THE EUROPEAN AEROSOL RESEARCH LIDAR NETWORK (EARLINET): AN OVERVIEW

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ABSTRACT

The European Aerosol Research LIdar NETwork (EARLINET) is the first aerosol lidar network on a continental scale with the main goal to provide a comprehensive, quantitative, and statistically significant database for the aerosol distribution over Europe.

Next, we present EARLINET along with the main network activities.

Index Terms—Lidar, aerosols, observation network, EARLINET, GEOSS.

1. INTRODUCTION

The European Aerosol Research LIdar NETwork (EARLINET) [1] started in 2000 under the EC 5th Framework Program (Energy, Environment and Sustainable Development program) as a coordinated network of ground-based lidar stations for the vertical profiling of aerosols at continental long-term scale.

Starting from the existing EARLINET infrastructure [2], the EARLINET-ASOS (Advanced Sustainable Observation System) EC (Coordination Action) project (March 2006-2011) is contributing to fill up the gap between the existing systems and methodologies and the required optimal performance of the network to become a leading instrument for the observation of the

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4-dimensional spatio-temporal distribution of aerosols on a continental scale. Central to this objective are harmonised multi-wavelength observations with enlarged spatial and temporal coverage, rigorous quality control, and fast-delivery of standard data products. These coordinating efforts are to establish common standards and interoperability links with the global aerosol observation community, in ongoing and future satellite missions such as CALIPSO (2006), ADM-Aeolus (2009), and EARTH-CARE (2012), and definitely with the GEOSS (Global Earth Observation System of Systems) worldwide initiative.

A more detailed EARLINET review is presented in Sect. 2 while the main network activities currently developed through EARLINET-ASOS project are discussed in Sect. 3. Concluding remarks are given in Sect. 4.

2. EARLINET

At present, EARLINET [1] merges into a single body 28 stations from Andøya (Norway) in the north of Europe (and north of the Artic circle) to Athens (Greece) in the south, and from Minsk (Belarus) in the East to the Spanish peninsula in the west, spanning 15 different countries (Fig. 1) and a wide range of climatological conditions (urban, marine, rural, alpine, continental), and hence, covering a wide range of aerosol types. EARLINET includes over 6 single backscatter lidar stations and 19 Raman lidar stations, 8 of them advanced *multi-wavelength Raman lidar* stations that enable to retrieve aerosol microphysical properties. 13 stations also form part of the (sun-photometer) AERONET (Tab. 1).

Since May 2000, the network has performed continued systematic unbiased measurements on a regular basis at three fixed days per week (i.e., one daytime measurement per week around noon, when the boundary layer is usually well developed, and two measurements per week after sunset, in low background light conditions). At present, we have more than 25000 categorised optical profiles (aerosol extinction, backscatter and lidar ratio), as described in Tab. 2.

Since CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation, NASA-CNES) launch in April 2006, EARLINET has also started correlative measurements at stations located within 80 km from satellite overpasses and additionally at the stations closest to the actually overpassed site. In contrast to elastic-backscatter lidars like CALIOP (the lidar instrument onboard CALIPSO satellite), both Raman lidars and High Spectral Resolutions Lidars (HSRL) enable *independent inversion* of both extinction and backscatter, and hence, they provide an invaluable tool for *ground truth validation* [3].

Central to these measurement strategies, a rigorous quality assurance (QA) program has been applied at both instrument and algorithm level. A standardised data format (netcdf) is used.

3. EARLINET-ASOS NETWORK ACTIVITIES

EARLINET-ASOS main objectives (Sect. 1) are deployed through the following network activities (NA):

1) Quality assurance (QA).

QA encompasses both *lidar systems* and *inversion algorithms.* The former involves: (I) inter-comparison of lidar systems (ad-hoc measurement campaigns with approved reference lidars) [4] and (II) collection, development and standardization of *tools for internal regular hardware quality checks* (e.g., partially

