VALIDATION OF THE PERFORMANCES OF THE EZ AEROSOL LIDAR AGAINST OTHER REMOTE OR IN-SITU SENSORS AND INSTRUMENT UNCERTAINTY ANALYSIS

S. Lolli[1], L. Sauvage[1], B. Guinot[1], M. Lardier[1]

[1]*Leosphere, 42 Rue de Clignancourt 75018 Paris, France(slolli@leosphere.fr)*

A compact and rugged eye safe UV lidar, the EZLIDAR™, was developed together by Laboratoire des Sciences du Climat et l'Environnement (LSCE) (CEA–CNRS) and LEOSPHERE (France) to study and investigate structural and optical properties of clouds and aerosols, thanks to the strong know-how of CEA and CNRS in the field of air quality measurements and cloud observation and analysis .

1. Introduction

EZLIDAR™ has been validated by different remote or in-situ instruments as MPL Type-4 lidar manufactured by NASA at ARM/SGP site or the LNA at Laboratoire de Metereologie Dynamique LMD(France) and in several intercomparison campaigns. Further 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).

2. 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 is available. The lidar system provides a real time measurement with scanning capabilities of backscattering and extinction coefficients, Aerosol Optical Depth (AOD), automatic detection of the Planetary Boundary Layer (PBL) height and clouds base and top from 50m up to 20 km.

In table 1 are schematically reported the instrument characteristics

Range	**50m-20km**	**Environment**	**-20°C../+50°C**
Temporal Res	**1s(PBL)/30s**	**Humidity**	**0-100%**
Spatial Res	**1.5m/15m**	**Waterproofing**	**IP65**
Angular Res	**0.2°**	**Weight**	**~48 kg**
ScanningSpeed	**8°/s**	**Eye Safety**	**IEC60825-1 2001**

Table 1 EZLIDAR technical characteristics

3. Validation campaign at LMD

EZ Lidar was deployed at LMD in Palaiseu, France to validate the PBL height measurements with those retrieved by the algorithm STRAT[5] from large field LNA data of LMD. The 12-days measurement campaign of 5 min of PBL averaged height shows (Figure 1) a correlation between the instruments of 95%

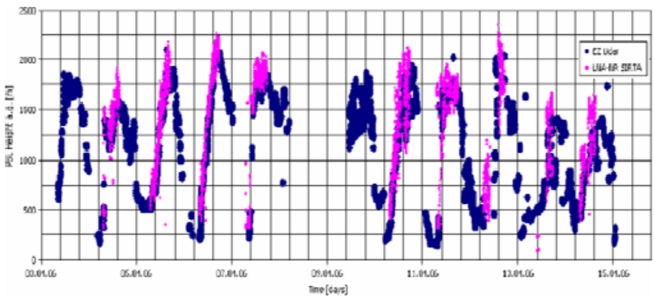


Figure 1 PBL Height retrieval from EZLIDAR (blue) and STRAT(fuchsia)

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

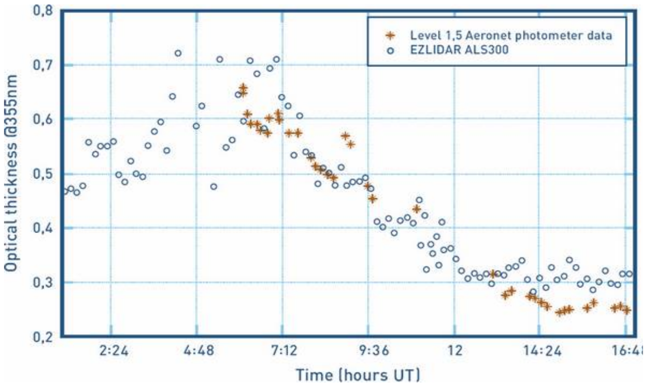


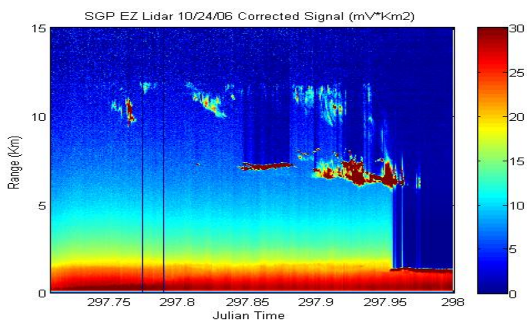
Figure 2 Level 1.5 Aeronet photometer data (red) AOD EZLIDAR retrieval (blue)

4. Validation campaign at ARM/SGP site

The 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' with an altitude of 320 meters above sea level. Raman Lidar (RL) data measurements are 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).



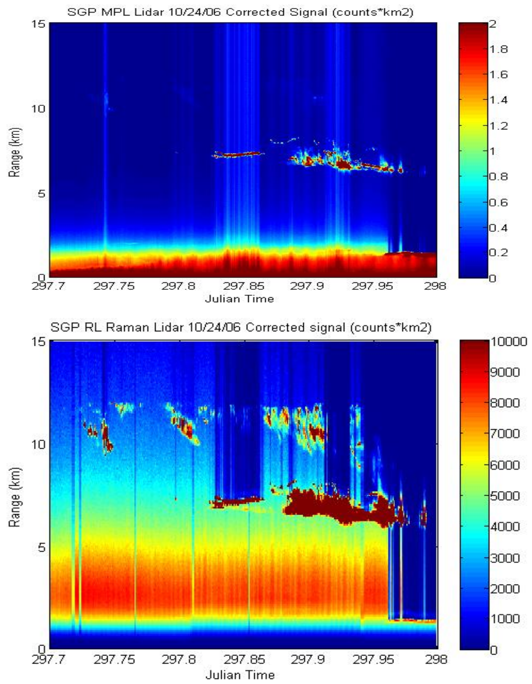


Figure 3 Range corrected signal for EZ lidar (top), MPL lidar (middle) and RL Raman Lidar (bottom) on 24th October 2006. Reference time is in UTC.

