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SUMMARY OF THE INTENSITY AND SPECTRAL DISTRIBUTION OF SOLAR RADIATION AT NEW ORLEANS 1931–40, INCLUSIVE

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In a previous paper, (1), data have been given on the intensity and spectral distribution of solar radiation at New Orleans from the beginning of 1928 through the first half of 1932, including measurements of total radiation (direct and diffuse, sun and sky) on a horizontal plane for 7 months in 1931 and for 8 months in 1932. A subsequent report (2) extended these data to cover 1933.

The present paper summarizes the data for the 10-year period 1931 through 1940. The work was aided by grants from the David Trautman Schwartz Research Fund of Tulane University.

The methods and procedures by which the values were obtained have remained essentially the same throughout this period except that in September 1939 the Richard recording millivoltmeter used in conjunction with the Eppley pyrheliometer for the continuous measurement of total radiation on a horizontal plane was replaced by a Leeds and Northrup recording potentiometer. For the most part, measurements of solar radiation at normal incidence and its spectral distribution—ultra-violet, luminous and infra-red—were made at 10 a. m., 12 m. and 2 p. m. on days when the sun was unobscured by clouds or haze. Measurements were also made at the same times of the spectral distribution of the total radiation, direct and diffuse, and of the diffuse sky radiation only, as received on a horizontal surface. Spectrograms to show the short-wave-length limit of the spectrum were also taken at these times. The determinations for 1931 were made from a tower about 40 feet above sea level, built on the roof of a small building adjacent to the laboratory; since January 1932, the measurements have been made from a better location on the roof of the laboratory building about 100 feet above sea level. This building is situated on the college campus about 4 miles from the business center, at latitude 29°56′ N., longitude 90°7′19″, and in an atmosphere reasonably clear of smoke and dust.

SOLAR RADIATION INTENSITIES AT NORMAL INCIDENCE

The averages intensities for the 10-year period are given in table 1. The values were calculated from at least 1 monthly determination for each of the 10 years, except for July and August when no measurements were made in 1934, 1935, 1936, 1938, and 1939. It is evident from these data that at 10 a. m. and 2 p. m. the solar radiation intensity at normal incidence throughout the year is close to or slightly exceeds a gram-calorie per square centimeter per minute, while at noon the value is usually definitely above this level. This highest value recorded during the 10-year period was 1.501 gr. cal. per sq. cm. per minute at noon on March 7, 1931.

TOTAL RADIATION ON A HORIZONTAL PLANE [1]

The values given in table 1 represent more or less momentary measurements of the amount of energy present in direct solar radiation on relatively clear days, which in New Orleans are only about a third of the days in the year. In table 2 are given the hourly averages of total radiation (direct and diffuse) for the different months of the year as calculated from the continuous records obtained with the Eppley pyrheliometer. No records were obtained in January, February, October, November, and December of 1931, and September and October of 1939. Records for occasional days or parts of days are incomplete because of difficulties with the recording apparatus. Otherwise the averages represent values calculated from the continuous daily records for the entire period. The average daily totals are given in the last column and are plotted as the mean curve in figure 1. This graph also shows the variation in the average daily total radiation for the different years of the 10-year period. Analysis of these values shows that in general they reflect the gradual change in solar altitude during the year as modified by variations in the clearness of the sky. This is particularly manifest in the maximum value for June 1936 during which month the percentage of sunshine (86 percent) was the highest obtained throughout the entire period of 10 years; the average cloudiness (in tenths of clouded sky) 3.5 was the lowest value obtained for the period with the exception of October 1940 when it was 3.1.

