EZ LIDAR AND SUN-PHOTOMETER MEASUREMENTS OF THE OPTICAL PROPERTIES OF THE TROPOSPHERIC AEROSOLS IN THE GANGE BASIN ALONG CALIPSO SATELLITE TRACK IN THE FRAME OF NASA TIGER-Z CAMPAIGN

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ABSTRACT

Lidar investigation of aerosol optical and microphysical atmospheric properties on continuous basis both spatially and temporally will play a key role in the future for monitoring the whole planet through world ground based networks. In this framework, an EZ Lidar™, manufactured by LEOSPHERE, validated in several campaigns as that one in Southern Great Plains (ARM) or at Goddard Space Flight Center (NASA) with cross-polarization capabilities was deployed in Kanpur, India in the frame of TIGER-Z campaign, organized by NASA/AERONET In addition, 12 sun-photometers were deployed during this campaign and CALIPSO (The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation) data were also acquired. In this work we present the results in retrieving aerosol extinction and backscattering coefficients from EZ Lidar™ measurements, and the validation of the space borne instrument CALIPSO under the satellite track in the Gange basin. EZ Lidar™ is also coupled with the photometers to provide the measurements of the Aerosol Optical Depth over the selected region. In the paper is shown that the sun-photometer is a powerful tool to calibrate the lidar in the UV region.

1. INTRODUCTION

The NASA Aerosol Robotic Network (AERONET) began on April 2008 a four-year intensive field campaign, called TIGER-Z, to measure aerosol microphysical and optical properties over India. Collaborating entities in India include the Department of Science and Technology, Ministry of Earth Sciences, IIT Kanpur, IIT Kharagpur, and the Indian Space Research Organization (ISRO). India collaborators are currently holding campaigns on measuring the monsoon and thunderstorms over India: Continental Tropical Convergence Zone (CTCZ) and STORMS. The AERONET/CALIPSO campaign share existing resources (e.g., facilities, aircraft, and manpower) established for the ongoing India-sponsored campaigns and utilize instruments through other international partnerships among them with LEOSPHERE (France).

2. MEASUREMENT SET-UP

EZ Lidar™ was deployed at the Indian Institute of Technology, in Kanpur (26.45N, 80.23E), India, in the end of April 08. The EZ Lidar instrument was placed together with some sun photometers on the track path of the CALIPSO satellite.

EZ 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 75m up to 20 km.

Figure 1 shows the CALIPSO satellite track for the days of interest, and Table 1 resumes the main technical characteristics of EZ Lidar™. Measurements took place during three days from 29th April 08 to 30th of May 08. Outside temperatures reached almost 50°C in those days.

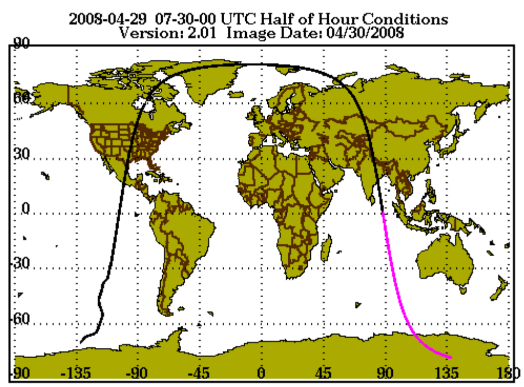

Figure 1 CALIPSO satellite track on 29th April 08. Kanpur site is located on the track at 26.45N, 80.23E

Range	75m-20km	**Environment**	-20°C../+50°C
TemporalRes	60s	**Humidity**	0-100%
Spatial Res	30m	**Water Proof**	IP65

AngularRes	0.2°	**Weight**	~48 kg
Scan speed	50°/s	**Eye-safety**	IEC60825-1 2001

Table 1 EZ Lidar technical specifications

Data availability (local time) during the measurement campaign, is represented in table 2

29 April 08	**6pm-12am**
30 April 08	**12am-1.16pm**

Table 2 Measurement Data availability in Local Time IST(UTC + 5:30)

During these dates, the EZ Lidar™ behaved correctly, giving good results. However, a laser failure imposed to stop the measurements and ship the Lidar back to France. The laser has been sent to the supplier for diagnostic.

