LIDAR SYSTEMS
AND RETRIEVED ATMOSPHERIC PARAMETER

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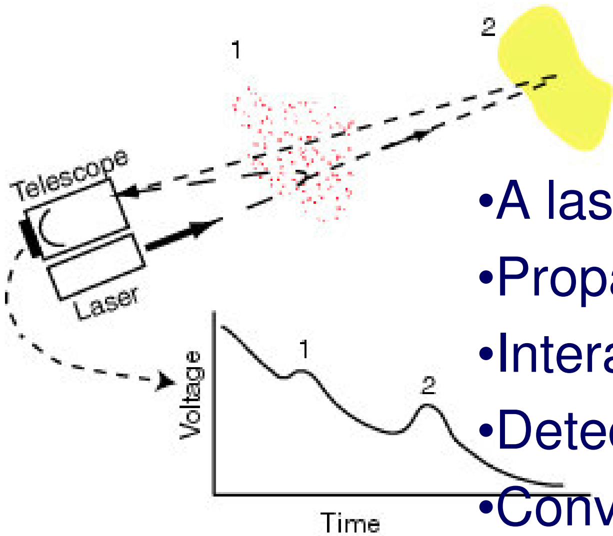
LIDAR : DEFINITION

The light detection and ranging (LIDAR) system is similar to Radar in that a pulse of energy is emitted and returned energy analyzed for elapsed time between emitted and received pulses. The major difference is the frequency of emitted energy. Radar uses high range radio frequencies which will reflect from any object that conducts electricity. The LIDAR system uses light energy in the near-infrared region. An additional factor is the effect of light scattering according to the type of reflecting object.

Elapsed time between transmission of a light pulse and backscattered energy is used to establish the distance to the reflecting object.

Lidar principle



•A laser emits a pulse of light lasting dt (10ns)

•Propagation into the atmosphere.

•Interaction with molecules, aerosols, ice and water clouds.

•Detection of backscatter signal by the receiver optics.

•Conversion of radiation into electronic signal (PDA or PMT)

•Translation into temporal and spatial information.

•Some exemple of IPSL lidar activities can be found at :

• **nemo.lmd.polytechnique.fr/~Lidar**

•**www.aero.jussieu.fr**

Lidar systems

Rayleigh scattering	Laser radiation elastically scattered from atoms or molecules $\lambda_e=\lambda_r$	Backscatter lidar molecular backscatter profile
Mie scattering $\lambda_e=\lambda_r$		Backscatter lidar aerosols, clouds
Rayleigh -Mie		HSR Llidar
Raman scattering $\lambda_e \neq \lambda_r$		Raman lidar $H_2 0$, N_2, others
Fluorescence		Fluorescence lidar
Absorption $\lambda_{1,}\ \lambda_2$		DIAL system O_3

Multiwavelength lidar

- Spectral dependence linked to particle microphysics
- Distinguish different types of aerosols in a given population (Sasano et Browell, 1989, Grant et al., 1997)
- Evaluate particle size (Uthe, 1982)
- Retrieve the particle size distribution (Wand et al., 1996; Müller et al., 1998)

HSRL

- Allow to discriminate the mie signal from the rayleigh signal using narrow spectral filters. Rayleigh signal is enlarged by doppler effect and particle signal is not.

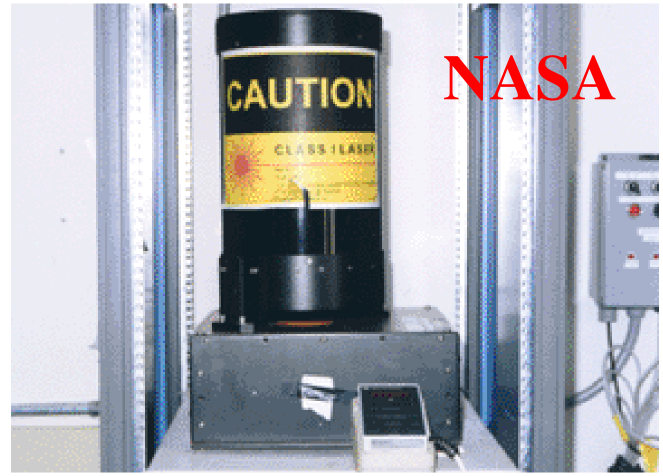
MICROLIDARS

CAML™ CE 370-1 specifications :

Transmitter	**Laser : Nd:YAG, SHG 532 nm**
Output wavelength	532 nm
Output energy per pulse	4 µJ
Repetition rate	5 kHz
Pulse duration	< 1 ns
Effective aperture	314 cm²
Field of view (full angle)	55 µrad
Filter bandwidth	0.5 nm
Detector	APD
Detection mode	Photon counting
Acquisition time	> 0.8 s
Vertical resolution	15 m
Size (diameter x height)	200 x 1000 mm
Weight	12.5 kg

is

CIMEL
www.cimel.fr



Main features :
- Eye safety
- **Self-alignement of the emission and reception axis**
- High detection range
- High temporel and vertical resolution (1s and 15m)
- Compact and portable

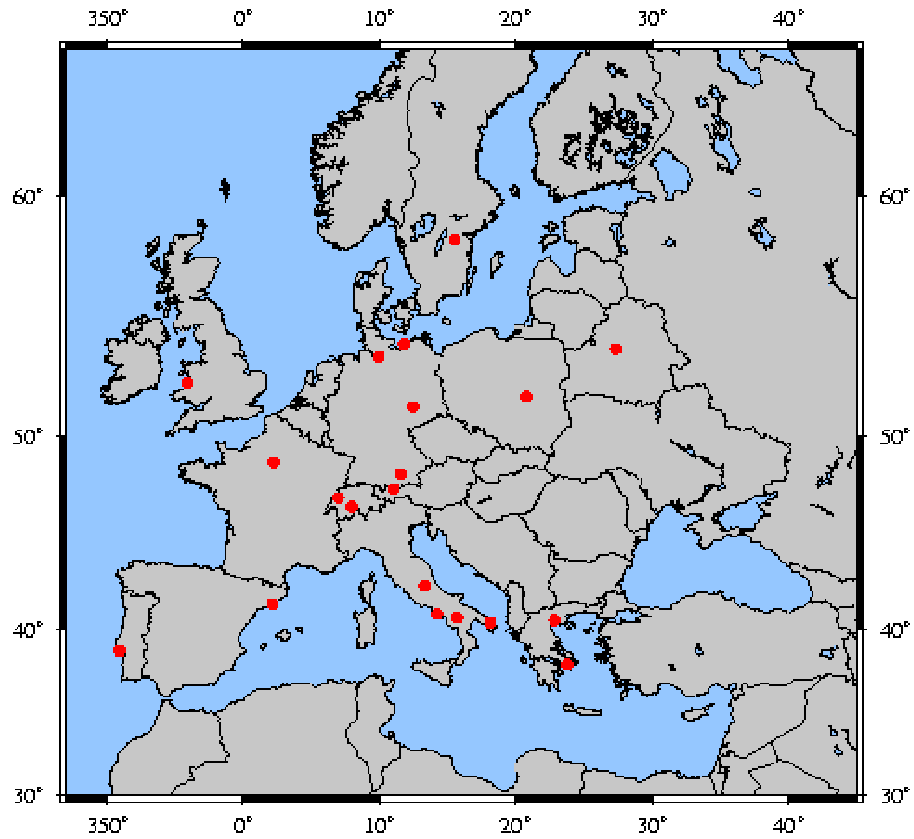
The Micropulse Lidar (MPL) has one measurement channel that records backscatter signals in 300 meter range bins, with the lowest valid range bin beginning at 120 meters above ground level, up to 20+ kilometers. The primary quantity obtained from this signal is the real-time reporting of the lowest detected cloud base in meters, obtained from 60 second averages.
Additional quantities possible through post-processing of the raw signal return include a relative backscatter profile (counts/sec/meter) with instrument effects removed. Instrument effects include a dead-time correction specific to the individual detector, near-range corrections for the overlap of the transmitting and detection optics, and removal of afterpulsing due to detector saturation from optical crosstalk as the pulse is transmitted.

