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PERIODS RELATED TO 273 MONTHS OR 22-3/4 YEARS

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This period was discovered in the variation of the measures of the solar constant of radiation, made daily by the Smithsonian Astrophysical Observatory from 1920 to 1952. It was first glimpsed in 1935,[1] and noted in various terrestrial phenomena, such as temperatures, precipitation, width of tree rings, and levels of lakes. The level of Lake Huron, since 1837, has followed related periods of about 23, 46, and 91 years. I ventured, in 1938, to predict droughts during the 1950's, the 1970's, and the 2020's, based on recurring periodic depressions of the level of Lake Huron. The first of these predictions is now verified.

1. PERIODS FOUND IN SOLAR-CONSTANT MEASUREMENTS

The "solar constant of radiation" is the term in use to describe quantitatively the intensity of the sun's radiation, as it would reach points in space outside the earth's atmosphere, at the earth's mean distance from the sun.

Smithsonian measurements over many years, made at stations ranging from sea level to 14,400 feet altitude, and supplemented by automatic records at 15 miles of elevation from sounding balloons, yield as the value of the solar constant 1.946 calories per square centimeter per minute. A recent revision by F. S. Johnson,[2] in which he used the latest data from high rocket flights to improve the Smithsonian estimates in the extreme ultraviolet spectrum, yielded the value 2.00 cal. ± 0.04 cal. His value differs from the Smithsonian value by little beyond the probable error of either one. For purposes of estimating solar periodic variations, this small difference as to the basic value is inconsequential.

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[1] C. G. Abbot, Solar radiation and weather studies, Smithsonian Misc. Coll., vol. 94, No. 10, 1935.

[2] Journ. Meteorol., vol. 11, No. 6, December 1954.

What is important for the proof of variation is the accidental error of Smithsonian daily observations of the solar constant. There are several determinations of it. From volume 6 of the Annals of the Smithsonian Observatory, page 163, I quote the differences, in thousandths of a calorie, between daily values of the solar constant obtained at Smithsonian stations in the Northern and the Southern Hemispheres, respectively. This comparison covered all days observed in both hemispheres for the years 1932 to 1936, numbering 616.

TABLE 1.—*Numbers of daily differences in solar-constant measures, 1932 to 1936, having different amplitudes.*

Amplitudes in thousandths of a calorie.

Amplitudes	22–28	20–22	18–20	16–18	15	14	12	11	10	
No. of days....	17	12	10	35	13	15	20	22	27	
Product	391	252	190	595	195	210	240	242	270	
Amplitudes	9	8	7	6	5	4	3	2	1	0
No. of days....	34	30	35	43	51	55	55	37	48	35
Product	306	240	245	258	255	220	165	74	48	0

Total days 616. Total of products 4,682.
Weighted mean daily difference, 7.60 thousandths of a calorie.

Mrs. Hill has made for me similar tables for more recent differences between daily solar-constant results, where measures at Montezuma, Chile, are compared to those of Table Mountain and Tyrone in the United States, and those at Table Mountain, Calif., to those at Tyrone, N. Mex. For these three cases the weighted mean differences are 7.68, 7.96, and 7.79 thousandths of a calorie. These results cover all days measured at both stations from 1940 to 1952. They number, respectively, 891, 283, and 202 days. The weighted mean difference is 7.75 thousandths calorie. As the results of these recent years differ but slightly from those of 1932 to 1936 shown in table 1, we may adopt 7.7 thousandths of a calorie as the weighted mean average daily accidental difference between results of widely separated stations observing the solar constant. Assuming the stations to be of equal accuracy, that gives for the percentage accidental error of a solar-constant measure of one day at one station:

$100 \times 0.00385 \times 0.84 \div 1.946 = 0.166$, or ⅙ percent of the solar constant.

I use 10-day and monthly solar-constant values in my investigations. For these the percentage probable error (if all days of these intervals were observed) becomes $\frac{1}{6} \div \sqrt{10}$ and $\frac{1}{6} \div \sqrt{30}$, or $\frac{1}{19}$ and $\frac{1}{33}$ percent of the solar constant.

A single supposed periodic appearance from mean monthly data, with an amplitude four times as great, or 4/33 percent, would have some claim to veridity. Using monthly means from 1924 to 1952, 348 in number, all periods shorter than 45 months would have 8 or more repetitions. The criterion for probable veridity would be a percentage range exceeding $\frac{4}{33} \div \sqrt{8} = \frac{1}{23}$ percent of the solar constant for a 45-month period. The requirement decreases as the square root of the number of repetitions increases. Thus for a period of 4⅓ months, my shortest used in syntheses, it would be 1/72 percent. The 1/23 percent of the solar constant is 0.0008 calories.

RANGES OF PERIODS IN SOLAR-CONSTANT MEASURES, WHICH ARE ALIQUOT PARTS OF 273 MONTHS

In my paper "Periodic Solar Variation,"[3] I list in table 2 64 periods. They range in amplitude as follows:

TABLE 2.—*Ranges of periods discovered, in percentage of the solar constant*

Periods in months	136.5–45	39–25	23–15	14–10	10–6	5–4.5
Number	5	5	5	5	5	5
Amplitudes, %	0.09–0.18	0.05–0.21	0.03–0.08	0.02–0.11	0.06–0.13	0.02–0.08
Periods in months	4.4–3.7	3.5–2.9	2.7–2.4	2.1–1.7	1.7–1.3	<1.3
Number	5	5	5	5	5	9
Amplitudes, %	0.03–0.06	0.03–0.04	0.02–0.08	0.02–0.04	0.02–0.04	>0.02

All these 64 periods, so far as ranges of amplitude indicate, fall within the criterion for veridity based on accidental error of observation.

OTHER EVIDENCES OF VERIDITY

Referring again to the last-cited paper, figures 1 and 2 therein show how the curves of observed periods which are aliquot parts of 273 months stand out more and more plainly, as superriding periods whose lengths are also aliquot parts of 273 months are removed. Figure 3 of that paper shows how strongly the smoothed curves resemble sine curves when cleared of such superriders.

Still more convincing indications of the veridity of a large number of the periods found in solar-constant measures will appear in following sections, as we note how periods in quite different phenomena are identical with them.

[3] Smithsonian Misc. Coll., vol. 128, No. 4, 1955.

2. PERIODS RELATED TO 273 MONTHS FOUND IN WEATHER

In an important paper published in 1947,[4] I discovered, both in solar variation and in Washington temperature departure from normal, a period of 6.6456 days. This solar periodic variation recurred with perfect regularity in its phases from 1923 to 1944. The Washington periodic variation in temperature departures, though frequently out of phase, yet for any single month of the 12 months of the year in the entire interval from 1910 to 1945 averaged exactly the same length as the sun's variation, namely 6.6456 days. I did not then understand why phase changes occurred from time to time in Washington temperature departure. It is now quite clear to me, as will appear below.

