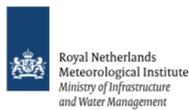




S5P Mission Performance Centre Aerosol Layer Height [L2__AER_LH] Readme



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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
Cloud mask is based on VIIRS ECM product (instead for VICMO) since OFFL orbit 12432 (see section 4.2)	1	2	11/03/2020
Table 2: addition of version 01.04.00	1	3	02/12/2020
<ul style="list-style-type: none"> Table 2: Adapting to V02.02.00 of the processor. Section 3.2: Validation results shortened, pointing to the routine Validation reports. 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 6.1: added format changes related to version 02.02.00. 	2	0	05/07/2021
<ul style="list-style-type: none"> Table 2: addition of version 02.03.01 Section 4.1: Added 'Data in <code>snow_ice_flag</code> variable for pixels with SZA > 88° Section 4.2: Added 'Geolocation co-added when they should not be (solved in 02.03.01)' 	2	1	17/11/2021
<ul style="list-style-type: none"> 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: Added radiometric calibration of L1B and new LER surface database information. 	2	2	20/07/2022
<ul style="list-style-type: none"> Table 2: addition of reprocessed dataset with version 02.04.00 Section 7: updates with information related to gaps on the reprocessed dataset 	2	3	22/02/2023
<ul style="list-style-type: none"> Table 2: addition of version 02.05.00 Section 6.1: added minor format changes related to version 02.05.00 	2	4	15/03/2023
<ul style="list-style-type: none"> Table 2: addition of version 02.06.00 Table 2: addition of a note on REPRO orbit for version 02.05.00 Section 4.2: change of cloud mask fallback in OFFL Section 5: Added description of the surface albedo fitting Section 6.1: removed old changes and added detailed format changes related to version 02.06.00 in the newly created ANNEX section (Section 9) Section 7: Replaced Open Data Hub with CDSE 	2	5	29/11/2023

1 Summary

This is the Product Readme file (PRF) for the Copernicus Sentinel 5 Precursor Tropospheric Monitoring Instrument (S5P/TROPOMI) Aerosol Layer Height (L2__AER_LH) Level 2 product and is applicable for the Near Real-Time (NRTI), Offline (OFFL) and Reprocessed (RPRO) timeliness data products.

Product Identifier: **L2__AER_LH**

Example filename:

S5P_OFFL_L2__AER_LH_20210908T001010_20210908T015140_20226_02_020200_20210909T165109.nc
S5P_NRTI_L2__AER_LH_20210908T002709_20210908T003209_20226_02_020200_20210908T013221.nc
S5P_RPRO_L2__AER_LH_20180501T165554_20180501T183724_02842_03_020400_20221125T084824.nc

The OFFL and RPRO data products have the following Digital Object Identifier (DOI):
<http://doi.org/10.5270/S5P-7g4iapn>

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 `aerosol_mid_pressure` and `aerosol_mid_height` which provide the air pressure at the center of the aerosol layer and the height at the center of the aerosol layer relative to the geoid, respectively. The aerosol layer mid pressure is computed for pixels that are free of ice, snow, and clouds. The maximum allowed cloud fraction is 2% (5% in NRTI), except if the UVAI is larger than 1.0, those pixels are always processed. The latter is to avoid volcanic ash and dust plumes mistakenly being filtered as clouds. As a user guideline, it is recommended to use only those pixels that contain no sunglint. The `sun_glint_warning` flag is available to filter those ALH pixels that are possibly sunglint contaminated. In general, the data quality is indicated by a `qa_value`. Pixels with a `qa_value` below 0.5 are not recommended for use.

Note: Starting from this processor version 2.4.0, new improved Level 1b version 2.1 data products are used as input [RD04].

The TROPOMI L2__AER_LH product is a relatively new product, released in September 2019, with little heritage. Aerosol vertical profile products exist from other satellite instruments, e.g., active measurements from Caliop onboard CALIPSO, and multi-angle measurements from MISR onboard Terra.

