EARLINET
The European Aerosol Research Lidar Network: Methods and Instruments

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- **Motivation**
- **Objectives**
- **Methodology**
- **Implementation**

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Motivation: Aerosol Research

Aerosols have important effects on human life:

- **Aerosols can be toxic, by composition or by structure (size or shape).**
  Many aerosol-induced diseases have been identified.
- **Ecosystems are affected by significant mass transport.**
  Eutrophication of lakes and seas
- **Aerosols influence atmospheric chemistry by providing reactive surfaces.**
  Stratospheric ozone depletion.
- **Aerosols affect the radiation budget and hence temperature distribution within the atmosphere and on the ground, including change in spectral distribution.**
  The details depend strongly on type and vertical distribution
- **IPCC has identified the effect of aerosols on climate as one of the most uncertain contributions:**
  Climate is affected directly by scattering and absorption
  Climate is affected indirectly by changing cloud formation and properties
- **Aerosol masking strongly influences spaceborne remote sensing, negatively affecting or prohibiting retrieval of any surface parameter**

Motivation: Lidar Network

Why measurements?

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!

Why lidar?

- **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.**

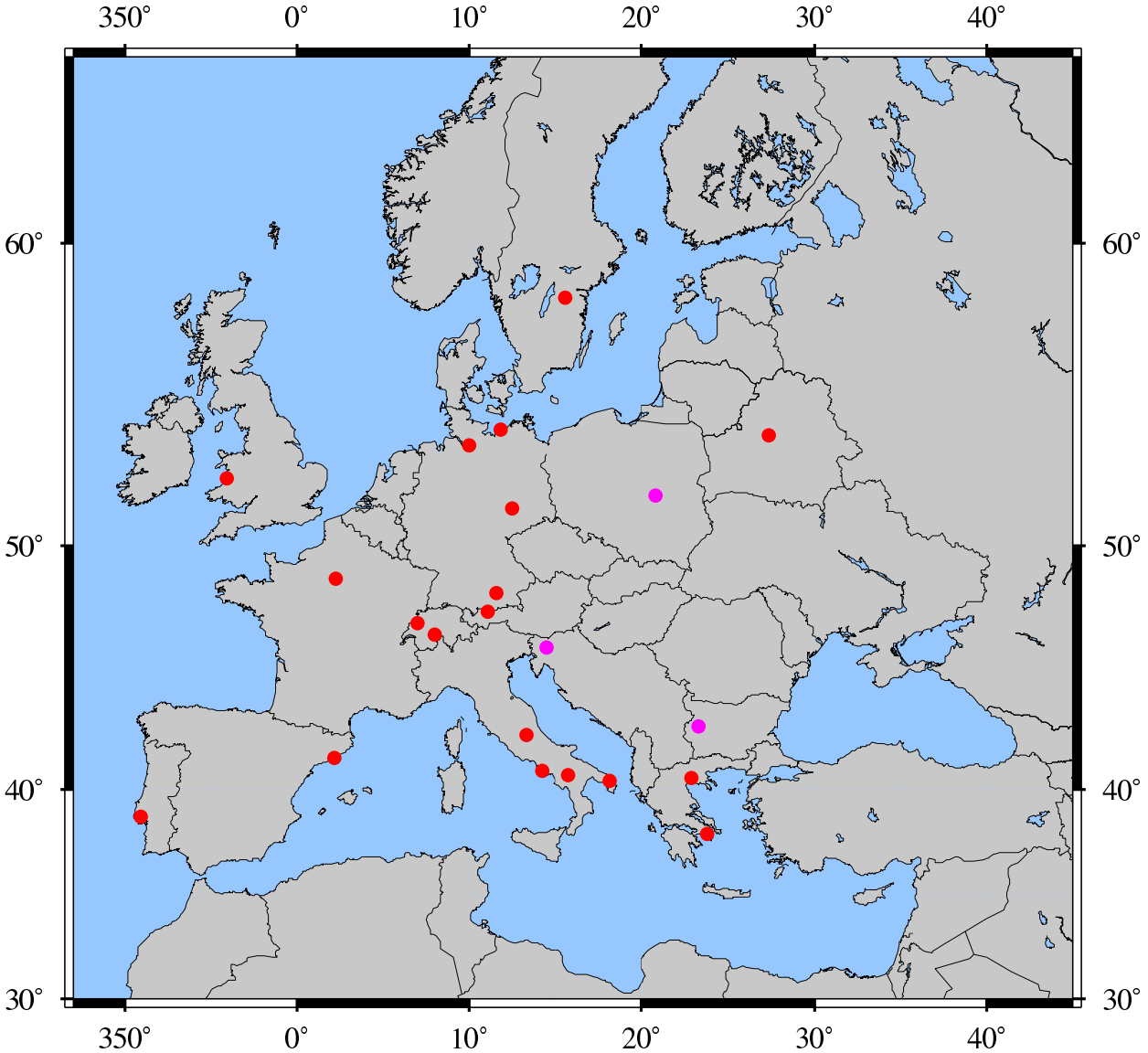
Why Network?

