

A 10-year climatology of the air pollution effect on erythematous UV-B doses reaching ground level at Athens, Greece

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Abstract. Ten years of observations in a central location in Athens of solar erythematous ultraviolet irradiance employing a Yankee Environmental Systems Pyranometer are analyzed to provide a climatological description of the erythematous UV exposure levels and their variability in this urban Mediterranean environment. The contribution of ozone column and cloud cover to the observed fluctuations of the erythematous UV are estimated. The comparison of clear sky total solar radiation and UV-B erythematous dose during ozone pollution episodes with the corresponding values under unpolluted conditions is investigated. It is shown that air pollution has a distinct and statistically significant reducing effect on UV-B erythematous dose reaching ground level. A clear statistical regression between UV-B reduction and surface ozone amounts can provide estimates on that effect. Model results do confirm the findings of these long term observations which also compare well with earlier findings.

Introduction

The solar UV-B radiation (280-320nm) which includes about 1.5% of the incident on top of the atmosphere total solar radiation, undergoes a great depletion in atmosphere by ozone absorption and by aerosols and clouds molecular scatter and absorption. Although the decline of stratospheric ozone in the past two decades is well established (Zerefos, 2002) the observation of an expected analogous trend in the UV-B is masked by the variability of the various factors that affect the UV radiation besides the stratospheric ozone (e.g. Estupinan et. al. 1996). However, Zerefos (2002) showed, for the period 1991–2001, a remarkable anticorrelation between total ozone and spectral UV irradiance in the 305 nm wavelength at Thessaloniki under low cloudiness. In this study we summarize the seasonal and daily variability of the erythematous UV exposure in an urban eastern Mediterranean setting and estimate the relative contributions of total ozone, cloud cover and other parameters in the determination of the UV climate in central Athens.

Results and Discussion

A Yankee (YES) pyranometer, UVB-1 model, is installed on the rooftop of the Academy of Athens Research Centre in the center of Athens city, reporting erythematous UV irradiance. The daily erythematous effective radiation (EER dose) for the period of observations (1993-2003) is shown in Fig.1. The dominant feature is the large annual variation following the change in solar zenith angle, similarly to the variation of the total solar radiation (Fig. 2), though, the relative variation of EER is three times larger. The EER

values vary from as low as close to zero in some winter days to 5 KJm⁻² in some summer days.

The upper panel in Fig. 2 shows the total radiation received at the top of the atmosphere (upper curve) and the average (1993-2002) daily total solar radiation received at the surface at the National Observatory of Athens. The difference between the best fit curve of the total solar radiation at the surface and the curve for radiation received at the top of the atmosphere represents the depletion of the solar beam by molecular absorption and backscatter which varies from 25% in summer to 35% in winter. Clouds produce an additional depletion of more than 60% particularly during winter. The time series of the average (1993-2002) daily total ozone values and polynomial best fit is shown in Fig.2 (middle panel). The daily observations of the ozone column are made at the University of Athens Laboratory of Meteorology, which kindly provided the data. The day today variability of the ozone values is very large particularly in winter and spring as it is obvious even in the average values. In the lower panel of Fig. 2 the daily EER dose values for the whole period (1993-2003) are shown. The envelope of the daily EER dose observations is calculated using the radiative transfer model developed by Madronich (1993), applying the monthly average ozone values. Remarkable is the larger scatter of the observations in spring than in fall which should be attributed to both the ozone variability and the meteorological conditions, as in the region of Athens spring is more variable than fall. The dependence of EER irradiance on the total ozone is shown in the scatter diagram of Fig. 3 where monthly means of erythematous irradiance observations during sunshine hours at SZA 45° are plotted against the corresponding monthly total ozone means. Bold line represents model calculations of EER irradiance assuming aerosols optical depth 0.2. nm. A case study of the erythematous irradiance of a pollution episode clear sky day (June 28,1999) is shown in Fig. 4 (asterisks) and a normal clear sky summer day (points, June 24, 1999) with the same total ozone amount (318 DU). The solid line represents the model calculations (optical depth 0.2). The erythematous dose of the polluted day is 30% lower than the calculated by the model and 20% lower than a normal day in agreement with previous findings (Mantis et. al. 2000, Koronakis et al. 2002). Fig. 5 displays the erythematous dose differences of 23 cases of pollution episode days in Athens from the corresponding model calculations versus the daily mean surface ozone.

