N95- 11088

THE MEASUREMENT OF ULTRAVIOLET RADIATION AND SUNBURN TIME OVER SOUTHERN ONTARIO

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ABSTRACT

Studies of the depletion of ozone which have been conducted from the TOMS instrument on the NIMBUS 7 satellite indicate that total ozone has declined by 5% over the last 12 years at most mid-latitudes in the northern hemisphere typical of southern Ontario. The measurement of the actual resultant increases in UVB is now important. A monitoring program of UVB (biologically active solar ultraviolet radiation) has been conducted for the last 24 months at a site near Bolton, Ontario. The sunburn time varies from less than 17 minutes in late July, to over 4 hours in December on clear days. The levels depend on solar insolation and total ozone column. The ultraviolet levels are strongly affected by cloud and sky conditions. The implications of present and future ozone depletion on the sunburn time are discussed.

1. INTRODUCTION

Investigations of trends in the ozone layer which have been conducted from ground based networks and from the TOMS instrument on the NIMBUS 7 satellite indicate that total ozone has declined 5% over the last 12 years at mid-latitudes in the northern hemisphere typical of southern Ontario (Stolarski et al; 1990). The measurement of the actual resultant increases in UVB (biologically active solar ultraviolet radiation) is now important. We expect even further decreases in the thickness of the ozone layer and resultant increases in UVB levels in the future. The long term enhancement of UVB radiation has the capacity to alter the species composition of ecosystems and to cause human health effects.

With this in mind, a program to monitor biologically active solar ultraviolet radiation was commenced in Southern Ontario.

2. EQUIPMENT

A monitoring program of biologically active solar ultraviolet radiation has been conducted for the last 24 months at a site near Bolton, Ontario. The UVB sensor used was a Solar light Model 500 UV-Biometer; this has a fluorescent film and a photodiode detector. The instrument has an RS 232 serial output interface so it can be easily interfaced to a computer. The sensor was controlled by a multitasking personal computer (Amiga 2000) and the data was automatically logged and processed into a sunburn time. The sunburn time can be delivered to the media from a remote dialup bulletin board. The computer system has 2 serial ports and a phone line to access the bulletin board program. The data is recorded on hard disk with a time resolution of 10 seconds.

The bulletin board produces a page for each day with readings at 10:00, 13:00 and 15:00. In May the sunburn time is typically about 20 minutes at solar noon just after 13:00. The prime unit of measurement of UVB radiation levels is in MEDs/hour. The detector has a wavelength response to erythemal radiation similar to human skin; one MED is the radiation dosage required to turn type 2 unprotected skin red after several hours. One MED equals an effective accumulated dosage of 21 mJ/cm^2. The sunburn time equals 60 minutes divided by the MED rate.

3. RESULTS

On a clear day, the variation of UVB levels with time is a very smooth function with a characteristic bell shape. The values at 10:00 and 16:00 are about one half of the levels at 13:00 near solar noon for Toronto. FIGURE 1 shows the measured ultraviolet radiation levels as a function of Eastern Standard time for a clear day in late July at Toronto. The MED rate at noon is about 3.7 MEDs/hr corresponding to sunburn time of less than 17 minutes. On cloudy days with heavy overcast, the UVB radiation is largely absorbed and the sunburn time is usually longer than 100 minutes, even in July. FIGURE 2 shows the ultraviolet radiation levels for a cloudy day in July at Toronto. When it is actually raining, the UVB is usually attenuated by more than a factor of five compared to a clear day.

The situation is more complicated on a day with broken cloud conditions; on these days, the UVB varies wildly over short periods of time. This is the case for cumulus activity and for cirrus clouds. Jet contrails frequently form cirrus cloud decks which can actually enhance the UVB dosage at ground level.

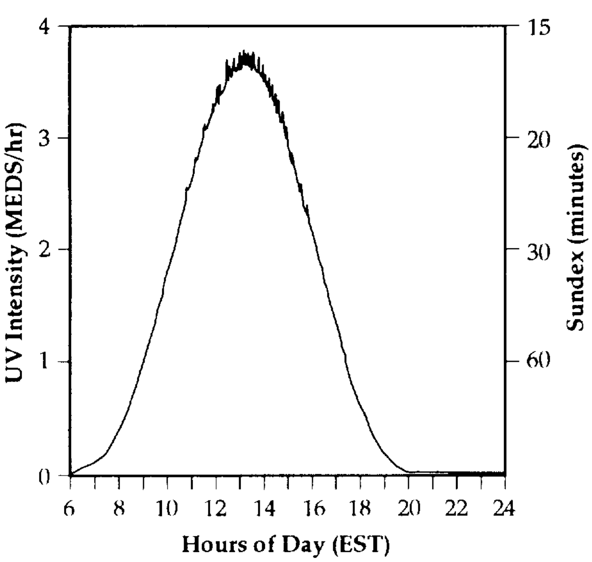

Figure 1. The ultraviolet radiation levels for a clear day in July at Toronto.

