

EZ LIDAR™ measurement results in the frame of Indian Monsoon TIGER-Z NASA campaign

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ABSTRACT

Lidar investigation of temporal and vertical optical atmospheric properties will play a key role in the future for a continuous monitoring over the whole planet through world ground based networks. The EZ Lidar™, manufactured by LEOSPHERE, has been validated in several campaigns as that one in Southern Great Plains (ARM) or at Goddard Space Flight Center (NASA). An EZ LIDAR™ with cross-polarization capabilities was deployed in Kanpur, India in the frame of TIGER-Z campaign organized by NASA/AERONET in order to measure aerosol microphysical and optical properties in the Gange basin. 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 from EZ Lidar™ measurements, and the validation of the space borne instrument CALIPSO under the satellite track. EZ Lidar™ is also coupled with the photometers to provide the measurements of the Aerosol Optical Depth over the selected region.

Keywords: Validation campaign, Aerosol Optical Depth, Aerosol Lidar

INTRODUCTION

The NASA Aerosol Robotic Network (AERONET) began on April 2008 a four-year intensive field campaign, called TIGERZ, 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).

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 50m up to 20 km.

Figure 1 shows the CALIPSO satellite track, 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.

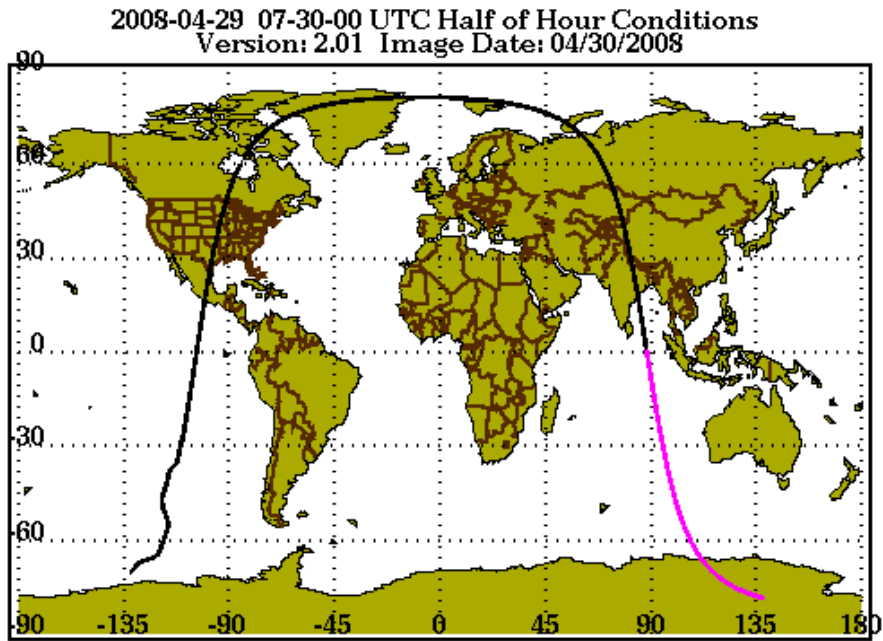


Figure 1 CALIPSO satellite track on 29th April 08. Kanpur site is located on the track at 26.45N, 80.23E

Range	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

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.

MEASUREMENT RESULTS

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

In the evening of 29th Apr. (Figure 3), the RDR 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).