First validation efforts by Sentinel-5 Precursor (S5p) Mission Performance Centre (MPC) Cal/Val experts and the S5p Validation Team (S5PVT) show that the ALH is stable and shows good overall agreement with Caliop retrievals, with Caliop generally retrieving higher ALH than TROPOMI for ocean scenes. A statistical pixel-by-pixel comparison of Caliop and S5P layer height retrievals from three desert dust cases and one smoke plume showed good correlation between the retrievals (regression slope 1.00), but on average Caliop retrievals were 0.53 km higher in altitude than S5P ALH. This is likely due to the different sensitivity, which for Caliop is to the top of the plume, while S5P is sensitive to the centroid of the layer altitude. This was confirmed by a study which compared smoke plumes heights over Canada from S5P and those retrieved by Caliop and MISR. The latter uses stereoscopic viewing to retrieve plume top height. The systematic difference between S5P TROPOMI ALH and MISR aerosol plume height is about 600 m. This is again due to differences in the sensitivity of the instruments and the differences in the algorithms (centroid vs. top retrieval).

Over land, TROPOMI ALH becomes unreliable for increasing surface albedo. Consequently, the difference between the plume height observed by TROPOMI and CALIOP depends significantly on the thickness of the plume. Thicker plumes seem to be better captured by TROPOMI and the mean difference reduces with the thickness of the plumes, the mean difference between the TROPOMI and CALIOP mid aerosol layer is just 50 m for very thick plumes (>3 km). The main reason is the insensitivity to the surface bias for thick plume in S5P ALH.

These above-mentioned studies and 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, and reports released after September 2021 include validation results based on processor version 2.x.x.

There is a notable difference between the NRTI and OFFL/RPRO cloud-free scene selections as of version 2.0.0 (see section 4.1). The target uncertainty requirements for ALH are defined in the S5p Calibration and Validation Plan [RD01] and summarized in Table 1. The ALH is compliant with the requirements over oceans and dark land surfaces.

Parameter	Data product	Vertical Resolution	Bias	Random
ALH	Aerosol Layer Height	Total column	<100hPa (1 Km)	<50hPa

Table 1: ALH data product requirements extracted from the S5p Calibration and Validation Plan [RD01]

2 Processing baseline description

Table 2 contains the history of the ALH processor versions. Note that the processor version for ALH 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 ALH product.

Processor Version	In operation starting from	In operation until	Relevant Improvements
02.06.00	NRTI: Orbit 31750, 2023-11-29 OFFL: Orbit 31705, 2023-11-26	Current version	<ul style="list-style-type: none"> - Introduction of the surface albedo in the Optimal Estimation feature vector, i.e., surface albedo is now fitted along with ALH and AOT, to improve results over land. - Use of FRESCO cloud mask as backup of the VIIRS Enterprise Cloud Mask (ECM) on a pixel-by-pixel basis for the OFFL product.
02.05.00	NRTI: Orbit 28078, 2023-03-15 OFFL: Orbit 28031, 2023-03-12 RPRO: orbit 25163, 2022-08-21	Orbit 31750, 2023-11-29 Orbit 31704, 2023-11-26 Orbit 25276, 2022-08-30	<ul style="list-style-type: none"> - Minor format changes - RPRO data: Users are recommended to use the RPRO data in the period 21-30 August 2022 because those products were generated with an optimal configuration of the auxiliary files (unlike the OFFL data).
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	<ul style="list-style-type: none"> - Introduction of S5P/TROPOMI-based LER surface database (see section 5) - Minor format changes <p>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, because the OFFL products in that orbit range will be removed.</p> <p>Note 2: Starting from this processor version, new improved Level 1b version 2.1 data products are used as input [RD04]</p>
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	Minor format changes: text changed in attribute description for two fields

