

Sentinel-5 Precursor Level 2 UPAS Processor

Input / Output Definition Document

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Class A**



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CHANGE RECORD

Issue	Date	Chapter	Change
0.1	2012-09-18	All	Completely new
0.2	2012-11-23	All	Entire document revised
0.3	2012-12-20	All	Entire document revised based on L1 input data information provided by KNMI in December 2012
0.4	2013-03-29	a) All, especially Chapter 2 b) Sec. 2.2.3 updated	a) Document revised according to SRR/PDR review of February 2013. b) Auxiliary data in Sec. 2.2.3 updated following S5P GS-PDR ERID - Actions 34483 and 35403
0.5/0.5.1	2013-07-12	a) Chapter 2 updated according to RIDs with reference L2IO_D-HN-03 and L2IO_D-HN-04 b) Chapter 3 c) All	a) Added specific information concerning I/O data required by different modalities (Near Real Time, Offline) as well as detailed workflows. b) Chapter changed based on newest information about L1b input product and PDGS JobOrder file. In addition, further information about L2 data and logging syntax have been provided. c) Document revised.
0.5.2	2013-11-20	Chapter 2.10.1 (L2 structure) and 2.10.1.1 (Metadata)	Highlight that the L2 netCDF-4 structure and metadata is being jointly defined between KNMI and DLR.
0.6.0	2013-12-13	All	Document updated accordingly to the latest versions of the documentations in the S5P framework.
0.6.1	2014-01-24	All	Redefinition of L3 product
1.0.0	2014-05-12	a) Chapter 2.9.3.2 (TM5) b) Chapter 2.10 (L2 Output) c) Chapter 1.3 (References) d) Table 2-4 (Aux) e) Figure 10 f) All	a) Added more technical details on TM5 model b) Removed sections of L2 Metadata and L2 output structure c) References updated d) Table of auxiliary inputs restructured e) Redrawn UPAS-L2 NRTI/OFFL diagrams f) Document entirely revised based on an informal review from Sneep (KNMI)
1.2.0	2014-10-14	a) All b) AUX data sections 2.9.3.1 and 2.9.3.2 c) Sections 1.3.2 and 2.10.1 d) Added section e) Sec 2.9.3 f) All g) Sec. 2.7.3 and Sec. 3.2.1.19	a) UPAS-L2 processor needs ECMWF auxiliary data according to the last version of the ATBD. Document is then updated with this information. b) Identifiers for AUX data have been harmonized with [AD07] and KNMI IODD. RIDs L2 CDR #3 and #4 solved. c) Precise information about PUMs references has been added. RID L2 CDR #6 solved. d) Added section explaining fall-back strategy in case of missing/corruption of aux dynamic data. RIDs L2 CDR #15 and #2 solved. e) Clarification about functionality in order to have one product at a time. Optimum set of aux data is the one reported. RID L2 CDR #14 and #16 solved. f) L3 O3 tropospheric renamed as L2c product. RID #41769 of GS CDR solved. g) Information about size and validity of background correction added. RIDs #12 and #13 of the L2 CDR solved.
2.0.0	2015-03-09	a) Applicable / Reference documents b) All c) Section ECMWF d) Table 3-2 e) All	a) Updated b) Modes (NRTI, OFFL, RPRO) changed accordingly to the S5p ESA tailoring S5P-TN-ESA-GS-106) c) Added description of ECMWF d) Updated references to L1B data type – Added L2__AER_AI as aux product e) Document revised
3.0.0	2015-12-15	a) All b) Applicable / Reference documents c) Auxiliary data Chapter 2.9.3 d) Intermediate output of upas-l2c Chapter 2.6 e) Intermediate output of upas-bc Chapter 2.7	a) Changes are red marked. b) Updated c) Updated with detailed information about selection rules as described in [AD05] d) Selection rules updated e) Section updated with new flowcharts and selection rules concerning this type of data



		f) Table 2-4 g) Chapter 3 (Detailed I/O) h) Appendix A and D	f) It considers the PDGS scenario g) - L1b information updated - L2 output sizes updated base on the new binning scheme proposed in October 2015 - Sub-section added explaining useful attribute flags added in the L2 product in order to understand which input where available while processing h) Added two new Appendixes containing the main structure of the netCDF-4 files of AUX_BGCHCO and AUX_BGS02_ intermediate outputs
3.0.1	2016-03-31	a) All b) Table 2-4	a) Changes merged b) Table restructured (same content, better readability)
3.1.0	2016-11-15	a) upas-bc Chapter 2.7 b) Appendix A and B	a) Added new interface for upas-bc processor that ingests L1b in order to compute the earthshine spectra. b) Updated with the last file format definition
3.3.0	2017-06-01	a) Applicable / Reference documents b) Chapter 3 (detailed I/O) c) All	a) Updated b) Data size and spec updated with the last version L1B IODD 7.0.0 c) Minor changes
3.6.1	2019-02-20	a) Applicable / Reference documents b) Table 7 c) Chapters 2.6.3, 2.8	a) Added the PDGS Selection rules document to the applicable documents b) Updated the table according to be consistent with the newest PDGS Auxiliary Product Selection Rules c) Updated the selection rules
3.5.0	2019-08-09	Section 2.4.2, Figure 4	Added L2_NP_BD3 and L2_NP_BD6 as inputs in the OFFL processing
3.5.0	2019-08-09	Section 2.6.2, Figure 9 / Figure 10	Added Figures for the background processing of CLOUD and O3 products
3.5.0	2019-08-09	Section 2.6.2	Added a paragraph with the selection rules for the inputs of the UPAS-BC processor for AUX_BGCLD_ and AUX_BGO3_ products
3.5.0	2019-08-09	Section 2.6.4	Added a section for the selection rules of the AUX_BGCLD_ and AUX_BGO3_ products
3.5.0	2019-08-09	Section 2.8.3, Table 7	Added L2_NP_BD3 and L2_NP_BD6 as input for the L2_CLOUD OFFL processing, added AUX_BGCLD and AUX_BGO3_ as input for the L2_CLOUD and L2_O3 (in NRTI and OFFL)
3.5.0	2019-08-09	Section 3.2.2.7	Added a section about the background correction products for L2_CLOUD and L2_O3_
3.5.0	2019-08-09	Section 2.8.3.4	Added section 2.8.3 for the regridded VIIRS data (L2_NP_BD3 and L2_NP_BD6) as input data for the cloud processing in OFFL mode
3.5.0	2019-08-09	Section 3.1	Added NPP-VIIRS data and the AUX_BGCLD_ and AUX_BGO3_ data to the list of I/O files employed
3.5.0	2019-08-09	Appendix	Added the format of the AUX_BGCLD_ and AUX_BGO3_ files
3.6.0	2020-04-08	Section 2.6.1, Section 2.6.2	Revised the sections for the NRTI and OFFL background corrections – added background correction for CLOUD and O3 in NRTI mode
3.6.0	2020-04-08	Section 2.6.1	Added figures 7 and 8 illustrating the background correction for CLOUD and O3 in NRTI modality
3.6.0	2020-04-08	Section 2.6.2	Rearranged the order of figures
3.6.0	2020-04-08	Section 2.8.3, Table 7	Defined L2_NP_BD3 and L2_NP_BD6 as optional for L2 CLOUD OFFL and also added it as optional input for L2 CLOUD NRTI
3.6.0	2020-04-08	Appendix A, Appendix B	Updated the file format information of the AUX_BGCLD_ and AUX_BGO3_ files
3.6.0	2020-04-08	Section 2	Replaced Figure 1 – now also with the L2_NP_BDx inputs
3.6.0	2020-04-08	Section 2.6.4	Rewrote this paragraph to reflect the fact that there is now a strict distinction between NRTI and OFFL regarding the background correction for CLOUD and O3 and that in the OFFL case the background correction is only available for the CLOUD product
3.6.0	2020-04-08	Section 2.6	Added Table 2-1 and Table 2-2 to summarize the inputs and selection rules regarding the background correction products
3.6.1	2020-06-18	Section 2.6	Updated Table 2-2 selection rules
3.6.1	2020-06-18	Section 2.6.1, Section 2.6.2	Added references to Table 2-1
3.6.1	2020-06-18	Section 2.6.3, Section 2.6.4	Added references to Table 2-2, clarified that these sections refer to



			inputs for the upas-l2 processor – not to the inputs for the upas-bc processor
3.6.1	2020-06-18	Section 2.6.3	Removed mentions of optional to be consistent with Table 2-4.
3.6.2	2020-07-14	Table 2-1, Table 2-2	Updated selection rules in Table 2-1 and improved the structure of both tables
3.6.2	2020-07-14	Section 2.6.3	Merged the content of section 2.6.4 to this section
3.6.2	2020-07-14	Appendix	Updated the file format information of the AUX_BGCLD_, AUX_BGO3_, AUX_BGHCHO and AUX_BGSO2_ files and changed the titles of the appendix sections
3.6.2	2020-07-14	Section 2.4	Added a section that briefly describes the used selection rules
3.6.2	2020-07-14	Section 3.2.19	Mentioned the placement of the "Status_reference_spectrum" flag in the HCHO and SO2 level-2 products





TABLE OF CONTENTS

Table of Signatures	3
1. Introduction	13
1.1 Purpose	13
1.2 Scope	13
1.3 References	13
1.3.1 Applicable Documents	13
1.3.2 Reference Documents	13
1.3.3 Electronic references	14
1.4 Terms and Abbreviations	15
1.4.1 Terms	15
1.4.2 Abbreviations	15
1.5 Document Overview	15
2. S5P UPAS processor overview.....	16
2.1 High-level overview of S5P UPAS processor	16
2.2 S5P UPAS processor architecture and modes	16
2.3 Principal blocks involved in S5P UPAS processor	17
2.4 Selection Rules	17
2.5 upas-l2: I/O and modalities	18
2.5.1 NRTI.....	18
2.5.2 OFFL/RPRO	18
2.6 upas-l2c: I/O and modalities.....	19
2.6.1 NRTI.....	19
2.6.2 OFFL/RPRO	19
2.7 upas-bc: I/O and modalities	20
2.7.1 NRTI.....	20
2.7.2 OFFL/RPRO	21
2.7.3 Selection rules of the Intermediate Output (AUX_BGCLD_, AUX_BGO3_, AUX_BGHCHO, AUX_BGSO2_).....	22
2.8 UpasPsmAdapter: Workflow and role	23
2.8.1 Testing modality	24
2.8.2 Multi-Core scheme.....	24
2.9 Input Data.....	24
2.9.1 L1b Product.....	24
2.9.2 Input Configurations.....	24
2.9.2.1 PDGS Configuration	25
2.9.2.2 UPAS Internal Configuration	25
2.9.2.3 UPAS static data.....	25
2.9.3 Auxiliary Data.....	25
2.9.3.1 Snow/Ice Data (AUX_NISE_)	26
2.9.3.2 Chemistry Transport Model (AUX_CTMFCT and AUX_CTMANA)	27
2.9.3.3 ECMWF meteo file (AUX_MET_TP, AUX_MET_QP, AUX_MET_2D)	29
2.9.3.4 Regridded VIIRS data (L2_NP_BD3, L2_NP_BD6).....	29
2.9.4 Fall-back solutions	30
2.10 Output Data	30
2.10.1 L2 Products.....	30
2.10.1.1 L2 Metadata.....	31
2.10.2 Logging Messages.....	31
2.10.3 Exit Code	31
3. Detailed I/O Data Format.....	32
3.1 List of I/O Files Employed	32



3.2	File Definition	33
3.2.1	Input Files	35
3.2.1.1	PDGS Configuration	35
3.2.1.2	L1b Irradiance Product UVN (L1B_IR_UVN)	36
3.2.1.3	L1b Radiance Product UV band 1 [270-300 nm] (L1B_RA_BD1)	37
3.2.1.4	L1b Radiance Product UV band 2 [300-320 nm] (L1B_RA_BD2)	38
3.2.1.5	L1b Radiance Product UVIS band 3 [310-405 nm] (L1B_RA_BD3)	39
3.2.1.6	L1b Radiance Product UVIS band 4 [405-500 nm] (L1B_RA_BD4)	40
3.2.1.7	L1b Radiance Product NIR band 5 [675-725 nm] (L1B_RA_BD5)	41
3.2.1.8	L1b Radiance Product NIR band 6 [725-775 nm] (L1B_RA_BD6)	42
3.2.1.9	Snow/Ice Data (AUX_NISE__)	43
3.2.1.10	TM5 Model Data (AUX_CTMECT and AUX_CTMANA)	44
3.2.1.11	ECMWF forecast data (AUX_MET_2D, AUX_MET_TP, AUX_MET_QP)	45
3.2.1.12	Aerosol Index (L2__AER_AI)	46
3.2.1.13	Aerosol Index (L2__NP_BD3, L2__NP_BD6)	46
	Output Files	48
3.2.1.14	L2 O ₃ total column (L2__O3__)	48
3.2.1.15	L2c O ₃ tropospheric column (L2__O3_TCL)	49
3.2.1.16	L2 SO ₂ (L2__SO2__)	50
3.2.1.17	L2 HCHO (L2__HCHO__)	51
3.2.1.18	L2 Clouds (L2__CLOUD_)	52
3.2.1.19	Background Correction (AUX_BGSO2_ and AUX_BGHCHO)	53
3.2.1.20	Background Correction (AUX_BGCLD and AUX_BGO3__)	54
3.2.1.21	Logging Messages	55
A.	Appendix – AUX_BGCLD_ structure	57
B.	Appendix – AUX_BGO3_ structure	64
C.	Appendix – AUX_BGHCHO structure	74
D.	Appendix – AUX_BGSO2_ structure	84

LIST OF FIGURES

Figure 1: Schema of I/O files and different modes of S5P UPAS processor	16
Figure 2: The four principal blocks belonging to S5P UPAS system	17
Figure 3: upas-l2 processor working in NRTI modality.	18
Figure 4: upas-l2 processor working in OFFL modality.	19
Figure 5: upas-l2c processor working in NRTI modality.	19
Figure 6: upas-l2c processor working in OFFL/RPRO modalities.	20
Figure 7: upas-bc processor working in NRTI modality for CLOUD case.	20
Figure 8: upas-bc processor working in NRTI modality for O ₃ case	21
Figure 9: upas-bc processor working in NRTI modality for SO ₂ case	21
Figure 10: upas-bc processor working in NRTI modality for HCHO case.	21
Figure 11: upas-bc processor working in OFFL modality for CLOUD case.	21
Figure 12: upas-bc processor working in OFFL modality for SO ₂ case.	22
Figure 13: upas-bc processor working in OFFL modality for HCHO case	22
Figure 14: UpasPsmAdapter processor	23

LIST OF TABLES

Table 1-1: Applicable Documents	13
Table 1-2: Reference Documents	14
Table 1-3: Electronic references	14
Table 1-4: Terms	15
Table 1-5: Abbreviations	15
Table 2-1: Inputs and selection rules for the products of the upas-bc processor	22
Table 2-2: Selection rules for the auxiliary background correction products inputs of the upas-l2 processor	23
Table 2-3: Spectral bands, spectral range and relative products of TROPOMI instrument.	24
Table 2-4: L2 products and their respective input data.	26
Table 2-5: File name conventions of NISE ancillary data.	27
Table 2-6: File name conventions of TM5 ancillary data.	28
Table 2-7: TM5 Data Volume	28
Table 2-8: ECMWF Data Volume after the conversion to netCDF-4	29
Table 3-1: Involved I/O files of the processor.	33
Table 3-2: Schema of I/O files and different modes of S5P UPAS L2 processor	56





1. Introduction

1.1 Purpose

The purpose of the Input / Output Data Definition document (IODD) is to provide a precise description of the input and output files as used and generated by the L2 UPAS processor for the Sentinel-5 Precursor.

1.2 Scope

This document is part of the Sentinel-5 Precursor L2 Project. The sections presented here describe the S5P Level 1 and auxiliary (input data) as well as the S5P Level 2 (output data) products that are employed and generated by the UPAS processor, respectively. The descriptions of the algorithms used to generate the output products (i.e., O₃ total column, O₃ tropospheric column, SO₂, HCHO, Clouds) are addressed in the corresponding ATBD document.

1.3 References

1.3.1 Applicable Documents

The following project documents contain provisions which, through reference in this text, become applicable to the extent specified in this document.

Document Title	Document ID	Issue	Date
[AD01] Sentinel-5 Precursor L2 Processor Software System Requirements	S5P-L2-DLR-SSR-3001	1.2	2015-11-30
[AD02] Input output data specification for TROPOMI L01b data processor	S5P-KNMI-L01B-0012-SD	7.0.0	2016-09-30
[AD03] S5P Level 2 Processor Development – Statement of Work	S5P-SW-ESA-GS-053	1.0	2012-03-02
[AD04] EO Ground Segment File Format Standard	PE-TN-ESA-GS-001	2.0	2012-05-03
[AD05] Generic IPF Interface Specification	MMFI-GSEG-EOPG-TN-07-0003	1.8	2009-08-03
[AD06] GS Requirements Document	S5P-RS-ESA-GS-092	1.0	2013-02-18
[AD07] Tailoring of the Earth Observation File Format Standard for the Sentinel 5-Precursor Ground Segment	S5P-TN-ESA-GS-106	2.2	2015-02-20
[AD08] Sentinel-5 Precursor L2 UPAS Processor – Software User Manual	S5P-L2-DLR-SUM-3005	00.11.00	2016-11-15
[AD09] Sentinel-5 Precursor L2 UPAS Processor – External ICD	S5P-L2-DLR-ICD-3003	1.0.0	2017-06-01
[AD10] Sentinel-5 Precursor PDGS – Revision of PDGS Auxiliary Product Selection Rules	S5P-PDGS-DLR-TEC-3304	1.6.1	2019-05-23
[AD11] Sentinel-5 Precursor PDGS Processor Generic ICD	S5P-PDGS-DLR-ICD-3015	1.0dr2	2014-07-31
[AD12] ESA Standard document	MMFIGSEG-EOPG-TN-07-0003	1.0	2007-05-02

Table 1-1: Applicable Documents

1.3.2 Reference Documents

The following standards or documents are referenced in this document. They have been used (in the sense of tailoring) to prepare the document on hand. Documents which are recognised best practices may be listed for the purpose of information.

