Terrestrial Magnetism *and* *Atmospheric Electricity*

VOLUME XXVI

MARCH-JUNE, 1921

NUMBERS 1-2

ON A SPECIAL FORM OF MAGNETIC DISTURBANCES.¹ By L. STEINER.

On days which are magnetically almost quiet, or only slightly disturbed, we sometimes find in the curves small disturbances of very regular course. Their period is of about one and one-half to two and one-half hours, and their chief characteristic feature is, that the horizontal intensity, starting from the quiet march of the curve, is in general gradually increasing or decreasing till it has attained a maximum or minimum value, and then gradually or with small oscillations returns to the undisturbed value, and the curve continues its quiet course. The disturbance appears in declination and vertical intensity, too. In the vertical intensity there is a gradual decrease or increase, and after the extreme values being attained there is a gentle return to the undisturbed value. In declination, the disturbance sometimes shows a more complicated feature, as it has a more oscillatory character.

The circumstance that the curve has a quiet march before and after the disturbance makes the investigation of these disturbances simpler and easier, since the normal curve can easily be drawn and the disturbing forces determined; the phenomenon of the "after disturbance" (Nachstoerung)—if perceivable at all—is small. In Fig. 1 we have a reproduction of such a disturbance.

The magnetograms of the Ogyalla Observatory for the years 1906-1917 have furnished us the observational data. We divided the disturbances into two classes, according to the horizontal intensity being augmented (Class I, or $+\Delta H$) or diminished (Class II, or $-\Delta H$). The normal curve was given by connecting the quiet portions of the curve before and after the disturbance, due regard being given to the normal diurnal change. The values of the disturbances were determined every six minutes by measuring the differences between the disturbed and the normal curve. Thus

¹ Abstract of a paper presented to the Hungarian Academy of Sciences (Budapest) at its session, January 17, 1921.

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were derived the disturbing forces, ΔH , $H\Delta D$, and ΔZ , respectively, in the directions magnetic north, magnetic east, and vertically downwards.

On the whole, 531 disturbances have been collected and measured; of these 428 belong to Class I and 103 to Class II. The

FIG. 1

frequency of Class I is to that of Class II as 4.2: 1. The period of the disturbances is about two hours. There is no systematic difference between the times of beginning and end of the disturbance in the horizontal intensity and those in declination; the disturbance in vertical intensity, however, generally begins 20 to 25 minutes later than in horizontal intensity.

Table I shows the number of these disturbances in the different years.

TABLE I.

Year	Class I (+ ΔH)	Class II (- ΔH)	Year	Class I (+ ΔH)	Class II (- ΔH)
1906	38	8	1912	52	8
1907	28	16	1913	43	6
1908	29	13	1914	45	8
1909	35	5	1915	40	11
1910	17	2	1916	36	9
1911	27	8	1917	38	9
Total 1906-1917, 428				103	

The small frequency in the years 1910 and 1911 is due to the circumstance that from June 28, 1910, till May 3, 1911, because of the insufficient sensibility of the bifilar instrument, we omitted the disturbances.

The data for the vertical intensity could be taken in consideration only in the years 1906-10 and 1914-17, as from 1911 the variometer of Mr. A. V. Bücky² did not work reliably and was replaced in 1914 by a Lloyd balance.

The *annual change of frequency*, when we take together the years 1906-09 and 1912-17, is as follows:

TABLE II.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Class I	41	35	36	33	25	12	19	27	43	42	36	35
Class II	11	4	5	6	3	7	6	8	9	9	12	13

Class I appears to show a double wave, whereas Class II, a single wave, with a maximum in winter. It seems that the latter has come about by the merging together of an autumn and a spring maximum. The maximum in January of Class I seems to be a displaced spring maximum. In the years 1914-17 (Table III) we see very distinctly the double wave with maxima in spring and autumn.

