ESA Climate Change Initiative Extension Aerosol_cci+ Phase 2

Product Specification Document

Version 4.3

Deliverable number: D1.2

Document reference: Aerosol_cci+_Phase2_PSD_v4.3.doc

DOCUMENT STATUS SHEET

	FUNCTION	NAME	DATE	SIGNATURE
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EXECUTIVE SUMMARY

This Product Specifications Document (PSD) provides the specification of the ECV test data products that will be produced in the Aerosol_cci+ Phase 2 project.

The specifications are based on the availability of satellite and needed ancillary and on the technical capabilities to retrieve information in response to user requirements. The latter were collected for the Aerosol_cci+ Phase 2 project and documented in the User Requirements Document (v6.1) [RD1].

The test datasets will consist of two instances: 1) 4 months in 4 seasons, 2) 12 months covering a full calendar year. They will be processed with two different algorithms for dual view sensors: The Swansea algorithm will be applied to ATSR-2, AATSR and SLSTR, while the CISAR algorithm of Rayference will only be applied to SLSTR. The algorithms will provide Aerosol Optical Depth (AOD) and Fine Mode AOD (FM-AOD) as level 2 (satellite projection) and gridded level 3 datasets. Each level2 product will include a pixel-wise error characterization.

The document is structured as follows: After an introduction the aerosol parameters to be provided are listed. Then format / structure, annotations, quality flags, grid and projection and ancillary data are specified. Finally, the current knowledge on error budget and the traceability to user requirements are discussed.

Issue	Date	Modified Items / Reason for Change
Aerosol_cci Phase 1		
0.1	17.02.2011	First draft
0.2	17.02.2011	Issue reviewed by science leader - extended executive summary - addition of sections 8 and 9
1.0	18.02.2011	Changes accepted, first issue submitted to ESA
1.1	18.04.2011	Response to RIDs
Aerosol_cci Phase 2		
1.2	02.09.2014	Aerosol-cci Phase2: addition of IASI and update of Phase 1 specifications for discussion in PM1
2.0	25.11.2014	Update based on DARD (v1.0) and URD (v2.4)
2.1	09.01.2015	Revision after discussion during PM2, with additional inputs by email in early January
2.2	26.03.2015	Minor format corrections (section 3) detected during file checks
2.3	06.11.2015	Minor changes and updates to address URD v2.6 requirements
3.0	04.01.2017	Update after year 2 aerosol_cci2, taking into account DARDv3.0
3.1	27.01.2017	Review by science leader, minor updates of table 7 based on last URD revision
3.2	12.03.2017	Addition of SEVIRI and PODLER / Africa to executive summary; completion of cover page
Aerosol_cci+ Phase 2		
4.0	28.08.2025	First update to Aerosol_cci+ Phase 2
4.1	24.09.2025	Updates, corrections based on partner feedback; mainly in section 5
4.2	27.11.2025	Updates, based on feedback from the ESA TO
4.3	09.12.2025	Few additions based on partner feedback

LIST OF TABLES

TABLE OF CONTENTS

1 INTRODUCTION

In conformance with the thematic requirements for the aerosol essential climate variables (ECVs), the Aerosol_cci+ Phase 2 project produces a set of global aerosol ECV test products from a set of European dual-view satellite instruments, i.e. ATSR-2 on ERS-2, AATSR on ENVISAT, SLSTR on SENTINEL3. The data sets include aerosol optical depth (AOD) and fine mode AOD. All L2 data sets include per pixel uncertainties.

This Product Specification Document (PSD) version 4.0 provides a detailed specification of the aerosol products which are intended to be available by the end of Aerosol_cci+ Phase 2. The products and their specifications are based on the availability of both Level 1 satellite data and necessary ancillary data products and on user consultations as described in the most recent version (version 6.1) of the URD (User Requirements Document). Section 2 will describe the products and their specifications. The product specification and variable naming has been harmonized following user comments and recommendations during various meetings, including CMUG, and discussions in the Aerosol_cci2 progress meetings. Furthermore, the CCI data standards working group (DSWG) with representatives from all CCI teams, has formulated data standards requirements for CCI data producers [RD3], which are followed as much as possible. These requirements are reflected in Section 3 where tables are provided describing both the global attributes and the Aerosol_cci+ specific attributes such as product and diagnostic variables. Section 4 provides the product grid and projection. Ancillary data used for each algorithm are briefly summarized in Section 5. Section 6 summarizes uncertainty issues. The traceability to user requirements is described in Section 7 and an overall conclusion is provided in section 8.

1.3 Scope

This document provides the specification of the ECV data products that will be produced in the Aerosol_cci+ Phase 2 project.

