SOLAR ENERGY AND SUNSHINE HOURS AT ATHENS, GREECE

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[Manuscript received November 3, 1958; revised December 15, 1958]

1. INTRODUCTION

Measurements of solar radiation at the earth's surface are restricted to widely scattered locations and in many cases represent relatively short periods of record. Measurements of the hours of sunshine, on the other hand, are more extensive in both time and space.

A number of investigators have successfully applied various forms of the linear relationship between the total daily amount of solar radiation incident on a horizontal surface and the hours of sunshine as proposed by Ångström [1]. This relationship may be expressed as follows:

$$\frac{Q}{Q_0}=a+b\,\frac{S}{S_0}$$

where Q=total amount of solar radiation impinging on a horizontal square centimeter at the earth's surface per day (expressed in ly. per day).

Q_0=maximum total amount of solar radiation impinging on a horizontal square centimeter at the earth's surface on a perfectly clear day (ly. per day).

S=number of hours of sunshine measured on a sunshine recorder.

S_0=maximum number of hours of sunshine recorded under perfectly clear conditions.

a and b are constants.

The application of such a formula makes it possible to make a quantitative estimate of solar radiation amounts in cases where only the more common sunshine measurements have been made. For example, at Athens, Greece the record of sunshine hours extends from 1901 to the present, while solar radiation measurements have been made only during the last few years [1] [12]. Thus the linear relationship cited above can be used to extend the estimate of solar radiation and its frequency distribution over a far longer period than actual records cover.

2. INSTRUMENTS

At the National Observatory, Athens, Greece [12] daily totals of solar radiation are measured by a Gorczinsky pyrheliometer (No. 111, Richard). For comparison a Kipp and Zonen Solarimeter (No. 604) is used. The number of hours of sunshine is recorded by a Campbell-Stokes Sunshine Recorder. Four years of simultaneous measurements of Q and S, 1953 through 1956, are included in this study.

3. CALCULATION OF THE LINEAR RELATIONSHIP

Daily values of $\frac{Q}{Q_0}$ versus $\frac{S}{S_0}$ were plotted for each month and the linear equation for each month was determined by the method of least squares. Examples of such scatter diagrams for the months of March and August are shown in figures 1 and 2.

A lack of scatter in the data for the months of June, July, and August, due to persistent clear conditions made the resulting linear relationships for these months of doubtful value. This difficulty was overcome by approximating the monthly values of b by the average value of b for the other nine months.

4. RESULTS

The monthly values of the constants a and b determined in the above manner are given in table 1. These values give an average of $a=.34$ and $b=.63$. These compare with the values found by Fritz and MacDonald [4] for the United States of $a=.35$ and $b=.61$.

The variation from month to month of a and b and the variation from location to location in annual values of

TABLE 1.—*Monthly values of solar energy (Q_0 and Q/Q_0), sunshine (S_0 and S/S_0), and linear regression coefficients* (a *and* b) *of Q/Q_0 vs S/S_0, Athens, Greece, 1953–56. Q_0 is in ly./day, S_0 in hours/day*

Month	Energy		Sunshine		Intercept a	Linear Slope b
	Q_0	Q/Q_0	S_0	S/S_0		
January	283	.65	9.6	.43	.39	.60
February	365	.72	10.4	.49	.39	.67
March	559	.61	11.5	.50	.29	.65
April	565	.83	12.3	.67	.37	.68
May	628	.83	13.2	.77	.34	.63
June	701	.84	14.2	.87	.29	.63
July	689	.89	14.2	.96	.29	.63
August	656	.85	13.0	.96	.25	.63
September	584	.78	12.5	.80	.32	.58
October	436	.67	10.9	.62	.30	.60
November	277	.74	9.4	.52	.41	.64
December	226	.76	8.6	.55	.44	.58

[1] Some earlier investigations of solar energy at Athens, Greece were reported by Karapiperis [10].

