

SMITHSONIAN MISCELLANEOUS COLLECTIONS
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CORRELATIONS OF SOLAR VARIATION
WITH WASHINGTON WEATHER

BY

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Research Associate, Smithsonian Institution



(PUBLICATION 3807)

CITY OF WASHINGTON
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TEMPERATURE AND SOLAR ACTIVITY

Nine years ago I showed that ups and downs in the values of the solar constant of radiation were attended by changes of large magnitude and long duration in the temperature of Washington and other stations. These effects were always symmetrically opposed like the right and left hands. Meteorologists have been reluctant to accept this finding, partly because the solar changes found seemed to them too small to be certainly observed, and partly because no mathematical theory had been worked out to show how such small percentage changes in the solar constant could so largely alter terrestrial temperatures.

Nevertheless further work convinced me of the reality of the effect, and recently I have obtained new evidence that seems to clinch it.

Everyone recognizes the validity of the measurements now being made at many stations of what is called "critical frequency" in ionization layers of our atmosphere. Among them is the quantity called " F_e ." This quantity was observed at all daylight hours and some night hours during the years from 1938 to 1944 by the Carnegie Institution stations at Huancayo, Peru, and Watheroo, Australia. Dr. Fleming has generously provided me with copies of these data, which, however, are in the war category "restricted," and therefore unpublished. For my purposes I computed for each day from 1938 to 1944 the mean value of F_e for 11 daylight hours. It is, of course, very clear that for the most part this quantity is a measure of some kind of solar radiation which travels with the speed of light, for the night values are very low, and there is an immediate rise at sunrise and fall at sunset. I am told, too, that F_e values go nearly to zero during total solar eclipses. These Carnegie Institution measurements seemed well

¹ Paper delivered May 31, 1945, before the Meteorological Section, American Geophysical Union, Washington, D. C.

suit to check my earlier results on the correlation of solar variation with temperature departures.

I made monthly graphs of my daily mean daylight values of F_e for Huancayo and Watheroo. The two stations do not fully agree, but they both show nearly simultaneously many rises and falls of the daily values. These changes observed at both stations frequently reach 10 percent or more, whereas the percentage changes found in the solar constant seldom exceed 1 percent.

I found from the 7 years available, 1938 to 1944, from 15 to 25 cases of rise, and 15 to 25 cases of fall of mean daily F_e values, for each of the 12 months, January to December. For each case I wrote

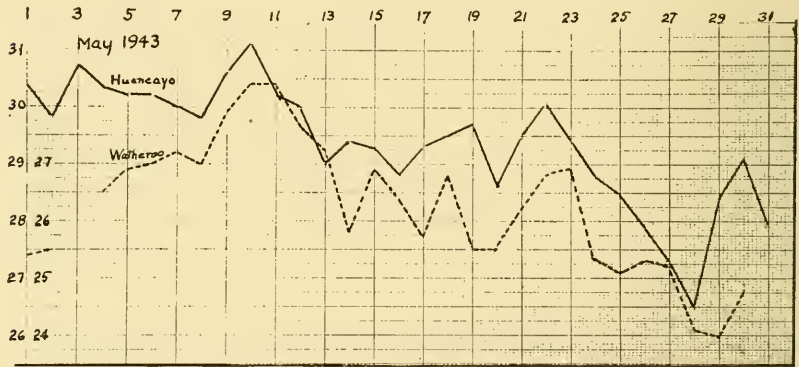


FIG. 1.—Comparison of daily ionization results of Huancayo, Peru, and Watheroo, Australia. Mean critical frequencies for layer F_e . Each point the mean of 11 daylight hours. Sequences of increase and decrease of solar activity indicated.

a line of the departures from normal temperature at Washington from 5 days before to 19 days after the zeroth day, when the solar change seemed to begin. Thus, for each of the 12 months of the year I had a table of 15 to 25 lines, and 25 columns. The mean values of the columns, when plotted, showed the average sequences of temperatures at Washington which are caused by the rise and fall of the solar activity during each month of the year.

These curves were almost exactly the same in phases and amplitudes as the curves obtained similarly from the dates when the solar constant rose and fell in the years 1924 to 1939.² The curves are indeed so nearly identical that there is no reason to separate the two sets of data, one derived from Smithsonian solar-constant work, and the other derived from Carnegie ionization measures. I have now

² See figure 4, Smithsonian Misc. Coll., vol. 104, No. 5, 1944.

mean curves of Washington temperature change for each month of the year, derived from the combined data of the years 1924 to 1944, and representing mean effects of rise and of fall in solar activity.

