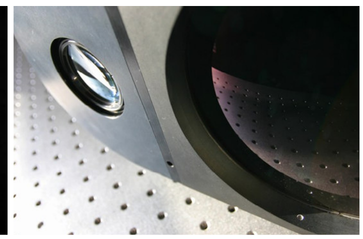
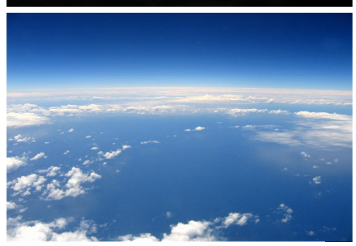
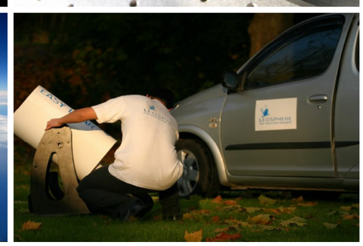
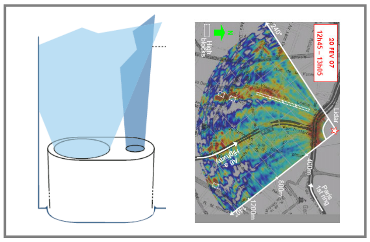
CLOUD & AEROSOL LIDAR
FOR ATMOSPHERIC MONITORING

ALS 300/450 Product Information

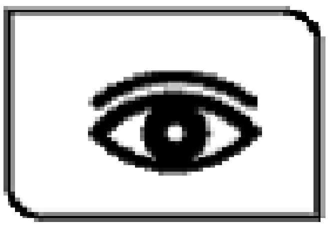
May 2009

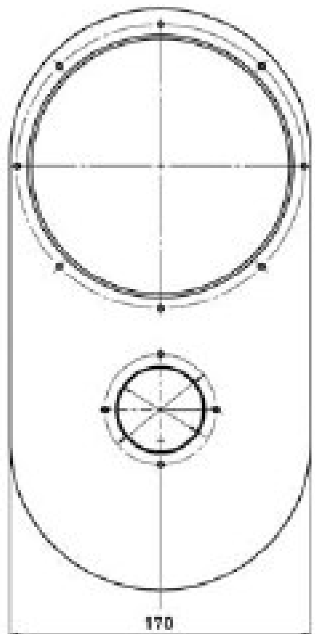
Very low overlap (200 m/500 m) & 3D scanning

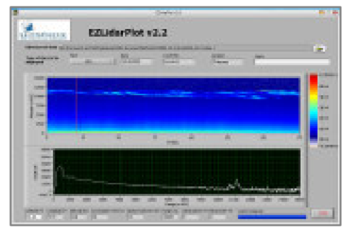


Lidar specialist
Wind and Aerosol EZ Lidar range



Eye-safety and invisibility



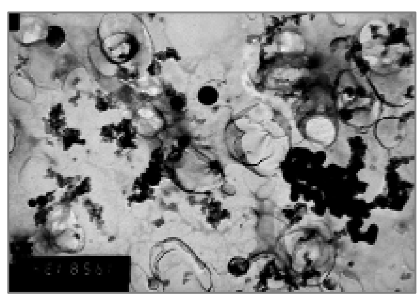


Sophisticated software features

Transportability and robustness

Upgradeability (Water Vapor)

ALS300/450



Compactness 17 kg (optical head)

Very high sensitivity (50 nm aerosol)
Very high resolution (1,5 m/1 s) by night and day time

IMPORTANT NOTICE

This document describes in details the performances and features of the ALS300/450 systems. Its content cannot be separated from LEOSPHERE's terms and conditions of sales and from any financial offer. In case of a purchase order, some or all of the following items may be incorporated into a contractual document.

SOMMAIRE

KEY BENEFITS OF EZ LIDARS

LEOSPHERE's value proposal will be exposed throughout this document. The following points shall be the key elements to remind.

- **Unmatched performance with spatial (1,5 m) and temporal (10 s) resolution** profiling up to 15 km, even at day time, that gives an optimal constraint to numeric models.
- An **upgradeable instrument** that allows enhancing research capability, while technologies are maturing, without re-investing into a new system (Raman, photon counting, depolarization).
- An **Easy LIDAR™**, **eye-safe and transportable**, that does work like any other meteorological sensor (24/7 unattended – outdoor – very light assistance), **on the ground or in the air**.
- A **nimble LIDAR specialist next door** both to get responsive technical support and to discuss atmospheric sciences with physics doctors.
- Validated beneath most latitudes and in the majority of the meteorological conditions, without any realignment constraints.

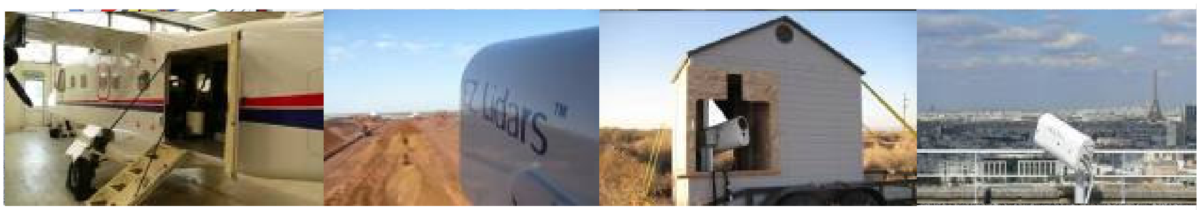


*Figure 1: **Easy Aerosol and Cloud Lidar** all over the world.*

RETURN ON INNOVATION

Whether you are a meteorological office feeding forecasting models with continuous atmospheric data, or a research institute leading atmospheric research field campaigns, you certainly need to access to a continuous and standardized measurement of atmospheric structures : vertical profile of aerosol structure, evolution of atmospheric boundary layer height, clouds' height, identification of aerosol plums in industrial areas. Until now, remote-sensing was partly realized by various techniques such as tethered balloons, ceilometers, non eye-safe laboratory LIDARs, passive spatial observations.

None of these allowed to collect simultaneously space resolved, real-time and high-resolution data on aerosol layers. Among these techniques, LIDARs were promising. However, their high level of maintenance discouraged atmospheric scientists and operators from using them as ordinary sensors.

EZ LIDAR ALS300 and ALS450 bring a definitive alternative to this situation by offering an unattended, eye-safe, compact LIDAR with unmatched performance, ideally designed for network atmospheric observations. Co-developed with the Climate and Environmental Science Laboratory (CNRS and CEA, France), EZ LIDAR is pioneering the era of network LIDAR observations.

A- FUNCTIONAL SPECIFICATIONS

1. ATMOSPHERIC PARAMETERS

1.1. Principle

LEOSPHERE's EZ Lidar is an active remote sensor based on Laser Detection and Ranging technique. EZ Lidars are dedicated to cloud and aerosol structure characterization in the troposphere. A nanosecond laser pulse is emitted into the atmosphere where it encounters atmospheric particles and molecules along the line of sight. A part of this radiation is scattered backward and collected onto the LIDAR reception system constituted of an opto-electronic device. The electrical signal is digitalized and recorded by a computer for real time or postponed processing.

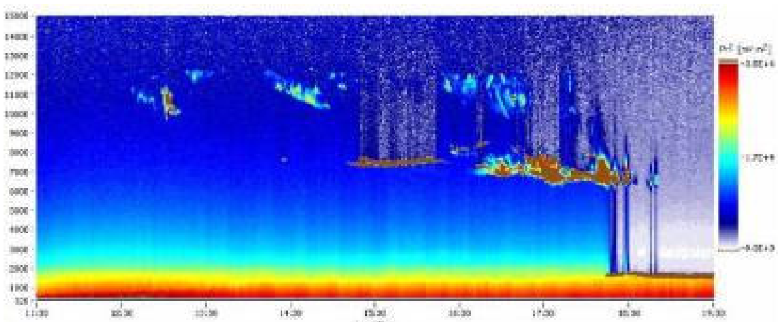


Figure 2: sample of Cloud monitoring

1.2. Saved parameters

EZ Lidar systems provide in real time both qualitative and quantitative information of the atmosphere:

- Atmospheric backscatter light intensity (raw data)
- Solid angle and background calibrated data
- Vertical backscatter and extinction profile
- Vertical Aerosol profile
- Planetary Boundary Layer and residual layer heights
- Semi-transparent cloud height and top
- Optical depth integrated over whole Lidar range
- Dynamic structure of the atmosphere (e.g gravity waves...)
- Asphericity information on the particle in order to discriminate some particles from others (soil dust from other aerosol, ice/water phase of the clouds…)

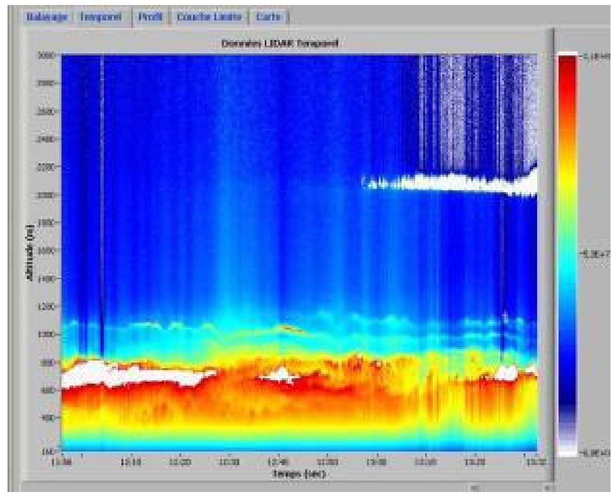
2. PERFORMANCES

The parameters of any LIDAR are linked to one another, especially where the detection range and the acquisition time are concerned. This is where ALS300/450 have high performance, since within the entire troposphere, the quality of its performance varies very little.

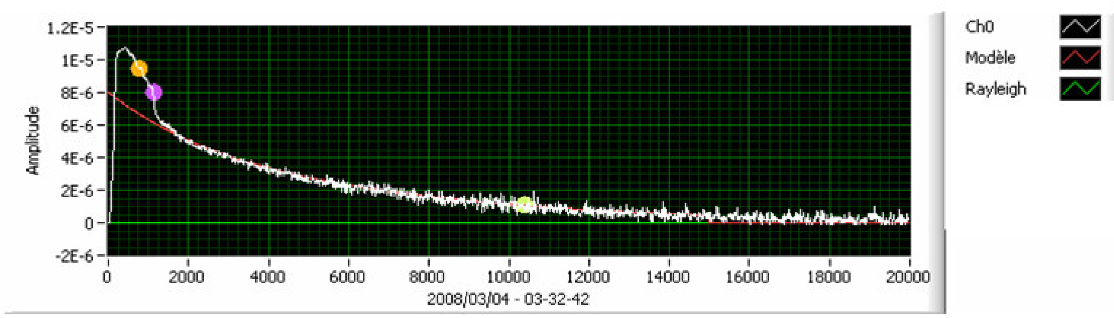
RANGE

Maximum
The actual measurement range depends on the required time resolution for a given parameter. A default number of LIDAR profiles accumulated to detect processes in the upper layers of the troposphere (up to 20 km) will be set by LEOSPHERE and will be tunable by the user.

