Generalized Aerosol Retrieval from Radiometer and Lidar Combined data / Generalized Retrieval of Aerosol and Surface Properties (GARRLiC/GRASP)

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Document Revision Record		
Issue Date	**Version**	**Description of Revision**
31-01-2019	1.00	Creation
06-03-2019	1.01	Include feedbacks from CNR-IMAA and Univ. Lille/CNRS-LOA. Mainly a more detailed separation between GARRLiC retrieved parameters and derived (calculated) aerosol properties.
17-07-2024	2.00	Add the management of different output levels
23-12-2024	2.01	Addition of the file level classification, filename description and station codes in the EARLINET database. Addition of the data access section.
05-02-2025	2.02	Clarification in output GARRLiC products levels as reported in the ACTRIS/EARLINET database, finalization authors list and addition of acknowledgment to GRASP.

Acronyms	
GARRLiC	Generalized Aerosol Retrieval from Radiometer and Lidar Combined data
GRASP	Generalized Retrieval of Aerosol and Surface Properties
AERONET	AErosol RObotic NETwork
ACTRIS	Aerosols, Clouds, and Trace Gases Research Infrastructure Network
EARLINET	European Aerosol Research Lidar Network
SCC	Single Calculus Chain
NetCDF	Network Common Data Form
CF Metadata Conventions	Climate and Forecast (CF) Metadata Conventions

Data Name Abbreviations	
AOD	Extinction Aerosol Optical Depth
EXT	Extinction coefficient
VC	Volume Concentration
VSD	Volume Size Distribution
LR	Lidar Ratio
SSA	Single Scattering Albedo
AC	Aerosol vertical concentration
BAC	aerosol BACk-scatter coefficient
ABS	aerosol ABSorbing coefficient
AAOD	Absorbing Aerosol Optical Depth
lid-wvl	Lidar wavelength [355, 532 and 1064 nm]

Data Type Abbreviations	
string	String of characters
float	Floating point, 32 bits
Int	Integer point, 32 bits

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1. Introduction

The synergistic approach of Generalized Aerosol Retrieval from Radiometer and Lidar Combined Data (GARRLiC) and General Retrieval of Aerosol and Surface Properties (GRASP) is a unified algorithm that combines primary data obtained from sun/sky photometer (spectral Extinction AOD and spectral radiance) and elastic attenuated backscatter LiDAR profiles at one or several wavelengths, typically at 355, 532 and 1064 nm.

The objective is to produce as much as possible aerosol optical and micro-physical properties. The results of this joint retrieval depend on the number of available QC LiDAR elastic channels.
In the nominal multi-wavelength LiDAR configuration ("BI-MOD inversion"), the **retrieved** aerosol properties are:

- the aerosol volume size distribution (column, fine and coarse modes),
- the complex refractive index (column, fine and coarse modes),
- the fraction of spherical particles (column)
- the height-resolved aerosol concentration for both fine and coarse modes.

Based on these retrievals, GARRLiC forward model is used to ***derive*** several column and height-resolved properties from these retrieved parameters:
The following variables are ***derived****:*

- height-resolved aerosol properties:
  - Extinction, Absorption, Scattering, Single Scattering Albedo profiles (at all LiDAR wavelengths)
  - Backscatter, LiDAR ratio, Linear Depolarization (at all LiDAR wavelengths)
  - Extinction Angström Exponent, Backscatter Angström Exponent (combination from LiDAR wavelengths).
- columnar properties:
  - Extinction AOD, Scattering AOD, Absorption AOD, Single Scattering Albedo (total, fine and coarse modes)
  - LiDAR ratio, Linear Depolarization (total, fine and coarse modes)
  - Angström Exponent (total, fine and coarse modes).