Of these curves, each a mean of from 30 to 50 individual cases of solar change, I remark:

1. Temperatures at other stations show the same sort of correlation with solar activity as does Washington for the same days of solar

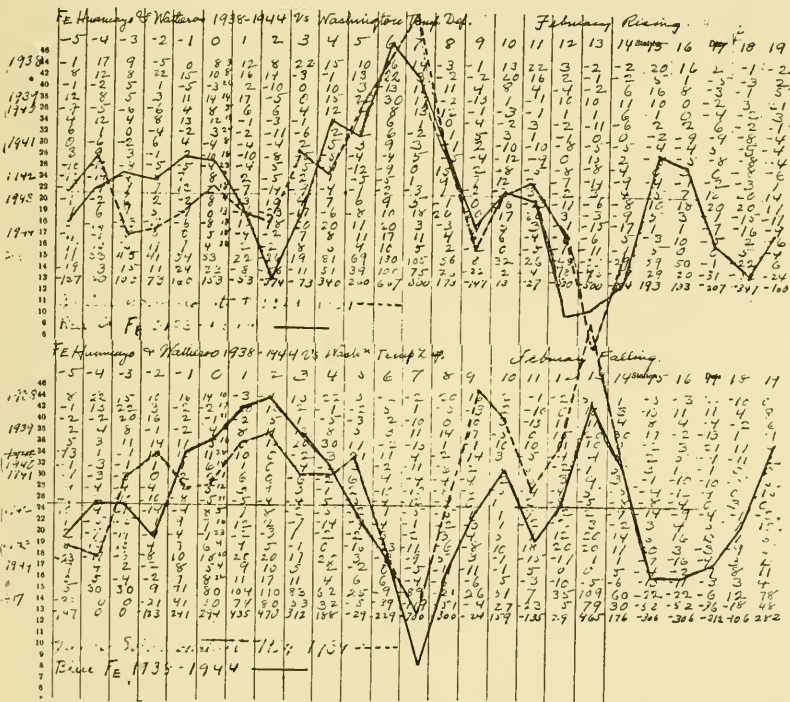


FIG. 2.—Comparison of mean march for 25 days of departures from normal temperature at Washington in February, associated (dotted curves) with ups and downs of the solar constant of radiation and (full curves) ups and downs of critical frequencies of ionization for the layer F₂. Solar change on zero day.

change, though varying as regards individual features, as would be expected, owing to different local conditions. At Western stations, for instance, features come several days earlier than at Washington, but the opposed symmetry still prevails.

2. At every station, and in nearly every month, the temperatures depart in opposite directions, attending, respectively, rising and falling solar activity. Thus comes about an axial symmetry of the pairs of curves, such for instance as subsists with one's right hand and one's left.

3. The march of the curves differs from month to month, and differs for the same month from station to station, yet the right and left symmetry nearly always prevails.