Minimum
The first measurement point is set as a standard at 75m but specific tuning can be asked. Full overlap can be reached as close as 150 m. It can even be corrected up to 300 m according to the principal needs.



Sample of low troposphere monitoring (aerosols and low clouds), Palaiseau, France

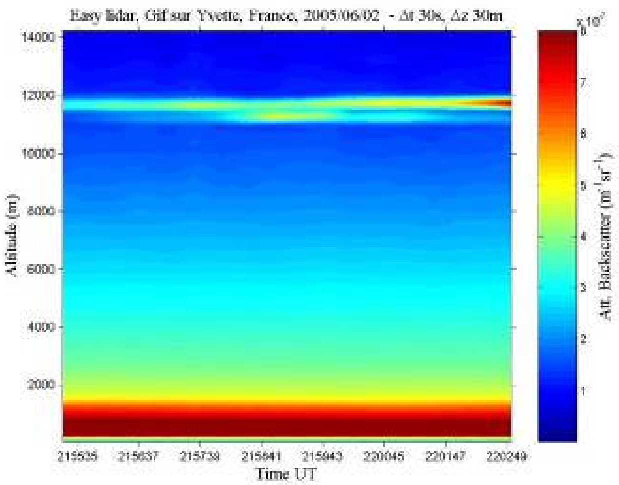


Spatial resolution	15m	15m	30m
Time resolution	30s	30s	60s
Max. range at night with OD of 0.3	13 km	14 km	15 km
Max. range at day with OD of 0.3	8 km	9 km	10 km

Example of full range measured with ALS450 in Orsay, for an optical depth (AOD) of 0.5 (strong load n aerosols,0.25 value is usually measured for average pollution in Paris).We see the good correlation between the signal and the reference molecular profile ***up to 20km****. The maximum range measured was 15 km at night time, with 30m resolution and 60s accumulation time.*

TEMPORAL RESOLUTION

Time resolution depends on the nature of the parameter, its position into the atmosphere, and the atmospheric conditions (aerosol load, presence of clouds, temperature). Also, the actual performance of the system regarding range correlated with integration time cannot be known until the system is tested under actual final atmospheric conditions.



Subvisible cirrus detection at 11.5 km

The following are actual performance measured in the Paris Region using regular analog detection:

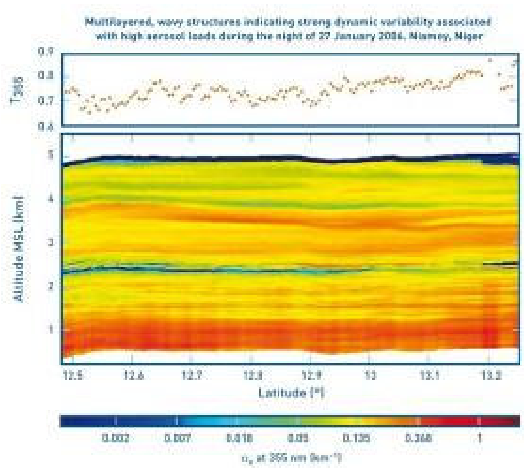
- Lower layers of the atmosphere can be retrieved in 5 to 30 s during the day. Within that range, certain parameters such as atmospheric boundary layers can be retrieved in 2 s.
- Upper clouds (Cirrus) require to average additional LIDAR profiles and to use greater integration bins (15 m for instance). The observed integration time may vary from 30 s to 5 min.

Though these results match most needs, performances can be enhanced by switching the system to photon counting detection mode. ALS300 can be supplied with 2 detection modes, one analog channel which is better in the low layers for PBL detection, and a photon counting mode which is suitable for high altitude clouds and thin aerosol in the free troposphere.

SPATIAL RESOLUTION

The ALS300/450 answers to the following spatial constraints:

- 1.5 m in analog detection. However, when 15 m are sufficient, it is profitable to give up this constraint in order to save computer memory space and to improve the signal noise ratio.
- Between 30 m and 150 m in photo counting detection.



3. OPERATIONS

Fixed station operations

The portable system can operate in various configurations, depending on the application and the duration of the campaign measurements. It can be a part of a fixed meteorological instrument set. The required power would not exceed 370W (550 W with additional heating module for cold areas) and an inverter might be necessary in case of electricity network oscillation or power failure. According to the casing choice, the Lidar system can operate in various configurations:

- **1 fixed vertical observation**: for long period, unattended, close to an air conditioned building, plugged to a network, for 1D measurement.

- **3D scanning Lidar:** All weather automated scanning device, unattended, connected to a power network, with punctual maintenance tasks.

3D dust plumes measurements in Australia, Nov 2007

Mobile campaigns (car, train, ship)

The system can operate inside a vehicle, attended and for short term periods. The system must be autonomous, it can be plugged into an auxiliary power supply and the data will be stored in a computer before being uploaded on a server. It can also be operating for mid-term period if a power network is available. An inertial central might be necessary to record the rolling and pitching data during the measurements so that the user can post correct the Lidar data with the aiming angle.

- **Zenithal 1D campaign Lidar**: for fixe measurement campaigns, short and medium term, unattended, connected to power network, with low maintenance operations.
- **3D campaign Lidar**: mobile unit with possible scanning operations, with surveillance, connected to power networks if available.

B- EZ LIDAR EXCHANGE

Throughout this chapter you shall discover an innovative range of applications allowed by the easiness and robustness performances of EZ Lidars. Of course the ALS300/450TM is well suited to be integrated in an instrumental set like any meteorological sensor.

4. EZ LIDARS PARTICIPATION TO NATIONAL AND INTERNATIONAL TERRAIN CAMPAIGNS

Because of his good performances outdoor, EZ Lidar has been chosen several times by atmospheric research teams for various terrain campaigns:

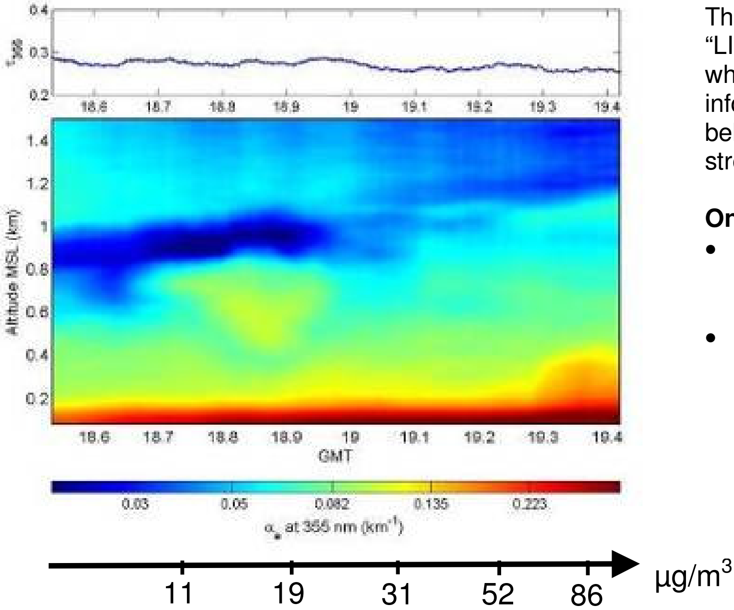
- LISAIR'05, Air quality in Paris area (**CNRS**), Paris [1].
- PARISFOG'06-07, Study on fog formation, maintenance and removal (**CNRS**), Palaiseau.
- AMMA'07, African monsoon (**INSU**), Niger [2].
- ASTAR'07, International Polar Year campaign (**AWI**), Spitzberg islands.
- OOMPH'07, campaign aboard Marion Dufresne (**IPEV**), South Atlantic.
- Validation CALIPSO, 2007 (**CNES**), en France.
- PACMAN'07, Study of Ocean-Atmosphere interface (**ENSATT, ONERA**), Porquerolles.
- Mission ballon – IASI (**CNES**), Test flight made in June 2007 at 18km
- CAREBEIJING'07, Beijing air quality (**IAP**).
- TIGERZ'08, CALIPSO validation and Indian monsoon (**NASA/GSFC**), Kanpur, India.
- EUCAARI, Air quality and climate study project at different levels (**6th PCRD**), Cabauw, The Netherlands.
- Proposal for ADM-AEOLUS validation by LSCE (**CNES**)
- European Project MEGAPOLI, on aerosol aging in the Parisian plume (**7th PCRD)**

4.1. Ground field campaigns

- **"Lisair", LSCE campaign, Paris, May 2005, 30 days**

The monitoring of the particle mass concentration over polluted areas is currently a serious matter for most urban decision makers. Horizontal mapping of pollution spots can help authorities to improve the efficiency of their policy. LIDAR, for instance, can follow the evolution of aerosol layers, optical depth and mass concentration from one point to another.

From Palaiseau (semi rural) to the center of Paris



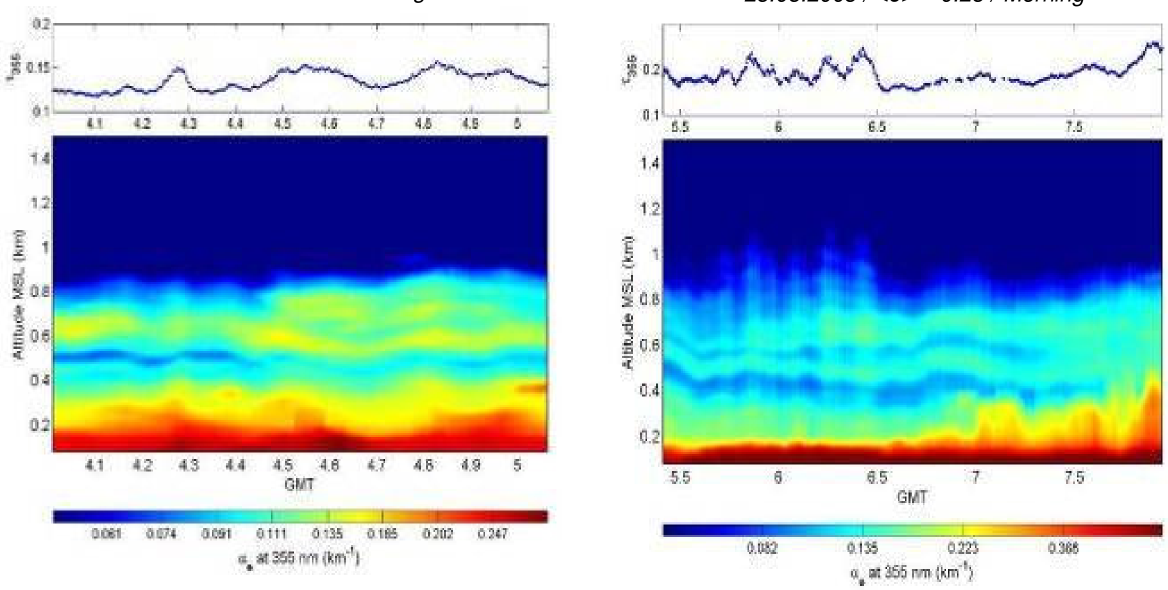
The ALS300 has been used during the "LISAIR" air quality campaign in Paris where a mobile LIDAR brought new information on the height dependent behaviour of aerosols and their flow within street canyons.

