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Deriving aerosol scattering ratio using range-resolved lidar ratio

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Abstract. The study on the optical characteristics of aerosol is carried out using the dual polarization lidar observations from the tropical inland station Gadanki (13.5°N, 79.2°E) for the period of observation during the year 2010. The summer and monsoon observation days show high scattering ratio at the tropical tropopause layer (TTL) and at the lower stratosphere region. The depolarization ratio is also high at this altitude due to the transport of particulates to the TTL layer by the active convection prevailing at the period. The study reveals more dependable values of scattering ratio that are seasonal and range-dependent.

Keywords. Aerosols; lidar; extinction; circulation.

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1. Introduction

The extinction-to-backscatter ratio, usually called as lidar ratio (LR) is an important parameter to obtain the nature of the scatters while studying the optical properties of clouds and aerosols using lidar. The LR values in combination with linear depolarization ratio (LDR) are used to suggest the type of aerosols. The altitude-dependent LR value was calculated from the method described in detail by Satyanarayana *et al* [1]. It can be seen that the variation of aerosol extinction coefficient with uniform LR is relatively high in the lower altitudes (up to 15 km). This clearly indicates that the nature and composition of aerosols in the lower altitudes are different from those of higher altitudes. At lower altitudes, the sources of the aerosols are more of local or regional origin and the particles are relatively large in size. Generally, it is known that the lower tropospheric aerosols are a mix of local or regional aerosols combined with those transported from far off regions due to atmospheric circulation, particularly during dust storm episodes [2,3]. Thus, it is appropriate to select a range-dependent LR to derive more accurate extinction profiles. Moreover, the method of classification of cloud days from cloud-free days have been widely done by using the derived scattering ratio (SR). Background SR is typically reported to be in the range 1.0–1.5 during any normal day [4]. These values are normally predicted by taking a LR value common for all periods. As said the LR value is a range-dependent and season-dependent entity and range-resolved LR values can give more accurate SR and backscattering values. Here we have used the range-resolved LR calculated by the method developed by Satyanarayna *et al* [1], to derive the SR and backscattering values. The monthly averaged range-dependent LR values are used to determine the aerosol extinction, backscattering and scattering ratio.

2. Experimental methods

The experiments are carried out using the elastic backscatter lidar system operational on a regular basis at NARL Gadanki. The lidar transmitter employs an Nd:YAG laser, operating at 532 nm, with an energy of 550 mJ per pulse (Model: Powerlite 8020: of Continuum, USA). The lidar system is aligned to make complete overlapping between the transmitter and receiver at a height of about 4 km to avoid the intense backscattered signals

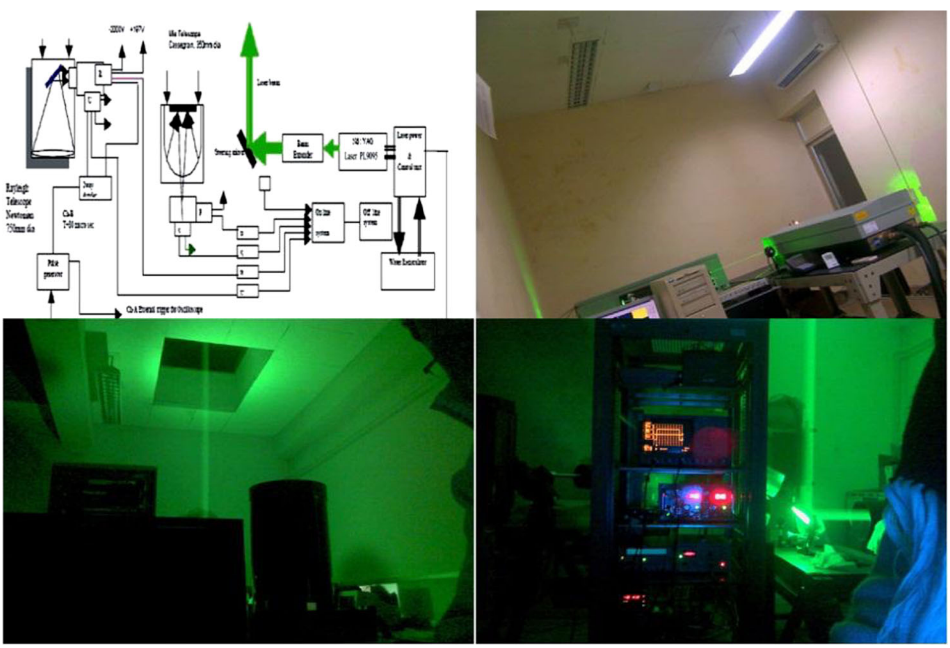

Figure 1. Block diagram of the Nd:YAG lidar system at NARL Gadanki, showing the laser, transmitter system and data accumulation system along with pictures of the laser system and telescope.

from the low altitude clouds and aerosols. Simultaneous data on temperature are taken from radiosonde experiments conducted at the station during the same period. Figure 1 shows the block diagram and pictures of laser and telescope assembly.

