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INTRODUCTION

The magnetic material collected during the years 1916—33 at *Dombås Observatory* and published by *Det Magnetiske Byrå* at Bergen in 1936 [1] builds the principal foundation for the investigations made in the present paper. As will be seen from the mentioned publication, the treatment of the material follows methods originally proposed and employed by Kr. Birkeland in his well known investigations of terrestrial magnetic phenomenæ at the beginning of this century [2]. In consequence of this method the variation of the D-, H- and V-curves are divided up into three variation-components designated by the three symbols: Q, S and C according to formula:

$$O = Q + S + C \tag{1}$$

where O corresponds to data given in the ordinary publications from magnetic observatories, and the definition of the three symbols is to be found in the paper mentioned [1].

In special cases we have also made use of magnetic data collected at other observatories — such data, however, also converted into variation-components corresponding to those given in formula (1).

In most of the investigations, made in this paper, I have chosen data for the year 1933— partly because this year forms a part of the international polar year, and partly because data for this year has previously been chosen for other special investigations based on the Dombås material.

As the publication of the magnetic results from Dombås only gives monthly hour-means, besides 7-day normals for quiet diurnal variation, the original data, used in some of the investigations, are not available in print, but the written tables are, of course, preserved at the bureau.

THE QUIET DIURNAL VARIATION

To get a general view of the quiet diurnal variation of magnetic elements I have worked out mean hour figures for D, H and V for the four seasons of the year 1933 for the three magnetic stations: *Tromsø*, (T), *Dombås*, (D), and *Rude Skov*, (R. S.). The geographical co-ordinates, and the annual mean values for D, H and V, for the three stations, are given in Table 1, and the three curves are plotted graphically in Fig. 1.

Table 1.

Station	Tromsø	Dombås	Rude Skov
φ λ	69° 39′.8 N 18° 56′.9 E	62° 04′.7 N 9° 09′.8 E	55° 50′.6 N 12° 27′.4 E
D H V	3° 28′.2 W 0.11488 0.50205	8° 30′ W[1] 0.14080[1] 0.46290[1]	5° 29′.8 W 0.16939 0.44837

[1] Only approximate values.

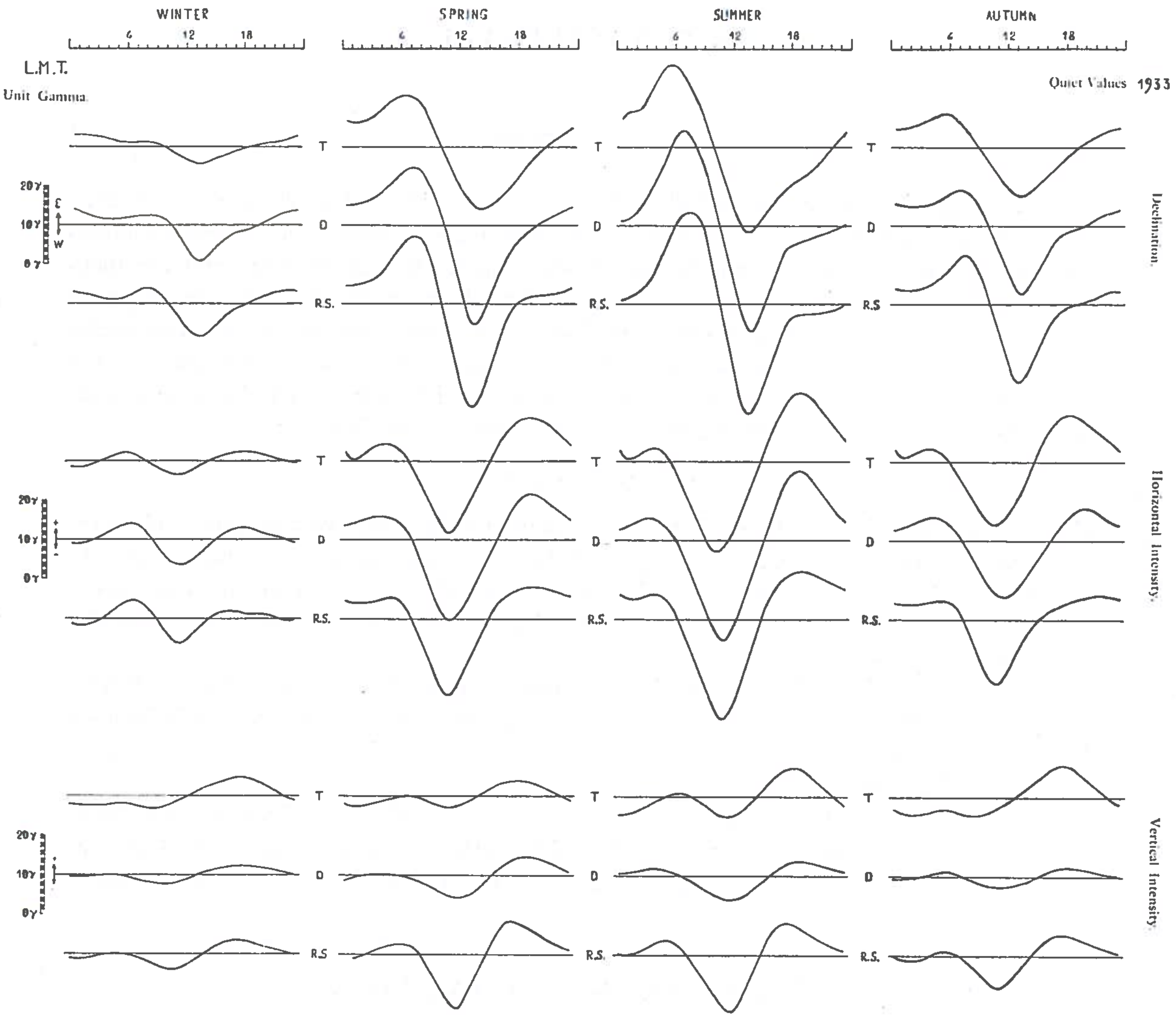

Fig. 1. The quiet diurnal variation in D, H and V for the four seasons of the year 1933 for the magnetic stations of Tromsø, (T), Dombås, (D) and Rude Skov, (R. S.).

The most characteristic feature in these curves is the increase in amplitude of daily range from winter to summer — the gradual progress from month to month being nicely exhibited by the monthly mean curves for H at Dombås, horizontally, below in Fig. 3.

Investigations show that in the data for range we have to do with an annual and a half-yearly period, besides smaller irregularities, which seem to suggest smaller periodicities. As the yearly and half-yearly waves have already been discussed in another paper [3], it is only the latter kind of variation we shall look at here.

If, for the range in the quiet diurnal variation, we plot with monthly mean values we get curves for the yearly progress equal to those drawn in Fig.2 , above. The letters T, D and R.S., stand for the above mentioned stations *Tromsø, Dombås* and *Rude Skov.*

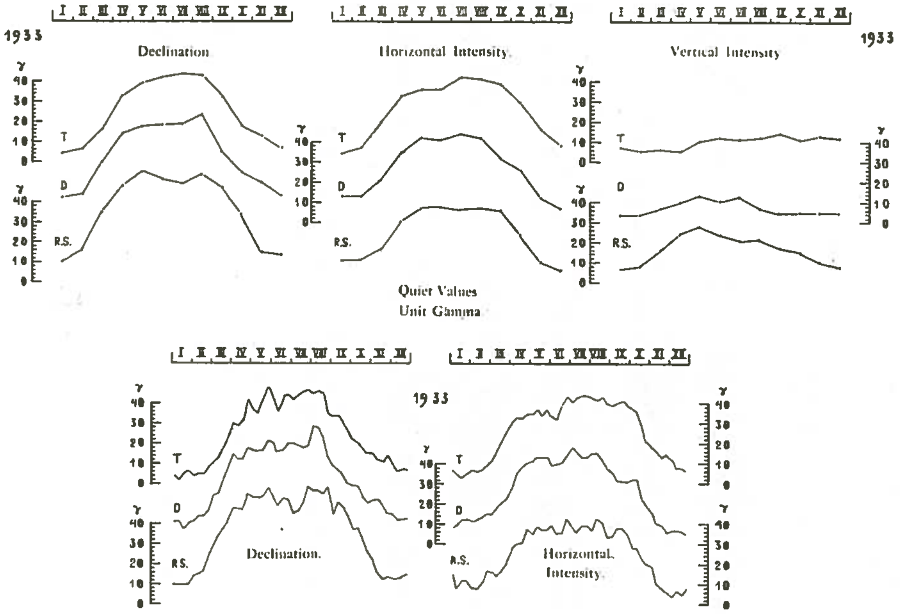

Fig. 2. Curves for the range in the diurnal variation of quiet days for D, H and V for the three stations Tromsø, Dombås and Rude Skov. Above monthly mean values and below corresponding curves, when 7-day values are employed.

The comparatively smooth character of these curves does not, however, give any good idea of the real nature of this variation, which is plainly seen by the second set of curves given below in Fig. 2. Here we have plotted with data for the daily range taken directly from the 7-day normals.

These curves are, as we see, very irregular and examination shows that, besides the before mentioned annual and half-yearly waves, we have suggestions to periodicities related to the rotation of the sun.