On the left picture:

- **Rise of the concentration near the ground**
- **Uplift of the PBL in Paris downtown**

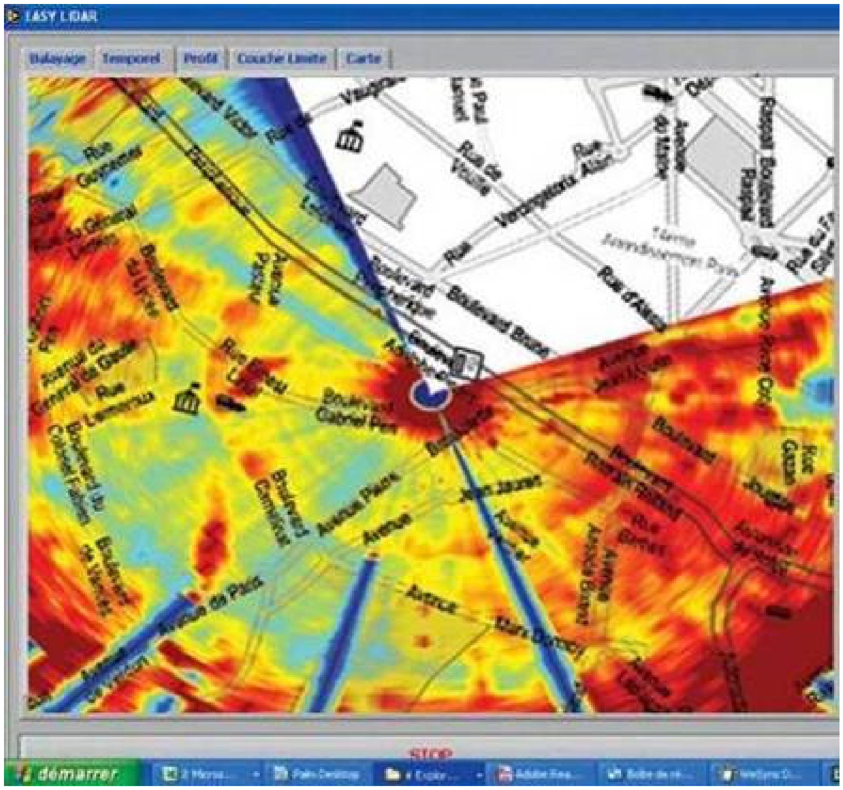
25.05.2005 / <δ> = 0.13 / Night

25.05.2005 / <δ> = 0.25 / Morning



Evolution of aerosol layers and global optical depth from night to morning above Parisian surrounding highway on May 25th 2005. Above one can see the residual boundary layer and the birth of PBL in the beginning of the day, the mass concentration is very high in the morning. The optical depth value doubles between 4 am and 7 am.

EZ Lidars, can monitor in 3D the dispersion of pollutants from local sources (plants, roads) towards dwellings.

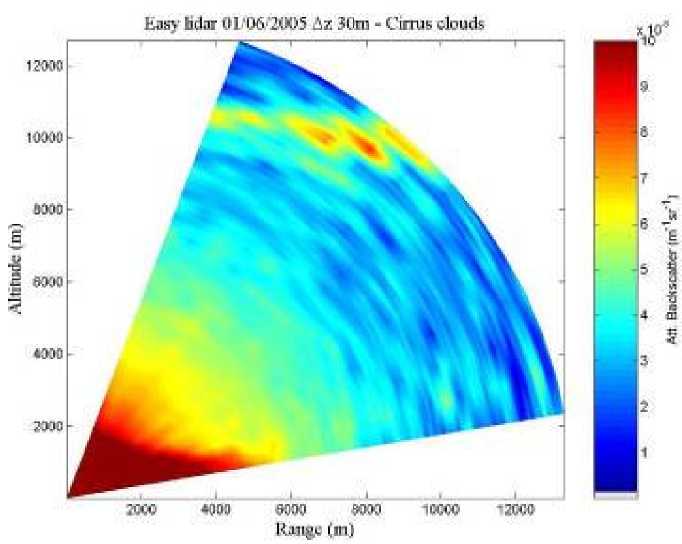


Daytime horizontal scanning to detect pollution sources over Malakoff, suburbs of Paris

- **Meteo France, Toulouse, June 2005, 1 day**

The local heating/cooling effect at each atmospheric level strongly depends on the existence of clouds, their fraction, height and morphology, as well as their optical properties. The behaviour of the clouds, the way they absorb or emit visible and infra red radiation strongly influences the global Earth radiative budget. The ALS450, operated like any other meteorological sensor provides continuously key structural and optical information on low and subvisible cirrus clouds along the atmospheric column.

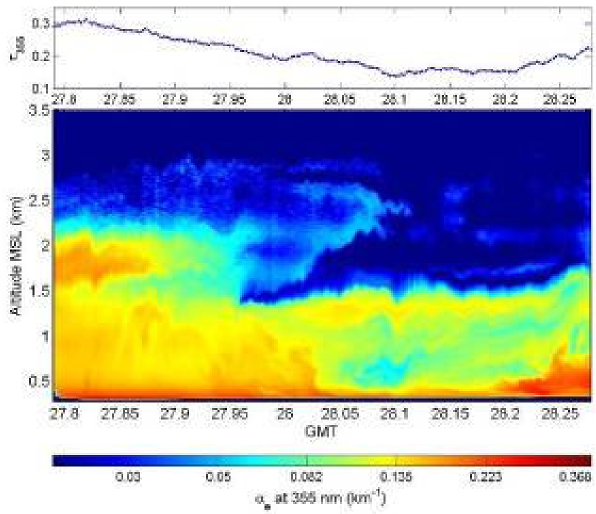
Many meteorology institutions are highly interested in observing dynamic structure of high clouds. The ALS450 has been able to vertically scan the sky up to 12 km, in only 30 s, during daytime!



Scan of attenuated backscatter with well captured Cirrus at 10 km taken on 1 July 2005 at Meteo France premises in Toulouse

- **AMMA campaign in Niamey, Niger, December 2005, 20 days**

Thanks to the close partnership with the French Science Laboratory for Climate and Environment (LSCE), fantastic observations of wavy structures and aerosol loads over the desert of Niamey have been performed.



Multiples layers, wavy structures indicating a strong dynamic variability associated with strong load in aerosols during January 27th night, 2006. Niamey, Nigeria

4.2. On board campaign

- **LOGIVEP 2007 campaign**

EZ LIDAR ALS300 has been installed by LSCE (CEA/CNRS) team on board « Le Marion Dufresne », an oceanographic ship as part as the instrumental setup of the OOMPH - LOGIPEV 2007 campaign.
The ALS300 has been taking measurements since mid January 2007 when the ship left La Reunion Island for a trip toward Puenta Arenas.

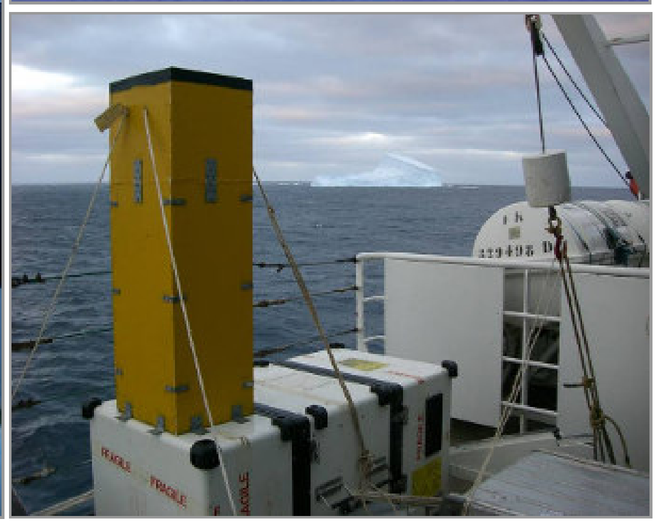


Figure 1 (left): EZ LIDAR ALS300 on board the "Marion Dufresne" oceanographic ship.
Figure 2 (top right): The « Marion Dufresne » near the coast of Kerguelen islands
Figure 3 (down right): EZLIDAR ALS300 during its trip in South Atlantic.
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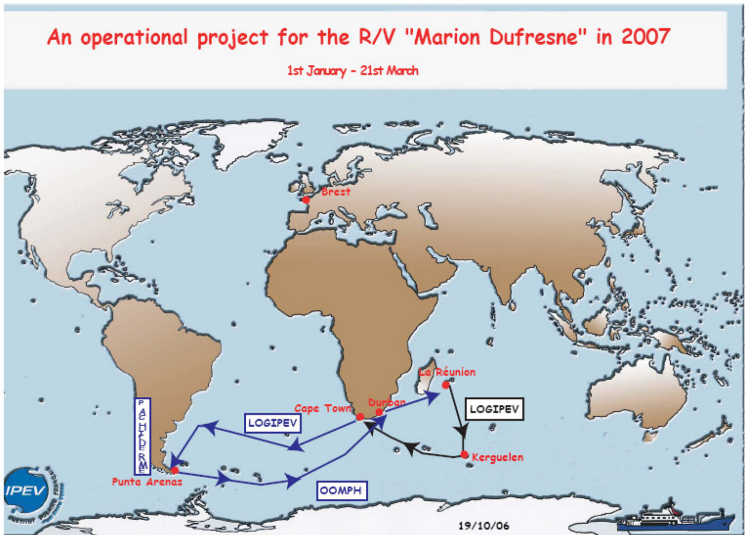
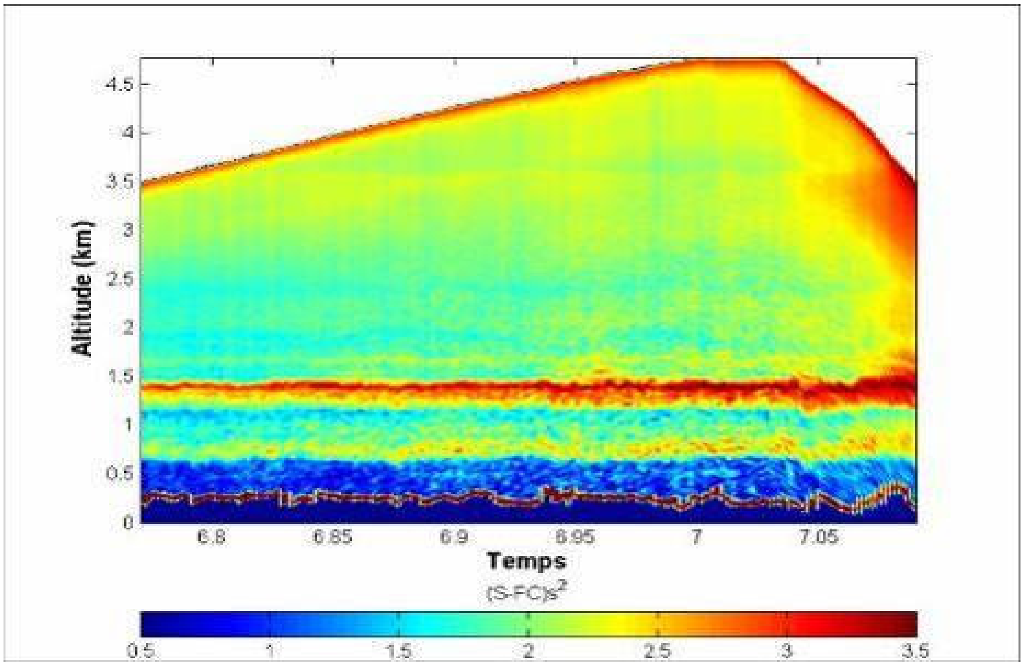


Figure 4: Itinerary of the « Marion Dufresne » during the LOGIPEV 2007 campaign.