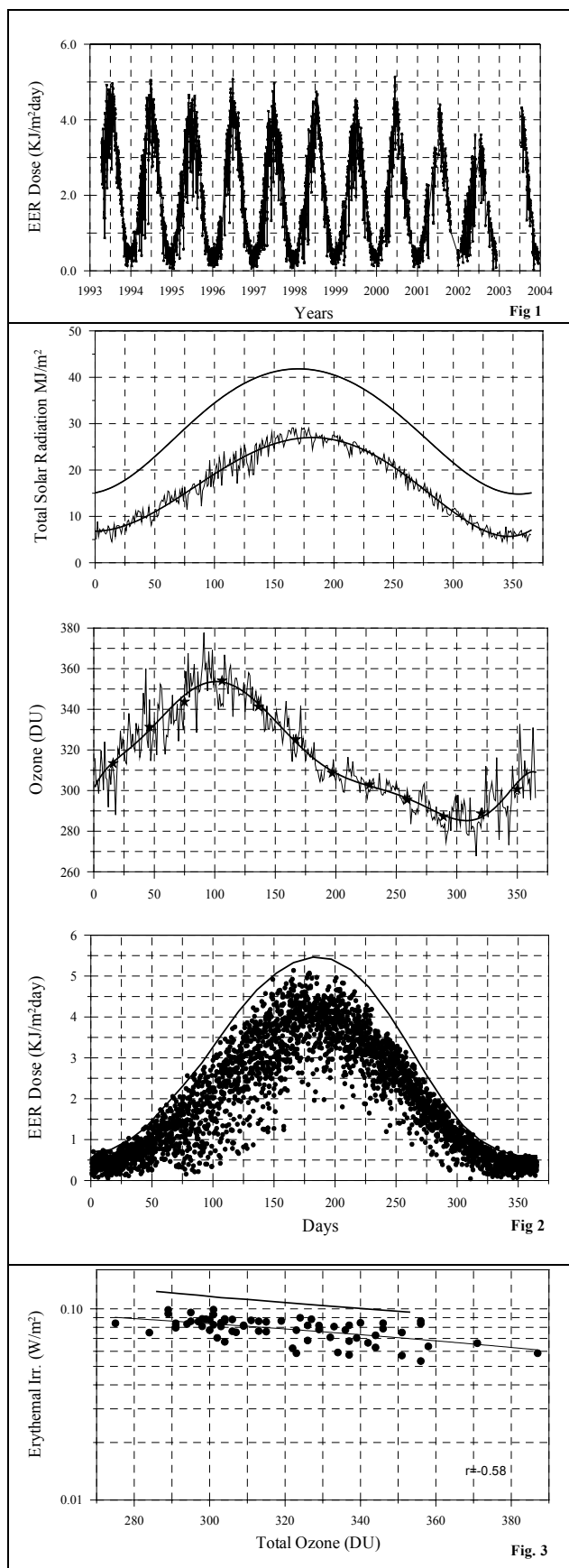


Fig. 1. Daily EER dose for Athens (1993- 2003).

Fig. 2. Upper panel: Total solar radiation at the top of the atmosphere (upper curve) and the average (1993-2002) daily values at the surface. Middle panel: Average (1993-2002) daily

total ozone values. Bold line polynomial best fit. Asterisks, monthly means. Lower panel: EER dose daily values (1993-2003). Solid line, model calculations.

Fig. 3. Monthly means of EER irradiance at SZA 45° versus total ozone. Bold line, model calculations.

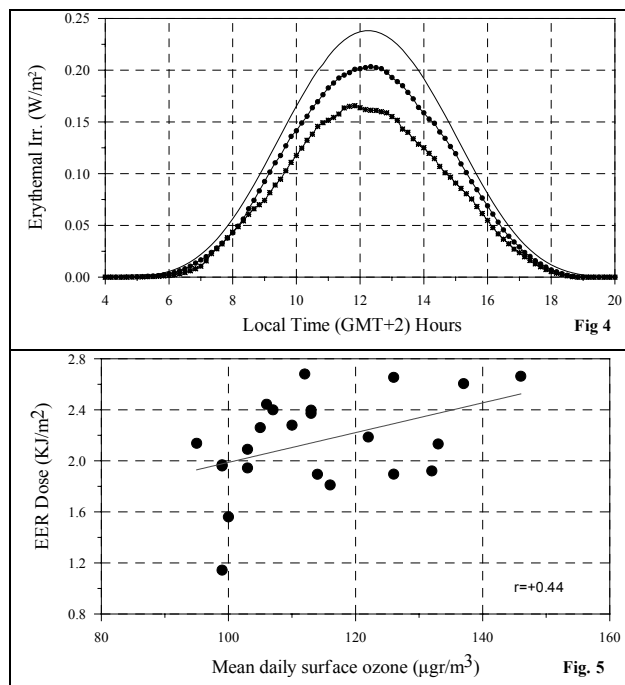


Fig. 4. Erythemal irradiance on a pollution episode day (asterisks) and on a normal summer day with similar total ozone (points). Solid line, model calculations.

Fig. 5. Deviations of the observed erythemal dose from the model calculation versus the daily mean surface ozone on pollution episode days.

The above analysis demonstrates the difficulty to detect an attributed to total ozone change trend in the EER in an urban polluted site, during the colder months due to the large variability in total ozone and in meteorological conditions while during the warmer months due to the large photochemical and aerosols pollution.

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