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	<ul style="list-style-type: none"> - The pixel selection scheme has been updated. The Enterprise Cloud Mask (ECM) cloud mask is now the primary cloud filter for OFFL, FRESCO cloud mask for NRTI, with the aerosol index used to add pixels that have both a too high cloud fraction and a high UV Aerosol Index (UVAI) value. These are likely thick aerosol events where the cloud mask considers this a cloud. Full details on the new pixel selection scheme are provided [RD02] - Changes in format <p>Note: Starting from this processor version, new improved Level 1b version 2.0 data products are used as input [RD04].</p>
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	No changes with respect to previous version
01.03.02	NRT: Orbit 10171, 2019-09-30 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	RPRO: Orbit 2818, 2018-04-30 OFFL: Orbit 7907, 2019-04-23	Orbit 7424, 2019-03-20 Orbit 8814, 2019-06-26	No changes with respect to previous version
01.03.00	OFFL: Orbit 7425, 2019-03-20	Orbit 7906, 2019-04-23	Initial version

Table 2: History of ALH processor versions

3 Product Quality

3.1 Recommendations for data usage

The ALH is very sensitive to cloud contamination. However, aerosols and clouds can be difficult to distinguish, and ALH is computed for all FRESCO effective cloud fractions smaller than 0.04 (NRTI) and VIIRS cloud fractions smaller than 0.02 (OFFL). Cloud flags are available from FRESCO and VIIRS, and are strongly recommended to filter for residual clouds. A sunglint mask is also available to screen sunglint regions, which are not filtered beforehand. These and other sources of uncertainties are indicated with the `qa_value`. Use of pixels with a `qa_value` below 0.5 is not recommended.

The variables `aerosol_mid_pressure_precision` and `aerosol_mid_height_precision` can also be further used to diagnose the quality of the ALH.

For further details, data users are encouraged to read the Product User Manual (PUM) [RD03] and Algorithm Theoretical Basis Document (ATBD) [RD02] associated with this data product, available on <https://sentinels.copernicus.eu/web/sentinel/technical-guides/sentinel-5p/products-algorithms>.

3.2 Validation results

The data are validated for reprocessed data using the data processor up to version 01.04.00, see section 1. These data were selected using high UV AI. Version 02.xx.xx will include more data: all pixels with sufficiently low cloud fraction. The UV AI is only used to avoid cloud filtering for thick plumes of smoke and volcanic ash, which are important to include in the retrieval. The validation results are valid for all versions, since the retrieval was not changed markedly in version 2. However, the selection of pixels is now based on different cloud filters in NRTI and OFFL. Details on the consequences of this and 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 latest change of including the surface albedo in the optimal estimation feature vector should improve the results over land, ideally removing the bias towards the surface, while the results over ocean should ideally not change (too much). The coming period will be used to investigate the behavior of the 02.06.00 version algorithm and published in the ROCVR. The ROCVR reports are issued quarterly, and reports released after September 2021 include validation results based on processor version 2.x.x.

4 Data Quality Remarks

Currently, the following data quality issues are known and should be kept in mind when looking at the Aerosol Layer Height product and also at validation results.

4.1 Known Data Quality Issues

Bias to clouds

As mentioned, the ALH is very sensitive to clouds, and the height will be strongly biased towards the cloud height for partially clouded pixels.

High surface albedo

It is known that high surface albedos negatively influence the ALH, biasing the ALH towards the surface. In general, the ALH over (dark) oceans is considered reliable to within the requirement of 1000 m or 100 hPa. Over land, especially bright surfaces, the accuracy may be lower. The processor version 02.06.00 may improve the situation but this needs to be verified.