The close correlation between the percentage of sunshine (average percent of possible sunshine hours as obtained from Weather Bureau records), average cloudiness, and total radiation are shown in figure 2. The curve designated "clear days" represents values on days when clouds covered 0.3 or less of the sky. Of particular interest is the drop in the amount of sunshine and in total radiation during July and August which, as shown in figure 1, is often quite marked. This finding was discussed in a previous paper (2) and was shown to be characteristic of localities situated at about latitude 30° N. as compared with more northern cities. It is chiefly due to the extreme distortion of the distribution of rainfall, in the form of thundershowers caused by convectional overturning, which is characteristic of these months, these showers usually occurring during the middle of the day and being preceded and followed by a period of several hours of cumulus cloud formation.

[1] These values were calculated on the basis of a constant calibration factor for the Eppley pyrheliometer; Woertz and Hand (3) have recently reported that this procedure involves some error. Hand (4) included part of these data (1936–39 inclusive) in his summary of the total solar and sky radiation measurements made in the United States.

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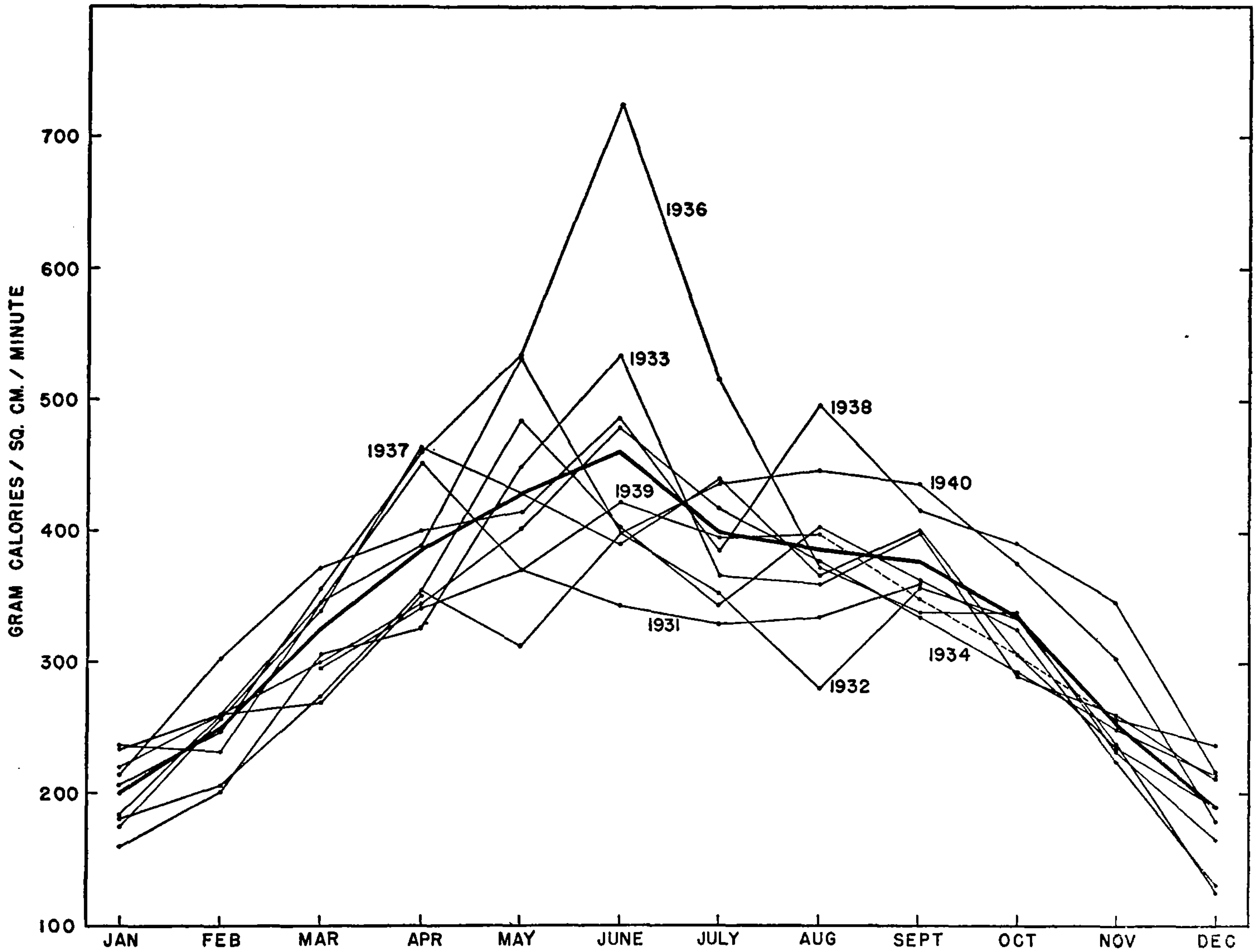