1.4 References

1.4.1 Applicable Documents

[AD1] Request for CCN proposal ESA-EOP-SC-AMT-2021-47: "Aerosol_cci+ Phase 2"

[AD2] its Annex B: Aerosol

[AD3] The Prime Contractor's Baseline proposal, ref. 3032766, v1.1 dated 16.04.2025

1.4.2 Reference Documents

[RD1] Aerosol_cci_URD_v6.1: Aerosol_cci+ Phase 2 User Requirements Document, version 6.1, dd. 28.08.2025.

[RD2] Holben, B. N., Eck, T. F. Sluster, I. Tanré, D., Buis, J. P., Setzer, A., Vermote, E., Reagan, J. A., Kaufman, Y. J., Nakajima T., Lavenu, F., Jankowiak, I., and Smirnov, Z.: AERONET—A Federated Instrument Network and Data Archive for Aerosol Characterization, Rem. Sens. Environ, 66, 1–16, 1998.

[RD3] Bennet, V. and S. James (2013). Data Standard Requirements for CCI Data Producers. Technical Note, Reference CCI-PRGM-EOPS-TN-13-0009, Issue 1, Revision 2 (09March12015); available at: http://cci.esa.int/sites/default/files/CCI_Data_Requirements_Iss1.2_Mar2015.pdf.

[RD4] Morel A. (1988). Optical Modeling of the upper Ocean in relation to its biogenous matter content (case I waters). *J. of Geophys. Res.,* 93: 10749-10768.

[RD5] Lyapustin, A., Y. W. (2018). Mcd19a3 modis/terra+aqua brdf model parameters 8-day l3 global 1km sin grid v006. Technical report.

1.1.1 Acronyms and abbreviations

AATSR	Advanced Along-Track Scanning Radiometer
AOD	Aerosol Optical Depth (also called Aerosol Optical Thickness, AOT)
ATSR-2	Along-Track Scanning Radiometer, no. 2
CCI	Climate Change Initiative
CEOS	Committee on Earth Observation satellites
CMUG	Climate Model User Group
ECV	Essential Climate Variable
ESA	European Space Agency
PSD	Product Specification Document
SLSTR	Sea and Land Surface Temperature Radiometer
URD	User Requirements Document
UV	Ultra-Violet

2 AEROSOL PARAMETERS TO BE PROVIDED

The Aerosol_cci+ Phase 2 project intends to produce the following set of aerosol test products′, see Table 1 for more detail:

- AOD and FM-AOD from ATSR-2, AATSR (1 algorithm) and SLSTR (2 algorithms);

It is noted that each of these products will be provided subject to the availability of Level 1 data as well as all necessary intrinsic and ancillary information. Furthermore, the aerosol retrievals will only be made for valid pixels and/or combinations of pixels (referred to as retrieval area) which are cloud-free and have not been flagged as invalid for any other reason (e.g., in a larger retrieval area there should be a sufficient, i.e. statistically relevant, number of valid pixels).

It is further noted that the temporal coverage of the products provided by the various instruments differs substantially. None of the instruments have sufficient swath width to provide daily global coverage but some of them are very close. The swath width of the instruments of ~500 to ~750 km means that it takes several days to a week to revisit each location on Earth. The revisit time obviously also affects the accuracy of aggregates covering longer time periods (monthly or seasonally gridded).

Table 1: Summary of Aerosol_cci+ Phase 2 products which are aimed to be available at the end of the project

Product name	Parameter(s)	sensors	level	period	Comment
Tropospheric / total column products					
Swansea algorithm	Total AOD / FM-AOD	SLSTR	Level2, 3	4 months	First CRDP, at M12
Swansea algorithm	Total AOD / FM-AOD	ATSR-2 AATSR SLSTR	Level2, 3	1 year	Second CRDP, at M18
CISAR algorithm	Total AOD / FM-AOD	SLSTR	Level2, 3	4 months	First CRDP, at M12
CISAR algorithm	Total AOD / FM-AOD	SLSTR	Level2, 3	1 year	Second CRDP, at M18

2.1 Dual view sensor aerosol variable naming

In Aerosol_cci+ Phase 2, ATSR / SLSTR aerosol products are retrieved by two retrieval teams participating in Aerosol_cci+: Swansea University (SU) and Rayference. In response to user requirements for AOD550, Aerosol_cci+ Phase 2 will produce AOD550 and FMAOD550 for ATSR-2 and AATSR (1 algorithm) and SLSTR (2 algorithms) as listed in Table 2.

Table 2. Aerosol_cci+ Phase 2 core variable naming

Parameter	Parameter name
Aerosol Optical Depth (AOD) at 550 nm	AOD550
Fine Mode AOD550	FM_AOD550

Table 2 lists only the parameters which will be delivered in Aerosol_cci+ Phase 2 from dual view sensors.

