Terrestrial Magnetism and Atmospheric Electricity

VOLUME VIII

DECEMBER, 1903

NUMBER 4

THE DIURNAL FIELD OF MAGNETIC DISTURBANCE.¹

BY DR. W. VAN BEMMELEN.

It has been known for some time that the Earth's magnetic force on days of disturbance shows a characteristic change, both in amount and direction, from the normal value as derived from quiet days. In 1895² the author inquired into this phenomenon by the method briefly described below.

Let $h_s, d_s, v_s; h_1, d_1, v_1; h_2, d_2, v_2; h_3, d_3, v_3$, etc., represent, respectively, the daily means of horizontal intensity, declination, and vertical intensity, on a day of disturbance and subsequent quiet days. For a number of n cases were computed the mean values:

$$\begin{aligned} H_s &= \frac{h_{1.s} + h_{2.s} + \dots + h_{n.s}}{n}, & D_s &= \frac{d_{1.s} + d_{2.s} + \dots + d_{n.s}}{n}, \\ V_s &= \frac{v_{1.s} + v_{2.s} + \dots + v_{n.s}}{n}, \\ H_1 &= \frac{h_{1.1} + h_{2.1} + \dots + h_{n.1}}{n}, & D_1 &= \frac{d_{1.1} + d_{2.1} + \dots + d_{n.1}}{n}, \\ V_1 &= \frac{v_{1.1} + v_{2.1} + \dots + v_{n.1}}{n}, \end{aligned}$$

$H_2 = \text{etc.}$

The values $(H_s - H_m)$ and $H(D_s - D_m)$, H being the mean value of the horizontal intensity, determine, with sufficient accuracy for the purpose, the horizontal component of the average dif

¹ Presented to the Royal Academy of Sciences at Amsterdam, October, 1903.

² *Meteorol. Zeitschr.* 1895, p. 321.

OBSERVATORIO MAGNETICO Y METEOROLOGICO DE LA
ISLA DE "AÑO NUEVO."

ferential vector for the days of disturbance and the m following days. The angle α determined by $\tan \alpha = \frac{H(D_s - D_m)}{H_s - H_m}$ is the mag-

netic azimuth of the differential vector, which we may call the disturbing vector.

A first result of these calculations was found to be that this angle α is fairly constant for any one station; a second result, derived from a consideration of this azimuth for twenty-eight stations distributed over the Earth, was that, generally speaking, this disturbing vector is directed perpendicularly to the isochasms (lines of equal frequency of aurora polaris), pointing away from the pole of the aurora borealis.

As we can always suppose that the magnetic force is caused by an electric current directed perpendicularly to the vector, this result led to the hypothesis of a system of electric currents circulating around the Earth parallel to the isochasms, the strength of the current being increased during disturbance, and decreased at a greater or lesser rate afterwards.

As Schmidt¹ has made it plausible that the more quickly occurring disturbances are caused by wandering current vortices, we are led to the following supposition: A system of electric currents encompasses the Earth; at the occurrence of a magnetic disturbance, not only the strength of current is increased, but numerous current vortices are formed which wander over the Earth.

This system exhibits a strong analogy to the great cyclonic movement of the atmosphere around the poles, with its accompanying wandering depressions, as has been recently described by Hildebrand Hildebrandson.²

It being obvious to suppose that such a system of currents, with an axis not coinciding with the axis of rotation, but inclined at an angle of about 10° , must be influenced in some manner by the terrestrial rotation, the investigation was extended as follows:

Representing the hourly values of the horizontal intensity and declination on the first or second day following a day of disturbance by $h'_1, h'_2, h'_3, \dots, h'_{24}; d'_1, d'_2, d'_3, \dots, d'_{24}$, and on the second or third day or on a still later day by

$$h''_1, h''_2, h''_3, \dots, h''_{24}; d''_1, d''_2, d''_3, \dots, d''_{24},$$

¹ *Meteorol. Zeitschr.* 1899, p. 385.

² *Les bases de la météorologie dynamique* No. 6, 1903.

then for a number of cases were computed,

$$(h_1'' - h_1'), (h_2'' - h_2') \dots (d_1'' - d_1') \dots (d_{24}'' - d_{24}'),$$

and the averages of these respective values,

$$H_1, H_2 \dots H_{24}, D_1, D_2 \dots D_{24}.$$

Letting the averages of these quantities be (H) and (D) respectively, then by taking the differences

$$\begin{aligned} \Delta h_1 &= H_1 - (H), & \Delta d_1 &= D_1 - (D), \\ \Delta h_2 &= H_2 - (H), & \Delta d_2 &= D_2 - (D), \\ &\text{etc.} & &\text{etc.} \\ \Delta h_{24} &= H_{24} - (H), & \Delta d_{24} &= D_{24} - (D), \end{aligned}$$

a system of hourly values was found for the components of the vector, representing the daily inequality of the vector of disturbance.

Vector diagrams were drawn according to these values, computed for a certain number of stations, but though they pointed to a real influence of terrestrial rotation, they were mostly too irregular to allow any conclusions to be reached as to the nature of this influence.

In 1899, Dr. Lüdeling¹ constructed the vector diagrams of the diurnal variation for the international polar stations and for Pawlowsk. He gives in his paper the rectangular components (NS and EW) for the horizontal vector. He found that the direction in which the vector curve progresses—whether *clockwise*, as prescribed by the Schuster and von Bezold researches, or *anti-clockwise*—depends primarily upon whether all days (disturbed and undisturbed), or simply the magnetically calm days (Wild's "normal" days), are embraced in the discussion.

