Deliverable D10.15: Final description document of GARRLiC products

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

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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..

N.B: The future updated versions of this document will be available at:

http://www.icare.univ-lille1.fr/actris/garrlic/docs

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

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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).

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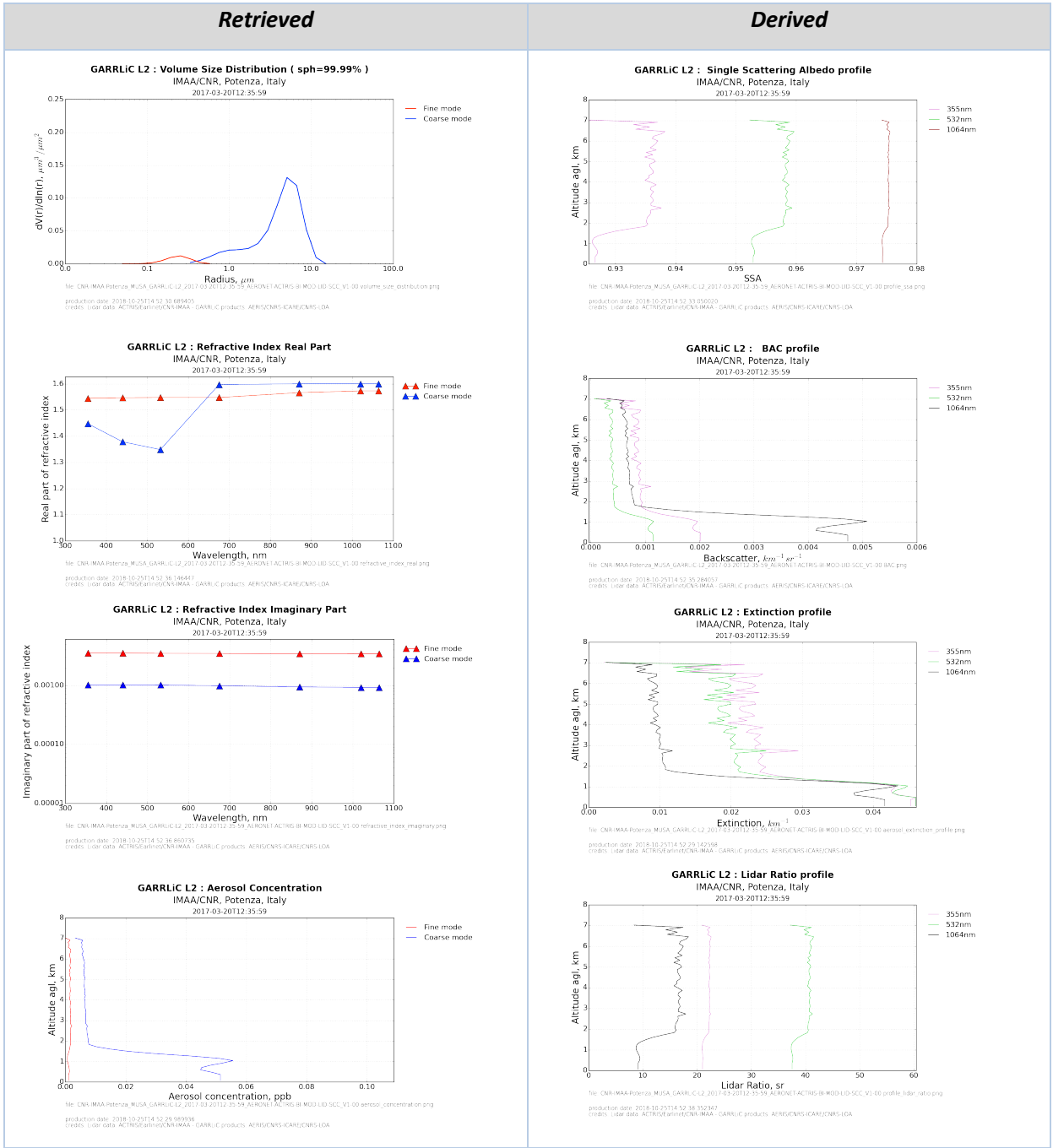

Figure 1: Example of retrieved variables and derived aerosol properties available in GARRLiC data sets. These examples are only for illustration (not for publication).