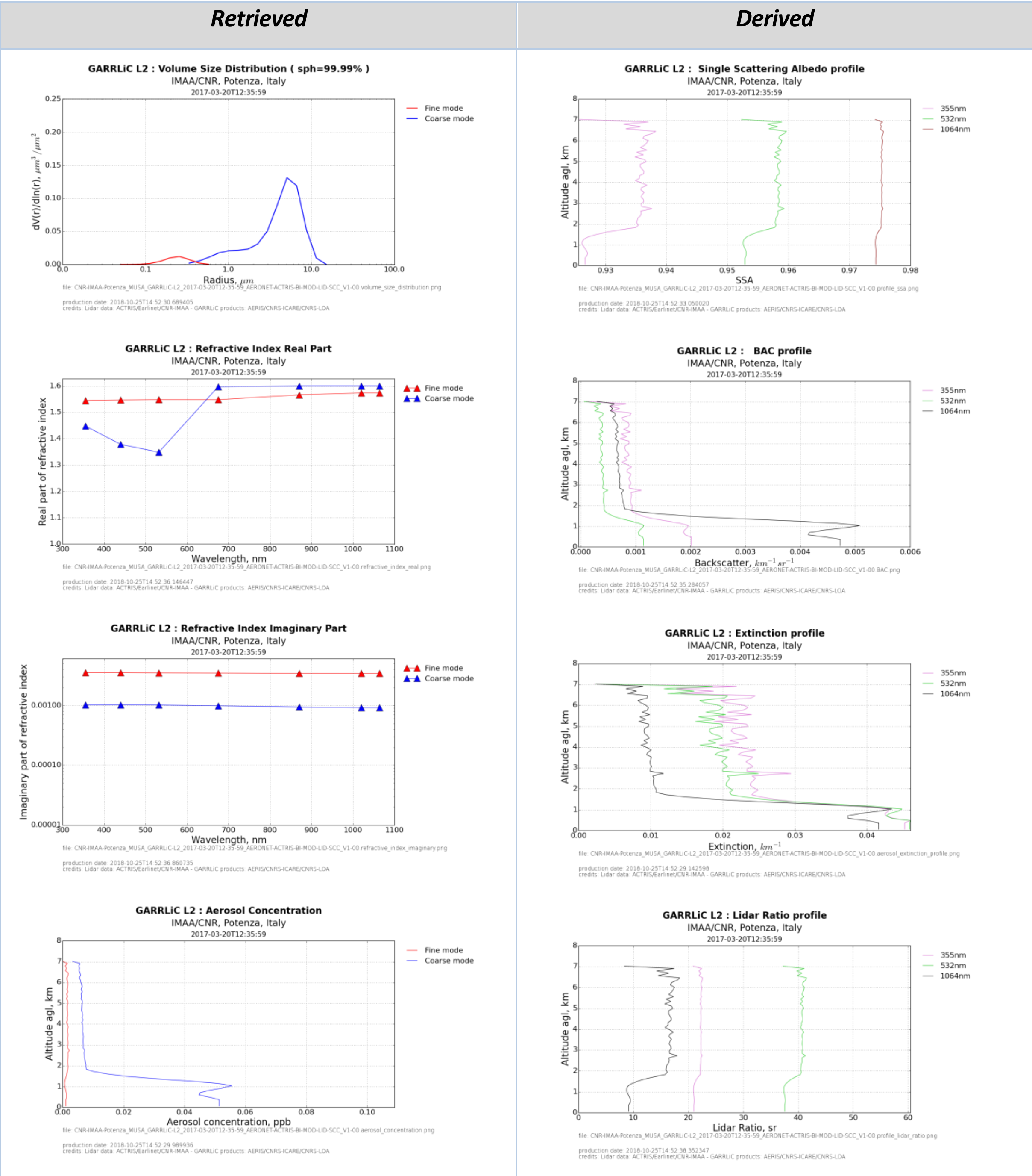


Figure 1: example of variables retrieved and derived aerosol properties with GARRLiC. These examples are only for illustration (not for publication).

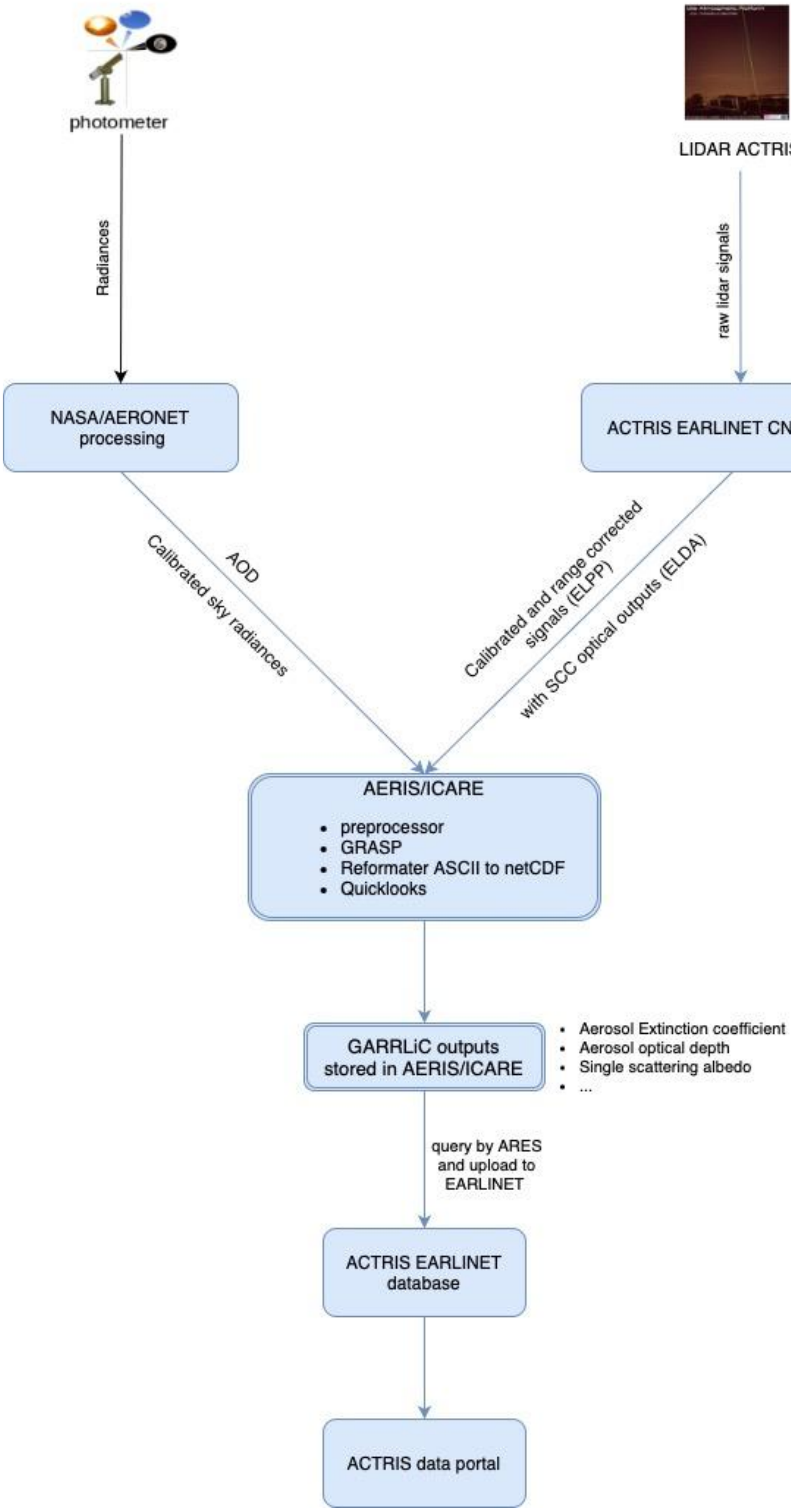
Since many LiDARs are operated at a single wavelength, a second Inversion mode (MONO-MOD) can be applied. In that configuration, *retrieved columnar properties* are the same but the *height-resolved retrieved aerosol concentration* is only for the entire size distribution (no distinction between fine/coarse). Hence, the *derived properties* are much less, those from the photometer plus extinction, backscatter, absorption profiles and column integrated LiDAR ratio.