The vector curves of the diurnal disturbing forces, with the exception of the one for Kingua Fjord (and partially for Godthaab), progressed in the *anti-clockwise* direction. He suggests, in conclusion, that the disturbances, as well as the diurnal variation, may be ascribed to a system of forces rotating around the Earth once in twenty-four hours, and that we may possibly be dealing with a system of ascending and descending electric currents rotating about some pole, as *e. g.* the magnetic or the polar-light pole.

¹ See *T. M.*, IV, p. 245.

The present paper gives the results of the investigation of the daily field of disturbing force and its rotation referred to above.

The history of magnetic science has shown that wrong notions of magnetic phenomena, such as the secular and the diurnal variations, disturbances, etc., prevailed as long as these phenomena were being investigated at one or at a small number of stations, and that a true understanding was reached only after an inquiry into the phenomenon in question was made at widely distributed points.

Accordingly, our first task was to derive the daily horizontal and vertical components of disturbing force for a number of stations distributed as widely as possible over the globe. The available material is scant, the necessary dates for "quiet" days failing for many stations. We may expect, however, that the publication of the recent international observations will materially enlarge the data.

The material used is as follows :

The values of the horizontal component derived by Lüdeling have been used without change; for the vertical component the following quiet days have been taken into account :

	1883
<i>Cape Thordsen :</i>	June 4, 5, 10, 12, 15. July 3, 4, 12, 20, 21, 22, 23, 28. August 4, 9, 10, 16, 17, 20.
<i>Kingua Fjord :</i>	June 4, 5, 6, 10, 11, 12, 15. July 3, 4, 12, 20, 21, 22, 23, 28.
<i>Novaja Semlja :</i>	June 4, 5, 15, 29. July 21, 22, 23, 28, 29. August 4, 9, 16, 17, 26, 31.
<i>Bossekop :</i>	June 5, 11, 15. July 21, 28, 29.
<i>Point Barrow :</i>	June 4, 5, 10, 11, 12, 15. July 3, 4, 20, 21, 22, 23, 28.
<i>Jan Mayen; Sodankylä, Fort Rae :</i>	} June, July { Results taken directly from the respective publica- tions.
<i>Pawłowsk :</i>	
	June 4, 5, 10, 11, 12, 15. July 3, 4, 12, 20, 21, 22, 23, 28.

The variations of the vertical intensity read at *Ssagastyr*, with the aid of a unifilar magnetometer provided with soft-iron induc-

tion bars, show such abnormal changes, that they evidently are less trustworthy, and, accordingly, they have not been used.

For *Greenwich* the hourly means of selected quiet days are published each year. Mean values for the components have been computed for the months of June and July of the ten years 1890–1899.

For *Tiflis* the days designated as normal or quiet for the three elements (*H*, *D*, and *Z*) at *Pawlowsk* have been used. The months of June and July for the years 1880–1884, 1886, 1887 have been selected for the horizontal component, and for the vertical component August was added.

For *Washington* the same quiet days as those for *Pawlowsk* for the months of June and July of the years 1889–1892, and also of 1894, have been chosen (taking into account the difference in time).

For *Batavia* the author had an opportunity to select the quiet days from the original magnetograms. The same dates have been adopted for *Zi-ka-wei*.

They are :

	June	July
1890	13, 14, 25	3, 16, 27, 28
1891	10, 11, 13	8, 9, 11, 13
1892	11, 12, 18	7, 8
1893	8, 17, 24	6, 8, 9, 31
1894	8, 27	27
1895	13, 14, 15, 20, 26	8, 10, 19, 25
1896	1, 2, 7, 11, 12, 13, 23, 24	
1897	9, 10	5, 13, 18

For *Cape Hoorn*¹ (June–July, 1883) the results for quiet days are given in the publication² for that station.

The results of the calculations for all these stations—viz., the components x_s , y_s , z_s , of daily inequality in disturbing force—have been collected in Table I.

¹ "*Hoorn*" is the true original spelling.

² *Mission Scientifique du Cap Horn*, 1882–1883, T. III.

TABLE I.

Diurnal Variation of Components of Disturbing Force.

[Unity = 0.00001 C. G. S.]

