Calibration of the vertical lidar measurement of tropospheric aerosol extinction coefficients

Hideki Kinjo*, Hiroaki Kuze, Hiroaki Matsusima and Nobuo Takeuchi
CEReS, Chiba University, 1-33 Yayoi-cho, Inage-ku, 263-8522 Japan
*e-mail: wood@rsirc.cr.chiba-u.ac.jp

In the derivation of aerosol profile from lidar data one has to assume an appropriate value for the aerosol extinction coefficient at a critical range which is usually set at a distance well outside the detection range. Since this value influences the absolute magnitude of the aerosol extinction through the atmosphere, it is desirable to have a means for calibration. Here we propose the use of ground-level extinction coefficient measured with an integrated nephelometer. For the calibration of atmospheric data collection lidar (ADCL) data the additional information obtained using a portable lidar is found to be useful for connecting the ground-level value with the retrieved value at the lowest altitude (ca. 100m) determined by the overlapping of the laser beams with telescope field-of-view.

1. Introduction

Recently we have constructed an atmospheric data collection lidar (ADCL) to obtain the aerosol data needed to perform the atmospheric correction to satellite remote-sensing data. To obtain good precision in inverting the ADCL data for the case that the condition of a large optical thickness cannot be fulfilled, here we propose to use the calibration value obtained with an integrated nephelometer set at ground level. In the case of our atmospheric data collection lidar the lowest altitude determined by the overlapping of the laser beams with telescope field-of-view is approximately 400 m above ground level in vertical measurement with 3 mrad field-of-view. This lower limit, which is introduced to prevent the saturation of the detection system, can be alleviated by employing a larger field-of-view angle, but cannot be eliminated completely. In order to obtain the relevant information between the ground level and the overlapping point we make use of a portable lidar set at an elevation angle of 20 degrees. In the actual process it is assumed that the medium between the laboratory level (about 60 m above sea level) and the full overlap point of the portable lidar (about 160 m above sea level) is homogeneous.

2. Experimental situation

Figure 1 shows the schematic diagram of the experiment.

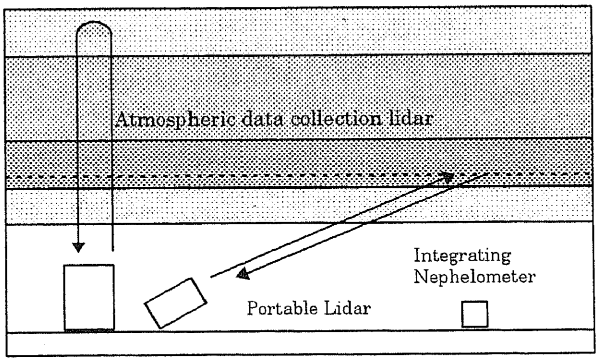

Fig.1 Schematic diagram of the experiment. All the instruments are located at an elevation height of approximately 60 m above mean sea level.

Aerosol vertical profile measurement at the Nd:YAG laser wavelength of 532 nm has been performed using our atmospheric data collection lidar. Simultaneously a portable lidar with a Nd:YAG laser; wavelength 532 nm at an elevation angle of 20 degree has been employed to collect the atmospheric information below the full overlap point of ADCL. To calibrate the lidar-derived extinction coefficient, an integrating nephelometer is operated continuously at the ground level. All the instruments are located at an elevation height of approximately 60 m above mean sea level, in our laboratory at Chiba University, located 30 km east of Tokyo.

3. Portable lidar measurement

First we examine whether it is reasonable to calibrate the portable lidar data by means of the ground level extinction coefficient measured with the integrating nephelometer. Figure 2 is the plot of aerosol extinction at the ground level measured with the two instruments. In the analysis of the lidar data with Fernald's inversion method$^{1)}$, the boundary value is assumed to be constant, 0.00022 m^{-1}. The reference altitude is chosen to be 500 m (1462 m slant range). For the extinction-to-backscattering ratio we have assumed S_1=30 through the lidar path. The lowest altitude of the interval considered is 100 m (292 m slant range) with a receiver field-of-view of 4 mrad. If the medium between the ground and this lowest altitude is assumed to be homogeneous, we can expect a value at the lowest altitude in agreement with the nephelometer-derived extinction data. This gives rise to a constraint with regard to the choice of the boundary value in the Fernald analysis.