3 FORMAT AND STRUCTURE OF AEROSOL_CCI+ PRODUCTS

The format of the Aerosol_cci+ Phase 2 products will, as much as possible, follow the standard data requirements as formulated by the CCI Data Standard Working Group (DSWG), see [RD3] for most recent document. RD3 lists eight requirements which must be used in the cci projects, addressing (see RD3 for detail):

R-1. Standard products: minimum requirements

R-2. Products for existing user communities requiring formats other than the standard CCI

R-3. Conformance with international standards: INSPIRE compliant

R-4. Common vocabulary: use terms from the CCI vocabulary tables in the netCDF global attributes (http://www.esa-cci.org/; click on data standards working group on left hand side), for missing terms, request that they are added

R-5. Gridded data – coordinate variables: as minimum the dimensions time, latitude, longitude

R-6. CCI data producers shall engage with the CF community to help develop the standards they require for satellite data

R-7. Use the common directory structure for all output data made available to users

R-8. File naming: use CCI file naming convention for all output data made available to users.

The filename specification is provided in Table 3. The requirements for the standard product contents can be divided in global requirements (Table 4) and Aerosol_cci+ specific requirements (Table 5). For detail, see RD3. The Aerosol_cci+ specific data provided will, as much as possible, be harmonized following recommendations by users as described in the URD (v6.1) [RD1] and further specified during user evaluations (e.g., CMUG) and users workshops and assessments planned in the course of the Aerosol_cci+ phase 2 project together with the Aerosol_cci+ Phase 2 user group minimizing discrepancies between different data provider teams. A consensus has been reached which is followed for the product variables in Table 6.

The data volumes of the Aerosol_cci+ Phase 2 products is summarized in the following:

- Swansea products (SLSTR; ATSR L2 files are less than half the size):
    - L2 orbit file: ~ 2-3 MB -> 1 day: ~ 35 MB -> 1 year: ~ 13 GB
    - L3 daily gridded file: ~ 350-400 kB -> 1 year: ~ 130 MB
    - L3 monthly gridded file: ~ 5-6 MB -> 1 year: ~ 65 MB
- CISAR products (SLSTR):
    - L2 daily accumulated file: ~ 350 - 450 MB -> 1 year: ~ 150 GB
    - L3 monthly gridded file: ~ 150 kB -> 1 year: ~ 2 MB

Table 3: Filename specifications

Filename (see RD3 for detail)	
	Generic: <Indicative Date>[<Indicative Time>]-ESACCI-<Processing Level>_<AEROSOL>-<Data Type>-<Product String>[-<Additional Segregator>][-v<GDS version>]-fv<File version>.**nc** Filename parts in [ ] are optional
Date and time	
	The identifying date for this data set. Format is YYYY[MM[DD]], where YYYY is the four digit year, MM is the two digit month from 01 to 12 and DD is the two digit day of the month from 01 to 31. The date used should best represent the observation date for the data set. It can be a year, a year and a month or a year and a month and a day. The identifying time for this data set in UTC. Format is [HH[MM[SS]]] where HH is the two digit hour from 00 to 23, MM is the two digit minute from 00 to 59 and SS is the two digit second from 00 to 59.
Processing level	
	L2P, L3, (L3C, L3U, L3S)
Date type	
	AER_PRODUCTS (multiple variable datasets) AOD (total column visible AOD datasets) FM_AOD (the fraction of AOD ascribed to fine mode aerosol particles)
Product string	
	Instrument_platform, e.g. AATSR-ENVISAT
	Algorithm, e.g. SU version 1.14
Additional segregators	
	Additional segregators are an optional part of the filename, see RD3 for examples: Orbit identifier - Length of period covered, e.g. daily, monthly, specified period - land or sea area - resolution (spatial)
Version information	
	v<GDS version> Including the version number of the GHRSST Data Specification is optional for the CCI filenaming convention. If used it shall be 02.0 **fv<File Version>** File version number in the form n{1,}[.n{1,}] (That is 1 or more digits followed by optional . and another 1 or more digits.)

Table 4: Format, structure and global attribute specifications of the data products provided by Aerosol_cci+ Phase2.

