Retrieval Of Aerosol Extinction Profile: Study By Using Ground Based LIDAR And Sun-Photometer

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Abstract

In the present study we have derived the aerosol extionction profile. Derived LIDAR extinction profile shows no extinction below 0.43 km because of neglisible concentration of aerosols due to boundary layer dynamics as the site in free troposphere. The integrated aerosol extinction profile by LIDAR is ~ 45 % that of derived aerosol optical depth (AOD) by sunphotometer. The rest of the optical depth is due to aerosols which are below the 0.43 km. We have considered the defalut profile of aerosol extinction from Radiative Transfor model below the 0.4 km to fill the gap which is not observed by LIDAR. We integrated derived extinction profile and equated to the aerosol optical depth observed by sunphotometer.

Keywords: Lidar; Sun-photometer; aerosol extinction; aerosol optical depth.

1. Introduction

Aerosols are the tiny suspended particles (solid or liquid form) in the atmosphere. The sources of aerosols are natural like sea salt spray, windblown dust and volcanic eruptions etc and anthropogenic like vehicular emissions and bio mass burning etc. Aerosols are important constituents of earth atmosphere, play very important role in regional and global climate directly by scattering and absorbing the incoming solar radiation and indirectly by modifying the cloud micro physical properties such as albedo, precipitation and life time etc [1] [19] [7]. Apart from the direct and indirect effect, aerosols cause semi-direct effect by substantially heating the atmosphere thereby causing 'burning of clouds' [1]. In addition to this recent studies showed that the importance of aerosol vertical profile as they can alter the thermal structure of atmosphere and affect the cloud formation [16]. Lack of information on aerosols vertical profile is one of the largest sources of uncertainty in the estimation of direct, semi-direct and indirect effect of aerosol radiative forcing [6]. Default profile of aerosols from Radiative Transfor models has been used in the estimation of aerosol radiative effects by earlier investigators over Manora peak [18] [8]. This profile cannot represent the actual aerosol profile. Because of the above reason, in this work we intend to derive the vertical profile of aerosols and its extinction profile by using LIDAR and sun-photometer. Now the derived aerosol extinction profile can be used in the calculation of radiative effects accurately.

Working of Light Detection and Ranging (LIDAR) is same as RADAR, but uses light pulse instead of radio pulse for probing the atmosphere. Received back scattered light by telescope are fed into the detection system for further process to get vertical profile of back scattered signal. Elastic LIDARs are the best active remote sensors for measuring the position of aerosols and clouds with high special and temporal resolutions [13] [3]. Sun-photometer is the passive remote sensor measures direct solar fluxes to get the budget of column aerosols in the atmosphere [10] [12].

Data in the present study were taken over Manora Peak (29.4^{o} N, 79.5 ^{o} E), Nainital in central Himalayan region during 15 & 22 October 2008. Manora peak is a high altitude station with the elevation ~ 1960 m AMSL and it is also for away from major antropogenic pollution [15].

2. Experimental

a. Lidar

A portable Boundary Layer LIDAR (BLL) designed and developed at National Atmospheric Research Laboratory (NARL), Gadanki [2] is used to study the vertical profile of aerosols. The system employs micro pulse technique and its technical configuration is quite different from the micro pulse lidar [17]. The LIDAR system employs a diode pumped Nd: YAG laser that operates at its second harmonic wavelength 0.532 µm with 10 µj energy and 2.5 kHz pulse repetition rate. The laser beam will go through the beam expander to reduce the divergence of laser and the expanded laser beam is sent into the atmosphere. LIDAR system uses 150 mm diameter Cassegrain telescope for collecting the laser-backscattered returns from the atmosphere. Back scattered photons will made to pass through the narrow band pass filters before entering the detector (Photo Multiplier Tube) to reduce undesired signal (noise). The backscattered photons from atmospheric constituents (aerosols and molecules) get stored with a bin width of 200 ns which corresponds to an altitude resolution of 30 m. The detailed system description is given elsewhere [1]. The LIDAR profiles were collected during night hours between 08:00 and 12:00 local time (LT) on 15 & 22 October 2008. The photon count profile corresponds to a time integration of 10 minutes.

b. Sun-photometer

The direct fluxes were measured at five wavelengths namely 0.38, 0.44, 0.50, 0.675, 0.87 µm, using Sun photometer (Microtops) II (Solar Light Company, Glenside, PA, USA) to get aerosol optical depth (AOD) at each wavelength. The information of time, location, altitude and pressure are provided by a global positioning system (GPS) receiver connected to the photometer. The observations were taken about 6-8 times in a day during the clear sky conditions on 15 & 22 October 2008. In the present study we have used aerosol optical depth at 0.5 µm as it is the Lidar operating wavelength. The typical error in the AOD measurement using Microtops II Sun photometer is ± 0.03. Details regarding the Sun Photometer, methodology of data acquisition and precautions during measurements and its calibrations are described elsewhere [10] [12] [8].

