LIDAR MEASUREMENTS OF THE RATIO BETWEEN AEROSOL EXTINCTION AND BACKSCATTER COEFFICIENTS

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ABSTRACT

Under typical background aerosol conditions, with scattering ratios in the region of 1.1, lidar backscatter measurements of stratospheric aerosols at visible region wavelengths suffer negligible extinction. For this reason it is not normally possible to use such measurements to measure the extinction. Shortly after a large volcanic injection, however, the extinction can become large enough to be measured. For measurements made at 589 nm by our lidar, situated at São José do Campos (23° S, 46° W) this was the case shortly after the eruption of Mt. Pinatubo in 1991. On one day at the end of July, and three days at the beginning of August, scattering ratios greater than 30 were observed between 20 and 25 km. Under these circumstances it was possible to estimate the extinction by comparing the lidar signals below and above the aerosol layer with those observed immediately prior to the arrival of Pinatubo aerosol at our location.

INTRODUCTION

A knowledge of the ratio between extinction and backscatter of stratospheric lidar signals is useful for two reasons: firstly it provides information on the particle size distribution and, secondly, it makes it possible to compare lidar backscatter profiles with satellite measurements of the long-path extinction. Unfortunately (or perhaps fortunately, depending on your point of view!), for vertical lidar sounding at visible wavelengths, the extinction of the lidar beam is generally too small to measure. Only under conditions of exceptionally high stratospheric aerosol burden does the extinction become measurably large. For our lidar this condition occurred in July and August of 1991, shortly after the arrival of the Pinatubo aerosol cloud. By comparing the backscatter profiles observed before and after the arrival of the Pinatubo aerosol it was possible to estimate the ratio of the extinction coefficient to the volume backscatter coefficient.

OBSERVATIONS AND ANALYSIS

At the time when the measurements were made the INPE lidar used a flashlamp-pumped dye laser tuned to 589 nm, with a photon counting receiver. Overlapping high and low sensitivity receiver channels enabled the non-resonant signal backscattered from the atmosphere to be measured between 10 and 60 km. The Pinatubo aerosol was first clearly visible on July 31, on which date the integrated backscatter was about 17 times the typical pre-Pinatuba values. Maximum values occurred on August 1, about 50 times the pre-Pinatubo level.

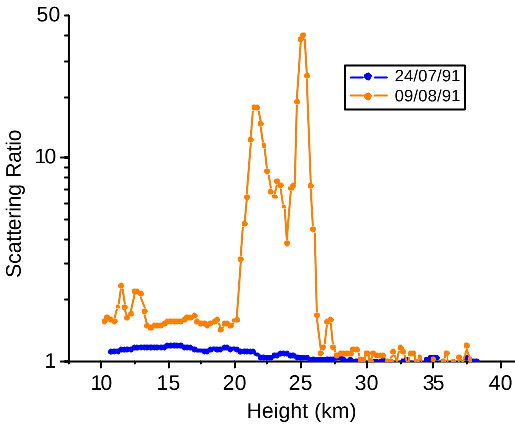

Fig. 1 Uncorrected scattering ratio profiles

In Figure 1 we show the height profile of the backscatter ratio for August 9, together with that for July 24, the latter being typical of the pre-Pinatubo period. The profiles plotted in Figure 1 are normalized to the molecular atmosphere at heights above 30 km and do not take extinction into account. The effects of extinction are clearly visible in the August 9 profile as a displacement of the lower part of the profile in comparison with the pre-Pinatubo "clean air" profile. The displacement is seen below the aerosol layer because we have normalized at heights above the layer. In actual fact, of course, it is the signal from above the layer that is attenuated by the aerosol scattering.

Since we are normalizing to the signal from above the aerosol layer, to correct for extinction we use

$$Rc(z_1) = Ra(z_1)\exp - 2\,\mathrm{Re}\int_{\infty}^{z(1)} \sigma_R(z)(Rc(z)-1)\,dz$$

where
Rc(z1) is the corrected scattering ratio at height z1;
Ra(z1) is the apparent scattering ratio at height z1;
Re is the ratio of the extinction to backscatter coefficient, assumed independent of height;
$\sigma_R(z)$ is the Rayleigh backscatter coefficient at height z

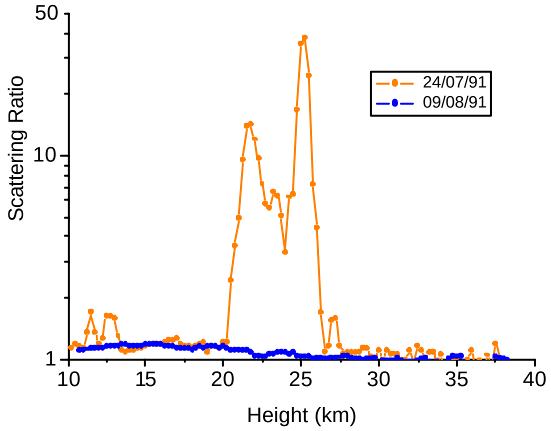

Fig. 2. Scattering ratio profile corrected for extinction

We then adjust the parameter Re, the ratio of the extinction to the backscattering coefficient, to obtain a good match between the post-Pinatubo profile and the "clear air" profile seen before the arrival of the Pinatubo aerosol at heights above and below the aerosol layer. The assumption of height independent Re is not necessarily altogether justified, but the S/N ratio of the data is not good enough for us to derive a height dependence. In Figure 2 we show the resulting profile for August 9. For this day a good fit was obtained for a value of Re equal to 60. On other days the values obtained were between 45 and 55. Optical depths of 0.24, 0.28, 0.16 and 0.14 were found for July 31, August 1, 5 and 9 respectively.

We can use Mie theory computations to estimate a particle size distribution consistent with the measured values of Re. Assuming a bimodal lognormal distribution of sulfuric acid particles with modal radii of

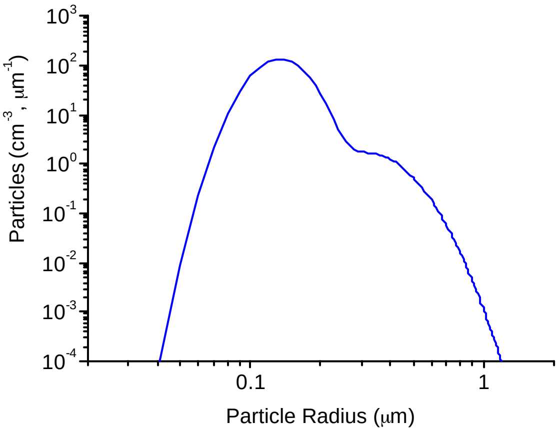

Fig. 3 Bimodal lognormal particle size distribution for August 9 data.

0.14 and 0.35 µm and distribution widths of 1.25 and 1.35 (Deshler et al., 1993) we get the distribution shown in Figure 3 for the August 9 data.

CONCLUSION

During conditions of very high volcanic aerosol burden it was possible to use lidar measurements to make a direct measurement of aerosol extinction. This was possible on 4 occasions immediately after the arrival of the Pinatubo aerosol cloud at our location in July/August 1991. A bi-modal lognormal particle size distribution for sulfuric acid particles consistent with the measured extinction/backscatter ratio for August 9, 1991, gave the distribution shown in Figure 3

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