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AND THE TEMPERATURES OF  
WASHINGTON AND NEW YORK

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# SHORT PERIODIC SOLAR VARIATIONS AND THE TEMPERATURES OF WASHINGTON AND NEW YORK

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In my paper read before the National Academy of Sciences in April 1949, fairly successful predictions of 55 minima of Washington temperatures for the year 1948 were discussed. The 55 dates in question were the dates when the period of 6.6456 days<sup>1</sup> would recur in the same phase as on January 17.0000, 1946. It was privately indicated to me, after the delivery of my paper, that certain correlation studies which had been made on New York City temperature departures raised doubts if similar results would have been obtained for that station. By the kindness of E. J. Christie, Meteorologist in Charge at New York, Weather Bureau forms 1030 giving departures from normal temperature for every day from January 1928 to date were furnished for me to study this question.

### WHY EXPECT SUCH A REACTION?

Before proceeding further, let us refresh our minds on the reasons for supposing that there should be a period of 6.6456<sup>1</sup> days in meteorology.<sup>2</sup> Solar radiation is the source which maintains the earth's temperature and other meteorological phenomena. If the solar radiation is variable, these must be expected to vary. Daily observations by Smithsonian observers carried on at Montezuma, a mountain 9,000 feet high in the Atacama Desert of northern Chile, show that small fluctuations of the sun's output of radiation do occur. A statistical study of them showed that there is an approximately regular solar variation of about  $6\frac{2}{3}$  days' period.

The departures from normal temperatures at Washington between the years 1910 and 1945 were tabulated in  $6\frac{2}{3}$ -day intervals for the months of May and November, separately. On plotting the  $6\frac{2}{3}$ -day

<sup>1</sup> As shown below a small correction now alters this period to 6.6485 days.

<sup>2</sup> See Smithsonian Misc. Coll., vol. 107, No. 4, Apr. 4, 1947.

curves for May, it was seen that a decided indication of a variation of about that period occurred, but sometimes from 1 to (rarely) 3 days before or after it was expected. However, upon scanning the whole 45 years of May values, it was clear that the period was either a little shorter than  $6\frac{2}{3}$  days (best value found to be  $6.6456^1$  days which is about  $1/55$  of a year) or else it must be about  $1/54$  or  $1/56$  of a year. Now turning to the tabulation for November, it was found that only the period  $6.6456^1$  days could serve. For if either  $1/54$  or  $1/56$  of a year were adopted, the November curves would be a half period out of phase with those of May.

Afterward, the solar-constant values of Montezuma, 1924 to 1945, were critically studied. They proved to exhibit this period of variation, and with perfect regularity. The displacements of from 1 to (rarely) 3 days in phase in Washington temperature departures from the normal do not occur in the solar variation. Considering the complexity of the earth, its atmosphere, and meteorological reactions, it is not surprising that such displacements of the phases of a terrestrial response to regular solar pulses should occur. But they impair the value of the solar period for forecasting purposes. It was shown, however, in Smithsonian Miscellaneous Collections, vol. 107, No. 4, that the temperature departures caused by this periodic solar variation range from  $2^\circ$  to  $20^\circ$  F. at Washington and also at St. Louis and at Helena, Mont.

#### PROCEDURE OF INVESTIGATION

Proceeding with the investigation of New York City temperature departures, I made monthly tables of the four or five recurrences of the 6.6456-day period in each month. These covered 21 years from 1928 to 1948, making 1,154 separate recurrences in all. The tables were based on January 17.000, 1946, so as to be comparable directly with the Washington work reported in Smithsonian Miscellaneous Collections, vol. 111, No. 6. The following sample, table 1, is for May 1929.

It will be noticed that only six values occur in lines 1 and 4 of the table and that the vacancies are distributed to the last and first columns. These adjustments take into consideration whether the fractions in the phase dates exceed 0.5 or not. The vacancies are distributed so that, in the year, as many fall in the first column as in the last. Proceeding in this way the New York data were all tabulated from 1928 to 1948 by individual monthly means. It was

then noticed that maxima and minima in the seven-column means occurred progressively later as the years went on.

