations for the wavelength fit.
wavelength_calibration.convergence_threshold 1.0
Convergence criterium (auto scaled).
processing.fitWindowExtent 3
the width of spectra retrieved outside the fit window.
processing.cloud_wavelength 440.0
avelength at which the cloud fraction calculation is done in band 4. (Should be equal to the value in the 'wavelength' variable in the "`LUT_NO2CLD`" file).
processing.cloud_wavelength_delta 1.0
verage over band this wide around the "processing.cloud_wavelength" parameter.
processing.reflectance_from_model true
Use the model from the DOAS fit to obtain the continuum reflectance for cloud fraction determination
processing.groupDem DEM_RADIUS_05000
Which DEM to use.
processing.groupLer OMI
Which LER database to use.
output.histogram.nitrogendioxide_tropospheric_column.range 1.66054e-06,0.00166054
Range for the histogram of the tropspheric NO_2 column.
output.histogram.nitrogendioxide_tropospheric_column.logarithmic true
The scale of the scale of the histogram is logarithmic.
output.histogram.nitrogendioxide_stratospheric_column.range 0,0.000166054
Range for the histogram of the stratospheric NO_2 column.
output.histogram.nitrogendioxide_stratospheric_column.logarithmic false
The scale of the scale of the histogram is linear.
output.histogram.nitrogendioxide_total_column.range 1.66054e-06,0.00166054
Range for the histogram of the total NO_2 column.
output.histogram.nitrogendioxide_total_column.logarithmic true
The scale of the scale of the histogram is logarithmic.
qa_value.input_spectrum_warning 100.0
he qa_value multiplication factor (in percent) for when the number of pixels in the input spectrum is below nominal.

qa_value.wavelength_calibration_warning 100.0
he qa_value multiplication factor (in percent) for when the wavelength calibration offset is larger than a configured threshold.
qa_value.extrapolation_warning 100.0
he qa_value multiplication factor (in percent) for when extrapolation was used in the retrieval.
qa_value.sun_glint_warning 93.0
he qa_value multiplication factor (in percent) for when the pixel is potentially affected by sun glint.
qa_value.south_atlantic_anomaly_warning 95.0
he qa_value multiplication factor (in percent) for when the instrument was flying through the South Atlantic Anomaly while taking this measurement.
qa_value.sun_glint_correction 100.0
he qa_value multiplication factor (in percent) for when the cloud fraction was corrected for sun glint.
qa_value.snow_ice_warning 100.0
he qa_value multiplication factor (in percent) for when the snow_ice_warning flag is raised.
qa_value.cloud_warning 100.0
he qa_value multiplication factor (in percent) for when the cloud_warning flag is raised.
qa_value.AAI_warning 100.0
he qa_value multiplication factor (in percent) for when the AAI_warning flag is raised.
qa_value.pixel_level_input_data_missing 90.0
he qa_value multiplication factor (in percent) for when the pixel_level_input_data_missing flag is raised.
qa_value.data_range_warning 100.0
he qa_value multiplication factor (in percent) for when the data_range_warning flag is raised.
qa_value.low_cloud_fraction_warning 100.0
he qa_value multiplication factor (in percent) for when the low_cloud_fraction_warning flag is raised.
qa_value.altitude_consistency_warning 100.0
he qa_value multiplication factor (in percent) for when the altitude_consistency_warning flag is raised.
qa_value.signal_to_noise_ratio_warning 100.0
he qa_value multiplication factor (in percent) for when the signal_to_noise_ratio_warning flag is raised.
qa_value.deconvolution_warning 100.0
he qa_value multiplication factor (in percent) for when the deconvolution_warning flag is raised.
qa_value.so2_volcanic_origin_likely_warning 100.0
he qa_value multiplication factor (in percent) for when the so2_volcanic_origin_likely_warning flag is raised.
qa_value.so2_volcanic_origin_certain_warning 100.0
he qa_value multiplication factor (in percent) for when the so2_volcanic_origin_certain_warning flag is raised.
qa_value.interpolation_warning 90.0
he qa_value multiplication factor (in percent) for when the interpolation_warning flag is raised.
qa_value.sza_max_1_threshold 81.2
First limit on θ in the QA value calculation
qa_value.sza_max_1_modification_percent 30.0
he qa_value multiplication factor (in percent) for when the solar zenith angle is between the first and second threshold.
qa_value.sza_max_2_threshold 84.5
Second limit on θ in the QA value calculation
qa_value.sza_max_2_modification_percent 10.0
he qa_value multiplication factor (in percent) for when the solar zenith angle larger than the second threshold.
qa_value.amf_trop_geo_ratio_threshold 0.1
Threshold on the ratio between the tropospheric and geometric airmass factors.
qa_value.amf_trop_geo_ratio_modification_percent 45.0
he qa_value multiplication factor (in percent) for when the ratio between the tropospheric and geometric airmass factors is larger than the threshold.
qa_value.no2_scd_precision_threshold 33.0e-6
Maximum allowed precision of the NO_2 slant column before reducing the QA value.
qa_value.no2_scd_precision_modification_percent 15.0
he qa_value multiplication factor (in percent) for when the precision of the NO_2 slant column exceeds the threshold.

qa_value.snow_ice_max_threshold 1
Maximum snow-ice value before pixel is treated as snow or ice contaminated.
qa_value.snow_ice_max_modification_percent 73.0
he qa_value multiplication factor (in percent) for when the pixel is treated as snow or ice contaminated.
qa_value.surface_albedo_threshold 0.3
The maximum surface albedo in the NO_2 fitting window before the QA value is reduced.
qa_value.surface_albedo_modification_percent 20.0
he qa_value multiplication factor (in percent) for when maximum surface albedo in the NO_2 fitting window is exceeded.
qa_value.cloud_radiance_fraction_threshold 0.5
qa_value.cloud_radiance_fraction_modification_percent 74.0
qa_value.minimum_scene_pressure_threshold 30000.0
qa_value.minimum_scene_pressure_modification_percent 25.0
qa_value.maximum_aerosol_index_threshold 1.0e10
qa_value.maximum_aerosol_index_modification_percent 40.0

10.2.3 Group "GRANULE_DESCRIPTION" in "METADATA"

Common granule level metadata.

Attributes in NO2/METADATA/GRANULE_DESCRIPTION

Group attributes attached to GRANULE_DESCRIPTION		
Name	*Value*	*Type*
GranuleStart		NC_STRING
Start of the granule as ISO date/time string in UTC: *YYYY***-***MM***-***DD***T***HH***:***MM***:***SS***.***mmmmmm***Z**. The formal definition of ISO date/time strings is given in [RD40].		
GranuleEnd		NC_STRING
End of the granule as ISO date/time string in UTC: *YYYY***-***MM***-***DD***T***HH***:***MM***:***SS***.***mmmmmm***Z**. The formal definition of ISO date/time strings is given in [RD40].		
InstrumentName	'TROPOMI' (static)	NC_STRING
The name of the instrument, fixed to "TROPOMI".		
MissionName	'Sentinel-5 precursor' (static)	NC_STRING
The name of the mission, fixed to "Sentinel-5 precursor".		
MissionShortName	'S5P' (static)	NC_STRING
The short name of the mission, fixed to "S5P".		
ProcessLevel	'2' (static)	NC_STRING
This is a level 2 product.		
ProcessingCenter	'%(processingcenter)s' (dynamic)	NC_STRING
Where was the processor run? The source is the probably the joborder, the most likely value for operational use is "DLR/Oberpfaffenhofen".		
ProcessingNode		NC_STRING
The name of the machine that processed the data. This may aid in diagnosing failures in the processing.		
ProcessorVersion	'%(version)s' (dynamic)	NC_STRING
The version number of the processor used to produce the file. This is a string formatted as "major.minor.bugfix".		
ProductFormatVersion	1 (static)	NC_INT
The version of the format of the product file. This should be incremented whenever a datafield is added to the files.		
ProcessingMode		NC_STRING
This attribute indicates the mode of the processor. Possible values: Near-realtime, Offline, Reprocessing, Test, SyntheticTest		
LongitudeOfDaysideNadirEquatorCrossing		NC_FLOAT

The longitude of the nadir-point at the day-side equator crossing. This gives a rough indication where the orbit is located. The value is calculated using an orbit propagator before the observation, so that a consisten value is used for all processing stages.		
ProductShortName	'L2__NO2___' (static)	NC_STRING
The short product name. For the NO_2 vertical column product the short name is fixed to "L2__NO2___".		

10.2.3.1 Group "ISO_METADATA" in "iso_metadata"

Metadata that is structured following the ISO metadata standards [RD34, RD44], especially part 2. The metadata in this group is structured using the methods from Level 1B, which is described in the Level 1B metadata specification [RD39].

All "`objectType`" attributes indicate the XML object when generating an ISO 19139 [RD44] compliant XML metadata file.