LIDAR NETWORKS

- EARLINET , CLOUDNET (EU)
- ARM / GEWEX (US)
- ASIAN NETWORK (South Korea, Japan, China).
- MEDLINET (P.I. : PH. Flamant, EU)
- South american network for stratospheric measurements.

EARLINET

An aerosol 3D climatology (2000 – 2003)



21 lidar stations
11 raman lidar

<u>Main achievements</u> :

-Establish a lidar network at the regional scale (Europe) allowing to create an homogeneous database for :

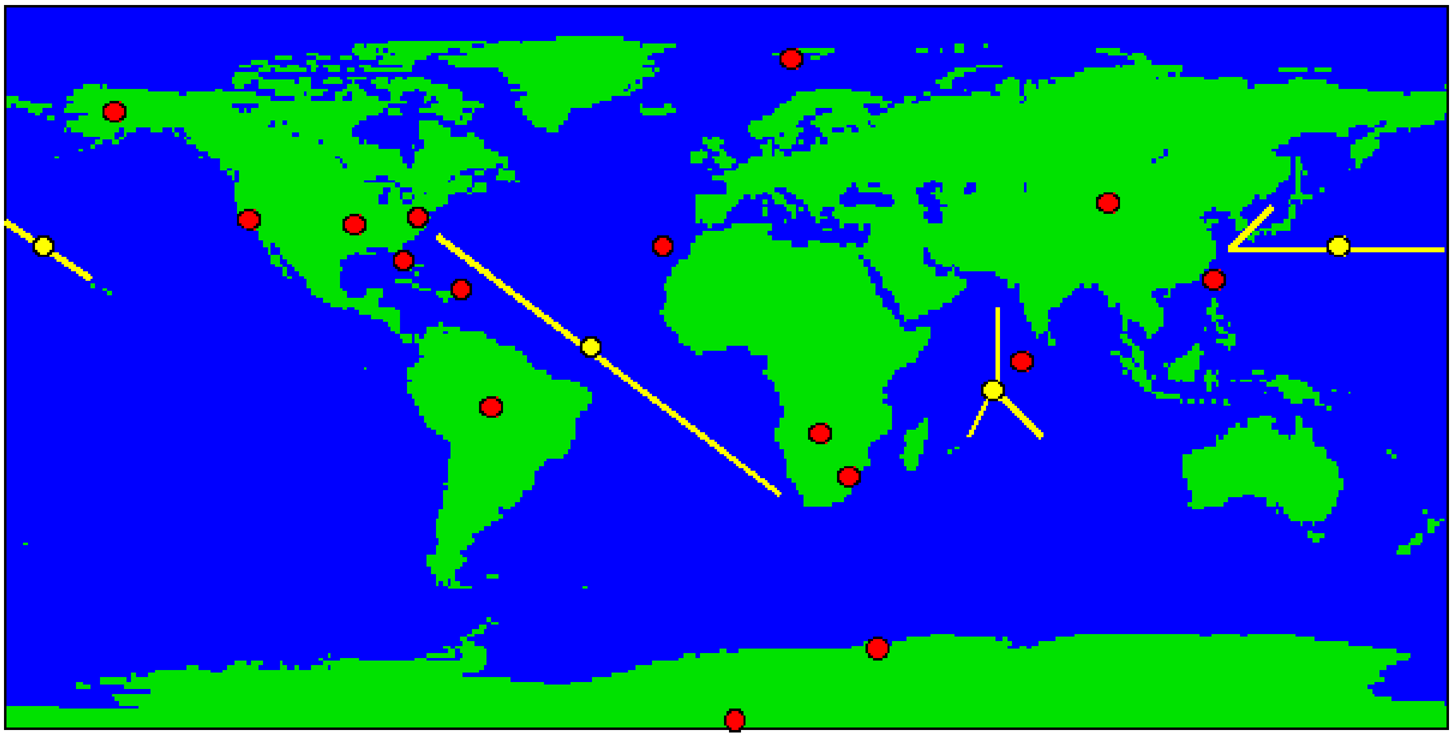
- Climatologic analysis of spatial distribution of aerosols and their radiative properties.

- Identification of different kind of aerosols, characteristics of transport above Europe, sources and tinks.

- Validation of spatial measurements

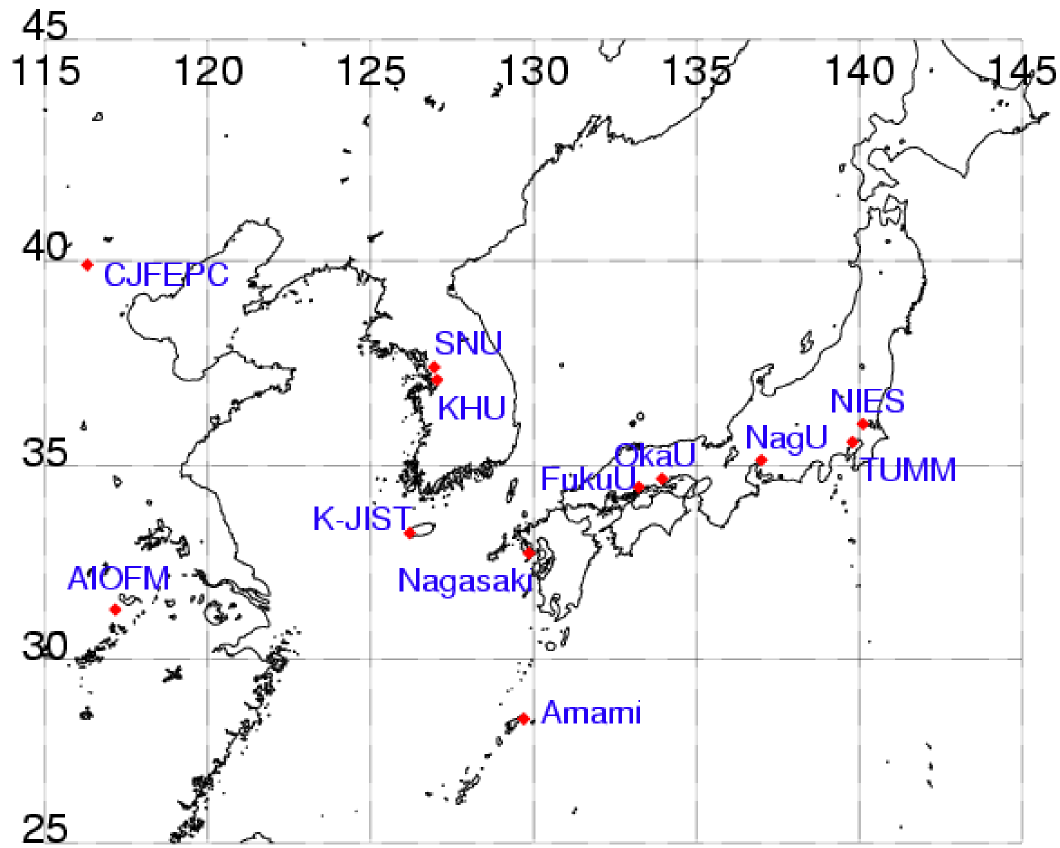
- Use for inputs in models of pollution and climate.