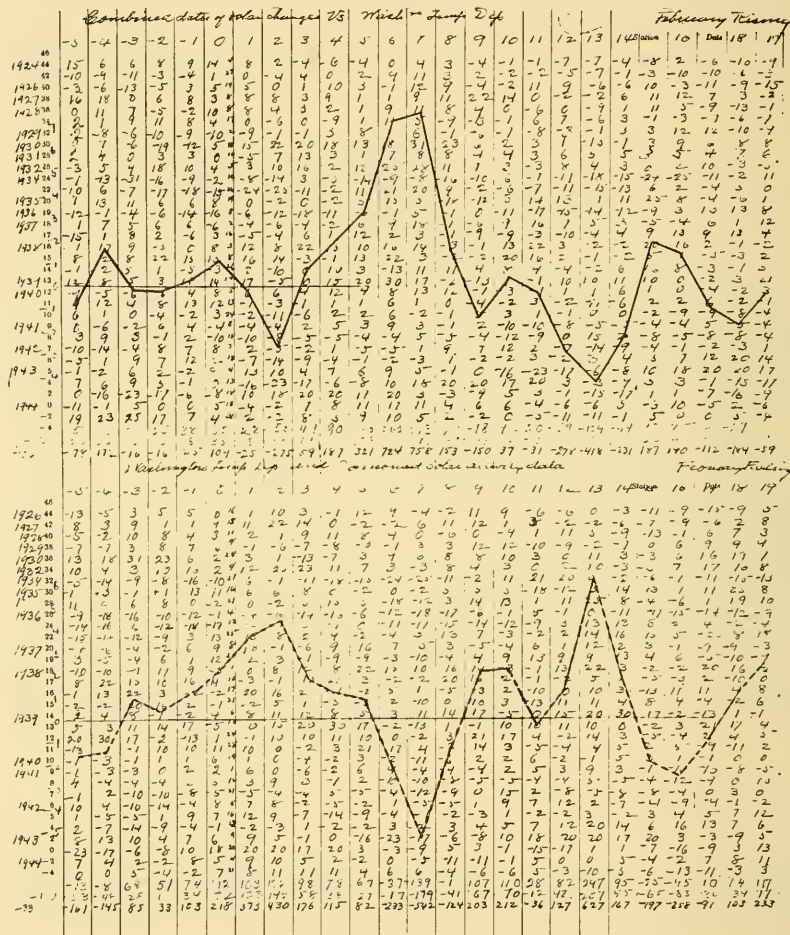


FIG. 3.—Mean march for 25 days of departures from normal temperature at Washington in February, years 1924 to 1938, as associated with ups and downs of the solar constant of radiation, years 1938 to 1944, as associated with ups and downs of critical frequencies of ionization for the layer F₂. Solar change on zero day.

4. The effects are large. Differences of temperature of the order of 10° Fahrenheit, or more, depend on whether a rising or a falling sequence of solar activity preceded them many days before.

5. The effects of solar changes on temperature persist for many

days. They may surely be traced from 3 days before to 14 days after the zeroth day of the solar sequence.

6. The coefficient of correlation between curves corresponding to rising and falling solar activity from -3 to $+15$ days for Washington temperature data of the month February (a fair sample) is -80 ± 5.5 percent.

7. Since far-separated cities respond similarly in these respects to the common system of dates given in the tables, this system of dates must have a cosmic significance. The system of dates, in other words, betrays an extraterrestrial selection, harmonious with the claim that on these dates changes in radiation occurred in the sun.

PRECIPITATION AND SOLAR ACTIVITY

Without much expectation of strong correlations, because of the sporadic character of precipitation, I nevertheless worked out tables of Washington precipitation accompanying the dates of change in solar activity from 1924 to 1944. To my surprise the curves representing the mean results of the tables showed strongly marked features, with symmetrical opposition in precipitation corresponding to rising and falling solar activity.

PREDICTION OF TEMPERATURES

From what has gone before it is clear that the sun's variations are a major factor in weather. The effects produced are large. In Washington temperatures it makes nearly 20° F. of difference in some months whether the solar constant rose or fell by $\frac{3}{4}$ of 1 percent a week or more previously. The effects are long continuing. They appear to begin 3 days before measurable changes in radiation occur, and to last at least until 14 days after, making an important sequence of at least 17 days in weather, attending each change of solar radiation.

The question arises whether solar observations may be utilized for weather prediction. Obviously it would be necessary to have all the dates when solar changes occur, for the effects are so large that to use some and omit others would lead to great error. Furthermore the exact dates are necessary. For the effects change rapidly from day to day.

In order to test the prospects with the present available data, I have attempted a solar weather forecast for the temperature at Washington covering the interval January 1 to May 28, 1943, and have compared it with the event. For illustration I present the solar expectation for the interval February 1 to March 14 in the accompanying

