

Report on the outcomes of a Virtual Mobility¹

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Full report

Objective

The objective of this activity is to assess which instruments/products involved in the HARMONIA COST Action [R.1] can support the generation of files compliant with the GEOMS (Generic Earth Observation Metadata Standard) format [R.5]. This involves verifying the existence of GEOMS templates for specific instruments, for instrument/product combinations, or evaluating the feasibility of generating GEOMS-compliant files based on the instruments and products listed in the Tables of Attributes Values (TAV) [R.6].

This work is intended to support not only the Harmonia initiative but also the broader scientific community interested in uploading and/or retrieving data from repositories that adopt the GEOMS format as EVDC (ESA Validation Data Centre) [R.4]. Additionally, it aims to offer constructive feedback to the team responsible for the development and maintenance of GEOMS templates.

This study contributes to the objectives of WG2.

¹ This report is submitted by the grantee to the Action MC for approval and for claiming payment of the awarded grant. The Grant Awarding Coordinator coordinates the evaluation of this report on behalf of the Action MC and instructs the GH for payment of the Grant.

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ACRONYMS

AE	Angstrom exponent
AF	Asymmetry Factor
AOD	Aerosol Optical Depth
BC	Black Carbon
DOAS	Differential Optical Absorption Spectroscopy
ESA	European Space Agency
EVDC	ESA Validation Data Centre
GEOMS	Generic Earth Observation Metadata Standard
LIDAR	Light Detection and Ranging
OPCs	Optical Particle Counters
PF	Phase Function
PFR	Precision Filter Radiometer
PI	Principal Investigators
PMOD	Physikalisch-Meteorologisches Observatorium Davos
PSR	Precision Solar Spectroradiometer
RI	Refractive Index
SSA	Single Scattering Albedo
TAV	Tables of Attributes Values
VSD	Volume Size Distribution
WRC	World Radiation Center

1. WORKFLOW OVERVIEW

The starting point for this activity was the consultation of the list of measurement campaigns considered within the Harmonia project. This list is included in the Harmonia deliverables D1.1 [R.2] and D2.1 [R.3], with additional details available in an Excel table shared among the Harmonia team (available on request).

Both these documents provide various pieces of information regarding the campaigns, the instruments involved, the derived and derivable products, and the acquisition modes (day/night).

Based on the campaign information, the first step was to compile a list of instruments and categorize them by type. Then, for each instrument, all associated products were then listed. Since not all this information is available in the Harmonia documents, it was obtained through targeted research on the instruments and, in some cases, with the support of the Principal Investigator (PI) of the measurement campaigns in which the instruments were used.

The diagram in Figure 1 outlines the sequential steps and key evaluation questions to be addressed, initially at the instrument level and subsequently at the product level.

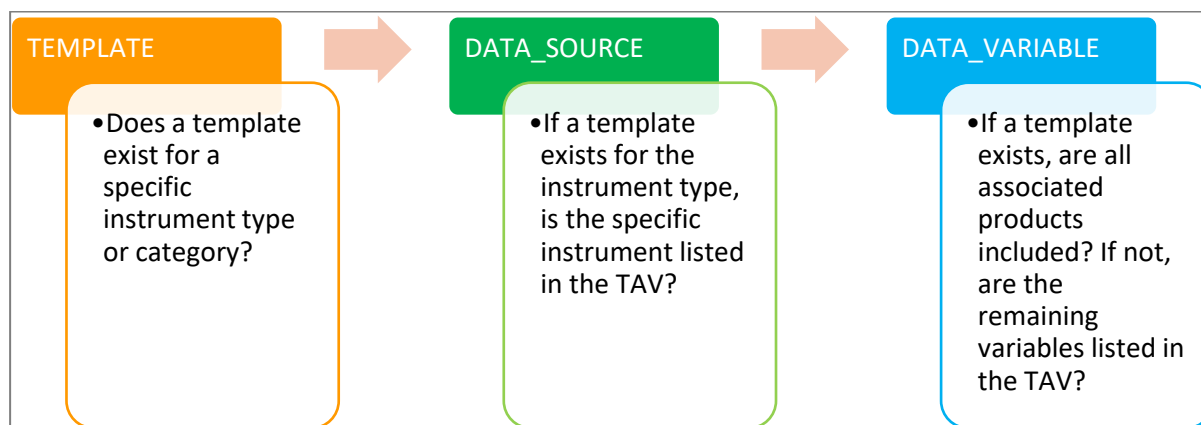


Figure 1 The diagram illustrates the main questions guiding the evaluation process, highlighting the logical steps and relationships between the different aspects analysed.

In the following two chapters, the instruments considered, and the measurable products will be listed. For each instrument and product, a brief description will be provided to highlight the available measurement methods (in the case of instruments) or the required ones (in the case of products, in order to derive the optical or physical properties of aerosols). Chapter four will offer an overview of the GEOMS format structure and its requirements, along with a description of the available templates for aerosol-related products. In the final chapter, all this information will be brought together to identify the current availability and existing gaps in achieving GEOMS-compliant data formatting.

2. CLASSIFICATION OF INSTRUMENTS

The measurement campaigns considered by HARMONIA are twenty-four, in addition to these there also twelve permanent monitoring stations.

The instruments involved can be classified into active and passive remote sensing instruments, in situ instrumentation, aircraft and sonde-based instruments. For the purposes of this activity, only instruments that allow the retrieval of aerosol-related products will be considered. In addition, to easily look for a dedicated template, these instruments will be grouped into subcategories, as shown in Figure 2.

The subcategories identify the main characteristics of each instrument, both in terms of technology and measurement method; the parameters that can be derived from their measurements depend on both these aspects. Therefore, in the following sections, each instrument will be briefly described, and the respective aerosol parameters will be listed.

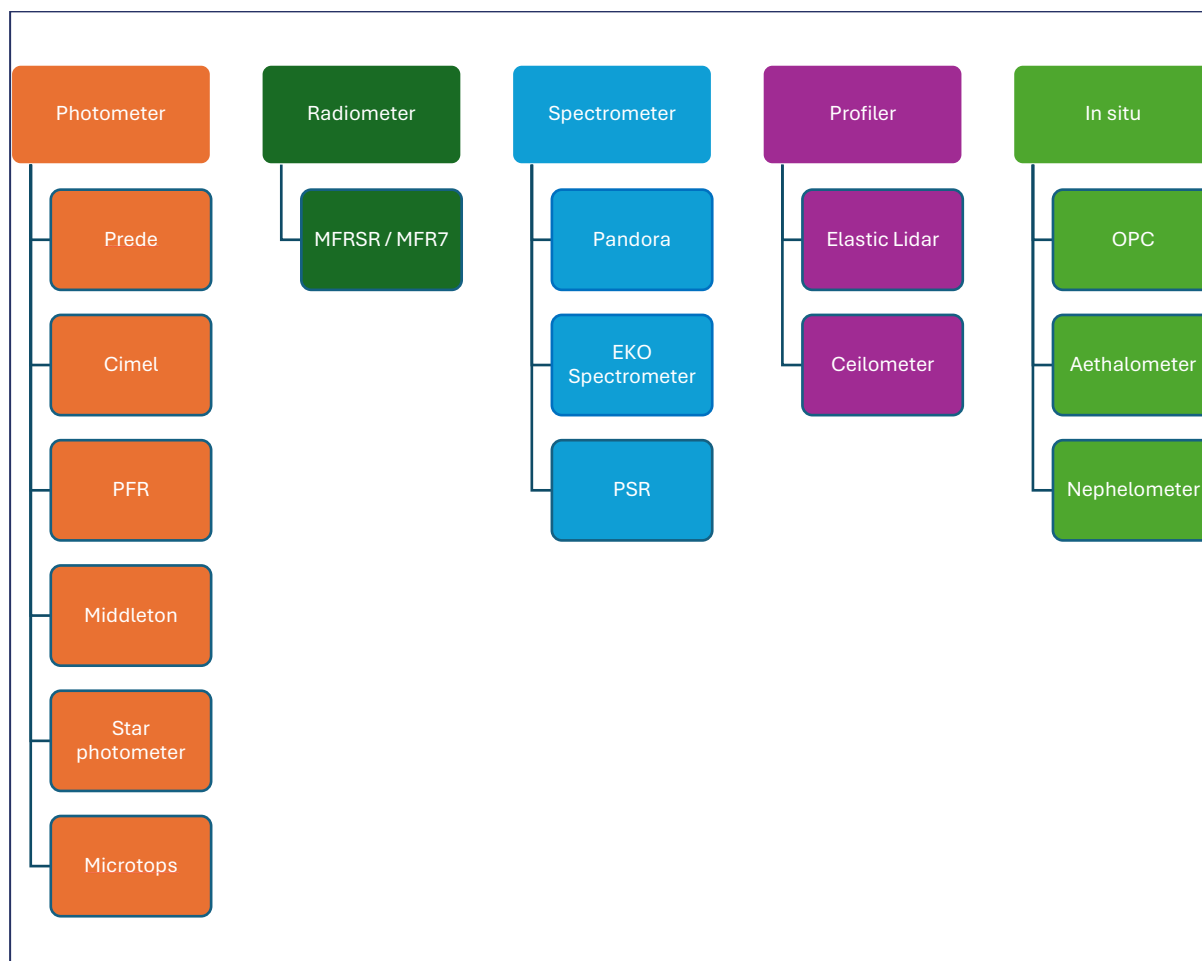


Figure 2 The figure illustrates the different categories analysed in the report and shows the specific instruments linked to each category.

The **Prede POM and Cimel photometers** are instruments equipped with a tracker capable of measuring direct radiation by pointing at the sun (some models can also track the moon), or at various azimuthal/zenithal angles. The sensors are equipped with filters for different wavelengths, which are mounted on a rotating filter wheel. With direct sun (or moon) measurements, the instruments can retrieve the Aerosol Optical Depth (AOD) for each wavelength, the Angstrom exponent (AE), and the water vapor column amount. The measurements taken out of sun direction (sky measurements) are used to

retrieve other parameters as single scattering albedo (SSA), refractive index (RI), volume size distribution (VSD), asymmetry factor (AF), phase function (PF) and aerosol direct radiative forcing.

The **PFR (Precision Filter Radiometer)** is a reference photometric instrument used for measuring direct solar irradiance and AOD at four nominal wavelengths. It is designed to ensure high precision and long-term stability in atmospheric observations.