Not until 1953 did I perceive that this period of 6.6456 days, so strongly evidenced, belongs to the family of submultiples of 22¾ years. For 22¾ × 365.2564 days = 8309.5831 days. Dividing by 6.6456, we have 1250.38, or within 1/30 percent of 1250. So it is probably an exact submultiple of 273 months, to an accuracy far beyond the precision of the data.

In the years 1952 to 1955 I published eight papers on the control of weather by the family of periods related to 273 months.[5]

Before particularizing these weather investigations, I wish to emphasize that they stand entirely on meteorological records. Meteorologists are apt to say that the variations of the sun are too small to influence terrestrial weather appreciably. But solar-variation measures play no part in my studies just cited. The periodicities in weather which relate to 273 months are to be found in weather records themselves. No further reference to solar measures is required. Periodic variations in precipitation are large. They range from 5 to 25 percent of normal for the individual periodicities. In temperature departures they range up to 5° F.

These large periodic changes of weather related to 273 months lie buried in the published records and may be demonstrated from them. No reference to solar variation is required to find them.

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[4] The sun's regular variation and its large effect on terrestrial temperatures, Smithsonian Misc. Coll., vol. 107, No. 4, 1947.

[5] Periodicities in the solar-constant measures, Smithsonian Misc. Coll., vol. 117, No. 10, 1952; Important interferences with normals in weather records, associated with sunspot frequency, ibid., No. 11, 1952; Solar variation and precipitation at Peoria, Illinois, ibid., No. 16, 1952; Solar variation and precipitation at Albany, N. Y., ibid., vol. 121, No. 5, 1953; Long-range effects of the sun's variation on the temperature of Washington, D. C., ibid., vol. 122, No. 1, 1953; Solar variation, a leading weather element, ibid., No. 4, 1953; Sixty-year weather forecasts, ibid., vol. 128, No. 3, 1955; Periodic solar variation, ibid., No. 4, 1955.

These periodicities in weather cannot be satisfactorily demonstrated without attending to several steps made necessary by changes of the atmosphere.

1. Normals and departures must be separately tabulated for times of high Wolf sunspot numbers, and of low Wolf numbers. I am accustomed to drawing the line at 20 Wolf numbers.

2. For all the shorter periods (i.e., <15 months) the months of the year must be used in several separate groups because atmospheric conditions differ. I am accustomed to dividing the year into three groups: January-April, May-August, September-December. I omit this grouping after periods of 15 months. Beyond that, too few columns would generally be available in a tabulation, and the division of the year into several groups is less important compared to the length of periods. The division of data into three groups mentioned above indeed leaves the tables with too few columns to yield satisfactory means. Therefore I make the assumption that the form and amplitude of periods in different seasons will be sufficiently similar to permit combination of six separate tables for the three seasons and two ranges of Wolf numbers into one by shifting them all to a common phase. But when such a combined table is used in a synthesis its general mean must always be restored to the proper phase in the synthesis.

3. As the earth is copiously bombarded with solar ions when sunspots are numerous, and these ions act to produce haze in the atmosphere, it is also necessary to separate tabulations for high and low Wolf numbers. I am accustomed to drawing the line at 20 Wolf numbers.

4. As the growth and shifting of populations and the invention of new devices, such as automobiles and airplanes, operate to alter the atmosphere, it is necessary to make a division of data for this. I am accustomed to drawing the line at the year 1900. That is not really adequate, but perfection is beyond reach, for with 23 periods to be synthesized, the precautionary measures mentioned above require 186 tables to be used.

5. As there are many periods, all exact aliquot parts of 273 months, it follows that most tabulations for a selected period are encumbered by shorter periods, exact aliquot parts of the period tabulated. I am accustomed to plotting the mean result of such a tabulation, scanning the graph for superriders, and, one after another, computing form and amplitude of these superriding periods, and removing them by subtraction till the wanted period stands out alone.

SOME RESULTS OF STUDIES OF WEATHER PERIODS

"Sixty-year Weather Forecasts," my Saint Louis precipitation paper, may be thought to have a sensational title. Critics are apt to say that when I use all the monthly mean values of precipitation at Saint Louis from 1854 to 1939 as a basis to determine the form and amplitude of 23 periods, no part of the synthesis of them between these dates is a forecast. On the contrary, 1,032 months are used to determine the features of these periods. No year has more than 12 months. Hence the form and amplitude of the curve representing the march of precipitation in any one year between 1854 and 1939 can have no more than $\frac{12}{1032} = 1.2$ percent influence on that year's curve. Therefore, each year's march of precipitation between 1854 and 1939 is *practically* an *independent* forecast. After 1939, up to 1957 when my synthesis ends, all years are *completely independent* forecasts. As the halfway point between 1854 and 1939 is the year 1897, forecasts may be regarded as made from 1897.

Thus, speaking approximately, every year from 1854 to 1957 is forecasted as if from 1897. As a fair specimen of such forecasts, I cite from "Sixty-year Weather Forecasts": figure 1 (here fig. 1), a facsimile of the 5-year Saint Louis forecast, 1875-1879; figures 2, 3, and 4 (here fig. 2), comparing forecasts with events for 6-year intervals, 1934-1939 in percentages of normal in the precipitation at Peoria and Saint Louis, and in the temperature departures from the normal at Washington, D. C.; and figure 5 (here fig. 3), comparing synthesis and event for Saint Louis precipitation, 1860-1887. Finally, I cite figure 6 (here fig. 4), comparing predictions for 1952-1957 of precipitation at Saint Louis and Peoria, prepared, of course, from wholly independent data. The predictions are in effect based on the year 1897, the halfway point between 1854 and 1939, which were the extremities of the basic interval employed. These two stations, Saint Louis and Peoria, are about 100 miles apart. Their 60-year forecasts run almost parallel. Both indicate the approach in 1952, waxing, maximum severity in 1956, and probable end of the drought in 1957.

