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THE PERIODOMETER: AN INSTRUMENT FOR FINDING AND EVALUATING PERIODICITIES IN LONG SERIES OF OBSERVATIONS

(WITH ONE PLATE)

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C. G. ABBOT
Secretary, Smithsonian Institution

(PUBLICATION 3138)

CITY OF WASHINGTON
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(With One Plate)

In a paper entitled "Weather Dominated by Solar Changes,"[1] I described and illustrated a method of finding and evaluating periodicities by computation. My method consisted first in plotting the lengthy series of observational data on a large scale and scanning them from a distance in order to perceive tendencies, if any, toward a repetition of minima at some nearly regular interval.

Such an interval of 8 months seemed to appear in the plot of solar variation in the years 1924 to 1930. To test it and evaluate it, I arranged the 10-day mean solar-constant values in a table of 24 columns. The top line contained the values for the first 8 months, the second line those for the second 8 months, and so on until the data were exhausted. Mean values of the vertical columns were then taken. These indicated plainly the reality of the 8-month periodicity in solar variation, and determined the distribution of it. The mean form found for the curve of this periodicity did not approximate a sine curve, but showed a short quick rise from the minimum and a long slow decline from the maximum to the minimum.

The second step in computation was to subtract from the original data values representing the average march of the 8-month periodicity. A new curve of partial solar variation resulted, from which the average 8-month periodicity had been cleared. This residual curve was next scanned, and seemed to display an 11-month periodicity. It was evaluated and removed from the residual data in the same way that the 8-month periodicity had been evaluated and removed from the original data. The 11-month periodicity showed a double maximum and still less resembled a sine form than the 8-month periodicity.

A 45-month periodicity and a 25-month periodicity were similarly discovered, evaluated, and removed. In Figure 1, the residual curve *C*

[1] Smithsonian Misc. Coll., vol. 85, no. 1, 1931.

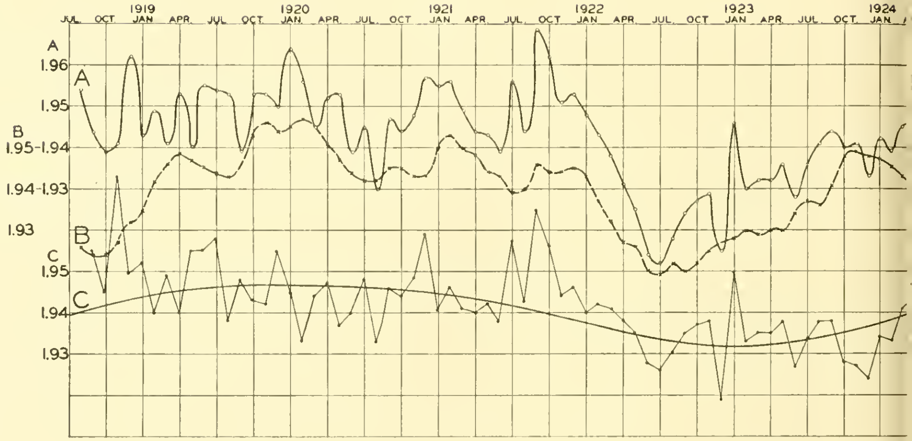
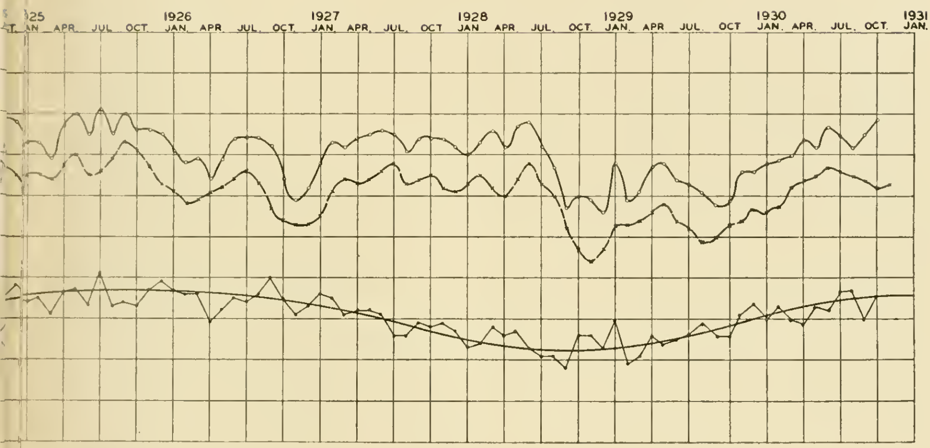


FIG. 1.—Monthly mean so



tins analysed for periodicity.

of solar variation, after thus evaluating and removing these four periodicities of 8, 11, 25, and 45 months, is compared with the original data shown in curve *A*. One other periodicity above 8 months appears conspicuously in curve *C*, namely, one of 68 months, as indicated by the smoothed curve. No other periodicity of importance remaining, the computation was concluded at that point. It had disclosed that the solar variation since 1918, as depicted by the march of monthly mean values, is adequately represented as the sum of five regular periodicities of 8, 11, 25, 45, and 68 months, whose sum is given in curve *B* of Figure 1. Curve *B* is drawn below curve *A* to avoid confusion, but will be seen to be a very close copy of curve *A*, except in the early years when the observations were least satisfactory.

