SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 95, NUMBER 19

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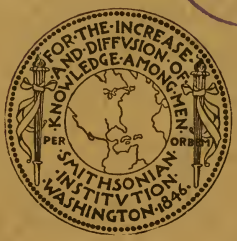

(PUBLICATION 3402)

CITY OF WASHINGTON
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In my paper "Solar Radiation and Weather Studies"[1], I showed that the variation of the sun's emission of radiation since 1920 is the summation of at least 12 periodicities ranging from 7 months to 23 years in length. All of them are approximately, perhaps exactly, aliquot parts of 23 years. Hence, 23 years is a cycle wherein we might expect the weather and things dependent on it would show marked recurring features. Furthermore, although hitherto mathematical analysis has not disclosed why the sun's radiation should exhibit a fundamental and many overtones like a violin string, yet since observations show that it does so, it may well be that the fundamental is not 23 years, but 46, 92, or some other multiple of 23 years.

In my paper just cited I went on to show that all of the solar periodicities are also found in weather records of six stations (one of them, Adelaide, Australia, by the way) during the past century. Moreover, the 23-year cycle is to be found in varves of glacial age, in widths of tree rings in California and the West, in the levels of lakes and rivers, in the weather of the United States, and in other phenomena. It proved also that in many phenomena, and notably so in the levels of the Great Lakes and in the associated droughts in the Northwest, the 46-year cycle is predominant.

Recently Prof. C. J. Lyon, of Dartmouth College, has published a paper[2] on his measurements of widths of tree rings at six localities in Vermont and New Hampshire. My attention was particularly drawn to his figure 3, wherein he plots the average results through the whole range of time they cover. The locality Fairlee, Vermont, has the longest record, extending from 1544 to the present time, almost four centuries. Having graduated a slip of paper in 23-year intervals, I thought I could see in Professor Lyon's diagram a well-marked cycle of variation of this period throughout the entire series.

Professor Lyon has been so kind as to send me his original observations on the trees at Fairlee, and has graciously consented to let me

[1] Smithsonian Misc. Coll., vol. 94, no. 10, 1935.
[2] Ecology, vol. 17, no. 3, July 1936.

publish a statement of my reduction of them from the point of view of the 23-year cycle.

In the first place, the range of tree-ring widths is very great. After 1800, the widths as measured averaged several times as great as from 1544 to 1720. Hence for a fair comparison I thought it necessary to first approximately reduce all the data to a common scale. That such a reduction might not introduce a deformation of any 23-year cycle, I made the reductions at intervals which were in every case multiples of 23 years after 1544. The factors employed were as follows:

Interval	1544-1727	1728-1796	1797-1842	1843-present
Reduction Factor.....	1.0	0.8	0.4	0.3

With these changes the resulting mean tree-ring widths from Professor Lyon's measurements for Fairlee, Vermont, are as shown in table 1.

The values are arranged in 17 successive cycles of 23 years each. At the head of each column stands the first year of the cycle, so that the dates corresponding to all values may readily be obtained.

It was soon noted that every fourth cycle, the 1st, 5th, 9th, 13th, and 17th, differed decidedly in type from the average form of the others. This is but to say, of course, that there is a pronounced 92-year cycle in the tree-ring widths. It was noted, too, that five of the cycles, some belonging to the group just mentioned, some to the majority group, were partly intermediate between this type and the prevailing type of the 23-year cycle fixed by the remaining twelve cycles. These of intermediate type are the 2d, 7th, 9th, 10th, and 13th. Columns 18, 19, and 20 of the table give the mean forms of the three types just described. They are shown graphically in figure 1, C, A, B.

The range in widths of the prevailing mean form is about 50 percent, and that of the 92-year type about 70 percent, as based in each case on the smallest mean values. A large difference in average widths also distinguishes the two types. The average width for the mean of the five cycles (curve C) is 0.41 and that of the mean of the twelve (curve A) is 0.50, a range of 22 percent.

I have also sought to discover a periodicity of 46 years in the tree-ring widths for Fairlee. For this purpose the values were arranged in eight columns of 46 successive years each. The last column ends with the year 1911. It was soon noted that the columns alternately revealed forms of contrasting types. In figure 1, D, E, I show the mean form of the odd-numbered 46-year cycles in the lower curve, and the