File format	
	netCDF-4 (classic)
File structure	
	Level 2 product (orbit projection): cell or pixel_number = <no of pixels in file>
	Gridded Level 3 product: longitude = <no of pixel columns in array> latitude = <no of pixel lines in array> time = 1
General metadata	
	Title: provide a succinct description of the dataset
	Institution: the organisation,,where the data was produced; use names from CCI common vocabulary (http://www.esa-cci.org/; click on data standards working group on left hand side), e.g. Finnish Meteorological Institute (FMI); not mandatory, alternative to “creator_name”
	Source: soriginal data source(s), e.g. AATSR L1B GBT, version as read in with the data file. Multiple source datasets separated by commas.
	History: processing history of dataset and software version number (e.g. “2012-08-21 13:56:16 - Product generated from ORAC-SW dual-view, 3.0. AATSR L1b ver. 6.03”
	References: references to algorithm, ATBD, technical note describing dataset or website where this can be found
	Tracking_id: a UUID (Universal Unique Identifier) value
	Conventions: (provide the CF Version) = “CF-1.6”
	Product_version: the product version of this data file
Global attributes	
	inputFileList = "ATS_TOA_1PRUPA20080122_003758_000065272065_00202_30817_9667.N1"
	startDate = "2008-01-22" (date of first observation); not mandatory
	dateTime = "2009-01-02 11:55:24" (UTC time of first observation of the data set processed); alternative to “time_coverage_start”
	productID = "20200701112241-ESA-CCI_AEROSOL-AER_PRODUCTS-SLSTR_Sentinel_S3A-SU_22768-v1.14.nc"; alternative to “id”
Optional global attributes (with examples of content: “content”)	
	platform = "ENVISAT"; separated by comma’s if more than one
	sensor = "AATSR"; separated by comma’s if more than one
	Spatial resolution = "10x10 km" (a string describing the approximate resolution of the product)

	projection = "Sinusoidal [Neq = 4008]"; also named as “resolution”
	content = "Aerosol Optical Depth"
Discovery metadata[#]	
	Summary: a paragraph describing the dataset
	Keywords: a comma separated list of key words and phrases
	Id: the filename; alternative for productID
	naming authority: the combination of the naming authority and the id should be a globally unique identifier for the dataset
	keywords_vocabulary: if you are following a guideline for the words/phrases in your “keywords” attribute, put the name of that guideline here
	cdm_data_type: the THREDDS data type appropriate for this dataset
	Comment: miscellaneous information about the data
	date_created: the date on which the data was created
	creator_name: name of the organisation which created the dataset
	creator_url: url of the organisation which created the dataset
	creator_email: email of the organisation which created the dataset
	Project: (the scientific project that produced the data) = “Climate Change Initiative – European Space Agency”
	geospatial_lat_min: decimal degrees north, range -90 to +90
	geospatial_lat_max: decimal degrees north, range -90 to +90
	geospatial_lon_min: decimal degrees east, range -180 to +180
	geospatial_lon_max: decimal degrees east, range -180 to +180
	geospatial_vertical_min: assumed to be in metres above ground unless geospatial_vertical_units: attribute defined otherwise; only for vertical profile products (GOMOS); n/a for dual-view sensors
	geospatial_vertical_max: assumed to be in metres above ground unless geospatial_vertical_units: attribute defined otherwise; only for vertical profile products (GOMOS); n/a for dual-view sensors
	time_coverage_start: format yyyymmddThhmmssZ
	time_coverage_end: format yyyymmddThhmmssZ
	time_coverage_duration: should be an ISO8601 duration string; not mandatory
	time_coverage_resolution: should be an ISO8601 duration string; not mandatory

	standard_name_vocabulary: the name of the controlled vocabulary from which variable standard names are taken (for names missing in the vocabulary inform the DSWG)
	license = “ESA CCI Data Policy: free and open access”
For **gridded (level3) data on a regular lat/lon grid**, the following attributes shall be included in the files (not compulsory for level2 data, or data on other grids, e.g. polar stereographic) :	
	geospatial_lat_units: units of the latitude vector
	geospatial_lon_units: units of the longitude vector
	geospatial_lon_resolution: resolution of longitude vector
	geospatial_lat_resolution: resolution of latitude vector

Discovery metadata allows information about the data to be harvested into catalogues and data federations. For dataset discovery, the netCDF attributes recommended in http://www.unidata.ucar.edu/software/netcdfjava/formats/DataDiscoveryAttConvention.html

Table 5 Aerosol-specific variables of the data products provided by Aerosol_cci+ Phase2.

