



Full documentation of ACTRIS/EARLINET data products delivered

Issued by: CNR IMAA / Lucia Mona, Claudio Dema, Pilar Gumà-Claramunt, Giuseppe D'Amico, Ermann Ripepi, Ina Mattis, Nikos Siomos, Nikolaos Papagiannopoulos

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Contributors

CONSIGLIO NAZIONALE DELLE RICERCHE ISTITUTO DI METODOLOGIE PER L'ANALISI AMBIENTALE (CNR-IMAA)

Lucia Mona
Pilar Gumà-Claramunt
Giuseppe D'Amico
Nikolaos Papagiannopoulos
Claudio Dema
Emilio Lapenna
Ermann Ripepi
Monica Proto
Simone Gagliardi

DWD

Ina Mattis

University of Munich

Nikolaos Siomos



Change Log

Version	Date	Description



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1. Introduction

Building on the heritage of ACTRIS data workflow and previous CAMS 21b contract, the current contract named ACTRIS-APP consists in the provision of aerosol profiling data collected at 11 ACTRIS/EARLINET stations aiming to the NRT provision and fully quality controlled data.

To fasten the data provision from the station to CAMS, automatic and machine-to-machine tools have been implemented. Typically, the submission from stations to ARES (Aerosol REmote Sensing) ACTRIS DC unit has been managed by the stations. Within this project, the automatic submission from the centralized processing suite of ARES to the ARES database has been made possible as a choice for the stations. Finally, an API has been developed on top of the ACTRIS/EARLINET database (DB) for guarantying to CAMS the access to all produced data through a machine-to-machine connection.

Quality Assurance and Quality Control procedures have been developed and implemented for improving the quality of the provided data products: such procedures involve the team at the stations, the central facility responsible for ACTRIS aerosol remote sensing component (namely CARS – Centre for Aerosol Remote Sensing) and the data centre. QA/QC procedures can be traced in the data as soon as they are uploaded to the ACTRIS/EARLINET database, so that already in NRT data, it is possible to obtain information about the compliance of data to all the QA/QC procedures.

The deliverable is organized as follows: first section describes the data collection object of the CAMS21b2 contract, the main blocks of the data workflow, and the general description of the data products provided to CAMS. After that, a section describing data products (from processed data on in the workflow) is reported, starting from aerosol optical product, which is the core of the data provision, followed by a first description of the experimental products. Conclusion section describes potential foreseen updates of the current documentation.



2. ACTRIS/EARLINET data collection within CAMS21b2

The CAMS21b pilot data provision is related to measurements performed by the ACTRIS/EARLINET lidar stations reported in Figure 1 with the following time schedule, established with the investigation reported in CAMS21b contract (Mona et al., CAMS21b, 2020):

- Monday daytime (11:30 - 14:30 LT)
- Monday nighttime (18:30 - 23:30 UT)
- Wednesday daytime (11:30 - 14:30 LT)
- Thursday nighttime (18:30 - 23:30 UT)
- Friday nighttime (18:30 - 23:30 UT)
- Saturday daytime (11:30 - 14:30 LT)

The schedule, however, is limited to cases for which weather conditions allowed the measurements (no precipitation, no low clouds, and no fog).

Whenever meteorological conditions allow the measurements, the lidar stations perform 3 hours of measurements providing for the aerosol optical properties three 1-hour profiles, which allows for temporal variability investigation.

Anyhow independently from such measurements schedule all measurements collected by ACTRIS/EARLINET stations are openly provided through an API system (<https://data.earlinet.org/api/swagger-ui/#>).

The main aim of CAMS21b contract is the provision of aerosol optical properties profiles to CAMS: in particular, aerosol backscatter coefficient profiles at different wavelengths (namely at 355, 532 and 1064 nm) and linear particle depolarization ratio profiles at 532 nm are provided. Additionally, in nighttime conditions, also the aerosol extinction profiles at 355 and 532 nm are provided. Besides these quantities, some intermediary products (like preprocessed signals at low and high resolution) are also provided for fully traceability.

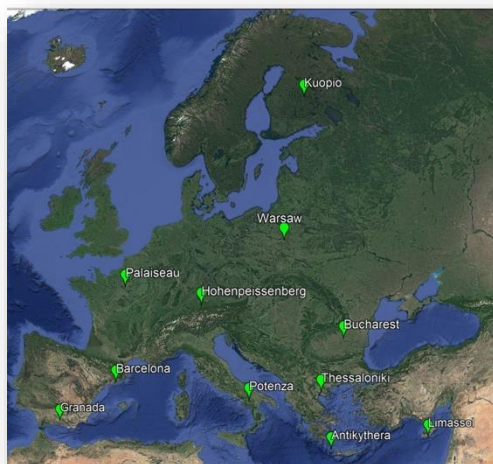


Figure 1 – ACTRIS/EARLINET Stations involved in the CAMS21b2 provision.

In this contract, CAMS21b2, actions have been taken for providing the best possible quality of data already in NRT: the same level of QA/QC procedures applied for delayed data provision are now applied for the NRT provision. In addition, in case of automatic data submission multiwavelength products are checked for consistency among the different retrieved optical products. All this in NRT.

Respect to the previous contract (CAMS21b), a big change has been implemented: data provided in NRT goes through the ACTRIS/EARLINET DB, which guarantees versioning and traceability instead of that from the processing suite (namely SCC). This also facilitates the users, that now have a unique file format and nomenclature to deal with.

The ACTRIS/EARLINET product types provided are summarized in Table 1: this includes the preprocessed data needed for obtaining geophysical products (processed products). Then, from the optical properties profiles additional quantities can be retrieved, such as the aerosol layers and the aerosol types.

Following the ACTRIS definition of data levels, Level 1 products are compliant with basic quality control procedures and Level 2 data are geophysical products approved and fully quality controlled. Therefore, only processed data are eligible to become Level 2 data products. At the time being only optical profiles provided by ELDA are eligible for the Level2 label, since the other Processed products are still experimental (reported in grey in the table).

All the products are in **NetCDF** format (<https://www.unidata.ucar.edu/software/netcdf/>) and are compliant with **CF (Climate and Forecast) version 1.7** (<http://cfconventions.org/Data/cf-conventions/cf-conventions-1.7/cf-conventions.html>).



Table 1. ACTRIS/EARLINET products provided to CAMS. * indicates module working on post processing server and not in the SCC main core. Experimental products are reported in grey.

Product Type	Content	SCC module
Un-calibrated low resolution Pre-processed	Range corrected signals	ELPP
Un-calibrated high resolution Pre-processed	Range corrected signals Volume depolarization ratio	HiRELPP
Cloud mask Pre-processed	Cloud mask	CloudMask
Low resolution pre-processed	Total attenuated backscatter	ELIC
High resolution pre-processed	Total attenuated backscatter Volume depolarization ratio	ELIC
Optical Processed	Aerosol extinction Aerosol backscatter Volume depolarization ratio Particle depolarization ratio	ELDA
Multiwavelength Products Processed	Optical Aerosol extinction Aerosol backscatter volume depolarization ratio particle depolarization ratio Lidar ratio Ångström exponent	ELDAmwl
Aerosol Layer - Processed		LTool
High resolution aerosol classification Preprocessed	Aerosol mask classification	HIRAC*
Low resolution aerosol typing Processed	Aerosol type for each layer	MAC*

Operational data products are obtained through the SCC (D'Amico et al., 2015; D'Amico et al, 2016; Mattis et al., 2016);the documentation is available here: <https://docs.scc.imes.cnr.it/en/latest/>.

The logic of the current interconnection among the SCC modules is provided in figure 2.

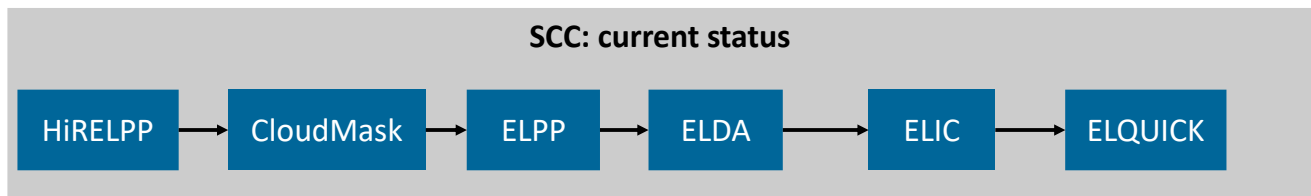


Figure 2: Simplified scheme representing the logic of SCC main processing modules.

Figure 2 shows the processing modules of the SCC which are independent but inter-connected modules. Basically there are two modules responsible for the pre-processing of raw lidar data (HiRELPP – High Resolution EARLINET Lidar Pre-Processor and ELPP – EARLINET Lidar Pre-Processor), and a module for the automatic cloud screening (CloudMask), a module for the retrieval of the aerosol optical products such as extinction, backscatter and particle/volume depolarization ratio (ELDA - EARLINET Lidar Data Analyser), and a module for the generation of calibrated pre-processed products (ELIC - EARLINET Lidar Calibrator). Finally, ELQUICK is a module that generates quicklook images, which are available at <https://quicklooks.earlinet.org>.

Further developments of interest for CAMS21b2 are planned for the near future (Figure 3) and are already working on the SCC development platform, namely these are ELDAmwl and LTool, which are responsible for the elaboration of all aerosol optical products in 1 unique file and the identification of aerosol layers respectively.

Finally, aerosol typing products are generated in the post processing server: HIRAC provides the aerosol classification at high vertical and temporal resolution, whilst MAC provides the aerosol classification at low resolution, based on the published and consolidated method described in Papagiannopoulos et al., 2018.

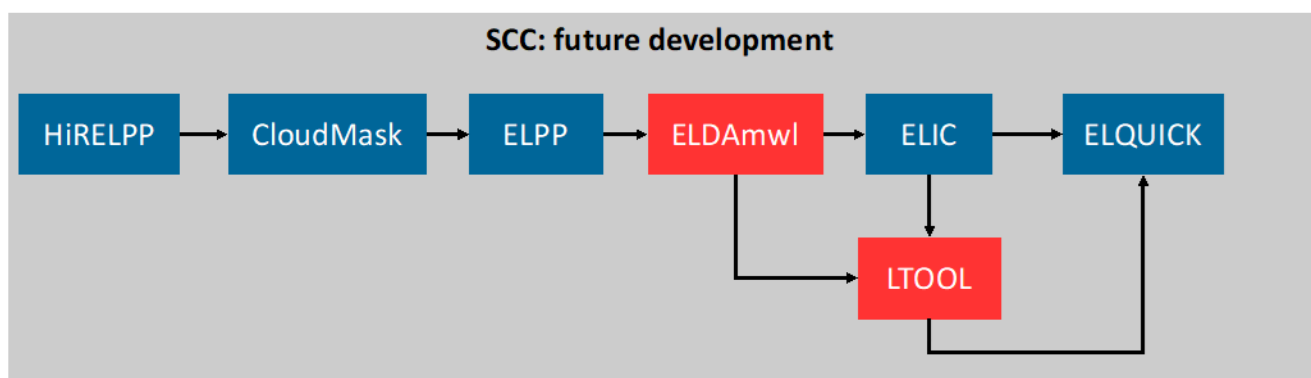


Figure 3: Simplified scheme representing the logic of SCC main processing modules with the implementation of the new modules.

Some samples of these 4 new product types have been made available via shared folder to CAMS. Following the implementation plan, these new products to be implemented into CAMS21b2, such



products will be operational in 2025 (beginning 2026 for ELDAmwl).

The description reported in this deliverable refers to the status of processing and data format as at the current state (November 2024). A new release of the processing chain is expected late Spring 2025, including ELDAmwl and LTOOL in SCC operational, and then post processing products related to typing will become operational both in high and low resolution. Related updates in the data format and algorithms will be documented through an update of the current document, if needed.

3. Aerosol optical properties profiles

All the documentation related to the SCC products is publicly available at the SCC website at https://docs.scc.ima.cnr.it/en/latest/file_formats/scc_product_format.html, however in the following geophysical products and in particular aerosol optical properties are described here being the core of the provision.

As reported above, during the submission to the ACTRIS/EARLINET DB, optical profiles are object of extensive quality control procedures. In case of automatic submission from SCC to the ACTRIS/EARLINET DB (as it is the case for the most of the CAMS21b2 data) a set of procedures for checking simultaneous files related to the same atmospheric scene assure the consistency of the different products resulting from the same observation. Only data compliant with all the applied control procedures are labelled as Level 2 products.

It is important to note that the data product is enriched with information about the quality control procedures applied to it.

In Appendix A and B an example of aerosol optical property files is provided.

File naming convention

Each product is stored in a CF compliant NetCDF file with a unique filename following the format:

EARLINET_AerRemSen_ccc_Levzz_tttt_YYYYMMDDHHMM_yyyymmddhhmm_vxx_qcyy.nc

The character “_” is used to separate different fields in the filename. The extension of the file is always “.nc”. The number of fields composing the filename (excluding the extension) is always 9. The following list describes, in order, each field that composes the filename.

Table 2. Description of the fields that compose the optical products filenames according to the file naming convention.