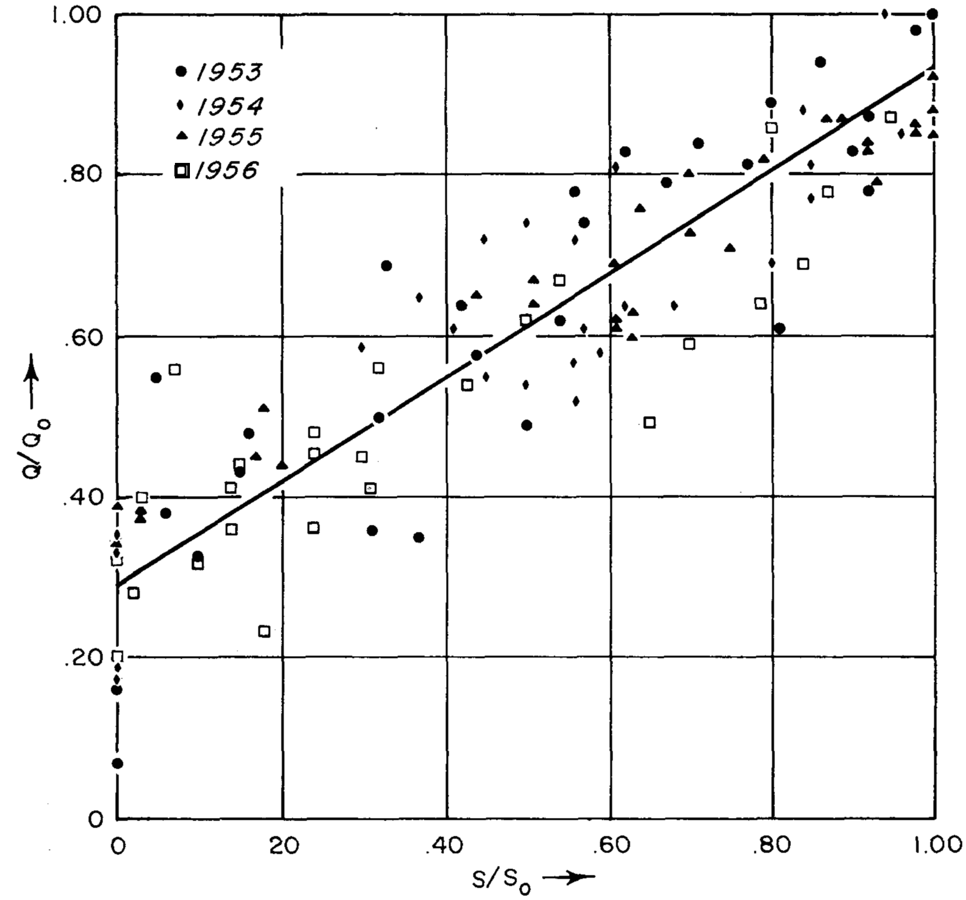

FIGURE 1.—Scatter diagram and linear regression line of Q/Q_0 vs S/S_0 for March, 1953–1956, Athens, Greece.

