REFURBISHMENT OF DURBAN FIXED UKZN LIDAR FOR ATMOSPHERIC STUDIES – CURRENT STATUS

Venkataraman Sivakumar

School of Chemistry and Physics, Discipline of Physics, University of KwaZulu Natal, Westville, Durban 4001, South Africa
venkataramans@ukzn.ac.za *or* svsk74@gmail.com

ABSTRACT

The fixed LIDAR system at University of KwaZulu-Natal (UKZN) in Durban was installed in 1999 and operated until 2004. In 2004, the system was relocated and operation closed due to various technical and instrument problems. The restructuring of the LIDAR system was initiated in 2013 and it is now used to measure vertical aerosol profiles in the height range 03-25 km. Here, we describe the present system in detail, including technical specifications and results obtained from a recent LIDAR calibration campaign.

1 INTRODUCTION

Besides their unquestionable importance in atmospheric physics, significant gaps in the scientific knowledge of aerosols (including vertical distributions) especially in the southern hemisphere still exist. LIDAR systems are unique in providing vertical profiles of aerosol characteristics, in contrast to any other instruments. Although LIDAR systems for atmospheric studies exist in many developed/developing countries, yet found to be a state-of-the-art for South Africa and African countries. There are currently three different LIDAR systems available in South Africa, one is located in Pretoria and a further two in Durban. Both the LIDARs (fixed and portable) in Durban are operated at University of KwaZulu-Natal (UKZN). The fixed LIDAR system was installed in 1999 and was operational from 1999 to 2004 under a French-South Africa bi-lateral agreement between the Reunion University and the Service d'Aéronomie (CNRS, IPSL,and Paris) for atmospheric studies. The system had three different receiving channels and used for measuring both aerosols in the upper troposphere and lower stratosphere (i.e.10-35 km) together with middle atmosphere temperature in the height range 30 to 70 km [1]. The system was operated during specific campaigns for several weeks each year from 1999 to 2004. After 2004, the system was relocated from one of the university campuses (Howard's College) to another (Westville) and no successful operations were possible due to various technical and instrument problems. Due to financial and human resource limitations, the restructuring of the LIDAR was not initiated until 2013 with the aim to make it re-operational. The refurbishment of the system is still on going and currently it is able to perform vertical aerosol profile measurements in the upper troposphere and lower stratosphere (i.e.,10-35 km). Figure-1 illustrates the current LIDAR system during operation. System details and technical specifications are described below as well as results obtained during a recent LIDAR calibration campaign.

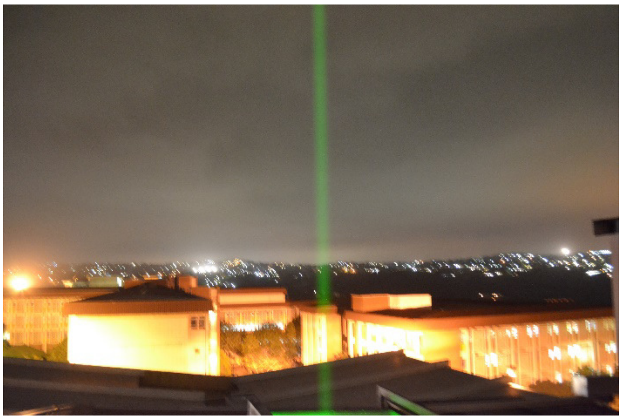

Figure-1: *Pictorial representation of UKZN fixed LIDAR system.*

2 SYSTEM DESCRIPTION

The UKZN-Durban fixed LIDAR is capable of measuring temperature profiles and aerosol backscatter coefficients. It employs a pulsed Nd:YAG laser operating at 30 Hz and a fundamental wavelength of 1064 nm. A frequency doubled laser emitting in the green, at 532-nm with approximately 150 mJ per pulse is used for transmission. The emitted laser beam after 10 times of expansion is directed vertically upward. The backscattered signals from the atmosphere are received by three different telescopes, simultaneously. The telescopes consist of parabolic mirrors with diameters of 445 mm (two) and 200 mm (one) and are designed to cover a wide dynamic range. The larger telescope (445 mm) was initially used for investigation of upper atmospheric levels while the smaller one (200 mm) covers the lower atmosphere. However, in the present reconfiguration, we have used both two large telescopes for addressing the laser backscatter signals from the lower atmosphere. We have also used the optical fiber combiner to reduce the number of data acquisitions into one. The received photons are collected at the focus point of the telescope and then transmitted to data-acquisition after passing through narrow-band filter (± 1 nm) and photo-multiplier tubes (PMT). The present data-acquisition (Licel) systems provide range-resolved measurements for every 7.5 m. The signal is then processed in an off-line system to retrieve the aerosol profiles. The future plan is to upgrade the system for measuring temperature in the altitude range 10- 70 km by combining Rayleigh and the Raman-N_2 channels using the large telescopes while aerosol profiles will be retrieved in the 4-38 km range based on data provided by the smaller telescope [2]. Important specifications of the current LIDAR system are provided in the table below.