4.3. Airborne field campaign

- **Calipso campaign: Spatial Lidat Validation, over Essone, France, November 2005**

Thanks to their robustness and reliability, EZ Lidar can easily be performed as airborne Lidars. The alignment is kept in spite of the plane's vibrations.



Aerosol layers evolutions during a 25 min flight, above Saclay, France

5. EZ LIDAR MEASUREMENT VALIDATION

5.1. An intensive validation will

LEOSPHERE's scientific team has performed several inter-comparison campaigns, compared to reference lidars in the atmospheric research world. These campaigns allowed determining the performances and limitations of EZ Lidar.

As for today, the performed campaigns are the following:

- SIRTA – AIRPARIF'06, boundary layer
    - Inter-comparison on the automatic restitution of the inversion layer altitude, in comparison with the backscatter lidar from SIRTA/IPSL – CNRS (Martial Haeffelin)

- ARM'06, aerosols and high clouds
    - Oct'06 campaign on ARM/SGP site, Oklahoma
    - Comparison with Micro-Pulse Lidar from DOE
    - Comparison with UV Raman Lidar (PI Dave Turner)

- PARIS – Airparif'07, horizontal structures and mass concentration

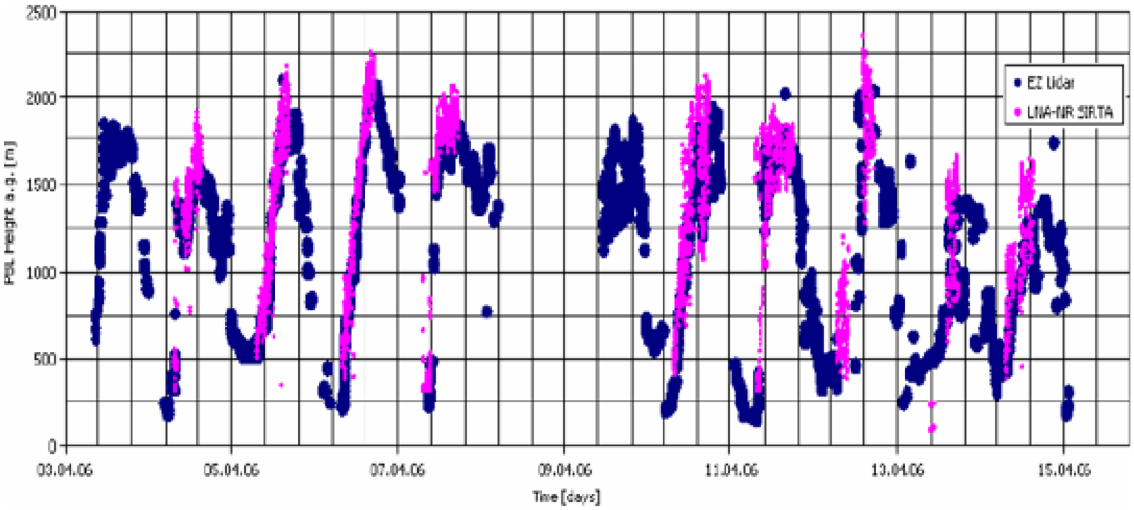
- PARIS subway – RATP'07, mass concentration in the RER

- NASA/GSFC'07, aerosol and high clouds
    - Campaign on May 07 at Greenbelt, Maryland, nearby a type 4 – MPL from MPLnet network (Judd Welton)
    - EZ Lidar data evaluation

5.2. Validation campaign at LMD

Mixing layer height determination

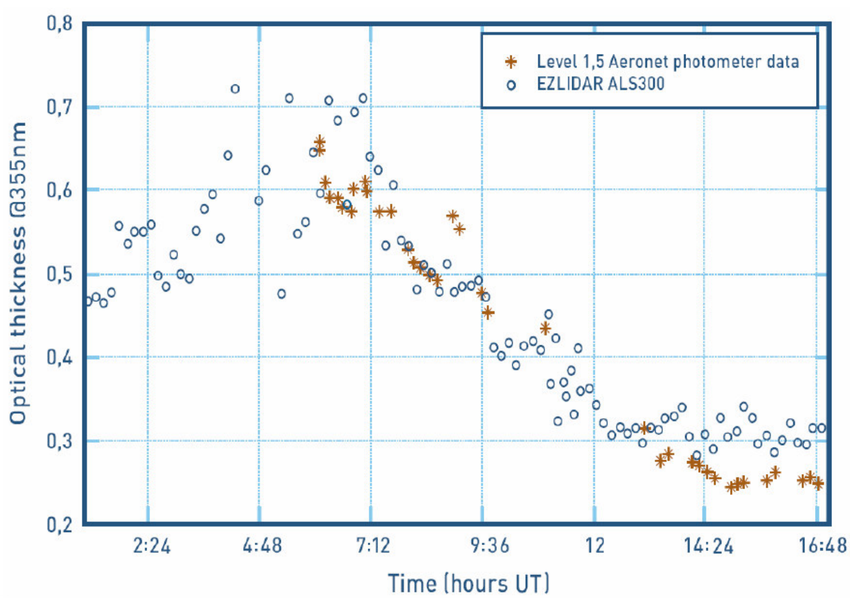
EZ Lidar has been deployed at LMD in Palaiseau, France, for validation of the estimation of mixing layer height, restored by the AEROSOFT automatic algorithm and by STRAT software from LMD [3] respectively applied to EZ Lidar and LNA (Clouds Aerosol Lidar) data. On a 12 consecutives days quasi-continuous measurement comparison, the correlation between the two mixing layers detection is 95% for a 5 minutes average.



Mixing layer height restitution from EZ Lidar and LNA + STRAT software (pink) data.

Optical depth calculation

AEROSOFT (level 2) analytic module automatically establishes the particles optical depth. On the next figure, measurements providing from EZ Lidar in Palaiseau (July 2005) are compared with sun photometer (P. Goloub, AERONET, France), during particles crossing from Germany. One can see a good correlation between the optical depth from the lidar and those from the photometer. Night and noon photometer's data were not available due to clouds crossing (day time).



AERONET data level 1.5 (orange crosses) and optical depths given by EZ Lidar AEROSOFT (bleu circles)

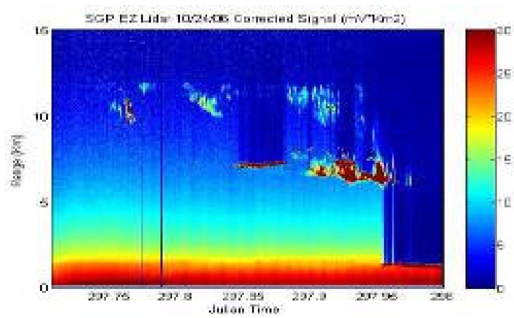
A slight shift on the afternoon is explained by the difference of probed volume in an heterogeneous atmosphere, the lidar was inspecting a more polluted area.

5.3. Validation campaign on ARM/SGP site [5]

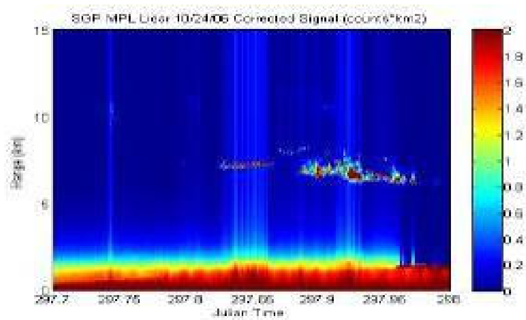
This inter-comparison campaign has been done on October 23 and 24, 2006 in Southern Great Plains, Oklahoma, USA. The coordinates of SGP Central Facility site are N36° 37' W97° 30' at 320m altitude ASL. Data from SigmaSpace Micro Pulse Lidar-4 (MPL) were available for 2 days. A 355 nm Raman Lidar (RL) was working on October 24 too.

Raw data from MPL and ALS300 EZ Lidar, in analogical mode only during this campaign, show a clear sky during the first day whereas several clouds shapes, cirrus between 10 and 12 km, alto stratus and cumulus were visible on October 24

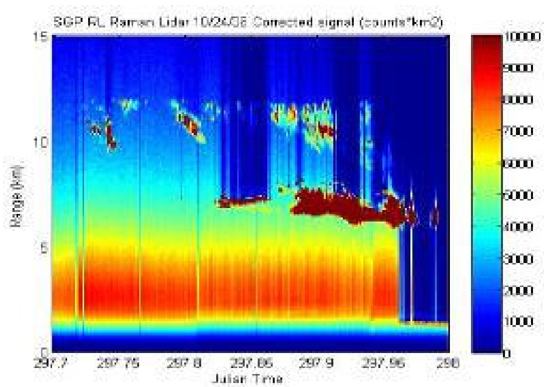
In order to compare directly the devices, the measurement range is extended from 5 PM to 12 AM (UTC) for both days. Due to varied meteorological conditions, we could have compared both devices on several kind of atmospheric conditions, during night and day. The results below represent background and solid angle corrected signal [4] vs time for the 3 lidars on October 24.



a)



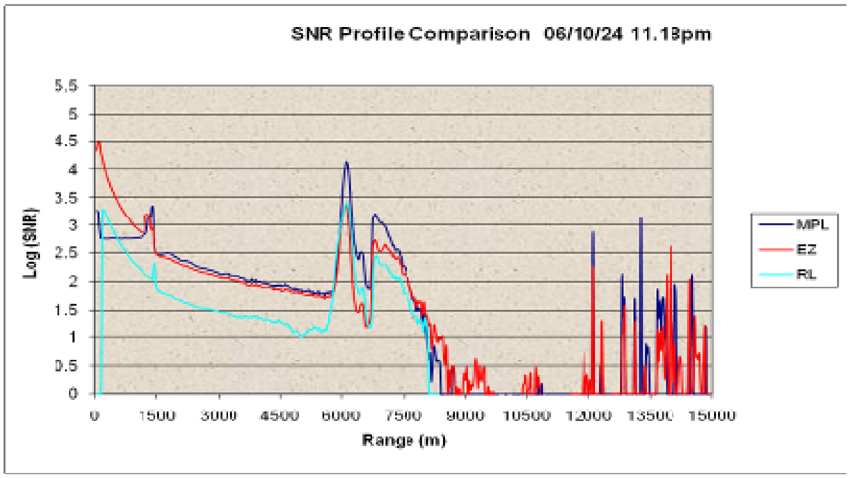
b)



c)

Background and solid angle corrected signal respectively by EZ lidar (a), le MPL (b) and UV Raman lidar (c),on October 24, 2006. Time scale is UTC.

