ONINKLIJK NEDERLANDS METEOROLOGISCH INSTITUUT

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A NEW ANALYSIS OF SOME FEATURES OF THE 11-YEAR AND 27-DAY CYCLES IN SOLAR ACTIVITY AND THEIR REFLECTION IN GEOPHYSICAL PHENOMENA

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PREFACE

PROFESSOR VISSER's new analysis of the two fundamental solar cycles, the cycle of the sun's activity and the cycle of the sun's rotation, as shown by sunspot numbers and some terrestrial phenomena, is an attempt to deduce some essential features of these cycles by means of a method of analysis specially adapted to this purpose.

The application of binomial averages of sunspot numbers through five successive solar rotations to the whole series of data running from 1863 to 1959 does mean an extremely time-consuming calculation which was undertaken by the author himself. A number of tables in appendix contains the results of the enumerations. Although indispensable, these tables are perhaps less instructive than the series of figures representing in detail the course of the nine solar cycles which have elapsed since 1863.

Moreover suggestive light is thrown on the fluctuations in geomagnetic, ionospheric and meteorological elements.

It is my hope that the present investigation and refinements of earlier analyses may contribute to the physical interpretation of some solar phenomena and some important solar-terrestrial relationships.

The Director in Chief
Royal Netherlands Meteorological Institute
IR. C. J. WARNERS

CONTENTS

1. GENERAL REMARKS

1.1 The character of the 27-day solar rotation period

The daily relative sunspot numbers as collected and published by the "Eidgenössische Sternwarte" at Zürich, are known over a great number of years. Zürich gives also monthly and annual averages of these daily numbers and moreover smoothed monthly values. Monthly and annual average sunspot numbers, however, have no heliophysical meaning because the month and the year are not relevant to the Sun's activity. The only acceptable average is that based upon the Sun's synodic rotation. A duration of 27,2753 days has been used in the Nautical Almanac. This figure is not as accurate as is suggested by the four decimal places, claiming an exactitude of 3,4 seconds. The Sun's rotation is variable depending on the heliographic latitude, and its synodic rotation changes in the course of a year in accordance with Kepler's second law. At high solar latitudes (35–40°) where sunspot activity starts anew at each minimum of the 11-year cycle, the duration is 27,75 days, at low solar latitudes, where the sunspots die out towards the end of the 11-year cycle, it is only 27,05 days. The average duration mentioned above is valid for a latitude of about 15°. The duration when the earth is in its perihelium (January) is 27,34 days, when the earth is in its aphelium (July) 27,20 days. These variations of the duration, even present in the first decimal place, show the unreliability of the 4 decimal places given. Yet I have adopted 27,275 days for the Sun's rotational period in order to link my results with the average duration generally accepted.

Actually the Sun's rotation is the cause of the appearance of an approximate 27-day periodicity in a number of solar and terrestrial phenomena. This 27-day periodicity, however, is highly capricious: it starts at some arbitrary moment, it dies out at another moment and it may be absent during long time intervals. When average values of its wave length and amplitude are calculated over many years the period fades out or is only poorly revealed.

As an example of the application of this unsatisfactory method Buys Ballot's investigation may be recalled here. The present author gave a short account of it in the Centenary Memorial Book 1854–1954 of the Royal Netherlands Meteorological Institute, in the following words.

> Buys Ballot occupied himself from 1846 to 1886 with the investigation of a temperature period of about 27 days. He arranged the daily temperatures observed at Zwanenburg from 1729–1861, and later at Utrecht, in 28 columns. When a sinusoidal 28-day period exists with a maximum in the first half and a minimum in the second half of the period the temperature differences between the days 1 and 15, 2 and 16 etc. must be positive. Buys Ballot arranged the differences

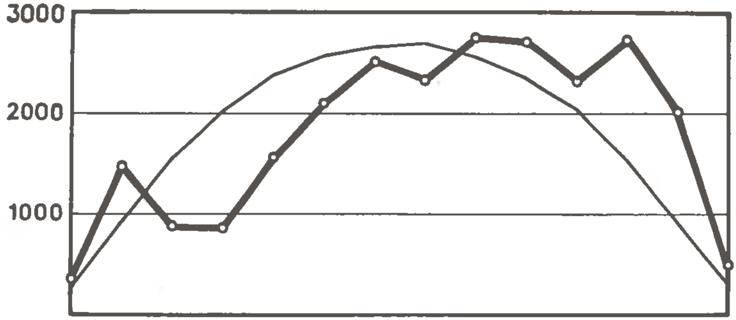

FIG. 1. Buys Ballot's period, 1729–1884.

in 14 columns and mentioned all positive differences "profit", all negative ones "loss". This profit and loss account gave a surplus of 26665 °F in 145 years. This impressive amount, however, shows a greatest difference of only 0,5 °F per period, being the amplitude of the temperature wave. By applying corrections BUYS BALLOT deduced in 1876 a duration of the period of 27,682 days. In his last publication (1886), concerning 2046 periods, he modified the duration to 27,675 days. His "Tableau récapitulatif" has been graphically reproduced in Fig. 1. The amount of profit in his tables is notably large. Some reality may be ascribed to this period, the practical value, however, is negligible. Today it is well known that solar activity influences atmospheric temperatures. Therefore BUYS BALLOT's temperature wave may be due to the Sun's rotation, but possibly the duration has been distorted by his method of working. A closer analysis of the data is required to disclose the cause of the discrepancy in his results.

A report of such a closer analysis is now given in chapter 5.

1.2 The enumeration of the solar rotations

There are two methods of enumerating the solar rotations.

1° The enumeration is based strictly on the Sun's synodic rotation (Carrington). In the Greenwich Photoheliographic Results it is used as follows: The commencement of each is defined by the coincidence of the assumed prime meridian with the central meridian, the assumed prime meridian being that meridian which passed through the ascending node of the Sun's equator on the ecliptic at mean noon of 1854, January 1, the assumed period of the Sun's sidereal rotation being 25,38 days. This definition has always been used in the Nautical Almanac (Greenwich, 1955). This enumeration reached No. 1396 in 1958, January 12,96 (U.T.).

2° The enumeration is based on a constant period of exactly 27 days (J. BARTELS). BARTELS speaks of the "geophysical rotation time" and may do so because as a rule the solar influence on geophysical phenomena is limited to sequences of only a few periods, the small discrepancies allowed being immaterial. Yet, as I have pointed out earlier, during long sequences the differences become obvious. BARTELS's enumeration started February 8, 1832. Rotation No. 1705 has been reached January 26, 1958.

1.3 The new analysis

The present investigation is concerned with solar observations made since January 1, 1863. Before this date WOLF published in his "Mitteilungen über Sonnenflecken" daily values of g (number of groups) and f (number of spots). He has added monthly averages of relative sunspot numbers, but it is not quite clear how he deduced these early averages. Therefore I have omitted the observations made in the years before 1863. From the above date onwards the "Mitteilungen" contain the daily relative sunspot numbers. Up to January 1872 the monthly means differ from those published by WALDMEIER [1957, p. 143; cited in this paper as E. und P.]. Yet I have preferred WOLF's daily figures for the years 1863–1871 inclusive. The number of missing days in these years amounts to an annual average of 13. They have been filled up by linear interpolation.

For the whole interval 1863–1958 running 27-day averages have been calculated. In order to deduce the average rotation period of 27,275 days, I have proceeded as follows. The duration of 100 periods of 27,27 days equals that of 101 periods of 27 days. Therefore I have omitted systematically one day in each 3 or 4 27-day periods in such an order that one period is eliminated in 101 periods. So we get a close approximation of a period of 27,27 days. The third decimal 5 is accounted for by deleting one day for each 200 27-day periods. As to the fourth decimal 3 (Nautical Almanac), in 1000 periods the difference amounts to 0,3 day. Since nowadays only 1400 periods have expired it is evident that the fourth decimal may be wholly neglected.

As the basis of this reduction the first day of Rotation No. 1369, January 7, 1956 (beginning January 7,51), has been taken. Comparison with the rotation numbers of Greenwich Observatory (1874–1954) showed that the difference with the true data never exceeded 1,5 days, this being immaterial for the present purpose.

In this way a series of running daily averages in which the rotation period is eliminated, has been obtained, representing the slow variations of solar activity (e.g. the 11-year cycle). The differences between the 27,275-day averages on one day and the sunspot numbers observed on the same day, give the rotation period, when present, by more or less regular sequences of positive and negative deviations.

This method has great advantages. The results are freed from the terrestrial units of months and years and they represent both the slow variations and the rotation period when present.

The same procedure has been applied to the daily maximum temperatures at Utrecht-De Bilt (since 1863), the magnetic character figures C (since 1891) and K (since 1940) both for De Bilt-Witteveen, and the ionospheric index I, determined at De Bilt since 1952 (daily sums of 8 three-hour intervals). These data will now be treated only briefly, but will be fully discussed in a following communication.

1.4 The smoothing of the relative sunspot numbers

WALDMEIER [E. und P., p. 140] has applied a smoothing method which he describes as follows.

> "Die ausgeglichenen Relativzahlen werden bestimmt, indem man je 12 aufeinanderfolgende Monatsmittel der beobachteten Relativzahlen zum Mittel zusammenfasst und aus je zwei solchen aufeinanderfolgenden Zahlen noch einmal das Mittel nimmt. Diese ist die ausgeglichene Relativzahl für die Mitte des mittleren der so vereinigten 13 Monate. Durch diese Ausgleichung werden die kurzperiodischen Schwankungen eliminiert und die langperiodischen treten deutlicher hervor. Tabelle 32 enthält die vollständige Reihe der ausgeglichenen Monatsmittel. Das in den Tabellen 31 und 32 enthaltene Material bildet den Grundstock, auf den sich fast alle die zahlreichen statistischen Untersuchungen über die Variationen der Fleckentätigkeit sowie über die solar-terrestrischen Zusammenhänge ausbauen."

This method has not been changed since WOLF in 1862 devised it. An uninterrupted homogeneous series of sunspot data has been obtained in this manner, but the smoothing method is not in essence statistically justified. It must be considered as an arbitrary step in the direction of characterizing sunspot activity. As a matter of fact strongly smoothed figures are arrived at, from which the short periods are eliminated. When we wish to investigate these short periods, then a more satisfying smoothing process is needed. Moreover it will be shown that WOLF-WALDMEIER's procedure gives to a certain extent a wrong picture of the course which the sunspot phenomenon takes.

In the present investigation I started with the smoothing method $(R_1 + 2R_2 + R_3) : 2^2$. In this way a new row of figures is obtained and hereupon the same procedure may be applied. The result is represented by the formula

$$(R_1 + 3R_2 + 3R_3 + R_4) : 2^3.$$

Proceeding in the same way, we obtain

$(R_1 + 4R_2 + 6R_3 + 4R_4 + R_5) : 2^4$
$(R_1 + 5R_2 + 10R_3 + 10R_4 + 5R_5 + R_6) : 2^5$
and so on.

Yet, after a few steps the "amelioration" becomes negligible. It appeared to be unnecessary to go beyond the 5 original data and the divisor 2^4 (see also 2.3).

The coefficients of the formulae are the binomial coefficients and the averages are obtained by successive powers of 2. These averages will be called "binomial averages of the *nth* power" and denoted by *Rbn*, *n* being the exponent of 2. They are calculated with the aid of $(n + 1)$ original data. So I have calculated the binomial averages of the 4th power, involving 5 data, *Rb*4.

The advantages of this smoothing method are

1. the time interval, 5 synodic solar rotation periods (about 4,5 months), is much shorter than the 13 months used in the Zürich method;
2. the central data receive more weight than the extreme ones, whereas the Zürich Observatory gives the same weight to all of them, with the exception of the two outermost ones which receive the weight $\frac{1}{2}$.

So the short periods stand out clearly and a much more satisfying insight into the features of sunspot activity is obtained.

1.5 The results

Table 1 (Appendix), containing the results, has been composed as follows. Since two years (730 days) have the same duration as 27 periods of 27 days (729 days), 27 periods have been distributed over two years in such a way that as a rule years with 13 and 14 periods alternate. The periods are inscribed so that the first day of the first period in each year falls in January, the last day of the last one in December. In this manner the 12 months are distributed regularly over the columns of the table.

Column 1 contains the years, from 1863 up to the beginning of 1959, column 2 the numbers of the 11-year sunspot cycles, 10–19, and the Carrington numbers referring to the dates in January in the next column. Then follow 27 columns with the data R_m, being the averages of the 27,275-day period, and *Rb*4, the smoothed averages calculated with the aid of the procedure *b*4, elucidated above. Predominant peaks have been printed in bold type, the maxima of the 11-year cycles are moreover underlined. The minima of these cycles have been printed in italics.

2. THE BEHAVIOUR OF THE 11-YEAR CYCLE

2.1 The epochs of the maxima and the minima

The epochs of the smoothed maxima and minima (*Rb*4) of the 11-year sunspot cycles, compared with those of WOLF-WALDMEIER, have been gathered in Table 2.

TABLE 2. *Maxima and Minima of the* 11-*year solar cycle*

	*Rb*4 - averages						Waldmeier			
No.	minimum			maximum			minimum		maximum	
	Carr.	year	min	Carr.	year	max	year	min	year	max.
11	178	1867,1	2,4	221	1870,3	163,0	1867,2	5,2	1870,6	140,5
12	338	1879,0	0,6	406	1884,1	89,4	1878,9	2,2	1883,9	74,6
13	483	1889,9	1,7	533	1893,6	101,0	1889,6	5,0	1894,1	87,9
14	641	1901,7	1,4	714	1907,1	84,2	1901,7	2,6	1907,0	64,2
15	798	1913,4	0,2	855	1917,6	136,3	1913,6	1,5	1917,6	105,4
16	941	1924,1	2,1	997	1928,2	88,4	1923,6	5,6	1928,4	78,1
17	1073	1933,9	1,3	1121	1937,5	138,6	1933,8	4,3	1937,4	119,2
18	1213	1944,4	2,8	1256	1947,6	181,2	1944,2	7,7	1947,5	151,8
19	1342	1954,0	1,4	1393	1957,8	237,4	1954,3	3,4	1957,8	199,0

Furthermore some notable differences between WALDMEIER's summarizing table 33 (E. und P., p. 153) and the smoothed amounts given by table 32 (p. 148–150) are assembled in Table 3.

TABLE 3. *Notable differences between Waldmeier's two tables of sunspot maxima and minima*

	table 33		table 32		
minimum	1889,6	5,0	1890, Feb	5,0	1889, Jun 6,3; Jul 6,5; Aug 6,3
minimum	1901,7	2,6	1902, Jan	2,6	1901, May 2,8; Jun 2,8; Jul 3,0; Aug 3,1
maximum	1907,0	64,2	1906, Feb	64,2	1906, Dec 60,1; 1907, Jan 56,9 Feb 55,0
maximum	1947,5	151,8	1947, May 1948, Oct	151,8 148,5	

As regards 1906 Baur (1951) has considered 1906,4 to be the epoch of the minimum.

Since WALDMEIER does not refer in table 32 to the epochs of table 33 (see righthand part of Table 3) I have considered the epochs of WALDMEIER's table 32 to represent the true extremes, which means the assumption of sunspot minima in 1890,2 and 1902,1, and of maxima in 1906,2 and 1947,5. Notable differences between WALDMEIER's extremes and those according to the *b*4-

procedure (see Table 2) are: *cycle* 11, maximum 1870,6 and 1870,3; *cycle* 13, minimum 1890,2 and 1889,9; maximum 1894,1 and 1893,6; *cycle* 14, minimum 1902,1 and 1901,7; maximum 1906,2 and 1907,1; *cycle* 16, minimum 1923,6 and 1924,1; *cycle* 19, minimum 1954,3 and 1954,0.

2.2 Waldmeier's three groups of solar cycles

WALDMEIER [1935] has subdivided the 18 eleven-year cycles since 1750 into three groups, characterized by different lengths of the ascending branch of the corresponding sunspot curves.

TABLE 4. *Waldmeier's three groups of sunspot cycles*

	mean max sunspot number smoothed	ascending branch		
		mean duration min – max	limiting durations	cycle No.
A. 6 strong cycles	145,1	3,5 years	2,9–4,6 years	3 and 9
B. 6 moderate cycles	102,1	4,3	3,2–6,3	2 and 1
C. 6 weak cycles	64,4	5,7	4,8–6,9	16 and 5

Cycle numbers. A. 3, 18, 8, 4, 11, 9;
B. 17, 2, 15, 10, 13, 1;
C. 16, 12, 7, 14, 5, 6.

The limiting durations of the ascending branch for each group show that group B is wholly overlapped by the groups A and C. It may better be deleted, by which the following arrangement results,

9 strong cycles	134,5	3,5 years	2,9–4,6
9 weak cycles	73,2	5,5	4,8–6,9

The same procedure applied to the *Rb*4 averages of the latest 9 cycles yields the following results,

	mean max sunspot number	ascending branch			
		mean duration in syn. rot.	mean duration in years	limiting durations in syn. rot.	limiting durations in years
5 strong cycles	171,3	48,4	3,6	43–57	3,2–4,2
4 weak cycles	76,2	61,8	4,6	50–73	3,7–5,4
The same cycles according to Waldmeier's method					
5 strong cycles	154,2		3,8		3,3–4,0
4 weak cycles	76,4		4,9		4,5–5,3

Cycle numbers. Strong cycles: 19, 18, 11, 17, 15;
Weak cycles: 13, 16, 12, 14.