To make an analysis with the 7-day values in order to exhibit said periods will not present a very convincing picture, but if we tried to work out data for the quiet diurnal variation day by day for the whole year, we should probably be able to get hold of the real nature of the variation, suggested by the lower set of curves in Fig. 2.

During the work with the Dombås material I conceived the posibility of making out curves for the quiet diurnal variation for every day. Experience shows that this variation is so pronounced that very few records are of such a nature that it should

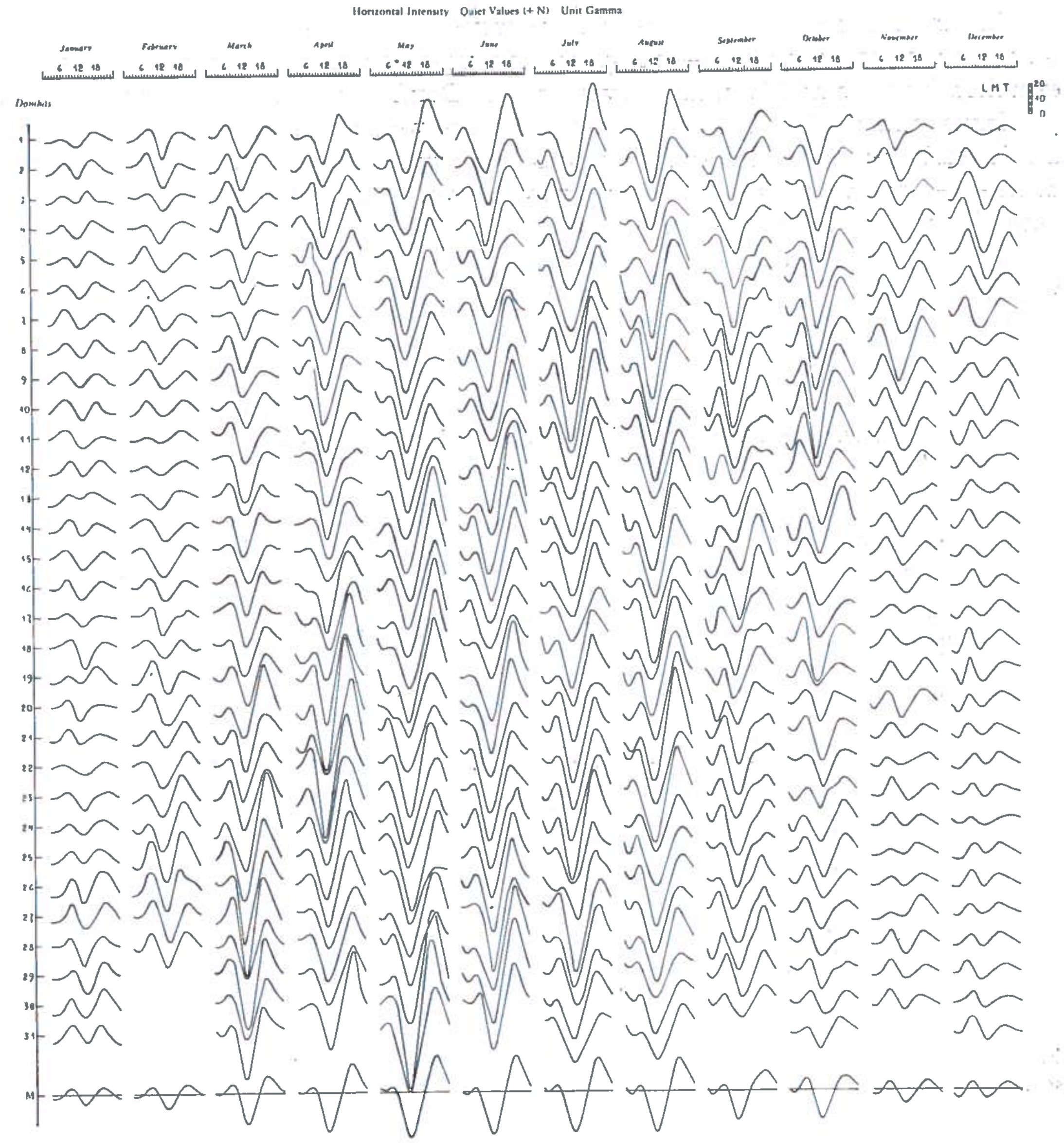

Fig. 3. The quiet diurnal variation for every day for H at Dombås for the year 1933. Below monthly mean curves.

not be possible to get hold of enough points to draw reliable curves for the quiet wave, even when a heavy magnetic storm is registered. In extremely difficult cases interpolation of the curve in question might be necessary, but in the present material — records for 1933 — I have been obliged to do so in only one single case.

In Fig. 3 I have plotted the mentioned curves for the quiet diurnal variation of every day for H, registered at Dombås during the year 1933. Below I have added mean monthly curves. To be able to distinguish between curves for actually calm days and those for other days, and especially those, where heavy magnetic storms are registered during the day — or part of it, I have, in Table 2, copied VAN DIJK's table for the five magnetically calm, and the five most disturbed days, with the mean international character numbers added.

Having the curves in Fig. 3, I do not find it necessary to print complete tables of

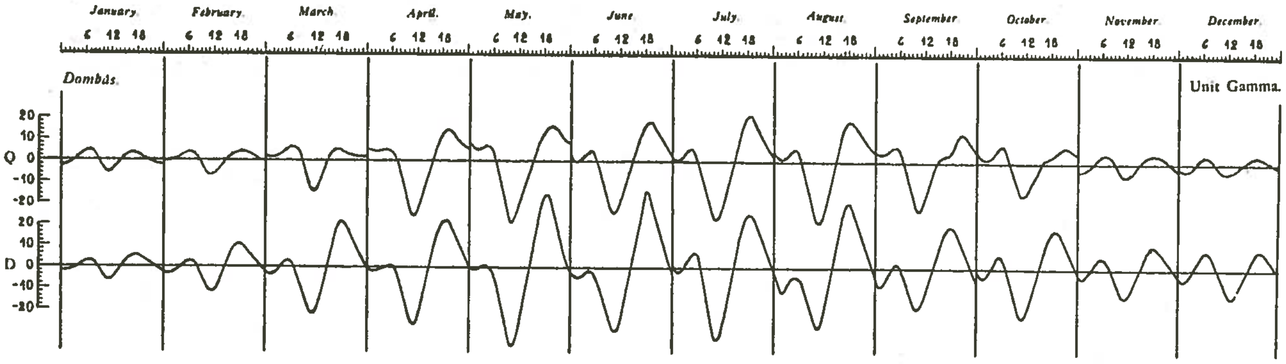

Fig. 4. Above the quiet diurnal variation — month by month — for the five international quiet days according to VAN DIJK's list, and below such curves for the five most disturbed days. Curves referring to *H* at Dombås for 1933.

Table 2. *International magnetic character numbers for 1933 according to* VAN DIJK.

Months	Calm Days for 1933						Most Disturbed Days for 1933				
	ch.	1	2	3	4	5	1	2	3	4	5
Jan. ..	(.005)	4	5	10	11	21	1 (1.2)	19 (1.4)	22 (1.4)	27 (1.4)	28 (1.2)
Feb. ..	(0.04)	6	11	13	16	17	19 (1.7)	21 (1.7)	22 (1.6)	23 (1.5)	24 (1.5)
Mar. ..	(0.08)	5	6	7	9	16	18 (1.5)	19 (1.5)	20 (1.6)	23 (1.5)	24 (1.5)
Apr. ..	(0.11)	11	12	13	28	29	15 (1.2)	16 (1.3)	17 (1.4)	19 (1.2)	30 (1.3)
May ..	(0.09)	9	10	12	24	26	1 (1.9)	18 (1.1)	29 (1.1)	30 (1.2)	31 (1.2)
Jun. ..	(0.05)	5	6	16	18	24	1 (1.1)	13 (1.6)	14 (1.2)	20 (1.2)	28 (1.0)
July ..	(0.08)	13	14	15	21	30	9 (1.3)	17 (1.0)	23 (1.5)	24 (1.6)	27 (1.1)
Aug. ..	(0.05)	1	9	10	11	31	5 (1.8)	6 (1.3)	13 (1.5)	18 (1.3)	21 (1.3)
Sep. ..	(0.23)	3	5	6	23	24	9 (1.9)	10 (1.2)	13 (1.7)	14 (1.4)	15 (1.5)
Oct. ..	(0.08)	1	16	21	28	29	5 (1.3)	7 (1.6)	9 (1.2)	13 (1.3)	14 (1.3)
Nov. ..	(0.08)	14	15	17	24	26	6 (1.6)	7 (1.5)	8 (1.5)	11 (1.1)	27 (1.1)
Dec. ..	(0.06)	1	14	15	24	30	3 (1.2)	4 (1.3)	5 (1.4)	9 (1.5)	10 (1.3)

Table 3. *The extremes of the quiet diurnal variation in the day- and night-waves of H at Dombås for 1933, besides the mean hour points for these occurrences in L. M. T.*