3. Results and discussions

LIDAR received signal at given height,

$$P(R) = C_0 T_0^2 \frac{\beta_\pi(R)}{R^2}\, e^{-2\,(\int_{R_0}^{R} K_t(x)dx)} + P_N(R)$$

Where C_0 is LIDAR system constant, $\beta_\pi(R)$ is back scattered intensity, R is altitude, $P_N(R)$ is the noise signal and

$$T_0^2 = e^{-2\int_0^{R_0} K_t(x)dx}$$

is extinction below overlap height and $e^{-2\,(\int_{R_0}^{R} K_t(x)dx)}$ is extinction above overlap height.

$$P_{Sig}(R) = P(R) - P_N(R),$$

Where $P_{sig}(R)$ is back scattered photons from atmospheric constituents; $P_N(R)$ is back ground signal.

Fig. 1 shows the noise corrected back scattering signal with height on 15 October 2008. The enhancement in the signal at about ~ 0.8 km is due to the presence of aerosol layer over the observational site.

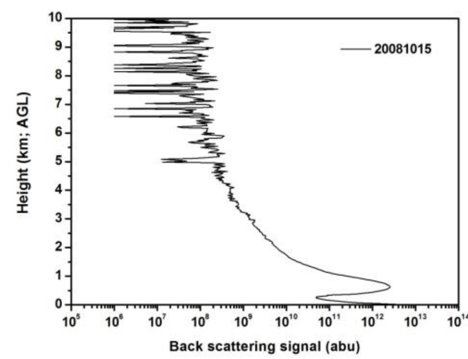

Fig. 1 The basic photon count profile from the BLL system, indicating the aerosol layer at ~ 0.8 km altitude over the observational site during 15, October 2008.

Backscattered photon-returns from the atmospheric aerosols were processed. We have used the algorithm described by Fernald [4] and Klett [9] for deriving the aerosol extinction coefficient profiles in clear sky conditions.

$$\beta(R) = \frac{\exp[-S'(R_{ref}) - S'(R)]}{1/\beta(R_{ref}) + \frac{2}{C}\int_R^{R_{ref}} dR' \exp[-S'(R_{ref}) - S'(R')]},$$

Where $\beta(R) = \beta_p(R) + \beta_r(R)$ (particulate and Rayleigh contribution), $\beta(R_{ref})$ the boundary condition set on $\beta(R)$ at the reference far-end range R_{ref};

For the inversion of the LIDAR signal, we have considered the reference height at 6 km as the aerosol contribution for back scattering coefficient is negligible and equals to the molecular scattering. The molecular (or Rayleigh) contribution to the signal was taken from the CIRA-1986 (Cospar International Reference Atmosphere) standard atmospheric model. The value of Lidar raio, which is ratio of extinction coefficient to back scattering coefficient was chosen as been equal to 35 sr for an environment like Manora Peak [11] [5].

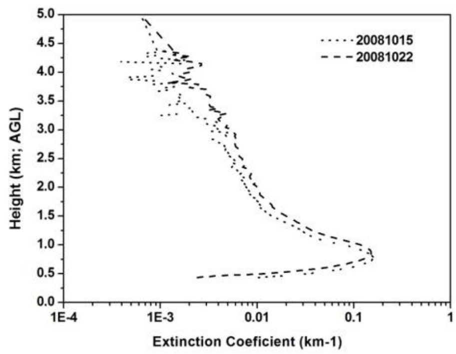

Fig. 2 Height profiles of mean aerosol extinction profile derived from LIDAR on 15 & 22 October 2008.