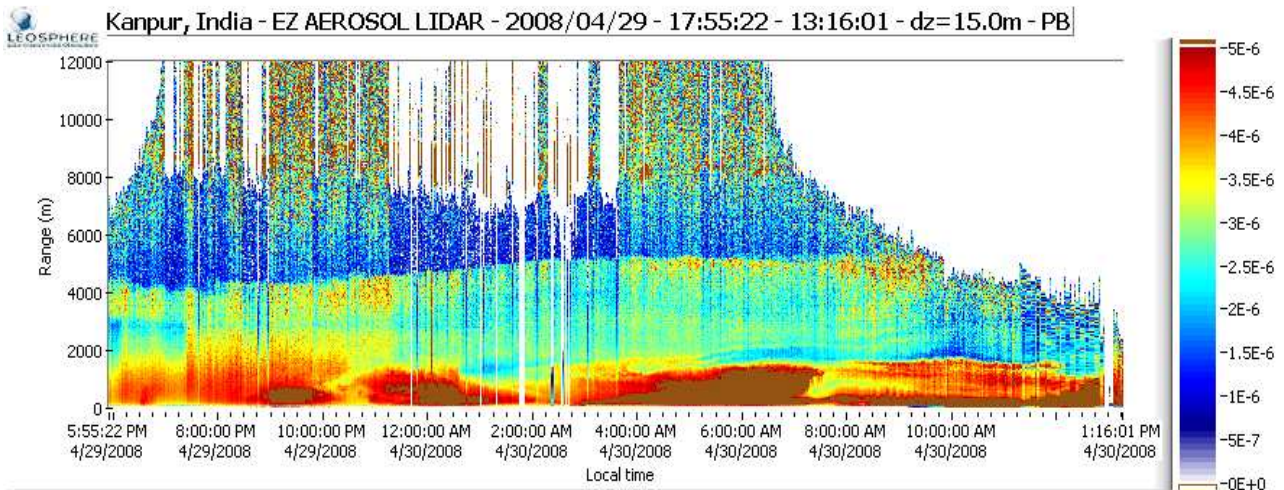


Figure 2 EZ Lidar retrieved Aerosol backscattering coefficient ($\text{m}^{-1} \text{sr}^{-1}$) on 29th April 08 in Kanpur, India

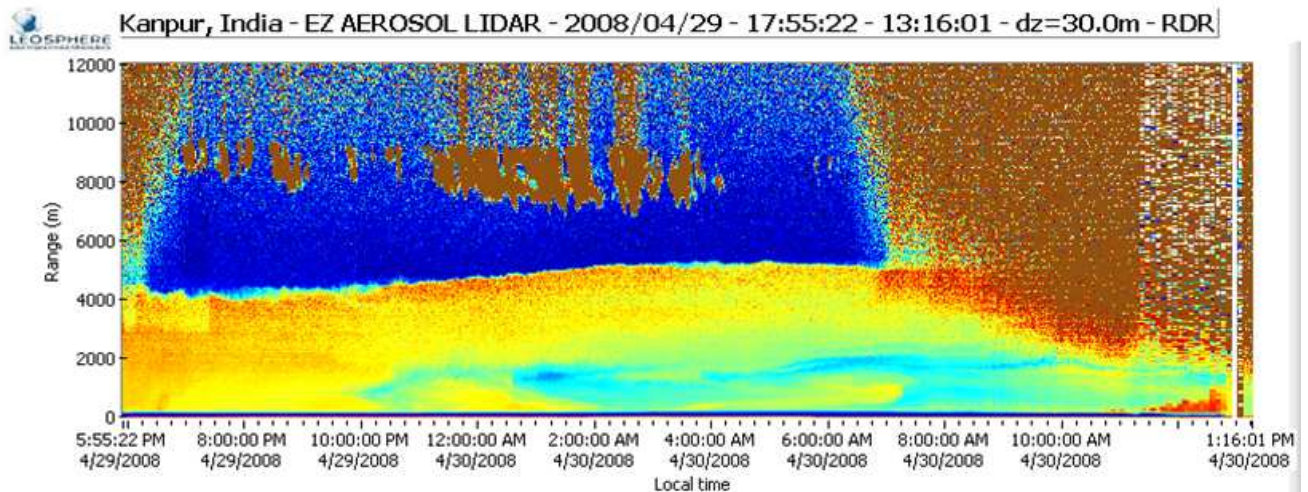


Figure 3 Relative depolarization Ratio determined from the EZ Lidar™ measurements. Yellow corresponds to about 10% of Linear Depolarization ratio, orange: 12.5% clear blue 5%.

