S5P Mission Performance Centre Nitrogen Dioxide [L2__NO2___] Readme

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[1] The S5PVT AO project summaries can be found at https://earth.esa.int/eogateway/news/announcement-of-opportunity-for-s5pvt

CHANGE LOG

Reason for change	Issue	Revision	Date
• Table 2: addition of version 01.04.00 • Added/updated `qa_value` filter for variables: – `nitrogendioxide_stratospheric_column` – `nitrogendioxide_total_column` – `nitrogendioxide_summed_total_column` • Section 5 (Algorithm Change Record) updated with version 01.04.00 information: text related to the improved data quality for anthropogenic emitted NO_2 measurements	1	6	26/11/2020
• Table 2: adapting to version 02.02.00 of the processor • Section 4.1 & section 0: some text moved from section 4.1 (Known Data Quality Issues) to section 0: (Solved Data Quality Issues) • Section 5: Algorithm change record updated • Section 6.1: added format changes related to version 02.02.00	2	0	05/07/2021
• Table 2: addition of version 02.03.01 • Section 4.1: last two paragraphs added • Section 4.2: last three paragraphs added • Section 6.1: format changes added, for version 02.03.01	2	1	17/11/2021
• Table 2: addition of version 02.04.00 • Section 4.1 & section 4.2: some text moved from section 4.1 (Known Data Quality Issues) to section 4.2: (Solved Data Quality Issues) • Section 5: Algorithm change record updated • Section 6.1: format changes added, for version 02.04.00	2	2	20/07/2022
• Table 2: addition of reprocessed dataset with version 02.04.00 • Section 7: updates with information related to gaps on the reprocessed dataset • Section 5: text related to Reprocessed (RPRO) dataset	2	3	27/02/2023
• Table 2: addition of version 02.05.00 • Section 5: addition of text related to version 02.05.00 • Section 6.1: added minor format changes related to version 02.05.00	2	4	16/03/2023

1 Summary

This is the Product Readme File (PRF) of the Copernicus Sentinel 5 Precursor Tropospheric Monitoring Instrument (S5P/TROPOMI) nitrogen dioxide (NO_2) Level 2 data product and is applicable for the Near Real Time (NRTI), Offline (OFFL) and Reprocessed (RPRO) timeliness products.

Product Identifier: **L2__NO2___**

Example filename:

S5P_NRTI_L2__NO2____20201007T202447_20201007T220617_15471_01_020200_20210515T213556.nc
S5P_OFFL_L2__NO2____20201007T202447_20201007T220617_15471_01_020200_20210515T213556.nc
S5P_RPRO_L2__NO2____20180515T173449_20180515T191619_03041_03_020400_20221129T133010.nc

The OFFL and RPRO data product has the following DOI: **http://doi.org/10.5270/S5P-9bnp8q8**

The Readme file describes the current processing baseline, product and quality limitations, and product availability status. More information on this data product is available from the Sentinel product webpage:

https://sentinels.copernicus.eu/web/sentinel/technical-guides/sentinel-5p/products-algorithms,

and from the TROPOMI product webpage http://www.tropomi.eu/data-products.

The data file contains the `nitrogendioxide_tropospheric_column` which gives the total atmospheric NO_2 column between the surface and the top of the troposphere. The respective error estimate originating from the spectral fit and other retrieval aspects is given in the data field `nitrogendioxide_tropospheric_column_precision`. As a user guideline for the data quality, a `qa_value` is provided with the data. In order to avoid misinterpretation of the data quality, it is recommended at the current stage to only use those pixels with a `qa_value` above 0.75 (or above 0.5 in case cloud covered scenes are also of interest).

Note that the NO_2 data product may be used in different ways, and depending on the application, different data fields in the file are relevant. For details on NO_2 data usage, we refer to the product user manual [RD03]. The averaging kernels are provided in the data product file and should be used, e.g., for comparisons with models or profile measurements. Stratospheric NO_2 columns (`nitrogendioxide_stratospheric_column`) and total as well as summed NO_2 columns (`nitrogendioxide_total_column` / `nitrogendioxide_summed_total_column`) are provided. For the stratospheric column, it is recommended at the current stage to use those pixels with a `qa_value` above 0.5. For the total and summed columns, the same recommendation as for the tropospheric column applies.

Note: Starting from processor version 02.02.00, new improved Level 1b version 2.0 data products are used as input [RD05].

Independent validation by S5p Mission Performance Centre (MPC) Cal/Val experts and the Sentinel-5 Precursor Validation Team (S5PVT) concludes that versions 02.02.00 and 02.03.01 of the NRTI / OFFL NO_2 data are compliant with the requirements as defined in the **S5P Calibration and Validation Plan** [RD01], see Table 1. The version 2 products show clear increases of the tropospheric columns and decreases of the biases. Version 02.04.00 makes use of a Directional Lambertian Equivalent Reflectivity climatology derived from TROPOMI observations which replaces the older OMI and GOME-2 datasets. First verification results indicate major changes (mainly increases) over forest areas (South America, Africa) and smaller (more neutral) average changes over Europe, US and East China.

Up to date validation results are available in the Routine Operations Consolidated Validation Reports (ROCVR) that are accessible through the MPC Validation Data Analysis Facility (VDAF) website at http://mpc-vdaf.tropomi.eu. The ROCVR reports are issued quarterly. Reports released after September 2021 include validation results based on processor version 02.xx.xx, while previous ROCVR reports cover validation results only for versions 01.02.xx up to 01.04.00.

Parameter	Data product	Vertical Resolution	Bias	Random
NO_2	Stratospheric NO_2	Stratospheric column	< 10%	0.5×10^{15} molec/cm^2
NO_2	Tropospheric NO_2	Tropospheric column	25-50%	0.7×10^{15} molec/cm^2

Table 1: NO_2 data product requirement extracted from the S5p Calibration and Validation Plan [RD01].

2 Processing baseline description

Table 2 contains the history of the NO_2 processor versions. Note that the processor version for NO_2 is changing when there is a change to any of the products belonging to the NL-L2 processor suite (NO2, CO, CH4, AI, ALH, O3 PR) even if the change is not affecting the NO_2 product.