Currently, it relies on AErosol RObotic NETwork (AERONET) aerosol products at a global scale, and on AERONET/ACTRIS for Europe for CIMEL sun/sky photometer, under the supervision of AERONET-Europe Expertise Center. ACTRIS/EARLINET LiDAR data are distributed by CNR-SCC (Single Calculus Chain), which is the standard ACTRIS/EARLINET tool to perform automatic and quality checked processing of raw lidar data. Hence, if you are focusing on extinction, backscatter and LiDAR ratio profiles, the recommended product is the ACTRIS/EARLINET one, where these parameters are retrieved, whereas they are derived in GARRLiC.

The quality of GARRLIC retrievals and derived products is first of all based on the QC at EARLINET and AERONET levels. Different levels of GARRLiC products are generated depending on the level of the AERONET products used as inputs.

2. GARRLiC/GRASP data flow and implementation

2.1. Data flow



2.2. Implementation

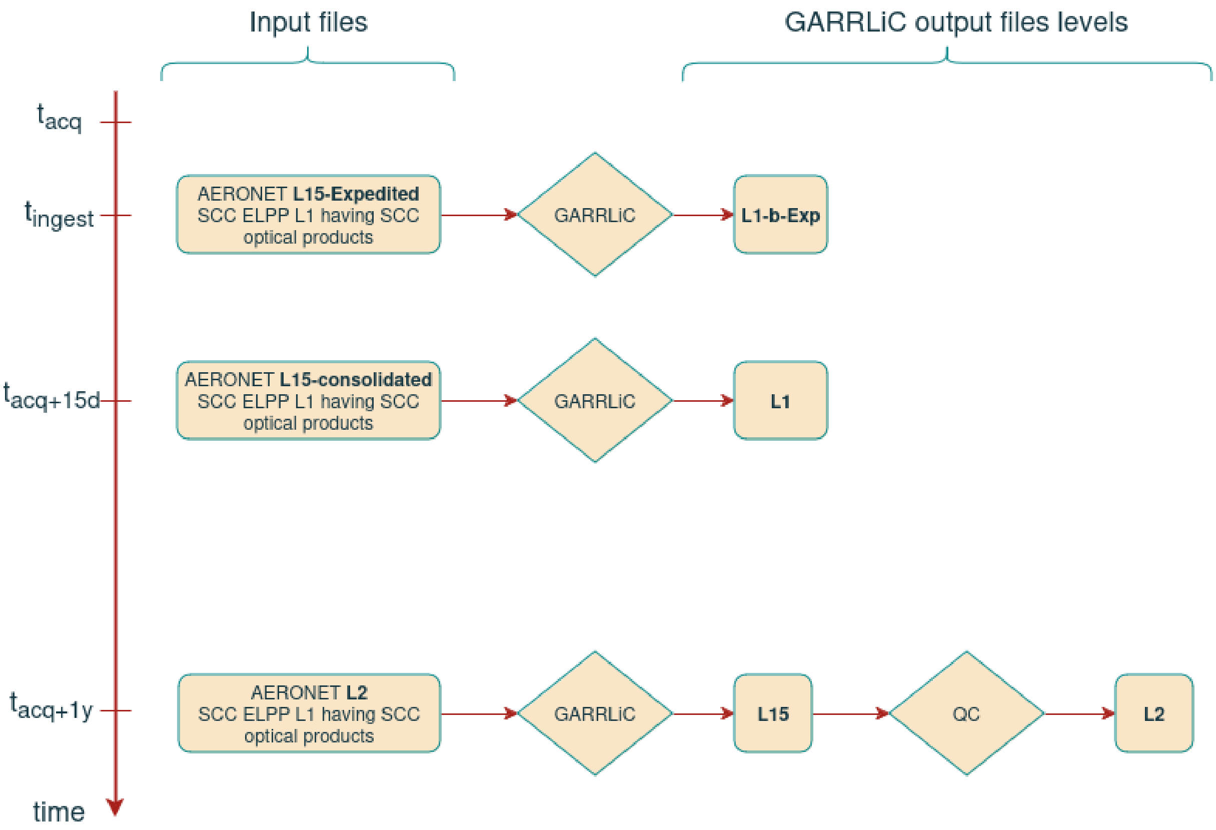
For each ACTRIS/EARLINET lidar profile, coincident AERONET AOD and Almucantar measurements are searched within ± 1 hour from the lidar measurement. If multiple AERONET measurements are found matching the temporal colocation criterion, the closest to the lidar measurement is used. If no coincident AOD or Almucantar measurement is found, the lidar profile is not processed.

GARRLiC works with mono and multi-wavelength LiDAR data. The algorithm uses spectral information of multiwavelength LiDAR to separate contributions of fine and coarse aerosol modes. Therefore, two inversion modes can be implemented for multi-wavelength LiDARs: one considering fine and coarse modes (bi-mod processing) and the second considering only one mode (mono-mod processing). For mono-wavelength LiDARs, only mono-mod processing can be implemented.

The input files used for the generation of the GARRLiC products can be found within them. The multi-wavelength LiDAR data used as input is the ELPP (EARLINET Lidar Pre-Processor) data produced by the Single Calculus Chain (SCC) and stored in the EARLINET database. The version in the ELPP filenames from the EARLINET database corresponds to the single file version. For example, the first time an ELPP product is uploaded, it will be stored as v01; if afterwards a newer ELPP product is uploaded for the same measurement, it will become v02. If a third version is uploaded, it will be v03, and so on. This ensures full traceability of the files if new versions are uploaded, as the previous version is always kept.

The implementation of the different output levels is managed based on the production date:

GARRLIC outputs level	Description
L1-exp	Outputs generated as soon as both lidar and photometric measurements are available, i.e. one or two days after the lidar measurement
L1	Outputs generated 15 days after the acquisition
L1.5	Outputs generated using AERONET L2 data and lidar data corresponding to lidar L1 optical products
L2	Outputs generated using AERONET L2 data and lidar data corresponding to lidar L2 optical products



After the production of the GARRLiC products by CNRS-AERIS/ICARE, they are updated into the ACTRIS/EARLINET database by the CNR-IMAA team. During the upload process, the file level is determined as follows:

GARRLiC product level	EARLINET database file level	Level assignation description during the upload process into the EARLINET database
L1-expedited	Lev01b	For consistency with the ACTRIS vocabulary, the L1-expedited files from CNR-AERIS/ICARE are categorized as Lev01b
L1	Lev001	The file remains level 1
L2	Lev001 / Lev1.5 / Lev002	All the input files used to generate GARRLiC products with AERONET level 2 data are checked during the upload into the EARLINET database. According to this, the original GARRLiC L2 products become: • Lev001: when not all the EARLINET ELPP products used as input do not correspond to level 2 optical products • Lev1.5: when all the ELPP products used correspond to level 2 optical products • Lev002: when all the ELPP products used correspond to level 2 optical products and the Quality Control checks on GARRLiC products are passed. These Quality Controls are still to be defined and implemented, so there are currently no level 2 files present in the ACTRIS/EARLINET database (as of February 2025)

3. Data description

3.1. File format

The GRASP/GARRLiC files are in netCDF4 format:

https://www.unidata.ucar.edu/software/netcdf/

and the metadata follow the CF-Convention-1.6:

http://cfconventions.org/

One product file contains one lidar profile.