Title	Document ID/Reference	Issue	Date
[RD01] Sentinel-5P Level 2 Processor Requirements Specifications	S5P-RS-ESA-GS-054	1.0	2012-03-02
[RD02] Sentinel-5 Precursor L2 UPAS Processor – Software Development Plan	S5P-L2-DLR-SDP-1007	1.0	2012-08-13
[RD03] Sentinel-5 Precursor PDGS – System Requirement	S5P-PDGS-DLR-RSP-3001	1.4	2014-01-28



Title	Document ID/Reference	Issue	Date
Document			
[RD04] Sentinel 5-precursor/TROPOMI KNMI and SRON L2 Input Output Data Definition	S5P-KNMI-L2-0009-SD	4.0	2015-10-30
[RD05] S5P/TROPOMI Static input for L2 processors	S5P-KNMI-L2CO-0004-SD	3.1	2016-03-21
[RD06] S5P PDGS TM5 Auxiliary Data Provider ICD	S5P-PDGS-DLR-ICD-3026	1.0	2014-07-30
[RD07] S5P PDGS NISE Auxiliary Data Provider ICD	S5P-PDGS-DLR-ICD-3027	1.0	2014-07-30
[RD08] S5P PDGS ECMWF Auxiliary Data Provider ICD	S5P-PDGS-DLR-ICD-3019	1.0	2015-02-25
[RD09] ISO Geographic information – Metadata.	ISO 19115:2003(E)	1.0	2003-05-01
[RD10] ISO Geographic information – Metadata – Part 2: Extensions for imagery and gridded data.	ISO 19115-2:2009(E)	1.0	2009-02-12
[RD11] ISO Geographic information – Data quality	ISO 19157	1.0	2013-10-10
[RD12] Earth Observation Metadata profile of Observations & Measurements.	Open Geospatial Consortium - OGC 10-157r3	1.0	2012-06-12
[RD13] S5p L2 Product User Manual – Ozone Total Column	S5P-L2-DLR-PUM-400A	00.11.04	2017-06-01
[RD14] S5p L2 Product User Manual – Clouds	S5P-L2-DLR-PUM-400I	00.11.04	2017-06-01
[RD15] S5p L2 Product User Manual – Ozone Tropospheric Column	S5P-L2-DLR-PUM-400C	00.11.04	2017-06-01
[RD16] S5p L2 Product User Manual – HCHO	S5P-L2-DLR-PUM-400F	00.11.04	2017-06-01
[RD17] S5p L2 Product User Manual – SO2	S5P-L2-DLR-PUM-400E	00.11.04	2017-06-01
[RD18] S5p L2 File Format Guidelines	S5P-KNMI-L2CO-0005-TN	0.0.5	2015-12-18

Table 1-2: Reference Documents

1.3.3 Electronic references

The following electronic links are referenced in this document.

Page	Title	URL	Date visited
[ER01]	Near-Real-Time SSM/I-SSMIS EASE-Grid Daily Global Ice Concentration and Snow Extent	http://nsidc.org/data/nise1.html	2013-03-29
[ER02]	The Transport-Chemistry model TM5	http://www.projects.science.uu.nl/tm5/	2013-03-29
[ER03]	Unidata – NetCDF library and documentation	http://www.unidata.ucar.edu/software/netcdf/	2013-04-19
[ER04]	Brian Eaton, Jonathan Gregory, Bob Drach et al., NetCDF Climate and Forecast (CF) Metadata conventions - Version 1.6	http://cfconventions.org	2014-05-13
[ER05]	BUFR format	http://www.ecmwf.int/products/data/software/bufr.html	2013-04-19
[ER06]	Infrastructure for Spatial Information in the European Community (INSPIRE) Directive 2007/2/EC	http://inspire.jrc.ec.europa.eu	2013-04-19
[ER07]	NetCDF Users Guide (2011)	http://www.unidata.ucar.edu/software/netcdf/docs/netcdf.html	2013-04-19
[ER08]	ECMWF forecast data	http://www.ecmwf.int	2014-10-01

Table 1-3: Electronic references



1.4 Terms and Abbreviations

1.4.1 Terms

As far as possible the technical terms used in reference documents have been reused. It is assumed that the reader is familiar with the technical terms used in the domain of EO missions and payload data ground segments. Terms with potentially ambiguous meaning are defined here with their meaning applied in the scope of this document.

Term	Definition
TBA	to be added in agreement with the European Space Agency (ESA)
TBC	to be confirmed in agreement with the European Space Agency (ESA)
TBD	to be defined in agreement with the European Space Agency (ESA)

Table 1-4: Terms

1.4.2 Abbreviations

Abbreviations used in this document are listed next.

Abbreviation	Meaning
DLR	Deutsches Zentrum für Luft- und Raumfahrt
ECMWF	European Centre for Medium-Range Weather Forecasts
EOC	Earth Observation Center
ESA	European Space Agency
GS	Ground Segment
KNMI	Koninklijk Nederlands Meteorologisch Instituut
I/O	Input / Output
IODD	Input / Output Data Definition
L0	Level 0 Product
L1b	Level 1 b Product
L2	Level 2 Product
NRTI	Near Real Time
OFFL	Offline
PDGS	Payload Data Ground Segment
RPRO	Reprocessing
S5P	Sentinel-5 Precursor
SW	Software
UPAS	Universal Processor for UV/VIS Atmospheric Spectrometers
XML	Extensible Markup Language

Table 1-5: Abbreviations

1.5 Document Overview

The document is organized as follows: Chapter 1 outlines the purpose of this document and lists the references that have been used for creating this document. Chapter 2 then gives an overview about the involved input/output data as well as a high-level description of the S5P UPAS architecture. Afterwards, the I/O data formats and definition for each I/O file are presented in greater detail in Chapter 3.

2. S5P UPAS processor overview

This chapter gives an overview of all the involved I/O files accounted from the processor and aims to show specific workflows of S5P UPAS processor for different modalities and purposes. High level structure of S5P UPAS processor is dealt in Section 2.1. Architecture and modality of S5P UPAS processor are shown in Section 2.2. Specific workflows concerning different modalities are rather addressed in Sections 2.4, 2.6 and 2.7.

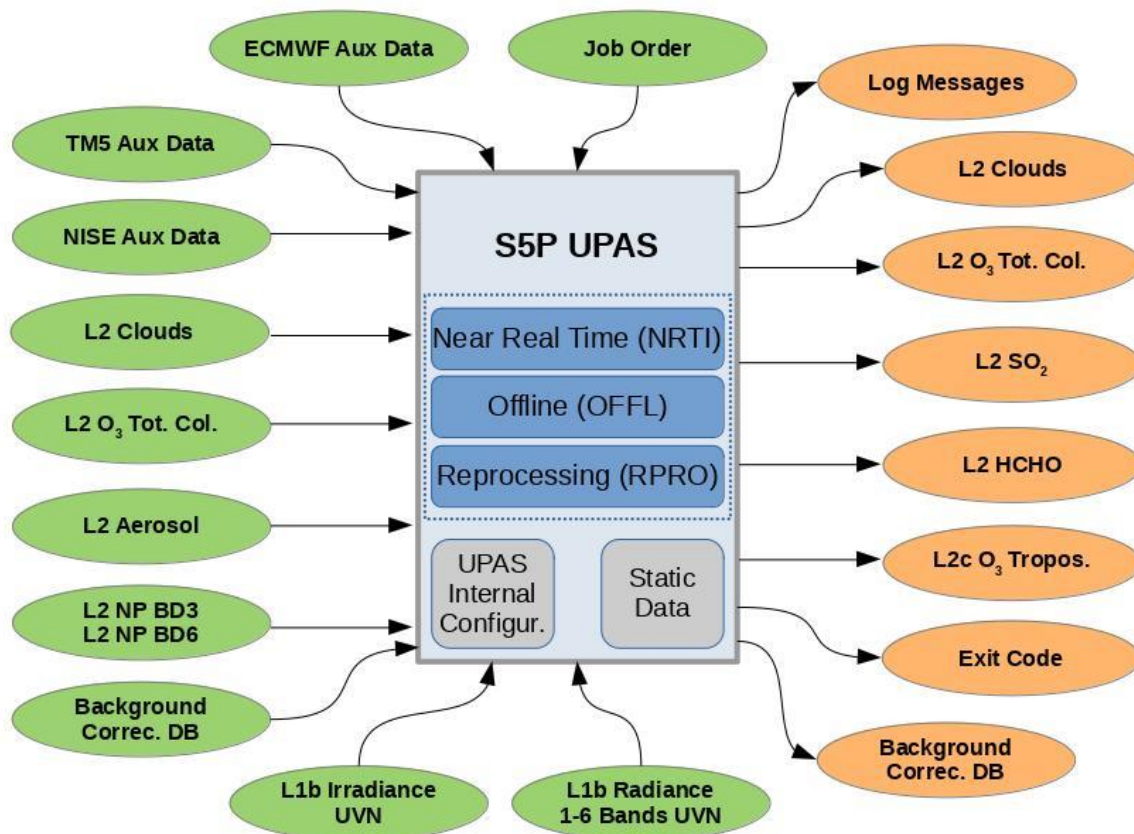


Figure 1: Schema of I/O files and different modes of S5P UPAS processor

2.1 High-level overview of S5P UPAS processor

Figure 1 shows the architecture of S5P UPAS processor concerning its different modalities and the involved I/O files. It is a high-level workflow very general that helps to understand what might be the inputs (green blobs) and the outputs (orange blobs) of the S5P UPAS drawn in the middle of the chart. The modalities the processor can adapt are labelled in dark blue and they are discussed further in the next sections. Internal configuration and static data (such as cross-sections used etc.) take place internally of the S5P UPAS processor.

2.2 S5P UPAS processor architecture and modes

S5P UPAS processor shall work in three different operational modes, i.e.:

1. NRTI Processing (NRTI)
2. Offline Processing (OFFL)
3. Reprocessing (RPRO)

Regarding the NRTI Processing, the L2 NRTI products are derived from the L1b NRTI products. A pipeline strategy processing is implemented in order to speed up the processing system (see Section 2.3.2 in [RD01]). The L0 product is divided in small data units which are sent in the processing and disseminating chain: in this way the L0, L1 and L2 processors can start to work in parallel maximizing the efficiency of the process.

Concerning the OFFL mode, the processor generates L2 OFFL product based on the consolidated L1b orbit products.

Finally, Reprocessing modality (RPRO) works as the same as OFFL mode, but it affects the whole data available since the S5P mission had started. The purpose of this task is to reprocess all the acquired orbits with the more updated version of S5P UPAS processor, L1b products and auxiliary data. The RPRO mode is designed with the aim of maximizing the total throughput.

Furthermore, the processor can ingest both full orbits and slices as indicated by the PDGS configuration.

It is worth noting that the scheme given in Figure 1 is a very high-level architecture aiming at showing independently from the operational modalities what S5P UPAS ingests as inputs and which outputs returns. Detailed workflows are given in the following sections of the document.

2.3 Principal blocks involved in S5P UPAS processor

The entire system might be divided in four most relevant modules as Figure 2 shows. The following bullets list gives explanation of role and goal of each block.

- upas-l2: It is the core of the S5P UPAS system since it is responsible to generate S5P L2 products, i.e., O₃ total column, SO₂, HCHO, Clouds. Specific workflows for OFFL/NRTI modalities accounting I/O data involved are extensively explained in Section 2.4.
- upas-l2c: It generates daily a global coverage of O₃ tropospheric column. Specific workflows for OFFL/NRTI modalities accounting I/O data involved are extensively explained in Section 2.6.
- upas-bc: It computes daily intermediate output as background correction used for L2 CLOUD, L2 O₃, L2 HCHO and L2 SO₂ products. Specific workflows for OFFL/NRTI modalities accounting I/O data involved are extensively explained in Section 2.7.
- UpasPsmAdapter: it is the interface between PDGS and the three blocks previously explained (upas-l2, upas-l2c and upas-bc). Specific workflow is extensively explained in Section 2.8.



Figure 2: The four principal blocks belonging to S5P UPAS system

2.4 Selection Rules

In order to precisely specify the inputs which should be selected for any of the upas processor modules, certain policies defined by the S5P PDGS are used. These are described in [AD10] in more detail. For upas, mainly the “ValIntersect” and “LatestValIntersect” policies are used. Those are described in [AD10] as follows:

ValIntersect: “This mode gets all files that cover partly time interval $[t_0 - \Delta t_0, t_1 + \Delta t_1]$ ”

LatestValIntersect: “This mode gets the latest file that covers partly time interval $[t_0 - \Delta t_0, t_1 + \Delta t_1]$. The latest record is the one with the more recent Generation Date.”

The two parameters Δt_0 and Δt_1 can be specified that enlarge the time interval of the current day (which equals $\Delta t_0 = 0$ and $\Delta t_1 = 0$).

2.5 upas-l2: I/O and modalities

The section leads to `upas-l2` processor and it is divided in two parts based on the modality adapted by S5P UPAS processor, i.e., NRTI and OFFL/RPRO. In each modality the processor may be configured in two ways: First mode, compute internally the Clouds product. Second mode, ingest as input a L2 Clouds already generated before. This makes the system more flexible and it meets every PDGS needs. Specific information about content of NRTI products might be found in each respective ATBD.

2.5.1 NRTI

In Figure 3 the workflow of `upas-l2` working in NRTI mode is reported. Background Correction DB NRTI is computed once a day by `upas-bc` processor. Refer to Section 2.7 for more details concerning this input. L2 Product such as O₃ total column, SO₂ and HCHO need Clouds in order to be generated. This might be done internally or by giving L2 Clouds as input to the processor.

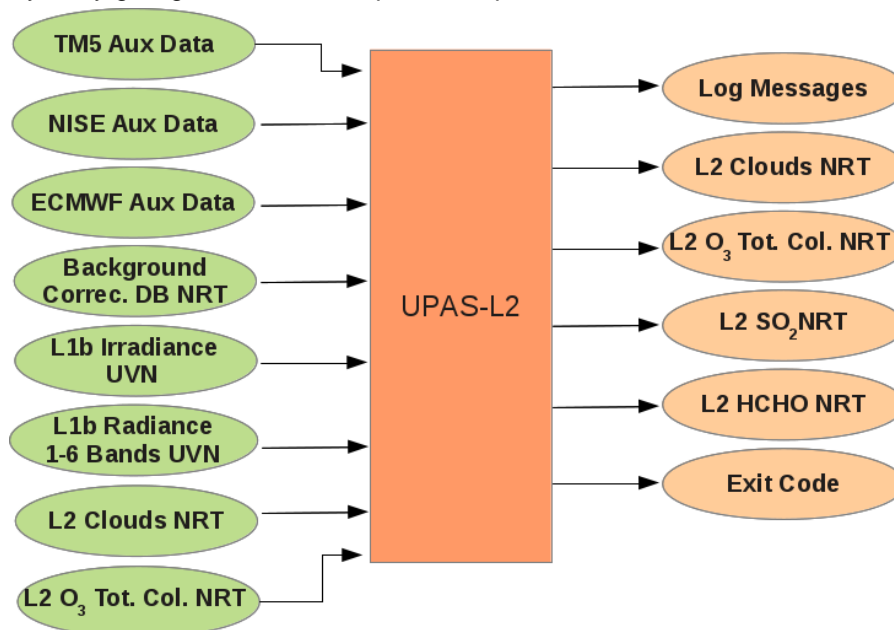


Figure 3: `upas-l2` processor working in NRTI modality.

2.5.2 OFFL/RPRO

The workflow presented in Figure 4 differs from NRTI case in I/O prospective only with the addition of L2 Aerosol Index as auxiliary data used to flag the L2 SO₂ and L2 HCHO products. Beside this, the input such as background correction input data is also an OFFL/RPRO data as better detailed in Section 2.7.