TABLE III.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Class I	8	13	18	18	12	4	8	9	23	19	12	10
Class II	2	2	2	5	1	2	3	5	2	3	6	4

Thus it appears that there exists a similar double wave in the annual change of frequency of the small regular as for the magnetic disturbances in general; the latter has already been determined for several places. I give here the results for Ogyalla from the years 1906-09 and 1912-17; the numbers represent the mean of the three elements, and are expressed in thousandth part of the whole number of disturbances:

² *Jahrb. d. k. Ung. Reichsanst. f. Meteor. u. Erdmagn.*, vol. xxxiv. 1904, 2nd part.

TABLE IV.—*Frequency of magnetic disturbances in general at Ogyalla, 1906-1909 and 1912-1917.*

Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
83	92	101	76	82	60	63	81	90	107	90	75

In determining these frequency numbers and those below concerning the diurnal change of the frequency of the disturbances in general, we followed the method of Eschenhagen,³ in the years 1906-09, and that of Nippoldt,⁴ in the years 1912-17.

2. In order to determine the *diurnal change of frequency*, the day has been divided in two-hour intervals and the disturbances of Classes I and II have been arranged in that interval in which the greatest part of the disturbance in declination took place. Thus was obtained Table V:

TABLE V.

	h h 0-2a	h h 2-4a	h h 4-6a	h h 6-8a	h h 8-10a	h h 10-12a	h h 0-2p	h h 2-4p	h h 4-6p	h h 6-8p	h h 8-10p	h h 10-12p
Class I	111	51	5	3	0	0	0	0	6	29	82	141
Class II	1	4	6	6	2	2	13	24	29	13	3	0

We see the disturbances of Class I begin in the interval 4-6p; then their frequency increases and attains the maximum at 10-12p; afterwards it diminishes, and from about 8^ha till 4^hp they are very rare. The disturbances of Class II are, on the contrary, very rare in the night and morning hours. Their frequency increases in the early afternoon hours and attains its maximum at 4-6 p. *All the time data are to be understood as referring to Ogyalla local mean time.*

There appears no distinct seasonal variation in the diurnal change of frequency; there appears only a slight tendency toward a secondary maximum in the early morning hours in Spring, Summer, and Autumn in Class II.

It is known that the frequency of magnetic disturbances in general shows a maximum in the evening and the early night hours. Table VI represents the diurnal frequency of disturbances in general for Ogyalla, taking 1,000 as the whole number of disturbances.

³ *Erg. Mag. Beob. Potsdam*, 1890, 1891 etc.

⁴ *Ibid*, 1905, p. 35.

The diurnal change of frequency of the small disturbances (Classes I and II) taken separately do not agree with the frequency of the disturbances in general; but taken together they fit better, as is seen from Table VII.

TABLE VI.

	<i>H</i> 10 Yrs.	<i>D</i> 10 Yrs.	<i>Z</i> 4 Yrs.	Mean		<i>H</i> 10 Yrs.	<i>D</i> 10 Yrs.	<i>Z</i> 4 Yrs.	Mean
<i>u n</i>					<i>n n</i>				
0-1a	52	71	48	59	0-1p	31	23	22	26
1-2	44	71	34	54	1-2	37	25	45	33
2-3	38	62	27	46	2-3	45	26	58	39
3-4	35	54	26	41	3-4	52	26	81	46
4-5	31	42	24	35	4-5	55	35	70	49
5-6	28	30	22	28	5-6	59	44	73	55
6-7	24	21	18	22	6-7	58	54	72	59
7-8	18	16	16	17	7-8	60	58	62	59
8-9	16	12	14	14	8-9	60	67	53	62
9-10	18	10	10	13	9-10	66	75	68	70
10-11	21	12	9	15	10-11	66	75	73	71
11-12	27	19	15	22	11-12	61	72	60	65

TABLE VII.

