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NOTE
SPECTRAL DISTRIBUTION OF RADIATION IN THE NORTHERN GREAT LAKES DURING WINTER

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ABSTRACT. Measurements of global radiation in the spectral bands 285-2800, 535-2800, 630-2800 and 700-2800 nm were collected at the eastern end of Lake Superior during the period January through May. Significant differences are reported between the various spectral bands on a monthly as well as on a daily and hourly basis, due to varying degrees and types of cloudiness. Values of net and downward radiation for the same period are also provided.

INTRODUCTION

Measurements of the spectral distribution of global radiation were made at the eastern end of Lake Superior (Whitefish Point, Michigan, 46°46′N, 84°57′W) from January through May 1967 (Table 1). These data are useful in forming radiation budgets to analyze the decay of ice in the northern Great Lakes (Brazel 1971), especially in Whitefish Bay where ice cover poses a severe problem to winter navigation. In addition, the spectral intervals chosen for this investigation give insight into the distribution of photosynthetically active radiation (Gates *et al.* 1965, Anderson 1971) which is essential for modeling lake productivity (Stadelmann *et al.* 1974). In the northern regions, there is a paucity of measurements for all wave radiation and the spectral composition of the global flux.

The measurements cover only the winter months and include solar altitudes 10-50°. Since maximum solar altitude in the Great Lakes region is only slightly over 70°, the global radiation values presented may be applied to other seasons, taking into account differences in attenuation due to seasonal variation of atmospheric water vapor content and to differences in diffuse sky radiation due to the snow and ice cover.

Instrumentation was located 2 meters above the surface with sensors maintained on a daily basis. All measurements were recorded on potentiometric autographic recorders, routinely calibrated, with periodic time checks from a time standard radio signal. The strip charts were manually integrated and the results transferred to punched cards for computer processing.

RESULTS

Figure 1 shows the daily average global radiation on a monthly basis for each spectral range. Values were not computed for January and May since data were collected for only a part of those months. For the period shown, radiation in the range 535-2800 nm accounted for 78% of the total global radiation (285-2800 nm), the range 630-2800 nm accounted for 68%, and the range 700-2800 nm accounted for 55%. In a Northern Greenland study, Bolsenga (1967a) found that near infrared global radiation (700-2800 nm) accounted for about 51% of the total global radiation during May and June. Atmospheric water vapor content computed from the surface dew point (Reitan 1963; Bolsenga 1965), averaged 0.59 cm over the entire measurement period.

Figure 2 shows the global radiation on a clear day (7 April) at solar altitudes ranging to nearly 50°. The curves in Figures 2 and 3 are drawn from hourly totals plotted on the half hour (i.e., integrated global radiation between 1000-1100 TST is shown on the graph at 1030 TST). Distribution in the various bands is shown in Table 2. Atmospheric water vapor, ω_T, averaged 0.93 cm for the day, slightly above normal for the area in April (10 year average slightly less than 0.90 cm for the Sault Ste. Marie area, Bolsenga 1967b). For clear

TABLE 1. Radiation measurements and instrumentation involved in this study.

Radiation Class	Band of Operation	Filter	Instruments
Total Global*	285-2800 nm	WG 7	Eppley Pyranometer
Spectral Global	535-2800 nm	OG 1	"
Spectral Global	630-2800 nm	RG 2	"
Spectral Global	700-2800 nm	RG 8	"
Net Radiation**	.3-40 μm	None – Thermopile	Beckman & Whitley
Downward Radiation***	.3-40 μm	None – Thermopile	"

*Downward direct + diffuse solar radiation, received on a horizontal surface.
**Net flux of downward and upward total (solar + terrestrial surface + atmospheric) radiation (also called net exchange).
***Downward solar and downward atmospheric radiation (also called total hemispherical).

sky conditions (7 April), the proportion of total global radiation contained within the various spectral intervals appears slightly greater (7-18%) than that obtained for other days in the following analysis when clouds were predominate (Table 2).