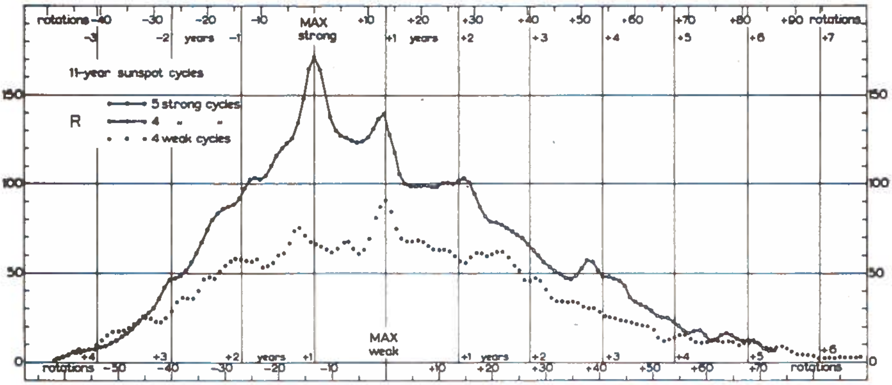

FIG. 2. Strong and weak 11-year sunspot cycles, based on the solar rotation period.

Following both smoothing methods the differences in length of the ascending branches of the sunspot curves have become smaller, whereas the scattering in the final values of these durations when WOLF's method is used, is less than when the binomial method is used.

It is worth while to calculate the average course of the sunspot numbers for each of the two groups of solar cycles now accepted. The results based upon the 27-day averages have been represented in figure 2. Since the present investigation included only the end of 1958, a great part of the descending branch of the mean sunspot curve for the strong cycles is only supported by four cycles. In concordance with the results set forth above the average sunspot maximum of the weak cycles has been plotted one year later than that of the strong cycles. In this manner both curves start with their minimum at the same place. Both curves show a striking similarity. Especially the maximum of the strong cycles coincides fairly well with a secondary maximum of the weak cycles, whereas the maximum of the weak cycles arrives at the same moment as a secondary maximum of the strong ones. The behaviour of the curves agrees rather well with the results concerning the secondary peaks arrived at in point 2.4.

I emphasize the steep rise of the ascending branch of the sunspot curve when solar activity is strong without well developed secondary peaks (see 2.4, Table 7).

Now, a remarkable feature is that the maximum mean sunspot number reached in the course of weak cycles, as selected here, does not surpass 90, since I have shown (1959) that in sunspot numbers an obvious threshold value exists near $R = 85$, and that the consequences of this fact are obvious in terrestrial phenomena too. I wish to point here to the following previous conclusions.

a. As regards the 2- to 3-year period in world weather, five of BERLAGE's six empirical rules regulating the Southern Oscillation (1957) may be united in one general rule concerning the different influence of solar activity in the two cases of 11-year sunspot cycles reaching maximum *R* above or below 85. Evidently the behaviour of strong and weak cycles differs not only with regard to the quantity of sunspots, but also with regard to the quality of solar activity. It appears that the duration of the Southern Oscillation is shortened to two years during strong solar activity but lengthened to three years during weak solar activity. This effect is steered by the sunspot maximum in such a way, that at its passage the connection with the 11-year period is reestablished by one interval of 3 and 2 years respectively.

b. As regards the 7-year period in world weather, two cycles of half this duration, say two air pressure peaks in 7 years occur during solar cycles with maximum *R* below 85, whereas during solar cycles with maximum *R* above 85 three peaks occur in the same interval.

c. The polar lights remain at a high level of frequency for six years after the sunspot maximum during strong cycles, while during weak cycles there is a polar light maximum for one year only, coinciding with the sunspot maximum (see Table 5 in the Appendix and Fig. 3, compiled from FRITZ's Tables (1873).

d. A similar opposition between times of high and low sunspot numbers exists in the halo phenomena in Java (ARCHENHOLD, 1930; VISSER, 1931).

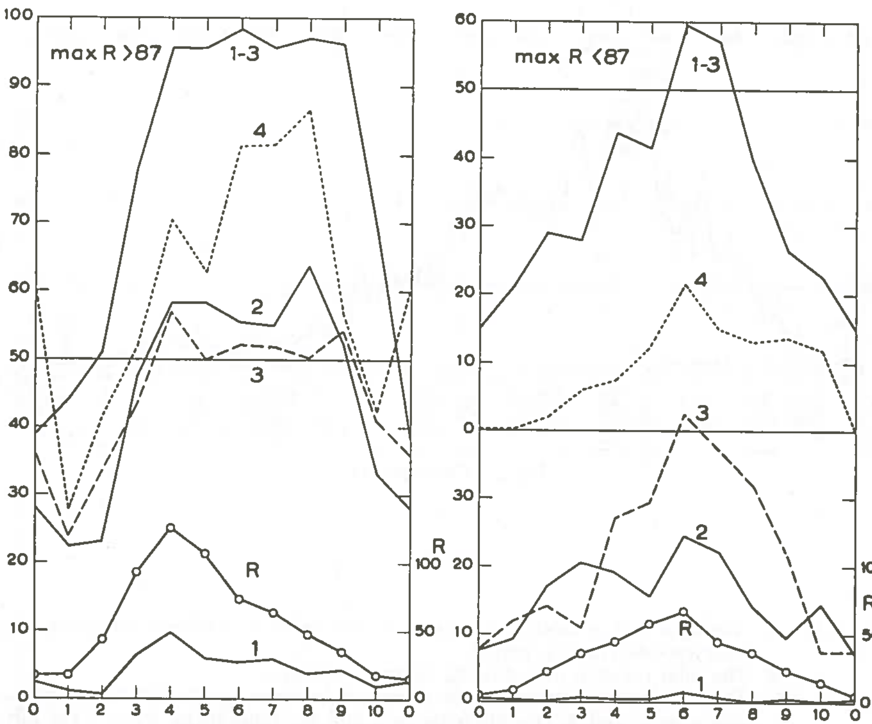

FIG. 3. Polar lights and the 11-year period, 1744–1866.
a. Max. $R > 87$; b. Max. $R < 87$.

Legenda to Figures 4–13 (*A*)

— — — — — —	*Rm*
————————	*Rb4*
• • • • • • •	Zürich smoothed monthly means
m and *M*	*Rb4* extremes
m_W and M_W	Zürich extremes

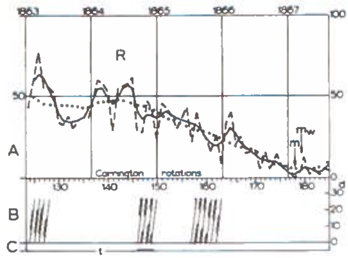

Fig. 4. Cycle no. 10

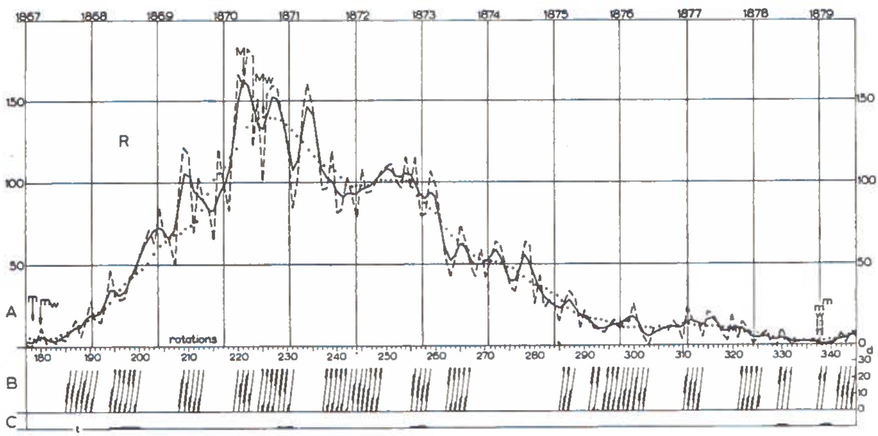

Fig. 5. Cycle no. 11

FIG. 4–13. A. Averages and smoothed averages of the sunspot numbers, based on the solar synodic rotation period.
B. The solar rotation period in the sunspot numbers.
C. The solar rotation period in the maximum temperature De Bilt, the magnetic character *C* and *K* De Bilt-Witteveen, and the ionospheric index *I* De Bilt.
D. Running *b*4 averages of *C*, *K* and *I*.

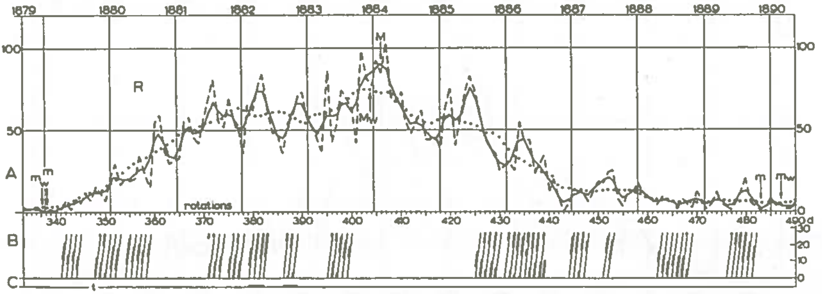

Fig. 6. Cycle no. 12

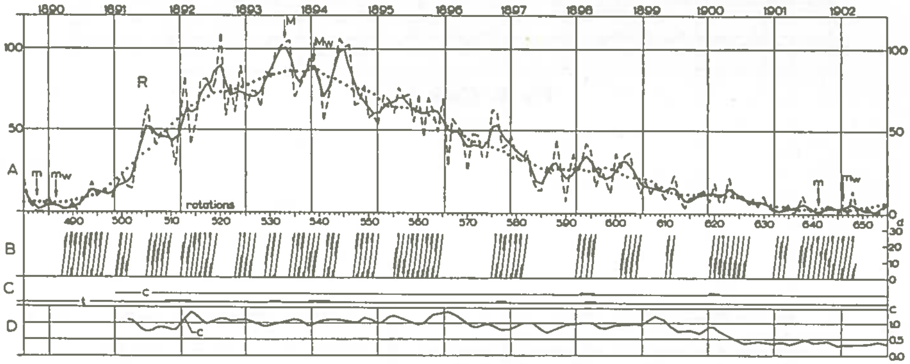

Fig. 7. Cycle no. 13

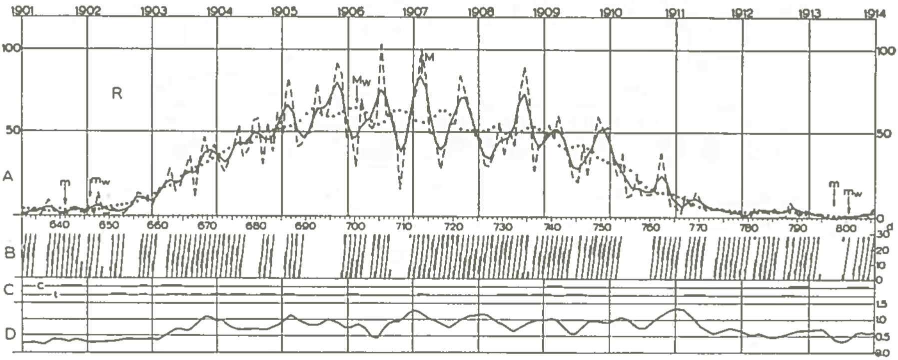

Fig. 8. Cycle no. 14

FIG. 4–13. A. Averages and smoothed averages of the sunspot numbers, based on the solar synodic rotation period. See Legenda p. 16.
B. The solar rotation period in the sunspot numbers.
C. The solar rotation period in the maximum temperature De Bilt, the magnetic character *C* and *K* De Bilt-Witteveen, and the ionospheric index *I* De Bilt.
D. Running *b*4 averages of *C*, *K* and *I*.

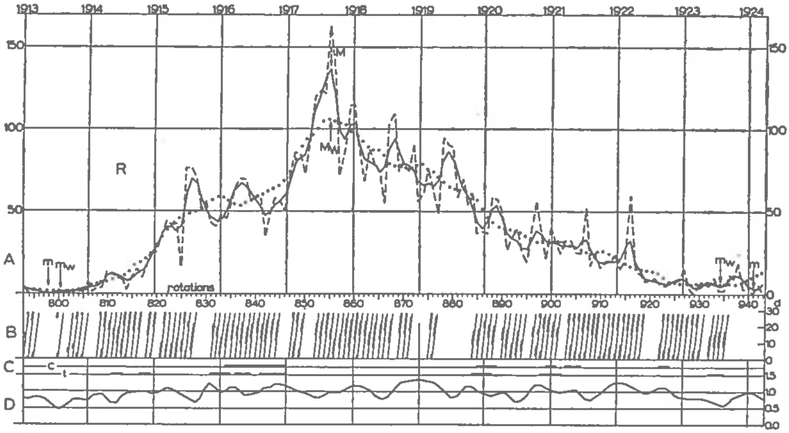

Fig. 9. Cycle no. 15

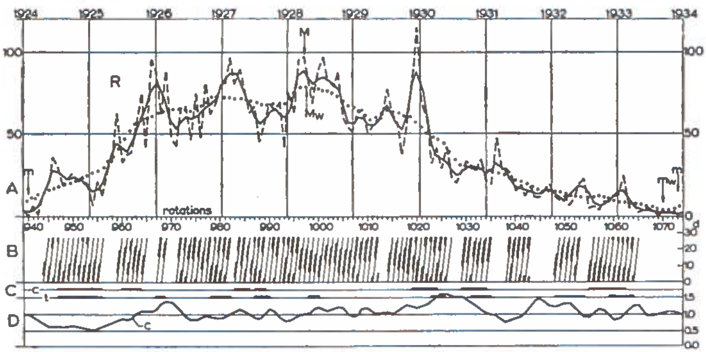

Fig. 10. Cycle No. 16

FIG. 4–13. A. Averages and smoothed averages of the sunspot numbers, based on the solar synodic rotation period. See Legenda p. 16.

B. The solar rotation period in the sunspot numbers.

C. The solar rotation period in the maximum temperature De Bilt, the magnetic character *C* and *K* De Bilt-Witteveen, and the ionospheric index *I* De Bilt.

D. Running *b*4 averages of *C*, *K* and *I*.

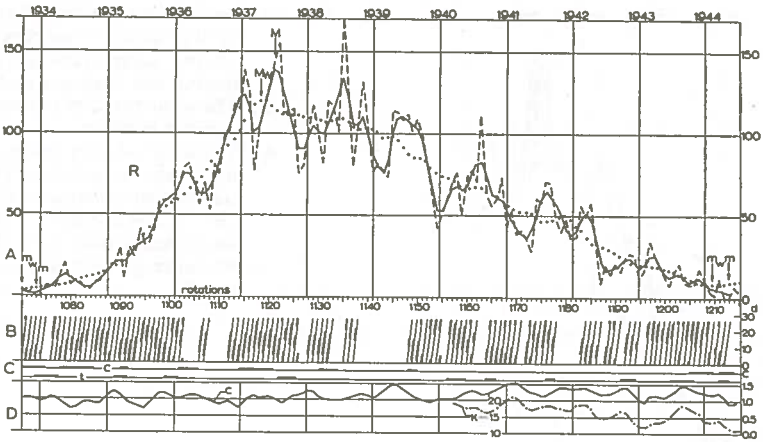

Fig. 11. Cycle no. 17

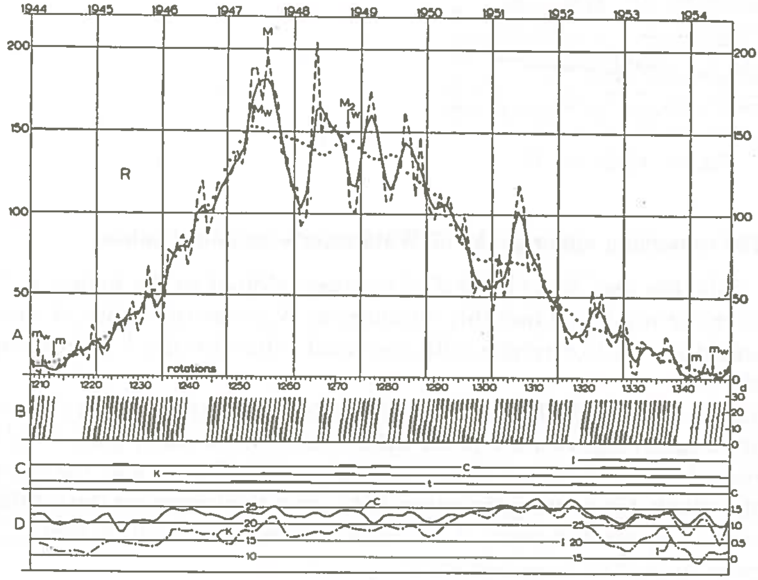

Fig. 12. Cycle no. 18

FIG. 4–13. A. Averages and smoothed averages of the sunspot numbers, based on the solar synodic rotation period. See Legenda p. 16.
B. The solar rotation period in the sunspot numbers.
C. The solar rotation period in the maximum temperature De Bilt, the magnetic character *C* and *K* De Bilt-Witteveen, and the ionospheric index *I* De Bilt.
D. Running *b*4 averages of *C*, *K* and *I*.