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

Attributes in NO2/METADATA/ISO_METADATA

Group attributes attached to ISO_METADATA		
Name	*Value*	*Type*
gmd:dateStamp	'2015-10-16' (static)	NC_STRING
Date of creation of the metadata, as ISO 8601 [RD40] string specifying year, month and day.		
gmd:fileIdentifier	'urn:ogc:def:EOP:ESA:SENTINEL.S5P_TROP_-%(shortname)s' (dynamic)	NC_STRING
Unique identifier for metadata file, see the Level 1B metadata specification [RD39, table 5] for a discussion of the value. Replace %(...)s with the "`ProductShortName`" value from the Level 2 "`/METADATA/GRANULE_-DESCRIPTION`" metadata group.		
gmd:hierarchyLevelName	'EO Product Collection' (static)	NC_STRING
Name of the hierarchy levels for which the metadata is provided.		
gmd:metadataStandardName	'ISO 19115-2 Geographic Information - Metadata Part 2 Extensions for imagery and gridded data' (static)	NC_STRING
Name of the metadata standard.		
gmd:metadataStandardVersion	'ISO 19115-2:2009(E), S5P profile' (static)	NC_STRING
Version (profile) of the metadata standard used.		
objectType	'gmi:MI_Metadata' (static)	NC_STRING
Name of the metadata class [RD39, table 5].		

10.2.3.2 Group "gmd:language" in "ISO_METADATA"

Language used for the metadata, fixed to English.

Attributes in NO2/METADATA/ISO_METADATA/gmd:language

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

10.2.3.3 Group "gmd:characterSet" in "ISO_METADATA"

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:characterSet

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

10.2.3.4 Group "gmd:hierarchyLevel" in "ISO_METADATA"

Scope to wich metadata applies.

Attributes in NO2/METADATA/ISO_METADATA/gmd:hierarchyLevel

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

10.2.3.5 Group "gmd:contact" in "ISO_METADATA"

Contact information for the product.

Attributes in NO2/METADATA/ISO_METADATA/gmd:contact

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

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

The detailed contact information.

Attributes in NO2/METADATA/ISO_METADATA/gmd:contact/gmd:contactInfo

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

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

The actual email address.

Attributes in NO2/METADATA/ISO_METADATA/gmd:contact/gmd:contactInfo/gmd:address

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

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

The role of the adress provided in this group.

Attributes in NO2/METADATA/ISO_METADATA/gmd:contact/gmd:role

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

10.2.3.9 Group "gmd:identificationInfo" in "ISO_METADATA"

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo

Group attributes attached to gmd:identificationInfo		
Name	*Value*	*Type*
gmd:abstract		NC_STRING

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

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

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

L2__NO2___ (KNMI) Nitrogen dioxide tropospheric column with a spatial resolution of $7 \times 7\,\mathrm{km}^2$ observed at about 13:30 local solar time from spectra measured by TROPOMI

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

L2__O3_TPR (KNMI) Tropospheric ozone profile with a vertical resolution of 6 km and a horizontal resolution of $7 \times 7\,\mathrm{km}^2$ observed at about 13:30 local solar time from spectra measured by TROPOMI

L2__CH4___ (SRON) Dry-air mixing ratio of methane for cloud-free observations with a spatial resolution of $7 \times 7\,\mathrm{km}^2$ observed at about 13:30 local solar time from spectra measured by TROPOMI

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

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

gmd:credit	'%(credit)s' (static)	NC_STRING
Recognition of those who contributed to the resource(s).		
gmd:language	'eng' (static)	NC_STRING
gmd:topicCategory	'climatologyMeteorologyAtmosphere' (static)	NC_STRING
Main theme(s) of the dataset.		
objectType	'gmd:MD_DataIdentification' (static)	NC_STRING
Name of the metadata class [RD39, table 10].		

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

Citation data for the resource.

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:citation

Group attributes attached to gmd:citation		
Name	*Value*	*Type*
gmd:title		NC_STRING
Name by which the cited resource is known. This is the same as the global "`title`" attribute.		
objectType	'gmd:CI_Citation' (static)	NC_STRING
Name of the metadata class [RD39, table 11].		

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:citation/gmd:date

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

10.2.3.12 Group "gmd:dateType" in "gmd:date"

Event used for reference date.

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:citation/gmd:date/gmd:dateType

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

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

Unique identifier for metadata file, see the Level 1B metadata specification [RD39, table 5] for a discussion of the value.

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:citation/gmd:identifier

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

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

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:pointOfContact

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

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:pointOfContact/gmd:contactInfo

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

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:pointOfContact/gmd:contactInfo/gmd:address

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

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:pointOfContact/gmd:role

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

10.2.3.18 Group "gmd:descriptiveKeywords#1" in "gmd:identificationInfo"

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#1

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

10.2.3.19 Group "gmd:type" in "gmd:descriptiveKeywords#1"

Subject matter used to group similar keywords.

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#1/gmd:type

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

objectType	'gmd:MD_KeywordTypeCode' (static)	NC_STRING

10.2.3.20 Group "gmd:thesaurusName" in "gmd:descriptiveKeywords#1"

Name by which the cited resource is known.

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#1/gmd:thesaurusNam

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

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

Reference date for the cited resource.

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#1/gmd:thesaurusNam gmd:date

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

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

What date is used for the reference date.

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#1/gmd:thesaurusNam gmd:date/gmd:dateType

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

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

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

L2__AER_AI (KNMI) ultraviolet_aerosol_index

L2__AER_LH (KNMI) height_of_elevated_aerosol_layer

L2__NO2___ (KNMI) troposphere_mole_content_of_nitrogen_dioxide, stratosphere_mole_content_of_nitrogen_dioxide, atmosphere_mole_content_of_nitrogen_dioxide

L2__O3__PR (KNMI) mole_fraction_of_ozone_in_air

L2__O3_TPR (KNMI) mole_fraction_of_ozone_in_air

L2__CH4___ (SRON) atmosphere_mole_fraction_of_methane_in_dry_air

L2__CO____ (SRON) atmosphere_mole_content_of_carbon_monoxide

L2__FRESCO (KNMI) air_pressure_at_cloud_optical_centroid, effective_cloud_area_fraction_assuming_-fixed_cloud_albedo, cloud_albedo_assuming_completely_cloudy_sky, air_pressure_at_cloud_optical_-centroid_assuming_completely_cloudy_sky

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#2

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

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

Name by which the cited resource is known.

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#2/gmd:thesaurusNam

Group attributes attached to gmd:thesaurusName		
Name	*Value*	*Type*
gmd:title	'CF Standard Name Table v29' (static)	NC_STRING
xlink:href	'http://cfconventions.org/standard-names.html' (dynamic)	NC_STRING
objectType	'gmd:CI_Citation' (static)	NC_STRING

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

Reference date for the cited resource.

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#2/gmd:thesaurusNam gmd:date

Group attributes attached to gmd:date		
Name	*Value*	*Type*
gmd:date	'2015-07-08' (static)	NC_STRING
objectType	'gmd:CI_Date' (static)	NC_STRING

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

What date is used for the reference date.

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:descriptiveKeywords#2/gmd:thesaurusNam gmd:date/gmd:dateType

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

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

Provides information about constraints which apply to the resource.

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:resourceConstraints

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

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

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:resourceConstraints/gmd:accessConstrain

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

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

Method used to spatially represent geographic information.

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:spatialRepresentationType

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

10.2.3.30 Group "gmd:spatialResolution" in "gmd:identificationInfo"

Ground sample distance.

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:spatialResolution

Group attributes attached to gmd:spatialResolution		
Name	*Value*	*Type*
gmd:distance	7.0 (dynamic)	NC_FLOAT
uom	'km' (static)	NC_STRING
objectType	'gmd:MD_Resolution' (static)	NC_STRING

10.2.3.31 Group "gmd:characterSet" in "gmd:identificationInfo"

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:characterSet

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

objectType	'gmd:MD_CharacterSetCode' (static)	NC_STRING

10.2.3.32 Group "gmd:extent" in "gmd:identificationInfo"

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:extent

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

10.2.3.33 Group "gmd:geographicElement" in "gmd:extent"

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:extent/gmd:geographicElement

Group attributes attached to gmd:geographicElement		
Name	*Value*	*Type*
gmd:eastBoundLongitude	180.0 (dynamic)	NC_FLOAT
gmd:northBoundLatitude	90.0 (dynamic)	NC_FLOAT
gmd:southBoundLatitude	-90.0 (dynamic)	NC_FLOAT
gmd:westBoundLongitude	-180.0 (dynamic)	NC_FLOAT
gmd:extentTypeCode	'true' (static)	NC_STRING
Indication of whether the bounding polygon encompasses an area covered by the data or an area where data is not present. The value "true" indicates *inclusion*.		
objectType	'gmd:EX_GeographicBoundingBox' (static)	NC_STRING

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:extent/gmd:temporalElement

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

10.2.3.35 Group "gmd:extent" in "gmd:temporalElement"

Time period covered by the content of the dataset.