Local Mean Time	KINGUA FJORD			GODTHAAB			CAPE THORSDSEN			JAN MAYEN			FORT RAE			POINT BARROW			NOVAJA SEMIJA			SSAGASTYR		
	X _s	Y _s	Z _s	X _s	Y _s	Z _s	X _s	Y _s	Z _s	X _s	Y _s	Z _s	X _s	Y _s	Z _s	X _s	Y _s	Z _s	X _s	Y _s	Z _s	X _s	Y _s	Z _s
Ia	+23	-17	-13	-3	-8	..	-8	+13	-32	-34	+34	-40	+6	-21	-24	-7	-23	-6	-52	+11	-10	-8	-16	..
2	+22	-13	-24	+4	-7	..	-9	+17	-32	-51	+40	-26	-3	-23	-28	-10	-9	..	-58	-16	-4	-33	-11	..
3	+24	-11	-30	-1	-1	..	-5	+28	-24	-65	+56	-30	-22	-26	-39	+16	-9	+24	-61	+19	-4	-49	+5	..
4	+26	-9	-17	-6	+16	..	-11	+44	-56	-43	+49	-26	-42	-28	-31	+16	-9	..	-37	+18	-4	-54	+4	..
5	+21	+7	-18	-8	+26	..	-17	+47	-49	-32	+49	-16	-42	-24	-68	-5	-8	+19	-24	+14	+3	-48	+16	..
6	+28	+13	-27	-34	+51	..	-13	+44	-30	-14	+37	-17	-52	-24	-67	-50	-5	..	-16	+9	+17	-35	+12	..
7	+15	+23	-27	-32	+61	..	+8	+26	-14	+2	+24	-7	-80	-11	-71	-68	-4	+37	-7	+3	+9	-13	+12	..
8	+16	+34	-19	-15	+43	..	+32	+16	-8	-7	+24	-5	-89	-4	-28	-73	0	..	+16	+1	+4	-21	+6	..
9	+7	+40	-31	-3	+36	..	+36	+15	-3	+8	+10	-1	-66	+2	+14	-60	+8	+38	+24	+2	+1	-17	+1	..
10	+11	+53	-5	+14	+31	..	+89	+4	+5	+26	+8	-1	-36	+10	+4	-19	+3	..	+25	+3	-5	-14	-3	..
II	+15	+61	+5	+17	+30	..	+67	+17	+18	+47	-2	+1	-3	+13	+6	+4	+6	+1	+20	+6	-11	-4	+8	..
Noon	+4	+61	+33	+81	+32	..	+57	+1	+31	+51	-6	+8	+12	+27	+1	+6	+4	..	+10	-1	-12	+5	+10	..
1p	-28	+39	+57	+86	+11	..	+34	0	+25	-72	-13	+17	+24	+37	-5	+13	-12	-8	+19	-1	-15	+7	+7	..
2	-56	+12	+36	+35	+5	..	+12	-9	+51	+60	-29	+1	-3	+10	-11	+10	+24	..	+45	0	-20	-4	+8	..
3	-56	-8	+34	+10	-3	..	+4	-19	+38	+70	-47	+40	+58	+42	+1	+15	-21	-14	+40	-5	-17	+30	+11	..
4	-36	-4	+21	-26	-21	..	-14	-43	+59	+62	-46	+53	+56	+36	+43	+27	+17	..	+31	-10	-3	+41	+12	..
5	-40	-22	+20	-30	-20	..	-25	-36	+52	+7	-36	+56	+61	+28	-38	+33	-13	-38	+39	-10	-1	+43	+10	..
6	-29	-35	+16	-32	-36	..	-47	-37	+39	+6	-44	+28	-55	+18	+65	+36	+11	..	+53	-11	+6	+42	+10	..
7	-12	-43	+6	-27	-51	..	-35	-34	+25	-20	-42	+32	+38	-2	+94	+42	+15	-42	+38	-13	+12	+56	+8	..
8	-5	-49	-3	-18	-51	..	-45	-33	+12	-42	-33	+15	+36	-7	+75	+44	+5	..	+20	-17	+13	+26	-14	..
9	+2	-45	-13	-13	-49	..	-29	-25	+3	-50	-26	-4	+28	-16	+51	+42	+6	-8	-8	-18	+13	+19	-18	..
10	+14	-35	-1	-10	-42	..	-25	-24	-20	-19	-7	-23	+5	-26	+43	+26	-15	..	-25	-15	+12	+2	-23	..
II	+14	-28	-21	0	-32	..	-9	-12	-40	-21	+2	-36	+2	-29	+3	+1	-23	-6	-49	-6	+10	-2	+34	..
Midnight	+15	-20	-16	-9	-12	..	-8	-6	-54	-27	+11	-47	+0	-11	-13	-6	-32	..	-45	+9	-2	-31	-34	..

TABLE 1—Continued.

Diurnal Variation of Components of Disturbing Force.

[Unity = 0.00001 C. G. S.]

