



S5P Mission Performance Centre UV Aerosol Index [L2__AER_AI] Readme



document number	S5P-MPC-KNMI-PRF-AER_AI	
issue	2.2	
date	2022-07-20	
product version	V02.04.00	
status	Released	
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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	1	6	02/12/2020
<ul style="list-style-type: none">Table 2: Adapting to V02.02.00 of the processorSection 3.2: Validation results shortened, pointing to the routine Validation reportsSection 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 02.03.01Section 4.2: added two solved issues with version 02.03.01Section 6.1: added format changes with version 02.03.01	2	1	17/11/2021
<ul style="list-style-type: none">Table 2: addition of version 02.04.00Section 6.1: added format changes with version 02.04.00	2	2	20/07/2022

1 Summary

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

Product Identifier: **L2__AER_AI**

Example filename:

S5P_NRTI_L2__AER_AI_20210908T002709_20210908T003209_20226_02_020200_20210908T012955.nc
S5P_OFFL_L2__AER_AI_20210908T001010_20210908T015140_20226_02_020200_20210909T135904.nc

The OFFL data product has the following Digital Object Identifier (DOI): <http://doi.org/10.5270/S5P-3dgz66p>

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_index_340_380` and `aerosol_index_354_388` which gives the UVAI calculated for two different wavelength pairs. Since version 2.4.0 of the processor, a new wavelength pair using 335 and 367 nm to perform an aerosol index calculation has been added to the processor (`aerosol_index_335_367`). This is in preparation for the Sentinel 5 mission which will include the same analysis. As a user guideline for the data quality a `qa_value` is given. In order to avoid the effects of sun glint it is recommended to only use those pixels with a `qa_value` above 0.8.

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

Independent validation by MPC Cal/Val experts and the Sentinel-5 Precursor Validation Team (S5PVT) concludes that the NRTI and OFFL UVAI are in good overall agreement with similar satellite data products from OMI and OMPS. A bias of just under 1 UVAI index point was found as compared to OMI and OMPS that is within the ESA mission requirements (see Table 1). However, starting in 2019 due to the wavelength dependent degradation in the diffuser affecting Band 3, the bias observed with version 1.4.0 was slightly larger than 1 UVAI index point as compared to OMI and OMPS (See Section 4). With version 2.2.0, the L1b was updated and the UVAI offsets were applied so that the UVAI is now within data product requirements. The standard deviation of the TROPOMI UVAI is similar as for the OMPS LER product. Thus, it is concluded that the TROPOMI product is within the limit for the random requirement of 0.1 UVAI units.

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.

The data product requirements are listed in the S5P Calibration and Validation Plan [RD01]

Parameter	Data product	Vertical Resolution	Bias	Random
Aerosol	Aerosol type	Total column	~1 AAI	<0.1 AAI

Table 1: Mission data requirements for the UVAI product, extracted from [RD01]

2 Processing baseline description

Table 2 contains the history of the UVAI processor versions. Version changes reflect updates in the data processor software only. Note that the processor version for UVAI is changing when there is a change to any of the products belonging to the NL-L2 processor suite (NO2, CO, CH4, UVAI, ALH, O3 PR) even if the change is not affecting the UVAI product.

Processor Version	In operation starting from	In operation until	Relevant Improvements
02.04.00	NRTI: orbit 24697, 2022-07-20 OFFL: orbit 24655, 2022-07-17	Current version	A new wavelength pair using 335 and 367 nm to perform an aerosol index calculation has been added to the processor (see section 6.1). This is in preparation for the Sentinel 5 mission which will include the same analysis. Note: Starting from processor version 2.4.0, new improved Level 1b version 2.1 data products are used as input [RD04].
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 (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	AAI offset correction added, for both pairs separately. The biggest change for AAI comes from the impact of the updated V2.0 L1b (switched into operations at the same time), as it includes a degradation correction in the irradiance. Note: Starting from processor version 2.2.0, new improved Level 1b version 2.0 data products are used as input [RD04].
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	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 7519, 2019-03-27 OFFL: orbit 7425, 2019-03-20	Orbit 7999, 2019-04-30 Orbit 7906, 2019-04-23	Added new variables: <code>eastward_wind</code> and <code>northward_wind</code> (see section 6.1)
01.02.02	NRTI: orbit 5932, 2018-12-05 OFFL: orbit 5833, 2018-11-28	Orbit 7518, 2019-03-27 Orbit 7424, 2019-03-20	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	Adjusted <code>qa_value</code> in case of eclipse

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	No changes with respect to previous version
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 UVAI processor versions

3 Product Quality

3.1 Recommendations for data usage

In order to avoid misinterpretation of the data quality and to avoid the effects of sun glint, it is recommended to only use those TROPOMI pixels associated with a `qa_value` above 0.8.

The variable(s) `aerosol_index_340_380_precision` can be used to diagnose the quality of the UVAI (where, this variable is available for all three wavelength pairs in the format `aerosol_index_3xx_3xx_precision`).