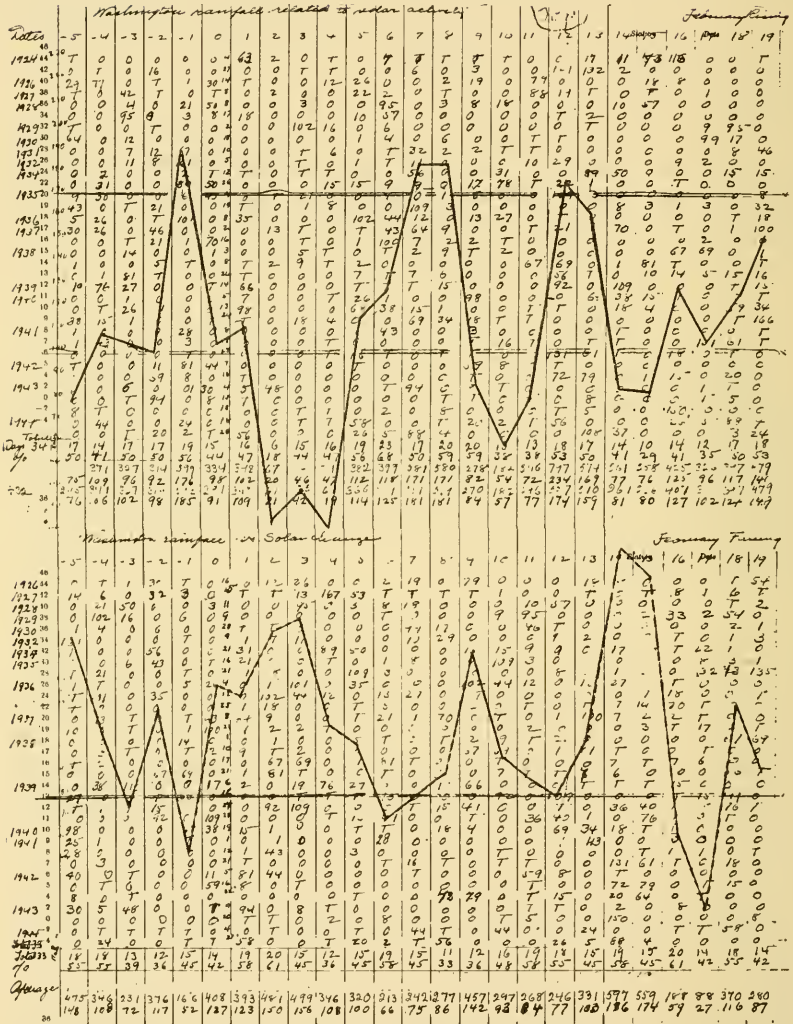


FIG. 4.—Mean march for 25 days of rainfall at Washington in February, years 1924 to 1938, as associated with ups and downs of the solar constant of critical frequencies of ionization for the layer F. Solar change on zero day.

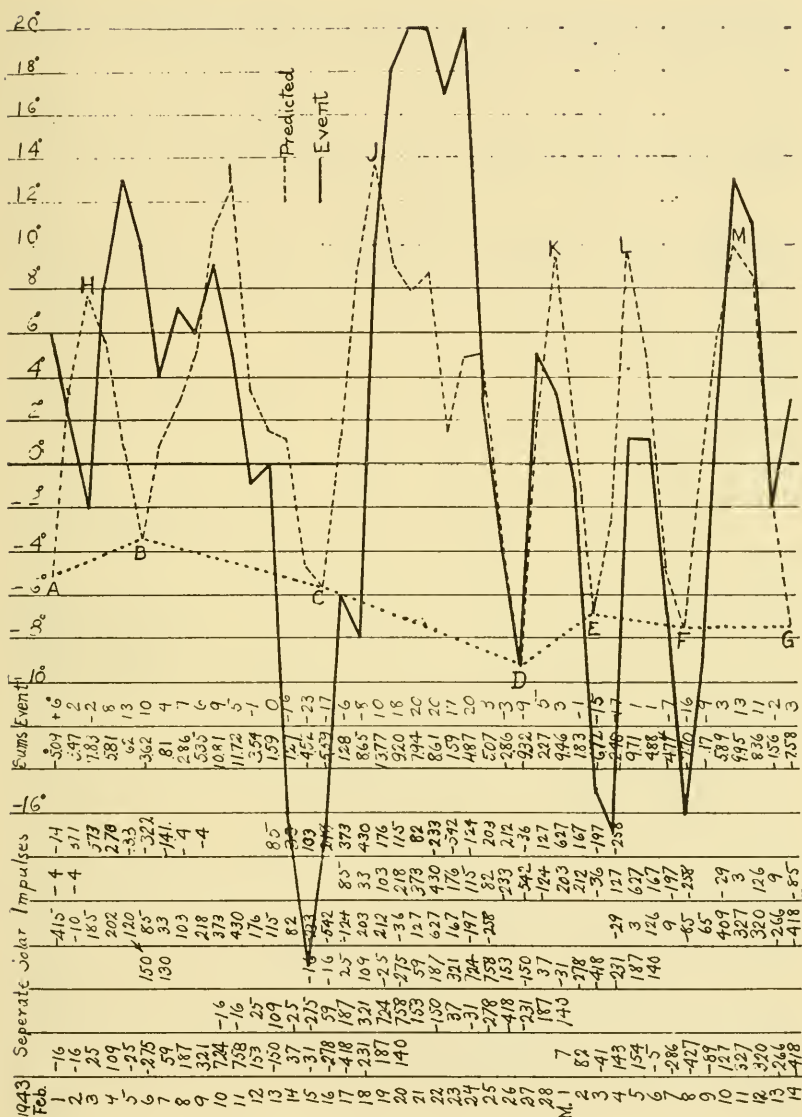


FIG. 5.—Predicted and observed departures from normal temperature at Washington February 1 to March 14, 1943. Prediction synthesized from individual effects of all observed ups and downs of solar activity affecting that interval of time.