	<i>h h</i> 0-2a	<i>h h</i> 2-4a	<i>h h</i> 4-6a	<i>h h</i> 6-8a	<i>h h</i> 8-10a	<i>h h</i> 10-12a	<i>h h</i> 0-2p	<i>h h</i> 2-4p	<i>h h</i> 4-6p	<i>h h</i> 6-8p	<i>h h</i> 8-10p	<i>h h</i> 10-12p
Classes I, II	210	104	21	17	4	4	24	45	66	79	160	266
Disturb. in general (Ogyalla)	113	87	63	39	27	37	59	85	104	118	132	136

A graphical representation of the diurnal frequency of disturbances in general and of those of Classes I and II shows that from about 9^hp to about 3^ha the disturbances of Classes I and II appear relatively more frequent than the disturbances in general. In the remaining part of the day they are, on the contrary, relatively more rare. From this we conclude that those disturbances which do not belong to the Classes I and II chiefly appear in the day and in the early evening hours.

3. As to the *disturbing forces* we found two peculiarities: (a) The first peculiarity refers to the horizontal component of the disturbing force perpendicular to the magnetic meridian, namely $H\Delta D$ (H being the horizontal intensity and ΔD the disturbance in declination); (b) the second peculiarity refers to the relative amount of the horizontal component in the magnetic meridian (ΔH) and of the vertical component (ΔZ).

(a) If we compute the average value of the disturbing force $H.\Delta D$ for every disturbance, dividing the sum of the measured values by the number of measurements, and then take the mean of these average values in every two-hour interval separately, we get the Table VIII. The figures in parentheses show the number of disturbances from which the results have been derived. The values of $H.\Delta D$ are expressed in units of 0.1γ ; + signifies a deflection, or a component, toward the magnetic east.

TABLE VIII.

	h h 0-2a	h h 2-4a	h h 4-6a	h h 6-8a	h h 8-10a	h h 10-12a	h h 0-2p	h h 2-4p	h h 4-6p	h h 6-8p	h h 8-10p	h h 10-12p
Class I	-11 (109)	-27 (49)	-134 (5)	-65 (3)					+170 (6)	+104 (29)	+78 (80)	+46 (137)
Class II	+17 (1)	-34 (5)	-58 (6)	-29 (6)	+85 (1)	-44 (2)	-9 (13)	+46 (23)	+68 (28)	+69 (13)	+49 (3)	

The figures for Class I show that from 4^h-6^hp the $H.\Delta D$ component is in the main directed toward magnetic East; it then gradually diminishes, and, beginning with 0^h-2^ha, it is directed toward magnetic West. A like peculiarity does appear, but less distinctly, in Class II. There too we see that from 2^h-4^hp the disturbing force $H.\Delta D$ is in the afternoon and evening hours directed toward magnetic East, and previously in the morning hours there is a tendency of its being directed toward magnetic West.

In connection with these peculiarities it might be mentioned that for the disturbances in declination, in general, the deviations toward East are most frequent in the evening and early night hours, when those toward West are rare. The latter, however, are more frequent after midnight and in the day hours, when the easterly deviations are scarce. We see that from the data referring to Parc Saint Maur, which we drew together in two-hour intervals (Table IX); the data refer to the years 1883-1897.

TABLE IX.

	h h 1, 2a	h h 3, 4a	h h 5, 6a	h h 7, 8a	h h 9, 10a	h h 11, 12a	h h 1, 2p	h h 3, 4p	h h 5, 6p	h h 7, 8p	h h 9, 10p	h h 11, 12p	Sum
Number of westerly deviations	249	300	329	396	437	423	506	483	353	171	111	174	3932
Number of easterly deviations	723	447	210	122	135	177	212	212	365	644	783	805	4835

