EARLINET for long-term observations of atmospheric aerosol

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Outline

- *Introduction*
- *Integrated observation strategy*
- *EARLINET*
- *Examples and case studies*
- *Global Aerosol Lidar Network*
- *Summary and remarks*

Aerosols are very difficult to handle in models

Aerosols are produced by many different processes, some sources are localized, others are distributed over large volumes

Aerosols interact dynamically in a nonlinear way (nucleation, condensation, coagulation, deposition)

Aerosols can be transported over large distances

Measurements are needed to assess and improve understanding of aerosol processes and their treatment in models!

- in situ measurements
- Ground based remote sensing measurements
- Satellite measurements

PARAGON : An Integrated Approach for Characterizing Aerosol Climate Impacts and Environmental Interactions (Diner, BAMS 2004)

Lidar measurements

It is in particular the information about the vertical distribution of aerosols that is missing!

The exact altitude of any aerosol layer is required to trace it back to the source.

Lidar provides excellent information about the vertical structure of aerosol layers.

Advanced lidar methods provide very good information about aerosol optical properties (extinction, backscatter, optical depth).

Advanced lidar plus advanced retrieval methods provide important information about microphysical properties of aerosols.

Lidar Network

Aerosol distribution is highly variable, single point measurements are insufficient for characterization.

At least continental scale coverage is needed for, e.g., climate impact studies, source localization, comparative statistics.

It helps to build a community with common understanding of aerosol related processes and observation techniques!

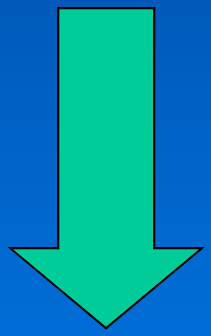
Aerosol profiling for climate and air quality research

Lidar measurements

Long term measurements

Distributed measurements

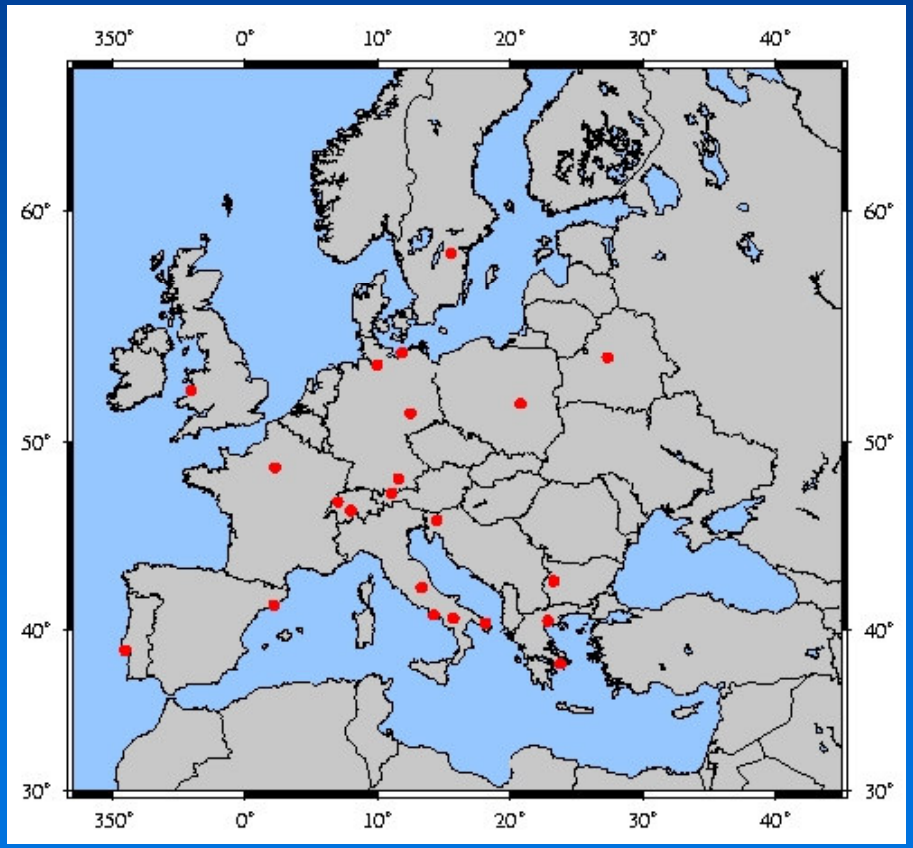
Advanced lidar systems for microphysical properties



EARLINET

EARLINET
European Aerosol Research LIdar NETwork

EARLINET was established in February, 2000 as a research project supported by the European Commission under the Fifth Framework Programme within the Energy, Environment and Sustainable Development Programme, contract No EVR1-CT-1999-40003.



- *22 lidar stations distributed over 14 European countries*
- *main objective: to establish a qualitatively and quantitatively significant database for the horizontal and vertical distributions of atmospheric aerosols over Europe*
- *3 systematic regular aerosol lidar measurements per week*
- *special measurement campaigns to study special events (Saharan dust outbreaks, volcanic eruptions, forest fires)*
- *system level and retrieval alghoritms intercomparisons*

EARLINET database

EARLINET measurements started in May 2000

The EARLINET database represents the largest database for the aerosol distribution on a continental scale

All the files are divided in different categories related to regular and special conditions:

- ***Climatology***
- ***Cirrus***
- ***Diurnal cycles***
- ***Volcanic eruptions***
- ***Forest Fires***
- ***Photosmog***
- ***Rural/urban***
- ***Saharan dust***
- ***Stratosphere***

A web-based interface to provide easy access to the data products for internal and external users has been developed and it is currently under internal test.

EARLINET ASOS
European Aerosol Research Lidar Network: Advanced Sustainable Observation System

EC Infrastructure Project Started on 1st March 2006

The overall objectives are:

- To extend the development of the European Aerosol Research Lidar Network as a world-leading instrument for the observation of the 4-dimensional spatio-temporal distribution of aerosols on a continental scale, resulting in accurate, well-defined, and easily accessible data products for use in science and environmental services.
- To enhance the operation of this instrument to foster aerosol-related process studies, validation of satellite sensors, model development and validation, assimilation of aerosol data into operational models, and to build a comprehensive climatology of the aerosol distribution.
- To play a leading role in the development of a global observation network for the aerosol vertical distribution as a major innovative element of GEOSS, by setting the standards for instruments, methodology, and organization in this specific area.