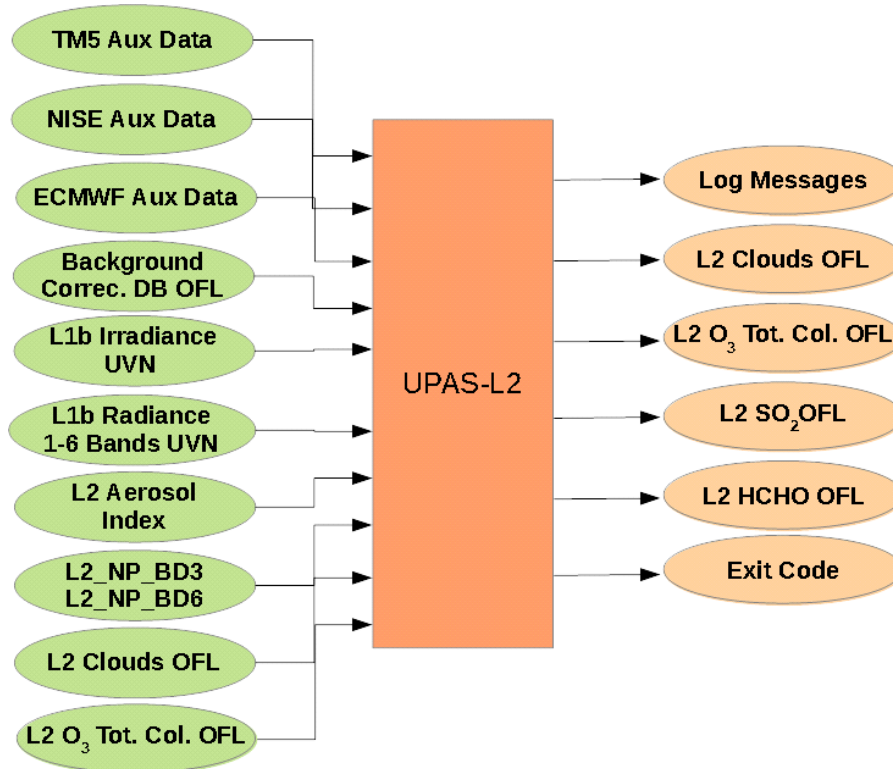


Figure 4: upas-12 processor working in OFFL modality.

2.6 upas-l2c: I/O and modalities

The section leads to upas-12c processor and no differences are reported for NRTI and OFFL/RPRO case concerning I/O data involved but only regarding type of data content.

2.6.1 NRTI

The chart shown in Figure 5 and Figure 6 and represent the I/O data involved for the generation of O₃ tropospheric product. Inputs are a set of L2 O₃ total column products (L2__O3__) covering a certain time windows defined to 6 days in the past, .i.e., “ValIntersect” policy with $\Delta t_0 = 6$ days and $\Delta t_1 = 0$.

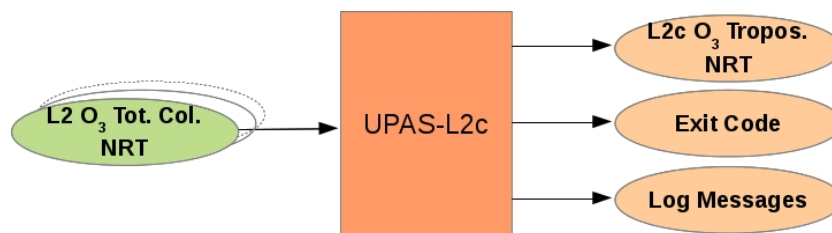


Figure 5: upas-12c processor working in NRTI modality.

2.6.2 OFFL/RPRO

The same assumptions of the NRTI case apply also to the OFFL processing chain.

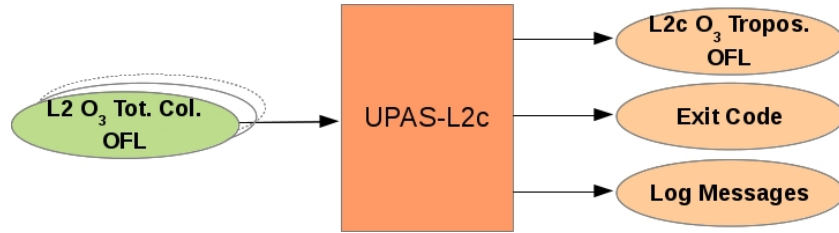


Figure 6: upas-l2c processor working in OFFL/RPRO modalities.

2.7 upas-bc: I/O and modalities

The section leads to upas-bc processor and it describes the inputs and selection rules based on the modality driven by the UpasPsmAdapter, i.e., NRTI and OFFL/RPRO. Finally, also the selection rules for the outputs of the upas-bc processor themselves, which are in turn again used as inputs for the upas-l2 processor, are specified. All this information is summarized in Table 2-1 and Table 2-2.

2.7.1 NRTI

upas-bc computes once a day intermediate output as background correction (AUX_BGCLD_, AUX_BGO3_, AUX_BGHCHO and AUX_BGS02_). A set of L2 CLOUD (L2_CLOUD_), O₃ (L2_O3_), SO₂ (L2_SO2_) and L2 HCHO (L2_HCHO_) data are used as input to the processor in order to generate background correction data for CLOUD, O₃, SO₂ and HCHO products, respectively. (Only for the generation of the AUX_BGO3_ data L2 CLOUD (L2_CLOUD_) data in addition to the L2 O₃ (L2_O3_) data). The generated data is then used for processing the L2 CLOUD, O₃, SO₂ and L2 HCHO product of the next day. The BC product is gridded in a L3 grid and it has global world coverage.

For CLOUD and O₃, a “ValIntersect” policy with $\Delta t_0 = 0.125$ days and $\Delta t_1 = 0$ days is used. This means the data of the last 27h is ingested. This is due to the fact that when the upas-bc is started (usually at midnight), not all level-2 files of the current might have been processed yet. Therefore, three more hours of the previous day are included. Additionally, to the L2 input data, also the latest AUX_BGCLD_ / AUX_BGO3_ files are ingested if they are available. This is done with the “LatestValIntersect” policy with $\Delta t_0 = 28$ days and $\Delta t_1 = 0$.

For SO₂ and HCHO, in the NRTI case, the time window of L2 data needed in order to compute the background correction is set to a coverage of the past 3 days plus the current day i.e. a “ValIntersect” policy with $\Delta t_0 = 3$ days and $\Delta t_1 = 0$. The upas-bc background processor has the option to ingest S5P L1b RA_BD3 data in order to compute earthshine spectrum that will be computed and written in the background correction file. This is an optional modality that it allows upas-l2 to use the earthshine spectra instead of solar spectra while retrieving SO₂ and HCHO L2 products. The area taken into account is currently set as follows:

- HCHO_: -5.0 < latitude < 5.0 ; -180.0 < longitude < -120.0
- SO₂_: -10.0 < latitude < 10.0 ; 160.0 < longitude < -120.0

The described selection rules are listed in Table 2-1.

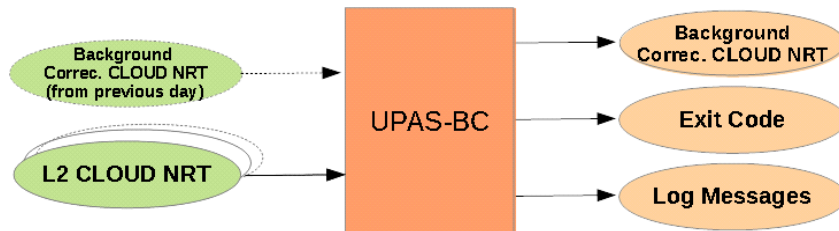


Figure 7: upas-bc processor working in NRTI modality for CLOUD case

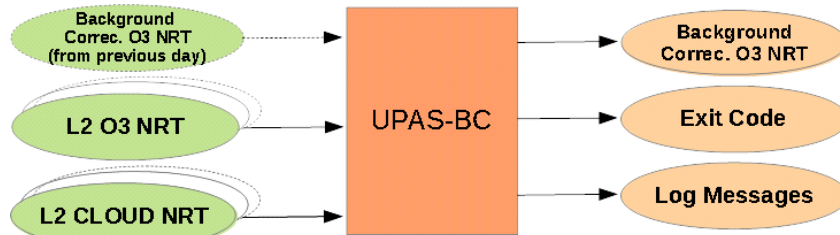
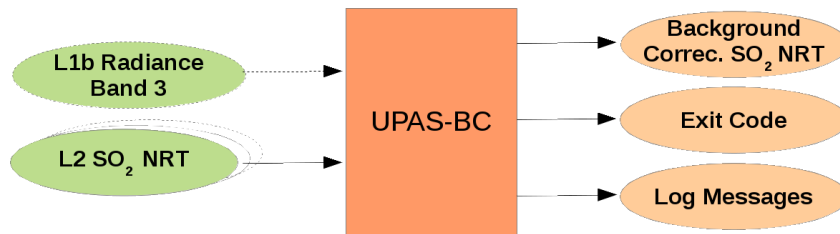
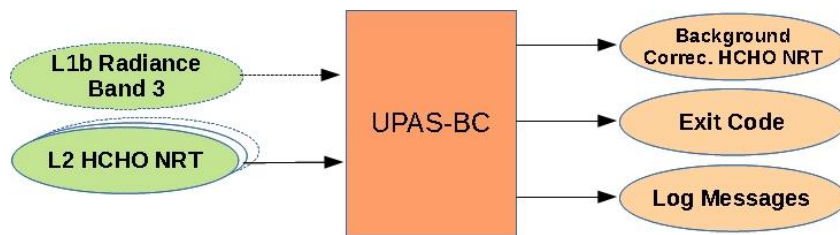

Figure 8: upas-bc processor working in NRTI modality for O₃ case

Figure 9: upas-bc processor working in NRTI modality for SO₂ case


Figure 10: upas-bc processor working in NRTI modality for HCHO case

2.7.2 OFFL/RPRO

In general, the same assumptions of the NRTI case apply also to the OFFL processing chain for the background correction.

For L2 CLOUD the time window of the L2 data is still 1.125 days. Therefore, the selection rule is still the “ValIntersect” policy with $\Delta t_0 = 0.125$ days and $\Delta t_1 = 0$ day.

For L2 SO₂ and L2 HCHO the time window of L2 data is also still 4 days of coverage. This corresponds again to a “ValIntersect” policy with $\Delta t_0 = 3$ days and $\Delta t_1 = 0$ days.

For L2 O₃, the algorithm in the offline case is different to the one in the NRTI case and does not need a background correction at all.

The described selection rules are listed in Table 2-1.

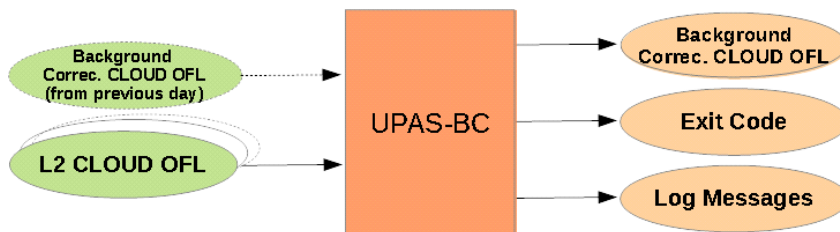


Figure 11: upas-bc processor working in OFFL modality for CLOUD case.

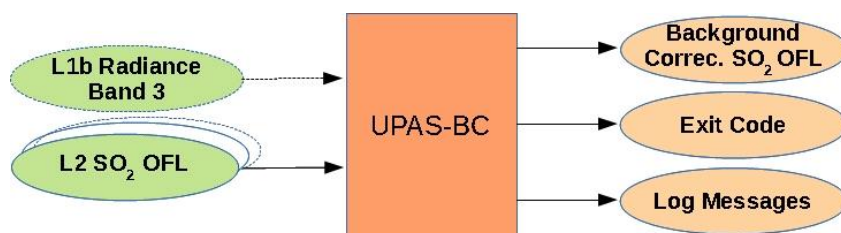
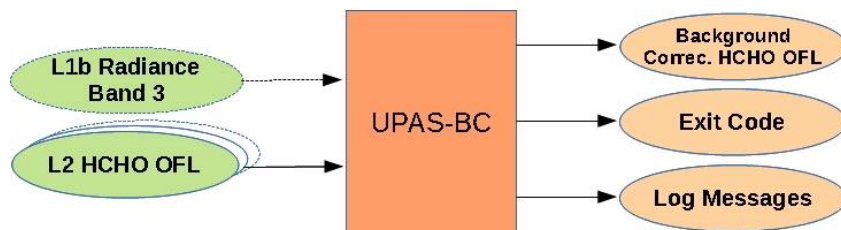

Figure 12: upas-bc processor working in OFFL modality for SO₂ case.


Figure 13: upas-bc processor working in OFFL modality for HCHO case

2.7.3 Selection rules of the Intermediate Output (AUX_BGCLD_, AUX_BGO3_, AUX_BGHCHO, AUX_BGSO2_)

A daily computation of background correction data used for the L2 CLOUD, L2 O₃, L2 HCHO and L2 SO₂ products is performed by the upas-bc processor for both NRTI and OFFL cases. This background correction data is then used by the upas-l2 processor as input. For AUX_BGCLD_ and AUX_BGO3_ the selection is done with the "LatestValIntersect" with $\Delta t_0 = 28$ days and $\Delta t_1 = 0$ in the NRTI processing chain. For the OFFL processing chain, the policy is the same as in NRTI for AUX_BGCLD_ while for L2 O₃ there is no background correction available.

In case of AUX_BGHCHO and AUX_BGSO2_, the used policy is "LatestValIntersect" with $\Delta t_0 = 4$ days and $\Delta t_1 = 0$ days – for both processing chains. These selection rules are also listed in Table 2-2.

Product	Mode	Inputs	Policy	Δt_0	Δt_1	Description
AUX_BGCLD_	NRTI	L2 CLOUD NRTI	ValIntersect	0.125	0	L2 files of current day + 1/8 of previous day
		AUX_BGCLD_NRTI	LatestValIntersect	28	0	Latest AUX_BGCLD_ NRTI file available of last 4 weeks
	OFFL	L2 CLOUD OFFL	ValIntersect	0.125	0	L2 files of current day + 1/8 of previous day
		AUX_BGCLD_OFFL	LatestValIntersect	28	0	Latest AUX_BGCLD_ OFFL file available of last 4 weeks
AUX_BGO3_	NRTI	L2 O3 NRTI	ValIntersect	0.125	0	L2 NRTI files (CLOUD + O3) of current day + 1/8 of previous day
		L2 CLOUD NRTI				
		AUX_BGO3_NRTI	LatestValIntersect	28	0	Latest AUX_BGO3_ NRTI file available of last 4 weeks
	OFFL	n/a				
AUX_BGSO2_	NRTI	L2 SO2 NRTI, L1b RA BD3	ValIntersect	3	0	L2 NRTI and L1 files of the last 4 days
	OFFL	L2 SO2 OFFL, L1b RA BD3	ValIntersect	3	0	L2 OFFL and L1 files of the last 4 days
AUX_BGHCHO	NRTI	L2 HCHO NRTI, L1b RA BD3	ValIntersect	3	0	L2 NRTI and L1 files of the last 4 days
	OFFL	L2 HCHO OFFL, L1b RA BD3	ValIntersect	3	0	L2 OFFL and L1 files of the last 4 days

Table 2-1: Inputs and selection rules for the products of the upas-bc processor

Product	Mode	AUX_BG input	Policy	Δt_0	Δt_1	Description
L2 CLOUD	NRTI	AUX_BGCLD_ NRTI	LatestValIntersect	28	0	Latest AUX_BGCLD_ NRTI file of the last 4 weeks
	OFFL	AUX_BGCLD_ OFFL	LatestValIntersect	28	0	Latest AUX_BGCLD_ OFFL file of the last 4 weeks
L2 O3	NRTI	AUX_BGO3_ NRTI	LatestValIntersect	28	0	Latest AUX_BGO3_ NRTI file of the last 4 weeks
	OFFL	none				
L2 SO2	NRTI	AUX_BGSO2_ NRTI	LatestValIntersect	4	0	Latest AUX_BGSO2 NRTI file of the last 5 days
	OFFL	AUX_BGSO2_ OFFL	LatestValIntersect	4	0	Latest AUX_BGSO2 OFFL file of the last 5 days
L2 HCHO	OFFL	AUX_BGHCHO NRTI	LatestValIntersect	4	0	Latest AUX_BGHCHO NRTI file of the last 5 days
	OFFL	AUX_BGHCHO OFFL	LatestValIntersect	4	0	Latest AUX_BGHCHO OFFL file of the last 5 days

Table 2-2: Selection rules for the auxiliary background correction products inputs of the upas-l2 processor

2.8 UpasPsmAdapter: Workflow and role

UpasPsmAdapter leads to the thin Layer Interface and its structure is addressed in Figure 14. It deals with the `JobOrder` input that has been shown in the high level chart of Figure 1. This is input from PGDS to the UpasPsmAdapter interface: the role of the adapter is to parse, process and forward the configuration and settings embedded in the `JobOrder` file to the respective UPAS processor. When the processing is done, an exit code (EC in the figure) representing the status and a detailed logging file are ingested as input from UpasPsmAdapter processor and forwarded to PDGS. Before this operation, the logging file is sorted out and only `stderr` messages are shown to PDGS side.

