ON THE YEAR TO YEAR VARIATION OF THE TEMPERATURE

BY

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Material and Method.

The material used in this paper is based on a nearly homogeneous series of temperature data for Oslo and Bergen covering the years 1816 to 1920. These series have been worked out by *B. J. Birkeland,* who published his results in *Geofysiske Publikasjoner, Vol. III, No. 9 and Vol. V, No. 8,* for Oslo and Bergen respectively.

Concerning the Oslo data Birkeland informs us[1]) that the series 1816—1838 has been collected by J. Esmark and that the rest of the data — 1837—1920 — are collected by the observer of the Astronomical Observatory of Oslo. The original note-books, containing Esmark's observations, are still to be found in the archive of the observatory, where of course also the rest of the series has been recorded in original. Both series consist of three observations a day, from which data daily means are derived. As to the series 1837 to 1925 Birkeland states: «Die Beobachtungen fangen mit 2 April 1837 an und sind auf der Universitäts-Sternwarte ausgeführt worden. Die Temperaturobservationen sind mit demselben Thermometern in denselben Aufstellungen bis 1920 gemacht, die 50-jährige Reihe 1841—1890 sind für die norwegischen Klimatabellen als Normalperiode benutzt worden.»

Concerning the Bergen series[2]) Birkeland says: «Die Beobachtungen in Bergen in älterer Zeit sind weder so vollständig noch so gut wie die Oslobeobachtungen. Aber durch Zuhilfenahme von kürzeren Beobachtungen auf dem norwegischen Westlande ist es uns einigermassen geglückt, die Observationen in Bergen in brauchbarer Form zu rekonstruiren. *Die Genauigkeit des Resultats ist natürlich machmal nicht so gross wie erwünscht, aber doch gross genug, um die Variation vom Monat zu Monat richtig zu geben.*»

After having given the whole material a close investigation, Birkeland succeeded in calculating the necessary corrections and by applying these corrections, he seems to have been able to construct monthly mean values for Oslo and Bergen for the years 1816 to 1925, so that the whole series may be considered homogeneous. The following 100-year normal for Oslo and Bergen given in Table I, refers to 1821—1920. The heights above sea-level are for the two stations 24.9 m. and 17.4 m. respectively. According to Birkeland the probable mean error of the figures of *Table I*, headed *Year*, may be put to 0.°05 and 0.°04, for Oslo and for Bergen respectively.

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[1]) B. J. Birkeland: Ältere Meteorologische Beobachtungen in Oslo. Geofysiske Publikasjoner Vol. III, No. 9.

[2]) B. J. Birkeland: Ältere Meteorologische Beobachtungen in Bergen. Geofysiske Publikasjoner Vol. V, No. 8.

Table I.

Stasjon	I	II	III	IV	V	VI	VII	VIII	XI	X	XI	XII	Year
Oslo	— 4.6	— 3.9	— 1.0	4.1	9.9	14.8	16.7	15.0	11.0	5.6	0.2	— 3.2	5.4
Bergen	1.1	1.2	2.4	5.7	9.6	12.9	14.4	13.9	11.2	7.6	3.9	2.2	7.2

Having fixed these normals, Birkeland could now proced to take out monthly residuals for the whole series of years 1816—1925, and these residuals are used as basis for the investigations made in this paper. I have not reprinted these figures and shall therefore refer the reader to Birkeland's two mentioned publications, where, in both cases they are found under the heading «*Abweichungen der Temperatur von 100-jährigen Mittel*» — *Table XIII a.* In the present paper I have limited myself to study the year-to-year variation of the winter and summer for said two stations Oslo and Bergen. As expression for the temperature of the winter, the mean of the mentioned residuals for December of one year and for January and February of the following year has been chosen, while for the summer the residuals for the three months June, July and August have been gathered into a mean figure.

As the year-to-year variation is of a rather complicated nature, we shall get a better picture of the variation, if we treat the table of residuals according to the *Cock-Blanford* Method.[1]) This method has been explained in an earlier paper,[2]) and I shall not repeat it here, but only remark that a certain period may be eliminated by using the same number of figures in the successive means, as the period itself indicates. Now studying the above mentioned table of residuals, it was evident, that the most dominating variation consisted in an almost unbroken series of oscillations, where the inter distance between one maximum (minimum) and the following amounted to 2 years. According to Cock-Blanford's method we should therefore build successive means with two figures, by which operation we get the 2-year oscillation eliminated. If now we subtract the figures of the original table, 0, from the corresponding figures in the smoothed table, I, we get a table, (I ÷ 0), giving the 2-year variation separated. As, however, 2 is an even number, none of the figures of the two tables will correspond directly in time, and for this reason it is more practical to use the figure 3 instead of 2, when building successive means. The error by this procedure is of no consequence for the character of the variation, though the amplitudes will be somewhat enlarged.