The present lidar inversion method makes use of the Klett's backward integration with suitable modification to obtain the range-dependent LR and the extinction coefficient profiles. To start with, the method requires a model aerosol extinction profile corresponding to the station and the experimentally measured lidar data. The 'model aerosol profile' (MP) is used in this study and the proportionality constants S and k of LR have values of 20 and 1 respectively in this MP. The LR value of 20 at the lidar wavelength of 532 nm corresponds to marine aerosols used [3,5]. The measured lidar data obtained from the experiments using the lidar system are used to derive the aerosol extinction profile which is designated as the observed profile (OP). For obtaining the OP from the measured lidar data, the same values of S and k should be used in deriving MP. The same reference altitude should be selected in deriving both the profiles. The 'synthetic lidar signal' can be derived by combining the MP and the molecular extinction profile (RP) corresponding to the station. Molecular extinction values of the stations under this study at each altitude were calculated from the appropriate molecular density profiles by using the Rayleigh theory. The air density values are taken from the atmospheric neutral density model developed by Sasi and Sengupta [6] using the sounding rocket and balloon experiments.

The calibration constant of the lidar system which depends on various lidar system parameters including the overall system efficiency, etc. can be derived by comparing the synthetic lidar signal of MP and measured lidar signal of OP at a particular altitude level. This normalization should be done at the highest altitude of lidar measurement to reduce the inaccuracies. This calibration constant can be used to normalize the 'synthetic lidar signal' derived as above by comparing it with the measured lidar signal of OP. This is the usual normalization practice in generating the synthesized lidar data or comparing the lidar signals at the two different stations using two different lidar systems. Using this 'synthetic lidar signal' after normalization, the aerosol extinction coefficient profiles are calculated by iteratively modifying the k value within the realistic range by keeping S as 20. The extinction coefficient with different k values can be compared with OP to get the best fit of the two profiles. The realistic range of k values chosen in this iteration is based on various physical parameters of the atmosphere and those of aerosols of different origin. The corresponding k value can be identified as its true value for further analysis. In the next step, using the extinction coefficient profile derived from normalized 'synthetic lidar signal' with the true value of k derived as above, an 'altitude-integrated synthetic lidar signal' profile can be generated by putting different values of S at different altitude bins covering the total region. Both the RP values and the lidar calibration constant used for the generation of 'synthetic lidar signal' should be taken for obtaining the 'altitude-integrated synthetic lidar signal'. By the repetitive iteration method, the optimum value of S corresponding to each altitude bin can be obtained. The value of S so obtained for each altitude bin corresponds to the range-dependent constant S which is a proportionality constant of LR. The integrated aerosol extinction profile with altitude-dependent S and k can be derived from the measured lidar signal and the corresponding LR values can be derived.

3. Results and discussion

Figure 2 shows the profiles of extinction, backscattering ratio, scattering ratio and depolarization ratio derived by using the range-resolved lidar ratio. Four cloud-free days of the year 2010 were taken for the study from the station (Gadanki, Tirupati, India (13.5°N, 79.2°E)). The four days fall in the four seasons of the year namely, winter (Dec.–Feb.), summer (Mar.–May) and monsoon season (June–Nov.). The profiles were obtained by taking monthly average of range-resolved lidar ratio.