Difference in NRTI and OFFL cloud-free scene selections (since version 2.0.0)

There is a notable difference between the NRTI and OFFL cloud-free scene selections as of version 2.0.0. During OFFL processing the VIIRS Enterprise Cloud Mask (ECM) cloud mask is used to select cloud-free scenes for ALH processing. However, during NRTI processing the VIIRS ECM information is not yet available, and the S5P/FRESCO cloud mask is used to select cloud-free scenes. Since the FRESCO cloud mask represents a (radiative) effective cloud fraction and the VIIRS ECM a geometric cloud fraction, differences between the cloud masks can be significant, which results in a notable different selection of cloud-free pixels. This is not an error, but for ALH purposes the VIIRS ECM cloud filter is considered to be superior to the FRESCO cloud mask. For pixels which were marked cloud-free by either cloud filter, the difference in retrieved ALH from NRTI and OFFL processing was very small.

4.2 Solved Data Quality Issues

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 ALH column data, hence the ALH data quality is not affected. This has been corrected in version 02.04.00.

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.

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, remained **unchanged** (hence not aligned to the improved resolution). These fields have been updated with the activation of Level 2 processors version 02.02.xx.

The VIIRS ECM was sometimes missing party in orbit files, which resulted in complete failing ALH orbits, since the availability of ECM was checked for complete orbits only. This is resolved in version 02.06.00: the availability of the ECM is checked on a pixel-by-pixel basis, with FRESCO cloud mask as a back-up for the ECM. The use of the back-up is marked by a lowered `qa_value`.

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 in few orbits (7-9 per week). Though this may seem anomalous, it is physically correct, and not related to any problem on the data geolocation.

New cloud mask for S-NPP used during OFFL ALH processing

NOAA no longer supports the VIIRS cloud mask (VCM or VICMO) product, which is discontinued (second quarter 2020) in favour of the Enterprise Cloud Mask (ECM). An update to the S5P-NPP L2 processor (to version 01.01.00) has happened (orbit 12432, date 07-03-2020) to ingest the new cloud mask. It should, however, be noted that there are significant differences between the cloud mask fields themselves: E.g., compared to VCM, ECM tends to indicate fewer confidently clear scenes over land, but more over sea. Therefore, values in the cloud/clear counts used to calculate the cloud fraction for the filtering of the OFFL AER_LH product are now different. Please note that the NRTI AER_LH does not use this cloud mask and is not affected.

The change in cloud fractions (sign and magnitude) are dependent on the day and location. However, the current thresholds for cloud filtering (which are the same for CH4) do not affect the AER_LH product, i.e., cloudy scenes are filtered properly. The new cloud mask values available to users are expected to perform better than before and the user is encouraged to use the available cloud masks to filter for residual clouds. Full assessment of data quality will come after the new processor has been running long enough.

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__AER_LH algorithm, please refer to the ATBD [RD02].

Version 02.06.00

- The Optimal Estimation feature vector has been extended with the surface albedo at two wavelengths in the continuum, one below and one beyond the O2-A band. This is a major change from the previous version because the optimal estimation framework uses derivatives with respect to the elements in the feature vector to compute the direction of the next iteration step. Since the forward model step is based on a neural network (NN)-trained spectrum and derivatives, the NN has to be retrained and extended with two NN's estimating the derivatives with respect to the surface albedo at the two wavelengths. The change has been tested on several test orbits with good results. However, the coming period should show the robustness of this implementation.
- The VIIRS ECM fallback in case of unavailability of the cloud mask is now checked on a pixel-by-pixel basis instead of per orbit.

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 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

The data format changes of processor version 02.06.00 respect to the previous version 02.05.00 are highlighted in the ANNEX.

7 Product Availability

All S5P/TROPOMI data are available on the Copernicus Data Space Ecosystem <https://dataspace.copernicus.eu>

Also, the full mission reprocessed products can be found on the mentioned Data Space Ecosystem 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

RPRO data between Aug 21 and Aug 30 (orbits 25163 - 25276): on top of the OFFL data, there are RPRO data in this period. Users are recommended to use the RPRO data because those products were generated with an optimal configuration of the auxiliary files (unlike the OFFL data).