The 2-year Period of the Temperature

The result of the smoothing with 3 figures is in the form (I ÷ 0) given in *Table II*, while the original table of residuals has been left out. These original figures may, however, easily be derived from the mentioned tables in Birkeland's publications. *Table II* will be seen to have the two headings, Oslo and Bergen, and for each of the two stations there are two columns — one for the winter (w) and one for the summer (s). As to the reference to the year, the figure for the summer can not be misunderstood, but regarding the winter I may point out especially that the temperature figure put in the same horizontal line as the year in question means that it stands for *the mean figure of January and February of that year and December of the preceeding year.*

The figures of *Table II* have been plotted graphically in Fig. 1 — winter for the two stations above and summer below. T_O stands for Oslo, T_B for Bergen. In all the

[1]) G. Hellmann: Die Niederschläge in den Norddeutschen Stromgebieten. Vol. I, page 38.

[2]) K. F. Wasserfall: On Periodic Variations in Terrestrical Magnetism. Geofysiske Publikasjoner Vol. V, No. 3.

Table II.

Year	Oslo		Bergen		Year	Oslo		Bergen		Year	Oslo		Bergen	
	w†	s	w†	s		w†	s	w†	s		w†	s	w†	s
	°	°	°	°		°	°	°	°		°	°	°	°
1818	— 3.0*	— 0.1*	— 1.5	— 0.1	1855	—1.7	+1.2	— 1.5	+ 0.9	1892	+ 0.9	÷ 0.7	+ 0.6	— 1.3
19	+ 3.7	+ 1.4	+ 1.3	+ 1.1	56	— 0.2*	— 2.0*	+ 0.6	— 1.6	93	— 3.2*	+ 0.6*	— 1.3	+ 0.6
20	— 2.1	± 0.0	— 0.5	— 0.9	57	— 0.7	+ 0.5	— 0.8	+ 0.4	94	+ 3.5*	+ 0.1*	+ 2.1	+ 0.4
21	— 2.1	— 1.7	— 0.9	+ 0.2	58	+ 1.5	+ 0.7	+ 0.9	+ 0.9	95	— 2.0	— 0.7	— 2.2	— 0.2
22	+ 4.2	+ 1.3	+ 2.4*	+ 0.2*	59	+ 1.3	+ 0.4	+ 1.4*	— 0.5*	96	+ 1.0	+ 0.4	+ 1.5	— 0.2
23	— 3.5*	— 0.3*	— 3.0*	— 0.5*	60	— 1.1	— 1.0	— 1.6	— 0.5	97	— 1.6	+ 0.9	— 1.5	+ 0.7
24	+ 2.0	± 0.0	+ 1.8	+ 0.3	61	— 0.8	+ 1.3	± 0.0*	+ 1.1*	98	+ 2.0	— 1.6	+ 1.3	— 1.0
25	— 0.1	— 0.6	— 0.6	— 0.1	62	— 0.9	— 1.1	— 0.3	— 0.7	99	— 0.1	+ 1.0	+ 0.6	+ 0.4
26	+ 0.7*	+ 1.5*	+ 1.2	+ 0.8	63	+ 2.1	+ 0.4	+ 1.6	+ 0.1	1900	— 0.7	— 0.9	— 1.5	— 0.2
27	— 1.4	— 1.7	— 1.2	— 1.3	64	— 0.2	— 0.2	— 0.7	— 0.2	01	— 0.6	+ 2.0	+ 0.7	+ 1.0
28	+ 0.9	+ 1.2	+ 0.7	+ 1.1	65	— 1.9	— 0.2	— 1.3	— 0.3	02	+ 0.7	— 1.7	— 0.3	— 0.9