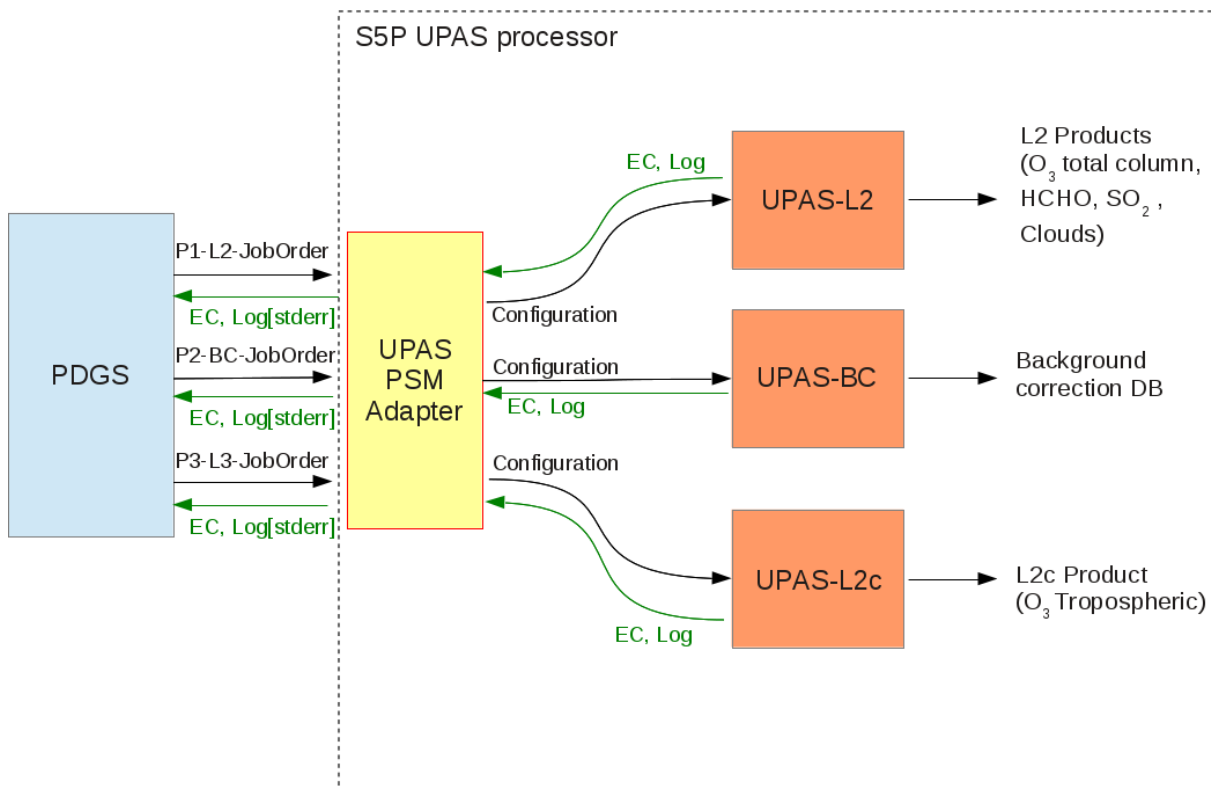


Figure 14: UpasPsmAdapter processor



2.8.1 Testing modality

Besides the operational modes, it is always possible to set up a test modality in order to generate intermediate outputs or any single or subset of products. Diagnostic tests might be carried out by a proper setting of the internal configuration of the processor. However, the testing mode is disabled in the delivered operational version of the processor due to performance issue.

2.8.2 Multi-Core scheme

One single UPAS processor is responsible to generate all the L2 species corresponding to a L1b product and it is compatible with a multi-core scheme. Since only one single UPAS is involved for processing a given L1b product, any possible intermediate outputs will be handled internally. However, single product can be activated independently using configuration settings.

2.9 Input Data

This subsection explains in high level the purpose of the various input files (L1b and PDGS configuration) and data which is employed to configure the processor.

2.9.1 L1b Product

L1b [AD02] is the basis for generating L2 product and it is the main input of S5P UPAS L2 processor. UPAS needs as input the irradiance and the radiance products in the 6 bands covered by medium wave ultraviolet (UV, Bands 1 and 2), long wave ultraviolet combined with visual (UVIS, Band 3) and near infrared (NIR, Bands 4 and 5) detectors in order to generate L2 NRTI/OFFL/RPRO data. Geolocation data is embedded in each radiance product. The ranges of wavelengths as well as their respective spectral bands and products are given in Table 2-3. Description of the L1B files is given in Section 3.2.1. According to [AD02], the products are distributed in different files, more in detail:

- A single netCDF-4 L1b file for the UVN module with the Irradiance Product
- 6 netCDF-4 L1b files for each band in the UVN with the Radiance Product

Instrument Model	UVN					
Spectral band	1	2	3	4	5	6
Spectral range [nm]	270-300	300-320	310-405	405-500	675-725	725-775
Products	CLOUD_	CLOUD_	CLOUD_ SO2_ HCHO_ O3_TCL O3_	CLOUD_	CLOUD_	CLOUD_

Table 2-3: Spectral bands, spectral range and relative products of TROPOMI instrument.

The HDF-5 compression flag for each file is turned OFF. The S5P L1b products are in netCDF-4 format [ER03] following the guidelines of Inspire directive [ER06] and CF-Metadata [ER04] standards, as described in [AD02]. Fletcher32 for validating the integrity of the data is expected in the L1b products. PDGS side is responsible to provide the appropriate radiance and irradiance files to UPAS L2 processor.

2.9.2 Input Configurations

Two are the parts of the configuration, i.e., the dynamic configuration for controlling the processor from PDGS and the internal algorithm configuration as addressed in detail in the following Sections 2.9.2.1 and 2.9.2.2. Moreover, in Section 2.9.2.3 the static data employed by the processor is shown and the relative reference document is given as well. Any change affecting either the static data or the internal configuration file implies a new version of UPAS.

2.9.2.1 PDGS Configuration

The format and specifications of the `JobOrder` file are deeply addressed in [AD08], which is tailoring of [AD12] concerning definitions and default values.

2.9.2.2 UPAS Internal Configuration

The input configuration file contains variables that control the execution of the L1b to L2 processing in all the possibly modes (NRTI, OFFL, and RPRO). The file is structured in classes which reflect the different implemented algorithms in the processor, i.e., O₃ total column, O₃ tropospheric column, SO₂, HCHO, Clouds. Besides this, it includes information about static data necessary to run some of the algorithms as well as the repository reference of the static auxiliary files. From the operational point of view, the availability of resources, databases and variables is checked immediately for validity before any further processing. The variables shall cover the following:

- Type of processing (NRTI, OFFL, RPRO)
- Fitting configuration for trace gases and clouds
- Auxiliary data location
- Tuning parameters for each trace gas

For all those retrieve algorithms that need intermediate steps for computing the specific trace gas, the processor will follow automatically different procedures in base on the selection indicated in the configuration file.

The internal configuration file is in XML format.

2.9.2.3 UPAS static data

Static data is used from the processor in order to generate L2 products and they are, e.g., cross-section, slit function, wavelength dependent surface albedo etc.

A separated document containing the harmonization of the static data between KNMI and DLR has been released. It is referenced in [RD05].

2.9.3 Auxiliary Data

Three types of input dynamic data are ingested from the processor, i.e., the snow/ice data from NASA, the a-priory TM5 model data needed for formaldehyde and SO₂ retrievals and the ECMWF forecast data. The dynamic data corresponding to L1b product should be provided by the PDGS.

A clear overview of which specific external data are required for each trace gas as well as for different modalities of the processor is clearly stated in Table 2-4. Note that this is the optimum set of aux data for both NRTI and OFFL cases.

Note that in any case the processor can generate one product at a time. However, in order to generate SO₂ product, the processor needs O₃ total column product. This specific case leads to better performance if the generation of O₃ total column and SO₂ are performed at the same time. The following table shows the operational scenario designed by PDGS where the `L2__CLOUD_` and `L2__O3__` products are ingested as input rather than being calculated.

Mode	L2 Output-Product	NISE Snow/Ice AUX (AUX_NISE_)	TM5 Profiles AUX	ECMFW Profiles AUX	Background Correction	L2_CLOUD	L2_O3	Other inputs
NRTI	Clouds (L2_CLOUD_)	optional		optional	X			L2_NP_BD3 L2_NP_BD6 - both Optional
NRTI	SO ₂ (L2_SO2_)		optional		X	X	X	
NRTI	HCHO (L2_HCHO_)		optional		X	X		
NRTI	O ₃ total column (L2_O3_)				X	X		
NRTI	O ₃ tropospheric column (L2_O3_TCL)						X (Set of)	
OFFL-RPRO	Clouds (L2_CLOUD_)	X		X	X			L2_NP_BD3 L2_NP_BD6 - both Optional
OFFL-RPRO	SO ₂ (L2_SO2_)		X		X	X	X	L2 Aerosol Index (L2_AER_AI)
OFFL-RPRO	HCHO (L2_HCHO_)		X		X	X		L2 Aerosol Index (L2_AER_AI) - optional
OFFL-RPRO	O ₃ total column (L2_O3_)					X		
OFFL-RPRO	O ₃ tropospheric column (L2_O3_TCL)						X (Set of)	

Table 2-4: L2 products and their respective input data.

A lack of auxiliary data (NISE, TM5, ECMWF) leads to employ climatological data always available to the L2 UPAS processor, in order to avoid any gap in the processing chain.

The following three subsections (Sections 2.9.3.1, 2.9.3.2 and 2.9.3.3) provide more information concerning data format, reliability and characteristic.

2.9.3.1 Snow/Ice Data (AUX_NISE_)

This information is needed by the computation of both Clouds and trace gas products. The baseline source of snow/ice ancillary data is the Near-real-time Ice and Snow Extent service (NISE) from NASA, detailed in the following list (information collected in [ER01]). However, more details are given in the respective ATDB documents of the products. Please note that in case L2_CLOUD_ product is ingested as input in order to generate the other products, this input is not needed at all for the remaining L2 products (see Table 2-4).

a) Format and range of the data (NISE)

Single HDF-EOS file containing four grid objects: one data grid and one age grid each for both the Northern and Southern hemispheres. The data grids contain snow extent, sea ice concentration, and coastal (mixed) pixels. The age grids contain the age of input data (from day of data acquisition to map production) in days relative to the date of the daily file. The data and age grids contain binary arrays of unsigned 1-byte (8-bit) data ranging in value from 0 to 255.

b) Frequency of the data (NISE)

One single file per day comprising the last available snow extent or sea ice concentration data for each pixel.

c) File Name Conventions (NISE)

The template of file name conventions of NISE is as follows:

NISE_SSMISF##_yyyymmdd.HDFEOS



Where:

Variable	Description
NISE	Near-real-time Ice and Snow Extent
SSMIS	Special Sensor Microwave Imager/Sounder: sensor
F##	DMSP Platform: F13, F17
yyyy	4-digit year
mm	2-digit month of year
dd	2-digit day of month

Table 2-5: File name conventions of NISE ancillary data.

Example: NISE_SSMISF17_20090801.HDFEOS

However, this has to be compliant with S5p filename conventions as reported in [AD07]. For this auxiliary file the identifier is therefore "AUX_NISE__".

d) File Size (NISE)

HDF-EOS data files: ~2.1 MB each.

e) Spatial coverage, resolution and projection (NISE)

Spatial coverage is global except for a gap of three degrees latitude from each pole (87 to 90 degrees latitude). The spatial resolution is 25 km. The data set uses the NSIDC NL and SL EASE-Grids of 721 columns by 721 rows. The respective pole is aligned with the centre of the pixel at the centre of the grid.

f) Data access (NISE)

The data is available via FTP. Subject to PDGS.

g) Selection Rules

For L2__CLOUD_, NRTI and OFFL, the selection rules are:

"LatestValIntersect" policy with $\Delta t_0 = 72$ hours and $\Delta t_1 = 0$ hours.

2.9.3.2 Chemistry Transport Model (AUX_CTMFCT and AUX_CTMANA)

Chemistry Transport models data are needed for SO₂ and HCHO retrievals for both NRTI and OFFL modes. The baseline source of the ancillary data is the Transport-Chemistry model TM5 data provided by KNMI and detailed in the following list (information collected in [ER02] and [RD06]). However, more details are given in the respective ATDB documents of the products.

a) Format and range of the data (TM5)

NRTI: Five files in Net-CDF-4 format including five days forecast (AUX_CTMFCT).

OFFL: One single netCDF-4 file (AUX_CTMANA).

b) Frequency of the data (TM5)

Once a day with time resolution set to half an hour ($t = 48$).

c) File Name Conventions (TM5)

The template of file name conventions is as follows:

S5P_<CCCC>_AUX_<DDDDDD>_<yyyymmddThhmmss>_<YYYYMMDDTHHMMSS>_<YYYYMMDDTHHMMSS>.nc

Where:



Variable	Description
<CCCC>	The file class, which is either NRTI for near-real-time processing or OFFL for offline processing.
<DDDDDD>	The product semantic descriptor. It can be either AUX_CTMFCT (forecast) or AUX_CTMANA (analysis). Both files have the same structure.
<yyyymmddThhmmss>	Product start validity time, consisting of 4-digit year, 2-digit month, 2-digit day, a separator 'T', 2-digit hour, 2-digit minute and 2-digit second.
<YYYYMMDDTHHMMSS>	Product stop validity time, consisting of 4-digit year, 2-digit month, 2-digit day, a separator 'T', 2-digit hour, 2-digit minute and 2-digit second.
<YYYYMMDDTHHMMSS>	Production time, consisting of 4-digit year, 2-digit month, 2-digit day, a separator 'T', 2-digit hour, 2-digit minute and 2-digit second.

Table 2-6: File name conventions of TM5 ancillary data.

Example:

S5P_NRTI_AUX_CTMFCT_20160101T000102_20160101T010105_20160101T010115.nc

The format of the TM5 filename is already compliant with [AD07].

d) File Size (TM5) TBD

Mode	Size / Day	Size / Year
NRTI	5 GB	1825 GB
OFFL	1GB	365 GB

Table 2-7: TM5 Data Volume

e) Spatial coverage, resolution and projection (TM5)

The spatial resolution is 1x1 degree and the vertical resolution is 34-layer. Time resolution is half a hour ($t=48$).

f) Data access (TM5)

Refer to [RD06]. Subject to PDGS.

g) Selection Rules

A set of files containing consecutive days of coverage is expected by the processor. In NRTI processing chain, for L2_HCHO__ and L2_SO2__, a set of AUX_CTMFCT files is expected, with the policy "LatestValIntersect" with $\Delta t_0 = 2$ days and $\Delta t_1 = 0$ days. However, this input is optional. In contrast, in the OFFL/RPRO processing chain, for L2_HCHO__ and L2_SO2__ a set of AUX_CTMFCT or AUX_CTMANA files has to be given to the processor. (These two types of files are both supported in all the processing chain's modalities since they contain the same file structure.) The selection rule in this case is:

- AUX_CTMANA with "ValIntersect" policy and $\Delta t_0 = 2$ days and $\Delta t_1 = 2$ days as first choice
- AUX_CTMFCT with "LatestValCover" policy as second choice
- AUX_CTMFCT with "LatestValIntersect" policy with $\Delta t_0 = 15$ days and $\Delta t_1 = 0$ days as third choice



2.9.3.3 ECMWF meteo file (AUX_MET_TP, AUX_MET_QP, AUX_MET_2D)

This information is needed by the computation of both Clouds and trace gas products. The baseline source of the pressure profiles data is the ECMWF data [ER08], detailed in the following list. However, more details are given in the respective ATDB documents of the products. Please note that in case L2_CLOUD_ product is ingested as input in order to generate the other products, this input is not needed at all for the remaining L2 products (see Table 2-4).

a) Format and range of the data (ECMWF)

GRIB format. However, this data shall be converted to netCDF-4 format outside the processor. Details in [RD04].

b) Frequency of the data (ECMWF)

Every 12 hours.

c) File Name Conventions (ECMWF)

Filename has to be compliant with S5p filename conventions as reported in [AD07]. For this auxiliary file the identifier shall be therefore AUX_MET_TP for the temperature profiles, AUX_MET_2D for the meteorological surface parameters and AUX_MET_QP specific humidity profiles.

d) File Size (ECMWF, netCDF-4 format)

Mode	Size / product	Type
NRTI	250MB	AUX_MET_TP
OFFL	600MB	AUX_MET_TP
NRTI	210MB	AUX_MET_2D
OFFL	500MB	AUX_MET_2D
NRTI	300MB	AUX_MET_QP
OFFL	700MB	AUX_MET_QP

Table 2-8: ECMWF Data Volume after the conversion to netCDF-4

e) Spatial coverage, resolution and projection (ECMWF)

Time resolution is every three hours covering 48 hours. Global coverage is provided by this model.

f) Data access (ECMWF)

Subject to PDGS.

h) Selection Rules

For the L2_CLOUD_ NRTI processing chain the "LatestValCover" policy with $\Delta t_0 = 0$ minutes and $\Delta t_1 = 0$ minutes is used – whereby this input is also optional. For the L2_CLOUD_ OFFL processing chain the input is mandatory, with the "LatestValIntersect" policy with $\Delta t_0 = 180$ minutes and $\Delta t_1 = 180$ minutes.

2.9.3.4 Regrided VIIRS data (L2_NP_BD3, L2_NP_BD6)

This information is needed by the CLOUD product in the OFFL case.

a) Format and range of the data (L2_NP_BD3/6)

The files are official S5P-level-2 files in netCDF4 format.

b) Frequency of the data (L2_NP_BD3/6)

Every orbit

c) File Name conventions

The template of file name conventions is as follows:

S5P_<CCCC>_L2_NP_BD_<yyyymmddThhmmss>_<YYYYMMDDTHHMMSS>_<OOOOO>_01_<VVVVVV>_<YYYYMMDDTHHMMSS>.nc

Where:



Variable	Description
<CCCC>	The file class, which is either OFFL for offline processing or RPRO for reprocessing.
	The band identifier. It can be either 3, 6 or 7. But only 3 and 6 are relevant for upas.
<yyyymmddThhmmss>	Product start validity time, consisting of 4-digit year, 2-digit month, 2-digit day, a separator 'T', 2-digit hour, 2-digit minute and 2-digit second.
<YYYYMMDDTHHMMSS>	Product stop validity time, consisting of 4-digit year, 2-digit month, 2-digit day, a separator 'T', 2-digit hour, 2-digit minute and 2-digit second.
<OOOOO>	Orbit number
<VVVVVV>	Version number
<YYYYMMDDTHHMMSS>	Production time, consisting of 4-digit year, 2-digit month, 2-digit day, a separator 'T', 2-digit hour, 2-digit minute and 2-digit second.

d) **File Size**

About 325MB for BD3 and BD6 and about 160MB for BD7

e) **Spatial coverage, resolution and projection**

Global coverage is the corresponding level-1 orbit

f) **Data access**

Subject to PDGS.

g) **Selection Rules**

The file with the exact same orbit number as the corresponding level-1 input data has to be used.