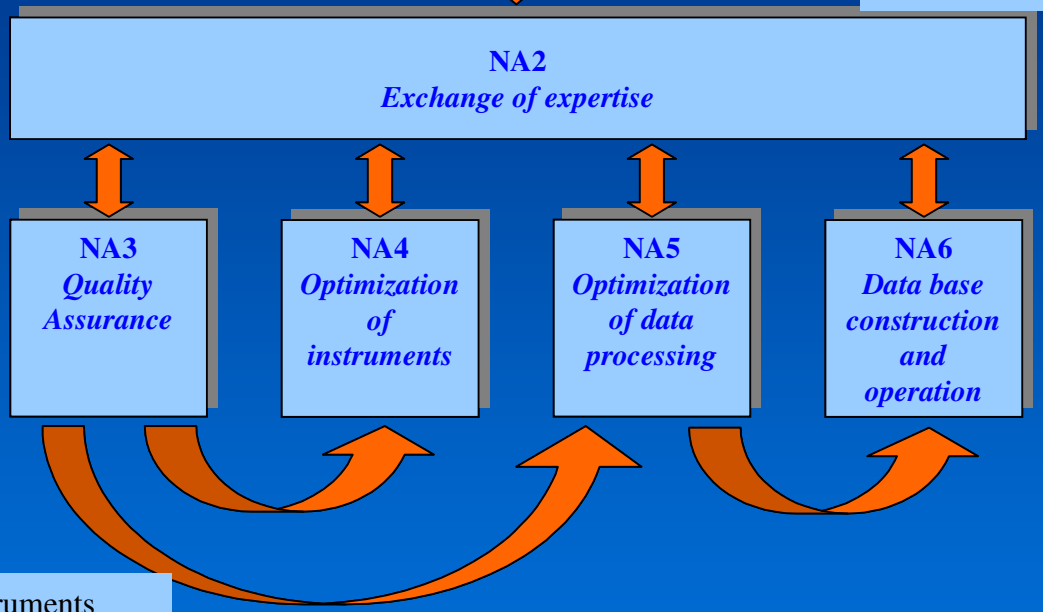
NA1 - Management of *CA*

Management will comprise the areas of communication with the Commission for all contractual and administrational matters, organization of annual and special reports, organization of consortium meetings, monitoring the progress of work based on milestones and deliverables.

NA2 - Exchange of expertise

- organized flow of information both between the participants and between the participants and the external scientific community.

- cooperation and coordination with the relevant observation and user communities



NA3 - Quality assurance

To establish a common European standard for routine quality assurance of lidar instruments and algorithms

NA4 - Optimisation of instruments

To improve the observation system on the basis of well defined subsystems and system integration by selection of the optimal approach from various solutions existing at individual stations.

NA5 - Optimisation of data processing

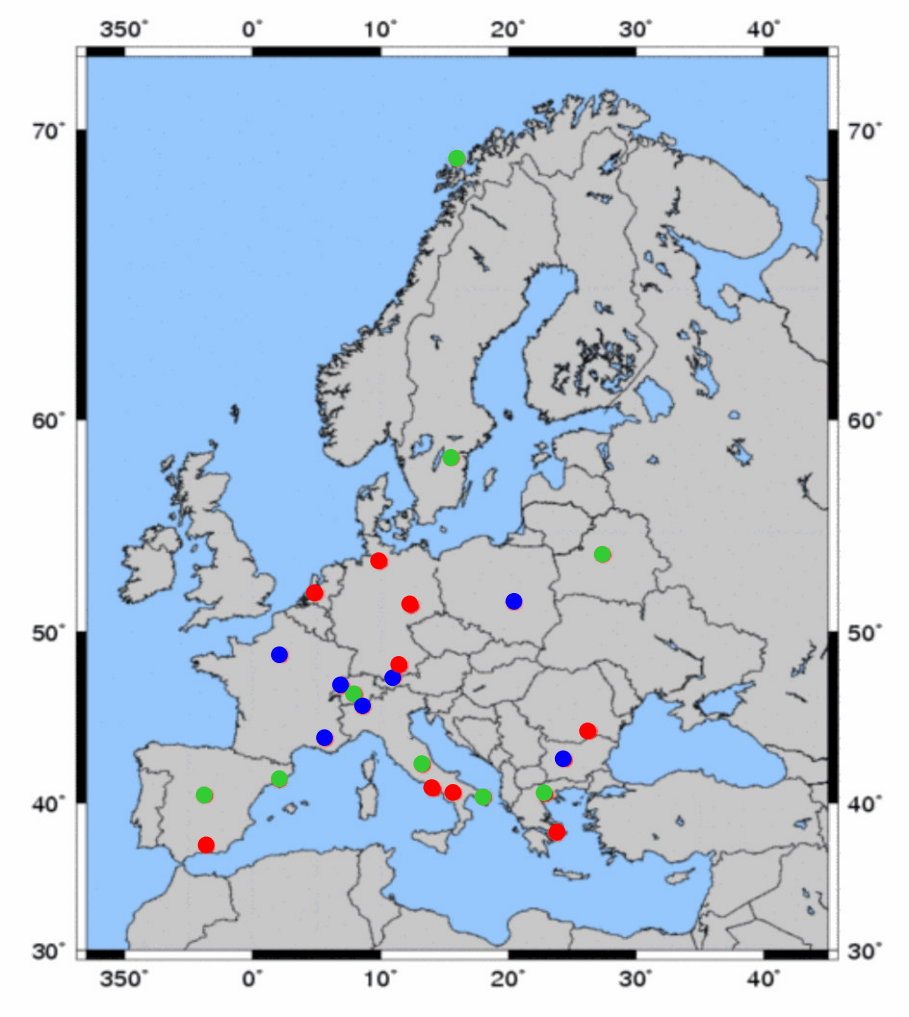
Optimisation of data processing to retrieve aerosol optical properties and microphysical properties.

Common single chain data processing procedure for the automatic retrieval of aerosol properties.

NA6 - Data base construction and operation

The establishment of the EARLINET-ASOS database and the development of a web-based interface to provide easy access to the data products for internal and external users.

EARLINET 2009



25 lidar stations

- **9 multiwavelength Raman lidar stations**

backscatter (355, 532 and 1064 nm) + extinction (355 and 532 nm) + depol ratio (532 nm)

- **9 Raman lidar stations**

- **7 single backscatter lidar stations**

EARLINET stations operational in the next future

- **Israel**
- **Georgia**
- **Ireland**
- **Portugal**

www.earlinet.org

EARLINET activities: "Saharan dust"

EARLINET is an optimal observation tool for Saharan dust events

- dust profiling

- stations located in Southern Europe

- high performance lidar stations

- coverage at continental scale to study transport and modification processes

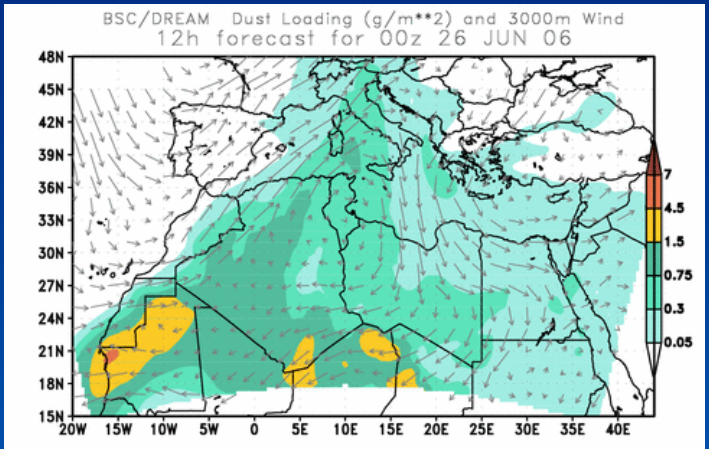
- a suitable observing methodology has been established within the network