#### CORRECTION OF THE PERIOD

By graphic methods applied to both maxima and minima, and to several different months of tabulation, it appeared that the secular displacement of features just referred to amounted to 3 days in 18

TABLE I.—*New York City temperature departures, May 1929, arranged in the 6.6456-day period*

	April	May				June	
Phase dates . . . .	28.6936	5.3392	11.9848	18.6304	25.2760	0.9216	
Temperature departures ..	-3°	-3°	1°	1°	-2°	-6°	
	5	1	-2	-8	-6	-5	-3°
	5	3	-4	10	2	-7	0
		2	-10	-14	-4	-9	-1
	-1	2	4	10	12	10	15
Mean. .	1.5	1.0	-2.2	-0.2	0.4	-3.4	2.7

years. As there are 55 recurrences of the period each year, this displacement corresponds to  $\frac{3}{18 \times 55} = 0.0030$  days per cycle. It is more convenient to use numbers ending in 5 than in 6, and the accuracy of the determination does not justify the inconvenience, so, instead of 0.0030, a correction of 0.0029 was applied, making the corrected period 6.6485 days.

By subtracting and adding this number of days many times to January 17.0000, 1946, a tabulation was prepared giving dates of all expected minima of temperatures at Washington from 1928 to 1948. Applying this table also at New York it would be found whether minima, occurring there by the effect of the periodic solar variation, fall on the same dates as at Washington.

#### PREPARATION OF THE DATA

Using Weather Bureau forms 1030, the departures from normal temperature were tabulated, exactly as in table I, for both Washington and New York, from January 1928 to December 1948. In these tabulations the newly corrected period 6.6485 days is used. As stated above, the tabulation is based on January 17.0000, 1946.

As the reader will note in table I, this arrangement results in tables of seven columns, and these were labeled 1 to 7. Each month—

January for instance—yields first a table of either four or five lines, depending on whether some January days were required to complete lines of December or February, or whether some days from one or both of those months were required to complete lines of January.

Mean values having been taken, as in table 1, there resulted a new table of 21 lines, of 7 columns each, for each one of the 12 months of the year, the entire 12 tables covering the interval 1928 to 1948.

### FREQUENCY DISTRIBUTION

From the 12 tables of mean monthly temperature departures were now read off from their 21 lines the days (1 to 7) on which maxima and minima of temperature occurred. Where identical mean departures came on more than one day, the reading was appropriately split up, as, for instance the same minimum occurring on days 1 and 7 was tabulated as  $\frac{1}{2}$  at 1 and  $\frac{1}{2}$  at 7.

Terrestrial responses to solar impulses lag behind their solar causes. Thus, for example, the coolest and warmest parts of the day occur several hours after midnight and noon, respectively. The lag differs from place to place, and from time to time, depending on terrestrial complexities. So it should not be expected that maxima and minima of temperatures at New York and Washington, due to a periodic solar change, would necessarily be coincident, or that at either station they would always be found at the same columns of the tables.

If, as hitherto generally supposed by meteorologists, weather is almost wholly governed by terrestrial influences, apparently accidental as to timing, then a study of the frequency of maxima and minima in my tables should show no marked preference for any columns over the others. But if, as indeed will be shown below, the regular solar periodic pulse is a principal cause of weather, then, despite the interference by terrestrial complexities, there should be found marked preferences for certain columns as seats of maxima and minima. Chance is largely subordinated by multiplicity in this study, for each month of the 12 monthly tables results from  $21 \times \frac{55}{12} = 96$  recurrences of the period.