2.9.4 Fall-back solutions

In case of not availability or corruption of the dynamic auxiliary data, UPAS reverts to a fall-back solution, i.e., by using climatological static data and adding a flag in the L2 product. This operation is done automatically, i.e., PDGS shall not provide fall-back static data by referring them in the joborder file. Therefore, it is not necessary to provide filename and type of this data since it is strictly handled internally.

2.10 Output Data

A common documentation covering L2 structure and metadata valid for both KNMI and DLR is work in progress. A detailed description of the structure of L2 products will be addressed in the Product User Manual (PUM). In a high-level view, three are the main types of outputs of the processor, i.e., L2 outputs (which include L2 metadata), logging files and Intermediate outputs. A short overview is therefore addressed in the following subsections.

2.10.1 L2 Products

This is the main output of the processor. A single file with .nc extension is provided from UPAS for each L2 S5P product, with a total of 5 files, i.e.:

- O₃ total column (PUM: [RD13]) O₃_____
- O₃ tropospheric column (PUM: [RD15]) O₃_TCL
- SO₂ (PUM: [RD17]) SO₂_____
- HCHO (PUM: [RD16]) HCHO_____
- Clouds (PUM: [RD14]) CLOUD_

In addition, information of geolocation, metadata and detailed results for each processed trace gas is embedded in each final L2 product.



The output format of the L2 products is netCDF-4 [ER03] following the guidelines of Inspire directive [ER06], CF-Metadata standards [ER04] and several ISOs standards [RD09] [RD10] [RD11] [RD12].

2.10.1.1 L2 Metadata

Metadata gives information about the satellite, algorithms, configuration version as well as other parameters useful for the interpretation of the processed data. Metadata has to comply with different sources and standards as following listed:

- Internal Metadata (S5P)
- CF-Conventions (CF) [ER04]
- NetCDF User Guide Conventions (NUG) [ER07]
- Fixed ESA Header (ESAH) [AD04]
- Inspire directive (INSP) [ER06]
- ISOs standard (ISO) [RD09] [RD10] [RD11] [RD12]

A detailed description of the L2 S5P Metadata conventions used in this framework can be found in [RD18] and in the corresponding Product User Manuals ([RD13], [RD14], [RD15], [RD16], [RD17]).

2.10.2 Logging Messages

The purpose of the Logging interface is to monitor the status of the S5P UPAS L2 processor. The set of messages generated from the processor are forwarded to a Management Layer which logs them in a Log file. Messages marked as errors and progress status will be shown directly to the operator.

The versions of the processor that will be delivered are a debug version and an operational version. The logging file generated from the UPAS debug binary will contain all the logging types defined in Table 3-2. On the other hand, the operational version will log only the progress and error messages for avoiding speed lost in processing.

The format of the logging messages follows the ESA Standard [AD12].

2.10.3 Exit Code

Exit code rules follow the processor ICD definitions [AD11] which is tailored from [AD12].



3. Detailed I/O Data Format

In this chapter, a summary of I/O files of S5P UPAS L2 PDGS processor is shown in Table 3-1 reported in Section 3.1. Moreover, there will be a sub-section for each I/O file employed (Sec. 3.2.1) and generated (Section 3.2.1.12) from the processor.

3.1 List of I/O Files Employed

The following Table 3-1 shows a list of the involved I/O files. Two are the types of files specified in the table, i.e.:

- Products
- Auxiliary data files

Furthermore, all those files indicated as mandatory are necessary for the processing chain, i.e., they are needed in order to generate L2 output and to fulfil the expected compulsory requirements ([AD01], [RD01]).

ID	Name	Type	I/O	Mandatory	ID
001_IN	PDGS Configuration	JobOrder	Input	Yes	JobOrder.XXXXXXXXXX
002_IN	L1b Irradiance Product UVN	Product	Input	Yes	L1B_IR_UVN
003_IN	L1b Radiance Product UV band 1 [270-300 nm]	Product	Input	Yes	L1B_RA_BD1
004_IN	L1b Radiance Product UV band 2 [300-320 nm]	Product	Input	Yes	L1B_RA_BD2
005_IN	L1b Radiance Product UVIS band 3 [310-405 nm]	Product	Input	Yes	L1B_RA_BD3
006_IN	L1b Radiance Product UVIS band 4 [405-500 nm]	Product	Input	Yes	L1B_RA_BD4
007_IN	L1b Radiance Product NIR band 5 [675-725 nm]	Product	Input	Yes	L1B_RA_BD5
008_IN	L1b Radiance Product NIR band 6 [725-775 nm]	Product	Input	Yes	L1B_RA_BD6
009_IN	Snow/Ice Data	Auxiliary	Input	No	AUX_NISE__
010_IN	TM5 Model Data	Auxiliary	Input	No	AUX_CTMFCT AUX_CTMANA
011_IN	ECMWF Data	Auxiliary	Input	No	AUX_MET_2D AUX_MET_QP AUX_MET_TP
012_IN	Aerosol Index data	Auxiliary	Input	No	L2__AER_AI
013_IN	Regridded NPP-VIIRS data for band 3 and band 6	Auxiliary	Input	Yes	L2_NP_BD3 L2_NP_BD6
014_OU	L2 O ₃ total column	Product	Output	Yes	L2__O3__
015_OU	L2c O ₃ tropospheric column	Product	Output	Yes	L2__O3_TCL
016_OU	L2 SO ₂	Product	Output	Yes	L2__SO2__
017_OU	L2 HCHO	Product	Output	Yes	L2__HCHO__
018_IO	L2 Clouds retrieval	Product	Input/	Yes	L2__CLOUD_



ID	Name	Type	I/O	Mandatory	ID
			Output		
019_IO	Background Correction	Auxiliary	Input/ Output	Yes	AUX_BGSO2_ AUX_BGHCHO
020_IO	Background Correction	Auxiliary	Input/ Output	Yes	AUX_BGCLD_ AUX_BGO3__
021_O	Logging Messages	Auxiliary	Output	Yes	-

Table 3-1: Involved I/O files of the processor

3.2 File Definition

Each file detailed in this document is classified by using a standardised template structured in categories, i.e., identifier, name, I/O, type, description, format, size, data volume, remarks. A definition of each category is given as follows:

Identifier

A unique identifier is defined for each I/O file used or generated from UPAS L2 processor. The identifiers are listed in Table 3-1.

Name

This field describes shortly the name of the file

I/O

It defines whereas the file is an Input or Output of the processor.

Type

Type defines the relation between the file and the processor. The types are defined as follows:

- Product: It refers either to the primary input data or the output data delivered from the processor to the end user.
- Auxiliary: It is an input of the processor and contains data external to the GS and the processor. Auxiliary data may be generated from external sources.

Description

Content and purpose of the file are addressed in this part.

Format

Data format and structure will be defined in this section. The specifications are TBD.

Size

It defines the criteria for the sizing of the files.

Data Volume

It defines the size for the whole reference data set.

Remarks

Relevant comments and explanations are reported in this section when necessary.



L2 status flags

Relevant L2 flags worth to be mentioned in the L2 products



3.2.1 Input Files

3.2.1.1 PDGS Configuration

Identifier

001_IN

Name

JobOrder.XXXXXXXXXX.xml

Where XXXXXXXXXX is a 9-digits counter starting from 000000001.

I/O

Input

Type

JobOrder file

Description

The specifications of the PDGS configuration file are detailed in the External ICD document [AD09].

Format

XML

Size

Not relevant.

Data Volume

<1MB

Remarks

N/A

**3.2.1.2 L1b Irradiance Product UVN (L1B_IR_UVN)****Identifier**

002_IN

Name

The file name conventions will follow the directives given by ESA in [AD07], chapter 4. A substring of the full filename for this product is as follows:

L1B_IR_UVN

I/O

Input

Type

Product

Description

The S5P L1b products are in netCDF-4 format [ER07] following the guidelines of Inspire and CF-Metadata standards, as described in [AD02]. It covers medium wave ultraviolet (UV), long wave ultraviolet combined with visual (UVIS) and near infrared (NIR). It is generated once a day and the selection rule for UPAS shall be "LatestValIntersect" policy with $\Delta t_0 = 26$ hours and $\Delta t_1 = 0$. If no files are found with this policy then use "LatestValidity".

Format

netCDF-4

Size

One single scanline

Data Volume

0.02 GByte

Remarks

Beside the data .nc file, an additional header file with .HDR in XML structure is generated out from L1B product by PDGS. It contains a variable as well as a fixed part of header/metadata information (details in Section 9 of L01B IODD [AD02]). The filename of the header file is as the same as the data file, except for the extension.

**3.2.1.3 L1b Radiance Product UV band 1 [270-300 nm] (L1B_RA_BD1)****Identifier**

003_IN

Name

The file name conventions will follow the directives given by ESA in [AD07], chapter 4. A substring of the full filename for this product is as follows:

L1B_RA_BD1

I/O

Input

Type

L1b Product

Description

The S5P L1b products are in netCDF-4 format [ER07] following the guidelines of Inspire and CF-Metadata standards, as described in [AD02]. Geolocation is included in the product. It covers spectral band 1 ranging from 270 up to 300 nm.

Format

netCDF-4

Size

3246 scanlines

Data Volume

1.7 GB (Appendix A in [AD02])

Remarks

Beside the data .nc file, an additional header file with .HDR in XML structure is generated out from L1B product by PDGS. It contains a variable as well as a fixed part of header/metadata information (details in Section 9 of L01B IODD [AD02]). The filename of the header file is as the same as the data file, except for the extension.

**3.2.1.4 L1b Radiance Product UV band 2 [300-320 nm] (L1B_RA_BD2)****Identifier**

004_IN

Name

The file name conventions will follow the directives given by ESA in [AD07], chapter 4. A substring of the full filename for this product is as follows:

L1B_RA_BD2

I/O

Input

Type

L1b Product

Description

The S5P L1b products are in netCDF-4 format [ER07] following the guidelines of Inspire and CF-Metadata standards, as described in [AD02]. Geolocation is included in the product. It covers spectral band 2 ranging from 300 up to 320 nm.

Format

netCDF-4

Size

3246 scanlines

Data Volume

6.0 GB (Appendix A in [AD02])

Remarks

Beside the data .nc file, an additional header file with .HDR in XML structure is generated out from L1B product by PDGS. It contains a variable as well as a fixed part of header/metadata information (details in Section 9 of L01B IODD [AD02]). The filename of the header file is as the same as the data file, except for the extension.

**3.2.1.5 L1b Radiance Product UVIS band 3 [310-405 nm] (L1B_RA_BD3)****Identifier**

005_IN

Name

The file name conventions will follow the directives given by ESA in [AD07], chapter 4. A substring of the full filename for this product is as follows:

L1B_RA_BD3

I/O

Input

Type

L1b Product

Description

The S5P L1b products are in netCDF-4 format [ER07] following the guidelines of Inspire and CF-Metadata standards, as described in [AD02]. Geolocation is included in the product. It covers spectral band 3 ranging from 310 up to 405 nm.

Format

netCDF-4

Size

3246 scanlines

Data Volume

6.1 GB (Appendix A in [AD02])

Remarks

Beside the data .nc file, an additional header file with .HDR in XML structure is generated out from L1B product by PDGS. It contains a variable as well as a fixed part of header/metadata information (details in Section 9 of L01B IODD [AD02]). The filename of the header file is as the same as the data file, except for the extension.

**3.2.1.6 L1b Radiance Product UVIS band 4 [405-500 nm] (L1B_RA_BD4)****Identifier**

006_IN

Name

The file name conventions will follow the directives given by ESA in [AD07], chapter 4. A substring of the full filename for this product is as follows:

L1B_RA_BD4

I/O

Input

Type

L1b Product

Description

The S5P L1b products are in netCDF-4 format [ER07] following the guidelines of Inspire and CF-Metadata standards, as described in [AD02]. Geolocation is included in the product. It covers spectral band 4 ranging from 405 up to 500 nm.

Format

netCDF-4

Size

3246 scanlines

Data Volume

6.1 GB (Appendix A in [AD02])

Remarks

Beside the data .nc file, an additional header file with .HDR in XML structure is generated out from L1B product by PDGS. It contains a variable as well as a fixed part of header/metadata information (details in Section 9 of L01B IODD [AD02]). The filename of the header file is as the same as the data file, except for the extension.

**3.2.1.7 L1b Radiance Product NIR band 5 [675-725 nm] (L1B_RA_BD5)****Identifier**

007_IN

Name

The file name conventions will follow the directives given by ESA in [AD07], chapter 4. A substring of the full filename for this product is as follows:

L1B_RA_BD5

I/O

Input

Type

L1b Product

Description

The S5P L1b products are in netCDF-4 format [ER07] following the guidelines of Inspire and CF-Metadata standards, as described in [AD02]. Geolocation is included in the product. It covers spectral band 5 ranging from 675 up to 725 nm.

Format

netCDF-4

Size

3246 scanlines

Data Volume

6.1 GB (Appendix A in [AD02])

Remarks

Beside the data .nc file, an additional header file with .HDR in XML structure is generated out from L1B product by PDGS. It contains a variable as well as a fixed part of header/metadata information (details in Section 9 of L01B IODD [AD02]). The filename of the header file is as the same as the data file, except for the extension.

**3.2.1.8 L1b Radiance Product NIR band 6 [725-775 nm] (L1B_RA_BD6)****Identifier**

008_IN

Name

The file name conventions will follow the directives given by ESA in [AD07], chapter 4. A substring of the full filename for this product is as follows:

L1B_RA_BD6

I/O

Input

Type

L1b Product

Description

The S5P L1b products are in netCDF-4 format [ER07] following the guidelines of Inspire and CF-Metadata standards, as described in [AD02]. Geolocation is included in the product. It covers spectral band 6 ranging from 725 up to 775 nm.

Format

netCDF-4

Size

3246 scanlines

Data Volume

6.1 GB (Appendix A in [AD02])

Remarks

A XML Header file with extension .HDR shall be extracted and generated out from the L2 product by PDGS.

Beside the data .nc file, an additional header file with .HDR in XML structure is generated out from L1B product by PDGS. It contains a variable as well as a fixed part of header/metadata information (details in Section 9 of L01B IODD [AD02]). The filename of the header file is as the same as the data file, except for the extension.

**3.2.1.9 Snow/Ice Data (AUX_NISE__)****Identifier**

009_IN

Name

Detailed file name conventions can be found in Sec. 2.9.3.1. However, the identifier for this data is AUX_NISE__.

I/O

Input

Type

Auxiliary Data

Description

The source of snow/Ice ancillary data is NISE provided by NASA.

Format

HDF-EOS

Size

~2.1 MB each file, one single file per day.

Data Volume

~770 MB / Year

Remarks

In case of not availability, climatological data will be used in order to not break the processing chain.

L2 status flags

A status flag is placed in each L2 product in the global attribute part called "Status_NISE__". It can assume two values, i.e. "Nominal" if valid AUX_NISE__ data was provided or "Fallback" otherwise.



3.2.1.10 TM5 Model Data (AUX_CTMFCT and AUX_CTMANA)

Identifier

010_IN

Name

Detailed file name conventions can be found in Sec. 2.9.3.2. The product semantic descriptor can be either AUX_CTMFCT (forecast) or AUX_CTMANA (analysis). Both files have the same structure.

I/O

Input

Type

Auxiliary data

Description

The source of climate models data ancillary data is TM5 provided by KNMI.

Format

netCDF-4

Size

5 files per day for NRTI, including 5 days forecast. One single file per day for the OFFL case.

Data Volume

See Table 2-7: TM5 Data Volume

Remarks

In case of not availability, climatological data will be used in order to not break the processing chain.

L2 status flags

A status flag is placed in the L2__HCHO__ and L2__SO2__ products in the global attribute part called "Status_CTMFCT_CTMANA". It can assume two values, i.e. "Nominal" if valid AUX_CTMFCT or AUX_CTMANA data was provided or "Fallback" otherwise.

**3.2.1.11 ECMWF forecast data (AUX_MET_2D, AUX_MET_TP, AUX_MET_QP)****Identifier**

011_IN

Name

The identifiers for this data shall be AUX_MET_2D, AUX_MET_TP and AUX_MET_QP). File name conventions shall follow the guidelines in [AD07].

I/O

Input

Type

Auxiliary data

Description

Pressure profiles forecast provided by ECMWF

Format

GRIB. However, a conversion in netCDF-4 outside the processor is expected.

Size

One new forecast every 12 hours.

Data Volume

See Table 2-8.

Remarks

In case of not availability, climatological data will be used in order to not break the processing chain.

L2 status flags

A status flag is placed in each L2 product in the global attribute part called "Status_MET_2D". It can assume two values, i.e. "Nominal" if valid AUX_MET_2D, AUX_MET_TP and AUX_MET_QP data were provided or "Fallback" otherwise.