29	— 0.1	— 0.1	— 0.2	— 0.3	66	+ 2.7	+ 0.6	+ 2.0	+ 0.9	03	— 0.4	+ 0.1	± 0.0	± 0.0
30	— 0.4	— 1.0	— 0.1*	— 1.2*	67	— 1.3	— 1.1	— 1.3	— 0.8	04	± 0.0	+ 0.1	— 0.1	— 0.2
31	— 1.0	+ 1.6	— 1.2	+ 1.8	68	± 0.0*	+ 1.8*	— 0.3*	+ 1.2*	05	+ 0.1	+ 0.1	± 0.0	+ 0.6
32	+ 1.4	— 1.0	+ 1.4	— 0.6	69	+ 0.1*	— 1.5*	+ 1.7	— 1.5	06	+ 0.7	+ 0.8	+ 0.7	+ 0.3
33	— 0.2	— 0.8	— 0.4	— 0.8	70	+ 0.7	+ 0.8	— 0.7	+ 0.4	07	— 0.7*	— 1.5*	— 0.9	— 1.1
34	— 0.5	+ 1.7	— 0.1*	+ 1.4*	71	— 0.9	— 0.5	— 1.7	— 0.2	08	+ 0.1	+ 0.9	+ 0.4	+ 1.1
35	+ 1.6	— 0.6	+ 1.1	— 0.3	72	+ 2.0	+ 0.4	+ 1.8	+ 0.7	09	± 0.0	— 0.4	+ 0.3	— 1.3
36	— 0.7	— 0.5	— 0.7	— 0.7	73	— 0.9	+ 0.1	— 1.2	+ 1.4	10	— 0.2	± 0.0	— 0.5	+ 1.1
37	+ 0.2	+ 0.2	+ 0.8	+ 0.2	74	+ 3.7	— 0.6	+ 2.4	— 0.5	11	+ 0.8	+ 0.4	+ 0.5	— 0.3
38	— 1.5	± 0.0	— 2.0	— 0.1	75	— 4.3*	+ 0.3*	— 2.5	— 0.4	12	— 1.1	— 0.1	— 0.4	+ 0.4
39	+ 0.9	+ 0.3	+ 1.3	+ 0.1	76	+ 2.6	+ 0.8	+ 1.4	+ 0.7	13	+ 1.0	— 0.8	+ 0.3	— 0.9
40	+ 1.1	± 0.0	+ 0.3	— 0.1	77	— 2.8	— 1.3	— 1.2	— 0.7	14	— 0.7	+ 1.7	+ 0.2*	+ 1.5
41	— 2.9	— 1.0	— 1.5	— 0.2	78	+ 2.8	+ 0.8	+ 2.1	+ 0.2	15	+ 1.0	— 1.0	+ 0.1	— 1.1
42	+ 1.8	+ 0.8	+ 1.2	+ 0.2	79	— 2.0	— 0.6	— 3.0*	+ 0.1*	16	± 0.0	— 0.5	+ 0.2	— 0.4
43	+ 0.9	+ 0.5	+ 0.1	+ 0.6	80	+ 1.9	+ 1.2	+ 2.8	+ 0.8	17	— 1.4	+ 1.1	— 1.0	+ 1.3
44	± 0.0	— 0.8	+ 0.3*	— 0.9*	81	— 3.4	— 1.2	— 3.0	— 1.5	18	+ 0.4	— 0.7	+ 0.4	— 0.6
45	— 2.5	— 0.6	— 2.0	— 0.3	82	+ 3.5*	+ 0.4*	+ 1.9*	+ 1.0*	19	+ 0.2	+ 0.2	— 0.1	— 0.3
46	+ 2.6	+ 1.4	+ 2.3	+ 1.6	83	— 1.7	± 0.0	— 1.7	— 0.3	20	— 0.5	— 0.1	± 0.0*	+ 0.8*
47	— 1,9*	+ 0.3*	— 1.4	— 0.5	84	+ 0.9	+ 0.4	+ 1.0	+ 0.8	21	+ 0.9	+ 0.2	+ 0.6	— 0.8
48	+ 1.2	— 0.9	+ 0.5	— 0.2	85	— 0.8	— 0.6	± 0.0*	— 1.0*	22	— 1.0	± 0.0	— 0.7	+ 0.4
49	+ 0.1	— 0.3	+ 0.5	— 0.5	86	+ 0.4	+ 0.1	— 0.9	+ 0.3	23	+ 1.5*	— 0.4*	+ 0.8	— 0.6
50	— 1.6	+ 1.0	— 1.5	+ 0.8	87	+ 0.9	— 0.5	+ 1.2	— 0.4	24	— 2.7	— 0.6	— 1.9*	— 0.1*
51	+ 1.3	— 1.7	+ 1.0	— 2.0	88	— 1.9	— 0.8	— 1.2	+ 0.2	25	+ 2.5	+ 1.0	+ 2.3	+ 0.7
52	+ 0.3*	+ 1.3*	+ 0.8*	+ 2.2*	89	+ 0.7	+ 0.6	+ 0.2	+ 0.8	26	— 0.3	+ 0.1	— 1.3	+ 0.4
53	— 0.5	— 0.4	— 0.9*	— 0.5*	90	+ 1.3	+ 0.6	+ 1.2	— 1.2	27	+ 0.2	+ 0.5	+ 0.8	+ 0.4
54	+ 1.4*	+ 0.1*	+ 0.9	— 0.1	91	— 0.7	— 0.3	— 1.1	+ 1.3	28	— 0.6	— 0.8	— 0.2*	— 1.2*

