RETRIEVAL OF ATMOSPHERIC BOUNDARY LAYER HEIGHT BY CSIR-NLC MOBILE LIDAR, PRETORIA (25.5° S; 28.2° E), SOUTH AFRICA

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ABSTRACT

In this paper, we present the preliminary methods for detection of the boundary layer based on backscattered signals from a mobile LIDAR (LIght Detection And Ranging) developed at Council for Scientific and Industrial Research (CSIR) National Laser Centre (NLC), Pretoria (25.5º S; 28.2º E), South Africa. We have concentrated on two different methods, such as (a) statistical and (b) slope. The preliminary study concludes that the statistical method provides a reasonable temporal evolution of the boundary layer height in comparison with the slope method.

***Index Terms*—** Atmospheric measurements, Remote sensing, Aerosols and Boundary layer

1. INTRODUCTION

The atmospheric Boundary Layer (BL) is a part of the lower troposphere where most living beings and natural/human activities occur. The BL is also known as the Stable/ Planetary Boundary Layer, depending on its process and time scale of observation (day/night). The BL plays a significant role in the earth-radiation budget, climate changes, weather forecasting and various pollutant dispersions. The BL is usually quite variable by space and time, and varies mostly during the day due to variations in solar-radiation (by several kilometers) and is quite stable at night.

The aerosol content or particulate matter in the lower atmosphere fluctuates under different background conditions (e.g., temperature, humidity and solar radiation). Such fluctuations in aerosol content, particularly in the atmospheric boundary layer, can easily be monitored by means of a LIDAR (Light Detection and Ranging). This is due to the scattering from aerosol particles which strongly contributes to the LIDAR backscattered signal intensity. Thus, the in-homogeneities/variations in aerosol content can be used as tracers of the structure and stratification of the Boundary Layer Height (BLH). Based on the LIDAR backscattered signal (or/and range corrected) and by applying different criteria, one would be able to identify the boundary layer height and thus the temporal evolution.

2. SYSTEM

LIDAR is an active remote sensing technique used predominantly for measuring atmospheric parameters such as composition, wind, temperature, pollutants/trace gages and aerosol/properties. Although ground-based LIDAR systems have been deployed for atmosphere studies in many developed countries, it is still in its infancy for South Africa and African countries.

The present work uses a recently developed mobile LIDAR system at the Council for Scientific and Industrial Research (CSIR) National Laser Centre (NLC), Pretoria (25.5º S; 28.2º E), South Africa.

The CSIR mobile LIDAR system is the only of its kind in South Africa and can remotely monitor the atmosphere up to an altitude of 40 km. The system has been favored for its capability of simultaneous analog and photon counting detection [1], which makes it highly suited to LIDAR applications by providing high dynamic range. The system measures atmospheric properties, such as particulate matter (e.g., dust particles) of the sizes of 0.532 and 0.355 micron, aerosol concentrations and its variations [2, 3], boundary layer evolution, plume dispersions, optical depth and cloud morphology. More details about the system and scientific/technical information are available in the earlier published research articles [1 and 2].

3. METHOD OF DEDUCTION

We have concentrated in this work on the deduction of BLH based on two methods, (a) statistical and (b) slope.

(a) The statistical method applies range (z) corrected (squared) LIDAR backscattered signal (P_r), i.e., $P_r * z^2$. The BLH is identified by the height where the maximum standard deviation in the range corrected signal. Here, the mean value is obtained by the integration of consecutive 5 profiles (corresponds to 50 sec) [4].

(b) The slope method is based on the LIDAR backscattered signal (P_r) and their gradient (dP_r/dz). The identified minimum value in the slope (between P_r and dP_r/dz) defines the BLH [5]. A typical example of such method is demonstrated in the Figure-1. A linear straight fit is applied to the height profile of range corrected signal and the identified minimum difference between the fit and the actual measurements, identifies the BLH. Based on it, the boundary layer height is identified at ~1842 mts.