**3.2.1.12 Aerosol Index (L2__AER_AI)****Identifier**

012_IN

Name

The identifiers for this data shall be L2__AER_AI. File name conventions shall follow the guidelines in [AD07].

I/O

Input

Type

Auxiliary data

Description

Aerosol Index product provided by L2 KNMI. This input is needed only in the OFFL chain for computing L2__SO2__ product.

Format

netCDF-4

Size

216 Mbyte / Orbit [RD04]

Data Volume

~1154 Gbyte / Year

Remarks

In case of not availability, climatological data will be used in order to not break the processing chain.

L2 status flags

A status flag is placed in the OFFL_L2__SO2__ and OFFL_L2__SO2__ products in the global attribute part called "Status_AER_AI". It can assume three values, i.e. "Nominal" if valid L2__AER_AI data were provided or "Fallback" otherwise. A third possible value is "Unneeded" which is present in the NRTI_L2__SO2__ / NRTI_L2__HCHO__ products.

3.2.1.13 Aerosol Index (L2__NP_BD3, L2__NP_BD6)**Identifier**

013_IN

Name

The identifiers for this data shall be L2__NP_BD3 and L2__NP_BD6. File name conventions shall follow the guidelines in [AD07].

I/O

Input

**Type**

Auxiliary data

Description

Regridded NPP-VIIRS information by L2 RAL. This input is needed only in the OFFL chain for computing the `AUX_BGCLD_` and `AUX_BGO3_` products.

Format

netCDF-4

Size

325 Mbyte / Orbit

Data Volume

~1737 Gbyte / Year

Remarks

In case of non-availability, the `AUX_BGCLD_` and `AUX_BGO3_` files cannot be updated by the background processor.

L2 status flags

Status flags are placed in the `OFFL_L2__CLOUD_` and `NRTI_L2__CLOUD_` products in the global attribute part called "Status_NP_BD3" and "Status_NP_BD6". It can take two values, i.e. "Nominal" if valid `L2__NP_BD3`, respectively `L2__NP_BD6` data was provided or "Unavailable" otherwise.

**Output Files****3.2.1.14 L2 O₃ total column (L2__O3__)****Identifier**

014_OU

Name

The file name conventions will follow the directives given by ESA in [AD07], chapter 4. A substring of the full filename for this product is as follows:

L2__O3__ _ _ _

I/O

Output

Type

L2 Product

Description

L2 product containing O₃ total column trace gas. Geolocation is appended in the product as well. Refer to the corresponding PUM [RD13] for a full description of this product.

Format

netCDF-4

Size

A reasonable number of scanlines set to 3300 was chosen with a number of ground pixel set to 450. Total pixels estimated: ~1500000. Data Volume reported with HDF-5 compression flag set to ON. The data Volume estimation accounts only one single processing mode.

Data Volume

0.74 GB / Orbit

4.1 TB / Year

Remarks

A XML Header file with extension .HDR shall be extracted and generated out from the L2 product by PDGS. The filename of the header file is as the same as the data file, except for the extension.

L2 status flags

A L2 status flag is placed in this L2 product in the global attribute part called "Status_L2__CLOUD_". It can assume two values, i.e. "External" if L2__CLOUD_ product was provided to the processor as input or "Internal" if the L2__CLOUD_ product was rather computed.

**3.2.1.15 L2c O₃ tropospheric column (L2__O3_TCL)****Identifier**

015_OU

Name

The file name conventions will follow the directives given by ESA in [AD07], chapter 4. A substring of the full filename for this product is as follows:

L2_ _O3_TCL

I/O

Output

Type

L2 Product

Description

L2c product containing O₃ tropospheric column trace gas. Geolocation is appended in the product as well. Refer to the corresponding PUM [RD15] for a full description of this product. The data Volume estimation accounts only one single processing mode.

Features:

- Global Coverage.
- ~1.500.000 pixels per orbit.
- ~14 orbits for a day coverage (time slot might be up to 6 days)

Format

netCDF-4

Size

<5Mbyte / product / day

Data Volume

~5 MByte / day

~1.8GByte / Year

Remarks

A XML Header file with extension .HDR shall be extracted and generated out from the L2 product by PDGS. The filename of the header file is as the same as the data file, except for the extension.

**3.2.1.16 L2 SO₂ (L2__SO2__)****Identifier**

016_OU

Name

The file name conventions will follow the directives given by ESA in [AD07], chapter 4. A substring of the full filename for this product is as follows:

L2__SO2__ _ _

I/O

Output

Type

L2 Product

Description

L2 product containing SO₂ trace gas. Geolocation is appended in the product as well. Refer to the corresponding PUM [RD17] for a full description of this product.

Format

netCDF-4

Size

A reasonable number of scanlines set to 3300 was chosen with a number of ground pixel set to 450. Total pixels estimated: ~1.500.000. Data Volume reported with HDF-5 compression flag set to ON. The data Volume estimation accounts only one single processing mode.

Data Volume

0.5 GB / Orbit

2.8 TB / Year

Remarks

A XML Header file with extension .HDR shall be extracted and generated out from the L2 product by PDGS. The filename of the header file is as the same as the data file, except for the extension.

L2 status flags

Two L2 status flags are placed in this L2 product in the global attribute part called: "Status_L2__CLOUD_", "Status_L2__O3_____". The first one can assume two values, i.e. "External" if L2__CLOUD_ product was provided to the processor as input or "Internal" if the L2__CLOUD_ product was rather computed. Moreover, the second flag might assume two values, i.e. "External" if L2__O3_____ product was provided to the processor as input or "Internal" if the L2__O3_____ product was rather computed.

**3.2.1.17 L2 HCHO (L2__HCHO__)****Identifier**

017_OU

Name

The file name conventions will follow the directives given by ESA in [AD07], chapter 4. A substring of the full filename for this product is as follows:

L2__HCHO__

I/O

Output

Type

L2 Product

Description

L2 product containing HCHO trace gas. Geolocation is appended in the product as well. Refer to the corresponding PUM [RD16] for a full description of this product.

Format

netCDF-4

Size

A reasonable number of scanlines set to 3300 was chosen with a number of ground pixel set to 450. Total pixels estimated: ~1.500.000. Data Volume reported with HDF-5 compression flag set to ON. The data Volume estimation accounts only one single processing mode.

Data Volume

0.4 GB / Orbit

2.2 TB / Year

Remarks

A XML Header file with extension .HDR shall be extracted and generated out from the L2 product by PDGS. The filename of the header file is as the same as the data file, except for the extension.

L2 status flags

A status flag is placed in this L2 product in the global attribute part called "Status_L2__CLOUD_". It can assume two values, i.e. "External" if L2__CLOUD_ product was provided to the processor as input or "Internal" if the L2__CLOUD_ product was rather computed.

**3.2.1.18 L2 Clouds (L2__CLOUD_)****Identifier**

018_IO

Name

The file name conventions will follow the directives given by ESA in [AD07], chapter 4. A substring of the full filename for this product is as follows:

L2_ _CLOUD_

I/O

Output

Type

L2 Product

Description

L2 product which contains retrieved clouds information. Geolocation is appended in the product as well. This is generated by UPAS-L2 (as output) and might be given as input to UPAS-L2 in order to generate other species. Refer to the corresponding PUM [RD14] for a full description of this product.

Format

netCDF-4

Size

A reasonable number of scanlines set to 3300 was chosen with a number of ground pixel set to 450. Total pixels estimated: ~1.500.000. Data Volume reported with HDF-5 compression flag set to ON. The data Volume estimation accounts only one single processing mode.

Data Volume

0.5 GB / Orbit

2.8 TB / Year

Remarks

A XML Header file with extension .HDR shall be extracted and generated out from the L2 product by PDGS. The filename of the header file is as the same as the data file, except for the extension.

**3.2.1.19 Background Correction (AUX_BGSO2_ and AUX_BGHCHO)****Identifier**

019_IO

Name

The file name conventions will follow the directives given by ESA in [AD07], chapter 4. The two file identifiers of the background correction are as follows:

AUX_BGSO2_

AUX_BGHCHO

I/O

Input/Output

Type

L2 Product

Description

Background Correction data generated by UPAS-BC (as output) and used by UPAS-L2 (as input). Daily global coverage gridded in L2c grid. The product shall be archived by PDGS. Examples of data structures are shown in Appendix A and D.

Format

netCDF-4

Size

<5Mbyte / file / day

Data Volume

~20 MByte / day

~7.3 GByte / Year

Remarks

None

L2 status flags

A status flag is placed in the L2__SO2__ and L2__HCHO__ products in the global attribute part called "Status_BG". It can assume two values, i.e. "Nominal" if valid AUX_BGSO2_ or AUX_BGHCHO data was provided or "Fallback" otherwise. Additionally, a status flag called "Status_reference_spectrum" is placed in those products to indicate whether the earthshine reference spectrum provided in the corresponding auxiliary product file has been used (value is "earthshine") or not (value is "solar").

**3.2.1.20 Background Correction (AUX_BGCLD and AUX_BGO3__)****Identifier**

020_IO

Name

The file name conventions will follow the directives given by ESA in [AD07], chapter 4. The two file identifiers of the background correction are as follows:

AUX_BGCLD__

AUX_BGO3__

I/O

Input/Output

Type

L2 Product

Description

Background Correction data generated by UPAS-BC (as output) and used by UPAS-L2 (as input). Daily global coverage gridded in L2c grid. The product shall be archived by PDGS. Examples of data structures are shown in Appendix A and D.

Format

netCDF-4

Size

50Mbyte / file / day

Data Volume

~100 MByte / day

~36.5 GByte / Year

Remarks

None

L2 status flags

A status flag is placed in the L2__CLOUD_ and L2__O3_____ products in the global attribute part called "Status_BG". It can assume two values, i.e. "Nominal" if valid AUX_BGCLD_ or AUX_BGO3__ data was provided or "Fallback" otherwise.



3.2.1.21 Logging Messages

Identifier

021_OU

Name

NONE

I/O

Output

Type

Auxiliary

Description

Purpose of the logging messages is to provide messages of error and progression for the operational version of the processor and, in addition, messages of status, debug and warning for the debug version of the processor.

Format

The log strings are in ASCII style, written in *stderr* (only for error and progressive messages) and *stdout* (all the other types of messages). Moreover, the *stderr* strings generated from the processor are shown directly to the operator.

The logging format is tailoring [AD12].

The logging messages consist in the following field separated by a blank character.

1. **Date and time:** variable consisting in 26 characters in the format yyyy-mm-ddThh:mm:ss.nnnnnn, where:

- a) yyyy denotes the year, e.g., 2015
- b) mm denotes the month, e.g, 05
- c) dd denotes the day, e.g., 01
- d) T is a separator character
- e) hh is the hour in 24 hours format, i.e., 15
- f) mm denotes the minutes, e.g., 55
- g) ss denotes the seconds, e.g., 06
- h) nnnnnn refers to microseconds

All the abovementioned values are left padded by 0 (zero) except for microseconds, where the 0 (zero) padded is right.

2. **Node name:** variable identifying which of the workstation node the processor is running on. Basically, this is retrieved through a *gethostname* system call.

3. **Processor Name:** alphanumeric variable without whitespaces identifying the name of the processor.

4. **Processor Version:** 6 characters in the format vv.vv.vv, e.g. 01.02.01

5. **PID:** 6 characters variable identifying the system level processor ID, obtained by *getpid* system call, in squared brackets.

6. **Header Separator:** 1 colon character.

7. **Message Type:** 3 characters variable used to identify the nature of the message being issued. The digits consist in two squared brackets surrounding a letter, i.e. [x], where x has to be one mode listed in the next Table 3-2:



Digits [x]	Meaning	Description	Channel
D	Debug Messages	Messages tracing the SW behavior	stdout
I	Informational Messages	Information on kind and status of operations	stdout
W	Warning Messages	An error occurred and the processor was able to continue	stdout
E	Error Messages	An error occurred and the processor was not able to continue	stderr
P	Progress Messages	Information on progress of operations	stderr

Table 3-2: Schema of I/O files and different modes of S5P UPAS L2 processor

8. **Message Text:** String with the text of the messages, no restrictions.

Examples of log messages are as follows:

```
2015-10-01T17:05:11.548200 wolga1 upas-12 01.01.00 [012523]: [I] Resources Initialized
2015-10-01T17:05:11.548200 wolga1 upas-12 01.01.00 [012523]: [I] XML configuration read
2015-10-01T17:05:11.548200 wolga1 upas-12 01.01.00 [012523]: [P] Start processing SO2 data
```

Size

N/A

Data Volume

N/A

Remarks

No physical file but *stdout/stderr* stream messages.

A. Appendix – AUX_BGCLD_ structure

Structure of the AUX_BGCLD_ file in NRTI case (same structure as in the OFFL case).

```
netcdf S5P_NRTI_AUX_BGCLD__20190729T205509_20190731T000153_20200626T162342 {

// global attributes:
    :Conventions = "CF-1.7" ;
    :institution = "DLR-IMF" ;
    :source = "Sentinel 5 Precursor, TROPOMI, space-borne remote sensing, L2" ;
    :history = "" ;
    :comment = "" ;
    :title = "TROPOMI/S5P Auxiliary information CLOUD" ;
    :references = "https://atmos.eoc.dlr.de/tropomi" ;
    :time_reference = "20190729T000000" ;
    :time_coverage_start = "20190729T205509" ;
    :time_coverage_end = "20190731T000153" ;
    :creation_time = "20200626T162342" ;
    :processor_version = "02.01.03" ;
    :orbit = 9285 ;
    :background_correction_valid = "true" ;
    :reference_file
"/mnt/datal/storage_nrt/pp_bgclد/S5P_NRTI_AUX_BGCLD__20190729T000957_20190730T000021_20200626T091109.nc" ;
    :reference_date = "2019-07-31" ;
    :revision_control_identifier = "0000" ;

group: PRODUCT {

    group: SURFACE_ALBEDO_MAPS {
        dimensions:
            months = 1 ;
            latitude = 1800 ;
            longitude = 3600 ;
            vza_correction_months = 12 ;
            vza_correction_surface_types = 3 ;
            vza_correction_polynomial_coefficients = 9 ;
        variables:
            float surface_albedo(months, latitude, longitude) ;
                surface_albedo:_FillValue = 1.e+20f ;
                surface_albedo:coordinates = "/PRODUCT/SURFACE_ALBEDO_MAPS/latitude
/PRODUCT/SURFACE_ALBEDO_MAPS/longitude" ;
                surface_albedo:long_name = "surface albedo in the ROCINN fitting window" ;
                surface_albedo:unit = "1" ;
                surface_albedo:comment = "Global gapless geometry-dependent LER (G3_LER) based either on the
normalized GE_LER retrieved under clear-sky conditions from the ingested level-2 file or the fallback LER
map" ;
            ubyte qa_value(latitude, longitude) ;
                qa_value:_FillValue = 255UB ;
                qa_value:coordinates = "/PRODUCT/SURFACE_ALBEDO_MAPS/latitude
/PRODUCT/SURFACE_ALBEDO_MAPS/longitude" ;
                qa_value:long_name = "QA value" ;
                qa_value:unit = "1" ;
                qa_value:comment = "QA value of the surface albedo - depending on the orbit number and the
availability of the cloud information from S5P OCRA/ROCINN and VIIRS" ;
            int orbit(latitude, longitude) ;
                orbit:_FillValue = 999999 ;
                orbit:coordinates = "/PRODUCT/SURFACE_ALBEDO_MAPS/latitude
/PRODUCT/SURFACE_ALBEDO_MAPS/longitude" ;
                orbit:long_name = "orbit number" ;
                orbit:unit = "1" ;
                orbit:comment = "Orbit number from which the surface albedo value was ingested - fill-value in
case the corresponding surface albedo is from the fallback map" ;
```



```
ubyte cloud_information_source(latitude, longitude) ;
    cloud_information_source: FillValue = 255UB ;
    cloud_information_source:coordinates = "/PRODUCT/SURFACE_ALBEDO_MAPS/latitude
/PRODUCT/SURFACE_ALBEDO_MAPS/longitude" ;
    cloud_information_source:long_name = "Cloud information source" ;
    cloud_information_source:unit = "1" ;
    cloud_information_source:comment = "Source of the cloud information that was used to determine
if the pixel was cloud free - 0: VIIRS, 1: S5P/ROCINN, 2: S5P/OCRA" ;
ubyte surface_type(latitude, longitude) ;
    surface_type: FillValue = 255UB ;
    surface_type:coordinates = "/PRODUCT/SURFACE_ALBEDO_MAPS/latitude
/PRODUCT/SURFACE_ALBEDO_MAPS/longitude" ;
    surface_type:long_name = "Surface type" ;
    surface_type:unit = "1" ;
    surface_type:comment = "Surface type of the pixel at the time of the update - 0: Land, 1: Wa-
ter, 2: Snow/Ice" ;
double vza_correction_coefficients(vza_correction_months, vza_correction_surface_types,
vza_correction_polynomial_coefficients) ;
    vza_correction_coefficients:long_name = "vza correction coefficients that have been used to re-
trieve the surface albedo from the level-2 file" ;
    vza_correction_coefficients:unit = "1" ;
    vza_correction_coefficients:comment = "Multiplicative factor needed to compute the geometry-
dependent LER as a function of the actual viewing zenith angle, month, and surface type" ;
float latitude(latitude) ;
    latitude:units = "degrees_north" ;
    latitude:long_name = "pixel center latitude" ;
    latitude:valid_min = -90. ;
    latitude:valid_max = 90. ;
float longitude(longitude) ;
    longitude:units = "degrees_east" ;
    longitude:long_name = "pixel center longitude" ;
    longitude:valid_min = -180. ;
    longitude:valid_max = 180. ;

// group attributes:
:climatology_file =
"/mnt/sw/IPF_S5P_L2_DLR/current/processors/support_data/s5p/aux/S5P_XXXX_AUX_BGCLD_FALLBACK#1.nc" ;
:updated_values_input_count = 1495188 ;
:updated_values_input_ratio = 0.230738888888889 ;
:updated_values_fallback_count = 4388766 ;
:updated_values_fallback_ratio = 0.677278703703704 ;
:expired_values_count = 0 ;
:expired_values_ratio = 0. ;
:no_update_values_count = 596046 ;
:no_update_values_ratio = 0.0919824074074074 ;
:input_data_ratio = 0.322721296296296 ;
:mean_orbit_age = 12.0039469518954 ;
} // group SURFACE_ALBEDO_MAPS
} // group PRODUCT

group: METADATA {

// group attributes:
:ProductShortName = "AUX_BGCLD_" ;
:Processor = "version" ;
:Mode = "mode" ;
:processingMode = "NRTI" ;
:input_files_l2 =
642855684/S5P_NRTI_L2_CLOUD_20190729T205515_20190729T210015_09285_96_020103_20200626T072440.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642855765/S5P_NRTI_L2_CLOUD_20190729T210015_20190729T210515_09285_96_020103_20200626T072532.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642855846/S5P_NRTI_L2_CLOUD_20190729T211015_20190729T211515_09285_96_020103_20200626T072826.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642855927/S5P_NRTI_L2_CLOUD_20190729T210515_20190729T211015_09285_96_020103_20200626T073005.nc
```