3.2. Typical sizes

MODE	File size (KB)
MONO-MOD	7 → 18
BI-MOD	15 → 18

3.3. Naming convention

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

GARRLiC_AerRemSen_ccc_Levzzz_AERONET-NASA-bb-MOD-LID-SCC_ 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 8. The following list describes, in order, each field that composes the filename.

	Field	Length	Description
1st	*GARRLiC*	7	This field always reports the string "GARRLiC"
2nd	*AerRemSen*	9	This field means "Aerosol Remote Sensing"
3rd	*ccc*	3	This field reports a three digit code representingunivocally an EARLINET station
4th	*Levzzz*	6	This field specifies the level of the product. Thelevels are assigned to the product on the base of the input files used and the quality control procedures.
5th	*AERONET-NASA-bb-MOD-LID-SCC*	12/	This field identifies the source of the AERONET data used (AERONET-NASA), the GARRLiC mode (MONO- or BI-MOD), and

			the lidar data source (LID-SCC)
6th	*YYYYMMDDHHMM*	12	This is a date-time field and it provides the startdate and time of the measurements contained in the product file. The time is UTC.
7th	*yyyymmddhhmm*	12	This is a date-time field and it provides the stop dateand time of the measurements contained in the product file. The time is UTC.
8th	*vxx*	3	This field specifies the version of the product. Thefirst character ’v’ is always present. The next 2 characters are always numeric. (e.g. v01 identifiesversion 1 of the file, v02 version 2 and so on).

Example:

GARRLiC_AerRemSen_pot_Lev01b_AERONET-NASA-BI-MOD-LID-SCC_202410150835_202410150935_v01.nc

Where:

- Station code: pot
- File level: Lev01b
- AERONET data source: AERONET-NASA
- GARRLiC mode: BI-MOD
- LIDAR data source: LID-SCC
- Lidar measurement start datetime: 202410150835
- Lidar measurement stop datetime: 202410150935
- File version: v01

3.4. File content

3.4.1. File attributes

Global attribute	Datatype	Dimensions	Content
conventions	string	1	The CF (Climate and Forecast) conventions, here **CF-1.6**
institution	string	1	Institute of the data provider
source	string	1	Description of input data
comment	string	1	Co-registration tolerance of LIDAR around AOD/ALM: 60 min
lidar_instrument_model	string	1	The name of the LIDAR model
location	string	1	The location of the observational platform
latitude	string	1	The latitude and unit of the observational platform, in deg N

Global attribute	Datatype	Dimensions	Content
longitude	string	1	The longitude and unit of the observational platform, in deg E
altitude	string	1	The altitude and unit of the observational platform, in m
contact	string	1	The email of the principal investigator of the lidar
references	string	1	References to existing documents, if any, ATBD otherwise
product_description	string	1	Aerosol retrievals derived using the GARRLiC algorithm
production_center	string	1	AERIS/ICARE Data and Services Center
production_date_time_format	string	1	YYYY-MM-DDThh:mm:ssZ
acquisition_date_time_format	string	1	YYYY-MM-DDThh:mm:ssZ
aeronet_source_description	string	1	AERONET-NASA or AERONET-ACTRIS
garrlic_retrieval_mode_description	string	1	MONO-MOD[Total]/ BI-MOD [Total+coarse+fine]
title	string	1	Full product description
product_name	string	1	GARRLiC-L1b|L1|L2
documentation	string	1	https://actris.nilu.no/Documentation/Products/GARRLiC
Distribution center	String	1	ACTRIS data portal
production_date	string	1	The date of production
product_version	string	1	The product version
History	string	1	History of the software version
Software_version	String	1	Software version
input_files	string	1	The file name of the input Lidar and AERONET data
Input_product_version	string	1	SCC and AERONET version
Lidar_measurement_id	String	1	SCC id of the lidar files
Lidar_beginning_acquisition_date	string	1	The beginning acquisition date and time of coincident observations
Lidar_end_acquisition_date	string	1	The end acquisition date and time of the end of coincident observations
time_lidar_unit	String	1	Unit of the time lidar (decimal hours)
time_lidar	string	1	The list of times of the Lidar input profiles
Lidar_wavelengths	String	1	The list of the lidar wavelengths
Photometer_serial_number	String	1	The serial number of the photometer
Photometer_last_date_processed_unit	String	1	YYYY-MM-DD
Photometer_last_date_processed	String	1	The date of the last aeronet process
AERONET_wavelengths	string	1	The list of the aeronet wavelenghts

3.4.2. Dimensions

Dimensions specific to MONO-MOD products in yellow

Dimensions specific to BI-MOD products in blue

Datasets common to both in white

Name	Length
time	1

altitude	61
Aeronet_wavelength	6
LIDAR wavelength	2-4
Radius_fine	10
Radius_coarse	15
Radius	22

3.4.3. Datasets

Datasets specific to MONO-MOD products in yellow
Datasets specific to BI-MOD products in blue
Datasets common to both in white