MPL data, not separated into polarized components, should be corrected with the recovered overlap function; also EZ data should be corrected by the overlap function. Both instrument overlap functions are plotted in Figure 4.

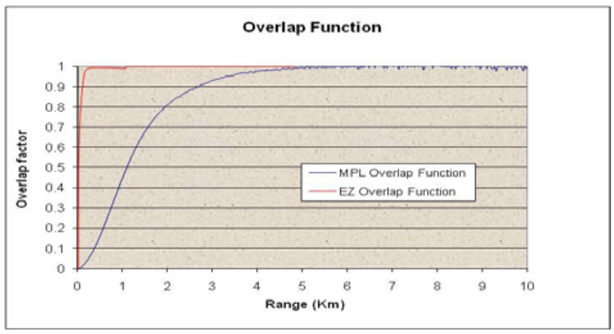


Figure 4 EZLIDAR(red) and MPL(blue) overlap function

It can be noticed that, due to the extremely narrow MPL Lidar field of view, complete overlap is reached around 5 km, while EZ lidar reaches it at 220 m (and 98% overlapping at 170m). 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

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]:

$$SNR\ (r) = \frac{NP\ (r)}{\sqrt{P(r)N\ +\ NP_{bkg}}} \qquad (1)$$

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.

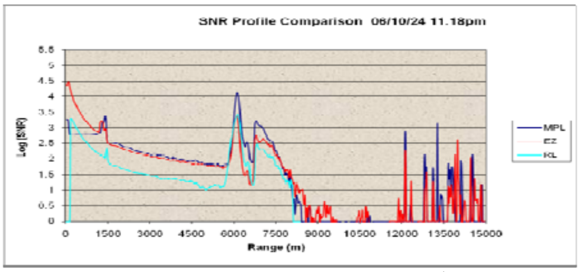


Figure 5 EZ, MPL, RL SNR profiles on 24th Oct, 11.18pm (UTC)

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)

5. 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:

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

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 L_R the lidar ratio. The relative uncertainty in retrieving the total backscattering coefficient is given by:

$$\Delta\beta_{tot}(z) = \sqrt{\sum\left(\frac{\delta\beta_{tot}}{\delta X_j}\Delta X_j\right)^2} \qquad (3)$$

with β_{tot} function of the lidar ratio L_R, the 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 as plotted in Figure 6, for a measured profile at SGP

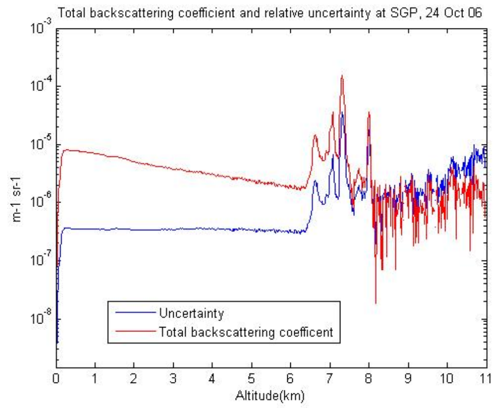


Figure 6 Total backscattering coefficient and relative uncertainty

The figure shows that the uncertainty on the backscattering coefficient retrieval is 100% at about 8000m. This is consistent with the lidar range calculated in table 3.

6. Conclusions

The EZLIDAR instrument has been validated in several intercomparison campaigns, with different remote o 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 shows that EZ lidar data quality is comparable with MPL data during daytime and under multi layered cloud conditions, and present a better maximum range under clear sky conditions. In these calculations, MPL data are referred to parallel polarization, while EZ data contain both.

Outdoor and unattended use capabilities of the EZLIDAR™ added to its measurements performances define then this instrument as a good candidate for deployment into growing global aerosol and cloud monitoring networks and research measurement campaigns.

7. References

[1] 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.

[2] Ansman, A, M Riebesell, and C Weitkamp. 1990. “Measurements of atmospheric aerosol extinction profiles with Raman lidar.” Optics Letters 15:746-748.

[3] J. D. Klett, "Stable analytical inversion solution for processing lidar returns," Appl. Opt. 20, 211- (1981)

[4]Dave Turner et al. “Raman lidar measurements of the aerosol extinction-to-backscatter ratio over the Southern Great Plains” Journal of geophysical Research, Vol. 106, NO. D17, Pages 20,333–20,347, 2001

[5] Y.Morille, M.Haeffelin, P.Drobinsky, J.Pelon, *STRAT:* an automated algorithm to retrieve the vertical structure of the atmosphere from single channel lidar data, JAOT, Volume 24, Issue 5 (May 2007) pp. 761–775.

[6] S. Lolli Ez “Lidar Uncertainty Analysis in AOD retrievals.” LEOSPHERE internal communications, 2008