MPL network

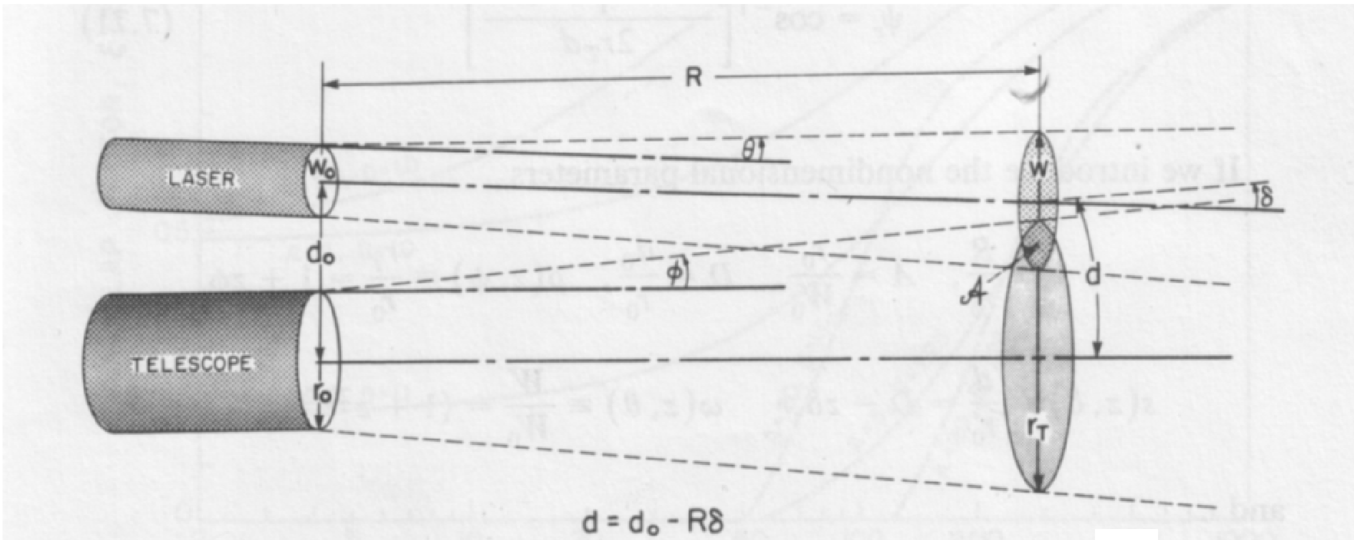


ASIAN DUST network

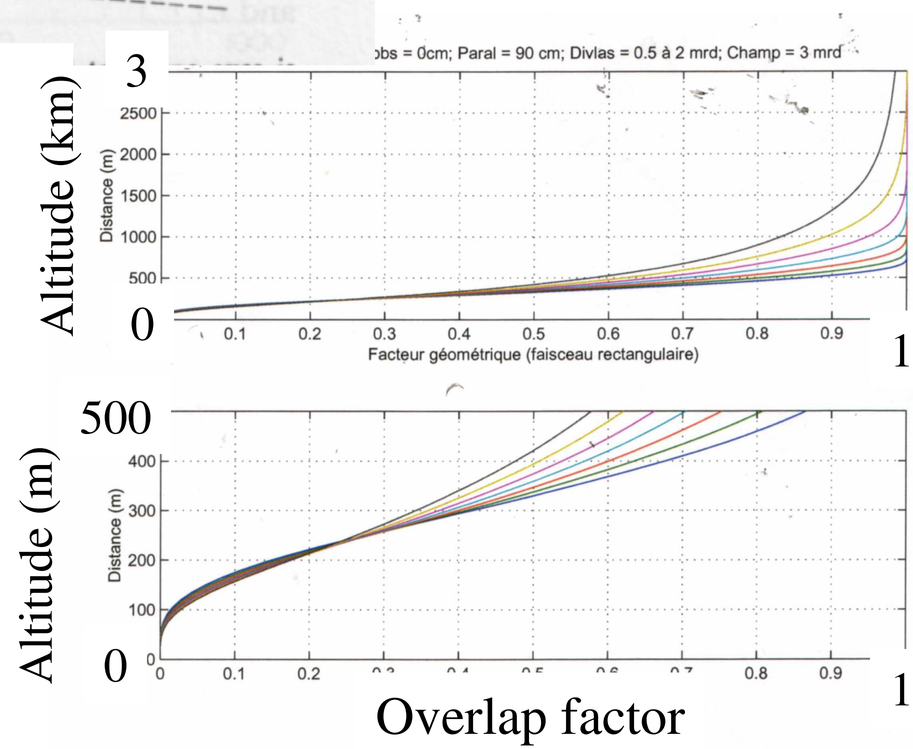
10 stations
With backscatter lidar and depolarization capabilities



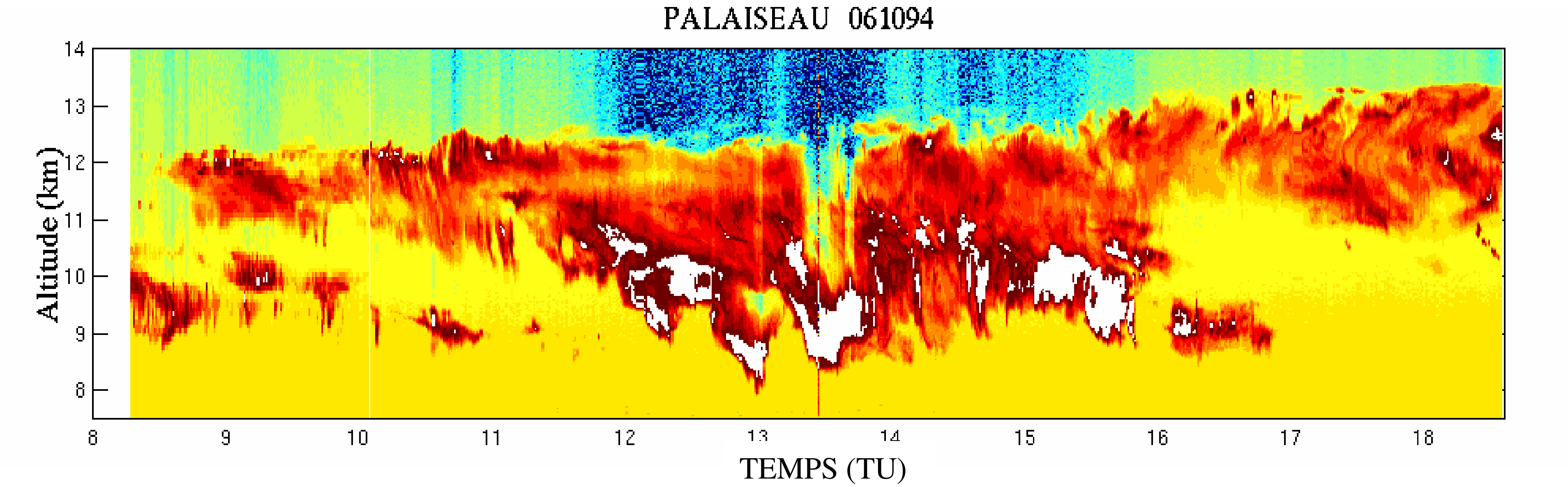
OVERLAP FACTOR



Overlap functions calculated for biaxial configuration
And several beam divergence values.

