A LONG PERIOD SUNSPOT VARIATION.[1]

It has long been known, and Dr. Rudolf Wolf of Zurich was the first to draw attention to it, that the length of a sunspot period is only in the *mean* eleven years, and that the real length of any one period might differ from this value by as much as ± two years. Another fact of observation is that the times of maxima do not occur a constant number of years after a preceding minimum, and Dr. Wolf determined the *mean* interval as 4·5 years. The minimum also follows the maximum in a *mean* interval of 6·5 years.

It has further been noticed that the intensity of each period, *i.e.* the total amount of spotted area included between one minimum and the next, was not constant. Dr. Wolf held that these quantities indicated a certain periodicity, and at first suggested a period of 178 years, and later 55·5 years, or a period extending over five eleven-year periods (11·1 × 5 = 55·5).

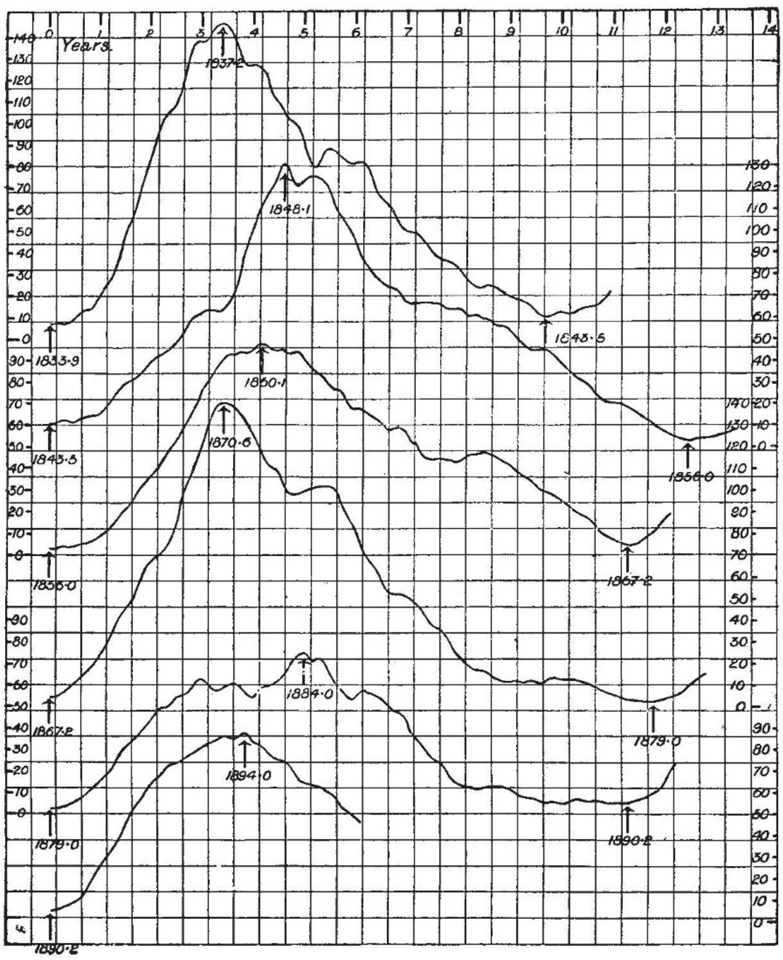

FIG. 1.

The present investigation was limited to the interval of time, namely, 1833–1900, over which *systematic* observations of the sun's surface have been regularly made, and as Dr. Wolf's relative numbers agree well with the actual facts of observation over this period, these numbers have been employed.

The important magnetic results obtained by Mr. William Ellis served as a check on the whole work, since he has shown that the curves for the magnetic elements are in almost exact accord with those of the sunspots. Any variations determined from the sunspot curves should, then, have their counterpart in the magnetic curves.

[1] Abstract of a paper, "The Solar Activity 1833–1900," read before the Royal Society on May 23, by Dr. William J. S. Lockyer.

Fig. 1 will give the reader an idea of each sunspot curve from minimum to minimum for the period above mentioned.

They are so arranged in order of date that each individual curve can be examined separately. The times of succeeding minima are arranged vertically under each other, so that any variation as regards acceleration or retardation of the following maxima, and any inequality in the length of the period minimum to minimum can be seen at a glance; each of these epochs is indicated in the figure by a short arrow with the corresponding dates.

