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ON THE DAILY MAXIMUM UV-B DOSES DURING THE SIGNIFICANT OZONE DEFICIENCIES IN THE TRANSITION SEASONS OF 1992/93

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ABSTRACT

The daily maximum UV-B dose rates during the significant ozone anomalies in October 1992 and March 1993 are calculated relative to the normal conditions of the period from 1979 to 1990. Gridded Total Ozone Mapping Spectrometer data have been used to determine the days with ozone deficiencies below the 2σ confidence level. For these days maps of maximum daily UV-B dose rates during these extreme ozone conditions show that UV-B dose rates increased from 10% to 50% at high latitudes. These changes compare well with observations at the Laboratory of Atmospheric Physics, of the Aristotle University of Thessaloniki, Greece and they provide an independent quality assurance and control of the accuracy of coarser model calculations under clear sky conditions. Our analysis shows that the largest increases in the UV-B dose rates during the extreme ozone deficiencies studied are confined to 10°N-40°N in March 1993 and to 10°S to 70°S in October 1992.

INTRODUCTION

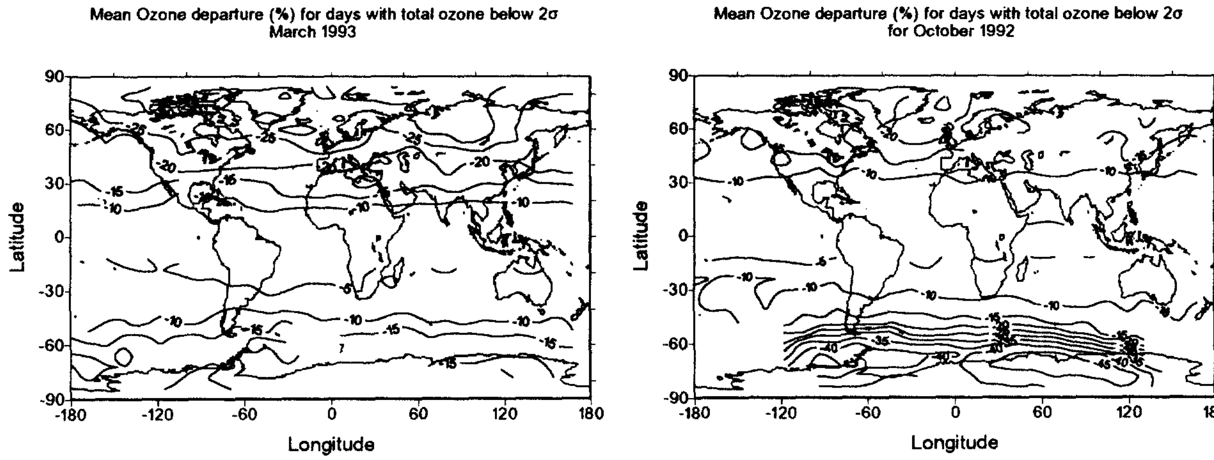
A decrease in total-column ozone causes an increase in penetration of the solar UV-B radiation to the Earth's surface. In the Northern Hemisphere in 1992 and 1993 elevated levels of the solar UV reaching the earth's surface were observed at mid-to-high latitudes (Zerefos et al., 1995a, Kerr et al., 1993), which corresponded to the very low ozone values during the winter-spring seasons of 1991/92 and 1992/93, as reported from both satellite and ground-based observations (Bojkov et al., 1993, Gleason et al., 1993, World Meteorological Organization, 1993). High levels of UV, due to the low ozone values, are well predicted by the radiative transfer theory under clear-sky conditions in various studies (e.g. Madronich et al. 1995, Tsay and Stamnes 1992). Since there is not a dense global network currently operating for monitoring the solar UV-B radiation reaching the earth's surface, there is no information on a global or hemispheric scale on the change in the solar UV-B during the above periods of abnormally low ozone. In this study an attempt is made to estimate the mean seasonal change relative to the pre-1990 levels of the UV-B levels reaching the ground on a global scale at local noon during days with significantly low ozone values, assuming clear sky conditions and background conditions for the stratospheric aerosols. The presence of clouds and aerosols can alter significantly these estimations (e.g. Forster, 1995). These estimations were verified with solar UV-B radiation measurements performed at Thessaloniki, Greece (40°N).

