The Effects of Sunshine, Cloudiness and Haze on Received Ultraviolet Radiation in New York

ANITA BAKER-BLOCKER

Advance Science Consultants, Inc., Ann Arbor, MI 48107

16 November 1979 and 28 March 1980

ABSTRACT

Ultraviolet data from Rochester, Schenectady and Whiteface Mountain, New York, for the period November 1975–December 1977, have been studied to ascertain the importance of extraterrestrial ultraviolet (UV) radiation, sunshine, cloudiness and haze on received ultraviolet radiation. The first three factors can be shown to have great influence on received UV, while haze cannot be shown to selectively attenuate UV. It appears that there is a linear relationship between sunshine duration and received UV, with a correlation coefficient of 0.88 for the data studied.

1. Introduction

Received ultraviolet radiation (UV) is an important although small fraction of total received radiation, since it is necessary to human and animal life. Despite its importance, and the controversy surrounding possible increases in UV due to reduced stratospheric ozone concentrations, few instruments are deployed in the field to monitor UV, and few attempts have been made to examine existing measurements. The amount of received UV varies by an order of magnitude through the course of a year. To determine the most important meteorological factors affecting received UV, records from three New York sites (shown in Fig. 1) for the period November 1975 through December 1977 have been examined.

Ultraviolet radiation measurements were made at these sites by the New York State Department of Environmental Conservation using Eppley Laboratory Solar and Sky Ultraviolet Radiometers, which are equipped with quartz windows and restrict the wavelength response to 295–385 nm using a bandpass filter.

During the record period, the average annual received UV for Whiteface Mountain was 4482 ly; for Rochester, 4010 ly; and for Schenectady, 3388 ly. During this record period, the monthly minimum (80 ly) and maximum (764 ly) for the three sites was at Whiteface Mountain.

2. Data analysis

Extraterrestrial UV radiation is one of the most important determinants of received UV. Table 1 shows a comparison between extraterrestrial and received UV for the three sites in June and December 1977. The amount of extraterrestrial UV in December is about what is received at the ground in June. All three sites received ~25% of the extraterrestrial UV in June compared to 14% in December. However, June was cloudier than May or July, and received substantially less UV than those two months.

Monthly received UV at the three stations is plotted against sunshine duration in Fig. 2, illustrating the effect that sunshine has on received UV. [Sunshine duration is taken from National Weather Service (NWS) records, and represents the duration of time that a shadow can be cast during the day.] Seventy months of combined data from the three sites is available for the study period, and the correlation coefficient between received UV and minutes of monthly sunshine was calculated to be 0.88. The correlation coefficients for Rochester and Schenectady were 0.95 and 0.78, respectively. The correlation between received UV on Whiteface Mountain and Burlington, Vermont, was 0.96, despite the geographic separation (Fig. 1), and a difference in elevation of 1382 m. Duration of sunshine should therefore be considered an important determinant of received UV radiation.

Studies by Bener[1] using observations of specific conditions at Davos, Switzerland, indicate that cloud cover plays an important role in received UV. Therefore, selective comparisons were made using specific days at the various New York stations. Because of the nature of cloud reporting by the NWS, days with total ($^{10}/_{10}$) sky cover would be expected to show great variability. A day when zero sunshine was reported at both Rochester and Schenectady was 29 July 1976. Fig. 3 portrays what the UV records for these stations showed on that day coupled with reported meteorological conditions. Ground fog can apparently reduce received UV to near zero, as demonstrated by the conditions at Rochester at 1300 EST, and at Schenectady at 1600 EST. Rochester received 5.8 ly of UV that day, compared with 2.5 ly received at Schenectady.