The **Middleton Sun-photometer** is a high-precision instrument designed for solar photometric measurements, primarily used for atmospheric aerosol characterization. It contains four narrowband spectro-pyrheliometers, each equipped with filters centred on specific wavelengths (typically in the visible and near-infrared range), allowing the retrieval of parameters such as, AOD, column ozone content, and water vapor content.

The **star photometer** is a passive remote sensing instrument designed to measure the spectral optical depth of the atmosphere by analysing attenuated starlight and allow to retrieve the AOD.

The **Microtops sun-photometer** is a portable, multispectral 5-channel instrument designed to measure AOD, direct solar irradiance, and column water vapor content. The instrument is lightweight, easy to operate in the field, and offers performance comparable to larger, more expensive instruments.

Both radiometers listed in **Error! Reference source not found.** belong to the **Multifilter Rotating Shadow-band Radiometer (MFR)** family, designed to measure spectral solar irradiance in its global, diffuse, and direct components. They use narrowband filters centred on specific wavelengths, plus one broadband channel. These instruments are used to derive AOD, ozone column content, and water vapor, and for radiative transfer studies.

The **Pandora** is a high-resolution ground-based spectrometer designed work in direct-Sun, zenith sky, and sky-scanning modes. It uses the Differential Optical Absorption Spectroscopy (DOAS) technique in to accurately retrieve total column and vertical profiles of atmospheric gases and aerosols. The AOD is one of the products under development for this instrument.

The **EKO spectroradiometer** is a compact, high-precision instrument designed for spectral direct solar irradiance measurements. It has been successfully used to retrieve AOD across multiple wavelengths, spectral range 340–870 nm.

The **Precision Solar Spectroradiometer (PSR)** is a high-resolution spectroradiometer developed by PMOD/WRC (Physikalisch-Meteorologisches Observatorium Davos / World Radiation Center) as an evolution of the PFR filter photometer. It is designed to measure direct spectral solar irradiance over a continuous wavelength range from 320 to 1040 nm, enabling the retrieval of AOD and atmospheric trace gases.

Both **Elastic LIDAR** (Light Detection and Ranging) and **Ceilometer** uses the same technology to analyse the vertical structure of the atmosphere, particularly the presence and distribution of aerosols and clouds. The Elastic Lidar uses laser pulses at one or more wavelengths (typically in the visible or UV range) and measures the backscattered radiation from atmospheric particles and provides high-resolution vertical profiles reaching altitudes of several tens of kilometres. The Ceilometer is a more compact and automated version of lidar, it uses infrared laser pulses (typically 905 or 1064 nm), has a shorter range than elastic lidar, but is ideal for continuous monitoring and operational use.

Optical Particle Counters (OPCs) are instruments that measure the number and size of aerosol particles suspended in the air. They work by passing particles through a laser beam and detecting the light scattered by each particle. The amount of scattered light is used to estimate the particle's size. OPCs are commonly used for monitoring air quality, measuring particulate matter (PM), and studying aerosol size distributions, typically for particles larger than about 0.3 μm .

Aethalometers are instruments used to measure the concentration of black carbon (BC) particles in the air. They work by drawing air through a filter and measuring the reduction in light transmitted through

the filter as particles accumulate. The amount of light absorbed is directly related to the concentration of black carbon, which is an important component of atmospheric aerosols due to its effects on climate and air quality. Aethalometers provide real-time data and are widely used in environmental monitoring and research.

Nephelometers are instruments used to measure the amount of light scattered by aerosol particles suspended in the air. By detecting the intensity of scattered light at specific angles, nephelometers provide information about the concentration and optical properties of aerosols. These measurements are important for assessing air quality, visibility, and the impact of aerosols on climate.

3. AEROSOL PRODUCTS

Key aerosol parameters are essential for understanding their behaviour and their impact on climate, air quality, and health. These parameters are typically grouped into three categories: optical parameters describe how aerosols interact with light; physical parameters describe the size, shape, and distribution of aerosol particles; chemical parameters define the composition and reactivity of aerosols.

Table 1 Overview of aerosol products, including a brief description of each and an indication of whether it is obtained through direct or indirect measurement or derived via inversion techniques.

	Aerosol products	Descriptions
1	Aerosol Optical Depth (AOD)	AOD quantifies the amount of aerosol particles in a vertical column of the atmosphere. It is typically retrieved by measuring the attenuation of radiation at different wavelengths. To obtain accurate readings, instruments must be pointed directly at the sun (or the moon, for nighttime measurements).
2	Ångström Exponent (AE)	AE describes the wavelength dependence of aerosol optical depth (AOD) and provides information about the size distribution of aerosol particles. Since it is derived from AOD values at different wavelengths, it requires direct measurements of solar (or lunar) radiation.
3	Single Scattering Albedo (SSA)	SSA is the ratio of aerosol scattering to total extinction (scattering + absorption), and it indicates how efficiently aerosol particles scatter incoming radiation compared to how much they absorb. It is derived from direct and diffuse solar radiation measurements at multiple wavelengths.
4	Refractive Index (RI)	RI is a complex number describing how aerosol particles interact with light, combining both scattering (real part) and absorption properties (imaginary part). It is retrieved through inversion of multi-wavelength radiometric data, such as aerosol optical depth and sky radiance.
5	VSD	VSD describes how the volume of aerosol particles is distributed across different particle sizes. It is retrieved through inversion of multi-angle sky radiance measurements and spectral AOD data.
6	Asymmetry Factor (AF)	AF quantifies the average direction in which aerosol particles scatter incoming radiation. This parameter is not directly measured but is retrieved through inversion of multi-angle sky radiance measurements.
7	Phase Function (PF)	PF describes the angular distribution of scattered radiation by aerosol particles. It indicates how much light is scattered in different directions (forward, backward, or sideways) and is retrieved through inversion of multi-angle sky radiance measurements.
8	Backscatter ratio	Ratio between the total backscattered signal (aerosol + molecular) and the molecular backscatter alone. It provides insight into aerosol presence and intensity.
9	Backscatter coefficient (β)	Quantifies the amount of light scattered by aerosols in the backward direction per unit distance and per unit solid angle.
10	Extinction coefficient (α)	Measures the total attenuation of light due to aerosols, including both scattering and absorption, per unit distance.
11	Absorption Coefficient (σ)	Measure of how much light is absorbed by particles per unit distance as it passes through a medium. It quantifies the fraction of incident light that is absorbed by the particles in a given volume of air.
12	Lidar ratio	Ratio of the extinction coefficient to the backscatter coefficient. It is indicative of aerosol type and composition.
13	Depolarization ratio	Ratio of cross-polarized to co-polarized backscattered light in linear polarization.
14	Transmission	Represents the two-way transmission of the lidar signal through the atmosphere, accounting for attenuation during both upward and downward paths.
15	Particle Number Concentration (PNC)	Number of airborne particles present in a given volume of atmospheric air, obtained from in-situ measurements.
16	Black Carbon concentration (BC)	Mass concentration of black carbon.

As previously mentioned, depending on the characteristics of the instrument and the measurement methods, each instrument may or may not be able to retrieve a specific type of product. The Table 1 provides a list of aerosol products that can be retrieved from the instruments listed in **Error! Reference source not found.**, along with a brief description of each product. The aim is to highlight the diversity of aerosol parameters and the specific measurement requirements associated with their retrieval. Parameters numbered 8 to 13 can also be obtained through LIDAR-type observations. In this case, these variables describe the vertical distribution of aerosol optical properties in the atmosphere and will collectively be referred to as aerosol profiles.

Based on the instruments presented in the Figure 2, and considering the information provided in the previous and current sections, the Table 2 outlines the correspondence between each instrument and the aerosol products it can retrieve.

Table 2 Correspondence between aerosol products and the instruments capable of retrieving them, based on the measurement principles described in the text.

Types	Instruments	Products											
		AOD	AE	SSA	RI	VSD	AF	PF	β	σ	BC	PNC	Aerosol profiles
Photometer	Prede	X	X	X	X	X	X	X					
	Cimel	X	X		X	X	X	X					
	PFR	X	X										
	Middleton	X											
	Star photometer	X											
	Microtops	X											
Radiometer	MFRSR / MFR7	X											
Spectrometer	Pandora	X											
	EKO Spectrometer	X											
	PSR	X											
Profiler	Elastic Lidar	X	X										X
	Ceilometer	X	X										X
In situ	OPC											X	
	Aethalometer									X	X		
	Nephelometer								X				

4. GEOMS FORMAT

The GEOMS format was created to ensure that data files are consistent in both their content and their structure. This standardization makes it easier for users to understand and use the data.

GEOMS-format files include a set of attributes that provide various types of metadata, such as the instrument type, location, instrument principal investigator, data usage policy, and a description of the data itself. In addition, all the name of the variables included in the file must be formatted precisely according to GEOMS specifications and must include a set of attributes that enhance readability and interpretability. These attributes include, for example, product description, dimensions, units of measurement, and data type.

The values assigned to both global attributes and variable-specific attributes, as well as the variable names themselves, must conform to those listed in the TAV [R.6], which are continuously updated based on user requests and needs.

Particular attention must be paid to the naming of variables. Since variables may refer to the specific parameter, but also to its measurement mode or to additional information related to it (for example, the measurement uncertainty). It is possible to compose the variable name using three entries, so that the variable name appears as follows:

Variable name[_Variable mode][_Variable descriptor]

Of these, only the name entry is mandatory; the other two are optional. Furthermore, for each entry, the allowed options are those listed in the TAV, referring respectively to DATA_VARIABLE_01, DATA_VARIABLE_02, and DATA_VARIABLE_03 (for details, please refer to the documentation [R.5]).

On the EVDC webpage [R.4], several templates are also available, each devoted to a particular instrument (e.g. Photometers) or instrument/product pair (e.g. Lidar/aerosol). Each template includes a list of mandatory and optional variables, with the correct variable names formatted according to GEOMS standards, along with the corresponding descriptions, units, data types, dimensions, and dependencies between variables.

The list of templates [R.7], as well as the templates themselves, are continuously updated. Currently, 41 templates are available; however, in the context of this activity, the focus is only on those templates related to aerosol products. The reference templates relevant to this report are listed below. The order in which they are presented follows the sequence established in the previous classification of the instruments.

- GEOMS-TE-PHOTOMETER-001
- GEOMS-TE-LIDAR-AEROSOL-006
- GEOMS-TE-LIDAR-AEROSOL-L3-001
- GEOMS-TE-OPC-AEROSOL-001
- GEOMS-TE-NEPHELOMETER-001

An individual examination of each template will now be conducted, with the objective of identifying their principal characteristics, assessing their potential applications, and highlighting any associated limitations or critical aspects. In what follows, all mandatory variables will be considered. However, variables such as ALTITUDE.INSTRUMENT, LATITUDE.INSTRUMENT and LONGITUDE.INSTRUMENT, which are common to all templates and do not provide meaningful contributions to the current discussion, will henceforth be excluded from further mention. A complete list of variables, together with additional relevant information, is available in the Appendices, which also include links to download the corresponding .csv files.