(b) In the vertical disturbing force (ΔZ) there appears the following peculiarity: In Class I ($+\Delta H$), ΔZ is in a preponderantly great number of the disturbances negative; in Class II ($-\Delta H$), ΔZ is chiefly positive. When there are positive values of ΔZ in the first case and negative values in the second case, they are very small. This rule scarcely admits of any exception. In the years 1911-13 the vertical component, on account of instrumental defects, has not been measured. In the years 1906-10 and 1914-17 the vertical component was measured in 367 disturbances. Among these there were only five with $+\Delta H$ and $+\Delta Z$, and only four with $-\Delta H$ and $-\Delta Z$. This peculiarity is well exhibited in Table X, in which another peculiarity strikes one at the same time, namely that to a greater absolute value of ΔH corresponds a greater absolute value of ΔZ . The forces ($\Delta H, \Delta Z$) are expressed in units of 0.1γ ; n is the number of disturbances of which the total number, disregarding the nine disturbances mentioned, is $367-9=358$.

TABLE X.

Class I			Class II		
ΔH	ΔZ	n	ΔH	ΔZ	n
+ 38.1	-10.8	77	- 34.1	+12.9	18
+ 74.6	-12.9	129	- 74.5	+10.8	34
+119.9	-18.4	62	-123.0	+17.6	18
+171.4	-23.5	15	-186.0	+40.8	2
+245.0	-40.0	3			

It is noteworthy that we find in general a similar property in the large disturbances. Here we mostly have $-\Delta H$ with $+\Delta Z$. Disturbances with $+\Delta H$ and $-\Delta Z$ are more rare, and such for which we have $-\Delta H$ with $-\Delta Z$, and $+\Delta H$ with $+\Delta Z$ are very scarce. We can see that from the following figures, which we deduced from the magnetic records in Ogyalla for the years 1905-13⁵). If we take the differences of the daily means of the elements on the greatly disturbed days⁶ and those on 1, 2, 3 days before and afterwards, we get a general idea of the course of the

⁵ *Jahrb. K. Ung. Reichsanst. f. Meteor. u. Erdmagn.*, 2nd part.

⁶ We took such disturbed days which had the characteristic number 3 or more in declination and horizontal intensity, and 2 or more in the vertical intensity. These numbers refer to the 1-5 scale of Eschenhagen (*Ergebn. Magn. Beob.*, Potsdam, 1890, 1891, etc.).

large disturbances.⁷ This we have done, and then we have taken the mean of these differences. Thus was obtained Table XI. The figures in brackets show the number of disturbances; the forces are expressed in units of 0.1γ .

TABLE XI.

	Before			Day of Dis- turbance	After		
	3d Day	2d Day	1st Day		1st Day	2d Day	3d Day
ΔH (63)	+179	+198	+188	0	+24	+73	+109
ΔZ (47)	- 55	- 56	- 58	0	- 8	-22	- 29
$H.\Delta D$ (43)	- 26	- 27	- 19	0	+16	+ 5	- 13

These figures show that, in general, we have $-\Delta H$ with $+\Delta Z$. (They show well also the phenomenon of the "after disturbance.")

4. When we wish to construct an average *vector-diagram* of the disturbances of Classes I and II, the circumstance that the disturbances are of different period offers a difficulty. We partly evaded that by proceeding in the following manner: The period of the disturbance in horizontal intensity was taken as unit of time and divided in 40 parts. The period of the disturbances being on the average about two hours, every interval represented about three minutes. The measured values have been ranged into these intervals. The measurements refer to the tenth parts of the hour, and are simultaneous in the three elements. In deriving the average vector-diagram, the values belonging to the same aliquot part of the period of the disturbance in horizontal intensity have been united into one mean. As the beginning and end of the disturbances in declination and vertical intensity do not generally agree with that of the horizontal intensity, the period of the latter had to be continued forwards and backwards. In this way the disturbances have been somewhat distorted; but as their periods are in general not too far from two hours, the distortion, we can assume, has not been too large.

