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(PUBLICATION 3806)

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It has been the chief work of the Astrophysical Observatory of the Smithsonian Institution to carry out at various high-altitude stations a long series of determinations of the solar constant, the intensity of the sun's radiation outside our atmosphere at mean solar distance. In 1942 the Observatory published in volume 6 of its Annals an extensive summary (table 24) of all solar-constant values for the period 1923 through September 1939. At that time a considerable number of good determinations scattered through the period included in table 24 were examined[1] for correlation with Wolfer sunspot numbers. It was concluded that the data showed little evidence of correlation. This was disappointing, since both solar constants and sunspot numbers are indications of solar activity, and it is therefore reasonable to expect some relationship.

During the past 6 months, my colleagues, Mrs. Gladys T. Bond and William H. Hoover, and I gave a large part of our time to an extension of table 24 to cover the period 1939 through 1944. The extended table thus includes final preferred solar-constant values for each day of observation from 1923 to 1945. This embraces a complete double sunspot period, beginning with the minimum in 1923, through that of 1933, and including the recent minimum in 1944. The time therefore seems opportune to examine these data carefully for a possible relationship with the sunspot cycle.

In order to include all the data available in the extended table 24, monthly means of the solar-constant values were used. These means were compiled from all the daily values, omitting only those graded "poor." In general there are 20 or more days included in each mean. Monthly means of the daily Wolfer sunspot numbers were taken, using in each month only the actual days upon which solar constants were obtained. A total of 251 monthly means of solar constants and corresponding sunspot numbers were included in the double sunspot period extending from July 1923 to May 1944, inclusive. These were

[1] Ann. Astrophys. Obs., vol. 6, p. 196, 1942.

divided into 10 groups of increasing sunspot numbers as summarized in table 1.

TABLE 1

(1923 to 1944)

Sunspot numbers included	No. of monthly means in group	Mean sunspot number	Mean solar constant
0 to 5	22	2.1	1.9449
5 to 11	20	8.3	450
11 to 17	24	13.5	463
17 to 26	26	20.9	472
26 to 38	23	31.0	472
38 to 55	21	44.6	454
55 to 63	29	57.9	454
63 to 74	24	68.4	455
74 to 90	27	81.5	445
90 to 117	22	101.3	439

The means of sunspot numbers and corresponding solar-constant means of table 1 are plotted as curve A (the circled points) in figure 1. The curve indicates an increase of solar constants with in-

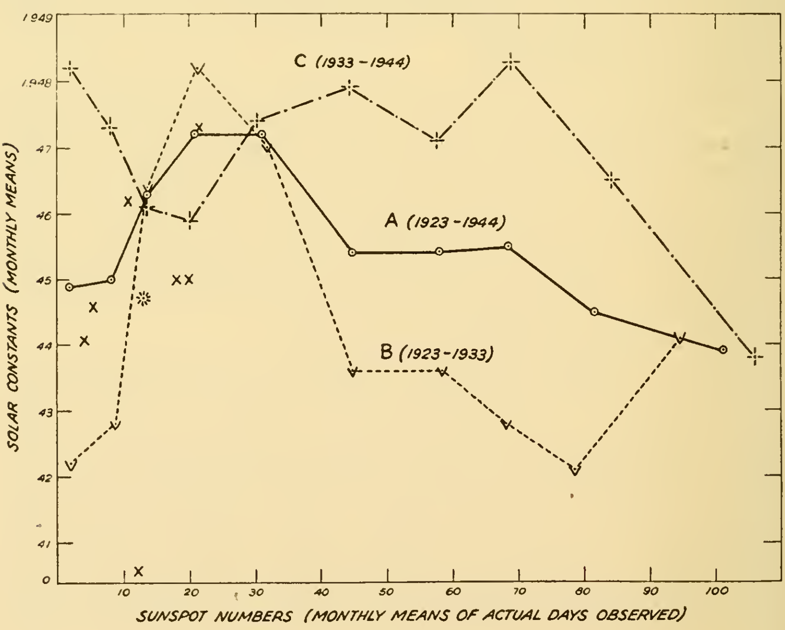

FIG. 1.

crease of sunspot numbers from 0 to 20, followed by a gradual decrease as sunspot numbers continue to increase. The magnitude of this change, about 0.15 percent in the solar-constant means, is disappointingly small, since the total range in solar-constant monthly means is 1 percent.

