# Aerosol measurements at the CSIR, Pretoria and at the University of KwaZulu Natal, Durban using the CSIR mobile LIDAR system

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**Abstract.** In this work we investigate the aerosol backscatter profile and the planetary boundary layer in Pretoria and Durban. The profile in Durban showed clouds at heights of 1.2 - 1.9 km and also showed the planetary boundary layer at 500 m while the Pretoria results showed the planetary boundary layer at a height of 800 m.

## 1. Introduction

Atmospheric aerosols are suspensions of solid and/or liquid particles in air. They are often observed as dust, smoke, and haze. Both atmospheric activities and natural processes contribute to aerosol concentrations. Aerosols in the troposphere play a major role with both direct and indirect effects in our climate [1]. So the characterization of aerosol properties is of crucial importance since aerosols impact Earth's climate through their direct effects on the Earth-atmosphere radiation budget and affect the hydrologic cycle through influences on cloud formation and precipitations [2]. To understand the aerosols role in meteorological and climatological processes, systematic observations with high vertical and temporal resolution with high accuracy are needed. The LIght Detection and Ranging (LIDAR) technique has the capabilities to characterise atmospheric aerosols in terms of vertical profiles of extinction and backscatter coefficients, lidar ratio and optical depth with high range resolution [3]. LIDAR can also be used to study the structure of the troposphere layer and planetary boundary layer (PBL), with the aerosols as passive tracers of the atmospheric dynamical processes [4].

In this paper we describe the instrumentation aspects of the Mie LIDAR developed at the CSIR. We present and discuss aerosol profiles obtained at two atmospherically varied locations in South Africa. Pretoria is situated on the Highveld and has an altitude above approximately 1500 m. The average maximum temperature in April is 28$^{o}$C and average rainfall is about 170 mm. Durban on the other hand has a humid subtropical climate, with relatively high rainfall, primarily falling in the summer months. The average summer temperature is about 27$^{o}$C and the average rainfall is about 206 mm in November.

## 2. CSIR mobile LIDAR system

The LIDAR system is divided into three sections: transmitter, optical receiver, and detector and data acquisition system. A schematic layout of the system is shown in Figure 1 and the major specifications of the NLC LIDAR system can be found in the publication by *A. Sharma et al* [5].

## 3. Experimental

In this work we used an Nd:YAG laser operated at the second harmonic at an energy of 150 mJ. The laser beam was transmitted vertically into the sky, which interacts with air molecules and aerosols (particles whose size varies between 0.1 and 1.0 mm) in the troposphere and stratosphere. The backscattered photons are collected by parabolic mirrors and transmitted to photomultiplier detectors. The acquisition of data is carried out in the photon counting mode. The return signal is integrated to generate a count vs. altitude profile.