Since many LiDAR are operated are on 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, and LiDAR data quality is verified by the LiCAL calibration center (at least for recent dataset). 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 AERONET and EARLINET levels.

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2. GARRLiC/GRASP data flow and implementation

2.1. Data flow

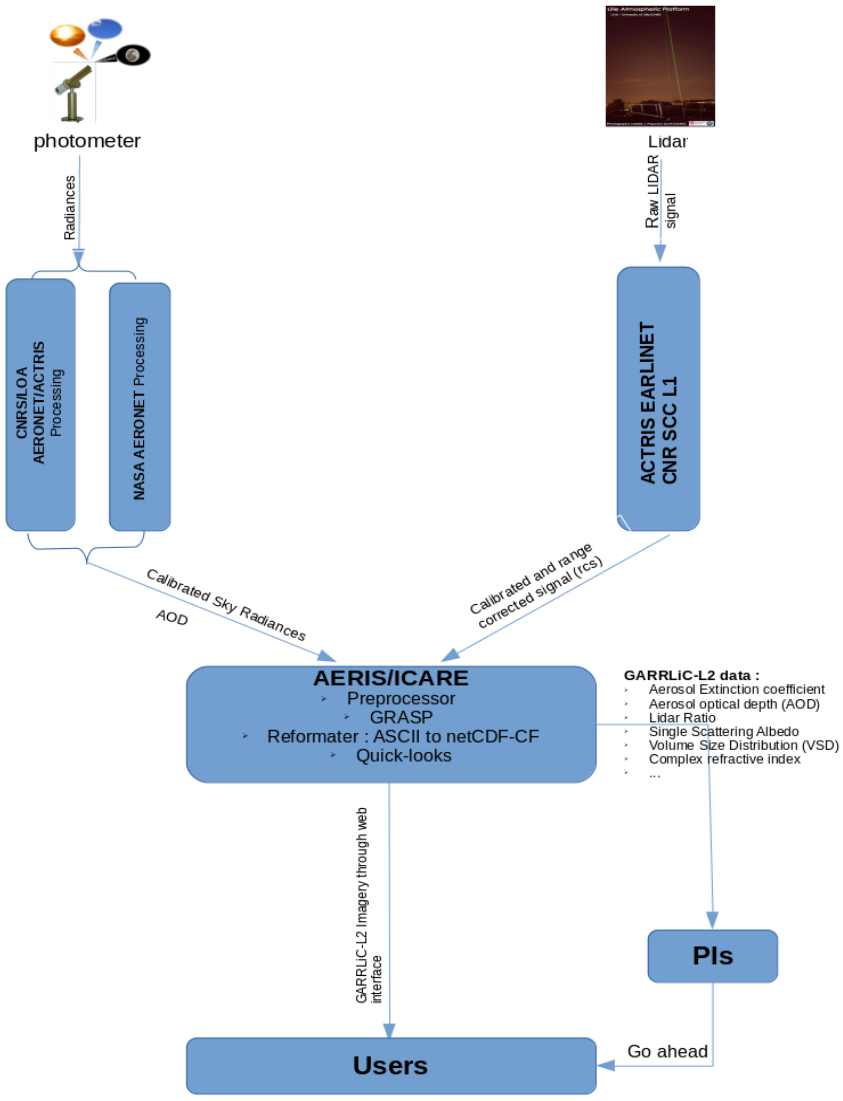

Figure 2: GARRLiC-GRASP data flow

2.2. Implementation

For each ACTRIS/Earlinet lidar profile, coincident AERONET AOD and Almucantar measurements are searched within +/- 1hr of lidar measurement. If multiple AERONET measurements are found matching the temporal colocation criterion, the nearest to the lidar measurement if used. If no coincident AOD or Almucantar measurement is found, the lidar profile is not processed.