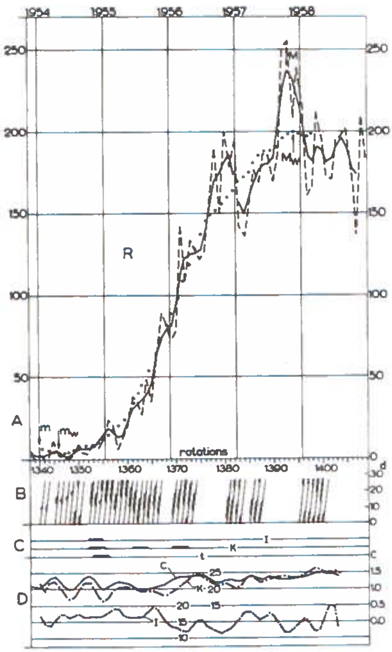

Fig. 13. Cycle no. 19

FIG. 4–13. A. Averages and smoothed averages of the sunspot numbers, based on the solar synodic rotation period. See Legenda p. 16.
B. The solar rotation period in the sunspot numbers.
C. The solar rotation period in the maximum temperature De Bilt, the magnetic character *C* and *K* De Bilt-Witteveen, and the ionospheric index *I* De Bilt.
D. Running *b*4 averages of *C*, *K* and *I*.

2.3 The remaining minor peaks of Waldmeier's smoothed values

The data *Rm* and *Rb*4 (Table 1) have been plotted in the figures 4–13 (A). Moreover the smoothed monthly amounts of WALDMEIER's table 33 have been represented and their extremes with corrected values for the 3 years mentioned in Table 3.

When the unsmoothed 27,275-day averages are compared with those of the monthly means of Zürich the peaks appear to coincide fairly well. This was to be expected because the rotational period of 27,275 days and the month do not differ much. Comparing, however, both smoothed series we state differences of the same character as those of the notable cases mentioned in Table 2. These differences appear to be systematical.

In many cases the minor peaks of WOLF-WALDMEIER's curves are situated just between the secondary peaks of the new curves (see the Figures 4–13 (A)).

This unexpected effect results because WOLF's interval of 13 months is unduely long, and the equal weight given to 11 of them deforms too much the real features. This is how the differences in the maxima of 1870, 1893 and 1907 have been caused. The same applies to the minima of 1889, 1901, 1924 and 1954: the Zürich minima occur between minima obtained by the *b*4 method. This deficiency of WOLF's method is well demonstrated in Table 6 (Appendix) for the years 1947–1949 inclusive. The first column contains the Carrington numbers, the second column the year, the third column the averages *Rm* (Table 1). Then follow, on the left side of the table the results of the smoothing method *Rbn* for *n* from 1 to 12, on the right side the results of the equal-weight smoothing method from $n = 2$ up to 12, and finally WOLF's last step for $n = 13$.

There is no sense in extending the *bn* method as far as $n = 12$ (divisor $2^{12} = 4096$). Yet it has been extended up to this value in order to get results comparable with those of the other method.

Evidently when the method of the binomial coefficients is used, the extremes remain throughout the whole table at the same level, but for some incidental differences of one rotation. Undoubtedly it is sufficient to stop the calculation at *b*4. By WOLF's method only exceptionally do the extremes maintain the same level (the maximum of rotation number 1256). Sometimes they run backward (the minimum of No. 1263) or forward (the maximum of No. 1266). In by far the most cases a remarkable reversal occurs, e.g.

rotation number	1266 (max) reversal between	$n = 9$ and	$n = 11$
	1274 (min)	9	10
	1277 (max)	7	8
	1280 (min)	8	9
	1284; the maximum disappears between 8 and 9.		

When the running time interval is too long and equal weight is attached to all parts of the overlapping series the central extreme is driven from its original position by the influence of an opposite extreme at one end of the interval; its sign is reversed by the influence of opposite extremes at both ends of the interval. For instance outstanding reversals appear in the 11-year cycles No. 14 and 18 (figures 8 and 12). With regard to cycle No. 18 it may be remarked that WALDMEIER, in his table 32, distinguished two maxima in sunspot numbers: 151,8 in May, 1947 and 148,5 in October, 1948. The second peak, marked M_2w in Figure 12, coincides fairly well with a secondary minimum. The next peak, 136,0 in June 1949, equally concurs with a minimum.

Which of the two smoothing methods is to be preferred depends on the purpose, as described above, but undoubtedly the binomial averages fit the observed data better and reveal a number of particulars which disappear or are distorted by WOLF's method. The consequence of the smoothing method propounded here is that for a number of extremes the epochs given by Zürich require correction.

2.4 The secondary peaks of the new sunspot curve

Is there some regularity in the occurrence of the outstanding secondary peaks? To answer this question the nine 11-year cycles available have been arranged in order of decreasing maxima, and the number of solar synodic rotations between the peaks, indicated in Table 1 by bold type, compiled in Table 7.

TABLE 7. *Intervals between secondary peaks in the sunspot cycles in synodic rotations*

No.	maximum *Rb*4	before maximum			after maximum				
19	237,4	..	..	12	11				
18	181,2	..	..	13	11	10	7	23	
11	163,0	..	..	12	6	7	16	..	
17	138,6	..	11	7	14	12	16	13	8
15	136,3	..	10	18	13	11	..	..	..
13	101,0	..	15	13	12	12	19		
12	89,4	9	8	17	18	..	..		
16	88,4		15	15	17	6	..		
14	84,2	10	9	8	9	12	6	10	

Notice that the number of secondary peaks before the maximum decreases from 3 to 1 for increasing *Rb*4. This feature concords with the steep rise of the curve in Fig. 2, mentioned in 2.2.

The intervals show a wide scattering from 6 to 19 synodic rotations and one exceptionally long duration of 23 units. The data given by Table 7, may be summarized as follows.

Average duration of peak intervals in synodic rotations

	before the maximum	after the maximum	total mean
max *Rb*4 > 105	11,9	11,9	11,9
max *Rb*4 < 105	11,9	12,1	12,0
total	11,9	12,0	12,0

The average duration of the intervals is 12 synodic rotations (nearly 11 months), differing distinctly from one year (13,5 rotations).

Table 8, exposing the frequencies of the different intervals between peaks in the new sunspot curve (*f* and *fb*4), shows some remarkable features.

Intervals of less than one year preponderate considerably. We note 30 intervals of 6 to 13 rotations against 12 intervals of 14 to 23 rotations. Each of the four groups shows the same effect. Moreover the most frequent interval before the maximum is smaller than the one after the maximum (9 rotations against 12), whereas during weak sunspot cycles it is smaller than during strong cycles (12 rotations against 9).

TABLE 8. *Frequencies of intervals between peaks in the sunspot curve*

synodic rotations	6	7	8	9	10	11	12	13	14	15	16	17	18	19	23	number of intervals 6–13 syn. rot.	number of intervals 14–23 syn. rot.
before maximum																	
f	0	1	2	2	2	1	2	2	0	3	0	1	1	0			
fb4	0,4	1,0	1,6	1,9	1,8	1,6	1,6	1,5	1,4	1,3	1,0	0,8	0,6	0,3		12	5
after maximum																	
f	3	2	1	1	2	3	4	2	1	0	2	1	1	1	1		
fb4	1,6	1,6	1,2	1,4	2,0	2,8	2,9	2,1	1,2	0,9	1,0	1,0	1,0	0,7		18	7
max *Rb4* > 105																	
f	1	3	1	0	2	4	3	3	1	0	2	0	1	0	1		
fb4	1,2	1,8	1,8	1,4	2,0	2,9	3,0	2,3	1,4	1,0	0,9	0,8	0,5	0,2		17	5
max *Rb4* < 105																	
f	2	0	2	3	2	0	3	1	0	3	0	2	1	1			
fb4	0,1	1,2	1,8	2,2	1,8	1,5	1,5	1,3	1,2	1,3	1,3	1,2	1,1	0,8		13	7
total																	
f	3	3	3	3	4	4	6	4	1	3	2	2	2	1	1		
fb4	2,0	2,8	3,0	3,3	3,8	4,0	4,6	3,7	2,6	2,2	2,2	2,0	1,8	1,2		30	12

3. THE LONG PERIOD OF EIGHT 11-YEAR CYCLES

Table 33 of WALDMEIER's treatise [E. und P. p. 153] contains the maxima among the smoothed relative sunspot numbers, 1615,5–1727,5, calculated by W. GLEISSBERG by means of backward extrapolation of the "long period". Here is meant the period of seven 11-year cycles, according to WALDMEIER (p. 156–157), after being devised by WOLF in 1862, propagated by K. STUMPF [1930] and W. GLEISSBERG [1941–1951]. Other adherents to the belief in a significant solar period of this duration are H. H. CLAYTON [1947], H. C. WILLETT [1951] and D. J. SCHOVE [1955]. Nevertheless, the duration of this long period most probably is 89 years (including eight 11-year cycles) as was shown by C. EASTON [1917] on the ground of his thorough investigation of the course of winter temperatures in Western Europe since A.D. 760. He was able to deduce an uninterrupted series of winter temperatures, starting with the year 1205, and pointed out a close connection between this 89-year period and the 11-year sunspot cycle. He showed that this long temperature cycle could be divided into four groups of two solar cycles, each group with its own characteristic features, thus recognizing the fundamentality of the two-cycle interval, long before the reversal of the magnetic polarity of the sunspots at the time of the minimum was detected by G. E. HALE [WALDMEIER, E. und P., p. 176–177]. Perhaps the strongest argument for the physical reality of the 89-year period is its accord with this 22-year sunspot period. Moreover the present extremely

TABLE 9. *Easton's period in Waldmeier's smoothed sunspot maxima*
(△ = interval between sunspot maxima in years)

1			2			3			4		
year	max R_W	△	year	max R_W	△	year	max R_W	△	year	max R_W	△
1750,3	92,6		1761,5	86,5		1769,7	115,8		1778,4	158,5	
		11,2			8,2			8,7			9,7
1837,2	146,9		1848,1	131,6		1860,1	97,9		1870,6	140,5	
		10,9			12,0			10,5			13,3
1928,4	78,1		1937,4	119,2		1947,5	151,8		1957,8	199,6	
		9,0			10,1			10,3			

5			6			7			8		
year	max R_W	△	year	max R_W	△	year	max R_W	△	year	max R_W	△
1788,1	141,2		1805,2	49,2		1816,4	48,7		1829,9	71,7	
		17,1			11,2			13,5			7,3
1883,9	74,6		1894,1	87,9		1907,0	64,2		1917,6	105,4	
		10,2			12,9			10,6			10,8

strong 11-year cycle is falling strictly into line with EASTON's long period, whereas according to WILLETT's forecast it should have been very weak and very long.

In Table 9 WALDMEIER's smoothed data have been arranged in eight columns.

AVERAGES	1		2		3		4		5		6		7		8	
Max R_W	105,9		112,4		121,8		**166,2**		107,9		68,6		*56,4*		88,6	
interval in years		10,4		10,1		9,8		11,5		13,6		12,0		12,0		9,0

It should be remarked that the sunspot numbers before 1819 are not trustworthy. According to BRUNNER [1945] the sunspot numbers for the years 1749–1783 are based on an annual average of 90 observations (1 in 4 days), for the years 1784–1818 on an average of 70 (1 in 5 days) and for the years 1819–1848 on an average of 260 (3 in 4 days). The small number of observations before 1819 does not allow of far-reaching conclusions.

It may be emphasized that great anomalies in the sunspot period (ranging from 7,3 to 17,1 years) occur only in the first row of Table 9. These discrepancies may have influenced the results. Yet the latest long period, starting in 1867, reveals the same effects.

Table 10 contains the results for this most recent long period, calculated with the *Rb*4 smoothing method (cycle No. 11–18). It contains also the averages of Table 9, arranged in such a way that they agree with the period 1867–1956; that is they start with cycle No. 5.

TABLE 10. *Easton's period, 1867–1956*
Rb4 averages, compared with the results of Table 9

No.	Max. Rb4	duration years	No.	Max. R_W (Waldmeier)	duration years
11	163,0		5	107,9	
		11,9			**12,0**
12	89,4		6	68,6	
		10,9			**12,0**
13	101,0		7	*56,4*	
		10,8			9,0
14	*84,2*		8	88,6	
		11,7			10,4
15	136,3		1	105,9	
		10,7			10,1
16	88,4		2	112,4	
		9,8			9,8
17	138,6		3	121,8	
		10,5			**11,5**
18	**181,2**		4	**166,2**	
		9,6			**13,6**

In both series the 89-year period is well developed. They show another remarkable feature, the unequal length of the eight 11-year cycles used. These unequal lengths are arranged systematically, making the ascending branch shorter than the descending one.

	ascending branch	descending branch
1750–1958	9,0 + 10,4 + 10,1 + 9,8 = 39,3 y	11,5 + 13,6 + 12,0 + 12,0 = 49,1 y
1867–1956	10,7 + 9,8 + 10,5 + 9,6 = 40,6 y	11,9 + 10,9 + 10,8 + 11,7 = 45,3 y

This feature is strikingly similar to a well-known feature of the 11-year cycle: a steep rise before the maximum and a slow fall thereafter.

Here again typical differences occur with regard to strong and weak sunspot cycles [Visser, 1959].

4. THE 27-DAY PERIOD

4.1 The 27-day period in sunspot numbers

Strips B of the Figures 4–13 contain the solar rotation period in a simplified form. Each slanting line represents one rotation in such a way that the completion of each rotation at the upper end joins the start of the following rotation at the lower end of the next slanting line, the positive deviations (the maxima) have been indicated by heavy lining. Interruptions in the sequences of these slanting lines show where periodicity is lacking. The Carrington numbers have been inscribed at the base line of the part A of the curves, the dates at the top line.

The very many cases and long sequences of recurrence reveal the prominence of the rotation period in sunspot numbers. The maxima in the slanting lines, however, demonstrate also the capricious character of this short sunspot cycle. It starts and ends unexpectedly, the phase is by no means constant. The phase can even change suddenly in long sequences. The maxima run forward or backward repeatedly, betraying the displacement of a disturbed region over the Sun's disc.

4.2 The 27-day period in terrestrial phenomena

The strips C of the Figures 4–13 indicate by heavy lining the sequences of the period in the daily maximum temperatures *t* at De Bilt since 1863, the magnetic character (*C* since 1891, and *K* since 1940) at De Bilt-Witteveen, and the ionospheric index *I* at De Bilt since 1952. These geophysical series always exhibit sunspot periods, sometimes all the items fluctuate simultaneously.

The strips D expose the running *b*4 averages of *C*, *K* and *I*. An outstanding feature of these curves is their relative independence of the sunspot curves A.

As it is the author's intention to devote a future publication to these terrestrial data he may confine reference here to his earlier publications on heat waves occurring in the years 1947 and 1953 [VISSER, 1954 and 1958]. The first paper deals with the daily maximum temperatures of 69 stations in Western Europe in 1947. The second paper concerning observations made at 74 stations in the United States in 1947 and 1953, is summarized here.

The research has been based on the pure 27-day period, introduced by BARTELS. The central day of five consecutive days with the highest relative sunspot numbers has been considered the epoch of the maximum. The temperature deviations have been arranged in such succession that each of the sunspot maxima selected coincided with the central day of the row of 27 temperature deviations. Thus the behaviour of the temperature during 13 days before up to 13 days after the sunspot maximum has been studied. The result is accumulative. The influence of each individual sunspot period on the temperature may be weak, but by repeating the method for consecutive periods in quite the same way, the influence becomes more and more obvious when actually present. For each series of selected recurrences the 27 daily averages both of the sunspot numbers and of the maximum temperatures have been calculated and the results harmonically analysed, the analysis being limited to the first harmonic.

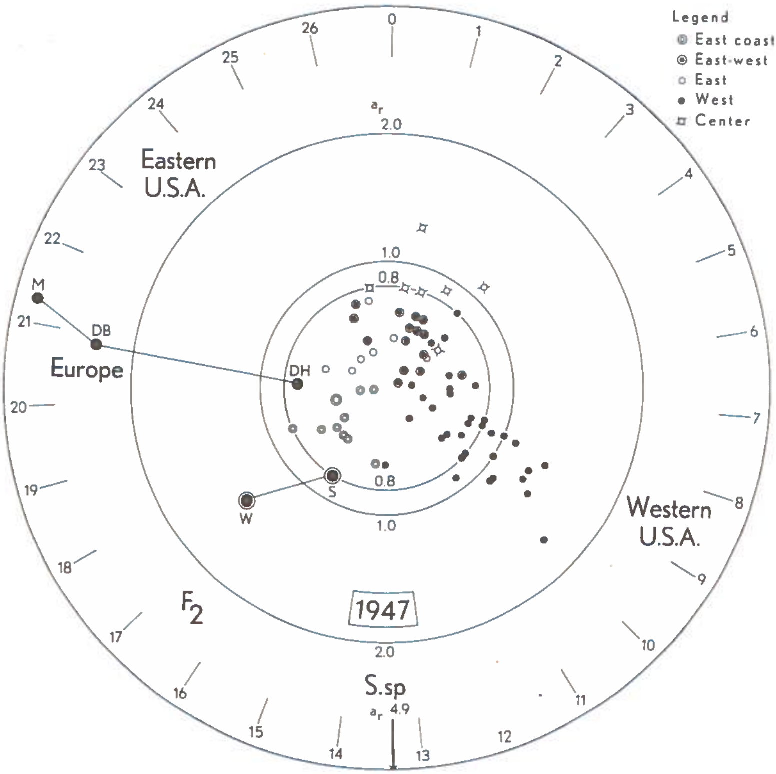

FIG. 14. Maximum day and reduced amplitude, 1947; sunspots, storms in the $F2$ layer, daily maximum temperatures in Europe and the United States.

To check the reliability of the harmonics found for each of the 27 values obtained, the difference "observed minus harmonic" has been determined, and the standard deviation σ of this series calculated. It is required that σ be small, or better that a/σ be large. The latter ratio is defined as the reduced amplitude a_r. For the sunspot numbers it amounted to 4 or more, for the temperatures it reached values of 1,5 and more. For $a_r > 1$ the concordance may be considered to be sufficient. Yet, $a_r = 0{,}8$ has been taken as the lowest amplitude acceptable[1].