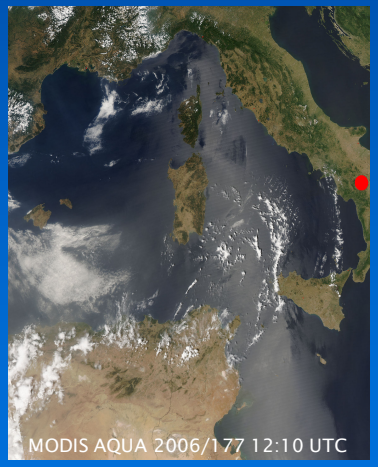
    forecasting scheme [DREAM, Skiron]

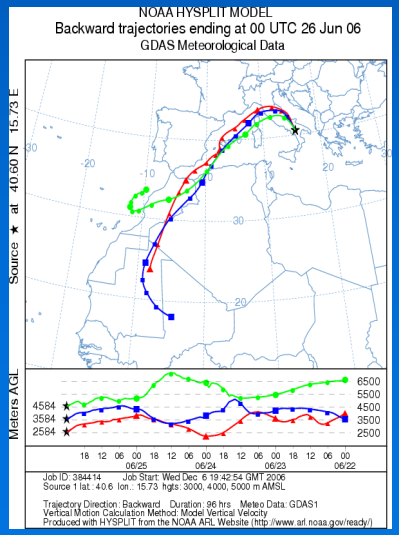
    alert (warnings: 24-48 h)

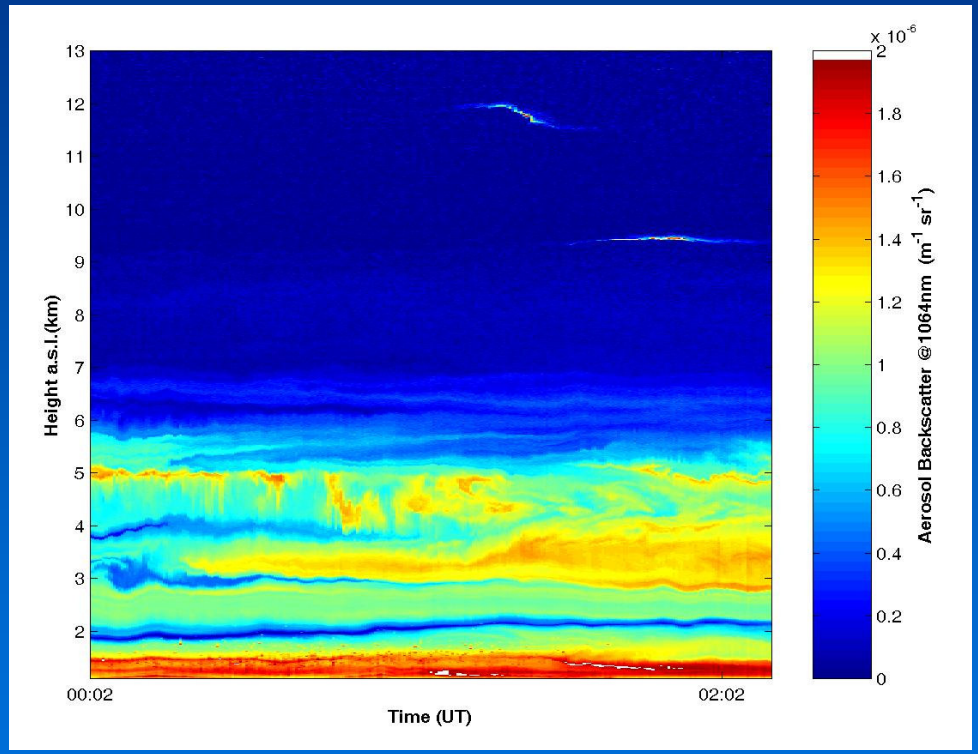
- use of air-mass back-trajectory analysis [German Meteorological Service (DWD/GME Model) and NOAA HYSPLIT] and satellite data analysis (EP/TOMS AI, SeaWiFS AOD, NOAA/AVHRR AOD, MODIS AOD, CALIPSO)

26 June 2006 Saharan dust observed over Potenza EARLINET lidar station (PEARL)









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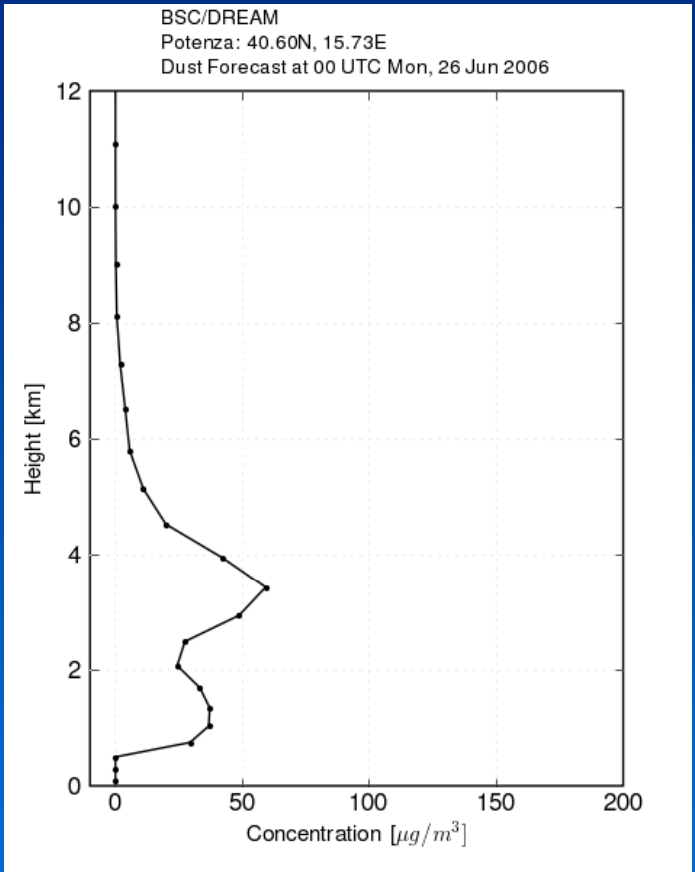
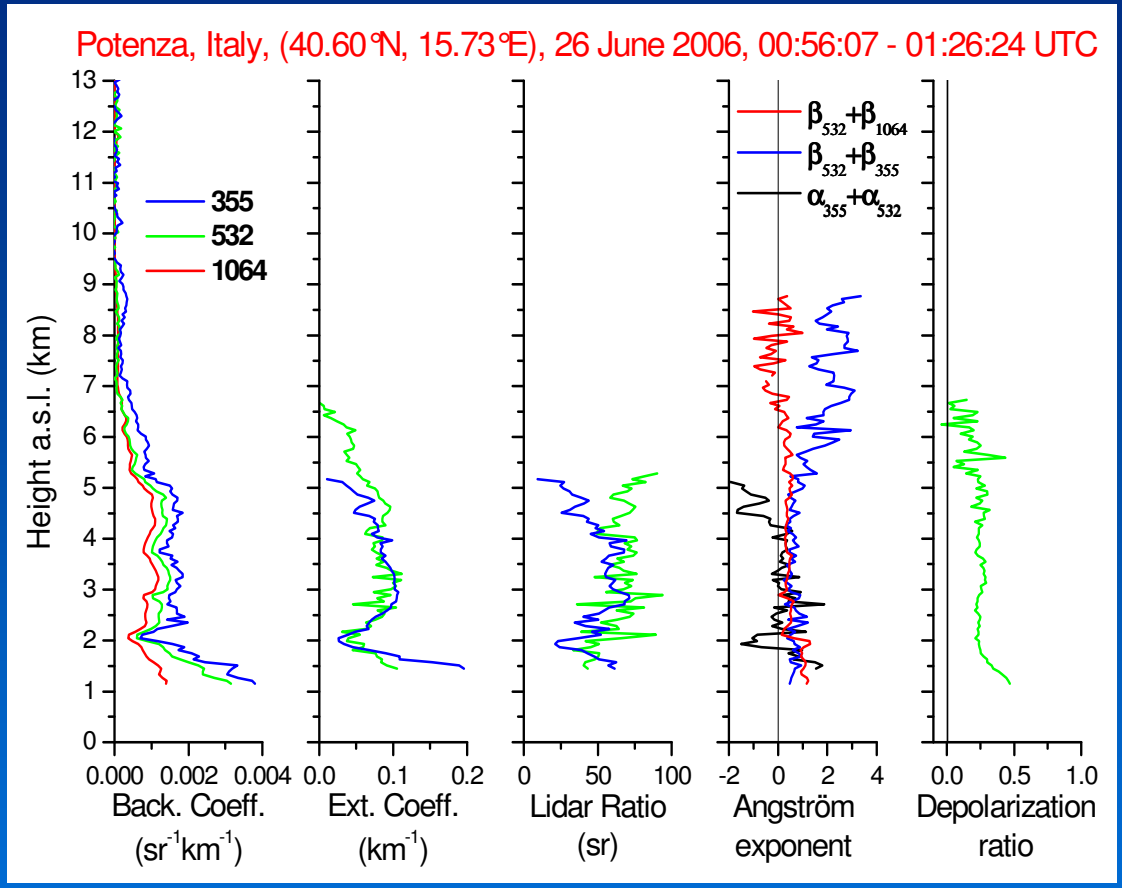




