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Mt. PINATUBO AEROSOL SIZE DISTRIBUTIONS DERIVED FROM 4-WAVELENGTHS LIDAR MEASUREMENTS IN THE ARCTIC WINTER 1991/92

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INTRODUCTION

The Mie scattering wavelength dependence of aerosol particles, measured by multispectral lidar, can be used to retrieve aerosol size distributions [1]. For stratospheric lidar measurements, the advent of flashlamp pumped Titanium:Sapphire Lasers has given access to the near infrared (690 nm -960 nm) where sensitive photocathode materials are still available and Rayleigh scattering is strong enough to calibrate the lidar signal with molecular atmosphere data. The eruptions of Mt. Pinatubo between June 12 and 16, 1991 increased the stratospheric aerosol load to the highest level ever measured with modern instruments. In polar regions and especially in the Arctic this aerosol is supposed to play an important role in chemical processes on its surface, converting chlorine reservoir species to their active forms [2]. Optical ozone measurement instruments like TOMS, Brewer spectrometers, SAOZ have to be corrected for the aerosol scattering contribution, which can be derived from the size distribution.

METHOD

Computations of the Mie backscatter coefficients for sulfric acid aerosol size distributions are shown in figure 1 for various wavelengths from UV to IR. The backscatter signal is increasing with the median particle radius and with shorter wavelengths up to 350 nm. The decrease for shorter wavelengths is caused by increase of the refractive index in the UV which corresponds to a smaller size parameter in the Mie computations. For narrow distributions (σ=1.105) an oscillating wavelength dependence of the backscatter coefficient can be observed which is caused by Mie resonances. Here Mie calculations for 2000

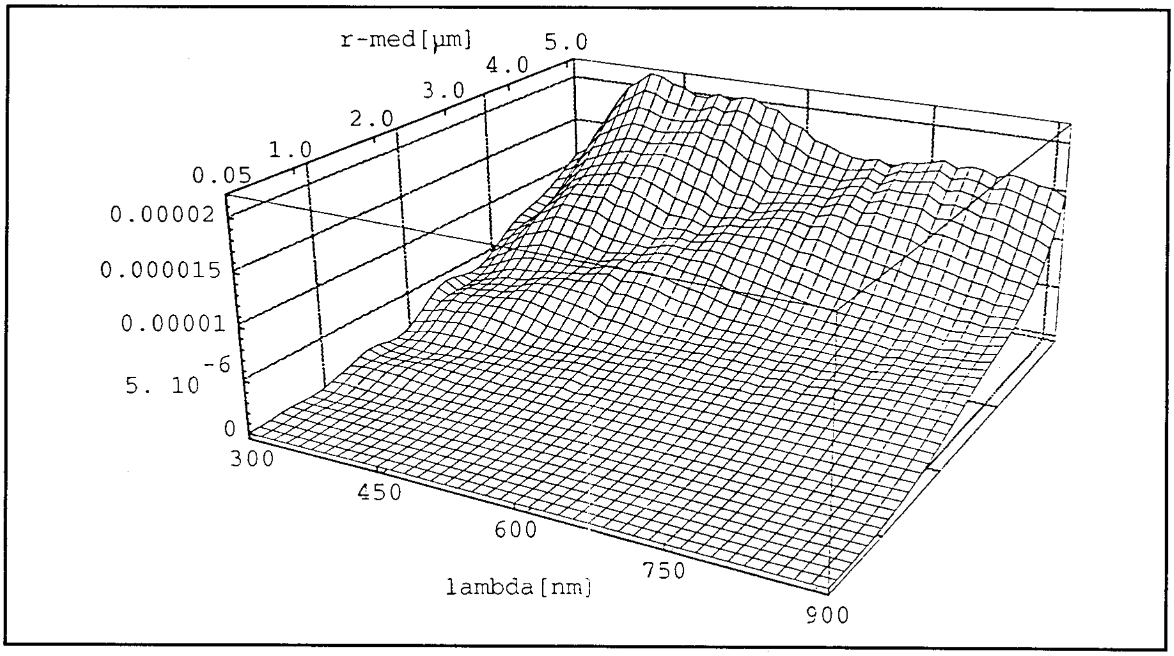

fig. 1: Wavelength dependence of Mie backscatter coefficients for sulfuric acid particle size distributions for different wavelengths. The width parameter is fixed to σ=1.105. 2000 size bins from 0.01 μm to 10 μm have been evaluated for each wavelength.

