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Portable lidar observations of aerosol layers over a tropical site Gadanki (13.5°N, 79.2°E) in India

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ABSTRACT

A portable backscatter lidar was developed at the National Atmospheric Research Laboratory (NARL), Gadanki (13.5°N, 79.2°E), India for monitoring the boundary layer aerosol dynamics. The lidar system has been monitoring the lower atmosphere since January 2005. The lidar system uses the principle of micro pulsing and employs diode pumped Nd:YAG laser that operates at 532 nm wavelength. The portable aerosol backscatter lidar nocturnal observations over Gadanki, a rural site in the tropical part of India, usually show a thick aerosol layer in the lowermost atmosphere, which corresponds to the local mixing layer. However, on several occasions during winter 2005, a thin aerosol layer was observed above the local boundary layer, in the free troposphere, between 3 and 4 km heights. It is considered that these layers were on the way of long-range transport. It has been reported that the air mass advecting from these regions contains significant contribution of carbonaceous aerosol. Such elevated aerosol plumes were also observed over the northern India and also over southern India, particularly during winter season due to dry convective lifting of pollutants at distant sources and subsequent horizontal upper air long-range transport. The aerosol layers found above the boundary layer could be transported several thousands of km without significant removal and can contribute appreciably to the column aerosol optical depth, at times more than the boundary layer. Moreover, we observed a significant variability in aerosol load and their height distribution in day to day profiles during the period of winter 2005 over the tropical site Gadanki.

1. Introduction

Aerosol measurements can be performed using passive and active remote sensing methods. The lidar remote sensing technique provides the vertical profiles of aerosol optical properties which are essential to know the vertical layering and long-range transport of aerosols in the atmosphere and their effects on the environment [1]. Recently a portable lidar system developed at NARL, India under the project boundary layer lidar (BLL) employs micro pulsing technique, but its technical configuration is not similar to the original micro pulse lidar [2]. In micro pulse lidars, the telescope employed is used for both transmitting and receiving the laser beam. This causes entry of a small portion of transmit laser beam inside the telescope often damages the sensitive detector. The BLL system employs two laser mirrors in the transmit path, for steering the laser beam to the telescope axis. This paper describes the retrieval of aerosol profiles from the BLL data using standard lidar inversion algorithm and present the preliminary measurements made during January 2005.

2. Lidar Instrument

The BLL system at NARL-Gadanki (13.5°N, 79.2°E, ~ 370 m MSL) site is in regular operation since 2005. The lidar system shown in fig.1 employs a diode pumped Nd:YAG laser that operates at 532 nm with 10 μJ and

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2500 Hz. The expanded laser beam is sent into the atmosphere using two diagonal mirrors kept at 45°angles in the transmit path as shown in Figure 1. The BLL system uses a 150 mm diameter classical Cassegrainin telescope for collecting the laser backscattered returns from the atmosphere. The design focal length of the telescope is 1350 mm. A pin-hole of 0.5 mm was used to obtain a receive FOV of about 400 µrad. A narrowband optical Interference filter is used to reduce background light. The BLL system employ photon counting electronics using a high gain PMT for photon detection, a fast discriminator (300 MHz) and a PC based Multi Channel Scalar (MCS) add-on card.. The detailed system description is given elsewhere by [3]. Figure 2 shows the typical photon count profile obtained from the BLL system during the nocturnal observation period between 02:13 and 02:23 Hrs LT on 6 January 2005. The photon count profile corresponds to a time integration of 10 minutes. A layer of strong scattering is clearly seen in the upper troposphere at heights between 12 and 14 km, which corresponds to the occurrence of high altitude cloud over the lidar site during the period of observation. Using the backward integration method (4)computer code has been developed for deriving the aerosol scattering coefficient from the BLL data. The developed lidar algorithm has been verified for different values of aerosol backscattering coefficient at the calibration point to check the sensitivity of the derived aerosol backscatter coefficient profile and also to estimate the error introduced in the derived aerosol backscattering coefficient. The developed algorithm has also been verified for different theoretical values of lidar ratio (LR_a) and also tested for different calibration heights. The range of variation of in the derived aerosol scattering coefficient appears less than 2% for the change of LR as well change in the calibration height.

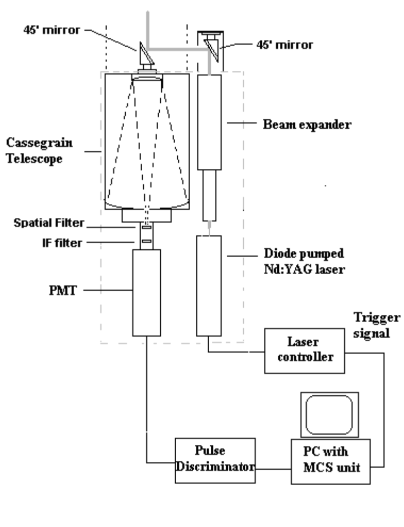

Figure 1. Schematic block diagram of boundary layer lidar (BLL) system

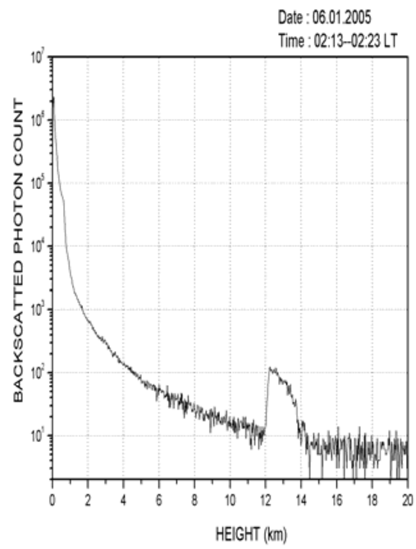

Figure 2. The basic photon count profile from the BLL system, indicating the occurrence of high altitude cloud over the lidar site during the observational period.