DATA

The gridded Nimbus 7 Total Ozone Mapping Spectrometer (TOMS) version 6 data (McPeters and Komhyr, 1991) , were used for the calculation of the daily northern hemisphere "normal" total ozone field, calculated for the 1979-1990 period, and for the determination of the significantly low ozone for the period 1991-1993. The days with total ozone at each grid below the 2σ level are calculated for the transitional months of March 1993 and October 1992, which contain the largest anomalies in the Nimbus 7 TOMS records. For the verification of the model results, broadband solar erythema weighted UV-B dose measurements were used, with a Yankee Environmental Systems pyranometer operating at Thessaloniki (40°N), Greece (Zerefos et al., 1995a, 1995b). Calculations of the erythema weighted UV-B dose rates have been performed with two widely quoted models, namely those of Green (Green et al., 1974) and of Madroncich (Madronich, 1993). As it will be shown later, for hemispheric studies of this type these two models provide similar results, although Green's model uses an empirical analytical solution for the diffuse radiation, while Madronich's model uses a two-stream approximation (Toon et al., 1989).

RESULTS AND CONCLUSIONS

Figure 1a shows a global map of the mean total ozone departure averaged over the days of March 1993 with ozone negative departures below the 2σ confidence level. A similar map for October 1992 is shown in Figure 1b.



(a) (b)

Fig 1: Mean ozone departures for days with total ozone below 2σ for March 1993 (a) and October 1992 (b)

The corresponding maps for the calculated mean changes in the UV-B dose rates (W/m^2) which pertain to the same days with total ozone below the 2σ levels are shown in Figures 2a and 2b respectively. These dose rates are calculated for local noon and assuming clear sky conditions at each grid point. The model calculations have been performed with both models mentioned in the previous paragraph, and have been shown to provide similar results under extreme conditions in spite of the fact that Madronich's model is based on a two-stream approximation is more accurate than the empirical Green's model. A separate comparison of these two models is shown in Figure 3 for the European grid points (different symbols correspond to different ranges of solar zenith angles). Figures 1a and 1b show that the largest ozone deficiencies are seen at high latitudes and that small changes are seen only over the tropics. This is of course correct only for total ozone. The changes in the daily maximum UV-B dose rates are higher over the latitude bands between 15°N and 40°N, over the northern hemisphere at the extreme March 1993 and between 10°S and 70°S during the extreme October 1992. It is interesting to point to the difference seen in the two hemispheres at extremely low ozone in these transition seasons. Not only is the increase in the daily maximum dose rate in the southern hemisphere about 20% more than the corresponding increase in the northern hemisphere, but also the area covered by large changes in the UV-B maximum dose rates is extended to higher southern latitudes, following the Antarctic ozone hole conditions.