TABLE 1.—*23-Year Periodicities*

1 1544 to 1566	2 1567 to 1589	3 1590 to 1612	4 1613 to 1635	5 1636 to 1658	6 1659 to 1681	7 1682 to 1704	8 1705 to 1727	9 1728 to 1750	10 1751 to 1773	11 1774 to 1796	12 1797 to 1819	13 1820 to 1842	14 1843 to 1865	15 1866 to 1888	16 1889 to 1911	17 1912 to 1934	18 Mean of 1-5-9-13-17	19 Mean of 2-4, 6-8, 10-12, 14-16	20 Mean of 2-7-9-10-13
2.4	2.4	3.0	5.4	6.0	4.0	4.2	3.6	5.6	5.8	4.8	2.9	3.8	3.1	6.1	6.4	3.4	4.2	4.2	4.4
2.4	3.0	4.2	4.8	6.0	3.6	4.2	5.4	6.6	6.2	5.8	2.2	3.6	4.4	5.8	7.6	4.3	4.6	4.6	4.7
4.2	3.6	3.0	4.8	7.0	2.9	4.8	4.2	6.7	5.8	5.6	2.4	4.3	4.4	5.1	6.7	3.8	5.2	4.4	5.0
4.8	3.0	3.0	6.1	4.8	2.3	4.8	3.7	7.7	5.8	7.7	2.8	5.2	3.2	3.2	7.3	4.4	5.4	4.3	5.3
3.6	3.7	3.6	4.8	3.7	2.6	4.8	4.8	6.6	5.3	6.8	3.6	4.8	3.3	5.0	7.0	5.5	4.8	4.4	5.0
3.6	3.6	3.6	4.3	3.6	3.7	4.8	3.2	6.6	7.2	5.8	4.2	4.5	5.2	4.7	5.0	3.7	4.4	4.6	5.3
3.6	3.7	3.6	6.0	4.8	3.0	4.8	4.2	7.7	6.6	7.7	4.0	3.5	4.5	3.8	4.4	2.6	4.4	4.6	5.3
1.2	4.8	4.7	4.8	4.8	2.5	5.4	5.0	6.7	5.3	6.6	3.4	5.0	2.2	3.2	5.0	3.7	4.3	4.1	5.4
2.4	4.8	5.4	5.7	4.0	3.5	5.0	3.0	6.6	6.7	6.8	4.6	5.3	7.1	5.2	5.7	2.6	4.2	5.1	5.7
2.4	6.0	3.7	4.8	2.4	3.6	3.6	4.7	7.7	7.7	6.2	3.4	4.2	5.6	5.3	7.8	4.7	4.3	5.4	5.8
2.4	6.0	5.0	6.0	2.4	3.6	4.8	5.4	7.2	6.7	5.8	5.3	4.8	4.5	4.6	4.4	3.9	4.1	5.2	5.9
1.8	6.0	4.2	6.0	3.6	2.5	5.4	3.2	6.2	5.6	6.6	5.1	4.9	4.2	3.8	3.8	2.8	3.9	4.6	5.6
2.8	3.6	6.0	8.4	3.1	5.4	4.3	5.0	6.7	6.2	8.6	5.8	4.1	4.9	5.6	4.3	3.8	4.1	5.4	5.0
2.8	4.2	6.0	9.6	2.4	4.8	6.0	6.6	4.8	7.7	8.2	6.2	5.5	6.4	4.5	6.7	4.0	3.9	6.5	5.6
2.5	5.0	5.4	7.2	2.4	5.4	5.4	6.0	5.8	5.3	8.2	7.4	5.8	6.2	6.6	6.5	3.9	4.1	6.1	5.5
2.5	4.7	4.8	6.6	3.2	6.6	4.8	6.0	4.0	4.0	6.8	6.8	4.0	6.2	4.5	4.8	4.2	3.6	5.9	4.3
4.8	3.7	4.2	7.0	3.6	5.4	4.8	7.3	5.3	3.8	5.3	4.9	3.0	4.3	6.0	4.4	4.6	4.3	5.1	4.1
3.6	3.0	3.7	7.0	3.6	6.0	4.0	5.4	5.3	3.8	4.8	5.5	3.0	5.5	4.3	4.3	4.8	4.1	5.1	3.8
3.6	3.7	4.8	5.0	4.2	6.0	3.0	3.6	5.3	5.8	4.3	6.6	4.5	5.0	4.6	3.7	2.6	4.0	4.9	4.5
3.6	2.4	4.8	4.8	2.5	6.6	4.2	6.0	5.3	4.8	5.8	5.4	3.2	4.4	3.7	3.7	1.8	3.3	4.8	4.0
3.6	2.4	5.4	4.8	4.7	4.2	4.2	6.0	3.8	5.8	5.6	5.2	3.6	5.9	5.0	3.1	2.0	3.5	4.7	4.0
3.6	3.0	4.8	5.4	3.6	6.0	4.2	7.0	3.8	5.8	5.8	4.6	3.4	4.7	4.6	3.8	1.4	3.2	5.0	4.0
3.0	3.6	4.8	4.0	2.5	6.0	3.5	7.0	4.8	5.8	5.8	4.7	5.4	4.3	4.9	2.6	1.1	3.4	4.8	4.6