Attributes in NO2/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:extent/gmd:temporalElement/gmd:extent

Group attributes attached to gmd:extent		
Name	*Value*	*Type*
gml:beginPosition	'2014-11-14T19:58:00' (dynamic)	NC_STRING
Time of the start of the granule, expressed as ISO 8601 [RD40] date-time string.		
gml:endPosition	'2014-11-14T20:08:00' (dynamic)	NC_STRING
Time of the end of the granule, expressed as ISO 8601 [RD40] date-time string.		
objectType	'gml:TimePeriod' (static)	NC_STRING

10.2.3.36 Group "gmd:dataQualityInfo" in "ISO_METADATA"

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

For the TROPOMI level 2 products the use of the contained class LI_Lineage (group "gmd:lineage", section 10.2.3.44 on page 105) is important for describing the sources which are either used or produced (output) in a series of process steps. The sources refer to the various L1b data products used as inputs (and the L0 products used in producing *those* products) and the auxiliary data (static and especially dynamic) when producing the L2 products.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo

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

10.2.3.37 Group "gmd:scope" in "gmd:dataQualityInfo"

The specific data to which the data quality information applies.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:scope

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

10.2.3.38 Group "gmd:level" in "gmd:scope"

Hierarchical level of the data specified by the scope.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:scope/gmd:level

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

10.2.3.39 Group "gmd:report" in "gmd:dataQualityInfo"

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:report

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

10.2.3.40 Group "gmd:result" in "gmd:report"

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:report/gmd:result

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

10.2.3.41 Group "gmd:specification" in "gmd:result"

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:report/gmd:result/gmd:specification

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

10.2.3.42 Group "gmd:date" in "gmd:specification"

Reference date for the cited resource.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:report/gmd:result/gmd:specification/gmd:date

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

10.2.3.43 Group "gmd:dateType" in "gmd:date"

Meaning of the reference date for the cited resource.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:report/gmd:result/gmd:specification/gmd:date/gmd:dateType

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

10.2.3.44 Group "gmd:lineage" in "gmd:dataQualityInfo"

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage

Group attributes attached to gmd:lineage		
Name	*Value*	*Type*

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

10.2.3.45 Group "gmd:processStep" in "gmd:lineage"

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep

Group attributes attached to gmd:processStep		
Name	*Value*	*Type*
objectType	'gmi:LE_ProcessStep' (static)	NC_STRING
gmd:description	'Processing of L1b to L2 %(product)s data for orbit %(orbit)d using the %(institute)s processor version %(version)s' (dynamic)	NC_STRING
Description of the event, including related parameters or tolerances. Insert short description of the actual Level 2 product, the orbit number, the name of the institude responsible for the CFI and the software version in this string (at the respective %(...)s and %(...)d).		

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

Description of the output.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:output

Group attributes attached to gmi:output		
Name	*Value*	*Type*
gmd:description		NC_STRING
Short description of the output, a copy of the global 'title' attribute.		
objectType	'gmi:LE_Source' (static)	NC_STRING

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

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:output/gmd:sourceCitation

Group attributes attached to gmd:sourceCitation		
Name	*Value*	*Type*
gmd:title	'%(logical_filename)s' (dynamic)	NC_STRING
Output file name without extension.		
objectType	'gmd:CI_Citation' (static)	NC_STRING

10.2.3.48 Group "gmd:date" in "gmd:sourceCitation"

Production date and time of the output file.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:output/gmd:sourceCitation/gmd:date

Group attributes attached to gmd:date		
Name	*Value*	*Type*
gmd:date		NC_STRING
Production date and time of the output file. Note that the definition in the XML schema appears to allow the use of a “CI_DateTime” instead of a “CI_Date”.		
objectType	‘gmd:CI_DateTime’ (static)	NC_STRING

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

Meaning of the reference date for the cited resource.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:output/gmd:sourceCitation/gmd:date/gmd:dateType

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

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

Identification of the output product.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:output/gmd:sourceCitation/gmd:identifier

Group attributes attached to gmd:identifier		
Name	*Value*	*Type*
gmd:code	‘%(shortname)s’ (dynamic)	NC_STRING
The product short name, a copy of the ‘ProductShortName’ attribute in ‘/METADATA/GRANULE_DESCRIPTION’.		
objectType	‘gmd:MD_Identifier’ (static)	NC_STRING

10.2.3.51 Group “gmi:processedLevel” in “gmi:output”

Process level of the output file.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:output/gmi:processedLevel

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

10.2.3.52 Group “gmi:processingInformation” in “gmd:processStep”

Description of the processor in more detail.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInf

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

10.2.3.53 Group "gmi:identifier" in "gmi:processingInformation"

Identification of the processor.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInfo gmi:identifier

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

10.2.3.54 Group "gmi:softwareReference" in "gmi:processingInformation"

Reference to document describing processing software.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInfo gmi:softwareReference

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

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

Release date (compile date) of the processor.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInfo gmi:softwareReference/gmd:date

Group attributes attached to gmd:date		
Name	*Value*	*Type*
gmd:date		NC_STRING
Release date of the processor expressed as an ISO 8601 date string [RD40].		
objectType	'gmd:CI_DateTime' (static)	NC_STRING

10.2.3.56 Group "gmd:dateType" in "gmd:date"

Confirm that this is the release date of the processor.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInfo gmi:softwareReference/gmd:date/gmd:dateType

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

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

Reference to the ATBD of the product.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInfo gmi:documentation#1

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

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

Release date of the ATBD.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInfo gmi:documentation#1/gmd:date

Group attributes attached to gmd:date		
Name	*Value*	*Type*
gmd:date	'%(date_atbd)s' (dynamic)	NC_STRING
Release date of the ATBD expressed as an ISO 8601 date string [RD40].		
objectType	'gmd:CI_Date' (static)	NC_STRING

10.2.3.59 Group "gmd:dateType" in "gmd:date"

Confirm that this is the date of publication.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInfo gmi:documentation#1/gmd:date/gmd:dateType

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

10.2.3.60 Group "gmi:documentation#2" in "gmi:processingInformation"

Reference to the PUM of the product.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInfo gmi:documentation#2

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

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

Release date of the PUM.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInfo gmi:documentation#2/gmd:date

Group attributes attached to gmd:date		
Name	*Value*	*Type*
gmd:date	'%(date_pum)s' (dynamic)	NC_STRING
Release date of the PUM expressed as an ISO 8601 date string [RD40].		
objectType	'gmd:CI_Date' (static)	NC_STRING

10.2.3.62 Group "gmd:dateType" in "gmd:date"

Confirm that this is the date of publication.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:processingInfo gmi:documentation#2/gmd:date/gmd:dateType

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

10.2.3.63 Group "gmi:report" in "gmd:processStep"

Short report of what occurred during the process step.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmi:report

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

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

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmd:source#1

Group attributes attached to gmd:source#1		
Name	*Value*	*Type*
objectType	'gmi:LE_Source' (static)	NC_STRING
gmd:description		NC_STRING

Description of the input data, including L1B, L2, dynamic auxiliary input data and semi-static auxiliary input data. Base strings are “TROPOMI L1B %s radiance product”, “TROPOMI L1B %s irradiance product”, “TROPOMI L2 %s product”, “Auxiliary ECMWF %s Meteorological forecast data”, “Processor %s configuration file”, “Auxiliary %s reference data”, “Auxiliary %s algorithm lookup table”, “Auxiliary CTM %s model input data”, “Auxiliary snow and ice input data” and “Auxiliary NPP/VIIRS cloud screening input data”. The %s to be replaced with specific descriptors.

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmd:source#1/gmi:processedLevel

Group attributes attached to gmi:processedLevel		
Name	*Value*	*Type*
gmd:code	*Empty!*	NC_STRING
objectType	‘gmd:MD_Identifier’ (static)	NC_STRING

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

Reference to the actual filename of the input data.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmd:source#1/gmd:sourceCitation

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

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmd:source#1/gmd:sourceCitation/gmd:date

Group attributes attached to gmd:date		
Name	*Value*	*Type*
gmd:date		NC_STRING
Production date and time of the input file(s) in this group expressed as an ISO 8601 date-time string [RD40]. Note that the definition in the XML schema appears to allow the use of a “CI_DateTime” instead of a “CI_Date”.		
objectType	‘gmd:CI_Date’ (static)	NC_STRING

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

Meaning of the reference date for the cited resource.

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmd:source#1/gmd:sourceCitation/gmd:date/gmd:dateType

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

10.2.3.69 Group "gmd:title" in "gmd:sourceCitation"

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmd:source#1/gmd:sourceCitation/gmd:title

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

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

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

Attributes in NO2/METADATA/ISO_METADATA/gmd:dataQualityInfo/gmd:lineage/gmd:processStep/gmd:source#1/gmd:sourceCitation/gmd:alternateTitle#1

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

10.2.3.71 Group "gmi:acquisitionInformation" in "ISO_METADATA"

Metadata regarding the acquisition of the original data.

Attributes in NO2/METADATA/ISO_METADATA/gmi:acquisitionInformation

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

10.2.3.72 Group "gmi:platform" in "gmi:acquisitionInformation"

The platform we are on.

Attributes in NO2/METADATA/ISO_METADATA/gmi:acquisitionInformation/gmi:platform

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

10.2.3.73 Group "gmi:identifier" in "gmi:platform"

Short identifier of the platform.

Attributes in NO2/METADATA/ISO_METADATA/gmi:acquisitionInformation/gmi:platform/gmi:identifier

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

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

The instrument used for the observations.

Attributes in NO2/METADATA/ISO_METADATA/gmi:acquisitionInformation/gmi:platform/gmi:instrument

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

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

Unique identifier for the instrument.