It was presumed that the lag of temperature response might differ in different parts of the year. Hence the 12 months were tabulated separately. Moreover, a great collection of unpublished studies on the terrestrial responses to 14 long-period solar variations has shown that such responses are apt to differ greatly with sunspot frequency. Hence, in each of the 12 monthly tables, the years 1928-30, 1936-41,

and 1946-48 were kept separate from the years 1931-35 and 1942-45. In anticipation, it may be remarked that slight displacements of maxima and minima seem to attend both the time of the year and the epoch of the sunspot cycle. But these displacements are so small, and the effect of the 6.6485-day period is so pronounced, that a direct mean of all the evidence, for all months and all years, shows distinctly the main features of the frequency of distribution of the temperature departure features.

TABLE 2.—*Frequency of temperature minima in the seven columns*

Lines	Station	1	2	3	4	5	6	7	No. of years
1.....	New York	52	30	30	42	25	26	47	21
2.....	Washington	44	35	23	46	26	23	55	21
3.....	New York	28	15	20	25	17	13	26	12
4.....	Washington	23	18	15	31	12	18	27	12
5.....	New York	26	15	10	17	8	13	21	9
6.....	Washington	21	17	8	15	14	5	28	9
7.....	New York	2.33	1.25	1.67	2.08	1.42	1.08	2.17	1
8.....	Washington	1.92	1.50	1.25	2.58	1.00	1.50	2.25	1
9.....	New York	2.67	1.67	1.11	1.89	0.89	1.44	2.33	1
10.....	Washington	2.33	1.89	0.89	1.67	1.56	0.56	3.10	1
11.....		+	+	-	-	±	±	+	

EXPLANATION.—Lines 1, 2 cover monthly means for all years, 1928-1948.

Lines 3, 4 cover monthly means for years of sunspot maximum.

Lines 5, 6 cover monthly means for years of sunspot minimum.

Lines 7-10 cover as lines 3-6, but are general averages for 1 year only.

Line 11 shows when years of sunspot minimum have higher frequencies.

In table 2 and figure 1 are given the frequencies with which minima in all the monthly mean tables combined (similar to table 1) fall in the seven different columns of the tabulations. For curiosity's sake the table also gives the average numbers per month of occurrences of mean minima for sunspot maximum and sunspot minimum years separately. Reducing the values to equal numbers of years, it will be seen from these latter tabulations that for both Washington and New York there is a tendency in sunspot minimum years for minima to occur with greater frequency in columns 1, 2, and 7, and lesser frequency in columns 3, 4, 5 and 6. This shows that the principal solar period has better control over terrestrial disturbances when sunspots are at minimum. But ignoring this subordinate result, the main results of the tabulation show that:

1. There is a great and nearly equal preponderance of frequency for both stations in columns 1 and 7, so that the minimum falls at about half a day after 7 in both cities.

2. There is a strong frequency in column 4, showing that another regular periodic solar variation exists of  $\frac{6.6485}{2} = 3.3242$  days in period. Its phases coincide with those of the primary period whenever possible.

3. There is no appreciable difference in lag between Washington and New York in response to the solar variations. In short, the two stations behave nearly alike in all respects.

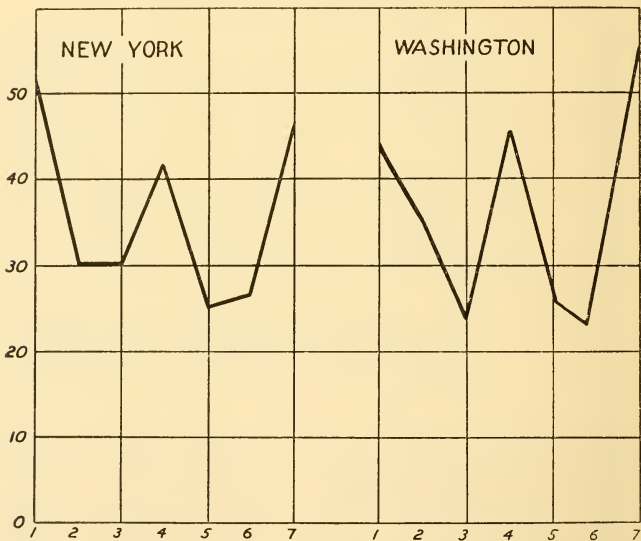


FIG. 1.

