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SHORT CONTRIBUTION

Seasonal variation of global UV-B flux and its dependence on atmospheric ozone and particulate at a low latitude station

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ABSTRACT

Seasonal variation of the ground reaching global UV-B flux at a low latitude non-industrial location Mysore (12.6° N, 76.6° E) is examined in comparison with the seasonal variation of atmospheric ozone data from the Dobson spectrophotometer operated at Kodaikanal (10.2° N, 77.5° E). The observed dissimilar variation of the global UV-B flux with ozone for different solar zenith positions indicates the role of seasonally varying atmospheric aerosols and particulate in producing enhanced scattering of UV-B radiation in summer period. Monthly variation of atmospheric turbidity coefficient β also indicates the seasonal variation of the atmospheric aerosol and particulate concentrations which are larger for the summer months.

1. Introduction

Global UV-B flux (sum of direct and diffuse radiations) data at four wavelengths 280, 290, 300 and 310 nm are recorded at several locations in India as part of Indian Middle Atmosphere Program (IMAP). The stations have been selected considering distinct geographic features and possible influence of atmospheric aerosols on the ground reaching UV-B flux. Mysore (12.6° N, 76.6° E) has been selected as a continental station, largely free from any industrial pollution and large scale bio-mass burning. We have examined the seasonal variation of the ground reaching global UV-B flux at Mysore with a view to establish the effect of seasonally varying atmospheric aerosols and particulate on the scattering of UV-B radiation. Our results indicate that the scattering of UV-B radiation is more in summer than in winter season and this is largely due to the naturally occurring enhanced atmospheric aerosols and particulate in summer months.

Recent field measurements of ground reaching UV-B, biologically effective ultraviolet radiation by Scotto et al. (1988a) have indicated the role of atmospheric pollutants in enhanced scattering of UV-B radiation (see also Grant, 1988 and Scotto et al., 1988b). Brühl and Crutzen (1989) have modeled the ground reaching UV-B flux in the presence of enhanced ozone at tropospheric heights. Increased tropospheric ozone coupled with the scattering of UV-B (due to air molecules and dust) is found to be an effective filter for the ground reaching UV-B flux. The effects of clouds and aerosols and also the ground reflection on the UV-B radiation are discussed by Madronich (1987), Frederick and Lubin (1988), Stamnes et al. (1988) and Frederick and Snell (1990).

The UV-B data analyzed in this paper refer to clear sky conditions and hence the effect of clouds is not considered in our study. Since the data on ozone height profiles or the pollution enhancement are not available for the Mysore station, the measured UV-B flux is not examined in terms of

the enhanced absorption of UV-B by ozone in the troposphere, but for total ozone observed at a nearby station.

2. Experiment

The experimental setup consists of a flux integrating sphere, filter wheel and a photomultiplier tube (along with the associated power supply) and gives an output (mV) proportional to the incident UV-B flux at each of the four wavelengths. Global radiation within a cone of about 70° enters the window of the integrating sphere.

The instrument is to be calibrated periodically for converting the photometer output (mV) into absolute flux ($W\,m^{-2}\,nm^{-1}$). The calibration was done in June, 1987 at the National Physical Laboratory, New Delhi using the UV-Spectroradiometer Model 742 of Optronics Laboratories, USA. The results of our study for the period January to December, 1988 are presented here. Monsoon period lasting from May/June to September/October is not conducive for UV-B observations and the data for this period are not available.

The central wavelengths of the filters, as per the manufacturer's specifications are 280, 290, 300 and 310 nm. These were, however, found to have the maximum transmission at the wavelengths 283, 295, 303 and 311 nm. Later it was found that the filter at 311 nm was damaged/deteriorated and hence the UV-B data for this filter are not presented in this paper. The half power bandwidth of the filters is 10 nm. A shift in the central wavelength at 280 or 290 nm results in an enormous change in the ground reaching UV-B flux as can be seen in model results (Barton and Paltridge, 1979). Because of the steep increase of UV-B solar radiation with wavelength, the measured absolute flux at lower wavelengths will be over estimated due to the finite bandwidth of the filters. However, this will not affect the results of this paper since the trend in the variation of UV-B flux with ozone is considered and not the absolute flux values in relation to ozone (or aerosols).