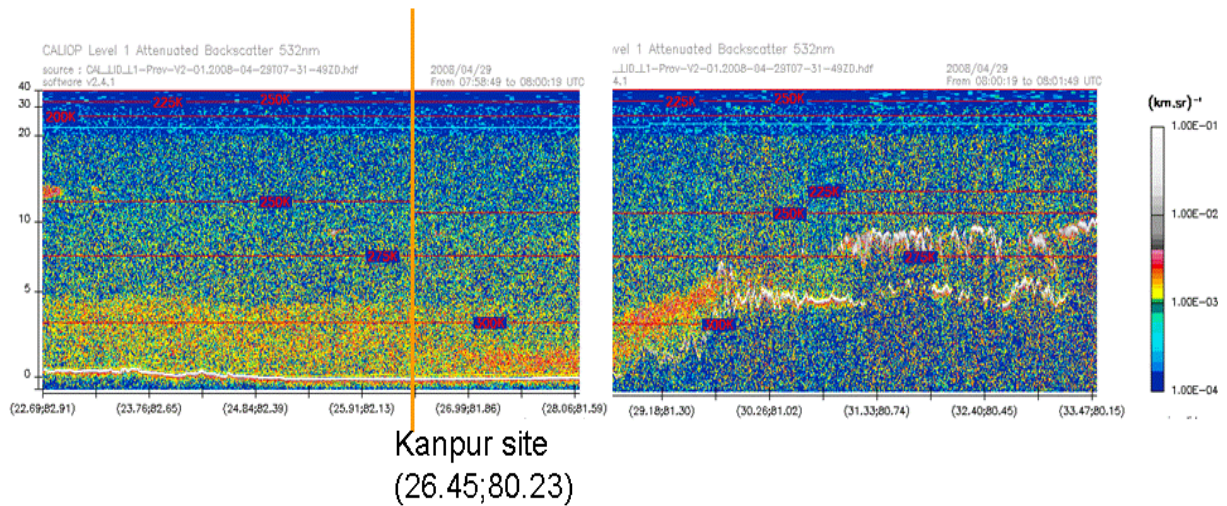


Figure 4 CALIPSO level 1 observations on the 29th of April around 8am UTC (01.30pm local time).CALIPSO flew around 200km east of Kanpur

In 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.

The retrieved total attenuated backscattering from CALIPSO satellite and EZ Lidar™ is then compared on 29th April 08. The vertical resolution is 60m and the vertical range goes from 0 to 6km. Calipso Laser frequency is 532nm, while that of EZ Lidar™ is 355nm. The intercomparison is showed in Figure 5. The molecular backscattering wavelength dependence is well known; regarding the aerosol backscattering coefficient, the wavelength dependence is related to the Angstrom coefficient that should be measured. The difference in main level in the total attenuated backscattering coefficient is due to the strong molecular dependence. The uncertainty in the EZ total attenuated backscattering coefficient is represented in figure 6 using equations fully developed in [3]. The intercomparison put in evidence common features of the retrieved total attenuated backscattering coefficients by EZ LIDAR™ and CALIPSO satellite. The difference in level is due, as told before to the different wavelength of the instruments.

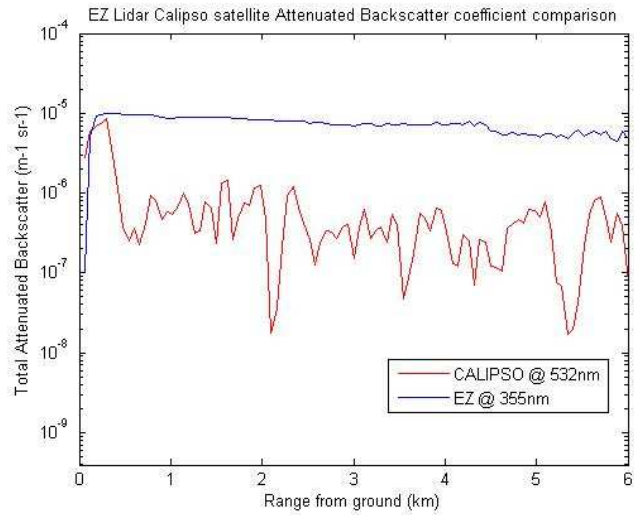


Figure 5 EZ(blue curve 10am Local Time) and Calipso(red curve 1.17pm Local Time) Total Attenuated Backscatter intercomparison on 29th Apr (range resolution 60m)

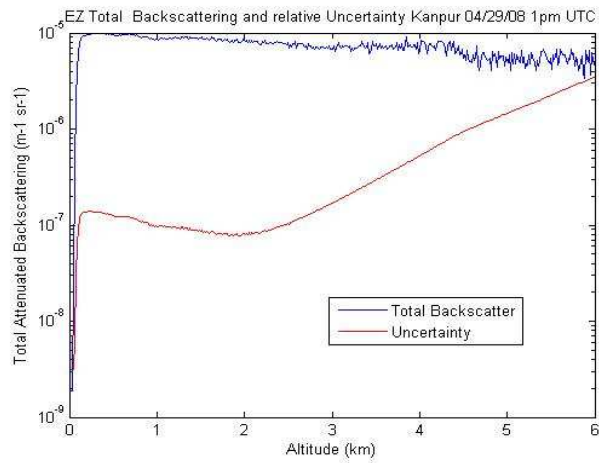


Figure 6 EZ Total Attenuated Backscatter with relative uncertainty on 04/29/08

For the perpendicular channel, the total attenuated backscattering coefficient retrieved by Calipso and EZ Lidar™ is retrieved in Figure 7