- **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!**

Objectives

- **Establish a climatology of the aerosol distribution on a continental scale:**
  - **layer structure,**
  - **optical properties (extinction, optical depth, backscatter),**
  - **phenomenology or microphysics.**
- **Identify and quantify sources of aerosol.**
- **Assess the effect on the radiation budget, in particular in the UV.**
- **Assess the importance of special events (Saharan dust, forest fires, etc.).**
- **Assess the importance of long range transport.**
- **Provide ground truth for spaceborne remote sensors.**

EARLINET



Methods

Quantitative retrieval of aerosol parameters from lidar measurements.

Backscatter lidar: $\frac{d}{dR} ln(P \cdot R^2) = \frac{d}{dR} ln\, \beta - 2\alpha$ **Is NOT quantitative!**

Raman lidar: $\frac{d}{dR} ln(P \cdot R^2) = \frac{d}{dR} ln\, \beta_R - 2\alpha$ **Weak signals!**

Scanning lidar: $\frac{d}{dR} ln \left(\frac{P_{\varphi_1}}{P_{\varphi_2}} \right) = -2 \frac{cos\varphi_2 - cos\varphi_1}{cos\varphi_2 \cdot cos\varphi_1} \alpha$ **Homogeneity required!**

Station no.	ab	at	ba	gp	hh	ju	kb	la	lc	le	li	lk	mi	mi.2	mu	na	ne	pl	po	th
Detection channels																				
elastic backscatter																				
solar blind UV					u															x
UV	x	x		x	x	x	x	x	x	x		x	x	u	x	x	x		x	u
VIS		x	u	x	x	x	x			x	u		x	x	x		x	x	x	u
IR			x	x	x	x	x			x	u	u	x	x	x		x	x		
N_2 Raman scattering																				
solar blind UV					x															
UV	x	x			x	x	x	x	x	x				x		x			x	x
VIS			x			x	x			x										
water vapor channel	x				u	x	u	x	u	x										
temperature channel						u	x			x										
depolarisation channel					u	x	x			x							x	x		
scanning capability			x	x					u		x	x	x	x	x					x
system transportable			x	x	x						x	x			x		x			x
altitude limit low	0.5	0.5	.25	0.2	0.3	4.0	1.0	0.3	0.4	0.3	0.3	0.1	0.1	0.5	0.2	.25	1.0	0.5	1.2	0.7
altitude limit high	8.0	7.0	10.	10.	9.0	11.	35.	12.	7.0	12.	5.0	10.	30.	10.	5.0	3.0	10.	15.	8.0	8.0
range resolution (raw)	30	7.5	7.5	15	15	7.5	50	300	15	60	1.5	7.5	15	15	3.75	15	30	15	15	7.5
time resolution (raw)	330	360	1800	10	10	100	33	300	180	30	1	.1	10	200	0.1	60	200	10	60	240

Table 1: Overview over main system characteristics.

ab	Aberystwyth	at	Athens	ba	Barcelona	gp	Garmisch-Partenkirchen	hh	Hamburg
ju	Jungfraujoch	kb	Kühlungsborn	la	L'Aquila	lc	Lecce	le	Leipzig
li	Lisboa	lk	Linköping	mi	Minsk	mu	München	na	Napoli
ne	Neuchâtel	pl	Palaiseau	po	Potenza	th	Thessaloniki		

Organisation

Main common tasks:

- **Routine measurements at fixed dates, 3 per week (on 2 days)**
- **Compilation of aerosol profile data, extinction and backscatter**
- **Compilation of back-trajectory data**

Task groups for special investigations:

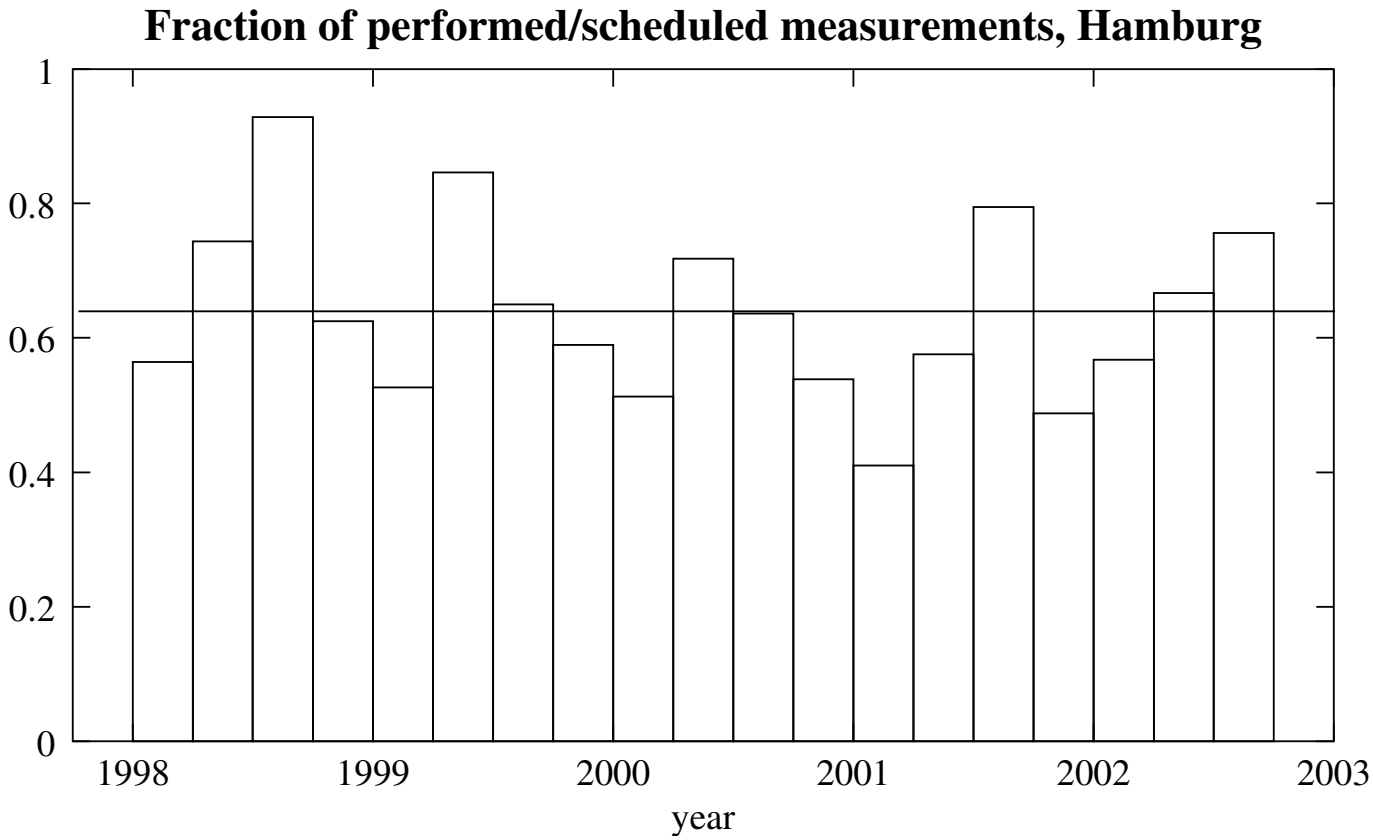
Quality assurance, instruments	**Matthias, Freudenthaler**
Quality assurance (instruments, algorithms)	**Böckmann, Pappalardo**
Temporal cycles (diurnal, weekly, annual)	**Pelon**
Observation of special events (Saharan dust, forest fires)	**Papayannis**
Impact on satellite retrievals	**Wiegner**
Air mass modification processes	**Ansmann**
Orography and vertical transport	**Trickl**
Stratospheric aerosol	**Calpini**
Differences rural-urban aerosols	**Pelon**
UV-B radiation and aerosol optical properties	**Balis**
Statistical analysis	**Bösenberg**
Compilation of "lidar ratio" data base	**Pappalardo**
Analysis of source regions	**Trickl**
Microphyscal retrieval algorithms	**Böckmann**