Obligatory auxiliary variables (vector for level2 products, grid for level 3 products)	
	latitude (at center; for level 3 vector with same value for each line of the data arrays, for level 2 also a complete vector with different values for each pixel)
	longitude (at center; for level 3 vector with same value for each column of the data arrays, for level 2 also a complete vector with different values for each pixel)
	time (UTC time of acquisition; one vector for level 2 with pixel acquisition times, two arrays with first and last time of acquisition of any contributing pixel for level 3)
	pixel_number (for level 2 / satellite projection polygons)
	pixel_corner_latitude[1-4] / pixel_corner_longitude[1-4] for level 2 satellite projection polygons
Product variables# (vector for level2 products, grid for level 3 products)	
	AOD550: aerosol optical depth at 550 nm
	AOD670, AOD870, AOD1600 (AATSR and SLSTR): AOD at other wavelengths available from AATSR or SLSTR
	ANG550_870 /(SU): Angström exponent between 550 and 870 nm
	AOD550_ uncertainty: uncertainty of AOD550
	FM_AOD550: Fine Mode AOD at 550 nm
	AAOD550 (SU): Absorbing AOD at 550 nm
Obligatory qualifier attributes for each product variable	
	long_name
	standard_name (see CF standard name list)
	units
	valid_range
	Coordinates
	_FillValue[&]
Diagnostic variables* (vector for level2 products)	
	sun_zenith at center
	satellite_zenith at center
	relative_azimuth at center
	quality_flag(s) (if defined for the algorithm in the ATBD)
	cloud_fraction (if defined for algorithm in ATBD)
	surface_albedo[440,550,670]
	vegetation_index (if defined for algorithm in ATBD)
	fraction_of_water (if defined for algorithm in ATBD)
	surface_type_number (if defined for algorithm in ATBD)
	D_AOD550, SSA550 (SU AATSR / SLSTR): Dust AOD, Single Scattering Albedo at 550 nm (obtained using the dust / sea salt fraction from the AEROCOM median climatology)
	fit_error or similar fit quality check (if defined for the algorithm in the ATBD)
Compliance check with CF convention	
	possible at: https://cfchecker.ncas.ac.uk http://cfconventions.org

Visualisation	
	with standard tools such as panoply http://www.giss.nasa.gov/tools/panoply/ for level 3
	with idl runtime code and source files for level 2.

There are several CF-compliant standard variable names for aerosol parameters of the dual view instruments ATSR and SLSTR (a wavelength specification is only added in the long_name):

- AOD: "atmosphere_optical_thickness_due_to_ambient_aerosol_particles"
- Angström exponent: Angstrom_exponent_of_ambient_aerosol_in_air"
- AAOD: "absorption atmosphere_optical_thickness_due_to_ambient_aerosol_particles"
- DAOD: "atmosphere_optical_thickness_due_to_dust_ambient_aerosol_particles"
- SSA: "single_scattering_albedo_in_air_due_to_ambient_aerosol_particles"

*Diagnostic variables are optional, as appropriate and defined in each ATBD, with explanation in the ATBD.

& In case of a missing value where the retrieval did not provide a valid result for a given input pixel (e.g. due to not converging) a fill_value is assigned as defined in the attribute _FillValue of this variable; for compliance with common tools **do not put 'NAN'**

3.1 Examples of attributes in the data files.

Reproduced from Swansea output file for Level 2 and for Level 3 daily data:

LEVEL 2:

```
:Conventions = "CF-1.6";
:tracking_id = "02ad913e-bc83-48be-afd2-3c337ce23c4f";
:naming_authority = "uk.ac.su.aatsraerosol";
:title = "AARDVARC C3S aerosol product level 2";
:product_version = "1.14";
:summary = "This dataset contains the level-2 aerosol properties products
from SLSTR satellite observations. Data are processed by Swansea
algorithm";
:id = "20200701000247-C3S-L2P_AEROSOL-AER_PRODUCTS-SLSTR_Sentinel_S3A-
SU_22762-v1.14.nc";
:sensor = "SLSTR";
:platform = "SENTINEL-S3A";
:resolution = "10km x 10km";
:projection = "sinusoidal [neq = 4008]";
:cdm_data_type = "Swath";
:cell = 57923; // int
:inputFileList =
"S3A_SL_1_RBT____20200701T000247_20200701T000547_20200702T051036_0179_060_0
74_3240_LN2_O_NT_004.SEN3
\nS3A_SL_1_RBT____20200701T000547_20200701T000847_20200702T051134_0179_060_
074_3420_LN2_O_NT_004.SEN3
\nS3A_SL_1_RBT____20200701T000847_20200701T001147_20200702T051233_0179_060_
074_3600_LN2_O_NT_004.SEN3
\nS3A_SL_1_RBT____20200701T011646_20200701T011946_20200702T065821_0180_060_
074_1620_LN2_O_NT_004.SEN3
\nS3A_SL_1_RBT____20200701T011946_20200701T012246_20200702T065916_0179_060_
074_1800_LN2_O_NT_004.SEN3
```