Processor Version	In operation from	In operation until	Relevant improvements
02.05.00	NRTI: orbit 28078, 2023-03-15 OFFL: orbit 28031, 2023-03-12	Current version Current version	– Small OFFL bug fix for `qa_value`, only affecting snow/ice covered pixels (see section 5)
02.04.00	NRTI: orbit 24697, 2022-07-20 OFFL: orbit 24655, 2022-07-17 RPRO: orbit 2818, 2018-04-30	Orbit 28074, 2023-03-15 Orbit 28030, 2023-03-12 Orbit 24779, 2022-07-25	– This version makes use of a Directional Lambertian Equivalent Reflectivity (DLER) climatology derived from TROPOMI observations ([RD02]) which replaces the older OMI and GOME-2 datasets used in versions 1.0.2 – 2.3.1. **Note 1**: It is recommended to use the RPRO products in the orbit range 24655 - 24779, period for which also OFFL products are available. This, in order to avoid products with possible instabilities, because generated during the first days of the operational switch to version 2.4.0 **Note 2**: Starting from processor version 2.4.0, new improved Level 1b version 2.1 data products are used as input [RD05].
02.03.01	NRTI: orbit 21223, 2021-11-17 OFFL: orbit 21188, 2021-11-14	Orbit 24697, 2022-07-20 Orbit 24654, 2022-07-17	– Few bugs fixed (see section 4.2) – Minor format changes (see section 6.1)
02.02.00	NRTI: orbit 19308, 2021-07-05 OFFL: orbit 19258, 2021-07-01	Orbit 21222, 2021-11-17 Orbit 21187, 2021-11-14	– New O2-O2 cloud algorithm integrated (this is the OMI cloud algorithm using the O_2–O_2 collision induced absorption around 477 nm). These cloud parameters are retrieved and stored in the output NO2 product, but not used in the conversion from NO2 slant column to vertical column (AMF calculations). This is foreseen for future versions. – The regridded FRESCO cloud parameters are written to the NO_2 product as well. – In the NO_2 window the surface albedo is now adjusted to avoid negative cloud fractions while maintaining radiance closure. **This leads to a significant increase of tropospheric NO2 for cloud-free scenes** on top of the increase for small cloud cover pixels in version 01.04.00 related to the FRESCO cloud retrieval upgrade**.** Similarly, for fully clouded scenes with bright clouds, the cloud albedo is adjusted, rather than allowing over-unity cloud fraction. – Cloud parameters used for the AMF calculation (for converting NO_2 slant columns to NO_2 vertical columns): for every ground pixel, the actual parameters used are written to the 'old' cloud variables. In this version, version 2.2, the cloud parameters are a copy of the FRESCO parameters. In the future, there will be rules to use O2-O2 or FRESCO cloud parameters depending on under which scene conditions they work best.

			– Implementation of a 'spike removal' algorithm, with a high positive impact on pixels that are not flagged for saturation or blooming in the L1b product, but nevertheless influenced, and on pixels over the South Atlantic Anomaly. – Correct the unit of the ghost column in the NRTI product. – OFFL only: metadata fix (in Chemistry Transport Model TM5 loop). **Note**: Starting from processor version 2.2.0, new improved Level 1b version 2.0 data products are used as input [RD05].
01.04.00	NRTI: orbit 16259, 2020-12-02 OFFL: orbit 16213, 2020-11-29	Orbit 19306, 2021-07-05 Orbit 19257, 2021-07-01	– The FRESCO-S cloud retrieval was updated (this is an auxiliary input for the NO_2 processing), resulting in an overall reduction of the cloud pressure, and a **substantial increase of NO_2** in the retrievals in polluted regions. – Users should be careful when performing trend studies using previous versions and version 01.04.xx (see section 5). A full mission reprocessing will be performed to harmonize the dataset.
01.03.02	NRTI: orbit 8906, 2019-07-03 OFFL: orbit 8815, 2019-06-26	Orbit 16256, 2020-12-02 Orbit 16212, 2020-11-29	– No changes with respect to previous version
01.03.01	NRTI: orbit 8000, 2019-04-30 OFFL: orbit 7907, 2019-04-23	Orbit 8906, 2019-07-03 Orbit 8814, 2019-06-26	– No changes with respect to previous version
01.03.00	NRTI: orbit 07519, 2019-03-27 OFFL: orbit 7425, 2019-03-20	Orbit 7906, 2019-04-23 Orbit 7999, 2019-04-30	– The FRESCO-S cloud retrieval has been updated (see section 5) – Definition of `qa_value` improved (see section 5) – New variables added (see section 6.1)
01.02.02	NRTI: orbit 5931, 2018-12-05 OFFL: orbit 5833, 2018-11-28 RPRO: orbit 2818, 2018-04-30	Orbit 7518, 2019-03-27 Orbit 7424, 2019-03-20 Orbit 5235, 2018-10-17	– No changes with respect to previous version
01.02.00	NRTI: orbit 5336, 2018-10-24 OFFL: orbit 5236, 2018-10-17	Orbit 5929, 2018-12-05 Orbit 5832, 2018-11-28	– Implementation of a "destriping" algorithm to remove across-track biases between the individual viewing angles (see section 5) – Improvement of the retrieval for high Solar Zenith Angles (SZA) and polar regions (see section 5) – Better algorithm for the computation of the thermal tropopause level resulting in a more realistic distribution of tropopause pressures (see section 5) – New variable added (see section 6.1) – Definition of `qa_value` improved for good quality retrievals over snow-ice (see section 5)
01.01.00	NRTI: orbit 3947, 2018-07-18 OFFL: orbit 3848, 2018-07-11	Orbit 5333, 2018-10-24 Orbit 5235, 2018-10-17	– Update of surface albedo database
01.00.02	NRTI: orbit 3745, 2018-07-04 OFFL: orbit 3661, 2018-06-28	Orbit 3946, 2018-07-18 Orbit 3847, 2018-07-11	– Initial operational version

Table 2: History of NO_2 processor versions. In orange, the data versions that are no longer available to the users on the Pre-operations hub.

3 Product Quality

3.1 Recommendations for data usage

The quality of the individual observations depends on many factors, including cloud cover, surface albedo, presence of snow-ice, saturation, geometry etc. These aspects are taken into account in the definition of the "quality assurance value" (`qa_value`), available for each individual observation, which provides the users of the data with an easy filter to remove less accurate observations. The `qa_value` is a continuous variable, ranging from 0 (error) to 1 (all is well). The main flag for data usage is as follows:

For the variables `nitrogendioxide_tropospheric_column`, `nitrogendioxide_total_column`, `nitrogendioxide_summed_total_column`:

- `qa_value` > 0.75

  This is the recommended pixel filter. It removes cloud-covered scenes (cloud radiance fraction > 0.5), partially snow/ice covered scenes, errors, and problematic retrievals.

- `qa_value` > 0.50

  Compared to the stricter filter, 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 filter may be useful for assimilation and model comparison studies.

For variable `nitrogendioxide_stratospheric_column`:

- `qa_value` > 0.50

For further details, data users are encouraged to read the Product User Manual (PUM) and Algorithm Theoretical Basis Document (ATBD) associated with this data product, available on https://sentinels.copernicus.eu/web/sentinel/technical-guides/sentinel-5p/products-algorithms.

3.2 Validation results

3.2.1 Status of product validation

Independent preliminary validation by S5p MPC Cal/Val experts and the S5PVT concludes that NRTI / OFFL NO_2 data is in overall agreement with (i) reference measurements collected from global ground-based networks, (ii) the corresponding satellite data products from OMI, and (iii) is compliant with the requirements as defined in S5p Calibration and Validation Plan [RD01], see Table 1.

The upgrade to version 01.04.00 involved a change (see section 5) of the FRESCO-S auxiliary cloud product which resulted in an expected substantial increase of the tropospheric NO_2 column with respect to the previous version 01.03.02. The upgrade to version 02.02.00 leads to a further increase of the tropospheric NO_2 columns for polluted cloud-free scenes (see section 5). Exhaustive validation of versions 01.04.00, 02.02.00, and 02.03.01 was performed by the S5P MPC Cal/Val team since the operational switches at the beginning of December 2020 and July 2021.