Transmitter	
Laser Source	Nd:YAG – Spectra Physics
Operating Wavelength	1064, 532 nm
Energy per pulse	120 mJ
Beam Expander	10 x
Pulse width	8-9 n sec
Pulse repetition rate	30 Hz
Beam Divergence	0.5 mRad
Receiver	
Telescope	Newtonian
Diameter	445 mm and 200 mm
Field of View	1 mrad
IF Filter (BW)	1 nm
PhotoMultiplier Tube	
Type	Hamamatsu R7400-U20
Optical Fibre	Multimode, 600 µm core
Filter bandwidth	1 nm
Data Processing	
Basic data structure	Analog & Photon count
Range Resolution	7.5 m
Data	
Aerosol/Cloud	4 km to 25 km (current)
Temperature	30 km to 80 km (year-2)
Water vapour	4 km to 25 km (year-3)

3 OBSERVATIONS AND CALIBRATION

After refurbishment of most of the components of the UKZN fixed LIDAR we describe recent observations to calibrate the system for the first time. The LIDAR calibration campaign was performed from 05th to 09th September 2016 using the Council for Scientific and Industrial Research (CSIR)-National Laser Centre (NLC) mobile LIDAR and UKZN portable LIDAR. All the three LIDAR systems were operated simultaneously and at the same site (UKZN Westville campus). Since, the UKZN fixed LIDAR system is not portable, the CSIR-NLC Mobile and Portable LIDAR were placed close to the fixed LIDAR location (see figure 2 and 3 below).

It is worth to note here the following points for comparison when addressing the calibration of UKZN fixed LIDAR system.

- UKZN fixed LIDAR operates with Nd:YAG Laser (Spectra Physics) with ~150 mJ at 30 Hz for 532 nm. Two large telescopes (each has 445 mm in diameter) are employed in this system.
- CSIR-NLC LIDAR operates with Nd:YAG Laser (Continuum) with ~165 mJ at 20 Hz for 532 nm. The receiving telescope has a diameter of 400mm.
- UKZN portable LIDAR operates with Nd:YAG Laser (Quantel) with ~40 mJ at 10 Hz for 355 nm, there is no 532 nm employed in this system. The receiving telescope has almost half the diameter of CSIR-NLC mobile LIDAR, i.e., 200 mm.

Apart from the above significant changes in specifications, more details about the CSIR-NLC mobile LIDAR one may refer to Sivakumar et al., 2009 [3] and UKZN portable LIDAR into Sivakumar et al., 2015 [4].

Figure-2: *Pictorial representation of LIDAR calibration set-up location site at UKZN (source from Google maps). Distance between the two location is ~220 m.*

Figure-3: *Pictorial representation of UKZN portable LIDAR (on left) and NLC mobile LIDAR(right) during calibration campaign at UKZN.*

A sample height-time color map of backscatter signal returns obtained for the night 06 September 2016 are shown in figure 4(a-c). The backscattered signal returns for the fixed LIDAR show a general feature of lower boundary layer aerosol structure and passage of clouds over the site. It is obvious from the figure 4(a) that a clear and strong backscattered signal returns from UKZN fixed LIDAR system in comparison to other two LIDAR system. The height of occurrence of passing clouds is unambiguously detected by all the LIDAR which indirectly gives evidence of good system performance. It is evident from the figure that the detection of thin cloud is in the height range 5 to 6 km and around 7 km. There was also a passage of high thick cloud during the middle of observations. Apart from the above cloud passage, the backscatter signal illustrates the detection of boundary layer around 2 km and the significant presence of aerosols.

Though all the three systems detect unambiguously the height of cloud occurrence, there are differences in backscatter signal strength. This is due to the fact that the system has different transmission and receiving capability, as indicated earlier. Thus, the results obtained indicate the system with high reception may provide a significant higher backscatter signal in comparison to the one with high transmission with similar area of reception (CSIR-NLC Mobile LIDAR). Furthermore, the UKZN portable LIDAR system has low transmission and smaller area of reception and does not illustrate most features of the cloud due to low backscatter signal (see. figure-4c). The less conspicuous features of the cloud in fig. 4c could also be due, at least partially; to the lesser contrast between the backscatter of clouds and Rayleigh backscatter at 355 nm (other two LIDAR's are operated at 532 nm) besides the smaller area of reception with low energy of transmission.