MODIS AOD (550 nm) =0.33

AERONET@500 nm = 0.25 (Lecce)

AERONET@500 nm = 0.3 (Rome)

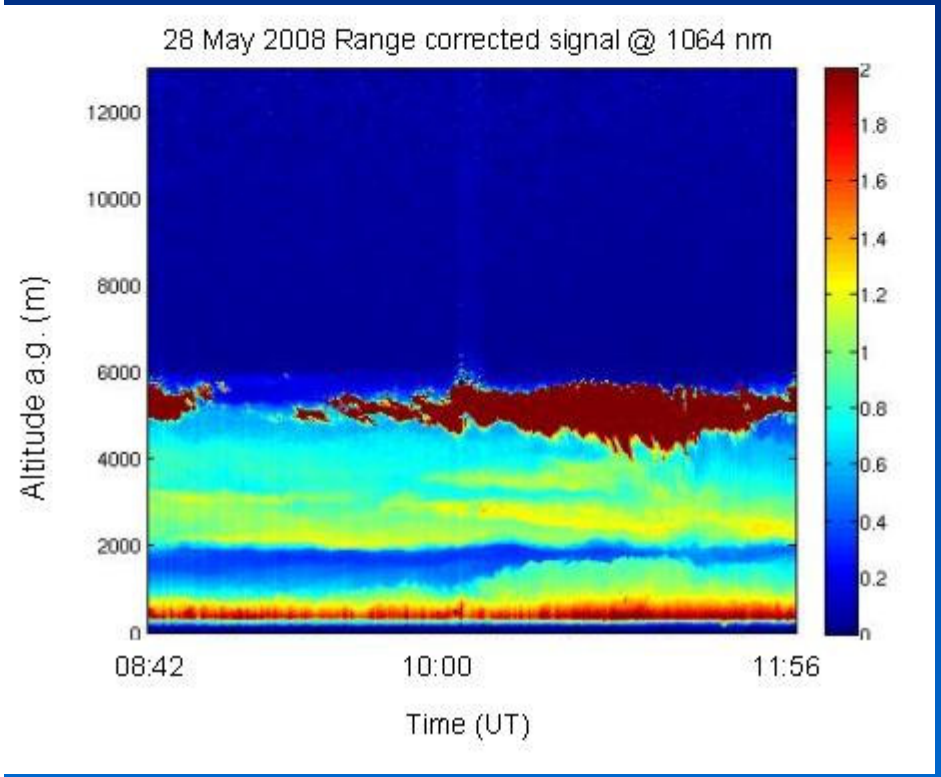
Potenza, Lidar

AOD@532 nm = 0.30 (in the dust layer = 0.25)

AOD@355 nm = 0.33 (in the dust layer = 0.25)

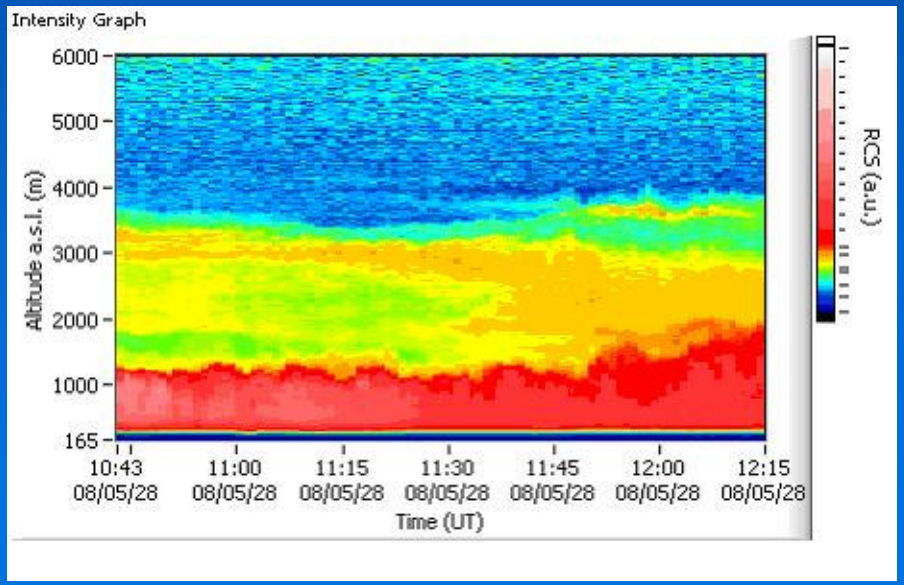
Typical AOD values @ 355 nm = 0.12 – 0.5 (<0.25>)