FIGURE 1.—Curves showing the mean monthly amounts of total radiation (direct and diffuse) received on a horizontal surface during 1931–40. The mean curve for the period is shown by the heavy line.

Table 3 shows the highest hourly averages as well as the highest daily totals found during each year of the 10-year period. Analysis of the daily records shows that particularly during May and July the radiation intensity frequently exceeds 1.5 gr.-cal. per sq. cm. per minute for short intervals, and at least once during each year there are momentary readings which exceed 2 gr.-cal. per sq. cm. per minute, the highest value which can be registered accurately on the recorder used.

SPECTRAL DISTRIBUTION OF ENERGY

The average percentage distribution of ultra-violet, luminous and infra-red energy in direct sunlight at normal incidence is given in table 4. The absolute values vary, of course, with the total radiation, but the percentage of each part relative to the total is quite consistent. With approximately similar total energy content the red and short infra-red energy (620 mμ to 1.4μ) tends to be higher during winter and early spring than in summer and fall; the decrease parallels the increase in water vapor pressure, which is about two and a half times as high in July as it is in January. The longer infra-red ($>$1.4μ) and the luminous (400–620 mμ) components are relatively constant, showing only slight changes throughout the year.

The similarity of the average values for the ultra-violet are of interest in view of the known variability of this component with atmospheric conditions as well as with the altitude of the sun. Except for the months of January and February, this component comprises from 2.5 to 3 percent of the total energy during the hours from 10 a. m. to 2 p. m. and even during these 2 months occasional high values are obtained. In fact the highest value recorded during the 10-year period was on January 18, 1933, when the ultra-violet component ($<$400 mμ) was 0.1049 gr.-cal. per sq. cm. per minute or 9 percent of the total energy.

Table 5 is similar to table 4 except that it represents the spectral distribution of the total radiation, direct and diffuse, as received on a horizontal surface. The highest percentage values for the ultra-violet tend to occur during winter and early spring but the highest absolute amounts are usually found in late spring, summer, and early fall. The maximum percentage, 22.5, was obtained at noon on March 6, 1939, March 22, 1932, and April 22, 1932. The highest absolute amount was 0.221 gr.-cal. per sq. cm. per minute on the second of these days.

