Mode radius and asymmetry factor of Mt. Pinatubo volcanic aerosols from balloon-borne optical measurements over Hyderabad during October 1991

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Abstract. Using Sun-tracking photometers onboard balloon, the Pinatubo volcanic aerosol layer has been studied over Hyderabad (17.5°N) in October 1991, about 4 months after the eruption. From the aerosol extinction coefficients the mode radius and from the angular distribution of the scattered radiation intensity measurements the asymmetry factor \( g \) are determined. Mode radii are found to be in the range of 0.22 ± 0.05 μm within the aerosol layer while \( g \) values are found to be 0.83 ± 0.04, indicating the presence of larger particles. The mass determination reveals that the mass of the Pinatubo layer is about 0.053 gm⁻² which is 3.75 times higher than the earlier reported value for El Chichon layer, about 4 months after the eruptions.

Introduction

Nature gave an opportunity by the eruption of Mt. Pinatubo (15.14°N, 120.35°E) in the Philippines on June 15, 1991, producing the largest impact at the stratospheric altitudes [McCormick and Veiga, 1992; Bluth et al., 1992] to study the various chemical and physical processes involved in the formation of stratospheric aerosol layer and its decay. The layer produced was found confined over the tropics from the tropopause to about 25 km [DeFoor et al., 1992], in the first few months after the eruption. In order to study the effect of the eruption over a tropical site a balloon experiment was conducted from Hyderabad (17.5°N, 78.6°E), on October 26, 1991, 4 months after the eruption.

A Sun-scanning multichannel photometer system [Jayaraman et al., 1987] was employed onboard balloon to measure the direct as well as the angular distribution of the scattered radiation intensities. Details of the instrument and the results obtained before Mt. Pinatubo eruption are reported earlier [Jayaraman and Subbaraya, 1988]. The instrument essentially consists of the sensor assembly containing six filter photometers, a tracking mechanism for the orientation of the photometers towards the Sun and a motor assembly for scanning the sky along the solar almucantar, ± 90° with respect to the Sun for scattered sky radiation measurements. The scanning is achieved in 18 s corresponding to an altitude ascent of about 90 m by the balloon, which is the lower limit of the altitude resolution of the various quantities that are measured. The spectral bands of the photometers are centered around 280, 310, 500, 750, 860 and 950 nm with a typical bandwidth of about 10 nm or less. In addition to the Sun-scanning photometer system a continuous Sun-tracking photometer system was also employed in order to get the altitude profiles of the direct solar radiation intensities uninterruptedly. The wavelengths used in the Sun-tracking system are 310, 440, 500, 850, 950 and 1050 nm with similar bandwidths.

Data analysis

The data analysis mainly involves the estimation of the attenuation of the incoming solar radiation at each altitude and deriving the angular distribution of the scattered radiation intensity measurements. The air density profile constructed from the temperature and pressure data obtained from the meteorological balloon soundings on the flight days and the mean ozone density profile available for Hyderabad are further used to correct the extinction coefficient profiles for Rayleigh scattering and ozone absorption, and altitude profiles of the aerosol extinction coefficients are obtained for all the individual wavelengths [Ramachandran et al., 1994]. From the angular distribution of the scattered radiation intensity measurements, mean normalised intensity variations with scattering angles are obtained for each altitude. The scattering angles are computed from the solar zenith angle and the photometer orientation. The data are compared with the theoretical Mie scattering phase functions to estimate asymmetry factor \( g \) as discussed in the later section.

Determination of Mode radius

Yue and Deepak [1983] have proposed a method of retrieving aerosol mode radius from the aerosol extinction coefficients \( \beta \) at two wavelengths. Mode radius \( r_m \) is retrieved, assuming that the stratospheric aerosol size distribution can be best fitted using a lognormal distribution function and a Zero Order Logarithmic Distribution (ZOLD) applicable after a major volcanic eruption such as Mt. Pinatubo [Toon and Pollack, 1976]. The lower and upper radii limits are chosen such that the aerosol number density falls by 1.0×10⁻⁶ with respect to the maximum value in the size distribution. Mie computations are made to obtain \( \beta \), for the selected photometer wavelengths of 440 and 1050 nm taking the refractive indices as 1.432±1.0×10⁻⁴ and 1.423±1.5×10⁻⁴ for the two wavelengths respectively. The ratio of extinctions, \( R(=\beta_{440}/\beta_{1050}) \) is plotted as function of \( r_m \) in Figure 1 for different \( \sigma \) values. In the present work, \( r_m \) values are determined separately from curves corresponding to lognormal distribution (LND) of \( \sigma = 1.86 \) and ZOLD with \( \sigma = 1.8 \).