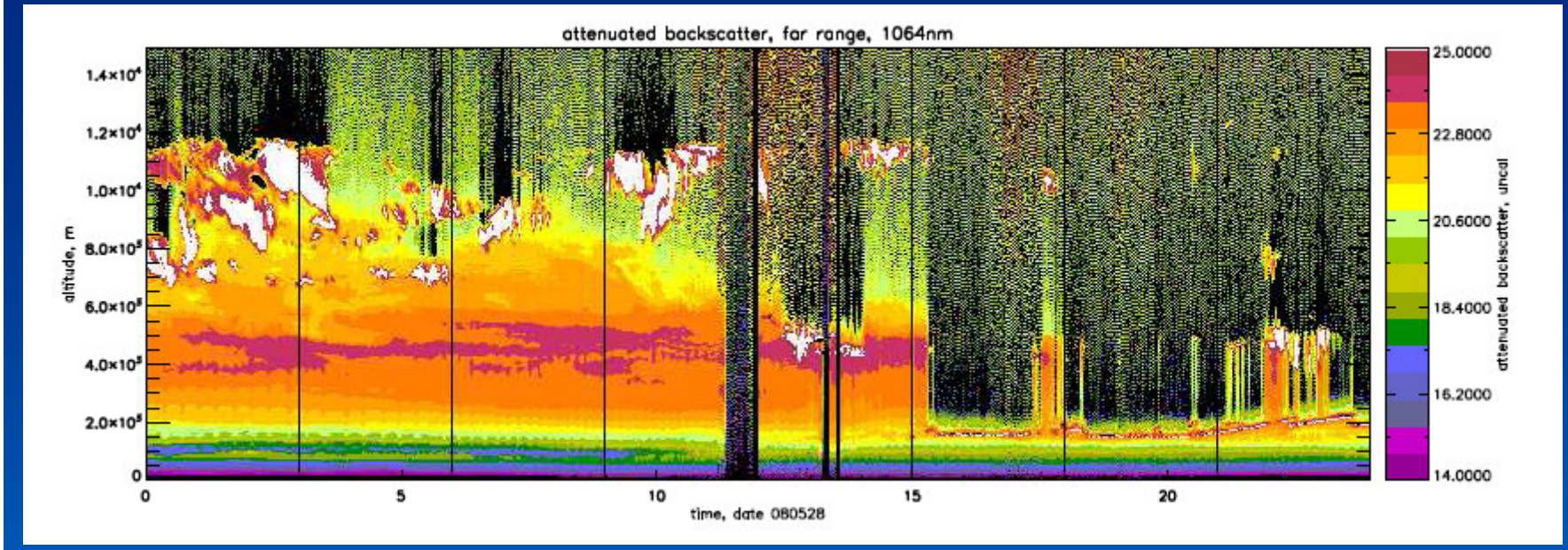
Saharan dust event 26-30 May 2008



Potenza, Italy

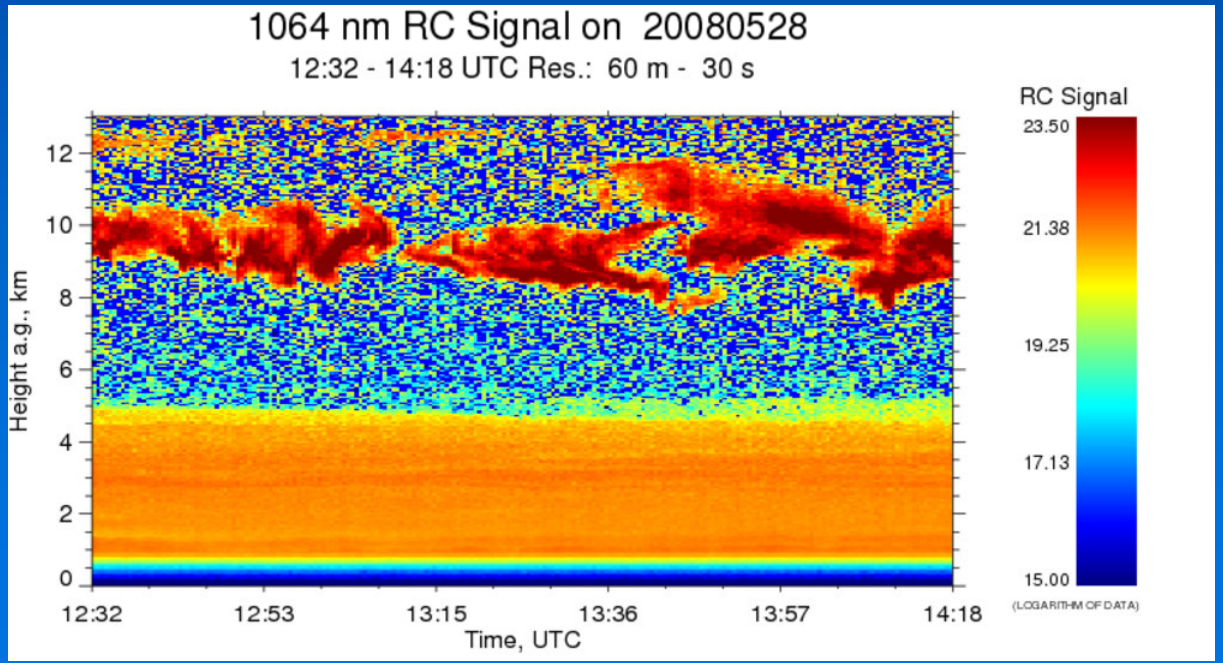
Bucharest, Romania





Hamburg, Germany

Leipzig, Germany



Since May 2000 we have observed more than 400 Saharan dust events

First statistical analysis for Saharan dust observations starting from the first 3 years of operation of the network *Papayannis et al., JGR 2008*

DREAM Forecast is provided for each EARLINET station through the Barcelona Supercomputing Center

A systematic comparison between DREAM model and lidar observations is currently in progress

Among all EARLINET stations, the Potenza station was selected as the one with the largest database of Saharan dust observations to develop a methodology for the comparison.

Comparison for May 2000 – April 2005 period between lidar observations and DREAM forecasts over Potenza.

Potenza EARLINET file : typically 30min as temporal resolution –
vertical resolution 60 m for backscatter
240 for extinction profiles

DREAM profiles: 3h as temporal resolution

Only cases in which a Saharan dust layer is identified in the lidar profiles are compared.

Comparisons in terms of:

Geometrical properties

base, top and center of mass of layers identified above the PBL determined starting from both EARLINET and DREAM profiles

Extensive properties

mean backscatter and extinction from lidar profiles and mean concentration for DREAM profiles in the identified layers

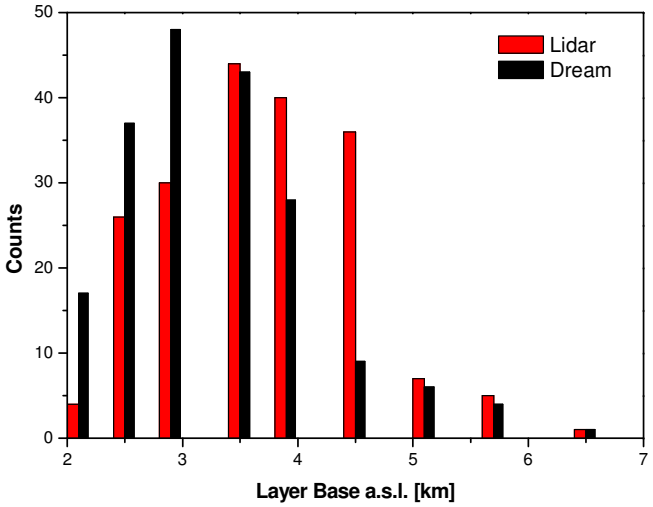
integrated quantities i.e. Integrated backscatter, optical depth and aerosol load, in the identified layers