	Field	Length	Description
1 st	<i>EARLINET</i>	8	This field always reports the string "EARLINET"
2 nd	<i>AerRemSen</i>	9	This field means "Aerosol Remote Sensing"



3 rd	<i>ccc</i>	3	This field reports a three digit code representing univocally an EARLINET station
4 th	<i>Levzz</i>	5	This field specifies the level of the product. The levels are assigned to the product on the base of specific quality control procedure.
5 th	<i>ttttt</i>	5	This field identifies the product type.
6 th	<i>YYYYMMDDHHMM</i>	12	This is a date-time field and it provides the start date and time of the measurements contained in the product file. The time is UTC.
7 th	<i>yyyymmddhhmm</i>	12	This is a date-time field and it provides the stop date and time of the measurements contained in the product file. The time is UTC.
8 th	<i>vxx</i>	3	This field specifies the version of the product. The first character 'v' is always present. The next 2 characters are always numeric. (E.g. v01 identifies version 1 of the file, v02 version 2 and so on).
9 th	<i>qcy</i>	4	This field specifies the quality control version of the product. The suffix 'qc' is always present. The next 2 characters are always numeric. (E.g. qc01 identifies the QC version 0.1 of the file, qc0.2 the version 0.2 and so on).

The **three digit codes** representing univocally the active ACTRIS/EARLINET stations are reported in Table 3 (in bold are reported stations participating in CAMS21b2).

Table 3. List of ACTRIS/EARLINET stations. In bold the stations participating in CAMS21b2.

ARR	Andøya	LAQ	L'Aquila
AKY	Antikythera	LEI	Leipzig
ATZ	Athens	LLE	Lille
BRC	Barcelona	LIM	Limassol
BGD	Belgrado	MDR	Madrid
COG	Belsk	MAS	Minsk
INO	Bucharest	NAP	Naples
CBW	Cabauw	HPB	Hohenpeissenberg
PUY	Clermont-Ferrand	SIR	Palaiseau
CLJ	Cluj	POT	Potenza
DUS	Dushanbe	PAY	Payerne
EVO	Evora	RME	Roma
GAR	Garmisch-Partenkirchen	SAL	Lecce
GRA	Granada	SOF	Sofia
IPR	Ispra	THE	Thessaloniki
KUO	Kuopio	WAW	Warsaw



The optical products uploaded become **Lev02** data if all the quality control running automatically on the EARLINET DB are passed by the specific data product and, in the case of automatic upload, if all the on-the-fly quality controls on the specific data product and on the set of data products corresponding to the same measurement are successful. If one or more of the advanced quality controls is failed, the product becomes **Lev01**.

The **product type** string identifies the type as e- or b-file, and is followed by the wavelength. “e” stands for e-file (where extinction calculated by Raman observation is mandatory), and “b” stands for b-file, where backscatter is instead mandatory. The numerical values represent all the wavelengths currently present in the EARLINET DB. At the moment, the following values have been recorded for this field: e0355, b0355, e0351, b0351, e0532, b0532, e1064, b1064, b0253, b0313, b0335, b0510, b0694 and b0817.

For the CAMS21b contract, the expected product types are e0355, b0355, e0532, b0532, e1064 and b1064.

Version of the product: the ACTRIS/EARLINET database is version controlled, so only 1 version of data is available for each data product, even if old versions are stored by the ARES data centre for full traceability and internally available in the DB. Further versions of the data could be possible and eventually released later on if a new centralized method is developed (like a new SCC module or a new QC procedure) or if at station level some system related correction becomes available. However, the upload of new data product version on the EARLINET DB is allowed only centrally by the datacenter in order to moderate the number of versions of files.

Quality control version: the current QC version is qc31. A new quality control version could be released in 2025 if needed for the upcoming products or other needs.

Variables description

Aerosol optical products have the **wavelength dimension** (accommodating products at different wavelength in the same variable) and **time dimension** (accommodating different profiles in the same time series). The **altitude dimension** is defined for reporting the information as a function of the altitude. The **dimension nv** is used following the CF Convention whenever a bound is needed for some evaluation. In our case nv is used for defining variables which have per definition some bounds, as `time_bounds` reported below.

time: this is the central time for which the optical property profile is reported. This is linked to the time dimension.

time_bounds: these are the extremes of the temporal range on which calculations are done. So the `time_bounds` variable reports the start and stop time for each optical product.

altitude: is the altitude for which the profiles are reported. The altitude grid is set up by the pre-processing module ELPP and it is reported above the sea level. This variable is linked to the altitude dimension.



wavelength: this variable reports the wavelengths now available for the aerosol extinction and backscatter products in EARLINET, i.e. 355, 532 and 1064 nm. This is linked to the wavelength dimension.

longitude: longitude in degrees of the ACTRIS/EARLINET station.

latitude: latitude in degrees of the ACTRIS/EARLINET station.

station_altitude: station altitude above sea level of the ACTRIS/EARLINET station.

zenith_angle: laser pointing angle with respect to the zenith of the ACTRIS/EARLINET lidar system.

shots: accumulated laser shots used for the calculation of the aerosol optical product.

quality_control_level: describes the level of the data product on the base of the quality control. Three possible values are allowed: 0 = file does not pass basic quality control; 1 = file passes all basic quality controls but fails one or more advanced quality controls; 2 = file passes all basic and advanced quality controls. For the CAMS21b case, all the products will be Lev01 or Lev02 data because no new files are accepted on the EARLINET DB if they are not passing all the basic quality control procedures.

basic_quality_control: indicates result of the basic quality control procedures to the file. The variable together with its attributes (`flag_masks`, `flag_meanings` and `valid_range`), describes a blend of independent boolean conditions and enumerated status codes, by which it is possible to trace which basic quality controls the product has passed.

The considered procedures are currently the following (in short): check if file contains data; check for Undefined Variables and Global Attributes; check coordinates consistency respect to station database information. Since 2020 an automatic screening is done in the uploading phase so that all data acquired after 2020 will pass all the basic quality controls and so this variable will be equal to 0.

advanced_quality_control: indicates result of the basic quality control procedures to the file. The variable together with its attributes (`flag_masks`, `flag_meanings` and `valid_range`), describes a blend of independent boolean conditions and enumerated status codes, by which it is possible to trace which Advanced quality controls the product has passed. The full documentation of QC procedures is reported in (EARLINET Data Quality Check v3.0). In particular, checks for assuring the use of the system approved by the ACTRIS calibration centre and one for the use of modelled atmospheric density profile in backscatter retrieval are included here. Moreover, QC procedure checks for negative errors; negative peaks; check on AOD/IB; check on LidarRatio values; check on volume depolarization; check on particle depolarization; check on water vapor mixing ratio.

backscatter (wavelength, time, altitude): aerosol backscatter coefficient value measured within the `time_bound` and correspondingly to the specific altitude range and wavelength.

error_backscatter (wavelength, time, altitude): statistical uncertainty of the aerosol backscatter



coefficient value measured within the `time_bound` and correspondingly to the specific altitude range and wavelength.

extinction (wavelength, time, altitude): aerosol backscatter coefficient value measured within the `time_bound` and correspondingly to the specific altitude range and wavelength.

error_extinction (wavelength, time, altitude): statistical uncertainty of the aerosol extinction coefficient value measured within the `time_bound` and correspondingly to the specific altitude range and wavelength.

lidarratio (wavelength, time, altitude): lidar ratio profile obtained as the ratio of the aerosol extinction to aerosol backscatter coefficient. Lidar ratio is reported exclusively if aerosol extinction is effectively measured and if the aerosol backscatter is obtained through Raman method.

error_lidarratio (wavelength, time, altitude): statistical uncertainty of the lidar ratio profile calculated starting from statistical uncertainty of aerosol extinction and aerosol backscatter coefficients. This quantity is reported exclusively if aerosol extinction is effectively measured and if the aerosol backscatter is obtained through Raman method.

volumedepolarization (wavelength, time, altitude): volume depolarization ratio value measured within the `time_bound` and correspondingly to the specific altitude range and wavelength.

error_volumedepolarization (wavelength, time, altitude): statistical uncertainty of the volume depolarization ratio value measured within the `time_bound` and correspondingly to the specific altitude range and wavelength.

particledepolarization (wavelength, time, altitude): aerosol linear depolarization ratio value measured within the `time_bound` and correspondingly to the specific altitude range and wavelength.

error_particledepolarization (wavelength, time, altitude): statistical uncertainty of the aerosol linear depolarization ratio value measured within the `time_bound` and correspondingly to the specific altitude range and wavelength.

vertical_resolution (wavelength, time, altitude): effective vertical resolution of the reported optical profile. The effective vertical resolution depends on the retrieval algorithm used for determining the aerosol optical property and the smoothing procedures applied. The SCC estimates the vertical resolution through the method reported in Iarlori et al. AMT 2015.

earlinet_product_type: indicates which is specifically the product reported in such file. It can assume values in the [1:14] range meaning respectively [e0355 b0355 e0351 b0351 e0532 b0532 e1064 b1064 b0253 b0313 b0335 b0510 b0694 b0817]. e stands for e file (where extinction calculated by Raman observation is mandatory and b stands for b- file where backscatter is instead mandatory. The numerical values represent all the wavelengths currently present in the EARLINET DB.

error_retrieval_method(wavelength): method used for the retrieval of uncertainties



correspondingly to the specific wavelength. Two options are available: Monte Carlo calculation (`error_retrieval_method=0`) or standard error propagation (`error_retrieval_method=1`). For CAMS21b, this value is set up in the SCC configuration. For backscatter retrieval through Klett-Fernald method only Monte Carlo option is possible in the SCC.

backscatter_calibration_value(wavelength): assumed backscatter-ratio value in calibration range needed for the aerosol backscatter calibration procedure correspondingly to the specific wavelength. For CAMS21b, this value is set up in the SCC configuration.

backscatter_evaluation_method (wavelength): method used for the aerosol backscatter retrieval and correspondingly to the specific wavelength. The following options are possible: 0 for Raman retrieval and 1 for elastic_backscatter. Depending on this value one of the following 2 variables is defined. For CAMS21b, this value is set up in the SCC configuration.

raman_backscatter_algorithm (wavelength): algorithm used for the aerosol backscatter coefficient retrieval implemented the use of Raman channel and correspondingly to the specific wavelength. The following options are possible: 0 stands for Ansmann algorithm, 1 for algorithm via_backscatter_ratio. For CAMS21b, this value is set up in the SCC configuration.

elastic_backscatter_algorithm (wavelength): algorithm used for the elastic backscatter coefficient retrieval and correspondingly to the specific wavelength. The following options are possible: 0: Klett-Fernald, 1: iterative. For CAMS21b, this value is set up in the SCC configuration.

backscatter_calibration_range_search_algorithm (wavelength): algorithm used for the search of the calibration_range for the calibration of the aerosol backscatter coefficient correspondingly to the specific wavelength. The following options are possible: the value 0 stands for algorithm searching the minimum_of_signal_ratio, 1 is if the minimum_of_elastic_signal is searched for. For CAMS21b, this value is set up in the SCC configuration.

backscatter_calibration_range_search_range (wavelength,nv): altitude range wherein calibration range is searched for the corresponding wavelength. backscatter_calibration_range_search_range reports the 2 extremes of the search altitude range (minimum and maximum altitude) for each wavelength. For CAMS21b, this value is set up in the SCC configuration.

backscatter_calibration_range (wavelength,nv): altitude range where the backscatter calibration is effectively calculated. backscatter_calibration_range reports the 2 extremes of the altitude range (minimum and maximum altitude) where the backscatter calibration factor is calculated for each wavelength.

extinction_assumed_wavelength_dependence (wavelength): assumed wavelength dependence for extinction retrieval correspondingly to the specific wavelength. For CAMS21b, this value is set up in the SCC configuration.

extinction_evaluation_algorithm (wavelength): algorithm used for the aerosol extinction coefficient retrieval correspondingly to the specific wavelength. The following options are possible: 0 stands for



weighted_linear_fit algorithm used for the derivative procedure and 1 for non-weighted_linear_fit. For CAMS21b, this value is set up in the SCC configuration.

atmospheric_molecular_calculation_source: defines the data source for the atmospheric molecular calculations needed for aerosol extinction and backscatter retrievals. The following options are possible: US standard atmosphere (=0), external measured values (like with collocated radiosounding) (=1), data provided by atmospheric models (ECMWF, icon-iglo-12-13 and GDAS, respectively labelled as 2, 3 and 4).

cloud_mask_type: algorithm used for identifying the presence of cloud. The following options are possible: 0=no_cloudmask_available, 1>manual_cloudmask, 2=automatic_cloudmask. For data processed with SCC, automatic cloudmask is applied through the Cloud Masking module whenever the acquisition at 1064 nm is available.

scc_product_type: type of configuration used in the SCC by the station for the processing. The following options are possible: 1=experimental, 2=operational. Operational configuration is the one labelled by ACTRIS Center for the Aerosol Remote Sensing (CARS).

cloud_mask (time, altitude): presence of identified cloud within the time_bound and correspondingly to the specific altitude range and wavelength. The mask assigns the following values: 0=no cloud, 1=unknown_cloud 2=cirrus_cloud 4=water_cloud.

cirrus_contamination: indicates if the profile is affected by cirrus (0=no, 1=yes)

cirrus_contamination_source: indicate show the info on cirrus contamination is obtained: 0=not_available; 1=user_provided and 2=automatic_calculated

All the variables are mandatory excepted the following cases:

Backscatter and Error_backscatter are mandatory only for b product.

backscatter_calibration_search_range_algorithm, backscatter_calibration_range, backscatter_calibration_value, backscatter_calibration_search_range, backscatter_evaluation_method are mandatory only if backscatter is present

raman_backscatter_method is mandatory only if backscatter_evaluation_method is 0

elastic_backscatter_method is mandatory only if backscatter_evaluation_method is 1

extinction and Error_extinction are mandatory only for e product

extinction_evaluation_algorithm is mandatory only if backscatter is present



Finally, it is right mentioning here that on the ACTRIS/EARLINET database additional variables are allowed for reporting additional information: these are not provided by the SCC and are reported typically only for old data (so not of interest for CAMS21b2 provision data). However, for the sake of completeness such additional variables are listed here:

- aerosol layer height (time): top of aerosol boundary layer height above the sea level
- mixing layer height (time): top of aerosol convective boundary layer height above the sea level
- __SkippedFraction (time): is a private variable with reports the fraction respect to the total of skipped profiles within averaged period
- water vapor mixing ratio (wavelength, time, altitude): in this variable is possible to report the profile of water vapor mixing ratio (e.g. determined with Raman water vapor channel use)
- error_water vapor (wavelength, time, altitude): statistical uncertainty of water vapor mixing ratio profiles
- user_defined_category: Data Originator can assign a category to the data product labeling the case as a case of interest for some specific studies. Binary code reporting 1 if the product belongs to each one of the following classes: cirrus, climatology, diurnal_cycles, etna, forest_fires, photosmog, rural_urban, saharan_dust, stratosphere, satellite_overpasses categories, respectively.