Climatology from routine measurements

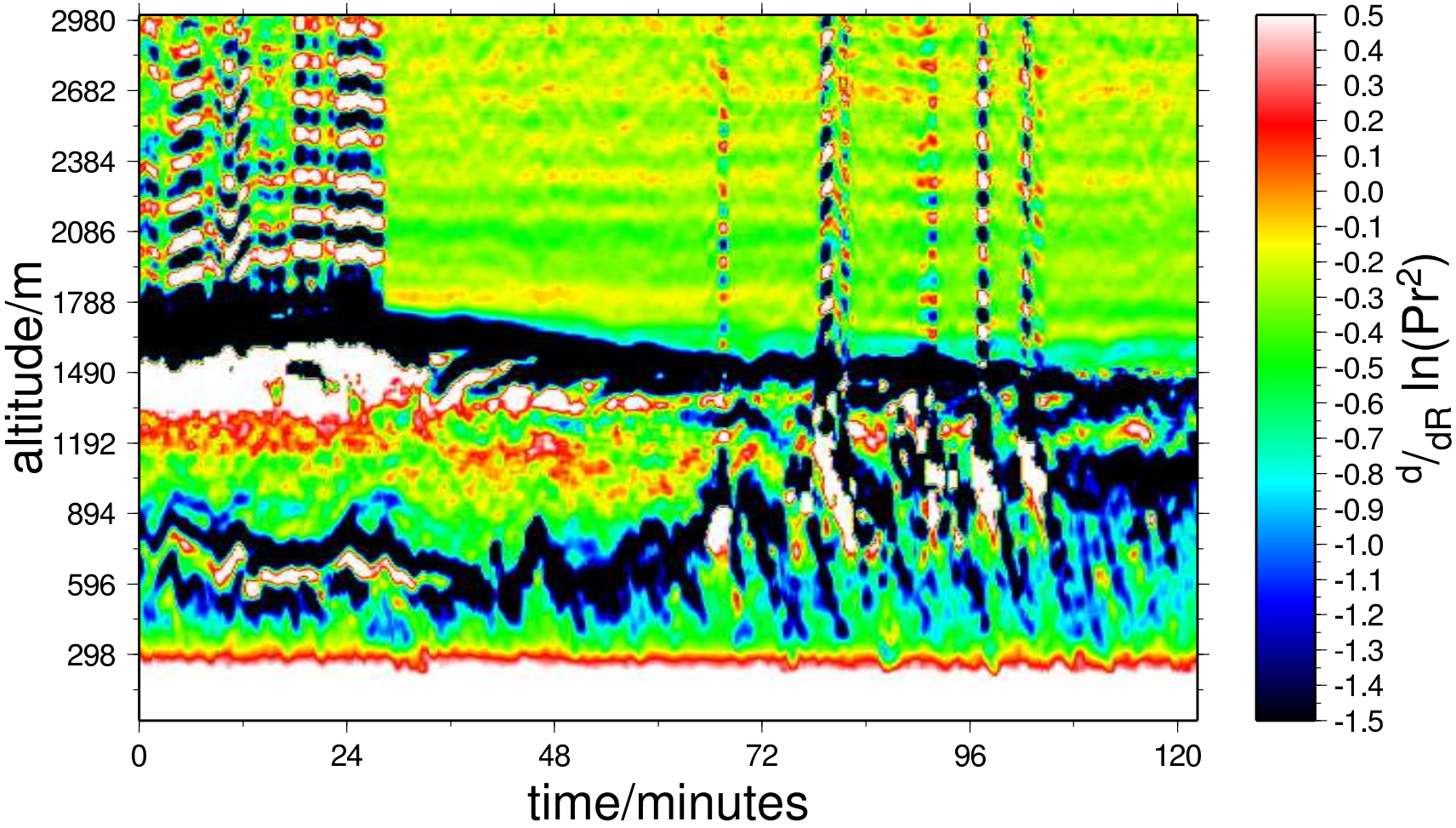
Essential for climatology: unbiased sampling.

- **Bias can be totally avoided only by continuous operation. Was impossible for EARLINET!**
- **Substitute: Operation on predetermined dates. (3 times per week on 2 days).**
- **Potential bias from diurnal cycle.**
- **Careful choice of observation time. Special measurements of diurnal cycle.**
- **Potential bias from weekly cycle.**
- **Probably not important. To be studied.**
- **Potential bias from weather conditions. Lidar is suspected to be ”sunshine instrument”.**
- **Inspect statistics! How important is aerosol during precipitation?**