size bins from 0.01μm to 10 μm have been performed to compute the Mie backscatter cross section for each size distribution and each wavelength. Since these calculations are time demanding, even on fast computers, a fit procedure has been used to retrieve size distribution parameters from multiwavelength lidar data. Using lognormal size distributions

$$n(r)=\frac{N_0}{\sqrt{2\pi}r\ln(\sigma)} \quad \exp\left[-\frac{1}{2}\left(\frac{\ln(r/r_{med})}{\ln(\sigma)}\right)^2\right]$$

a minimum of

$$\chi^2=\sum_{j=1}^{4}\left(\frac{\beta_j-\beta[n(r)]_j}{\Delta\beta_j}\right)$$

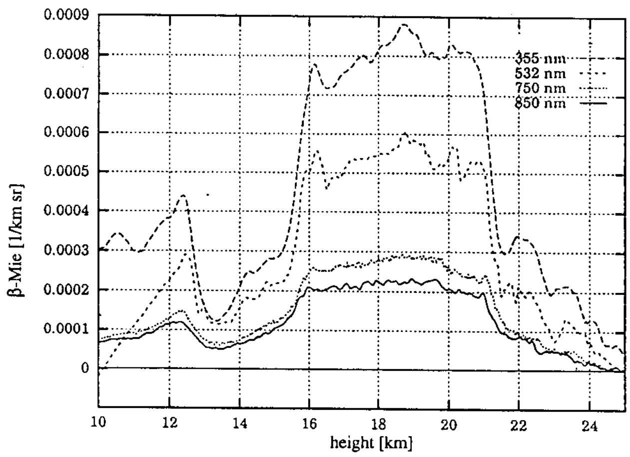

fig. 3: Profiles of 4 wavelengths Mie backscatter cross sections on Feb. 22, 1992.

was searched, where βj represent the backscatter coefficients measured at the wavelength λj and Δβj are the standard deviations of the measured quantities. A minimum of χ^2 occurs when the measured wavelength behaviour of β fits to β(n(r)) which describes the Mie scattering of a size distribution n(r).

RESULTS

During the European Arctic campaign, EASOE, lidar measurements have been performed in Sodankylä, Finland (67°N, 26°E). Using a flashlamp pumped Titanium:Sapphire laser at 750 nm and 850 nm together with a frequency doubled and tripled Nd:YAG Laser at 532 nm and 355 nm, lidar signals at 4 wavelengths were acquired consecutively. A typical measurement at 750 nm is shown in fig. 2 with the high aerosol load up to 22 km height.

Rayleigh and Mie scattering contributions were then separated by comparing the signal to the molecular density profile above 25 km, derived from balloon soundings, where only background aerosol is present. Profiles of the Mie scattering coefficients for the 4 wavelengths are shown in fig. 3. The profiles have been corrected for aerosol extinction by using the Klett method with constant extinction/backscatter ratios of 24 ,41, 53 and 57 at 355, 532, 750 and 850 nm. These values have been retrieved from the average aerosol size distribution which was computed from the extinction/backscatter ratio of all measurements [3].

Assuming unimodal lognormal size distributions of sulfuric acid particles with a refractive index according to local pressure, temperature and humidity, particle concentration, median radius and width parameter for every 1 km altitude have