Dataset	Data Type	Dimensions	Units	_FillValue	long_name
Time	Float32	[time]	Hours since the date_time _acquisition	-99999.0	Time of the retrievals, in decimal hours
altitude	Float32	[range]	m	-99999.0	Altitude of the vertical bin, in meters
Aeronet_wavelength	Float32	[wavelength]	um	-99999.0	Photometer wavelengths
Lidar_wavelength	Float32	[wavelength]	um	-99999.0	lidar wavelengths
radius	Float32	[radius]	um	-99999.0	The effective radius of particle size distribution,
radius_fine	Float32	[radius_fine]	um	-99999.0	The effective radius of particle size distribution, fine mode
radius_coarse	Float32	[radius_coarse]	um	-99999.0	The effective radius of particle size distribution, coarse mode
VC_total	Float32	[time]	um3/um2	-99999.0	Aerosol volume concentration
VC_fine	Float32	[time]	um3/um2	-99999.0	Aerosol volume concentration, fine mode
VC_coarse	Float32	[time]	um3/um2	-99999.0	Aerosol volume concentration, coarse mode
angstrom_exponent	Float32	[time]	1	-99999.0	440nm/870nm Angstrom exponent
sphericity	Float32	[time]	%	-99999.0	Spherical particle fraction
abs_[*lid_wvl*]	Float32	[range, time]	1	-99999.0	Absorbing aerosol coefficient vertical profile at 355 or 532 or 1064 nm
aaod_total	Float32	[wavelength, time]	1	-99999.0	Absorbing aerosol optical thickness
aaod_fine	Float32	[wavelength, time]	1	-99999.0	Absorbing aerosol optical depth, fine mode
aaod_coarse	Float32	[wavelength, time]	1	-99999.0	Absorbing aerosol optical depth, coarse mode
AC_total	Float32	[range, time]	ppm	-99999.0	Aerosol concentration vertical profile
AC_fine	Float32	[range, time]	ppm	-99999.0	Aerosol concentration vertical profile, fine mode

Dataset	Data Type	Dimensions	Units	_FillValue	long_name
AC_coarse	Float32	[range, time]	ppm	-99999.0	Aerosol concentration vertical profile, coarse mode
bac_[*lid_wvl*]	Float32	[range, time]	km-1	-99999.0	Backscatter aerosol coefficient vertical profile at 355 or 532 or 1064 nm
LR_total	Float32	[wavelength, time]	sr	-99999.0	Spectral Lidar extinction to backscatter ratio
LR_fine	Float32	[wavelength, time]	sr	-99999.0	Spectral Lidar extinction to backscatter ratio, fine mode
LR_coarse	Float32	[wavelength, time]	sr	-99999.0	Spectral Lidar extinction to backscatter ratio, coarse mode
LR_[*lid_wvl*]	Float32	[range, time]	sr	-99999.0	Lidar ratio vertical profile, at 355 or 532 or 1064 nm
aod_total	Float32	[wavelength, time]	1	-99999.0	Spectral aerosol optical depth
aod_fine	Float32	[wavelength, time]	1	-99999.0	Spectral aerosol optical depth, fine mode
aod_coarse	Float32	[wavelength, time]	1	-99999.0	Spectral aerosol optical depth, coarse mode
refractive_index_imaginary_total	Float32	[wavelength, time]	1	-99999.0	Imaginary part of refractive index
refractive_index_imaginary_fine	Float32	[wavelength, time]	1	-99999.0	Imaginary part of refractive index, fine mode
refractive_index_imaginary_coarse	Float32	[wavelength, time]	1	-99999.0	Imaginary part of refractive index, coarse mode
refractive_index_real_total	Float32	[wavelength, time]	1	-99999.0	Real part of refractive index
refractive_index_real_fine	Float32	[wavelength, time]	1	-99999.0	Real part of refractive index, fine mode
refractive_index_real_coarse	Float32	[wavelength, time]	1	-99999.0	Real part of refractive index, coarse mode
ssa_total	Float32	[aeronet_wavelength, time]	1	-99999.0	Total spectral single scattering albedo
ssa	Float32	[range, time, lidar_wavelength]	1	-99999.0	Single scattering albedo vertical profile
ssa_fine	Float32	[aeronet_wavelength, time]	1	-99999.0	Spectral columnar single scattering albedo, fine mode
ssa_coarse	Float32	[aeronet_wavelength, time]	1	-99999.0	Spectral columnar single scattering albedo, coarse mode
volume_size_distribution_total	Float32	[radius, time]	um3/um2	-99999.0	Particle volume size distribution dV(r)/dln(r)
volume_size_distribution_fine	Float32	[radius_fine, time]	um3/um2	-99999.0	Particle volume size distribution dV(r)/dln(r), fine mode
volume_size_distribution_coarse	Float32	[radius_coarse, time]	um3/um2	-99999.0	Particle volume size distribution dV(r)/dln(r), coarse mode

Dataset	Data Type	Dimensions	Units	_FillValue	long_name
Ext	Float32	[time, altitude, lidar_wavelength]	km-1	-99999.0	Aerosol extinction vertical profile