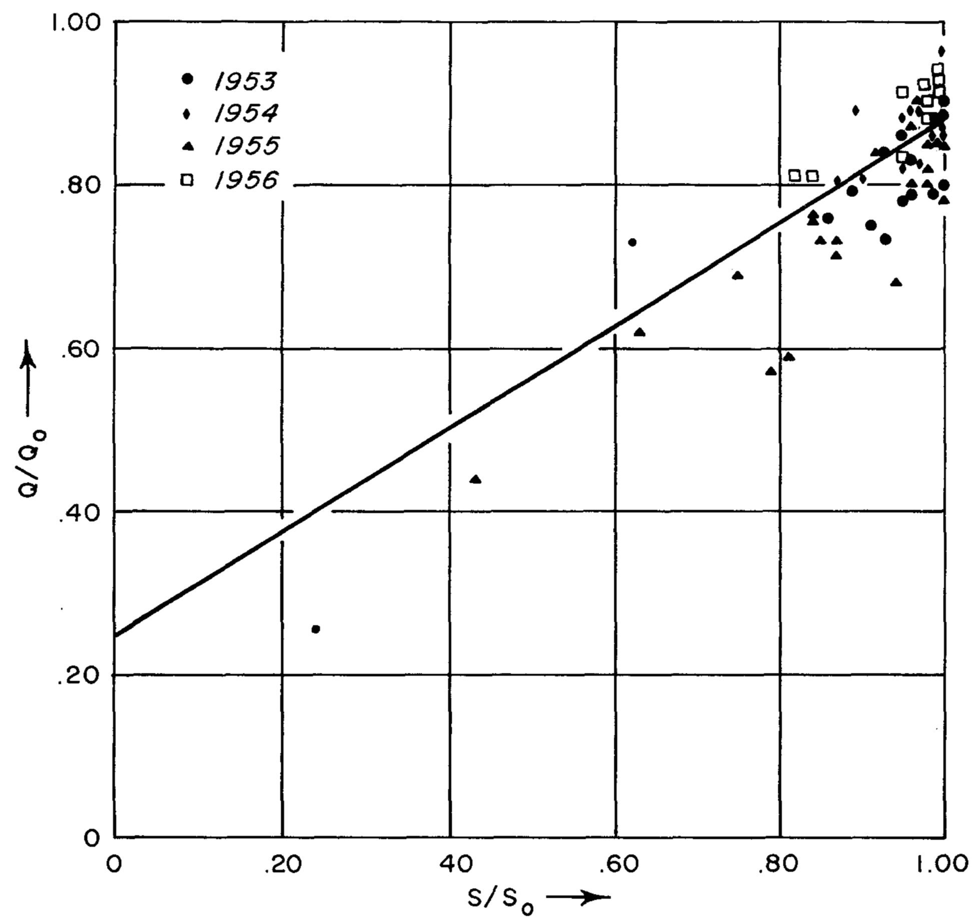

FIGURE 2.—Scatter diagram and linear regression line of Q/Q_0 vs S/S_0 for August, 1953–1956, Athens, Greece.

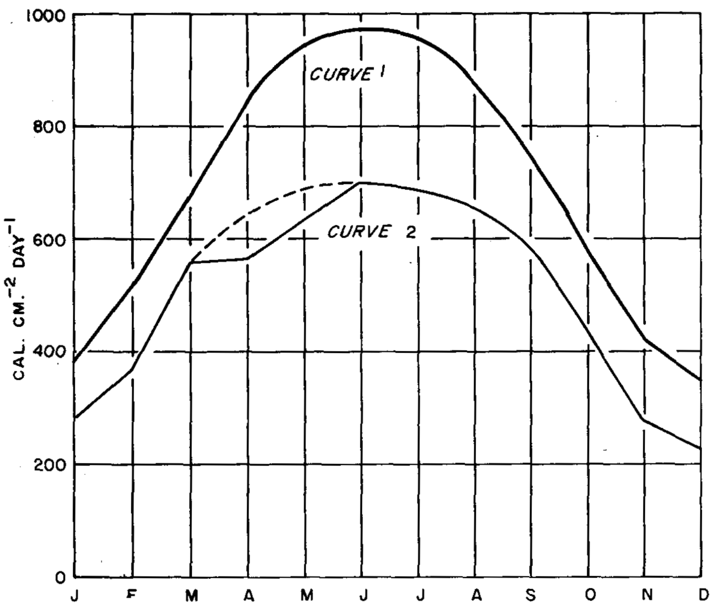

FIGURE 3.—Annual march of solar insolation at top of atmosphere at latitude of Athens, Greece (curve 1). Annual march of maximum solar insolation possible at surface on clear days at latitude of Athens, Greece (curve 2).