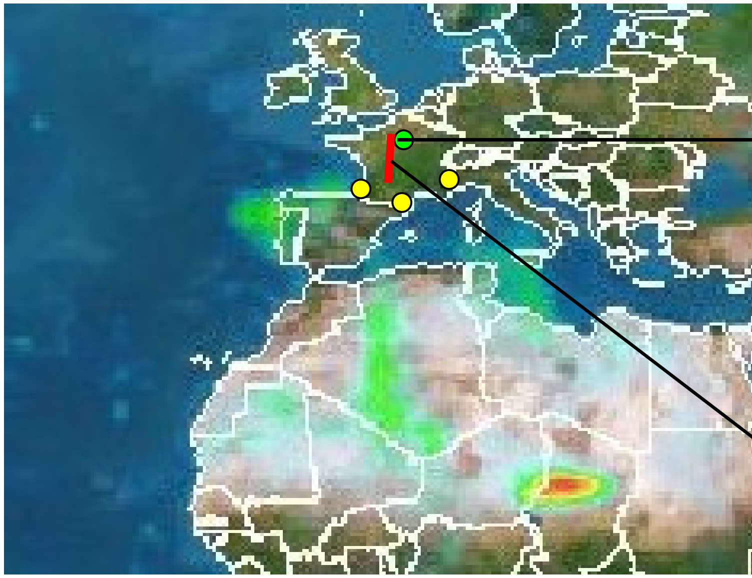


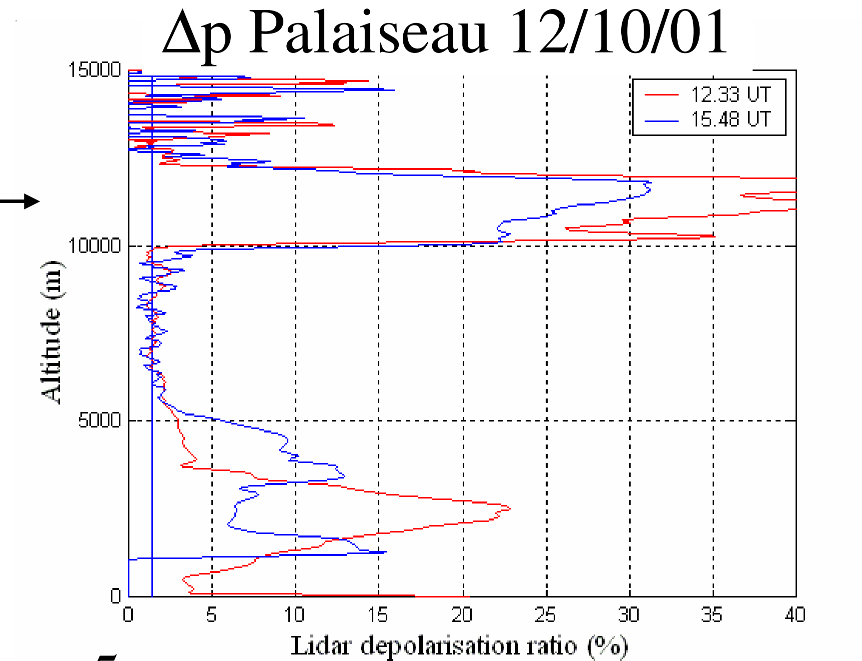
Retrieval of cloud parameters from backscatter lidar

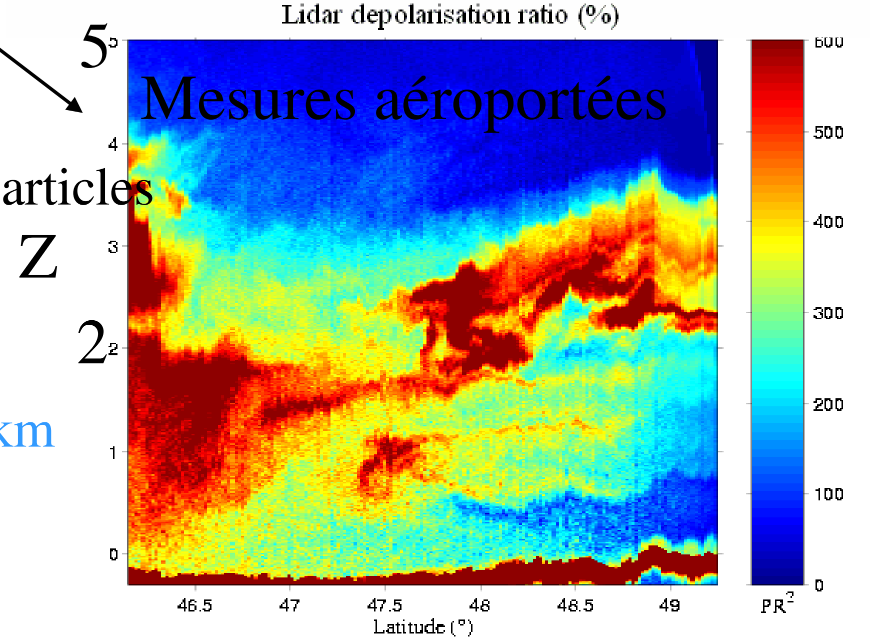


Bases and top of cloud and aerosol layers	⇨	Temperature
Optical depth	⇨	Radiative properties
Depolarisation ratio	⇨	Ice / water phase Shape of particules Orientation of cristals
Phase function	⇨	Microphysics

DUST STORM OVER EUROPE







High depolarisation ratio ⇨ non spherical particles
Angström coeff. Near zero ⇨ Micronic size.
It does agree with photometer measurements

The structure is conserved over more than 5000km along the flow.

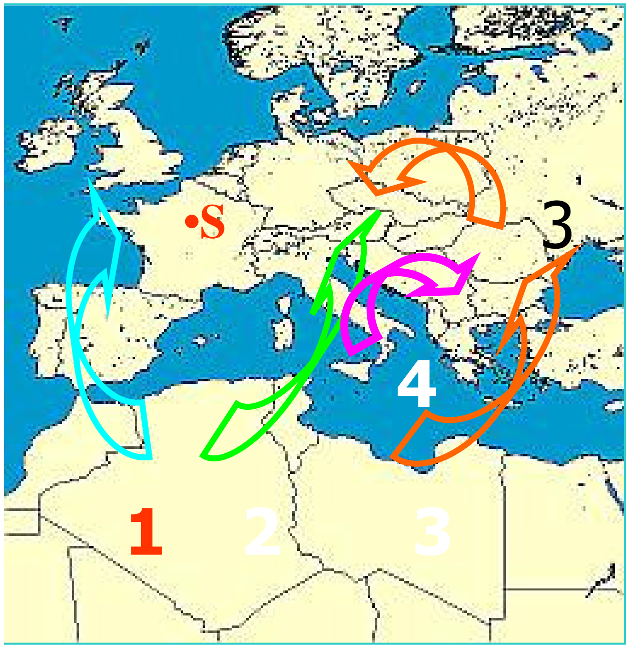
SAHARAN DUST TRANSPORT OVER EUROPE

Dust events observed over Palaiseau :

17 events in 2001 (63 days)

20 events in 2002 (1- 10/02)

Each event lasts between 1 to 3 days



- Layer thickness **(0.2-2.5 km)**
- Layer height **(1.5-6 km asl.)**
- Z max. **~8-10 km** (coexistence with cirrus clouds)
- Travel time **(2-4 days)**
- Aerosol α_{aer}/β_{aer} (LR)
  - **LR(355nm)= 10-35 sr**
  - **LR(532nm)= 20-55 (80) sr [Mie theory k=35 sr]**

Track 1: ~ 20% of observed cases

Aerosols are mainly produced at the surface : They are tracers of dynamics in The atmospheric Boundary Layer (ABL)

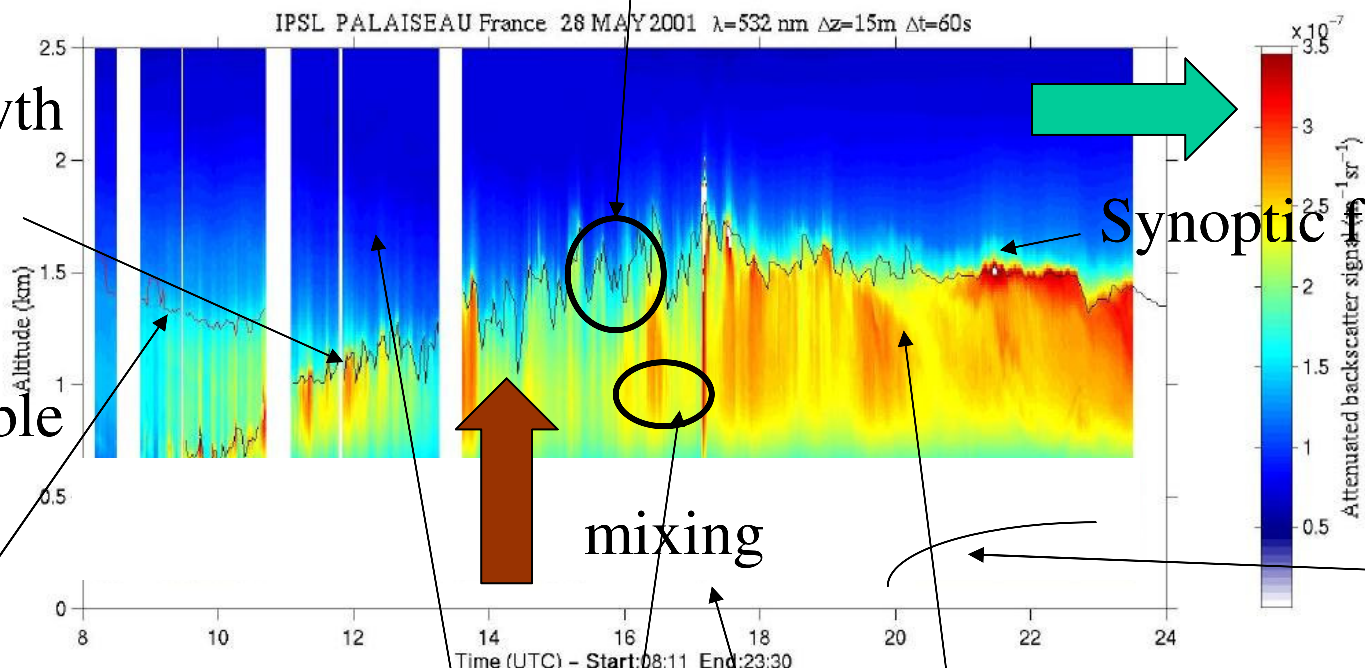
→ They are mixed in the unstable boundary layer which develops during daytime
The number of particles is depending upon source strength and location
→ The ABL behaviour is determined by the dynamical and Thermal forcing at the surface, synoptic divergence and advection, and summital entrainment
→ The concentration of particles is diluted in the unstable ABL and particles are further transported in the FT (residual layer)
→ The optical parameters are strongly depending upon relative humidity