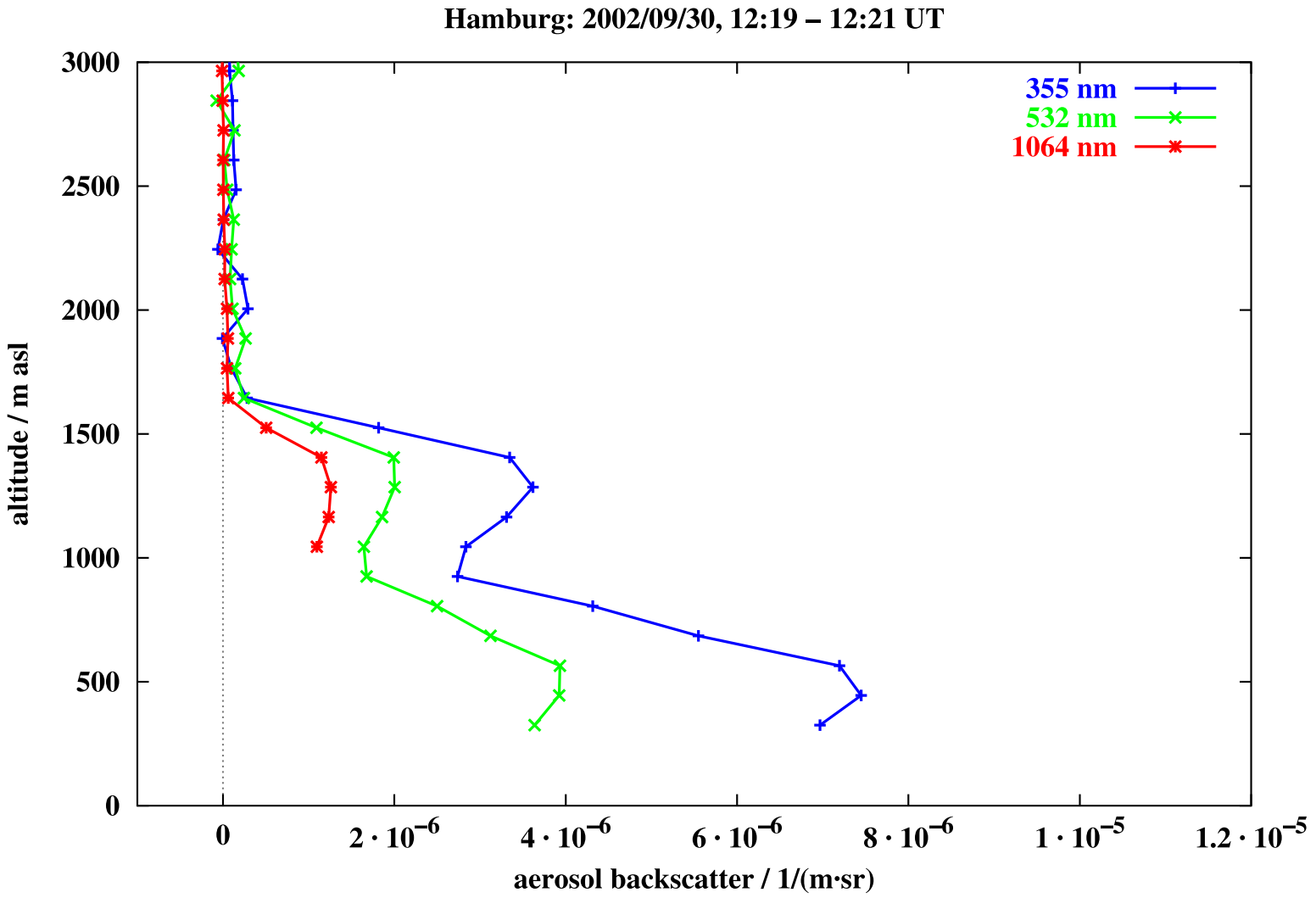
Sunshine Instrument?



Clouds below 2 km : 17 %



$^{d}/_{dR}$ ln(Pr^2), λ = 355 nm, starting time 30.09.02 11:06 UT


Hamburg: 2002/09/30, 12:19 – 12:21 UT
355 nm
532 nm
1064 nm
altitude / m asl
3000
2500
2000
1500
1000
500
0
0
2 · 10−6
4 · 10−6
6 · 10−6
8 · 10−6
1 · 10−5
1.2 · 10−5
aerosol backscatter / 1/(m·sr)

Compilation of extinction and backscatter profiles.