Up to date validation results are available in the ROCVR reports that are accessible through the MPC VDAF website at http://mpc-vdaf.tropomi.eu. The ROCVR reports are issued quarterly and reports released after September 2021 include validation results based on processor version 02.xx.xx, while previous ROCVR reports cover validation results only for versions 01.02.xx up to 01.04.00.

4 Data Quality Remarks

4.1 Known Data Quality Issues

Currently, the following data quality issues are known, not covered by the quality flags, and should be kept in mind when using the NO_2 product.

Bands 4 and 6 spatial misalignment

The band 4 (450 pixels per scanline) footprints, used for the NO_2 DOAS retrieval, are not fully aligned with the band 6 footprints, used for cloud and scene pressure retrievals. In the worst case, the misalignment can be in the order of half a ground pixel. The misalignment requires interpolation of the cloud and scene pressure, which may introduce additional uncertainty in those parameters. These parameters are used in the NO_2 air-mass factor calculations. Note that the cloud fraction is determined in the NO_2 fitting window, avoiding the uncertainty by misalignment for this parameter.

Surface albedo climatology

The surface albedo climatology up to version 02.03.01 has a spatial resolution of 0.5°x0.5°, which is coarse compared to the much higher spatial resolution of S5p TROPOMI of 3.5 x 5.5 km. As a consequence, the albedo grid affects the NO_2 column products quality for instance at coastal areas. In version 02.04.00 the TROPOMI DLER is introduced in the NIR band (cloud retrieval) and NO_2 fit window around 440 nm. This greatly improves the spatial resolution to 0.125°x0.125°.

Conservative filtering

The pixel flagging, reflected in the `qa_value`, is defined in a conservative way. When the FRESCO cloud retrieval reports an error, in combination with the misalignment issue, one consequence is the loss of the first row (west side of the orbit), even though good NO_2 slant column retrievals are possible. Another example is the removal of observations when the albedo database shows suspiciously high values.

Variables in the NO_2 DOAS fit with an across-track low-order “wave” (since version 02.02.00)

Some variables in the NO_2 DOAS fit have an across-track low-order "wave", causing unexpected values mainly in the western part of the swath. The variables concerned are the slant columns of ozone, liquid water and O_2-O_2 in the NO_2 fit. The NO_2 slant columns are *not* significantly affected. This indicates the effect is caused by something that varies smoothly with wavelength and thus may be related to the L1b degradation correction, i.e.: to the fact that the irradiance is corrected for degradation (since the usage of L1b version 02.00.00, beginning of July 2021, see Table 2) while the radiance is not. The issue may change once the radiance degradation correction is also in place.

4.2 Solved Data Quality Issues

NRTI data gaps northern hemisphere (solved in version 01.01.00)

The NRTI data stream shows data gaps over Kazakhstan, southern part of Russia and Canada due to a miss-configuration of the processing facility. This issue is solved with the activation of processor version 01.01.00 on July 2018 (see Table 2).

Orbit numbering in NRTI and OFFL (solved in version 01.02.02)

NRTI orbit numbers are set with respect to the downlink orbit while OFFL orbit numbers are set with respect to the equator crossing time. This creates an inconsistency between the NRTI and OFFL orbit numbers. This problem was solved with the activation of processor version 01.02.02 (see Table 2), after which the orbit numbers are consistent.

Metadata/Attributes (solved in version 02.02.00)

The spatial resolution of the TROPOMI measurements is improved by bringing the along track ground pixel size from 7.0 to 5.5 km starting on 6th August 2019. Note that, after this operations change, the metadata/Attributes fields related to the spatial resolution, remain **unchanged** (hence not aligned to the improved resolution). These fields have been updated with the activation of Level 2 processors version 02.02.00.

Metadata values exchanged (solved in version 02.02.00)

The global attributes `geospatial_lon_min` and `geospatial_lon_max` values are exchanged; therefore, the user is advised to switch the values for these fields, making note that the `geospatial_lat_min` and `geospatial_lat_max` values are correct. This is an issue traceable to L1b data (version 01.00.00) and is corrected since the switch to version 02.00.00 of the Level 1B processor.

Flagging of Saturation (solved in version 02.02.00)

Some TROPOMI pixels over bright scenes are affected by saturation. Those pixels are flagged and their quality is reflected in the `qa_value`. Nevertheless, in the vicinity of saturated pixels there might be pixels also affected by saturation due to the so-called blooming effect. The pixels affected by blooming effect have been flagged since version 02.00.00 of the Level 1b processor, operational since July 2021.

Wavelength assignment (solved in version 02.02.00)

The selection of the spectral index range that comprises the wavelength window needed for the wavelength calibration and DOAS retrieval steps has been optimised. The impact is very small, limited to only about 20 rows, and only visible in the slant column uncertainty.

NRTI Ghost Column (solved in version 02.02.00)

The unit of the ghost column is corrected in the NRTI product.

OFFL metadata (solved in version 02.02.00)

Offline only: metadata fix (in Chemistry Transport Model TM5 loop).

Wavelength window (solved in version 02.03.01)

The window of the wavelength was not correct in version 02.02.00, with negligible effect on the NO_2 column data. The fit window has been corrected in version 02.03.01: [405, 465] nm.

Wavelength calibration variables not filled in correctly (solved in version 02.03.01)

The wavelength calibration variables were not filled in correctly in version 02.02.00. This has been fixed in version 02.03.01. The variables are:

```
wavelength_calibration_offset, wavelength_calibration_offset_precision,
wavelength_calibration_chi_square,
wavelength_calibration_irradiance_offset,
wavelength_calibration_irradiance_offset_precision,
wavelength_calibration_irradiance_chi_square,
polynomial_coefficients, polynomial_coefficients_precision
```

Geolocation co-added when they should not be (solved in version 02.03.01)

In version 02.02.00, the geolocation of pixels near the pole show a shift of up to 300 meters due to a co-addition activity performed by mistake. This has been corrected in version 02.03.01.

Data in `snow_ice_flag` variable for pixels with SZA > 88° (solved in version 02.04.00)

The `snow_ice_flag` value for ground pixels with SZA > 88° is incorrectly set to 255, the NISE flag for "ocean", rather than the FillValue 254 (the NISE flag for an error). Since ground pixels with SZA > 88° are not processed, these pixels do not have NO_2 column data, hence the NO_2 data quality is not affected.

4.3 Data Features

This section describes some characteristics of the data that might seem anomalous, however they are physically correct and not related to any problem.

Pixel geolocation around North Pole (feature)

The solar irradiance is measured on a daily basis over the North Pole at a reference azimuth angle to remove seasonal effects on the measurements. To this end, a yaw manoeuvre is executed when the instrument is still in radiance mode, causing possible distortion on the scanlines observed during this manoeuvre (i.e. crossing scanlines, "bow-tie" ground pixel shape instead of rectangular). This occurs at most during the last 26 seconds of radiance measurements every 15th orbit (once every 25 hours). Though this may seem anomalous, it is physically correct, and not related to any problem on the data geolocation.

4.4 Mission Operations Changes

A change in the Copernicus Sentinel 5P operations scenario, increasing the spatial resolution from 7.0 km to 5.5 km along track for all measurements, became operational starting from 6 August 2019, orbit 9388.

5 Algorithm Change Record

For a detailed description of the L2__NO2___ algorithms, please refer to the ATBD [RD02].