Attribute description

The attributes of the variables are structured in such a way to provide all needed information about units, corresponding name (if existing) in the CF Convention and FillValue.

Global Attributes are mainly information related to traceability of the data, and they report information about:

convention applied for the names

information on the **dataset** (some references or info on source of the data and history of the modifications)

station information: ID following the code reported in Figure 1, location, name of the lidar system, institution and eventually comments

measurements info: ID assigned to the raw data by SCC in the submission phase and start and stop time

PI and **Data Originator** information: in particular, in agreement with the GEOMS definition (<https://evdc.esa.int/documents/1/geoms-1.0.pdf>), the Data Originator is the person that generated and quality controlled the data: in this case is the person that was responsible for the submission of raw data to the SCC. The Data Originator may or may not be the same person as the PI, which is the person responsible for the aerosol lidar station.

system specification: each ACTRIS/EARLINET lidar system is described in detail in the Handbook of Instrument (HoI). Such information are relevant for the preprocessing and in some cases processing modules of the SCC. Information about which lidar system and specific configuration as reported in the HoI is included in the global attributes of the data products.

software used for generating the data product: all information about SCC version and processor version is here reported



input files: for traceability in each product is reported the reference of all files used as input to produce the data products, so that means the input file to the SCC processor and eventually the overlapcorrection file.

4. Multiwavelength aerosol optical properties product

A first sample of ELDAmwl output has been provided to CAMS in November 2024. The meaning and nomenclature of variables and attributes is following the same attributed in single wavelength products for homogeneity.

An important difference between operational optical properties profiles and ELDAmwl ones is that the ELDAmwl NetCDF file is organized with groups: groups are like directories in a file system, except they are all within a file. The use of groups in such complex files like the ELDAmwl ones improves the readability and enables an easier use of the files. An important technical difference to be noted is that a "global" attribute is now global to the group, not the file.

Documentation of the ELDAmwl is available at <https://eldamwl.readthedocs.io/en/latest/>.

Figure 4 reports the main schema of the file organization into groups.

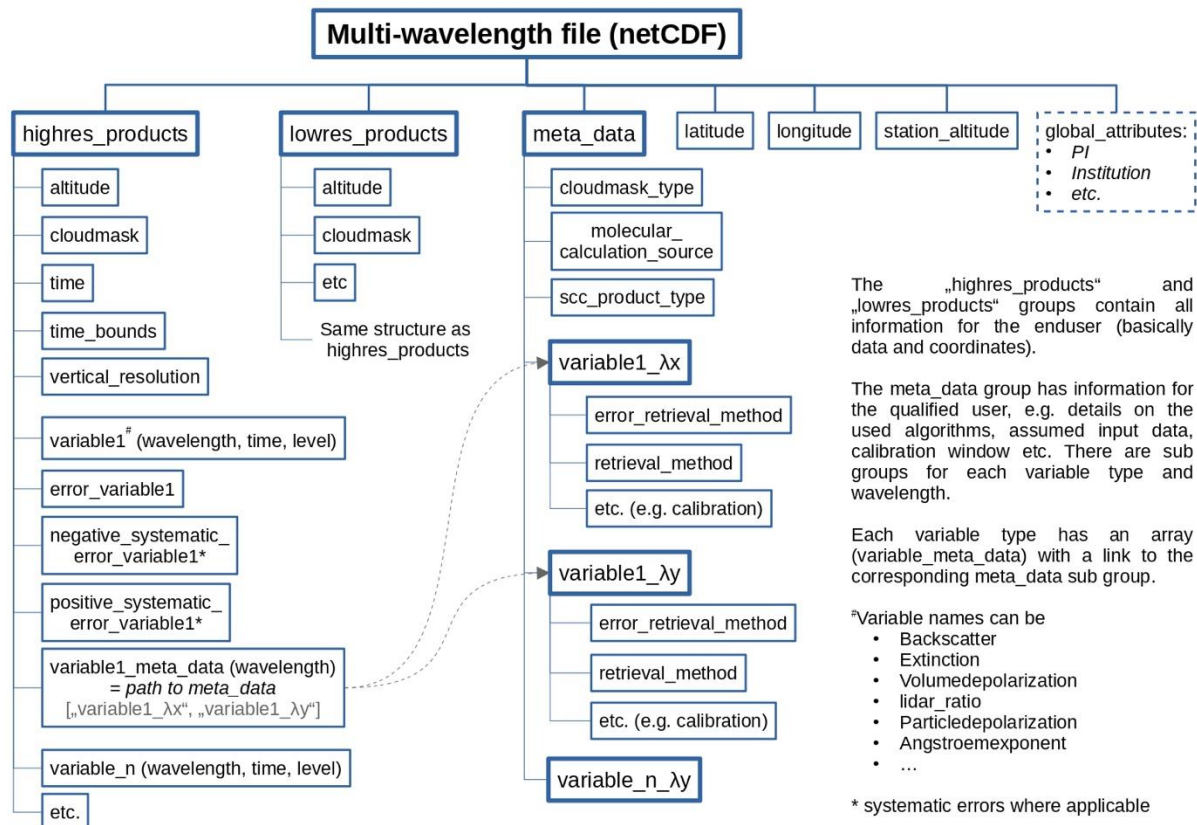


Figure 4: Organization of the ELDAmwl output containing the multi-wavelength aerosol optical properties profiles. Groups into the NetCDF allow a better organization and readability of the files.



This product is still experimental, and some modifications are to be expected in the future. In particular for what concerns the names of the files that will be modified accordingly to the ACTRIS/EARLINET DB overarching nomenclature schema once the files will be uploaded on the DB (i.e. when the production of them will become operational).

Currently the **filename** of the ELDAmwI output is codified as follows:

ccc_aaa_bbbbbbb_YYYYMMDDHHMM_yyyymmddhhmm_nnnnnnnnnnnnnnnn_ELDAmwI_vx.x.x.nc

- ccc** (length =3) reports a three digit code representing univocally an EARLINET station (see section3)
 - aaa** (length=3) reports the SCC-internal id for the type of the product.
 - bbbbbbb** (length=7) reports the SCC-internal productid
 - YYYYMMDDHHMM** (length =12) provides the start date and time of the measurements contained in the product file. The time is UTC.
 - yyymmddhhmm** (length=12) provides the stopdate and time of the measurements contained in the product file. The time is UTC.
 - nnnnnnnnnnnnnnnn** (length=15) provides the measurements ID uniquely associated to the measurement run when raw data are submitted to the SCC.
- The final part of the filename describes the SCC modules used for obtaining the file and its version.

The sample files provided already follow the file naming conventions of the EARLINET database, as they will be once they become operational and available in the operational DB. Their filename follows this nomenclature:

EARLINET_AerRemSen_ccc_Levzz_ELDAmwI_YYYYMMDDHHMM_yyyymmddhhmm_vxx_qcyy.nc

The character “_” is used to separate different fields in the filename. The extension of the file is always “.nc”. The number of fields composing the filename (excluding the extension) is always 9. Each of the fields that composes the filename is described in Table 4.

Table 4. Description of the fields that compose the ELDAmwI products filenames according to the file naming convention.

	Field	Length	Description
1 st	<i>EARLINET</i>	8	This field always reports the string "EARLINET"
2 nd	<i>AerRemSen</i>	9	This field means "Aerosol Remote Sensing"
3 rd	<i>ccc</i>	3	This field reports a three digit code representing univocally an EARLINET station



4 th	<i>Levzz</i>	5	This field specifies the level of the product. The levels are assigned to the product on the base of specific quality control procedure.
5 th	<i>ELDAmwl</i>	8	This field identifies the product type.
6 th	<i>YYYYMMDDHHMM</i>	12	This is a date-time field and it provides the start date and time of the measurements contained in the product file. The time is UTC.
7 th	<i>yyyymmddhhmm</i>	12	This is a date-time field and it provides the stop date and time of the measurements contained in the product file. The time is UTC.
8 th	<i>vxx</i>	3	This field specifies the version of the product. The first character 'v' is always present. The next 2 characters are always numeric. (E.g. v01 identifies version 1 of the file, v02 version 2 and so on).
9 th	<i>qcy</i>	4	This field specifies the quality control version of the product. The suffix 'qc' is always present. The next 2 characters are always numeric. (E.g. qc01 identifies the QC version 0.1 of the file, qc0.2 the version 0.2 and so on).

Next, specifications are reported for **variables/attributes** different or additional to the ones reported in Section 4, and an example of file is reported in Appendix C.

assumed_particle_lidar_ratio (time, level): reports the assumed particle lidar ratio for the elastic-only backscatter retrieval.

Being the ELDAmwl output really complex, properties related to retrieval methods have been somehow grouped and associated values have different meanings depending on quantities to which they refer:

retrieval_method: method used for the retrieval of the specific properties. For aerosol backscatter the following options are possible: 0 for Raman retrieval and 1 for elastic_backscatter. For the depolarization, it indicates the method used for the retrieval of volume linear depolarization ratio. At the present the only option is the method Freudenthaler et al. 2022;

evaluation_algorithm: algorithm used for the calculation of the property. For the extinction: 0 for weighted_linear_fit, 1 for the non-weighted_linear_fit. For the elastic backscatter: 0 for Klett, 1 for iterative. For backscatter Raman, 0 for Ansmann_method and 1 for method based on backscatter_ratio;



positive_systematic_error_volumedepolarization (wavelength, time, level): variable available for low resolution product which reports the positive absolute systematic uncertainty of volume depolarization.

negative_systematic_error_volumedepolarization (wavelength, time, level): variable available for low resolution product which reports the negative absolute systematic uncertainty of volume depolarization.

Among attributes, the following has been added to the ELDAmwl output:

molecular_calculation_source_file which provides the name of the file containing the information needed for the atmospheric molecular profile calculation.

5. Aerosol layer products

A first sample of LTOOL output is provided to CAMS in November 2024. The description of the methods used in LTOOL for the automatic identification of aerosol layers are reported in Siomos et al., 2018.

Currently, the LTOOL module is running in SCC development, and the **filename** of the LTOOL output in the SCC is codified as follows:

ccc_aaa_www_bbbbbbb_YYYYMMDDHHMM_yyyymmddhhmm_nnnnnnnnnnnnnn_ltool_vx.x.x.nc

ccc (length=3) reports a three digit code representing univocally an EARLINET station (see section3)

aaa (length=3) reports the SCC-internal id for the type of the product.

www (length=4) reports the wavelength of backscatter used for the calculation

bbbbbbb (length=7) reports the SCC-internal product id

YYYYMMDDHHMM (length=12) provides the start date and time of the measurements contained in the product file. The time is UTC.

yyymmddhhmm (length=12) provides the stopdate and time of the measurements contained in the product file. The time is UTC.

nnnnnnnnnnnnnnn (length=15) provides the measurements ID uniquely associated to the measurement run when raw data are submitted to the SCC.

The final part of the filename describes the SCC modules used for obtaining the file and its version.

As in the case of the ELDAmwl products, the LTOOL sample files provided already follow the file naming conventions of the EARLINET database, as they will be once they become operational and available in the operational DB. Their filename follows this nomenclature:

Layering_AerRemSen_ccc_Levzz_LTOOL_www_YYYYMMDDHHMM_yyyymmddhhmm_vxx.nc

The character “_” is used to separate different fields in the filename. The extension of the file is always



“.nc”. The number of fields composing the filename (excluding the extension) is always 9. Each of the fields that composes the filename is described in Table 5.