In this way both the horizontal (ΔH , $H.\Delta D$) and the vertical (ΔH , ΔZ) vector-diagrams have been constructed for two-hour intervals separately. In accordance with Table VIII the horizontal vector-diagram (ΔH , $H.\Delta D$) of Class I is in the magnetic Northeast quadrant in the evening hours, then gradually takes a

⁷ The differences are taken in the sense 1st, 2nd, 3rd day — day of disturbance.

more northern direction, and at about midnight goes over into the magnetic Northwest quadrant; thus, as a whole, turns in anti-clockwise direction. The horizontal vector itself turns in anti-clockwise direction in the evening and early night hours, and in clockwise direction after midnight.

In Class II the turning of the vector-diagram, as a whole, is not so obvious. In the afternoon hours it is in the southeast quadrant; while during the morning hours, as far as the small number of disturbances in these hours admit of any inference, it occurs in the southwest quadrant; thus it seems to turn in anti-

FIG. 2

clockwise direction. The horizontal disturbing force turns in anti-clockwise direction during the afternoon hours and in clockwise direction during the morning hours. [See Fig. 2. In this figure we reproduced only those vector-diagrams for which there are observational data in sufficient number. The slight difference in the number of disturbances (figures in parentheses), compared with the numbers in Table VIII, is due to the circumstance that we omitted the nine exceptional disturbances (see 3b).]

The vertical vector-diagram (ΔH , ΔZ) of Class I is in the upper north quadrant, and that of Class II in the lower south quadrant. The turning of the vector for Class I generally takes place in anti-clockwise direction; for Class II the turning at 4^h-6^h p is in clockwise direction.

5. It seems that, on the whole, our results fit into the general conception we have regarding magnetic disturbances according to the theory of Birkeland and Stoermer. Let us imagine that in those places where, according to Stoermer's theory, the districts of precipitation of such negative particles are to be found, the paths of which strike the center of the Earth,⁸—there may be such electric current-systems, the magnetic fields of which represent the magnetic field of Birkeland's *polar* storms.⁹ These current-systems consist of a horizontal and two very long vertical branches.

These districts of precipitation are determined by their distances from the magnetic pole and by their angular distance (ϕ) from the Sun, measured along the magnetic equator. Computing ϕ for different declinations and different hour-angles of the Sun, we find the positions of these districts relative to the place and time of observation. If we make assumptions about the current-strength, the length of the horizontal part of the current-system and its height above the Earth's surface, we can compute the disturbing forces.

In general there are several districts of precipitation: $\phi_1, \phi_2, \phi_3, \phi_4$, some of which may fall out on certain days and hours, according to different declinations of the Sun. Birkeland's experiments¹⁰ permit the conclusion that the precipitations in the different districts are of unlike strength, and especially that the first two ϕ_1, ϕ_2 , are the strongest; further, in accordance with Birkeland¹¹, we assume that in ϕ_1 there is the center of a current-system corresponding to a *positive* polar storm, and in ϕ_2 one corresponding to a *negative* polar storm. We shall see that ϕ_1 shows analogy to the disturbances of Class II and ϕ_2 to those of Class I.

(a) If we compute ϕ for different declinations of the Sun (δ) and for two-hour intervals, and afterward count how often they appear, we get the following:

TABLE XII.

	$\delta = -23^\circ.5$ (Dec. 21)	-15° (Feb. 8, Nov. 3)	-10° (Feb. 23, Oct. 20)	0° (Mar. 21, Sept. 23)	$+10^\circ$ (Apr. 16, Aug. 27)	$+23^\circ.5$ (June 21)
ϕ_1	5	8	11	12	12	12
ϕ_2	5	8	11	12	9	3
ϕ_3	3	7	9	12	9	3
ϕ_4	3	7	9	7	5	0

⁸ BIRKELAND: *The Norwegian Polar Expedition*, 1902-03, 1st section, pp. 158-160.

⁹ *Ibid.*, p. 95, etc.

¹⁰ *Ibid.*, p. 590.