† Mean of January and February of the year, written in the same horizontal line, and December of the preceeding year.

four curves we see the nearly unbroken series of 2-year oscillations, only broken when transformation of phase takes place. The cases when maximum of the undulations falls in with even number of the figures of the year, the curves have been drawn in full lines, in case the maximum falls in with years written with odd figures, the curves have been drawn with dotted lines.

Having become aware of *Woeikof's* various papers, I may in this connection mention his examination of the temperature series 1757—1906 for Stockholm (cp. *Perioden in der Temperatur von Stockholm* von *A. Woeikof*, Meteorologische Zeitschrift for 1906, page 433), where he also points out the 2-year period and remarks: «Die 2-jährige - Periode zeigt värmere *«paare»* als *«unpaare»* Winter, namentlich in den letzten 40 bis 80 Jahren. Diese Erscheinung habe ich schon in mehreren Abhandlungen beachtet und nach mir die Herren *Pettersson*, *Meinardus* und *Lesshaft.*»

We see that for intervals from 2 to 19 years in succession we have alternately a comparatively cold and a comparatively warm winter (summer) and then suddenly we get two warm (cold) winters (summers) in succession, whereon again the cold and the warm winter (summer) follows each other as regularly as before. There seems to be no system for the time when transformation of phase takes place, but that the mean length of the series drawn with full lines are about 10 years, while the other type does not last more than 5 years on an average — from 2 to 9 years. When transformation of phase accurs in Oslo, it usually also occurs at Bergen, and when it happens in winter, it also appears in the records for the following summer. The fact that there seems to be very little system for the time, when transformation of phase takes place, is very inconvenient, because if there had been a rule, we could more or less foretell, when we might expect *2 warm (cold) summers (winter) in succession* — an occurrence which is of very great consequence from both a botanical and a zoological point of view.[1])

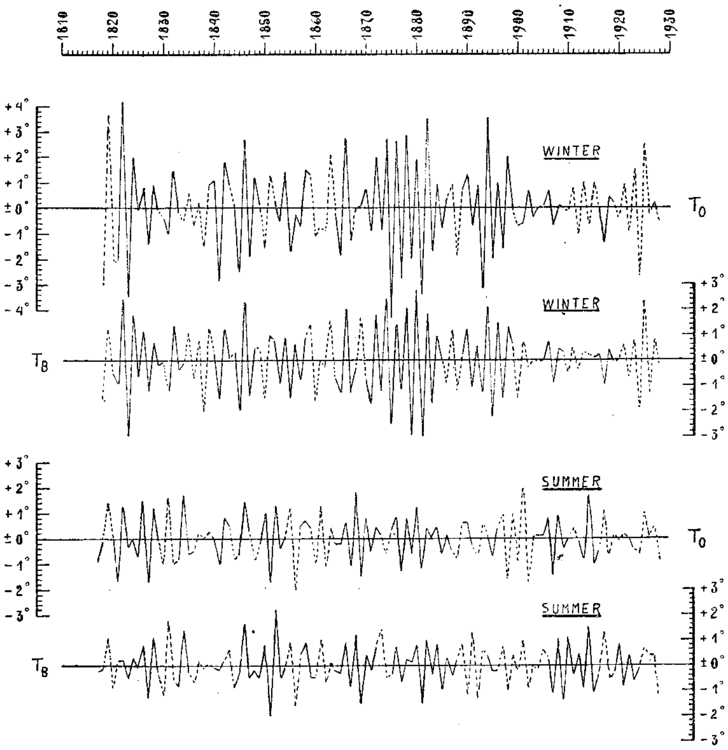

Fig. 1. The 2-year variation of the temperature of the winter and that of the summer for Oslo, T_O, and Bergen, T_B, Type (I ÷ 0).

In a series of articles,[2]) published in the Norwegian magazine for popular science, «*Naturen*», O. Krogness has shown, that the 2-year variation was fairly well developed in the temperature records of 22 Norwegian stations. Furthermore he has found this same undulation in measurements of the sea-temperature along the Norwegian coast, and finally he has found it in magnetic elements — especially in the so-called magnetic stormines — collected at Oslo Observatory. In all cases his curves cover the time interval 1875—1910.

Krogness has also suggested a possible explanation for the existence of the said 2-year variation — namely that it is brought about by interference between the yearly (and half-yearly) wave of the temperature and a shorter undulation of about 8 months In 1866 *Wolf* called attention to a possible oscillation of $7^2/_3$ months' duration in the sun spots, but seemingly this suggestion was forgotten again till in our days several scientists have taken up the question with the result, that the existence of such an undulation in the sun spots may now be considered an established fact. *Kr. Birkeland* pointed out that one might expect an eight-monthly period in the sun spots on account of the

[1]) A later examination seems to point in the direction, that the transformation of phase has something to do with the 11 year period of the sun spots.

[2]) O. Krogness: De magnetiske stormes betydning i meteorologien «Naturen», mars—april, 1917.

combined action of *Venus* and *Jupiter*, according as to whether these stand in conjunction or in opposition. In his above mentioned paper Krogness found, as said, an 8-monthly period in the amplitudes of the daily variation of the declination in Oslo and suggested that this period might be due to the same period in the sun spots brought about in the way mentioned by Birkeland. *Helland-Hansen and Nansen* have actually found that the said period is fairly well developed in the sun spot data, when *Wolfers* figures are treated according to Cock-Blanford's method, whereby the period in question can be separated. In their large oceanographic paper[1]) they give a curve for the separated 8-monthly oscillation of the sun spots during the interval 1875—1910, showing a fairly unbroken series of said oscillations and on page 261 of the English edition we read: «The curve shows particularly great variations in the neighborhood of sun spot maximum and the greater excursions seem to have a regular time interval. This holds especially in the years 1904 to 1910, when the average time interval between these excursions amounted to eight months.» Farther down we read: «Curve IV, figure 92, for the air pressure difference in the North Atlantic Ocean, shows also great excursions, with intervals between, which correspond to the excursions we have noted in the curve of the sun spots.»