Dealing with the inequalities of the interval minimum to maximum, it is found that there is a regular variation having a period of about thirty-five years. Curve B, Fig. 2, shows this variation, the abscissæ representing the time element and the ordinates the intervals minimum to maximum plotted at the epochs of the minima.

Dealing with the intervals minimum to maximum of the magnetic curves in a similar way, the result obtained is shown in the same figure, curve C.

Both these curves thus indicate that there is some law at work which introduces a secular variation by retarding periodically the sunspot maxima in relation to the preceding minima. The actual epoch of maximum relative to the preceding minimum oscillates about the mean value 4·12 years, its greatest amplitude being in the mean about 0·8 year.

Another point of great importance is that when the epoch of maximum spotted area follows in the shortest interval of time after a minimum, the spotted area for the whole period is greater than at any other time.

Thus, if the spotted area included between consecutive minima be summed up for each period, and these values, used as ordinates, be plotted at the epochs of minima, as done previously, and the curve inverted, curve D Fig. 2 is the result. It will be noticed that this curve is very similar to the two immediately above it, and shows a period of about the same length, namely, about thirty-five years. It may be here remarked that the value for the total spotted area for the period 1833·9 to 1843·5, the earliest value in point of time dealt with, is not quite in harmony with the other values. There seems, however, sufficient evidence to indicate that the small value may be due to the fact that the observations were not then made quite on a uniform plan. That the maximum of 1836 was a great one, and only equalled by that of 1870, is well known.

The discussion of these observations thus leads to the important conclusion that *underlying the ordinary sunspot period of about eleven years there is another cycle of greater length, namely, about thirty-five years.*

This cycle not only alters the time of occurrence of the maxima in relation to the preceding minima, but causes changes in the total spotted area of the sun from one eleven-year period to another.

A glance at Fig. 1 will show that the length of the period minimum to minimum seems to alternate, the magnitude of these alternations becoming smaller. An attempt was made to see if any law could be traced, but although there was a variation suspected in the length of both the magnetic and sunspot periods (reckoning from minimum to minimum), which increases and decreases in *alternate* eleven-year periods from a mean value, the observations do not extend over a sufficient interval of time to allow a more definite conclusion to be drawn.

It is generally conceded that the spots on the surface of the sun are the result of greater activity in the circulation in the solar atmosphere, and therefore indicate greater heat and, therefore, light. This being so, the curve representing the spotted area may be regarded as a light curve of the sun

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The sun may thus be considered a variable star (1) the light of which (reckoning from minimum to minimum) is variable, with a mean value of about 11·1 years; (2) the epoch of maximum does not occur a constant number of years after the preceding minimum, but varies regularly, the cycle of variations covering about thirty-five years.

It is interesting, therefore, to know that the sun is not the only star which exhibits variations similar in kind to those mentioned above, for the light curve of η Aquilæ not only has a more rapid rise to maximum and slow fall to minimum, but the periods from minimum to minimum vary in length, and the interval minimum to maximum has a regular variation.

Since then, in addition to the well-known eleven-year period of sunspot frequency, there is another cycle which extends over about thirty-five years, and which is indicated clearly, as has been shown, both by the changes in the times of the occurrence of the epochs of maxima and in the variations in area included in consecutive eleven-year periods of both sunspot and magnetic curves, it is only natural to suppose that this long-period variation is the effect of a cycle of disturbances in the sun's atmosphere itself.

Such a cycle, if of sufficient intensity, should cause a variation from the normal circulation of the earth's atmosphere, and should be indicated in all meteorological and like phenomena.

We are indebted to Prof. Ed. Brückner for the great work on the changes in climates, and in this investigation he sought variations in the observations of the height of the waters in inland seas, lakes and rivers; in the observations of rainfall, pressure and temperature; in the movements of glaciers; in the frequency of cold winters; growth of vines, &c.

The result of the whole of the investigation led him to the conclusion that there is a *periodical variation in the climates over the whole earth, the mean length of this period being* 34·8 ± 0·7 *years*.

Prof. Brückner was so convinced of the undoubted climate variations which he deduced, and so certain that such variations could only be caused by an external influence, that he investigated Wolf's sunspot numbers to see whether such a cycle was indicated. Not finding any he was led to make the bold suggestion that such a variation as he sought must really exist in the sun, but might possibly be independent of sunspots. He finally concluded that the climate variations are the first symptom of a long period variation in the sun, which probably will be discovered later.

In the light of the secular period of solar activity dealt with in this article, Prof. Brückner's conclusions are of great interest, because not only does the length of the period, but the critical epochs of his cycle completely harmonise with those found in the present discussion of the sunspot and magnetic curves.

