NEW EYE SAFE AUTONOMOUS EZ LIDAR™ FOR POLLUTION AND METEOROLOGICAL CONTINUOUS MONITORING

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ABSTRACT

A compact, unattended and rugged eye safe UV lidar, the EZLIDAR™, was developed together by LSCE (Lab. Of CEA and CNRS) and LEOSPHERE (France) to monitor the vertical structure and optical properties of clouds and aerosols over long periods. We describe in this paper the specifications of this innovative lidar. This upper air sensor is answering the need of the meteorological community for a reliable and automatic system to be used in a global lidar network.

Keywords: Observing network, Pollution, Aerosol Optical Depth, Aerosol Lidar

INTRODUCTION

Last international scientific work on Climate change indicate the remaining uncertainties on the direct and indirect radiative effect of aerosols. Moreover, the limitations of the models are due to a lack of precise vertical information on clouds and aerosols.

LEOSPHERE developed the EZLIDAR™, the first outdoor autonomous eye-safe lidar that can probe the atmosphere from lowest altitude in the Planetary Boundary Layer up to the low stratosphere. It has been validated against different remote or in-situ instruments during several inter-comparison campaigns, as a MicroPulseLidar Type-4 lidar on ARM/SGP site in Oklahoma. It is already used by different meteorological services as METEOFRANCE, the KNMI or the Beijing Met Bureau.

Moreover EZLIDAR™ was deployed in different air quality and long distance aerosol transport research campaigns (LISAIR'05, AMMA Niger campaign in January 2006, ASTAR/IPY in April 2006, TIGERZ'08 together with NASA/AERONET).

EZLIDAR™ INSTRUMENT

EZLIDAR™ Lidar uses a tripled pulse laser source ND:YAG at 355nm wavelength with an energy of 16mJ and pulse repetition frequency of 20 Hz. Both analog and photon counting detection are available. The lidar system provides a real time measurement of backscattering and extinction coefficients, Aerosol Optical Depth (AOD), an automatic Planetary Boundary Layer (PBL) height and cloud base and top from 100m up to 20 km.

In table 1 are schematically reported the instrument characteristics

Range	**50m-20km**	**Environment**	**-20°C../+50°C**
Temporal Res	**30s**	**Humidity**	**0-100%**
Spatial Res	**15m**	**Waterproofing**	**IP65**
Angular Res	**0.2°**	**Weight**	**~48 kg**
ScanningSpeed	**8°/s**	**Eye Safety**	**IEC60825-1 2001**

Table 1 EZ Lidar(TM) main technical characteristics and features

PLANETARY BOUNDARY LAYER VALIDATION CAMPAIGN AT LMD

EZ Lidar was deployed at LMD in Palaiseau, France in order to validate the PBL height retrieval form LEOSPHERE's AEROSOFT method with those retrieved by the algorithm STRAT[5] from large field LNA data of the Laboratoire de Météorologie Dynamique (CNRS). During the twelve-days measurement campaign, 5 min of PBL averaged height has been provided by both instruments. Results show (Figure 1) a very high correlation of 95%

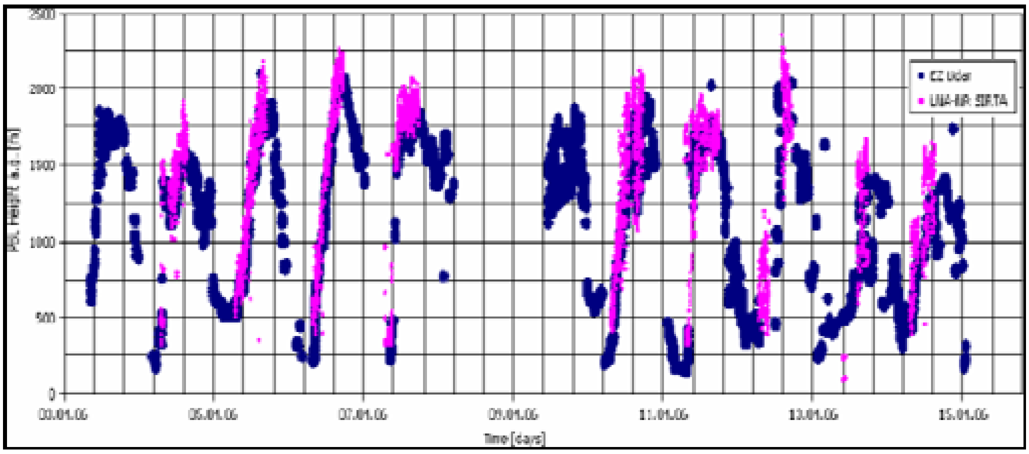


Figure 1 PBL Height retrieval from EZLIDAR (blue) and STRAT(fuchsia)

In addition, the EZ automatically retrieved Aerosol Optical Depth has been compared with sunphotometer data (P.Goloub, AERONET, France) (Figure 2). Around noon sunphotometer data were not available due to passing of subvisible clouds.