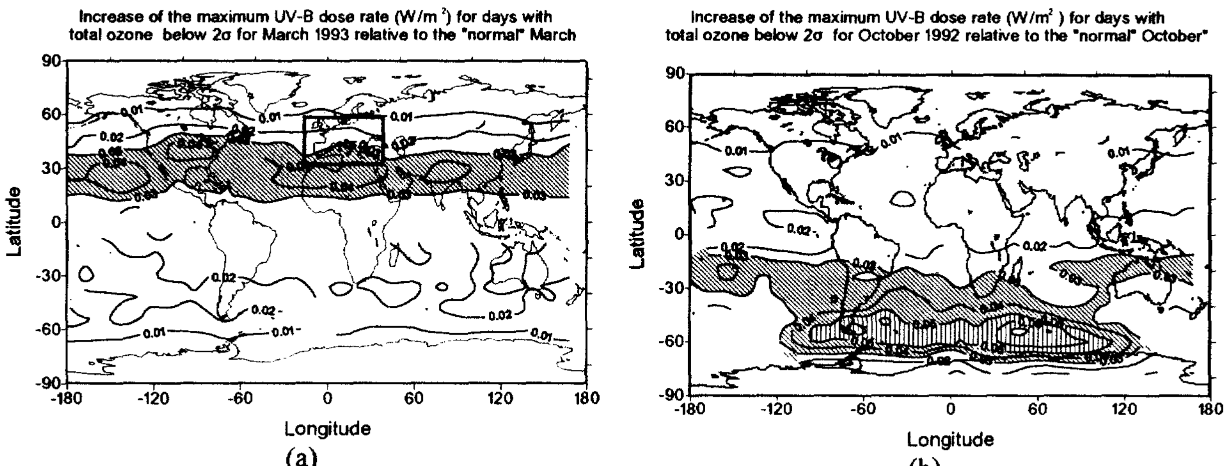


Fig 2: Increase of the maximum erythema weighted UV-B dose rate (W/m^2) for days with total ozone below 2σ for March 1993 (a) and October 1992 (b)

A tentative conclusion from Figures 2a and 2b can be stated as follows: extreme ozone deficiencies in the transition seasons occur mostly at middle-to-high latitudes in both hemispheres, with typical example of the Antarctic ozone hole conditions. The associated increase of the UV-B dose rates, however, depend (the other factors assumed constant) on latitude. This is because there is a positive latitude gradient for ozone and at the same time a negative gradient in the solar flux. These opposing gradients result in the calculated maximum in the increase of the UV-B dose rate which is now found between 15°N and 40°N in March 1993. Similar arguments can be suggested for October 1992.

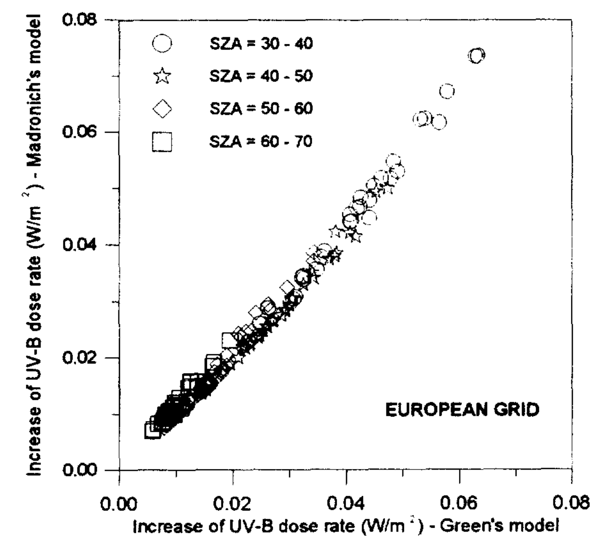


Fig. 3: Comparison of the results of the two models used (Green's and Madronich's)

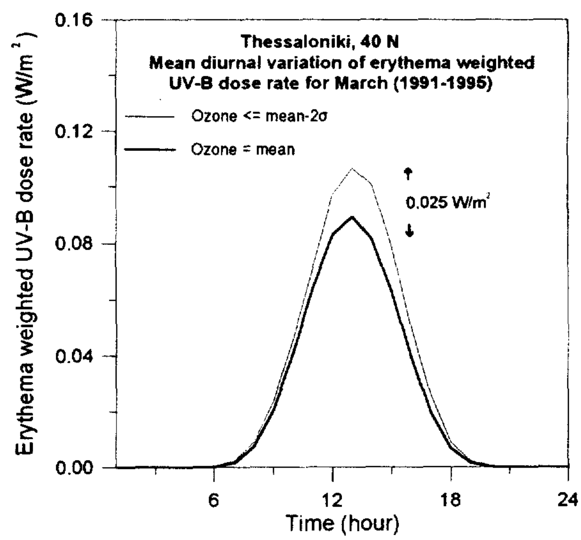


Fig. 4: The diurnal variation of erythema weighted UV-B dose rates for March at Thessaloniki 40°N

Finally an independent check of the accuracy of the calculations at extreme ozone deficiencies is seen in Figure 4 from the measurements of the diurnal variation of the UV-B dose rates at Thessaloniki (40°N) . The observed increase is of the order of 0.025 W/m^2 and compares well with the increase shown in Figure 2a as calculated by the model.

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