3.4.4. *Example*

CNR-IMAA-Potenza_MUSA_GARRLiC-L1_2024-09-28T09-09-32_AERONET-NASA-BI-MOD-LID-SCC_V2-11.nc

3.4.4.1. *File attributes*

:conventions = "CF-1.6" ;
:institution = "Consiglio Nazionale delle Ricerche - Istituto di Metodologie per l\'Analisi Ambientale (CNR-IMAA), Potenza" ;
:source = "Lidar : ground-based observation with the MUSA Lidar/AERONET : AERONET-NASA data " ;
:comment = "Co-registration tolerance of lidar between AOD/ALM: 60 min" ;
:lidar_instrument_model = "MUSA" ;
:location = "Potenza, Italy" ;
latitude = "40.6 deg N" ;
:longitude = "15.72 deg E" ;:altitude = "760 m" ;
:contact = "aldo.amodeo@imaa.cnr.it" ;
:references = "ATBD" ;
product_description = "GARRLiC algorithm Aerosol retrievals" ;
:production_center = "AERIS/ICARE Data and Services Center" ;
production_date_time_format = "YYYY-MM-DDThh:mm:ssZ" ;
acquisition_date_time_format = "YYYY-MM-DDThh:mm:ssZ" ;
:aeronet_source_description = "AERONET-NASA or AERONET-ACTRIS/AERONET : AERONET-NASA data " ;
:garrlic_retrieval_mode_description = "MONO-MOD[Total] or BI-MOD [Total+coarse+fine]" ;
:title = "GARRLiC-L1: AERONET-NASA-BI-MOD-LID-SCC " ;
:product_name = "GARRLiC-L1" ;
:documentation = "https://actris.nilu.no/Documentation/Products/GARRLiC" ;
:distribution_center = "ACTRIS Data portal" ;
:production_date = "2024-10-24T07:48:18Z" ;
:product_version = "V2-11" ;
:history = "Software Version, GARRLiC v2-11 / Software Version, GRASP v0.8.1 / Software Version, Preprocessor v0.5.6 " ;
:software_version = "grasp : v0.8.1 / preprocessor : v0.5.6 / GARRLiC : v2-11" ;
:input_files = "LIDAR :
EARLINET_AerRemSen_pot_ELPP_003_0355_202409280909_202409281004_v01_qc03.nc ,
EARLINET_AerRemSen_pot_ELPP_003_0355_202409281004_202409281100_v01_qc03.nc ,
EARLINET_AerRemSen_pot_ELPP_003_0355_202409281100_202409281155_v01_qc03.nc ,
EARLINET_AerRemSen_pot_ELPP_003_0355_202409281155_202409281250_v01_qc03.nc ,
EARLINET_AerRemSen_pot_ELPP_003_0532_202409280909_202409281004_v01_qc03.nc ,
EARLINET_AerRemSen_pot_ELPP_003_0532_202409281004_202409281100_v01_qc03.nc ,
EARLINET_AerRemSen_pot_ELPP_003_0532_202409281100_202409281155_v01_qc03.nc ,
EARLINET_AerRemSen_pot_ELPP_003_0532_202409281155_202409281250_v01_qc03.nc ,
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EARLINET_AerRemSen_pot_ELPP_008_0355_202409281004_202409281100_v01_qc03.nc ,
EARLINET_AerRemSen_pot_ELPP_008_0355_202409281100_202409281155_v01_qc03.nc ,

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EARLINET_AerRemSen_pot_ELPP_008_0355_202409281155_202409281250_v01_qc03.nc ,
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EARLINET_AerRemSen_pot_ELPP_008_0532_202409281100_202409281155_v01_qc03.nc ,
EARLINET_AerRemSen_pot_ELPP_008_0532_202409281155_202409281250_v01_qc03.nc , \n",
        "       AOD :  AERONET_AOD-L15_2024-09-28_IMAA_Potenza_V3-00.txt\n",
        "       ALM :  AERONET_ALM_2024-09-28_IMAA_Potenza_V3-00.txt" ;
:input_product_versions = "SCC version: 01 / AOD version: 3-00 / ALM version: 3-00" ;
:lidar_measurement_id = "20240928pot091N" ;
:lidar_beginning_acquisition_date = "2024-09-28T09:09:32Z" ;
:lidar_end_acquisition_date = "2024-09-28T10:09:32Z" ;
:time_lidar_unit = "decimal hours" ;
:time_lidar = "9.16" ;
:LIDAR_wavelengths = "355.0 [nm] , 532.0[nm]" ;
:photometer_serial_number = 19 ;
:photometer_last_date_processed = "2024-10-01" ;
:photometer_last_date_processed_unit = "YYYY-MM-DD" ;
:AERONET_wavelengths = "355.0 [nm] , 440.0 [nm] , 532.0 [nm] , 675.0 [nm] , 870.0 [nm] , 1020.0[nm]"
;
```

3.4.4.2. File datasets

```
float time(time) ;
        time:long_name = "Time of the retrievals, in decimal hours" ;
        time:units = "hours since 2024-09-28T09:09:32" ;
        time:valid_range = 0.f, 24.f ;
float altitude(altitude) ;
        altitude:long_name = "Altitude of the vertical bin, in meters" ;
        altitude:units = "m" ;
        altitude:valid_range = 60.f, 7100.f ;
float aeronet_wavelength(aeronet_wavelength) ;
        aeronet_wavelength:long_name = "AERONET wavelength" ;
        aeronet_wavelength:units = "um" ;
        aeronet_wavelength:valid_range = 0.355f, 1.064f ;
float lidar_wavelength(lidar_wavelength) ;
        lidar_wavelength:long_name = "LIDar wavelength , [0.355um, 0.532um, 1.064um]" ;
        lidar_wavelength:units = "um" ;
        lidar_wavelength:valid_range = 0.355f, 1.064f ;
float radius_fine(radius_fine) ;
        radius_fine:long_name = "The effective radius of particle size distribution, fine mode" ;
        radius_fine:units = "um" ;
        radius_fine:valid_range = 0.f, 1.f ;
float radius_coarse(radius_coarse) ;
        radius_coarse:long_name = "The effective radius of particle size distribution, coarse mode" ;
        radius_coarse:units = "um" ;
        radius_coarse:valid_range = 0.f, 15.f ;
float VC_fine(time) ;
        VC_fine:long_name = "Aerosol volume concentration, fine mode" ;
        VC_fine:units = "um3/um2" ;
        VC_fine:valid_range = 0.f, 0.3f ;
float VC_coarse(time) ;
        VC_coarse:long_name = "Aerosol volume concentration, coarse mode" ;
        VC_coarse:units = "um3/um2" ;
        VC_coarse:valid_range = 0.f, 3.f ;
float angstrom_exponent(time) ;
```