3. Results and discussion

Fig. 1(a) shows the (raw) daily values of global UV-B flux (mV) with filter for the wavelength $\lambda = 283$ nm and for the solar zenith angles $\chi = 40°$, 50° and 60° for the prenoon (AM) period. The points in Fig. 1(a) (and also in Fig. 1b) refer to the experimental data and these have been connected for clarity. A marked diurnal asymmetry in the UV-B data for pre-noon and after-noon (PM) period is noticed but the PM data are not shown here. Considerable fluctuation in the observed data is seen although the data selected refer to clear sky conditions. Such fluctuations are also noticed in the UV-B flux data reported by Lubin et al. (1989) and Stamnes et al. (1990). The day-to-day fluctuations seen in our data could be due to changes in the vertical distribution of ozone as well as total ozone and also due to the variable nature of scattering of UV-B by atmospheric aerosol. Lubin et al. (1989) ascribe the rapid day-to-day variations in their measured UV-B data to changes both in the cloudiness and ozone abundance.

Vertical ozone distribution is not measured at Mysore. We have used the atmospheric ozone data (DU) from the Dobson spectrophotometer operated at Kodaikanal (10.2° N, 77.5° E) by India Meteorology Department (IMD). Kodaikanal meteorology station is located in a hilly region with negligible industrial pollution similar to the conditions at Mysore. Total ozone data at Kodaikanal are recorded six times a day and we have compared the UV-B flux data at Mysore with the ozone data at Kodaikanal for about the same time (IST) of the day. Because of this, a limited number of UV-B data (Mysore) and ozone data (Kodaikanal) are available for comparison although both UV-B and ozone data are recorded throughout the day at Mysore and Kodaikanal respectively.

The diurnal mean total ozone data for the year 1988 are shown in Fig. 1(b). We note the highly variable nature of the day-to-day ozone concentration and hence the consequent day-to-day variations in the recorded ground reaching UV-B data. The long term average annual ozone variation shown as broken line in Fig. 1(b) is based on the statistical analysis of sixteen years of data (Kundu, 1982). The generally accepted picture of the anti-correlation between the ground reaching UV-B flux and total ozone is evident in Fig. 1.

However, we note a steeper decrease (January–May) or increase (October–December) in UV-B flux at the smaller zenith angle 40°. This is because of the direct and diffuse components in the global