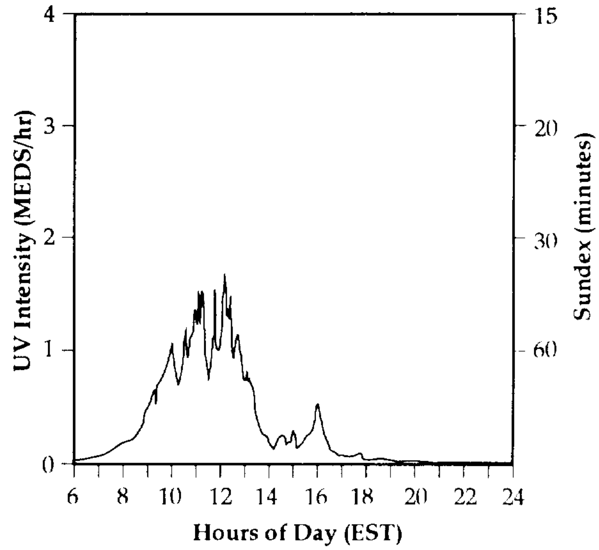

Figure 2. The ultraviolet radiation levels for a cloudy day in July at Toronto.

FIGURE 3 shows the ultraviolet radiation levels for a broken cloud day in July at Toronto. Note the elevated and highly variable levels; on some days, the UVB levels can be 25% above the corresponding clear sky values at the same solar elevation.

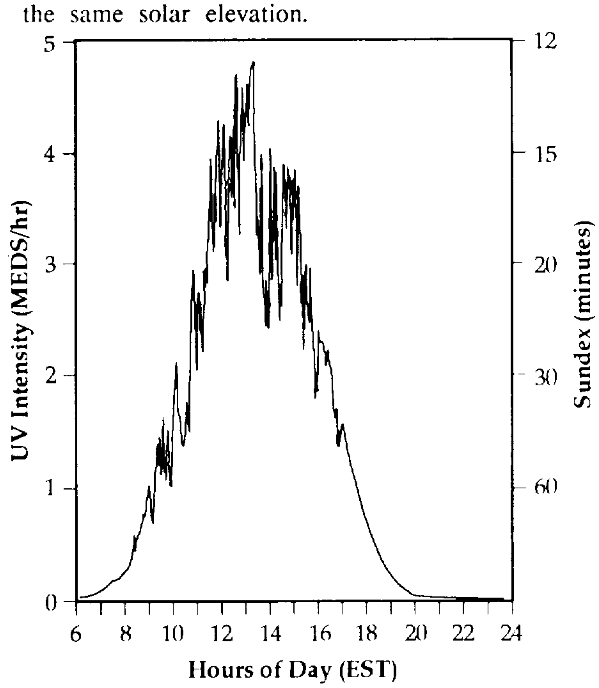

Figure 3. The ultraviolet radiation levels for a broken cloud day in July at Toronto.

It was also found that the amount of haze and pollution in the lower atmosphere can reduce the UVB levels significantly; tropospheric haze and gases can change the UVB levels as much as the day to day changes in the stratospheric ozone layer. The ground albedo is important in winter and spring when snow is covering the ground.

The sunburn time varies with several factors. In order of importance, these are: the solar elevation angle, the sky cloudiness conditions, the tropospheric haze and pollution and finally, the thickness of the ozone layer. The ozone layer explains only about 15% of the variance. The sunburn time varies from less than 17 minutes in July to over 4 hours in December at Toronto. On clear days a bell shaped curve is produced with the UVB radiation at 10:00 and 16:00 being about one half of the noon value at 13:00. On overcast and rainy days, the UVB is attenuated by a large factor. On broken cloud days, the UVB levels vary strongly with attenuations up to a factor of two. On days with light broken cloud and on cirrus cloud days, an actual enhancement of UVB has been observed of up to 25%; the sunburn time went below 15 minutes on several days in July, 1990. Clouds represent a major problem for the development of a good forecasting process.

The elevation angle of the sun is a strong factor in the determination of the UVB levels. FIGURE 4 shows the seasonal variation of UVB levels on cloudy and clear days in 1990. The sunburn time varies from less than 17 minutes in July to over 4 hours in December at Toronto. Similar results for the UV levels were obtained in 1991. FIGURE 5 shows the seasonal variation of UVB levels throughout 1991 on clear days only and demonstrates the strong effect of solar elevation angle on the UVB level.