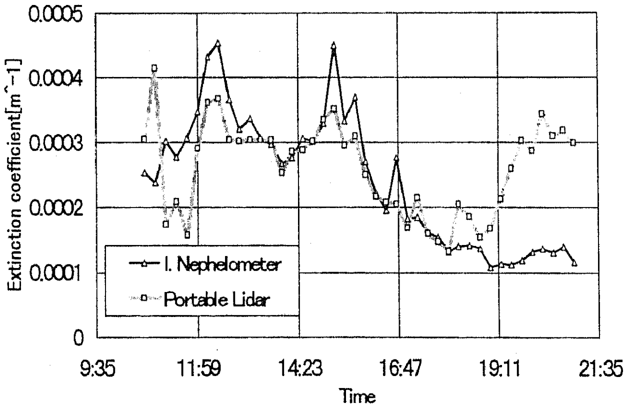

Fig2 Extinction coefficients measured with the nephelometer near ground level (60 m ASL) and the portable lidar. The latter is at 160 m altitude derived from Fernald method. (12 August 1997. S1=30.)

Two results agree well around 14:00, when the atmospheric condition at the reference altitude (500 m) is considered to be stable with time.

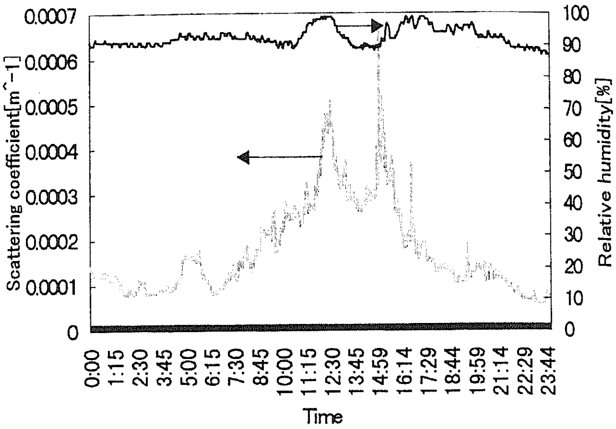

Fig3 Scattering coefficient and relative humidity measured with the integrating nephelometer on 12 August 1997.

Since the mean value of the relative humidity observed on the experimental day at our laboratory is approximately 92% (Fig.3), the value of single-scattering albedo is considered to be high. It is reasonable to suppose that the ground-level extinction value can serve as the calibration value in the analysis of the portable lidar data.

4. Calibration of the ADCL data

Figures 4 and 5 show the range corrected profiles measured with the two lidars (19:15JST, 13 August, 1997). The profile associated with an aerosol layer is observed between the altitude of 300 m to 600 m in both cases.

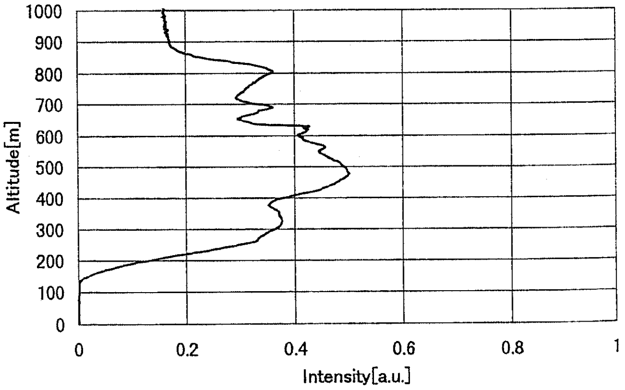

Fig. 4 Range corrected signal measured with an atmospheric data colleciton lidar at 19:15 on 13 Augst 1997.

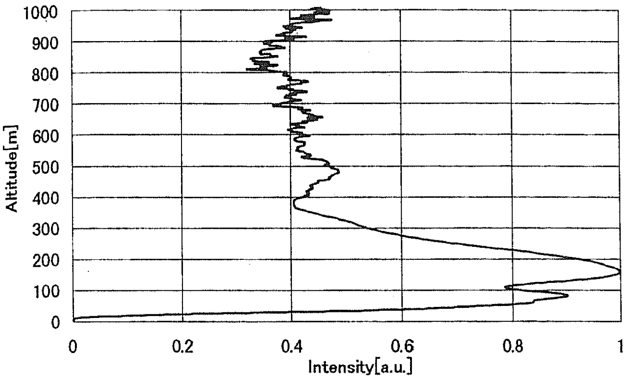

Fig.5 Range corrected signal measured with a portable lidar at 19:15 on 13 Augst 1997.

The vertical extinction profiles in Figs.6 and 7 have been composed from the atmospheric data collection lidar measurement in the altitude between 400 m and 3500 m and the portable lidar measurement in the altitude between 100 m and 400 m. The boundary value at 400 m altitude for the inversion of the portable lidar data is chosen utilizing the ground-level calibration value. This boundary value also serves as a calibration value for the inversion of the ADCL data. Below 100 m the aerosol extinction coefficient is assumed to be constant. Figure 8 exhibits the change of the extinction coefficient between Fig.6 (19:15JST, 13 August, 1997) and Fig.7 (19:30JST, 13 August, 1997). The mean value of the relative humidity observed on the relavant day at our laboratory is approximately 93%.