Important notes for users:

- The upgrade to version 02.02.00 (5 July 2021) leads to an increase of the tropospheric NO_2 columns for cloud-free pixels. The previous upgrade to version 01.04.00 (2 December 2020) led to a substantial increase of the tropospheric NO_2 columns over polluted areas for scenes with small cloud fractions. Studies including both data before and after the activation of these versions will therefore show artificial (positive) jumps.
- Studies of time series, trend studies or comparisons between years should ideally be based on consistent datasets, and users are encouraged to use the latest reprocessed (RPRO) dataset based on version 02.04.00 in combination with the offline version 02.04.00 from 26 July 2022 onwards.

Version 02.05.00

The version 02.05.00 NO_2 product implements a small bug fix in the OFFL code. The change only affects the `qa_value` field in the datafiles, and only over snow or ice covered regions. In the corrected OFFL version there are more pixels that receive a `qa_value` > 0.75, in case the scene pressure over snow/ice matches the surface pressure to within 4% (was 2% in previous versions). The OFFL 02.04.00 code, operational since 17 July 2022, did not receive this latest change. This update makes OFFL consistent with NRTI, RPRO v02.04.00 and the ATBD [RD02].

Version 02.04.00

The version 02.04.00 NO_2 product implements one major change compared to version 02.02.00 (or 02.03.01). In this version the original OMI and GOME-2 derived surface albedo climatologies in the NO_2 fitting window were replaced by a surface albedo climatology derived from TROPOMI observations. This new TROPOMI surface albedo climatology (Directional Lambertian Equivalent Reflectivity or DLER) is consistently applied in the FRESCO cloud fraction and cloud pressure retrievals, in the cloud fraction retrievals in the NO_2 window, and in the air-mass factor calculation.

The TROPOMI DLER has several advantages:

- It accounts for the directionality or viewing-angle dependence of the scattering at the surface. Especially over vegetation in the near infrared this is a strong effect, impacting the FRESCO cloud retrieval.
- It improves the spatial resolution of the database from 0.5x0.5 degree to 0.125x0.125 degree, better resolving the variability.
- It is representative of more recent years.
- It shows less remnants of clouds and snow than the previous OMI LER.

The impact was tested for September 2020 and is shown in **Figure 1**. Over Europe, North America and East China the averaged difference in the tropospheric column is relatively minor, but especially over vegetated regions like South America or Central Africa the changes are substantial.

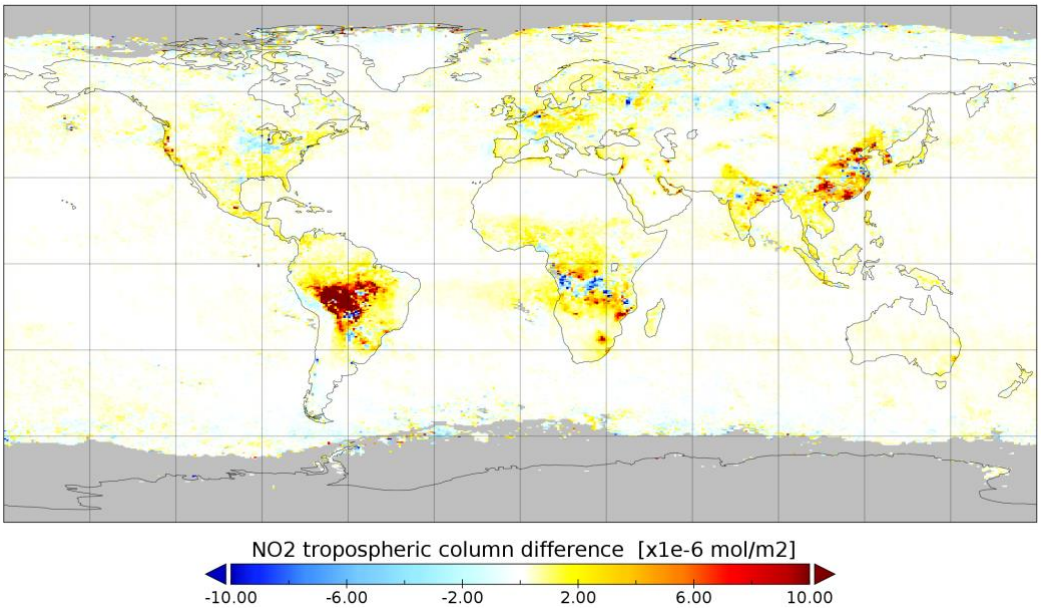

Figure 1: *Tropospheric column difference (v02.04.00-v02.03.01) comparing v02.04.00, using the TROPOMI DLER database, with v02.03.01 using the OMI LER in the NO_2 fit window, and the GOME-2 LER for the FRESCO cloud retrieval in the NIR. Note that 10^{15} molec/cm^2 corresponds to about 16 µmol/m^2. Data is gridded and averaged for September 2020.*

Version 02.02.00

The main changes in the upgrade from version 01.04.00 to 02.02.00 are:

- The main change in the NO_2 tropospheric column as compared to version 01.04.00 is linked to a different treatment of the surface albedo. In the NO_2 window the surface albedo is now adjusted to avoid negative cloud fractions while maintaining radiance closure. **This leads to a significant increase (10-15%) of tropospheric NO_2 for polluted cloud-free scenes** on top of the increase for pixels with a small but non-zero cloud cover in v01.04.00 related to the FRESCO cloud retrieval upgrade **(Figure 2)** Similarly, for fully clouded scenes with bright clouds, the cloud albedo is adjusted, rather than allowing cloud fractions > 1. Similar changes were made before in the FRESCO cloud fraction retrieval.

- The snow/ice information is now taken from the daily ECMWF meteorological analyses, replacing the NISE snow-ice flag. This solves the issue that NISE is undetermined around coastlines and improves the resolution and reliability.

- The results of a newly developed O_2-O_2 cloud algorithm are integrated (this is similar to the OMI cloud algorithm using the O_2-O_2 collision induced absorption around 477 nm). These cloud parameters are retrieved and stored in the output NO_2 product, but not used in the conversion from NO_2 slant column to vertical column (AMF calculations). This is foreseen for future versions. The regridded FRESCO-wide cloud parameters (see version 01.04.00 upgrade below) are written to the NO_2 product as well, and these parameters are used in the retrieval.

- The updates of the level-1b (ir)radiance spectra have a relatively small impact on the absolute value of the NO_2 SCD, SCD error and RMS error of the fit of on average +2%, −1% and −6%, respectively. The increase of the SCD mainly impacts the stratospheric column.

