INTERRELATIONSHIP BETWEEN SOLAR ULTRAVIOLET RADIATION AND TOTAL OZONE CONTENT: OBSERVATIONS IN GREECE

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Measurements of the solar ultraviolet radiation have been made in Argolida (location not influenced by air pollution), South–East Greece (37.5°N, 24°E), since July of 1993. The data presented here show the daily and monthly variability within the ultraviolet–B wave band and its relation to the total ozone amount during the summer – fall period, mainly characterized by the lowest total ozone values ever observed in Southern Europe since 1978.

1. INTRODUCTION

A specific feature of the ultraviolet solar radiation transfer in the atmosphere is the dominating impact of very strongly wavelength–dependent ozone absorption and molecular scattering. Of course, an important factor is also cloudiness. An overcast cloud cover of the sky decreases the biologically active ultraviolet radiation by about 70% (see Ref. 1). This attenuation is approximately independent of wavelength over the UV–B region.[2]

Solar ultraviolet–B radiation (UV–B, 280–320 nm) is predominantly absorbed by ozone in the stratosphere, with a strong wavelength dependence and absorption decreasing with increasing wavelength. The strong wavelength dependence of the ozone absorption results in irradiance changes at the surface of three orders of magnitude for wavelengths less than 300 nm (see Ref. 3). Solar UV–B is also strongly affected by Rayleigh scattering (molecular scattering).

It is now well known that the amount of ozone in the atmosphere is subject to both natural and anthropogenic impacts.[4] There are two important man's influences: the emissions of chlorofluorocarbons (CFC's) that reach the stratosphere and the pollution of the troposphere. The CFC's are the stimulators of catalytic chain reactions that destroy stratospheric ozone.[4,5] The tropospheric pollutants, such as NO_x and hydrocarbons from industry and transport systems, provide increasing sources of atomic oxygen, enhancing ozone levels in the troposphere. It should be noted here that the tropospheric ozone absorbs scattered radiation more efficiently than direct solar radiation.[6,7]

The anthropogenically induced ozone depletion has resulted in public concern about the possible biological consequences of increasing ultraviolet radiation at the ground level.[8] Sensitivity of eyes to ultraviolet radiation has been documented in both animal and human studies. The ocular toxicity of ultraviolet radiation has been demonstrated in acute photokeratitis and is suspected of contributing to cataractogenesis and senile muscular degeneration.[9] UV–B radiation is known to be carcinogenic considering that sunlight exposure is the principal factor in the aetiology of squamous cell skin cancer.[10] Other UV–induced effects are on plants, marine life, and whole ecosystems, both terrestrial and aquatic.[11]

In order to understand more of the effects of changing UV–B on biological systems, measurements of solar UV–B radiation are required. Presented here are data showing the natural daily and monthly variations in the UV–B irradiance at a location not influenced by air pollution and its relation to the total ozone amount, for the year 1993 characterized by the lowest total ozone values ever observed in Southern Europe.

2. INSTRUMENTATION

2.1. UV–B instrumentation

The solar UV–B irradiance was measured with the commercially available Model UVB–1 pyranometer (Yankee Environmental Systems, U.S.A.). The instrument has a sensitivity of 2.5 V/W/m^2 and a cosine response better than ±5% for 0°–60° solar zenith angles. The UVB–1 pyranometer utilizes a fluorescent phosphor to convert UV–B light to visible light, which is accurately measured by a solid–state photodiode. Solar radiation, both direct and scattered, is transmitted through the UV transmitting weather dome. Visible light, except for a small fraction of the red light, is absorbed by the first filter, a UV–transmitting black glass. Light transmitted through this filter strikes the UV–B sensitive phosphor. This materials absorbs UV–B radiation and re–emits it as visible light predominantly in the green wavelengths. The second, green glass filter, passes the fluorescent light from the phosphor while blocking any of the red light transmitted by the black glass.

The intensity of the fluorescent light is measured by a solid–state (GaAsP) photodiode. A thermally stable transimpedance amplifier drives a line amplifier to provide a low–impedance 0–5 VDC output signal. The glass filters, phosphor, and photodiode are all held at +45°C to ensure that the output signal is not sensitive to changes in ambient temperature. The sensor is housed in a rugged, cast aluminium for permanent outdoor installation. The unit is purged with dry air before sealing and is provided with a visible humidity indicator plug. The unit is fitted with an optical quality UV–transmitting Schott glass weather dome.