[1] Bener, P., 1964: Investigation on the influence of clouds on ultraviolet sky radiation. Report, Contract AF 61(052-618), Davos, Switzerland,

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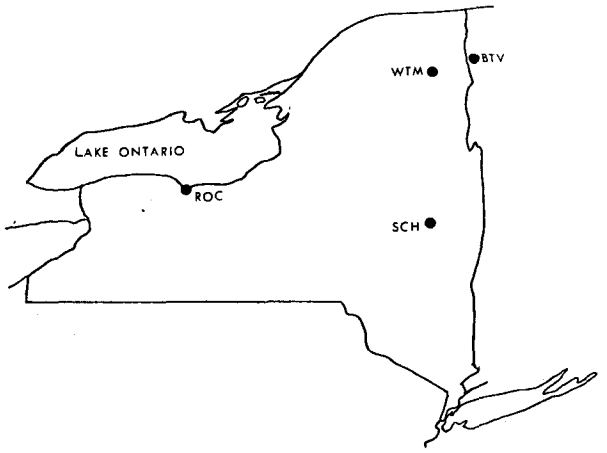

FIG. 1. Locations of received ultraviolet radiation sensors used in this study. Whiteface Mountain (WTM) 44°21′55″N, 73°54′13″W, Rochester (ROC) 43°47′50″N, 77°31′01″W, and Schenectady (SCH) 42°47′50″N, 73°56′07″W. BTV is the NWS WSO at Burlington, Vermont, the closest site to WTM having standard weather sensors.

TABLE 1. Calculated extraterrestrial and observed received UV radiation for Whiteface Mountain, Rochester and Schenectady, for June and December 1977. Extraterrestrial UV radiation was calculated by the method outlined by Sellers (1965) for total radiation, multiplied by 0.077 the percentage of the solar constant between wavelengths of 295 and 400 nm.

	June 1977		December 1977	
	Extra-terrestrial UV radiation (ly)	Received UV (ly)	Extra-terrestrial UV radiation (ly)	Received UV (ly)
Whiteface Mountain	2286	581	570	80
Rochester	2287	598	676	110
Schenectady	2287	542	683	89

Sky cover can play a relatively subtle role in influencing received UV on days which record 100% possible sunshine, but when considerable cloudiness exists. One example of this is shown in Fig. 4, with a UV reduction at Rochester on 27 May 1977, with 4/10 sky cover and 100% possible sunshine (4/10 sky cover is the maximum reported on a day with 100% possible sunshine during the study period). On 7 May 1977, a day with no clouds and 100% possible sunshine, 25.6 ly were recorded, while 23 were recorded on the 27th. Thus, a 10% reduction in UV

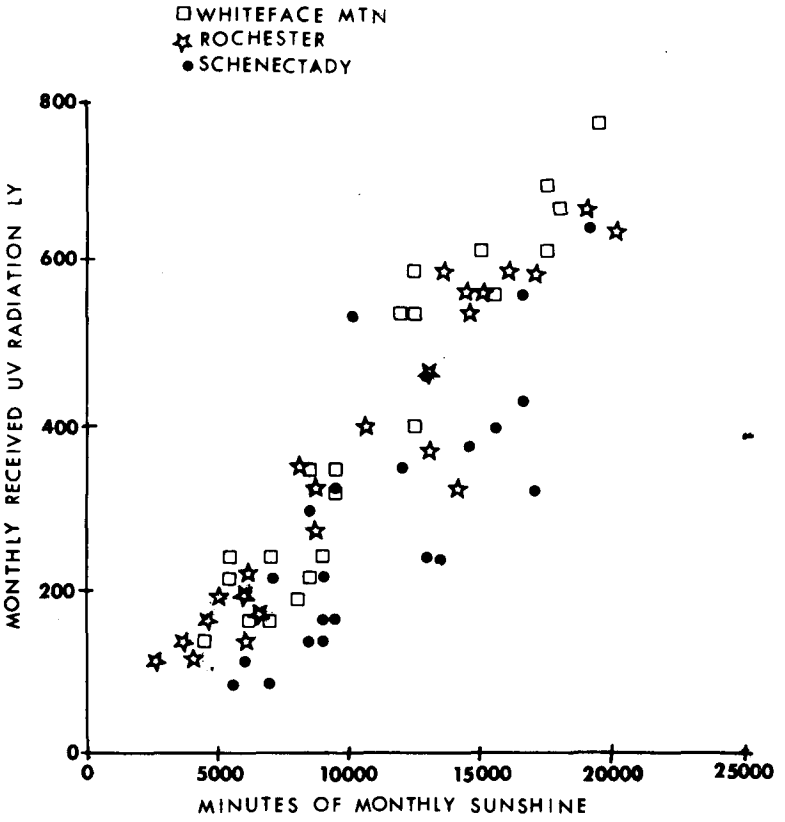

FIG. 2. Scatter plot of monthly values of received UV radiation at Whiteface Mountain, Rochester and Schenectady versus minutes of sunshine during the month from NWS instruments at Burlington, Rochester and Albany for the months November 1975–December 1977.