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3. Data Description (product version V1-00)

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:
http://cfconventions.org/

One product file contains one lidar profile.

3.2. Typical sizes

MODE	File size (KB)
MONO-MOD	6.7 → 18.3
BI-MOD	14.7 → 18.4

3.3. Naming convention

[Platform]_[Instrument]_[Product]_[Date]_[Variation]_[Version]. [extension]

Where:

- **[Platform]_[Instrument]:** The name of the observational platform (usually [institute]-[site]) and instrument, see
- **[Product]:** The name of the product GARRLiC-L2 (Lidar + photometer)
- **[Date]:** Lidar acquisition date and time in UTC ISO format: YYYY-MM-DDThh-mm-ss, Where,
  - YYYY: 4-digit year (0001-9999)
  - MM: 2-digit month (01-12)
  - DD: 2-digit day of month (01-31)
  - "T": Calendar time separator
  - hh: 2-digit hour (00-23)
  - mm: 2-digit minute (00-59)
  - ss: 2-digit second (00-60, 60 is used for leap seconds only)
- **[Variation]**:
  - **[AERONET source]**
    - AERONET-NASA: for input data Radiances issued from NASA AERONET.
    - AERONET-ACTRIS: for input data Radiances issued from ACTRIS AERONET.
    -
  - **[MODE-LID-SCC]**
    - MONO-MOD-LID-SCC: for mono mode, lidar input data from SCC with only one wavelength
    - BI-MOD-LID-SCC: for fine and coarse mode, lidar-SCC with 2 or more wavelengths
- **[Version]:** The product version is defined using the VX-YY format.
  Where,
  - X: Major release number, tracks a major product release
  - YY: Minor release number, tracks a minor product release
- **[extension]:** Extension of the file: nc

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3.4. Example

UPC-Barcelona_UPCLIDAR-NEW_GARRLiC-L2_2012-07-10T05-58-41_AERONET-NASA-BI-MOD_V1-00.nc

Where:

- **LIDAR input files**: From **EARLINET-Barcelona**
- **The Lidar acquisition date:** 2012-07-10
- **The AERONET acquisition time**: 05:58:41 UTC.
- **AERONET AOD and Almucantar input files**: Barcelona data from NASA.
- **BI-MOD**: GARRLiC for fine mode and coarse mode.
- **LID-SCC:** Barcelona data from ACTRIS/EARLINET SCC.
- **Version**: V1-00.

3.5. File content

3.5.1. File attributes

Global attribute	Datatype	Dimensions	Content
Conventions	string	1	The CF (Climate and Forecast) conventions, here **CF-1.7**
feature Type	string	1	type of discrete sampling geometry: point, time series, profile, trajectory
title	string	1	Full product description
source	string	1	Description of input data
history	string	1	Software version, GARRLiC VX-YY
references	string	1	References to existing documents, if any, ATBD otherwise
comment	string	1	Co-registration tolerance of LIDAR around AOD/ALM: 60 min
product_description	string	1	Aerosol retrievals derived using the GARRLiC algorithm
product_name	string	1	GARRLiC-L2
production_center	string	1	AERIS/ICARE Data and Services Center
production_date	string	1	The date of production
product_version	string	1	The product version
production_date_format	string	1	YYYY-MM-DDThh:mm:ssZ
acquisition_time_format	string	1	Hh:mm::ssZ
year	int	1	The year of LIDAR acquisition time-stamp
month	int	1	The month of LIDAR acquisition time-stamp
day	int	1	The day of LIDAR acquisition time-stamp
institution	string	1	Institute of the data provider
location	string	1	The location of the observational platform
latitude	string	1	The latitude and unit of the observational platform, in deg N
longitude	string	1	The longitude and unit of the