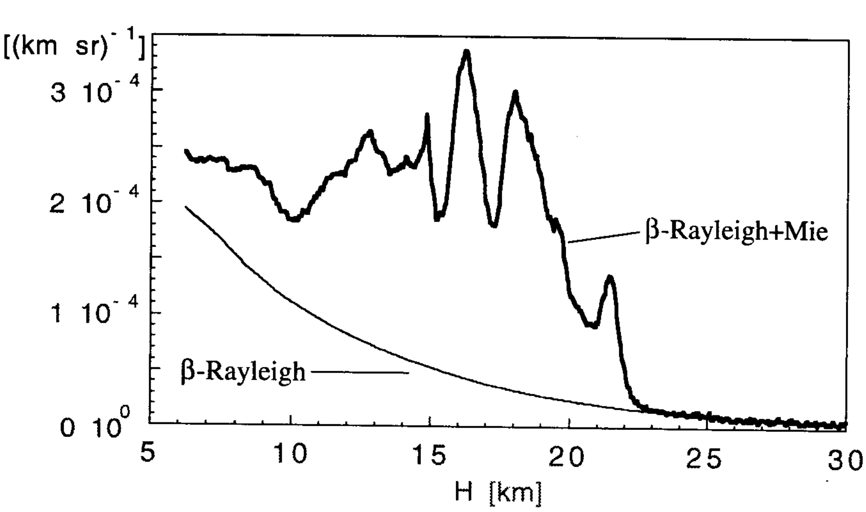

fig. 2: Typical lidar signal with Titanium Sapphire Laser at 750nm. Measurement at Sodankylä, Feb. 12, 1992.

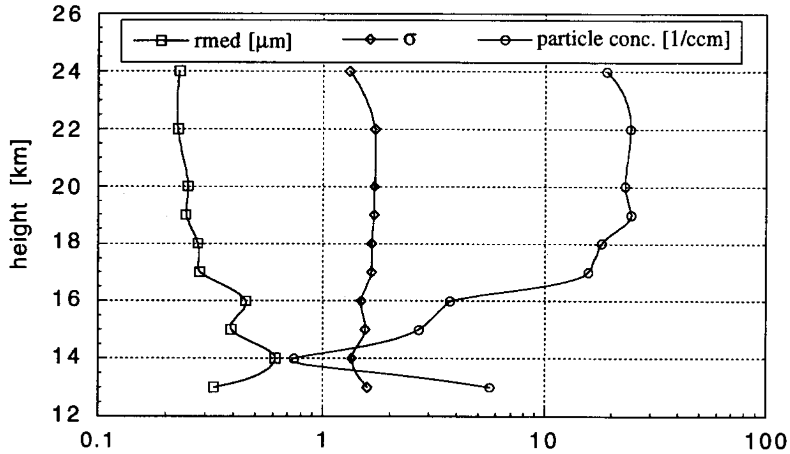

fig. 4: Size distribution parameters retrieved from the 4 wavelengths measurement shown above.

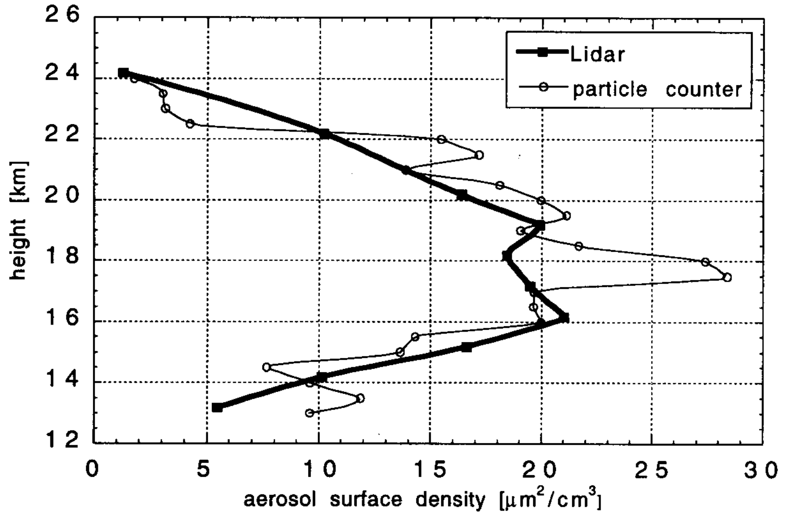

fig. 5: Aerosol surface density on Feb. 13, 1992, measured by lidar in Sodankylä and with an optical particle counter on a balloon launched at Kiruna on the same day [4].

been retrieved using the method described above (fig. 4). A discrimination of liquid sulfuric acid particles and solid polar stratospheric cloud particles has been performed, using depolarization measurements on the 4 wavelengths. With the exception of few days, where the temperature dropped below the existence temperature of nitric acid trihydrate, observed depolarization ratios were below 1% in the aerosol layer, indicating liquid and therefore spherical aerosol particles. Size distribution parameters for the volcanic aerosol were retrieved for several days and heights between 11 and 22 km with an average medium radius of 0.22 µm and an average width parameter of 1.7. A typical profile of the derived aerosol surface density is shown in fig. 5. These results are in good agreement with values derived from optical particle counter measurements from a ballon flight passing nearby Sodankylä on the same day [4].

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