AN INNOVATIVE EYE SAFE AND COMPACT EZ LIDAR™ FOR POLLUTION AND CLOUD MONITORING

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1. Introduction

A compact and rugged eye safe UV lidar, the EZLIDAR™, was developed together by CEA/LMD and LEOSPHERE (France) to study and investigate structural and optical properties of clouds and aerosols.

EZLIDAR™ has been validated by different remote and in-situ instruments as MPL Type-4 Lidar manufactured by NASA at ARM/SGP site or the LNA(Lidar Nuage Aerosol) at the Laboratoire de Metereologie Dynamique LMD (France) and during several intercomparison campaigns. Further the EZLIDAR™ was deployed in different air quality and long distance aerosol transport research campaigns (RATP, LISAIR'05, AMMA Niger campaign in January 2006, ASTAR/IPY in April 2006, TIGERZ'08 together with NASA/AERONET).

Due to its characteristics, EZLIDAR™ is suitable for continuous remote observations of highly resolved structures of tropospheric aerosols and clouds (Fog, low clouds, subvisible cirrus clouds), from 0.1 and up to 20km. The system is a mature meteorological turnkey and unattended remote sensor and then can well serve for operational meteorological networks and pollution agencies as a standardized tool.

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 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. Planetary Boundary Layer height determination

Bigger strongly urbanized cities in the world are often exposed to atmospheric pollution events. To understand the chemical and physical processes that are taking place in these areas it is necessary to describe correctly the Planetary Boundary Layer (PBL) dynamics and the PBL height evolution.

EZLIDAR™ algorithm retrieves automatically the PBL height in real-time. The instrument was deployed at LMD in Palaiseau, France to validate the PBL height estimation with those retrieved by the algorithm STRAT [5] from data acquired by the LNA. The 12-days measurement campaign shows (Figure 1) a correlation between the instruments of 95% (for 5 minutes averaging).

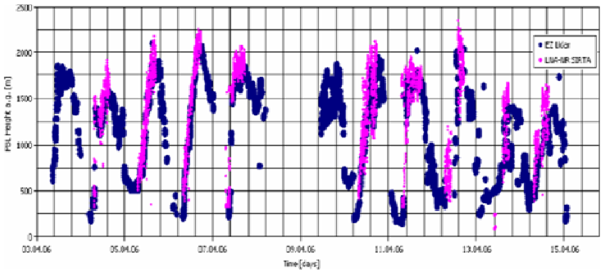

Figure 1 PBL Height retrieval from EZLIDAR (blue) and STRAT (fuchsia)

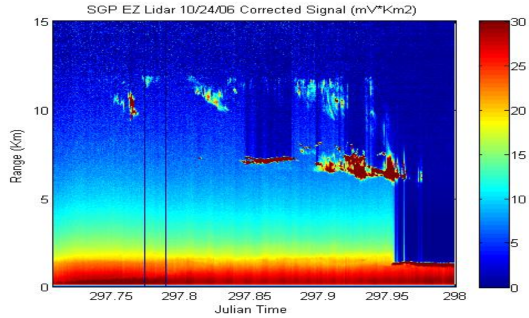

Figure 2 Range corrected signal for EZ lidar at SGP/ARM site, 10/24/06. It is possible to retrieve the height of the cloud layers (cumuli, cirri and altocumuli)

4. Cloud and Aerosol Observations

Knowledge of the vertical structure of cloud and aerosol scattering characteristics or layers from varying climates regimes is fundamental. There are many variables and measurements required to fully understand the radiative impact of cloud and aerosols, but accurate measurements of occurrence, height and thickness are relatively inaccurate and not on large scale. Ongoing research, in order to gather this information needs operational long-term observing sites equipped with diverse arrays of passive and active remote sensing, as well as in situ instrumentation. The direct detection of atmospheric cloud and aerosol generally involves active-based remote sensing techniques such as lidars, that are sensitive to molecular and aerosol particles.

One of the most notable EZ LIDAR™ feature is that its transmitted energy pulses are invisible (UV region) and eye safe, a main requirement for a lidar to be deployed in a continuous running observational site. Data measurements are processed for standard products, including the heights of cloud layers and the vertical distribution of backscattering and extinction coefficients in order to calculate the Aerosol Optical Depth (AOD). In figure 2 is reported the temporal plot of the range normalized measured backscattered signal (NRB)[3] at Southern Great Plain ARM site in Oklahoma, United States, where it can be observed the evolution of some cloud layers.

5. Cloud phase determination

The polarization of the light changes if in the scattering process are involved non-spherical particles as for ice crystals, snow flakes or dust. The particles can be assumed to be spherical in case of wet haze, fog, cloud droplets, and small raindrops. Thus, Lidar measurements of atmospheric depolarization can be used to distinguish between liquid and solid phases of water in the atmosphere and presence of dust. Figures 3 and 4 put in evidence a dust transit from Sahara with relative descent in the Planet Boundary Layer (PBL) over the rural suburbs of Paris.