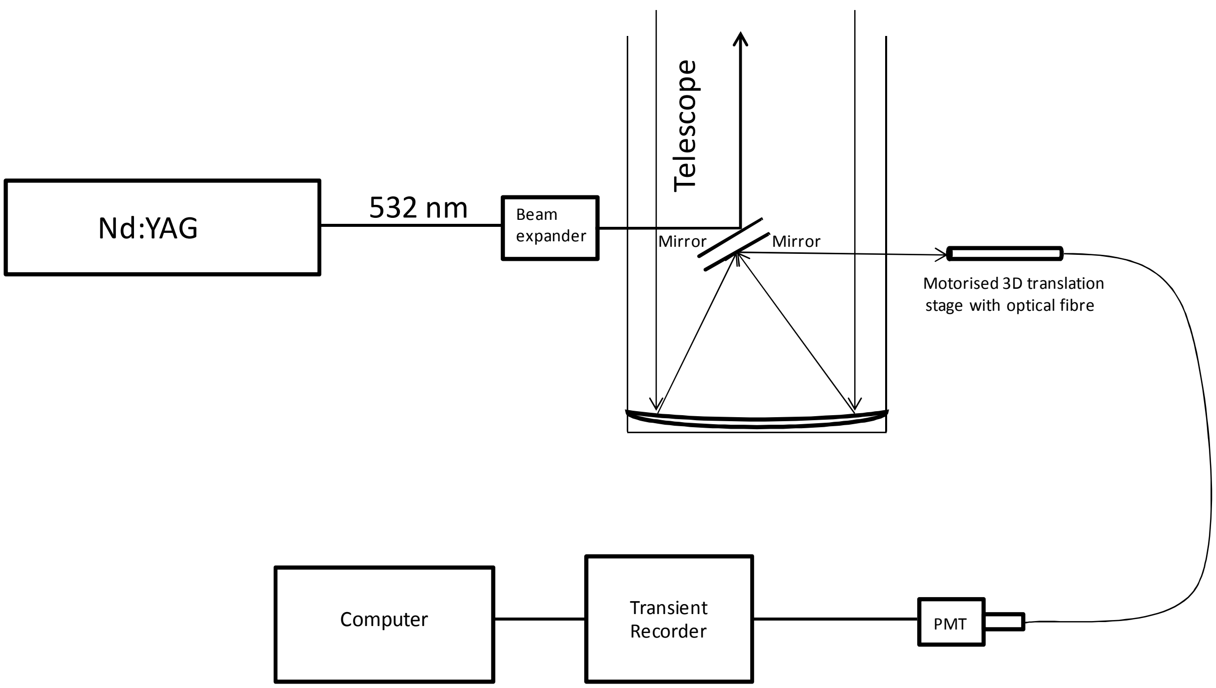



**Figure 1.** Schematic layout of the LIDAR system

## 4. Data Analysis

The measurements at the CSIR (25°53'7"S 27°42'28"E) and at the University of KwaZulu Natal (29°49'2.04"S 30°56'38.44"E) were taken between 09h00 and 14h00. The vertical and temporal resolutions are 10 m and 10 s, respectively. The LASER pulses were fired at a pulse repetition frequency of 10 Hz with pulse energy of about 150 mJ.

The received intensity, $I(r)$ in terms of photon counts, is obtained over 256 range bins with a pulse width of 7 ns which is given by the standard LIDAR equation [6,7] as

$$I(r) = I_0 C \beta(r) r^{-2} e^{-2\int_0^r \sigma(r') dr'}, \qquad (1)$$

where $I_0$ is the transmitted laser intensity in terms of photon counts at 532 nm, $C$ is the system constant, $\beta(r)$ is the backscattering coefficient, $\sigma(r)$ is the extinction coefficient and $r$ is the range. The system constant $C$ is given by

$$C = \frac{\eta A_r c \tau}{2}, \qquad (2)$$

where $\eta$ is efficiency of receiver system, $A_r$ is receiving telescope area, $c$ is the speed of light and $\tau$ is the pulse width of the transmitted laser beam. The backscattering and extinction coefficients are given by contribution of both aerosols and molecules and are expressed as:

$$\beta(r) = \beta_{aer}(r) + \beta_{mol}(r) \qquad (3)$$

$$\sigma(r) = \sigma_{aer}(r) + \sigma_{mol}(r) \qquad (4)$$

where subscript (aer) and (mol) indicate aerosols and molecules, respectively.

Molecular contributions were calculated by taking data from CIRA 1986 standard atmosphere model [8]. The molecular backscatter coefficient $\beta_{mol}(r)$ is estimated by considering the theoretical molecular LIDAR ratio $S_{mol} = \sigma_{mol}/\beta_{mol}$ as $8\pi/3$ sr, under the condition of zero molecular absorption [7, 8].

There are various methods to solve equation (1), for our present analysis we adopted Fernald method by assuming the aerosol LIDAR ratio, $S_{aer} = \sigma_{aer}/\beta_{aer}$ , constant that is, 60 over the range of 8 km [9]. The Fernald method can be expressed as:

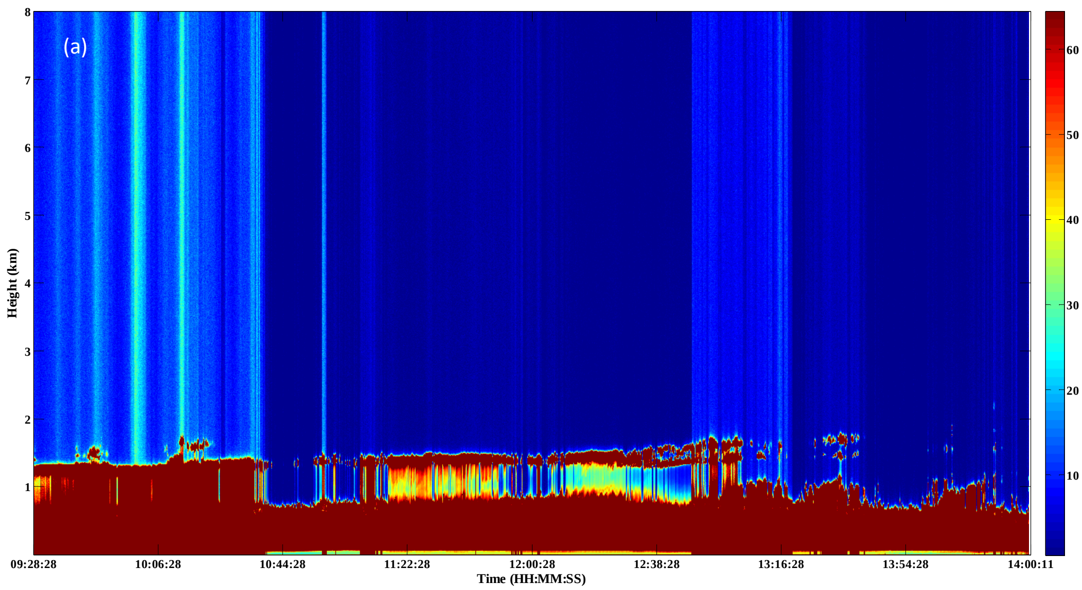
$$\beta_{aer}(r) + \beta_{mol}(r) = \frac{X(r)\exp[-2(S_{aer}(r) - S_{mol})]\int_{r_c}^{r} \beta_{mol}(r)dr}{\frac{X(r_c)}{\beta_{aer}(r_c) + \beta_{mol}(r_c)} - 2S_{aer}\{\int_{r_c}^{r} X(r)\exp[-2(S_{aer} - S_{mol})\int \beta_{mol}(r')dr']dr\}} \qquad (5)$$