Season	Day Extremes					Night Extremes				
	Max.	Hour.	Min.	Hour,	Ampl.	Max.	Hour.	Min.	Hour.	Ampl.
	γ	h m	γ	h m	γ	γ	h m	γ	h m	γ
Winter....	6.0	18 12	— 7.8	11 46	13.8	5.3	6 37	—3.2	1 13	8.5
Spring	20.3	18 45	—26.1	11 05	46.4	5.3	5 31	—1.0	1 47	6.3
Summer ..	23.8	18 41	—27.8	10 56	51.6	4.3	4 55	—2.1	1 57	6.4
Autumn ..	10.9	19 23	—16.2	11 21	27.1	7.0	6 11	—3.2	1 57	10.2
Year	15.2	18 45	—19.5	11 17	34.7	5.5	5 48	—2.4	1 44	7.9

Table 4. *Relation between the sun's seasonal altitude and some characteristic points in the quiet diurnal variation for the five internationally most disturbed (below) and calm (above) days. H at Dombås for 1933.*

Season	Night Extremes					Day Extremes				
	Max.	Hour.	Min.	Hour.	Ampl.	Max.	Hour.	Min.	Hour.	Ampl.
	γ	h m	γ	h m	γ	γ	h m	γ	h m	γ
Winter....	3.9	6 30	—1.9	0 40	5.8	3.7	18 00	— 5.8	11 30	9.5
Spring	6.1	5 10	3.5	1 40	2.6	11.9	19 00	—23.2	11 10	35.1
Summer ..	5.3	4 50	0.3	2 10	5.0	19.5	19 00	—26.5	10 50	46.0
Autumn ..	6.3	6 10	0.7	1 50	5.6	8.0	20 10	—14.7	11 10	22.7
Year	5.4	5 40	0 6	1 35	4.7	10.8	19 00	—17.5	11 10	28.3
Winter....	4.5	6 40	— 3.5	1 00	8.0	8.0	18 00	—10.6	11 50	18.6
Spring	1.3	4 50	— 1.9	2 00	3.2	25.4	18 40	—28.5	11 10	53.9
Summer ..	0.2	5 10	— 5.7	2 15	5.9	30.5	18 30	—30.4	10 50	60.9
Autumn ..	4.3	5 40	— 5.7	1 50	10.0	16.1	18 40	—18.4	11 10	34.5
Year	2.8	5 40	— 4.2	1 45	6.8	20.0	18 30	—22.0	11 15	42.0

Table 5.

Results obtained for:	Night Extr.		Day Extr.	
	Max.	Min.	Max	Min.
	h m	h m	h m	h m
Quiet days alone ......Table 4	5 40	1 35	19 00	11 10
Disturbed days alone .. » 4	5 35	1 45	18 30	11 15
Each day of the month » 3	5 48	1 44	18 45	11 17
Earlier (Table 1 of [3])	—	—	19 27	11 48
Mean values	5 41	1 42	18 44	11 20

the figures for the quiet diurnal variation, nor complete tables giving data for the extremes. In Table 3, however, we shall find mean seasonal figures for such data.

As it should be of interest to know if there is any decided difference between the curves for quiet diurnal variation for actually quiet days, and those for the most disturbed days, we might extract monthly mean values for the five international quiet days, and the five international most disturbed days — according to VAN DIJK's list (Table 2). Results of these two sets of data are plotted in Fig. 4. Above we have monthly mean diurnal curves for the international quiet days and below such mean curves for the international most disturbed days.

A look at the curves in Fig. 4 shows that the form is more or less the same for both set of curves, but the amplitude of the extremes in both the day- and night-waves are considerably larger in the last set of curves. To get a general view of the particularities of such curves, I have worked out Table 4.

In order to see how the hour points of the extremes agree in the various cases I have, in Table 5, tabulated time for the night- and day-waves as mean yearly values. The first two horizontal rows are taken from Table 4. In the third row I have added corresponding data from Table 3, and in the last row I have finally put in results taken from Table 1 of the above mentioned paper [3].

The hour points of the night extremes agree well in the three cases, but the agreement is not so good in the data for the day maximum. Considering, however, the comparatively great individual discrepancy in the form of the curves from day to day (cp. Fig. 3), we can probably not expect a better agreement between the various mean values. We may, however, be entitled to say that there is no decided difference in time for the extremes in the quiet, and the most disturbed days when mean values are taken.

As a general view of the seasonal changes in time for maximum and minimum in the quiet diurnal variation has been exhibited graphically in Fig. 13 — in connection with corresponding curves for the storminess data — we shall limit ourselves by referring to this graph.

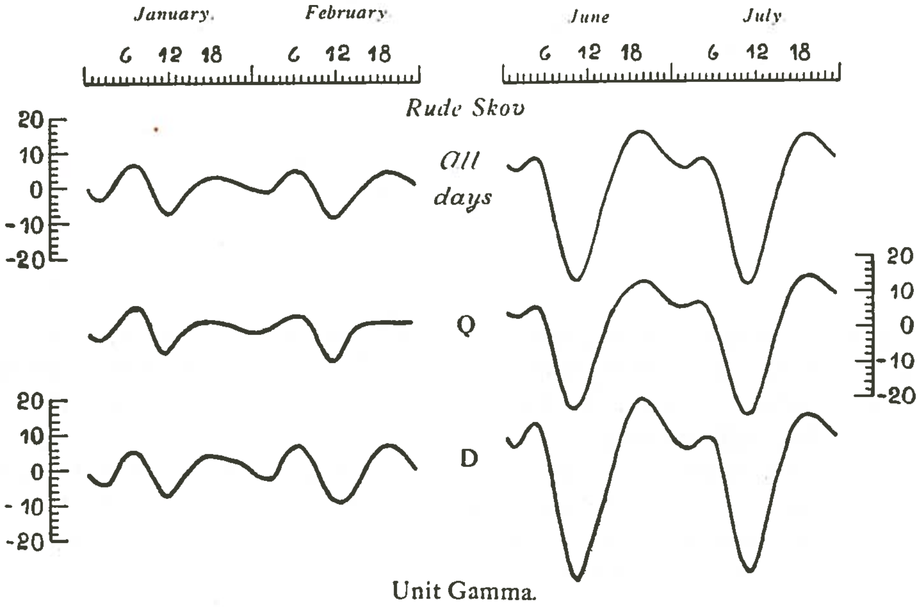

Fig. 5. Mean quiet diurnal variation for H at Rude Skov for Jan—Feb and Jun—Jul, 1933. Above *all days*, and below the five international quiet and the five *most disturbed* days — designated by Q and D, respectively.

Verification of some of the results by aid of corresponding data for Rude Skov: Some of the results in the preceding pages — for instance the displacement during the year of the night extremes — are of such a nature, that verification seems desirable.

From earlier investigations [6] we know that the Q-data for mean monthly diurnal variation at Dombås and Rude Skov show high degree of parallelity. It is thus very probable that this is also the case with the individual data for Q. In order to compare such individual data for the two stations I have worked up curves for quiet diurnal variation for every day for two summer- and two winter-months for H at Rude Skov.

In Fig. 5 we have plotted such mean monthly Q-data for the intervals Jan—Feb and Jun—Jul, 1933. To compare the seasonal displacement of the extremes I have, in Table 6, noted down time for these occurrences in the nigth- and day-extremes for both stations — taking the difference between data for summer and winter as expression for seasonal change.

Table 6. *Comparison between Dombås and Rude Skov in regard to seasonal displacement of the extremes in the quiet diurnal variation.*

Season	Dombås				Rude Skov			
	Night Extr.		Day Extr.		Night Extr.		Day Extr.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
	h m	h m	h m	h m	h m	h m	h m	h m
Winter	4 30	2 30	19 30	10 30	4 45	1 50	19 40	10 40
Summer	6 30	0 30	17 30	11 30	7 00	1 40	18 55	12 15
Diff.	2 00	—2 00	—2 00	1 00	2 55	—0 10	—0 45	1 35

Table 7.

Range for	Dombås			Rude Skov		
	S	W	Diff.	S	W	Diff.
	γ	γ	γ	γ	γ	γ
Quiet days	45	10	35	36	10	26
Disturbed days ..	65	20	45	48	14	34
Diff.	20	10	10	12	4	8

The general tendency in the seasonal changes in the hour-points of the extremes seems to agree for these two stations. The hour distance between corresponding maxima and minima is larger in winter than in summer for the day-extremes and *vice versa* for the night-extremes.

Concerning the range of the day extremes of the quiet diurnal variation we have, in Table 7, compared the results for quiet and disturbed days for both stations. We see from the last horizontal row. — Diff., that the range of the quiet diurnal wave is considerably larger for disturbed days than for quiet days, and that they are larger during the summer, *S*, than during the winter, *W*. Both stations agree well on this point — the phenomena being only more accentuated at Dombås, as might be expected.

Discussion: The particularities in the variation of the quiet diurnal wave of magnetic elements may, according to theories introduced by BARTELS [4] and CHAPMAN [5], be explained by accepting as origin the existence of an electric current system in the ioniced part of the atmosphere. In paper [6] the authors have made a close comparison between: monthly mean values for the quiet diurnal hour data for magnetic elements at Dombås for the year 1933, and BARTELS' current diagram — according to directions given by CHAPMAN. This comparison, between observed and theoretical data, shows that there exists an astonishingly good agreement. Especially is the agreement striking during the interval when the day system passes, but the more complicated variation during the passage of the weaker night system seems also to furnish a good description for the variation actually observed.