The spectral response of the instrument is determined primarily by the absorption spectrum of the phosphor, which depends on the thickness and uniformity of the phosphor layer. Typical measured spectral responses of the instrument are shown in Fig. 1. The relative spectral response of the instrument is similar to the erythemal action spectrum and is well suited to measuring erythemally effective solar irradiance. The convolution of the solar irradiance spectrum (zenith angle of 30°) with erythemal action spectrum and the relative response of the instrument is shown in Fig. 2. The overlap

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between the erythemally effective solar irradiance and the effective spectrum measured by the instrument does not vary appreciably with zenith angle up to 60° and hence the output signal of the instrument can be used to determine the erythemally effective radiant exposure.

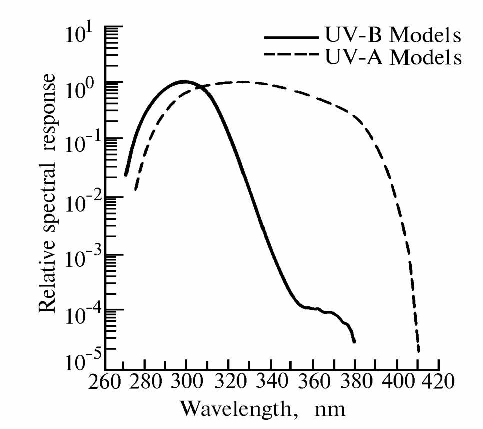

FIG. 1. Relative spectral response of the Model UVB–1 pyranometer.

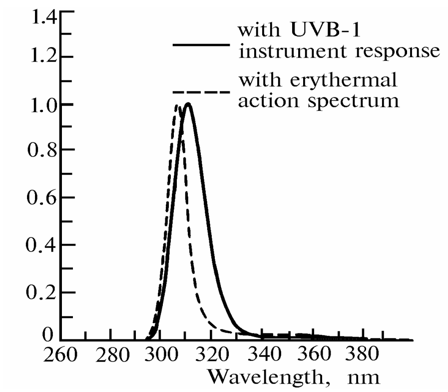

FIG. 2. Convolution of the solar irradiance spectrum with erythemal action spectrum and the relative response of the Model UVB–1 pyranometer.

2.2. Total ozone instrumentation

The total ozone measurements presented here were made with the Dobson spectrophotometer (No. 118). The Dobson spectrophotometer[12] has been the standard instrument for atmospheric total ozone measurements since its development by G.M. Dobson around 1927. This instrument uses two monochromators, with one monochromator being used to disperse the radiation and the second one being used to reject interfering scattered radiation. By using direct sunlight, the total ozone observations are usually made on AD double–pair wavelengths, where A pair is at 305.5 and 325.4 nm, while the *D* pair is at 317.6 and 339.8 nm (see Ref. 13).

3. RESULTS AND DISCUSSION

The UV–B data presented here are the measurements made with the Model UVB–1 pyranometer and no correction has been made to the data. For instance, Fig. 3 illustrates the broadband solar ultraviolet radiation and its UV–B component for a cloudless day (24.9.1993). The time lag of approximately half an hour between the two curves is artificial and is due to the recording technique of the data recorder. It should be mentioned that amplitudes of the two curves as they are shown in Fig. 3 do not reveal their proportionality.

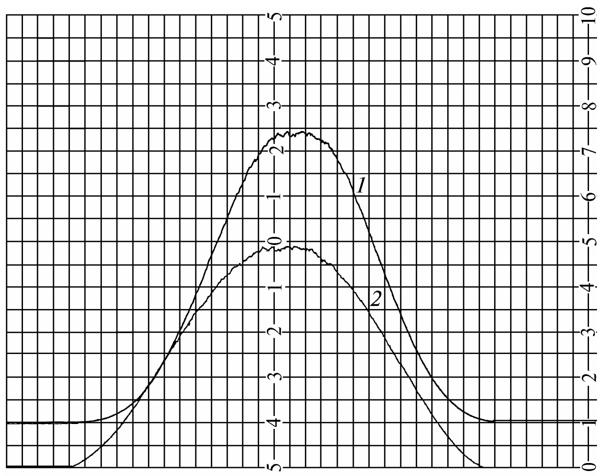

FIG. 3. Broadband solar ultraviolet radiation (1) and its UV–B component (2) for a cloudless day 24.09.1993 measured in Argolida, Greece.