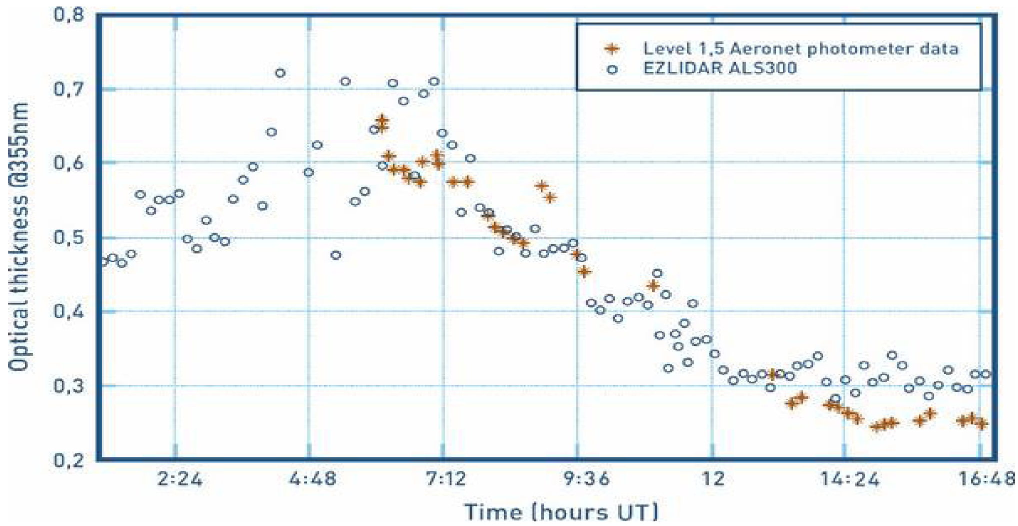
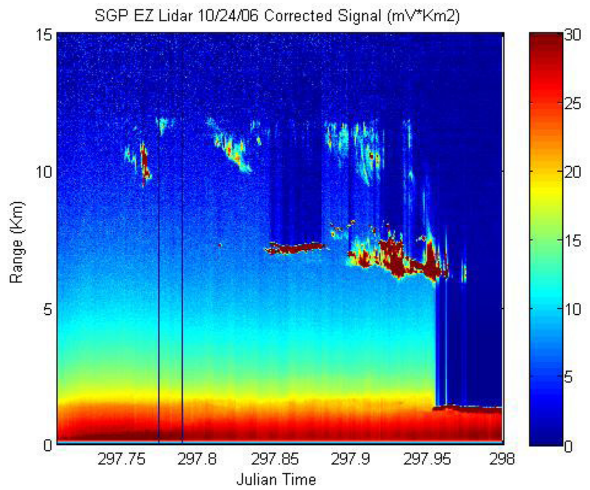


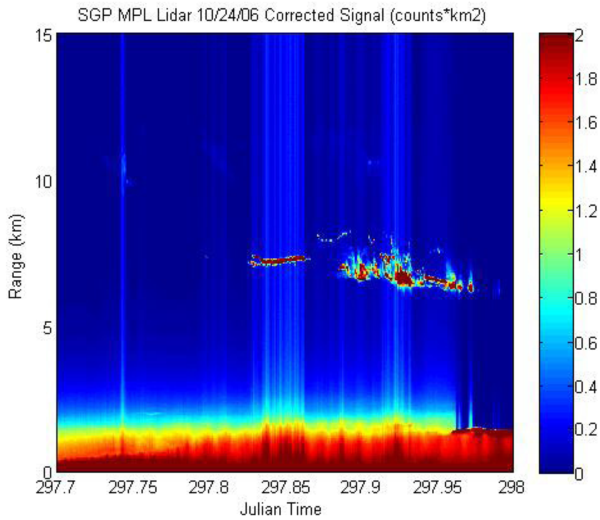
Figure 2 Level 1.5 Aeronet photometer data (red cross) AOD EZLIDAR retrieval (blue circles)