Table 5. Description of the fields that compose the LTOOL products filenames according to the file naming convention.

	Field	Length	Description
1 st	<i>Layering</i>	8	This field always reports the string "Layering"
2 nd	<i>AerRemSen</i>	9	This field means "Aerosol Remote Sensing"
3 rd	<i>ccc</i>	3	This field reports a three digit code representing univocally an EARLINET station
4 th	<i>Levzz</i>	5	This field specifies the level of the product. The levels are assigned to the product on the base of specific quality control procedure.
5 th	<i>LTOOL</i>	5	This field identifies the product type.
6 th	<i>www</i>	4	This field specifies the wavelength for which the LTOOL product has been produced
7 th	<i>YYYYMMDDHHMM</i>	12	This is a date-time field and it provides the start date and time of the measurements contained in the product file. The time is UTC.
8 th	<i>yyyymmddhhmm</i>	12	This is a date-time field and it provides the stop date and time of the measurements contained in the product file. The time is UTC.
9 th	<i>vxx</i>	3	This field specifies the version of the product. The first character 'v' is always present. The next 2 characters are always numeric. (E.g. v01 identifies version 1 of the file, v02 version 2 and so on).

Next, specifications are reported for **variables/attributes** different or additional to the ones reported in Section 4-5, and an example of file is reported in Appendix D.

layers is a dimension and takes into account how many layers are identified by LTOOL for the specific case.

residual_layer_flag(layers): is a flag for identifying the first layer. It is 1 when its true base is not identified. In this case, the first range bin is used as the base instead and the layer is marked as a potential candidate for the residual layer.



base (layers): is the altitude of the layer base.

top (layers): is the altitude of the layer top.

center_of_mass (layers): is the altitude of the layer center of mass. It is the average altitude weighted by the product values.

peak (layers): is the height between base and top altitude range where the maximum value of the optical product is observed.

thickness (layers): is the geometrical thickness of the layer (top – base).

base_sig(layers): is the product value observed at the base of the layer

top_sig(layers): is the product value observed at the top of the layer

peak_sig(layers): is the maximum value of the optical product observed within the layer.

depth(layers): is the integrated product within the layer

sharpness(layers): minimum absolute difference between the product value at the peak and the product value at the base or top;

trend(layers): difference between the product value at the top and the product value at the base.

weight(layers): the weight of the layer respect to the column. It is the fraction of the integrated product within the layer to the whole columnar integral.

snr_factor: product to noise ratio limit applied to the WCT normalized by the noise vertically. It is used to discern between noise and actual layers

wct_peak_margin: absolute WCT ratio threshold. It represents the WCT values of a number of subsequent features of the same kind (either solely bases or solely tops) divided by the maximum absolute WCT value among them. Features with values less than this threshold are rejected. It is used to identify most suitable feature among a number of subsequent candidates

dilation: the dilation value (window) used for the WCT calculations

6. Aerosol typing products

A first sample of HIRAC and MAC output is provided to CAMS in November 2024. As for section 5, specifications are reported for variables/attributes different or additional to the ones reported in previous sections and an example of file is reported in Appendix E and F respectively.



HIRAC stands for High Resolution Aerosol Classification, and it provides time-height lidar plots of shape (particle/volume depolarization ratio) and size (Ångström exponent) directly provide insight for the user to deduce the aerosol type. The aerosol type product classifies aerosol into four aerosol classes (small, large spherical, mixture, large non-spherical). The classification is based on their physical features (shape and size) and not on the source origin, i.e. it is an objective classification.

Baars et al.: Target categorization of aerosol and clouds by continuous multiwavelength-polarization lidar measurements, *Atmos. Meas. Tech.*, 10, 3175–3201, <https://doi.org/10.5194/amt-10-3175-2017>, 2017"

Currently the **filename** of the HIRAC output (High Resolution Aerosol Classification) is codified as follows:

Typing_AerRemSen_ccc_Levzz_HIRAC_YYYYMMDDHHMM_yyyymmddhhmm_vxx.nc

ccc (length=3) reports a three digit code representing univocally an EARLINET station (see section3)

Levzz (length=5) specifies the level of the product. The levels are assigned to the product on the base of specific quality control procedure. Currently only Levo01 is allowed to typing product.

YYYYMMDDHHMM (length=12) provides the start date and time of the measurements contained in the product file. The time is UTC.

yyyymmddhhmm (length=12) provides the stopdate and time of the measurements contained in the product file. The time is UTC.

vxx specifies the version of the file. The first character 'v' is always present. The next 2 characters are always numeric (e.g. v01 identifies version 1 of the file, v02 version 2 and so on).

The following **variables** (different from the ones already defined in previous files) are included:

aerosol_classification(time, altitude): is a variable describing the aerosol classification, the following values and meanings are possible 0.5 (Clean atmosphere), 1.5 (Not-typed), 2.5 (Aerosol:small), 3.5 (Aerosol:large-spherical), 4.5 (Aerosol:mixture,partly-nonspherical), 5.5 (Aerosol:large,nonspherical);

aerosol_backscatter_0532(time, altitude): this variable reports the 532 nm quasi particle backscatter coefficient at that time and altitude. Quasi particle backscatter represents the best estimate for the particle backscatter coefficient obtained by the calibrated preprocessed signals through an iterative procedure (Baars et al., 2017).

aerosol_backscatter_1064(time, altitude): this variable reports the 1064 nm quasi particle backscatter coefficient at that time and altitude. Quasi particle backscatter represents the best



estimate for the particle backscatter coefficient obtained by the calibrated preprocessed signals through an iterative procedure (Baars et al., 2017).

aerosol_backscatter_0355(time, altitude): this variable reports the 355 nm quasi particle backscatter coefficient at that time and altitude. Quasi particle backscatter represents the best estimate for the particle backscatter coefficient obtained by the calibrated preprocessed signals through an iterative procedure (Baars et al., 2017).

aerosol_depolarization_0532(time, altitude): this variable reports the 532 nm quasi particle depolarization ratio at that time and altitude. Quasi particle depolarization ratio is the particle depolarization obtained using the quasi particle backscatter following Baars et al., 2017.

For less experienced users, a more descriptive classification, even if at a lower time resolution, would be desirable. To this end, advanced algorithms were developed and compared (e.g., 1,2,4). These kind of algorithms run on aerosol multi-wavelength optical properties at the same resolution (ELDA outputs or ELDAmwl output) and provide a classification relatable to the aerosol sources. The Mahalanobis Aerosol Classification (MAC) algorithm, which makes use of machine learning techniques (Papagiannopoulos et al., 2018), has been utilized with this purpose .

Currently the **filename** of the MAC output for aerosol typing at low resolution is codified as follows:

Typing_AerRemSen_ccc_Levzz_MAC_YYYYMMDDHHMM_yyyymmddhhmm_vxx.nc

ccc (length=3) reports a three digit code representing univocally an EARLINET station (see section3)
Levzz (length=5) specifies the level of the product. The levels are assigned to the product on the base of specific quality control procedure. Currently only Levo01 is allowed to typing product.

YYYYMMDDHHMM (length=12) provides the start date and time of the measurements contained in the product file. The time is UTC.

yyyymmddhhmm (length=12) provides the stopdate and time of the measurements contained in the product file. The time is UTC.

vxx specifies the version of the file. The first character 'v' is always present. The next 2 characters are always numeric (e.g. v01 identifies version 1 of the file, v02 version 2 and so on).

The following **variables** specific for MAC output are included:

aerosol_classification(layers): is a variable describing the aerosol type related to the source for the different identified layers in the profile. The following values and meanings are possible: 0 (Not classified), 1 (clean continental), 2 (smoke), 3 (dust), 4 (marine), 5 (polluted dust), 6 (polluted continental), 7 (mixed dust).



angstrom_exponent(layers): reports the mean 532-nm/1064-nm backscatter-related Ångström exponent for each layer in the profile

lidar_ratio(layers): reports the mean 532-nm lidar ratio for each layer in the profile

ratio_of_lidar_ratios(layers): reports the mean ratio of 355-nm/532-nm lidar ratios for each layer in the profile

depolarization(layers): reports the mean 532-nm particle linear depolarization ratio for each layer in the profile

7. Conclusions

This document describes the geophysical products provided both as operational and experimental products to CAMS. The operational data (namely the aerosol optical profiles) are provided in NRT if the operation at the station results in a fast and efficient submission of data to the data center and provides authorization for the NRT submission.

We plan to update the document during CAMS21b2 once per year if needed: in the near future improvements in the data format are expected in terms of overall harmonization between the different products and, even more relevant, thanks to the interaction with modeling group as big users of our data, an interaction that is being pushed forward in WP2.

8. References

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D'Amico, G., Amodeo, A., Baars, H., Biniatoglou, I., Freudenthaler, V., Mattis, I., Wandinger, U., and Pappalardo, G.: EARLINET Single Calculus Chain – overview on methodology and strategy, *Atmos. Meas. Tech.*, 8, 4891–4916, <https://doi.org/10.5194/amt-8-4891-2015>, 2015.

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9. Appendix A

```
netcdf EARLINET_AerRemSen_pot_Lev01_b0355_202411222028_202411222128_v01_qc03.nc
{
  dimensions:
    time = 1;
    altitude = 179;
    wavelength = 1;
    nv = 2;
  variables:
    double time(time=1);
      :axis = "T";
      :bounds = "time_bounds";
      :calendar = "gregorian";
      :long_name = "time";
      :standard_name = "time";
      :units = "seconds since 1970-01-01T00:00:00Z";

    double time_bounds(time=1, nv=2);

    double altitude(altitude=179);
      :axis = "Z";
      :long_name = "height above sea level";
      :positive = "up";
      :standard_name = "altitude";
      :units = "m";

    float wavelength(wavelength=1);
      :long_name = "wavelength of the transmitted laser pulse";
      :units = "nm";

    float backscatter_calibration_value(wavelength=1);
      :long_name = "assumed backscatter-ratio value in calibration range";
      :units = "m-1*sr-1";
      :_FillValue = 9.96921E36f; // float

    byte error_retrieval_method(wavelength=1);
      :long_name = "method used for the retrieval of uncertainties";
      :_FillValue = -127B; // byte
      :flag_values = 0B, 1B; // byte
      :flag_meanings = "monte_carlo error_propagation";

    byte backscatter_evaluation_method(wavelength=1);
      :long_name = "method used for the backscatter retrieval";
      :_FillValue = -127B; // byte
```



```
:flag_values = 0B, 1B; // byte
:flag_meanings = "Raman elastic_backscatter";
```

```
byte backscatter_calibration_range_search_algorithm(wavelength=1);
:long_name = "algorithm used for the search of the calibration_range";
:_FillValue = -127B; // byte
:flag_values = 0B, 1B; // byte
:flag_meanings = "minimum_of_signal_ratio minimum_of_elastic_signal";
```

```
byte raman_backscatter_algorithm(wavelength=1);
:_FillValue = -127B; // byte
:flag_values = 0B, 1B; // byte
:flag_meanings = "Ansmann via_backscatter_ratio";
:long_name = "algorithm used for the retrieval of the Raman backscatter profile";
```

```
float longitude;
:long_name = "longitude of station";
:standard_name = "longitude";
:units = "degrees_east";
```

```
float latitude;
:long_name = "latitude of station";
:standard_name = "latitude";
:units = "degrees_north";
```

```
float station_altitude;
:long_name = "station altitude above sea level";
:units = "m";
:_FillValue = 9.96921E36f; // float
```

```
float zenith_angle;
:long_name = "laser pointing angle with respect to the zenith";
:units = "degrees";
:_FillValue = 9.96921E36f; // float
```

```
int shots(time=1);
:_FillValue = -2147483647; // int
:long_name = "accumulated laser shots";
:units = "1";
```

```
byte atmospheric_molecular_calculation_source;
:long_name = "data source of the atmospheric molecular calculations";
:_FillValue = -127B; // byte
:valid_range = 0B, 8B; // byte
:flag_values = 0B, 1B, 2B, 3B, 4B, 5B, 6B, 7B, 8B; // byte
```



```

:flag_meanings = "US_standard_atmosphere radiosounding ecmwf icon_iglo_12_23
icon_iglo_24_35 icon_iglo_36_47 gdas era5-1-12 era5-7-18";

byte cirrus_contamination;
:long_name = "do the profiles contain cirrus layers?";
:_FillValue = -127B; // byte
:valid_range = 0B, 3B; // byte
:flag_values = 0B, 1B, 2B; // byte
:flag_meanings = "not_available no_cirrus cirrus_detected";

byte cirrus_contamination_source;
:long_name = "how was cirrus_contamination obtained?";
:_FillValue = -127B; // byte
:valid_range = 0B, 3B; // byte
:flag_values = 0B, 1B, 2B; // byte
:flag_meanings = "not_available user_provided automatic_calculated";

int quality_control_level;
:long_name = "Quality Control Level";
:flag_values = 0, 1, 2; // int
:flag_meanings = "File_does_not_overcome_one_or_more_on_fly_quality_control
File_does_overcome_all_on_fly_quality_control_but_fails_one_or_more_technical_quality_control
File_does_overcome_all_technical_quality_control_and_physical_quality_control ";
:version = "2.0";
:references = "https://www.earlinet.org/index.php?id=293";

int basic_quality_control;
:long_name = "Basic Quality Control";
:valid_range = 0, 7; // int
:flag_masks = 1, 2, 4; // int
:flag_meanings = "Check_if_file_contains_data Check_Coordinates_Consistency
Check_for_Undefined_Variables_and_Global_Attributes";
:references = "https://www.earlinet.org/index.php?id=293";

int advanced_quality_control;
:long_name = "Advanced Quality Control";
:valid_range = 0, 2027; // int
:flag_masks = 1, 2, 8, 32, 64, 128, 256, 512, 1024; // int
:flag_meanings = "Checks_for_Negative_Errors Negative_peaks Check_on_IB
Check_on_Volumedepolarization Check_on_Particledepolarization
Check_on_Watervapormixingratio Check_on_atmospheric_molecular_calculation_source
Check_on_old_cirrus_product Check_on_SCC_product_type";
:references = "https://www.earlinet.org/index.php?id=293";

double backscatter(wavelength=1, time=1, altitude=179);