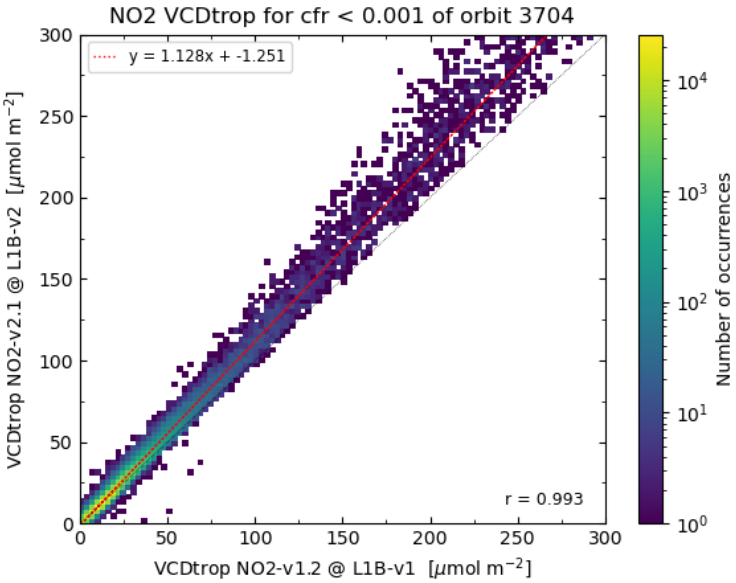

Figure 2: *Comparison of the NO_2 tropospheric VCD of orbit 03704 of 1 July 2018, showing all ground pixels for which both the v1.2 (x-axis) and v2.1 (y-axis) cloud retrieval gives zero cloud fraction, and for which the surface albedo may have been adjusted, and the tropospheric VCD was found to be positive. The linear fit coefficient is 1.128, indicating a 13% increase of the tropospheric NO_2 column for cloud-free scenes and columns up to 300 µmol/m^2.*

- The spike removal introduced in version 02.02.00 has a strongly positive impact on pixels which are not flagged for saturation or blooming in L1b but are, nevertheless, influenced by saturation effects. Over bright clouds the number of good quality retrievals has increased, of importance e.g., for lightning NOx studies. Furthermore, the spike removal improves the quality of the retrievals over the South Atlantic Anomaly region, with strong reductions of the slant column noise.

Version 01.04.00

The main changes in the upgrade from version 01.03.02 to 01.04.00 are:

- The FRESCO-S cloud retrieval scheme is updated to span a wider range of wavelengths in the O2-A band, including the weaker absorption features (FRESCO-wide). As a result, the cloud pressures show an overall decrease, especially for low clouds. For high clouds the changes are relatively minor. **Figure 3** shows the change in cloud pressure for pixels with a `qa_value` > 0.75, which are pixels with a cloud radiance fraction < 0.5, pixels which are mostly cloud-free. More detailed inspection shows that the updated FRESCO provides more realistic pressures, for instance in the case of heavy aerosol loads or in the case of low clouds over sea/ocean. In the latter case the previous FRESCO version often shows pressures equal to the sea surface pressure, but the FRESCO update produces more realistic elevated cloud heights.
  As a result of the higher clouds, the air-mass factor is reduced between 0 and 50%, depending on the location and cloud fraction. For a cloud fraction equal to zero there is no difference (see **Figure 4**, left). As a consequence, the tropospheric NO_2 column is increased between 0 and about 50% (see **Figure 4**, right). Similar results are found over other continents.
- Because of the overall decrease in cloud pressure, the criterion to decide if pixels above snow and ice are cloudy or cloud-free was also adjusted. This criterion is based on the difference between surface and cloud pressure as described in the ATBD [RD02].

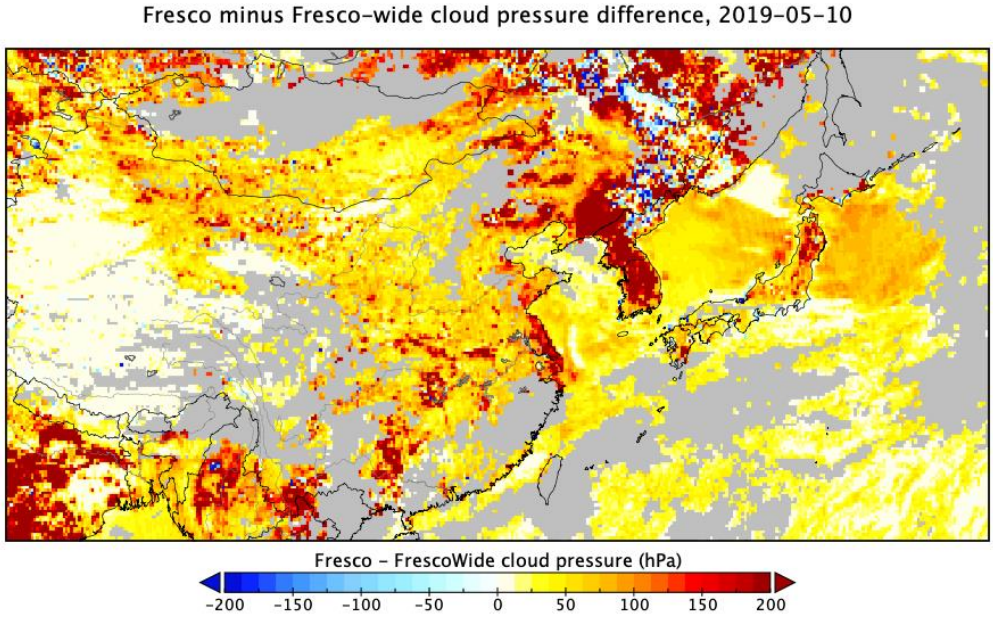

Figure 3: *he cloud pressure difference (V01.03.02 using previous FRESCO minus V01.04.00 using the new FRESCO-wide) for 10 May 2019 over East Asia (unit: hPa). Note that the data has been filtered for* `qa_value` *> 0.75, which implies nearly cloud free pixels. For the cloud pressure retrieval this is the most difficult subset of pixels (but also the relevant subset for NO_2 retrievals). Over land, the retrieved pressures for these nearly cloud free pixels may differ by more than 200 hPa for small cloud fractions. The new FRESCO V01.04.00 shows lower cloud pressures in most cases (yellow-red colors). Over sea and ocean, the differences are smaller, up to 50 hPa. For cloud-covered pixels (not shown) the differences are smaller.*

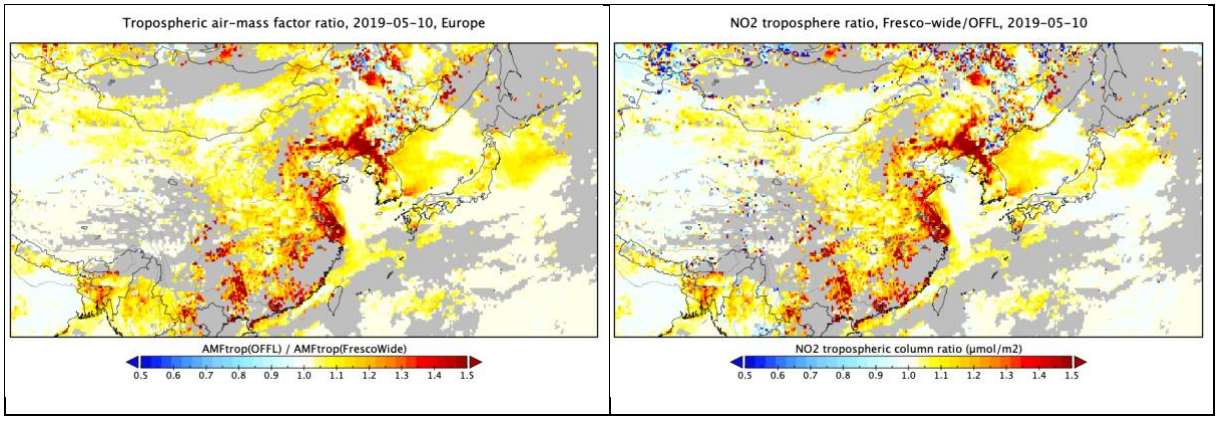

Figure 4: L*eft: the air-mass factor ratio (V01.03.02/V01.04.00). Right: the NO_2 tropospheric column ratio (V01.04.00/ V01.03.02). White and yellow colours indicate small changes < 15% for most of the domain, but a substantial fraction of observations, including polluted regions, shows columns enhanced by up to 50% (red).*

Version 01.03.00

The main changes in the upgrade from version 01.02.00 to 01.03.00 are:

- 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 (see **Figure 5**).