CHAPMAN's investigations seem to prove that the type of the quiet diurnal variation is more or less constant, though on individual quiet days the extremes may occur earlier or later than the average by an hour or more. The range, however, is subject to variation from day to day, month to month, etc. This is exactly what can be read out of the curves for Dombås, (cp. Fig. 3 and Fig. 4).

The evidences regarding the variation of the point of time, when the extremes of the quiet diurnal waves occur — in the way this has been exhibited in the tables 3—6 may very well be in good agreement with theory. It must in this connection be remembered that Bartels' current diagram is idealized and consequently only comparable with average data of the observed magnetic material.

Chapman has on various occasions studied the variability of the range in the quiet diurnal data and in a paper published in 1931 [7], he summed up the results of his investigations as follows: »It is found that the ranges vary from day to day in an irregular way, and that there is a definite correlation between the changes in the different elements and at different stations — the correlation being less, the more distant the stations.« »It is found that very quiet days often occur in sequence of two or more, and that there is a tendency for abnormalities of range to persist two or more days.«

The material exhibited in the present paper seems to verify Chapman's above given conclusion fairly well. It may especially be pointed out that the *»sequence of two or more days«* in the distribution of very quiet days holds good also when it concerns the most disturbed days.

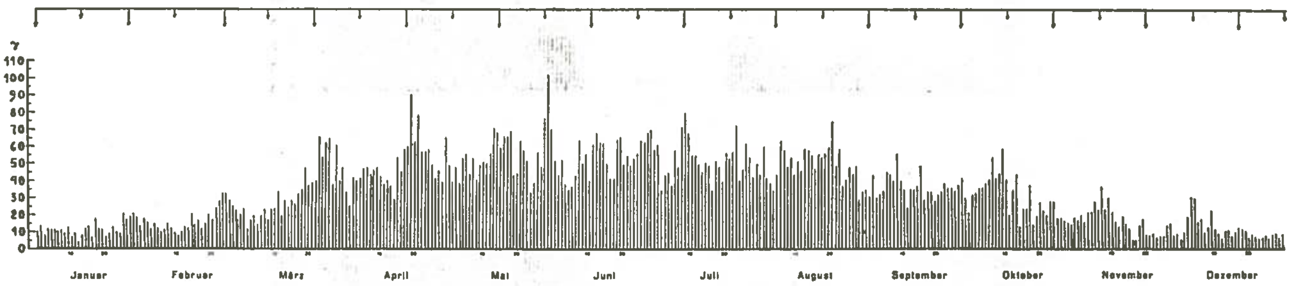

Fig. 6. Graph for the diurnal range of the chief extremes in the quiet diurnal wave of H at Dombås for every day in the year 1933.

In order to get a general view of the variability of the diurnal range of the chief extremes in the quiet diurnal wave we have in Fig. 6 plotted the daily figure for range, derived from the curves in Fig. 3. Examination of the curve in Fig. 6 shows that the somewhat irregular variation from day to day is not without system. The annual wave is dominant in the distribution, but a closer investigation shows plainly that comparatively high and comparatively low values group themselves so, that groups of high value average about points of time which more or less coincide with the small arrows above, while the groups of smaller values average at points in between. The interdistance between the larger of these arrows is exactly 27 days, and suggests thus a relation between the range of the quiet diurnal wave of magnetic elements and the rotation of the sun, as mentioned on page 5.

It is well known that Wolfer has frequently pointed out the peculiarity of the longitudinal distribution of the sunspots — namely that they have a strong tendency to concentrate along two meridians, which have an interdistance of about 180°. The grouping about one of these meridians is heavier than that of the other and we have thus a primary and a secondary area of sunspots building on the surface of the sun.

The nature of the distribution of range in the quiet diurnal variation of magnetic elements, such as this has been exhibited by the curve in Fig. 6, corresponds exactly to what might be expected as a terrestrial effect of the 27-day rotation of the spotted sun. The somewhat irregular character in the figures for range from day to day is no doubt due to the constantly changing intensity in solar activity and it is therefore surprising to find that the relation is so marked as that exhibited by Fig, 6.

In order to verify the 27-day periodicity in the range of the day extremes of the quiet diurnal variation, in the way this phenomena has been illustrated in Fig. 6, we have made a direct comparison between data for Dombås (above) in Fig. 7, and those for Rude Skov (below). In the parallelism of the variation from day to day for the two stations there occur occasionally some disagreement. These may in some cases be real, but may also be due only to inexactness in the drawing of the curves for quiet diurnal variation. On the whole the parallelism between data for the two stations may be said to be fairly good.

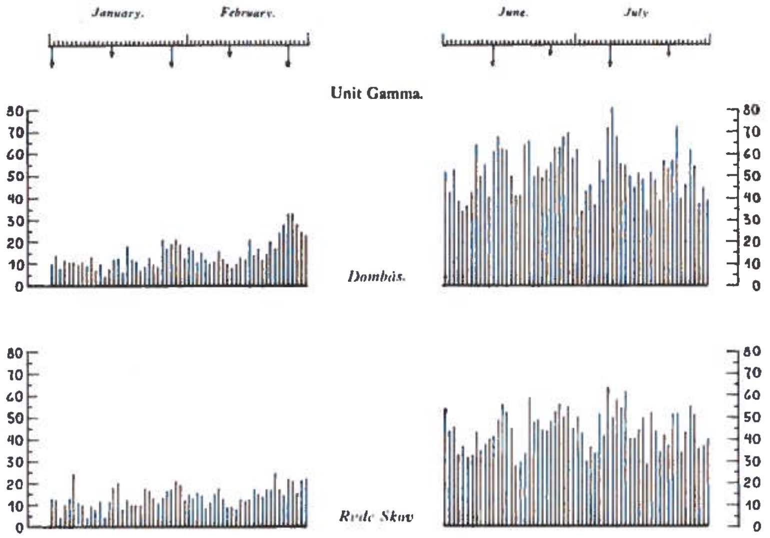

Fig. 7. Graph for the range of the day-extremes in the quiet diurnal wave of *H* at Dombås (above) and Rude Skov (below) for two winter- and two summer-months of the year 1933.

The connection between Birkeland's *so-called »cyclo-meridian storm« and* Dellinger's *discovery of simultaneousness in radio fade-outs:* Dellinger's important discovery of simultaneousness in radio fade-outs and certain special types of magnetic disturbances has to be mentioned. Dellinger's discovery was published in a brief account in October 1935, [8], and the author's suggestions were met with wide-spread interest. Fleming [9] was the first to recognize that this special magnetic disturbance, occuring on quiet days over the sunlit hemisphere alone, consisted of *an augmentation* of the normal quiet-day diurnal variation. Further foundation for discussion was furnished in 1937 by: Dellinger [10], Mc. Nish [11] and Chapman [12].

Dellinger states that sudden fade-outs of radio signals, reflected from the ionosphere, had been observed to have an apparent recurrence-tendency of about 54 days. This does not agree with what can be seen in Fig. 6, where the recurrence-tendency of augmentation in the normal quiet diurnal wave seems to be markedly related to the sun-rotation period of 27 days. On the other hand, however, does not ability of chronosphere eruptions to produce radio fade-outs seem entirely to depend upon the situation of the active area on the Sun's disc, as eruptions occuring on the limb of the Sun are also reported to have produced fade-outs.

The marked tendency of augmentation in the usual quiet diurnal wave of 27 days — as seen in Fig. 6 — is in my opinion explainable by the fact, that the typical form of the magnetic variation, simultaneous to the radio fade-outs, is difficult to recognize, when, at just the same time, a regular magnetic storm is registered, and magnetic storminess seems also to possess a recurrence-tendency of 27 days. It is, therefore, not strange that Dellinger found the figure: 54, which corresponds to 2 × 27 days.

It may also be mentioned that Birkeland discribed this special type of magnetic disturbance — now known to be associated with radio fade-outs and bright chronosphere eruption — though he failed to recognize that this special kind of disturbance consisted of an augmentation of the normal quiet-day diurnal variation, as pointed out by Chapman [12]. Birkeland designated, as we know, this special kind of disturbance by »*cyclo-median storm*«.

THE DIURNAL VARIATION OF STORMINESS.

In the preceding pages we have seen that it it is possible to work out data for quiet diurnal variation of magnetic elements for every day. The results show plainly that this procedure is the only one which can be generally accepted as satisfactory. On the other hand, however, there is no doubt that average data for 7 — or even 30 — days, as foundation for the separation of storminess data, may — in certain cases — be justifiable.

However this be, it is clear that it will be of some consequency for the data for storminess which procedure of the above mentioned, we make use of in regard to the Q-data. In order to get this question settled, I have worked out a complete new set of hourly data for the storminess in the H-component for Dombås for the year 1933, now based

Table 8. *Comparison between S-data, when extracted by aid of 7-day normals for Q, (II) and by aid of Q-data for every day, (I).*

ΔH	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
II	—2.8	—2.8	—1.7	—0.2	—5.8	—0.9	—0.8	1.6	—2.4	—1.5	—2.8	—1.9
I	—2.1	—2.3	—3.0	—2.6	—4.6	—1.0	0.6	0.6	—1.4	—1.6	—1.7	—1.5

Table 9.