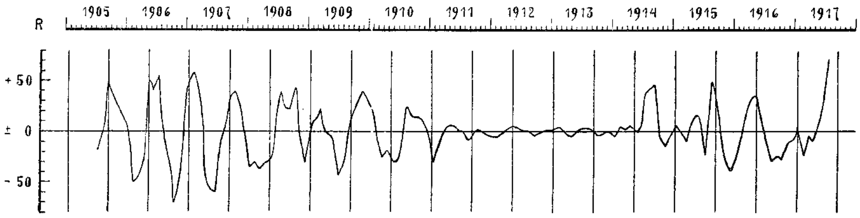

Fig. 2. The 8-monthly period in the sun spots for the interval 1905 to 1917. Type (I ÷ II).

Finally the author of this paper has worked out the graph given in Fig. 2. The curve is of the type (I ÷ II) — the half-yearly period being eliminated before the smoothing with 8 numbers took place. The diminishing of the amplitudes which the smoothing brings with it (cp. Geofysiske Publikasjoner Vol. V, No. 10, page 6) has in Fig. 2 been corrected, so that the scale put to the left of the figure is more or less true. Also in this case we have large oscillations during the interval of maximal spottedness and quite small undulations at time of minimum. Comparing the *size* of the oscillations of the curves in Fig. 1 with those in Fig. 2, we do not, however, find much connection. This fact may point in the direction that the absolute degree of intensity in the solar activity is not decisive for the size of the amplitudes of the air temperature — a thing which will also be seen in Fig. 4, where the 11-year fluctation of the temperature is compared with the same period in the sun spots. However, there is still the possibility that the connection is larger than it seems to be — in other words, there may exist a masked relation.

However this is, there is every reason to suspect a rather complicated distribution of the large and small oscillations in the curves of Fig. 1. Thus I may mention, that there is a 4-year periodicity and probably also an 8-yearly, beside traces of one the length of which is about 52 years. If furthermore the theory, of the connection between the 2-year period and the conjunction and opposition of *Venus* and *Jupiter*, is correct, the following circumstance is of interest: The time between two conjunctions is not exactly 8 months, but somewhat less — 7,79 months or 236,2 days. Putting

[1]) B. Helland-Hansen and F. Nansen: Temperaturschwankungen des Nordatlantischen Ozeans und in der Atmosphäre. Videnskapsselskapets Skrifter, Mat.-Naturv. Klasse I, 1916, No 9. — Temperature Variations in the North Atlantic Ocean and in the Atmosphere. Smithsonian Miscell. Collections. Vol. 70, No. 4, Washington 1920 — «Naturen», Bergen 1920.

243 days for 8 months we have a lag of (243 ÷ 236) = 7 days each time, and shall therefore have large oscillations only at intervals of about 35 years. As we reckon with seasons of three months, the duration of such a series of large oscillations should be about 13 years. A series of this length is seen 1870 og 1883. Finalle I may remark that the above mentioned periodicity of 35 years corresponds exactly to the well known *Brückener Cyklus* (see page 11).

Comparison between the Variation of the Winter with that of the Summer.

Looking at the variation in the curves of Fig. 1, we see that there seems to be some connection between the winter and the following summer. *Hellmann* has called attention to this fact as early as 1899. In «*Meteorologische Zeitschrift*» for said year (page 58) he has written an article[1]) in which comparison between the temperature of the winter and that of the following summer leads to the following conclusion: «Theilt man die milden Winter nach ihrer Intensität in zwei Gruppen, nämlich mässig milde, und sehr milde, so ergibt sich folgender Zusammenhang zwischen den milden Winter und den Charakter der nachfolgender Sommermonate July und August.

Nach mässig milden	sehr milden Winter war der	Juli	August
7 Mal = 28 %	10 Mal = 44 %	zu warm	zu warm
4 » = 16 %	7 » = 30 %	» warm	» kalt
7 » = 28 %	1 » = 4 %	» kalt	» warm
7 » = 28 %	5 » = 22 %	» kalt	» kalt

Nach einem sehr milden Winter darf man also mit Grösserer Wahrscheinlichkeit einen warmen Sommer erwarten, als nach einem mässig milden.»

Using Birkeland's residuals for Oslo, attempts have been made to correlate the variation of the winter with that of the following summer. The result was, however, that the correlation coefficient was too small to allow any forecast, though there could