4.1. GEOMS-TE-PHOTOMETER-001

As indicated by its title, this template is specifically intended for instruments belonging to the photometer category. The two variables related to aerosol properties are AEROSOL.OPTICAL.DEPTH and AEROSOL.ANGSTROM.EXPONENT.

The AEROSOL.OPTICAL.DEPTH variable is two-dimensional: the first dimension is associated with the DATETIME variable, which specifies the date and time of the measurement, while the second dimension is linked to the WAVELENGTH variable, which indicates the wavelength considered.

Similarly, the AEROSOL.ANGSTROM.EXPONENT variable is also two-dimensional, with DATETIME as one dimension, and as the second one AEROSOL.ANGSTROM.EXPONENT_WAVELENGTH.INDEX. The latter, together with the AEROSOL.ANGSTROM.EXPONENT_WAVELENGTH.PAIR variable, allows identification of the two wavelengths used in the retrieval.

Other variables present in the template are ANGLE.SOLAR_ZENITH.ASTRONOMICAL and AIR.MASS, which indicate the possibility of using this template for direct solar radiation measurements. The last mandatory variable is the instrument's internal temperature, INTERNAL.INSTRUMENT.TEMPERATURE, which serves as an indicator of the instrument's operational stability.

No additional aerosol variables, such as those that may be among the products of photometers, as shown in the table, are included in this template. Furthermore, there is no provision for including AOD and AE values derived from lunar measurements, as there is no variable available for recording the lunar azimuth angle.

4.2. GEOMS-TE-LIDAR-AEROSOL-006

This template is specifically designed for a particular instrument, the elastic lidar, and most of the variables associated with aerosol parameters are optional, facilitating the adaptation of the format to systems with several characteristics and capabilities, while still establishing a standard for variable naming and definition. Here, the description begins with the mandatory variables.

The timing of the measurement is indicated by the variables DATETIME.START and DATETIME.STOP, which represent the start and end of the measurement period, respectively, while DATETIME denotes the central value of this time interval.

The variables WAVELENGTH_EMISSION and WAVELENGTH_DETECTION, as suggested by their names, refer to the laser emission and system reception wavelengths. These variables may be multidimensional, which is particularly useful in the case of multi-wavelength lidar systems.

The zenith angle at which the lidar is pointed, and optionally the azimuth angle if the pointing mode is not vertical, are represented by ANGLE.VIEW_ZENITH and ANGLE.VIEW_AZIMUTH variables, respectively. Both variables may be constant or dependent on DATETIME or the emitted wavelength, depending on the system configuration. Finally, the variable ALTITUDE reports the altitude at which the measurement is performed.

The variables MOLECULAR.BACKSCATTER.COEFFICIENT_INDEPENDENT, representing the computed molecular profile used in the retrieval process, and MOLECULAR.BACKSCATTER.COEFFICIENT_INDEPENDENT_SOURCE, describing its origin, are the last two mandatory variables.

As previously mentioned, all other variables contained in the template are optional. However, the inclusion of any of these variables requires the simultaneous inclusion of additional related variables,

which provide important contextual information linked to the parameter in question. To simplify reading, the Table 3 presents the values of the two fields, VARIABLE_01 and VARIABLE_02, which together constitute the variable name. To clarify, if one intends to include a variable from the first column, it is necessary to also include all variables whose names are formed by combining that variable with each of those listed in the second column.

Table 3 The table reports the values of the two fields, VARIABLE_01 and VARIABLE_02, which together constitute the variable name of the optional variables included in template GEOMS-TE-LIDAR-AEROSOL-006.

DATA_VARIABLE_01	DATA_VARIABLE_03
AEROSOL.BACKSCATTER.RATIO	UNCERTAINTY.COMBINED.STANDARD
AEROSOL.BACKSCATTER.COEFFICIENT	UNCERTAINTY.RANDOM.STANDARD
AEROSOL.BACKSCATTER.COEFFICIENT	UNCERTAINTY.SYSTEMATIC.STANDARD
AEROSOL.BACKSCATTER.COEFFICIENT.CIRCULAR	RESOLUTION.ALTITUDE
AEROSOL.LIDAR.RATIO	INTEGRATION.TIME
AEROSOL.LIDAR.RATIO.CIRCULAR	RETRIEVAL.METHOD
AEROSOL.ANGSTROM.EXPONENT	
AEROSOL.DEPOLARIZATION.RATIO.LINEAR	
AEROSOL.DEPOLARIZATION.RATIO.CIRCULAR	
AEROSOL.TRANSMISSION.TWOWAY	
VOLUME.DEPOLARIZATION.RATIO.LINEAR	
VOLUME.DEPOLARIZATION.RATIO.LINEAR	
VOLUME.DEPOLARIZATION.RATIO.CIRCULAR	
AEROSOL.LAYER.BASE.HEIGHT	
AEROSOL.LAYER.TOP.HEIGHT	

4.3. GEOMS-TE-LIDAR-AEROSOL-L3-001

This template is also dedicated to elastic lidar and is very similar to the previous one. There are some differences in the list of variables, here they are fewer, and in the additional information associated with them. The mandatory variables are the same as those listed for the previous template. As in the previous case, to simplify reading, the entries which compose the name of the variables, are listed in a Table 4.

Table 4 The table reports the values of the two fields, VARIABLE_01 and VARIABLE_02, which together constitute the variable name of the optional variables included in template GEOMS-TE-LIDAR-AEROSOL-L3-001.

DATA_VARIABLE_01	DATA_VARIABLE_03
AEROSOL.BACKSCATTER.RATIO	MEAN
AEROSOL.BACKSCATTER.COEFFICIENT	MEAN.STANDARD
AEROSOL.EXTINCTION.COEFFICIENT	MEDIAN
AEROSOL.LIDAR.RATIO	UNCERTAINTY.COMBINED.STANDARD
AEROSOL.ANGSTROM.EXPONENT	COUNT
AEROSOL.LINEAR.DEPOLARIZATION.RATIO	RESOLUTION.ALTITUDE ²
VOLUME.LINEAR.DEPOLARIZATION.RATIO	INTEGRATION.TIME
AEROSOL.LAYER.BASE.HEIGHT ³	RETRIEVAL.METHOD ⁴
AEROSOL.LAYER.TOP.HEIGHT ³	
MIXING.LAYER.BASE.HEIGHT ³	
MIXING.LAYER.TOP.HEIGHT ³	

² Required for all variables except AEROSOL.ANGSTROM.EXPONENT

³ These variables require as additional information only MEAN, MEAN.STANDARD and MEDIAN

⁴ Required for all variables except AEROSOL.LINEAR.DEPOLARIZATION.RATIO and VOLUME.LINEAR.DEPOLARIZATION.RATIO

4.4. GEOMS-TE-OPC-AEROSOL-001

This template is designed for OPCs and includes a single aerosol-related variable: AEROSOL.NUMBER.DENSITY, which represents the particle number concentration. To define this variable correctly, three other variables are needed: DATETIME, which provides the timestamp of the measurement, PARTICLE.SIZE, which indicates the average particle size for each bin, and PARTICLE.SIZE.BOUNDARIES, which defines the lower and upper size limits for each bin.

In addition to these, the template includes a mandatory variable, AEROSOL.NUMBER.DENSITY_UNCERTAINTY.COMBINED.STANDARD, which gives the uncertainty estimate of the number concentration for each size bin, and an optional variable, AEROSOL.NUMBER.DENSITY_FLAG, used to indicate the data quality of the measurement.

4.5. GEOMS-TE-NEPHELOMETER-001

This template refers to nephelometers, and the variable related to aerosols is AEROSOL.BACKSCATTER.COEFFICIENT, where it is possible to enter the values of the aerosol backscattering coefficient obtained at different wavelengths, specified in the WAVELENGTH variable, and for each measurement performed by the instrument (DATETIME is the time variable). There is also the TOTAL.SCATTERING.COEFFICIENT variable, which refers to the total backscattering parameter, with the same dependencies as the previous one.

The other mandatory variables provide information about the integration time of the measurement (INTEGRATION.TIME) and the conditions under which it is performed, specifically the temperature, pressure, and humidity measured inside the instrument; these parameters are associated with the variables INTERNAL.INSTRUMENT.TEMPERATURE, INTERNAL.INSTRUMENT.PRESSURE and INTERNAL.INSTRUMENT.HUMIDITY.RELATIVE. The template also includes additional mandatory variables where information on measurement quality can be provided in the form of flags (see the appendix for further details).

Even though the name of the template is GEOMS-TE-NEPHELOMETER, without specifying the type or model of the instrument, reading the descriptions of variables AEROSOL.BACKSCATTER.COEFFICIENT and TOTAL.BACKSCATTER.COEFFICIENT, there is a reference to a specific instrument, the TSI 3563 Nephelometer. Similarly, in the description of the variable WAVELENGTH, same wavelengths are specified. Such detailed and specific descriptions of the variables might suggest that the template is dedicated to this specific instrument.

5. INTEGRATION OF INSTRUMENTS, PRODUCTS, AND TEMPLATES: AVAILABILITY AND GAPS

Having described the available instruments, the corresponding retrievable products, and the set of GEOMS templates, this section brings these elements together. Specifically, we analyse the association between each instrument and its related products and verify whether a suitable GEOMS template exists for each case. This analysis provides a comprehensive overview of the current coverage of GEOMS templates with respect to the instrument–product associations considered in this study and helps to identify any gaps that may require future development or adaptation of templates.

The steps for this activity, as well as the key questions to be addressed at this stage, are illustrated in the diagram shown in **Error! Reference source not found.**. As a starting point for this assessment, reference is made to Table 2, in particular to the first two columns, which specify the type and the instrument. In order to enhance the clarity of the information presented, the cells of this table have been reproduced in a revised, color-coded format in Table 5 and the significance of each colour is detailed in the accompanying legend Table 6**Error! Reference source not found.**

Table 5 Correspondence between aerosol products and the instruments capable of retrieving them as in Table 2. Here, the coloured cells help to indicate the availability of templates, as well as the presence of instruments and products within the TAVs. For the colour legend, please refer to the Table 6.