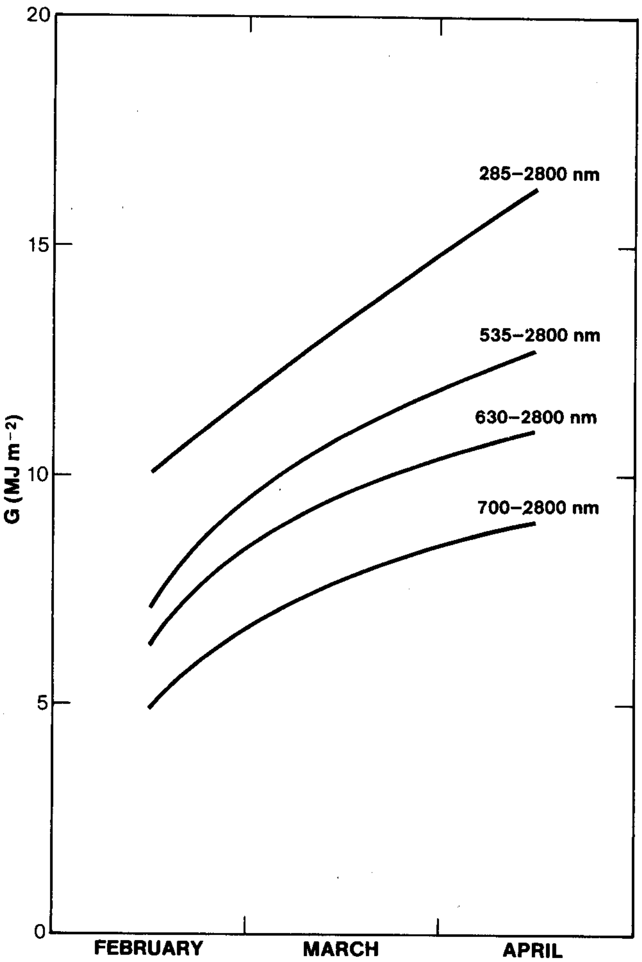

FIG. 1. Average daily global radiation totals in four spectral ranges.

Figure 3 shows global radiation on days with varying degrees and types of cloudiness for different solar altitudes. The January 24 observations were made on a day when total sky cover was reported as 10/10ths during every hourly observation at the site. The lowest layer consisted of stratocumulus during all hours and the second and third layers varied from altocumulus to cirrostratus, singly or in combination. Atmospheric water vapor was 0.64 cm, slightly above normal for the area in January (10 year average is 0.50 cm). Table 2 shows the distribution in each spectral band. Observations on February 22 (Figure 3) were made under 10/10ths total sky cover at every hour with the lowest layer being mostly stratocumulus and the second layer stratus. Surface observations indicated an increasing amount of stratocumulus in the lower cloud layer in the afternoon accounting

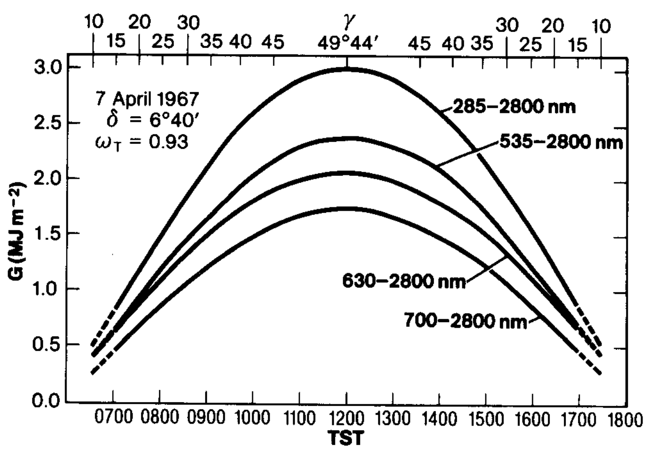

FIG. 2. Hourly global radiation totals in four spectral bands as a function of solar altitude, γ, and associated true solar time, TST, on a clear day. Atmospheric water vapor, ω_T, and solar declination, δ, are also shown.