To illustrate more fully this connection and to take only one case, namely, rainfall, three rainfall curves which have been copied from his book are reproduced in Fig. 2 (curves E, F, G).

E and F represent the secular variations for what Prof. Brückner calls "Reguläre Gebiete I and II," while curve E is the mean for the whole set of observations he has employed, and represents the secular variation of rainfall over the whole earth so far as can be determined.

The comparison of these curves with those representing the sunspot and magnetic results given above them shows that when the epoch of maximum spotted area (curve B) follows late after the preceding epoch of minimum (1843, 1878), or when the spotted area from minimum to minimum is least (curve D), the long period rainfall curve is at its maximum or we have a wet cycle. When, on the other hand, the maximum (curve B) follows soon after the preceding minimum (1867), and the spotted area for this cycle is at a maximum (curve D), the rainfall curve is at a minimum or a dry cycle is in progress.

Prof. Ed. Richter, in a detailed investigation of the movement of glaciers, has also found a cycle of thirty-five years, and he pointed out that the variations agreed generally with Brückner's climate variations, the glacier movement being accelerated during the wet and cool periods.

Again, Mr. Charles Egeson not only finds a secular period of about thirty-three to thirty-four years in the occurrence of rainfall, thunderstorms and westerly winds in the month of April for Sydney, but the epochs of maxima of the two latter harmonise with the epochs of the thirty-five yearly period deduced for sunspots.

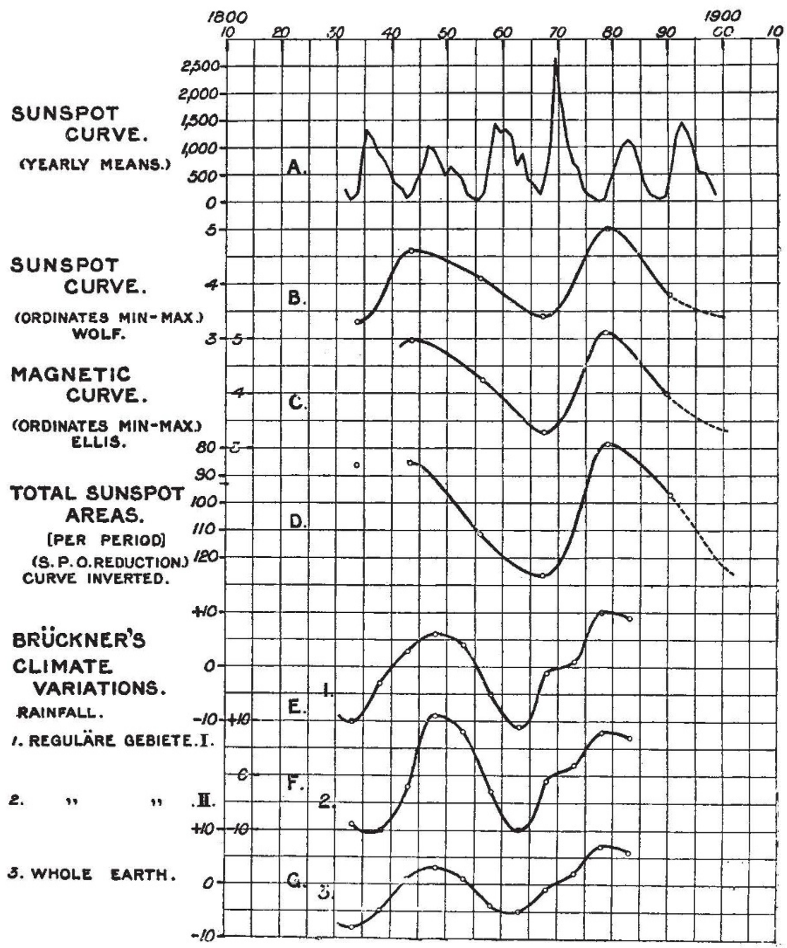

FIG. 2.

There seems little doubt that, during the interval of time covered by the present sunspot discussion, the meteorological phenomena, number of auroræ, and magnetic storms show secular variations of a period of about thirty-five years, the epochs of which harmonise with those of the secular variations of sunspots. As we are now beginning to approach another maximum of sunspots which should correspond both in intensity and in time of occurrence after the epoch of the present minimum with that of 1870·8, it will be interesting to observe whether all the solar, meteorological and magnetical phenomena of that period will be repeated.

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