Types	Instruments	Products											
		AOD	AE	SSA	RI	VSD	AF	PF	β	σ	BC	PNC	Aerosol profiles
Photometer	Prede	X	X	X	X	X	X	X					
	Cimel	X	X		X	X	X	X					
	PFR	X	X										
	Middleton	X											
	Star photometer	X											
	Microtops	X											
Radiometer	MFRSR / MFR7	X											
Spectrometer	Pandora	X											
	EKO Spectrometer	X											
	PSR	X											
Profiler	Elastic Lidar	X	X										X
	Ceilometer	X	X										X
In situ	OPC											X	
	Aethalometer									X	X		
	Nephelometer								X				

Table 6 This table show the meaning of the colours used in the Table 5.

Template available for the instrument type or for a specific instrument
DATA_SOURCE or DATA_VARIABLE defined for a specific instrument or product
Template, DATA_SOURCE, or DATA_VARIABLE not available
DATA_VARIABLE is available and, if a template exists, it is included in the template
DATA_VARIABLE is available but, if a template exists, it is not included in the template
DATA_VARIABLE not available

In this table, there are five types of instruments listed, but only one of them, the photometer, has a dedicated template GEOMS-TE-PHOTOMETER-001 [A14.1].

However, if we also consider the second column, which lists the specific instruments, it is possible to use template for other instruments. For the Elastic Lidar there are two option GEOMS-TE-LIDAR-AEROSOL-006 [A2] and GEOMS-TE-LIDAR-AEROSOL-L3-001 [A3], the selection of the appropriate template depends on which variables are intended or technically feasible to include in the file. This is determined by the specific characteristics and measurement capabilities of the instrument in question. For the OPC and Nephelometer the dedicated templates are respectively GEOMS-TE-OPC-AEROSOL-001 [A4] and GEOMS-TE-NEPHELOMETER-001 [A5].

By cross-referencing the list of instruments with the possible options for the DATA_SOURCE field defined in the GEOMS format, it becomes evident that only six valid correspondences exist. Specifically, these are:

- PHOTOMETER.CIMEL
- PHOTOMETER.PREDE
- LIDAR.AEROSOL
- CEILOMETER.AEROSOL
- OPC.AEROSOL
- NEPHELOMETER

Regarding the products, as indicated in the Table 5, the majority already have a corresponding DATA_VARIABLE defined. For the remaining products, however, an appropriate DATA_VARIABLE still needs to be established. Below, all products are listed together with their corresponding entries, apart from those belonging to Aerosol profiles, for which reference should be made to Table 1 and Table 5.

- AOD → AEROSOL.OPTICAL.DEPTH
- AE → AEROSOL.ANGSTROM.EXPONENT
- SSA → AEROSOL.SINGLE.SCATTERING.ALBEDO
- AF → AEROSOL.ASYMMETRY.FACTOR
- β → BACKSCATTERING.COEFFICIENT
- σ → ABSORPTION.COEFFICIENT
- PNC → AEROSOL.NUMBER.DENSITY

Products β and σ in the table are associated exclusively with instrument Aethalometer, which is primarily used to measure black carbon properties. The corresponding DATA_VARIABLE entries indicated here are generic, meaning that they do not specify whether the measurement refers to aerosols or other substances. Should a dedicated template be developed for this instrument in the future, it is possible that these variables could be defined in a more specific manner, and in line with the approach adopted for other variables, the options could, be BC.BACKSCATTERING.COEFFICIENT and BC.ABSORPTION.COEFFICIENT.

The Table 5 provides a comprehensive overview of the status and enables a series of technical considerations regarding existing data gaps.

Each of the instruments listed, both ground-based and in-situ, provides products of significant value for calibration and validation activities and beyond. Facilitating the sharing and access to these data within the EVDC user community would be highly advantageous. Furthermore, these instruments are widely deployed, and their inclusion would contribute to the establishment of a substantial and unquestionably valuable data repository. It is therefore recommended to introduce specific entries for these instruments among the permissible values of the DATA_SOURCE attribute.

A more detailed examination of the information in the Table 5 allows for additional observations and comments.

The photometer template [A1] is generally applicable to all instruments of this type, although certain modifications are required (further details are provided later in the text). The only potential exception is represented by Star photometers, which measure radiation originating from stellar sources. The current template is incompatible with these instruments due to the mandatory `ANGLE.SOLAR_ZENITH.ASTRONOMICAL` variable (as specified in 4.1), which is not relevant in this context. It would thus be necessary to define two new variables representing the zenith and azimuth observation angles, or alternatively, to develop a dedicated template for this specific instrument.

Similarly, MFRSR radiometers and their updated version, MFR7, could utilize a template analogous to that of photometers, potentially excluding products related to sky measurements (which are not performed by these instruments), but including the optional variables `H2O.COLUMN_ABSORPTION.SOLAR` and `O3.COLUMN_ABSORPTION.SOLAR`, as they are a derivable products. Additionally, variables associated with direct and diffuse global radiation measurements for specific wavelengths and broadband, as measured by the instrument, could be included. It should be noted that a dedicated template for radiometers already exists, `GEOMS-TE-RADIOMETER-BROADBAND-001`, and several of the required variables are already defined (refer to A6 for further details).

Regarding spectrometers, starting with Pandora, and by analogy with the existing templates dedicated to measurement type for gases, it would be appropriate to develop a specific template for aerosol products, as well as a corresponding value for the `DATA_SOURCE` attribute, such as `PANDORA.AEROSOL` (given the existence of entries such as `PANDORA.O3` and `PANDORA.NO2`). In any case, as previously stated, these products are currently under development, and it would be prudent to wait before assessing which aerosol-related parameters can be reliably retrieved from Pandora measurements.

Although templates already exist for spectrometers, they are primarily designed for gas products. A unified template for aerosol products could be developed, taking into account the specific measurement and retrieval techniques used by these instruments.

As previously discussed, two templates are available for lidar instruments; however, neither includes the `AEROSOL.OPTICAL.DEPTH` variable, except as an independent variable in the `GEOMS-TE-LIDAR-AEROSOL-006` template. At present, no template exists for ceilometers, which can provide both aerosol and cloud products; all such products could be incorporated into a single template. It should be noted, however, that two options currently exist for the `DATA_SOURCE` attribute for this instrument: `CEILOMETER.AEROSOL` and `CEILOMETER.CLOUD`, which would not be applicable in the case of a unified template.

Finally, among the listed in-situ instruments, only the Aethalometer lacks a defined template. Given the specificity of this instrument, particularly its focus on black carbon (BC), and the considerable importance of this product, it would be advisable to consider the development of a dedicated template.

Focusing on the photometer template, it is useful to carefully examine the variables it contains to assess its applicability to all the instruments listed. This template includes several mandatory variables, but not all these variables can be derived from other instruments within the same category. For instance, the AAE product cannot be retrieved from the Middleton, Star photometer, or Microtops instruments. To ensure template applicability across these cases, it would be necessary to revise the template by making the `AEROSOL.ANGSTROM.EXPONENT` variable, and its dependent variables `AEROSOL.ANGSTROM.EXPONENT_WAVELENGTH.INDEX` and `AEROSOL.ANGSTROM.EXPONENT_WAVELENGTH.PAIR`, optional.

Additional derived products, such as SA, RI, VSD, AF, and PF, cannot be obtained from all photometers. Therefore, it would be advisable to define the associated variables as optional within the template to accommodate these limitations.

Another important aspect concerns the two distinct measurement modalities supported by photometers:

- Direct measurements, performed by targeting the sun or moon.
- Indirect measurements, conducted by observing at various zenith and azimuth angles.

These modalities are executed at different times, implying that the derived parameters will have distinct timestamps. Specifically, direct measurements yield AOD and AE, whereas RI, VSD, AF, and PF are obtained from indirect measurements. The timestamp is recorded in the DATETIME variable, for this variable, if the value corresponds to a direct measurement, AEROSOL.OPTICAL.DEPTH and AEROSOL.ANGSTROM.EXPONENT should be populated, while the remaining variables should be assigned a fill value. Conversely, for indirect measurements, the roles are reversed.

To improve clarity regarding the measurement type and enhance file interpretability, it would be beneficial to introduce a new variable containing a flag to explicitly indicate the measurement modality. An alternative approach would be to implement a dual-template system, like what is done for other instruments such as Pandora, which uses:

- GEOMS-TE-PANDORA-DIRECTSUN-GAS-003
- GEOMS-TE-PANDORA-OFFAXIS-GAS-001

The single-template approach offers the advantage of consolidating all parameters into one file, simplifying data management. However, this comes at the cost of increased file size and a high number of fill value entries. The dual-template solution, on the other hand, results in smaller and likely more readable files, but has the drawback of doubling the number of files required per instrument.

Further considerations pertain to lunar measurements: the existing template cannot be used due to the mandatory `ANGLE.SOLAR_ZENITH.ASTRONOMICAL` variable. A new variable, `ANGLE.LUNAR_ZENITH.ASTRONOMICAL`, would be required, and both should be optional. Referring to the two previously proposed approaches (single vs. dual template):

- In the single-template scenario, the `ANGLE.LUNAR_ZENITH.ASTRONOMICAL` variable should be added, along with an additional flag value to distinguish lunar measurements.
- In the dual-template scenario, lunar measurements should be included only in the template for direct measurements. In both cases, the inclusion of `ANGLE.LUNAR_ZENITH.ASTRONOMICAL` and a flag to differentiate between solar and lunar direct measurements would be useful.

6. REFERENCES

R.1 HARMONIA COST Action: <https://harmonia-cost.eu/>

R.2 HARMONIA Deliverable 1.1, Create a list of existing and foreseen campaigns or experiments needed for night and day aerosol measurements and report on the data collection and analysis of the data/measurements: https://harmonia-cost.eu/wp-content/uploads/2023/10/COST_CA21119_HARMONIA-WG1_Deliverable-D11.pdf

R.3 HARMONIA Deliverable 2.1, Report on synergistic approaches towards better quality products: https://harmonia-cost.eu/wp-content/uploads/2023/10/Harmonia_D21_v2.pdf

R.4 EVDC: <https://evdc.esa.int/>

R.5 GEOMS: <https://evdc.esa.int/documentation/geoms/>

R.6 Table of Attributes Value version: tableattrvalue_04R101.dat
https://git.nilu.no/geoms/documentation/blob/master/tableattrvalue_04R101.dat

R.7 Templates list: <https://evdc.esa.int/tools/data-formatting-templates/>

7. APPENDICES

7.1. GEOMS Templates

The following tables refer to the templates under consideration in this report and in **Error! Reference source not found.** paragraph. Each table lists the variables contained within the respective template, and the final column indicates whether the variable is mandatory (marked with x) or optional (marked with o). For each template, the corresponding download link is provided.