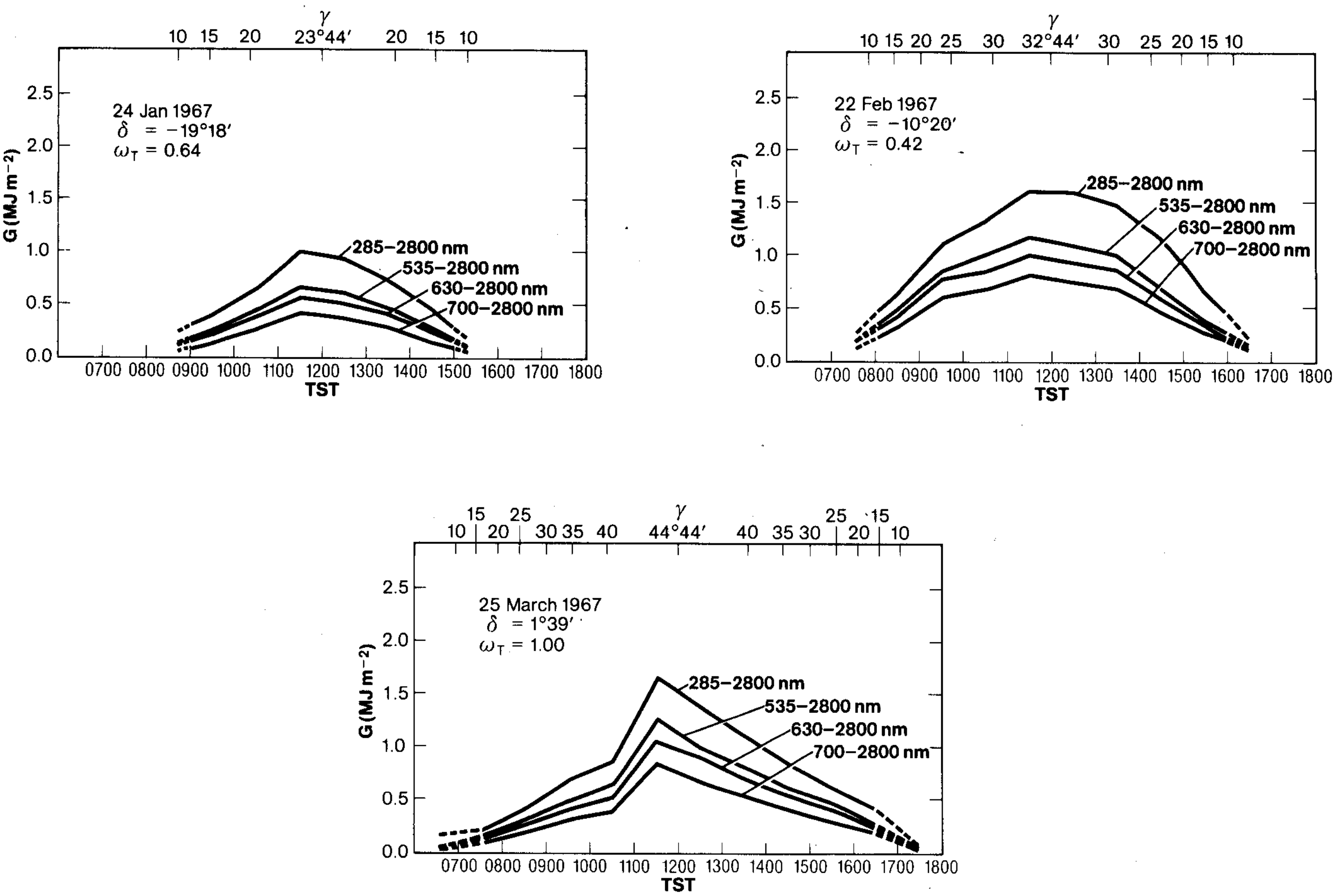

FIG. 3. Hourly global radiation totals in four spectral bands as a function of solar altitude, γ, and associated true solar time, TST, on three days with varying degrees and types of cloudiness. Atmospheric water vapor, ω_T, and solar declination, δ, are also shown.

for the asymmetry of radiation with respect to true solar noon. Atmospheric water vapor (0.42 cm) was slightly below normal (nearly 0.50 cm) for the area in February. Distribution of radiation in the various spectral ranges is given in Table 2. Figure 3 also shows global radiation on a day (25 March) when total sky cover was reported as 10/10ths stratus during every hourly observation at the site. The asymmetry of the curves with respect to true solar noon is due to a lack of uniformity in the cloud cover from morning to afternoon. Atmospheric water vapor was 1.00 cm, which is high for the area in March (10 year average slightly greater than 0.60 cm). Table 2 shows the distribution in the various bands.

The range of values in the various spectral bands during all days of the measurement period was quite large. The 535-2800 nm region accounted for 51 to 88% of the total global radiation, the 630-2800 nm region from 42 to 81%, and the 700-2800 nm region from 30 to 68%. In the near infrared range, differences from the Greenland values are significant since near infrared global radiation in Greenland remained in the 50-53% range. In the Greenland study atmospheric water vapor averaged 0.16 cm with a range of 0.13-0.18 cm. A much wider range of atmospheric water vapor in this study probably accounts for most of the radiation differences.

Monthly averages of net, downward, and global radiation are shown in Table 3. Subtracting the average daily global radiation flux from the average daily downward radiation approximates average daily incoming long-wave radiation as a residual. As indicated in Table 3, these values compare favorably with incoming long-wave radiation computed by Bolsenga (1975) for Lake Huron using an equation developed by Anderson and Baker (1967). Similar radiation values were calculated from measurements by Portman and Ryznar (1961) over a snow field in northern Michigan.

TABLE 2. Distribution of spectral global radiation on clear (7 April) and cloudy (24 January, 22 February, 25 March) days

Date	Spectral Range (nm)	Total (MJm^{-2})	Portion of Total Global (%)
7 Apr	285-2800	23.76	
	535-2800	18.90	80
	630-2800	16.80	71
	700-2800	13.53	57
24 Jan	285-2800	4.65	
	535-2800	3.02	65
	630-2800	2.60	56
	700-2800	1.80	39
22 Feb	285-2800	10.35	
	535-2800	7.21	70
	630-2800	6.24	60
	700-2800	4.94	48
25 Mar	285-2800	8.51	
	535-2800	6.20	73
	630-2800	5.32	63
	700-2800	4.02	47

TABLE 3. Average daily net downward and global radiation (MJm^{-2}) from this study. Downward and global values are used to estimate incoming long-wave radiation as a residual (difference). Comparisons are favorable to incoming long-wave values estimated by Bolsenga (1975) for Lake Huron.

Month	Net radiation (net exchange)	Average daily downward radiation (total hemispherical)	Average daily global radiation	Downward minus global	Average daily incoming long-wave radiation (Lake Huron)
Feb	-0.88	31.93	10.06	21.87	21.91
Mar	2.81	37.25	13.32	23.93	24.13
Apr	7.12	38.97	16.43	22.54	25.39

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