/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642856089/S5P_NRTI_L2_CLOUD_20190729T212515_20190729T213015_09285_96_020103_20200626T073200.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642856008/S5P_NRTI_L2_CLOUD_20190729T211515_20190729T212015_09285_96_020103_20200626T073139.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642856251/S5P_NRTI_L2_CLOUD_20190729T220515_20190729T221015_09286_96_020103_20200626T073419.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642856170/S5P_NRTI_L2_CLOUD_20190729T212015_20190729T212515_09285_96_020103_20200626T073345.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642856332/S5P_NRTI_L2_CLOUD_20190729T221015_20190729T221515_09286_96_020103_20200626T073739.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642856413/S5P_NRTI_L2_CLOUD_20190729T221515_20190729T222015_09286_96_020103_20200626T073935.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642856494/S5P_NRTI_L2_CLOUD_20190729T222015_20190729T222515_09286_96_020103_20200626T074047.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642856575/S5P_NRTI_L2_CLOUD_20190729T222515_20190729T223015_09286_96_020103_20200626T074236.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642856845/S5P_NRTI_L2_CLOUD_20190729T223015_20190729T223515_09286_96_020103_20200626T074354.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642857043/S5P_NRTI_L2_CLOUD_20190729T223515_20190729T224015_09286_96_020103_20200626T074618.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642857124/S5P_NRTI_L2_CLOUD_20190729T224015_20190729T224515_09286_96_020103_20200626T074857.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642857205/S5P_NRTI_L2_CLOUD_20190729T224515_20190729T225015_09286_96_020103_20200626T075033.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642857286/S5P_NRTI_L2_CLOUD_20190729T225015_20190729T225515_09286_96_020103_20200626T075205.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642857367/S5P_NRTI_L2_CLOUD_20190729T225515_20190729T230015_09286_96_020103_20200626T075423.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642857448/S5P_NRTI_L2_CLOUD_20190729T230015_20190729T230515_09286_96_020103_20200626T075520.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642857529/S5P_NRTI_L2_CLOUD_20190729T230515_20190729T231015_09286_96_020103_20200626T075621.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642857610/S5P_NRTI_L2_CLOUD_20190729T235015_20190729T235515_09287_96_020103_20200626T075930.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642857691/S5P_NRTI_L2_CLOUD_20190729T235515_20190730T000015_09287_96_020103_20200626T080116.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642857772/S5P_NRTI_L2_CLOUD_20190730T000015_20190730T000515_09287_96_020103_20200626T080252.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642857853/S5P_NRTI_L2_CLOUD_20190730T000515_20190730T001015_09287_96_020103_20200626T080548.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642857934/S5P_NRTI_L2_CLOUD_20190730T001015_20190730T001515_09287_96_020103_20200626T080656.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642858015/S5P_NRTI_L2_CLOUD_20190730T002015_20190730T002515_09287_96_020103_20200626T080934.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642858096/S5P_NRTI_L2_CLOUD_20190730T001515_20190730T002015_09287_96_020103_20200626T081101.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642858177/S5P_NRTI_L2_CLOUD_20190730T002515_20190730T003015_09287_96_020103_20200626T081242.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642858258/S5P_NRTI_L2_CLOUD_20190730T003015_20190730T003515_09287_96_020103_20200626T081421.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642858684/S5P_NRTI_L2_CLOUD_20190730T003515_20190730T004015_09289_96_020103_20200626T092803.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642858769/S5P_NRTI_L2_CLOUD_20190730T004015_20190730T004515_09289_96_020103_20200626T093431.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642858850/S5P_NRTI_L2_CLOUD_20190730T004515_20190730T005015_09289_96_020103_20200626T093710.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642859191/S5P_NRTI_L2_CLOUD_20190730T013015_20190730T013515_09288_96_020103_20200626T093919.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642859272/S5P_NRTI_L2_CLOUD_20190730T013515_20190730T014015_09288_96_020103_20200626T094106.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642859353/S5P_NRTI_L2_CLOUD_20190730T014515_20190730T015015_09288_96_020103_20200626T094359.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642859434/S5P_NRTI_L2_CLOUD_20190730T014015_20190730T014515_09288_96_020103_20200626T094500.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642859515/S5P_NRTI_L2_CLOUD_20190730T015015_20190730T015515_09288_96_020103_20200626T094743.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642859596/S5P_NRTI_L2_CLOUD_20190730T015515_20190730T020015_09288_96_020103_20200626T094923.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642859677/S5P_NRTI_L2_CLOUD_20190730T020015_20190730T020515_09288_96_020103_20200626T095052.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642860005/S5P_NRTI_L2_CLOUD_20190730T021015_20190730T021515_09288_96_020103_20200626T095353.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642860086/S5P_NRTI_L2_CLOUD_20190730T020515_20190730T021015_09288_96_020103_20200626T095453.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642860329/S5P_NRTI_L2_CLOUD_20190730T023015_20190730T023515_09288_96_020103_20200626T095759.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642860167/S5P_NRTI_L2_CLOUD_20190730T021515_20190730T022015_09288_96_020103_20200626T095703.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642860248/S5P_NRTI_L2_CLOUD_20190730T022015_20190730T022515_09288_96_020103_20200626T095752.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642860507/S5P_NRTI_L2_CLOUD_20190730T031015_20190730T031515_09289_96_020103_20200626T100025.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642860426/S5P_NRTI_L2_CLOUD_20190730T022515_20190730T023015_09288_96_020103_20200626T100009.nc



/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642860588/S5P_NRTI_L2_CLOUD_20190730T032015_20190730T032515_09289_96_020103_20200626T100430.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642860669/S5P_NRTI_L2_CLOUD_20190730T031515_20190730T032015_09289_96_020103_20200626T100654.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642860750/S5P_NRTI_L2_CLOUD_20190730T032515_20190730T033015_09289_96_020103_20200626T100746.nc
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/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642872376/S5P_NRTI_L2_CLOUD_20190730T191147_20190730T191647_09298_96_020103_20200626T133420.nc
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642872907/S5P_NRTI_L2_CLOUD_20190730T201647_20190730T202147_09299_96_020103_20200626T134120.nc
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642872988/S5P_NRTI_L2_CLOUD_20190730T201147_20190730T201647_09299_96_020103_20200626T134237.nc
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642873555/S5P_NRTI_L2_CLOUD_20190730T205147_20190730T205647_09299_96_020103_20200626T135541.nc

```

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642874203/S5P_NRTI_L2_CLOUD_20190730T221647_20190730T222147_09300_96_020103_20200626T141416.nc
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/mnt/data1/storage_nrt/pp_cloud/CLOUD-
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/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642874446/S5P_NRTI_L2_CLOUD_20190730T222647_20190730T223147_09300_96_020103_20200626T141756.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642874608/S5P_NRTI_L2_CLOUD_20190730T224647_20190730T225147_09300_96_020103_20200626T142039.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642874527/S5P_NRTI_L2_CLOUD_20190730T223647_20190730T224147_09300_96_020103_20200626T142003.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642874689/S5P_NRTI_L2_CLOUD_20190730T232647_20190730T233147_09301_96_020103_20200626T142226.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642874770/S5P_NRTI_L2_CLOUD_20190730T224147_20190730T224647_09300_96_020103_20200626T142413.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642874851/S5P_NRTI_L2_CLOUD_20190730T233147_20190730T233647_09301_96_020103_20200626T142635.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642874932/S5P_NRTI_L2_CLOUD_20190730T233647_20190730T234147_09301_96_020103_20200626T142750.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642875013/S5P_NRTI_L2_CLOUD_20190730T234147_20190730T234647_09301_96_020103_20200626T143006.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642875094/S5P_NRTI_L2_CLOUD_20190730T234647_20190730T235147_09301_96_020103_20200626T143159.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642875175/S5P_NRTI_L2_CLOUD_20190730T235147_20190730T235647_09301_96_020103_20200626T143315.nc
/mnt/data1/storage_nrt/pp_cloud/CLOUD-
642875256/S5P_NRTI_L2_CLOUD_20190730T235647_20190731T000147_09301_96_020103_20200626T143612.nc" ;

        :input orbits_l2 = 9285, 9285, 9285, 9285, 9285, 9285, 9286, 9285, 9286, 9286, 9286, 9286,
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9300, 9300, 9300, 9300, 9300, 9300, 9300, 9300, 9300, 9301, 9300, 9301, 9301, 9301, 9301, 9301,
9301 ;

} // group METADATA

```



B. Appendix – AUX_BGO3__ structure

Structure of the AUX_BGO3__ file in NRTI case.

```
netcdf S5P_NRTI_AUX_BGO3__20190729T000957_20190730T000021_20200626T091426 {

// global attributes:
    :Conventions = "CF-1.7" ;
    :institution = "DLR-IMF" ;
    :source = "Sentinel 5 Precursor, TROPOMI, space-borne remote sensing, L2" ;
    :history = "" ;
    :comment = "" ;
    :title = "TROPOMI/S5P Auxiliary information O3" ;
    :references = "https://atmos.eoc.dlr.de/tropomi" ;
    :time_reference = "20190729T000000" ;
    :time_coverage_start = "20190729T000957" ;
    :time_coverage_end = "20190730T000021" ;
    :creation_time = "20200626T091426" ;
    :processor_version = "02.01.03" ;
    :orbit = 9273 ;
    :background_correction_valid = "true" ;
    :reference_file = "/mnt/sw/IPF_S5P_L2_DLR/current/processors/support_data/s5p/aux/S5P_XXXX_AUX_BGO3__FALLBACK#1.nc" ;
    :reference_date = "2019-07-30" ;
    :revision_control_identifier = "0000" ;

group: PRODUCT {

    group: SURFACE_ALBEDO_MAPS {
        dimensions:
            months = 1 ;
            latitude = 1800 ;
            longitude = 3600 ;
            vza_correction_months = 12 ;
            vza_correction_surface_types = 3 ;
            vza_correction_polynomial_coefficients = 9 ;
        variables:
            float surface_albedo(months, latitude, longitude) ;
            surface_albedo:_FillValue = 1.e+20f ;
            surface_albedo:coordinates = "/PRODUCT/SURFACE_ALBEDO_MAPS/latitude
/PRODUCT/SURFACE_ALBEDO_MAPS/longitude" ;
            surface_albedo:long_name = "surface albedo in the total ozone fitting window" ;
            surface_albedo:unit = "1" ;
            surface_albedo:comment = "Global gapless geometry-dependent LER (G3_LER) based either on the
normalized GE_LER retrieved under clear-sky conditions from the ingested level-2 file or the fallback LER map" ;
            ubyte qa_value(latitude, longitude) ;
            qa_value:_FillValue = 255UB ;
            qa_value:coordinates = "/PRODUCT/SURFACE_ALBEDO_MAPS/latitude
/PRODUCT/SURFACE_ALBEDO_MAPS/longitude" ;
            qa_value:long_name = "QA value" ;
            qa_value:unit = "1" ;
            qa_value:comment = "QA value of the surface albedo - depending on the orbit number and the
availability of the cloud information from S5P OCRA/ROCINN and VIIRS" ;
            int orbit(latitude, longitude) ;
            orbit:_FillValue = 999999 ;
            orbit:coordinates = "/PRODUCT/SURFACE_ALBEDO_MAPS/latitude
/PRODUCT/SURFACE_ALBEDO_MAPS/longitude" ;
            orbit:long_name = "orbit number" ;
            orbit:unit = "1" ;
            orbit:comment = "Orbit number from which the surface albedo value was ingested - fill-value in
case the corresponding surface albedo is from the fallback map" ;
            ubyte cloud_information_source(latitude, longitude) ;
```




```
cloud_information_source: FillValue = 255UB ;
cloud_information_source: coordinates = "/PRODUCT/SURFACE_ALBEDO_MAPS/latitude
/PRODUCT/SURFACE_ALBEDO_MAPS/longitude" ;
cloud_information_source: long_name = "Cloud information source" ;
cloud_information_source: unit = "1" ;
cloud_information_source: comment = "Source of the cloud information that was used to determine
if the pixel was cloud free - 0: VIIRS, 1: S5P/ROCINN, 2: S5P/OCRA" ;
ubyte surface_type(latitude, longitude) ;
surface_type: FillValue = 255UB ;
surface_type: coordinates = "/PRODUCT/SURFACE_ALBEDO_MAPS/latitude
/PRODUCT/SURFACE_ALBEDO_MAPS/longitude" ;
surface_type: long_name = "Surface type" ;
surface_type: unit = "1" ;
surface_type: comment = "Surface type of the pixel at the time of the update - 0: Land, 1: Wa-
ter, 2: Snow/Ice" ;
double vza_correction_coefficients(vza_correction_months, vza_correction_surface_types,
vza_correction_polynomial_coefficients) ;
vza_correction_coefficients: long_name = "vza correction coefficients that have been used to
retrieve the surface albedo from the level-2 file" ;
vza_correction_coefficients: unit = "1" ;
vza_correction_coefficients: comment = "Multiplicative factor needed to compute the geometry-
dependent LER as a function of the actual viewing zenith angle, month, and surface type" ;
float latitude(latitude) ;
latitude: units = "degrees_north" ;
latitude: long_name = "pixel center latitude" ;
latitude: valid_min = -90. ;
latitude: valid_max = 90. ;
float longitude(longitude) ;
longitude: units = "degrees_east" ;
longitude: long_name = "pixel center longitude" ;
longitude: valid_min = -180. ;
longitude: valid_max = 180. ;

// group attributes:
:climatology_file =
"/mnt/sw/IPF_S5P_L2_DLR/current/processors/support_data/s5p/aux/S5P_XXXX_AUX_BGO3__FALLBACK#1.nc" ;
:updated_values_input_count = 1310769 ;
:updated_values_input_ratio = 0.202279166666667 ;
:updated_values_fallback_count = 5169231 ;
:updated_values_fallback_ratio = 0.797720833333333 ;
:expired_values_count = 0 ;
:expired_values_ratio = 0. ;
:no_update_values_count = 0 ;
:no_update_values_ratio = 0. ;
:input_data_ratio = 0.202279166666667 ;
:mean_orbit_age = 7.49697391378649 ;
} // group SURFACE_ALBEDO_MAPS
} // group PRODUCT

group: METADATA {

// group attributes:
:ProductShortName = "AUX_BGO3__" ;
:Processor = "version" ;
:Mode = "mode" ;
:processingMode = "NRTI" ;
:input_files_l2 =
642841087/S5P_NRTI_L2_O3_20190729T000912_20190729T001412_09273_96_020103_20200625T121331.nc
/mnt/datal/storage_nrt/pp_o3/O3-
642841168/S5P_NRTI_L2_O3_20190729T001412_20190729T001912_09273_96_020103_20200625T121855.nc
/mnt/datal/storage_nrt/pp_o3/O3-
642841249/S5P_NRTI_L2_O3_20190729T001912_20190729T002412_09273_96_020103_20200625T122424.nc
/mnt/datal/storage_nrt/pp_o3/O3-
642841335/S5P_NRTI_L2_O3_20190729T002412_20190729T002912_09273_96_020103_20200625T122906.nc
/mnt/datal/storage_nrt/pp_o3/O3-
642841416/S5P_NRTI_L2_O3_20190729T002912_20190729T003412_09273_96_020103_20200625T123351.nc
```