¹¹ *Ibid.*, c. pp. 560-591.

From this we see that the frequency of ϕ_2 shows a very distinct annual change, with maxima about the equinoxes; in ϕ_1 the annual change is not so apparent, and gives rather a minimum in winter. This reminds us of what we found for Classes I and II. Certainly our conclusion would be exactly valid only in that case if the radiations of the Sun, which cause the precipitations in the districts ϕ_1 ϕ_2 , should be uniformly constant during the whole year, and the frequency of the ϕ -centers would only depend on the position of the Sun.

(b) One should expect that at the time when in the course of the day the centers of the current-systems are next to the place of observation, the frequency of the disturbances, on account of the greater disturbing forces, would be greater, as they can more distinctly be recognized on the magnetograms. Now ϕ_1 and ϕ_2 are next to the place of observation at 2^h-4^h in the afternoon (ϕ_1) and at 8^h-10^h in the evening (ϕ_2); the disturbances II and I are most frequent at 4^h-6^h in the afternoon (II) and at 10^h-12^h in the night (I), hence about two hours later. Thus there appears a displacement of about two hours.

(c) By means of the tables given by Birkeland¹² we computed the disturbing forces of the combined effect of ϕ_1 and ϕ_2 in the course of the day. With regard to the annual frequency of the disturbances I and II, we give the results (Table XIII) only for zero declination of the Sun. For the declinations +10° and -10° we get, on the whole, the same result. For the horizontal parts of the current-systems ($\Delta\mu$) 60° have been assumed. These branches, lying in the magnetic parallel of magnetic latitude 70°¹³, the cur-

TABLE XIII. ($\Delta\mu = 60^\circ$; $\delta = 0^\circ$)

M. T. gyalla	ΔX	ΔY	ΔZ	L. M. T. Ogyalla	ΔX	ΔY	ΔZ	L. N. T. Og a la	ΔX	ΔY	ΔZ
^h				^h				^h			
0	- 24	-169	-102	8a	+ 8	- 67	+ 12	4p	- 59	+336	+196
1a	- 44	-111	- 43	9	+ 6	- 95	+ 28	5	+ 22	+346	+ 74
2	- 35	- 70	- 16	10	- 12	-138	+ 68	6	+ 76	+345	- 30
3	- 24	- 50	- 6	11	- 76	-178	+145	7	+154	+306	-139
4	- 14	- 39	- 2	12	-179	-153	+270	8	+242	+220	-302
5	- 7	- 37	0	1p	-252	- 36	+363	9	+280	+ 45	-384
6	- 1	- 39	+ 2	2	-249	+139	+384	10	+205	-146	-354
7	+ 5	- 49	+ 5	3	-161	+282	+314	11	+ 74	-214	-232

¹² l. c. pp. 428-432.¹³ The magnetic pole is taken here as the point where the magnetic axis of the Earth cuts the surface; its distance from the geographical pole is assumed to be 11° 25'.

rent strength is equal to 10^6 C. G. S., and the height of the horizontal branch of the current-system, 400 km.¹⁴ The disturbing forces are determined for a place the magnetic parallel of which is 50° (for Ogyalla it is $47^\circ 17'.1$). The forces ΔX , ΔY , ΔZ , are expressed in units of 0.1γ .

The disturbing forces have been computed for other lengths, too, of the horizontal part of the current system ($\Delta\mu = 90^\circ, 120^\circ$); in the main they give like results. The quantities ΔX , ΔY , ΔZ , have practically the same meaning as ΔH , H , ΔD , ΔZ , used before.