A1. GEOMS-TE-PHOTOMETER-001

The complete template can be found at the following link: <https://git.nilu.no/geoms/templates/-/blob/master/GEOMS-TE-PHOTOMETER-001.csv>

DATETIME	x
WAVELENGTH	x
ALTITUDE.INSTRUMENT	x
LATITUDE.INSTRUMENT	x
LONGITUDE.INSTRUMENT	x
INTERNAL.INSTRUMENT.TEMPERATURE	x
ANGLE.SOLAR_ZENITH.ASTRONOMICAL	x
AIR.MASS	x
AEROSOL.OPTICAL.DEPTH	x
H2O.COLUMN_ABSORPTION.SOLAR	o
AEROSOL.ANGSTROM.EXPONENT_WAVELENGTH.INDEX	x
AEROSOL.ANGSTROM.EXPONENT_WAVELENGTH.PAIR	x
AEROSOL.ANGSTROM.EXPONENT	x
SOURCE.PRODUCT	o

A2. GEOMS-TE-LIDAR-AEROSOL-006

The complete template can be found at the following link: <https://git.nilu.no/geoms/templates/-/blob/master/GEOMS-TE-LIDAR-AEROSOL-006.csv>

LATITUDE.INSTRUMENT	x
LONGITUDE.INSTRUMENT	x
ALTITUDE.INSTRUMENT	x
DATETIME	x
DATETIME.START	x
DATETIME.STOP	x
WAVELENGTH_EMISSION	x
WAVELENGTH_DETECTION	x
ANGLE.VIEW_ZENITH	x
ANGLE.VIEW_AZIMUTH	0
ACCUMULATED.LASER.SHOTS	0
ALTITUDE	x
AEROSOL.BACKSCATTER.RATIO	0
AEROSOL.BACKSCATTER.RATIO_UNCERTAINTY.COMBINED.STANDARD	x if AEROSOL.BACKSCATTER.RATIO is provided
AEROSOL.BACKSCATTER.RATIO_UNCERTAINTY.RANDOM.STANDARD	x if AEROSOL.BACKSCATTER.RATIO is provided
AEROSOL.BACKSCATTER.RATIO_UNCERTAINTY.SYSTEMATIC.STANDARD	x if AEROSOL.BACKSCATTER.RATIO is provided
AEROSOL.BACKSCATTER.RATIO_RESOLUTION.ALTITUDE	x if AEROSOL.BACKSCATTER.RATIO is provided
AEROSOL.BACKSCATTER.RATIO_INTEGRATION.TIME	x if AEROSOL.BACKSCATTER.RATIO is provided
AEROSOL.BACKSCATTER.RATIO_RETRIEVAL.METHOD	x if AEROSOL.BACKSCATTER.RATIO is provided
CALIBRATION.ZONE	0
AEROSOL.BACKSCATTER.COEFFICIENT	0
AEROSOL.BACKSCATTER.COEFFICIENT_UNCERTAINTY.COMBINED.STANDARD	x if AEROSOL.BACKSCATTER.COEFFICIENT is provided
AEROSOL.BACKSCATTER.COEFFICIENT_UNCERTAINTY.RANDOM.STANDARD	x if AEROSOL.BACKSCATTER.COEFFICIENT is provided
AEROSOL.BACKSCATTER.COEFFICIENT_UNCERTAINTY.SYSTEMATIC.STANDARD	x if AEROSOL.BACKSCATTER.COEFFICIENT is provided
AEROSOL.BACKSCATTER.COEFFICIENT_RESOLUTION.ALTITUDE	x if AEROSOL.BACKSCATTER.COEFFICIENT is provided

AEROSOL.BACKSCATTER.COEFFICIENT_INTEGRATION.TIME	x if AEROSOL.BACKSCATTER.COEFFICIENT is provided
AEROSOL.BACKSCATTER.COEFFICIENT_RETRIEVAL.METHOD	x if AEROSOL.BACKSCATTER.COEFFICIENT is provided
AEROSOL.BACKSCATTER.COEFFICIENT.CIRCULAR	0
AEROSOL.BACKSCATTER.COEFFICIENT.CIRCULAR_UNCERTAINTY.COMBINED.STANDARD	x if AEROSOL.BACKSCATTER.COEFFICIENT.CIRCULAR is provided
AEROSOL.BACKSCATTER.COEFFICIENT.CIRCULAR_UNCERTAINTY.RANDOM.STANDARD	x if AEROSOL.BACKSCATTER.COEFFICIENT.CIRCULAR is provided
AEROSOL.BACKSCATTER.COEFFICIENT.CIRCULAR_UNCERTAINTY.SYSTEMATIC.STANDARD	x if AEROSOL.BACKSCATTER.COEFFICIENT.CIRCULAR is provided
AEROSOL.BACKSCATTER.COEFFICIENT.CIRCULAR_RESOLUTION.ALTITUDE	x if AEROSOL.BACKSCATTER.COEFFICIENT.CIRCULAR is provided
AEROSOL.BACKSCATTER.COEFFICIENT.CIRCULAR_INTEGRATION.TIME	x if AEROSOL.BACKSCATTER.COEFFICIENT.CIRCULAR is provided
AEROSOL.BACKSCATTER.COEFFICIENT.CIRCULAR_RETRIEVAL.METHOD	x if AEROSOL.BACKSCATTER.COEFFICIENT.CIRCULAR is provided
MOLECULAR.BACKSCATTER.COEFFICIENT_INDEPENDENT	x
NUMBER.DENSITY_INDEPENDENT	0
PRESSURE_INDEPENDENT	0
TEMPERATURE_INDEPENDENT	0
MOLECULAR.BACKSCATTER.COEFFICIENT_INDEPENDENT_SOURCE	x
NUMBER.DENSITY_INDEPENDENT_SOURCE	x if NUMBER.DENSITY_INDEPENDENT is provided
PRESSURE_INDEPENDENT_SOURCE	x if PRESSURE_INDEPENDENT is provided
TEMPERATURE_INDEPENDENT_SOURCE	x if TEMPERATURE_INDEPENDENT is provided
AEROSOL.EXTINCTION.COEFFICIENT	0
AEROSOL.EXTINCTION.COEFFICIENT_UNCERTAINTY.COMBINED.STANDARD	x if AEROSOL.EXTINCTION.COEFFICIENT is provided
AEROSOL.EXTINCTION.COEFFICIENT_UNCERTAINTY.RANDOM.STANDARD	x if AEROSOL.EXTINCTION.COEFFICIENT is provided
AEROSOL.EXTINCTION.COEFFICIENT_UNCERTAINTY.SYSTEMATIC.STANDARD	x if AEROSOL.EXTINCTION.COEFFICIENT is provided
AEROSOL.EXTINCTION.COEFFICIENT_RESOLUTION.ALTITUDE	x if AEROSOL.EXTINCTION.COEFFICIENT is provided
AEROSOL.EXTINCTION.COEFFICIENT_INTEGRATION.TIME	x if AEROSOL.EXTINCTION.COEFFICIENT is provided
AEROSOL.EXTINCTION.COEFFICIENT_RETRIEVAL.METHOD	x if AEROSOL.EXTINCTION.COEFFICIENT is provided
AEROSOL.EXTINCTION.COEFFICIENT.CIRCULAR	0
AEROSOL.EXTINCTION.COEFFICIENT.CIRCULAR_UNCERTAINTY.COMBINED.STANDARD	x if AEROSOL.EXTINCTION.COEFFICIENT.CIRCULAR is provided
AEROSOL.EXTINCTION.COEFFICIENT.CIRCULAR_UNCERTAINTY.RANDOM.STANDARD	x if AEROSOL.EXTINCTION.COEFFICIENT.CIRCULAR is provided
AEROSOL.EXTINCTION.COEFFICIENT.CIRCULAR_UNCERTAINTY.SYSTEMATIC.STANDARD	x if AEROSOL.EXTINCTION.COEFFICIENT.CIRCULAR is provided

AEROSOL.EXTINCTION.COEFFICIENT.CIRCULAR_RESOLUTION.ALTITUDE	x if AEROSOL.EXTINCTION.COEFFICIENT.CIRCULAR is provided
AEROSOL.EXTINCTION.COEFFICIENT.CIRCULAR_INTEGRATION.TIME	x if AEROSOL.EXTINCTION.COEFFICIENT.CIRCULAR is provided
AEROSOL.EXTINCTION.COEFFICIENT.CIRCULAR_RETRIEVAL.METHOD	x if AEROSOL.EXTINCTION.COEFFICIENT.CIRCULAR is provided
AEROSOL.LIDAR.RATIO_INDEPENDENT	0
AEROSOL.LIDAR.RATIO_INDEPENDENT_SOURCE	x if AEROSOL.LIDAR.RATIO_INDEPENDENT is provided
AEROSOL.LIDAR.RATIO	0
AEROSOL.LIDAR.RATIO_UNCERTAINTY.COMBINED.STANDARD	x if AEROSOL.LIDAR.RATIO is provided
AEROSOL.LIDAR.RATIO_UNCERTAINTY.RANDOM.STANDARD	x if AEROSOL.LIDAR.RATIO is provided
AEROSOL.LIDAR.RATIO_UNCERTAINTY.SYSTEMATIC.STANDARD	x if AEROSOL.LIDAR.RATIO is provided
AEROSOL.LIDAR.RATIO_RESOLUTION.ALTITUDE	x if AEROSOL.LIDAR.RATIO is provided
AEROSOL.LIDAR.RATIO_INTEGRATION.TIME	x if AEROSOL.LIDAR.RATIO is provided
AEROSOL.LIDAR.RATIO_RETRIEVAL.METHOD	x if AEROSOL.LIDAR.RATIO is provided
AEROSOL.LIDAR.RATIO.CIRCULAR	0
AEROSOL.LIDAR.RATIO.CIRCULAR_UNCERTAINTY.COMBINED.STANDARD	x if AEROSOL.LIDAR.RATIO.CIRCULAR is provided
AEROSOL.LIDAR.RATIO.CIRCULAR_UNCERTAINTY.RANDOM.STANDARD	x if AEROSOL.LIDAR.RATIO.CIRCULAR is provided
AEROSOL.LIDAR.RATIO.CIRCULAR_UNCERTAINTY.SYSTEMATIC.STANDARD	x if AEROSOL.LIDAR.RATIO.CIRCULAR is provided
AEROSOL.LIDAR.RATIO.CIRCULAR_RESOLUTION.ALTITUDE	x if AEROSOL.LIDAR.RATIO.CIRCULAR is provided
AEROSOL.LIDAR.RATIO.CIRCULAR_INTEGRATION.TIME	x if AEROSOL.LIDAR.RATIO.CIRCULAR is provided
AEROSOL.LIDAR.RATIO.CIRCULAR_RETRIEVAL.METHOD	x if AEROSOL.LIDAR.RATIO.CIRCULAR is provided
AEROSOL.ANGSTROM.EXPONENT	0
AEROSOL.ANGSTROM.EXPONENT_UNCERTAINTY.COMBINED.STANDARD	x if AEROSOL.ANGSTROM.EXPONENT is provided
AEROSOL.ANGSTROM.EXPONENT_UNCERTAINTY.RANDOM.STANDARD	x if AEROSOL.ANGSTROM.EXPONENT is provided
AEROSOL.ANGSTROM.EXPONENT_UNCERTAINTY.SYSTEMATIC.STANDARD	x if AEROSOL.ANGSTROM.EXPONENT is provided
AEROSOL.ANGSTROM.EXPONENT_INTEGRATION.TIME	x if AEROSOL.ANGSTROM.EXPONENT is provided
AEROSOL.ANGSTROM.EXPONENT_RETRIEVAL.METHOD	x if AEROSOL.ANGSTROM.EXPONENT is provided
AEROSOL.DEPOLARIZATION.RATIO.LINEAR	0
AEROSOL.DEPOLARIZATION.RATIO.LINEAR_UNCERTAINTY.COMBINED.STANDARD	x if AEROSOL.DEPOLARIZATION.RATIO.LINEAR is provided
AEROSOL.DEPOLARIZATION.RATIO.LINEAR_UNCERTAINTY.RANDOM.STANDARD	x if AEROSOL.DEPOLARIZATION.RATIO.LINEAR is provided