Attributes in NO2/METADATA/ISO_METADATA/gmi:acquisitionInformation/gmi:platform/gmi:instrument/gmi:identifier

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

10.2.3.76 Group “EOP_METADATA” in “EOP_metadata”

Based on the OGC 10-025 standard for Observations & Measurements [RD45], an Earth Observation Product (EOP) schema was developed which refines an observation into the feature type earth observation. This schema was then extended with sensor-specific thematic schemas.

Attributes in NO2/METADATA/EOP_METADATA

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

10.2.3.77 Group “om:phenomenonTime” in “EOP_METADATA”

Time coverage of the granule.

Attributes in NO2/METADATA/EOP_METADATA/om:phenomenonTime

Group attributes attached to om:phenomenonTime		
Name	*Value*	*Type*
gml:beginPosition		NC_STRING
Start of time coverage of the data in the granule expressed as an ISO 8601 date-time string [RD40].		
gml:endPosition		NC_STRING
End of time coverage of the data in the granule expressed as an ISO 8601 date-time string [RD40].		
objectType	‘gml:TimePeriod’ (static)	NC_STRING

10.2.3.78 Group “om:procedure” in “EOP_METADATA”

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

Attributes in NO2/METADATA/EOP_METADATA/om:procedure

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

10.2.3.79 Group “eop:platform” in “om:procedure”

Platform name and orbit type.

Attributes in NO2/METADATA/EOP_METADATA/om:procedure/eop:platform

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

10.2.3.80 Group “eop:instrument” in “om:procedure”

Instrument descriptor.

Attributes in NO2/METADATA/EOP_METADATA/om:procedure/eop:instrument

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

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

Sensor description.

Attributes in NO2/METADATA/EOP_METADATA/om:procedure/eop:sensor

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

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

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

Attributes in NO2/METADATA/EOP_METADATA/om:procedure/eop:acquisitionParameters

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

10.2.3.83 Group "om:observedProperty" in "EOP_METADATA"

An xlink to the observed property definition.

Attributes in NO2/METADATA/EOP_METADATA/om:observedProperty

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

10.2.3.84 Group "om:featureOfInterest" in "EOP_METADATA"

Attributes in NO2/METADATA/EOP_METADATA/om:featureOfInterest

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

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

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

Attributes in NO2/METADATA/EOP_METADATA/om:featureOfInterest/eop:multiExtentOf

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

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

Attributes in NO2/METADATA/EOP_METADATA/om:featureOfInterest/eop:multiExtentOf/gml:surfaceMembers

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

10.2.3.87 Group "gml:exterior" in "gml:surfaceMembers"

Attributes in NO2/METADATA/EOP_METADATA/om:featureOfInterest/eop:multiExtentOf/gml:surfaceMembers/gml:exterior

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

10.2.3.88 Group “eop:metaDataProperty” in “EOP_METADATA”

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

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

Attributes in NO2/METADATA/EOP_METADATA/eop:metaDataProperty

Group attributes attached to eop:metaDataProperty		
Name	*Value*	*Type*
objectType	‘eop:EarthObservationMetaData’ (static)	NC_STRING
eop:acquisitionType	‘NOMINAL’ (dynamic)	NC_STRING
Used to distinguish at a high level the appropriateness of the acquisition for “general” use, whether the product is a nominal acquisition, special calibration product or other. Copy from L1b. For Level 2 this should *always* be ‘NOMINAL’.		
eop:identifier	‘%(logical_filename)s’ (dynamic)	NC_STRING
Logical file name.		
eop:doi	‘%(product_doi)s’ (dynamic)	NC_STRING
Digital Object Identifier identifying the product (see `http://www.datacite.org` for DOIs for datasets).		
eop:parentIdentifier	‘urn:ogc:def:EOP:ESA:SENTINEL.S5P_TROP_-%(shortname)s’ (dynamic)	NC_STRING
Unique collection identifier for metadata file, see the Level 1B metadata specification [RD39, table 5] for a discussion of the value.		
This is a copy of the “gmd:fileIdentifier” attribute in the “/METADATA/ISO_METADATA” group.		
eop:productType	‘S5P_%(mode)s_%(product)s’ (dynamic)	NC_STRING
Product type identifier. Replace %(mode)s with the operational mode the processor is running in (‘NRTI’, ‘OFFL’ or ‘RPRO’, as per [RD25]) and %(product)s with the 10 character output file name semantic descriptors as given in [RD46, RD47, RD48].		
eop:status	‘ACQUIRED’ (dynamic)	NC_STRING
Refers to product status. Values listed in the standard: ‘ARCHIVED’, ‘ACQUIRED’, ‘CANCELLED’, ‘FAILED’, ‘PLANNED’, ‘POTENTIAL’, ‘REJECTED’, ‘QUALITY-DEGRADED’. Copied from L1B.		
eop:productQualityStatus	‘NOMINAL’ (dynamic)	NC_STRING
Indicator that specifies whether the product quality is degraded or not. Allowed values: ‘DEGRADED’, ‘NOMINAL’.		
eop:productQualityDegradationTag	‘NOT APPLICABLE’ (dynamic)	NC_STRING
Contains further textual information concerning the quality degradation. According to the metadata standards it shall be provided *only* if “eop:productQualityStatus” value is set to ‘DEGRADED’. Because the way we generate out output files, this attribute will always be present, even when “eop:productQualityStatus” value is ‘NOMINAL’. In those cases the value shall be set to “NOT APPLICABLE”.		
Possible values are “MISSING AUXILIARY INPUT” and “NOT APPLICABLE”. Note that Level 1B does not set this value, so only problems detectable in the processor are covered.		

10.2.3.89 Group “eop:processing” in “eop:metaDataProperty”

Processing information.

Attributes in NO2/METADATA/EOP_METADATA/eop:metaDataProperty/eop:processing

Group attributes attached to eop:processing		
Name	*Value*	*Type*
objectType	‘eop:ProcessingInformation’ (static)	NC_STRING
eop:processingCenter	‘%(processingcenter)s’ (dynamic)	NC_STRING

The processing center, taken from the "`Processing_Station`" key in the joborder.		
eop:processingDate	'YYYY-mm-ddTHH:MM:SSZ' (dynamic)	NC_STRING
The processing date, as an ISO 8601 date-time string [RD40].		
eop:processingLevel	'L2' (static)	NC_STRING
These are all Level 2 products.		
eop:processorName	'%(processor_name)s' (static)	NC_STRING
The name of the processor, "`tropnll2dp.exe`" for KNMI and "`upas-l2`" for DLR.		
eop:processorVersion	'%(version)s' (dynamic)	NC_STRING
Version of the processor, as "major.minor.bugfix".		
eop:nativeProductFormat	'netCDF-4' (static)	NC_STRING
Native product format.		
eop:processingMode	'%(mode)s' (dynamic)	NC_STRING
Processing mode taken from mission specific code list. For S5P we use the *File Class* identifiers [RD25, section 4.1.2]: 'TEST', 'OGCA', 'GSOV', 'OPER', 'NRTI', 'OFFL', 'RPRO'.		

10.2.3.90 Group "ESA_METADATA" in "ESA_metadata"

Metadata defined in the ESA file format standard [RD33].

10.2.3.91 Group "earth_explorer_header" in "ESA_METADATA"

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header

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

10.2.3.92 Group "fixed_header" in "earth_explorer_header"

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

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/fixed_header

Group attributes attached to fixed_header		
Name	*Value*	*Type*
objectType	'Fixed_Header' (static)	NC_STRING
File_Name	'%(logical_filename)s' (dynamic)	NC_STRING
The *logical* file name, i.e. the file name without extension.		
File_Description		NC_STRING
This is a copy of the global "title" attribute.		
Notes		NC_STRING
This is a copy of the global "comment" attribute.		
Mission	'S5P' (static)	NC_STRING
The mission identifier for the Sentinel 5-precursor mission is "S5P".		
File_Class	'%(mode)s' (dynamic)	NC_STRING
The file class of the output. Values are taken from the tailoring of the EO file format tailoring for S5P [RD25, section 4.1.2].		
File_Type	'%(shortname)s' (dynamic)	NC_STRING
Following the EO file format tailoring for S5P [RD25, sections 4.1.3.1 and 4.1.3.2].		
File_Version	0 (dynamic)	NC_INT

The file version information is not part of the file name conventions for S5P. If a file version number is to be recorded in this attribute, then it has to be provided by the PDGS via the job order. If provided, then the value is ≥ 1. If not provided the fill value is 0.

10.2.3.93 Group "validity_period" in "fixed_header"

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/fixed_header/validity_period

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

10.2.3.94 Group "source" in "fixed_header"

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/fixed_header/source

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

10.2.3.95 Group "variable_header" in "earth_explorer_header"

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header

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

10.2.3.96 Group "gmd:lineage" in "variable_header"

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

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage

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

10.2.3.97 Group "gmd:processStep" in "gmd:lineage"

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

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep

Group attributes attached to gmd:processStep		
Name	*Value*	*Type*
objectType	'gmi:LE_ProcessStep' (static)	NC_STRING
gmd:description	'Processing of L1b to L2 %(product)s data for orbit %(orbit)d using the %(institute)s processor version %(version)s' (dynamic)	NC_STRING
Description of the event, including related parameters or tolerances. Insert short description of the actual Level 2 product, the orbit number, the name of the institude responsible for the CFI and the software version in this string (at the respective %(...)s and %(...)d).		