A division of the United States into six areas was made; East Coast, East and Center (in the East); transition zone East-West, West and West Coast (in the West). It was not always possible to fix the limits between these areas exactly

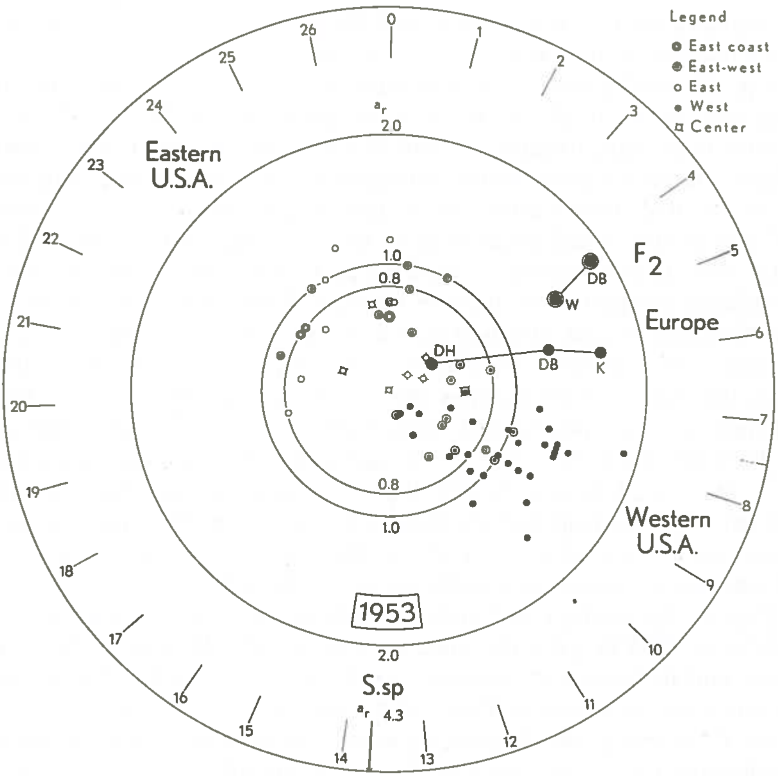

FIG. 15. Maximum day and reduced amplitude, 1953; sunspots, storms in the *F*2 layer, ionospheric index, daily maximum temperatures in Europe and the United States.

and so I have preferred the periodic character above the geographical position. Thus, for example, Akron, Ohio and Elkins, West Virginia, are among the East Coast stations, though they are over 200 miles inland.

---

[1] As W. VAN DER BIJL pointed out to me, the experimental limit $a_r = 0{,}8$ (that is $a_r > 0{,}75$) fits the statistical 5% limit, derived from formula (30.82), Kendall II, p. 434.

The complete results of the investigation are represented in the clock diagrams, Figure 14 for 1947 and Figure 15 for 1953. The 27 days of the period have been arranged as the figures of a clock-face and the stations have been plotted by means of the maximum day and the reduced amplitude as polar coordinates.

The lower limit of $a_r = 0{,}8$ has been indicated. In these figures some other phenomena have been introduced which will be discussed later.

As a consequence of the method used the sunspot maximum occurs at Day 13,5; its reduced amplitude lies far outside the limits of the figures.

In Fig. 14, starting with the maximum sunspot day 13,5, we find a maximum of magnetic storms in the *F*2 layer of the ionosphere at Day 16–17. The *F*2 data refer to Slough, England (S) and Washington D.C. (W). They represent the daily number of storm hours, harmonically analysed in the same way as those of the other observations. Both stations agree very well and, obviously, the 27-day period is well established in the magnetic storms of the *F*2 layer.

Some days later temperature maxima in Europe occur (Day 20–21). The three stations plotted in the diagram are Den Helder (DH) and De Bilt (DB) in the Netherlands and Marburg in Germany (M). The results closely agree with those earlier deduced for Western Europe [Visser, 1954]. As to the stations in the western United States the results may be interpreted as follows. The temperature minimum must occur with a time interval of a half period after the temperature maximum. This means that the minimum must present itself at Day 22–23, two days later than the European maximum. It may be concluded that in Europe and the western United States the phases of the temperature wave are opposite. At about the same epoch the eastern United States have their maximum, though poorly developed.

In Fig. 15 the western and eastern areas of the United States are shown to behave in 1953 in quite the same way as in 1947. However, effects in the *F*2 layer and in Europe are contrary to those noted in 1947. The *F*2 storms experience their maximum at Day 4 and, therefore, their minimum at Day 18. The two *F*2 points in the diagram represent the daily amount of storm hours at Washington (as in 1947) and the *I*-index in De Bilt. Again there is a good agreement and the period is well developed in the ionosphere. In 1953 as in 1947 European temperature maxima follow the *F*2 storm maxima (Den Helder and De Bilt, as before, and Kassel-Harleshausen, K, in Germany) at Day 5. Their minimum occurs at Day 19. The results are combined in Table 11.

In Table 12 are summarized the final results of the harmonic analysis of the sunspot numbers, and of the daily maximum temperatures at two stations in the Netherlands (Den Helder and De Bilt for 1947 and 1953) and at two stations in Germany (Marburg for 1947 and Kassel-Harleshausen for 1953), as well as of the harmonic analysis of the daily numbers of *F*2 storm hours at Slough and Washington, and of the ionosphere index at De Bilt.

TABLE 11. *The 27-day period; results 1947 and 1953*

	1947	1953
SOLAR ACTIVITY	strong	weak
rotations	1559–1566	1637–1640
average R	165	13
amplitude a	64,9	14,9
standard deviation σ	13,1	3,5
reduced amplitude a_r	4,5	4,3
maximum day	13,3	13,6
F2-STORMS		
number of observations	2	2
amplitude a	2,0	2,0
standard deviation σ	1,7	3,6
reduced amplitude a_r	1,1	1,7
maximum day	16,2	4,4
minimum day	....	17,9
DAILY MAXIMUM TEMPERATURE (Celsius degrees)		
Europe		
number of observations	2	2
amplitude a	3,0	2,2
standard deviation σ	1,2	1,4
reduced amplitude a_r	2,6	1,5
maximum day	21,0	5,7
minimum day	....	19,2
Western U.S.A. (area West)		
number of observations	16	21
amplitude a	1,4	2,5
standard deviation σ	1,3	1,9
reduced amplitude a_r	1,1	1,3
maximum day	8,7	8,8
minimum day	22,2	22,3
Eastern U.S.A.		
number of observations	7	11
amplitude a	1,2	1,9
standard deviation σ	1,3	2,0
reduced amplitude a_r	0,9	1,0
maximum day	(26,9)	(24,0)

The averages have been calculated for all values of $a_r \geqslant 0,8$.

TABLE 12. *The 27-day period; harmonic constants* 1947 *and* 1953

		1947					1953				
Station	Symbol	a	φ	D	σ	a_r	a	φ	D	σ	a_r
Sunspot Number		64,9	272°16′	13,3	13,1	4,9	4,9	262°32′	13,6	3,3	4,3
Daily maximum Temperature:											
De Bilt, Neth.	*DB*	2,7	172°55′	20,8	1,2	2,3	1,7	16°14′	5,5	1,3	1,3
Den Helder, Neth.	*DH*	0,8	179°15′	20,3	1,2	0,7	0,4	34°34′	4,2	1,1	0,4
Marburg, Germ.	*M*	3,2	165°26′	21,3	1,1	2,8	—	—	—	—	—
Kassel-Harlesh. Germ.	*K*	—	—	—	—	—	2,7	11°31′	5,9	1,6	1,7
Ionosphere; F2 storms											
Slough F2, Gr. Br.	*S*	0,5	250°09′	15,0	0,6	0,8	—	—	—	—	—
Washington F2, D.C.	*W*	3,6	217°45′	17,4	2,7	1,4	6,0	29°45′	4,5	4,0	1,5
De Bilt I, Neth.	*DB*	—	—	—	—	—	6,0	34°04′	4,2	3,1	1,9

a = harmonic amplitude; φ = phase angle; D = maximum day; σ = standard deviation; a_r = reduced amplitude.

4.3 The sunspot areas

The Greenwich Observatory publishes, since 1874, the photoheliographic observations of sunspot areas. In order to compare the daily results of these measurements with the daily relative sunspot numbers, I have tested a number of cases, making use of the daily amounts of whole spot projected areas.

As to this point WALDMEIER [E. und P. p. 140] states:

> Die Beziehung zwischen Relativzahl und Fläche für einen einzelnen Tag ist ziemlich locker; dagegen zeigt sich schon in den Monatsmitteln ein sehr enger Zusammenhang zwischen diesen beiden Masszahlen. Im Mittel besteht zwischen der Greenwicher Fläche F und der Zürcher Relativzahl R die Beziehung:
>
> $$F = 16{,}7\ R.$$
>
> Dabei ist F inbezug auf perspektivische Verkürzung korrigiert und in Millionsteln der Sonnenhalbkugel ausgedrückt. Die Bestimmung von F erfordert einen längeren Arbeitsgang und setzt gute photographische Sonnenaufnahmen voraus, während R auch mit sehr einfachen Mitteln bestimmt werden kann und sofort zur Verfügung steht. Bei R geben neben der Gruppenzahl die kleinen Flecken den Ausschlag, bei F die grossen; da aber gegen den Sonnenrand hin die kleinen mehr und mehr verschwinden, kommt bei R den Flecken der Zentral-

zone automatisch ein grösseres Gewicht zu als den randnahen, was wohl der Grund dafür ist, dass sich R bei der statistischen Untersuchung solarterrestrischer Zusammenhänge besser bewährt hat als F.

When considering the terrestrial influence of sunspots, beyond doubt greater importance should be attached to the spots in the Sun's central zone than to those near the Sun's rim. Hence the projected areas (the areas as "measured in the photograph") should be preferred above the corrected areas chosen by WALDMEIER. A control of both the projected areas and the corrected areas for 12 solar rotations in 1947 and 12 solar rotations in 1953, revealed that the reduced amplitude was larger for the corrected areas in 1947, but smaller in 1953 (compare Table 14). These results, however, were not sufficient to induce me to quit the projected areas.

The general average of the A proj$/R$ ratio, through 138 27-day periods involving 3726 days, amounts to

$$A \text{ proj}/R = 21{,}8.$$

The scattering is rather large, as shown in Table 13.

TABLE 13. *The scattering in the A proj/R ratio*

R	n	Rm	Am	A proj$/R$	extremes
1– 10	23	6,7	88,6	13,2	1,0 and 47,4
11– 20	22	14,4	214,8	14,9	5,0 and 37,2
21– 40	26	27,6	582,4	21,6	9,8 and 39,2
41– 80	24	61,8	1076,4	17,4	13,1 and 28,2
81–120	22	100,4	2261,5	22,6	13,8 and 33,5
121–209	21	148,6	3670,0	24,7	16,1 and 40,0
general mean		59,9	1349,7	21,8	

The results suggest an increase of the A proj$/R$ ratio with increasing sunspot numbers. This feature may be due to R being underestimated or A being overestimated. I favour the first supposition, which would betray a certain insufficiency of WOLF's method of counting R at high solar activity. The corrected areas (1947 and 1953) show the same effect, viz.

	R	n	Rm	A corr	A corr$/R$	extremes
1953	1– 25	12	13,7	141,2	10,3	1,0 and 19,6
1947	121–209	12	156,7	2707,4	17,4	12,0 and 30,0

4.4 Harmonic analyses

Table 14 (Appendix) contains the results of the harmonic analysis of 91 27-day waves in 15 groups.

It is impossible to analyse harmonically a wave through a broken number of days (i.c. 27,275), since the observations refer to full days. The best approximation of this time interval is 27 days. The discrepancies in the phase angle do not matter when different observations during the same time interval are compared, because they influence all results in the same way. Another solution of the difficulty is using time intervals of no more than 4 or 5 solar rotations, for in this case the differences may be neglected. This method is useful when seasonal effects are surmised, for then the number of rotations can be restricted to one season.

Contrary to the method earlier applied for the U.S. temperatures [VISSER, 1958] the data have now been inscribed in chronological order in 27 rows. Therefore the accumulative effect is lost (see point 4.2), but the advantage is that now the true location of the sunspot maximum on the Sun's disc is found.

The phenomena analysed are, *R*, the relative sunspot number; *A*, the projected area; *Ac*, the corrected area; *Fac*, faculae projected area; *t*, the maximum temperature De Bilt; *C* and *K*, the magnetic character figures De Bilt-Witteveen; *F*2, the number of ionospheric storm hours Washington; *I*, the ionospheric index De Bilt; *P*, the air pressure Jakarta.

The results of the harmonic analysis are, *m*, the average value; *a*, the amplitude; φ, the phase angle; *D*, the maximum day; σ, the standard deviation; a_r, the reduced amplitude.

When these results are compared with those arrived at in my paper on the U.S. temperatures (1958) the following displacements of the maximum day may be stated.

	Maximum day	now	displacement
1947 *R*	13,3	15,1	+ 1,8 day
F2 storms Washington	16,2	19,0	2,8
Temperature De Bilt	20,8	22,3	1,5
mean displacement			+ 2,1
1953 *R*	13,6	23,2	+ 9,6 day
F2 storms Washington	4,4	13,2	8,7
Temperature De Bilt	5,5	13,4	7,9
mean displacement			+ 8,7 day

The displacement of the sunspot maximum day is due to the fact that this maximum day has been fixed originally on day 13,5 but now is set at its true location on the Sun's disc. The terrestrial phenomena follow exactly the same course. It means that the dials of the clocks in the Figures 14 and 15 must be put forward over 2,1 and 8,7 days respectively, in order to give the true locations.

As a rule the maximum days and the reduced amplitudes of *R* and *A* (projected area) behave similarly: the average maximum day is 13,1 in both cases, the reduced amplitudes are 3,6 and 3,7 respectively. Also the corrected area falls into line (1947 and 1953). However, the maximum faculae projected area lags far behind; obviously its connection with the rotation period is very loose.

For each of the 15 groups the *A*/*R* ratio has been calculated. These values behave in the same way as the general means shown above. It might have been

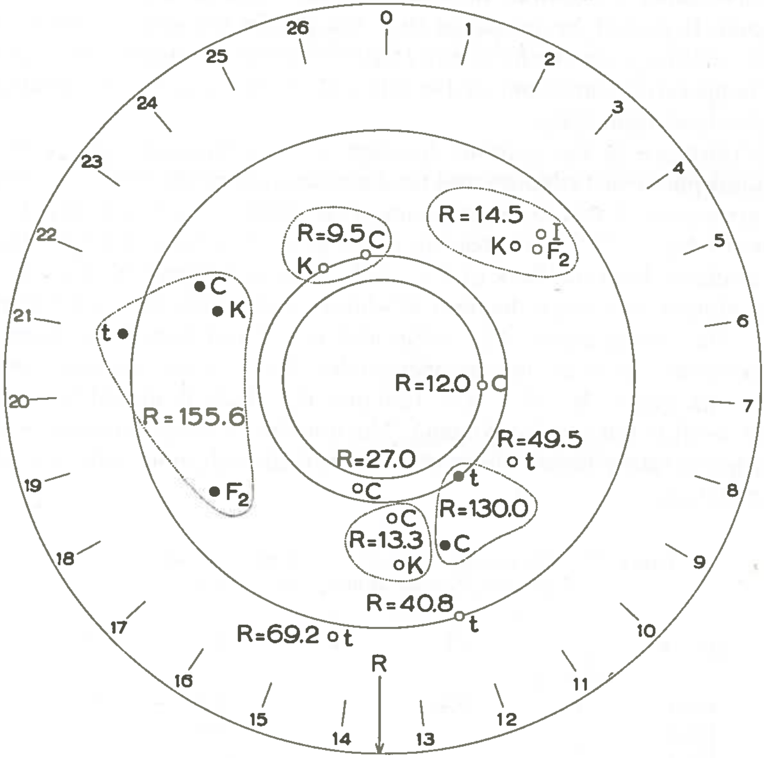

FIG. 16. The opposite character of strong and weak sunspot cycles for *R* max. day = 13,5.

expected that the same ratio existed for the amplitudes *a*. This, however, does not appear to be the case. Generally the latter ratio is greater, sometimes considerably greater. It may give an indication that harmonic analysis also yields better results for the sunspot areas than for the relative sunspot numbers.

In cases when both *C* and *K* are available, both the maximum days and the reduced amplitudes are in good concordance, except during the year 1953, and even then the maximum days coincide.

The *F*2-storm hours and the ionospheric index, when available, are in reasonable agreement with the geomagnetic character figures.

The year 1916 has shown a remarkable development of the solar rotation period, following exactly the duration of 27,275 days through 12 rotations (see Table 16, Appendix). In Table 14 two groups of 4 rotations, *I* and *II*, have been distinguished. They show a displacement of the maximum day of 11,4 — 9,9 = 1,5 days. The displacement for one rotation is 27,275 — 27 = 0,275 days, hence 5 rotations involve 1,375 days. The concordance is remarkably good. It should be remarked that, though the reduced amplitude of the sunspot numbers is smaller for group *I* than for group *II*, the reduced amplitudes of the temperature variations at De Bilt and of the air pressure variations at Jakarta behave oppositely.