\nS3A_SL_1_RBT____20200701T012246_20200701T012546_20200702T070011_0179_060_074_1980_LN2_O_NT_004.SEN3
\nS3A_SL_1_RBT____20200701T012546_20200701T012846_20200702T070105_0179_060_074_2160_LN2_O_NT_004.SEN3
\nS3A_SL_1_RBT____20200701T012846_20200701T013146_20200702T070200_0179_060_074_2340_LN2_O_NT_004.SEN3
\nS3A_SL_1_RBT____20200701T013146_20200701T013446_20200702T070255_0179_060_074_2520_LN2_O_NT_004.SEN3
\nS3A_SL_1_RBT____20200701T013446_20200701T013746_20200702T070350_0179_060_074_2700_LN2_O_NT_004.SEN3
\nS3A_SL_1_RBT____20200701T013746_20200701T014046_20200702T070446_0179_060_074_2880_LN2_O_NT_004.SEN3
\nS3A_SL_1_RBT____20200701T014046_20200701T014346_20200702T070542_0180_060_074_3060_LN2_O_NT_004.SEN3
\nS3A_SL_1_RBT____20200701T014346_20200701T014646_20200702T070639_0179_060_074_3240_LN2_O_NT_004.SEN3
\nS3A_SL_1_RBT____20200701T014646_20200701T014946_20200702T070735_0179_060_074_3420_LN2_O_NT_004.SEN3
\nS3A_SL_1_RBT____20200701T014946_20200701T015246_20200702T070831_0179_060_074_3600_LN2_O_NT_004.SEN3";
:time_coverage_start = "20200701T000246Z";
:time_coverage_end = "20200701T015246Z";
:geospatial_lat_min = -45.0052f; // float
:geospatial_lat_max = 77.65146f; // float
:geospatial_lon_min = 106.136086f; // float
:geospatial_lon_max = 164.25545f; // float
:date_created = "20210126T121720Z";
:project = "Climate Change Initiative - European Space Agency";
:references = "http://www.esa-aerosol-cci.org";
:creator_name = "College of Science, Swansea University";
:creator_url =
"https://www.swansea.ac.uk/staff/science/geography/p.r.j.north/";
:creator_email = "p.r.j.north@swansea.ac.uk";
:source = "IPF-SL-1 v06.17";
:keywords = "satellite,observation,atmosphere";
:keywords_vocabulary = "NASA Global Change Master Directory (GCMD) Science Keywords";
:standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention version 18";
:license = "ESA CCI Data Policy: free and open access";

LEVEL 3 DAILY:

:Conventions = "CF-1.6";
:tracking_id = "744020a4-8f0d-406b-955e-bd6af353c4db";
:naming_authority = "uk.ac.su.aatsraerosol";
:title = "AARDVARC C3S aerosol product level 3";
:product_version = "1.14";
:summary = "This dataset contains the level-3 daily mean aerosol properties products from SLSTR satellite observations. Data are processed by Swansea algorithm";
:id = "20200101000321-C3S-L3C_AEROSOL-AER_PRODUCTS-SLSTR_SENTINEL_S3A-SU_DAILY-v1.14.nc";
:sensor = "SLSTR";
:platform = "SENTINEL-S3A";

:resolution = "1x1 degrees";
:projection = "equirectangular";
:cdm_data_type = "grid";
:lon = 360; // int
:lat = 180; // int
:time = "1";
:time_coverage_start = "20200101T000321Z";
:time_coverage_end = "20200201T000238Z";
:geospatial_lat_min = "-90.0";
:geospatial_lat_max = "90.0";
:geospatial_lon_min = "-180.0";
:geospatial_lon_max = "180.0";
:geospatial_lat_units = "degrees_north";
:geospatial_lon_units = "degrees_east";
:geospatial_lat_resolution = "1.0";
:geospatial_lon_resolution = "1.0";
:date_created = "20210126T121723Z";
:project = "Climate Change Initiative - European Space Agency";
:references = "http://www.esa-aerosol-cci.org";
:creator_name = "Swansea University";
:creator_url = "https://www.swansea.ac.uk/staff/science/geography/p.r.j.north/";
:creator_email = "p.r.j.north@swansea.ac.uk";
:source = "IPF-SL-1 v06.16";
:history = "Level 3 product from Swansea algorithm";
:keywords = "satellite,observation,atmosphere";
:keywords_vocabulary = "NASA Global Change Master Directory (GCMD) Science Keywords";
:standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention version 18";
:license = "ESA CCI Data Policy: free and open access";
:inputfilelist = "20200101-C3S-L3C_AEROSOL-AER_PRODUCTS-SLSTR_SENTINEL_S3A-SU_DAILY-v1.14.nc", …";

4 PRODUCT GRID AND PROJECTION

The level 2 products contain each variable as a vector (e.g. in a sinusoidal 10km x 10km grid in satellite projection along sensor line and column, covering one orbit or all daily accumulated pixels in one file. Each pixel is geolocated by its latitude and longitude information and has its time coordinate.