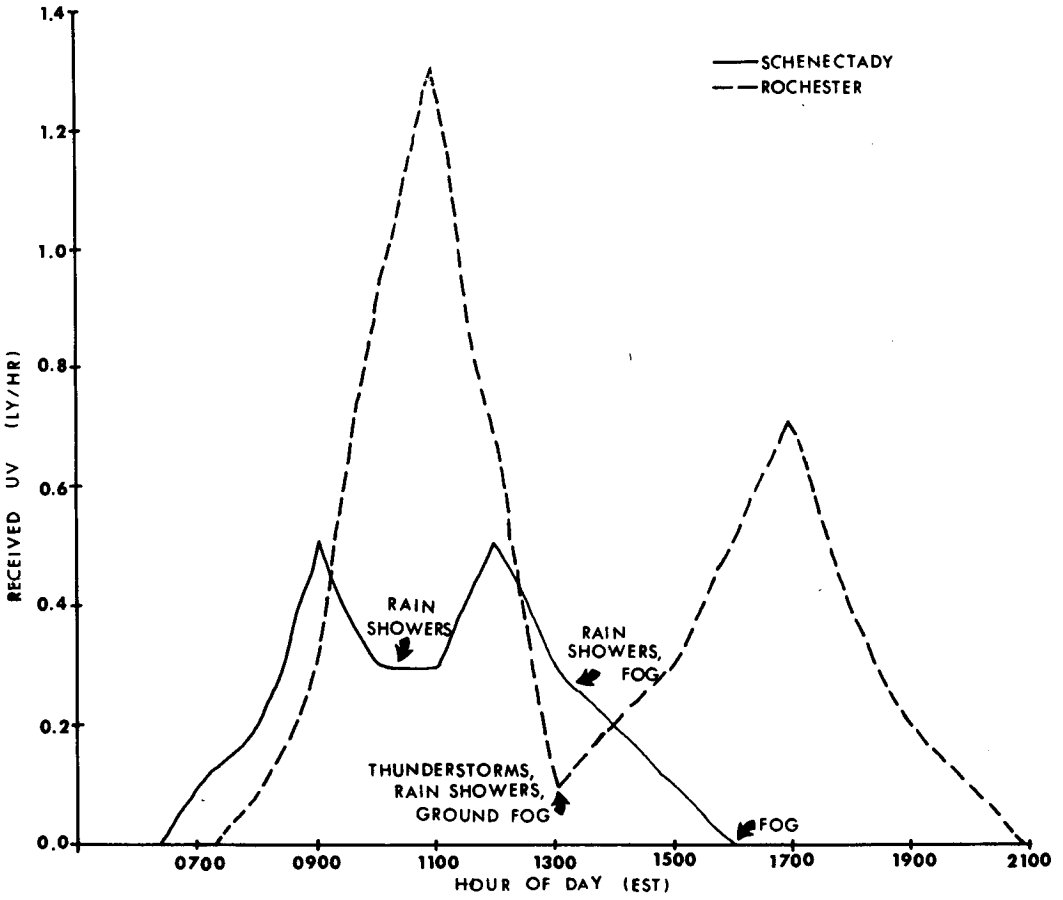

FIG. 3. Received UV radiation records for Rochester and Schenectady for 29 July 1976, when both stations experienced total overcast. Visibility at Rochester at 1300 LST was ¾ mi (1.2 km) and at Albany at 1600 LST, the visibility was 3 mi (4.8 km).

can occur on a day with considerable cloudiness (in this case, cirrus with heights reported of 25 000 ft or 7600 m).