The tabulation of Saint Louis precipitation for 104 years (1,248 months) is preserved at my home in a roll 25 columns wide, 1,248 lines long, and about 20 feet from end to end. Comparing its two curves of synthesis and event for 100 years, 1854-1954, 70 of the 100 years were of the same degree of similarity in time, form, and amplitude of range, shown by figure 3 of the present paper. In the other 30 years the features of the parallel curves were similar, but

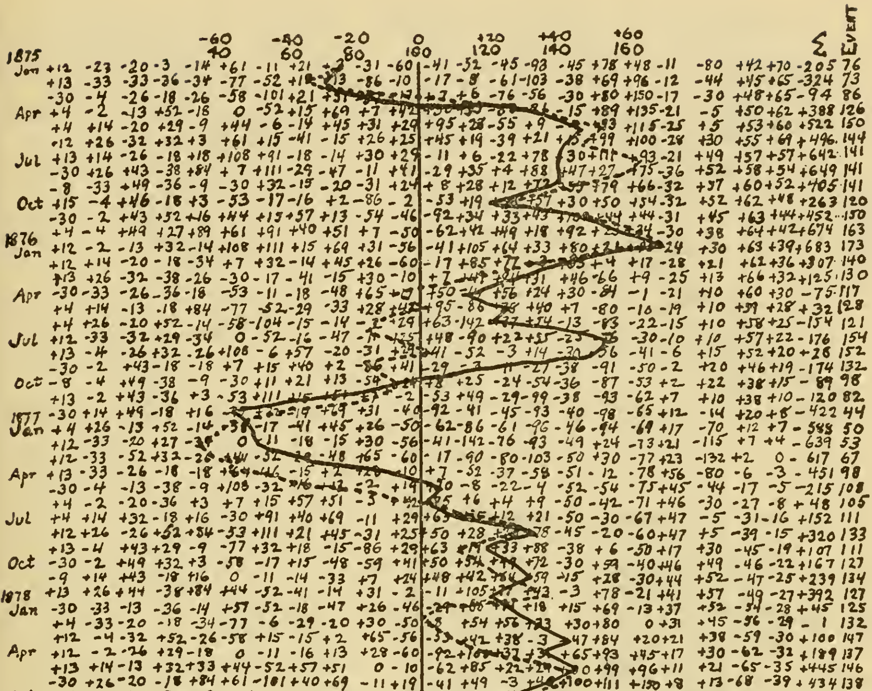

FIG. 1.—Facsimile of computation of St. Louis precipitation, 1875-1879, compared with the observed precipitation as percentage of normal. Data from monthly mean precipitation smoothed by 5-month running means. Dotted curve from summation of 22 regular periodicities, determined as averages over the 84-year epoch, 1854-1939. Full curve, the event.

displaced one or more months. These displacements seemed generally to follow either great volcanic eruptions, such as Krakatoa, Colima, and Katmai, or great bombing periods, as in the war years 1916-1918 and 1940-1945, and recent tests of atomic bombs.

The results, though subject to such blemishes, seem to offer a useful means of mapping countries for decades in advance to exhibit probable precipitation in percentages of the normal. Suppose 50

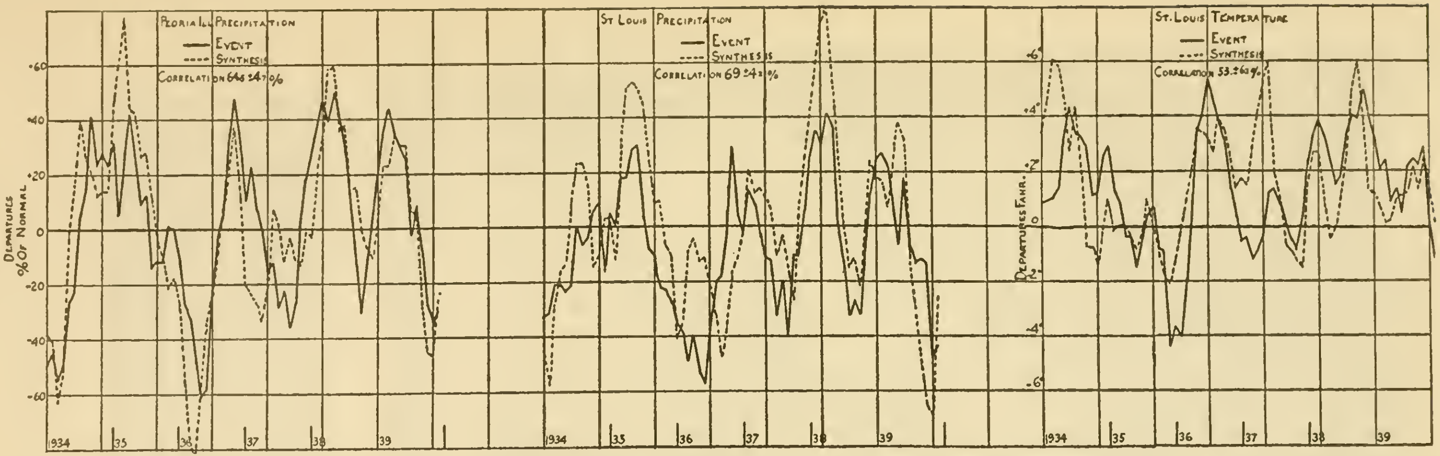

FIG. 2.—Three 6-year predictions 40 years in advance. Precipitation (Peoria and St. Louis) and temperature (St. Louis) computations 1934-1939 compared to the events. Precipitation, percentages of normal; temperature, departures from normal. Dotted curves, computed; full curves, events. All from 5-month smoothed running means.

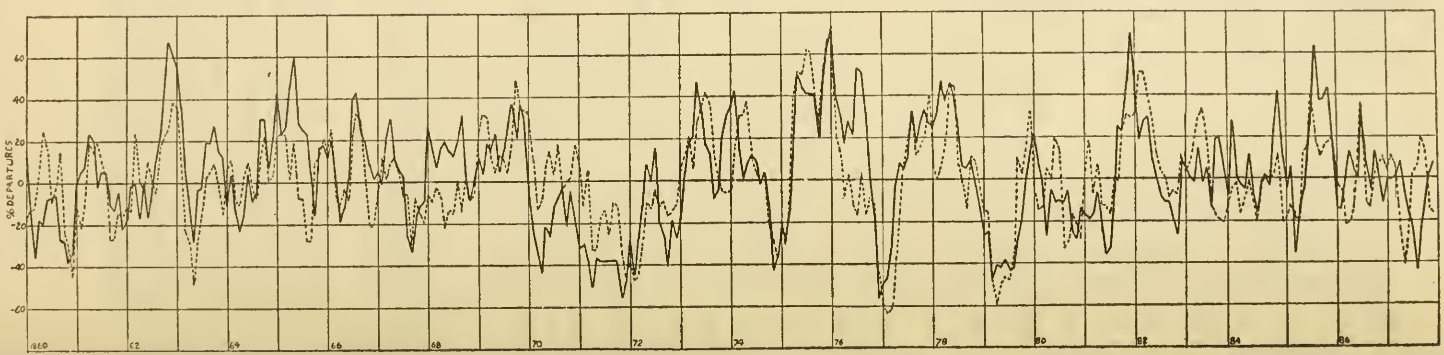

FIG. 3.—Synthesis of computations, 1860-1887, of St. Louis precipitation compared to the event. Dotted curve, computed; full curve, the event.

stations east of the Rocky Mountains in the United States were treated as I have done at Saint Louis, Peoria, and Albany. Lines of equal probable percentage of normal precipitation could be drawn for each season of the year for 10 years in advance. A success of 70 percent, as in Saint Louis, would be a boon to industry, and moderate phase displacements in 30 percent would be no serious failure. After all, it is *seasonal* weather that is most desired to be known. Three-month averages would remove most of the blemishes.