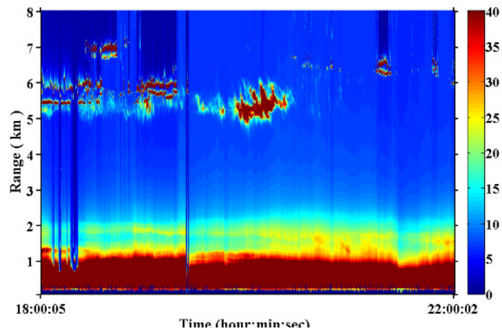

Figure 4a. *Height-time (GMT) color map of UKZN Durban Fixed LIDAR backscatter signal returns for the night of 06 September 2016.*

 https://doi.org/10.1051/epjconf/201817605056

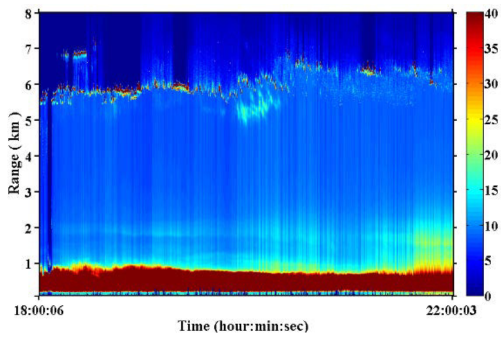

Figure 4b. *Height-time (GMT) color map of CSIR-NLC mobile LIDAR backscatter signal returns for the night of 06 September 2016.*

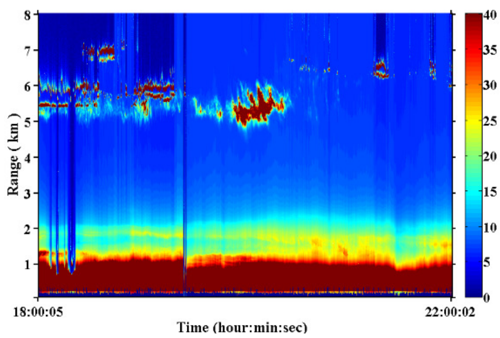

Figure 4c. *Height-time (GMT) color map of UKZN Portable Durban LIDAR backscatter signal returns for the night of 06 September 2016.*

4. FUTURE PERSPECTIVES

The current plan is to restructure the complete system and optimize operation.. The system will then be employed for long-term data acquisition in order to investigate temperature and aerosol variability over Durban. Simultaneous measurements are envisaged together with the CSIR-NLC mobile LIDAR systems which is currently planned to be installed at University of Zululand (170 km from UKZN) and LIDAR observations at Maido Observatory at Reunion University (ReunionIsland).

ACKNOWLEDGEMENTS

We are thankful to the different South Africa funding agency, National Research Foundation (NRF) (Grant no: 78682 and 78663), African Laser Centre (ALC), Centre National de la Recherché Scientifique (CNRS) (France) and Directorate General for Scientific Research and Technological Development (DG-RSDT) (Algeria).

REFERENCES

[1] Moorgawa, A, Bencherif H, Michaelis M M, Porteneuve J, Malinga S, 2007: The Durban atmospheric LIDAR, *Optics & Laser Technology*, 39, 306-312.

[2] Mbatha N M, Sivakumar V, Bencherif H, Malinga S B, Pillay S R, Moorgawa A and Michaelis M M, 2012: Analyses of the Middle atmosphere thermal structure over Durban using a ground-based Rayleigh LIDAR system and satellite experiments (HALOE and SABER), *S. Afr. J. Sci*., 108, 612.

[3] Sivakumar, V., Tesfaye, M., Alemu, W., Moema, D., Sharma, A., Bollig, C., and Mengistu, G., 2011: CSIR South Africa mobile LIDAR—First scientific results: comparison with satellite, sun photometer and model simulations, *S. Afr. J. Sci*. 105.11-12.

[4] Sivakumar, V., Ogunnuyi, J., Adesina, J., Singh P., and Shikwambana, L., 2015: A new 2-D scan portable Durban LIDAR for atmospheric studies – system description and first scientific result, *Proc. of 31st Annual conference of South African society for atmosphere science, ISBN 978-0-620-67825-4.*