I would like to emphasize that none of these five periodicities is of sine form, though the 68-month residual is not far from it. I would like also to remark that these five necessary and sufficient constituents of the solar variation since 1918 are not related to each other in length in the ratios $1 : \frac{1}{2} : \frac{1}{3} : \frac{1}{4} : \frac{1}{5}$ as would have been the periodicities used in Fourier analyses. It seems to me that the method which I have used leads more directly to true and significant relations than the arbitrary fitting of a curve by the classical methods based on Fourier analysis.

It occurred to me that the various steps used in computing might be done by a machine. Having suggested its design, I was so fortunate as to receive a grant of $1,000 from the Research Corporation of New York to aid in the construction. The work was done mainly by Mr. A. Kramer, instrument maker of the Smithsonian Astrophysical Observatory. Finding some difficulty, however, with the two large grooved barrels, each equipped with 152 sliders and a clamping device, these parts were very accurately made to my order by the Gaertner Scientific Corporation of Chicago.

Plate 1 gives a photograph of the completed instrument. A steel scale, *a*, with double graduation into millimeters and half millimeters, respectively, enables the observer to set up the data on the right-hand drum. This he does by rotating the knurled wheel, *b*, which, through gearing, engages a rack at *o*, on which is carried a vertical displaceable pawl. This pawl is adapted to engage successively the sliders, *d*, *d*, 152 in number, and push them along their grooves to proper settings, as measured by the scale, *a*. Check screw-clamps are provided to stop the rack at zero of the scale, *a*, on each return motion, whether to left as just indicated or to right as mentioned below. Thus a long curve, determined by the original data, is set up on the right-hand drum, and its sliders are clamped and fixed immovably by the screw and band, *e*, *e*. A small vice-clamp, *f*, operated by a knurled head now grasps one of the sliders on the left-hand drum. The vertical pawl used in pushing the sliders of the right-hand drum to their positions is now pushed by the rack and knurled wheel, *b*, until it touches the slider lying at the top of the right-hand drum. A train of gearing, *g*, *h*, variable through ratios $\frac{1}{5}$, $\frac{1}{4}$, $\frac{1}{3}$, and $\frac{1}{2}$ operates simultaneously a rack carrying the knurled head and its vise-clamp, *f*, and thereby pushes the front slider on the left-hand drum through $\frac{1}{5}$ (or other preferred fraction) of the travel of the pawl.

Returning to zero of the scale, *a*, the two drums are then moved forward one division by making a single rotation of the knurled wheel, *i*. The above process is repeated until as many sliders are set on the left-hand drum as there are data in the periodicity sought. Let us assume for illustration that these data number 8. Thus the individual values of this interval of 8 data are reproduced on $\frac{1}{5}$ scale on the left-hand drum. That drum is now reversed to its starting position, and a new series of 8 pushes is made. As these new pushes start from the positions already attained, we now have the average of the first 16 data reproduced on $\frac{2}{5}$ scale. Repeating the process until 40 data are covered, the left-hand drum then exhibits the mean value of the 8-datum periodicity over an interval of 40 data.