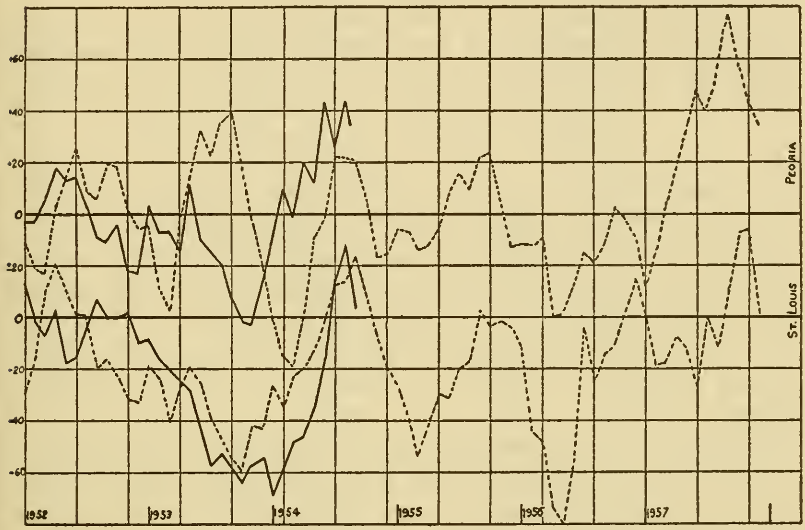

FIG. 4.—Predicted precipitation, Peoria (upper) and St. Louis (lower), 1952-1957, from mean forms of 22 periodicities over the epoch 1854-1939. End of prediction 18 years after 1939 and 60 years after middle of base, 1897. Dotted curves, prediction; full curves, event. Horizontal lines represent normal precipitation. Drought indicated ending 1957.

3. SNOW-COVERED DATES AT TOKYO, JAPAN

My friend Dr. H. Arakawa recently published [6] dates of the earliest wintry snow coverage for Tokyo since 1632. Many years are missing, but about 200 years are included. Dr. Arakawa treats the data very interestingly, but in large groupings. It occurred to me to plot all the dates of first coverage, reckoned after November 30, in days for each year given. I plotted blank years in the same regular order as the rest. Though the long plot showed many breaks, I seemed to see in it a tendency to a period of 45½ years, twice 273 months.

[6] Quart. Journ. Roy. Meteorol. Soc., vol. 82, No. 352, p. 222, April 1956.

I then tabulated all the data. The mean march of them is shown in curve A, figure 5. A period of 45½÷3, equaling 15⅙ years, seemed indicated, as shown in curve B. Subtracting its smoother ordinates (42+smooth△), the final column of the mean table, △, results, and is plotted in curve C. Though rough, a period of 45½ years, with an amplitude of 8 days, is found. The smoothed curve B for 15⅙ years has the amplitude of 7 days. From curve C, one would expect a snow coverage at Tokyo averaging a week earlier for the years 1955-1970 than the average which prevailed from 1930-1945.

Casting the eye along any of the 45 lines of the table (fig. 5), one sees no well-marked tendency for a change in amplitude at any phase of the 45½-year period from the seventeenth to the twentieth century.

GLACIAL ADVANCES RELATED TO 273 MONTHS

I recently received from the author, Herbert Grünhagen of Stadtoldendorf, Germany, a paper entitled "Die Klimawellen der Eiszeit." [7] He refers to a beautifully printed small book by W. Soergel, professor of geology and paleontology at the University of Freiburg, entitled "Die Vereisungskurve." [8] In this paper Soergel gives a curve to represent the fluctuation of latitudes of ice penetration in central Europe as glaciation advanced and receded from the direction of Sweden.

Grünhagen smooths Soergel's curve by using mean values for each successive 65,000 years. The curve thus treated he plots in 102 points, covering the interval from minus 565,000 to minus 30 years earlier than the year 1800 of our era.

Grünhagen's prior researches had disclosed to him periodic variations related to various phenomena. He had noted that when such a period was found, the double of it was also apt to be a recognizable period in the phenomena.

In these circumstances, a copy of my paper "Sixty-year Weather Forecasts" came to him, and some of the solar periods I used agreed closely with some periods he had found. He calls attention to families among my solar periods, in one of which the periods go in the order 1, ½, ¼, ⅛; and another in which the order 1, ⅓, ⅙, 1/12 is found.

It occurred to Grünhagen to see if longer periods than mine, increasing by powers of 2, might perhaps be found in the smoothed Soergel curve. He puts forward six such periods as follows: 15 years multiplying by 2^{12}, 2^{13}, 2^{14}, yielding 61,440, 122,880, and 245,760

[7] Separate from Niedersachsen, a periodical for home and culture, Heft 1, 1956.

[8] Published by Borntraeger Brothers, Berlin, 1937.