AEROSOL.DEPOLARIZATION.RATIO.LINEAR_UNCERTAINTY.SYSTEMATIC.STANDARD	x if AEROSOL.DEPOLARIZATION.RATIO.LINEAR is provided
AEROSOL.DEPOLARIZATION.RATIO.LINEAR_RESOLUTION.ALTITUDE	x if AEROSOL.DEPOLARIZATION.RATIO.LINEAR is provided
AEROSOL.DEPOLARIZATION.RATIO.LINEAR_INTEGRATION.TIME	x if AEROSOL.DEPOLARIZATION.RATIO.LINEAR is provided
AEROSOL.DEPOLARIZATION.RATIO.CIRCULAR	0
AEROSOL.DEPOLARIZATION.RATIO.CIRCULAR_UNCERTAINTY.COMBINED.STANDARD	x if AEROSOL.DEPOLARIZATION.RATIO.CIRCULAR is provided
AEROSOL.DEPOLARIZATION.RATIO.CIRCULAR_UNCERTAINTY.RANDOM.STANDARD	x if AEROSOL.DEPOLARIZATION.RATIO.CIRCULAR is provided
AEROSOL.DEPOLARIZATION.RATIO.CIRCULAR_UNCERTAINTY.SYSTEMATIC.STANDARD	x if AEROSOL.DEPOLARIZATION.RATIO.CIRCULAR is provided
AEROSOL.DEPOLARIZATION.RATIO.CIRCULAR_RESOLUTION.ALTITUDE	x if AEROSOL.DEPOLARIZATION.RATIO.CIRCULAR is provided
AEROSOL.DEPOLARIZATION.RATIO.CIRCULAR_INTEGRATION.TIME	x if AEROSOL.DEPOLARIZATION.RATIO.CIRCULAR is provided
AEROSOL.TRANSMISSION.TWOWAY	0
AEROSOL.TRANSMISSION.TWOWAY_UNCERTAINTY.COMBINED.STANDARD	x if AEROSOL.TRANSMISSION.TWOWAY is provided
AEROSOL.TRANSMISSION.TWOWAY_UNCERTAINTY.RANDOM.STANDARD	x if AEROSOL.TRANSMISSION.TWOWAY is provided
AEROSOL.TRANSMISSION.TWOWAY_UNCERTAINTY.SYSTEMATIC.STANDARD	x if AEROSOL.TRANSMISSION.TWOWAY is provided
AEROSOL.TRANSMISSION.TWOWAY_RESOLUTION.ALTITUDE	x if AEROSOL.TRANSMISSION.TWOWAY is provided
AEROSOL.TRANSMISSION.TWOWAY_INTEGRATION.TIME	x if AEROSOL.TRANSMISSION.TWOWAY is provided
AEROSOL.TRANSMISSION.TWOWAY_RETRIEVAL.METHOD	x if AEROSOL.TRANSMISSION.TWOWAY is provided
VOLUME.DEPOLARIZATION.RATIO.LINEAR	0
VOLUME.DEPOLARIZATION.RATIO.LINEAR_UNCERTAINTY.COMBINED.STANDARD	x if VOLUME.DEPOLARIZATION.RATIO.LINEAR is provided
VOLUME.DEPOLARIZATION.RATIO.LINEAR_UNCERTAINTY.RANDOM.STANDARD	x if VOLUME.DEPOLARIZATION.RATIO.LINEAR is provided
VOLUME.DEPOLARIZATION.RATIO.LINEAR_UNCERTAINTY.SYSTEMATIC.STANDARD	x if VOLUME.DEPOLARIZATION.RATIO.LINEAR is provided
VOLUME.DEPOLARIZATION.RATIO.LINEAR_RESOLUTION.ALTITUDE	x if VOLUME.DEPOLARIZATION.RATIO.LINEAR is provided
VOLUME.DEPOLARIZATION.RATIO.LINEAR_INTEGRATION.TIME	x if VOLUME.DEPOLARIZATION.RATIO.LINEAR is provided
VOLUME.DEPOLARIZATION.RATIO.CIRCULAR	0
VOLUME.DEPOLARIZATION.RATIO.CIRCULAR_UNCERTAINTY.COMBINED.STANDARD	x if VOLUME.DEPOLARIZATION.RATIO.CIRCULAR is provided
VOLUME.DEPOLARIZATION.RATIO.CIRCULAR_UNCERTAINTY.RANDOM.STANDARD	x if VOLUME.DEPOLARIZATION.RATIO.CIRCULAR is provided
VOLUME.DEPOLARIZATION.RATIO.CIRCULAR_UNCERTAINTY.SYSTEMATIC.STANDARD	x if VOLUME.DEPOLARIZATION.RATIO.CIRCULAR is provided
VOLUME.DEPOLARIZATION.RATIO.CIRCULAR_RESOLUTION.ALTITUDE	x if VOLUME.DEPOLARIZATION.RATIO.CIRCULAR is provided
VOLUME.DEPOLARIZATION.RATIO.CIRCULAR_INTEGRATION.TIME	x if VOLUME.DEPOLARIZATION.RATIO.CIRCULAR is provided

LAYER.INDEX	0
TARGET.CLASSIFICATION	0
AEROSOL.LAYER.BASE.HEIGHT	0
AEROSOL.LAYER.TOP.HEIGHT	0
MIXING.LAYER.BASE.HEIGHT	0
MIXING.LAYER.TOP.HEIGHT	0
ALTITUDE.TROPOPAUSE_INDEPENDENT	0
ALTITUDE.TROPOPAUSE_INDEPENDENT_SOURCE	x if ALTITUDE.TROPOPAUSE_INDEPENDENT is provided
AEROSOL.OPTICAL.DEPTH_INDEPENDENT	0
AEROSOL.OPTICAL.DEPTH_INDEPENDENT_SOURCE	x if AEROSOL.OPTICAL.DEPTH_INDEPENDENT is provided
ROLL	0
PITCH	0
SPEED.HORIZONTAL	0
AEROSOL.BACKSCATTER.RATIO_RESOLUTION.ALTITUDE.DF.NORMALIZED.FREQUENCY	0
AEROSOL.BACKSCATTER.RATIO_RESOLUTION.ALTITUDE.DF.TRANSFER.FUNCTION	0
AEROSOL.BACKSCATTER.RATIO_RESOLUTION.ALTITUDE.DF.CUTOFF	0
AEROSOL.BACKSCATTER.RATIO_RESOLUTION.ALTITUDE.IMPULSE.RESPONSE	0
AEROSOL.BACKSCATTER.COEFFICIENT_RESOLUTION.ALTITUDE.DF.TRANSFER.FUNCTION	0
AEROSOL.BACKSCATTER.COEFFICIENT_RESOLUTION.ALTITUDE.DF.CUTOFF	0
AEROSOL.BACKSCATTER.COEFFICIENT_RESOLUTION.ALTITUDE.IMPULSE.RESPONSE	0
AEROSOL.EXTINCTION.COEFFICIENT_RESOLUTION.ALTITUDE.DF.TRANSFER.FUNCTION	0
AEROSOL.EXTINCTION.COEFFICIENT_RESOLUTION.ALTITUDE.DF.CUTOFF	0
AEROSOL.EXTINCTION.COEFFICIENT_RESOLUTION.ALTITUDE.IMPULSE.RESPONSE	0
AEROSOL.DEPOLARIZATION.RATIO_RESOLUTION.ALTITUDE.DF.TRANSFER.FUNCTION	0
AEROSOL.DEPOLARIZATION.RATIO_RESOLUTION.ALTITUDE.DF.CUTOFF	0
AEROSOL.DEPOLARIZATION.RATIO_RESOLUTION.ALTITUDE.IMPULSE.RESPONSE	0
SOURCE.PRODUCT	0

A3. GEOMS-TE-LIDAR-AEROSOL-L3-001

The complete template can be found at the following link: <https://git.nilu.no/geoms/templates/-/blob/master/GEOMS-TE-LIDAR-AEROSOL-L3-001.csv>