```
		angstrom_exponent:long_name = "440nm/870nm Angstom exponent" ;
		angstrom_exponent:units = "1" ;
		angstrom_exponent:valid_range = -1.f, 2.5f ;
	float sphericity(time) ;
		sphericity:long_name = "Spherical particle fraction" ;
		sphericity:units = "%" ;
		sphericity:valid_range = 0.f, 100.f ;
	float abs(time, altitude, lidar_wavelength) ;
		abs:long_name = "Absorbing aerosol coefficient vertical profile" ;
		abs:units = "1" ;
		abs:valid_range = 0.f, 0.2f ;
	float aaod_total(time, aeronet_wavelength) ;
		aaod_total:long_name = "Total absorbing aerosol optical depth" ;
		aaod_total:units = "1" ;
		aaod_total:valid_range = 0.f, 0.4f ;
	float aaod_fine(time, aeronet_wavelength) ;
		aaod_fine:long_name = "Absorbing aerosol optical depth, fine mode" ;
		aaod_fine:units = "1" ;
		aaod_fine:valid_range = 0.f, 0.1f ;
	float aaod_coarse(time, aeronet_wavelength) ;
		aaod_coarse:long_name = "Absorbing aerosol optical depth, coarse mode" ;
		aaod_coarse:units = "1" ;
		aaod_coarse:valid_range = 0.f, 0.4f ;
	float AC_fine(time, altitude) ;
		AC_fine:long_name = "Aerosol concentration vertical profile, fine mode, in ppm" ;
		AC_fine:units = "1" ;
		AC_fine:valid_range = 0.f, 0.7f ;
	float AC_coarse(time, altitude) ;
		AC_coarse:long_name = "Aerosol concentration vertical profile, coarse mode, in ppm" ;
		AC_coarse:units = "1" ;
		AC_coarse:valid_range = 0.f, 1.5f ;
	float Ext(time, altitude, lidar_wavelength) ;
		Ext:long_name = "Aerosol extinction vertical profile" ;
		Ext:units = "km-1" ;
		Ext:valid_range = 0.f, 4.f ;
	float bac(time, altitude, lidar_wavelength) ;
		bac:long_name = "Backscatter aerosol coefficient vertical profile" ;
		bac:units = "1" ;
		bac:valid_range = 0.f, 0.2f ;
	float LR(time, altitude, lidar_wavelength) ;
		LR:long_name = "Lidar Ratio vertical profile" ;
		LR:units = "1" ;
		LR:valid_range = 4.f, 990.f ;
	float LR_total(time, aeronet_wavelength) ;
		LR_total:long_name = "Total spectral columnar Lidar extinction to backscatter ratio" ;
		LR_total:units = "sr" ;
		LR_total:valid_range = 6.f, 660.f ;
	float LR_fine(time, aeronet_wavelength) ;
		LR_fine:long_name = "Spectral Lidar extinction to backscatter ratio, fine mode" ;
		LR_fine:units = "sr" ;
		LR_fine:valid_range = 7.f, 560.f ;
	float LR_coarse(time, aeronet_wavelength) ;
		LR_coarse:long_name = "Spectral Lidar extinction to backscatter ratio, coarse mode" ;
		LR_coarse:units = "sr" ;
		LR_coarse:valid_range = 4.f, 1230.f ;
	float aod_total(time, aeronet_wavelength) ;
```