Date	ΔH_{II}	ΔH_{I}	Date	ΔH_{II}	ΔH_{I}
	γ	γ		γ	γ
1	— 11.4	— 6.4	13	3.3	1,9
2	— 11.1	— 5.6	14	5.7	2.4
3	— 9.8	— 5.9	15	6.3	2.8
4	— 6.6	— 5.7	16	6.3	2.3
5	— 3.9	— 4.8	17	5.1	2.0
6	— 2.0	— 4.0	18	3.0	0.5
7	— 1.4	— 2.4	19	2.5	— 1.6
8	— 0.4	— 1.3	20	0.0	— 1.0
9	— 3.3	0.9	21	— 3.9	— 2.1
10	— 2.0	— 1.1	22	— 4.7	— 5.2
11	— 0.3	0.9	23	— 7.4	— 6.2
12	1.0	1.5	24	— 7.5	— 5.7

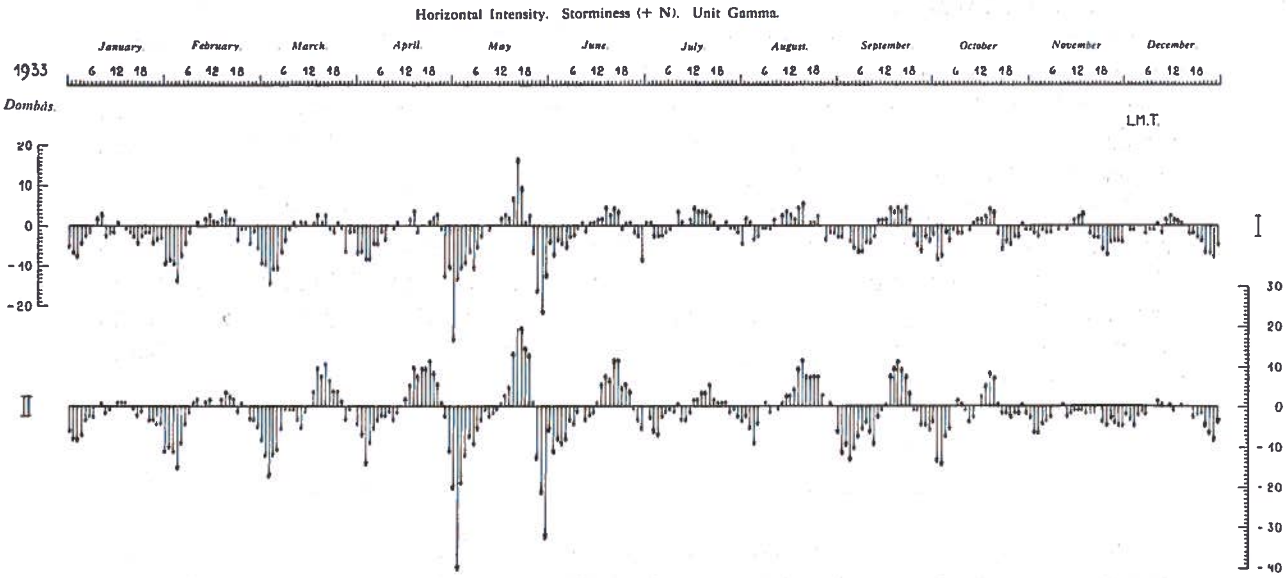

Fig. 8. Graph for mean monthly data for the diurnal variation of storminess in H at Dombås for 1933. In curve I individual data for Q have been used by the separation of the S-data, while in curve II, below, 7-day normals for Q have been employed.

on individual data for the quiet variation. To compare the two sets of data I have, in Table 8, noted down mean *monthly values* for S, where II refers to data where 7-day tables for Q have been used, while the new set of data — where individual figures for Q were employed — are marked I. In Table 9 I have tabulated corresponding mean annual data, I an II, for *the diurnal variation* of storminess.

In Fig. 8 I have plotted mean monthly data for the diurnal variation of storminess in H at Dombås, where curve II below, represents data in which the 7-day normals for Q have been used for the separation of storminess (cp. [1], the table on page 55), and where curve I, above, represents such data, when individual data for Q have been employed.

We see from the two tables 8 and 9 that the two sets of data differ considerably, and it is evident that the disagreement is still more marked in the single day tables. We note that the values in the new tables are smaller in average than those in the original tables, which, of course, might be expected.

As, however, the most characteristic feature in the diurnal variation of the S-data is quite clear in both curves, the kind of procedure we employ for the separation is entirely dependent on the use we intend to make of the results. For the following investigation it is thus obvious that the individual Q-data have to be the foundation for the separation.

If we look at the tables containing hourly values for storminess for every day (such tables have not been published for Dombås, but are of course at hand as manuscript) we will notice that the figures for S are never equal to zero during a whole day — even for days pointed out by VAN DIJK as international types for calm days. The reason is that the origin of the S-component in the variation of magnetic elements is never out of action. It varies so that, during certain intervals, it diminishes in strength far enough to make it insignificant for stations situated at lower latitudes. At a station so far north as Dombås, however, the S-component will play a certain part in the variation, even during the five internationally most calm days. It might, therefore, be of interest to make a comparison between curves for storminess during the five internationally calm days and the five most disturbed days.

Table 10.

Hour	P_d	P_q
	γ	γ
1	—12.7	0.7
2	—12.6	— 0.4
3	—15.4	— 0.3
4	—15.8	— 1.0
5	—15.2	— 1.3
6	—11.4	— 1.0
7	— 9.7	— 0.6
8	— 5.9	— 0.1
9	— 2.0	— 0.7
10	— 1.4	— 1.4
11	2.1	— 0.1
12	2.4	0.3
13	2.2	— 0.1
14	7.0	1.5
15	10.4	1.6
16	11.9	0.5
17	21.5	— 1.3
18	16.4	— 2.1
19	4.6	— 2.0
20	2.0	— 1.7
21	— 8.6	— 0.7
22	—18.6	— 1.1
23	—23.7	— 1.8
24	—27.4	0.6
M	—4.2	— 0.5

In Table 10 I have noted down the yearly average for the diurnal variation in the *S*-data for the monthly five internationally most disturbed days in *H* at Dombås for the year 1933 — these data signified by *Pd*. Under the heading *Pq* we find corresponding data for the monthly five most calm days.

Horizontal Intensity.

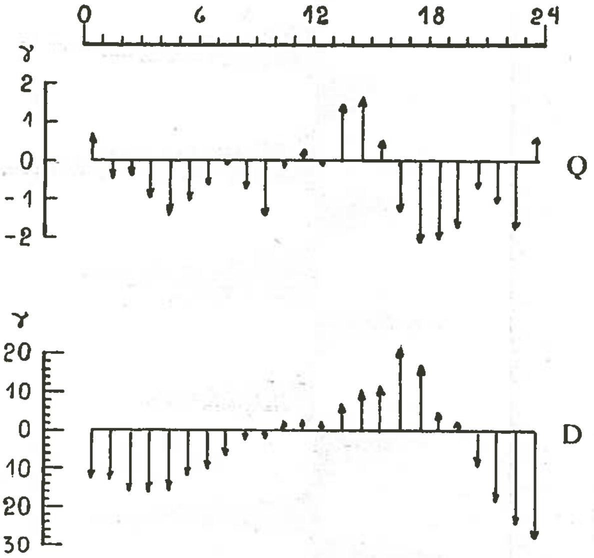

Fig. 9. Comparison between the diurnal variation in the storminess data for quiet and disturbed days in *H* at Dombås for the year 1933. (notice the scale).

Table 11.

Month	AS_d	AS_q
	γ	γ
Jan. ..	221	57
Feb. ..	368	35
Mar. ..	483	40
Apr. ..	353	86
May ..	888	70
Jun. ..	378	56
Jul	253	73
Aug. ..	425	78
Sep. ..	705	83
Oct. ..	224	61
Nov. ..	204	88
Dec. ..	327	55
M	402	65

In Table 11 I give monthly averages for »*absolute storminess*« (cp. [1], page 15), designated *AS*, where the index *d* refers to disturbed days and *q* to the calm days. In Fig. 9 the data stated in Table 10 have been plotted — above the figures for calm days, marked *Q*, and below those for the most disturbed days, marked *D*. Time is *L. M. T.* and the scale has been chosen *ten times greater* for the data referring to calm days.

We see that the character of the diurnal wave for disturbed days agrees well with that of the average for all days — only that the amplitude here may be put at 33 γ, while the corresponding figure of the yearly average for all days may be put at 14 γ. The diurnal wave in the data for calm days shows a somewhat different form, which also must be expected according to theory. Before we enter upon any discussion of these results (cp. page 22), however, we shall have a look at how the diurnal variation in the *S*-data changes in referance to latitude.