10.2.3.98 Group "gmi:output" in "gmd:processStep"

Description of the output.

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:output

Group attributes attached to gmi:output		
Name	*Value*	*Type*
gmd:description		NC_STRING
Short description of the output, a copy of the global 'title' attribute.		
objectType	'gmi:LE_Source' (static)	NC_STRING

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

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

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:output/gmd:sourceCitation

Group attributes attached to gmd:sourceCitation		
Name	*Value*	*Type*
gmd:title	'%(logical_filename)s' (dynamic)	NC_STRING
Output file name without extension.		
objectType	'gmd:CI_Citation' (static)	NC_STRING

10.2.3.100 Group "gmd:date" in "gmd:sourceCitation"

Production date and time of the output file.

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep/gmi:output/gmd:sourceCitation/gmd:date

Group attributes attached to gmd:date		
Name	*Value*	*Type*
gmd:date		NC_STRING
Production date and time of the output file. Note that the definition in the XML schema appears to allow the use of a “CI_DateTime” instead of a “CI_Date”.		
objectType	‘gmd:CI_DateTime’ (static)	NC_STRING

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

Meaning of the reference date for the cited resource.

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmi:output/gmd:sourceCitation/gmd:date/gmd:dateType

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

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

Identification of the output product.

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmi:output/gmd:sourceCitation/gmd:identifier

Group attributes attached to gmd:identifier		
Name	*Value*	*Type*
gmd:code	‘%(shortname)s’ (dynamic)	NC_STRING
The product short name, a copy of the ‘ProductShortName’ attribute in ‘/METADATA/GRANULE_DESCRIPTION’.		
objectType	‘gmd:MD_Identifier’ (static)	NC_STRING

10.2.3.103 Group “gmi:processedLevel” in “gmi:output”

Process level of the output file.

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmi:output/gmi:processedLevel

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

10.2.3.104 Group “gmi:processingInformation” in “gmd:processStep”

Description of the processor in more detail.

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmi:processingInformation

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

10.2.3.105 Group "gmi:identifier" in "gmi:processingInformation"

Identification of the processor.

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmi:processingInformation/gmi:identifier

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

10.2.3.106 Group "gmi:softwareReference" in "gmi:processingInformation"

Reference to document describing processing software.

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmi:processingInformation/gmi:softwareReference

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

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

Release date (compile date) of the processor.

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmi:processingInformation/gmi:softwareReference/gmd:date

Group attributes attached to gmd:date		
Name	*Value*	*Type*
gmd:date		NC_STRING
Release date of the processor expressed as an ISO 8601 date string [RD40].		
objectType	'gmd:CI_DateTime' (static)	NC_STRING

10.2.3.108 Group "gmd:dateType" in "gmd:date"

Confirm that this is the release date of the processor.

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmi:processingInformation/gmi:softwareReference/gmd:date/gmd:dateType

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

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

Reference to the ATBD of the product.

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmi:processingInformation/gmi:documentation#1

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

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

Release date of the ATBD.

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmi:processingInformation/gmi:documentation#1/gmd:date

Group attributes attached to gmd:date		
Name	*Value*	*Type*
gmd:date	'%(date_atbd)s' (dynamic)	NC_STRING
Release date of the ATBD expressed as an ISO 8601 date string [RD40].		
objectType	'gmd:CI_Date' (static)	NC_STRING

10.2.3.111 Group "gmd:dateType" in "gmd:date"

Confirm that this is the date of publication.

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmi:processingInformation/gmi:documentation#1/gmd:date/gmd:dateType

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

10.2.3.112 Group "gmi:documentation#2" in "gmi:processingInformation"

Reference to the PUM of the product.

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmi:processingInformation/gmi:documentation#2

Group attributes attached to gmi:documentation#2		
Name	*Value*	*Type*
objectType	'gmd:CI_Citation' (static)	NC_STRING
gmd:title	'%(title_pum)s' (dynamic)	NC_STRING
The filename of the current release of the PUM of the current product.		

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

Release date of the PUM.

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmi:processingInformation/gmi:documentation#2/gmd:date

Group attributes attached to gmd:date		
Name	*Value*	*Type*
gmd:date	'%(date_pum)s' (dynamic)	NC_STRING
Release date of the PUM expressed as an ISO 8601 date string [RD40].		
objectType	'gmd:CI_Date' (static)	NC_STRING

10.2.3.114 Group "gmd:dateType" in "gmd:date"

Confirm that this is the date of publication.

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmi:processingInformation/gmi:documentation#2/gmd:date/gmd:dateType

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

10.2.3.115 Group "gmi:report" in "gmd:processStep"

Short report of what occurred during the process step.

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmi:report

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

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

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

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmd:source#1

Group attributes attached to gmd:source#1		
Name	*Value*	*Type*
objectType	'gmi:LE_Source' (static)	NC_STRING
gmd:description		NC_STRING

Description of the input data, including L1B, L2, dynamic auxiliary input data and semi-static auxiliary input data. Base strings are “TROPOMI L1B %s radiance product”, “TROPOMI L1B %s irradiance product”, “TROPOMI L2 %s product”, “Auxiliary ECMWF %s Meteorological forecast data”, “Processor %s configuration file”, “Auxiliary %s reference data”, “Auxiliary %s algorithm lookup table”, “Auxiliary CTM %s model input data”, “Auxiliary snow and ice input data” and “Auxiliary NPP/VIIRS cloud screening input data”. The %s to be replaced with specific descriptors.

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

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmd:source#1/gmi:processedLevel

Group attributes attached to gmi:processedLevel		
Name	*Value*	*Type*
gmd:code	*Empty!*	NC_STRING
objectType	‘gmd:MD_Identifier’ (static)	NC_STRING

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

Reference to the actual filename of the input data.

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmd:source#1/gmd:sourceCitation

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

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

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmd:source#1/gmd:sourceCitation/gmd:date

Group attributes attached to gmd:date		
Name	*Value*	*Type*
gmd:date		NC_STRING
Production date and time of the input file(s) in this group expressed as an ISO 8601 date-time string [RD40]. Note that the definition in the XML schema appears to allow the use of a “CI_DateTime” instead of a “CI_Date”.		
objectType	‘gmd:CI_Date’ (static)	NC_STRING

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

Meaning of the reference date for the cited resource.

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmd:source#1/gmd:sourceCitation/gmd:date/gmd:dateType

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

10.2.3.121 Group "gmd:title" in "gmd:sourceCitation"

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmd:source#1/gmd:sourceCitation/gmd:title

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

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

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

Attributes in NO2/METADATA/ESA_METADATA/earth_explorer_header/variable_header/gmd:lineage/gmd:processStep gmd:source#1/gmd:sourceCitation/gmd:alternateTitle#1

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

11 Units

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

Making the UDUnits package [ER10] a requirement, and thereby forcing all units to be compliant with formal SI units[3] is a good thing for consistency and will help avoid confusion in the long run. In the short term it will require adjustments within the earth observation community, as many of the units that the user community is accustomed to are not SI, and are therefore not available within the UDUnits package. The MAG has decided that Sentinel 5 precursor will represent all level 2 output in SI units. In particular, all column amounts will be given in $\mathrm{mol\,m^{-2}}$.

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

multiplication_factor_to_convert_to_molecules_percm2 Multiply the contents of the variable with this scale factor ($6.02214 \times 10^{+19}$) to obtain columns in $\mathrm{molecules\,cm^{-2}}$

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

multiplication_factor_to_convert_to_photons_persecond_pernm_percm2_persr Multiply the contents of the variable with this scale factor ($6.02214 \times 10^{+19}$) to obtain a radiance in photons $\mathrm{s^{-1}\,nm^{-1}\,cm^{-2}\,sr^{-1}}$.

12 Quality Assurance parameters

The Level 2 output will include automated quality assurance parameters. These include 'event counters' for each of the flags defined in the processing quality flags, see tables 15 and 16. 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 8.

[3] And some deeply entrenched non-SI units such as DU.

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

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

$$f_{\text{pdf}}(x_j) = \frac{1}{N}\sum_{i=0}^{N}\frac{\cos\left(\delta_{\text{geo},i}\right)}{\sigma_i\sqrt{2\pi}}\exp\left[\frac{(x_j - x_i)^2}{2\sigma_i^2}\right] \tag{12}$$

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

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

Table 8: 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.
number_of_reflectance_range_error_occurrences	Number of ground pixels where "any of the reflectances is out of bounds ($R < 0$ or $R > R_{\text{max}}$)" occurred.
number_of_ler_range_error_occurrences	Number of ground pixels where "lambert-equivalent reflectivity out of range error" occurred.
number_of_snr_range_error_occurrences	Number of ground pixels where "too low signal to noise to perform retrieval" occurred.
number_of_sza_range_error_occurrences	Number of ground pixels where "solar zenith angle out of range, maximum value from configuration" occurred.
number_of_vza_range_error_occurrences	Number of ground pixels where "viewing zenith angle out of range, maximum value from configuration" occurred.
number_of_lut_range_error_occurrences	Number of ground pixels where "extrapolation in lookup table (airmass factor, cloud radiances)" occurred.
number_of_ozone_range_error_occurrences	Number of ground pixels where "ozone column significantly out of range of profile climatology" occurred.