VALIDATION CAMPAIGN AT ARM/SGP SITE

The ARM/site intercomparison measurement campaign took place on 23rd and 24th October 2006 at Southern Great Plains, situated in Oklahoma, United States. SGP Central Facility coordinates are: N36° 37' W97° 30' at an altitude of 320 meters above sea level. We made the assessment of EZLIDAR performances using the Micro Pulse Lidar, used by the NASA for climate monitoring, as a reference. Raman Lidar (RL) data measurements were available on 24th October. Raw data from MPL and EZLIDAR show for the first day clear atmosphere conditions, while on 24th October cirrus clouds between 10 and 12km, alto stratus and cumulus are present during the day.

In order to compare directly the instruments, the measurement time run from 5pm to 0am (UTC) on both days. Due to the different atmospheric conditions, it is possible to compare both systems in different features. The following plots show the range corrected signal [1] as function of the time for EZ, MPL and RL on 24th Oct).





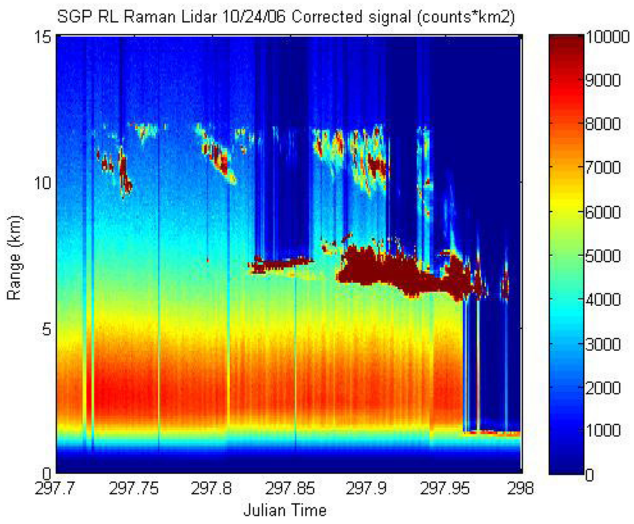


Figure 3 Range corrected signal for EZ lidar (top), MPL lidar (middle) and RL Raman Lidar (bottom) on 24th October 2006. Reference time is in UTC.

MPL data needed to be corrected with the recovered overlap function (representing the area of partial view of the instrument) to retrieve for the first kilometers of the troposphere. EZ data didn't need any post processing due to its enhanced range capabilities. Both instrument overlap functions are plotted in Figure 4.

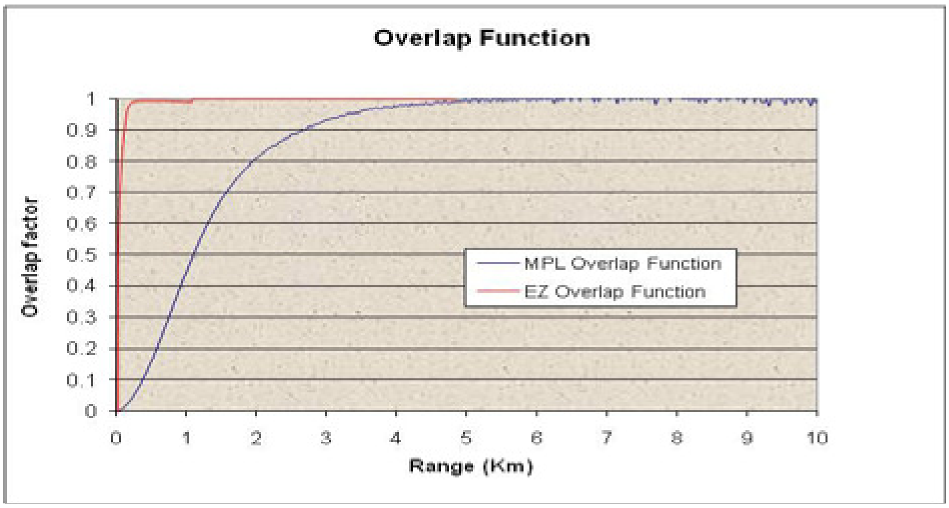


Figure 4 EZLIDAR(red) and MPL(blue) overlap function

It can be noticed that, due to the extremely narrow MPL Lidar field of view, its complete overlap is reached around 5 km, while EZ lidar full overlap is set to 220 m (and 98% overlapping at 170m) for this campaign. A narrow field of view permits to reduce unwanted solar background and effects due to the multiple scattering, but presents less accuracy in the recovering region. Specific optical design of the EZLIDAR allows rejecting most of the background signal and thus allow to use a wider field of view.