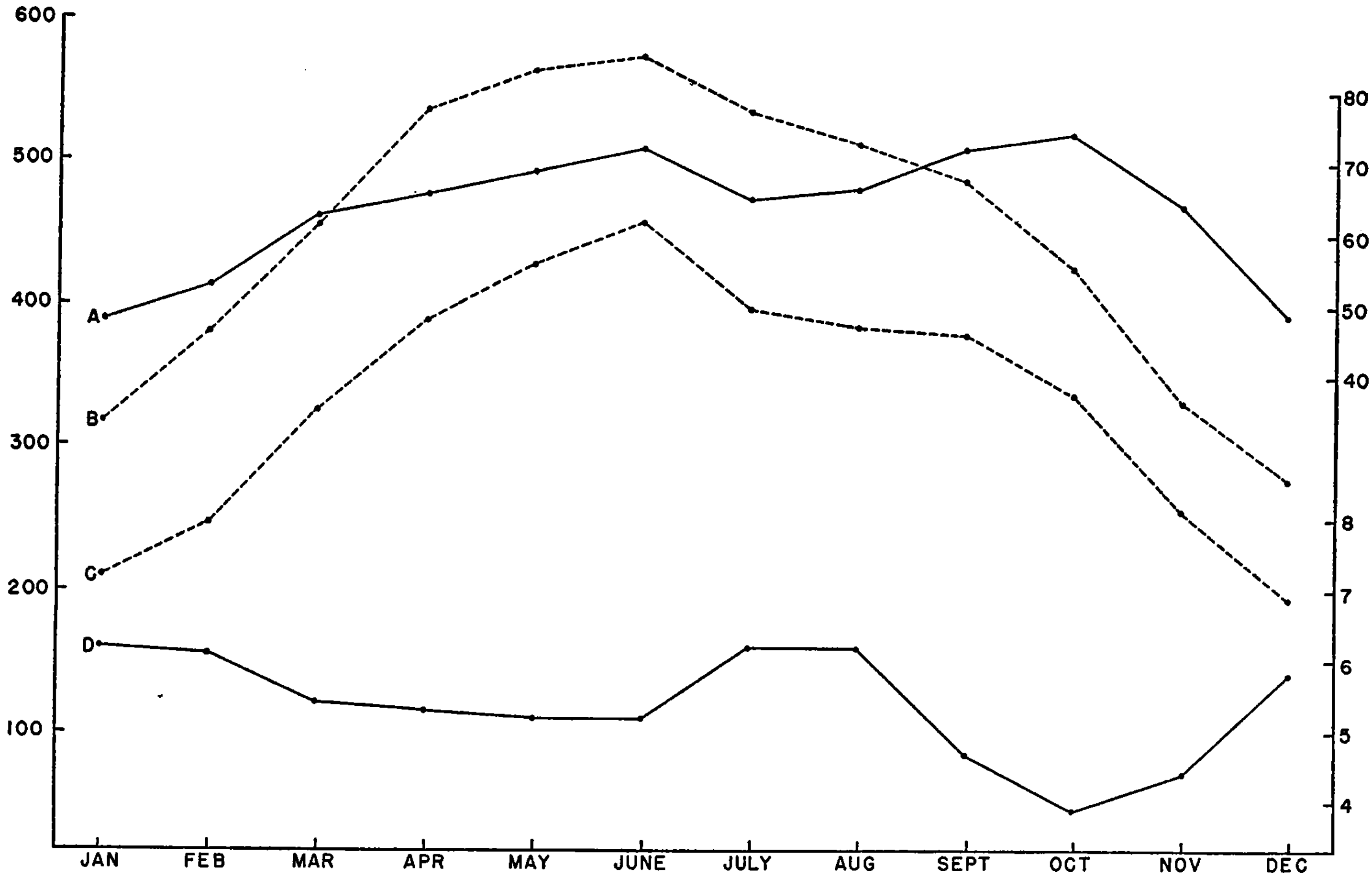

FIGURE 2.—Relation between total radiation (direct and diffuse) and percentages of sunshine and cloudiness. All values are means for the 10-year period 1931–40. A. Percent of possible sunshine. B. Total daily radiation, on clear days only, gr.-cal. per sq. cm. C. Total daily radiation on all days, gr.-cal. per sq. cm. D. Cloudiness in tenths of total sky.

TOTAL ENERGY AND SPECTRAL DISTRIBUTION OF SKY RADIATION

The average total energy and spectral distribution of the diffuse radiation from the hemispherical dome of the sky, determined by shielding the Eppley pyrheliometer from the direct sun, are shown in table 6. Throughout the year between the hours of 10 a. m. and 2 p. m. the sky contributes approximately 10 percent of the total (sun and sky) radiation. The presence of clouds in the vicinity of the sun, but not obscuring it, considerably increases the total contributed by the sky. Thus the highest value during the 10-year period, 0.2496 gr.-cal. per sq. cm. per minute, was recorded on April 22, 1932, at 10 a. m. when the sun was surrounded, but not obscured, by cumulus clouds. This represented 26 percent of the total radiation at this time.