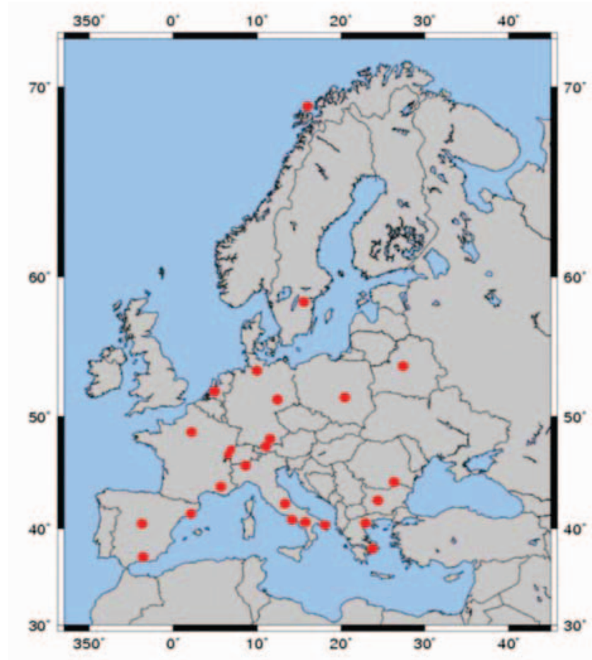

Fig. 1. Distribution of EARLINET lidar stations (June 2008).

covered telescope-aperture tests, development of test pulse generators, etc.). Point II is also related to “activity” 2 below.

The latter (QA on inversion algorithms) involves the inter-comparison of algorithms used for the retrieval of aerosol optical parameters (this a particularly important issue for recently new stations on the network and for all the stations that have upgraded to a Raman system) [5][6].

QA is a vertebral activity to ensure data products with the highest possible quality and a *sustainable network.*

2) Optimisation of instruments.

Key objectives are: (I) Specs. compilation of all lidar sub/system setups of the network into a *Handbook of Instruments (HoI),* (II) improvement of the existing observation instrumentation (systems, sub-systems and system integration) by selecting the *optimal approach* from the various solutions existing at individual stations (consider e.g., transmitter/receiver topics such as the geometrical form-factor, close/far-range detector solutions, homogeneous illumination of photo-detectors, and the definition of optimal wavelength separation filters, or receiver electronics and data acquisition issues such as grounding and shielding; see companion paper [8] for further insight), (III) *automated operation* (ideally unmanned) to increase temporal coverage, and (IV) instrument *standardization.* The envisaged standard is a *3+2 multi-wavelength elastic/Raman* lidar with 3 transmitted wavelengths UV-VIS-NIR (355, 532, and 1064 nm) and 5 received wavelengths (the aforementioned 3 elastic wavelengths plus the N_2-Raman shifts at 387 and 607 nm).

3) Optimisation of data processing.

The main goal here is to develop a common *Single Calculus processing Chain (SCC)* [7] for data inversion from raw signals to final products *without the need for operator interaction.* Aerosol extinction, backscatter, lidar ratio, optical depth, and Ångström coefficients will be derived from Raman signals whereas aerosol microphysical properties (particle size, surface and volume concentrations, refractive index, and single-scattering albedo, which is a key parameter for climate models) from multi-spectral lidar measurements. Besides, the SCC will add the capability of constraining the inversion algorithms with sun-photometer measurements and include system-dependent pre-processing.

A major added value is that inverted data will be available in *near real-time.*

4) Common database construction and operation.

The aim is to implement and continuously run a centralised *common database* (accessible through a web-based interface) that automatically collects data products provided by each individual station and makes them available to both internal and external users. A relational database approach will enable to search for data meeting specific criteria.

4. CONCLUSIONS

EARLINET has provided –and is to continue to provide- key results in environmental topics such as the aerosol distribution over Europe [9], climatology [10][11], microphysical aerosol characterization [12][13], analysis of Saharan dust events [14][15], long-range transport [16][17], solar-aerosol radiative forcing [18], dust-weather forecast interplay [19], biomass burning [20], volcanic eruptions [21], and CALIPSO ground-truth validation [3] [22].

All in all, EARLINET is a truly world-leading instrument for the observation of 4-dimensional spatio-temporal distribution of aerosols on a continental scale and a key element for GEOSS.