LATITUDE.INSTRUMENT	x
LONGITUDE.INSTRUMENT	x
ALTITUDE.INSTRUMENT	x
DATETIME	x
DATETIME.START	x
DATETIME.STOP	x
WAVELENGTH_EMISSION	x
WAVELENGTH_DETECTION	x
ANGLE.VIEW_ZENITH	x
ANGLE.VIEW_AZIMUTH	0
ALTITUDE	x
AEROSOL.BACKSCATTER.RATIO_MEAN	0
AEROSOL.BACKSCATTER.RATIO_MEAN.STANDARD	0
AEROSOL.BACKSCATTER.RATIO_MEDIAN	0
AEROSOL.BACKSCATTER.RATIO_UNCERTAINTY.COMBINED.STANDARD	x if AEROSOL.BACKSCATTER.RATIO_MEAN is provided
AEROSOL.BACKSCATTER.RATIO_COUNT	0
AEROSOL.BACKSCATTER.RATIO_RESOLUTION.ALTITUDE	x if AEROSOL.BACKSCATTER.RATIO_MEAN is provided
AEROSOL.BACKSCATTER.RATIO_INTEGRATION.TIME	x if AEROSOL.BACKSCATTER.RATIO_MEAN is provided
AEROSOL.BACKSCATTER.RATIO_RETRIEVAL.METHOD	x if AEROSOL.BACKSCATTER.RATIO_MEAN is provided
CALIBRATION.ZONE	x
AEROSOL.BACKSCATTER.COEFFICIENT_MEAN	0
AEROSOL.BACKSCATTER.COEFFICIENT_MEAN.STANDARD	0
AEROSOL.BACKSCATTER.COEFFICIENT_MEDIAN	0
AEROSOL.BACKSCATTER.COEFFICIENT_UNCERTAINTY.COMBINED.STANDARD	x if AEROSOL.BACKSCATTER.COEFFICIENT_MEAN is provided
AEROSOL.BACKSCATTER.COEFFICIENT_COUNT	0

AEROSOL.BACKSCATTER.COEFFICIENT_RESOLUTION.ALTITUDE	x if AEROSOL.BACKSCATTER.COEFFICIENT_MEAN is provided
AEROSOL.BACKSCATTER.COEFFICIENT_INTEGRATION.TIME	x if AEROSOL.BACKSCATTER.COEFFICIENT_MEAN is provided
AEROSOL.BACKSCATTER.COEFFICIENT_RETRIEVAL.METHOD	x if AEROSOL.BACKSCATTER.COEFFICIENT_MEAN is provided
MOLECULAR.BACKSCATTER.COEFFICIENT_INDEPENDENT_MEAN	x
NUMBER.DENSITY_INDEPENDENT_MEAN	0
PRESSURE_INDEPENDENT_MEAN	0
TEMPERATURE_INDEPENDENT_MEAN	0
MOLECULAR.BACKSCATTER.COEFFICIENT_INDEPENDENT_SOURCE	x
NUMBER.DENSITY_INDEPENDENT_SOURCE	x if NUMBER.DENSITY_INDEPENDENT_MEAN is provided
PRESSURE_INDEPENDENT_SOURCE	x if PRESSURE_INDEPENDENT_MEAN is provided
TEMPERATURE_INDEPENDENT_SOURCE	x if TEMPERATURE_INDEPENDENT_MEAN is provided
AEROSOL.EXTINCTION.COEFFICIENT_MEAN	0
AEROSOL.EXTINCTION.COEFFICIENT_MEAN.STANDARD	0
AEROSOL.EXTINCTION.COEFFICIENT_MEDIAN	0
AEROSOL.EXTINCTION.COEFFICIENT_UNCERTAINTY.COMBINED.STANDARD	x if AEROSOL.EXTINCTION.COEFFICIENT_MEAN is provided
AEROSOL.EXTINCTION.COEFFICIENT_COUNT	0
AEROSOL.EXTINCTION.COEFFICIENT_RESOLUTION.ALTITUDE	x if AEROSOL.EXTINCTION.COEFFICIENT_MEAN is provided
AEROSOL.EXTINCTION.COEFFICIENT_INTEGRATION.TIME	x if AEROSOL.EXTINCTION.COEFFICIENT_MEAN is provided
AEROSOL.EXTINCTION.COEFFICIENT_RETRIEVAL.METHOD	x if AEROSOL.EXTINCTION.COEFFICIENT_MEAN is provided
AEROSOL.LIDAR.RATIO_MEAN	0
AEROSOL.LIDAR.RATIO_MEAN.STANDARD	0
AEROSOL.LIDAR.RATIO_MEDIAN	0
AEROSOL.LIDAR.RATIO_UNCERTAINTY.COMBINED.STANDARD	x if AEROSOL.LIDAR.RATIO_MEAN is provided
AEROSOL.LIDAR.RATIO_COUNT	0
AEROSOL.LIDAR.RATIO_RESOLUTION.ALTITUDE	x if AEROSOL.LIDAR.RATIO_MEAN is provided
AEROSOL.LIDAR.RATIO_INTEGRATION.TIME	x if AEROSOL.LIDAR.RATIO_MEAN is provided
AEROSOL.LIDAR.RATIO_RETRIEVAL.METHOD	x if AEROSOL.LIDAR.RATIO_MEAN is provided
AEROSOL.ANGSTROM.EXPONENT_MEAN	0

AEROSOL.ANGSTROM.EXPONENT_MEAN.STANDARD	0
AEROSOL.ANGSTROM.EXPONENT_MEDIAN	0
AEROSOL.ANGSTROM.EXPONENT_UNCERTAINTY.COMBINED.STANDARD	x if AEROSOL.ANGSTROM.EXPONENT_MEAN is provided
AEROSOL.ANGSTROM.EXPONENT_COUNT	0
AEROSOL.ANGSTROM.EXPONENT_INTEGRATION.TIME	x if AEROSOL.ANGSTROM.EXPONENT_MEAN is provided
AEROSOL.ANGSTROM.EXPONENT_RETRIEVAL.METHOD	x if AEROSOL.ANGSTROM.EXPONENT_MEAN is provided
AEROSOL.LINEAR.DEPOLARIZATION.RATIO_MEAN	0
AEROSOL.LINEAR.DEPOLARIZATION.RATIO_MEAN.STANDARD	0
AEROSOL.LINEAR.DEPOLARIZATION.RATIO_MEDIAN	0
AEROSOL.LINEAR.DEPOLARIZATION.RATIO_UNCERTAINTY.COMBINED.STANDARD	x if AEROSOL.LINEAR.DEPOLARIZATION.RATIO_MEAN is provided
AEROSOL.LINEAR.DEPOLARIZATION.RATIO_COUNT	0
AEROSOL.LINEAR.DEPOLARIZATION.RATIO_RESOLUTION.ALTITUDE	x if AEROSOL.LINEAR.DEPOLARIZATION.RATIO_MEAN is provided
AEROSOL.LINEAR.DEPOLARIZATION.RATIO_INTEGRATION.TIME	x if AEROSOL.LINEAR.DEPOLARIZATION.RATIO_MEAN is provided
VOLUME.LINEAR.DEPOLARIZATION.RATIO_MEAN	0
VOLUME.LINEAR.DEPOLARIZATION.RATIO_MEAN.STANDARD	0
VOLUME.LINEAR.DEPOLARIZATION.RATIO_MEDIAN	0
VOLUME.LINEAR.DEPOLARIZATION.RATIO_UNCERTAINTY.COMBINED.STANDARD	x if VOLUME.LINEAR.DEPOLARIZATION.RATIO_MEAN is provided
VOLUME.LINEAR.DEPOLARIZATION.RATIO_COUNT	0
VOLUME.LINEAR.DEPOLARIZATION.RATIO_RESOLUTION.ALTITUDE	x if VOLUME.LINEAR.DEPOLARIZATION.RATIO_MEAN is provided
VOLUME.LINEAR.DEPOLARIZATION.RATIO_INTEGRATION.TIME	x if VOLUME.LINEAR.DEPOLARIZATION.RATIO_MEAN is provided
AEROSOL.LAYER.BASE.HEIGHT_MEAN	0
AEROSOL.LAYER.BASE.HEIGHT_MEAN.STANDARD	0
AEROSOL.LAYER.BASE.HEIGHT_MEDIAN	0
AEROSOL.LAYER.TOP.HEIGHT_MEAN	0
AEROSOL.LAYER.TOP.HEIGHT_MEAN.STANDARD	0
AEROSOL.LAYER.TOP.HEIGHT_MEDIAN	0
MIXING.LAYER.BASE.HEIGHT_MEAN	0
MIXING.LAYER.BASE.HEIGHT_MEAN.STANDARD	0

MIXING.LAYER.BASE.HEIGHT_MEDIAN	0
MIXING.LAYER.TOP.HEIGHT_MEAN	0
MIXING.LAYER.TOP.HEIGHT_MEAN.STANDARD	0
MIXING.LAYER.TOP.HEIGHT_MEDIAN	0
AEROSOL.OPTICAL.DEPTH_INDEPENDENT_MEAN	0
AEROSOL.OPTICAL.DEPTH_INDEPENDENT_SOURCE	x if AEROSOL.OPTICAL.DEPTH_INDEPENDENT_MEAN is provided
SOURCE.PRODUCT	0

A4. GEOMS-TE-OPC-AEROSOL-001

The complete template can be found at the following link: <https://git.nilu.no/geoms/templates/-/blob/master/GEOMS-TE-OPC-AEROSOL-001.csv>

DATETIME	x
DATETIME.START	o
DATETIME.STOP	o
INTEGRATION.TIME	o
ALTITUDE	x
LATITUDE	x
LONGITUDE	x
FLOWRATE	o
TEMPERATURE	o
TEMPERATURE_UNCERTAINTY.COMBINED.STANDARD	x if TEMPERATURE is provided
HUMIDITY.RELATIVE	o
HUMIDITY.RELATIVE_UNCERTAINTY.COMBINED.STANDARD	x if HUMIDITY.RELATIVE is provided
PARTICLE.SIZE	x
PARTICLE.SIZE.BOUNDARIES	x
AEROSOL.NUMBER.DENSITY	x
AEROSOL.NUMBER.DENSITY_UNCERTAINTY.COMBINED.STANDARD	x
AEROSOL.NUMBER.DENSITY_FLAG	o
SOURCE.PRODUCT	o

A5. GEOMS-TE-NEPHELOMETER-001

The complete template can be found at the following link: <https://git.nilu.no/geoms/templates/blob/master/GEOMS-TE-NEPHELOMETER-001.csv>

DATETIME	x
INTEGRATION.TIME	x
LATITUDE.INSTRUMENT	x
LONGITUDE.INSTRUMENT	x
ALTITUDE.INSTRUMENT	x
INTERNAL.INSTRUMENT.TEMPERATURE	x
INTERNAL.INSTRUMENT.TEMPERATURE_FLAG	x
INTERNAL.INSTRUMENT.PRESSURE	x
INTERNAL.INSTRUMENT.PRESSURE_FLAG	x
INTERNAL.INSTRUMENT.HUMIDITY.RELATIVE	x
INTERNAL.INSTRUMENT.HUMIDITY.RELATIVE_FLAG	x
WAVELENGTH	x
TOTAL.SCATTERING.COEFFICIENT	x
TOTAL.SCATTERING.COEFFICIENT_FLAG	x
AEROSOL.BACKSCATTER.COEFFICIENT	x
AEROSOL.BACKSCATTER.COEFFICIENT_FLAG	x
SOURCE.PRODUCT	0