With reference to the opposite location in clock diagrams of the maxima of the ionospheric disturbances and the European temperatures (Fig. 14 and 15) I have arranged in Table 17 the locations of the different maximum days reduced to *R* max. day = 13,5 in decreasing order of *R*. It means that now the dial of the clock has been put back to *R* = 13,5. Therefore Figure 16, showing these data as plotted in a clock diagram is wholly comparable with the Figures 14 and 15. The strong cycles, *R* = 155,6 and *R* = 130,0 have been represented by black circles, the weak ones by open circles. The opposite location is obvious for the weak cycles, *R* = 9,5, *R* = 12,0 and *R* = 14,5. It should be conceded that the result is not very convincing. The number of cases, however, is small, the scattering rather large. This matter will be dealt with more fully in a following publication.

TABLE 17. *The opposite character of strong and weak cycles. Maximum days for R max. day = 13,5.*

Year	Max. *R*	*F*2	*I*	*C*	*K*	*t*
1947	155,6	17,4	—	22,0	21,7	20,7
1938	130,0	—	—	11,6	—	10,6
1937	126,4	—	—	—	—	—
1936	122,0	—	—	—	—	—
1938	107,8	—	—	—	—	—
1916I	69,2	—	—	—	—	14,1
1916II	49,5	—	—	—	—	8,9
1930	40,8	—	—	—	—	11,9
1930	27,0	—	—	14,2	—	—
1931	18,0	—	—	—	—	—
1953	14,5	3,5	3,3	—	2,9	—
1943	13,3	—	—	12,8	12,8	—
1934	12,0	—	—	6,8	—	—
1944	9,5	—	—	26,1	24,9	—

5. THE 27-DAY PERIOD IN THE ZWANENBURG TEMPERATURES

A good deal of BUYS BALLOT's investigation, mentioned in 1.1 has been based on the temperature observations at Zwanenburg, midway between Amsterdam and Haarlem, 1729–1861, a series of data of invaluable importance. It was considered to be worth while to apply the insights arrived at in this paper to these old observations. To this purpose the data from the years 1743–1793 inclusive have been analysed in the same way as those of the years 1863–1958. It is not necessary to investigate all Zwanenburg temperatures; the interval of 51 years suffices to test solar influences.

No daily temperature maxima are available. Therefore harmonic analysis has been applied to the highest daily temperature given. The enumeration started on January 16, 1735. This date was chosen so that Rotation No. 1314 coincides with Rotation No. 1 according to BARTELS. The rotations in the years considered run from No. 109 (1743, January 10) to No. 798 (1793, December 16).

The results show exactly the same features as those obtained in recent years: 27-day recurrences in the temperature are numerous and as capricious as they are nowadays.

The daily sunspot numbers obtained in the years considered are too scanty to have any analytical value. We may even venture to state that the temperatures teach us more of the number of sunspots occurring in these times than the sunspot observations do themselves.

Table 15 (Appendix) contains the harmonic constants of 14 obvious recurrences through intervals varying from 4 to 6 rotations (totalling 68 rotations), which is only a small part of those available during the 51 years investigated. The temperature constants, m, a and a_r, have been expressed in centigrade degrees.

The three series of 1777 and 1778 have been studied before (VISSER, 1954). Then the periods were detected by simply noting the recurrence of maximum temperatures with intervals of about 27 days. Now, by applying a more severe statistical test, the earlier results are confirmed, for instance my statement (loc. cit. p. 378) that only a weak correlation between temperatures and sunspot numbers existed in the second series of 1778, in which the maxima occurred at about the place of the minima in the first series. The reduced amplitude of the second series attains a value of only 0,6, which is below the permitted limit of 0,8, and the time difference of the maxima appears to be 9,4 days.

The results are quite similar to those obtained in recent years. The general averages are as follows,

	n	a	σ
1753–1792	13	1,7	1,0
1863–1958	7	1,5	1,0

One conclusion appears unavoidable. The period of temperature fluctuations given by BUYS BALLOT (compare 1.1) is a mere result of the erroneous method of analysis which he applied, this method being based on the assumption of an uninterrupted recurrence of the period during the whole interval of 155 years surveyed.

6. SUMMARY

The aim of the present paper is to analyse the sunspot cycles of about 11 years and of about 27 days and to deduce some of their features in ways which improve in certain respects on analyses made at the Zürich Astronomical Observatory.

1.3 The new analysis is concerned with data running from January, 1863, up to the end of 1958. Running 27-day averages have been calculated following BARTELS's enumeration of solar rotations. Reductions have been applied in order to let these averages fit in with the rotation period of 27,275 days.

1.4 The author started with the smoothing method $(R_1 + 2R_2 + R_3)$: 2^2, applying this same method to the results arrived at and so on, up to 5 original data. The final averages have been called "binomial averages of the fourth power".

1.5 Table 1 (Appendix) and the figures 4–13 (*A*) contain the solar rotational averages *Rm* and the smoothed averages *Rb*4 following the method explained in 1.4.

2.1 Table 2 contains the epochs of the smoothed sunspot maxima and minima, Table 3 some notable differences in WALDMEIER's two tables of these epochs.

2.2 A division of the data into only two groups, strong and weak cycles, much better reveals a characteristic level of solar activity (*Rm* between 85 and 90) (Fig. 2), compared with WALDMEIER's three groups of strong, moderate and weak cycles. This result wholly agrees with the features of a number of geophysical phenomena, the Southern Oscillation, the 7-year period in world weather, the polar lights and the halo phenomena in Java.

2.3 In many cases the minor peaks of WALDMEIER's sunspot curves are situated just between the secondary peaks of the new curves. WOLF's smoothing method is evidently based on unduely long intervals whereas the equal weights given to the data deforms too much the real features (Table 6, Appendix).

2.4 The average duration of the secondary waves in solar activity is equal to 12 synodic solar rotations, but intervals of less than one year preponderate considerably (Table 7). Table 8 demonstrates some features of the frequency of the duration.

3. A long cycle including seven 11-year cycles apparently does not exist. The true duration of a long cycle is obviously eight 11-year cycles, as stated in 1917 by Easton. A period of this length is clearly present (Table 9).

Its ascending branch is shorter than its descending branch. This feature is strikingly similar to a well known feature of the 11-year cycle.

4.1; 4.2 The figures 4–13 (strips *B* – *D*) show for each 11-year cycle the course of different geophysical phenomena at De Bilt, the daily maximum temperatures, the geomagnetic figures *C* and *K*, the ionospheric index *I*. The figures 14 and 15 include some phenomena as observed in Europe and the United States.

4.3 The projected sunspot areas of Greenwich Observatory appear to reveal the influence of sunspots on geophysical phenomena better than the corrected areas according to WALDMEIER. The scattering in the *A* proj/*R* ratio suggests that the relative sunspot number undervalues solar activity, if this is high (Table 13).

4.4 The results of harmonic analysis of 91 27-day periods, 1916–1953, have been presented in Table 14 (Appendix). The phenomena analysed are: *R*, relative sunspot number; *A*, projected area; *Ac*, corrected area; *Fac*, faculae projected area; *t*, maximum temperature De Bilt; *C* and *K*, geomagnetic character figures De Bilt-Witteveen; *F*2, number of storm hours Washington; *I*, ionospheric index De Bilt; *P*, pressure Jakarta.

For each of the 15 groups the *A*/*R* ratio has been calculated. As a result of the harmonic analysis the ratio of the harmonic amplitudes *aA* and *aR* appears to be generally greater, sometimes considerably greater than the *A*/*R* ratio. It may indicate that also the harmonic analysis yields better results for the sunspot areas than for the relative sunspot numbers.

The geomagnetic character figures, the *F*2 storms and the ionospheric index, when available, are in good agreement.

The opposite location in the clock diagrams of ionospheric data and European temperatures, published earlier (Fig. 14 and 15), is again shown in the results now arrived at, however, not very convincingly (Fig. 16).

5. The Zwanenburg temperatures in the 18th century show exactly the same features as those of recent years. Table 15 (Appendix) contains the harmonic constants of 14 selected series of 27-day waves in these temperatures, involving 68 rotations.

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APPENDIX

TABLE 1. *Averages and smoothed averages of the sunspot numbers for synodic rotations (Nr. 124—1*

Year	Carr. No.	1 14	2 15	3 16	4 17	5 18	6 19
	10						
1863	124	Jan 17	Feb 13	Mar 13	Apr 9	May 6	Jun 3
Rm		43	59	77	55	55	52
Rb4		—	—	**63,5**	60,6	54,3	47,2
1864	137	Jan 7	Feb 3	Mar 1	Mar 29	Apr 25	May 22
Rm		48	60	58	53	29	54
Rb4		47,9	54,5	54,8	48,9	44,0	48,4
1865	151	Jan 22	Feb 18	Mar 18	Apr 14	May 12	Jun 8
Rm		46	43	39	30	35	43
Rb4		39,3	40,8	38,0	35,1	35,2	34,8
1866	164	Jan 12	Feb 8	Mar 7	Apr 4	May 1	May 28
Rm		33	40	20	25	15	16
Rb4		27,5	30,4	26,7	21,6	18,2	16,0
	11						
1867	177	Jan 2	Jan 29	Feb 25	Mar 24	Apr 21	May 18
Rm		2	0	3	13	2	5
Rb4		2,8	*2,4*	4,6	6,4	5,6	4,0
1868	191	Jan 18	Feb 15	Mar 13	Apr 9	May 6	Jun 3
Rm		17	15	26	48	31	29
Rb4		19,6	21,1	28,5	35,0	34,4	31,9
1869	204	Jan 7	Feb 3	Mar 2	Mar 30	Apr 26	May 23
Rm		85	68	67	50	92	122
Rb4		73,3	70,8	65,7	70,4	88,7	**106,4**
1870	218	Jan 24	Feb 20	Mar 19	Apr 15	May 13	Jun 9
Rm		83	131	167	159	103	124
Rb4		106,8	125,8	151,8	**163,0**	159,3	146,6
1871	231	Jan 13	Feb 9	Mar 9	Apr 5	May 2	May 29
Rm		85	103	143	161	148	125
Rb4		106,8	113,6	134,2	**147,4**	142,0	124,0
1872	244	Jan 3	Jan 30	Feb 26	Mar 24	Apr 21	May 18
Rm		80	109	94	95	102	108
Rb4		93,3	96,2	97,6	98,2	101,8	106,4
1873	258	Jan 18	Feb 15	Mar 14	Apr 10	May 7	Jun 4
Rm		81	108	98	76	54	50
Rb4		90,8	95,0	91,2	76,4	61,2	55,1
1874	271	Jan 9	Feb 5	Mar 4	Apr 1	Apr 28	May 25
Rm		55	65	62	46	36	33
Rb4		54,9	59,2	56,8	47,9	40,2	40,6
1875	285	Jan 25	Feb 22	Mar 21	Apr 17	May 15	Jun 11
Rm		15	27	34	29	11	22
Rb4		23,3	25,8	28,4	24,7	19,4	17,2
1876	298	Jan 15	Feb 11	Mar 10	Apr 6	May 3	May 30
Rm		15	15	27	13	6	0
Rb4		14,8	17,6	18,4	14,0	7,8	5,6
1877	311	Jan 4	Jan 31	Feb 27	Mar 26	Apr 23	May 20
Rm		24	15	14	5	21	19
Rb4		15,1	15,6	13,0	12,7	15,6	16,6

9 22	10 23	11 24	12 25	13 26	27	Carr. No.	Year
Aug 23 38 34,4	Sep 20 30 34,2	Oct 17 26 34,9	Nov 13 37 36,7	Dec 10 36 40,7		**10** 124	1863 Rm Rb4
Aug 12 61 49,6	Sep 8 29 39,4	Oct 5 28 35,6	Nov 2 48 38,6	Nov 29 42 38,6	Dec 20 25 37,0	137	1864 Rm Rb4
Aug 29 29 29,2	Sep 25 24 24,3	Oct 22 16 20,8	Nov 18 26 19,5	Dec 16 9 21,6		151	1865 Rm Rb4
Aug 18 10 10,5	Sep 14 5 10,4	Oct 12 15 10,0	Nov 8 7 8,3	Dec 5 6 5,4		164	1866 Rm Rb4
Aug 8 4 7,2	Sep 4 12 10,4	Oct 1 17 12,0	Oct 28 6 12,8	Nov 25 15 16,2	Dec 22 28 19,8	**11** 177	1867 Rm Rb4
Aug 23 44 47,6	Sep 20 57 55,6	Oct 17 64 62,9	Nov 13 72 67,0	Dec 11 63 71,2		191	1868 Rm Rb4
Aug 13 104 91,6	Sep 9 90 89,4	Oct 7 85 85,1	Nov 3 66 88,8	Nov 30 124 98,2	Dec 27 99 101,2	204	1869 Rm Rb4
Aug 30 155 143,0	Sep 26 160 **153,2**	Oct 23 158 151,4	Nov 20 138 138,4	Dec 17 126 119,6		218	1870 Rm Rb4
Aug 19 120 101,0	Sep 16 82 94,2	Oct 13 84 91,2	Nov 9 103 93,4	Dec 6 95 93,4		231	1871 Rm Rb4
Aug 8 100 103,9	Sep 4 97 103,4	Oct 1 116 105,5	Oct 29 97 105,4	Nov 25 116 100,0	Dec 22 80 92,0	244	1872 Rm Rb4
Aug 24 64 60,8	Sep 21 49 53,4	Oct 18 43 49,7	Nov 14 59 49,9	Dec 12 42 51,0		258	1873 Rm Rb4
Aug 15 62 51,8	Sep 11 26 41,7	Oct 8 44 34,3	Nov 5 23 29,8	Dec 2 28 27,0	Dec 29 25 24,8	271	1874 Rm Rb4
Sep 1 11 10,6	Sep 28 8 10,4	Oct 25 12 11,9	Nov 21 16 13,2	Dec 19 11 13,6		285	1875 Rm Rb4
Aug 20 11 10,3	Sep 16 9 11,4	Oct 14 16 11,8	Nov 10 11 10,9	Dec 7 3 11,8		298	1876 Rm Rb4
Aug 10 3 8,8	Sep 6 19 10,2	Oct 3 4 10,8	Oct 30 15 10,4	Nov 27 10 8,2	Dec 24 1 5,2	311	1877 Rm Rb4

Table 1. *Averages and smoothed averages of the sunspot numbers for synodic rotations (Nr. 124—14*

Year	Carr. No.	1	2	3	4	5	6
		14	15	16	17	18	19
1878	325	Jan 20	Feb 17	Mar 16	Apr 12	May 9	Jun 6
Rm		4	6	9	0	0	11
Rb4		4,4	5,6	5,1	3,2	3,2	4,7
	12						
1879	338	Jan 10	Feb 6	Mar 5	Apr 2	Apr 29	May 26
Rm		0	1	0	2	7	1
Rb4		*0,6*	0,6	1,2	2,6	3,8	4,5
1880	352	Jan 27	Feb 23	Mar 21	Apr 17	May 15	Jun 11
Rm		29	16	20	19	20	34
Rb4		21,7	20,6	19,4	20,3	23,4	25,6
1881	365	Jan 15	Feb 11	Mar 11	Apr 7	May 4	May 31
Rm		32	55	58	44	41	55
Rb4		39,0	47,8	51,1	48,2	47,9	50,3
1882	378	Jan 5	Feb 1	Feb 28	Mar 27	Apr 24	May 21
Rm		36	65	61	77	84	61
Rb4		50,4	56,8	65,9	**73,0**	72,7	63,4
1883	392	Jan 21	Feb 18	Mar 17	Apr 13	May 10	Jun 7
Rm		52	44	37	86	42	53
Rb4		51,0	47,1	52,0	58,1	57,4	58,5
1884	405	Jan 11	Feb 7	Mar 6	Apr 2	Apr 29	May 26
Rm		93	84	103	69	66	72
Rb4		86,4	**89,4**	86,6	77,8	69,8	64,4
1885	419	Jan 27	Feb 23	Mar 22	Apr 18	May 16	Jun 12
Rm		62	75	39	56	73	83
Rb4		57,0	58,8	54,8	58,4	69,1	**74,4**
1886	432	Jan 16	Feb 12	Mar 12	Apr 8	May 5	Jun 2
Rm		31	25	55	43	44	23
Rb4		29,5	35,2	42,3	43,9	38,2	31,4
1887	445	Jan 6	Feb 2	Mar 1	Mar 28	Apr 25	May 22
Rm		13	12	10	5	14	18
Rb4		9,8	11,1	9,9	9,8	12,6	16,0
1888	459	Jan 22	Feb 19	Mar 17	Apr 13	May 10	Jun 7
Rm		12	7	7	4	9	6
Rb4		11,6	8,6	6,6	6,3	6,7	6,4
	13						
1889	472	Jan 12	Feb 8	Mar 8	Apr 4	May 1	May 28
Rm		1	4	12	5	3	1
Rb4		4,4	5,4	7,0	5,9	3,8	4,0
1890	485	Jan 2	Jan 29	Feb 25	Mar 24	Apr 21	May 18
Rm		9	4	4	2	2	5
Rb4		4,6	4,9	3,7	2,8	2,8	3,2
1891	499	Jan 18	Feb 15	Mar 14	Apr 10	May 7	Jun 4
Rm		15	22	15	14	34	43
Rb4		15,3	17,1	17,6	21,0	32,0	44,8
1892	512	Jan 8	Feb 4	Mar 2	Mar 30	Apr 26	May 23
Rm		66	82	43	58	81	82
Rb4		47,6	63,4	60,3	63,0	72,6	77,8