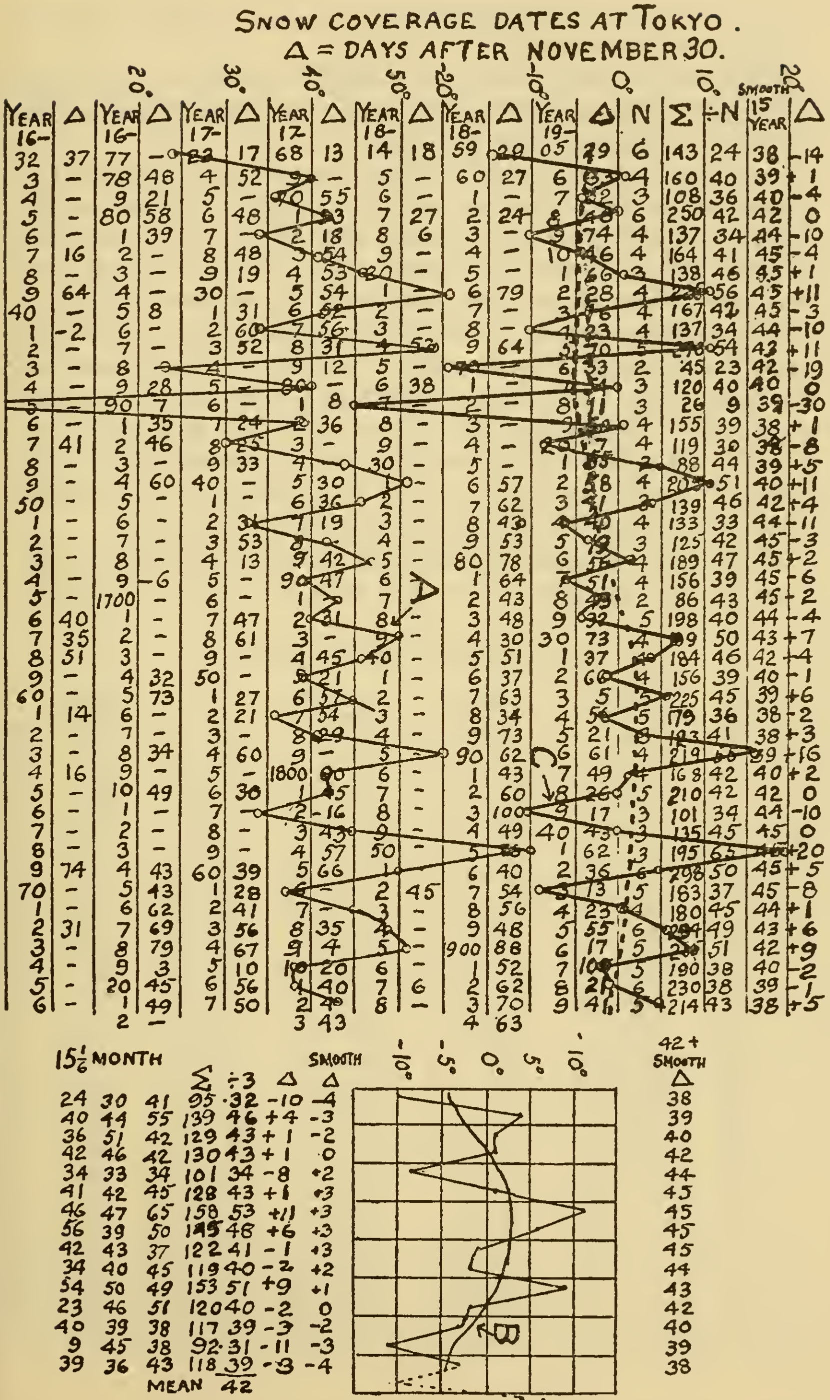

FIG. 5.—Snow coverage of Tokyo (Arakawa). The periods of 15⅙ and 45½ years are multiples of 273 months.

years; also 11.25 years multiplied by 2^{14}, 2^{15}, 2^{16} yielding 184,320, 368,640, and 737,280 years.

Grünhagen publishes, along with Soergel's smoothed curve of latitudes of penetration, another curve made up, as he states, from these six periods. The parallelism is striking.

I could not interpret from Grünhagen's paper how he obtained the phases, forms, and amplitudes in which he combined the six periods which he formed out of my 273-month solar period. I therefore read off 102 points of his smoothed Soergel curve. I computed from them the mean forms, phases, and amplitudes of the four shortest of Grünhagen's six periods. The longer two were not repeated enough times to compute good mean values. However, as I have found all my solar periods to be exact submultiples of 22¾ years, I used for these four Grünhagen periods $7\frac{1}{2} \times (2^{13}, 2^{14}, 2^{15})$ and $22\frac{3}{4} \times (2^{13}, 2^{14}, 2^{15})$. This gives for my first three periods the same values as his first three, but for my last three 186.4, 372.7, and 745.5 in thousands of years, instead of the value which he based on 11.25 years.

In the following table I give the mean latitudes computed from the smoothed Soergel curve to suit periods of 61.4, 122.9, 186.4, and

TABLE 3.—*Glacial periods synthesized*

Periods in years	61,400 Mean	61,400 Δ	122,900 Mean	122,900 Δ	186,400 Mean	186,400 Δ	245,800 Mean	245,800 Δ	ΣΔ+56°8		Soergel smooth curve	0.7ΣΔ+56°8	
1	57°0	0°2	55°9	—0°8	55°3	—1°3	58°7	1°7	—0°2	56°6	59°4	—0°1	56°7
2	56.8	0.0	56.0	—0.7	55.4	—1.2	59.0	2.0	0.1	56.9	59.3	0.1	56.9
3	57.1	0.3	56.2	—0.5	55.6	—1.0	59.3	2.3	1.1	57.9	59.4	0.8	57.6
4	57.0	0.2	56.2	—0.3	56.0	—0.6	60.0	3.0	2.3	59.1	60.5	1.6	58.4
5	57.0	0.2	56.6	—0.1	56.4	—0.2	60.6	3.6	3.5	60.3	61.2	2.4	59.2
6	56.8	0.0	56.7	0.0	56.7	0.1	60.5	3.5	3.6	60.4	61.4	2.5	59.3
7	56.7	—0.1	56.7	0.0	57.1	0.5	60.5	3.5	3.9	60.7	61.3	2.7	59.5
8	56.7	—0.1	57.0	0.3	57.4	0.8	60.5	3.5	4.5	61.3	61.3	3.1	59.9
9	56.7	—0.1	57.6	0.9	58.0	1.4	61.5	4.1	6.3	63.1	61.8	4.4	61.2
10	56.7	—0.1	57.9	1.2	58.3	1.7	61.5	4.5	7.3	64.1	62.1	5.1	61.9
11	56.6	—0.2	58.2	1.5	58.4	1.8	62.1	5.1	8.2	65.0	62.5	5.7	62.5
12	56.8	0.0	58.2	1.5	58.6	2.0	62.7	5.7	9.2	66.0	63.0	6.4	63.2
13	....	0.2	58.2	1.7	59.0	2.4	62.7	5.7	10.0	66.8	63.6	7.0	63.8
14	....	0.0	58.4	1.4	59.3	2.7	62.0	5.0	9.1	65.9	63.3	6.4	63.2
15	....	0.3	58.1	0.8	59.4	2.8	61.1	4.1	8.0	64.8	62.7	5.6	62.4
16	....	0.2	57.5	1.0	59.1	2.5	60.7	3.7	7.4	64.2	61.6	5.2	62.0
17	....	0.2	57.4	0.7	58.8	2.2	59.7	2.7	5.8	62.6	60.8	4.1	60.9
18	....	0.0	56.9	0.2	58.2	1.6	59.0	2.0	3.8	60.6	60.0	2.7	59.5
19	....	—0.1	56.7	0.0	57.5	0.9	58.2	1.2	2.0	58.8	59.0	1.4	58.2
20	....	—0.1	56.5	—0.2	57.4	0.8	57.8	0.8	1.3	58.1	58.6	0.9	57.7
21	....	—0.1	56.0	—0.7	57.3	0.7	57.0	0.0	—0.1	56.7	57.4	—0.1	56.7
22	....	—0.1	55.7	—1.0	57.3	0.7	56.0	—1.0	—1.4	55.4	56.8	—1.0	55.8
23	....	—0.2	55.1	—1.6	57.2	0.6	54.9	—2.1	—3.3	53.5	55.4	—2.3	54.5
24	....	0.0	54.7	—2.0	57.0	0.4	53.8	—3.2	—4.8	52.0	54.6	—3.4	53.4
25	....	0.2	54.3	—2.4	56.1	—0.5	52.9	—4.1	—6.8	50.0	53.2	—4.8	52.0
26	....	0.0	....	—0.7	55.6	—1.0	52.7	—4.3	—6.0	50.8	52.7	—4.2	52.6
27	....	0.3	....	—0.5	55.6	—1.0	52.8	—4.2	—5.4	51.4	52.7	—3.8	53.0
28	....	0.2	....	—0.3	55.6	—1.0	52.8	—4.2	—5.3	51.5	52.7	—3.7	53.1
29	....	0.2	....	—0.1	55.6	—1.0	52.8	—4.2	—5.1	51.7	52.7	—3.6	53.2
30	....	0.0	....	0.0	55.3	—1.7	52.8	—4.2	—5.9	50.9	52.7	—4.1	52.7
31	....	—0.1	....	0.0	54.8	—1.6	52.8	—4.2	—5.7	51.1	52.6	—4.0	52.8
32	....	—0.1	....	0.3	54.7	—1.9	52.9	—4.1	—5.8	51.0	52.6	—4.1	52.7
33	....	—0.1	....	0.9	54.5	—2.1	53.2	—3.8	—5.1	51.7	52.5	—3.6	53.2
34	....	—0.1	....	1.2	54.6	—2.0	53.1	—3.9	—4.8	52.0	52.5	—3.4	53.4
35	....	—0.2	....	1.5	55.0	—1.6	53.9	—3.1	—3.4	53.4	52.6	—2.4	54.4
36	....	0.0	....	1.5	55.4	—1.2	54.0	—3.0	—2.7	54.1	53.0	—1.9	54.9
37	....	0.1	....	1.7	55.6	—1.0	54.1	—2.9	—2.1	54.7	53.2	—1.5	55.3