3. Results and discussion

The BLL system was operated for a period of 18 days in January 2005 between 1900 and 2200 hrs LT. The lidar profiles obtained on each day over lidar site is further averaged and the daily mean aerosol profile for each day is computed. Figure 3 gives the averaged profiles of aerosol backscatter observed on selective days plotted along with the variability in the data. The most regular feature of all profiles shown is the presence of a large particle layer in the lower most troposphere. This layer most likely corresponds to the local mixing layer (ML) and the tops of ML over lidar site, varies between 1 and 3 km. The height of the nighttime ML is an important parameter for the characterization of the air exchange with the free troposphere and for an estimation of the aerosol dilution within the boundary layer.

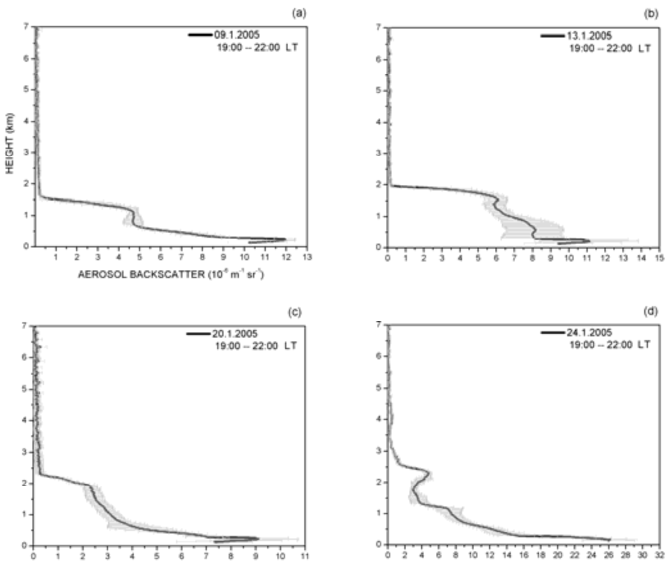

Figure 3. Height profiles of mean aerosol backscatter observed on selected days to show the aerosol backscatter variability shown as shaded lines about the mean aerosol profile.

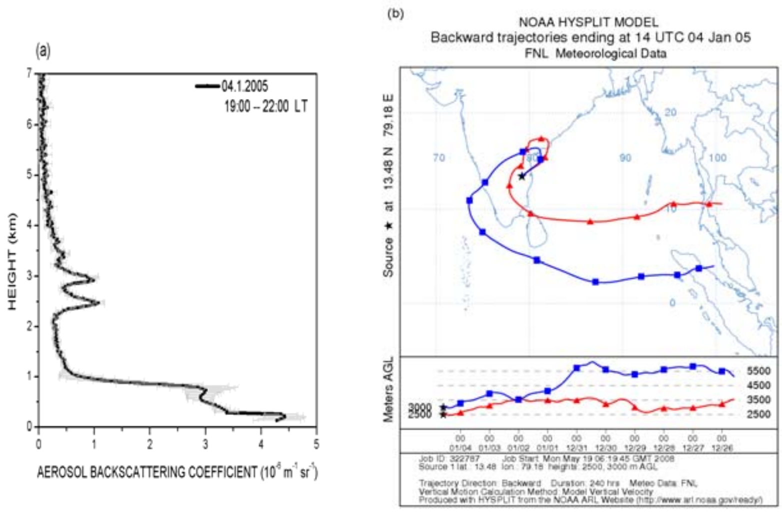

Figure 4 (a) BLL observation of elevated aerosol layer detected on 4 January 2005 over lidar site, (b) A 10-day back trajectories showing the air mass advection from Far East

Lidars have been used identify the advection of aerosol plumes and transport of particles in the free troposphere that originating from remote areas such as arid and semi arid regions. Figure 4(a) shows the altitude profile of aerosol scattering coefficient derived from the lidar data on 4 January 2005. An elevated thin aerosol layer was observed above the local boundary layer between 2 and 3 km. Usually the air masses formation and their passage over different parts of globe cause collection of particles emitted from sources. History of air masses can be used in conjunction with lidar measurement to better characterize vertical structure and temporal evolution of aerosol layers. The origin of such aerosol layers can be found if one considers three dimensional air mass backward trajectory analyses. The trajectory model used in this work is a generally used model called HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) [5] developed by the NOAA Air Resources Laboratory. Trajectories shown in figure 4(b) represent the movement of air that reaches the Gadanki site at 0:00 UTC on 4 January, 2005. The trajectory at a height of 3.0 km passes over the Bay of Bengal and is characterized by isentropic type. The 10 day HYSPLIT air back trajectory shows the air mass pathway from the Far East region. It has been reported that the air mass advecting from these regions contains significant contribution of carbonaceous aerosol.

4. Conclusion

A new portable micro pulse lidar system, popularly known as Boundary Layer Lidar (BLL), was developed to monitor the tropical aerosol scattering properties in the lower troposphere and has been in regular observation since January 2005. The aerosol backscatter measurements are obtained in the lower troposphere Using the Fernald-Klett inversion algorithm and employing standard atmospheric molecular data, the height profiles of aerosol backscatter were derived up to an altitude range of 7 km with an altitude height resolution of typically 30 m. The initial lidar observations over the Gadanki site have indicated the presence of thick aerosol layer in the lower most troposphere, which was considered as the local mixing layer.

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