- 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.
- Two output fields were added, the "`air_mass_factor_clear`" and "`air_mass_factor_cloudy`" (see section 6.1.6), which are the tropospheric air-mass factors for cloud fraction 0 and 1, respectively.
- The wind speed at 10m altitude was added for interpretation of the observations (direction of the pollution plumes).

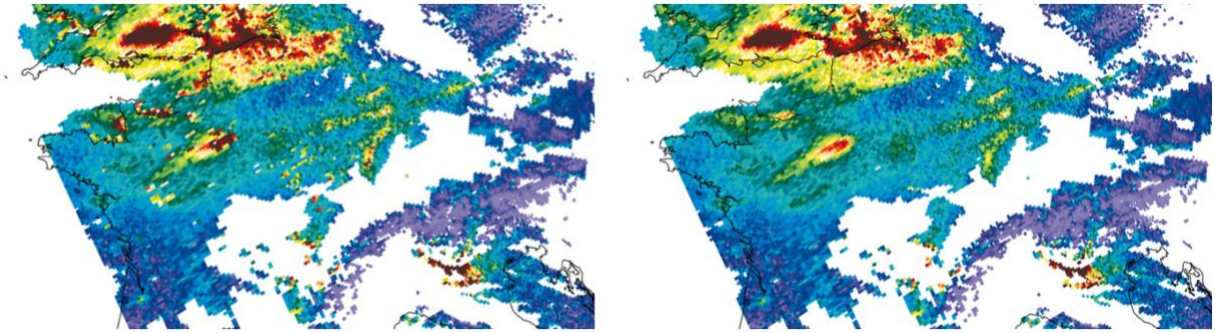

Figure 5: *the retrieval of tropospheric NO_2 over France on 24 February 2018, for version 01.02.00 (left) and version 01.03.00 (right). Data has been filtered for clouds (white area). In the (relatively rare) case that the cloud fraction from the NO_2 spectral window is positive, but FRESCO-S (v01.00-01.02) retrieves a negative cloud fraction with unrealistic cloud pressures, this was resulting in high, noisy NO_2 spots around Paris (left panel, v01.00-01.02). With the new treatment in FRESCO-S, resulting in more realistic cloud pressures, these spots disappear and we observe a well-defined pollution plume from Paris transported by the wind from the north-east (right panel, v01.03).*

Version 01.02.00

The main changes in the upgrade from version 01.01.00 to 01.02.00 can be summarized as follows:

- A "destriping" algorithm is used to remove across-track biases between the individual viewing angles. A stripe amplitude is computed on a daily basis over the (clean) tropical Pacific Ocean, averaged over a 30-degree latitude region and over a period of 7 days. The array of stripe amplitudes is provided in the L2 files and also in the product support file (see **6**).
- The retrieval for the high Solar Zenith Angles (SZA) and polar regions has improved through several changes. In the TM5-MP model, the photolysis for SZA > 85º was improved, impacting in particular the stratospheric NO_2 columns at high latitudes. The assimilation of NO_2 observations is now restricted to the ascending part of the orbit (see **Figure 7**).
- Good quality retrievals over snow-ice now receive a `qa_value` > 0.75 when the scene pressure from the FRESCO-S cloud retrieval is close to the surface pressure. The cloud retrieval cannot distinguish clouds from snow/ice, but the near equivalence of the scene pressure and surface pressure indicates that the scene is (nearly) cloud-free. Together with the high SZA improvements, the number of reliable retrievals over high latitude regions has increased substantially.
- The computation of the thermal tropopause level now uses a more advanced algorithm, resulting in a more realistic distribution of tropopause pressures.

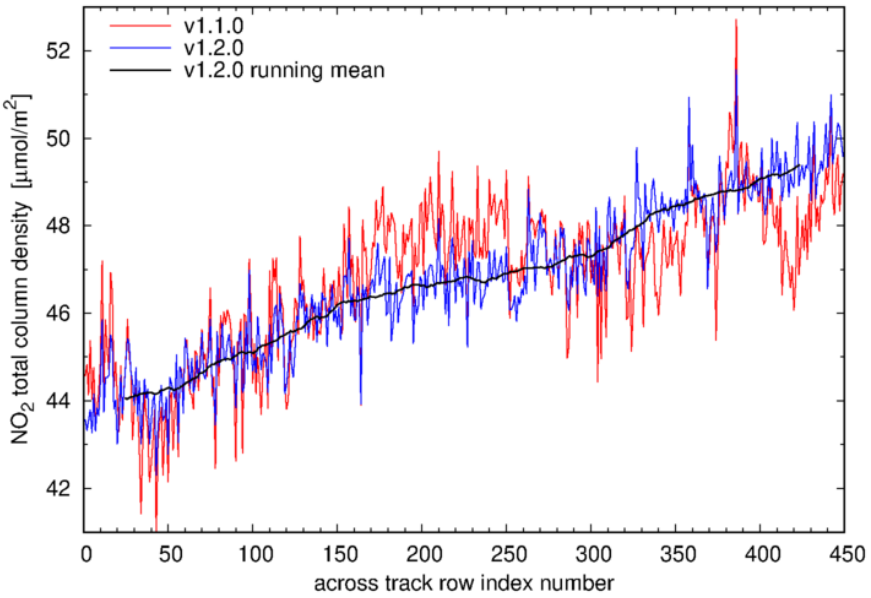

Figure 6: *A comparison of the mean total column (stratosphere plus troposphere) averaged over the tropical Pacific on 15 July 2018 as a function of the viewing angle, or row index. The red curve is the v1.1.0 results without destriping, and the blue curve is the v1.2.0 result with the destriping (the stripe correction is averaged over a week). In black we show a 50-row running mean of the blue curve. The red curve shows single-row spikes, as well as correlated structures, such as the high values around row 200 and the low values around 40, 320 or 420. The plot shows that the stripe filtering removes the major part of both the high and low frequency variability. Note that the amplitude of the structures in the red curve is small, generally within 5% of the column over the clean Pacific Ocean. Also note that we expect an increase of the total column in the stratosphere from left to right, as indicated by the black curve, due to the diurnal cycle of stratospheric NOx chemistry.*