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Global attribute	Datatype	Dimensions	Content
			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
instrument_manufacturer	string	1	The name of the LIDAR instrument manufacturer
instrument_model	string	1	The name of the LIDAR model
beginning_acquisition_date	string	1	The beginning acquisition date and time of coincident observations
end_acquisition_date	string	1	The end acquisition date and time of the end of coincident observations
aeronet_source_description	string	1	AERONET-NASA or AERONET-ACTRIS
garrlic_retrieval_mode_description	string	1	MONO-MOD[Total]/ BI-MOD [Total+coarse+fine]
garrlic_input_mode_description	string	1	Photometer only Photometer+Lidar
output_file	string	1	The name of the GARRLiC-GRASP output file name
input_files	string	1	The file name of the input Lidar and AERONET data
software_version	string	1	The version of GRASP and PREPROCESSOR
time_lidar	string	1	The list of times of the Lidar input profiles (decimal hours)

3.5.2. Dimensions

Name	Length
time	1
range	61
Photometer wavelengths	7
Radius, radius fine, radius coarse	10-100

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3.5.3. 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
range	Float32	[range]	m	-99999.0	Altitude of the vertical bin- in meters)
wavelength	Float32	[wavelength]	um	-99999.0	Photometer 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
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,	sr	-99999.0	Spectral Lidar extinction to

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Dataset	Data Type	Dimensions	Units	_FillValue	long_name
		time]			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	[wavelength, time]	1	-99999.0	Spectral single scattering albedo
ssa_[*lid_wvl*]	Float32	[range, time]	1	-99999.0	Single scattering albedo vertical profile at 355 or 532 or 1064 nm
ssa_fine	Float32	[wavelength, time]	1	-99999.0	Spectral columnar single scattering albedo, fine mode
ssa_coarse	Float32	[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
Ext_[*lid_wvl*]	Float32	[range, time]	km-1	-99999.0	Aerosol extinction vertical profile at 355 or 532 or 1064 nm

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3.5.4. Example

UPC-Barcelona_UPCLIDAR-NEW_GARRLiC-L2_2012-07-10T05-58-41_AERONET-NASA-BI-MOD_V1-00.nc

3.5.4.1. File attributes

Global attribute	Value
Conventions	**CF-1.7**
feature Type	profile
title	GARRLiC-L2
source	Surface observation with the UPCLIDAR-NEW using AERONET Data
history	GARRLiC V1-00
references	ATBD
comment	Co-registration tolerance of LIDAR around AOD/ALM: 60 min
product_description	Aerosol retrievals derived using the GARRLiC algorithm
product_name	GARRLiC-L2
production_center	AERIS/ICARE Data and Services Center
production_date	2018-10-25T16:05:29Z
product_version	The product version
production_date_format	YYYY-MM-DDThh:mm:ssZ
acquisition_time_format	Hh:mm:ssZ
year	2012
month	07
day	10
institution	UPC/TSC remote sensing laboratory
location	Barcelona, Spain
latitude	41.386 deg N
longitude	2.117 deg E
altitude	115 m
contact	comeron@tsc.upc.es
instrument_manufacturer	UPC
instrument_model	UPCLIDAR-NEW
beginning_acquisition_date	2012-07-10T05:58:41Z
end_acquisition_date	2012-07-11T05:58:41Z
aeronet_source_description	AERONET-NASA or AERONET-ACTRIS
garrlic_retrieval_mode_description	MONO-MOD[Total]/ BI-MOD [Total+coarse+fine]
garrlic_input_mode_description	Photometer+Lidar
output_file	UPC-Barcelona_UPCLIDAR-NEW_GARRLiC-L2_2012-07-10T05-58-41_AERONET-NASA-BI-MOD_V1-00.nc

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Global attribute	Value
input_files	LIDAR: 20120710ba24_203.nc 20120710ba24_206.nc 20120710ba24_207.nc AOD: AERONET_AOD-L15_2012-07-10_Barcelona_V2-00.txt ALM: AERONET_ALM_2012-07-10_Barcelona_V2-00.txt
software_version	GRASP: v0.8.1 PREPROCESSOR: v0.3.1
time_lidar	5.97805555556