A comparison between Signal to Noise Ratio (SNR) for EZ Lidar, MPL and RL are shown in the figure below.



SNR profile for EZ Lidar, MPL and RL on October 24, 11:18 PM (UTC)

It's interesting to see that EZ Lidar has the best SNR on the first 1500m, due to a better geometrical overlap, and is comparable then. The results are shown in a table, where the lidar maximum range is defined by SNR = 1. The bias shows the difference percentage between the reference molecular backscatter profile, modeled from a worldwide climatic data base or calculated from radio probes data, and the normalized lidar signal.

10/23/06 10.56pm	Lidar Range	SNR 10	Overlap	Bias @ 6km
EZ	~12300 m	~6600 m	~320m	< 5 %
MPL	~9800m	~5700 m	~5000m	< 10%
RL	n/a	n/a	n/a	n/a

10/24/06 11.18pm	Lidar Range	SNR 10	Overlap	Bias @ 6km
EZ	~9000 m	~8500m	~320m	< 20 %
MPL	~8800 m	~8500 m	~5000m	< 15%
RL	~8000 m	~5000 m	n/a	<5%

Comparison results on October 23, 2006, 10:56PM (UTC), clear sky, and October 11:18PM (UTC) with multi layer high clouds observation.

5.4. Conclusion

EZ Lidar has been validated during several inter-comparison campaigns, by analyzing his performances compared to reference devices.
The automatic mixing layer height determination shows 95% of correlation with STRAT algorithm data developed by SIRTA/LMD-CNRS.

The study done after the American campaigns on ARM/SGP and GSFC/NASA sites show that the quality and the measurement performances of EZ Lidar are comparable to those from an MPL-4 lidar, chosen by MPLnet network.

All weather and unattended use capabilities of EZ Lidar, associated to his measurement performances, make this device a good candidate for aerosol and clouds observation network deployment, as indicated in the white paper of GALION worldwide lidars network project [6].

5.5. References

[1] J.-C. Raut and P. Chazette, Retrieval of aerosol complex refractive index from a synergy between lidar, sunphotometer and in situ measurements during LISAIR experiment, Atmos. Chem. Phys., 7, 2797–2815, 2007.

[2] P.Chazette, J.Sanak, F.Dulac, L. Sauvage, Characterisation of multiple aerosol layers originating from various sources above the Sahel region by a synergism of sunphotometer, scatterometer and airborne compact UV LIDAR, Geophysical Research Abstracts, Vol. 9, 10963, 2007.

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[4] J. R., Campbell, D. L. Hlavka, E. J. Welton, C. J. Flynn, D. D. Turner,J. D. Spinhirne, V. S. Scott, and I. H. Hwang, 2002: Full-time,eye-safe cloud and aerosol lidar observation at Atmospheric Radiation Measurement Program sites: Instrument and data processing. J. Atmos. Oceanic Technol., 19, 431–442.

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C- TECHNICAL SPECIFICATIONS AND TECHNOLOGY

EASY Lidar is the result of 15 years of research in CEA and CNRS laboratories. Its inventors have overcome major technological challenges to give birth to one of the best systems ever made.

1. SPECIFICATIONS

Emission specifications	
Wavelength	354.7 nm (tripled Nd:YAG)
Repetition rate	20 Hz
Power	16 mJ (±5% pulse by pulse)
Eye safety	IEC 60825-1
Divergence	< 0.25 mrad
Pumping	Flash lamp

Reception specifications	
Opening diameter	150 mm
Interference filter width	0.3 nm
Detectors	Photomultipliers

Acquisition	
Detection channel	Analog & photon counting (software)
Digitalization	14 bits – 100 Mhz

Environnement	
Min-Max Temperature	-15°C to 35°C (with temperature monitoring option)
Casing certification	IP65
Portability	Portable (1 person)

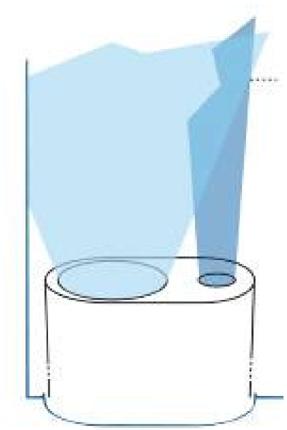
Weight and dimensions	
Weight	- Lidar head: 16 kg - Control unit: ≤ 35 kg
Dimensions	- Lidar head: 650 x 356 x 190 mm³ - Control unit: 8U rack

Data format	
Format	Binary & ASCII
Transfert	Local & Ethernet

Power supply	
Voltage	230 VAC / 50 Hz
Power consumption	≤ 1 kW (with heater)

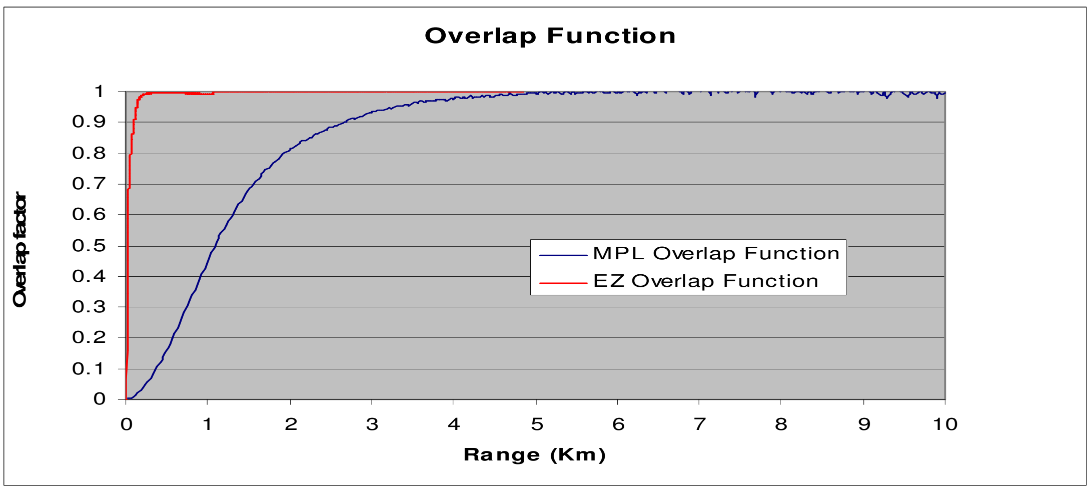
- Invisible beam
- Excellent molecular sensitivity
- Small particles detection down to 100nm
- Low full overlap (thanks to the field of view)
- More efficient in H2O Raman (10 times better diffusion) than at 532 nm.

2. Detection / Acquisition



Emission and detection are parallel. A stable alignment is ensured thanks to an exclusive optical design (CEA-CNRS 04/50115, BD1527-22/01/04 patent). The alignment robustness has been tested during several airborne missions, in order to experiment it in tough conditions.

Overlap function
Unlike many Lidar systems that are totally or partially blind in the first hundreds or first kilometres of observation range, full vision is reached at 200m for the ALS300 and 500m for the ALS450.



Typical overlap functions of EZ Lidar and MPL

Optical Architecture
Optimization of the optical design results in very high total transmission (90% without the interference filter) to our system. The final transmission depends on the type of interference filter used for the particular application. There should be no disturbance of the signal if the user puts the Lidar head in contact with the quartz window. However, adding an anti-reflective coating on the window is a recommended operation.

Background signal
The LIDAR efficiency is highly dependent on the background radiation due to natural or other sources of light. Collecting the "right photon" among a tremendous amount of light is not easy. It induces a large difference in the performances of most of the remote-sensing systems during daylight. LEOSPHERE's engineers managed to solve this problem by applying a spatial filtering method that reduces the background signal down to 1%. As a result, EZ LIDAR gets higher performance during daytime than traditional lidar system.

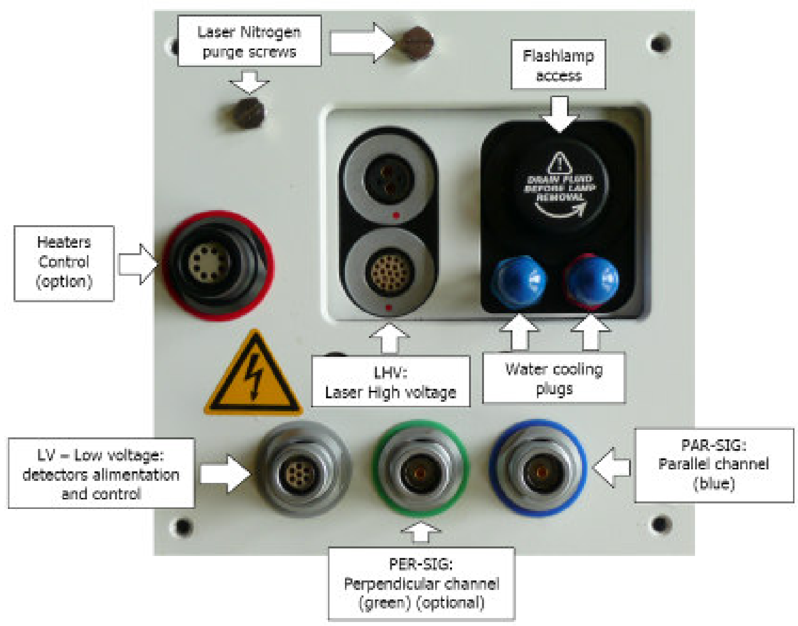
3. STANDARD LIDAR CONTENTS & PLUGS

For a standard ALS300/450 system (without option), the lidar package includes:

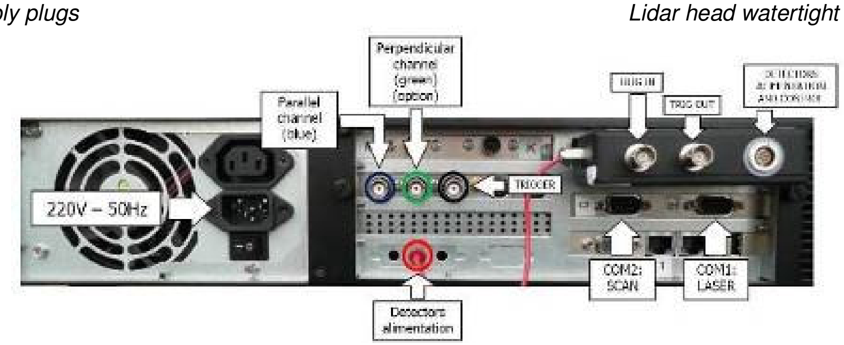
- Optical head receiver LEOSPHERE ALS300
- Industrial computer AREMO-2173E-00-00B
- ULTRA Laser power rack unit
- ULTRA Laser power rack remote control
- Temperature Controller rack unit
- Aluminum support pod (kit)
- Pair of hydraulic cables 5 meters long
- Set of electrical cables 5 meters long - 5 cables
- IEC power supply cables
- Laser Fill-in kit
- Set of keys
- Set of accessories

EZ Lidar plugs have been studied in order to be fast and easy. All the connectors are different in order to avoid any mishandling from the users.