```



```
:ancillary_variables = "error_backscatter vertical_resolution";  
:coordinates = "longitude latitude";  
:long_name = "aerosol backscatter coefficient";  
:plausibility = "parameter passed the EARLINET quality assurance.";  
:units = "m-1*sr-1";  
:_FillValue = 9.969209968386869E36; // double
```

```
double error_backscatter(wavelength=1, time=1, altitude=179);  
:coordinates = "longitude latitude";  
:long_name = "statistical uncertainty of aerosol backscatter";  
:plausibility = "parameter passed the EARLINET quality assurance.";  
:units = "m-1*sr-1";  
:_FillValue = 9.969209968386869E36; // double
```

```
double vertical_resolution(wavelength=1, time=1, altitude=179);  
:long_name = "effective vertical resolution according to Pappalardo et al., appl. opt. 2004";  
:units = "m";  
:_FillValue = 9.969209968386869E36; // double
```

```
double volumedepolarization(wavelength=1, time=1, altitude=179);  
:coordinates = "longitude latitude";  
:long_name = "volume linear depolarization ratio";  
:plausibility = "parameter not quality assured by EARLINET.";  
:units = "1";  
:_FillValue = 9.969209968386869E36; // double
```

```
double error_volumedepolarization(wavelength=1, time=1, altitude=179);  
:coordinates = "longitude latitude";  
:long_name = "statistical uncertainty of volume linear depolarization ratio";  
:plausibility = "parameter not quality assured by EARLINET.";  
:units = "1";  
:_FillValue = 9.969209968386869E36; // double
```

```
double particledepolarization(wavelength=1, time=1, altitude=179);  
:long_name = "aerosol linear depolarization ratio";  
:plausibility = "parameter not quality assured by EARLINET.";  
:units = "1";  
:_FillValue = 9.969209968386869E36; // double  
:coordinates = "longitude latitude";
```

```
double error_particledepolarization(wavelength=1, time=1, altitude=179);  
:coordinates = "longitude latitude";  
:long_name = "statistical uncertainty of aerosol linear depolarization ratio";  
:plausibility = "parameter not quality assured by EARLINET.";  
:units = "1";
```



```
:_FillValue = 9.969209968386869E36; // double

int earlinet_product_type;
:long_name = "Earlinet product type";
:_FillValue = -2147483647; // int
:valid_range = 1, 14; // int
:flag_values = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14; // int
:flag_meanings = "e0355 b0355 e0351 b0351 e0532 b0532 e1064 b1064 b0253 b0313 b0335
b0510 b0694 b0817";

int user_defined_category;
:long_name = "User defined category of the measurement";
:_FillValue = -2147483647; // int
:valid_range = 0, 1023; // int
:flag_masks = 1, 2, 4, 8, 16, 32, 64, 128, 256, 512; // int
:flag_meanings = "cirrus climatology diurnal_cycles volcanic forest_fires photosmog rural_urban
saharan_dust stratosphere satellite_overpasses";
:comment = "Those flags might have not been set in a homogeneous way. Before using them,
contact the originator to obtain more detailed information on how these flags have been set.";

float backscatter_calibration_range(wavelength=1, nv=2);
:long_name = "altitude range where calibration was calculated";
:units = "m";
:_FillValue = 9.96921E36f; // float

float backscatter_calibration_search_range(wavelength=1, nv=2);
:long_name = "altitude range wherein calibration range is searched";
:units = "m";
:_FillValue = 9.96921E36f; // float

byte cloud_mask_type;
:long_name = "cloud mask type";
:_FillValue = -127B; // byte
:valid_range = 0B, 3B; // byte
:flag_values = 0B, 1B, 2B; // byte
:flag_meanings = "no_cloudmask_available manual_cloudmask automatic_cloudmask";

byte scc_product_type;
:long_name = "SCC product type";
:_FillValue = -127B; // byte
:valid_range = 1B, 2B; // byte
:flag_values = 1B, 2B; // byte
:flag_meanings = "experimental operational";
```



```
// global attributes:
:Conventions = "CF-1.7";
:title = "Profiles of aerosol optical properties";
:source = "Ground based LIDAR measurements";
:references = "Project website at http://www.earlinet.org";
:history = "2024-11-23T01:02Z : Assigned version 1\r\n 2024-11-23T01:02:00Z : File uploaded on
Earlinet database\r\n 2024-11-22T22:07:36Z: elpp -d sccoperational -m 20241122pot202N -c
elpp.config; 2024-11-22T22:09:17Z: elda 20241122pot202N -c elda.ini";
:station_ID = "pot";
:location = "Potenza, Italy";
:system = "Fixed Lidar Raymetrics L1";
:institution = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per l'Analisi Ambientale
- CNR-IMAA";
:comment = ;
:measurement_ID = "20241122pot202N";
:measurement_start_datetime = "2024-11-22T20:28:13Z";
:measurement_stop_datetime = "2024-11-22T21:28:31Z";
:PI = "Aldo Amodeo";
:PI_affiliation = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per l'Analisi
Ambientale";
:PI_affiliation_acronym = "CNR-IMAA";
:PI_address = "Contrada S.Loja, Zona Industriale - Tito Scalo I-85050 Potenza";
:PI_phone = "+39 0971 427263";
:PI_email = "aldo.amodeo@cnr.it";
>Data_Originator = "aldo.amodeo";
>Data_Originator_affiliation = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per
l'Analisi Ambientale";
>Data_Originator_affiliation_acronym = "CNR-IMAA";
>Data_Originator_address = "Contrada S.Loja, Zona Industriale - Tito Scalo I-85050 Potenza";
>Data_Originator_phone = "+39 0971 427263";
>Data_Originator_email = "aldo.amodeo@cnr.it";
:data_processing_institution = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per
l'Analisi Ambientale (CNR-IMAA)";
:hoi_system_ID = 181; // int
:hoi_configuration_ID = 891; // int
:scc_version = "5.2.9";
:scc_version_description = "SCC vers. 5.2.9 (HiRELPP vers. 1.1.5, CloudMask vers. 1.6.0, ELPP vers.
7.1.3, ELDA vers. 3.4.8.1, ELIC vers. 1.0.8, ELQUICK vers. 1.0.7, ELDEC vers. 2.1.4)";
:processor_name = "ELDA";
:processor_version = "3.4.8.1";
:__file_format_version = "2.1";
:input_file =
"pot_007_0002093_202411222028_202411222132_20241122pot202N_elpp_v5.2.9.nc";
:overlap_correction_file = ;
}
```