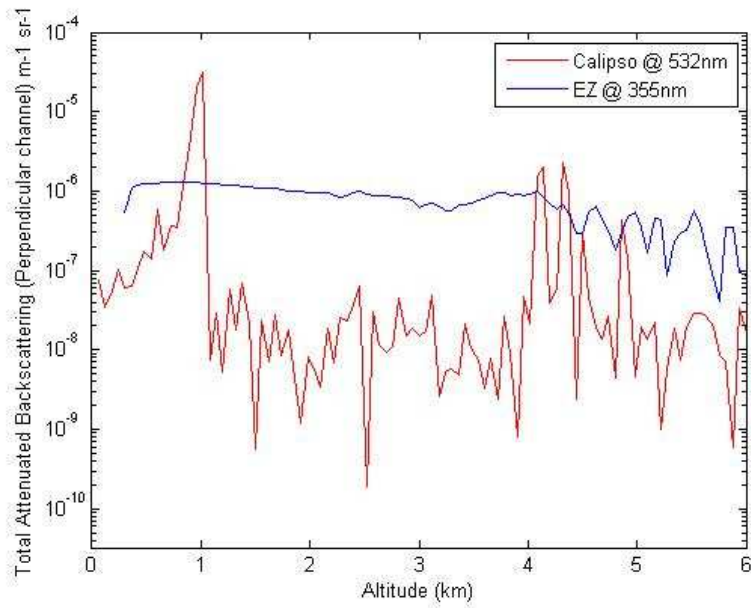


Figure 7 Perpendicular attenuated backscattering retrievals (Calipso red curve 1.17pm Local Time), EZ Lidar™ (blue curve 10 am Local time)

Again, both curves have more or less the same trend; the difference in level is due to the different used wavelengths between the instruments. Difference in shape is due to the different collocation of both instruments.

INTERCOMPARISON WITH SUN PHOTOMEMETER

The retrieved EZ Lidar™ Aerosol Optical Depth (AOD) is validated against the in-situ sun photometer. 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™ integrate over the entire atmospheric column the extinction coefficient retrieved by Klett backward inversion algorithm[1]. The particle extinction is retrieved by knowing a priori the Lidar Ratio[1] by the formula:

$$\alpha_p = L_R \beta_p \quad (1)$$

Where L_R is the Lidar ratio(sr), and β_p is the particle backscattering (m⁻¹ sr⁻¹) as represented in (2):

$$\beta_p = \frac{\exp(S(z)-Sm)}{\frac{1}{\beta_m} + 2L_R \int \exp(S(z')-Sm) dz'} \quad (2)$$

With $S(z)$ the logarithm of the normalized range backscattering, as fully described in [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:

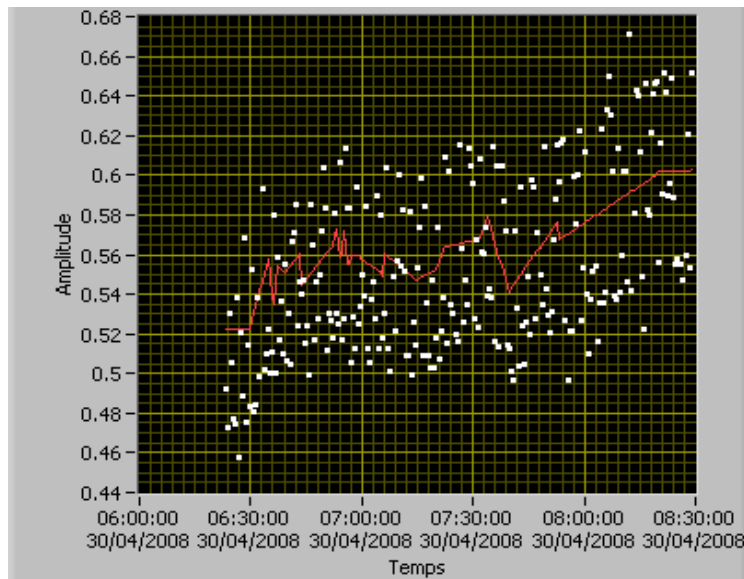


Figure 8 AOD intercomparison. Red curve represent the temporal evolution of AOD measured by the photometer, while the white points represent the EZ Lidar™ measurements on 30th Apr. 08

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 high. It is possible to retrieve the uncertainty in the AOD calculation as described in [3]. The uncertainty in AOD calculations is expressed in (3):

$$\Delta AOD = \sum \Delta \alpha_{part} \quad (3)$$

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

	29/04/2008	30/04/2008
Mean AOD sun-photometer	0.512	0.564
Mean AOD EZLIDAR	0.510	0.565
Mean Lidar Ratio (sr)	50.21	89.4
STD LR (sr)	20.39	22.28

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

CONCLUSIONS

The EZLIDAR 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. 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

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