A6. GEOMS-TE-RADIOMETER-BROADBAND-001

The complete template can be found at the following link: <https://git.nilu.no/geoms/templates/-/blob/master/GEOMS-TE-RADIOMETER-BROADBAND-001.csv>

DATETIME	x
LATITUDE.INSTRUMENT	x
LONGITUDE.INSTRUMENT	x
ALTITUDE.INSTRUMENT	x
RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE	o
RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE_MEAN	o
RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE_MINIMUM	x if RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE_MEAN is provided
RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE_MAXIMUM	x if RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE_MEAN is provided
RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE_MEAN.STANDARD	x if RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE_MEAN is provided
RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE_FLAG	x if RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE_MEAN is provided
RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE_SOURCE	x if RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE_MEAN is provided
RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE_INTEGRATION.TIME	x if RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE_MEAN is provided
RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE.INFRARED	o
RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE.INFRARED_FLAG	x if RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE.INFRARED is provided
RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE.INFRARED_SOURCE	x if RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE.INFRARED is provided
RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE.INFRARED_INTEGRATION.TIME	x if RADIATION.DOWNWELLING.GLOBAL_SHORTWAVE.INFRARED is provided
RADIATION.DOWNWELLING_LONGWAVE_MEAN	o
RADIATION.DOWNWELLING_LONGWAVE_MINIMUM	x if RADIATION.DOWNWELLING_LONGWAVE_MEAN is provided
RADIATION.DOWNWELLING_LONGWAVE_MAXIMUM	x if RADIATION.DOWNWELLING_LONGWAVE_MEAN is provided
RADIATION.DOWNWELLING_LONGWAVE_MEAN.STANDARD	x if RADIATION.DOWNWELLING_LONGWAVE_MEAN is provided
RADIATION.DOWNWELLING_LONGWAVE_FLAG	x if RADIATION.DOWNWELLING_LONGWAVE_MEAN is provided
RADIATION.DOWNWELLING_LONGWAVE_SOURCE	x if RADIATION.DOWNWELLING_LONGWAVE_MEAN is provided
RADIATION.DOWNWELLING_LONGWAVE_INTEGRATION.TIME	x if RADIATION.DOWNWELLING_LONGWAVE_MEAN is provided
RADIATION.UPWELLING.REFLECTED_SHORTWAVE	o
RADIATION.UPWELLING.REFLECTED_SHORTWAVE_MEAN	o

RADIATION.UPWELLING.REFLECTED_SHORTWAVE_MINIMUM	x if RADIATION.UPWELLING.REFLECTED_SHORTWAVE_MEAN is provided
RADIATION.UPWELLING.REFLECTED_SHORTWAVE_MAXIMUM	x if RADIATION.UPWELLING.REFLECTED_SHORTWAVE_MEAN is provided
RADIATION.UPWELLING.REFLECTED_SHORTWAVE_MEAN.STANDARD	x if RADIATION.UPWELLING.REFLECTED_SHORTWAVE_MEAN is provided
RADIATION.UPWELLING.REFLECTED_SHORTWAVE_FLAG	x if RADIATION.UPWELLING.REFLECTED_SHORTWAVE_MEAN is provided
RADIATION.UPWELLING.REFLECTED_SHORTWAVE_SOURCE	x if RADIATION.UPWELLING.REFLECTED_SHORTWAVE_MEAN is provided
RADIATION.UPWELLING.REFLECTED_SHORTWAVE_INTEGRATION.TIME	x if RADIATION.UPWELLING.REFLECTED_SHORTWAVE_MEAN is provided
RADIATION.UPWELLING.REFLECTED_SHORTWAVE.INFRARED	0
RADIATION.UPWELLING.REFLECTED_SHORTWAVE.INFRARED_FLAG	x if RADIATION.UPWELLING.REFLECTED_SHORTWAVE.INFRARED is provided
RADIATION.UPWELLING.REFLECTED_SHORTWAVE.INFRARED_SOURCE	x if RADIATION.UPWELLING.REFLECTED_SHORTWAVE.INFRARED is provided
RADIATION.UPWELLING.REFLECTED_SHORTWAVE.INFRARED_INTEGRATION.TIME	x if RADIATION.UPWELLING.REFLECTED_SHORTWAVE.INFRARED is provided
RADIATION.UPWELLING_LONGWAVE_MEAN	0
RADIATION.UPWELLING_LONGWAVE_MINIMUM	x if RADIATION.UPWELLING_LONGWAVE_MEAN is provided
RADIATION.UPWELLING_LONGWAVE_MAXIMUM	x if RADIATION.UPWELLING_LONGWAVE_MEAN is provided
RADIATION.UPWELLING_LONGWAVE_MEAN.STANDARD	x if RADIATION.UPWELLING_LONGWAVE_MEAN is provided
RADIATION.UPWELLING_LONGWAVE_FLAG	x if RADIATION.UPWELLING_LONGWAVE_MEAN is provided
RADIATION.UPWELLING_LONGWAVE_SOURCE	x if RADIATION.UPWELLING_LONGWAVE_MEAN is provided
RADIATION.UPWELLING_LONGWAVE_INTEGRATION.TIME	x if RADIATION.UPWELLING_LONGWAVE_MEAN is provided
RADIATION.DIRECT_MEAN	0
RADIATION.DIRECT_MINIMUM	x if RADIATION.DIRECT_MEAN is provided
RADIATION.DIRECT_MAXIMUM	x if RADIATION.DIRECT_MEAN is provided
RADIATION.DIRECT_MEAN.STANDARD	x if RADIATION.DIRECT_MEAN is provided
RADIATION.DIRECT_FLAG	x if RADIATION.DIRECT_MEAN is provided
RADIATION.DIRECT_SOURCE	x if RADIATION.DIRECT_MEAN is provided
RADIATION.DIRECT_INTEGRATION.TIME	x if RADIATION.DIRECT_MEAN is provided
RADIATION.DIFFUSE_MEAN	0
RADIATION.DIFFUSE_MINIMUM	x if RADIATION.DIFFUSE_MEAN is provided
RADIATION.DIFFUSE_MAXIMUM	x if RADIATION.DIFFUSE_MEAN is provided
RADIATION.DIFFUSE_MEAN.STANDARD	x if RADIATION.DIFFUSE_MEAN is provided

RADIATION.DIFFUSE_FLAG	x if RADIATION.DIFFUSE_MEAN is provided
RADIATION.DIFFUSE_SOURCE	x if RADIATION.DIFFUSE_MEAN is provided
RADIATION.DIFFUSE_INTEGRATION.TIME	x if RADIATION.DIFFUSE_MEAN is provided
SURFACE.TEMPERATURE	0
SURFACE.TEMPERATURE_SOURCE	x if SURFACE.TEMPERATURE is provided
SURFACE.PRESSURE	0
SURFACE.PRESSURE_SOURCE	x if SURFACE.PRESSURE is provided
HUMIDITY.RELATIVE.SURFACE	0
HUMIDITY.RELATIVE.SURFACE_SOURCE	x if HUMIDITY.RELATIVE.SURFACE is provided
SOURCE.PRODUCT	0

Report on the outcomes of a Virtual Mobility¹

Action number: CA21119

Grantee name: Anna Maria Iannarelli

Virtual Mobility Details

Title: HARMONIA activity for the ESA Validation Data Center (EVDC)

Start and end date: 02/05/2025 to 25/08/2025

Description of the work carried out during the VM

The objective of this activity is to assess which instruments and products involved in the HARMONIA COST Action can support the generation of files compliant with the GEOMS (Generic Earth Observation Metadata Standard) format. This includes verifying the existence of GEOMS templates for specific instruments, for instrument-product combinations, and evaluating the feasibility of generating GEOMS-compliant files based on the instruments and products listed in the Tables of Attribute Values (TAV).

Based on the campaign information, the initial steps involved compiling a list of instruments and all associated aerosol products, followed by an investigation into the available options for each. This included identifying existing GEOMS templates and determining the values required for the various entries needed to generate files in GEOMS format.

The instruments were classified according to their technological characteristics, with particular attention given to their measurement methods, as the parameters derivable from each instrument depend on both aspects. Care was also taken to ensure the correct definition of products, which is essential for accurately identifying variables and their corresponding definitions in the GEOMS tables.

It was also necessary to study both the guidelines for creating GEOMS-compliant files and the existing templates and TAVs, which contain all permissible values for the various fields to be defined -namely, the global attributes of the files, the list of variables, and the attributes associated with each.

This information was instrumental in providing an overview of the instruments and products available for aerosol studies and their properties. The entire analysis was summarized in a table, which served as the starting point for identifying available templates for conversion to the GEOMS format and determining which instruments and products are currently covered by the TAVs.

¹ This report is submitted by the grantee to the Action MC for approval and for claiming payment of the awarded grant. The Grant Awarding Coordinator coordinates the evaluation of this report on behalf of the Action MC and instructs the GH for payment of the Grant.

Description of the VM main achievements and planned follow-up activities

The first outcome of this activity was the development of an overview of the instruments and products available—both ground-based and in situ—for studying aerosols and their properties. This analysis extended beyond photometers, encompassing all aerosol-related instruments used in the measurement campaigns considered within the COST Harmonia framework. This broader approach enabled a comprehensive understanding of the available products and the instruments from which they are derived and facilitated the identification of those currently compatible or incompatible with the GEOMS format.

Another key result was the compilation of a list of missing instruments and products that could be of interest to the satellite and scientific communities, and which may be considered for inclusion in the EVDC database. Existing templates for aerosol products were carefully examined, with a focus on identifying the instruments to which they apply, the variables they include, and any missing elements.

Particular attention was given to the photometer template, as photometers are the primary instruments used for retrieving aerosol optical properties. The analysis highlighted potential modifications and additions required to extend the template's applicability beyond the two currently supported photometers, Prede and Cimel, and to incorporate variables that are not yet considered. Some limitations in the use of the current template were also identified, which may restrict its applicability to other instruments or hinder the inclusion of relevant aerosol parameters. The work carried out may prove valuable to the EVDC team responsible for formatting files in GEOMS format, as it provides both a general overview of the current landscape and a foundation for expanding the range of products shared through the data center. If adopted, the proposed recommendations could support the creation or revision of templates, thereby making them accessible to a broader user community.

This study contributes to the objectives of WG2.