TABLE 3.—Continued

Periods n years	61,400 Mean	Δ	122,900 Mean	Δ	186,400 Mean	Δ	245,800 Mean	Δ	ΣΔ+56°.8		Soergel smooth curve	0.7ΣΔ+56°.8	
38	....	0.2	....	1.4	....	—1.3	54.5	—2.5	—2.2	54.6	53.8	—1.5	55.3
39	....	0.0	....	0.8	....	—1.2	54.8	—2.2	—2.6	54.2	54.0	—1.8	55.0
40	....	0.3	....	1.0	....	—1.0	55.3	—1.7	—1.4	55.4	54.4	—1.0	55.8
41	....	0.2	....	0.7	....	—0.6	55.3	—1.8	—1.5	55.3	54.6	—1.1	55.7
42	....	0.2	....	0.2	....	—0.2	55.3	—1.7	—1.5	55.3	55.0	—1.1	55.7
43	....	0.0	....	0.0	....	0.1	55.1	—1.9	—2.0	54.8	55.5	—1.4	55.4
44	....	—0.1	....	—0.2	....	0.5	55.3	—1.7	—1.5	55.3	56.7	—1.1	55.7
45	....	—0.1	....	—0.7	....	0.8	55.4	—1.6	—1.6	55.2	57.0	—1.1	55.7
46	....	—0.1	....	—1.0	....	1.4	55.6	—1.4	—1.1	55.7	57.2	—0.8	56.0
47	....	—0.1	....	—1.6	....	1.7	55.9	—1.1	—1.1	55.7	57.6	—0.8	56.0
48	....	—0.2	....	—2.0	....	1.8	55.9	—1.1	—1.5	55.3	57.7	—1.1	55.7
49	....	0.0	....	—2.4	....	2.0	56.1	—0.9	—1.3	55.5	57.7	—0.9	57.7
50	....	0.2	....	—0.8	....	2.4	....	1.7	3.5	60.3	58.0	2.4	59.2
51	....	0.0	....	—0.7	....	2.7	....	2.0	4.0	60.8	58.8	2.8	59.6
52	....	0.3	....	—0.5	....	2.8	....	2.3	4.9	61.7	59.2	3.4	60.2
53	....	0.2	....	—0.3	....	2.5	....	3.0	5.4	62.2	59.6	3.8	60.6
54	....	0.2	....	—0.1	....	2.2	....	3.6	5.9	62.7	59.9	4.1	60.9
55	....	0.0	....	0.0	....	1.6	....	3.5	5.1	61.9	59.7	3.6	60.4
56	....	—0.1	....	0.0	....	0.9	....	3.5	4.3	61.1	59.6	3.0	59.8
57	....	—0.1	....	0.3	....	0.8	....	3.5	4.5	61.3	59.7	3.2	60.0
58	....	—0.1	....	0.9	....	0.7	....	4.1	5.6	62.4	60.9	3.9	60.7
59	....	—0.1	....	1.2	....	0.7	....	4.5	6.3	63.1	60.9	4.4	61.2
60	....	—0.2	....	1.5	....	0.6	....	5.1	7.0	63.8	61.7	4.9	61.7
61	....	0.0	....	1.5	....	0.4	....	5.7	7.6	64.4	62.4	5.3	62.1
62	....	0.2	....	1.7	....	—0.5	....	5.7	7.1	63.9	61.7	5.0	61.8
63	....	0.0	....	1.4	....	—1.0	....	5.0	5.4	62.2	60.6	3.8	60.6
64	....	0.3	....	0.8	....	—1.0	....	4.1	4.2	61.0	59.5	2.9	59.7
65	....	0.2	....	1.0	....	—1.0	....	3.7	3.9	60.7	58.8	2.7	59.5
66	....	0.2	....	0.7	....	—1.0	....	2.7	2.6	59.4	58.5	1.8	58.6
67	....	0.0	....	0.2	....	—1.7	....	2.0	0.5	57.3	58.0	0.4	57.2
68	....	—0.1	....	0.0	....	—1.6	....	1.2	—0.5	56.3	57.5	—0.4	56.4
69	....	—0.1	....	—0.2	....	—1.9	....	0.8	—1.4	55.4	57.1	—1.0	55.8
70	....	—0.1	....	—0.7	....	—2.1	....	0.0	—2.9	53.9	56.6	—2.0	54.8
71	....	—0.1	....	—1.0	....	—2.0	....	—1.0	—4.1	52.7	55.3	—2.9	53.9
72	....	—0.2	....	—1.6	....	—1.6	....	—2.1	—5.5	51.3	54.4	—3.8	53.0
73	....	0.0	....	—2.0	....	—1.2	....	—3.2	—6.4	50.4	53.0	—4.5	52.3
74	....	0.1	....	—2.4	....	—1.0	....	—4.1	—7.4	49.4	52.6	—5.2	51.6
75	....	0.2	....	—0.8	....	—1.1	....	—4.3	—6.0	50.8	52.7	—4.2	52.6
76	....	0.0	....	—0.7	....	—1.3	....	—4.2	—6.2	50.6	52.9	—4.3	52.5
77	....	0.3	....	—0.5	....	—1.2	....	—4.2	—5.6	51.2	53.0	—3.9	52.9
78	....	0.2	....	—0.3	....	—1.0	....	—4.2	—5.3	51.5	52.9	—3.7	52.1
79	....	0.2	....	—0.1	....	—0.6	....	—4.2	—4.7	52.1	52.9	—3.5	53.3
80	....	0.0	....	0.0	....	—0.2	....	—4.2	—4.4	52.4	53.1	—3.1	53.7
81	....	—0.1	....	0.0	....	—0.1	....	—4.1	—4.3	52.5	53.2	—3.0	53.8
82	....	—0.1	....	0.3	....	0.5	....	—3.8	—3.1	53.7	54.0	—2.2	54.6
83	....	—0.1	....	0.9	....	0.8	....	—3.9	—2.3	54.5	55.1	—1.6	55.2
84	....	—0.1	....	1.2	....	1.4	....	—3.1	—0.6	56.2	55.2	—0.4	55.4
85	....	—0.2	....	1.5	....	1.7	....	—3.0	0.0	56.8	55.1	0.0	56.8
86	....	0.0	....	1.5	....	1.8	....	—2.9	0.4	57.2	55.0	0.3	57.1
87	....	0.2	....	1.7	....	2.0	....	—2.5	1.4	58.2	55.3	1.0	57.8
88	....	0.0	....	1.4	....	2.4	....	—2.2	1.6	58.4	55.7	1.1	57.9
89	....	0.3	....	0.8	....	2.7	....	—1.7	2.1	58.9	56.3	1.5	58.3
90	....	0.2	....	1.0	....	2.8	....	—1.8	2.2	59.0	56.0	1.5	58.3
91	....	0.2	....	0.7	....	2.5	....	—1.7	1.7	58.5	55.7	1.2	58.0
92	....	0.0	....	0.2	....	2.2	....	—1.9	0.5	57.3	54.8	0.3	57.1
93	....	—0.1	....	0.0	....	1.6	....	—1.7	—0.2	56.6	54.0	—0.1	56.7
94	....	—0.1	....	—0.2	....	0.9	....	—1.6	—1.0	55.8	53.9	—0.7	56.1
95	....	—0.1	....	—0.7	....	0.8	....	—1.4	—1.4	55.4	54.2	—1.0	55.8
96	....	—0.1	....	—1.0	....	0.7	....	—1.1	—1.5	55.3	54.2	—1.1	55.7
97	....	—0.2	....	—1.6	....	0.7	....	—1.1	—2.2	54.6	54.5	—1.5	55.3
98	....	0.0	....	—2.0	....	0.6	....	—0.9	—2.3	54.5	54.0	—1.6	55.2
99	....	0.2	....	—0.8	....	0.4	....	1.7	1.5	58.3	53.3	1.1	57.9
100	....	0.0	....	—0.7	....	—0.5	....	2.0	0.8	57.6	53.4	0.6	57.4
101	....	0.3	....	—0.5	....	—1.0	....	2.3	1.1	57.9	54.5	0.8	57.6
102	....	0.2	....	—0.3	....	—1.0	....	3.0	1.9	58.7	55.4	1.3	58.1
										Mean	56.8°		