8 21	9 22	10 23	11 24	12 25	13 26	 27	Carr. No.	Year
30 0 ,3	Aug 26 3 2,0	Sep 23 2 2,2	Oct 20 2 2,2	Nov 16 3 2,0	Dec 14 1 1,2		325	1878 Rm Rb4
	Aug 16 11 8,6	Sep 12 7 10,4	Oct 9 16 11,6	Nov 6 11 11,4	Dec 3 6 12,8	Dec 30 20 18,2	12 338	1879 Rm Rb4
4 15 ,8	Sep 1 54 42,5	Sep 28 59 47,6	Oct 25 37 41,2	Nov 21 29 33,6	Dec 19 31 32,7		352	1880 Rm Rb4
25 30 ,1	Aug 21 55 61,8	Sep 18 51 58,4	Oct 15 69 59,2	Nov 11 56 56,9	Dec 8 53 51,2		365	1881 Rm Rb4
	Aug 11 35 45,4	Sep 7 54 50,7	Oct 4 57 59,1	Nov 1 70 **65,4**	Nov 28 72 65,3	Dec 25 56 59,1	378	1882 Rm Rb4
61 58 ,6	Aug 28 63 61,7	Sep 24 41 68,2	Oct 21 99 76,3	Nov 17 81 82,4	Dec 15 76 83,4		392	1883 Rm Rb4
	Aug 16 54 53,4	Sep 12 61 53,0	Oct 10 44 48,8	Nov 6 44 44,8	Dec 3 44 43,9	Dec 30 39 48,6	405	1884 Rm Rb4
6 53 ,8	Sep 2 44 46,0	Sep 29 38 38,8	Oct 26 35 33,0	Nov 23 24 28,8	Dec 20 27 27,6		419	1885 Rm Rb4
26 4 .4	Aug 22 12 20,3	Sep 19 20 14,9	Oct 16 9 9,4	Nov 12 0 5,6	Dec 9 5 6,4		432	1886 Rm Rb4
	Aug 12 26 18,7	Sep 8 7 12,2	Oct 5 3 8,2	Nov 2 12 9,5	Nov 29 11 12,4	Dec 26 17 13,3	445	1887 Rm Rb4
1 1 5	Aug 28 8 4,7	Sep 24 4 4,8	Oct 22 2 5,8	Nov 19 13 7,2	Dec 16 6 6,2		459	1888 Rm Rb4
2 4 4	Aug 18 20 13,2	Sep 14 6 8,9	Oct 12 3 3,9	Nov 8 0 *1,7*	Dec 5 0 2,0		13 472	1889 Rm Rb4
	Aug 8 8 10,4	Sep 4 19 12,8	Oct 1 9 12,5	Oct 29 13 11,2	Nov 25 10 10,4	Dec 22 8 12,0	485	1890 Rm Rb4
8 0 8	Aug 25 40 46,8	Sep 21 49 46,2	Oct 18 48 45,3	Nov 14 43 42,3	Dec 12 28 45,8		499	1891 Rm Rb4
	Aug 13 109 **89,6**	Sep 9 57 79,4	Oct 7 78 71,2	Nov 3 61 72,4	Nov 30 90 74,0	Dec 27 62 72,7	512	1892 Rm Rb4

TABLE 1. *Averages and smoothed averages of the sunspot numbers for synodic rotations (Nr. 124—1407*

Year	Carr. No.	1	2	3	4	5	6	
		14	15	16	17	18	19	2
1893	526	Jan 24	Feb 20	Mar 19	Apr 15	May 13	Jun 9	
Rm		74	74	64	86	82	98	
Rb4		71,4	71,5	73,8	79,5	87,0	94,4	
1894	539	Jan 13	Feb 9	Mar 9	Apr 5	May 2	May 29	
Rm		90	81	56	74	89	106	
Rb4		89,2	79,4	71,4	75,7	88,2	98,2	
1895	552	Jan 3	Jan 30	Feb 26	Mar 25	Apr 22	May 19	Ju
Rm		53	72	69	60	76	70	
Rb4		60,8	65,0	66,9	67,6	69,8	**70,1**	
1896	566	Jan 19	Feb 16	Mar 14	Apr 10	May 8	Jun 4	
Rm		28	57	51	48	26	48	
Rb4		50,0	48,6	48,8	43,8	39,8	40,8	
1897	579	Jan 8	Feb 4	Mar 3	Mar 31	Apr 27	May 24	Ju
Rm		46	33	31	37	21	13	
Rb4		40,1	36,5	34,6	33,5	26,8	18,7	
1898	593	Jan 25	Feb 21	Mar 20	Apr 17	May 14	Jun 10	
Rm		29	42	37	15	27	20	
Rb4		31,4	34,4	31,4	25,5	21,8	20,2	
1899	606	Jan 14	Feb 11	Mar 10	Apr 6	May 3	May 31	
Rm		20	11	17	15	8	15	
Rb4		15,4	15,0	14,6	13,5	13,0	14,8	
1900	619	Jan 4	Jan 31	Feb 27	Mar 27	Apr 23	May 20	Ju
Rm		6	19	7	7	23	9	
Rb4		11,2	11,4	11,0	12,2	14,0	12,9	
	14							
1901	633	Jan 21	Feb 17	Mar 16	Apr 12	May 10	Jun 6	
Rm		1	2	5	0	5	10	
Rb4		1,6	2,3	2,8	3,3	4,9	5,8	
1902	646	Jan 10	Feb 6	Mar 6	Apr 2	Apr 29	May 26	Ju
Rm		6	0	14	0	0	4	
Rb4		3,4	5,0	5,6	3,7	1,9	1,7	
1903	660	Jan 27	Feb 23	Mar 22	Apr 19	May 16	Jun 12	
Rm		10	17	18	28	13	17	
Rb4		10,6	15,3	19,4	20,4	18,8	19,9	
1904	673	Jan 17	Feb 14	Mar 12	Apr 8	May 5	Jun 2	
Rm		31	25	33	39	54	34	
Rb4		32,6	30,4	33,6	40,0	43,0	42,0	
1905	686	Jan 6	Feb 2	Mar 1	Mar 29	Apr 25	May 22	Ju
Rm		48	82	68	40	42	49	
Rb4		60,6	**66,1**	61,6	50,7	45,4	48,8	
1906	700	Jan 23	Feb 19	May 18	Apr 15	May 12	Jun 8	
Rm		49	29	70	54	51	58	
Rb4		46,0	46,1	52,7	55,8	58,0	67,4	
1907	713	Jan 12	Feb 8	Mar 8	Apr 4	May 1	May 29	
Rm		74	101	83	49	48	27	
Rb4		76,8	**84,2**	76,2	59,1	44,6	38,6	

9 22	10 23	11 24	12 25	13 26	27	Carr. No.	Year
Aug 30	Sep 26	Oct 23	Nov 20	Dec 17		526	1893
105	70	76	82	94			Rm
94,0	83,1	79,0	83,8	90,1			Rb4
Aug 19	Sep 16	Oct 13	Nov 9	Dec 6		539	1894
66	67	78	57	60			Rm
78,2	71,1	68,2	63,4	59,4			Rb4
Aug 9	Sep 5	Oct 2	Oct 30	Nov 26	Dec 23	552	1895
72	46	70	62	48	71		Rm
60,6	59,9	60,7	61,3	61,1	56,8		Rb4
Aug 25	Sep 21	Oct 18	Nov 14	Dec 12		566	1896
33	63	31	39	41			Rm
43,0	51,6	**53,0**	47,0	42,5			Rb4
Aug 14	Sep 10	Oct 8	Nov 4	Dec 1	Dec 28	579	1897
23	44	25	6	30	23		Rm
29,0	30,6	25,2	20,2	21,8	26,4		Rb4
Aug 31	Sep 27	Oct 24	Nov 21	Dec 18		593	1898
27	35	36	21	11			Rm
30,8	31,2	27,4	21,8	17,3			Rb4
Aug 20	Sep 17	Oct 14	Nov 10	Dec 7		606	1899
3	9	9	12	13			Rm
7,4	7,6	9,6	10,9	11,1			Rb4
Aug 10	Sep 6	Oct 3	Oct 31	Nov 27	Dec 24	619	1900
5	9	4	11	4	1		Rm
7,6	7,0	7,0	6,7	4,8	2,4		Rb4
						14	
Aug 27	Sep 23	Oct 20	Nov 16	Dec 14		633	1901
1	1	5	4	0			Rm
1,4	2,2	3,2	3,2	2,8			Rb4
Aug 16	Sep 12	Oct 10	Nov 6	Dec 3	Dec 30	646	1902
3	6	13	12	8	4		Rm
3,5	7,0	10,2	10,6	8,6	7,8		Rb4
Sep 2	Sep 30	Oct 28	Nov 24	Dec 21		660	1903
10	32	46	35	42			Rm
25,2	30,5	37,2	39,6	56,6			Rb4
Aug 23	Sep 19	Oct 16	Nov 12	Dec 10		673	1904
58	29	55	37	62			Rm
49,1	45,0	44,6	48,0	53,0			Rb4
Aug 12	Sep 8	Oct 6	Nov 2	Nov 29	Dec 26	686	1905
59	59	72	92	84	46		Rm
64,2	65,6	73,7	**80,1**	73,6	58,0		Rb4
Aug 29	Sep 25	Oct 22	Nov 19	Dec 16		700	1906
61	48	14	45	63			Rm
57,2	43,4	36,2	43,8	60,6			Rb4
Aug 18	Sep 15	Oct 12	Nov 8	Dec 5		713	1907
55	84	75	63	47			Rm
61,8	70,8	**71,1**	62,2	51,4			Rb4

TABLE 1. *Averages and smoothed averages of the sunspot numbers for synodic rotations (Nr. 124—14*

Year	Carr. No.	1 14	2 15	3 16	4 17	5 18	6 19
1908	726	Jan 2	Jan 29	Feb 25	Mar 24	Apr 20	May 17
Rm		46	30	29	40	57	36
Rb4		42,2	35,4	34,8	40,7	45,4	45,6
1909	740	Jan 17	Feb 14	Mar 13	Apr 9	May 7	Jun 3
Rm		55	45	60	46	39	23
Rb4		48,8	**51,2**	51,2	46,5	37,2	29,0
1910	753	Jan 7	Feb 3	Mar 2	Mar 30	Apr 26	May 23
Rm		35	24	38	11	13	24
Rb4		38,2	31,3	26,0	19,8	16,7	16,7
1911	767	Jan 24	Feb 20	Mar 19	Apr 16	May 13	Jun 9
Rm		1	13	6	15	9	4
Rb4		5,8	7,9	9,8	10,4	8,7	6,0
1912	780	Jan 13	Feb 10	Mar 8	Apr 4	May 1	May 29
Rm		0	0	6	5	4	3
Rb4		1,6	2,4	3,7	4,6	4,2	4,0
	15						
1913	793	Jan 2	Jan 29	Feb 25	Mar 25	Apr 21	May 18
Rm		4	1	3	1	0	0
Rb4		3,2	2,4	1,8	1,2	0,4	*0,2*
1914	807	Jan 19	Feb 15	Mar 14	Apr 10	May 8	Jun 4
Rm		1	3	3	13	11	11
Rb4		3,2	3,4	5,9	9,3	10,8	9,8
1915	820	Jan 8	Feb 4	Mar 4	Mar 31	Apr 27	May 24
Rm		25	36	44	41	42	16
Rb4		28,4	34,8	39,9	40,1	37,6	42,2
1916	834	Jan 25	Feb 21	Mar 19	Apr 16	May 13	Jun 9
Rm		45	54	66	68	69	56
Rb4		48,8	55,2	62,4	**66,1**	64,7	61,0
1917	847	Jan 13	Feb 10	Mar 9	Apr 5	May 2	May 30
Rm		72	83	84	73	91	120
Rb4		69,7	78,7	81,2	83,8	95,3	110,6
1918	860	Jan 3	Jan 30	Feb 26	Mar 26	Apr 22	May 19
Rm		115	87	68	87	79	74
Rb4		102,9	91,0	81,1	79,3	77,2	72,3
1919	874	Jan 21	Feb 17	Mar 16	Apr 13	May 10	Jun 6
Rm		62	76	65	49	95	91
Rb4		66,0	66,8	65,5	68,8	80,2	**86,8**
1920	887	Jan 10	Feb 7	Mar 5	Apr 1	Apr 28	May 26
Rm		36	59	57	50	26	34
Rb4		43,6	50,8	52,6	45,4	36,8	33,6
1921	901	Jan 26	Feb 23	Mar 22	Apr 18	May 15	Jun 11
Rm		30	24	32	32	25	24
Rb4		30,4	29,0	29,4	29,2	28,1	31,2
1922	914	Jan 16	Feb 12	Mar 11	Apr 7	May 5	Jun 1
Rm		14	20	60	14	12	7
Rb4		21,0	28,4	32,6	25,0	14,0	9,0

8	9 22	10 23	11 24	12 25	13 26	 27	Carr. No.	Year
	Aug 7 73 68,1	Sep 3 91 **73,6**	Sep 30 68 61,9	Oct 28 26 45,6	Nov 24 42 41,0	Dec 21 44 44,7	726	1908 Rm Rb4
27 44 1,1	Aug 24 23 35,3	Sep 20 43 43,0	Oct 17 61 51,2	Nov 13 51 **52,8**	Dec 11 54 47,1		740	1909 Rm Rb4
	Aug 13 13 14,8	Sep 9 14 20,4	Oct 7 39 24,8	Nov 3 22 20,8	Nov 30 6 11,8	Dec 28 6 6,2	753	1910 Rm Rb4
g 3 5 4,6	Aug 30 5 4,2	Sep 26 3 3,4	Oct 23 2 3,0	Nov 20 4 2,7	Dec 17 2 1,8		767	1911 Rm Rb4
22 1 2,7	Aug 18 0 3,5	Sep 15 10 5,4	Oct 12 6 5,4	Nov 8 1 4,0	Dec 6 5 3,6		780	1912 Rm Rb4
	Aug 8 0 1,1	Sep 4 2 1,3	Oct 2 1 1,7	Oct 29 3 2,2	Nov 25 1 3,0	Dec 22 7 3,5	**15** 793	1913 Rm Rb4
28 2 6,6	Aug 25 9 8,7	Sep 21 15 11,2	Oct 18 9 13,2	Nov 15 16 17,0	Dec 12 25 22,4		807	1914 Rm Rb4
	Aug 14 70 66,0	Sep 11 49 57,4	Oct 8 56 50,8	Nov 4 43 46,2	Dec 1 40 43,8	Dec 29 47 45,0	820	1915 Rm Rb4
g 3 59 2,2	Aug 30 35 47,8	Sep 26 50 49,4	Oct 24 59 53,9	Nov 20 56 55,8	Dec 17 50 59,8		834	1916 Rm Rb4
23 121 2,2	Aug 20 163 **136,3**	Sep 16 132 121,0	Oct 13 72 98,5	Nov 9 84 93,5	Dec 7 114 102,4		847	1917 Rm Rb4
	Aug 9 109 **93,4**	Sep 6 74 85,8	Oct 4 79 79,0	Oct 31 74 78,1	Nov 27 90 75,1	Dec 24 56 68,4	860	1918 Rm Rb4
31 58 0,4	Aug 27 69 63,2	Sep 23 54 58,2	Oct 20 59 51,2	Nov 17 36 43,1	Dec 14 37 39,5		874	1919 Rm Rb4
	Aug 15 19 26,8	Sep 12 28 32,7	Oct 9 55 38,6	Nov 5 34 36,0	Dec 3 21 31,0	Dec 30 39 31,0	887	1920 Rm Rb4
g 5 16 7,5	Sep 1 24 21,4	Sep 28 16 19,0	Oct 26 19 18,8	Nov 22 19 19,5	Dec 19 23 19,4		910	1921 Rm Rb4
25 9 7,6	Aug 22 6 6,6	Sep 18 5 5,9	Oct 15 6 6,3	Nov 12 8 7,7	Dec 9 8 9,3		914	1922 Rm Rb4

Table 1. *Averages and smoothed averages of the sunspot numbers for synodic rotations (Nr. 124—1407)*

Year	Carr. No.	1 14	2 15	3 16	4 17	5 18	6 19	20
1923	927	Jan 5	Feb 1	Mar 1	Mar 28	Apr 24	May 21	Jun
Rm		15	3	0	5	6	5	
Rb4		8,8	5,6	3,3	3,9	5,3	6,0	
	16							
1924	941	Jan 22	Feb 18	Mar 16	Apr 13	May 10	Jun 6	
Rm		0	6	1	12	19	36	
Rb4		*2,1*	3,4	6,0	12,1	21,0	27,4	
1925	954	Jan 10	Feb 7	Mar 6	Apr 2	Apr 29	May 27	Jun
Rm		6	21	12	29	33	62	
Rb4		14,5	15,4	19,5	27,4	38,0	43,9	4
1926	968	Jan 27	Feb 23	Mar 23	Apr 19	May 16	Jun 12	
Rm		63	88	47	42	66	67	
Rb4		76,2	68,6	58,2	53,6	57,7	60,6	
1927	981	Jan 17	Feb 13	Mar 12	Apr 8	May 6	Jun 2	
Rm		81	97	80	89	77	63	
Rb4		83,6	**87,1**	86,4	82,7	76,1	67,9	
1928	994	Jan 6	Feb 2	Mar 1	Mar 28	Apr 24	May 22	Jun
Rm		75	64	95	97	80	69	
Rb4		64,8	75,2	85,6	**88,4**	82,9	80,1	8
1929	1008	Jan 22	Feb 18	Mar 17	Apr 14	May 11	Jun 7	
Rm		65	65	50	54	59	60	
Rb4		59,9	59,7	56,2	55,3	58,6	64,6	
1930	1021	Jan 11	Feb 8	Mar 7	Apr 3	May 1	May 28	
Rm		69	58	32	41	29	43	
Rb4		76,6	57,0	43,0	37,0	35,3	32,9	
1931	1034	Jan 1	Jan 28	Feb 24	Mar 24	Apr 20	May 17	Jun
Rm		22	19	48	29	29	26	
Rb4		26,5	28,6	33,2	33,0	27,9	21,8	1
1932	1048	Jan 18	Feb 14	Mar 12	Apr 8	May 6	Jun 2	
Rm		12	9	13	6	18	20	
Rb4		13,6	11,2	10,5	11,8	15,5	18,4	
	17							
1933	1061	Jan 6	Feb 3	Mar 2	Mar 29	Apr 25	May 23	Jun
Rm		13	25	5	8	3	4	
Rb4		15,0	15,2	11,2	6,8	4,7	4,2	
1934	1075	Jan 24	Feb 20	Mar 20	Apr 16	May 13	Jun 9	
Rm		6	6	5	12	21	7	
Rb4		4,1	5,8	8,1	11,8	13,5	11,6	
1935	1088	Jan 14	Feb 10	Mar 9	Apr 5	May 3	May 30	
Rm		19	20	29	11	30	24	
Rb4		18,0	21,0	21,6	21,6	24,4	29,4	
1936	1101	Jan 3	Jan 30	Feb 27	Mar 25	Apr 21	May 18	Jun
Rm		59	70	79	81	67	56	
Rb4		63,3	69,6	**75,2**	74,8	68,7	63,6	6
1937	1115	Jan 19	Feb 15	Mar 14	Apr 11	May 8	Jun 4	
Rm		138	125	77	104	116	128	
Rb4		123,6	114,2	102,0	103,0	115,2	129,0	