The Signal-To-Noise Ratio (SNR) is a parameter to assess lidar performances. For a given lidar signal, being the received number of photons small enough to approximate the detected signal by a Poisson distribution, SNR can be retrieved using the following equation [1]:

$$SNR(r) = \frac{NP(r)}{\sqrt{NP(r)} + NP_{bkg}}$$

where N is the number of accumulated shots in 30s, P(r) is the received signal from range r and P_{bkg} is the received power due to the solar background.

It is now possible to compare SNR profiles for EZ, MPL and RL instruments, as plotted in figure 5.

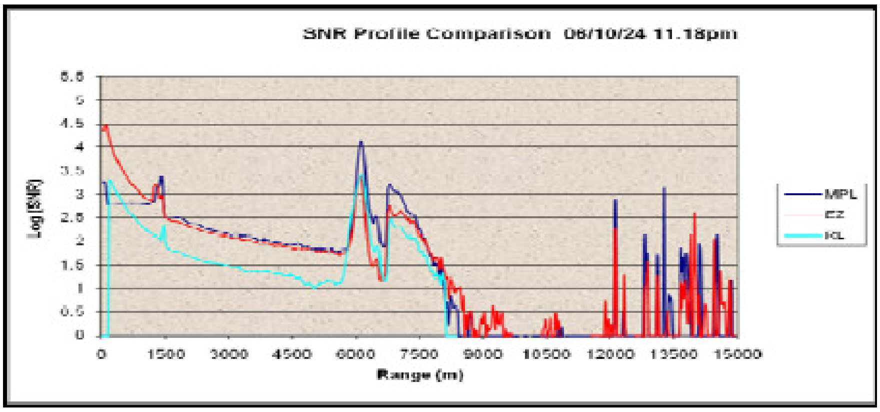


Figure 5 EZ, MPL, RL SNR profiles on 24th Oct, 11.18pm (UTC)

It is interesting to notice that EZ SNR is better in the first 1.5 km and it is comparable further. This is a consequence of a lower EZ full overlap, as showed in Figure 4. The results are schematically reported in Table 2, where the Lidar range is defined as the range at which SNR=1. Bias indicates the percentage divergence between the measured molecular signal and the normalized range corrected lidar signal

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%

Table 3 Comparison result for 24th Oct, 11.18pm (UTC)

UNCERTAINTY ANALYSIS

The total and particle backscattering and extinction coefficients are directly retrieved processing the lidar signal returns as described in [3]. The total backscattering coefficient is given by:

$$\beta_{tot}(z) = \frac{\beta_m exp^{(S'(z)-S'_m)}}{1 + 2\beta_m L_R \int_{z_m}^{z} exp^{(S'(z)-S'_m)} dz'}$$

Where z_m is the reference altitude at which the inversion starts, β_m is the known molecular backscattering coefficient at z_m, S' is the normalized range corrected lidar signal return (NRB) and LR the lidar ratio. The relative uncertainty in retrieving the total backscattering coefficient is given by:

$$\Delta\beta_{tot}(z) = \sqrt{\sum\left(\frac{\delta\beta_{tot}}{\delta X_j}\Delta X_j\right)^2}$$

Where Xj is respectively the relative source error in the backscattering coefficient (lidar ratio LR, molecular backscattering β_{mol} and the NRB). Each source error has been evaluated in a previous study [6], and from (3), it is possible to retrieve the backscattering coefficient with the relative uncertainty. We show that the uncertainty on the backscattering coefficient retrieval is 100% at about 9000m for this specific atmospheric conditions encountered on the 24th of october. This is consistent with the lidar range calculated in table 3.

CONCLUSIONS

The EZLIDAR instrument has been validated in several intercomparison campaigns, with different remote in-situ instruments. PBL height retrieval shows a correlation of 95% with STRAT retrieval algorithm at LMD. The analysis of the obtained results at ARM/SGP campaign in 2006 shows that EZ lidar data quality in analog detection mode is comparable with MPL data during daytime and under multi layered cloud conditions, and present a better maximum range under clear sky conditions. Outdoor and unattended use capabilities of the EZLIDAR™ added to its measurements performances define then this instrument as a very good candidate for deployment into growing global aerosol and cloud monitoring networks and research measurement campaigns

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