Profiles

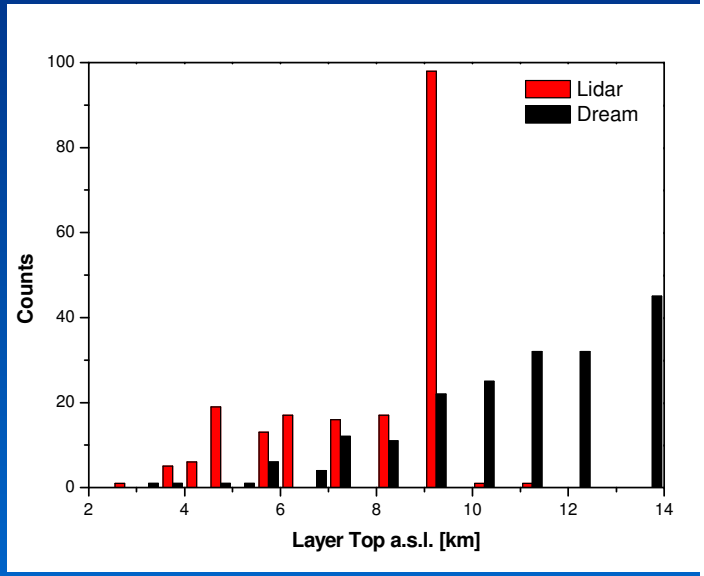
mean profiles of extinction, backscatter and concentration and their variability

correlation coefficient for each identified case between extinction (or backscatter) and concentration in the identified layer

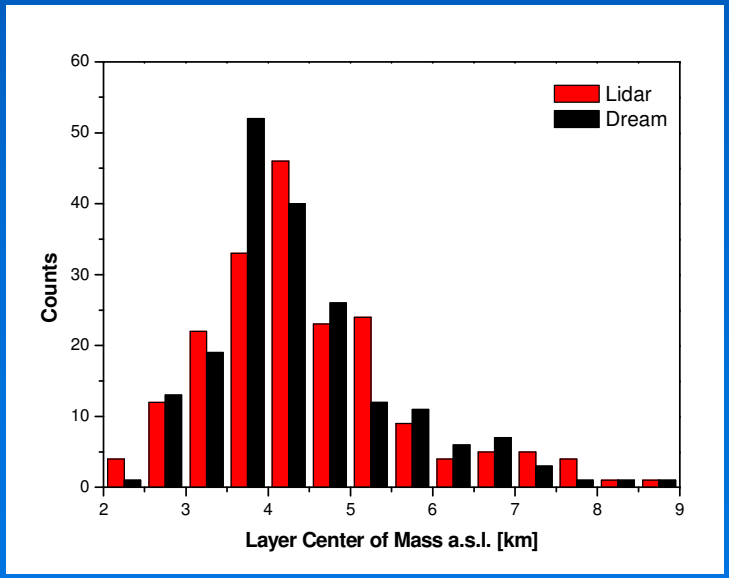
Geometrical properties



$Base_{Lidar}$ = (3.6 ± 0.9) km
$Base_{Dream}$ = (3.2 ± 0.9) km

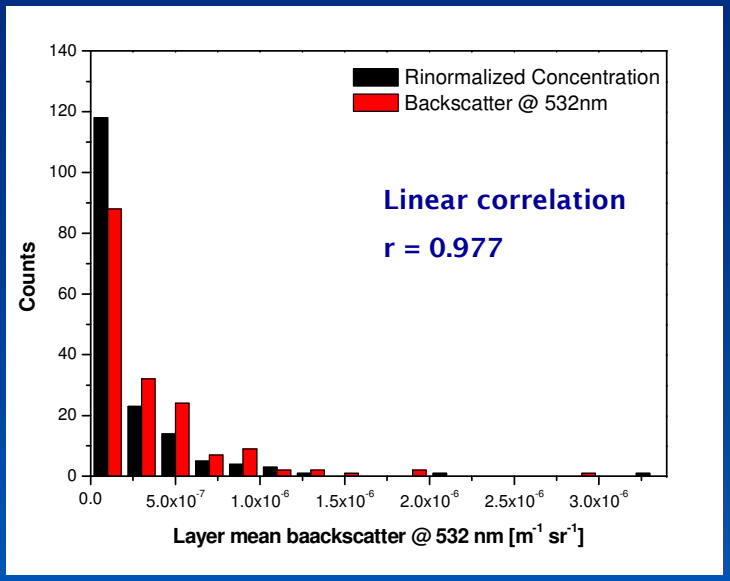


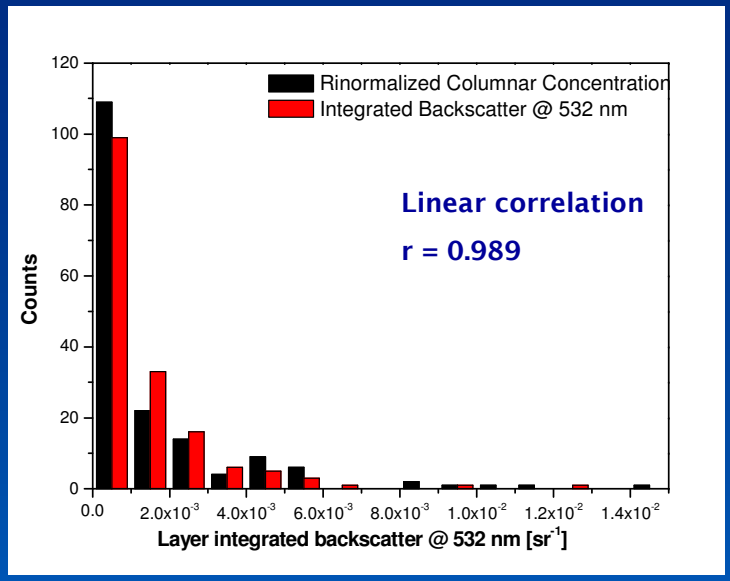
Top_{Lidar} = (8.5 ± 1.8) km
Top_{Dream} = (11 ± 2) km