Table 8: Common quality assurance parameters. (continued).

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” occurred.
number_of_cloud_filter_convergence_error_occurrences	Number of ground pixels where “the cloud filter did not converge” occurred.
number_of_max_iteration_convergence_error_occurrences	Number of ground pixels where “no convergence because retrieval exceeds maximum number of iterations. Maximum value from configuration” occurred.
number_of_aot_lower_boundary_convergence_error_occurrences	Number of ground pixels where “no convergence because the aerosol optical thickness crosses lower boundary twice in succession” occurred.
number_of_other_boundary_convergence_error_occurrences	Number of ground pixels where “no convergence because a state vector element crosses boundary twice in succession. Note that a separate failure flag is defined for non-convergence due to crossing of lower AOT boundary” occurred.
number_of_geolocation_error_occurrences	Number of ground pixels where “geolocation out of range” occurred.

Table 8: Common quality assurance parameters. (continued).

Name	Description
number_of_ch4_noscat_zero_error_occurrences	Number of ground pixels where "the CH_4 column retrieved by the non-scattering CO algorithm from the weak band or strong band is 0" occurred.
number_of_h2o_noscat_zero_error_occurrences	Number of ground pixels where "the H_2O column retrieved by the non-scattering CO algorithm from the weak band or strong band is 0" occurred.
number_of_max_optical_thickness_error_occurrences	Number of ground pixels where "maximum optical thickness exceeded during iterations" occurred.
number_of_aerosol_boundary_error_occurrences	Number of ground pixels where "boundary hit of aerosol parameters at last iteration" occurred.
number_of_boundary_hit_error_occurrences	Number of ground pixels where "fatal boundary hit during iterations" occurred.
number_of_chi2_error_occurrences	Number of ground pixels where "χ^2 is not-a-number or larger than 10^{10}" occurred.
number_of_svd_error_occurrences	Number of ground pixels where "singular value decomposition failure" occurred.
number_of_dfs_error_occurrences	Number of ground pixels where "degree of freedom is not-a-number" occurred.
number_of_radiative_transfer_error_occurrences	Number of ground pixels where "errors occurred during the radiative transfer computations, no processing possible" occurred.
number_of_optimal_estimation_error_occurrences	Number of ground pixels where "errors occurred during the optimal estimation, processing has been terminated" occurred.
number_of_profile_error_occurrences	Number of ground pixels where "flag that indicates if there were any errors during the computation of the ozone profile" occurred.
number_of_cloud_error_occurrences	Number of ground pixels where "no cloud data" occurred.
number_of_model_error_occurrences	Number of ground pixels where "forward model failure" occurred.
number_of_number_of_input_data_points_too_low_error_occurrences	Number of ground pixels where "not enough input ozone columns to calculate a tropospheric column" occurred.
number_of_cloud_pressure_spread_too_low_error_occurrences	Number of ground pixels where "cloud pressure variability to low to estimate a tropospheric column" occurred.
number_of_cloud_too_low_level_error_occurrences	Number of ground pixels where "clouds are too low in the atmosphere to assume sufficient shielding" occurred.
number_of_generic_range_error_occurrences	Number of ground pixels where "generic range error" occurred.
number_of_generic_exception_occurrences	Number of ground pixels where "catch all generic error" occurred.

Table 8: Common quality assurance parameters. (continued).

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

Table 8: Common quality assurance parameters. (continued).

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

Table 8: Common quality assurance parameters. (continued).

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

Table 8: Common quality assurance parameters. (continued).

Name	Description
number_of_time_range_filter_occurrences	Number of ground pixels where “time is out of the range that is to be processed” occurred.
number_of_pixel_or_scanline_index_filter_occurrences	Number of ground pixels where “not processed because pixel index does not match general selection criteria” occurred.
number_of_geographic_region_filter_occurrences	Number of ground pixels where “pixel falls outside the specified regions of interest” occurred.
number_of_input_spectrum_warning_occurrences	Number of ground pixels where “number of good pixels in radiance, irradiance or calculated reflectance below threshold from configuration” occurred.
number_of_wavelength_calibration_warning_occurrences	Number of ground pixels where “offset from wavelength fit is larger than limit set in configuration” occurred.
number_of_extrapolation_warning_occurrences	Number of ground pixels where “pressure or temperature outside cross section LUT range, other lookup table extrapolation” occurred.
number_of_sun_glint_warning_occurrences	Number of ground pixels where “sun glint posibility warning” occurred.
number_of_south_atlantic_anomaly_warning_occurrences	Number of ground pixels where “TROPOMI is inside the south Atlantic anomaly while taking these measurements” occurred.
number_of_sun_glint_correction_occurrences	Number of ground pixels where “A sun glint correction has been applied” occurred.
number_of_snow_ice_warning_occurrences	Number of ground pixels where “snow/ice flag is set, i.e. using scene data from the cloud support product” occurred.
number_of_cloud_warning_occurrences	Number of ground pixels where “cloud filter based on FRESCO apparent surface pressure (VIIRS not available), cloud fraction above threshold or cloud pressure adjusted to force cloud above surface” occurred.
number_of_AAI_warning_occurrences	Number of ground pixels where “possible aerosol contamination as indicated by the AAI” occurred.
number_of_pixel_level_input_data_missing_occurrences	Number of ground pixels where “dynamic auxiliary input data (e.g.. cloud) is missing for this ground pixel. A fallback option is used” occurred.
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.
number_of_low_cloud_fraction_warning_occurrences	Number of ground pixels where “low cloud fraction, therefore no cloud pressure retrieved” occurred.

Table 8: Common quality assurance parameters. (continued).

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.
number_of_signal_to_noise_ratio_warning_occurrences	Number of ground pixels where "signal to noise ratio in SWIR and/or NIR band below threshold from configuration" occurred.
number_of_deconvolution_warning_occurrences	Number of ground pixels where "failed deconvolution irradiance spectrum (not pixel-specific, but row-specific)" occurred.
number_of_so2_volcanic_origin_likely_warning_occurrences	Number of ground pixels where "warning for SO_2 BL product, UTLS products: volcanic origin except for heavily polluted sites" occurred.
number_of_so2_volcanic_origin_certain_warning_occurrences	Number of ground pixels where "warning for SO_2 BL product, UTLS products: volcanic origin certain" occurred.
number_of_interpolation_warning_occurrences	Number of ground pixels where "warning for interpolation on partially missing data. In this case the valid available data is used, potentially leading to a bias" occurred.
number_of_saturation_warning_occurrences	Number of ground pixels where "saturation occurred spectrum, possibly causing biases in the retrieval" occurred.
number_of_high_sza_warning_occurrences	Number of ground pixels where "warning for high solar zenith angle. In this case, the processing can be performed with less final quality" occurred.
number_of_cloud_retrieval_warning_occurrences	Number of ground pixels where "warning occurring when the retrieval diagnostic indicates a degraded quality of the cloud retrieval" occurred.
number_of_cloud_inhomogeneity_warning_occurrences	Number of ground pixels where "the cloud coregistration inhomogeneity parameter is above a given threshold" occurred.

13 Generic metadata and attributes

Metadata gives information about the satellite, algorithms, configuration as well as other parameters useful for the interpretation of the processed data and tracing the production process of the level 2 files. The Sentinel 5 precursor product files, both for level 1B and level 2 contain a rich amount of metadata, both at the variable level and at the granule level. The full description of the metadata in the files for the Nitrogendioxide product is given in the file format description, in section 10.2. Here we provide some background on what can be found in which location. The abbreviations listed in table 9 are used in the following part of this document to better identify the nature of the attributes.

Table 9: The abbreviations used in metadata descriptions to indicate the origin of a specific attribute, and the abbreviations used to indicate the type of an attribute.

Abbreviation	Description
NUG	netCDF-4 Users Guide [ER7]
CF	Climate and Forecast metadata conventions [ER5], which includes the COARDS [ER11] conventions
ISO	ISO standards 19115, 19115-2 and 19157 [RD34, RD35, RD36]
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 [RD33]
S5P	Internal use – mostly for retrieval settings, possibly as an extension to ISO 19115 [RD34]
S	Attribute is a string attribute
P	Attribute has the data-type of the variable with which it is associated (‘parent’ data type).
I	Attribute is an integer value
F	Attribute is a floating point value (either 32-bit or 64-bit).
T	Attribute is a CCSDS-ASCII time representation (“`UTC=`” + ISO 8601 [RD40])

We follow several metadata conventions in the S5P level 2 files, as can be seen in table 9. These include ISO 19115-2 [RD35], OGC 10.157r3 [RD37], the ESA earth observation header [RD33] 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, RD39]. The short version is that the attributes in the data file can be exported as NcML [RD49], which can be translated into the desired output using an XSLT transformation. Support attributes are added to the data file to facilitate this. Creating such a transformation script has been declared out of scope for the level 1B and level 2 processor CFI providers.