The Convective Atmospheric Boundary Layer : Cycling the aerosol

Entrainment

Advection

ABL growth
During
Daytime
Erodes
Ntime stable
layer



Synoptic forcing w

mixing

Form
A new
Stable
ABL

Residual aerosol layer from
The previous days

Sedimentation

Surface forcing(T,U)

Backscattering : RH impact on the size of particles (up-downdraft)

TEMPORAL CYCLES

Ground-based Lidar measurements allow :

- the identification of the height of the ABL top

- the determination of the entrainment zone in clear air (few clouds)

- the identification of the altitude of the residual ABL h (D-1 advected)

- the determination of the backscattering coefficient in the ABL and above
- the determination of the Angström coefficient to help identifying aerosol type and RH effect

TEMPORAL CYCLES

Two approaches in the frame of EARLINET :

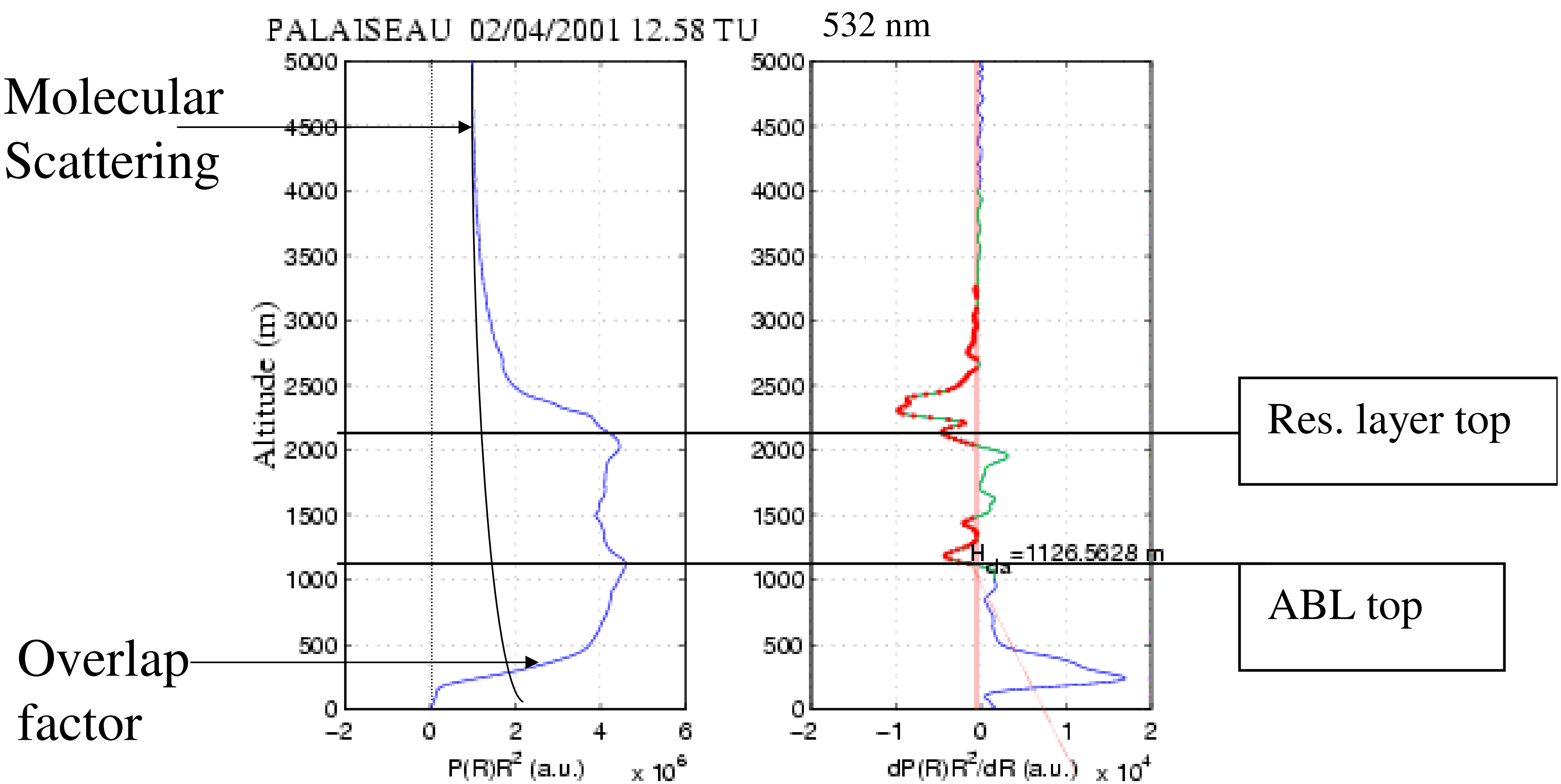
- DIURNAL cycle : focus on short scales
- SEASONAL cycle : seasonal forcing and sources

Comparisons of the evolution over different sites

Evidence of different behaviours

→ local forcing (orography)
→ aerosol sources
→ humidity control depending on aerosol type

A methodology to determine the ABL h



Gradient method (Melfi et al., 1980) and spatial/temporal evolution constraint (Flamant and Pelon, 1999)

Determination of the ABL height

Other method : Variance analysis (Hooper et al., 1975)

Advantages/Drawbacks

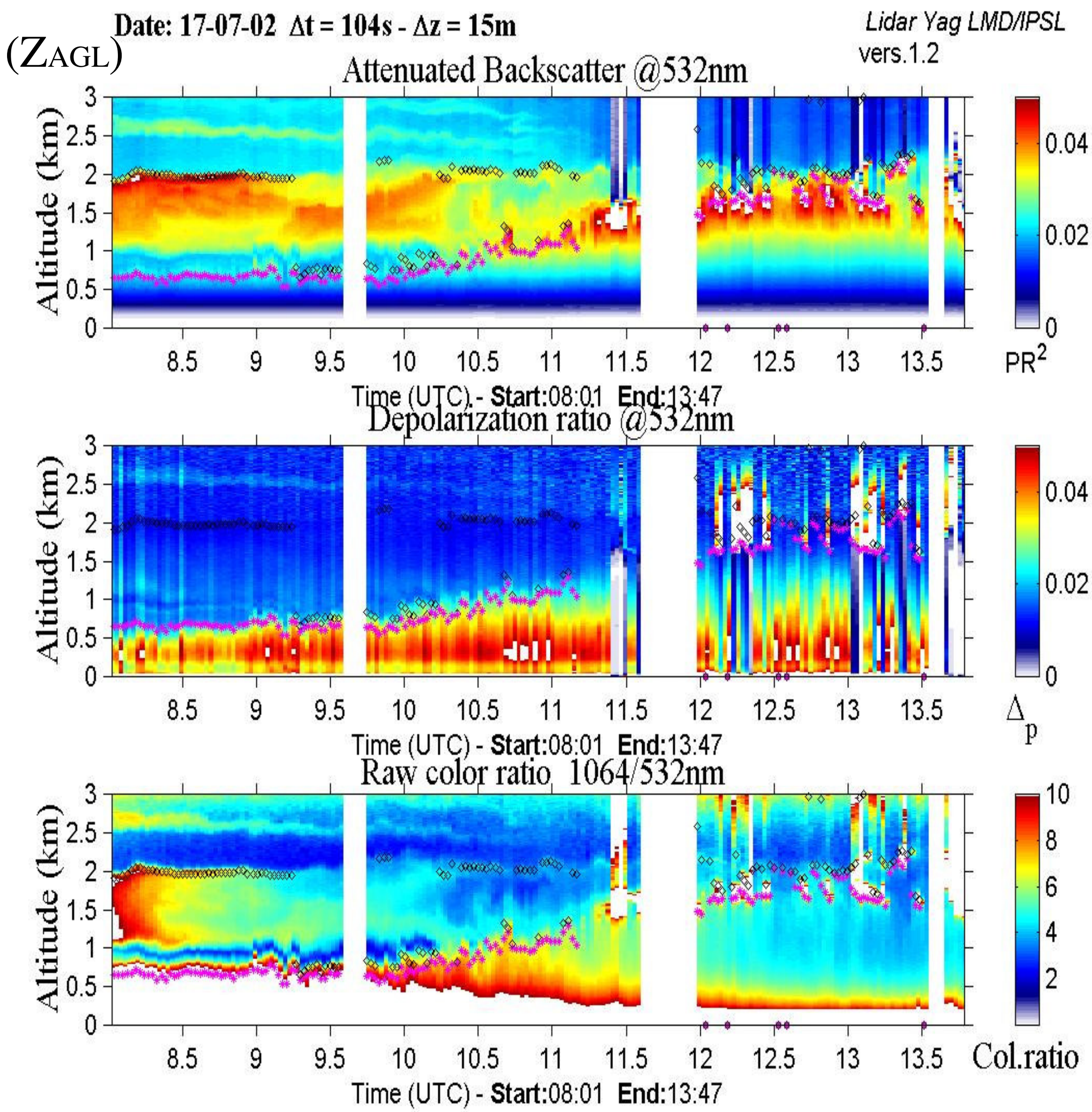
→ variance method biased by backscattering enhancement
→ Only gradient method applicable to single profiles
→ analysis at low altitude (typ. 200-300 m) requires to overcome overlap factor problem