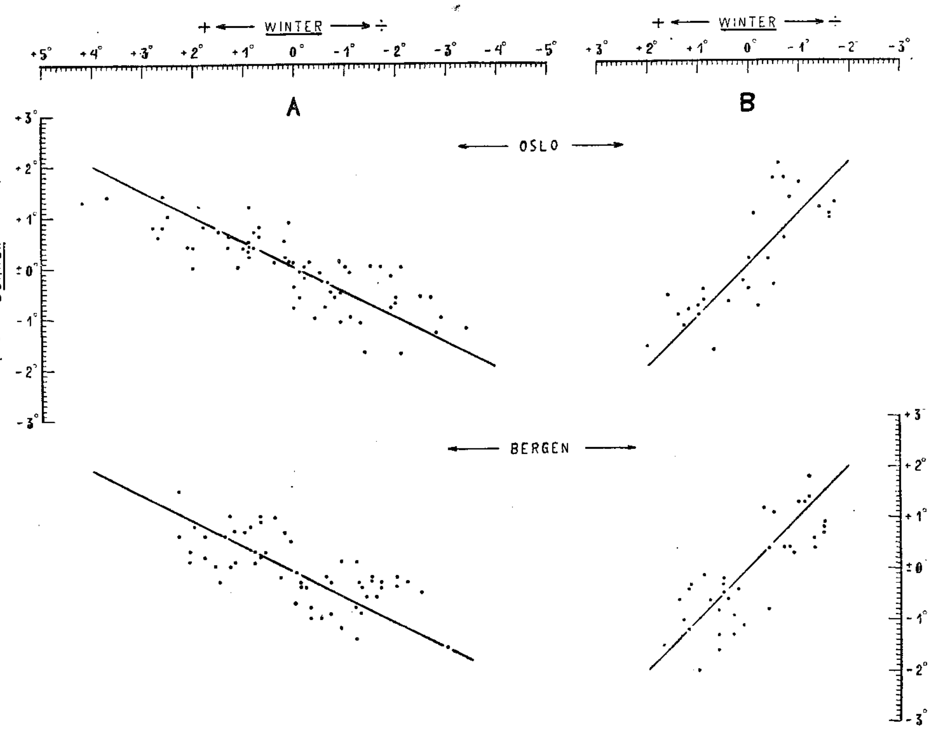

Fig. 3. Relation between the winter departure and that of the summer for Oslo and Bergen.

1) G. Hellmann: Zur Charakteristik Milder Winter.

be no doubt about a rather strong sporadic connection. The reason why so small correlation was found, will be understood by studying *Table II*, where the temperature data will be seen printed partly in ordinary types and partly in fat types. This has been done, because the relation between the variation of the winter and that of the following summer *appeared to be divided in two different types*. Let us refer to these two types as an *A-type*, printed in ordinary types, and a *B-type*, put in fat types. The relation of the *A-type* appears to be positive — high (low) winter temperature corresponds to high (low) summer temperature, while by the *B-type* the relation is negative — high (low) winter temperature corresponds to low (high) summer temperature. The exactness of said relation will be seen from Fig. 3, where the winter data have been used as abscissa and the summer data as ordinate. Oslo above, Bergen below, the *A-type* to the left, the *B-type* to the right. The proportion between the temperature of the winter and that of the summer, refferred to the average line through the points, may be written:

$$\eta = \frac{\triangle T_s}{\triangle T_w} \tag{I}$$

$\triangle T_w$ and $\triangle T_s$ standing for degrees above or below the normal, or rather corresponding respectively to the data given in the same horizontal line in *Table II*. The indexes refer to winter and summer. It appears then from Fig. 3 that $\eta_A = + {}^1/_2$ and $\eta_B = \div 1$. The percentage for the frequency of each type, for Oslo and Bergen, will be seen in *Table III*, where the heading U refers to the more or less «wild» cases — cases where the relation between winter and summer do not belong either to *Type A*, or *Type B*. We see that for both stations the cases of Type A are dominating, espesially for Oslo. The uncertain cases (U) are for both stations 20 %, and are in *Table II* marked with a star.

Table III.

Oslo			Bergen		
A	B	U	A	B	U
60 %	20 %	20 %	50 %	30 %	20 %

As the *A-type* and the *B-type* are rather seldom mixed up, but divided from each other in long series, and because the relation is, in both cases, rather high, it is not impossible that this peculiarity may prove to be of practical use as a base for forecasting.

The 11-year Period and the Secular Variation of the Temperature at Oslo and Bergen.

Having studied the 2-year period, we may now have a look at the remainder of the combined variation of the temperature. As we remember, the first smoothing was made with 3 figures in the successive means. The data thus smoothed were plotted and showed that the temperature, at least partly, varied in correspondance to the 11-year period of the sun spots. Consequently a second smoothing was made with 11 figures in order to eliminate said period. The separated 11-year period was arrived at in the usual way by making out a table of differences (I ÷ II), and the resulting data were plotted graphically with the result seen in Fig. 4. Winter is put above, summer below. T_O standing for Oslo, T_B for Bergen. The second curve from above and below represent the sun spot curve for the winter and summer respectively, composed of data for the same three months for the summer and for the winter as those used by the temperature data. There seems to be no doubt of a rather close relation between the variation of the temperature and that of solar activity. To get the picture clearer, the cases, where there is *negative* relation between the temperature variation and that of the sun spots, have been drawn with full lines, the cases drawn with dotted lines represent either *positive* relation or «*wild*» cases — for instance the curious strong oscillations between 1851 and 1858. Writing the relation in the following form:

$$\text{(II)} \qquad T = \varepsilon\,(R_0 \div R)$$

where R_0 represent the value of R corresponding to $\pm\,0°$ in the temperature curves, we get for R_0 and the coefficient ε the following average values given in *Table IV*. For Oslo the value of ε wil be seen to be 0.04 for the winter and only 0.01 for the summer, while at Bergen the value is 0.02 for both summer and winter. Formula (II) and the values for R_0 and ε, given in *Table IV*, do not pretend to be of practical use, because the relation between T and R is by no means direct. The amplitudes of the oscillations of R correspond rather badly with those of T, and the time for maximum and minimum of R and T are sometimes displaced several years, comparing one curve to the other. The relation between R and T is, as mentioned, negative in the majority of cases both for Oslo and Bergen. This indicates, according to *Helland-Hansen and Nansen* (cp. Geofysiske Publicasjoner, Vol. V, No. 3, page 18), that winds carrying a comparatively low temperature prevail for these stations.