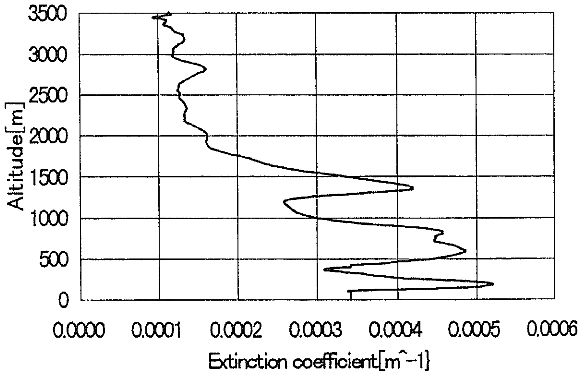

Fig6 Aerosol extinction coefficint with Fernald method from multi-wavelength and portable lidar return measured at 19:15 on 13 August 1997. S1=30.

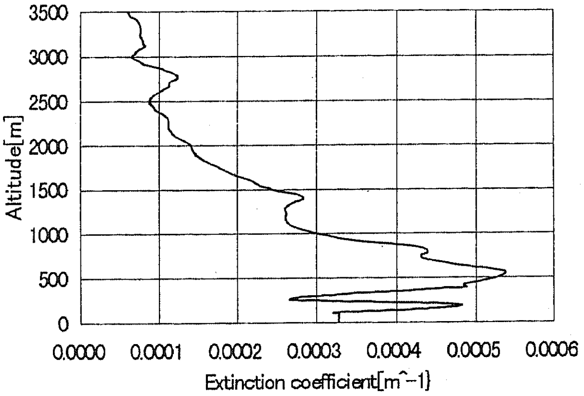

Fig7 Same as Fig.6 at 19:30 on13 August 1997.

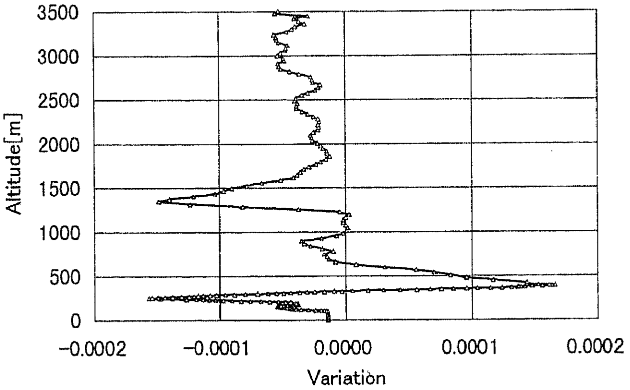

Fig.8 Variation of extinction coefficient between Fig.5 and Fig.6.

We can see a multi-layered structure of aerosols which changes rapidly with time. The growth of the layer thickness between the altitude of 300 m to 1000 m is explained by the descent of the concentrated aerosol layer.

5. S_1 dependence of optical thickness

The two profiles shown in Figs.6 and 7 are calculated with the extinction-to-backscattering ratio of 30 in the lidar path. In this section, we investigate the S_1 dependence of the optical thickness. The optical thickness between 0 and 3500 m is calculated with the S_1 value between 30 and 60. The results show an increase of 3.6% in the case of 19:15 data (Fig.6), while there is 2.2% increase in the case of 19:30 data (Fig.7). Owing to the high value of the relative humidity, it appears that the change of S_1 parameter does not affect the resulting optical thickness significantly.

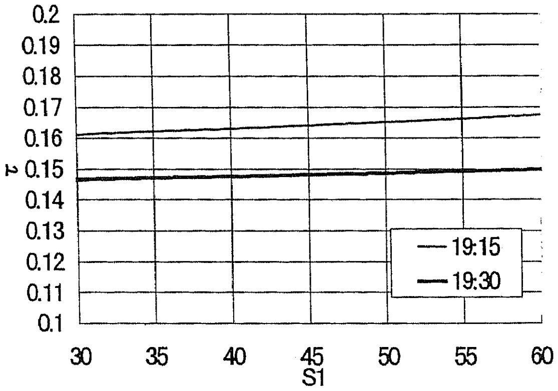

Fig.9 Effect of extinction to backscattering ratio S1 on the optical thickness. S1 is assumed to be constant over any interval measured with the two lidars.

6. Conclusions

In this report we have demonstrated the improvement of the lidar-data processing utilizing the nephelometer-derived extinction data. Even under the situation where the inverted profile is sensitive to the choice of the boundary value of the aerosol extinction (optical thickness is less than unity), the aerosol distribution can be inverted accurately from lidar data with this type of calibration method.

1)F.G.Fernald , "Analysis of Atmospheric Lidar Observations : Some Comments", Appl.Opt.23,652 (1984)