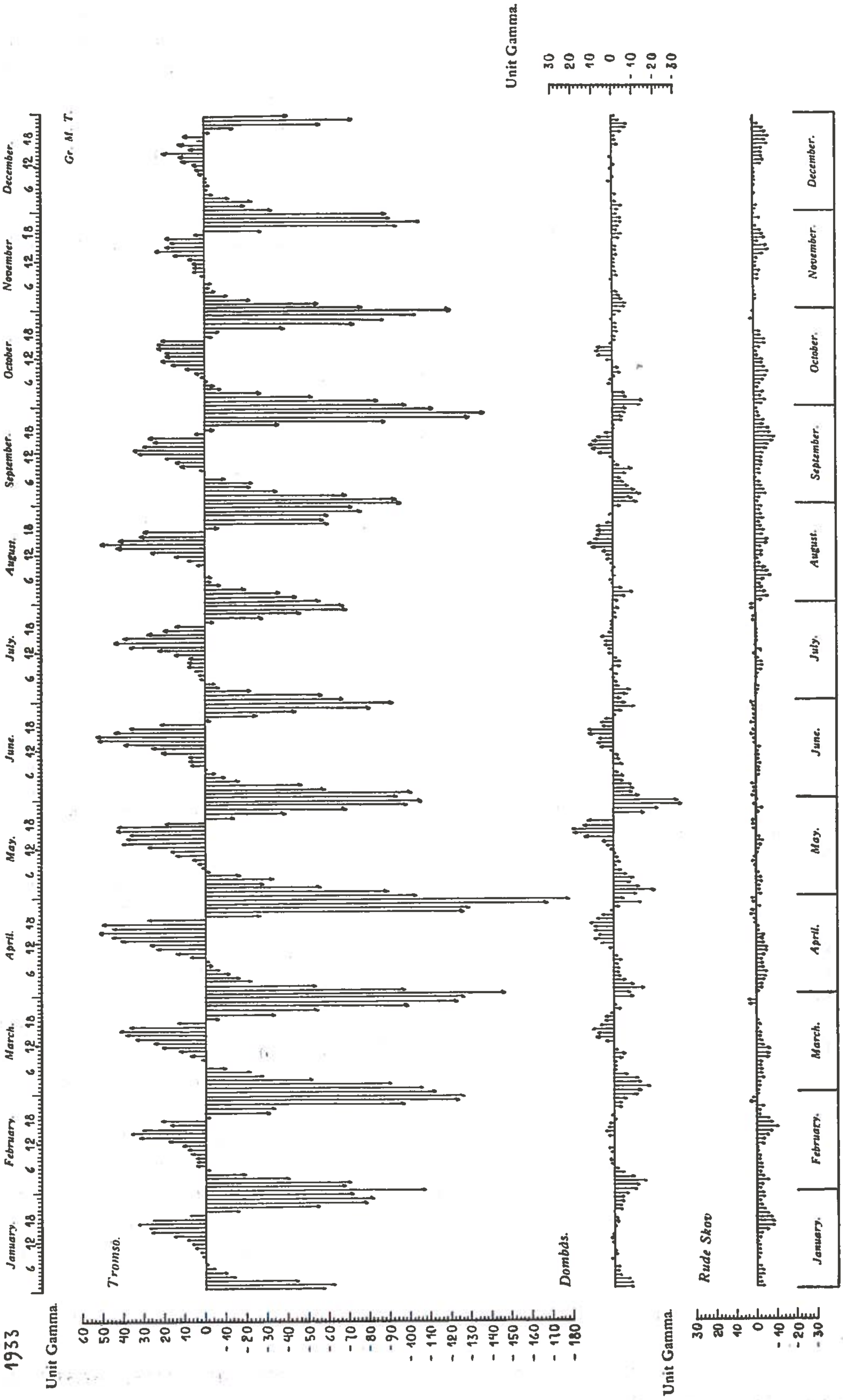

Fig. 10. Graph illustrating change in the diurnal variation of storminess in reference to latitude.

In Fig. 10 we give a graph plotted with monthly mean hour-data for storminess in the H-component for 1933 of the three stations *Tromsø, Dombås* and *Rude Skov*. The geographical data for these stations are stated in Table 1, and here we see that longitudinally they vary only between 9° and 19°E of Gr. We see that the positive and negative perturbations are of considerable magnitude at Tromsø, which station is situated only some few minutes to the south of the line for places of the greatest frequency of observed aurora. At Dombås the value have diminished to about $^1/_7$, and at Rude Skov they are still smaller.

As to the distribution of positive and negative perturbations during the 24 hours, there is a close connection between Tromsø and Dombås—only that in average the maximum at Dombås occurs about one hour later, and the minimum 2 hours later than at Tromsø. At Rude Skov, however, maximum and minimum have changed places in comparison to the two other stations. To get a general view of these occurrences we have worked out Table 12, where we find data for maximum, minimum and the point of time when they occur, besides the amplitudes.

In Fig. 11 we have, for the same three stations, plotted monthly mean data for pos. and neg. diurnal variation in H for 1933, besides data for (PS—NS) (cp. [1] p. 15*). We notice the characteristic development in reference to latitude.

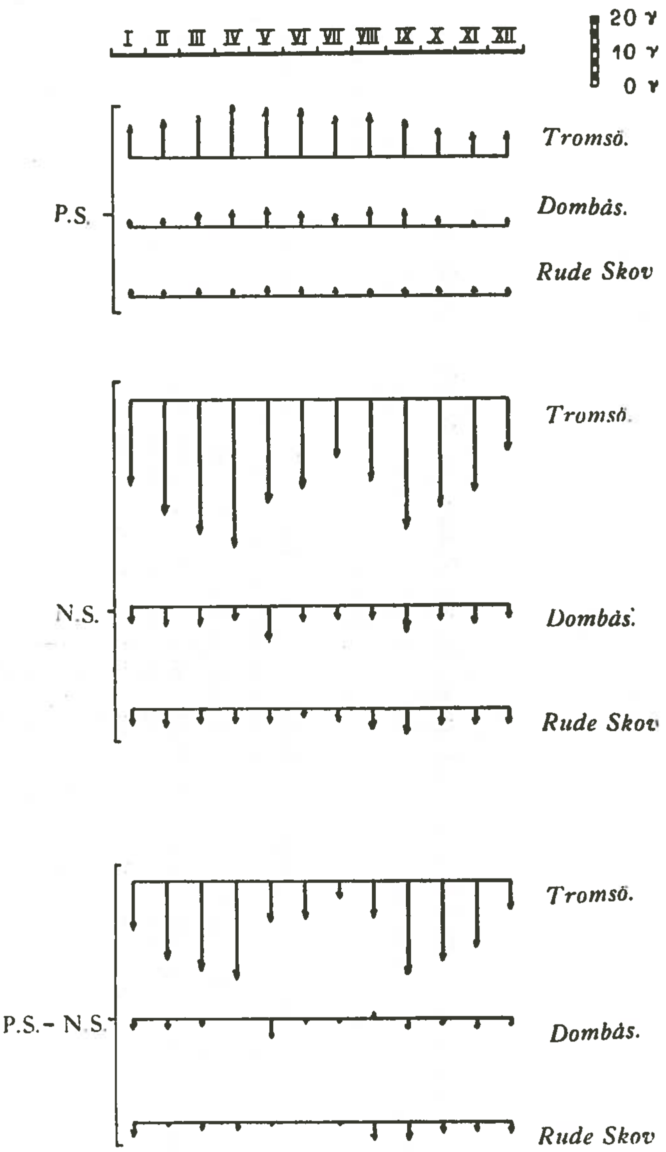

Fig. 11. Graph illustrating latitudinal development in monthly mean data for pos. and neg. diurnal variation in H for 1933, besides such data for (PS—NS).

To get a still broader view of the problem, we have in Fig. 12 plotted the mean monthly diurnal waves in the S-data for D, H and V of June 1933, not only for the three stations, mentioned above, but also added corresponding data for the two stations *Sitka* (Alaska) and *Godhavn* (Greenland), ([6] p. 8).—in all cases the curves are referred to $L. M. T.$

From this graph we see that the curves for diurnal variation at Sitka are very closely connected with corresponding data from Dombås, in spite of the fact that the Sitka station is situated more than 144° — $9^h\ 36^m$ — to the west of Dombås. A glance at the curves for Godhavn shows that also this station indicates a diurnal variation in the S-data of the same character as that of the other stiatons, but in comparison with Dombås