13.1 The Climate and Forecast conventions

The CF metadata conventions [ER5] provide guidelines for attributes for variables so that the link between data and its geolocation and time of observation can be made automatically. Applying the CF-metadata conventions to the output products already limits the number of choices we will have to make. Units and other attributes are

already defined and some structure is provided by the CF-conventions, for instance in linking data fields with geolocation.

13.2 NetCDF User Guide Conventions

A full description of the conventions might be found in the NetCDF user manual [ER7]]. In general, names starting with underscore character are always reserved for use by the NetCDF library. NUG conventions are a subset of the CF-conventions.

13.3 Global attributes

Global attributes that are present at the `root` level of a S5p L2 product as described in section 10. These are mostly `string` attributes.

13.4 ESA earth observation header

The ESA earth observations file format guidelines and tailoring for S5P [RD33, RD25] specify the creation of a header file with a basic description of the contents of an output file. This header file consists of a fixed part and a customizable variable part. The variable part contains the lineage of the product is repeated, see section 10.2.3.44 for a description the the attributes contained in this part of the header. The fixed header is described in tables 10 – 12.

Table 10: Metadata in the fixed header required by the ESA earth observation file format standard. The data types refer to the short list in table 9.

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__Nitrogendioxide”. It is redundant with the File Type element embedded in the File Name.
Validity_Period	Group, see table 11	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 12	Information about the ground segment facility where the product was generated.

Table 11: Fields in the Validity_Period group. The data types refer to the short list in table 9.

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

Table 12: Fields in the source group. The data types refer to the short list in table 9.

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

Table 12: Fields in the source group (continued).

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

13.5 Inspire directive

INSPIRE is based on the infrastructures for spatial information established and operated by the 27 Member States of the European Union. The INSPIRE directive came into force on 15 May 2007 and will be developed in several stages until a complete release with due date set in 2019. The INSPIRE directive aims to create a European Union (EU) spatial data infrastructure. This will enable the sharing of environmental spatial information among public sector organizations and better facilitate public access to spatial information across Europe. The European Commission issued a Metadata Regulation [RD50] 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 [RD51] define how the Regulation can be implemented using ISO 19115. As also reported in [RD39], the conclusion of the study pointed out the following:

1. The conformance of an ISO 19115 metadata set to the ISO 19115 Core does not guarantee the conformance to INSPIRE.
2. The use of these guidelines to create INSPIRE metadata ensures that the metadata is not in conflict with ISO 19115. However, full conformance to ISO 19115 implies the provision of additional metadata elements which are not required by INSPIRE.

13.6 ISO and OGC standards

Two ISOs standards useful for the description of collection of Earth Observation products and to the description of individual EO products are ISO 19115-2 [RD35] and ISO 19156 [RD52], 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 [RD44]
2. OGC 10-025C [RD53]
3. OGC 10-157 [RD37]

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 [RD39].

13.7 Attributes

In Table 14 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 9. The NetCDF attribute `_FillValue` which represents missing or undefined data can assume the default values listed in Table 13.

Table 13: netCDF-4 type definitions and fill values. In order to avoid rounding errors, it is recommended to use the hexadecimal notation when specifying fill values for float and double types. Note that these are the netCDF-4 default fill values, there should be no need to specify these values explicitly. In some cases the fill value for float or double variables may fall within the valid range of a variable. For those cases an explicit fill value must be set, the value $-9.9692099683868690 \times 10^{36}$ (hex: `-0x1.ep+122`) is recommended for these cases.

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

Table 14: Attributes for variables used in S5p netCDF-4 files. The data types refer to the short list in table 9.

Name	Type	Std.	Description
ancillary_variables	S	CF	Identifies a variable that contains closely associated data, e.g. the measurement uncertainties of instrument data.
bounds	S	CF	Connects a boundary variable to a coordinate variable.
cell_measures	S	CF	Identifies variables that contain cell areas or volumes. This can be used to connect approximate ground pixel coverage in km^2 to data-fields.
comment	S	CF	Miscellaneous information about the data or methods used to produce it.
coordinates	S	CF	Identifies auxiliary coordinate variables, providing a connection between data and geolocation, time.
_FillValue	P	NUG	Value to represent missing or undefined data. Recommended (default) values are given in table 13.
flag_masks	P	CF	Provides a list of bit fields expressing Boolean or enumerated flags.
flag_meanings	S	CF	Use in conjunction with flag_values to provide descriptive words or phrases for each flag value.
flag_values	P	CF	Provides a list of the flag values. Use in conjunction with flag_meanings.
formula	S	CF	Formula to calculate the values for an adaptive grid, for instance for a dimensionless vertical coordinate. Example: "`hyam hybm (mlev=hyam+hybm*aps)`".
formula_terms	S	CF	Identifies variables that correspond to the terms in a formula, for instance for a dimensionless vertical coordinate. Example: "`ap: hyam b: hybm ps: aps`"
institution	S	CF	Specifies where the original data was produced.
long_name	S	CF	A descriptive name that indicates a variable's content. This name is not standardized.
positive	S	CF	Direction of increasing vertical coordinate value ('up' for z in m or 'down' for p in hPa).
references	S	CF	References that describe the data or methods used to produce it.
source	S	CF	Method of production of the original data.

Table 14: Attributes for variables used in S5p netCDF-4 files (continued).

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

A Flag descriptions

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

Table 15: Processing quality flags, errors, processing failures and filter conditions for S5P Level 2. Warnings are listed in table 16. The value in the first column is the result of a bitwise 'and' of 255 (0xFF) and the value in the "processing_quality_flags" variable.

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

Table 15: Processing quality flags, errors, processing failures and filter conditions for S5P Level 2 (continued).

#	Short name	Description	Algorithm
21	max_iteration_convergence_error	No convergence because retrieval exceeds maximum number of iterations. Maximum value from configuration.	ALH
22	aot_lower_boundary_convergence_error	No convergence because the aerosol optical thickness crosses lower boundary twice in succession.	ALH
23	other_boundary_convergence_error	No convergence because a state vector element crosses boundary twice in succession. Note that a separate failure flag is defined for non-convergence due to crossing of lower AOT boundary.	ALH
25	ch4_noscat_zero_error	The CH_4 column retrieved by the non-scattering CO algorithm from the weak band or strong band is 0.	CH_4
26	h2o_noscat_zero_error	The H_2O column retrieved by the non-scattering CO algorithm from the weak band or strong band is 0.	CH_4
27	max_optical_thickness_error	Maximum optical thickness exceeded during iterations.	CH_4
28	aerosol_boundary_error	Boundary hit of aerosol parameters at last iteration.	CH_4
29	boundary_hit_error	Fatal boundary hit during iterations.	CH_4
30	chi2_error	χ^2 is not-a-number or larger than 10^{10}.	CH_4
31	svd_error	Singular value decomposition failure.	CH_4
32	dfs_error	Degree of freedom is not-a-number.	CH_4
33	radiative_transfer_error	Errors occurred during the radiative transfer computations, no processing possible.	O_3 profile
34	optimal_estimation_error	Errors occurred during the optimal estimation, processing has been terminated.	O_3 profile
35	profile_error	Flag that indicates if there were any errors during the computation of the ozone profile.	O_3 profile
36	cloud_error	No cloud data.	Cloud
37	model_error	Forward model failure.	Cloud, Total O_3 column
38	number_of_input_data_points_too_low_error	Not enough input ozone columns to calculate a tropospheric column.	Tropospheric O_3 column
39	cloud_pressure_spread_too_low_error	Cloud pressure variability to low to estimate a tropospheric column.	Tropospheric O_3 column
40	cloud_too_low_level_error	Clouds are too low in the atmosphere to assume sufficient shielding.	Tropospheric O_3 column
41	generic_range_error	Generic range error.	All
42	generic_exception	Catch all generic error.	All
43	input_spectrum_alignment_error	Input radiance and irradiance spectra are not aligned correctly.	All
44	abort_error	Not processed because processor aborted prematurely (time out or user abort)	All

Table 15: Processing quality flags, errors, processing failures and filter conditions for S5P Level 2 (continued).