Although frequent statements concerning the attenuation of UV by air pollution and haze are made in meteorological literature, most are based on clear sky comparisons between urban and suburban areas (Peterson and Demerjian, 1976). Such cloudless days are rare in New York, and no day during the record period was reported cloudless by all three stations simultaneously. Since the NWS reports haze only when visibility is less than 7 miles, most days that can be characterized as hazey are also cloudy. To study the effects of haze on received UV radiation, days with relatively high amounts of sunshine, little cloud cover, and consistent reports of haze were selected for study. Three cases were studied in detail. Rochester reported haze conditions consistently during 20 July 1977, 83% possible sunshine, and less than 1/10 sky cover or obscuration. Some of the obscuration may have been attributable to haze. This day was compared with 27 July 1977, when 100% possible sunshine, and a 2/10 sky cover (a combination of scattered cumulus and broken cirrus) were reported. Pictoral comparison is shown in Fig. 5. To determine possible reduction in UV due to haze a linear extrapolation of the expected UV total for the 20th was made, assuming that sunshine totals for the days would be the same. Such a calculation predicted that 23.4 ly would be received, while 23.3 ly were observed, since 27.7 ly were observed on the 27th.

Two other haze dates were examined using data from Schenectady: 18 June 1976 and 21 August 1976. Extrapolation using cloudless days close to each of those haze days predicted that 16.1 ly would be received on 18 June, when 17.4 were observed, and 13.1 ly would be expected on 21 August, when 12.8 were observed.

3. Conclusions

Important factors in determining received UV radiation include the amount of extraterrestrial radiation incident at the top of the atmosphere, duration of sunshine and the amount of cloudiness. Haze