3. MEASUREMENT RESULTS

On 29th-30th April 08, the EZ Lidar™ aerosol backscattering coefficient quick look is plotted in Figure 2, while Figure 3 shows the relative depolarization ratio while Figure 4 represents the CALIPSO level 1 Lidar attenuated backscatter coefficient (29th Apr).

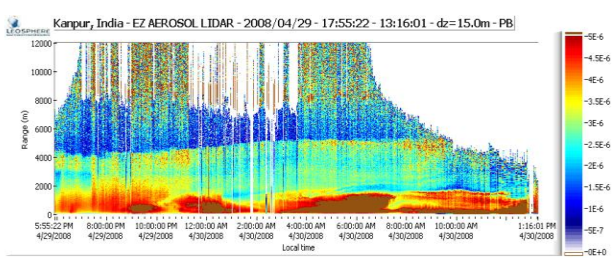

Figure 2 EZ Lidar retrieved Aerosol backscattering coefficient (m^{-1} sr^{-1}) on 29th April 08 in Kanpur, India

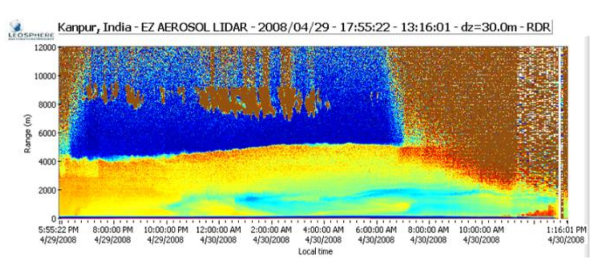

Figure 3 DR**(**Depolarization Ratio) determined from the EZ Lidar™ measurements. Yellow corresponds to about 10% of Linear Depolarization ratio, orange: 12.5% clear blue 5%.

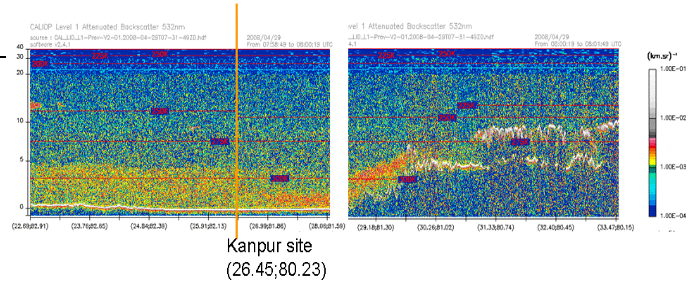

Figure 4 CALIPSO level 1 observations on the 29th of April around 8am UTC (01.30pm local time).CALIPSO flew around 200km east of Kanpur

In the evening of 29th Apr. (Figure 3), the DR(Depolarization Ratio) is around 10-12% and at 9pm we start observing the creation of a new layer from the ground and up to 2km, with a RDR between 4% and 8%, indicating a mix between pollution and dust which is confirmed by the increasing of the Lidar ratio between the 29th and 30th April from 50sr to 90sr (@355nm).

In both EZ Lidar™ and CALIPSO satellite quick looks, even if the time scale is different, we can observe the presence of a thick aerosol layer, up to almost 5km. In Figure 4 we also see an increase of the backscatter coefficient on the foothills of the Himalayas, either due to a change in the aerosol type, as biomass burning, or to a higher aerosol concentration

On 30th of April, the EZ Lidar™ quick looks put in evidence the temporal evolution of some altocumulus clouds, as depicted in Figure 3. A high depolarization ratio in the clouds reveals a high concentration of ice crystals.

DR then is an indicator of irregularly shaped particle. Lidar measurements reveal particles such as dust, biomass burning and sea-salt would exhibit clear depolarization properties owing to irregular shape.

This is fundamental in correcting the retrieval of the microphysical properties of the aerosols by the sun-photometers considering regions of non spherical particles. The Lidar provides then an effective measurement along the atmospheric column that can be integrated for a better retrieval by the sun-photometer.