The extinction profile derived from LIDAR showed no extinction from surface to near ~ 0.43 km and then increased with altitude with a mean extinction coefficient of about ~ 0.15 (±0.005) km^{-1} at ~ 0.82 (±0.05) km and finally showing continuous decrease until reaching the top of aerosol layer which is near ~ 4 to 5 Km. The aerosol optical depth between 0.4 km to 5km is obtained by integrating extinction profile from 0.4 km to 5 km, which is about ~ 0.09 (±0.003). This type of elevated aerosol layers can be attributed due to dry convective lifting of pollutants at distant sources and subsequent horizontal upper air long rang transport of aerosols [8]. LIDAR profile shows no extinction below 0.43km because of low concentrations of aerosols due to boundary layer dynamics during the operational times (night times) and/or its instrumental limitation as the LIDAR has overlap height about ~ 0.15 m.

$$AOD\ (LIDAR) = \int_{0.4km}^{5km} K_t(x)dx$$

Sun-photometer derived aerosol optical depth at 0.5 µm on the same period is about ~ 0.2 (0.002), which is column integrated extinction from ground. We have not observed any increment in the LIDAR received signal above 5 km. This observation made us to conform that there is no aerosol contribution to extinction above 5 km. The aerosol optical depth observed by LIDAR is only 45% that of observed by sun-photometer. This is because sun-photometer operated in day time and LIDAR operated in night time.

During daytime due to thermal convection the aerosols which are below the site (in the nearby valleys) would came up and contributed to the aerosol optical depth gives excess contribution. In night time thermal convections ceases because of no solar radiation and consequently aerosols settle down to near surface (in the nearby vallyes). To know the extinction profile from ground, we subtracted averaged LIDAR AOD (Integrated extinction from 0.4 km to 5 km) from Sun-photometer AOD (Integrated extinction over entire atmospheric-column).

$$AOD\ (Sun-photometer) = \int_0^{5km} K_t(x)dx$$

$$\int_0^{0.4km} K_t(x)dx = AOD\ (Sunphotometer) - AOD\ (LIDAR)$$

$$\int_0^{0.4km} K_t(x)dx = 0.11$$

This is the aerosol optical depth due to the uplifted aerosols due to convection in the day time. We have used standard extinction profile form Santa Barbara Radiative Transfer (SBDART) model [14] below 0.4 km to equate the 55 % of AOD observed by sun-photometer.

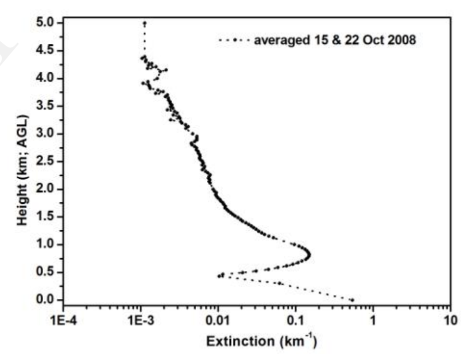

Fig. 3 Height profiles of averaged aerosol extinction profile derived from LIDAR and Sun-photometer during 15 & 22 October 2008.

Figure shows the average vertical aerosol extinction profile derived from the LIDAR system and Sun-photometer, which depends on the variation of aerosol concentration with height. It is clearly observed that, the extinction profile decreases from surface and reached minimum at 0.43 km. Extinction then increased with altitude up to 0.82 (±0.05) km, finally decrease until reaching the top of the layer. This extinction profile can be used for the estimation of radiative effects of aerosols accurately.

5. Conclusions

Boundary layer LIDAR and sun-photometer is used to derive aerosol extinction profile in the atmosphere. Aerosol back scattering coeficient was derived by using Fernald-Klett inversion algorithm and employing standard atmospheric molecular data. The LIDAR profile shows extinction from 0.43 km to 5 km and iintegrated LIDAR extinction is ~ 45% that of derived aerosol optical depth from the sun photometer. Rest 55% of aerosol extinction is due to the aerosols below 0.43 km. We have used the default aerosol extinction profile which is exponential below 0.43 km and equated this integrated extinction with 55 % of AOD observed by sunphotometer. The derived aerosol extinction profile can be used in the estimation of radiative effects of aerosls to reduce the on of the uncertinities.

6. Acknowledgements

This work was carried out as a part of the ARFI and ABLN&C project under Indian Space Research Organization - Geosphere Biosphere Program. Mr Kishore Reddy is grateful to CSIR for awarding research fellowship. The authors are also thankful to the Director ARIES, Manora Peak, Nainital for their constant encouragement to undertake this work.

10. References

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