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 Copernicus Data Space Ecosystem 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://sentinel.esa.int/documents/247904/2474724/Sentinel-5P-Calibration-and-Validation-Plan.pdf>
- [RD02] Sentinel-5 precursor/TROPOMI Level 2 Algorithm Theoretical Basis Document of the Aerosol Layer Height
source: KNMI; **ref:** S5P-KNMI-L2-0006-RP;
url: <https://sentinels.copernicus.eu/documents/247904/2476257/Sentinel-5P-TROPOMI-ATBD-Aerosol-Height>
- [RD03] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual Aerosol Layer Height
source: KNMI; **ref:** S5P-KNMI-L2-0026-MA;
url: <https://sentinel.esa.int/documents/247904/2474726/Sentinel-5P-Level-2-Product-User-Manual-Aerosol-Layer-Height>
- [RD04] 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>
- [D01] VIIRS Calibration Support Team (VCST). (2017). VIIRS/NPP Day/Night Band 6-Min L1B Swath SDR- 750m NRT [Data set]. NASA LANCE MODIS at the MODAPS. https://doi.org/10.5067/viirs/vnp02dnb_nrt.001
- [D02] Winker, D. (2016). CALIPSO LID L1 ValStage1 HDF File - Version 3.40 [Data set]. NASA Langley Atmospheric Science Data Center DAAC. https://doi.org/10.5067/caliop/calipso/cal_lid_l1-valstage1-v3-40

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 corresponding TROPOMI product webpage <http://www.tropomi.eu/data-products>.

Abbreviations and acronyms

(A)AI	(Absorbing) Aerosol Index
ALH	Aerosol Layer Height
ATBD	Algorithm Theoretical Basis Document
BIRA-IASB	Royal Belgian Institute for Space Aeronomy
DLR	German Aerospace Center / Deutsches Zentrum für Luft- und Raumfahrt
DOI	Digital Object Identifier
ECM	Enterprise Cloud Mask
ESA	European Space Agency
ESL	Expert Support Laboratory
KNMI	Royal Netherlands Meteorological Institute / Koninlijk Nederlands Meteorologisch Instituut
LER	Lambertian-Equivalent Reflectivity
MPC	Mission Performance Centre
NASA	National Aeronautics and Space Administration
NRTI	Near Real Time (timeliness of products)
OFFL	Offline (timeliness of products)
OMI	Ozone Monitoring Instrument
OMPS	Ozone Mapper and Profiling Suite
PRF	Product Readme File
PUM	Product User Manual
QWG	Quality Working Group
ROCVR	Routine Operations Consolidated Validation Report
S5P	Sentinel-5 Precursor
S5PVT	Sentinel-5 Precursor Validation Team
TCCON	Total Carbon Column Observing Network
TROPOMI	Tropospheric Monitoring Instrument
UVAI	UV Aerosol Index
VCM	VIIRS Cloud Mask
VDAF	Validation Data Analysis Facility

9 ANNEX

Items removed in the new release

Dimension `albedo`

The dimension 'albedo' in `/PRODUCT` has been removed. This was a dimension that was only used for variables that contain debug information.

Attribute `assumed_layer_pressure_thickness_Pa`

The attribute 'assumed_layer_pressure_thickness_Pa' in `/PRODUCT/aerosol_mid_pressure` and in `/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/aerosol_mid_pressure_not_clipped` has been removed. The thickness if the aerosol layer is now expressed in a geometric thickness, see the `assumed_layer_pressure_thickness_m` attribute below.

Items added in the new release

Dimension and variable `albedo_wavelength`

The dimension and variable 'albedo_wavelength' in `/PRODUCT` has been added. The surface albedo is now retrieved at two wavelengths. This dimension is for the wavelength dependence of the surface albedo.

Variable `surface_albedo_precision`

The variable 'surface_albedo_precision' in `/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS` has been added. The surface albedo is now retrieved, and therefore it has a precision.