4. INTERCOMPARISON WITH THE SUN-PHOTOMETERS

The retrieved EZ Lidar™ Aerosol Optical Depth (AOD) is validated against the in-situ collocated sun photometers. The intercomparison took place on 29th April 08 from 10.15pm to 12.00am and 30th April 08, from 6.28am to 8.28am (Local Time). In order to calculate the Aerosol Optical Depth, the EZ Lidar™ algorithm integrates over the entire atmospheric column the extinction coefficient, retrieved by Fernald-Klett backward inversion algorithm [1]. The particle extinction coefficient is retrieved by knowing a priori the Lidar Ratio[1] as follows:

$$\alpha_p = L_R \beta_p \tag{1}$$

Where L_R is the Lidar ratio(sr), and β_p is the particle backscattering coefficient (m-1 sr-1) as retrieved from Fernald-Klett algorithm (2):

$$\beta_p(z) = \frac{\exp(S(z) - S_m)}{\frac{1}{\beta_m(z_{ref})} + 2L_R \int_0^z \exp(S(z') - S_m) dz'} \tag{2}$$

With S(z) the logarithm of the range corrected backscattered signal, $S_m = S(z_{ref})$ with z_{ref} reference altitude of a free aerosol region[2].

By default the Lidar ratio has been set to 35 in the software. We compared AOD from the EZ Lidar™ and the AOD retrieved from the sun-photometer located at IITK.

After an iterative process, we conclude that a mean LR of 50sr on the 29th and of 90sr on the 30th is more adapted for the inversion process of the lidar data. On 30th April 08 we have:

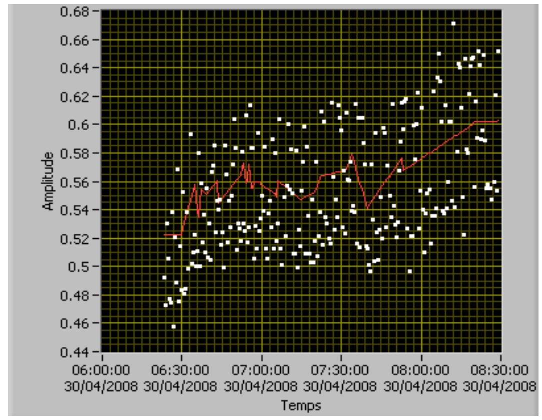

Figure 5 AOD intercomparison. Red curve represent the temporal evolution of AOD measured by the photometer, while the white points represent the EZ Lidar™ measurements on 30th Apr. 08

The red curve is the AOD coefficient retrieved by the sun photometer. The white spots are the temporal evolution of the AOD retrieved by the EZ Lidar™. If we smooth and average the EZ AOD values, we have in this temporal interval a mean for the AOD of 0.565. The AOD average measurement value from the photometer is 0.564. The agreement between the instruments is very good. It is possible to retrieve the uncertainty in the AOD calculation as described in [3]. The uncertainty in AOD calculations is expressed in (3):

$$\Delta AOD = \sum \alpha_p \tag{3}$$

where $\Delta\alpha_p$ is the uncertainty of the particle extinction coefficient. The total uncertainty is then the sum over the entire profile of the uncertainties on the extinction. in this case ΔAOD=0.005. Resuming over different time intervals we have:

	29/04/2008	**30/04/2008**
Mean AOD sun-photometer	0.512	0.564
Mean AOD EZLIDAR	0.51	0.565
Mean Lidar Ratio (sr)(sun-photometer)	50.21	89.4
STD LR (sr) (sun-photometer)	20.39	22.28

Table 3 Results of AOD retrievals intercomparison between EZ Lidar™ and a co-located sun photometer

From table 3 then the sun-photometer is a valid tool to calibrate the Lidar in the UV region, obtaining an agreement up to 5%.

5. CONCLUSIONS

The EZ Lidar instrument has been validated in the frame of TIGER-Z /NASA campaign against in-situ photometers and remote sensor as CALIPSO satellite showing a very good agreement.

The iterative method, using the columnar Lidar Ratio measured values from the sun-photometer interpolated at the lidar wavelength in Klett algorithm; it is a very efficient tool to calibrate the lidar even in the UV region.

Moreover, in a reverse way, other than assuring the cloud-free condition, the lidar depolarization measurement data are extremely useful to correct the retrievals of microphysical properties of the aerosols by the sun-photometers taking into account other shapes than spherical.

Measurements put in evidence the possibility that the synergy between the two instruments permits to retrieve the bimodal size distribution as a function of the range

Outdoor and unattended use capabilities of the EZLIDAR™ (external temperatures up to 50 C) 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. We would like to acknowledge Brent Holben and S. N. Tripathi for the sun photometer data and for the fruitful discussions regarding aerosol microphysics and dynamics over India

6. REFERENCES

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