where $X(r)$ is the range normalized signal given by $I(r)r^2$ and $r_c$ is the reference height [10, 11].

## 5. Results and Discussion

Experiments were conducted using the CSIR mobile LIDAR system under different atmospheric conditions ranging from overcast and cloudy sky to clear sky conditions. Figures 2 (a) – (b) shows a temporal evolution of the backscattered LIDAR signal. Figure 2(a) shows clouds at various heights of 1.2-1.9 km. These types of clouds are called stratus clouds. However, there were a few cumulus clouds that were observed between 13:55 and 14:00. The planetary boundary layer was observed with changes at approximately 800 m from the ground. On the other hand, Figure 2(b) does not show any profiles of clouds which mean that the returned signal were purely from the aerosols. With no clouds present the planetary boundary layer was observed without much change at approximately 500 m from the ground.

Figure 3(a) shows the backscatter coefficient profile of lidar return signals obtained from the clouds. It clearly revealed the strong return signals from the clouds in the range between 1.2 km and 1.4 km. After the clouds there was a decrease in the aerosol backscatter coefficient with increasing height. Figure 3(b) shows the aerosol backscatter coefficient decreases gradually with increasing height. This gradual decrease, unlike a sharp decrease in the aerosol backscatter, indicates that there is a high load of aerosol in the atmosphere between 300m and 6 km. There is however a change in the concentration of the aerosols at higher heights.



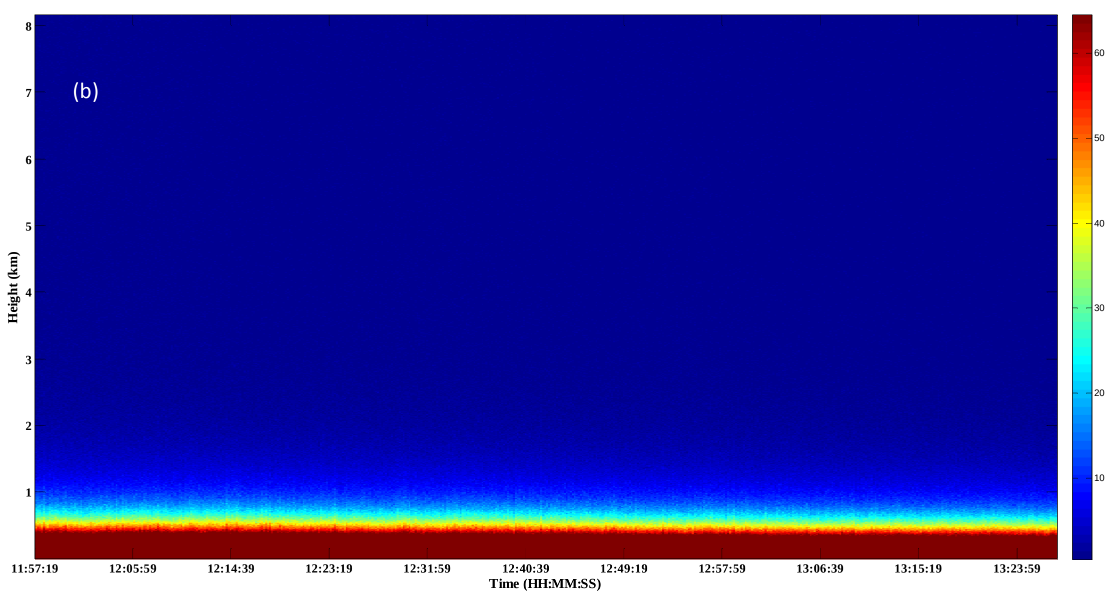




**Figure 2 .** Height-time-colour map of LIDAR signal returns for (a) 21 November 2012, Durban and (b) 05 April 2013, Pretoria.