9 22	10 23	11 24	12 25	13 26	27	Carr. No.	Year
Aug 11	Sep 7	Oct 5	Nov 1	Nov 28	Dec 26	927	1923
2	11	9	18	3	4		Rm
5,1	8,1	11,0	10,7	7,2	3,5		Rb4
Aug 27	Sep 23	Oct 20	Nov 17	Dec 14		16 941	1924
23	26	22	24	19			Rm
22,8	23,6	23,3	21,2	17,3			Rb4
Aug 17	Sep 13	Oct 10	Nov 6	Dec 4	Dec 31	954	1925
38	55	75	42	95	87		Rm
43,8	53,6	60,7	67,0	76,4	**80,2**		Rb4
Sep 2	Sep 30	Oct 27	Nov 23	Dec 20		968	1926
47	81	62	68	79			Rm
63,4	66,6	68,4	70,8	76,8			Rb4
Aug 23	Sep 19	Oct 16	Nov 13	Dec 10		981	1927
58	69	65	69	42			Rm
58,3	63,6	65,1	61,6	59,8			Rb4
Aug 11	Sep 8	Oct 5	Nov 1	Nov 28	Dec 26	994	1928
82	79	87	60	54	51		Rm
82,0	80,4	75,8	65,8	57,5	56,7		Rb4
Aug 28	Sep 24	Oct 22	Nov 18	Dec 15		1008	1929
58	38	56	84	115			Rm
54,7	51,9	62,3	81,0	**88,6**			Rb4
Aug 18	Sep 14	Oct 11	Nov 7	Dec 5		1021	1930
27	33	30	28	35			Rm
26,7	29,6	30,4	30,2	28,6			Rb4
Aug 7	Sep 3	Oct 1	Oct 28	Nov 24	Dec 21	1034	1931
12	19	12	12	17	20		Rm
15,6	15,0	14,0	14,2	15,8	16,0		Rb4
Aug 23	Sep 19	Oct 16	Nov 13	Dec 10		1048	1932
6	4	9	9	12			Rm
7,8	6,2	7,8	9,7	12,1			Rb4
Aug 13	Sep 10	Oct 7	Nov 3	Dec 1	Dec 28	17 1061	1933
0	4	2	3	0	0		Rm
2,2	2,4	2,5	1,9	*1,3*	2,1		Rb4
Aug 30	Sep 27	Oct 24	Nov 20	Dec 17		1075	1934
4	4	9	9	14			Rm
5,6	5,8	7,8	10,6	14,0			Rb4
Aug 20	Sep 16	Oct 13	Nov 10	Dec 7		1088	1935
33	42	59	59	60			Rm
36,9	44,4	53,2	58,2	60,1			Rb4
Aug 8	Sep 5	Oct 2	Oct 29	Nov 25	Dec 23	1101	1936
81	75	100	101	118	114		Rm
73,0	83,0	94,0	104,2	112,9	**123,8**		Rb4
Aug 25	Sep 21	Oct 19	Nov 15	Dec 12		1115	1937
112	113	114	75	80			Rm
125,0	113,2	101,8	90,7	89,8			Rb4

TABLE 1. *Averages and smoothed averages of the sunspot numbers for synodic rotations (Nr. 124—140*

Year	Carr. No.	1 14	2 15	3 16	4 17	5 18	6 19	
1938	1128	Jan 8	Feb 5	Mar 4	Mar 31	Apr 27	May 25	J
Rm		104	117	99	81	120	116	
Rb4		99,4	104,8	100,6	99,6	106,7	114,4	
1939	1142	Jan 25	Feb 21	Mar 21	Apr 17	May 14	Jun 10	
Rm		82	77	63	114	113	108	
Rb4		79,5	77,1	83,6	98,4	109,0	**110,2**	
1940	1155	Jan 15	Feb 11	Mar 9	Apr 6	May 3	May 30	
Rm		51	59	71	76	50	74	
Rb4		52,8	60,0	66,6	67,1	65,6	68,9	
1941	1168	Jan 3	Jan 30	Feb 26	Mar 26	Apr 22	May 20	J
Rm		43	53	39	41	36	28	
Rb4		53,8	47,5	43,0	39,2	37,0	40,9	
1942	1182	Jan 20	Feb 16	Mar 16	Apr 12	May 9	Jun 5	
Rm		33	57	49	58	39	8	
Rb4		40,5	47,4	**51,6**	47,8	35,4	22,5	
1943	1195	Jan 10	Feb 6	Mar 5	Apr 1	Apr 29	May 26	J
Rm		12	16	35	25	21	13	
Rb4		18,9	21,0	25,6	25,4	20,0	14,5	
1944	18 1209	Jan 26	Feb 23	Mar 21	Apr 17	May 14	Jun 11	
Rm		4	1	12	0	0	7	
Rb4		6,1	5,0	5,0	3,5	*2,8*	4,5	
1945	1222	Jan 15	Feb 11	Mar 10	Apr 7	May 4	May 31	
Rm		19	12	16	29	38	26	
Rb4		19,7	17,0	19,8	26,8	31,4	33,7	
1946	1235	Jan 4	Jan 31	Feb 28	Mar 27	Apr 23	May 20	.
Rm		34	78	73	81	86	67	
Rb4		48,7	63,3	74,6	79,2	78,8	78,6	
1947	1249	Jan 21	Feb 17	Mar 16	Apr 13	May 10	Jun 6	
Rm		125	138	129	142	178	188	
Rb4		126,1	131,4	137,6	150,9	168,1	177,9	
1948	1262	Jan 10	Feb 7	Mar 5	Apr 1	Apr 28	May 26	.
Rm		115	91	98	132	204	148	
Rb4		108,5	102,7	112,5	140,0	162,7	**164,3**	
1949	1276	Jan 27	Feb 23	Mar 23	Apr 19	May 16	Jun 13	
Rm		151	175	156	139	107	108	
Rb4		150,9	**159,7**	153,1	135,5	119,2	114,3	
1950	1289	Jan 17	Feb 13	Mar 12	Apr 9	May 6	Jun 2	
Rm		103	96	113	101	111	95	
Rb4		106,8	102,9	104,8	105,8	102,8	96,4	
1951	1302	Jan 6	Feb 2	Mar 2	Mar 29	Apr 25	May 23	
Rm		41	76	50	60	94	118	
Rb4		55,8	58,8	61,2	70,6	89,5	**101,8**	
1952	1316	Jan 23	Feb 19	Mar 18	Apr 14	May 11	Jun 7	
Rm		35	21	25	29	22	27	
Rb4		35,5	27,9	25,4	25,6	27,2	33,6	

	9	10	11	12	13		Carr. no.	Year
	22	23	24	25	26	27		
	Aug 15	Sep 11	Oct 8	Nov 4	Dec 2	Dec 29	1128	1938
	116	80	104	132	100	77		Rm
	122,5	105,2	105,5	110,3	101,4	87,4		Rb4
4	Aug 31	Sep 28	Oct 25	Nov 21	Dec 18		1142	1939
1	109	99	81	64	42			Rm
1	103,0	95,0	80,6	64,2	53,3			Rb4
4	Aug 20	Sep 16	Oct 13	Nov 10	Dec 7		1155	1940
0	111	63	56	60	73			Rm
6	**83,2**	73,5	63,2	61,4	59,9			Rb4
	Aug 9	Sep 6	Oct 3	Oct 30	Nov 26	Dec 24	1168	1941
	70	69	48	40	48	31		Rm
	65,0	61,7	57,7	50,8	40,8	38,0		Rb4
0	Aug 26	Sep 22	Oct 20	Nov 16	Dec 13		1182	1942
4	21	16	25	27	26			Rm
2	18,2	20,1	23,0	24,6	22,0			Rb4
	Aug 16	Sep 12	Oct 9	Nov 5	Dec 3	Dec 30	1195	1943
	21	9	8	8	18	10		Rm
	15,1	12,2	9,7	10,7	12,0	9,8		Rb4
							18	
4	Aug 31	Sep 28	Oct 25	Nov 21	Dec 19		1209	1944
3	12	21	12	9	32			Rm
6	14,0	15,2	14,8	16,8	20,5			Rb4
5	Aug 21	Sep 17	Oct 14	Nov 11	Dec 8		1222	1945
6	27	35	68	47	36			Rm
1	37,0	42,6	49,9	47,9	42,8			Rb4
	Aug 10	Sep 6	Oct 4	Oct 31	Nov 27	Dec 24	1235	1946
	119	86	96	118	116	118		Rm
	104,3	100,2	101,7	110,0	116,2	120,4		Rb4
1	Aug 27	Sep 23	Oct 21	Nov 17	Dec 14		1249	1947
5	177	169	137	132	113			Rm
2	176,2	162,3	144,8	129,8	118,4			Rb4
	Aug 17	Sep 13	Oct 10	Nov 6	Dec 4	Dec 31	1262	1948
	154	145	142	104	100	138		Rm
	150,2	144,2	131,3	117,2	116,4	132,0		Rb4
6	Sep 2	Sep 30	Oct 27	Nov 23	Dec 20		1276	1949
6	161	148	111	146	113			Rm
0	**143,4**	140,5	132,2	126,4	117,6			Rb4
7	Aug 23	Sep 19	Oct 16	Nov 13	Dec 10		1289	1950
9	78	51	60	53	60			Rm
2	75,6	63,1	57,1	55,6	54,5			Rb4
	Aug 12	Sep 9	Oct 6	Nov 2	Nov 29	Dec 27	1302	1951
	71	77	56	52	41	52		Rm
	72,2	67,9	60,2	51,8	47,1	43,1		Rb4
1	Aug 28	Sep 24	Oct 22	Nov 18	Dec 15		1316	1952
7	52	24	20	24	38			Rm
8	39,4	30,8	25,1	26,9	29,5			Rb4

Table 1. *Averages and smoothed averages of the sunspot numbers for synodic rotations (Nr. 124—1*

Year	Carr. No.	1	2	3	4	5	6	
		14	15	16	17	18	19	
1953	1329	Jan 12	Feb 8	Mar 7	Apr 3	May 1	May 28	
Rm		31	4	3	24	22	19	
Rb4		23,8	13,8	11,4	16,7	20,1	18,3	
	19							
1954	1342	Jan 1	Jan 28	Feb 24	Mar 24	Apr 20	May 17	J
Rm		3	0	1	11	2	1	
Rb4		*1,4*	1,6	3,4	4,9	3,8	1,8	
1955	1356	Jan 18	Feb 14	Mar 13	Apr 10	May 7	Jun 3	
Rm		24	21	5	10	19	38	
Rb4		17,8	16,4	12,3	13,4	21,6	30,0	
1956	1369	Jan 7	Feb 4	Mar 2	Mar 29	Apr 25	May 23	J
Rm		72	78	142	109	133	126	
Rb4		81,4	94,7	112,8	122,4	125,0	125,4	
1957	1383	Jan 23	Feb 19	Mar 19	Apr 15	May 12	Jun 8	
Rm		141	136	160	177	168	186	
Rb4		156,2	149,4	157,6	168,5	175,3	179,6	
1958	1396	Jan 13	Feb 9	Mar 8	Apr 4	May 2	May 29	
Rm		216	150	161	212	195	172	
Rb4		201,3	178,6	176,6	188,6	189,8	182,0	
1959	1409	Jan 2 (187)						

8	9 22	10 23	11 24	12 25	13 26	27	Carr. No.	Year
21 10 5,2	Aug 18 26 19,0	Sep 14 21 17,4	Oct 11 9 11,0	Nov 7 3 4,9	Dec 5 0 2,0		1329	1953 Rm Rb4
	Aug 7 9 5,3	Sep 3 4 5,5	Oct 1 3 5,9	Oct 28 9 7,1	Nov 24 7 9,3	Dec 22 11 13,7	**19** 1342	1954 Rm Rb4
28 26 5,3	Aug 24 49 39,2	Sep 20 34 46,4	Oct 17 57 60,3	Nov 14 89 74,7	Dec 11 82 79,4		1356	1955 Rm Rb4
	Aug 12 161 156,0	Sep 9 189 168,8	Oct 6 149 174,4	Nov 2 200 180,6	Nov 30 178 **185,1**	Dec 27 193 173,1	1369	1956 Rm Rb4
g 2 68 3,1	Aug 29 186 202,1	Sep 26 251 228,2	Oct 23 256 237,4	Nov 19 208 231,0	Dec 16 239 221,0		1383	1957 Rm Rb4
22 00 1,0	Aug 19 200 **196,8**	Sep 15 201 189,2	Oct 12 174 172,5	Nov 9 127 166,6	Dec 6 (205)		1396	1958 Rm Rb4
							1409	1959

TABLE 5. *The 11-year period. Polar lights, 1744–1866*

	0	1	2	3	4	5	6	7	8	9	10	Total	ratio n_1/n_2
ıx. $R > 87$												n_1	
ean Sunspot Number	17.0	17.3	42.7	93.2	**125.0**	105.7	82.7	65.8	46.3	34.5	18.7	3893	2.3
Group 1	2.5	1.2	0.7	6.5	**9.7**	**6.0**	**5.2**	**6.0**	3.7	4.2	1.8	283	13.5
Group 2	28.2	22.3	23.0	47.0	**58.0**	**58.2**	**55.3**	**54.8**	**63.5**	**52.2**	33.0	2974	3.4
Group 3	35.7	23.7	33.5	43.2	**56.7**	**50.2**	**52.2**	**51.8**	**50.1**	**56.5**	41.0	2966	2.5
Group 4	60.5	27.7	41.7	51.7	**70.3**	**62.7**	**81.3**	**81.5**	**86.5**	56.8	42.2	3856	7.5
Group 1–3	38.9	44.0	51.0	77.7	**95.2**	**95.5**	**98.2**	**95.5**	**97·0**	**96.3**	69.0	5066	2.6
Group 1–4	85.5	64.5	78.5	108.2	**134.0**	**133.8**	**142.3**	**150.0**	**143.5**	**131.0**	96.5	7643	3.4
ıx. $R < 87$												n_2	
ean Sunspot Number	5.5	8.8	21.8	36.0	44.2	57.8	**66.8**	44.0	35.8	25.2	14.2	1686	—
Group 1	0.4	0.2	0.0	0.6	0.2	0.4	**1.4**	0.8	0.0	0.2	0.0	21	—
Group 2	7.6	9.2	17.2	20.4	19.2	15.6	**24.2**	22.2	14.0	9.6	14.4	868	—
Group 3	7.4	11.8	14.2	11.0	26.8	29.4	**42.2**	37.2	31.8	21.8	7.6	1202	—
Group 4	0.0	0.0	2.0	6.0	7.4	12.2	**21.4**	14.8	13.0	13.6	11.6	510	—
Group 1–3	15.4	20.6	28.8	28.0	43.6	41.6	**59.0**	56.8	38.8	26.4	22.8	1009	—
Group 1–4	15.4	20.6	30.2	31.2	49.0	49.8	**70.0**	65.2	49.8	40.0	31.4	2268	—