245.8 thousands of years, and the departures of each of these mean curves from the general mean for each.

In figure 6 I plot the smoothed Soergel curve A; then curve B, which is the synthesis of my four long periods plus 56.8°; and finally

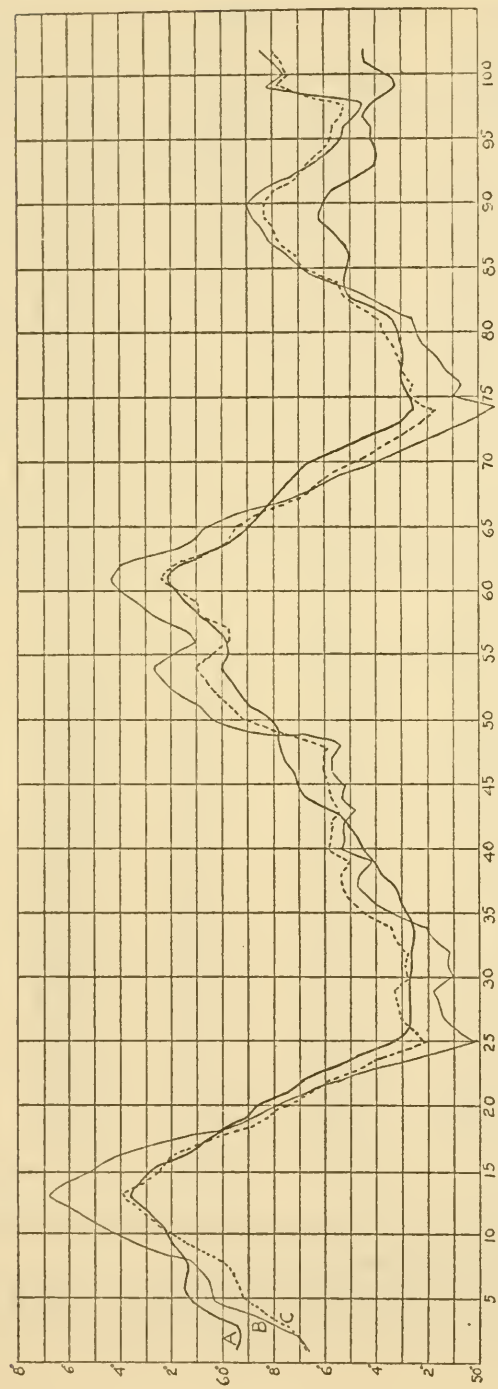

FIG. 6.—Glacial penetration in Germany. A, Soergel's curve as smoothed by Grünhagen. B, Synthesis of four periods, multiples of 273 months. C, Curve B reduced to 1/10 in ordinates.

curve C, which is my synthesis multiplied by 7/10 plus 56.8°. It is plain that the principal features and even most details of the smoothed Soergel curve are closely duplicated in my curve C. As Grünhagen used 6 periods, and I used but 4, the scale difference, 10 to 7, may be for lack of the others.

I do not fully understand how Soergel derived the time scale for these very ancient events. Doubtless he used several disciplines, including paleontology and stratigraphy. It is extraordinary how closely my *exact* time scale fits with his time scale, which must have been built up from rather *loosely timed* data.