#	Short name	Description	Algorithm
45	wrong_input_type_error	Wrong input type error, mismatch between expectation and received data.	All
46	wavelength_calibration_error	An error occurred in the wavelength calibration of this pixel	All
47	coregistration_error	No colocated pixels found in a supporting band	All
51	signal_to_noise_ratio_error	The signal to noise ratio for this spectrum is too low for processing	All
52	configuration_error	Error while parsing the configuration	All
53	key_error	Key does not exist	All
54	saturation_error	Saturation in input spectrum	All
64	solar_eclipse_filter	Solar eclipse.	All
65	cloud_filter	The cloud filter triggered causing the pixel to be skipped.	CO, ALH, CH_4
66	altitude_consistency_filter	Too large difference between ECMWF altitude and DEM altitude value.	CO, CH_4
67	altitude_roughness_filter	Too large standard deviation of altitude in DEM.	CO, ALH, CH_4
68	sun_glint_filter	For pixels over water, viewing direction inside sun glint region. Definition of sun glint angle and threshold value from ATBD.	ALH
69	mixed_surface_type_filter	Pixel contains land and water areas (e.g. coastal pixel).	ALH
70	snow_ice_filter	Pixel contains snow/ice: Snow/ice flag according to dynamic input OR climatological surface albedo at VIS wavelength is larger than 0.5.	ALH
71	aai_filter	AAI smaller than 2.0.	ALH
72	cloud_fraction_fresco_filter	Pixel contains clouds: The FRESCO effective cloud fraction is larger than threshold. Threshold value from ATBD.	ALH
73	aai_scene_albedo_filter	Pixel contains clouds: The difference between scene albedo at 380 nm from AAI calculation and the climatologcal surface albedo exceeds threshold. Threshold value from ATBD. This test filters out clouds.	ALH
74	small_pixel_radiance_std_filter	Pixel contains clouds: Standard deviation of radiances in small-pixel column exceeds threshold. Threshold value from ATBD.	ALH, CH_4
75	cloud_fraction_viirs_filter	Pixel contains clouds: The cloud fraction from VIIRS / NPP exceeds theshold. Threshold value from ATBD.	ALH
76	cirrus_reflectance_viirs_filter	Pixel contains clouds: Cirrus reflectance from VIIRS / NPP exceeds threshold. Threshold value from ATBD.	ALH
77	cf_viirs_swir_ifov_filter	Fraction of cloudy VIIRS pixels wihtin S5P SWIR ground pixel exceeds a priori threshold from configuration.	CH_4

Table 15: Processing quality flags, errors, processing failures and filter conditions for S5P Level 2 (continued).

#	Short name	Description	Algorithm
78	cf_viirs_swir_ofova_filter	Fraction of cloudy VIIRS pixels wihtin S5P SWIR OFOVa exceeds a priori threshold from configuration.	CH_4
79	cf_viirs_swir_ofovb_filter	Fraction of cloudy VIIRS pixels wihtin S5P SWIR OFOVb exceeds a priori threshold from configuration.	CH_4
80	cf_viirs_swir_ofovc_filter	Fraction of cloudy VIIRS pixels wihtin S5P SWIR OFOVc exceeds a priori threshold from configuration.	CH_4
81	cf_viirs_nir_ifov_filter	Fraction of cloudy VIIRS pixels wihtin S5P NIR ground pixel exceeds a priori threshold from configuration.	CH_4
82	cf_viirs_nir_ofova_filter	Fraction of cloudy VIIRS pixels wihtin S5P NIR OFOVa exceeds a priori threshold from configuration.	CH_4
83	cf_viirs_nir_ofovb_filter	Fraction of cloudy VIIRS pixels wihtin S5P NIR OFOVb exceeds a priori threshold from configuration.	CH_4
84	cf_viirs_nir_ofovc_filter	Fraction of cloudy VIIRS pixels wihtin S5P NIR OFOVc exceeds a priori threshold from configuration.	CH_4
85	refl_cirrus_viirs_swir_filter	Average VIIRS cirrus reflectance within SWIR ground pixel exceeds a priori threshold from configuration.	CH_4
86	refl_cirrus_viirs_nir_filter	Average VIIRS cirrus reflectance within NIR ground pixel exceeds a priori threshold from configuration.	CH_4
87	diff_refl_cirrus_viirs_filter	Difference in VIIRS average cirrus reflectance between SWIR and NIR ground pixel exceeds a priori threshold from configuration.	CH_4
88	ch4_noscat_ratio_filter	The ratio between $[CH_4]_{weak}$ and $[CH_4]_{strong}$ is below or exceeds a priori thresholds from configuration.	CH_4
89	ch4_noscat_ratio_std_filter	The standard deviation of $[CH_4]_{weak}/[CH_4]_{strong}$ within the SWIR pixel and the 8 neighbouring pixels exceeds a priori threshold from configuration.	CH_4
90	h2o_noscat_ratio_filter	The ratio between $[H_2O]_{weak}$ and $[H_2O]_{strong}$ is below or exceeds a priori thresholds from configuration.	CH_4
91	h2o_noscat_ratio_std_filter	The standard deviation of $[H_2O]_{weak}/[H_2O]_{strong}$ within the SWIR pixel and the 8 neigbouring pixels exceeds a priori threshold from configuration.	CH_4
92	diff_psurf_fresco_ecmwf_filter	Difference between the FRESCO apparent surface pressure and the ECMWF surface pressure exceeds a priori threshold from configuration.	CH_4

Table 15: Processing quality flags, errors, processing failures and filter conditions for S5P Level 2 (continued).

#	Short name	Description	Algorithm
93	psurf_fresco_stdv_filter	The standard deviation of the FRESCO apparent surface pressure in the NIR pixel and the 8 surrounding pixels exceeds a priori threshold from configuration.	CH_4
94	ocean_filter	The ground pixel is over ocean (and ocean glint retrievals are not switched on).	CH_4
95	time_range_filter	Time is out of the range that is to be processed.	All
96	pixel_or_scanline_index_filter	Not processed because pixel index does not match general selection criteria.	All
97	geographic_region_filter	Pixel falls outside the specified regions of interest.	All

Table 16: Processing quality flags, warnings for S5P Level 2. Errors, processing failures and filter conditions are listed in table 15. 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 15 for details.	All
8	0x00000100	input_spectrum_warning	Number of good pixels in radiance, irradiance or calculated reflectance below threshold from configuration.	All
9	0x00000200	wavelength_calibration_warning	Offset from wavelength fit is larger than limit set in configuration.	Most
10	0x00000400	extrapolation_warning	Pressure or temperature outside cross section LUT range, other lookup table extrapolation.	CO, CH_4
11	0x00000800	sun_glint_warning	Sun glint posibility warning.	All
12	0x00001000	south_atlantic_anomaly_warning	TROPOMI is inside the south Atlantic anomaly while taking these measurements.	All
13	0x00002000	sun_glint_correction	A sun glint correction has been applied.	Cloud
14	0x00004000	snow_ice_warning	Snow/ice flag is set, i.e. using scene data from the cloud support product.	NO_2
15	0x00008000	cloud_warning	Cloud filter based on FRESCO apparent surface pressure (VIIRS not available), cloud fraction above threshold or cloud pressure adjusted to force cloud above surface.	CH_4, O_3 profile
16	0x00010000	AAI_warning	Possible aerosol contamination as indicated by the AAI.	O_3 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_4

Table 16: Processing quality flags, warnings for S5P Level 2 (continued).

Bit #	Mask (hex)	Short name	Description	Algorithm
19	0x00080000	low_cloud_fraction_warning	Low cloud fraction, therefore no cloud pressure retrieved.	Cloud
20	0x00100000	altitude_consistency_warning	Difference between ECMWF surface elevation and high-resolution surface elevation exceeds threshold from configuration.	CH_4
21	0x00200000	signal_to_noise_ratio_warning	Signal to noise ratio in SWIR and/or NIR band below threshold from configuration.	CH_4
22	0x00400000	deconvolution_warning	Failed deconvolution irradiance spectrum (not pixel-specific, but row-specific).	CO, CH_4
23	0x00800000	so2_volcanic_origin_likely_warning	Warning for SO_2 BL product, UTLS products: volcanic origin except for heavily polluted sites.	SO_2
24	0x01000000	so2_volcanic_origin_certain_warning	Warning for SO_2 BL product, UTLS products: volcanic origin certain.	SO_2
25	0x02000000	interpolation_warning	Warning for interpolation on partially missing data. In this case the valid available data is used, potentially leading to a bias.	All
26	0x04000000	saturation_warning	Saturation occurred spectrum, possibly causing biases in the retrieval	All
27	0x08000000	high_sza_warning	Warning for high solar zenith angle. In this case, the processing can be performed with less final quality.	All
28	0x10000000	cloud_retrieval_warning	Warning occurring when the retrieval diagnostic indicates a degraded quality of the cloud retrieval.	Cloud
29	0x20000000	cloud_inhomogeneity_warning	The cloud coregistration inhomogeneity parameter is above a given threshold	Cloud

Table 17: Surface classification for S5P Level 2. This is a combined land/water mask and surface classification data field. For land the “Global Land Cover Characteristics Data Base Version 2.0” is used [ER8], specifically the “USGS Land Use/Land Cover System (Modified Level 2)” classification. Over water the classification from the NASA SDP toolkit [ER9], which is based on [RD43].

Bit #	Mask (hex)	Short name	Description
0	0x03	Land	The pixel is over land, for more than 50 %
1	0x03	Water	The pixel is over water, for more than 50 %
2	0x03	some_water	Pixel contains water (however small the fraction), i.e. at least one of the 15×15 arcsecond subpixels in the SDP dataset is classified as water
3	0x03	coastline	Pixel is water, but contains land (coastline)
0	0x04	mixed_surface	Pixel has a mixed surface type. Classification is result of highest bin, not overwhelming majority, i.e. type covers less than 50 % of pixel surface

Table 17: Surface classification for S5P Level 2 (continued).

Bit #	Mask (hex)	Short name	Description
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
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

Table 17: Surface classification for S5P Level 2 (continued).

Bit #	Mask (hex)	Short name	Description
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