Table 12. *Max., min. and ampl. of the S-data for the three stations.*

St.	Tromsø							Dombås							Rude Skov						
Month	Max.			Min.			Ampl.	Max.			Min.			Ampl.	Max.			Min.			Ampl.
	γ	h	m	γ	h	m	γ	γ	h	m	γ	h	m	γ	γ	h	m	γ	h	m	γ
January ..	33	15	30	— 82	21	30	115	1	12	30	— 9	1	00	10	—2	21	30	— 9	16	30	7
February..	37	14	30	—127	23	30	164	4	14	30	—16	2	30	20	3	21	30	—11	15	30	14
March	42	14	30	—127	23	30	169	11	15	30	—18	1	30	29	4	22	30	— 7	10	30	11
April	52	14	30	—179	23	30	231	12	17	30	—15	1	30	27	3	19	30	— 6	11	30	9
May	41	12	30	—106	23	30	147	20	16	00	—41	0	30	61	2	18	30	— 4	13	30	6
June	53	14	30	— 90	23	30	145	12	16	00	—12	0	30	24	2	18	30	— 3	12	30	5
July	44	13	30	— 69	22	30	113	6	15	30	— 7	1	30	13	2	22	30	— 3	12	30	5
August ..	51	14	30	— 77	22	30	128	12	14	30	—10	2	30	22	—3	19	30	— 6	15	30	3
September	35	12	30	—136	22	30	171	12	14	30	—14	2	30	26	—2	22	30	—10	16	30	8
October ..	23	15	00	—121	23	30	144	9	13	30	—15	2	30	24	2	21	30	— 6	15	30	8
November	24	14	30	—106	21	30	130	0	16	30	— 7	1	00	7	0	21	30	— 7	14	30	7
December	20	14	30	— 72	22	30	92	1	13	30	— 8	—2	30	9	1	22	30	— 7	16	30	8
M	37.9	14	13	—107.8	22	50	145.7	8.3	15	00	—14.3	1	15	22.6	1.0	21	00	—6.6	14	15	7.6

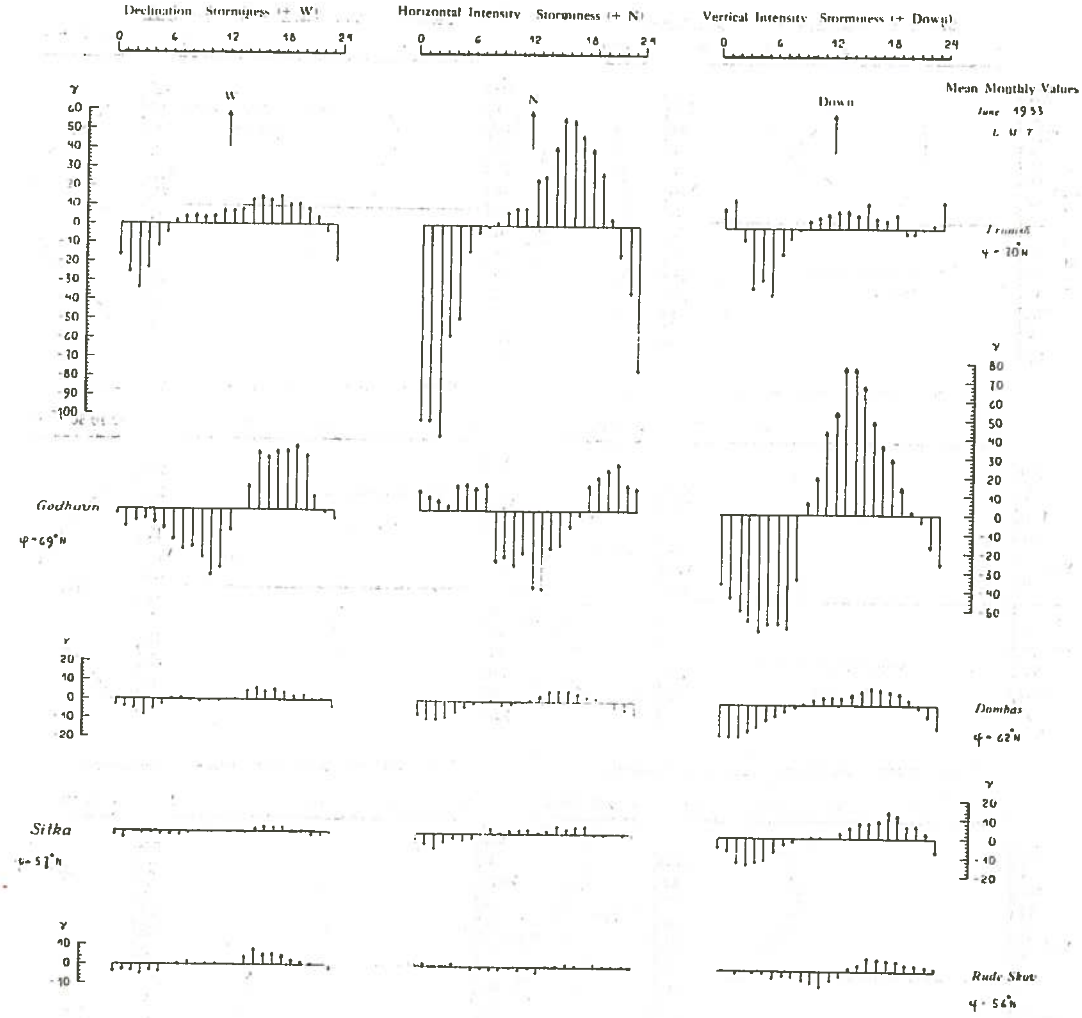

Fig. 12. Mean monthly diurnal variation in the S-data for D, H and V for June 1933 for the five stations named in the figure.

or Tromsø we will notice, that while the curve for V runs more or less parallel to the corresponding curves for said stations, the curves for D — and still more that for H — differ considerably. These particulatities are no doubt due to the singular geo-magnetic situation of Godhavn, where the quiet diurnal variation also present certain peculiarities (cp. [6]).

The seasonal change in the diurnal variation of the S-data compared to that of the diurnal variation of the Q-data;

We have seen that the Q-data, as well as the S-data, of magnetic elements present nicely developed diurnal variation. This diurnal variation is for both kind of data subject to seasonal changes due to the Sun's varying altitude, as well as to the varying relative situation in reference to the rotating movements of the Sun and the Earth. To get a general view of these phenomenæ we shall here give the illustration in Fig. 13, where we can compare the seasonal changes in the diurnal variation for the Q-data and the S-data in regard to the changes in the hour point for maximum and minimum, besides the change in the amplitudes. As basis for this examination we have chosen the average curves for the epoch 1923—33, [3].

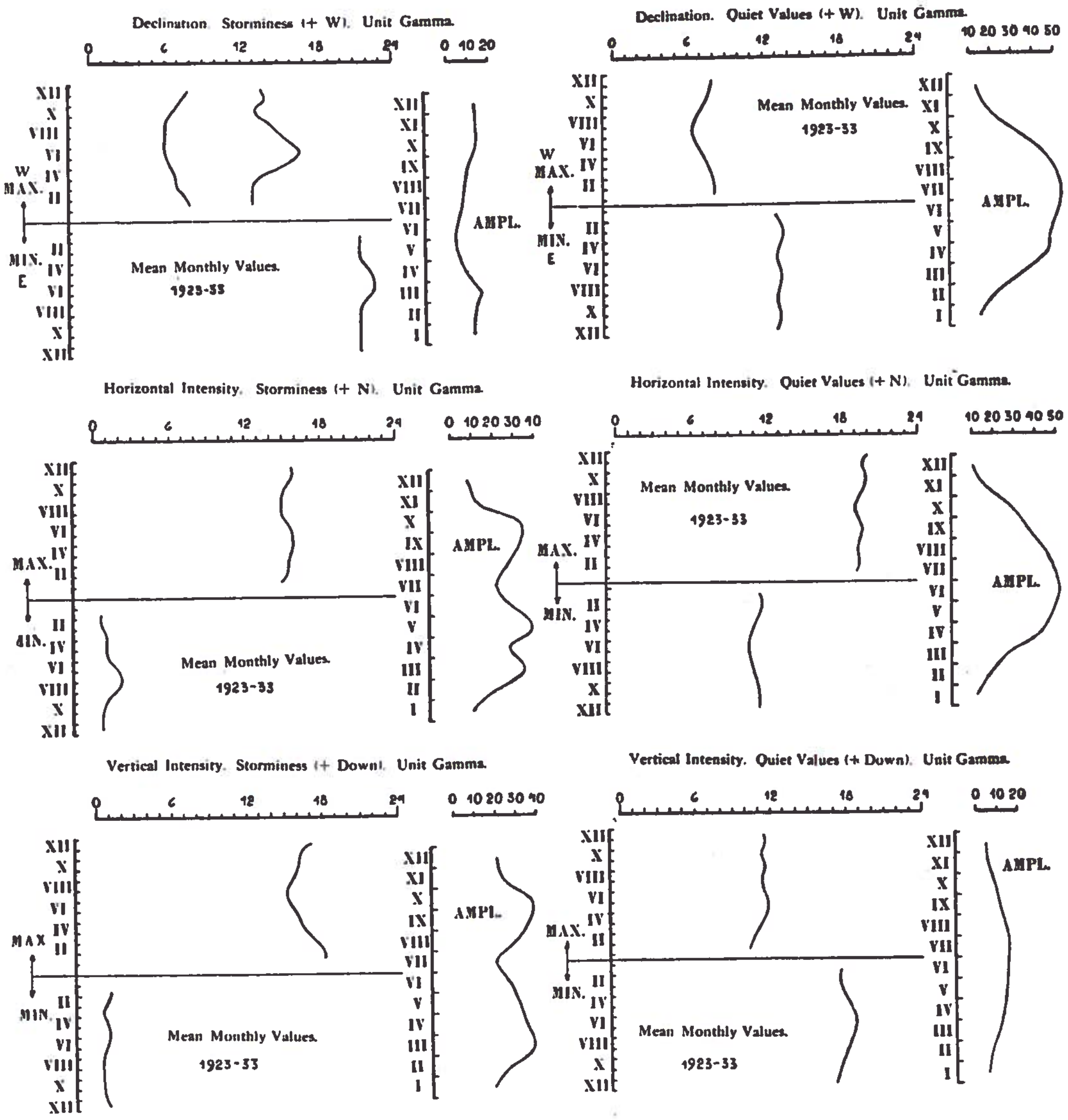

Fig. 13. Graph illustrating the seasonal change in the point of time for maximum and minimum, besides the amplitude of the Q-data, as well as for the S-data, of D, H and V for Dombås. Average data 1923—33.