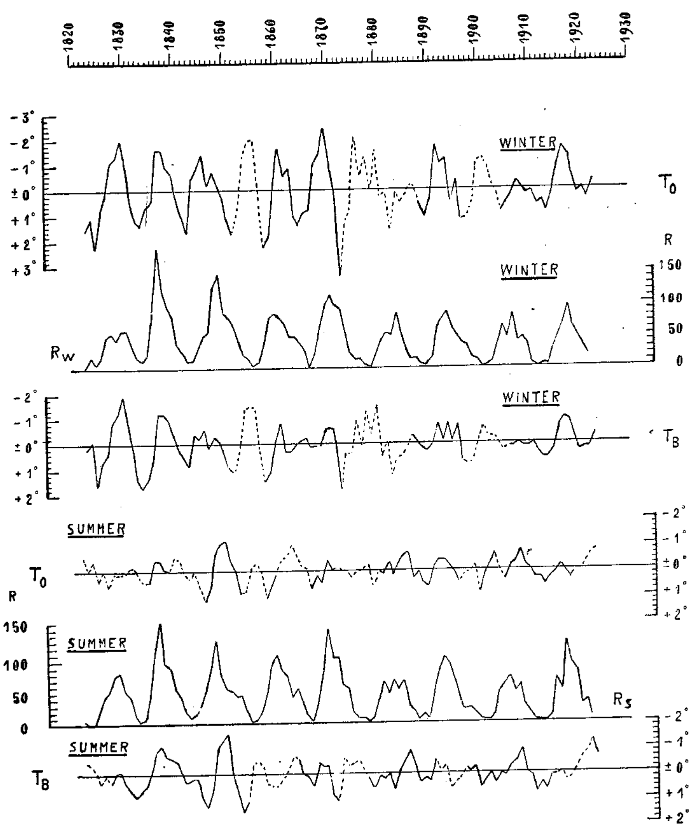

Fig. 4. The 11-year variation of the temperature of the winter and that of the summer for Oslo, T_O, and Bergen, T_B, Type (II ÷ I), compared with the sun spots for the same seasons, R_W and R_S. The temperature curves are reversed.

Going back to the general variation of the temperature curves, we shall now look at the curve comming out, when we plot the data arrived at by the second smoothing with 11 figures. These curves have been drawn in Fig. 5, and represent the so-called «secular» variation of the temperature. The curves are of the type III. As before winter is above and summer below, T_0 standing for Oslo T_B for Bergen. The curve in the midle (full line), marked R, is a sun spot curve smoothed in a similar way as the temperature curves. The T-curves for the winter are inverted, while the summer curves are direct.

Table IV.

Element	Oslo		Bergen	
	w	s	w	s
R_O	50	70	70	40
ε	0.04	0.01	0.02	0.02

What does the secular variation of the temperature mean? Probably as by other geophysical elements a large wave, supposed to cover about one hundred years. In the first place this secular movement was found in the data for the sun spots and those of the frequency of northern (southern) light. Thanks to old Chinese notations, the variation of these phenomenæ can be traced back to about year 450 B. C.[1]), and seem to suggest various *large periods*, the shortest of which is about 450 years. Magnetic elements are, as we know, supposed to be closely connected with the two mentioned cosmical phenomenæ and according to *Scott*[2]) the secular variation of the declination consist of a secondary period of about 80 years and a chief wave of about 450 years — or the same wave as found for the sun spots and northern light. In 1877 *Wolf*[3]) called attention to a period in the sun spots, the length of which he puts to about 178 years with a secondary wave of half this length — thus about 90 years.

There seems, however, to be considerable disagreement as to the length of various periods found — both between the results of the scientists themselves, treating the same phenomena, and between the periods of the different elements. This fact does not, however, mean that there is disagreement in reallity, but is merely a consequence of the fact, that we do not as yet, for any of the mentioned elements, possess sufficiently trustworthy data of sufficient length and homogenity.

There exists a great deal of literature treating the periods here mentioned and as space does not allow us to go into details we shall limit ourselves to look at the curves given in Fig. 5. However, before we do so, it is of interest to point out the fact, that nearly all investigators, treating above mentioned periodic phenomenæ, relate the existence of them with the behaviour of the large planets — especially *Venus* and *Jupiter*, the conjunction of which has also been supposed to be the cause of the above mentioned 8-monthly period of the sun spots.