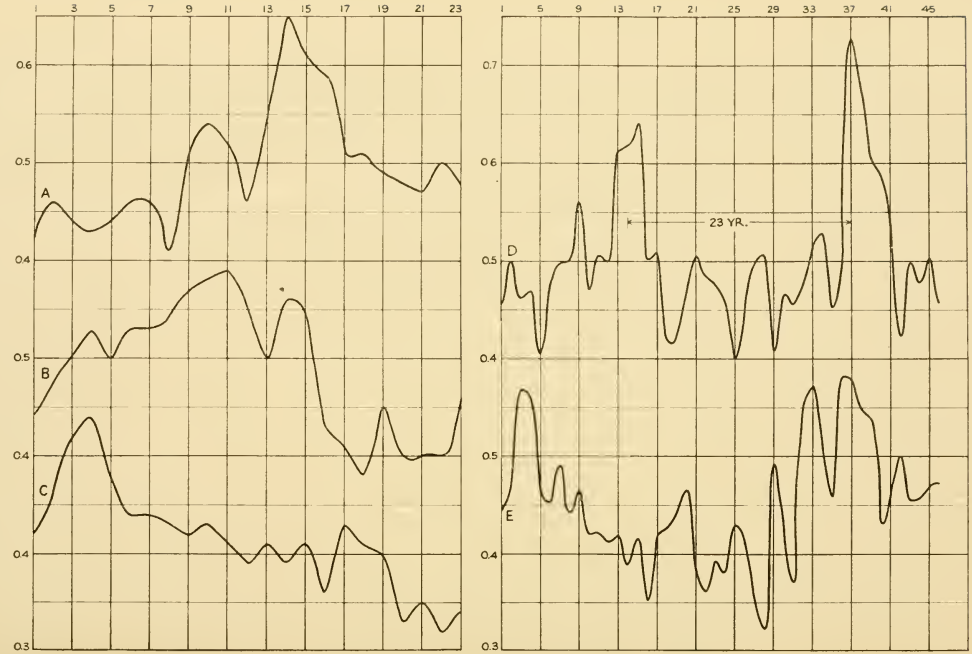

FIG. 1.—Cycles of 23, 46, and 92 years in tree-ring widths, Fairlee, Vermont.

A, the usual 23-year cycle, mean of 12 recurrences. B, an intermediate form of 23-year cycle, mean of 5 recurrences. C, the 23-year cycle which occurs once each 92 years, mean of 5 recurrences. D and E, alternate forms of the 46-year cycle. Each is the mean of 4 recurrences which occur in regular alternation in these contrasting forms. The 23-year cycle shown in D therefore confirms the 92-year cycle shown in C.

mean form of the even-numbered 46-year cycles in the upper curve. It will be observed at once that they differ in that the upper curve shows a strong 23-year cycle additional to that of 46 years, while in the lower curve this feature is missing. This, of course, is but to emphasize the fact already brought out above, namely, there is a strong 92-year cycle besides those of 23 and 46 years.

I suspect that meteorologists are rather inclined to distrust the origin and existence of the 23-year cycle which was indicated in my former paper as arising from the variability of solar radiation and expressing itself in weather and many phenomena depending thereon. Their hesitation is no doubt due to the smallness of the percentage and the absence of a theory of the solar variations, and to the reversals of phase which occur in the terrestrial manifestations of the subordinate solar periodicities, as strikingly illustrated in figures 16 and 17 of my paper "Solar Radiation and Weather Studies". I have still nothing to offer but statistical proofs of the important influences of the many periodicities integrally related to 23 years, but I feel somewhat supported in my conclusions by the recent paper of E. A. Cornish[3] on the precipitation at Adelaide, Australia, and the unreserved acceptance of this period as real by Dr. F. J. W. Whipple while he criticized the method of Mr. Cornish in presenting it.

In closing, I may draw attention to an important inference from this study of Professor Lyon's measurements of the tree-ring widths at Fairlee, Vermont. The 46-year cycle seems to be clearly in evidence since the year 1544, and covering eight recurrences of it. Counting back from the year 1911 when the eighth cycle ends (see curve D, fig. 1), we find that the low phase, corresponding no doubt to deficient water supply, ended about 1896. Now referring to figure 26 B of my paper "Solar Radiation and Weather Studies", the low phases of Lakes Huron and Erie also ended about 1896, and also 46 years previously thereto, at the ends of the great droughts of the forties and the nineties of the nineteenth century in our Northwestern States. Does not this long-continued series of 46-year precipitation cycles at Fairlee plainly warn us of the probable recurrence of a major drought beginning soon after the year 1975, and lasting about 10 years?

[3] Quart. Journ. Roy. Met. Soc., vol. 62, p. 481, 1936.