Laser power supply plugs



Lidar head watertight plugs



Acquisition and monitoring computeur plugs

4. CASING

Three level of casing are available on the shelf.

	CASING 1		CASING 2		CASING 3	
	MODULAR AEROSOL STATION		1D VERTICAL CAMPAIGN AEROSOL LIDAR / ALL CIMATE		ALL OUTDOOR MODULAR AEROSOL STATION	
						
Operation	Outdoor optical head Indoor electronic units		The whole bloc is outdoor		Outdoor optical head Outdoor electronic units	
	Optical head	**Control unit**	**Optical head**	**Control unit**	**Optical head**	**Control unit**
Environmental protection						
Temperature operating (°c)	-15°C/+35°C	+15°C/+25°C	-20°C/+40°C		-15°C/+35°C	-20°C/+40°C
Waterproofness & airtightness	IP65	Bare units	IP65		IP65	IP65
Anti-condensation	YES	NO	YES		YES	YES
Corrosion	YES	NO	YES		YES	YES
Rain protection	YES	NO	YES		YES	YES
Thunder protection	YES	NO	YES		NO	NO
EMC	NO	NO	NO		NO	NO
Polluting attacks	NO	NO	NO		NO	NO
Options (NOT INCLUDED)						
Motorized scanning device	YES				YES	
Heater	YES	NO			YES	YES
Autonomy (electric/data transfert)	NO		NO		NO	
Transportability						
	Transportable (2 people) for mid term campaign		Transportable (2 people) for mid term campaign		Transportable (2 people) for mid term campaign	
Required installations/infrastructures						
Reception platform (ground)	Specific (4 fastening holes)	Table/cabinet	Standard (ground, roof…)		Standard (ground, roof…)	
Infrastructures	Not isolated (for inst : lab, roof)		Semi - isolated (building or campaign)		Semi-isolated (for instance : vehicle)	
Power supply	High quality network		Low quality network		Alternative power supply	
Data transfert	Ethernet network		Ethernet network / GSM / local		GSM network / local backup	
Security	Secured location		Semi secured location		Secured location	
Required maintenance/attendance						
Qualified manpower	YES (trained technician)		YES (trained technician)		YES (engineer required)	
Frequency	Weekly / monthly		Weekly / monthly		Permanent	
Dimensions						
Size (mm)	650x356x190	482x508x297	1270x640x720		650x356x190 (head)	500x400x300
Weight (kg)	16	22	40 (air con) + 2x25 (head+electronics)		17 (regular pod) 34 (motorized pod)	5 (PC) + 15 (power)

EZ Lidar systems can be provided with a fixed pod which allows the system to operate outdoor in all weather conditions.

A 3D all climate module (scanning device/software) can also be supplied as an option with the following specifications : 360 azimuthally, 89.9° zenithal, 0.2° accuracy.

Fixed pod at Chilbolton observatory *3D scanning device in Port Hedland, Australia*

5. Upgradability of the system

The **ALS300/450** can be easily upgraded by adding a cross-polarised module. Such a plug-in will enhance the capabilities of the LIDAR to indicate the non-sphericity of the particles so that the user gets the cloud phase (water or ice) or can discriminate soil dust from other aerosols when present. The shape of particles is linked with the aging effects, the toxicology or in-cloud transformation.
Water vapour and nitrogen Raman detection channels with their acquisition software will also be easily retrofitted onto the existing systems allowing continuous detection of the humidity factor.

SOFTWARE / DATA

All calculations are intrinsic to the equipment and do not require further software development. Raw and processed data are accessed based on a TCP-IP or Telnetprotocol. The software is written in a modular manner so that other protocols can be handled after specification by the LIDAR device.

Unlike other Lidar systems that are provided with basic acquisition software (equivalent to our level 1 features or below), ALS systems are supplied with one license of the **exclusive user-friendly and highly sophisticated software EZ-AEROSOFT™** v1.0, Windows compatible, which includes the following functions (broken down in two levels):

STANDARD Level 1 : basic data acquisition and edition, low level processing

Instrument control (fixed station)
Data acquisition (all channels)
Data shaping (correction, noise filtering)
Data edition (Real-time display of measurement)

OPTIONAL Level 2 : Acquisition, high level processing, basic data edition

Instrument control features
- Scanning device control (various pre-programmed scenarios)
- Remote control of the instrument and data collection via a specific software modem or TCP/IP

Data edition features:
- Computation and display of instant and temporal background range corrected profiles (PR2)

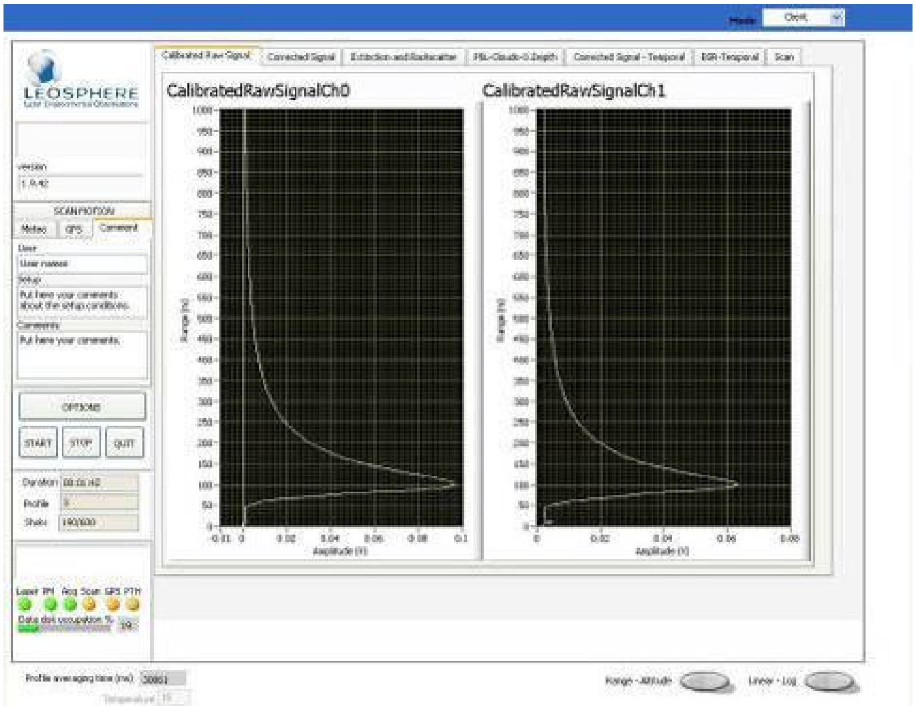
Real time & post processed data (From PR²)
- Normalized signal compared to Rayleigh model (reprocessed in function of geographic situation, season, pressure and temperature conditions).
- Backscatter profile, extinction profile, integrated optical depth, boundary layer height automatic tracking, residual layer height, clouds automatic detection

Operating alerts:
- Hardware diagnosis is automatically made and evaluated regularly thank to specific means. A log file keeps the history of the LIDAR. Failure indications are saved with acquisition configuration file. This file can be accessed through TCP-IP link.
- A specific message alerts for the presence of clouds. It is also saved in configuration data. In slave mode these alerts cannot be active but are reachable inside the data files (within the data stream) without the use of a specific command.
- Photomultiplier saturation are detected automatically and the system is turned down until the saturation source has disappeared (low clouds for instance)

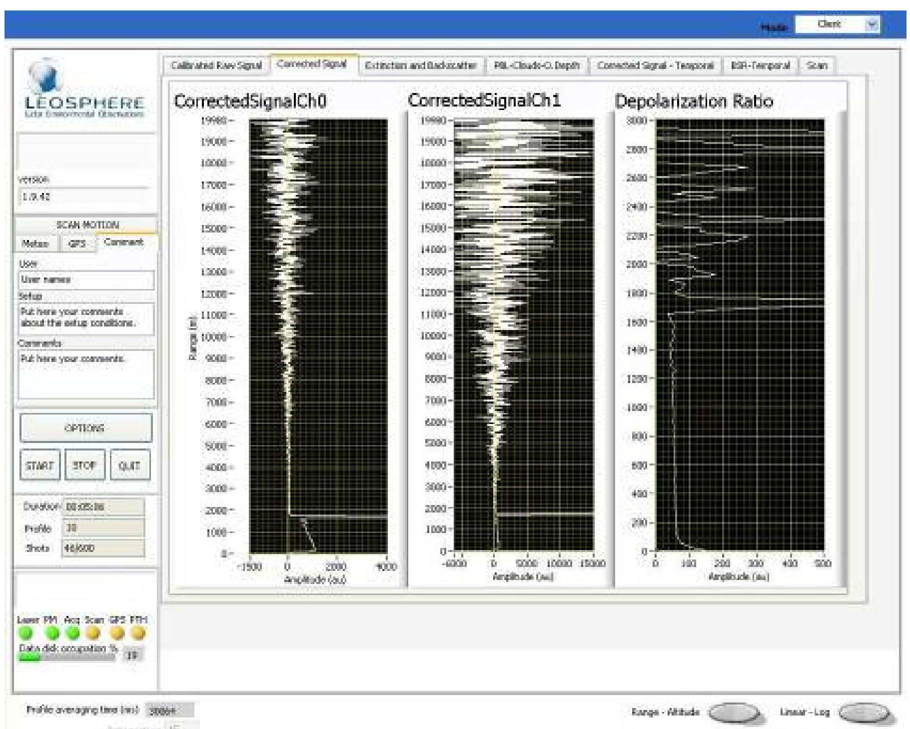
EZ-AEROSOFT™ v1.0 is already included and installed in the acquisition computer that is delivered with the system. Thus EZ- AEROSOFT™ v1.0 is intrinsically a part of the system.

EZ-AEROSOFT™ Viewer is available for sale, so that the EZ Lidar data can be read with another computer.

