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In an earlier paper [1] I gave preliminary figures that indicated periods in ionospheric data which agreed in length with periods in solar variations and in weather. They are integral submultiples of 273 months. In a still earlier paper [2] I showed other relationships appearing to exist between solar variation and ionospheric data. The ionospheric data then available were insufficient to yield fully convincing conclusions on these relationships. With more recent data now available, I return to the subject.

THE MASTER PERIOD

Before going on I will refer to the master period which I assign as 273 months. My friend Herbert Grünhagen has discussed this period with me in correspondence. His own extensive studies of periodic phenomena have led him to prefer 22.6 years, or 271.2 months. Though the difference from 273 months is less than 1 percent, yet in a long series like 90 years a subordinate integrally related period would many times trend in opposite phases, using these two different values. I therefore wished to decide definitely between them. As precise solar-constant values are recorded only since 1920, it is necessary to use the longer records of some related phenomenon. The 10⅑-month period $\left(\frac{273}{27}\text{ months}\right)$ is strong in Washington precipitation, though I believe meteorologists do not yet give it credence. I therefore computed the amplitude of the period, 1/27 the disputed master period, from Washington precipitation of 1854 to 1957. I made three such computations with $\frac{271.2}{27}$, $\frac{273}{27}$, and $\frac{275}{27}$ months. In these computations I used the precautions I employ in my weather forecasts, as

[1] Smithsonian Misc. Coll., vol. 122, No. 4, 1953.
[2] Smithsonian Misc. Coll., vol. 107, No. 4, 1947.

described in several of my papers.[3] In the tabulations for the present purpose I used only months when Wolf sunspot numbers exceeded 20. These months were 790 in number. The results found were as follows, zero phase, January 1, 1957.

TABLE 1.—*Values in Washington precipitation in percentages of normal*

Period											Range
271.2/27	105.7	103.4	102.5	100.7	100.9	96.3	97.3	97.9	98.0	97.7	9.4%
273/27	95.7	95.8	93.4	96.1	99.3	102.0	103.7	108.0	104.8	101.1	14.6%
275/27	109.8	102.4	103.3	99.3	95.4	92.9	96.2	97.6	98.8	104.5	16.9%

As expected, the phases of the three periods differ. The ranges of the last two are, within the precision of the determination, approximately equal, and are both definitely greater than the range of the first. As it is more convenient in computation to use the integral submultiples of 273 than those of 275, I shall continue to use 273 as the master period.

PERIODS IN IONOSPHERIC PHENOMENA

The periods I am about to consider are exact integral submultiples of 273 months, and are approximately the same I have used in long-range weather forecasts. The list with several recent additional ones was published January 1958 in the Journal of the Association for Applied Solar Energy, at Phoenix, Ariz. Values of the quantity $h'F_2$, published by the Bureau of Standards in "Ionospheric Data," July 1944 to June 1957, were employed. From these tabulations Mrs. Hill computed the daily mean values for the average of the hours 11, 12, 13, and from these the monthly mean values. In a few cases (about 5 in total number), where the observations were fragmentary, monthly values were interpolated harmonious to the trend of the complete observations of similar months.

As I had used these observations for the years 1944 to 1952 in an earlier publication, I employed the mean monthly value 315, then determined, rather than to do that earlier work all over, using the mean from 1944 to 1957. It makes little difference in the departures from the mean, merely altering the whole list of departures by a few units up or down, all in the same direction.

[3] See, for instance, Smithsonian Misc. Coll., vol. 134, No. 1, p. 5, 1956; or Journ. Solar Energy, Sci. and Eng., vol. 1, No. 1, pp. 3, 4, 1957.

Taking the monthly departures of $h'F_2$ from 315, I arranged them in a table by months of the year and found the mean monthly normals and their average departures from the means as follows:

TABLE 2.—*Monthly mean departures of $h'F_2$ from 315*

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
−69±9	−60±14	−27±24	+29±30	+88±26	+89±25	+93±19	+73±35	0±11	−52±13	−71±10	−73±9

From these figures the mean average deviation is ±19 and the mean probable error of the monthly mean departures from 315 is ±15. I subtracted the appropriate values in table 2 of the monthly departures of $h'F_2$ from the mean value 315, for the interval July 1944 to June 1957. I then tabulated these departures from the monthly means for many periods up to 20 months, which are integral submultiples of