→ Correction of the overlap factor : use a reference measurement, Calculation, residual error due to day-to-day variations

→Relative analysis as proposed by U. Wandinger :

$$S = PR^2 \rightarrow S' = \frac{S - S_{ave}}{S_{ave}}$$

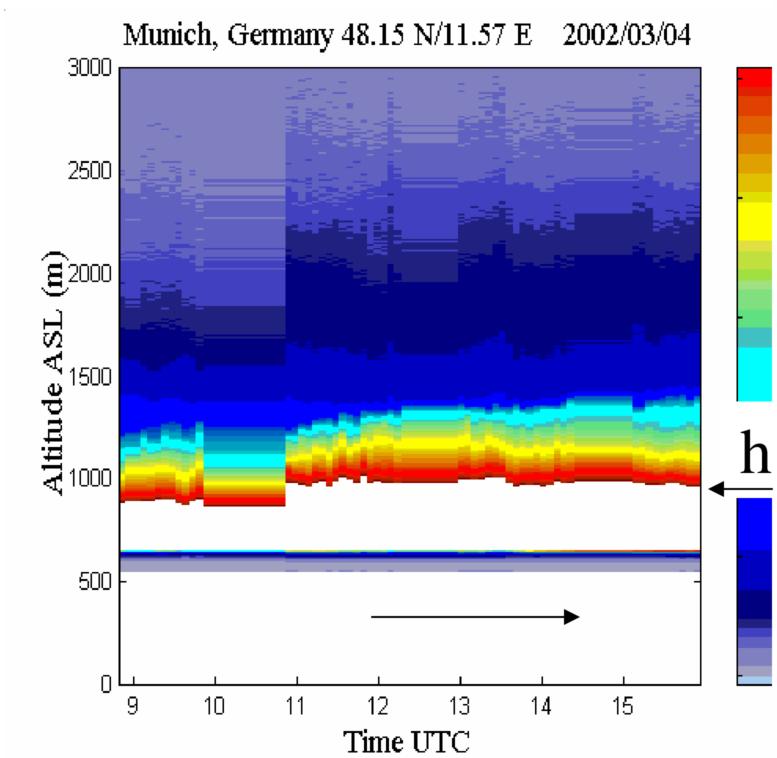
Diurnal Evolution

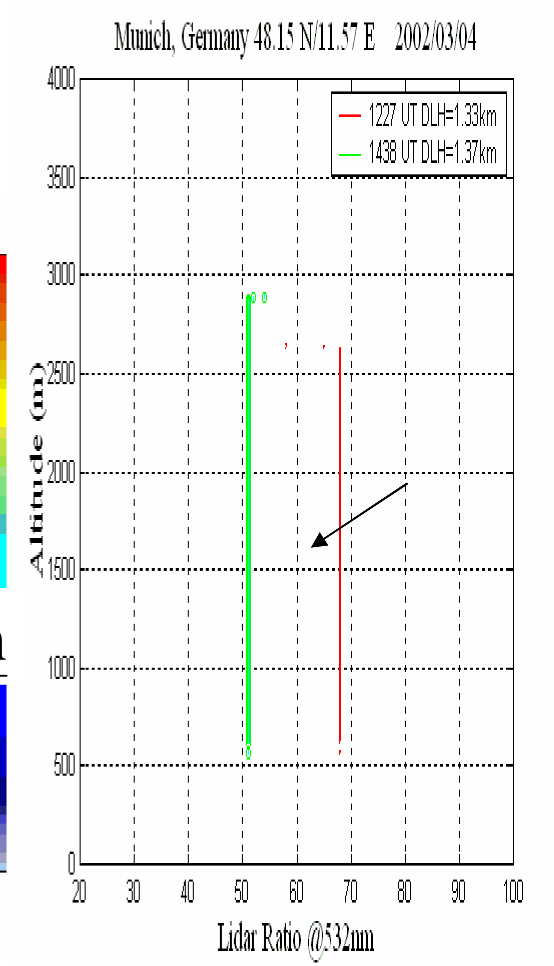


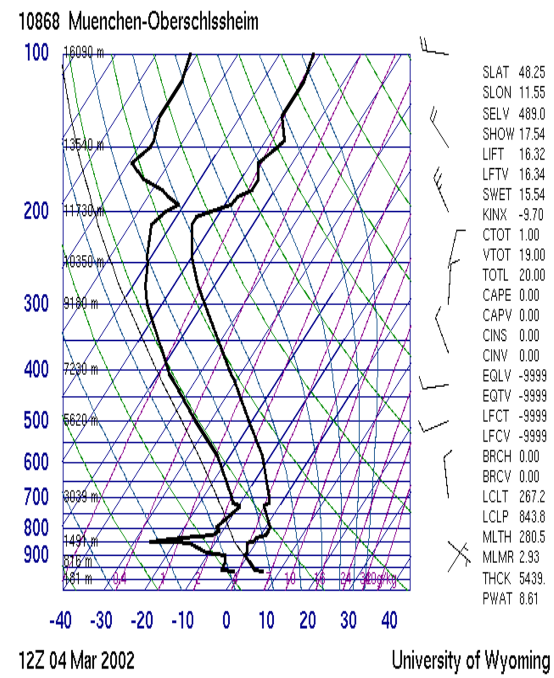
Decrease in depolarisation and
Angström coefficient above
RHc correspond to a more spherical
Shape and increase in size