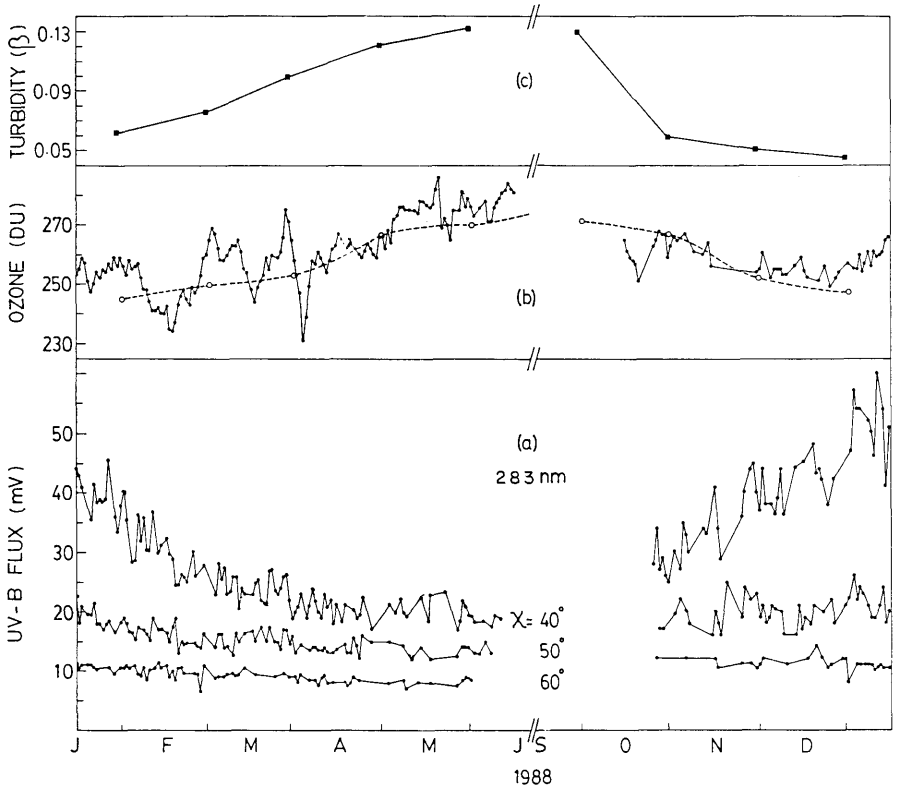

Fig. 1. (a) Daily values of UV-B flux data at the wavelength $\lambda = 283$ nm for solar zenith angles $\chi = 40°$, 50° and 60°. (b) Daily mean values of atmospheric ozone. Points refer to experimental data and these are connected for clarity. Broken line shows the annual variation of ozone (see text). (c) Annual variation of turbidity coefficient β.

UV-B flux being not the same throughout the day. These components are nearly equal (50% each) for the solar zenith angle $\chi = 0°$ and the diffuse component increases (while the direct component decreases) for large zenith angles (e.g., Barton and Paltridge, 1979). It is noticed that the degree of variation of the measured global UV-B flux with total ozone is less when the contribution of diffuse component is more. This is also verified using the flux data of direct and diffuse radiations from the model results of Dave and Halpern (1976).

Fig. 2 shows the plots of UV-B flux (for $\lambda = 283$ nm, 295 nm and 303 nm) versus the corresponding atmospheric ozone at solar zenith positions near about 34°, 58.5° and 68° for the pre-noon data. The after-noon data are rather sparse and these are not shown here. It is seen that the trend of UV-B flux variation with ozone is different for summer (February–May) and winter (November–January) months at $\chi = 34°$. But at large zenith angles, 58.5° and 68°, the trend is nearly the same for both the summer and winter seasons. Least square lines are fitted for the summer and winter data at $\chi = 58.5°$ and 68° and only for the summer data (open circles) at $\chi = 34°$. The winter data (filled circles) for $\chi = 34°$ do not show the linear trend.

The diffuse component is generally more at large zenith angles since the scattering occurs higher in the atmosphere. Similar trends seen in the variation of flux at 58.5° and 68° indicate the dominance of diffuse component in both summer and winter data at large zenith angles. It is also evident that the diffuse component is dominant in summer data even at $\chi = 34°$. At the small zenith angle 34°, the winter data do not show the linear