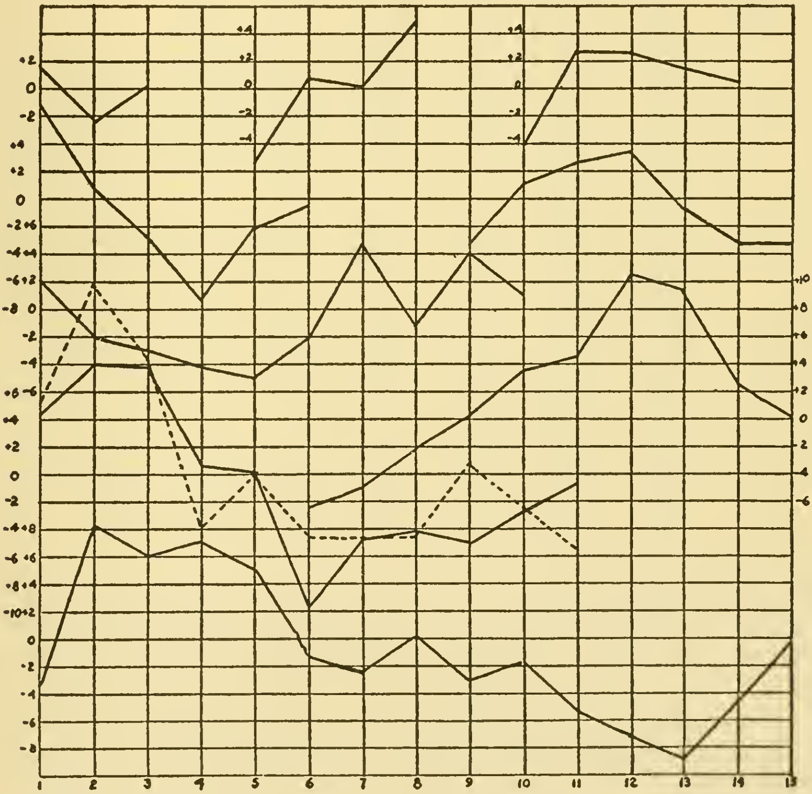

FIG. 1.—Periods in months integrally related to 273 months. Top line: $2\frac{23}{34}$, $4\frac{1}{3}$, $5\frac{1}{18}$ months. Second line: $6\frac{1}{15}$, 7 months. Third line: $9\frac{3}{4}$, $10\frac{1}{8}$ months. Fourth line: $11\frac{3}{8}$ months; dotted curve, preliminary. Fifth line: $15\frac{1}{6}$ months.

273 months. In several cases where small but real amplitudes were expected, the curves carried subordinate overriding periods, integrally related to those sought. I give two instances. The period $8\frac{1}{34}$ months was found to be almost completely comprised of the period $8\frac{1}{34} \div 3$ and another $8\frac{1}{34} \div 4$. So the period $8\frac{1}{34}$ months disappeared. The period $11\frac{3}{8}$ months carries a feeble superrider of $11\frac{3}{8} \div 3$. I show

TABLE 3.—*Periodicities in monthly values of departures in $h'F_2$*

Monthly periods	March of departures and probable errors							
$2\frac{23}{24}$	+1.6	−2.5	+0.2					
	±1.1	±1.1	±1.1					
$4\frac{1}{3}$	−5.4	+0.7	+0.1	+4.8				
	±1.5	±1.5	±1.5	±1.5				
$5\frac{1}{18}$	−4.2	+2.6	+2.6	+1.5	+0.5			
	±1.6	±1.6	±1.5	±1.5	±1.5			
$6\frac{1}{15}$	+6.9	+2.7	−2.7	−7.4	−2.2	−0.6		
	±1.8	±1.8	±1.8	±1.8	±1.8	±1.8		
7	−3.3	+1.1	+2.6	+3.4	−0.7	−3.3	−3.2	
	±2.0	±2.0	±2.0	±2.0	±2.0	±2.0	±2.0	
$9\frac{3}{4}$	+2.1	−2.9	−4.2	−5.0	−2.2	+4.6	−1.4	−4.4
	±2.1	±2.1	±2.1	±2.1	±2.1	±2.1	±2.1	±2.1
	+3.9	+1.0	..	..	..	..	..	..
	±2.1	±2.1	..	..	..	..	..	..
$10\frac{1}{9}$	−8.5	−7.2	−4.1	−1.7	+1.6	+2.4	+8.5	+7.2
	±2.1	±2.1	±2.1	±2.1	±2.1	±2.1	±2.1	±2.1
	−0.5	−3.9	..	..	..	..	..	..
	±2.1	±2.1	..	..	..	..	..	..
$11\frac{3}{8}$	+4.2	+7.9	+7.8	+0.5	+0.1	−10.0	−4.9	−4.3
	±2.2	±2.2	±2.2	±2.2	±2.2	±2.2	±2.2	±2.2
	−5.1	−2.8	−0.7	..	..	..	..	..
	±2.2	±2.2	±2.2	..	..	..	..	..
$15\frac{1}{6}$	−3.4	+8.3	+6.0	+7.1	+5.1	−1.4	−2.5	+0.2
	±2.3	±2.3	±2.3	±2.3	±2.3	±2.3	±2.3	±2.3
	−3.1	−1.7	−5.3	−7.3	−8.7	−4.7	−0.3	..
	±2.3	±2.3	±2.3	±2.3	±2.3	±2.3	±2.3	..

these two cases in figure 1 and table 3. Figure 1 gives curves for $2\frac{2}{3}$ and $4\frac{1}{68}$ months derived from a tabulation for $8\frac{1}{34}$ months. The dotted curve with $11\frac{3}{8}$ months is the preliminary before removing $11\frac{3}{8} \div 2$. In six other tabulations which I made (not here shown), superriding integrally related periods were entangled with the periods sought, in complexities which I did not take time to ferret out and so I omit those 6 cases. As will appear in table 3 and figure 1, I present nine clear cases of periodicity in the quantity $h'F_2$ not obscured by overriders.

By inspection of table 3 and figure 1 readers will see the march of $h'F_2$ values in the periods integrally related to 273 months. Within the limits of precision indicated by the probable errors, the curves are fairly regular. The ranges of amplitude of the curves are from $1\frac{1}{3}$ to 5 percent of the average monthly value 315. These ranges are only about one-fifth as great in percentage as the ranges of weather periods found in percentages of normal precipitation. Yet they are about 20 times as large as the percentage changes of the solar constant of radiation. All alike, these three varieties of phenomena proceed in periods integrally related to 273 months. A theoretical solution of their correlation would be interesting indeed.