The total energy, in general, rises with increase in solar altitude; the increase is distributed chiefly in the ultra-violet and luminous regions, each of which tends to show higher percentage values in winter than in summer. The high ultra-violet content of sky radiation is due to the fact that it is the diffuse solar radiation scattered by the atmosphere. Since, in a perfectly dry, dust-free atmosphere, the scattering is inversely proportional to the fourth power of the wave length, the ultra-violet is relatively much more increased than the other components. A comparison of the mean annual intensities (table 7) shows that between the hours of 10 a. m. and 2 p. m. approximately 40 percent of the total ultra-violet radiation found in sunshine and sky radiation is furnished by the sky. There is considerable variation in the amount of ultra-violet in sky radiation relative to that in sunshine, the latter intensity usually being much greater. It is of interest, however, that during August the ultra-violet intensity in radiation from the sky equals or exceeds that of sunshine even at noon. This is probably due, in large measure, to the extreme cloudiness which usually occurs at this time of the year.

ANTIRACHITIC RADIATION

Considerable interest has centered about the short ultra-violet region (wave lengths shorter than 313 mμ) of the spectrum because of its effectiveness in preventing and curing rickets. Its variability has been emphasized as reflecting, more than any other part of the spectrum, the local atmospheric conditions at the time of measurement. The 10-year averages for the different months are given in table 8. They indicate that except for November and the winter months there is usually the equivalent of about 500 microgr.-cal. per sq. cm. per minute in solar radiation as measured at normal incidence between the hours of 10 a. m. and 2 p. m. Even in the winter months, however, values were obtained, particularly at noon, which equaled or exceeded those found at other times of the year. The highest value was obtained on May 6, 1940, at noon, when the antirachitic radiation amounted to 1,890 microgr. cal. per sq. cm. per minute (0.00189 gr.-cal.) or 4.1 percent of the total ultra-violet component and 0.14 percent of the total radiation.

In table 9 the monthly averages for the total (sun and sky) antirachitic energy as measured on a horizontal surface are compared with similar averages for sky antirachitic radiation only. There is a general tendency for the amounts in sunshine to increase with solar altitude, high values being common in both sun and sky during the late spring and summer months. It is of interest to emphasize again that at low solar altitudes during the fall and winter months the amount of antirachitic radiation in sky radiation may equal or exceed that in direct sunshine.

The highest value for the antirachitic component in sunshine was 3,860 microgr.-cal. per sq. cm. per minute on May 30, 1934, at noon. The maximum value for the sky was obtained at noon on June 26, 1940, when the antirachitic component was equivalent to 972 microgr-cal. per sq. cm. per minute or 1.7 percent of the total energy at that time. Ives and Gill (5) measured the total antirachitic intensity from sun and sky in New Orleans on April 26, 1932, using an uranium photoelectric cell. Their noon value of 94.2 microwatts per sq. cm. (1,340 microgr.-cal. per sq. cm. per minute) was the highest obtained in their study of 14 American cities and is to be compared with our mean noon value of 1,272 microgr.-cal. per sq. cm. per minute for this month.

Measurement of the short wave-length limit of the solar spectrum with a Zeiss quartz spectrograph shows that it seldom extends to 300 mμ even at noon on very clear days. Analysis of the spectrograms taken during the 10-year period shows only one spectrogram with a wave-length limit shorter than 300 mμ. This was photographed on July 2, 1937, at noon and showed a short wave-length limit of 298 mμ. In general, the limit is about 304 mμ. during the spring, summer and fall months and above 306 mμ during the winter. It should be emphasized, however, that these are general trends and that even in June, July, and August there are many days when the spectrum does not extend below 308 or 310 mμ. and, likewise, there are clear days during the winter when the spectrum extends to 302 mμ.

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TABLE 1.—*Monthly mean intensities of direct solar radiation at normal incidence—1931–40*

[Gr. cal./sq. cm./min.]

