Estimation of Aerosols from Solar UV-B Measurements

B N SRIVASTAVA & M C SHARMA
Radio Science Division, National Physical Laboratory, New Delhi 110012

Received 14 March 1986

Using ultraviolet radiometer measurements of UV radiation by 280, 290 and 310 nm interference filters, vertical column density of aerosol particles in the atmosphere on monthly basis for the year 1984 has been estimated. The aerosol optical depth has been derived from the direct component of solar UV-B radiation received at ground. The day-to-day and season-to-season variation in aerosol content is quite large, being maximum during the summer months and minimum during October.

1 Introduction
Aerosols are solid or liquid particles suspended in air. The knowledge of their physical or chemical properties is important as they play a critical role in many processes which have direct or indirect impact on our environment relating to health and climate. The difficulty in understanding aerosols arises in part due to the fact that aerosols are end products of vast physical and chemical processes. Consequently, aerosol properties can exhibit a great deal of variations in both time and space. In atmosphere, both the Rayleigh scattering due to air molecules and the scattering due to particulates (aerosols) are important. Rayleigh scattering coefficient is virtually independent of time and space; its values are available in literature for a wide range of wavelengths in ultraviolet, visible and infrared. Aerosol scattering coefficient depends mainly on dimensions, chemical compositions and concentrations of aerosol particles and is highly variable in time and space. Using direct sampling technique, Junge showed that particles of haze, which are larger than Aitken nuclei, are in general composed of solid and soluble particles of smoke, dust and water droplets. Scattering of radiation by such particles can only be computed with the help of the rigorous theory of Mie. Bullrich has given an expression for calculating aerosols from scattering of these particles. In this paper, optical properties of aerosols have been used in the estimation of aerosol column density.

2 Procedure for Deriving Aerosols
At the National Physical Laboratory (NPL), New Delhi, the intensities of UV radiation at wavelengths 280, 290 and 310 nm are recorded regularly; the experimental set-up is described elsewhere. Observations are taken for direct and diffuse radiations. The intensity of solar UV radiation for different filters are derived at 30°, 40° and 50° solar zenith angles on the availability of measurements. From these measurements, optical depth due to aerosols is derived. The direct UV radiation received at ground is a function of various parameters including aerosol, and is expressed as

\[ I_\lambda = I_{0\lambda} \exp \left( T_R + Kx + T_A \right) \sec \psi \]... (1)

where

- \( I_\lambda \): Intensity of UV radiation of wavelength \( \lambda \)
- \( I_{0\lambda} \): Unattenuated intensity of UV radiation
- \( \lambda \): Wavelength of radiation
- \( T_R \): Rayleigh optical depth
- \( x \): Amount of ozone in atmosphere (Atm-cm)
- \( K \): Absorption coefficient of ozone
- \( T_A \): Optical depth due to aerosols
- \( \psi \): Zenith angle of the sun

The optical depth due to aerosols can be derived by using Eq.(1). The ozone values are taken from the India Meteorological Department (IMD). Optical depth of Rayleigh scattering is taken from Pendorf. The values of \( K \) are taken as 5.71 and 3.82, respectively, for interference filters of central wavelengths, viz. 290 and 310 nm derived from our measurements. The direct component of UV radiation at 50° solar zenith angle has been used in this calculation, as for this angle, measurements are available throughout the year at New Delhi (28.6°N, 77.1°E). At 50° solar zenith angle, we have derived the optical depth due to aerosols for each observation during the year 1984. There is appreciable variation in day-to-day optical depth. This is mainly due to surface aerosol and haze condition.

The optical depth \( T_A \) is expressed by

\[ T_A = \int_{r_1}^{r_2} \int_{\psi_1}^{\psi_2} \pi r^2 Q N \, dr \, d\psi \]
where

\[ r \quad \text{Radius of aerosol} \]
\[ Q \quad \text{Scattering efficiency} \]
\[ N \quad \text{Number density of aerosols} \]
\[ h \quad \text{Height} \]

The radius of the aerosols is taken to vary between 0.05 and 10 \( \mu \text{m} \). From this expression, \( \int N dh \) is derived, which is the column density above the ground. For each day the optical depth due to aerosols is derived which in turn is used to derive aerosol content \( (\int N dh) \) for the corresponding day. Monthly mean values of aerosol contents are plotted in Fig. 1 for the year 1984. The daily variation of aerosol content in a month is also shown with arrows, indicating the upper and the lower quartiles.

3 Results and Discussion

It is clear from Fig. 1 that there is a large day-to-day variation in aerosol content. Rocket measurements of aerosol from 4 to 25 km on 16 February 1980 at Trivandrum have been reported by Subbaraya and Jayaraman\(^6\). The aerosol content at Trivandrum after integrating their height profiles is \( \approx 2.2 \times 10^8 \text{ cm}^3 \) column which is of the same order as obtained by our calculations. Our results are also consistent with those reported by Junge\(^2\). We find that the aerosol content is maximum during the summer months and minimum in the month of October. This is possible because during the summer months the dust particles are lifted up from the ground and remain there for quite some time. During the rainy season, these particles come down to ground and just after this the atmosphere becomes clear, resulting in lower values of aerosol during the months of October and September. The maximum values of aerosols during the summer months have also been reported by Erving \textit{et al.}\(^7\). More accurate results are expected with our newly built integrating-type radiometer in which measurements are being done at 290, 300 and 310 nm filters at 5-min intervals.

Fig. 1 — Seasonal variation of total aerosol content over Delhi derived from solar UV-B radiation for the year 1984

Acknowledgement

This work is part of the IMAP programme undertaken at NPL, New Delhi. The authors are grateful to Dr A P Mitra for his encouragement and valuable suggestions. Daily observation of solar UV-B data were recorded by Messrs R S Tanwar and Shambhu Nath, and their help in scaling of these observations deserves the authors’ appreciation and thanks. Thanks are also due to Miss Anju Bali, JRF, for some useful discussions.

References