Attribute `assumed_layer_pressure_thickness_m`

The attribute 'assumed_layer_pressure_thickness_m' in `/PRODUCT/aerosol_mid_pressure` and `/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/aerosol_mid_pressure_not_clipped` has been added. This is the replacements of the `assumed_layer_pressure_thickness_Pa` attribute.

Attribute `ancillary_variables`

The attribute 'ancillary_variables' in `/PRODUCT/aerosol_mid_pressure`, `/PRODUCT/aerosol_mid_height`, `/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/aerosol_mid_pressure_not_clipped`, `/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/aerosol_optical_thickness` and `/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/surface_albedo` has been added. The references to support variables was missing.

Attribute `number_of_internal_cloud_mask_filter_occurrences`

The attribute 'number_of_internal_cloud_mask_filter_occurrences' in `/METADATA/QA_STATISTICS` has been added. This counts the number of occurrences of the new value in the processing quality flags in the methane processor.

Other changes

Variable `surface_albedo`

The variable 'surface_albedo' in /PRODUCT/SUPPORT_DATA/DETAILED_RESULTS has a new dimension. This is to accomodate the two wavelengths at which the surface albedo is retrieved.

- Old value: 'time, scanline, ground_pixel'.
- New value: 'time, scanline, ground_pixel , **albedo_wavelength**'.

Attribute `product_version`

The attribute 'product_version' in / has a new value or dimension.

- Old value: '1.5.0'.
- New value: '1.6.0'.

Attribute `status_NISE__`

The attribute 'status_NISE__' in / has a new value or dimension. The NISE input is no longer used.

- Old value: ''.
- New value: 'Retired'.

Attribute `flag_meanings`

The attribute 'flag_meanings' in /PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/processing_quality_flags has a new value or dimension.

- Old value: 'success radiance_missing irradiance_missing input_spectrum_missing reflectance_range_error ler_range_error snr_range_error sza_range_error vza_range_error lut_range_error ozone_range_error wavelength_offset_error initialization_error memory_error assertion_error io_error numerical_error lut_error ISRF_error convergence_error cloud_filter_convergence_error max_iteration_convergence_error aot_lower_boundary_convergence_error other_boundary_convergence_error geolocation_error ch4_noscat_zero_error h2o_noscat_zero_error max_optical_thickness_error aerosol_boundary_error boundary_hit_error chi2_error svd_error dfs_error radiative_transfer_error optimal_estimation_error profile_error cloud_error model_error number_of_input_data_points_too_low_error cloud_pressure_spread_too_low_error cloud_too_low_level_error generic_range_error generic_exception input_spectrum_alignment_error abort_error wrong_input_type_error wavelength_calibration_error coregistration_error slant_column_density_error airmass_factor_error vertical_column_density_error signal_to_noise_ratio_error configuration_error key_error saturation_error max_num_outlier_exceeded_error solar_eclipse_filter cloud_filter altitude_consistency_filter altitude_roughness_filter sun_glint_filter mixed_surface_type_filter snow_ice_filter aai_filter cloud_fraction_fresco_filter aai_scene_albedo_filter small_pixel_radiance_std_filter cloud_fraction_viirs_filter cirrus_reflectance_viirs_filter cf_viirs_swir_ifov_filter cf_viirs_swir_ofova_filter