3.5.4.2. Datasets

Dataset	Dimensions	range
Time	1	5.9827776 → 5.9827776
range	61	60 → 7041.6
wavelength	7	0.355 → 1.064
radius_fine	10	0.05 → 0.57623
radius_coarse	15	0.33472 → 15
VC_fine	1	0.078114 → 0.078114
VC_coarse	1	0.076791 → 0.076791
angstrom_exponent	1	1.3548 → 1.3548
sphericity	1	99.99 → 99.99
abs_355	[61,1]	3.3400602e-07 → 0.027150137
abs_532	[61,1]	1.4204414e-07 → 0.01750742
abs_1064	[61,1]	1.07064096e-07 → 0.01123748
aaod_total	[7,1]	2.9018e-3 → 9.7799e-3
aaod_fine	[7,1]	0.0014682 → 0.006469
aaod_coarse	[7,1]	0.0014336 → 0.0033109
AC_fine	[61,1]	2.0390878e-06 → 0.1423159
AC_coarse	[61,1]	1.2915478e-06 → 0.5029427
Ext_355	[61,1]	1.37162915e-05 → 0.86617285
Ext_532	[61,1]	5.6611657e-06 → 0.60725754
Ext_1064	[61,1]	2.1856492e-06 → 0.64684814
bac_355	[61,1]	4.28809358e-07 → 0.0895818
bac_532	[61,1]	3.95013871e-07 → 0.10244622
bac_1064	[61,1]	2.53695873e-07 → 0.08544832
LR_total	[7,1]	8.26566982 → 27.38731956
LR_fine	[7,1]	15.14505959 → 60.2164917
LR_coarse	[7,1]	5.50216007 → 28.93103981
LR_355	[61,1]	6.14497089 → 59.57207489

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Dataset	Dimensions	range
LR_532	[61,1]	5.54984188 → 30.78500366
LR_1064	[61,1]	7.54427528 → 15.2157402
aod_total	[7,1]	0.11849 → 0.55400997
aod_fine	[7,1]	0.020761 → 0.47371
aod_coarse	[7,1]	0.0803 → 0.097729
refractive_index_imaginary_fine	[7,1]	0.0016467 → 0.0016663
refractive_index_imaginary_coarse	[7,1]	0.00075966 → 0.00078394
refractive_index_real_fine	[7,1]	1.39833999 → 1.42742002
refractive_index_real_coarse	[7,1]	1.39093995 → 1.6
ssa_total	[7,1]	0.97400999 → 0.98234999
ssa_355	[61,1]	0.95882136 → 0.98601204
ssa_532	[61,1]	0.97086233 → 0.97740114
ssa_1064	[61,1]	0.92994678 → 0.98522556
ssa_fine	[7,1]	0.92927998 → 0.98633999
ssa_coarse	[7,1]	0.95876998 → 0.98532999
volume_size_distribution_fine	[10,1]	0.00010964 → 0.09331498
volume_size_distribution_coarse	[15,1]	0.00029557 → 0.0404128

4. Supported ACTRIS EARLINET sites (as of 2019-01-31)

[Platform]_[Instrument]	location
NOA-Athens_EOLE	Athens
UPC-Barcelona_UPCLIDAR-NEW	Barcelona
IGF-Belsk_LIDAR	Belsk
INOE-Bucharest_RALI	Bucharest
KNMI-Cabauw_LIDAR	Cabauw
OPGC-Clermont-Ferrand_LR112	Clermont-Ferrand
UCC-Cork_UCLID	Cork
CGE-Evora_PAOLI	Evora
UGR-Granada_LR321	Granada
CIEMAT-Madrid_LIRIC	Madrid
FMI-Kuopio_PollyXT	Kuopio
CETEMPS-Aquila-Coppito_SLAQ-UNIAQ	Aquila-Coppito
TROPOS-Leipzig_PollyXT	Leipzig
CUT-TEPAK-Limassol_LIDAR	Limassol
CNR-IMAA-Potenza_MUSA	Potenza
AUTH-Thessaloniki_AUTH	Thessaloniki
UW-Warsaw_ADR	Warsaw

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