The level 3 products are gridded regularly along longitude and latitude by averaging the level 2 product values within each grid cell (e.g. 1.0 x 1.0 lat-lon grid). Level 3 products are averaged per day and per month. Each variable is provided as an array covering the entire globe. Due to the limited swath width of the dual view sensors, but also as result of cloud masking, quality filtering or low solar elevation angle, the gridded level 3 products contain a large number of empty cells, which are then set to a pre-defined fill value (as defined in the attributes of each variable).

5 ANCILLARY DATA USED

The ancillary data used in the retrieval algorithms for ECV production include both satellite and non-satellite data. Table 6 summarizes the ancillary data sources for the various algorithms.

Table 6: Summary of ancillary data used in the Aerosol_cci+ Phase 2 algorithms

Ancillary data set	**Swansea**	**CISAR**
Sensors	ATSR-2, AATSR, SLSTR	SLSTR
Elevation model	N/A	SRTM30 (available at: https://dwtkns.com/srtm30m/)
Aerosol models	Algorithm intrinsic	Algorithm intrinsic
Aerosol Layer Height, AOT Climatology		Kinne et al. (2013)
BRDF models / surface reflectance spectra	Algorithm intrinsic	RPV model
BRDF data set	N/A	MODIS MCD19A3 (Lyapustin, 2018)
Cloud masks	Algorithm intrinsic	Algorithm intrinsic
Land-sea mask	Algorithm intrinsic	NAVOCEANO (Naval Oceanographic Office: https://www.cnmoc.usff.navy.mil/navoceano/)
Ocean colour	Fixed value: ocean pigment concentration is assumed to be a global constant of 0.1 mg/m^{-3} (case I water reflectance model dependent on pigment concentration after Morel 1988)	Fixed value : 0.1 mg/m^{-3}
Surface wind speed	Fixed value : wind speed of 9m/s (used for the glint detection)	ERA5 (https://cds.climate.copernicus.eu/datasets/reanalysis-era5-single-levels)
Aerosol component climatology	MACv2 Aerosol Model climatology (Kinne et al. 2006)	
Cross section reference data	N/A	N/A
Gases concentration (water vapour, ozone) and surface pressure		ERA5

6 UNCERTAINTY CHARACTERIZATION

The Aerosol_cci+ project aims to produce a variety of aerosol products using different techniques and algorithms applied to different types of sensors. The uncertainties in the data products are important for various reasons and therefore need to be characterized. Different methods can be used to provide the uncertainty. A commonly used method used for MODIS and MISR is to plot the retrieval value (in particular AOD) versus an independently measured co-located value (in particular from AERONET CIMEL sun photometer observations, [RD2]) to determine the envelope as the standard deviation from the regression line. AERONET data are available from many stations worldwide (http://aeronet.gsfc.nasa.gov/) and are the most widely used standard for the validation of satellite-derived aerosol properties. However, there are also vast areas where no AERONET or other independent validation data are available and the envelope error is assumed to apply over such areas. Furthermore, the validation statistics using AERONET data may vary for different regions and seasons. Therefore, other approaches may be preferred to provide an independent uncertainty estimate based on known errors.

An overview of the uncertainties as they are included in Aerosol_cci+ products is available in the End-to-end ECV Uncertainty Budget (E3UB, to be updated under this project). The E3UB provides an overview of definitions of errors and uncertainties, sources of uncertainties, methods of determining uncertainties for each algorithm used in the project, their validation and guidelines for using the products.

7 TRACEABILITY TO USER REQUIREMENTS

Table 6 summarizes the traceability of the products specified in this document to the user requirements contained in the URD v6.1.

Table 6: Traceability of user requirements (URD v6.1) to specifications

No.	User requirement	Product specification response
Product parameters		
	AOD at 2-4 wavelengths	*AOD will be provided at 550 reference wavelength (and 2-3 additional wavelengths)*
	Fine mode AOD	*based on fitting reflectances at 4 wavelengths – needs further improvement*
	Coarse mode AOD	*CM_AOD can be computed from the difference between AOD and FM_AOD*
	Dust AOD at 10 µm and 0.55µm	*Is assumed based on AEROCOM climatology*
	Absorption: AAOD or SSA, at 2 wavelengths	*Not in focus for dual view instruments; based on AEROCOM climatology*
	Aerosol above clouds	*Not in focus for dual view instruments*
	Aerosol Index (AI)	*Not in focus for dual view instruments*
	Co-located aerosol and cloud products	*This is the focus of the CISAR algorithm*
	Layer height	*Not in focus for dual view instruments*
	AOD in three layers (low, mid, high)	*Not in focus for dual view instruments*
	Extinction profile	*Not in focus for dual view instruments*
	Stratospheric AOD	*Not in focus for dual view instruments*
	Aerosol effective radius of sulphate aerosol in the stratosphere r,eff (strato)	*Not in focus for dual view instruments*
	PSC	*Not in focus for dual view instruments*
	Depolarization or aerosol shape (non-spherical)	*Not in focus for dual view instruments*
Numerical specifications		
	Accuracy	*To be established by validation*
	Precision	*To be established by validation*
	Geographic coverage	*Global (except high winter latitudes)*
	Horizontal resolution	*Default 10 x 10 km^2 / 1° x 1°*
	Vertical resolution	*N/A*
	Temporal resolution	*Daily (with gaps due to limited swath width; monthly*
	Temporal sampling (nr of observed locations per hour)	*Depends on meteorological conditions (cloud cover)*
	Temporal extent (1982-present)	*Test dataset of 4 months / 1 full year; operational processing done by C3S*
	Stability	*Cannot be evaluated with the test datasets*
Technical specifications		
	Format	*netCDF as required*