Local Mean Time	BOSSKOP			SODANKYLÄ			PAWLOWSK			GREENWICH			WASHINGTON			TIFLIS			ZI-WA-KEI			BATAVIA			CAPE HOORN		
	X _s	Y _s	Z _s	X _s	Y _s	Z _s	X _s	Y _s	Z _s	X _s	Y _s	Z _s	X _s	Y _s	Z _s	X _s	Y _s	Z _s	X _s	Y _s	Z _s	X _s	Y _s	Z _s	X _s	Y _s	Z _s
1a	-69	+25	+30	-59	+17	-41	-3	+4	+15	..	..	..	..	..	..	..	..	..	+0.4	+0.2	+0.8	-1.4	-0.5	-0.9	-0.4	-3.0	+0.4
2	-78	+24	+54	-52	+10	-37	+1	+3	+13	+0.7	+1.0	..	+1.7	-2.2	+2.8	+4.7	+2.2	+1.6	+0.8	+1.1	+0.7	-0.6	+0.3	-1.0	-2.2	-2.7	+0.2
3	-92	+37	+65	-45	+11	-32	+1	+1	+12	..	..	..	..	..	..	..	..	..	+1.3	+1.9	+0.7	0.0	-0.7	-1.2	-0.5	-3.7	-0.2
4	-62	+27	+74	-32	+7	-23	2	+1	9	+0.8	+2.0	..	+1.2	-1.5	+4.4	+4.2	+1.2	+2.0	+1.5	+2.0	+0.8	+0.8	+1.2	-1.1	-0.4	-3.3	-0.5
5	-38	+16	+51	-22	+2	-14	2	+4	4	+0.9	+4.6	..	..	..	..	..	..	..	+1.0	+2.9	+0.7	-1.7	+1.2	-1.1	+0.8	-2.1	-0.4
6	-19	+3	+40	-13	-2	-1	2	+4	4	..	..	..	+2.2	+0.4	+4.7	+3.2	-1.3	+2.4	+0.4	+2.3	+0.5	-2.8	-1.5	-1.6	-2.4	-1.0	-1.1
7	0	+3	+12	-2	0	-9	3	-2	2	..	..	..	..	..	..	..	..	..	+0.9	+1.2	+1.2	-2.6	-1.6	-0.3	+1.1	+1.4	+0.3
8	+6	0	1	+1	+1	-10	3	-2	1	-0.5	+5.3	..	-1.5	+0.5	+3.0	+1.4	-4.1	+1.0	+0.5	+0.4	+1.4	+3.0	+0.7	+1.0	-2.2	-2.9	-0.4
9	+9	0	7	+1	+1	-15	5	0	1	..	..	..	..	..	..	..	..	..	+0.1	-0.4	+1.2	-3.4	-0.3	-1.2	-3.5	-3.4	-0.9
10	+17	+2	9	+5	+5	-18	5	1	0	-2.2	+2.2	..	-1.5	+1.9	+2.2	+0.4	-0.6	+0.2	+0.3	-1.1	+1.2	+3.2	-1.3	-1.9	-2.4	+3.2	-0.3
11	+15	+1	11	+5	+5	-24	7	0	-4	..	..	..	..	..	..	..	..	..	-1.2	-1.2	+1.0	-3.0	-1.4	-3.4	+1.6	+3.1	-0.3
Noon	+36	-1	-38	+16	+3	+27	3	-10	-3	-0.3	-3.8	..	-1.0	+2.9	-1.0	-3.2	+1.5	-1.8	-1.4	-0.6	0.0	-2.0	-0.8	-2.4	+0.6	+1.9	-1.6
1p	+55	-4	-57	+21	+1	+26	2	-10	..	..	..	..	..	..	..	..	..	..	-1.4	-1.2	+0.5	+1.5	-0.8	-1.7	-0.1	+1.9	-0.3
2	+60	-12	-57	+36	-7	+21	1	-3	-13	-1.7	-5.6	..	..	-1.6	-2.2	-4.1	+1.4	-0.8	-1.0	-1.4	+1.1	0.0	-0.1	-0.2	+0.6	+1.8	-1.1
3	+69	-20	-77	+42	-10	+18	5	-2	-13	..	..	..	..	..	..	..	..	..	-0.3	-1.7	0.0	-1.9	-0.8	-0.1	+1.3	+1.6	-0.4
4	+75	-23	-75	+48	-15	+26	8	-3	-14	0.0	-3.5	..	..	-1.6	-1.0	-3.9	-1.4	..	-0.4	-0.5	0.7	-2.7	-1.0	-0.4	+0.4	+0.9	-0.2
5	+89	-31	-76	+60	-14	+24	13	-0	-8	+1.3	-1.4	..	-0.6	+0.2	-4.4	-1.6	-0.3	-0.9	-0.3	-0.0	-0.8	-3.2	-1.0	-0.3	-1.7	+1.5	+1.1
6	+73	-29	-63	+47	-10	+10	7	0	8	..	..	..	..	..	..	..	..	..	-1.5	-0.6	1.1	-2.5	+0.6	-0.1	-2.2	+0.1	+1.1
7	+48	-32	-28	+40	-16	+14	+7	+2	5	+1.6	-0.8	..	-2.8	+0.6	-4.9	-0.9	+1.9	-1.0	-0.4	-0.4	-1.5	-2.4	+0.1	-0.2	-2.5	0.0	+1.5
8	+27	-25	-12	+16	-11	+4	+3	+1	1	..	..	..	..	..	..	..	..	..	+0.9	-0.3	-1.3	-2.9	-0.6	0.0	-1.5	-0.5	+1.3
9	-12	+8	-19	-9	+1	-6	+2	+4	3	..	..	..	..	..	..	..	..	..	+0.4	-0.5	-1.6	-3.4	-0.6	-0.1	-2.7	-0.5	+1.3
10	+43	-1	+53	-19	+1	-14	+4	+5	9	+1.1	-0.4	..	-0.2	+0.8	-1.6	-0.5	+2.6	-0.9	+0.9	-0.5	-1.6	-2.4	-1.2	-0.4	-2.9	-2.8	+0.6
11	-62	+13	+53	-37	-10	-19	-4	+5	9	..	..	..	..	..	..	..	..	..	+0.5	-0.7	-1.4	-1.8	-0.8	-0.8	-2.1	-3.7	+1.2
Midnight	-80	+26	+48	-48	+13	-19	-5	+3	+12	+0.9	+0.4	..	+0.4	-2.8	+1.5	+0.1	-4.0	-0.6	-0.6	+0.1	+0.7	-1.8	-0.8	-0.8	-2.1	-3.7	+1.2

VECTOR DIAGRAMS OF THE HORIZONTAL COMPONENT OF THE
DIURNAL DISTURBING FORCE.

The first plate¹ exhibits these vector diagrams for *Kingua Fjord*, *Godthaab*, *Jan Mayen*, *Sodankylä*, *Greenwich*, *Tiflis*, *Zi-ka-wei*, *Batavia*, and *Cape Hoorn*, drawn with the aid of "smoothed" components, and using different scales, in order to preserve the general shape as much as possible.

The characteristic features of these diagrams, taking them in the order of succession determined by these characteristics, briefly described are:

Kingua Fjord. The vector moves clockwise throughout the day, with only small change in magnitude.

Godthaab. From 3^ha till 3^hp the vector moves anti-clockwise, and clockwise during the rest of the day; it vanishes as the direction of rotation changes. The vector diagram approaches the form of the figure 8.