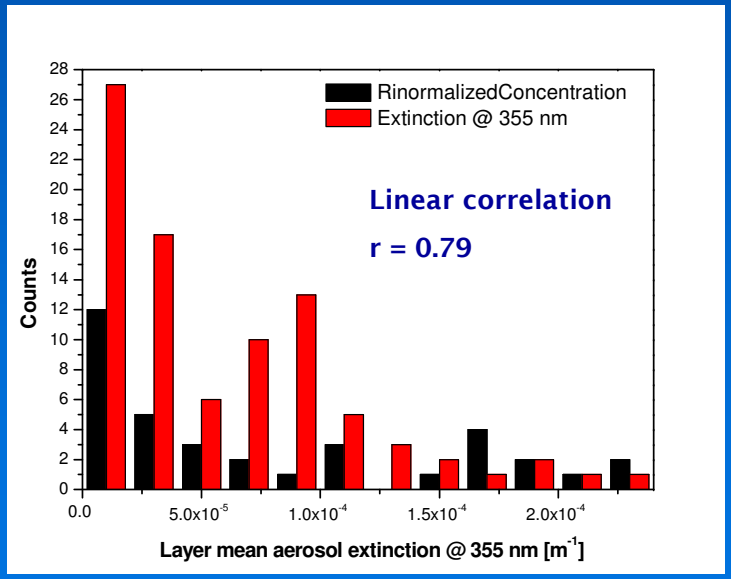


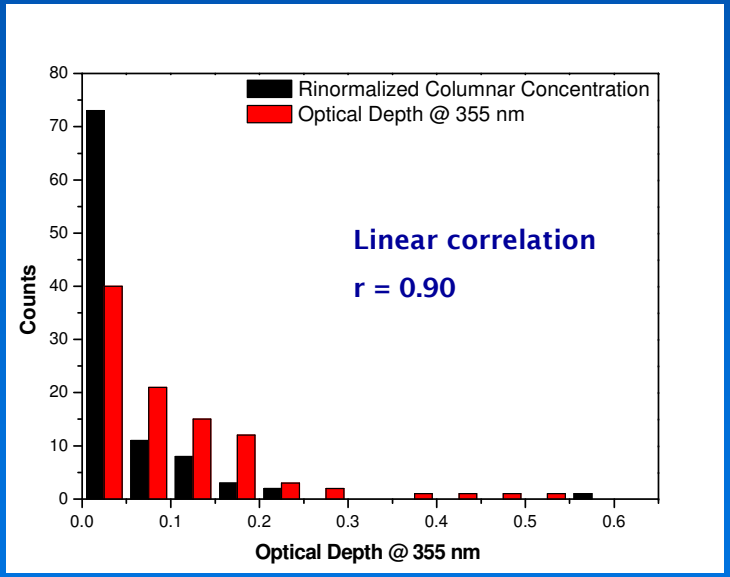
CDM_{Lidar} = (4.5 ± 1.2) km
CDM_{Dream} = (4.4 ± 1.1) km

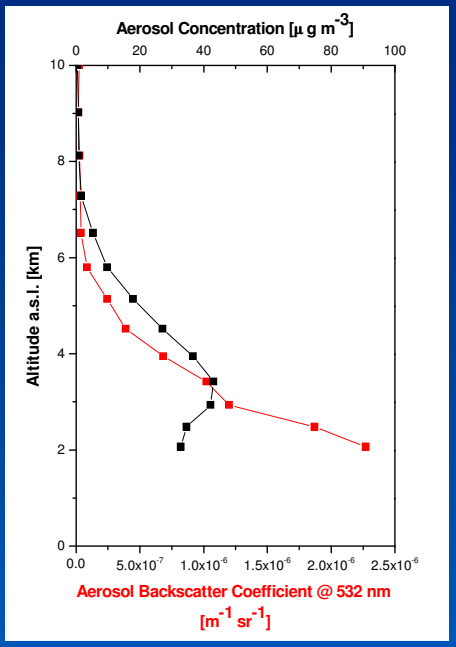
Extensive properties

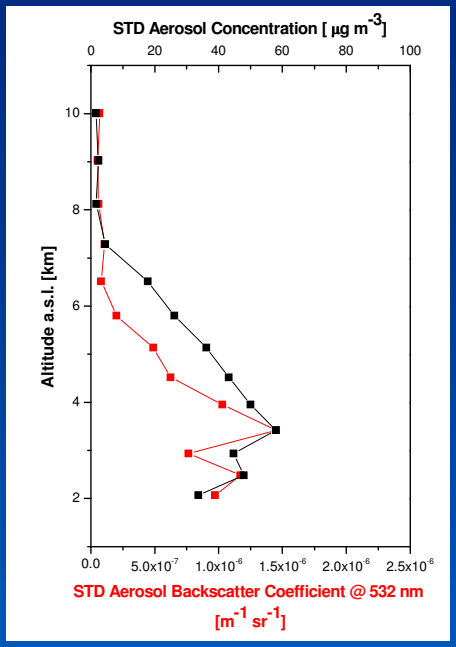






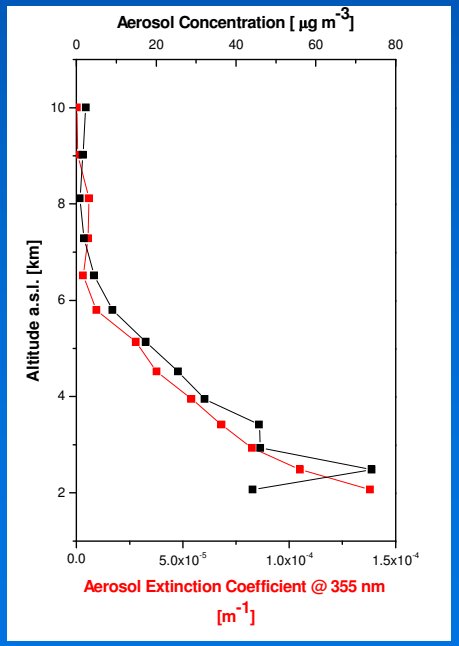


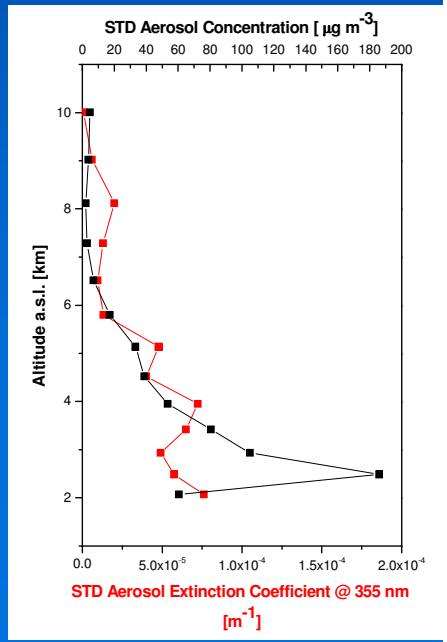




Backscatter profiles

Extinction profiles





EARLINET programs in support to current and future satellite missions

- ESA "Aerosols and Clouds: Long Term Database from Spaceborne Lidar Measurements" (2008-2010)
- ESA *VALID* (2008-2013) "MULTI-MISSION QUALITY ANALYSIS BY LIDAR"

The objective of this project is to provide the input for geophysical validation of atmospheric products from multi-mission validation activities, using ground-based lidars.

- ESA *CEOS (Committee on Earth Observation Satellites) intercalibration of groundbased spectrometers and lidar* (2008 – 2013)

Support for inter-comparison campaigns for EARLINET stations for reference EARLINET dataset to be used for long-term multi-mission calibration/validation.

GALION – the GAW Aerosol Lidar Observation Network

The objective:

The GAW aerosol program strives "to determine the spatio-temporal distribution of aerosol properties related to climate forcing and air quality up to multidecadal time scales".

The specific objective of GALION is to provide the vertical component of this distribution through advanced laser remote sensing in a network of ground-based stations.

The aerosol properties to be observed include the identification of aerosol layers, profiles of optical properties (backscatter and extinction coefficients at selected wavelengths, lidar ratio, Ångström coefficients), aerosol type (e.g. dust, maritime, fire smoke, urban haze), and microphysical properties (e.g., volume and surface concentrations, size distribution parameters, refractive index).