```
        aod_total:long_name = "Total spectral  aerosol optical depth" ;
        aod_total:units = "1" ;
        aod_total:valid_range = 0.f, 3.f ;
    float aod_fine(time, aeronet_wavelength) ;
        aod_fine:long_name = "Spectral  aerosol optical depth, fine mode" ;
        aod_fine:units = "1" ;
        aod_fine:valid_range = 0.f, 1.5f ;
    float aod_coarse(time, aeronet_wavelength) ;
        aod_coarse:long_name = "Spectral  aerosol optical depth, coarse mode" ;
        aod_coarse:units = "1" ;
        aod_coarse:valid_range = 0.f, 2.f ;
    float refractive_index_imaginary_fine(time, aeronet_wavelength) ;
        refractive_index_imaginary_fine:long_name = "Imaginary part of refractive index, fine mode" ;
        refractive_index_imaginary_fine:units = "1" ;
        refractive_index_imaginary_fine:valid_range = 0.f, 0.1f ;
    float refractive_index_imaginary_coarse(time, aeronet_wavelength) ;
        refractive_index_imaginary_coarse:long_name = "Imaginary part of refractive index, coarse
        mode" ;
        refractive_index_imaginary_coarse:units = "1" ;
        refractive_index_imaginary_coarse:valid_range = 0.f, 0.1f ;
    float refractive_index_real_fine(time, aeronet_wavelength) ;
        refractive_index_real_fine:long_name = "Real part of refractive index, fine mode" ;
        refractive_index_real_fine:units = "1" ;
        refractive_index_real_fine:valid_range = 1.f, 2.f ;
    float refractive_index_real_coarse(time, aeronet_wavelength) ;
        refractive_index_real_coarse:long_name = "Real part of refractive index, coarse mode" ;
        refractive_index_real_coarse:units = "1" ;
        refractive_index_real_coarse:valid_range = 1.f, 2.f ;
    float ssa(time, altitude, lidar_wavelength) ;
        ssa:long_name = "Single scattering albedo vertical profile" ;
        ssa:units = "1" ;
        ssa:valid_range = 0.1f, 1.f ;
    float ssa_total(time, aeronet_wavelength) ;
        ssa_total:long_name = "Total spectral single scattering albedo" ;
        ssa_total:units = "1" ;
        ssa_total:valid_range = 0.3f, 1.f ;
    float ssa_fine(time, aeronet_wavelength) ;
        ssa_fine:long_name = "Spectral single scattering albedo, fine mode" ;
        ssa_fine:units = "1" ;
        ssa_fine:valid_range = 0.1f, 1.f ;
    float ssa_coarse(time, aeronet_wavelength) ;
        ssa_coarse:long_name = "Total spectral single scattering albedo, coarse mode" ;
        ssa_coarse:units = "1" ;
        ssa_coarse:valid_range = 0.5f, 1.f ;
    float volume_size_distribution_fine(time, radius_fine) ;
        volume_size_distribution_fine:long_name = "Particle volume size distribution dV(r)/dln(r), fine
        mode" ;
        volume_size_distribution_fine:units = "um3/um2" ;
        volume_size_distribution_fine:valid_range = 0.f, 0.8f ;
    float volume_size_distribution_coarse(time, radius_coarse) ;
        volume_size_distribution_coarse:long_name = "Particle volume size distribution dV(r)/dln(r),
        coarse mode" ;
        volume_size_distribution_coarse:units = "um3/um2" ;
        volume_size_distribution_coarse:valid_range = 0.f, 5.f ;
```

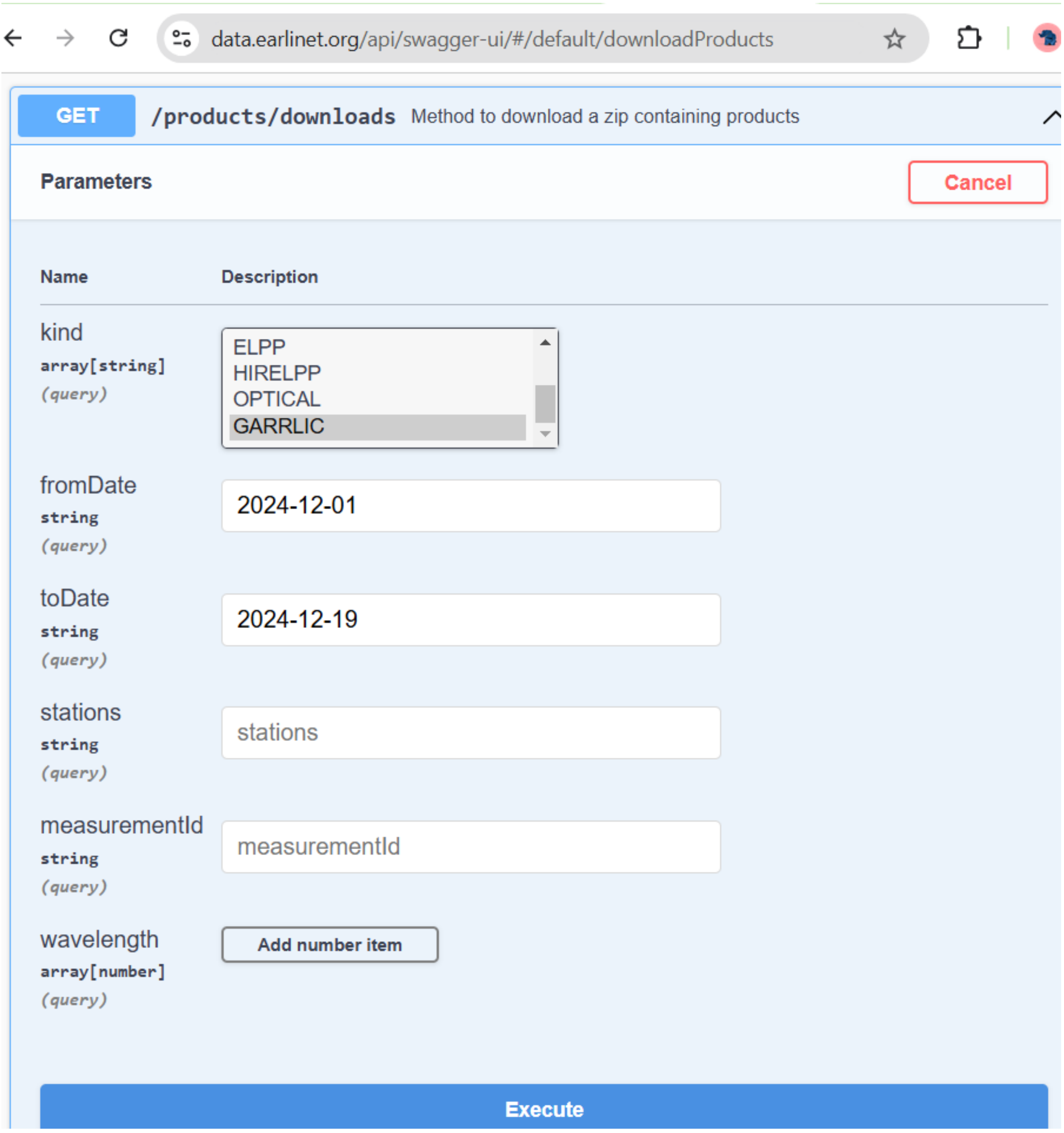
4. Supported ACTRIS EARLINET sites

As of 13th of June 2024, this is the list of ACTRIS EARLINET sites supported by GARRLiC:

[Platform]_[Instrument]	location	EARLINET station code
NOA-Athens_EOLE	Athens	ATZ
UPC-Barcelona_UPCLIDAR-NEW	Barcelona	BRC
IGF-Belsk_LIDAR	Belsk	COG
INOE-Bucharest_RALI	Bucharest	INO
KNMI-Cabauw_LIDAR	Cabauw	CBW
OPGC-Clermont-Ferrand_LR112	Clermont-Ferrand	PUY
UCC-Cork_UCLID	Cork	UCC
CGE-Evora_PAOLI	Evora	EVO
UGR-Granada_LR321	Granada	GRA
LOA-Lille_LILLE-SCC	Lille	LLE
LECCE-UNIVERSITY_LIDAR	Lecce	SAL
CIEMAT-Madrid_LIRIC	Madrid	MDR
FMI-Kuopio_PollyXT	Kuopio	KUO
CETEMPS-Aquila-Coppito_SLAQ-UNIAQ	Aquila-Coppito	LAQ
TROPOS-Leipzig_PollyXT	Leipzig	LEI
CUT-TEPAK-Limassol_LIDAR	Limassol	CYC/LIM
IPSL-SIRTA-Palaiseau_IPRAL-SCC	Palaiseau	SIR
CNR-IMAA-Potenza_MUSA	Potenza	POT
AUTH-Thessaloniki_AUTH	Thessaloniki	THE
UW-Warsaw_ADR	Warsaw	WAW

5. Data access

The GARRLiC products can be accessed by using the products/downloads method from the data.earlinet.org [API](API):



Example:

https://data.earlinet.org/api/services/restapi/products/downloads?kind=GARRLIC&fromDate=2024-09-28&toDate=2024-09-29

6. Credits

Any publication, presentation, or other derivative work based on the results obtained using the GARRLiC products shall acknowledge GRASP-OPEN for the use of the GRASP code and the "Laboratoire d'Optique Atmosphérique" (LOA) for the development of the original GARRLiC prototype.

Example of acknowledgment: *"The authors acknowledge the use of GRASP inversion algorithm software (https://www.grasp-open.com) and the LOA (https://www.loa.univ-lille.fr) for the original GARRLiC algorithm in this work."*