The profiles showed that during the observation day in January (winter period) the scattering ratio is high in the range of 2.5–3.5. There is an increase in depolarization ratio at around 28 km. The same period also showed high scattering ratio. The observation days on March 3 also showed similar pattern as the day in January (high scattering ratio). The observation days of 5 May and 1 September showed high scattering ratio in the tropical tropopause layer (TTL, 12–16 km) and lower stratosphere region with high depolarization ratio [7]. The increase in scattering ratio during the winter periods and at the beginning of summer is due to the transport of particulates to higher altitude by circulation like the Dobson Brewer circulation. The summer and monsoon observation days show high

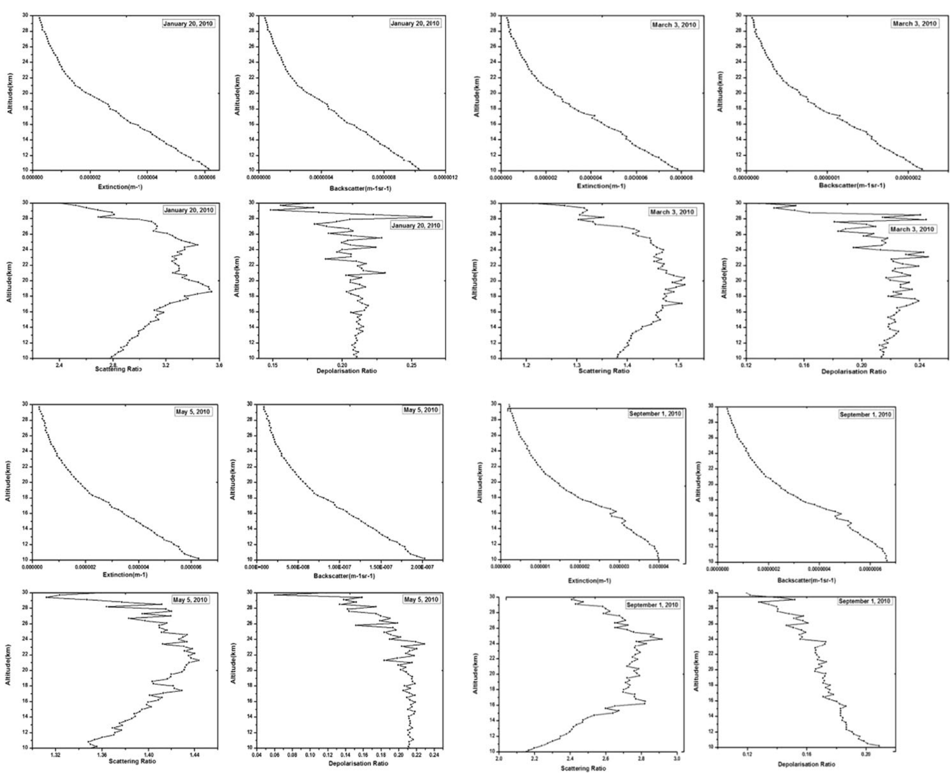

Figure 2. Extinction, backscatter ratio, scattering ratio and depolarization ratio profiles using the range-resolved lidar ratio for January 20, March 3, May 5 and September 1 of the year 2010.

scattering ratio due to the active convection activity at the TTL region during this period. The depolarization is also high at this altitude due to the transport of particulates to the TTL layer by the active convection prevailing at the period.

4. Conclusion

The study discusses the measure of scattering ratio, backscattering ratio, extinction coefficient and depolarization ratio by using the range-resolved lidar ratio. The study will give more dependable values of scattering ratio which is seasonal and range-dependent. The work is to be amalgamated and assimilated in a seasonal base and to be presented. The data will serve as input for aerosol modelling.

References

[1] M Satyanarayana, S R Radhakrishnan, S Veerabhuthiran, V P Mahadevan Pillai, B Presennakumar, V S Murty and K Raghunath, *J. Appl. Rem. Sens*. **4**, 043503 (2010)
[2] A Ansmann, D Althausen, U Wandinger, K Franke, D Muller, F Wagner and J Heitzenberg, *Geophys. Res. Lett*. **27**, 963 (2000)
[3] M Satyanarayana, S Veerabuthiran, D Ramakrishna Rao and B Presennakumar, *Aer. Sci. Technol*. **38**, 24 (2004)
[4] A Jayaraman, S Ramachandran, Y B Acharya and B H Subbaraya, *J. Geophys. Res*. **100**, D11, 23209 (1995)
[5] S Veerabuthiran and M Satyanarayana, *Ind. J. Rad. Space. Phys*. **32**, 158 (2003)
[6] M N Sasi and A K Sengupta, *Scientific Report SPL: SR: 006:85*. (1985)
[7] S V Sunilkumar, K Parameswaran, K Rajeev, B V Krishna Murthy, S Meenu, S K Mehta and A Babu, *J. Atmos. Solar Terr. Phys*. **72**, 745 (2010)