We shall leave out the full tables and only give average annual figures — in Table 13 for the size of the wave, and in Table 14 for the point of time for the various occurrences in the S-data.

Graphs for the seasonal change in the zero-point passage of the diurnal variation have been left out, as no decided variation of this kind seems to occur, except in the 16 o'clock zero-point passage of the D-curve, where June and July figures with the hour 20, while the rest of the months average about 16 o'clock.

For each of the elements the hour division will be found horizontally above, while the month-scale — vertically to the left — has been divided into two parts — upwards for the maximum curves and downwards for the minimum curves. To the right of each set of curves we have added curves for the seasonal change in the range of the diurnal variation. The plotting of the Q-data has been done directly with the values stated in paper [1], while for the plotting of the S-data we have given the figures slight smoothing.

In the S-data for declination we have recorded two maxima — one about 7 o'clock and one about 14 o'clock (cp. the tables 13 and 14). Looking at the curves for the Q-data we will see that the seasonal curve for maximum will more or less cover the forenoon curve for the S-data, which fact may point in the direction that the secondary 7 o'clock maximum in the S-data is not real, but only due to small systematic errors in the drawing of the Q-curves. A systematic error of this kind may very well occur, because the form of the diurnal variation of the Q-curves depends in each special case on judgement as to whether each individual hour ordinate might be considered *quiet* or not.

As to the variation in the diurnal range during the year we notice maximal values in all the three elements in March and October, and minimum points in the middle of the summer and at new year.

Table 13.

Element	Max.		Min.	Ampl.
	a. m.	p. m.		
	γ	γ	γ	γ
D	2.9	2.2	— 8.6	10.8
H	—	9.7	—15.4	25.1
V	—	10.6	—18.4	29.0

Table 14.

Element	Zero pass.	Max.		Zero pass.	Min.
		a. m.	p. m.		
	h m	h m	h m	h m	h m
D	4 35	6 47	14 12	16 05	21 45
H	11 10	—	15 25	19 10	1 08
V	8 47	—	16 28	20 27	0 42

Discussion: Before discussing the results obtained in the previous pages we shall have a look at the theory of magnetic storminess in regard to how this side of the question stands today.

While the theory concerning the Q-data of magnetic elements has had considerable development during the last years, because new and promising evidences have been discovered, the theory of the S-data seems more or less to stand where it stood, when BIRKELAND in 1908 published his great, classic work [2], in which is also included STØRMER'S famous calculation of the trajections of negative electrically charged electrons radiated by the sun towards the earth.

It may, however, in this connection be mentioned that also in regard to the variation of the S-data some few new evidences are pointed out and that these may prove to be of high importance for further development of the already existing current-system theories for the disturbance field of magnetic variation. These evidences are the discovery of the ionized layer F_2 at about 250 km, the records of echo signals from still higher altitudes, besides STØRMER'S photographs of the so called sunlit auroræ at a height of 700 to 800 km. A review of the evidences in regard to the S-data up to the present date is to be had through [14].

It will be known that objections have been raised against the physical tenability of the BIRKELAND—STØRMER theories. From a physical point of view there seems to be a discrepancy between the electrostatic repulsion of the individual electrons and the large concentrations of the precipitation demanded to produce a magnetic field strong enough to account for the intensity of the perturbations during magnetic storminess.

However this be, the ionized regions above the auroral zones seem satisfactorily explained by BIRKELAND and STØRMER's theories. The particularities of the phenomenon here being due to the deflection in the Earth's magnetic field of streams of charged particles coming from the sun, which must necessarily enter the atmosphere in a fairly limited region round each pole.

There seems to be no doubt that magnetic storminess is due to variations in — or caused by — some kind of electric current-system — or systems — situated above the Earth's surface in one or other of the highly ioniced regions at heights of about 100 km, 180 km and 250 km respectively. Regarding the form and location of the supposed current-system — or systems — BIRKELAND has proposed one and, among others, CHAPMAN proposed another. [15].

As long as details of the theory are so uncertain as they actually are at the present time, we shall discuss the results for the S-data only in regard to evidences and see if there exists agreement between what can be extracted from our material — consisting of average data — and that used by BIRKELAND — individual data. BIRKELAND founded, as we know, his investigations on a large collection of records for different types for magnetic storminess — *individual cases* — while the evidences exhibited in the preceding pages are based on *average diurnal data.*

Regarding the changes in the diurnal variation of storminess with latitude we have Fig. 11 and the data stated in Table 12, where we see that the perturbations decrease rapidly with the distance from the storm centre, so that the Dombås data for P_h is only 22 % and 13 % of that at Tromsø, for positive and negative perturbations respectively. At Rude Skov the values are still smaller and *here they have changed sign,* so that maximum at Tromsø and Dombås corresponds to minimum at Rude Skov. The average positive deflections at Tromsø are seen to be only 34 % of those in negative directions. These evidences are in full harmony with what BIRKELAND found for his individual cases of moderate storms.

The latitudinal development is also seen from Fig. 12. Comparing the average L. M. T. diurnal variation of storminess at Dombås and Sitka to such dato for the individual cases we see almost complete parallelism, while consequently a comparison in reference to Gr. M. T. would give *»current arrows«* equal to those found by BIRKELAND for his individual cases.

In Fig. 14 we give a graph for the average diurnal waves in the storminess of D, H and V for Dombås for the epoch 1923—33, and below we find the vector diagram for D and H. This figure presents an excellent illustrates of the entire development of the polar storm in reference to time, or, if we look at the thing geographically, it illustrates the development from station to station along the geomagnetical parallel of said station.

Changes, caused by varying intensity in the current system, or rather the terrestrial magnetic effect of such variation, get a good expression in what is stated in the two tables 10 and 11, and in the graph in Fig. 9. According to BIRKELAND's way of expressing it, the *current arrows* will, during intervals of quiet magnetic conditions, bend east (or west) at a higher northern latitude, than is the case during intervals of increased storminess — which fact gets its expression in the characteristic difference in the diurnal waves of the Q- and D-data in Fig. 9 — especially if we added the corresponding curves for declination.

To wind up the different points in the results of the investigations of the average data for the diurnal variation in the magnetic storminess we may finally, concerning the seasonal changes exhibited in Fig. 13, express it so: Independent of the existing theory it seems quite clear that the evidences, here exhibited, are a natural consequence of the interplay between the diurnal revolution of the Earth under influence of a more or less fixed current system, or systems — and its changing terrestrial-magnetic effects with the annual passage of the Earth along the ecliptic.

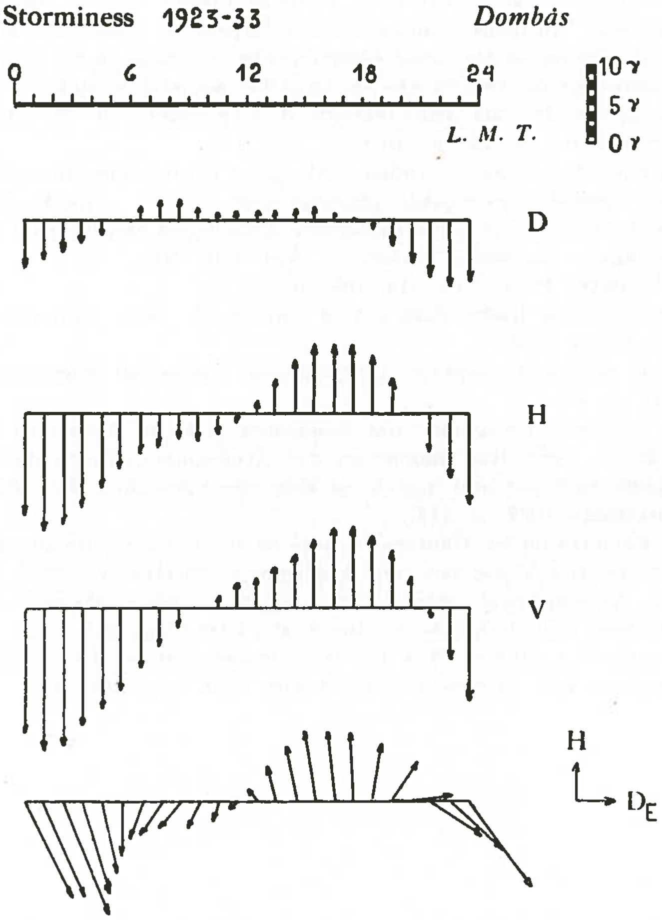

Fig. 14. The diurnal variation of *D*, *H* and *V* in the storminess data at Dombås as average curves for the epoch 1923—33. Below we have the vector diagram for *D* and *H*.

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