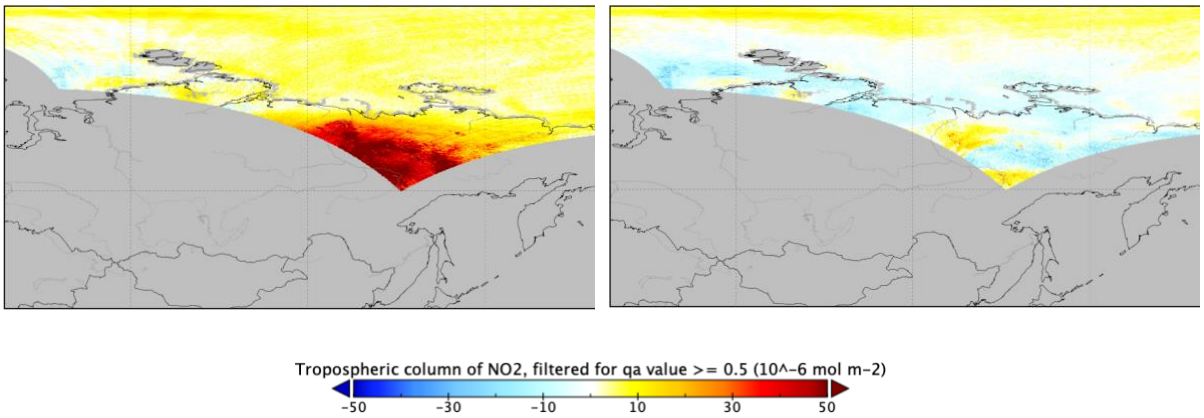

Figure 7: *The NO_2 tropospheric column retrievals for the descending part of orbit 3623, 25 June 2018, 19 UTC, over Siberia. Version 1.0.2 is shown on the left and version 1.2.0 on the right. Prominent unrealistic positive biases are observed in v1.0.2 (as it also occurs in v1.1.0) for the highest solar zenith angles on the left side of the orbit, while v1.2.0 has much more realistic values close to zero with a tendency towards a weak negative bias.*

6 Data Format

The product is stored as NetCDF4 file. The NetCDF4 file contains both the data and the metadata for the product.

For OFFL data the product is stored as a single file per satellite orbit, for NRTI data the product is stored as multiple files (5 minute granules) per orbit.

Please note that consecutive data granules of the NRTI product show an overlap of about 12 scan lines.

Details of the data format are provided in the Product User Manual (PUM) [RD03].

6.1 Data format changes

6.1.1 Version 02.05.00

Attribute fields with text changes

In variable `/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/wavelength_calibration_offset` attribute `'long_name'` → text changed (from 'wavelength offset' to '**radiance** wavelength offset')

In variable `/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/wavelength_calibration_offset_precision` attribute `'long_name'` → text changed (from 'wavelength offset precision' to '**radiance** wavelength offset precision'

In variable `/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/wavelength_calibration_stretch` attribute `'long_name'` → text changed (from 'wavelength stretch' to '**radiance** wavelength stretch')

In variable `/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/wavelength_calibration_stretch_precision` attribute `'long_name'` → text changed (from 'wavelength stretch precision' to '**radiance** wavelength stretch precision')

In variable `/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/wavelength_calibration_chi_square` attribute `'long_name'` → text changed (from 'wavelength calibration chi square' to '**radiance** wavelength calibration chi square')

In variable `/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/wavelength_calibration_irradiance_chi_square` attribute `'long_name'` → text changed (from 'wavelength calibration **irradiance** chi squared' to '**irradiance** wavelength calibration chi squared')

6.1.2 Version 02.04.00

New fields added

`/METADATA/QA_STATISTICS/number_of_thermal_instability_warning_occurrences`

In variable:
`/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/processing_quality_flags`

Added element to attribute `'flag_meanings': [success, radiance_missing, irradiance_missing, input_spectrum_missing, …, **thermal_instability_warning**]`
Added element to attribute `'flag_masks': [255, 255, 255, …, **1073741824**]`
Added element to attribute `'flag_values': [0, 1, 2, 3, 4, …, **1073741824**]`

6.1.3 Version 02.03.01

New fields added

`/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_wavelength_calibration_irradiance_offset_precision`

Removed fields

`/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_cloud_fraction_crb_not_clipped`
`/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_cloud_pressure_crb_not_clipped`

Renamed fields

`/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/wavelength_calibration_irradiance_offset` attribute `'long_name'` → text changed (from 'wavelength offset' to '**irradiance** wavelength offset'

`/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/wavelength_calibration_irradiance_offset` attribute `'ancillary_variables'` → text changed (from 'wavelength_calibration_offset_precision' to 'wavelength_calibration_**irradiance**_offset_precision'

6.1.4 Version 02.02.00

New fields added

`/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/cloud_selection_flag` (The configuration of version 2.2.0 fixes this to FRESCO)

```
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_cloud_fraction_crb

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_cloud_fraction_crb_not
_clipped

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_cloud_fraction_crb
_precision

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_cloud_pressure_crb
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_cloud_pressure_crb_not
_clipped

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_cloud_pressure_crb
_precision

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_cloud_height_crb
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_cloud_height_crb_precision
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_cloud_albedo_crb
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_scene_albedo
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_scene_albedo_precision
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_apparent_scene_pressure
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_apparent_scene_pressure
_precision

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_chi_square
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_continuum_at_reference
_wavelength

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_continuum_at_reference
_wavelength_precision

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_polynomial_coefficient
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_polynomial_coefficient
_precision

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_ring_coefficient
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_ring_coefficient_precision
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_nitrogendioxide_slant
_column_density

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_nitrogendioxide_slant
_column_density_precision
```

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_oxygen_oxygen_dimer_slant_column_density

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_oxygen_oxygen_dimer_slant_column_density_precision

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_oxygen_oxygen_dimer_slant_column_density_correction_factor

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_ozone_slant_column_density

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_ozone_slant_column_density_precision

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_surface_albedo

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_wavelength_calibration_irradiance_offset

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_wavelength_calibration_offset

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_wavelength_calibration_offset_precision

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_wavelength_calibration_stretch

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/O22CLD/o22cld_wavelength_calibration_stretch_precision

/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/FRESCO
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/FRESCO/fresco_cloud_fraction_crb
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/FRESCO/fresco_cloud_pressure_crb
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/FRESCO/fresco_scene_albedo
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/FRESCO/fresco_apparent_scene_pressure
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/FRESCO/fresco_cloud_albedo_crb
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/FRESCO/fresco_surface_albedo
/PRODUCT/SUPPORT_DATA/INPUT_DATA/surface_albedo attribute ancillary_variables
/PRODUCT/SUPPORT_DATA/INPUT_DATA/cloud_pressure_crb attribute ancillary_variables
/PRODUCT/SUPPORT_DATA/INPUT_DATA/cloud_fraction_crb attribute ancillary_variables
/PRODUCT/SUPPORT_DATA/INPUT_DATA/cloud_albedo_crb attribute ancillary_variables
/PRODUCT/SUPPORT_DATA/INPUT_DATA/scene_albedo attribute ancillary_variables
/PRODUCT/SUPPORT_DATA/INPUT_DATA/apparent_scene_pressure attribute ancillary_variables

/METADATA/QA_STATISTICS attribute number_of_missing_scanlines
/METADATA/QA_STATISTICS attribute number_of_max_num_outlier_exceeded_error_occurrences