	10 a. m.	12 m.	2 p. m.	Absolute maximum	Date
January	1.157	1.187	0.997	1.360	Jan. 14, 1931
February	1.046	1.159	0.985	1.380	Feb. 2, 1933
March	1.200	1.310	1.212	1.501	Mar. 7, 1931
April	1.107	1.178	1.042	1.210	Apr. 22, 1931
May	1.169	1.196	1.027	1.496	May 1, 1940
June	1.158	1.166	1.180	1.221	June 14, 1933
July	1.084	1.146	1.052	1.217	July 2, 1931
August	1.101	1.168	1.109	1.247	Aug. 12, 1940
September	1.079	1.076	1.114	1.198	Sept. 28, 1931
October	1.085	1.148	1.088	1.230	Oct. 12, 1936
November	1.057	1.099	0.994	1.178	Nov. 26, 1940
December	1.046	1.121	1.023	1.240	Dec. 20, 1939
Mean	1.107	1.163	1.069	----------	

TABLE 2.—*Hourly mean intensities of total radiation (direct and diffuse) received on a horizontal surface—All days, 1931–40*

[Gr. cal./sq. cm./min.].

Hour ending (apparent time)	7	8	9	10	11	12	1	2	3	4	5	6	Mean daily total (gr. cal./sq. cm.)
January	0.003	0.045	0.164	0.323	0.460	0.542	0.555	0.501	0.394	0.248	0.102	0.012	201.0
February	.005	.068	.220	.403	.530	.614	.628	.611	.509	.343	.171	.041	247.8
March	.027	.153	.346	.551	.704	.796	.804	.749	.623	.448	.236	.075	325.1
April	.066	.251	.469	.656	.810	.884	.902	.844	.706	.532	.324	.137	388.3
May	.126	.325	.547	.731	.867	.929	.930	.848	.749	.580	.376	.167	430.5
June	.206	.408	.627	.775	.910	.967	.941	.882	.737	.570	.434	.195	459.1
July	.166	.374	.569	.705	.806	.849	.820	.738	.619	.472	.330	.202	398.7
August	.126	.334	.544	.701	.780	.792	.790	.736	.633	.488	.316	.158	385.1
September	.091	.287	.523	.698	.800	.866	.846	.771	.643	.454	.265	.102	379.8
October	.047	.210	.442	.639	.780	.856	.812	.730	.573	.370	.162	.036	337.7
November	.011	.125	.301	.489	.621	.690	.681	.596	.437	.242	.076	.008	256.5
December	.002	.052	.177	.336	.474	.533	.532	.469	.373	.200	.058	.002	190.5
Mean	.078	.225	.417	.589	.716	.780	.774	.720	.587	.420	.245	.091	333.3

TABLE 3.—*Maximum intensities (direct and diffuse) as received on a horizontal surface*

Year	Highest hourly mean		Highest daily total	
	Date	Gr.cal./sq. cm./min.	Date	Gr.cal./sq. cm./min.
1931	May 24, 12 m.–1 p. m.	1.312	Aug. 12	564.6
1932	Oct. 6, 11 a. m.–12 m.	1.227	Oct. 6	549.0
1933	June 10, 11 a. m.–12 m.	1.345	June 18	651.0
1934	Apr. 24, 12 m.–1 p. m.	1.418	July 4	654.1
1935	Sept. 2, 11 a. m.–12 m.; Sept. 4, 1 p. m.–2 p. m.	1.386	Apr. 13	627.0
1936	June 16, 11 a. m.–12 m.	1.624	June 16	857.8
1937	May 5, 12 m.–1 p. m.; May 8, 11 a. m.–12 m.; May 14, 12 m.–1 p. m.	1.470	May 3	678.1
1938	August 18, 11 a. m.–12 m.	1.620	May 11	645.4
1939	Apr. 20, 12 m.–1 p. m.	1.561	May 3	680.6
1940	May 13, 11 a. m.–12 m.	1.508	May 2	673.1