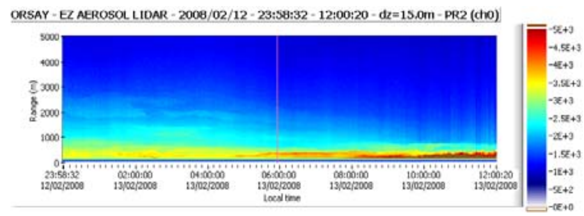

Figure 3 range normalized backscattered signal evidences some aerosols to 3km for a non cloudy sky on the 02/12/08 above Orsay, France

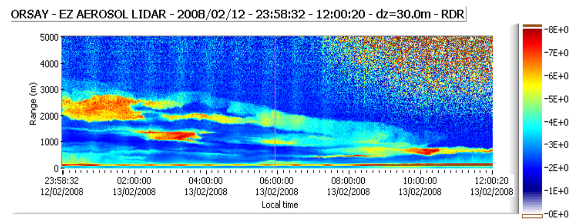

Figure 4 high depolarization ratio (colour map) put in evidence a dust transit from 3km to 1 km (inside the PBL) on the 02/12/08 above Orsay, France

The depolarization ratio, in presence of clouds, put in evidence the presence of ice and super-cooled water, as represented in Figure 6:

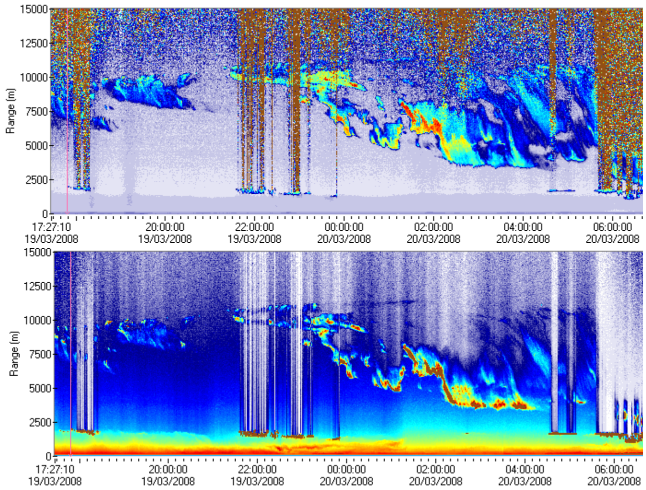

Figure 5 Range normalized measured backscattered signal (upper) evidences the presence of altocumuli and cirri. Depolarization ratio(lower) evidences supercooled water and ice crystals in the clouds (color map) in Chibolton, England, on 03/19/08.

6. Uncertainty analysis

The total and particle backscattering and extinction coefficients are directly retrieved processing the lidar signal returns as described in [3] and plotted in Figure1.. The total backscattering coefficient is given by:

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

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) plotted in Fig.,2 S'_m is the NRB at the reference altitude z_m and L_R the lidar ratio. The relative uncertainty in retrieving the total backscattering coefficient β_{tot} is given by:

$$\Delta\beta_{tot}(z) = \sqrt{\sum_{j=1}^{3}\left(\frac{\delta\beta_{tot}}{\delta X_j}\Delta X_j\right)^2} \qquad (3)$$

with ΔX_j respectively the uncertainty on: lidar ratio L_R, molecular backscattering β_{mol} and 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 at 3.59pm on 10/24/06

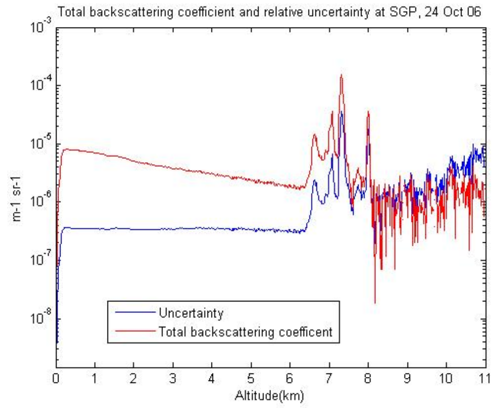

Figure 6 Total backscattering coefficient and relative uncertainty for 3.59pm of 10/24/06 at SGP (NRB plotted in fig.1)

The figure shows that the uncertainty on the backscattering coefficient retrieval is 100% at about 8000m after sounding through the cirrus cloud. This is consistent with the lidar range calculated as described in [7]

7 Conclusions

The EZ LIDAR™ instrument has been validated in several intercomparison campaigns, with different remote and in-situ instruments as sun photometers. PBL height retrieval shows a correlation of 95% with STRAT retrieval algorithm at LMD. [5] Also cloud structure, extinction profile, depolarization ratio and AOD can be retrieved on real-time from validated software.

Outdoor and unattended use capabilities of the EZLIDAR™, already deployed in meteorological observations networks such CLOUDNET, added to its measurements performances define then this instrument as a good candidate for deployment into growing global aerosol and cloud monitoring networks, research measurement campaigns and pollution measurements or future Lidar in Space missions (CALIPSO, EARTHCARE).

8 References

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