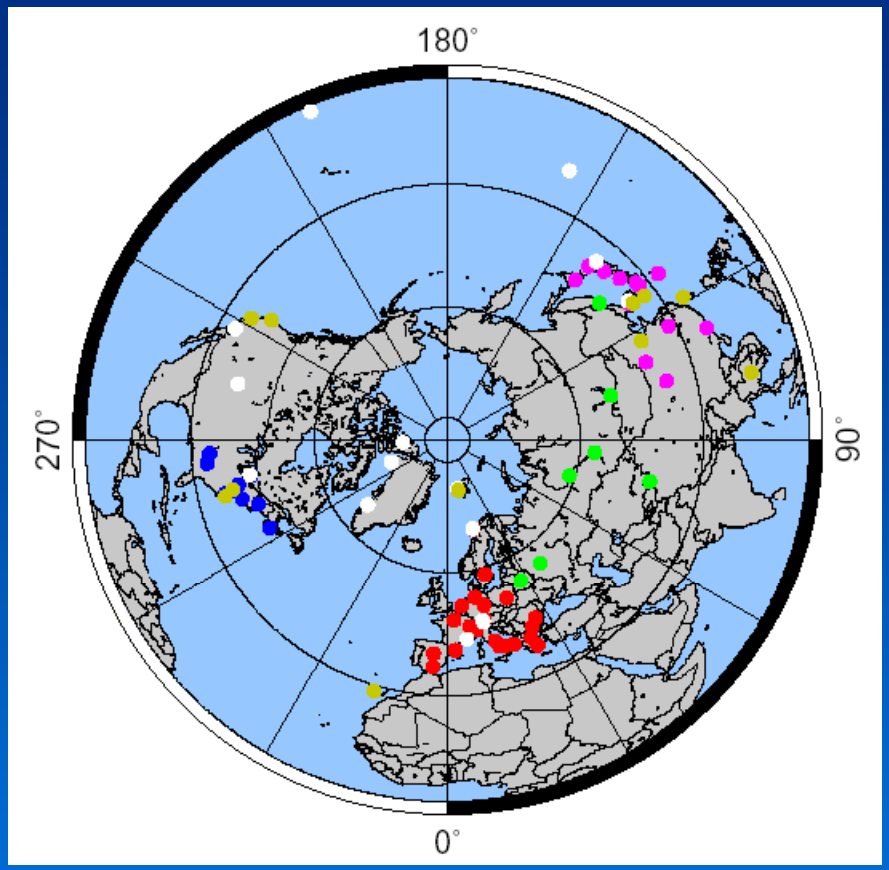
The operation will be designed to serve the following main areas:

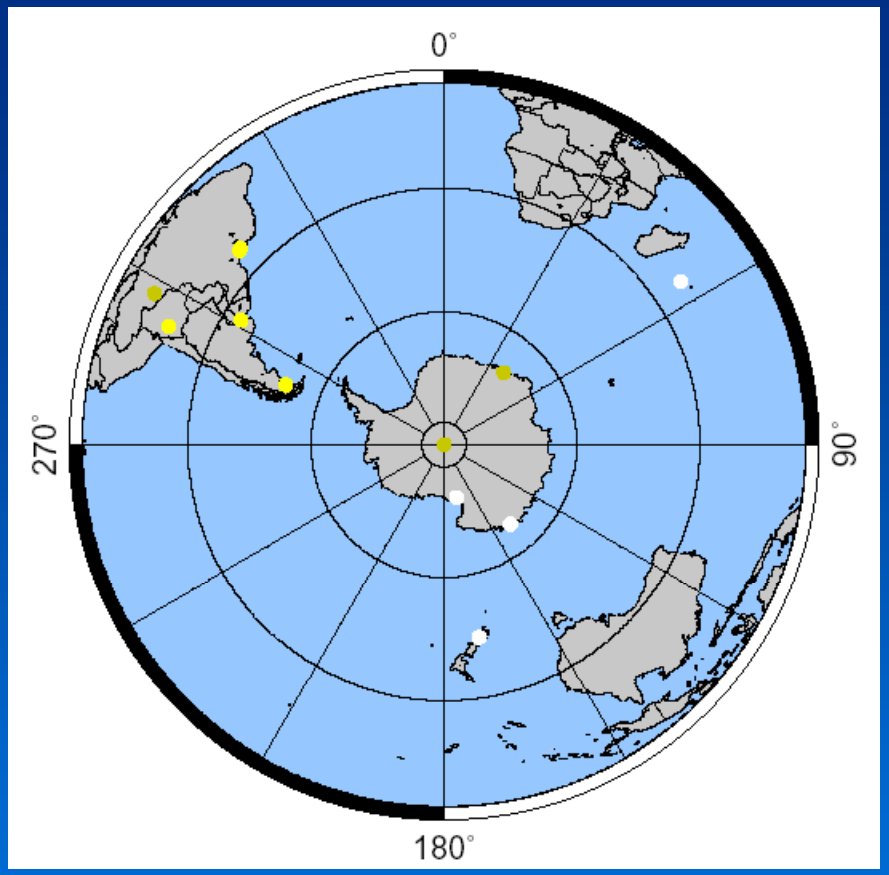
1. Climate research and assessment
   - 1.1 Global climatology
   - 1.2 Model evaluation
   - 1.3 Aerosol transport and tracers
   - 1.4 Impact on radiation, particularly UV, direct effect
2. Air quality
   - 2.1 Air quality assessment
   - 2.2 Air quality forecast
3. Plumes from special events
4. Support for spaceborne observations

GALION is organized as a Network of Networks, coordinating

- ALINE, Latin America
- AD-Net, East Asia
- CIS-LINET, Commonwealth of Independent States
- EARLINET, Europe
- NDACC, Global Stratosphere
- REALM, Eastern North America
- MPLNET, Global, Micropulse Lidar

Distribution of stations





- ALINE, Latin America
- AD-Net, East Asia
- CIS-LINET, Commonwealth of Independent States
- EARLINET, Europe
- NDACC, Global Stratosphere
- REALM, Eastern North America
- MPLNET, Global, Micropulse Lidar

The GALION report has been published and is available at: *ftp://ftp.wmo.int/Documents/PublicWeb/arep/gaw/gaw178-galion-27-Oct.pdf*

Of course there are plans to harmonize "everything" among the networks, but this will take some time and be successful in part only.

The important decision already made is that a regular measurement scheme is implemented for establishing a climatology, tentatively following the EARLINET scheme.

A GALION mailing has been established.

An alerting system for special events has been established.

Summary and perspectives

- *Strong need for integrated long term aerosol observations*
- *4-dimensional space-time distribution of aerosols*
- *aerosol profiling → LIDAR → EARLINET*
- *cooperation and coordination with the relevant observation and user communities*
- *contribution to the implementation of the WWRP/GAW SDS WS*
- *support to current and future satellite missions with lidar onboard*
- *GALION*

ACKNOWLEDGEMENT

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NASA for MODIS images

Maltese Euromediterranean Center (ICoD) and Barcelona Supercomputing Center for Dust Regional Atmospheric Model (DREAM)

The CALIPSO team of the NASA Langley Research Center for the provision of the CALIPSO ground track data

CALIPSO data were obtained from the NASA Langley Research Center Atmospheric Science Data Center