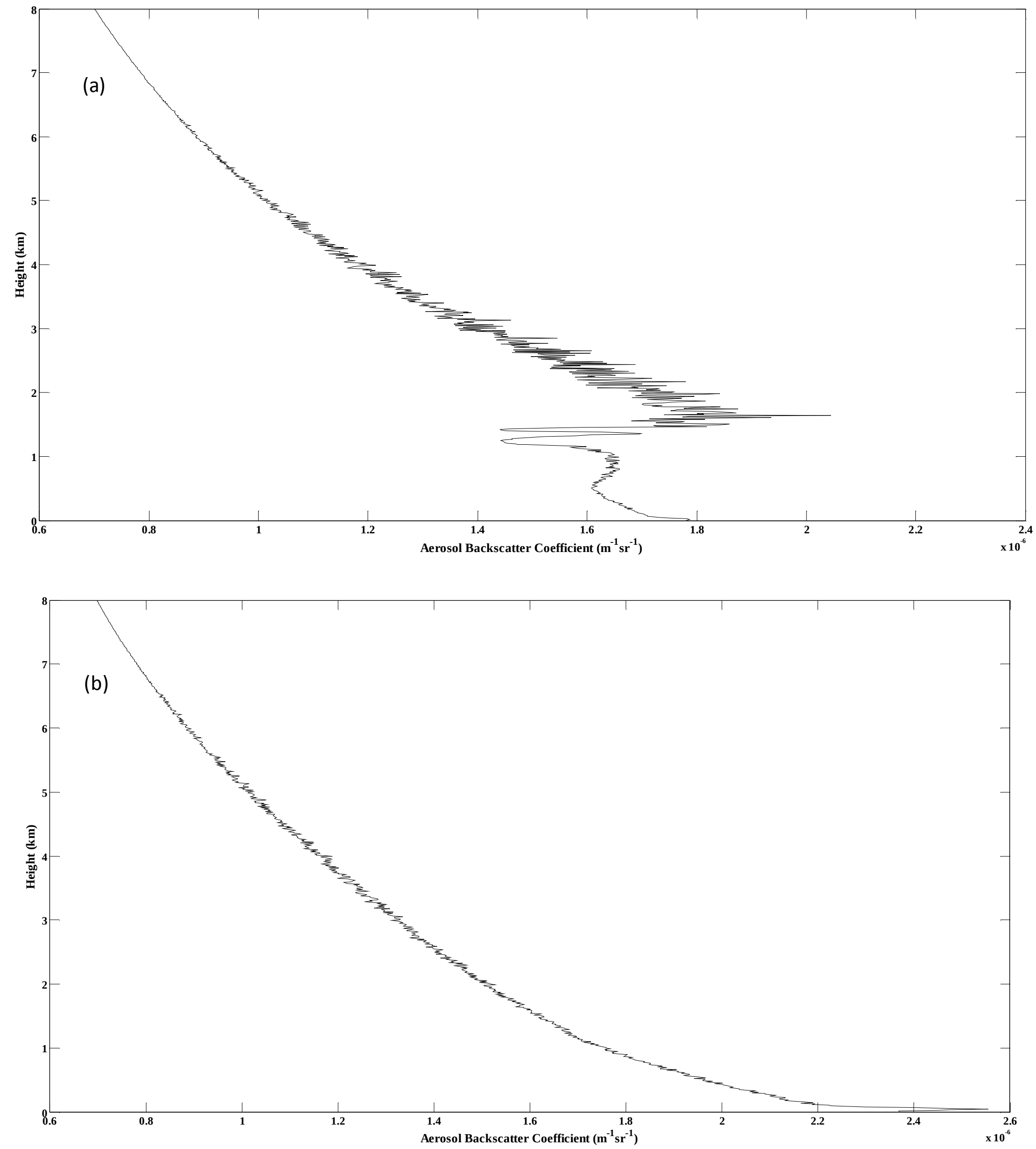



**Figure 3.** Height profile of aerosol backscatter coefficient retrieved for LIDAR (a) 21 November 2012, Durban and (b) 05 April 2013, Pretoria.

## 6. Conclusion

The measurements taken at two different sites in South Africa showed different profiles of the backscatter coefficients at varying heights. The profiles in Durban showed clouds at heights of 1.2 -1.9 km and also showed the planetary boundary layer at 500 m. On the other hand, the Pretoria results showed the planetary boundary layer at a height of 800 m. The aerosol backscatter coefficient showed a gradual decrease in the backscatter coefficient which means high volumes of aerosols were present.

## 7. References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