Year	*Rm*	*b*1	*b*2	*b*3	*b*4	*b*5	*b*6	*b*7	*b*8	*b*9	*b*10	*b*11	*b*12	2	3	4	5	6	7	8	9	10	11	12	Wolf
1947	125		126		126		126		126		126		126		127		125		127		129		130		126
		132		129		129		129		129		130		132		127		128		133		125		129	
	138		132		131		132		132		133		133		131		130		135		139		138		131
		134		134		134		136		136		137		134		134		138		142		135		134	
	129		134		138		139		141		141		142		136		142		145		145		147		138
		136		142		144		146		146		147		136		147		150		148		142		143	
	142		149		151		152		152		152		153		150		155		153		153		152		146
		160		160		159		159		159		158		160		159		157		158		150		149	
	178		172		168		166		165		164		163		169		161		163		160		155		151
		183		176		173		171		170		169		**183**		169		165		164		156		154	
	188		**180**		178		176		174		173		172		177		174		168		165		159		154
		178		180		179		178		176		175		178		**182**		175		168		161		155	
	168		179		180		**180**		**179**		**178**		**176**		**180**		**181**		**174**		165		**159**		156
		180		181		**181**		**180**		**179**		**177**		180		**182**		**179**		**169**		**162**		**156**	
	195		**183**		**181**		**180**		178		177		176		179		179		173		**165**		157		**156**
		186		**181**		179		177		175		174		**186**		177		172		168		162		156	
	177		180		176		174		172		171		170		**189**		169		167		162		154		155
		173		171		169		168		167		165		173		170		163		166		160		154	
	169		163		163		162		161		160		159		161		162		156		155		151		152
		153		153		154		154		153		153		153		154		154		151		157		150	
	137		144		145		146		146		146		146		146		146		147		144		144		149
		134		136		137		138		139		139		134		138		140		141		148		147	
	132		128		130		131		131		132		133		127		133		133		136		*137*		145
		122		123		124		125		125		126		122		124		126		129		140		*143*	
	113		118		118		119		120		120		122		120		118		122		*129*		142		144
		114		113		113		116		116		117		114		113		114		*123*		*136*		144	
1948	115		108		108		110		111		113		115		106		110		*117*		132		137		143
		103		104		*106*		*108*		*110*		*113*		103		*104*		*112*		128		137		143	
	91		*99*		*103*		*107*		*110*		*113*		*115*		*101*		*110*		126		130		136		141
		94		*102*		108		112		115		117		*94*		109		124		129		134		140	
	98		105		112		117		120		122		123		107		128		130		133		135		139
		115		123		126		128		129		130		115		131		131		133		*133*		137	
	132		142		140		139		138		138		137		145		135		136		135		136		137
		168		157		152		148		146		145		168		146		139		137		134		136	
	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]

Wolf's method: columns 2–12 and Wolf

	154		150		150		150		149		148		148		149		150		143		145		143		138
		150		148		147		146		145		145		150		148		142		138		144		140	
	145		146		144		143		142		141		140		147		139		136		*138*		**145**		142
		144		140		138		137		136		136		144		136		132		137		**144**		**144**	
	142		133		131		131		131		132		132		130		129		*133*		138		142		**143**
		123		123		124		126		127		129		123		123		*130*		*135*		139		143	
	104		112		117		*120*		*123*		*126*		*127*		115		*126*		133		140		143		143
		102		*112*		*117*		*120*		*123*		*126*		*102*		*121*		130		139		142		144	
	100		*110*		*116*		*120*		124		126		128		*114*		127		136		141		141		143
		119		121		124		127		129		130		119		123		135		139		141		143	
	138		132		132		133		134		134		135		130		134		138		139		137		141
		144		143		141		141		140		140		144		141		137		138		140		138	
1949	151		154		151		148		146		145		143		155		144		138		135		133		137
		163		159		155		152		149		147		163		155		143		*134*		136		135	
	175		**164**		**160**		**156**		**153**		**150**		**148**		**161**		**152**		138		*131*		131		134
		166		**160**		**156**		**153**		**150**		**148**		**166**		**155**		**144**		134		132		132	
	156		156		153		150		148		146		145		157		146		**139**		133		*130*		*131*
		148		146		144		143		142		141		148		144		139		137		*130*		*130*	
	139		135		136		136		136		136		136		134		137		137		136		135		*131*
		123		125		127		129		130		131		123		128		134		136		132		132	
	107		115		119		122		124		126		128		118		126		133		**138**		**139**		134
		108		*113*		*117*		*120*		122		*124*		*108*		119		*126*		137		138		136	
	108		*111*		*114*		*117*		*120*		*122*		124		*112*		*120*		131		138		137		136
		115		115		118		120		*122*		*123*		115		*116*		127		133		**139**		137	
	122		120		121		123		124		125		126		119		135		130		131		136		**137**
		124		127		128		128		128		128		124		129		129		128		135		**138**	
	126		134		134		133		132		132		131		136		133		*126*		130		131		136
		144		141		139		137		135		134		144		139		129		129		132		134	
	161		**149**		**143**		**140**		**138**		**137**		135		**145**		134		132		127		126		131
		154		**146**		**142**		**140**		**138**		**137**		**154**		136		**136**		**129**		128		128	
	148		142		140		139		138		**137**		**136**		140		**138**		**132**		127		122		126
		130		136		136		136		135		134		130		**142**		134		129		124		123	
	111		129		132		133		133		132		132		135		136		127		125		123		122
		128		129		129		129		129		129		128		130		130		125		123		121	
	146		129		126		126		125		125		125		123		124		125		124		122		121
		130		124		122		131		121		121		130		118		120		124		124		120	
	113		119		118		117		117		117		117		121		114		119		121		121		120

14. *Harmonic constants*, 1916—1953. *Selected cases.* (* a_r insufficient ($\leqslant$ 0,7)).

first day	rotations	n		m	a	φ	D	σ	a_r	A/R	aA/aR
Jan 31—Nov 23	1137—1148	12	*R*	58,6	32,0	307,4	10,6	7,5	4,2	16,9	25,6
			A	992	818	313,7	10,2	169	4,8		
			C	1,1	0,1	354,6	7,1	0,2	0,6*		
			t	14,1	1,1	304,7	11,0	0,7	1,6		
			P	758,1	0,3	275,5	13,0	0,1	2,2		
Mar 25—Jun 14	1139—1142	4	*R*	69,2	37,0	318,2	9,9	13,8	2,7	18,8	26,8
			A	1282	992	312,8	9,6	258	3,8		
			C	1,0	0,2	351,8	6,9	0,3	0,6*		
			t	16,3	3,0	309,9	10,5	1,4	2,2		
			P	758,2	0,8	267,2	10,7	0,2	3,4		
Aug 7—Oct 27	1144—1147	4	*R*	49,5	39,9	297,2	11,4	6,9	5,8	15,1	24,2
			A	746	815	294,5	11,7	215	3,9		
			C	1,2	0,2	349,6	7,5	0,4	0,4*		
			t	16,2	1,4	359,2	6,8	1,2	1,2		
			P	758,3	0,2	301,2	11,1	0,3	0,6*		
Jan 20—May 8	1326—1330	5	*R*	40,8	16,4	197,1	19,0	5,7	2,9	21,8	30,2
			A	823	495	196,4	19,0	125	4,0		
			C	1,5	0,2	322,0	9,6	0,4	0,4*		
			t	11,5	1,8	217,4	17,4	0,9	2,0		
Jul 14—Jan 19	1332—1339	8	*R*	27,0	10,8	290,4	12,0	3,2	3,4	18,0	41,2
			A	487	404	271,8	13,2	54	7,6		
			C	1,3	0,3	280,8	12,7	0,3	0,9		
			t	13,7	0,4	37,5	4,0	0,7	0,6*		
Apr 24—Aug 10	1343—1347	5	*R*	18,0	9,8	188,0	19,6	2,8	3,5	12,3	17,0
			A	221	167	200,0	18,8	57	2,9		
			C	0,9	0,1	208,8	18,1	0,2	0,4*		
			t	20,0	0,5	181,6	20,1	1,4	0,4*		
Apr 8—Jul 25	1383—1387	5	*R*	12,0	8,6	238,0	15,9	2,2	3,9	23,2	34,8
			A	278	299	255,2	14,6	66	4,6		
			C	0,7	0,2	329,0	9,2	0,3	0,8		
			t	20,6	0,2	336,8	8,5	1,4	0,2*		
Nov 18—Jan 28	1418—1421	4	*R*	122,0	50,0	104,4	1,9	8,0	6,2	23,2	32,6

			t	18,0	1,1	238,8	15,8	1,8	0,6*		
Jan 14—May 2	1434—1438	5	*R*	107,8	30,7	25,9	4,8	9,0	3,4	26,1	26,4
			A	2816	809	33,9	4,2	435	1,9		
			C	1,2	0,2	259,4	14,3	0,2	0,6*		
			t	11,3	0,8	220,0	17,2	1,4	0,6*		
Jun 25—Aug 18	1440—1442	3	*R*	130,0	60,0	234,9	16,1	11,4	1,8	22,5	27,7
			A	2919	1664	217,9	17,4	624	2,7		
			C	1,1	0,4	259,9	14,2	0,3	1,4		
			t	21,5	1,1	274,5	13,2	1,1	1,0		
Apr 15—Dec 14	1505—1514	10	*R*	13,3	4,8	346,7	7,7	2,1	2,2	23,5	63,6
			A	312	30,5	342,1	8,1	103	3,0		
			C	1,3	0,3	357,0	7,0	0,3	1,1		
			K	16,3	4,8	357,4	7,0	3,2	1,5		
			t	15,9	0,5	253,4	14,8	0,8	0,6*		
Jan 10—Nov 20	1515—1527	13	*R*	9,5	2,6	188,6	19,6	1,4	1,9	13,8	14,0
			A	132	36	213,0	17,8	40	0,9		
			C	1,0	0,2	20,8	5,2	1,9	1,0		
			K	12,6	2,0	36,2	4,0	2,0	1,0		
			t	13,7	0,7	30,0	10,9	0,7	1,0		
Jan 21—Nov 14	1556—1567	12	*R*	155,7	32,4	248,0	15,1	5,2	6,2	23,5	37,0
			A	3647	1200	215,2	17,6	263	4,5		
			Ac	2706	769	212,9	17,8	151	5,1		
			Fac	2319	165	267,7	13,7	219	0,8		
			F2	4,9	4,1	197,0	19,0	2,6	1,6		
			C	1,4	0,2	135,8	23,6	0,1	1,6		
			K	18,7	2,0	138,4	23,3	1,4	1,4		
			t	15,4	1,6	152,8	22,3	0,8	2,1		
Jan 16—Apr 17	1637—1640	4	*R*	14,5	15,2	141,6	23,2	3,9	3,9	17,6	28,0
			A	247	316	143,8	22,9	9,7	3,2		
			Ac	180	178	135,9	23,9	6,6	2,7		
			Fac	331	151	128,1	24,1	148	1,0		
			F2	4,5	5,6	274,4	13,2	3,6	1,6		
			I	18,8	7,6	276,2	13,0	4,4	1,7		
			C	1,3	0,4	271,3	13,4	0,6	0,6*		
			K	12,2	25,4	278,8	12,8	16,7	1,5		
			t	9,4	1,5	271,2	13,4	2,1	0,7*		
			P	1009,7	0,3	152,5	22,3	0,2	1,3		

TABLE 15. *Harmonic constants of 14 Zwanenburg temperature series*

year	first day	rotations	n	m	a	φ	D	σ	a_r
1753	May 17 – Aug 6	249–252	4	18,9	1,7	185,8	19,8	1,2	1,4
1758/59	Dec 2 – Apr 16	324–329	6	8,3	1,6	261,4	14,1	0,7	2,3
1766	Aug 10 – Oct 30	428–431	4	15,0	1,7	182,5	20,1	1,1	1,6
1770/71	Dec 20 – Mar 11	487–490	4	3,3	1,8	293,0	11,8	0,8	2,1
1773	May 29 – Oct 11	520–525	6	18,3	1,3	186,0	19,8	1,0	1,4
1777	May 26 – Oct 8	574–579	6	17,8	1,6	93,6	26,7	0,8	1,8
1778	Mar 19 – Jun 8	585–588	4	15,0	2,2	170,6	20,9	1,3	1,6
1778	Jul 5 – Nov 17	589–594	6	14,4	0,4	295,9	11,5	0,8	0,6 *
1780	Jul 5 – Nov 12	618–622	5	10,0	1,6	93,6	26,7	0,8	1,8
1783	Oct 4 – Dec 24	660–663	4	4,4	2,0	208,0	18,2	1,7	1,2
1786	Jun 2 – Sep 18	696–700	5	16,7	1,6	169,3	21,0	0,7	2,5
1789	Jan 29 – Apr 20	732–735	4	6,1	1,8	138,3	23,4	0,6	2,4
1790	May 20 – Sep 15	750–754	5	16,7	1,3	119,2	24,8	0,9	1,4
1792	May 28 – Sep 17	777–781	5	17,2	1,4	200,0	18,8	0,9	1,4

* insufficient ($< 0,7$)

Table 16. *The solar rotation period in the year 1916*

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1137	Jan 31	**4**	**29**	**31**	**5**	14	**3**	**21**	**15**	**34**	**13**	**38**	**25**	**33**	**16**	**5**	6	7	23	15	24	11*	**8**	22	21	30	33	27
1138	Feb 27	33	15	25	6	**14**	**16**	**53**	**34**	**45**	**23**	**41**	**1**	**18**	**8**	15	28	62	35	18	5	**14***	22	26	28	**6**	**21**	**11**
1139	Mar 25	**13**	10	8	11	12	23	**86**	**20**	**53**	**60**	**58**	**60**	**29**	6	1	7	4	1	13	14	14	10*	21	20	25	26	37
1140	Apr 21	**23**	25	21	38	**4**	**11**	**5**	7	**16**	**24**	**43**	**41**	**30**	**41**	7	**17**	**8**	14	19	13	**2**	10*	14	39	39	16	32
1141	May 18	31	19	17	4	**3**	**24**	**22**	**44**	**64**	**77**	**95**	**20**	**27**	**2**	21	56	33	11	3	21	32	42*	46	18	30	28	26
1142	Jun 14	29	33	33	26	31	15	**17**	**35**	**62**	**96**	**99**	**106**	**50**	**40**	**38**	**12**	6	15	9	12	27	35*	24	16	10	28	30
1143	Jul 11	35	45	45	41	42	40	36	19	9	**16**	**50**	**76**	**72**	**62**	**84**	**62**	**53**	**4**	**4**	28	36	23	29*	37	42	32	2
1144	Aug 7	16	5	2	16	14	1	6	**9**	**18**	**13**	**12**	**16**	**27**	**54**	**40**	**21**	**10**	22	34	35	35	15	7*	24	20	13	20
1145	Sep 3	20	8	7	22	**7**	1	4	**1**	1	**12**	**35**	**28**	**35**	**29**	**25**	**35**	**45**	**29**	39	1	24	31	39*	28	32	26	34
1146	Sep 30	34	48	54	23	36	25	16	**21**	**57**	**80**	**42**	**54**	**59**	**59**	**47**	**23**	**8**	**7**	**3**	16	31	38	51*	38	39	40	32
1147	Oct 27	38	26	14	15	14	**3**	**14**	**16**	**51**	**36**	**61**	**52**	**46**	**45**	**8**	**13**	**11**	**3**	11	4	9	12	32	50*	47	45	**2**
1148	Nov 23	**12**	**8**	**24**	**10**	9	26	**8**	6	2	**15**	**27**	**6**	**14**	**45**	29	**34**	**19**	**8**	**16**	**4**	12	9	29	33*	22	10	16

Bold types: positive deviations
* Beginning of the Carrington rotations 835–846.

Van de reeks MEDEDELINGEN EN VERHANDELINGEN *zijn bij hel Staatsdrukkerij- en Uitgeverijbedrijf nog verkrijgbaar de volgende nummers:*

23, 25, 26, 27, 29*b*, 30, 31, 33, 34*b*, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48. alsmede:

49. A. Labrijn. Het klimaat van Nederland gedurende de laatste twee en een halve eeuw. — The climate of the Netherlands during the last two and a half centuries. 1945. (114 blz. met 6 fig. en 1 kaart) . . . . f 1,15

50. J. P. M. Woudenberg. Het verband tussen het weer en de opbrengst van wintertarwe in Nederland. — The correlation between weather and yield of wheat in the Netherlands. 1946. (43 blz. met 6 fig.) 0,70

51. S. W. Visser. Weersverwachtingen op langen termijn in Nederland. — Long range weather forecasts in the Netherlands. 1946. (143 blz. met 25 fig.) 2,05

52. R. J. v. d. Linde en J. P. M. Woudenberg. Een methode ter bepaling van de breedte van een schaduw in verband met den tijd van het jaar en de oriëntatie van het beschaduwde object. — A method for determining the daily variation in width of a shadow in connection with the time of the year and the orientation of the overshadowing object. 1946. (6 blz. met 2 fig. en 2 kaarten) 0,40

53. A. Labrijn. Het klimaat van Nederland. Temperatuur, neerslag en wind. — The climate of the Netherlands. Temperature, precipitations and wind. 1946. (71 blz. met 1 kaart) 2,50

54. C. Kramer. Electrische ladingen aan berijpte oppervlakten. — Electric charges on rime-covered surfaces. 1948. (128 blz. met 17 fig. en 1 afb.) 3,00

55. J. J. Post. Statistisch onderzoek naar de samenhang tussen het weer, de grasproductie en de melkaanvoer. — Statistical research on the correlation between the weather, grass production and milk supply. 1949. (119 blz. met 25 fig. en 6 tab.) 3,00

56. R. J. v. d. Linde and J. P. M. Woudenberg. On the microclimatic properties of sheltered areas. The oak-coppice sheltered area. — Over de microklimatologische eigenschappen van beschutte gebieden. Het landschap met eikenhakhoutwallen. 1950. (151 blz. met 52 fig.) 3,00

57. C. Kramer, J. J. Post en W. Wilten, Klimaat en brouwgerstteelt in Nederland. — Climate and growing of malting-barley in the Netherlands. 1952. (149 blz. met 27 fig.) 2,25

58. W. van der Bijl. Toepassing van statistische methoden in de klimatologie. — Applications of statistical methods in climatology. 1952. (197 blz. met 19 fig.) 7,60

59. Tien wetenschappelijke bijdragen, uitgegeven bij het 100-jarig bestaan van het K.N.M.I. — English summary. 1954. (198 blz. met 53 fig.) 12,50

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