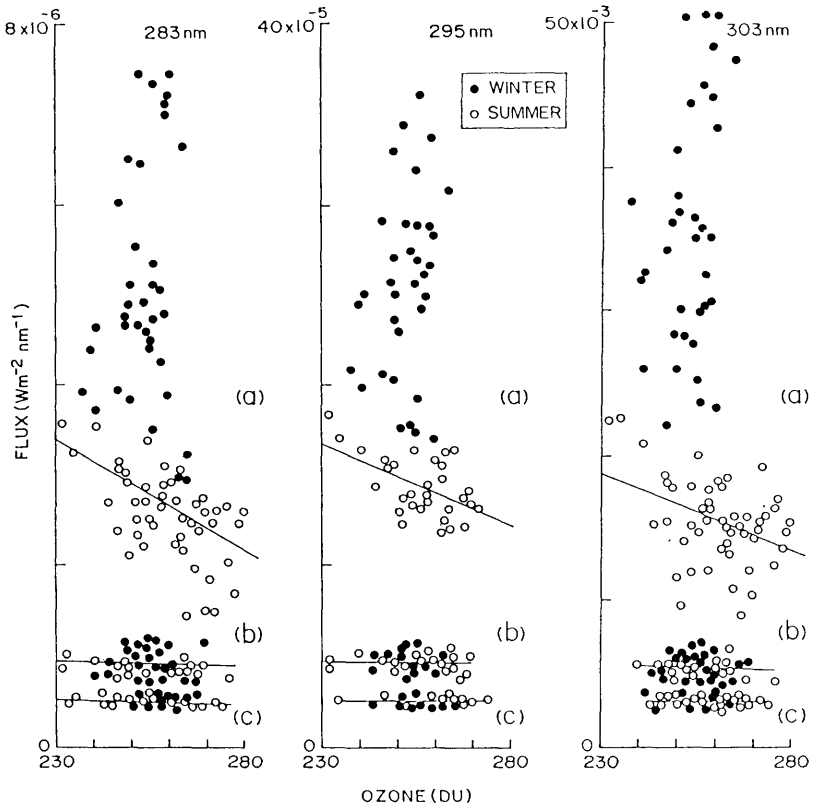

Fig. 2. Variation of UV-B flux (at filter wavelengths $\lambda = 283$, 295 and 303 nm) with ozone at solar zenith angles (a) $\chi = 34°$, (b) $\chi = 58.5°$ and (c) $\chi = 68°$.

trend of variation with total ozone although ozone varies from about 240 DU to 260 DU during this period. The relatively large UV-B data for winter at $\chi = 34°$ and the absence of a linear variation with ozone (as with the summer data) indicate the dominance of direct radiation. Also, the large variations are due to aerosols as they occur at all wavelengths. The influence of the variations in aerosol scattering and changes in tropospheric ozone in our measured UV-B data cannot be ascertained in the absence of ozone height profiles. The striking difference in the trend of UV-B flux variation at $\chi = 34°$ for winter (post-monsoon) and summer (pre-monsoon) months is illustrative of the seasonal variation of atmospheric aerosols and particulate which are responsible for less scattering of the UV-B radiation in winter and therefore the observed variation of the UV-B data.

Atmospheric turbidity is a measure of the total vertically integrated particulate in the atmosphere, and the Angstrom's formula for the aerosol extinction coefficient τ_a is given by $\tau_a = \beta\lambda^{-\alpha}$, where β is the turbidity coefficient (indicative of aerosol particle concentration) and α is indicative of the particle size. From the Volż sun-photometer measurements, Mani et al. (1969) have observed increased turbidity during summer at Indian stations and attributed this to the increase in precipitable water content. Pueschel et al. (1972) have reported that in general, the turbidity increases during summer in northern hemisphere and attributed this to the combined effects of increase in water vapor content, increase in tropospheric mixing and to photochemical processes.

We have calculated the turbidity coefficient β by

the nomogram method of Rangarajan and Mani (1984), using the direct and diffuse solar radiation data for Mandya (12.5° N, 76.8° E) since the radiation data are not tabulated for Mysore. These values also shown in Fig. 1 refer to clear sky, noon conditions. The turbidity values show increase and decrease in the atmospheric aerosol/particulate concentrations in summer and winter respectively. Consequently the UV-B radiation suffers more scattering in summer than in winter.

For the weather conditions at Mysore, the atmospheric aerosol and dust concentrations would be less in the post-monsoon (winter) period than in the pre-monsoon (summer) period. From this point of view, the observed seasonal variations in UV-B scattering ($\chi = 34°$) at Mysore is due to naturally occurring seasonal variations in the concentrations of atmospheric aerosols and dust. At small solar zenith angles absorption by tropospheric ozone enhances the extinction by tropospheric aerosol significantly which might have occurred during the measurements. Since no vertical distributions of ozone are available, this study cannot be compared with the theoretical study by Brühl and Crutzen (1989). It just shows that changes in tropospheric turbidity influence penetrating UV more than changes in total ozone in the observed variation range.

4. Concluding remarks

Biologically effective solar UV radiation undergoing increased scattering in the presence of enhanced atmospheric pollutants has been reported from actual field measurements. Similar results are obtained based on model calculations combined with experimental observations. An examination of the seasonal variation of the ground reaching global UV-B flux at a low latitude non-industrial location supports these conclusions on the role of atmospheric aerosols and particulate in enhanced scattering of the solar UV-B radiation in summer months.

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