10. Appendix B

```
netcdf EARLINET_AerRemSen_pot_Lev01_e0355_202411222028_202411222128_v01_qc03.nc {
  dimensions:
    time = 1;
    altitude = 178;
    wavelength = 1;
    nv = 2;
  variables:
    double time(time=1);
      :axis = "T";
      :bounds = "time_bounds";
      :calendar = "gregorian";
      :long_name = "time";
      :standard_name = "time";
      :units = "seconds since 1970-01-01T00:00:00Z";

    double time_bounds(time=1, nv=2);

    double altitude(altitude=178);
      :axis = "Z";
      :long_name = "height above sea level";
      :positive = "up";
      :standard_name = "altitude";
      :units = "m";

    float wavelength(wavelength=1);
      :long_name = "wavelength of the transmitted laser pulse";
      :units = "nm";

    float backscatter_calibration_value(wavelength=1);
      :long_name = "assumed backscatter-ratio value in calibration range";
      :units = "m-1*sr-1";
      :_FillValue = 9.96921E36f; // float

    float extinction_assumed_wavelength_dependence(wavelength=1);
      :long_name = "assumed wavelength dependence for extinction retrieval";
      :units = "1";
      :_FillValue = 9.96921E36f; // float

    byte error_retrieval_method(wavelength=1);
      :long_name = "method used for the retrieval of uncertainties";
```



```
:_FillValue = -127B; // byte
:flag_values = 0B, 1B; // byte
:flag_meanings = "monte_carlo error_propagation";
```

```
byte backscatter_evaluation_method(wavelength=1);
:long_name = "method used for the backscatter retrieval";
:_FillValue = -127B; // byte
:flag_values = 0B, 1B; // byte
:flag_meanings = "Raman elastic_backscatter";
```

```
byte backscatter_calibration_range_search_algorithm(wavelength=1);
:long_name = "algorithm used for the search of the calibration_range";
:_FillValue = -127B; // byte
:flag_values = 0B, 1B; // byte
:flag_meanings = "minimum_of_signal_ratio minimum_of_elastic_signal";
```

```
byte extinction_evaluation_algorithm(wavelength=1);
:long_name = "algorithm used for the extinction retrieval";
:_FillValue = -127B; // byte
:flag_values = 0B, 1B; // byte
:flag_meanings = "weighted_linear_fit non-weighted_linear_fit";
```

```
byte raman_backscatter_algorithm(wavelength=1);
:long_name = "algorithm used for the retrieval of the Raman backscatter profile";
:_FillValue = -127B; // byte
:flag_values = 0B, 1B; // byte
:flag_meanings = "Ansmann via_backscatter_ratio";
```

```
float longitude;
:units = "degrees_east";
:long_name = "longitude of station";
:standard_name = "longitude";
```

```
float latitude;
:long_name = "latitude of station";
:standard_name = "latitude";
:units = "degrees_north";
```

```
float station_altitude;
:long_name = "station altitude above sea level";
:units = "m";
:_FillValue = 9.96921E36f; // float
```

```
float zenith_angle;
:long_name = "laser pointing angle with respect to the zenith";
```



```
:units = "degrees";
:_FillValue = 9.96921E36f; // float

int shots(time=1);
:long_name = "accumulated laser shots";
:units = "1";
:_FillValue = -2147483647; // int

byte atmospheric_molecular_calculation_source;
:long_name = "data source of the atmospheric molecular calculations";
:_FillValue = -127B; // byte
:valid_range = 0B, 8B; // byte
:flag_values = 0B, 1B, 2B, 3B, 4B, 5B, 6B, 7B, 8B; // byte
:flag_meanings = "US_standard_atmosphere radiosounding ecmwf icon_iglo_12_23
icon_iglo_24_35 icon_iglo_36_47 gdas era5-1-12 era5-7-18";

byte cirrus_contamination;
:long_name = "do the profiles contain cirrus layers?";
:_FillValue = -127B; // byte
:valid_range = 0B, 3B; // byte
:flag_values = 0B, 1B, 2B; // byte
:flag_meanings = "not_available no_cirrus cirrus_detected";

byte cirrus_contamination_source;
:long_name = "how was cirrus_contamination obtained?";
:_FillValue = -127B; // byte
:valid_range = 0B, 3B; // byte
:flag_values = 0B, 1B, 2B; // byte
:flag_meanings = "not_available user_provided automatic_calculated";

int quality_control_level;
:long_name = "Quality Control Level";
:flag_values = 0, 1, 2; // int
:flag_meanings = "File_does_not_overcome_one_or_more_on_fly_quality_control
File_does_overcome_all_on_fly_quality_control_but_fails_one_or_more_technical_quality_control
File_does_overcome_all_technical_quality_control_and_physical_quality_control ";
:version = "2.0";
:references = "https://www.earlinet.org/index.php?id=293";

int basic_quality_control;
:long_name = "Basic Quality Control";
:valid_range = 0, 7; // int
:flag_masks = 1, 2, 4; // int
:flag_meanings = "Check_if_file_contains_data Check_Coordinates_Consistency
Check_for_Undefined_Variables_and_Global_Attributes";
```



```
:references = "https://www.earlinet.org/index.php?id=293";
```

```
int advanced_quality_control;  
:long_name = "Advanced Quality Control";  
:valid_range = 0, 2039; // int  
:flag_masks = 1, 2, 4, 16, 32, 64, 128, 256, 512, 1024; // int  
:flag_meanings = "Checks_for_Negative_Errors Negative_peaks Check_on_AOD  
Check_on_LidarRatio Check_on_Volumedepolarization Check_on_Particledepolarization  
Check_on_Watervapormixingratio Check_on_atmospheric_molecular_calculation_source  
Check_on_old_cirrus_product Check_on_SCC_product_type";  
:references = "https://www.earlinet.org/index.php?id=293";
```

```
double backscatter(wavelength=1, time=1, altitude=178);  
:ancillary_variables = "error_backscatter vertical_resolution";  
:coordinates = "longitude latitude";  
:long_name = "aerosol backscatter coefficient";  
:plausibility = "parameter passed the EARLINET quality assurance.";  
:units = "m-1*sr-1";  
:_FillValue = 9.969209968386869E36; // double
```

```
double error_backscatter(wavelength=1, time=1, altitude=178);  
:coordinates = "longitude latitude";  
:long_name = "statistical uncertainty of aerosol backscatter";  
:plausibility = "parameter passed the EARLINET quality assurance.";  
:units = "m-1*sr-1";  
:_FillValue = 9.969209968386869E36; // double
```

```
double extinction(wavelength=1, time=1, altitude=178);  
:ancillary_variables = "error_extinction vertical_resolution";  
:coordinates = "longitude latitude";  
:long_name = "aerosol extinction coefficient";  
:plausibility = "parameter passed the EARLINET quality assurance.";  
:units = "m-1";  
:_FillValue = 9.969209968386869E36; // double
```

```
double error_extinction(wavelength=1, time=1, altitude=178);  
:long_name = "statistical uncertainty of aerosol extinction";  
:plausibility = "parameter passed the EARLINET quality assurance.";  
:units = "m-1";  
:_FillValue = 9.969209968386869E36; // double  
:coordinates = "longitude latitude";
```

```
double vertical_resolution(wavelength=1, time=1, altitude=178);  
:long_name = "effective vertical resolution according to Pappalardo et al., appl. opt. 2004";  
:units = "m";
```



```
:_FillValue = 9.969209968386869E36; // double
```

```
double lidarratio(wavelength=1, time=1, altitude=178);  
:ancillary_variables = "error_lidarratio";  
:coordinates = "longitude latitude";  
:long_name = "aerosol extinction-to-backscatter ratio";  
:plausibility = "parameter calculated from backscatter and extinction.";  
:units = "sr";  
:_FillValue = 9.969209968386869E36; // double
```

```
double error_lidarratio(wavelength=1, time=1, altitude=178);  
:coordinates = "longitude latitude";  
:long_name = "statistical uncertainty of lidar ratio";  
:plausibility = "parameter calculated from error_backscatter and error_extinction.";  
:units = "sr";  
:_FillValue = 9.969209968386869E36; // double
```

```
int earlinet_product_type;  
:long_name = "Earlinet product type";  
:_FillValue = -2147483647; // int  
:valid_range = 1, 14; // int  
:flag_values = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14; // int  
:flag_meanings = "e0355 b0355 e0351 b0351 e0532 b0532 e1064 b1064 b0253 b0313 b0335  
b0510 b0694 b0817";
```

```
int user_defined_category;  
:long_name = "User defined category of the measurement";  
:_FillValue = -2147483647; // int  
:valid_range = 0, 1023; // int  
:flag_masks = 1, 2, 4, 8, 16, 32, 64, 128, 256, 512; // int  
:flag_meanings = "cirrus climatology diurnal_cycles volcanic forest_fires photosmog rural_urban  
saharan_dust stratosphere satellite_overpasses";  
:comment = "Those flags might have not been set in a homogeneous way. Before using them,  
contact the originator to obtain more detailed information on how these flags have been set.";
```

```
float backscatter_calibration_range(wavelength=1, nv=2);  
:long_name = "altitude range where calibration was calculated";  
:units = "m";  
:_FillValue = 9.96921E36f; // float
```

```
float backscatter_calibration_search_range(wavelength=1, nv=2);  
:long_name = "altitude range wherein calibration range is searched";  
:units = "m";  
:_FillValue = 9.96921E36f; // float
```



```
byte cloud_mask_type;
:valid_range = 0B, 3B; // byte
:flag_values = 0B, 1B, 2B; // byte
:flag_meanings = "no_cloudmask_available manual_cloudmask automatic_cloudmask";
:long_name = "cloud mask type";
:_FillValue = -127B; // byte

byte scc_product_type;
:long_name = "SCC product type";
:_FillValue = -127B; // byte
:valid_range = 1B, 2B; // byte
:flag_values = 1B, 2B; // byte
:flag_meanings = "experimental operational";

// global attributes:
:Conventions = "CF-1.7";
:title = "Profiles of aerosol optical properties";
:source = "Ground based LIDAR measurements";
:references = "Project website at http://www.earlinet.org";
:history = "2024-11-23T01:02Z : Assigned version 1\r\n 2024-11-23T01:02:00Z : File uploaded on
Earlinet database\r\n 2024-11-22T22:07:50Z: elpp -d sccoperational -m 20241122pot202N -c
elpp.config; 2024-11-22T22:09:05Z: elda 20241122pot202N -c elda.ini";
:station_ID = "pot";
:location = "Potenza, Italy";
:system = "Fixed Lidar Raymetrics L1";
:institution = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per l'Analisi Ambientale
- CNR-IMAA";
:comment = ;
:measurement_ID = "20241122pot202N";
:measurement_start_datetime = "2024-11-22T20:28:13Z";
:measurement_stop_datetime = "2024-11-22T21:28:31Z";
:PI = "Aldo Amodeo";
:PI_affiliation = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per l'Analisi
Ambientale";
:PI_affiliation_acronym = "CNR-IMAA";
:PI_address = "Contrada S.Loja, Zona Industriale - Tito Scalo I-85050 Potenza";
:PI_phone = "+39 0971 427263";
:PI_email = "aldo.amodeo@cnr.it";
:Data_Originator = "aldo.amodeo";
:Data_Originator_affiliation = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per
l'Analisi Ambientale";
:Data_Originator_affiliation_acronym = "CNR-IMAA";
:Data_Originator_address = "Contrada S.Loja, Zona Industriale - Tito Scalo I-85050 Potenza";
:Data_Originator_phone = "+39 0971 427263";
:Data_Originator_email = "aldo.amodeo@cnr.it";
```



```
:data_processing_institution = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per
I\`Analisi Ambientale (CNR-IMAA)";
:hoi_system_ID = 181; // int
:hoi_configuration_ID = 891; // int
:scc_version = "5.2.9";
:scc_version_description = "SCC vers. 5.2.9 (HiRELPP vers. 1.1.5, CloudMask vers. 1.6.0, ELPP vers.
7.1.3, ELDA vers. 3.4.8.1, ELIC vers. 1.0.8, ELQUICK vers. 1.0.7, ELDEC vers. 2.1.4)";
:processor_name = "ELDA";
:processor_version = "3.4.8.1";
:__file_format_version = "2.1";
:input_file =
"pot_002_0002101_202411222028_202411222132_20241122pot202N_elpp_v5.2.9.nc";
:overlap_correction_file = ;
}
```



11. Appendix C

netcdf

EARLINET_AerRemSen_hpb_Lev01_ELDAmwl_202308170200_202308170400_v01_qc03.nc {

variables:

double latitude;

 :_FillValue = NaN; // double

 :standard_name = "latitude";

 :long_name = "measurement site latitude";

 :units = "degrees_north";

double longitude;

 :_FillValue = NaN; // double

 :standard_name = "longitude";

 :long_name = "measurement site longitude";

 :units = "degrees_east";

double station_altitude;

 :_FillValue = NaN; // double

 :units = "m";

 :long_name = "station altitude above sea level";

group: meta_data {

variables:

byte cloud_mask_type;

 :_FillValue = -127B; // byte

 :units = "1";

 :long_name = "cloud mask type";

 :valid_range = 0B, 2B; // byte

 :flag_values = 0B, 1B, 2B; // byte

 :flag_meanings = "no_cloudmask_available manual_cloudmask automatic_cloudmask";

byte scc_product_type;

 :_FillValue = -127B; // byte

 :units = "1";

 :long_name = "SCC product type";

 :valid_range = 1B, 2B; // byte

 :flag_values = 1B, 2B; // byte

 :flag_meanings = "experimental operational";

byte molecular_calculation_source;

 :_FillValue = -127B; // byte

 :units = "1";

 :long_name = "source used to compute the atmospheric molecular density";