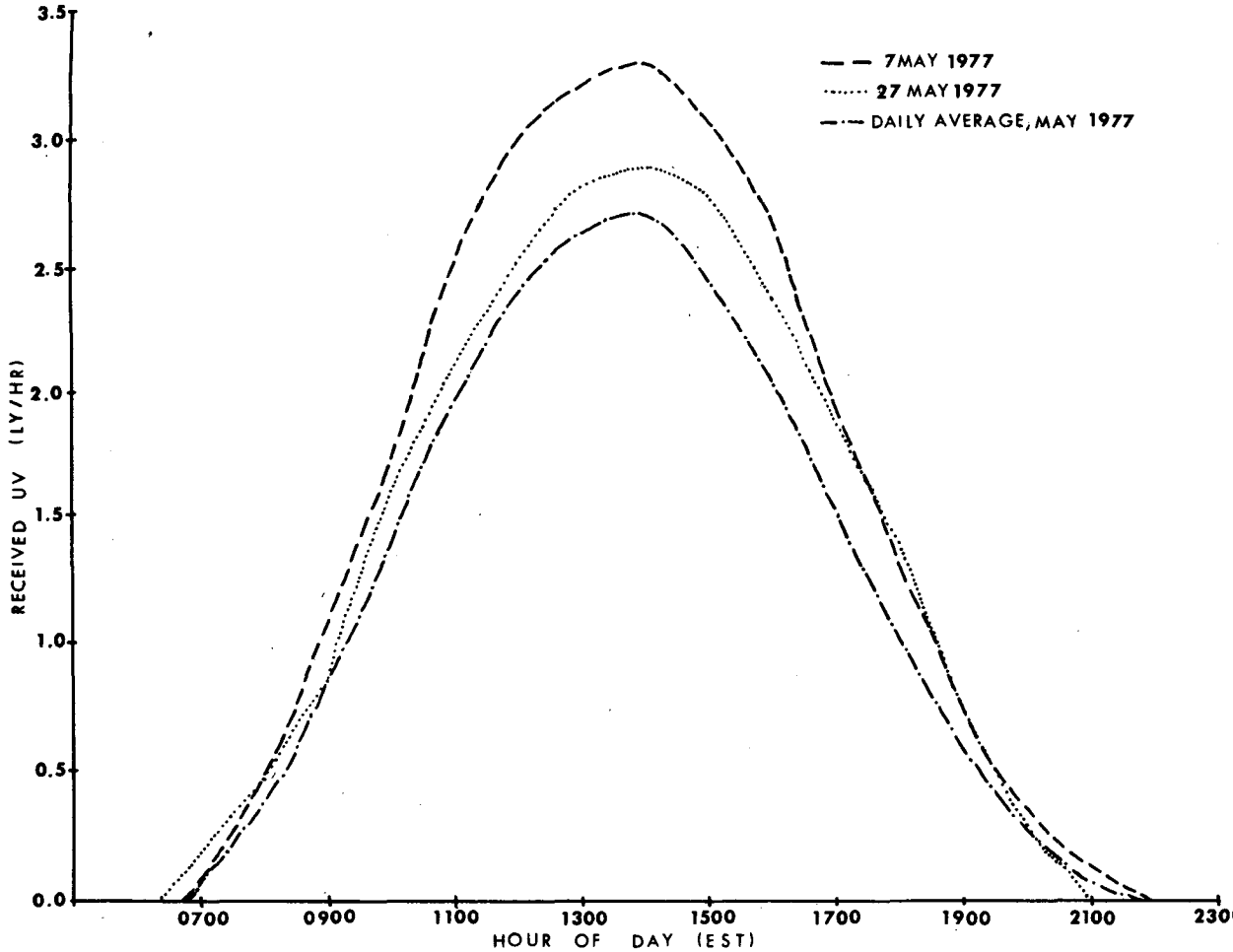

FIG. 4. Daily average received UV radiation during May 1977, and the amount received on 7 May under clear skies and 100% possible sunshine, and on 27 May, when 4/10 sky cover and 100% possible sunshine were reported.

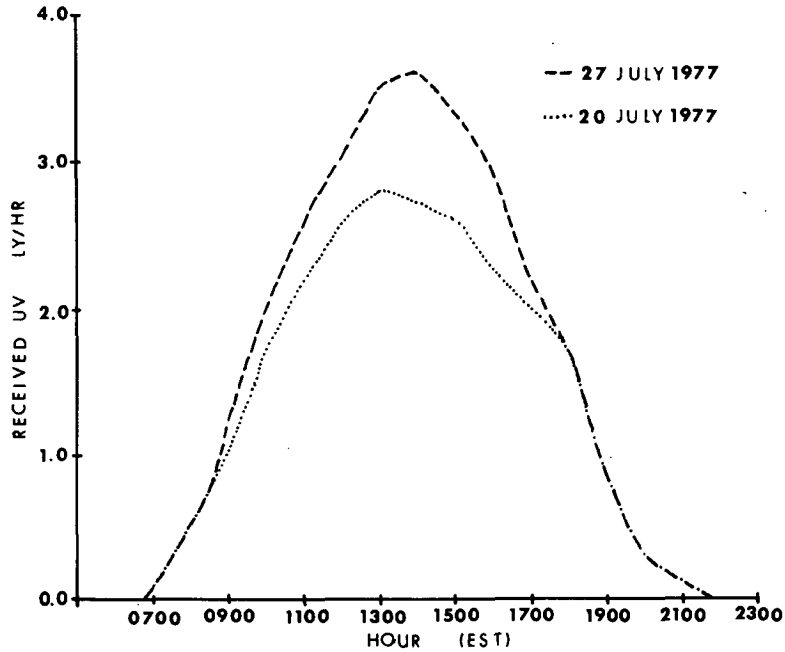

FIG. 5. Received UV records for Rochester for 20 and 27 July 1977.

cannot be shown to attenuate UV selectively, based on three comparisons between hazey and clear days. Ground fog attenuates UV strongly. Cirrus overcast can cause reductions in received UV of up to 10% on days which receive 100% possible sunshine. Received UV is well correlated (0.88) with sunshine duration in this data set.

Acknowledgments. Dennis G. Baker provided the calculations of extraterrestrial UV radiation and also encouraged the writing of this paper. The UV data were acquired through Bill Delaware of the New York Department of Environmental Conservation.

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