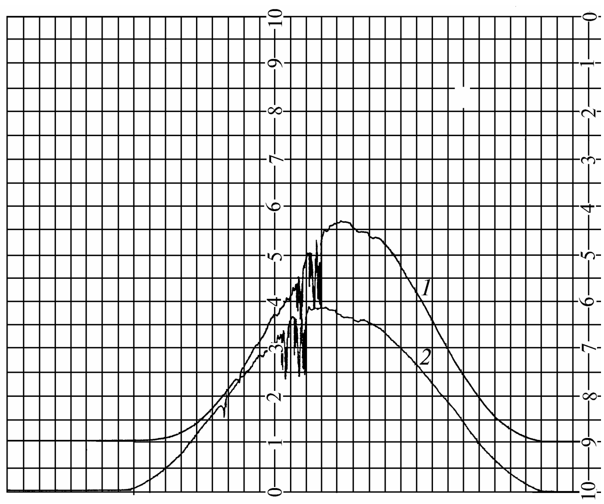

FIG. 4. As in Fig. 3, but for a partly cloudy day during 10:00–11:00, LT.

Figure 4 presents both the broadband solar ultraviolet radiation and its UV–B component as Fig. 3, but for a cloudy day during 10:00–11:00 LT period. Shown in this figure is the decrease of the solar UV–B component caused by a cloud passage through the line of sight between the sun and the UV sensor. It should be stressed here that the decrease in UV–B due to the cloud presence depends on cloud properties. However, as is seen from Fig. 4, the ratio between UV–B and broadband SUVR does not practically depend on cloud properties (see also Fig. 5).

Figure 5 data (a case of overcast cloudiness) confirm the conclusion of Josefsson[1] that under overcast cloudiness the attenuation of the UV–B reaches about 70%. It is worth noting here again that the UV–B attenuation due to the cloud presence (shown in Figs. 4 and 5) is approximately independent of wavelength within UV–B spectral region.[2]

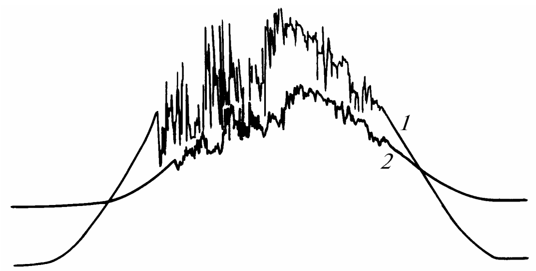

FIG. 5. As in Fig. 3, but for overcast cloudiness.

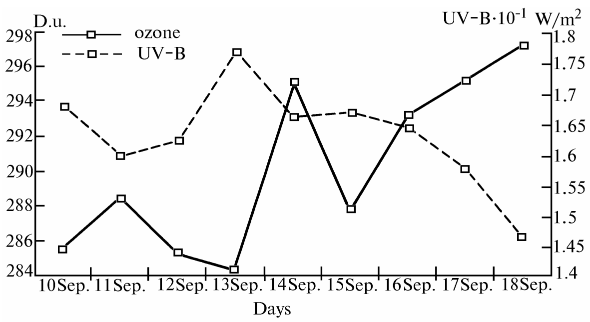

FIG. 6. Total ozone amount in Dobson units (D.u.) and UV–B radiation (10^{-1} W/m^2) reaching the ground in Argolida, Greece.

A period with continuously clear sky days was observed between 10.09 and 18.09.1993. During that period the total ozone amount was measured with the Dobson spectrophotometer No. 118. The total ozone amount during this period was characterized by the lowest values ever measured since 1978. Both the total ozone amount and the solar UV–B radiation are plotted in Fig. 6 in order to characterize the relationship between them. The variation of the total ozone amount during the period indicates an increasing trend while the UV–B radiation decreases. This behavior is expected because the higher total zone the higher attenuation in solar UV–B radiation. As is also seen from Fig. 6, the same rule holds for the inter–daily variations of total ozone and solar UV–B radiation.

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