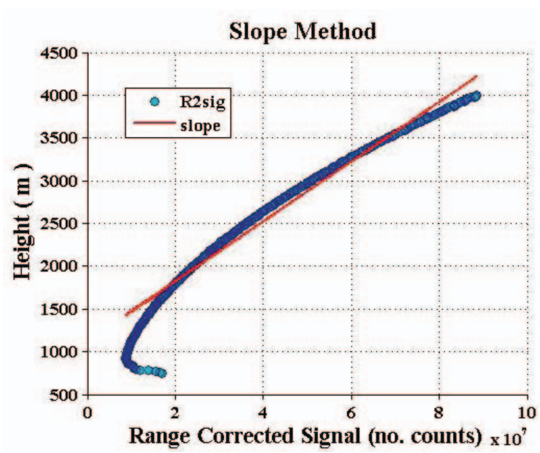

Figure-1: Height profile of range corrected LIDAR signal returns and the illustration of detection of Boundary Layer by slope method.

3. RESULTS AND DISCUSSION

We have applied the above method of BLH detection to the CSIR-NLC Mobile LIDAR backscattered signal and one such example is presented in Figure-2(a). Figure-2(a) shows the temporal (~2 hrs) evolution of LIDAR backscattered signal for the day of 10 August 2010. The corresponding day seems to be clear (no presence of cloud) and appears to show purely the aerosol backscattering. The CSIR-NLC mobile LIDAR is capable of providing analog and photon count signals. Later, both the analog and photon count signals are appropriately combined to obtain a 'glued' signal [1, 2]. The glued signals are expressed in photon counts which further improves the dynamic range of the system.

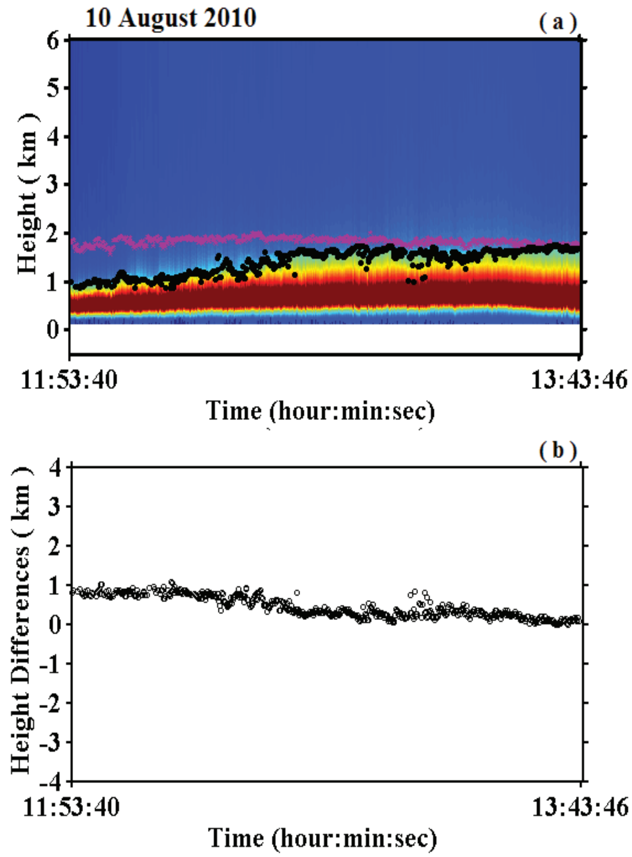

Figure-2(a): Height-Time-Color map of LIDAR signal returns (arb.unit) for 10 August 2010. The figure is overlapped by the determined boundary layer height (Black: statistical based on range corrected signal, Pink: slope method)

Figure-2(b): Temporal evolution of difference in detected boundary layer height.

The figure is superimposed by the deducted BLH based on the two methods, statistical (yellow circle) and slope (pink star). It is clear from the figure that the BLH varies significantly over time. The maximum BLH is found during the noon. It is expected during the day that the earth's surface heats up due to solar radiation and this results in various thermodynamic chemical reactions causing turbulence in the PBL. The boundary layer height is therefore expected to vary more during the day and to stabilize after sun-set. The slope method provided a higher value in comparison with the statistical method (based on standard deviation). The difference is found to be ~1 km (see figure 2b) during the beginning of observation and slowly approaches a near zero difference by end of the observations.