Data set:

- **Distributed collection rather than central data base. Full responsibility of owner.**
- **Mirrored at MPI, including some consistency checks.**
- **Common format: netcdf with standard parameter names.**
  - **flexible**
  - **self-describing**
  - **platform independent**
  - **professionally maintained**
- **standard filenames**
- **separate extinction and backscatter files**

Advantage: **fosters early availability of preliminary results. Essential for startup phase.**

Disadvantage: **not user-friendly. Need to improve for user phase.**

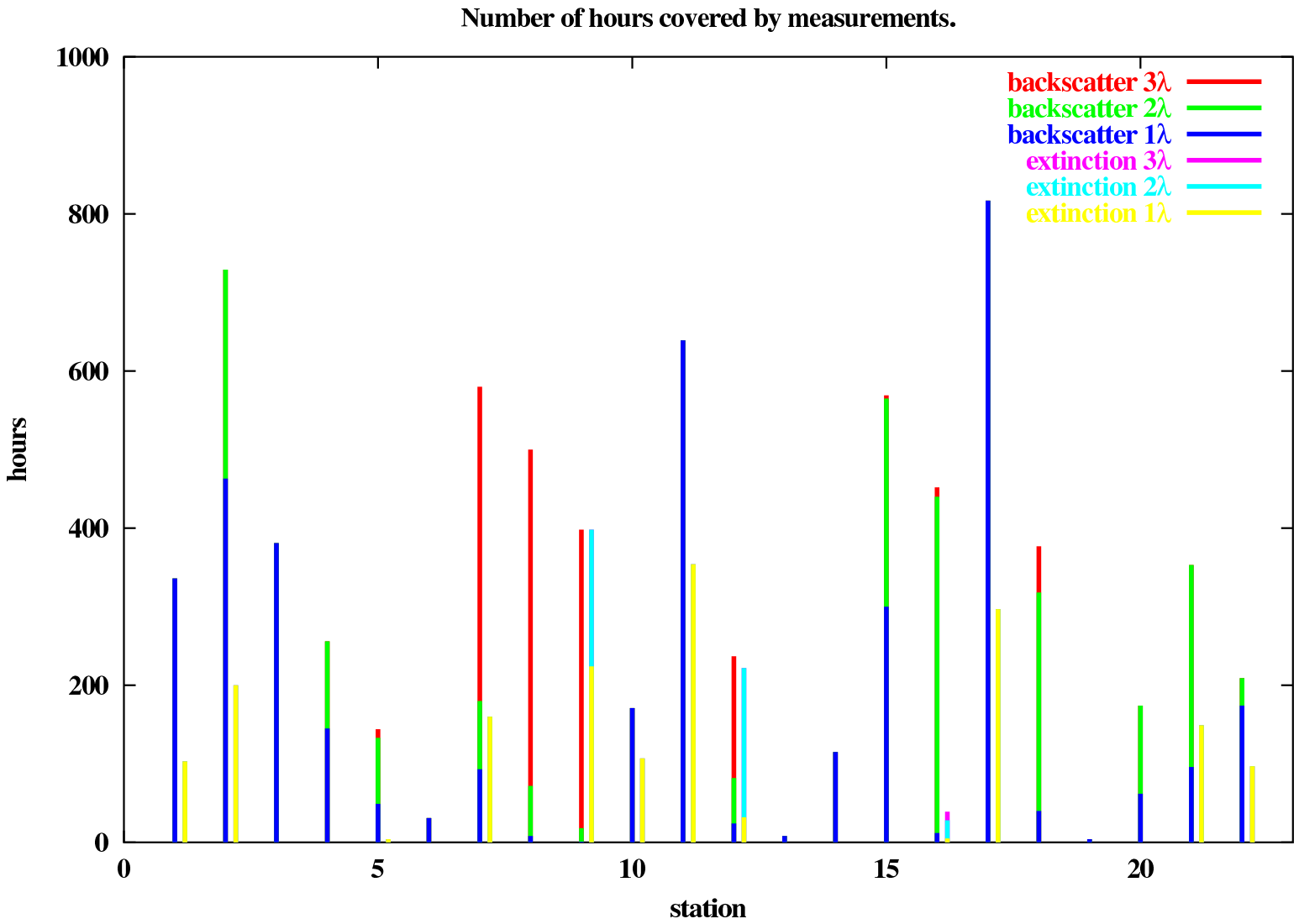
Compilation of extinction and backscatter profiles.

Before January 31, 2003 we collected

- **13530 files with backscatter and/or extinction profiles**
  - **4906 files for the climatology**
  - **1985 files for Saharan dust studies**
  - **1651 files for studies of the diurnal cycle**
- **7678 hours covered by measurements**
- **2130 hours covered by true extinction measurements**

But: very inhomogeneous distribution in time, space, and wavelengths!

More continuous measurements are needed!