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

The S5P UV Aerosol Absorbing Index data is in good overall agreement with similar satellite data products from EOS-Aura OMI and Suomi-NPP OMPS. Although compliant with the mission requirement of 1 UVAI unit in 2018, the bias observed with version 1.4.0 was larger than 1 UVAI unit as compared to OMI and OMPS until version 2.2.0 when the L1b processor was updated and the UVAI offsets were applied. The UVAI is now within data product requirements.

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.

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 looking at the UV Aerosol Index products and also at preliminary validation results.

Bias as compared to other satellite datasets

The aerosol index is highly sensitive to the calibration of absolute irradiance and radiance and any small deviations in the Level 1B input data. As a result of observed wavelength-dependent degradation in both the irradiance and the radiance (degradation stronger at shorter wavelengths), there was an apparent increase of the reflectance at the shortest wavelength and therefore the aerosol index was exhibiting a large, increasing negative bias. With the V2.0 L1b update this negative bias has been removed, but a positive offset was introduced. As a result, offsets have been applied to the pairs so that the global mean is closer to other aerosol index measurements from other satellite missions including OMI and OMPS. The offset factors applied to the aerosol index will continue to be optimized as the L1b data is further updated to include correction for degradation in the radiance.

Since the degradation is wavelength dependent, the various UVAI pairs react differently, where the shorter wavelength exhibits a larger effect. As such, offset values unique to each pair have been applied. With the application of the fully updated L1b and the reprocessed dataset, these offset values will be re-evaluated and updated as needed

Large negative and positive values for clouds

Large negative and positive values related to clouds can be seen at higher latitudes. These appear to be related to cloud 3D effects and cloud shadows. Investigation is ongoing.

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 mid-July 2018 (see Table 2).

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

Note that 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, which is removed with the activation of processor version 01.02.02 (see Table 2).

Metadata values exchanged (solved)

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 on July 2021.

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 02.02.00 on July 2021.

Precision calculation (solved in version 02.03.01)

The calculation of the precision of the aerosol index parameters – a propagation of the random noise in the input radiance and irradiance – contained an error in the use of parentheses. The result of this was

a severe overestimation of the error. Note that the offsets mentioned in the known data quality issues are not covered by this precision estimate, this is *only* a propagation of the noise error in the L1b.

Geolocation co-added when they should not be (solved in 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.

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

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

6.1.1 Version 02.04.00

New fields added

```
/PRODUCT/aerosol_index_335_367  
/PRODUCT/aerosol_index_335_367_precision  
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/scene_albedo_367  
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/scene_albedo_367_precision  
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/reflectance_measured_335  
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/reflectance_measured_335_precision  
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/reflectance_measured_367  
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/reflectance_measured_367_precision  
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/reflectance_calculated_335  
/PRODUCT/SUPPORT_DATA/DETAILED_RESULTS/reflectance_calculated_335_precision  
/METADATA/QA_STATISTICS/aerosol_index_335_367_histogram_axis (dimension)  
/METADATA/QA_STATISTICS/aerosol_index_335_367_pdf_axis (dimension)  
/METADATA/QA_STATISTICS/aerosol_index_335_367_histogram_axis  
/METADATA/QA_STATISTICS/aerosol_index_335_367_pdf_axis  
/METADATA/QA_STATISTICS/aerosol_index_335_367_histogram_bounds  
/METADATA/QA_STATISTICS/aerosol_index_335_367_pdf_bounds  
/METADATA/QA_STATISTICS/aerosol_index_335_367_histogram  
/METADATA/QA_STATISTICS/aerosol_index_335_367_pdf  
/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**]

6.1.2 Version 02.03.01

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')
```

6.1.3 Version 02.02.00

New fields added

/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

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

6.1.4 Version 01.04.00

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

6.1.5 Version 01.03.00

New fields added

/PRODUCT/SUPPORT_DATA/INPUT_DATA/eastward_wind

/PRODUCT/SUPPORT_DATA/INPUT_DATA/northward_wind

7 Product Availability

All S5P/TROPOMI data are available on the Copernicus Open Data Hub <https://scihub.copernicus.eu>.

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.

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 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 UV Aerosol Index
source: KNMI; **ref:** S5P-KNMI-L2-0008-RP;
url: <https://sentinels.copernicus.eu/documents/247904/2476257/Sentinel-5P-TROPOMI-ATBD-UV-Aerosol-Index>
- [RD03] Sentinel-5 precursor/TROPOMI Level 2 Product User Manual UV Aerosol Index
source: KNMI; **ref:** S5P-KNMI-L2-0026-MA;
url: <https://sentinels.copernicus.eu/documents/247904/2474726/Sentinel-5P-Level-2-Product-User-Manual-Aerosol-Index-product>
- [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>

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
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
ESA	European Space Agency
ESL	Expert Support Laboratory
KNMI	Royal Netherlands Meteorological Institute / Koninklijk Nederlands Meteorologisch Instituut
LER	Lambertian-Equivalent Reflectivity
MPC	Mission Performance Centre
MPIC	Max Planck Institut für Chemie
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 Reports
S5P	Sentinel-5 Precursor
S5PVT	Sentinel-5 Precursor Validation Team
TROPOMI	Tropospheric Monitoring Instrument
UVAI	UV Aerosol Index
VDAF	Validation Data Analysis Facility