Diurnal Evolution

Münich, 600 m ASL
Multi-angle Back. Lidar



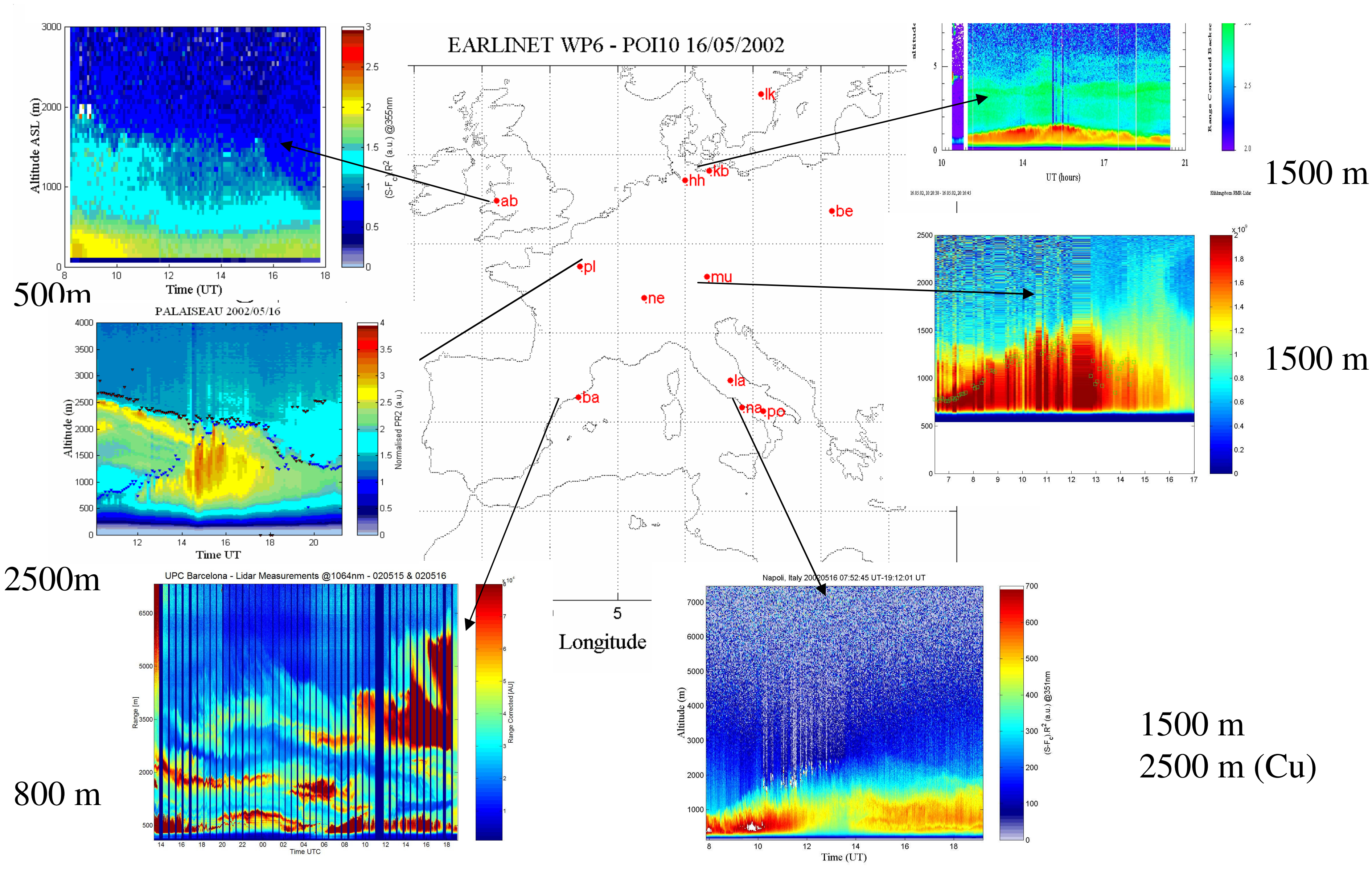




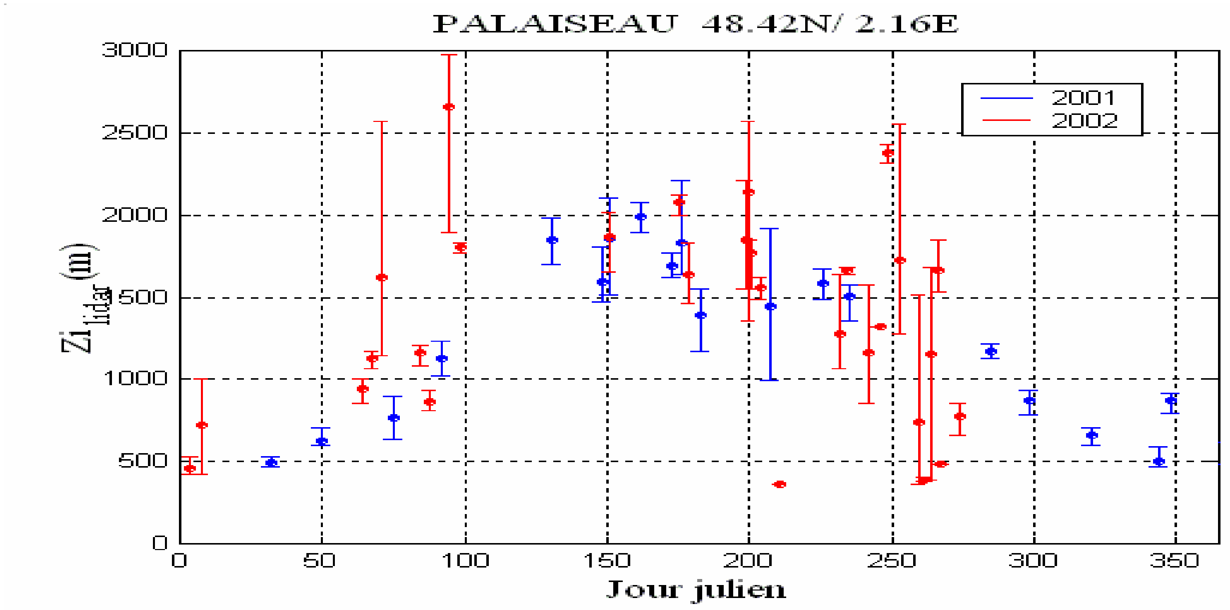
Evolution in Lidar Ratio and RH during daytime → aerosol type

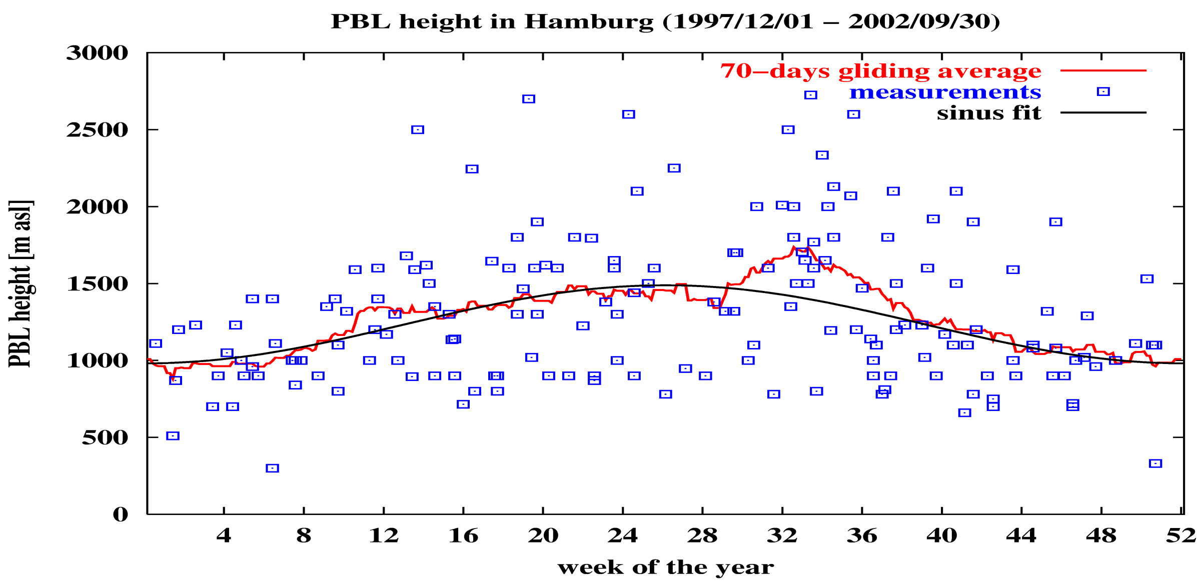
For continental aerosols LR increases with RH (Ackermann, 1998)