Cape Thorsden. The diagram for this station may be considered to be derived from that of the preceding station of *Godthaab* by turning around the afternoon part in which the vector rotates clockwise. At 1^ha and 4^hp the vector nearly vanishes, but the rotation is anti-clockwise for the whole day.

Jan Mayen, *Fort Rae*, *Point Barrow*, *Novaja Semlja*, and *Ssagastyr*. The vector moves more or less regularly in an anti-clockwise direction; at the hours after midnight and noon it is larger than at about midnight and noon.

This latter feature is strongly developed at *Bossekop*; hence the diagram for this station exhibits a very oblongated form.

At *Sodankylä* the lower parts of the diagram seem to have crossed each other, forming a small loop. The curve progresses partly in the clockwise direction and partly in the opposite direction.

Pawlowsk. The vector moves anti-clockwise in the morning and clockwise in the afternoon; the diagram does not show the figure-8 form, but is partially curved inwardly, and approaches the simpler form of the *Greenwich* diagram, where the vector rotates regularly for almost the whole day in a clockwise direction.

Tiflis. The direction is anti-clockwise for the first part of the day and clockwise during the second part, the diagram showing the

¹ Both plates were printed at Batavia, and the requisite number furnished to the Journal by the author.—ED.

Disturbing Vectors in the Arctic Region.
Mean civil time of Göttingen.

Daily Variation of Disturbing Force.

Vector diagrams of horizontal component

Curves of vertical component.

figure-8 form and the vector vanishing before midnight and before noon.

Also for *Washington* such a diagram has been found, but of a more complicated character, evidently an effect of insufficient material. Notwithstanding, the vector rotates anti-clockwise regularly from 4^h a till 4^h p.

Zi-ka-wei. The diagram may be compared with that of *Sodankylä*. For both stations the diagram is so oblongated that the vector may be said to keep a constant direction, changing only in amount. The direction is nearly N/S for *Sodankylä*, but more E/W for *Zi-ka-wei*.

Batavia. The diagram is almost the same as that for *Tiflis*, only that the vector vanishes in this case shortly after midnight and noon.

The diagram of our most southerly station, *Cape Hoorn*, shows nearly the same features as that for *Greenwich*.

These stations for which diagrams have been described are recapitulated here, together with their geographical and their auroral latitudes. By the latter are meant the complements of the spherical distance from the pole of the aurora borealis.

Station	Latitude		Station	Latitude	
	Geogr.	Auroral.		Geogr.	Auroral.
Kingua Fjord	67°	77°	Sodankylä	68°	63°
Godthaab	64	74	Pawlowsk	60	54
Cape Thordsen	78	73	Greenwich	51	52
Jan Mayen	71	71	Washington	39	51
Fort Rae	63	70	Tiflis	42	35
Point Barrow	71	70	Zi-ka-wei	31	21
Novaja Semlja	72	63	Batavia	— 6	—17
Ssagastyr	73	62	Cape Hoorn	—55	—45
Bossekop	70	66			

The regularity in decrease shown by the auroral latitude, as contrasted with the irregular succession of geographical latitudes, is obvious; this is not wholly unexpected, as the vector of disturbance is directed perpendicularly to the isochasms, which have a course resembling that of true parallels around the auroral axis. And as these isochasms show certain deviations from the true auroral parallels, the small irregularity in the succession above mentioned shown by *Bossekop* and *Sodankylä* (respectively 66° and 63°) may be safely disregarded.

The deviations of the isochasms from the auroral parallels make it impossible to determine accurately the place of the aurora-pole. From his observations of aurora, Nordensköld¹ adopted 81° N and 80° W, this place corresponding very nearly with the point where the meridians of disturbing vectors, mentioned above, converge. (Nachstörungenmeridiane, Cf. *Meteorol. Zeitschr.* 1895 1. c.)

It is by reason of this uncertainty in the place of aurora-pole, that for our purpose another pole has been used, situated close to it, viz., in 79° N and 78° W, which may be called the pole of disturbance, and which will be considered further on.

VERTICAL COMPONENT OF THE DIURNAL DISTURBING FORCE.

(Directed positive towards zenith.)

In general this component exhibits a single diurnal variation with amplitude of the same order as for the horizontal component. For the stations: *Kingua Fjord*, *Cape Thordsen*, *Jan Mayen*, *Fort Rae* and *Sodankylä* the character of the inequality is chiefly the same with a minimum in the morning and a maximum in the afternoon. For *Novaja Semlja* we find two maxima and two minima and a small amplitude; the oscillation seems to be of a transitional form between the former type and that for *Pawłowsk*, *Greenwich*, *Tiflis* and *Zi-ka-wei*, where we find just the contrary type with a maximum in the morning and a minimum in the afternoon.

In two cases this regular system is broken, viz. for *Point Barrow* and *Bossekop* where the diurnal inequality is just the contrary of what is to be expected. This is especially remarkable for *Bossekop*, as the corresponding horizontal hourly vectors at the neighboring station, *Sodankylä*, have nearly the same directions as those at *Bossekop*.

The rest of the stations falling in so well with the general system of the diurnal inequality of the vertical component, I think it best to consider these two cases as local deviations caused perhaps by abnormal phenomena of induction discussed later.

The inequality at *Batavia* shows a maximum at about noon and a minimum in the morning, and for *Cape Hoorn* we find the same type again as for *Pawłowsk*, *Greenwich*, *Tiflis*, and *Zi-ka-wei*.

A tabulation of the direction of the horizontal vector and of the maxima and minima of the vertical component is as follows :

¹ *Ann. de Chimie et de Physique*, 1884.