cf_viirs_swir_ofovb_filter cf_viirs_swir_ofovc_filter cf_viirs_nir_ifov_filter
cf_viirs_nir_ofova_filter cf_viirs_nir_ofovb_filter cf_viirs_nir_ofovc_filter
refl_cirrus_viirs_swir_filter refl_cirrus_viirs_nir_filter diff_refl_cirrus_viirs_filter
ch4_noscat_ratio_filter ch4_noscat_ratio_std_filter h2o_noscat_ratio_filter
h2o_noscat_ratio_std_filter diff_psurf_fresco_ecmwf_filter psurf_fresco_stdv_filter
ocean_filter time_range_filter pixel_or_scanline_index_filter
geographic_region_filter input_spectrum_warning wavelength_calibration_warning
extrapolation_warning sun_glint_warning south_atlantic_anomaly_warning
sun_glint_correction snow_ice_warning cloud_warning AAI_warning
pixel_level_input_data_missing data_range_warning low_cloud_fraction_warning
altitude_consistency_warning signal_to_noise_ratio_warning
deconvolution_warning so2_volcanic_origin_likely_warning
so2_volcanic_origin_certain_warning interpolation_warning saturation_warning
high_sza_warning cloud_retrieval_warning cloud_inhomogeneity_warning
thermal_instability_warning'.

- New value: 'success radiance_missing irradiance_missing input_spectrum_missing
reflectance_range_error ler_range_error snr_range_error sza_range_error
vza_range_error lut_range_error ozone_range_error wavelength_offset_error
initialization_error memory_error assertion_error io_error numerical_error lut_error
ISRF_error convergence_error cloud_filter_convergence_error
max_iteration_convergence_error aot_lower_boundary_convergence_error
other_boundary_convergence_error geolocation_error ch4_noscat_zero_error
h2o_noscat_zero_error max_optical_thickness_error aerosol_boundary_error
boundary_hit_error chi2_error svd_error dfs_error radiative_transfer_error
optimal_estimation_error profile_error cloud_error model_error
number_of_input_data_points_too_low_error
cloud_pressure_spread_too_low_error cloud_too_low_level_error
generic_range_error generic_exception input_spectrum_alignment_error
abort_error wrong_input_type_error wavelength_calibration_error
coregistration_error slant_column_density_error airmass_factor_error
vertical_column_density_error signal_to_noise_ratio_error configuration_error
key_error saturation_error max_num_outlier_exceeded_error solar_eclipse_filter
cloud_filter altitude_consistency_filter altitude_roughness_filter sun_glint_filter
mixed_surface_type_filter snow_ice_filter aai_filter cloud_fraction_fresco_filter
aai_scene_albedo_filter small_pixel_radiance_std_filter cloud_fraction_viirs_filter
cirrus_reflectance_viirs_filter cf_viirs_swir_ifov_filter cf_viirs_swir_ofova_filter
cf_viirs_swir_ofovb_filter cf_viirs_swir_ofovc_filter cf_viirs_nir_ifov_filter
cf_viirs_nir_ofova_filter cf_viirs_nir_ofovb_filter cf_viirs_nir_ofovc_filter
refl_cirrus_viirs_swir_filter refl_cirrus_viirs_nir_filter diff_refl_cirrus_viirs_filter
ch4_noscat_ratio_filter ch4_noscat_ratio_std_filter h2o_noscat_ratio_filter
h2o_noscat_ratio_std_filter diff_psurf_fresco_ecmwf_filter psurf_fresco_stdv_filter
ocean_filter time_range_filter pixel_or_scanline_index_filter
geographic_region_filter **internal_cloud_mask_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

Attribute `coordinates`

The attribute `'coordinates'` in

```
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/aerosol_mid_pressure_not_clipped,  
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/aerosol_optical_thickness,  
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/surface_albedo,  
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/aerosol_optical_thickness_precision,  
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/root_mean_square_error_of_fit,  
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/chi_square and
```

`/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/degrees_of_freedom` has a new value or dimension. The attribute now uses a reference that can actually be followed.

- Old value: `'longitude latitude'`.
- New value: `'/PRODUCT/longitude /PRODUCT/latitude'`.

Attribute `source`

The attribute `'source'` in `/PRODUCT/SUPPORT_DATA/INPUT_DATA/snow_ice_flag` has a new value. The value is now fixed because NISE has been retired.

- Old value: `''`.
- New value: `'ECMWF'`.