TEMPORAL CYCLES

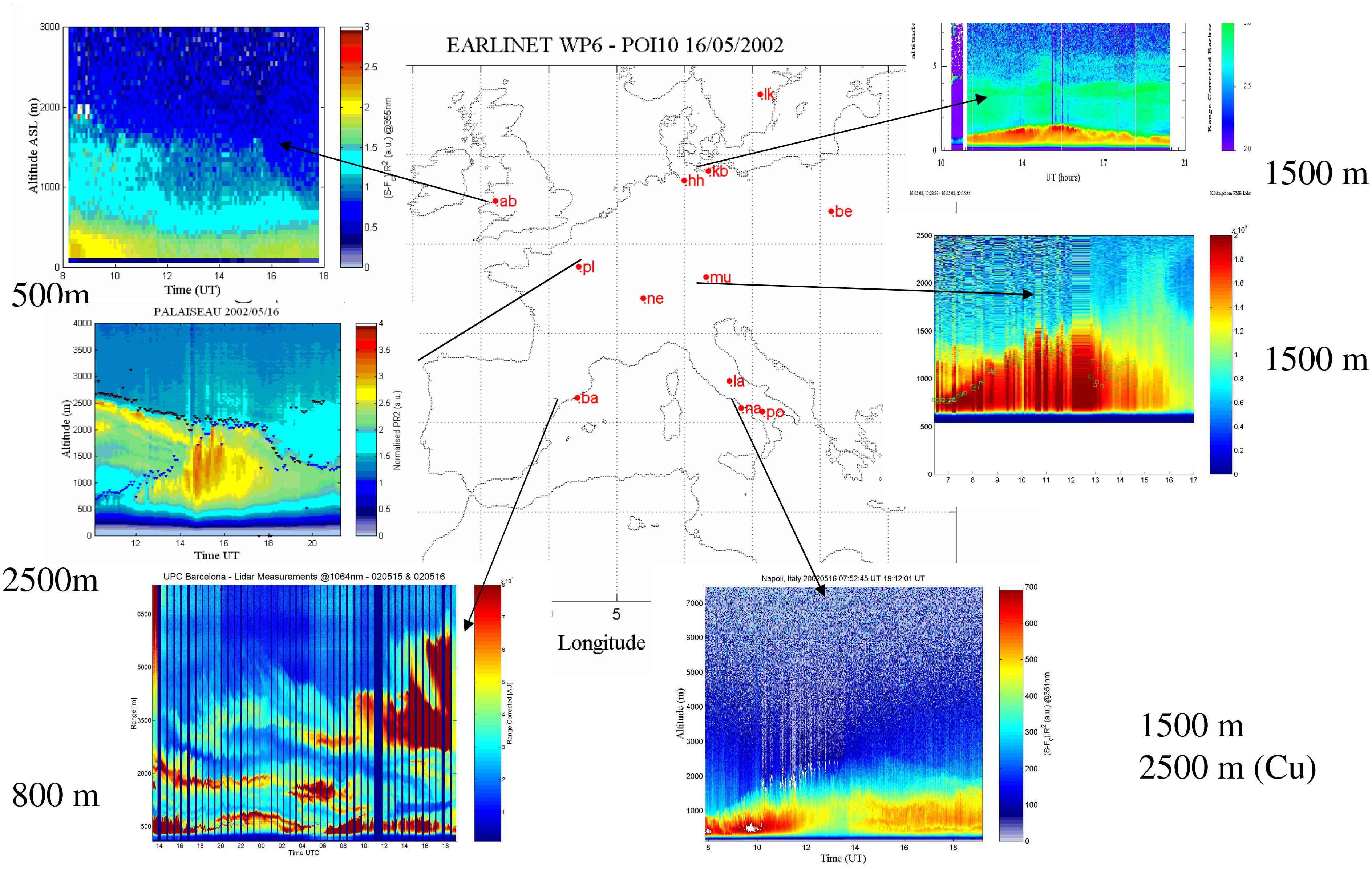


WP6 : Seasonal evolution of ABL h





TEMPORAL CYCLES



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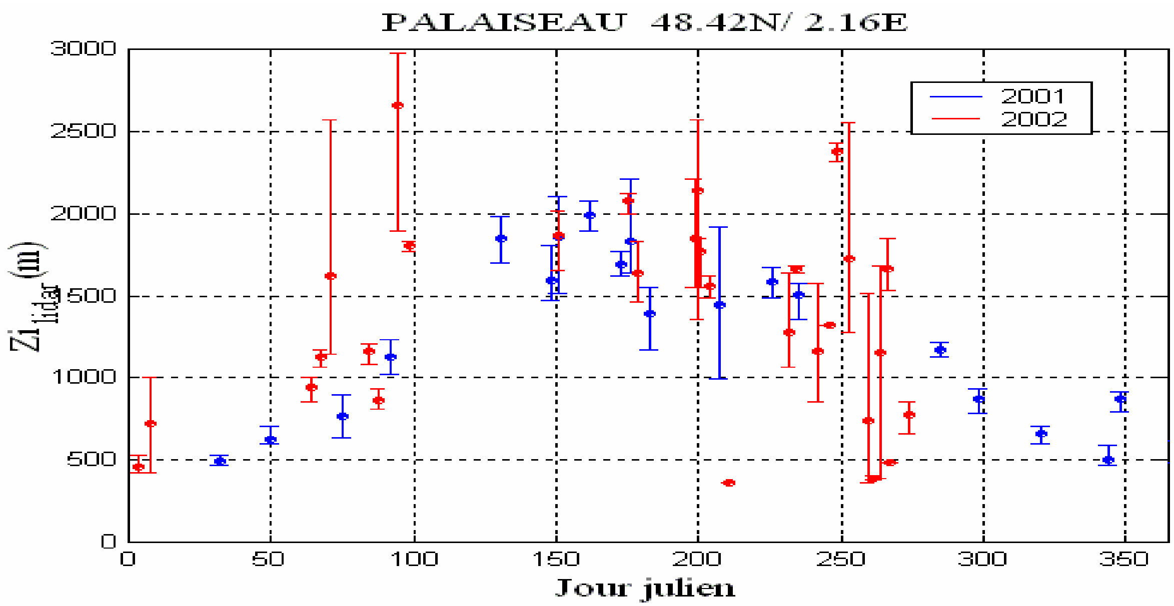

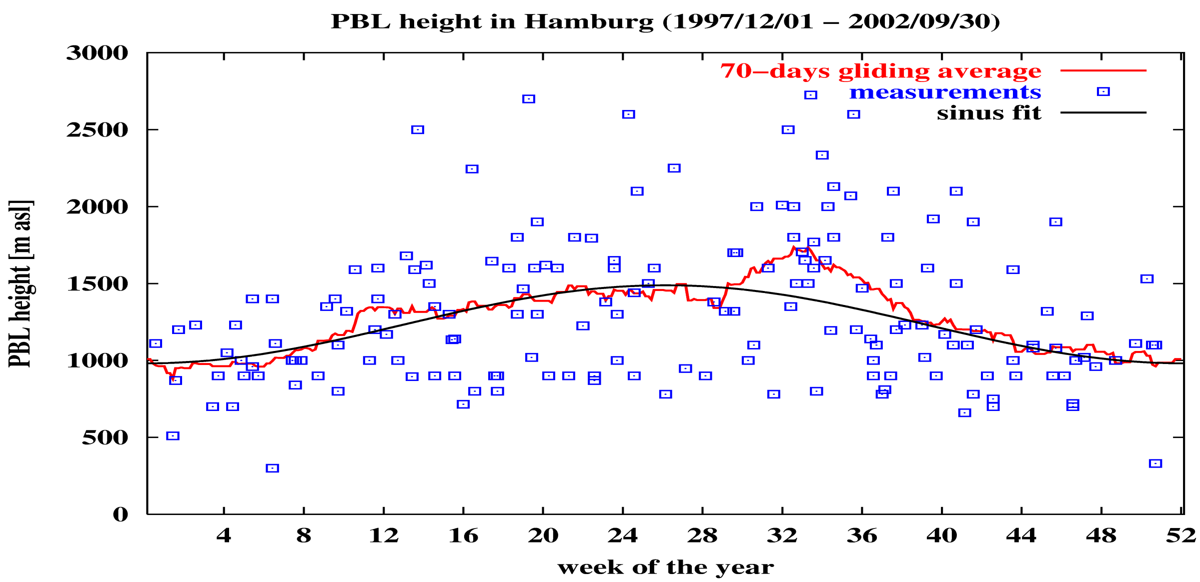

CONCLUSION

Many different kind of lidar

Largely used in atmospheric research community

Rising of network measurements

A few commercial systems available

Many optical and morphological parameters can be retrieved from backscatter lidar signal