	Metadata	*compliant with CF metadata convention 1.6*
	Grid	*lat-lon for level3 as required*
	Product levels	*Level3 as required* *Level2* based on MACC need / assimilation*
	Time series length	*Test dataset of 4 months / 1 full year; operational processing done by C3S*
	Cloud – aerosol product associations / 3D histograms	*Can be analysed with CISAR*
Ancillary parameters		
	Cloud fraction (also for pixels without AOD) Clear-sky detection	*Cloud mask for Swansea algorithm; probabilistic assignment for CISAR algorithm*
	Solar surface albedo	*Surface reflectance is co-retrieved from dual view algorithms*
	Local error	*Pixel uncertainty will be provided for each product*
Data access		
	Easy availability	*via ICARE ftp server*
	Timeliness	*NRT not foreseen*
	Long-term record	*Test dataset of 4 months / 1 full year; operational processing done by C3S*
	Error documentation (indicating source of error)	*A per-pixel uncertainty is provided*
System specifications		
	Easy reprocessing	*C3S processing system is designed to optimize re-processing*

* Note that Level 2 in Aerosol_cci refers to a product for a certain retrieval area (depending on instrument, e.g. 10x10 km^2 for ATSR) including a statistically significant number of instrument pixels.

Requirements for accuracy, precision and stability will be implemented as far as possible. Validation of the test datasets will show how far this can be achieved. The ongoing algorithm evolution efforts will provide the basis for a refinement of the respective product specifications.

Requirements from the various user groups were evaluated versus the planned products. Some of the requirements can be met, others can be partly met and a few are not feasible with the current sensor suite used in Aerosol_cci+. Limitations are the swath width and resulting coverage and revisit time. The retrieval accuracy for the instruments used in Aerosol_cci+ has been tremendously improved in the course of the earlier projects and further improvements are still possible but not as readily as initially. Some of the accuracy requirements are too strict to expect that they can be met within Aerosol_cci+. The provision of most aerosol products is also limited to the availability of sunlight (using EO instruments, with a limitation of the solar zenith angle that can be used).

In summary, the GCOS and CMUG requirements as regards accuracy and coverage are partly met and further investigation is expected to further improve the situation. The AeroCom requirements are mostly met and further improvement is expected from the options. For MACC the requirements are partly met but NRT is not foreseen as part of Aerosol_cci+. Consistency is under investigation in the overall CCI team, involving other ECVs such as land cover / ocean colour. The requirements from the Aerosol_cci+ core users are overall quite well met, and the interaction between users and EO teams certainly helps to

get the best possible products through user feedback. For aerosol-cloud interactions, the requirements on clouds need to come from the Cloud_cci team and the aerosol to CCN relationship at cloud base is a difficult one due to vertical resolution and physical constraints on the ability of aerosol particles to act as CCN.

Aerosol parameters requested in URD v6.1 (Chapter 4) are available or under study, those on accuracy (Chapter 5) are partly met and those on resolution (Chapter 7) are met.

8 CONCLUSION

The Aerosol_cci+ dataset aimed to be produced in Phase 2 will consist of test datasets (4 months or full calendar year) from dual view sensors with 2 algorithms providing aerosol optical depth (AOD) and fine mode AOD. These are the level 2 products which form the basis for provision of level 3 products. Each product will include a pixel-wise error characterization. Gridded daily and monthly level3 products will be derived from the level3 datasets.

The data products will be provided following the DSWG guidelines, with specific attributes for Aerosol_cci+ products. Most products are developed in response to the user requirements, although not all of them can be met with the sensor suite currently used in Aerosol_cci+, and some can be partly met. Accuracy, precision and stability need to be evaluated.

Aerosol_cci+ partners include representatives from several large climate user communities, in addition to CMUG, which will help evaluate the aerosol products in the course of the project and advise on the usability and further improvement for specific areas. They have strong links to the respective wider communities which will increase the visibility of Aerosol_cci products and promote their use.

End of the document