Also, the variation of UVB levels in 1992 to date has been measured; the UVB levels in May, 1992 have been consistently above the May levels for 1990 and 1991 by over 10%. A physical model has been developed which calculates the sunburn time on clear days (Evans and Poulin; 1992).

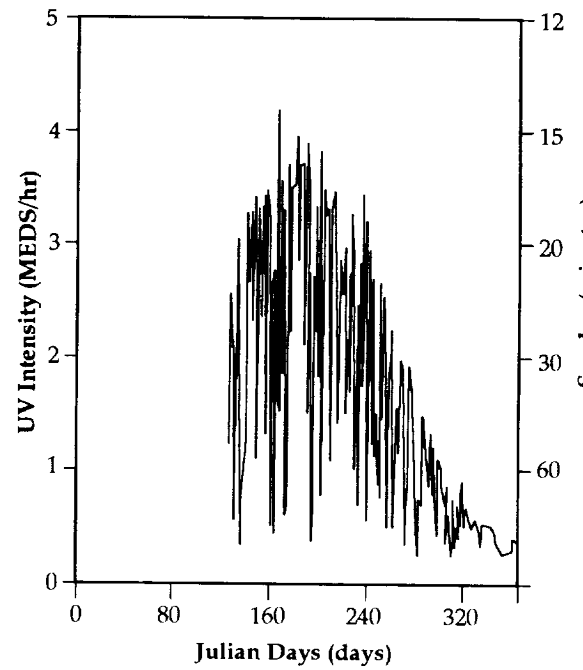

Figure 4. The seasonal variation of UVB in 1990.

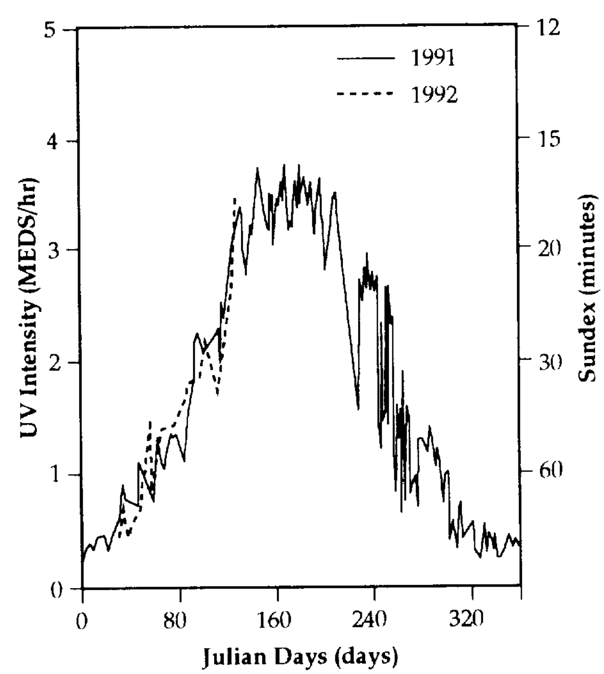

Figure 5. The seasonal variation of UVB in 1991 and 1992.

This model calculates the ozone layer field from upper air maps and then a simple radiative transfer model is used to calculate the MED rates and the sunburn times. A haze layer in the troposphere has been included in this model, but more work remains to be done to properly include this term on a geographical basis. The clear sky sunburn times for mid May over Canada which have been calculated from this METOZ model agree well with the measured times on clear days at Toronto.

4. CONCLUSIONS

A monitoring program of biologically active solar ultraviolet radiation has been conducted for the last 24 months at a site near Bolton, Ontario. The sunburn time varies with several factors. In order of importance, these are: the solar elevation angle, the sky cloudiness conditions, the tropospheric haze and pollution, and the thickness of the ozone layer. The ozone layer explains about 15% of the variance. The sunburn time varies from less than 17 minutes in July to over 4 hours at Toronto. On clear days a bell shaped curve is produced with the UVB radiation at 10:00 and 16:00 being about one half of the noon value at 13:00. On overcast and rainy days, the UVB radiation is attenuated by a large factor. On broken cloud days, the UVB levels vary strongly with attenuations up to a factor of two. On days with light broken cloud and on cirrus cloud days, an actual enhancement of UVB has been observed of up to 25%; the sunburn time went below 15 minutes on several days in July. Clouds represent a major problem for the development of a good forecasting process for UVB levels.

A model has been developed which successfully calculates the sunburn time on clear days. This work is important since we expect even further decreases in the thickness of the ozone layer and resultant increases in UVB levels in the future.

ACKNOWLEDGEMENTS

This research was supported by Coppertone (Scholl-Plough, Canada) and by the Ontario Ministry of the Environment. The computer data system was expertly operated by P.J. Evans

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