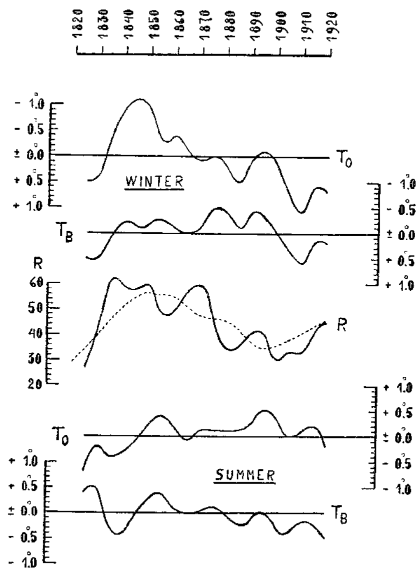

Fig. 5. The secular movement of the temperature for winter and summer for Oslo and Bergen, compared to the secular change in the sun spot dato.

The chief movement of the sun spot curve — the stipled curve in the middle, arrived at by still another smoothing— has a maximum about 1850 and as it is supposed to represent a fragment of the above mentioned secondary wave of about 90 years, the next maximum ought to occur in 1940. Now looking at the temperature curve for the winter in Oslo, we see a remarkable likeness between this curve and that of the sun spots. Going into details we see that in both curves — and also in the rest of the curves — there are some smaller undulations, the length of which are of a somewhat irregular character. Regarding this secondary undulation, it may be remarked that theoretically a $(3 \times 11) = 33$ yearly period in the sun spots has been suggested. It is not inprobable that the smaller undulations of our curves in Fig. 5 have something to do with this period. It may also be of interest to notice that these oscillations have nearly the same length as the *Brückener Cyclus*[4]) of 35 years duration, a period which is very pronounced

[1]) Herman Fritz: DieWichtigsten Periodische Erscheinungen der Meteorologie und Kosmologie. Leipzig 1889, page 373.

[2]) E. Mascart: Traité de Magnétism. Paris 1900.

[3]) Astronomische Mitteilungen. Zürick 1877.

[4]) cp. Meteorologische Zeitschrift 1899, page 273.

in the temperature records for Central Europe. Another point is that the horizontal component of the magnetic force, which has been regularly observed at Oslo Magnetic Observatory from 1842 till our days, show a year-to-year variation the character of which is remarkably like what we have found for our temperature data. The 11-year period is for instance very pronounced, the secular movement show a decided maximum about 1908 and a suggestion of a secondary minimum about 1843 — thus just the years pointed out for the temperature curves of Fig. 5. Beside this the magnetic curve of Oslo shows a secondary undulation suggesting a 33-yearly period.

Regarding the secular variation in magnetic elements and its cause, this is an old question, which is still much discussed, because no definite solution has as yet been generally accepted. To begin with, it was the phenomena itself, as it was exhibited in Hansteen's old isogonic charts, which consumed all the interest, but it did not last long before the question arose: «What is the cause of the secular variation?» «Is the source of the secular variation of the earth's magnetism within or without the earth's crust?» Literature is, as said, copious and space does not allow us to discuss this interesting question in datail. I shall therefore only mention that *Gauss*, in his renowned memoir on the earth's magnetism, has already worked out a matematical method for the separation of the internal and external sources. In later years *L. A. Bauer*[1]) and *Ad. Schmidt* have several times taken up the question and I may especially mention what Schmidt says in one of his papers,[2]) in which he discusses the secular period of the Potsdamer series. On page 23 we read: «Nun lässt aber ein Blick auf das ausserordentlich scharfe Maximum von H am Beginn dieses Jahrhunderts erkennen, dass hier die Annahme einer Periode von 480 Jahren vollkommen versagen würde, wenn man nicht stark ausgeprägte Oberwellen hinzufügte. Statt dies zu tun, was bei der Kürze der Beobachtungsreihe doch nur formale Bedeutung hätte, ziehe ich es vor, die Periodelänge so zu wählen, dass sich der auf das erste Glied beschränkte Ausdruck den Beobachtungen möglichst nahe anschmiegt. Da nun die älteren Messungen nach Ermans Formel am besten durch einen Ausdruck dargestellt werden, der um das Jahr 1816 ein Minimum besitzt, während die neueren ein sehr deutliches auf 1905 fallendes Maximum aufwiesen, *so ist ohne jene Rechnung klar, dass die Annahme einer Periode von rund 180 Jahren dem Zwecken am besten entsprechen wird.*» As we see, we have again to do with a period of the same length as the before mention wave Wolf pointed out for the sun spots.

Regarding the secular period observed in magnetic elements, we know that the whole magnetic field of our globe is gradually displaced, and it seems to me, that an analogeous movement in the phenomenæ governing the variation of the meteorological elements would not be out of question. If, for instance, we supposed a gradual displacement of the great pressure centres, the Azorial maximum and the Islandian minimum, this would probably explain the secular variation of the temperature and the origin of such a displacement may be exactly the same unknown force which causes the secular variation in both terrestrial and cosmical data.

[1]) Terrestral Magnetism and Atmospheric Electricity conducted by L. A. Bauer.

[2]) Ergebnisse der Magnetischen Beobachtungen in Potsdam und Seddin in den Jahren 1900—1910 von Ad. Schmidt. Berlin 1916.

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