 :flag_values = 0B, 1B, 2B, 3B, 4B, 5B, 6B, 7B, 8B; // byte



```
:flag_meanings = "US_standard_atmosphere radiosounding ecmwf icon_iglo_12_23
icon_iglo_24_35 icon_iglo_36_47 gdas era5-1-12 era5-7-18";
:valid_range = 0B, 8B; // byte

group: backscatter_1064 {
  dimensions:
    nv = 2;
    time = 2;
    level = 1734;
  variables:
    byte error_retrieval_method;
      :_FillValue = -127B; // byte
      :long_name = "method used for the retrieval of uncertainties";
      :flag_values = 0B, 1B; // byte
      :flag_meanings = "monte_carlo error_propagation";

    byte retrieval_method;
      :_FillValue = -127B; // byte
      :long_name = "method used for the backscatter retrieval";
      :flag_values = 0B, 1B; // byte
      :flag_meanings = "Raman elastic_backscatter";

    byte calibration_range_search_algorithm;
      :_FillValue = -127B; // byte
      :long_name = "algorithm used for the search of the calibration_range";
      :flag_values = 0B, 1B; // byte
      :flag_meanings = "minimum rayleigh-fit";

    long nv(nv=2);

    double calibration_search_range(nv=2);
      :long_name = "height range wherein calibration range is searched";
      :units = "m";
      :_FillValue = NaN; // double

    double calibration_value;
      :_FillValue = NaN; // double
      :long_name = "assumed backscatter-ratio value (unitless) in calibration range";
      :units = "1";

    byte evaluation_algorithm;
      :flag_values = 0B, 1B; // byte
      :_FillValue = -127B; // byte
      :long_name = "algorithm used for the retrieval of the elastic backscatter profile";
      :flag_meanings = "Klett iter";
```



```
long time(time=2);
:units = "hours since 2023-08-17 02:00:00";
:calendar = "proleptic_gregorian";

double calibration_range(time=2, nv=2);
:_FillValue = NaN; // double
:long_name = "height_axis range where calibration was calculated";
:units = "m";

long level(level=1734);

double altitude(time=2, level=1734);
:_FillValue = NaN; // double
:units = "m";
:standard_name = "altitude";
:long_name = "altitude above sea level";
:_ChunkSizes = 2U, 1734U; // uint

double assumed_particle_lidar_ratio(time=2, level=1734);
:_FillValue = NaN; // double
:units = "sr";
:long_name = "assumed particle lidar ratio for the elastic-only backscatter retrieval";
:coordinates = "altitude";

}

group: extinction_355 {
variables:
byte evaluation_algorithm;
:_FillValue = -127B; // byte
:long_name = "algorithm used for the extinction retrieval";
:flag_values = 0B, 1B; // byte
:flag_meanings = "weighted_linear_fit non-weighted_linear_fit";

double angstroem_exponent;
:units = "1";
:_FillValue = NaN; // double
:long_name = "assumed Angstroem exponent for the extinction retrieval";

byte error_retrieval_method;
:_FillValue = -127B; // byte
:long_name = "method used for the retrieval of uncertainties";
:flag_values = 0B, 1B; // byte
:flag_meanings = "monte_carlo error_propagation";
```



```
// group attributes:
:overlap_correction_file = " ";
}

group: backscatter_355 {
  dimensions:
    nv = 2;
    time = 2;
  variables:
    byte error_retrieval_method;
      :_FillValue = -127B; // byte
      :long_name = "method used for the retrieval of uncertainties";
      :flag_values = 0B, 1B; // byte
      :flag_meanings = "monte_carlo error_propagation";

    byte retrieval_method;
      :_FillValue = -127B; // byte
      :long_name = "method used for the backscatter retrieval";
      :flag_values = 0B, 1B; // byte
      :flag_meanings = "Raman elastic_backscatter";

    byte calibration_range_search_algorithm;
      :_FillValue = -127B; // byte
      :long_name = "algorithm used for the search of the calibration_range";
      :flag_values = 0B, 1B; // byte
      :flag_meanings = "minimum rayleigh-fit";

    long nv(nv=2);

    double calibration_search_range(nv=2);
      :_FillValue = NaN; // double
      :long_name = "height range wherein calibration range is searched";
      :units = "m";

    double calibration_value;
      :_FillValue = NaN; // double
      :long_name = "assumed backscatter-ratio value (unitless) in calibration range";
      :units = "1";

    byte evaluation_algorithm;
      :_FillValue = -127B; // byte
      :long_name = "algorithm used for the retrieval of the Raman backscatter profile";
      :flag_values = 0B, 1B; // byte
      :flag_meanings = "Ansmann_method via_backscatter_ratio";
```



```
double time(time=2);
:long_name = "time";
:calendar = "standard";
:_FillValue = NaN; // double
:axis = "T";
:bounds = "time_bounds";
:units = "seconds since 1970-01-01T00:00:00+00:00";
:_ChunkSizes = 2U; // uint

double calibration_range(time=2, nv=2);
:units = "m";
:_FillValue = NaN; // double
:long_name = "height_axis range where calibration was calculated";

}

group: extinction_532 {
variables:
byte evaluation_algorithm;
:_FillValue = -127B; // byte
:long_name = "algorithm used for the extinction retrieval";
:flag_values = 0B, 1B; // byte
:flag_meanings = "weighted_linear_fit non-weighted_linear_fit";

double angstroem_exponent;
:units = "1";
:_FillValue = NaN; // double
:long_name = "assumed Angstroem exponent for the extinction retrieval";

byte error_retrieval_method;
:_FillValue = -127B; // byte
:long_name = "method used for the retrieval of uncertainties";
:flag_values = 0B, 1B; // byte
:flag_meanings = "monte_carlo error_propagation";

// group attributes:
:overlap_correction_file = " ";
}

group: backscatter_532 {
dimensions:
nv = 2;
time = 2;
variables:
```



```
byte error_retrieval_method;
:_FillValue = -127B; // byte
:long_name = "method used for the retrieval of uncertainties";
:flag_values = 0B, 1B; // byte
:flag_meanings = "monte_carlo error_propagation";

byte retrieval_method;
:_FillValue = -127B; // byte
:long_name = "method used for the backscatter retrieval";
:flag_values = 0B, 1B; // byte
:flag_meanings = "Raman elastic_backscatter";

byte calibration_range_search_algorithm;
:_FillValue = -127B; // byte
:long_name = "algorithm used for the search of the calibration_range";
:flag_values = 0B, 1B; // byte
:flag_meanings = "minimum rayleigh-fit";

long nv(nv=2);

double calibration_search_range(nv=2);
:_FillValue = NaN; // double
:long_name = "height range wherein calibration range is searched";
:units = "m";

double calibration_value;
:_FillValue = NaN; // double
:long_name = "assumed backscatter-ratio value (unitless) in calibration range";
:units = "1";

byte evaluation_algorithm;
:_FillValue = -127B; // byte
:long_name = "algorithm used for the retrieval of the Raman backscatter profile";
:flag_values = 0B, 1B; // byte
:flag_meanings = "Ansmann_method via_backscatter_ratio";

double time(time=2);
:long_name = "time";
:calendar = "standard";
:_FillValue = NaN; // double
:axis = "T";
:bounds = "time_bounds";
:units = "seconds since 1970-01-01T00:00:00+00:00";
:_ChunkSizes = 2U; // uint
```



```
double calibration_range(time=2, nv=2);
  :_FillValue = NaN; // double
  :long_name = "height_axis range where calibration was calculated";
  :units = "m";
}

group: volumedepolarization_532 {
  variables:
    byte error_retrieval_method;
      :_FillValue = -127B; // byte
      :long_name = "method used for the retrieval of uncertainties";
      :flag_values = 0B, 1B; // byte
      :flag_meanings = "monte_carlo error_propagation";

    byte retrieval_method;
      :_FillValue = -127B; // byte
      :long_name = "method used for the retrieval of volume linear depolarization ratio";
      :flag_values = 0B; // byte
      :flag_meanings = "V_Freudenthaler_2022";
}

group: lidarratio_532 {
  variables:
    byte error_retrieval_method;
      :_FillValue = -127B; // byte
      :long_name = "method used for the retrieval of uncertainties";
      :flag_values = 0B, 1B; // byte
      :flag_meanings = "monte_carlo error_propagation";
}

// group attributes:
:hoi_system_ID = 49; // int
:hoi_configuration_ID = 193; // int
:molecular_calculation_source_file = "20230817_hohenpeissenberg_gdas1.nc";
}

group: lowres_products {
  dimensions:
    level = 1734;
    time = 2;
    wavelength = 3;
  variables:
```



```
long level(level=1734);

double altitude(time=2, level=1734);
:_FillValue = NaN; // double
:units = "m";
:standard_name = "altitude";
:long_name = "altitude above sea level";
:_ChunkSizes = 2U, 1734U; // uint

double time(time=2);
:long_name = "time";
:calendar = "standard";
:_FillValue = NaN; // double
:axis = "T";
:bounds = "time_bounds";
:units = "seconds since 1970-01-01T00:00:00+00:00";
:_ChunkSizes = 2U; // uint

long cloud_mask(time=2, level=1734);
:long_name = "cloud mask";
:flag_meanings = "unknown_cloud cirrus_cloud water_cloud";
:units = "1";
:coordinates = "altitude";
:valid_range = 0B, 7B; // byte
:flag_masks = 1B, 2B, 4B; // byte

double vertical_res(time=2, level=1734);
:_FillValue = NaN; // double
:long_name = "effective vertical resolution of the products";
:units = "m";
:coordinates = "altitude";

double wavelength(wavelength=3);
:_FillValue = NaN; // double
:long_name = "wavelength of the transmitted laser pulse";
:units = "nm";

double backscatter(wavelength=3, time=2, level=1734);
:_FillValue = NaN; // double
:long_name = "particle backscatter coefficient";
:units = "1/(m*sr)";
:ancillary_variables = "error_backscatter vertical_resolution";
:coordinates = "altitude";

double error_backscatter(wavelength=3, time=2, level=1734);
```



```
:_FillValue = NaN; // double
:long_name = "absolute statistical uncertainty of backscatter";
:units = "1/(m*sr)";
:coordinates = "altitude";
```

```
String backscatter_meta_data(wavelength=3);
:long_name = "path to meta data";
```

```
double extinction(wavelength=3, time=2, level=1734);
:_FillValue = NaN; // double
:long_name = "particle extinction coefficient";
:units = "1/m";
:ancillary_variables = "error_extinction vertical_resolution";
:coordinates = "altitude";
```

```
double error_extinction(wavelength=3, time=2, level=1734);
:_FillValue = NaN; // double
:long_name = "absolute statistical uncertainty of extinction";
:units = "1/m";
:coordinates = "altitude";
```

```
String extinction_meta_data(wavelength=3);
:long_name = "path to meta data";
```

```
double lidarratio(wavelength=3, time=2, level=1734);
:long_name = "particle lidar ratio";
:units = "sr";
:ancillary_variables = "error_lidarratio vertical_resolution";
:coordinates = "altitude";
:_FillValue = NaN; // double
```

```
double error_lidarratio(wavelength=3, time=2, level=1734);
:_FillValue = NaN; // double
:long_name = "absolute statistical uncertainty of lidarratio";
:units = "sr";
:coordinates = "altitude";
```

```
String lidarratio_meta_data(wavelength=3);
:long_name = "path to meta data";
```

```
double volumedepolarization(wavelength=3, time=2, level=1734);
:_FillValue = NaN; // double
:long_name = "volume linear depolarization ratio";
:units = "1";
:ancillary_variables = "error_volumedepolarization vertical_resolution";
```



```

:coordinates = "altitude";

double error_volumedepolarization(wavelength=3, time=2, level=1734);
:long_name = "absolute statistical uncertainty of volumedepolarization";
:coordinates = "altitude";
:_FillValue = NaN; // double
:units = "1";

String volumedepolarization_meta_data(wavelength=3);
:long_name = "path to meta data";

double positive_systematic_error_volumedepolarization(wavelength=3, time=2, level=1734);
:long_name = "positive absolute systematic uncertainty of volumedepolarization";
:coordinates = "altitude";
:_FillValue = NaN; // double
:units = "1";

double negative_systematic_error_volumedepolarization(wavelength=3, time=2, level=1734);
:_FillValue = NaN; // double
:long_name = "negative absolute systematic uncertainty of volumedepolarization";
:units = "1";
:coordinates = "altitude";

}

group: highres_products {
  dimensions:
    level = 1734;
    time = 2;
    wavelength = 3;
  variables:
    long level(level=1734);

    double altitude(time=2, level=1734);
    :_FillValue = NaN; // double
    :units = "m";
    :standard_name = "altitude";
    :long_name = "altitude above see level";
    :_ChunkSizes = 2U, 1734U; // uint

    double time(time=2);
    :long_name = "time";
    :calendar = "standard";
    :_FillValue = NaN; // double
    :axis = "T";

```



```
:bounds = "time_bounds";  
:units = "seconds since 1970-01-01T00:00:00+00:00";  
:_ChunkSizes = 2U; // uint
```

```
long cloud_mask(time=2, level=1734);  
:long_name = "cloud mask";  
:flag_meanings = "unknown_cloud cirrus_cloud water_cloud";  
:units = "1";  
:coordinates = "altitude";  
:valid_range = 0B, 7B; // byte  
:flag_masks = 1B, 2B, 4B; // byte
```

```
double vertical_res(time=2, level=1734);  
:_FillValue = NaN; // double  
:long_name = "effective vertical resolution of the products";  
:units = "m";  
:coordinates = "altitude";
```

```
double wavelength(wavelength=3);  
:_FillValue = NaN; // double  
:long_name = "wavelength of the transmitted laser pulse";  
:units = "nm";
```

```
double backscatter(wavelength=3, time=2, level=1734);  
:_FillValue = NaN; // double  
:long_name = "particle backscatter coefficient";  
:units = "1/(m*sr)";  
:ancillary_variables = "error_backscatter vertical_resolution";  
:coordinates = "altitude";
```

```
double error_backscatter(wavelength=3, time=2, level=1734);  
:_FillValue = NaN; // double  
:long_name = "absolute statistical uncertainty of backscatter";  
:units = "1/(m*sr)";  
:coordinates = "altitude";
```

```
String backscatter_meta_data(wavelength=3);  
:long_name = "path to meta data";
```

```
double volumedepolarization(wavelength=3, time=2, level=1734);  
:_FillValue = NaN; // double  
:long_name = "volume linear depolarization ratio";  
:units = "1";  
:ancillary_variables = "error_volumedepolarization vertical_resolution";  
:coordinates = "altitude";
```



```
double error_volumedepolarization(wavelength=3, time=2, level=1734);
:_FillValue = NaN; // double
:long_name = "absolute statistical uncertainty of volumedepolarization";
:units = "1";
:coordinates = "altitude";

String volumedepolarization_meta_data(wavelength=3);
:long_name = "path to meta data";

double positive_systematic_error_volumedepolarization(wavelength=3, time=2, level=1734);
:_FillValue = NaN; // double
:long_name = "positive absolute systematic uncertainty of volumedepolarization";
:units = "1";
:coordinates = "altitude";

double negative_systematic_error_volumedepolarization(wavelength=3, time=2, level=1734);
:_FillValue = NaN; // double
:long_name = "negative absolute systematic uncertainty of volumedepolarization";
:units = "1";
:coordinates = "altitude";

}

// global attributes:
:measurement_ID = "20230817hpb0200";
:comment = "";
:title = "Profiles of aerosol optical properties";
:source = "lidar surface observation";
:references = "Project website at https://www.earlinet.org";
:station_ID = "hpb";
:location = "Hohenpeissenberg, Germany";
:institution = "DWD Meteorological Observatory Hohenpeissenberg";
:PI_name = "Ina Mattis";
:PI_affiliation = "";
:PI_affiliation_acronym = "";
:PI_address = "";
:PI_phone = "+49 69 80629723";
:PI_email = "Ina.Mattis@dwd.de";
:Data_Originator_name = "Ina Mattis";
:Data_Originator_affiliation = "Deutscher Wetterdienst";
:Data_Originator_affiliation_acronym = "DWD";
:Data_Originator_address = "";
:Data_Originator_phone = "";
:Data_Originator_email = "ina.mattis@dwd.de";
```



```
:data_processing_institution = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per  
l'Analisi Ambientale (CNR-IMAA)";  
:system = "RALPH";  
:hoi_system_ID = 49; // int  
:hoi_configuration_ID = 193; // int  
:processor_name = "ELDAmwl";  
}
```