Number of hours covered by measurements.
backscatter 3λ
backscatter 2λ
backscatter 1λ
extinction 3λ
extinction 2λ
extinction 1λ
hours
station
0
200
400
600
800
1000
0
5
10
15
20

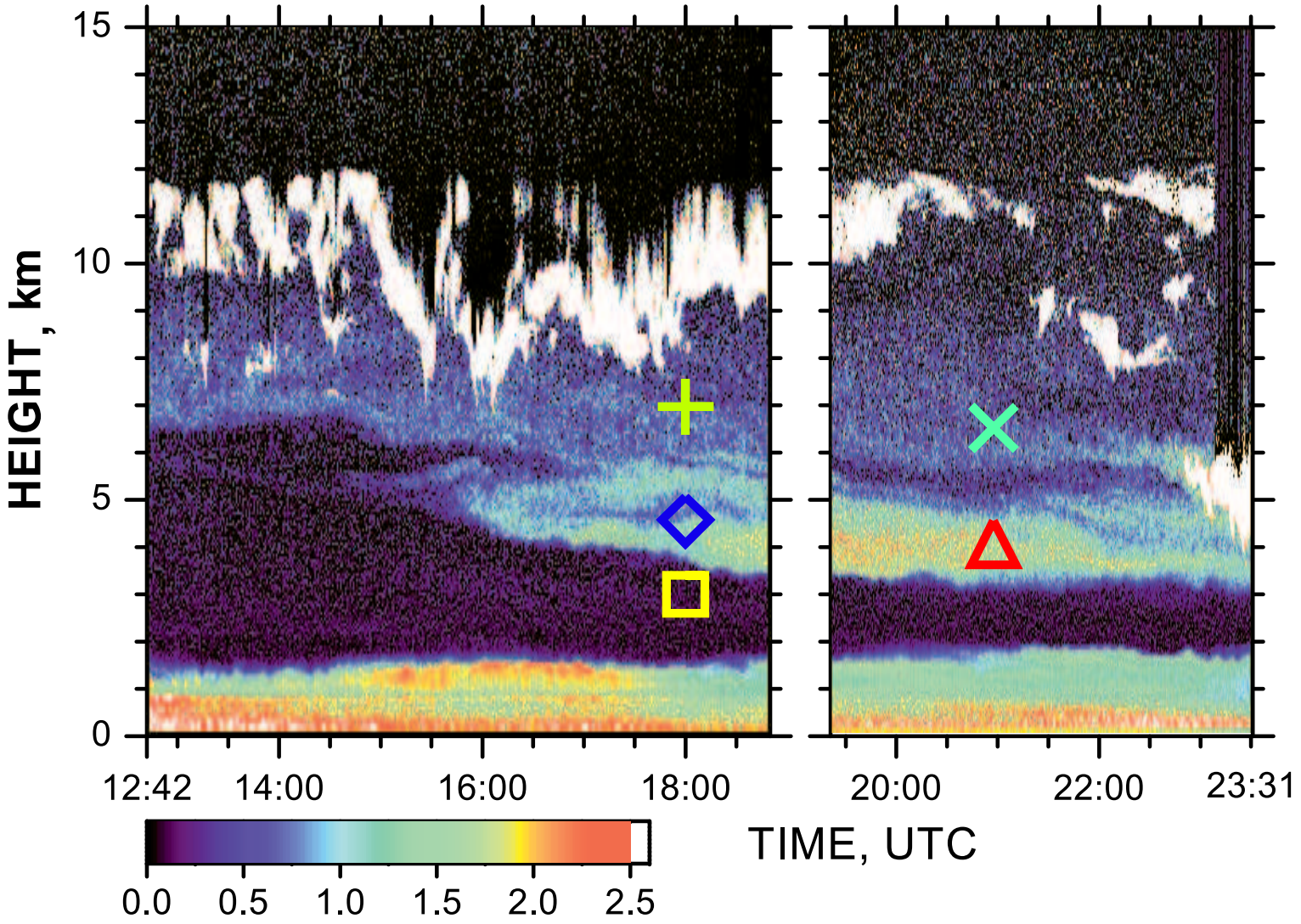
Compilation of back-trajectories

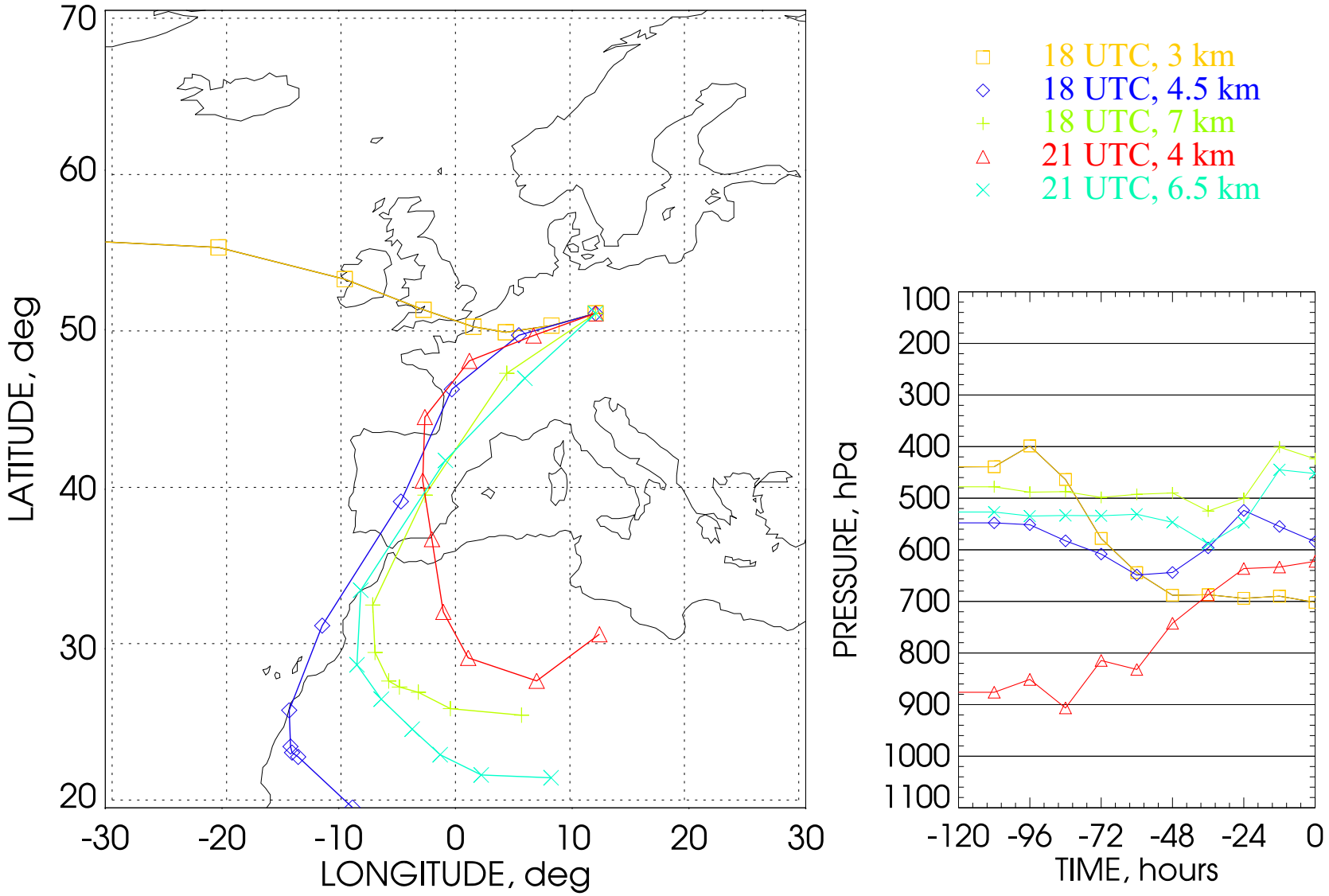
History of airmass characterised by backtrajectories.
Produced centrally by DWD, stored by IfT Leipzig. DWD support is much appreciated!

- **All stations, 2 times a day**
- **6 levels**
- **diagnostic 96 hours back**
- **prognostic 48 hours in advance (for experiment planning)**
- **software package for display**
- **used for case studies**
- **cluster analysis**

Special trajectories can be provided (cooperation with A. Stohl, TU München) with

- **longer history**
- **selectable arrival altitude**
- **selectable arrival time**


HEIGHT, km
15
10
5
0
12:42
14:00
16:00
18:00
20:00
22:00
23:31
TIME, UTC
0.0
0.5
1.0
1.5
2.0
2.5


18 UTC, 3 km
18 UTC, 4.5 km
18 UTC, 7 km
21 UTC, 4 km
21 UTC, 6.5 km
LATITUDE, deg
70
60
50
40
30
20
-30
-20
-10
0
10
20
30
LONGITUDE, deg
PRESSURE, hPa
100
200
300
400
500
600
700
800
900
1000
1100
-120
-96
-72
-48
-24
0
TIME, hours

Summary

EARLINET uses

- **quantitative lidar techniques**
- **quality controlled instruments**
- **quality controlled evaluation algorithms**
- **routine measurements on regular schedule**
- **extra measurements for special situations**
- **common set of backtrajectories**
- **distributed data base**

EARLINET has implemented the necessary infrastructure to collect aerosol profiles in systematic and quality controlled way. A large data set is accessible for extended studies.