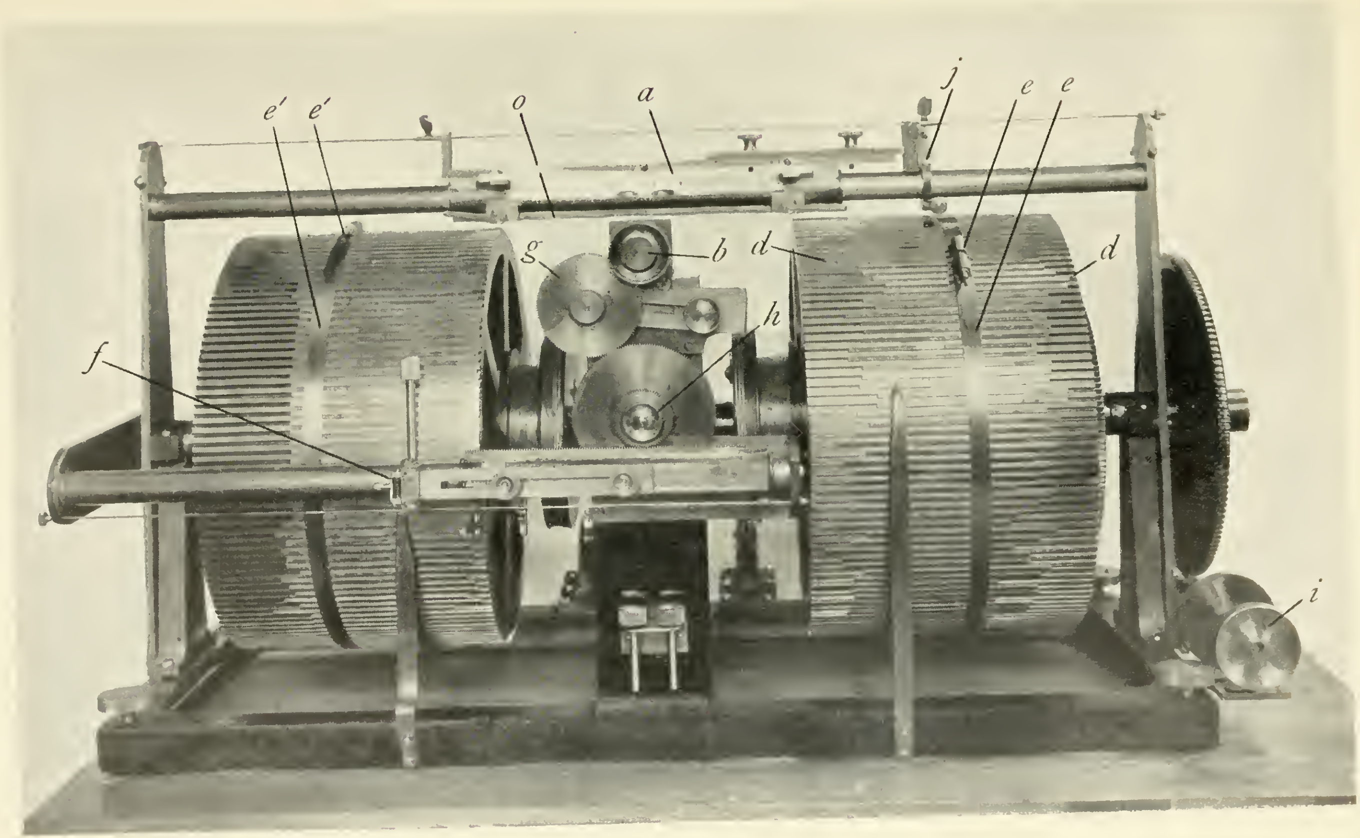
If the periodicity sought seems real, as revealed by the form of the mean curve thus determined, it may next be read off and recorded. Fresh data on the right-hand drum may then be used to give a second and a third determination of the 8-datum period. If these new determinations of it harmonize fairly with the first, then it is clear that the 8-datum period exists throughout the whole interval of the data. A mean of the three determinations is taken to represent it.

The general mean form of the 8-datum periodicity is next set up on the left-hand drum and clamped. The sliders of the right-hand drum are loosened. Then, employing the vise-clamp, *j*, and a second pawl available for the left-hand drum, all the sliders on the right-hand drum are moved toward the left through distances determined by the periodic setting of the sliders of the left-hand drum. This average 8-datum periodicity is used end to end successively so as to remove completely the average 8-datum periodicity from all the original data. Thus a residual curve remains, from which the average 8-datum periodicity has been eliminated.

The same procedure is repeated with any other periodicities which seem to be displayed by the settings of the sliders on the right-hand drum, until all promising possibilities are exhausted.

It is frequently desirable to take consecutive means of several data at a time in order to smooth a long series of observations. This is readily done with the periodometer. The original data are set up as usual on the right-hand drum. They are then all consecutively transferred to the left-hand drum on a scale of $\frac{1}{5}$, $\frac{1}{4}$, or accordant to any preferred smoothing grouping of five or less. The left-hand drum is then set back by the interval of one groove, and the transfer of all the data is made a second time. This process is repeated five times, four times, or to correspond with whatever consecutive grouping is chosen. The left-hand drum will then have set up upon it a curve on the same scale as the original curve, but smoothed by consecutive means. This curve may be read off and recorded or it may be transferred back to the right-hand drum as follows: Set the right-hand check screw-clamp corresponding to zero of the scale, *a,* and all the right-hand sliders at zero. Disconnect the gear train, *g, h,* and set the left-hand pawl as described above for eliminating evaluated periodicities. Turn the knurled wheel, *b,* towards the left till the pawl touches a slider, clamp the right-hand clamp, *j,* and turn back to zero of scale, *a.* Repeat for all the data of the smoothed curve, and the right-hand drum will then have upon it the smoothed curve set up ready for periodicity determinations.

As yet the periodometer has not been extensively used. It may be that after longer experience with it additional automatic features may be introduced which will promote speed of operation. In its present form it works well.



The Periodometer.