Software are available in French/English under Windows XP



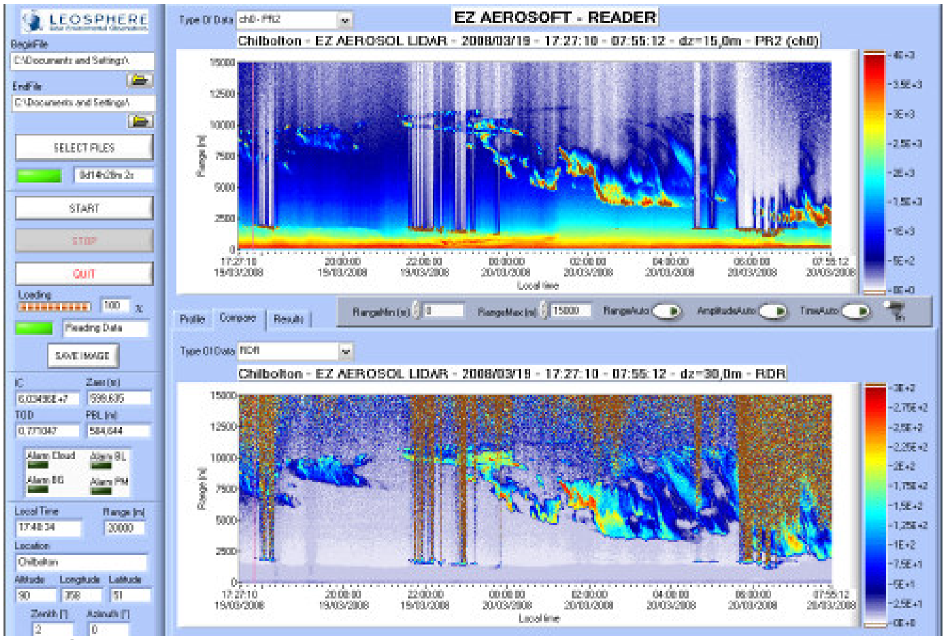
Sample of raw signal, elastic channel, 355 nm, parallel polarization (left side) and cross polarization (right)



PR² in parallel polarization (left), cross polarization (middle)and relative depolarization ratio (right).

Data features:

- Data format: They are provided in binary or ASCII format. A net CDF format may be implemented as an option.
- Back-up of primary data with all the acquisition parameters.



Sample of PR2 in parallel polarization (up) and relative depolarization ratio (down).

Remote control using a graphical interface or using telnet prompt commands

The remote control interface allows users to take the control of the remote computer from any place in order to follow the real time display of the data. A telnet connection is also possible and allows the user to type for any command or information that is present on the **EZ-AEROSOFT™** software. It will act on the local software in real time.

6. LIFETIME

LEOSPHERE Lidar systems are robust and long lasting meteorological instruments. Its replacement must be justified by new technological breaks, and not by a high usury level rending it inoperable. A 5-year operation cycle can be forecasted as a minimum.

Light maintenance adapted to the frequency of you operating
Mean time between 2 failures (MTBF) is evaluated at 14 months given the quality of sub-components used and the designers experience and knowledge. Typically, the laser's MTBF is 2 years. Nevertheless there isn't a long enough operating backtrack to provide empirical data at this point. Maintenance programs proposed by LEOSPHERE ensure an optimal management of the key subcomponents in order to optimize the continuity and the entire system lifetime.

Our Lidar systems use flash bulbs: Official documentation from manufacturer indicates a warranty of 20 million shots for the lamp. Experimental records all indicate 30 to 50 million shots. That means that continuous operation can be warranted to 416 hours at 20Hz laser shots.

Thus, we can estimate 52-days operating duration with an 8h/day continuous use or a 34-day operating duration if alternating 1 minute on/1minute off acquisition 24hours a day (equivalent to 12hours continuous per day).

The software also holds a measurement automat which can include lamp saving automatic procedure and optimize the flash bulbs utilization, respecting the specifications in the same time.

Technical bulb specs			Measurement scenario		
Lifetime (number shots)	Laser frequency (Hz)	Duration (hours)	Daily measuring time (hours)	Duration (days)	Required number of flash bulb / year
50 000 000	20	694,4	8,0	86,8	4,2
50 000 000	20	694,4	12,0	57,9	6,3
50 000 000	20	694,4	24,0	28,9	12,6

Example of operating scenarios

SPARES

LEOSPHERE can ensure an optional service to supply spares as a warranty against optics, laser or detector damage in order to ensure continuous operation. This option generates savings for our clients thanks to the volumes managed by LEOSPHERE for its various clients.

7. POWER SUPPLY

The system requires a 110-230 V electricity supply. Average power consumption is 370 W. However, during laser pulses at maximum energy level, consumption peak may require a 550 W power input. The system may also be operated under DC 24 V power supply using a power adapter / transformer.

8. COMPATIBILITY WITH OTHER EQUIPMENT

LEOSPHERE uses “CE” certified components for EMC purpose so that other equipments should not be disturbed. The device is protected under indirect thunder impact other conducted electrical impulses. Theoretically the laser emission can not be detected by other optical measuring instruments. If necessary, an optional study can be performed to evaluate the backscattered lights impact of the atmosphere on a nearby instrumental system.

The Lidar can be integrated in a conventional network using standard hardware so that instruments networking should not be disturbed as far as the network complies with standard definition (cable length, and power consumption).

9. CERTIFICATION / HEALTH AND SAFETY

EUROPEAN CERTIFICATION

Eye-safety (EN 60825-1) is guaranteed by LEOSPHERE.

According to EN60825-1 regulation, for wavelengths from 315 to 400 nm, maximum permitted energy (MPE), at the eye level, for direct exposure to laser radiation, is limited to 48 J/m² with a 5 ns pulse duration. In order to remain far below that level, we set the system (output beam diameter) so that the output Density of Laser Energy never exceeds 30 J/m².

Thus, the ALS300/450™ is an eye-safe system though it uses as a radiation source a class IV Laser. This also means the laser itself is not eyesafe and maintenance operations must be performed according to instructions that are written in the user's manual and by authorized and trained staff. Also, though the system is totally eyesafe, in order to increase safety and to prevent someone to play with the system, we write the following additional instructions in the manual:

- Direct long exposure of skin and eye to UV radiation can be dangerous, as it might cause cancer.

- Avoid long and direct exposure of skin and eye to the Laser UV radiation. It can be dangerous as such exposure might cause cancer.
- Wear gloves when hands are near the beam, as well as a face and eye protection against UV radiation.
- Avoid putting hands into the invisible beam and use fluorescent screens to define the Laser beam.

Our systems do not create any hazard of any kind for the users and the people in their surroundings. Also, they can be integrated into other instruments platform without disturbing their performance.

D- SERVICES

Our clients are naturally welcome to participate to final atmospheric tests in our premises.

1. DEPLOYMENT

- Packaging – wooden box with tiltwatch testing
- Air shipping and delivery all around the world
- Custom Tax / exportation duties
- Installation and calibration
- Tests and commissioning (1,5 days at LEOSPHERE premises or on-site) – Includes a performance check in actual atmospheric conditions

2. TRAINING

Documentation
LEOSPHERE provides one set of printed handbooks with maintenance instructions and an electronic copy of this manual.

User's training (2 days)
This training gives fundamental teaching on Lidar operations and light maintenance:

- Operation of the equipment.
- Processing (manipulation) of data.
- Basic interpretation of data from LIDAR.
- Advanced training of the software.
- Maintenance procedures.
- Optimization of scenario measuring.
- All operations and maintenance manuals.

3. RENTAL AND ENGINEERING SERVICES

LEOSPHERE offers to its clients rental and engineering Lidar services. The rental contract is adapted for punctual field campaigns; it has been designed to provide a high availability and a great using comfort. The rental contract (10 days minimum) entails:

- Devices and software during the period of the contract
- Material warranty
- Using tutorial
- 3 hours Hotline support
- Consumables (flash bulbs) in a limit of 1 replacement per month
- Insurance

Insurance, exportation taxes and delivery costs are not included but may be offered as an optional service.

Moreover, it is recommended to choose the module “EASY LIDAR Quick Start” which contains:

- 2 days initial training
- First Lidar installation on site
- 5 hours Hotline support (in addition of the 3 initial hours)

Atmospheric engineers can eventually intervene downstream and upstream for:

- Determine the measuring Lidar scenario
- Data post processing
- Data interpretation

LEOSPHERE provides engineering services that can go from the conception, integration, to the realization of various optomechanical or electronical modules for Lidar systems.

4. Support, Warranty and Maintenance

Our products (hardware and software) benefit from a 1 year full warranty contract (subcomponents and manpower), exclusive of travel costs of personnel and related costs.

LEOSPHERE LIDAR systems are designed so that no optical re-alignment is needed. The only scheduled operations are installation, commissioning, calibration, and light maintenance. In case the customer uses its own scanning system, a particular attention should be paid on the accessibility of the maintenance apertures.

Light maintenance is very easy and is performed by the user with possible support from LEOSPHERE.

- Lamp state and maintenance needs are automatically monitored by the software.
- Cooling water and flow filters must be changed every 6 months.

E- LEOSPHERE AT A GLANCE

Atmospheric Lidar Specialists

LEOSPHERE, inc. is 100% specialized in LIDAR (laser-radar) remote atmospheric observations.

Its corporate mission is to provide clients with a high-end and differentiated range of products and services based upon 3 dimensions: The EZ LIDAR™ concept, a strong atmospheric sciences background and, an exclusive dual range of aerosol LIDAR and wind LIDAR systems.

LEOSPHERE controls the entire chain of jobs that guarantees that the performances and features of its final products will match the users’ initial expectations: from atmospheric research, optoelectronics development, and data treatment, to industrial solutions design and assembly.

Over 30% of the company’s total revenue (industry average: 10%) is dedicated to research and development to ensure a consistent level of innovativeness which guarantees that the clients will have many opportunities to update their product.

LEOSPHERE takes care of the manufacturing, the testing, the delivery, the set-up, the commissioning, the training, the technical support and the maintenance for all its systems and clients.

LEOSPHERE also proposes engineering services associated to LIDAR technology in order to provide to many people the opportunity to try and use LIDARs without purchasing one: field surveys, on–demand development, renting, data analysis.

As LEOSPHERE has clients in several application fields, such as meteorology, air quality monitoring, atmospheric research, wind farming, and air traffic management, the company makes all its client benefit from technical improvements gathered throughout this wide range of users, as well as from associated economies of scale.

80% of LEOSPHERE's turnover is realized on non-domestic markets, mainly in Asia, Northern Europe, and North America, where exclusive partners represent the company and its product.

1. PEOPLE AND PARTNERS

LEOSPHERE has a wide and strong range of skills within its team of researchers and engineers. The duality of profiles, atmospheric researchers plus optronics, optics and software engineers enables to set up reliable and robust instruments that atmospheric physicists can trust, and that can be operated under any condition.

14 people, including 6 physics or optronics doctors, compose our team. The researchers act first as "demanding clients", upstream the development phase, then as "experts" feeding developers with the latest ideas collected throughout their network, and at last, as "users" to validate that the product match their needs.