Latitude of Disturbance	Station	Horizontal vector moves	Vertical component has a maximum minimum	
			in the	
77°	Kingua Fjord	clockwise	afternoon	morning.
74	Godthaab	clockwise and anticlockwise	?	
73	Cape Thordsen	anti-clockwise	afternoon	morning.
71	Jan Mayen	"	"	"
70	Fort Rae	"	"	"
70	Point Barrow	"	morning!	afternoon!
63	Novaja Semlja	"	tends to disappear.	
62	Ssagastyr	"	?	
66	Bossekop	"	morning!	afternoon!
63	Sodankylä	anti-clockwise and clockwise	afternoon	morning.
54	Pawlowsk	clockwise and anti-clockwise	morning	afternoon.
52	Greenwich	clockwise	"	"
51	Washington	anti-clockwise and clockwise	"	"
35	Tiflis	" " "	"	"
21	Zi-ka-wei	constant direction	"	"
-27	Batavia	anti-clockwise and clockwise	noon	morning.
-45	Cape Hoorn	clockwise	morning	afternoon.

Having thus investigated and correlated the character of the vector diagrams and the inequality of the horizontal and the vertical components at various stations, the natural step next was to study the synchronous system of vectors for different moments during one rotation of the Earth.

For this purpose we may restrict ourselves to the Arctic stations which lie relatively close to each other; the original observations at these stations having been taken at the Göttingen hours they are consequently truly synchronous.

To obtain a survey of these synchronous systems, 12 maps of the north polar cap have been constructed in stereographic projection. They are reproduced on the first plate (left hand side), inserted between pages 160 and 161.

The star with four rays represents the north pole, and the arrows give the direction and length of the horizontal vectors. The values of the components x_s and y_s , as given by Lüdeling in his quoted paper, have been used.

The names of the stations, viz. Kingua Fjord, Godthaab, Cape Thordsen, Jan Mayen, Bossekop, Sodankylä, Novaja Semlja, Ssagastyr, Point Barrow, and Fort Rae have not been inscribed in order not to confuse the aspect of the system of synchronous vectors corresponding to the 12 moments: 0^h, 2^h, 4^h - - - 22^h mean time of Göttingen. An inspection of these 12 maps shows

that one portion of the vectors points towards one focus, and that the other portion radiates from another focus.

This is especially striking for the vectors at the neighboring stations, Cape Thordsen, Jan Mayen, Bossekop, Sodankylä and Novaja Semlja for the hours, 0^h, 12^h, 14^h, 22^h.

On each map the places of these foci have been indicated by small circles in which a + or — sign has been inscribed, the + sign for the focus towards which the vectors point, and the — sign for the one from which they radiate. As there is chance for personal bias in the choice of these places, the maps are reproduced subject to the reader's criticism.

For a determination of the foci a rectangular system of co-ordinates, with the origin in the north pole, has been used. For the positive X axis and positive Y axis, respectively, the meridians of 180° and 90° W from Greenwich have been taken. For unit of length $2 \tan 0^\circ.5$ has been chosen, because the maps have been drawn in stereographic projection from the south pole; accordingly $\sqrt{(x^2 + y^2)} = \tan p$, p being the polar distance expressed in degrees. As p is small for most Arctic stations, we may take p for $\tan p$, and consequently consider one degree as the unit of length.

Göttingen mean time	Positive focus		Negative focus	
	x	y	x	y
Midnight	7.4	—22.2	— 8.2	1.6
2 ^h	9.6	—17.0	—13.2	— 5.4
4	11.2	—11.0	—13.2	— 8.8
6	11.2	— 6.2	—16.0	—11.6
8	8.8	2.2	—12.6	—21.2
10	0.0	2.2	— 8.8	—28.0
Noon	— 4.4	2.2	2.2	—23.6
14	— 8.8	— 0.6	8.8	—23.6
16	—11.8	— 6.6	13.8	—10.4
18	—14.0	—15.4	9.4	— 6.0
20	—13.2	—26.2	2.8	8.2
22	— 8.8	—30.2	— 6.2	6.2
Mean	— 1.1	—10.7	— 3.4	—10.2

The 12 maps show that both foci change their positions from hour to hour; combining the 12 positions for each focus in a special map, it is obvious that the orbit for each approaches a common circle, in which the foci lie diametrically opposite to each other.

To investigate this, the harmonic formulæ representing the four series, respectively for x_+ , x_- , y_+ , and y_- , have been computed.

$$\begin{aligned} + \text{ focus } & \begin{cases} x_+ = -1.1 + 13.5 \sin(t + 15^\circ) + 2.1 \sin 2(t + 19^\circ) \\ y_+ = -10.7 + 14.3 \sin(t + 14^\circ - 90^\circ) + 2.4 \sin 2(t - 2^\circ) \end{cases} \\ - \text{ focus } & \begin{cases} x_- = -3.3 + 13.6 \sin(t + 24^\circ + 180^\circ) + 3.2 \sin 2(t - 15^\circ) \\ y_- = -10.2 + 15.7 \sin(t + 24^\circ + 90^\circ) + 3.0 \sin 2(t - 50^\circ) \end{cases} \end{aligned}$$

The mean values of x_+ , y_+ , x_- , and y_- , viz., the constant terms of these formulæ, are nearly the same for both foci:

$$-1.1 \text{ and } -3.4 \quad ; \quad -10.7 \text{ and } -10.2.$$

Accordingly both paths have nearly the same central point.

The terms of the second order are small compared with those of the first order; neglecting them and considering those of the first order only, we see that the amplitudes are nearly of the same magnitude, and that the phase angles, viz. for x - - - 15° and $24^\circ + 180^\circ$ and for y - - - $14^\circ - 90^\circ$ and $24^\circ + 90^\circ$, differ nearly 180° , thus pointing to a circular path, in which the two foci have a diametrical position.