4. MAGNETIC AND ELECTRICAL RELATIONS TO THE PERIOD OF 273 MONTHS

Nearly 50 years ago Dr. G. E. Hale discovered magnetism in sunspots. When this phenomenon had been followed long enough, the well-known remarkable reversal of polarities at intervals of double the sunspot period of 11⅜ years was found. So the 273-month period is surely a magnetic period in the sun.

When, about 1935, the ionosphere became systematically observed, the fluctuation of these electrical phenomena proved to be closely associated with sunspot frequency. But later I discovered that ionospheric changes were also associated with the variations of measures of the solar constant. I will merely refer here to publications on this relationship.[9]

5. THE HUMAN PULSE RATE

In a former publication[10] I mentioned that my friend Dr. F. P. Marshall had kept a record of her pulse rate for three years, which indicated a regular period of 212 days and submultiples thereof. The observations were made every day before rising, and form a continuous record for 1,095 days of basal pulse rates.

Dr. Marshall has kindly permitted me to use this evidence, which is unpublished. It shows clearly a period of 212 days and six periods, aliquot parts thereof (fig. 7), and others which I have not investigated.

Dr. Marshall was familiar with my first studies on the solar constant of radiation, about 1935. She followed much the same course with the pulse observations. However, as the 15-year record of solar-

[9] Smithsonian Misc. Coll., vol. 107, No. 4, pp. 24-26, 1947; ibid., vol. 122, No. 4, pp. 9-11, 1953.

[10] Periodic solar variation, Smithsonian Misc. Coll., vol. 128, No. 4, pp. 3, 6, 1955.

constant measures then available had many breaks in the continuity of the daily observations, I was constrained to use 10-day and monthly

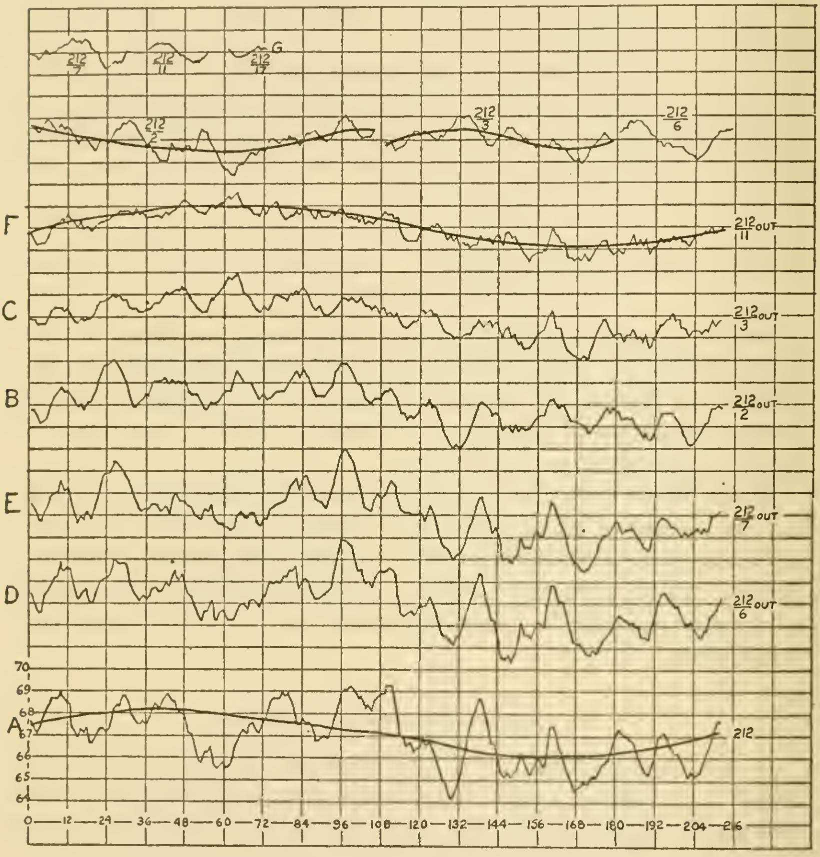

FIG. 7.—Basal pulse rates (Marshall). A, Mean march of 212-day period for 3 years. D, Period of $212/6$ removed. E, Period of $212/7$ removed. B, Period of $212/2$ removed. C, Period of $212/3$ removed. F, Period of $212/11$ removed. G, Remaining period of $212/17$, not removed. Seven months, $1/39 \times 273$ months, is 213.07 days. Therefore all seven periods found are submultiples of 273 months.

mean values in my work. As she had an unbroken daily record of almost 1,100 days, she employed daily values of pulse.

Plotting these in their complete continuity, her figure, like my solar-constant figure, resembled a wide ribbon, with its many closely lying ups and downs. But the pulse values, not being subject to accidental errors, were more satisfactory to investigate than the solar-constant values in which accidental errors were of about the same magnitude as real variations of the sun. Still her ribbon plot was so wide that it was found desirable to smooth the record. This she did by taking 7-day overlapping means. The range of pulse remaining after smoothing was approximately from 60 to 70 pulses per minute.

Scanning the smoothed pulse record, it appeared to present a recurring period of 106 days. The range of that period seemed to show alternately maxima and minima. So a period of 212 days was sought for by tabulation. With five repetitions of the 212-day tabulation, their mean was as represented by the line A in figure 7. It is easy to see that, though loaded with many irregularities, the line A is fairly indicative of an approximate sine curve, with a range of two pulses, as shown by the smooth line.

Following the procedure of my weather-variation papers, the curve A was cleared successively of five periods, which are aliquot parts of 212 days, respectively ½, ⅓, ⅙, ⅐, and $\frac{1}{11}$ of 212 days. These are shown in the upper part of figure 7. The successive removals of them show the successive smoothing of curve A, in curves D, E, B, C, and F. There still remains, as shown in curve G, a period of $\frac{212}{17}$ days, or 12½ days, and doubtless others. But curve F is so smooth that little doubt remains that the smooth line upon curve F is the veritable period of 212 days, as relieved of superriders. This smooth line is almost exactly the same in form and amplitude as that drawn free-hand on curve A. It has a range of two pulses or about 3 percent of the average pulse rate per minute.

In the solar variation, a 7-month period is one of the stronger ones. Reduced to days, a 7-month period is $\frac{1}{39} \times 22\frac{3}{4}$ years, which is $\frac{22.75 \times 365.2564}{39} = 213.07$ days. This, of course, to well within the probable error, is the same as Dr. Marshall's 212 days. Hence I conclude that Dr. Marshall's physiological period and its exact submultiples are all aliquot parts of my master solar period of 273 months. Doubtless this relationship is not accidental, and physiologists will, I am sure, note it with interest.

SUMMARY

The author shows that weather, glaciation, dates of snow coverage in Japan, magnetism in the sun, variations of the ionosphere, and human pulse rates all present regular periods which are exact multiples or submultiples of the master period of 273 months in the variation of the sun's emission of radiation.