MULTIANGLE LIDAR OBSERVATIONS OF THE ATMOSPHERE

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ABSTRACT

Atmospheric Lidars are used extensively to get aerosol parameters like backscatter coefficient, backscatter ratio etc. National Atmospheric Research Laboratory, Gadanki (13ºN, 79ºE), India has a powerful lidar which has alt-azimuth capability. Inversion method is applied to data from observations of lidar system at different azimuth and elevation angles. Data Analysis is described and Observations in 2D and 3D format are discussed. Presence of Cloud and the variation of backscatter parameters are seen in an interesting manner.

1 INTRODUCTION

Study of Atmospheric aerosols is of general interest. Aerosol parameters like backscatter coefficient, extinction coefficient, backscatter ratio and optical depth are important for these studies. Observations from a vertical looking lidar system are plenty around the world. However observations from a scanning lidar are very limited and aerosol studies from such a lidar opens up new frontiers of research fields. Here a lidar system which is capable of movement in both azimuth and elevation angles is employed to observe atmosphere in a conical volume. National Atmospheric Research Laboratory (NARL), Gadanki, India has a powerful backscatter lidar that is capable of taking observations in the above said mode. The data is subjected to Inversion technique to derive backscatter ratio which gives an estimate of aerosols in the atmosphere.

1.1 System Description

The lidar system consist of monostatic biaxial system where a Nd:YAG laser with a 2nd harmonic generator transmitting a beam of 10-mm width at 532-nm wavelength is used as transmitter which generates the laser beam of width 10mm. The beam is expanded to a beam diameter width of 80mm. The repetition frequency of output pulse is 50Hz and average power is 30 W. Newtonian telescope with diameter of 750mm is used as receiver. The data collected by telescope is given to PMT and discriminator combination through an optical fiber cable having core diameter of 1.5mm and numerical aperture of 0.37. To collect data from optical cable very high gain photomultiplier tube is used which have gain of order 10^7. In receiver system in detector unit, interference filter is used which having 50% peak transmission. To remove the noise signal from collected signal discriminator is used, which is driven by high speed negative pulses generated by PMT. After the noise removal, photon counting is done with the use of multichannel scalar card.

Important parameters of the system are given in Table 1.

Table 1 Specifications of Lidar System

Parameter	Specification
Laser	Nd:YAG
Laser power	30W @50Hz repetition rate
Wavelength of operation	532nm
Receiver	Newtonian type of telescope
Detector	PMT
Type of Feed	Optical fiber
Region of operation	5-35km
Signal Recovery	Photon counting method
Time integration	4 minutes
Height resolution	300m

2 METHODOLOGY

To determine the important parameters like backscatter coefficient, extinction coefficient, backscatter ratio and optical depth, methods as proposed by Fernald [1], Klett [2], Kano [3] and Hamilton [4].

In the Lidar used here, telescope and laser beam are ganged together such that axis of telescope and laser beam is parallel all time. So when telescope is moved in a particular azimuth angle and elevation angle, laser beam is also tilted in the same direction. To do this kind of movement telescope controller software is used. In user interface of software, values for tilts in the North-South (NS) and East-West (EW) or Azimuth (AZ) and Elevation (EL) are given.

If any alignment is disturbed because of any reasons, proper alignments are made by giving NS offset and EW offset so that overlap takes place at required height.

Here time resolution of 250 seconds and height resolution of 300m is taken. So it takes 4 minutes to generate each raw data profile of photon counts.

2.1 Scanning with constant elevation angle:

Fernald [1] method is used to calculate the backscatter coefficient for range of 5-35km. Backscatter ratio is calculated from the received power (photon counts) that is due to aerosols in atmosphere, the lidar equation which relates the transmitted and received power is given in Eq 1. Backscatter parameters are calculated by solving the equation.

$$P_r(z) = K\beta(Z)\, T_1^2(Z)\, T_2^2(Z) / Z^2 \qquad \ldots (1)$$

Where,

K = System constant which includes the optical losses at both transmitting and receiving sides and receiving telescope aperture.

$\beta(Z)$ = sum of $\beta_1(Z)$ aerosol and $\beta_2(Z)$ molecular backscattering coefficient.