Hale's discovery of the reversal of polarity in the magnetic fields of sunspots with the advent of a new cycle at sunspot minimum indicated an actual sunspot period of 23 years instead of $11\frac{1}{2}$ years. Abbot's studies of periodicities in solar-constant values also point to the importance of a 23-year period. To test whether any asymmetry

TABLE 2

(1923 to 1933)

Sunspot numbers included	No. of monthly means in group	Mean sunspot number	Mean solar constant
0 to 5	12	2.1	1.9422
5 to 11	10	8.7	428
11 to 17	15	13.6	464
17 to 26	15	21.4	482
26 to 36	12	31.7	470
36 to 55	12	44.6	436
55 to 63	14	58.4	436
63 to 73	12	68.1	428
73 to 85	12	78.5	421
85 +	9	94.5	441

TABLE 3

(1933 to 1944)

Sunspot numbers included	No. of monthly means in group	Mean sunspot number	Mean solar constant
0 to 5	10	2.1	1.9482
5 to 11	10	7.9	473
11 to 17	9	13.4	461
17 to 26	11	20.1	459
26 to 38	11	30.2	474
38 to 52	9	44.6	479
52 to 63	15	57.5	471
63 to 74	12	68.7	483
74 to 100	15	84.0	465
100 to 117	13	106.0	438
117 +	13	132.4	470

existed in the solar constant–sunspot relationship in the two halves of a 23-year period, our 251 monthly means were divided thus:

(1) The 123 months from the minimum in July 1923 to the minimum in September 1933 were grouped as shown in table 2, and plotted as the dotted curve (curve B) in figure 1.

(2) The 128 months from the minimum in September 1933 to the minimum of May 1944 were grouped as shown in table 3, and plotted as the dot-dash curve (curve C) in figure 1.

The contrast between the two curves—B, the first half of the double sunspot period, and C, the second half—is very marked. Curve B starts with low solar-constant values, for zero sunspot numbers. The solar constant increases with increase in sunspot numbers to 20, gradually decreases up to about 80 sunspot numbers, and then again increases. Curve C, on the other hand, starts at zero sunspots with high solar-constant values, decreases with increasing sunspot numbers up to 20, increases gradually to 70 sunspot numbers, and finally decreases rapidly. The range from maximum to minimum solar-constant mean in each of these curves is about 0.3 percent, twice as great as in curve A.

The question naturally arises as to whether these curves would repeat themselves in other sunspot cycles. From a review of the Mount Wilson solar-constant work in the years 1905 to 1920, we can draw no conclusion because the values are so few and so comparatively inaccurate. For the cycle succeeding the 1944 minimum we have 7 months available. The individual monthly means are added as crosses in figure 1. All seven points tend to cluster more nearly around curve B than curve C, and the mean of the seven (the starred point) lies fairly near curve B. Thus the present cycle may be repeating the 1923 to 1933 curve.

These results probably modify somewhat the prediction as to solar variation shown in figure 14 of the Annals, volume 6. The extension of curve B of figure 14 from 1939 to 1945 was based on table 32, wherein the aggregate effect of 14 periodicities in solar variation is computed. These periodicities did not include any consideration of sunspot effects. Now if curve B of figure 1 continues to be followed in 1944 and 1945, there should be superposed on the extension of curve B of figure 14, Annals, volume 6, a rapid rise of .006 calorie as the sunspots increase from the minimum value in May 1944. This would considerably modify the form shown in the predicted curve. In fact, the predicted curve was followed fairly closely until November 1944, but November and December have carried the curve up instead of down. If it is suggested that the sunspot effect should have similarly affected the solar-constant minimum of 1922-1923, it may be pointed out that the minimum of sunspots occurred in July 1923, 2 years later, with respect to the solar-constant drop of 1922, than the minimum of May 1944 with respect to the expected solar-constant drop in 1944. Hence its effect in 1923 would not be similar to that of 1944.

No adequate explanation is offered for the surprisingly opposite trend of the curves B and C of figure 1, nor for the inversion points at 20 sunspot numbers and again at about 75 sunspot numbers. Possibly the average transmissivities of the external envelopes of the solar atmosphere change in a complex and undiscovered way with the development of the sunspot cycle, resulting in the curious relationships shown in the two curves.

The following words which form the concluding paragraph of Dr. Evershed's recent article "The Magnetic Effect in Sunspot Spectra" [2] are apropos:

> It seems that sunspots, with all their very widespread subsidiary phenomena, which at times are highly spectacular, must indicate something fundamental in the constitution of the Sun. So much has been discovered about these strange markings, and yet so little success has been achieved in co-ordinating all the facts, and forming a consistent picture of what is actually taking place, or is causing these remarkable phenomena. Perhaps we may never know why there should be these periodical outbursts of solar magnets. Terrestrial physics may fail us. One would have thought that by this time, that is to say after two or three thousand million years, a great mass of gas like the Sun would have settled down to a state of calm uniformity without spots or prominences or other strange happenings.

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[2] The Observatory, vol. 65, p. 193, June 1944.