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642841759/S5P_NRTI_L2_O3_20190729T003412_20190729T003912_09273_96_020103_20200625T123737.nc
/mnt/data1/storage_nrt/pp_o3/03-
642841840/S5P_NRTI_L2_O3_20190729T003912_20190729T004412_09273_96_020103_20200625T124149.nc
/mnt/data1/storage_nrt/pp_o3/03-
642841921/S5P_NRTI_L2_O3_20190729T004412_20190729T004912_09273_96_020103_20200625T124647.nc
/mnt/data1/storage_nrt/pp_o3/03-
642842002/S5P_NRTI_L2_O3_20190729T004912_20190729T005412_09273_96_020103_20200625T125214.nc
/mnt/data1/storage_nrt/pp_o3/03-
642842083/S5P_NRTI_L2_O3_20190729T005412_20190729T005912_09275_96_020103_20200625T125648.nc
/mnt/data1/storage_nrt/pp_o3/03-
642842250/S5P_NRTI_L2_O3_20190729T010412_20190729T010912_09275_96_020103_20200625T130518.nc
/mnt/data1/storage_nrt/pp_o3/03-
642842169/S5P_NRTI_L2_O3_20190729T005912_20190729T010412_09275_96_020103_20200625T130416.nc
/mnt/data1/storage_nrt/pp_o3/03-
642842331/S5P_NRTI_L2_O3_20190729T014912_20190729T015412_09274_96_020103_20200625T130741.nc
/mnt/data1/storage_nrt/pp_o3/03-
642842412/S5P_NRTI_L2_O3_20190729T015412_20190729T015912_09274_96_020103_20200625T131240.nc
/mnt/data1/storage_nrt/pp_o3/03-
642842755/S5P_NRTI_L2_O3_20190729T015912_20190729T020412_09274_96_020103_20200625T131718.nc
/mnt/data1/storage_nrt/pp_o3/03-
642842836/S5P_NRTI_L2_O3_20190729T020412_20190729T020912_09274_96_020103_20200625T132102.nc
/mnt/data1/storage_nrt/pp_o3/03-
642842917/S5P_NRTI_L2_O3_20190729T020912_20190729T021412_09274_96_020103_20200625T132451.nc
/mnt/data1/storage_nrt/pp_o3/03-
642842998/S5P_NRTI_L2_O3_20190729T021412_20190729T021912_09274_96_020103_20200625T132917.nc
/mnt/data1/storage_nrt/pp_o3/03-
642843079/S5P_NRTI_L2_O3_20190729T021912_20190729T022412_09274_96_020103_20200625T133329.nc
/mnt/data1/storage_nrt/pp_o3/03-
642843160/S5P_NRTI_L2_O3_20190729T022412_20190729T022912_09274_96_020103_20200625T133741.nc
/mnt/data1/storage_nrt/pp_o3/03-
642843241/S5P_NRTI_L2_O3_20190729T022912_20190729T023412_09274_96_020103_20200625T134234.nc
/mnt/data1/storage_nrt/pp_o3/03-
642843342/S5P_NRTI_L2_O3_20190729T023412_20190729T023912_09274_96_020103_20200625T134711.nc
/mnt/data1/storage_nrt/pp_o3/03-
642843423/S5P_NRTI_L2_O3_20190729T023912_20190729T024412_09274_96_020103_20200625T135142.nc
/mnt/data1/storage_nrt/pp_o3/03-
642843585/S5P_NRTI_L2_O3_20190729T024912_20190729T025412_09274_96_020103_20200625T135515.nc
/mnt/data1/storage_nrt/pp_o3/03-
642843504/S5P_NRTI_L2_O3_20190729T024412_20190729T024912_09274_96_020103_20200625T135541.nc
/mnt/data1/storage_nrt/pp_o3/03-
642843666/S5P_NRTI_L2_O3_20190729T032912_20190729T033412_09275_96_020103_20200625T135817.nc
/mnt/data1/storage_nrt/pp_o3/03-
642843747/S5P_NRTI_L2_O3_20190729T033412_20190729T033912_09275_96_020103_20200625T140425.nc
/mnt/data1/storage_nrt/pp_o3/03-
642843828/S5P_NRTI_L2_O3_20190729T033912_20190729T034412_09275_96_020103_20200625T140941.nc
/mnt/data1/storage_nrt/pp_o3/03-
642843909/S5P_NRTI_L2_O3_20190729T034412_20190729T034912_09275_96_020103_20200625T141427.nc
/mnt/data1/storage_nrt/pp_o3/03-
642843990/S5P_NRTI_L2_O3_20190729T034912_20190729T035412_09275_96_020103_20200625T141816.nc
/mnt/data1/storage_nrt/pp_o3/03-
642844071/S5P_NRTI_L2_O3_20190729T035412_20190729T035912_09275_96_020103_20200625T142222.nc
/mnt/data1/storage_nrt/pp_o3/03-
64284414/S5P_NRTI_L2_O3_20190729T035912_20190729T040412_09275_96_020103_20200625T142836.nc
/mnt/data1/storage_nrt/pp_o3/03-
642844495/S5P_NRTI_L2_O3_20190729T040412_20190729T040912_09275_96_020103_20200625T143151.nc
/mnt/data1/storage_nrt/pp_o3/03-
642844576/S5P_NRTI_L2_O3_20190729T040912_20190729T041412_09275_96_020103_20200625T143627.nc
/mnt/data1/storage_nrt/pp_o3/03-
642844657/S5P_NRTI_L2_O3_20190729T041412_20190729T041912_09275_96_020103_20200625T144008.nc
/mnt/data1/storage_nrt/pp_o3/03-
642844738/S5P_NRTI_L2_O3_20190729T041912_20190729T042412_09275_96_020103_20200625T144443.nc
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- *Restricted: Project Internal* -

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} // group METADATA
```

C. Appendix – AUX_BGHCHO structure

Structure of the AUX_BGHCHO file in NRTI case (the same structure is present in OFFL case too).

```
netcdf S5P_NRTI_AUX_BGHCHO_20190729T000957_20190730T000021_20200626T081942 {
dimensions:
    polynomial_coefficients = 9 ;
    latitude_grids = 36 ;
    detector_rows = 450 ;
    wavelengths = 9000 ;
variables:
    float offsets(detector_rows) ;
        offsets:_FillValue = 9.96921e+36f ;
        offsets:units = "mol m-2" ;
    float offsets_scd0(detector_rows) ;
        offsets_scd0:_FillValue = 9.96921e+36f ;
        offsets_scd0:units = "mol m-2" ;
    float polynomial_coefficients(polynomial_coefficients) ;
        polynomial_coefficients:_FillValue = 9.96921e+36f ;
        polynomial_coefficients:units = "1" ;
    float polynomial_coefficients_scd0(polynomial_coefficients) ;
        polynomial_coefficients_scd0:_FillValue = 9.96921e+36f ;
        polynomial_coefficients_scd0:units = "1" ;
    float amf_scd0_median(latitude_grids, detector_rows) ;
        amf_scd0_median:_FillValue = 9.96921e+36f ;
        amf_scd0_median:units = "1" ;
    float amf_scd0_error_median(latitude_grids, detector_rows) ;
        amf_scd0_error_median:_FillValue = 9.96921e+36f ;
        amf_scd0_error_median:units = "1" ;
    float vcd_scd0_median(latitude_grids, detector_rows) ;
        vcd_scd0_median:_FillValue = 9.96921e+36f ;
        vcd_scd0_median:units = "molec cm-2" ;
    float vcd_scd0_error_median(latitude_grids, detector_rows) ;
        vcd_scd0_error_median:_FillValue = 9.96921e+36f ;
        vcd_scd0_error_median:units = "molec cm-2" ;
    float earthshine_reference_wavelength(wavelengths) ;
        earthshine_reference_wavelength:_FillValue = 9.96921e+36f ;
        earthshine_reference_wavelength:units = "nm" ;
    float earthshine_reference_radiance(detector_rows, wavelengths) ;
        earthshine_reference_radiance:_FillValue = 9.96921e+36f ;
        earthshine_reference_radiance:units = "mol.m-2.nm-1.sr-1.s-1" ;
    int detector_rows(detector_rows) ;
        detector_rows:units = "1" ;
        detector_rows:long_name = "detector_rows dimension index" ;
    int wavelengths(wavelengths) ;
        wavelengths:units = "1" ;
        wavelengths:long_name = "wavelengths dimension index" ;
    int latitude_grids(latitude_grids) ;
        latitude_grids:units = "1" ;
        latitude_grids:long_name = "latitude grids dimension index" ;
    float clear_amf_scd0(latitude_grids, detector_rows) ;
        clear_amf_scd0:_FillValue = 9.96921e+36f ;
        clear_amf_scd0:units = "1" ;

// global attributes:
    :Conventions = "CF-1.7" ;
    :institution = "DLR" ;
    :title = "TROPOMI/S5P Auxiliary background correction HCHO" ;
    :time_reference = "20190729T000000" ;
```



```
:time_coverage_start = "20190729T000957" ;
:time_coverage_end = "20190730T000021" ;
:orbit = 9273 ;
:processor_version = "02.01.03" ;
:revision_control_identifier = "0000" ;
:valid_latitude_start = -65. ;
:valid_latitude_end = 90. ;
:creation_time = "20200626T081942" ;
:background_correction_valid = "true" ;
:earthshine_reference_valid = "true" ;
```

group: METADATA {

// group attributes:

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/mnt/datal/storage_nrt/pp_hcho_11b/S5P_NRTI_L1B_RA_BD3_20190729T230009_20190729T230521_09286_96_010000_20200626T
074334.nc
/mnt/datal/storage_nrt/pp_hcho_11b/S5P_NRTI_L1B_RA_BD3_20190729T225509_20190729T230021_09286_96_010000_20200626T
074333.nc
/mnt/datal/storage_nrt/pp_hcho_11b/S5P_NRTI_L1B_RA_BD3_20190729T235009_20190729T235521_09287_96_010000_20200626T
074342.nc
/mnt/datal/storage_nrt/pp_hcho_11b/S5P_NRTI_L1B_RA_BD3_20190729T235509_20190730T000021_09287_96_010000_20200626T
074343.nc" ;
    } // group METADATA
}
```



D. Appendix – AUX_BGSO2_structure

Structure of the AUX_BGSO2_file in NRTI case (the same structure is present in OFFL case too).

```
netcdf S5P_NRTI_AUX_BGSO2__20190729T000957_20190730T000021_20200626T085319 {
dimensions:
    lat_grid = 36 ;
    o3_grid = 52 ;
    detector_rows = 450 ;
    wavelengths = 9000 ;
variables:
    float o3_grid(o3_grid) ;
        o3_grid:_FillValue = 9.96921e+36f ;
        o3_grid:units = "DU" ;
    float lat_grid(lat_grid) ;
        lat_grid:_FillValue = 9.96921e+36f ;
        lat_grid:units = "degrees_north" ;
    float window1_north(o3_grid, detector_rows) ;
        window1_north:_FillValue = 9.96921e+36f ;
        window1_north:units = "mol m-2" ;
    float window1_south(o3_grid, detector_rows) ;
        window1_south:_FillValue = 9.96921e+36f ;
        window1_south:units = "mol m-2" ;
    float window2(lat_grid, detector_rows) ;
        window2:_FillValue = 9.96921e+36f ;
        window2:units = "mol m-2" ;
    float window3(lat_grid, detector_rows) ;
        window3:_FillValue = 9.96921e+36f ;
        window3:units = "mol m-2" ;
    float earthshine_reference_wavelength(wavelengths) ;
        earthshine_reference_wavelength:_FillValue = 9.96921e+36f ;
        earthshine_reference_wavelength:units = "nm" ;
    float earthshine_reference_radiance(detector_rows, wavelengths) ;
        earthshine_reference_radiance:_FillValue = 9.96921e+36f ;
        earthshine_reference_radiance:units = "mol.m-2.nm-1.sr-1.s-1" ;
    int detector_rows(detector_rows) ;
        detector_rows:units = "1" ;
        detector_rows:long_name = "detector_rows dimension index" ;
    int wavelengths(wavelengths) ;
        wavelengths:units = "1" ;
        wavelengths:long_name = "wavelengths dimension index" ;

// global attributes:
    :Conventions = "CF-1.7" ;
    :institution = "DLR" ;
    :title = "TROPOMI/S5P Auxiliary background correction SO2" ;
    :time_reference = "20190729T000000" ;
    :time_coverage_start = "20190729T000957" ;
    :time_coverage_end = "20190730T000021" ;
    :orbit = 9273 ;
    :processor_version = "02.01.03" ;
    :revision_control_identifier = "0000" ;
    :creation_time = "20200626T085319" ;
    :background_correction_valid = "true" ;
    :earthshine_reference_valid = "true" ;

group: METADATA {

// group attributes:
```



```
:ProductShortName = "AUX_BGS02_" ;

:input_orbits_l2 = 9273, 9273, 9273, 9273, 9273, 9273, 9273, 9273, 9273, 9273, 9275, 9275, 9275,
9274, 9274, 9274, 9274, 9274, 9274, 9274, 9274, 9274, 9274, 9274, 9274, 9274, 9275, 9275, 9275, 9275, 9275,
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9286, 9286, 9286, 9286, 9286, 9287, 9287 ;

:input_files_l2 = "/mnt/datal/storage_nrt/pp_so2/SO2-
642841090/S5P_NRTI_L2_SO2_20190729T000912_20190729T001412_09273_96_020103_20200625T121351.nc
/mnt/datal/storage_nrt/pp_so2/SO2-
642841171/S5P_NRTI_L2_SO2_20190729T001412_20190729T001912_09273_96_020103_20200625T122003.nc
/mnt/datal/storage_nrt/pp_so2/SO2-
642841252/S5P_NRTI_L2_SO2_20190729T001912_20190729T002412_09273_96_020103_20200625T122532.nc
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642841338/S5P_NRTI_L2_SO2_20190729T002412_20190729T002912_09273_96_020103_20200625T123012.nc
/mnt/datal/storage_nrt/pp_so2/SO2-
642841419/S5P_NRTI_L2_SO2_20190729T002912_20190729T003412_09273_96_020103_20200625T123451.nc
/mnt/datal/storage_nrt/pp_so2/SO2-
642841762/S5P_NRTI_L2_SO2_20190729T003412_20190729T003912_09273_96_020103_20200625T123839.nc
/mnt/datal/storage_nrt/pp_so2/SO2-
642841843/S5P_NRTI_L2_SO2_20190729T003912_20190729T004412_09273_96_020103_20200625T124257.nc
/mnt/datal/storage_nrt/pp_so2/SO2-
642841924/S5P_NRTI_L2_SO2_20190729T004412_20190729T004912_09273_96_020103_20200625T124758.nc
/mnt/datal/storage_nrt/pp_so2/SO2-
642842005/S5P_NRTI_L2_SO2_20190729T004912_20190729T005412_09273_96_020103_20200625T125318.nc
/mnt/datal/storage_nrt/pp_so2/SO2-
642842086/S5P_NRTI_L2_SO2_20190729T005412_20190729T005912_09275_96_020103_20200625T125745.nc
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642842253/S5P_NRTI_L2_SO2_20190729T010412_20190729T010912_09275_96_020103_20200625T130540.nc
/mnt/datal/storage_nrt/pp_so2/SO2-
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/mnt/datal/storage_nrt/pp_so2/SO2-
642842334/S5P_NRTI_L2_SO2_20190729T014912_20190729T015412_09274_96_020103_20200625T130755.nc
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/mnt/datal/storage_nrt/pp_so2/SO2-
642842758/S5P_NRTI_L2_SO2_20190729T015912_20190729T020412_09274_96_020103_20200625T131828.nc
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/mnt/datal/storage_nrt/pp_so2/SO2-
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/mnt/datal/storage_nrt/pp_so2/SO2-
642843163/S5P_NRTI_L2_SO2_20190729T022412_20190729T022912_09274_96_020103_20200625T133846.nc
/mnt/datal/storage_nrt/pp_so2/SO2-
642843244/S5P_NRTI_L2_SO2_20190729T022912_20190729T023412_09274_96_020103_20200625T134339.nc
/mnt/datal/storage_nrt/pp_so2/SO2-
642843345/S5P_NRTI_L2_SO2_20190729T023412_20190729T023912_09274_96_020103_20200625T134809.nc
/mnt/datal/storage_nrt/pp_so2/SO2-
642843426/S5P_NRTI_L2_SO2_20190729T023912_20190729T024412_09274_96_020103_20200625T135245.nc
/mnt/datal/storage_nrt/pp_so2/SO2-
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642843750/S5P_NRTI_L2_SO2_20190729T033412_20190729T033912_09275_96_020103_20200625T140503.nc
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```



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/mnt/data1/storage_nrt/pp_so2/SO2-
642845408/S5P_NRTI_L2_SO2_20190729T052412_20190729T052912_09276_96_020103_20200625T150605.nc
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/mnt/data1/storage_nrt/pp_so2/SO2-
642846502/S5P_NRTI_L2_SO2_20190729T065412_20190729T065912_09277_96_020103_20200625T154532.nc
/mnt/data1/storage_nrt/pp_so2/SO2-
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/mnt/data1/storage_nrt/pp_so2/SO2-
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/mnt/data1/storage_nrt/pp_so2/SO2-
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/mnt/data1/storage_nrt/pp_so2/SO2-
642847448/S5P_NRTI_L2_SO2_20190729T071912_20190729T072412_09277_96_020103_20200625T161012.nc
/mnt/data1/storage_nrt/pp_so2/SO2-
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/mnt/data1/storage_nrt/pp_so2/SO2-
642847610/S5P_NRTI_L2_SO2_20190729T072912_20190729T073412_09277_96_020103_20200625T161732.nc
/mnt/data1/storage_nrt/pp_so2/SO2-
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