12. Appendix D

```
netcdf Layering_AerRemSen_pot_Lev01_LTOOL_1064_202406191255_202406191354_v01.nc {
  dimensions:
    layers = 3;
  variables:
    int residual_layer_flag(layers=3);
      :values = "0 for normal layers, 1 for the residual layer";
      :long_name = "Flag for the first layer.It is 1 when its true base is not identified. In this case, the
first range bin is used as the base instead and the layer is marked as a potential candidate for the
residual layer";
      :units = "";

    double base(layers=3);
      :long_name = "The layer base (ASL)";
      :units = "km";

    double center_of_mass(layers=3);
      :long_name = "The layer center of mass. It is the average altitude weighted by the product
values (ASL)";
      :units = "km";

    double top(layers=3);
      :long_name = "The layer top (ASL)";
      :units = "km";

    double peak(layers=3);
      :long_name = "The height of the product maximum within the layer (ASL)";
      :units = "km";

    double thickness(layers=3);
      :long_name = "The layer thickness (top - base)";
      :units = "km";

    double base_sig(layers=3);
      :long_name = "The product value at the base of the layer";
      :units = "m-1 sr-1";

    double top_sig(layers=3);
      :long_name = "The product value at the top of the layer";
      :units = "m-1 sr-1";

    double peak_sig(layers=3);
      :long_name = "The product value at the peak of the layer";
      :units = "m-1 sr-1";
```



```
double depth(layers=3);
:long_name = "Integrated product within the layer";
:units = "m-1 sr-1";

double sharpness(layers=3);
:units = "m-1 sr-1";
:long_name = "Minimum absolute difference between the product value at the peak and the
product value at the base or top";

double trend(layers=3);
:long_name = "Difference between the product value at the top and the product value at the
base";
:units = "m-1 sr-1";

double weight(layers=3);
:long_name = "Fraction of the integrated product within the layer to the whole columnar
integral";
:units = "";

double snr_factor;
:_FillValue = NaN; // double
:long_name = "Product to noise ratio limit applied to the WCT normalized by the noise vertically.
It is used to discern between noise and actual layers.";
:units = "";

double wct_peak_margin;
:_FillValue = NaN; // double
:long_name = "Absolute WCT ratio threshold. It represents the WCT values of a number of
subsequent features of the same kind (either solely bases or solely tops) divided by the maximum
absolute WCT value among them. Features with values less than this threshold are rejected. It is
used to identify most suitable feature among a number of subsequent candidates.";
:units = "";

double dilation;
:_FillValue = NaN; // double
:long_name = "The dilation value (window) used for the WCT calculations.";
:units = "km";

double wavelength;
:_FillValue = NaN; // double
:long_name = "The wavelength of the ELDA product used to obtain the geometrical properties";
:units = "nm";

// global attributes:
:measurement_ID = "20240619pot125N";
```



```

:system = "Fixed Lidar Raymetrics L1";
:institution = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per l'Analisi Ambientale
(CNR-IMAA), Potenza - CNR IMAA";
:location = "Potenza, Italy";
:station_ID = "pot";
:PI = "Aldo Amodeo";
:PI_affiliation = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per l'Analisi
Ambientale";
:PI_affiliation_acronym = "CNR-IMAA";
:PI_address = "Contrada S.Loja - Zona Industriale - Tito Scalo I-85050 Potenza, Italy";
:PI_phone = "+39 0971 427263";
:PI_email = "aldo.amodeo@imaa.cnr.it";
:Data_Originator = "pilar";
:Data_Originator_affiliation = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per
l'Analisi Ambientale";
:Data_Originator_affiliation_acronym = "CNR-IMAA";
:Data_Originator_address = "Contrada S.Loja, Zona Industriale - Tito Scalo I-85050 Potenza";
:Data_Originator_email = "pilar.guma@imaa.cnr.it";
:data_processing_institution = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per
l'Analisi Ambientale (CNR-IMAA)";
:comment = "";
:scc_version = "5.3.0";
:scc_version_description = "SCC vers. 5.3.0 (HiRELPP vers. 1.1.6, CloudMask vers. 1.6.0, ELPP vers.
7.1.4, ELDA vers. 3.4.13, ELIC vers. 1.0.9, ELQUICK vers. 1.0.8, LTOOL vers. 1.7.8, ELDEC vers. 2.1.5,
LTOOL vers. 1.7.8)";
:processor_name = "ltool";
:processor_version = "1.7.8";
:history = "2024-07-16T13:13:15Z: elpp -d sccdevelopment -m 20240619pot125N -c elpp.config;
2024-07-16T13:13:49Z: elda 20240619pot125N -c elda.ini; 2024-07-16T13:14:38Z: ltool -m
20240619pot125N -c ltool.ini";
:title = "Geometrical properties of aerosol layers";
:source = "Ground based LIDAR measurements";
:references = "Project website at http://www.earlinet.org";
:__file_format_version = "1.0";
:Conventions = "CF-1.7";
:hoi_system_ID = 68; // int
:hoi_configuration_ID = 204; // int
:input_file =
"pot_003_1064_0000692_202406191255_202406191354_20240619pot125N_elda_v5.3.0.nc";
:measurement_start_datetime = "2024-06-19T12:55:24Z";
:measurement_stop_datetime = "2024-06-19T13:54:48Z";
:layer_method = "Wavelet Correlation Transform";
}

```



13. Appendix E

```
netcdf Typing_AerRemSen_pot_Lev01_HIRAC_202404292205_202404292301_v01.nc {
dimensions:
  time = 55;
  altitude = 3078;
variables:
  double aerosol_classification(time=55, altitude=3078);
    :_FillValue = 9.969209968386869E36; // double
    :long_name = "Aerosol classification";
    :values = "0.5(Clean atmosphere), 1.5(Not-typed), 2.5(Aerosol:small), 3.5(Aerosol:large-
spherical), 4.5(Aerosol:mixture,partly-nonspherical), 5.5(Aerosol:large,nonspherical)";
    :units = "";

  double aerosol_backscatter_0532(time=55, altitude=3078);
    :_FillValue = 9.969209968386869E36; // double
    :long_name = "532 nm quasi particle backscatter coefficient";
    :units = "1/m 1/sr";

  double aerosol_backscatter_1064(time=55, altitude=3078);
    :_FillValue = 9.969209968386869E36; // double
    :long_name = "1064 nm quasi particle backscatter coefficient";
    :units = "1/m 1/sr";

  double aerosol_depolarization_0532(time=55, altitude=3078);
    :_FillValue = 9.969209968386869E36; // double
    :long_name = "532 nm quasi particle depolarization ratio";
    :units = "";

  double station_altitude;
    :long_name = "station altitude above sea level";
    :units = "m";

  double longitude;
    :long_name = "measurement site longitude";
    :units = "degrees_north";

  double latitude;
    :long_name = "measurement site latitude";
    :units = "degrees_east";

  double time(time=55);
```



```
:long_name = "time";
:units = "seconds since 1970-01-01T00:00:00Z";
:calendar = "standard";
:axis = "T";

double altitude(altitude=3078);
:_FillValue = 9.969209968386869E36; // double
:long_name = "altitude above sea level";
:units = "m";
:standard_name = "altitude";

// global attributes:
:Conventions = "CF-1.7";
:title = "High resolution aerosol classification - HiRAC";
:source = "lidar surface observation";
:references = "Baars et al.: Target categorization of aerosol and clouds by continuous
multiwavelength-polarization lidar measurements, Atmos. Meas. Tech., 10, 3175–3201,
https://doi.org/10.5194/amt-10-3175-2017, 2017";
:location = "Potenza, Italy";
:station_ID = "pot";
:PI = "Aldo Amodeo";
:PI_affiliation = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per l'Analisi
Ambientale ";
:PI_affiliation_acronym = "CNR-IMAA";
:PI_address = "Contrada S.Loja, Zona Industriale - Tito Scalo I-85050 Potenza";
:PI_phone = "+39 0971 427263";
:PI_email = "aldo.amodeo@imaa.cnr.it";
>Data_Originator = "Aldo Amodeo";
>Data_Originator_affiliation = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per
l'Analisi Ambientale";
>Data_Originator_affiliation_acronym = "CNR-IMAA";
>Data_Originator_address = "Contrada S.Loja, Zona Industriale - Tito Scalo I-85050 Potenza";
>Data_Originator_phone = "+39 0971 427263";
>Data_Originator_email = "aldo.amodeo@imaa.cnr.it";
:institution = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per l'Analisi Ambientale
(CNR-IMAA), Potenza - CNR-IMAA";
:system = "\'LOTTO_1\'";
:hoi_system_ID = 181; // int
:hoi_configuration_ID = 677; // int
:measurement_ID = "20240429pot220N";
:measurement_start_datetime = "2024-04-29T22:05:58Z";
:measurement_stop_datetime = "2024-04-29T23:01:22Z";
:comment = "";
:scc_version_description = "SCC vers. 5.2.8 (HiRELPP vers. 1.1.5, CloudMask vers. 1.6.0, ELPP vers.
7.1.3, ELDA vers. 3.4.8.1, ELIC vers. 1.0.7, ELQUICK vers. 1.0.7, ELDEC vers. 2.1.4, HIRAC vers. 1.0)";
```



```
:scc_version = "5.2.8";
:processor_name = "hirac";
:processor_version = "1.0";
:history = "2024-05-07T12:32:29Z: elic -d sccoperational -m 20240429pot220N -c elic.config; 2024-
11-18T14:33:27Z: hirac ";
:__file_format_version = "1.0";
:data_processing_institution = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per
l'Analisi Ambientale (CNR-IMAA)";
:input_file =
"pot_009_0002111_202404292205_202404292301_20240429pot220N_elic_v5.2.8.nc";
}
```



14. Appendix F

```
netcdf Typing_AerRemSen_pot_Lev01_MAC_202404300113_202404300158_v01.nc {
  dimensions:
    layers = 6;
  variables:
    int residual_layer_flag(layers=6);
      :values = "0 for normal layers, 1 for the residual layer";
      :long_name = "Flag for the first layer. It is 1 when its true base is not identified. In this case, the
first range bin is used as the base instead and the layer is marked as a potential candidate for the
residual layer";
      :units = "";

    double base(layers=6);
      :long_name = "The layer base (ASL)";
      :units = "km";

    double top(layers=6);
      :long_name = "The layer top (ASL)";
      :units = "km";

    double aerosol_classification(layers=6);
      :_FillValue = NaN; // double
      :values = "0 (Not classified), 1 (clean continental), 2 (smoke), 3 (dust), 4 (marine), 5 (polluted
dust), 6 (polluted continental), 7 (mixed dust)";
      :long_name = "The aerosol classification output for the different identified layers in the profile.";
      :units = "";

    double station_altitude;
      :_FillValue = NaN; // double
      :long_name = "station altitude above sea level";
      :units = "m";

    double longitude;
      :_FillValue = NaN; // double
      :long_name = "measurement site longitude";
      :units = "degrees_north";

    double latitude;
      :_FillValue = NaN; // double
      :long_name = "measurement site latitude";
      :units = "degrees_east";

    double angstrom_exponent(layers=6);
      :_FillValue = NaN; // double
```



```
:long_name = "Mean Angstrom exponent";  
:values = "Mean 532-nm/1064-nm b-related Angstrom exponent";  
:units = "";
```

```
double lidar_ratio(layers=6);  
:_FillValue = NaN; // double  
:long_name = "Mean lidar ratio";  
:values = "Mean 532-nm lidar ratio";  
:units = "sr";
```

```
double ratio_of_lidar_ratios(layers=6);  
:_FillValue = NaN; // double  
:long_name = "Mean lidar ratio color ratio";  
:values = "Mean ratio of 355-nm/532-nm lidar ratios";  
:units = "";
```

```
double depolarization(layers=6);  
:_FillValue = NaN; // double  
:long_name = "Mean depolarization ratio";  
:values = "Mean 532-nm particle linear depolarization ratio";  
:units = "";
```

```
// global attributes:  
:measurement_ID = "20240429pot011N";  
:system = "Fixed Lidar Raymetrics L1";  
:institution = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per l'Analisi Ambientale  
(CNR-IMAA), Potenza - CNR-IMAA";  
:location = "Potenza, Italy";  
:station_ID = "pot";  
:PI = "Aldo Amodeo";  
:PI_affiliation = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per l'Analisi  
Ambientale ";  
:PI_affiliation_acronym = "CNR-IMAA";  
:PI_address = "Contrada S.Loja, Zona Industriale - Tito Scalo I-85050 Potenza";  
:PI_phone = "+39 0971 427263";  
:PI_email = "aldo.amodeo@imaa.cnr.it";  
:Data_Originator = "aldo.amodeo";  
:Data_Originator_affiliation = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per  
l'Analisi Ambientale";  
:Data_Originator_affiliation_acronym = "CNR-IMAA";  
:Data_Originator_address = "Contrada S.Loja, Zona Industriale - Tito Scalo I-85050 Potenza";  
:Data_Originator_phone = "+39 0971 427263";  
:Data_Originator_email = "aldo.amodeo@imaa.cnr.it";  
:data_processing_institution = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per  
l'Analisi Ambientale (CNR-IMAA)";
```



```
:comment = "";
:scc_version = "5.2.8";
:scc_version_description = "SCC vers. 5.2.8 (HiRELPP vers. 1.1.5, CloudMask vers. 1.6.0, ELPP vers. 7.1.3, ELDA vers. 3.4.8.1, ELIC vers. 1.0.7, ELQUICK vers. 1.0.7, ELDEC vers. 2.1.4, MAC vers. 0.0)";
:processor_name = "mac";
:processor_version = "0.0";
:history = "2024-04-30T06:52:42Z: elpp -d sccoperational -m 20240429pot011N -c elpp.config; 2024-04-30T06:57:08Z: elda 20240429pot011N -c elda.ini; 2024-10-01T09:52:19Z: mac ";
:title = "Mahalanobis aerosol classification - MAC";
:source = "Ground based LIDAR measurements";
:references = "Papagiannopoulos et al.: An automatic observation-based aerosol typing method for EARLINET, Atmos. Chem. Phys., 18, 15879–15901, https://doi.org/10.5194/acp-18-15879-2018, 2018.";
:__file_format_version = "1.0";
:Conventions = "CF-1.7";
:hoi_system_ID = 181; // int
:hoi_configuration_ID = 677; // int
:input_file =
"pot_007_0355_0002093_202404300113_202404300158_20240429pot011N_elda_v5.2.8.nc";
:measurement_start_datetime = "2024-04-30T01:13:19Z";
:measurement_stop_datetime = "2024-04-30T01:58:38Z";
:layer_method = "Wavelet Correlation Transform";
:type_method = "Mahalanobis distance aerosol classification - MAC";
}
```



Copernicus Atmosphere Monitoring Service

ECMWF - Robert-Schuman-Platz 3, 53175 Bonn, Germany

Contact: <https://support.ecmwf.int/>

atmosphere.copernicus.eu

copernicus.eu

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