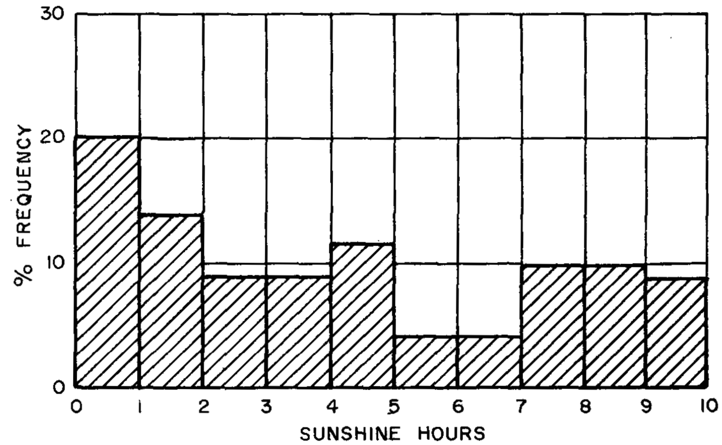

FIGURE 4.—Histogram of total hours of sunshine for January, 1953–1956, Athens, Greece.

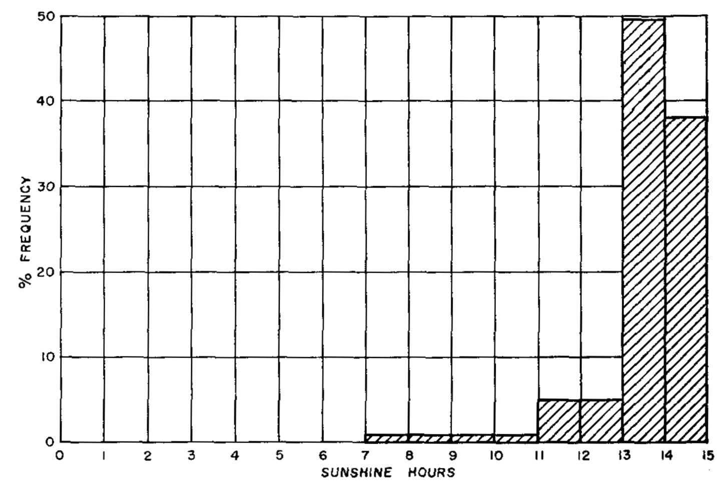

FIGURE 5.—Histogram of total hours of sunshine for July, 1953–1956, Athens, Greece.

these constants are discussed by Ångström [2], Fritz and MacDonald [4], Fritz [5], Kimball [8], [9] and others [6], [7]. Of particular importance in this case are marked seasonal variations in the physical characteristics and distribution of clouds.

Table 1 also contains monthly values of S_o and Q_o as determined from the examination of the maximum perfectly clear day values of S and Q recorded during each month during the period of record.

5. DEPLETION OF SOLAR ENERGY BY THE ATMOSPHERE

Curve 1 of figure 3 is the plot of average daily totals of solar radiation outside the atmosphere at the latitude of Athens, from data by Bernhardt and Philipps [3]. This may be compared with curve 2, a plot of S_o, to illustrate the monthly variation in the depletion of solar radiation by a "clear" atmosphere. The atmosphere is clearer and also drier during the fall and winter than in the summer.

During the months of April and May, the radiation at the surface is lower than expected as curve 2 indicates. This may be due to the additional absorption of solar energy by water vapor in the moist air masses which move off the Mediterranean from the southwest, and which are prevalent in these two months. In other months of the year the prevailing winds are northeasterly [11] and the water vapor content of the atmosphere is much lower.

6. FREQUENCY DISTRIBUTIONS OF TOTAL HOURS OF SUNSHINE

Frequency distribution histograms of the total hours of sunshine were determined for Athens on the basis of records from 1901 until 1956. Two examples of these histograms from 1953 to 1956 are illustrated in figures 4 and 5. Of particular importance is the frequent occurrence of clear days during the summer months. In July 87 percent of the days have more than 13 hours of sunshine. This is in sharp contrast with the more nearly uniform distribution of the winter months with January showing 20 percent of its days with less than one hour of sunshine.

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