illustration. The method of computing it is simple. From the records of F_e ionization data, one takes all the dates when ups and downs of solar radiation occur. Opposite each one of these dates he writes in a column of 20 days the departures from normal temperature appropriate to the observed solar change. He then adds the columns algebraically to give in sequence the combined temperature effect of all the solar changes. This procedure is clearly shown in figure 5.

In the illustration I show in dotted lines the departures from normal temperature due to integrated solar effects, and in full lines the actual event. It will be seen that the two curves show the same number of principal peaks and troughs. These fall nearly in the same phases. Their phase differences in days are as follows:

Maxima	H	I	J	K	L	M	
Phase differences	+2	+1	+2	-1	0	0	
Minima	A	B	C	D	E	F	G
Phase differences	+2	+1	-1	0	+1	0	-1

Average phase change: Regarding sign, +0.47 day; disregarding sign, ± 0.91 day.

The magnitudes of the actual swings from peaks to troughs exceed those of the solar integration in the ratio 5/4. While the general similarity of the curves is obvious, the differences in phase and in magnitude of swings lead to such wide divergences that the day-to-day correlation coefficient is small, only 9 percent.

I have sought to find a mathematical comparison between the two curves which would take groups of several days as its basis. For this purpose I join points A B C D E F G at the troughs of the dotted curve. At the midpoints of the lines AB, BC, etc., I observe the departures. I then sum up the departures of the several days within each triangle as they would be if measured from horizontal base lines through these midpoints. I also treat the full curve in the same way, except that their base lines are determined, not by the trough points of the full curve, but by the points of the identical dates used with the dotted curve. This procedure yields the following comparison:

Triangle	AHB	BIC	CJD	DKE	ELF	FMG	Algebraic total
Sums:							
(1) Dotted	+33.3	+73.8	+117.7	+37.6	+36.2	+60.5	+359.1
(2) Full	-7.0	+46.0	+190.0	+43.0	+40.0	+48.5	+360.5

This comparison shows that in all but one of the six cycles of temperature change from low to high and return which occurred during the intervals from February 1 to March 14, 1943, the solar

integration and the actual event were in approximate accord regarding the phases, signs, and magnitudes of the changes. The one case of disagreement was caused by the solar integration having preceded the event by 2 days.

To determine how far solar predictions, if they were made, could be expected to anticipate the event, I have recourse to the columns used to give the aggregate. (See fig. 5 and fig. 3.)

On February 10 the result was almost entirely fixed by the solar rise of February 4 and the solar fall of February 9. Unless the latter could have been anticipated there would have been little range of prediction.

On February 15 the result depended chiefly on the solar fall of February 9 and the solar rise of February 13. Unless the latter could have been anticipated there would have been little range of prediction.

On February 20 the result depended mainly on the solar rise of February 13. Five other solar changes involved nearly canceled themselves out.

On February 25 the result depended mainly on the solar rise of February 18. Four other solar changes involved nearly canceled themselves out.

On March 3 the result depended mainly on the solar rise of February 18.

On March 8 the result depended mainly on the solar rise of March 4 and the solar fall of February 20.

It appears from these comparisons that approximate predictions a week in advance could be made of dates of peaks and troughs of Washington temperature if (1) daily reports of F_e were obtained from a sufficient number of ionization stations, and (2) if means could be found to anticipate by a few days closely the date of the next approaching solar change. Its sign would always be known to be opposite to that last observed. From present records we should expect solar changes of the same sign to follow each other at intervals of about 9 days, with changes of opposite sign intervening. The several effects of solar ups and downs of 1 to 3 weeks previous being known, we have only to estimate the effect a week hence of the change which is just about now occurring. We may hope that means may be found to anticipate by a few days more exactly the date of the next approaching solar change. Its sign will always be known, and also the effect that it will produce upon the temperature when it does occur. There is, I think, a fair hope that such important dates as

heavy frosts may become predictable a week in advance from solar observations by this method.

The method would appear to be applicable to any station in the world for which daily temperature records for the past 20 years are available.