/METADATA/GRANULE_DESCRIPTION attribute CollectionIdentifier

Removed fields

/METADATA/ISO_METADATA/gmd:identificationInfo/gmd:spatialResolution
/PRODUCT/SUPPORT_DATA/INPUT_DATA/surface_albedo_nitrogendioxide_window attribute radiation_wavelength (removed by mistake, will be added at the first opportunity)

/PRODUCT/SUPPORT_DATA/INPUT_DATA/surface_albedo attribute radiation_wavelength
/PRODUCT/SUPPORT_DATA/INPUT_DATA/cloud_pressure_crb attribute source
/PRODUCT/SUPPORT_DATA/INPUT_DATA/cloud_fraction_crb attribute source
/PRODUCT/SUPPORT_DATA/INPUT_DATA/cloud_albedo_crb attribute source
/PRODUCT/SUPPORT_DATA/INPUT_DATA/scene_albedo attribute source
/PRODUCT/SUPPORT_DATA/INPUT_DATA/scene_albedo attribute radiation_wavelength
/PRODUCT/SUPPORT_DATA/INPUT_DATA/apparent_scene_pressure attribute source

Renamed fields

/PRODUCT/qa_value attribute valid_min_ → /PRODUCT/qa_value attribute valid_min
/PRODUCT/qa_value attribute valid_max_ → /PRODUCT/qa_value attribute valid_max
/METADATA/QA_STATISTICS attribute number_of_aai_warning_occurrences
→ /METADATA/QA_STATISTICS attribute number_of_AAI_warning_occurrences

6.1.5 Version 01.04.00

There are no format changes with respect to the previous version.

6.1.6 Version 01.03.00

New fields added

/PRODUCT_SUPPORT_DATA/DETAILED_RESULTS/air_mass_factor_clear
/PRODUCT_SUPPORT_DATA/DETAILED_RESULTS/air_mass_factor_cloudy
/PRODUCT/SUPPORT_DATA/INPUT_DATA/eastward_wind
/PRODUCT/SUPPORT_DATA/INPUT_DATA/northward_wind

6.1.7 Version 01.02.00

New variables

/PRODUCT_SUPPORT_DATA/DETAILED_RESULTS/nitrogendioxide_slant_column_density_stripe_amplitude (added also to the auxiliary input CTMFCT files)

7 Product Availability

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

Also, the full mission reprocessed products can be found on the mentioned Open Access Hub and can be identified by the file class 'RPRO' in the filenames. The collection identifier is '03', the same used for the operational dataset that is available since mid-July 2022 (all with version 2.4.0).

The list of major mission data gaps due to acquisition faults or satellite/instrument disruption is available at https://sentinel.esa.int/web/sentinel/missions/sentinel-5p/mission-status. For those periods the data are permanently lost.

RPRO dataset gaps: additional gaps are present on the reprocessed dataset (see Table 3) due to the unavailability of Level 0 (L0) input data during the full mission reprocessing campaign.

Orbit	Gap start time	Gap stop time
3546	20/06/2018 08:31:35	20/06/2018 08:51:37
9755	31/08/2019 23:46:24	01/09/2019 00:06:25
10782	12/11/2019 08:39:57	12/11/2019 09:29:55
19782	07/08/2021 18:09:52	07/08/2021 18:27:54
19785	07/08/2021 22:34:02	07/08/2021 22:50:52
20254	10/09/2021 00:01:42	10/09/2021 00:21:43

Table 3: Gaps on RPRO dataset due to the unavailability of L0 input data during the full mission reprocessing campaign

Information on data handling tools is available from the web page http://www.tropomi.eu/tools.

For further questions regarding S5P/TROPOMI data products please contact EOSupport@Copernicus.esa.int.

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.

8 References

[RD01] Sentinel-5 Precursor Calibration and Validation Plan for the Operational Phase
source: ESA; **ref**: ESA-EOPG-CSCOP-PL-0073;
url: https://sentinels.copernicus.eu/documents/247904/2474724/Sentinel-5P-Calibration-and-Validation-Plan.pdf

[RD02] Sentinel-5 precursor/TROPOMI Level 2 Algorithm Theoretical Basis Document Total and Tropospheric NO_2 Data Products,
source: KNMI; **ref**: S5P-KNMI-L2-0005-RP;
url: https://sentinels.copernicus.eu/documents/247904/2476257/Sentinel-5P-TROPOMI-ATBD-NO2-data-products

[RD03] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Nitrogen Dioxide
source: KNMI; **ref**: S5P-KNMI-L2-0021-MA;
url: https://sentinels.copernicus.eu/documents/247904/2474726/Sentinel-5P-Level-2-Product-User-Manual-Nitrogen-Dioxide

[RD04] Validation Reports of the Sentinel-5 Precursor Operational Data Products
Source: BIRA; ref: S5P-MPC-IASB-ROCVR;
url: http://mpc-vdaf.tropomi.eu/

[RD05] Algorithm theoretical basis document for the TROPOMI L01b data processor
source: KNMI; ref: S5P-KNMI-L01B-0009-SD;
url: https://sentinels.copernicus.eu/documents/247904/2476257/Sentinel-5P-TROPOMI-Level-1B-ATBD

More information on this data product is available from the Copernicus Sentinel product webpage:
https://sentinels.copernicus.eu/web/sentinel/technical-guides/sentinel-5p/products-algorithms,
and from the corresponding TROPOMI product webpage http://www.tropomi.eu/data-products.

Abbreviations and acronyms

AO	Announce of Opportunities
ATBD	Algorithm Theoretical Basis Document
BIRA-IASB	Royal Belgian Institute for Space Aeronomy
DLER	Directional Lambertian Equivalent Reflectivity
DLR	German Aerospace Center / Deutsches Zentrum für Luft- und Raumfahrt
DOAS	Differential Optical Absorption Spectroscopy
DOI	Digital Object Identifier
ECCC	Environment and Climate Change Canada
ESA	European Space Agency
ESL	Expert Support Laboratory
ESRIN	European Space Research Institute of ESA
FMI	Finnish Meteorological Institute
IUPB	University of Bremen
FRESCO	Fast REtrieval Scheme for Clouds from the Oxygen A band
KNMI	Koninklijk Nederlands Meteorologisch Instituut – Royal Dutch Meteorological Institute
LATMOS-CNRS	Laboratoire Atmosphères, Observations Spaciales - Centre National de la Recherche Scientifique
MAX-DOAS	Multi Axis Differential Optical Absorption Spectroscopy
MPC	Mission Performance Centre
MPI-Mainz	Max Planck Institut, in Mainz
NASA	National Aeronautics and Space Administration
NRT	Near-Real Time
NRTI	Near-Real TIme (data product)
OFFL	Off-line (non-time-critical data product)
OMI	Ozone Monitoring Instrument
PRF	Product Readme File
PUM	Product User Manual
QDOAS	Cross-platform application for DOAS retrievals, developed by BIRA-IASB
QWG	Quality Working Group
ROCVR	Routine Operations Consolidated Validation Reports
RPRO	Retrieval reprocessing product
S5P	Sentinel-5 Precursor
S5PVT	Sentinel-5 Precursor Validation Team
TROPOMI	TROPOspheric Monitoring Instrument
VCD	Vertical Column Density
VDAF	Validation Data Analysis Facility