If we adopt the path as being the same for both foci, having its center at $x_0 = \frac{1}{2}(-1.1 - 3.4) = -2.3$, and $y_0 = \frac{1}{2}(-10.7 - 10.2) = -10.5$ and the foci occupying diametrical positions, the values: $(x - x_0)^{1/2}$, $(y - y_0)^{1/2}$, $-(x - x_0)^{1/2}$, $-(y - y_0)^{1/2}$ must represent the same quantity, and we may derive a new set of 12 values by taking the mean of each group of four. The harmonic formula computed for this set is:

$$X_+ = -2.3 + 14.5 \sin(t + 22^\circ) + 1.3 \sin 2(t + 28^\circ).$$

The term of the second order has been still more diminished; furthermore the phase angles, viz. the angles $2 \times 19^\circ$, $-2 \times 2^\circ$, $-2 \times 15^\circ$ and $-2 \times 50^\circ$, show no regularity at all; accordingly we are justified in neglecting the term of the second order and in putting forth the conclusion:

The positive and negative foci of the Arctic vectors of the diurnal variation of the disturbing force move daily in a clockwise direction, with constant velocity and diametrically opposite to each other in a circular path of $14^\circ.5$ radius, having its center in 79° N and 78° W.

Combining the two results, viz.:

1°. The Arctic vectors point to a couple of foci, which rotate daily clockwise around the pole of disturbance;

2°. The character of the vector diagrams is chiefly dependent on the distance from this same pole; it is quite natural to draw the conclusion:

The daily inequality of disturbing force is caused by a constant field of force rotating from E to W around the axis of disturbance.

This constancy should be understood in this way, that the rotating field suffers only minor alterations, when the disturbance influence to which the Earth is exposed does not vary.

For the pole of aurora borealis, I accepted $80^{\circ}.5$ N and 80° W and according to Schmidt, the magnetic axis for 1885 cuts the Earth's surface in $78^{\circ}.5$ N and $68^{\circ}.5$ W, hence in the vicinity of the place where the disturbance axis found above, cuts the surface.

THE DIURNAL FIELD OF DISTURBANCE.

In order to obtain a representation of this field it is best to distribute the successive hourly values of the components of a certain number of stations, situated on different parallels along the parallels and to draw the lines of equal vertical component together with the horizontal vectors. Parallels must be taken with regard to the axis of disturbance.

It is obvious that the features of the system of lines of equal vertical component will suffer strongly from local deviations from the general type of inequality pertaining to the region in which the station is situated. For instance, if to the vertical components of the stations: Kingua Fjord, Cape Thordsen, Jan Mayen, and Sodankylä, which exhibit one and the same type of inequality, are added those for Barrow and Bossekop, of the contrary type, then the lines of equal vertical component will acquire a distorted aspect. The aim being a knowledge of the causes of the phenomenon, a representation of the field exhibiting only the chief characteristic features free from local deviations is required. The investigation of the local deviations is of later care; for the present the knowledge that important deviations exist may be considered to be sufficient.

Of course we may suppose the field to change during one rotation in such a degree, that it would be necessary to derive a representation of it for each hour, but the agreement between most of the vector diagrams (the two stations: Point Barrow and Bossekop included) points to the contrary conclusion.

Just as Schuster,¹ in his representation of the diurnal variation field, selected a small number of stations situated on parallels

¹ *Philosophical Transactions* 180, p. 467.

already known as critical for the phenomenon, so in our case those stations have been selected, which have well developed diagrams, characteristic for each of the different types.

Accordingly Kingua Fjord, Jan Mayen, Sodankylä, Greenwich, Tiflis, Zi-ka-wei, Batavia, and Cape Hoorn have been chosen; (Godthaab has been omitted, the vertical component for that station not being available).

First, the hourly values of the components for these stations have been smoothed graphically, because it was clear that the irregularities in the series had been caused chiefly by want of material. From the smoothed curves representing the values of x_s , y_s , and z_s for the selected stations, the values for the full hours of Göttingen mean time have been read. They are given in Table II. Now these values have been computed in most cases for the same pair of months, viz., June—July, but not for the same years. As it is probable that the diurnal inequality of disturbing force increases and decreases together with the force itself in the eleven year period, the figures are not comparable directly. A factor reducing them to the same year may be found as follows:

In the "Observations made at the Royal Magnetical and Meteorological Observatory at Batavia," 1898 part II, table 69, we find the mean horizontal disturbance (s_h) per day and from these values we may derive the formula

$$s_h = 22 + 1.00 R,$$

R being Wolf's Sun-spot number.

With this formula we find for the reducing factors: Greenwich, 1.27; Tiflis, 1.27; Batavia, 1.17.

As these factors differ not much from unity and are moreover approximations, and also as the components of these stations themselves are small in comparison with Arctic values, no use has been made of these factors.

The construction of the field has been performed in the following manner.

A map of the Earth has been constructed after Mercator's projection, not with the axis of rotation as chief axis, but with regard to the axis of disturbance. The great circle passing through the pole of disturbance and the place, where the Sun stands in the zenith at Greenwich mean noon of July 1st, has been chosen as middle or zero meridian.

The place occupied in this projection by the other stations selected has been computed to be:

TABLE II.

*Diurnal Variation of Components of Disturbing Force.
Smoothed Values for Eight Selected Stations.*

[Unity = 0.00001 C. G. S.]