Let us consider the values for $\delta = 0^\circ$ ($\delta = \pm 10^\circ$, gives, on the whole, the same). ΔX shows considerable values between 11^ha and 11^hp. The disturbances of Classes I and II show their greatest frequency in the course of the day between 0^h-2^hp and 2^h-4^ha, thus, with a displacement of about two hours, in the same part of the day. ΔX is negative about noon and in the early afternoon hours (thus corresponding to the disturbance of Class II), and positive in the late afternoon, evening, and early night hours (thus corresponding to the disturbance of Class I). During the time while ΔX has negative values, ΔY is negative in the first part of this time and positive in the second part; and during the time while ΔX shows positive values ΔY is positive in the first part of this time and negative in the second part. These properties are the same as those exhibited in Table VIII and in the anti-clockwise rotation of the horizontal vector-diagram, as a whole, of the disturbances I and II in the course of the day.

Further we see that during the greater part of the day ΔZ is positive when ΔX is negative, and ΔZ negative when ΔX is positive. These properties are the same as those exhibited in Table X concerning the disturbances I and II.

There appears, however, a contradiction of greater weight between the values of Table XIII and the observational data. According to Table XIII, ΔZ is larger than, or of the same magnitude, as ΔX , whereas in the disturbances I and II, ΔZ is much smaller than ΔH (Table X). This contradiction can perhaps be explained by the magnetic effect of the induced currents which arise in the Earth's crust, either by displacement of the primary current-system or by variations of the current-strength in it.

The parallelism between the absolute values of ΔH and ΔZ (Table X) might be due to the different strength of the current-

¹⁴ BIRKELAND, I. c., p. 428.

system, which would alter the different components in the same proportion.

6. The values of Table XIII are to be interpreted in the following manner. If at the different hours of the day which are in the first column there come such radiations from the Sun as are supposed in the Birkeland-Stoermer theory and the magnetic action of which can be represented by the simple current-system assumed in Birkeland's polar storms, then in Ogyalla there will be such disturbing forces as are represented in Table XIII. If we assume that the current-systems do not appear at once in their full strength, but develop gradually, the current attaining its full strength of 10^5 C. G. S., little by little, and then disappearing gradually, we can draw the vector-diagrams. If we do that, we find the anti-clockwise turning of the horizontal vector-diagram, as a whole, and this much more distinctively than in the disturbances I and II. The turning of the horizontal vector is always anti-clockwise, and there we do not find the change in the turning direction as in Class I. One explanation, though not quite satisfactory, of the later phenomenon could perhaps be found in an easterly displacement of the current-system. In the disturbances which Birkeland investigated there are some cases of such a displacement.¹⁵

The situation and form of the vertical vector-diagram (ΔX , ΔZ), as well as the direction of the turning of the vector itself, is in agreement with the observations. The vertical component, however, is much larger than in the disturbances I and II.

8. At last we mention that the opinion recently asserted by different authors¹⁶ that the aurora phenomena, and thus in Birkeland's conception the magnetic disturbances too, are due to positive particles, cannot, at least with such simple assumptions as made above, be brought into agreement with the disturbances of Classes I and II; thus, for instance, in the diurnal change of frequency the maxima would be as 3^{h} a for Class I and at 8^{h} a for Class II.

On the whole, it seems that there is an analogy between the disturbances of Classes I and II and the negative and positive polar storms of Birkeland. This analogy extends over the annual and, with some displacement in time, over the diurnal change of

¹⁵ BIRKELAND, l. c., pp. 113, 137, and 223.

¹⁶ J. STARK: Das Nordlichtspektrum ein spektrum positiver Strahlen. *Ann. d. Physik.* Bd. 54, pp. 598-614.

frequency; also over the horizontal vector diagram and, allowance being made for the influence of the induced currents, over the vertical vector-diagram too. But with the simple scheme above we do not find explained the relative frequency of the disturbances of Classes I and II and the change of direction in the turning of the horizontal vector. But not too much stress must be laid upon the latter circumstance, first, because the sense of turning of the horizontal vector is much influenced by the movement of the current-system itself, and secondly, our simple supposition that the strength of the current gradually increases and, after reaching a maximum value, gradually dwindles away, will in rare cases be fulfilled.