$= [\beta_1(Z) + \beta_2(Z)]$

$T_1(Z)$ = Transmittance by aerosols

$= \exp[-\int_0^z \sigma_1(z)\, dz]$

$T_2(Z)$ = Transmittance by molecules

$= \exp[-\int_0^z \sigma_2(z)\, dz]$

Where $\sigma_1(z)$ and $\sigma_2(z)$ are extinction coefficients of aerosol and molecular respectively.

$$\beta_1(z-1) = \frac{X(z-1)}{\frac{X(z)}{\beta_1(Z)} + S1[X(z)+X(z-1)]\Delta z} \qquad \ldots (2)$$

$$\sigma_1(z-1) = \frac{X(z-1)}{\frac{X(z)}{\sigma_1(z)} + [X(z)+X(z-1)]\Delta z} \qquad \ldots (3)$$

Where,

$S1 = \frac{\sigma_1(z)}{\beta_1(Z)}$ which is extinction to backscatter ratio. [5]

The above equations are for turbid atmosphere and not applicable for all types of atmosphere conditions. In above equations X (z) is a range normalized signal which is given by

$$X(z) = P(z)\, z^2 \qquad \ldots (4)$$

Δz = Range resolution

After calculating the backscatter coefficient due to aerosol and extinction coefficient, backscatter ratio can be computed as follows,

$$SR(z) = 1 + \frac{\beta_1(z)}{\beta_2(Z)} \qquad \ldots (5)$$

Backscatter ratio is used to determine the amount of aerosols in the total observation volume. It gives the information regarding how aerosols concentration is varying with range.

The lidar system is operated in the following mode: System is scanned from 0-360° in azimuth direction with step resolution angle of 5° at fixed off-zenith angle of 40°.

3 RESULTS

3.1 Results with fixed elevation angle:

The lidar system is installed at Gadanki, India which is a rural site. The lidar location is around 375 m above from the sea level.

Experiment was carried out in clear sky and cirrus cloud conditions. The experiment started at 1905 hrs on 23/01/2017 and ended at 0305 hrs on 24/01/2017.

The system was operated in the above mode for several nights. In the azimuth angle of 50° and 55° in north-east direction because of obstruction from tree, data was not collected and hence a gap in the plot. In Figure 1 and 2, range squared intensity is plotted against azimuth angle and range. (It is not converted to height).

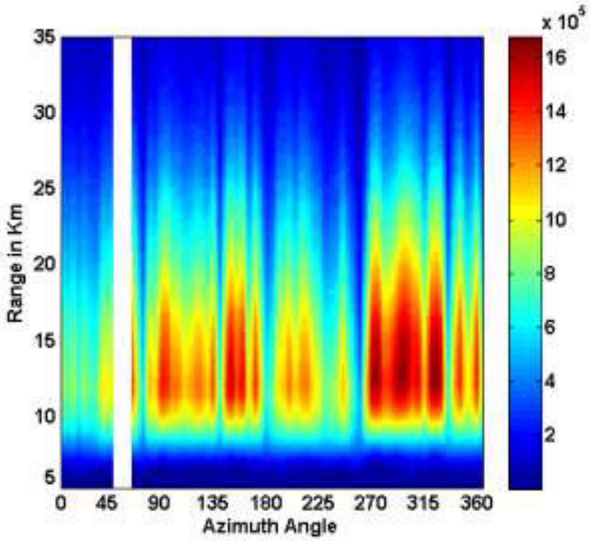

Figure 1 Raw Photon Count Profile on 23/1/2017 which is range corrected for range of 5-35km.

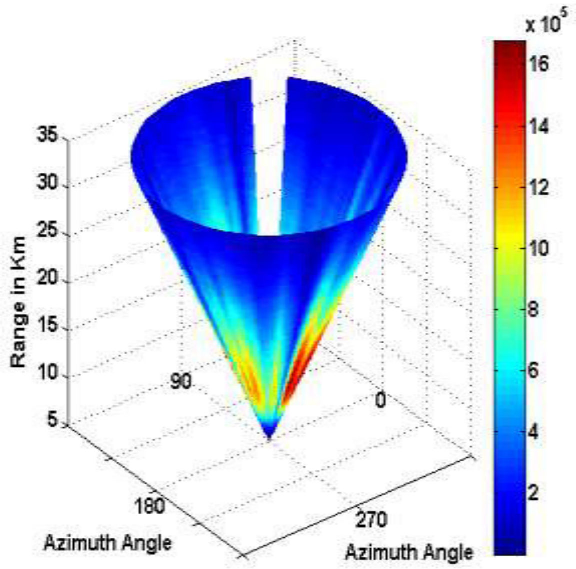

Figure 2 Raw Photon Count Profile on 23/1/2017 which is range corrected for range of 5-35km.

Backscatter ratio is calculated from Eq. 2-5 assuming turbid atmosphere. Molecular backscatter values are taken from CIRA model. Backscatter ratio profiles are shown in Figure 3 and 4.