Diurnal variations

A 24 hour LIDAR experiment was planned and operated continuously at University of Pretoria on 16-17 October 2008 to obtain a better understanding of the atmosphere boundary layer evolution and aerosol (solid particles suspended in the air) concentrations. The experimental data was collected over 23 hours from 16 October, 16h00 to 17 October 15h00. Figure 3 illustrates the obtained LIDAR backscatter measurement for the above said 23 hours of observation at University of Pretoria. It also shows the presence of low level cloud from 23:00 hrs to 02:00 hrs and over the height region from 3.8 km to 5.5 km and for longer than 3 hours. Other than the cloud structure, the aerosol structure evidences the temporal evolution of planetary (nocturnal) boundary layer (PBL). The PBL is found to be around 2 km and found to vary with time. During the night it is found to be more stable and vary largely during the day time.

We have used the above datasets to study the diurnal variation of BL. The measured LIDAR backscattered signals, during the above time period, is presented in Figure-3(a). The period is early summer (post winter) with frost atmospheric conditions during the night. The above method of detection of the boundary layer was applied to this particular observation, for studying the diurnal variation of BL. It shows a quite variable BL during the day/night. Similar to the earlier result, the statistical method seems to be reasonable. However, both the methods failed to accurately detect the BL during the cloudy atmospheric condition. During the presence of upper level clouds, the slope method provided a good result in comparison to the statistical method. The difference in the detected BL by slope and statistical method, show positive values during the beginning of observation and later moved to negatives (see Figure-3b). Such a diurnal evolution also concludes the deficiency of detection of BL by both the methods and requires further improvement.

4. CONCLUDING REMARKS

In this paper, we have demonstrated the method of detection of Boundary Layer height by CSIR Mobile LIDAR observations. The results show that the deduction of BLH by the statistical method provides better results compared to the slope method which is found to be higher and almost constant over time. The detection of BL for a diurnal period concludes a high variation and failure in detections. The failures in detections are due to the different atmosphere background conditions (such as fog, cloud and mist). The preliminary result concludes that further studies are required to detect BLH more accurately. The deductions of BLH based on few different methods are in progress and will be highlighted in future.

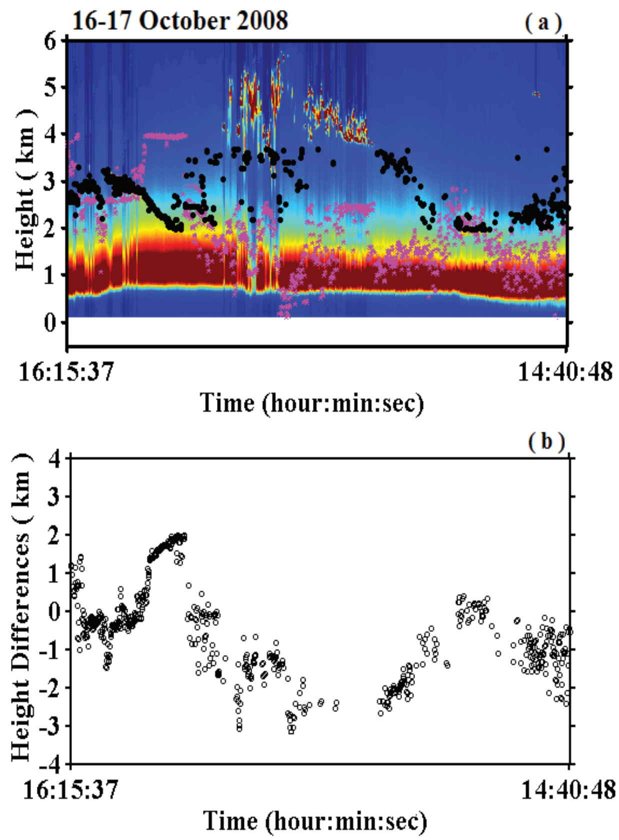

Figure-3(a): Height-Time(diurnal)-Color map of LIDAR signal returns (arb.unit) for 16-17 October 2008. The figure is overlapped by the determined boundary layer height (Black: statistical based on range corrected signal, Pink: slope method)

Figure-3(b): Temporal evolution of difference in detected boundary layer height.

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