Scientific references (publications and conferences)

L.SAUVAGE, J.PELON, F.FIERLI, Y.BALKANSKI, J.F.LEON, P.GOLOUB, C.MUOZ, *Dust aerosol properties and source region analysis derived from EARLINET and AERONET networks, satellite observations and Transport model*, First EARLINET symposium, Hamburg, Allemagne, février 2003.

SAUVAGE L., V. RIZI, F.FIERLI, *Raman lidar measurements for aerosol extinction and water vapor concentration retrieval,* first Astroparticle and Atmosphere workshop, Collège de France,Paris ,mai 2003.

J.PELON, **L. SAUVAGE**, *Temporal cycle in the aerosol distribution,* First EARLINET symposium, Hamburg, Allemagne, février 2003.

L. SAUVAGE, J.PELON, F. FIERLI, Y. BALKANSKI, P.CHAZETTE, P. GOLOUB, J.F. LÉON, C. MUNOZ, M. K SRIVASTAVA, *Long-range transport of Saharan dust aerosol particles over Europe derived from lidar sun photometers and satellite observations*, European Aerosol Conference, Madrid, Espagne, Sept. 2003.
http://www.leosphere.com/files/lidar/library/Long-range%20transport%20of%20Saharan-ILRC_2004.pdf

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STUBENRAUCH C., F. EDDOUNIA, **L.SAUVAGE**, *Cirrus physical properties fromIR vertical sounder (TOVS) observations*, first Astroparticle and Atmosphere workshop, Collège de France,Paris ,mai 2003.

CHEPFER H., **SAUVAGE L.**, FLAMANT P.H., PELON J., GOLOUB P., BROGNIEZ G., SPINHIRNE J., LAVORATO M., SUGIMOTO N., *VALIDATION OF POLDER/ADEOS data using a ground based lidar network : preliminary results for semi-transparent and cirrus clouds,*19th International Laser Radar Conference, Anapolis, 1998.

Closely involved in the product development process, two major public research groups enrich the company's research and development human potential. Two technical cooperation agreements have been signed with :

1. The « Laboratoire des Sciences du Climat et de l'Environnement » - CEA (Atomic Energy Commission) - CNRS (National Research Center) joint laboratory – who holds recognized skills in the development and use of LIDARs for air quality monitoring and the climate change analysis.. LEOSPHERE's first compact LIDAR

system was developed in cooperation with this institution. This project led to an exclusive and worldwide licence agreement from the laboratory to the company to manufacture and sell the system.

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Chazette P., *The monsoon aerosol extinction properties at Goa during INDOEX as measured with lidar*, J. Geophys. Res., 108, 4187, 2003.

Hodzic A., H. Chepfer , R. Vautard, P. Chazette, M. Beekmann, B. Bessagnet, B. Chatenet, J. Cuesta, P. Drobinski, P. Goloub, M. Haeffelin, Y. Morille, *Comparison of aerosol chemistry transport model simulations with lidar and Sun photometer observations at a site near Paris*. J. Geophys. Res. 109 (D23), D23201, 10.1029/2004JD004735, 2004.

Hodzic A., R. Vautard, P. Chazette et L. Menut, *Aerosol chemical and optical properties over the Paris area within ESQUIF project*, SRef-ID: acpd-2005-0247, 2005.

Chazette P., P. Couvert, H. Randriamiarisoa, J. Sanak, B. Bonsang, P. Moral, S. Berthier, S. Salanave and F. Toussaint, *Three dimensional survey of pollution during winter in French Alps valleys,* Atmosph. Env., 39, 1345-1047, 2005.

2. The « Département d'optique appliquée » (DOTA) within the ONERA (National Aersospace Research Institute) who conducts optronic studies applied to defence and aerospace on behalf of the CNES (National Center for Space Studies), the DGA (Department of national security) and other institutions linked with the airline and airspace industries. The DOTA holds a 10 year experience in the field of turbulences modelization and detection and is part of numerous European projects dealing with wakewortex : Eurowake (« Wake vortex creation »); Wavenc (Evolution of wakevortex and impact on air traffic); C-Wake (caracterization and control of the wake vortex); S-Wake (Evaluation of dangers related to wake vortex); EC AWIATOR; Wakenet2. Moreover, the DOTA holds robusts skills in the entire optical chain (from laser sources to post-treatment): characterization (models and experiments) of optical signals (UV, visible and near IR), development and evaluation of measurement systems, image re-construction, laser sources, LIDAR systems, data optical transmission. Main applications for these fundamental skills include laser anemometry, speedmeters, laser vibrometry.

LEOSPHERE and the DOTA have developed a range of wind and turbulence measurement solutions dedicated to meteorology, windfarming, and air traffic management. LEOSPHERE enjoys an exclusive licence to manufacture and commercialize this technology.

2. CLIENTS

LEOSPHERE LIDAR systems are marketed towards public research institutions, agencies, engineering and consulting firms, airports and industrialists.

Until now, EZ LIDAR systems have been sold in the following countries: Japan, China, UK, The Netherlands, France.

Some of our clients and partners may be contacted to collect their feelings and experience about EZ LIDAR systems. Please request us their contact information to get in touch with them.

Institut/Company	Logo	City/Country	Application	Operation
University of Durham - Department of Physics	Durham University	Durham/ United Kingdom	Astrophysics research - Exctinction measurements	ALS300 - Fixed operations
National Institute of Environmental Studies (NIES) – Department of atmospheric studies		Tsukuba / Japan	Atmospheric research - Satellite data validation	ALS300 - Mobile campaign operations (airborne)
University of Reading - Department of Meteorology	University of Reading	Reading / United Kingdom	Meteorological research - Upper clouds study	ALS450 with depolarization – Fixed operations
Chinese Academy of science (CAS)- Institute of Atmospheric Physics (IAP)	IAP	Beijing / PRC	Atmospheric research - boundary layer monitoring	ALS300 - Mobile campaign operations
Institut Pierre Simon Laplace (IPSL) - Research platform of atmospheric remote instruments (SIRTA)	SIRTA Site Instrumental de Recherche par Télédétection Atmosphérique	Palaiseau / France	Atmospheric research - Upper clouds study	ALS450 with depolarization – Fixed operations
KNMI (National Meteorological Dutch agency)	KNMI	Cabaw / The Netherlands	Meteorological research - Upper clouds study	ALS450 with depolarization – Fixed operations
Atomic Energy center (CEA) - Environmental sciences and climate Laboratory (LSCE)	cea	Saclay / France	Air quality research	Two ALS300 units - Mobile campaign operations (airborne and car)
National Meteorological French Agency – Meteorological Research department		Toulouse / France	Meteorological research – Aerosol and clouds monitoring	ALS300 – fixed operations

Beijing Municipal Environmental Protection Bureau (BMEPB) – Beijing municipal environmental monitoring center (BMEMC)		Beijing / PRC	Air Quality research - boundary layer monitoring	ALS300 - mobile campaign operations
University of Virginia - Department of Environmental Sciences		Charlottesville / USA	Atmospheric research - Aerosols and clouds detection in boundary layer and middle troposphere	ALS300 with depolarization and scanning – Mobile and fixed campaign operations
National superior school of applicated and technological sciences – ENSSAT		Porquerolles / France	Atmosphere and ocean interaction feasibility study	Windcube and ALS300 – fixed operations
Paris public transport agency (RATP) – Environmental department		Paris / France	Indoor air quality – Study of aerosol distribution in an underground subway station in Paris	ALS300 – Fixed operations
BHPBilliton - Superintendent Clear Air Task Force		Port Hedland / Australia	Feasibility study of lidar operation for the real time identification of dust sources	ALS300 in fixed fast scanning operations and dedicated real time data retrieval software
Washington State University		USA	Air Quality research - boundary layer monitoring	ALS 300. Mobile campaign
Met office		UK	Air Quality research -	ALS 300 for airborne campaign

3. Corporate Information

LEOSPHERE SAS is an independent, private incorporated firm sponsored by the main French and European Institutions promoting innovation: Ministry of Research and Technologies, CNRS, CEA, ONERA, Ministry of Sustainable Development, European Space Agency, Eurocontrol…. The company was established thanks to the common wish from several LIDAR research experts to create a first-rank European LIDAR company.

Financial and legal information

LEOSPHERE's long term financial resources ensure the company, its clients, employees, sponsors and suppliers a safe long-term relationship.

- Equity : 1 M€ at the end of year 2007.
- Total assets : 672 k€
- Forecasted revenue for the year 2008 is 4,250 M€

LEOSPHERE's activity is covered for all risks it can engender in the frame of its activity and notably towards its clients:

- Public professional liability covering corporal, material, immaterial damages which can have been engendered by the use of its products or/and services (750 k€ worldwide)

Awards

- LEOSPHERE has been awarded by the French Ministry of Research in the frame of the 2004 national innovative venture prize.
- It also received an award from the French senate in the frame of the 7th Paris Venture Capital summit in 2005.
- LEOSPHERE is also supported by the Paris's district since the company won the Paris Innovation Prize in December 2003.

- LEOSPHERE has European antennas and support since it has been selected by the European space agency within the ESA technology transfer program.

Premises
LEOSPHERE's headquarters are located in Orsay (France). A subsidiary was opened in Leiden (The Netherlands – ESTEC site).

Technical facilities, especially opto-mechanical production lines, and atmospheric validation sites, are located in Orsay (France) where development and product integration are realized.

4. QUALITY INSURANCE – TECHNICAL, FACILITIES AND MEASURING

CUSTOMER SATISFACTION PROCESS
LEOSPHERE's corporate philosophy since its creation has been to place user's needs as a permanent constraint for product development in a very pragmatic way. From the whitepaper product definition phase to the prototype and product commissioning phase, clients, who are mostly researchers, have been involved to set their scientific problematic and operational constraints.

QUALITY PROCESS
LEOSPHERE has established product quality standards, measurement tools and non conformity elimination procedure to ensure a solid quality insurance process. This regards product design and product manufacturing.

ASSEMBLY AND TESTS
The systems manufactured by LEOSPHERE are assembled according to consistent and homogeneous procedures. Electronics, mechanical and optical assembly/alignments/tests are performed step by step in laboratory.

The Lidar technology imposes to perform long intermediary tests in indoor laboratories before the external / real environment tests can start. This ensures a repeatable quality control that is not impacted by atmospheric conditions.

The procedure is defined so that no additive optical or mechanical alignment is needed for external operations. The atmospheric tests allow to adjust the system to the clients functional needs (air quality within the boundary layer, high altitude clouds etc…)

The software (basic or advanced module) is developed according to the same philosophy, respecting progressive functional checking and compliance with the reference specification document.

When the LIDAR is completed, a compliance review is done in reference to the customer specifications reference document. A certificate of quality and a certificate of compliance are signed by the manufacturing manager and remitted to the client, as a guarantee of the staff's commitment in the quality of the final product.
The integration tasks are performed by fully trained employees. No subcontracting is used during this last sensitive phase.