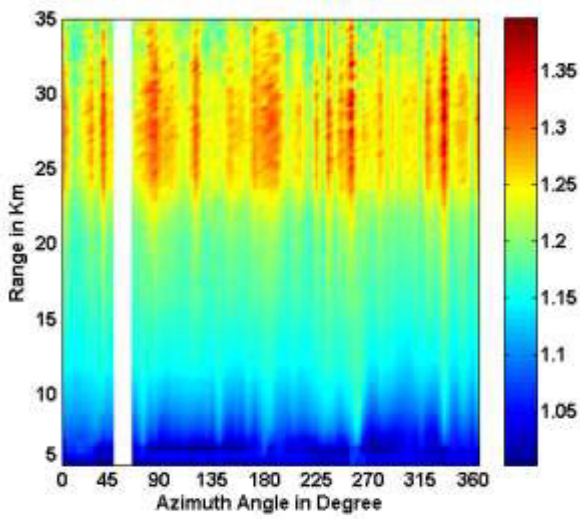

Figure 3 Backscatter Ratio Profile on 23/1/2017 for range of 5-35km.

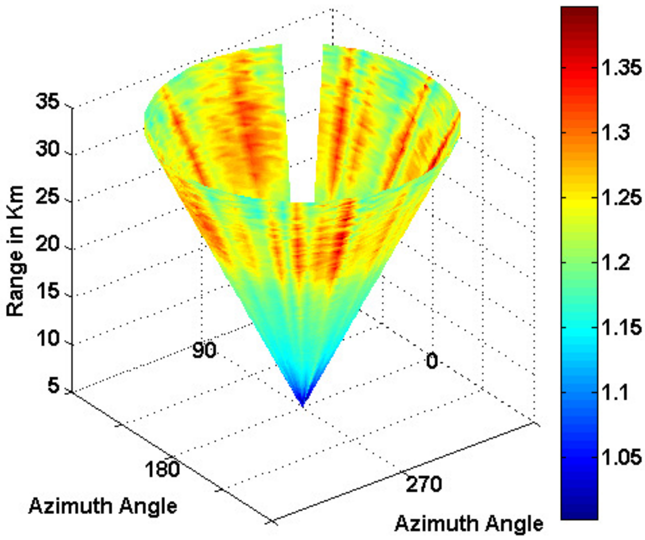

Figure 4 Backscatter Ratio Profile on 23/1/2017 for range of 5-35km.

Lidar data was operated with 2 minute time integration on 24/01/2017. The experiment started at 1905 hrs on 24/01/2017 and ended at 0004 hrs on 25/01/2017. The observations are at 40 degree off-zenith angle and steps of 5 degrees in azimuth angle and is shown in Figure 5. The backscatter ratio profile has shown cirrus cloud presence. Backscatter ratio values of 1-1.25 on 23/1/2017 in Figure 3 & 4 and upto 7 was observed on 24/1/2017 in Figure 5. It may be noted that turbid atmosphere was assumed in backscatter ratio value computation. The values for generalized atmosphere will be calculated in due course using appropriate solution. The high values of backscatter ratio beyond range of 15km are being looked into. Employing Fernald method for slant angle observations is also being studied.

Observations with varied elevation angles can be explored for further cloud evolution studies.

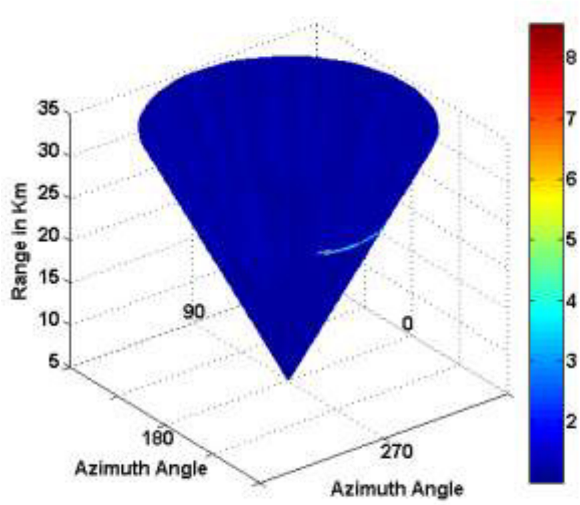

Figure 5 Backscatter Ratio Profile on 24/1/2017 for range of 5-35km.

4 CONCLUSIONS

The observations from multi angle lidar is presented and visualized. The backscatter ratio plots in a conical atmosphere volume give an idea of the presence of aerosols. It also gives the presence of clouds at appropriate heights hitherto not possible with vertical looking systems. Computation of other aerosol parameters like backscatter ratio and optical depth will give more insight into these studies.

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