5. ACKNOWLEDGEMENTS

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LOCATION	Institution	LAT.	LONG.	ALTITUDE [m] asl	355 nm	387 nm	407 nm	532 nm	607 nm	660 nm	1064 nm	sun-photom.
Andøya, NORWAY	l	69.28° N	16.01° E	380	x	x	x	p,c	x	x	x	A
Athens, GREECE	m	37.96° N	23.78° E	200	x	x	x	x	x		x	x
(and Oxylithos, Greece)	m	38.55° N	24.13° E	200				x				x
Barcelona, SPAIN	a	41.39° N	2.11° E	115				x	x		x	
Belsk, POLAND	r	51.84° N	20.79° E	180				x			x	A
Bilthoven, THE NETHERLANDS	g	52.12° N	5.20° E	5	x	x	x	x	x,p,c		x	x
(and Cabauw, The Netherlands)	g	51.97° N	4.93° E	1							x	A
Bucharest-Magurele, ROMANIA	o	44.45° N	26.03° E	90				x			x	
Garmisch-Partenkirchen, GERMANY	z	47.48° N	11.06° E	730	x			x,p,c				
(HSRL)	z	47.48° N	11.06° E	730	x			x			x	
Granada, SPAIN	f	37.16° N	3.61° W	680	x	x	x	p,c	x		x	A
Hamburg, GERMANY	e	53.59° N	9.97° E	25	x,RR			x,RR			x	A
Ispra, ITALY	t	45.80° N	8.6° E	NA				x				A
L'Aquila, ITALY	v	42.38° N	13.32° E	683	x^{351}	x^{382}	$x^{393, 403}$					
Lecce, ITALY	q	40.3° N	18.1° E	30	p,c	x	x					A
Leipzig, GERMANY	b	51.35° N	12.43° E	90	x	x	x	x,p,c	x		x	A
(see note 2)	b	51.35° N	12.43° E	100	x	x		x	x	x	x	A
	b	51.35° N	12.43° E	100				x	x			A
Linköping, SWEDEN	k	58.39° N	15.57° E	80	x	x		x	x			
Madrid, Spain	s	40.45° N	3.73° W	669				x	x			
Minsk, BELARUS	i	53.92° N	27.60° E	200	x	x		x,p,c			x	A
Munich, GERMANY	j	48.15° N	11.57° E	539	x,p,c	x						A
(and Maisach, Germany)	j	48.21° N	11.26° E	515	x	x		x,p,c	x		x	
Naples, ITALY	x	40.84° N	14.18° E	118	x	x	x	x	x			
Neuchâtel, SWITZERLAND	n	47.00° N	6.96° E	487				p,c				
Observatoire de Haute-Provence, FRANCE	u	43.94° N	5.71° E	683				x	x	x		
Palaiseau, FRANCE	u	48.7° N	2.2° E	162				p,c			x	
Payerne, SWITZERLAND	w	46.82° N	6.93° E	456	x	x	x					
Potenza-Tito Scalo, ITALY	d	40.60° N	15.72° E	760	x	x	x	x,p,c	x		x	A
Sofia, BULGARIA	y	42.67° N	23.33° E	550				x,x^{511}				
Thessaloniki, GREECE	h	40.63° N	22.95° E	60	x	x		x				A
Potsdam, GERMANY	c				Retrieval of microphysical aerosol properties							
Leipzig, GERMANY	b											
Barcelona, SPAIN	p				Operation of DREAM, housing of SCC							A
Kjeller, NORWAY	l				Operation of particle dispersion model FLEXPART							

(1) Key measurement channels based on Handbook of Instruments (HoI, April 2008). Each row is a lidar instrument.
Sun-photometer: "A" indicates that the station belongs to AERONET.
"x" stands for "existing channel/instrument", "p" for "parallel polarised channel", "c" for "cross polarised", and "RR" for "rotational Raman"
(2) Leipzig station has additional channels (not listed) for temperature/relative humidity mesurement.

CATEGORY	DESCRIPTION
Climatology	Regular measurements (3 times/week)
Cirrus	Cirrus clouds
Diurnal cycle	Diurnal/seasonal cycle (boundary-layer aerosols)
Volcanic eruptions	Etna observation events (2001-2002)
Forest fires	
Photosmog	Photochemical smog episodes (large cities)
Rural/urban	Nearly simultaneous meas. at pairs of stations (sufficiently close to minimise large-scale effects but far apart to reflect rural/urban differences)
Saharan dust	Co-ordinated alert-based special observations
Statrosphere	Stratospheric aerosol observations
CALIPSO	Correlative measurements coincident with satellite overpasses (see Sect. 2).

Tab. 1 (left) Locations of EARLINET stations and overview of the key measurement features. The institution *identification letters* are identical to the *affiliation letters* of the authors. (Adapted from [1]/HoI/April 2008, [3][7]).

Tab. 2 (right above) Data categories related to regular/special measurements.