#### MAGNITUDE OF THE EFFECT

Owing to terrestrial interferences in lag and otherwise, and to the interference caused by the existence of the secondary solar period of half the length of the primary one, the positions of maxima and minima fluctuate. Comparatively seldom does a whole month go by without shifts of 1, 2, or rarely 3 days in the place of minima. On this account the mean monthly values seldom show the full measure of the effect of the solar change on terrestrial temperatures. However three months have been selected from many among the tempera-



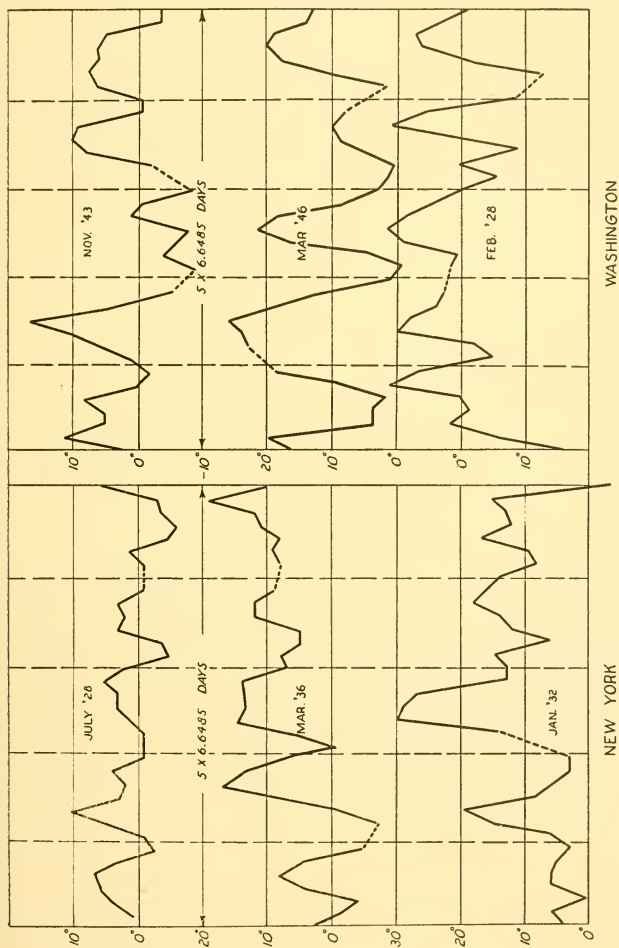


FIG. 2.

ture departures for each of the two stations, when the regularity of the periods was little disturbed during the whole month. Months were chosen fairly well distributed throughout the year. Plots of these temperature departures are given in figure 2. By drawing straight lines across the bottom of each hump, values have been read off giving roughly the numbers of degrees by which the temperatures were raised by the solar influence. As is well known, the temperature changes of all sorts are much less in July than in the cooler months of the year, in the Eastern United States. Hence it is not surprising that this appears in figure 2 and in table 3.

TABLE 3.—*Average magnitude of the temperature fluctuations in degrees F.*

New York	Washington
Jan. 1932, 12°6	Feb. 1928, 15°2
Mar. 1936, 14°2	Mar. 1946, 14°0
July 1938, 7°8	Nov. 1943, 12°4

By inspection of these exhibits one sees that throughout most of the year, in Washington and in New York, the temperature is affected either four or five times each month by a change in solar radiation, by amounts ranging from 10° to 20° F.

#### CONCLUSION

Contrary to the suggestion referred to at the beginning of this paper, Washington and New York respond almost alike to the short regular variations of solar radiation. Two such variations are known. The primary one has a period of 6.6485 days, and the subordinate one half that length. Thus the primary solar change recurs either four or five times each month. Temperature changes of 10° to 20° F. attend its every recurrence during most months of the year, but during summer the effect is somewhat less. The phases of the temperature changes appear to be the same at Washington and New York.