Mean Geetlingen Time	KINGUA FJORD			JAN MAYEN			SODANKYLÄ			GREENWICH			TIFLIS			ZI-KA-WEI			BATAVIA			CAPE HOORN		
	X _s	Y _s	Z _s	X _s	Y _s	Z _s	X _s	Y _s	Z _s	X _s	Y _s	Z _s	X _s	Y _s	Z _s	X _s	Y _s	Z _s	X _s	Y _s	Z _s	X _s	Y _s	Z _s
Ia	-5	-49	+2	-27	+16	-47	-52	+13	-38	+0.8	+4.8	+5.0	+4.5	+1.6	+1.9	0.0	0.0	+1.2	-3.2	+0.9	+0.4	-1.4	-1.2	+1.4
2	+3	-45	-3	-35	+30	-40	-44	+10	-37	+1.2	+4.7	+7.4	+4.1	+0.7	+2.1	-0.4	-0.5	+1.1	-3.4	0.0	+1.5	-1.4	-1.9	+1.4
3	+9	-36	-8	-41	+34	-34	-33	+6	-31	+1.7	+5.0	+7.4	+3.6	-0.4	+2.3	-0.8	-0.8	+1.1	-3.3	-1.1	+2.3	-1.2	-2.4	+1.3
4	+14	-28	-12	-65	+52	-28	-22	+2	-23	+1.2	+5.4	+5.0	+2.9	-1.9	+2.1	-1.1	-1.0	+0.9	-2.9	-1.5	+2.8	-0.8	-3.1	+1.0
5	+18	-21	-16	-46	+53	-23	-12	0	-13	-0.6	+5.2	+3.6	+2.0	-3.7	+1.6	-1.2	-1.1	+0.7	+2.3	-1.1	+2.6	+0.1	-3.5	+0.8
6	+21	-17	-19	-30	+46	-18	-2	-1	-3	-3.3	+3.6	+5.6	+1.2	-3.8	+1.1	-1.2	-1.2	+0.4	+1.4	-0.7	+1.5	-0.7	-3.7	+0.5
7	+23	-13	-21	-19	+37	-13	0	0	+5	-4.6	+1.7	+6.9	+0.7	-1.5	+0.4	-1.1	-1.3	+0.1	-0.3	-0.2	+0.4	+1.3	-3.7	+0.2
8	+24	-9	-23	-8	+29	-9	+1	+2	+12	-4.8	0.0	+5.9	+0.2	-0.1	-0.3	-1.0	-1.2	-0.2	-1.2	+0.3	0.0	+1.7	-3.3	-0.2
9	+24	-3	-24	+1	+21	-4	+4	+5	+17	-4.9	-0.9	+4.7	+1.6	+1.0	-1.1	-0.9	-1.0	-0.5	-2.2	+0.7	-0.2	+2.0	-2.5	-0.4
10	+23	+5	-24	+11	+13	-2	+8	+5	+21	-5.0	-1.3	+3.6	+3.5	+1.7	-1.5	-0.8	-0.8	-0.8	-2.6	+0.9	-0.2	+2.2	-1.2	-0.5
II	+22	-14	-24	+35	+6	-1	+15	+3	+24	-4.8	-1.3	+2.0	+4.0	+1.8	-1.3	-0.7	-0.6	-1.1	-2.9	+1.0	-0.2	+1.9	+0.6	-0.5
Noon	+20	-23	-23	+43	-1	+2	+23	-1	+25	-4.3	-0.5	-0.1	+4.2	+1.0	-1.1	-0.6	-0.5	-1.3	-3.0	+0.8	-0.2	+1.4	+2.4	-0.5
ip	+18	+32	-21	+56	-8	+8	-32	-6	-26	+3.5	+0.3	-1.3	-4.2	-0.5	-1.0	-0.5	-0.4	-1.4	-3.1	+0.2	-0.1	+0.8	+4.0	-0.6
2	+15	+42	-16	+65	-17	+18	-41	-10	-26	-2.5	-0.7	-0.4	-3.7	-1.5	-1.0	-0.4	-0.4	-1.5	-3.1	-0.4	-0.1	+0.2	+4.6	-0.6
3	+11	+53	-7	+70	-28	+30	-51	-14	-25	-1.3	-3.5	-1.0	-2.2	-1.0	-1.0	-0.2	-0.4	-1.4	-3.0	-0.7	-0.1	-0.1	+4.1	-0.6
4	+7	+61	+7	+68	-40	+41	-60	-15	+23	+0.6	-4.4	-9.3	-1.4	+1.1	-1.0	0.0	-0.1	-0.8	-2.4	-1.0	-0.3	-0.3	+3.3	-0.6
5	-3	+61	+33	+58	-44	+53	-50	-16	+19	-2.7	-4.9	-9.3	-1.1	+1.1	-1.0	+0.2	+0.3	+0.4	-2.0	-0.9	-0.6	-0.5	+2.1	-0.6
6	-28	+39	+57	+29	-44	+50	-35	-15	+15	+6.3	-4.0	-11.0	-0.8	+1.9	-1.0	+0.7	+0.9	+0.8	-1.4	-0.5	-0.9	-0.6	+2.1	-0.6
7	-56	+17	+43	-1	+43	+42	-15	-11	+9	+7.5	-2.0	-11.5	-0.6	+2.6	-0.9	+1.2	+1.5	+0.7	-0.8	0.0	-1.0	-0.8	-1.8	-0.5
8	-56	0	+33	-22	-40	+26	-8	-4	+3	+7.0	-0.2	-10.5	-0.4	+3.1	-0.9	+1.4	+2.2	+0.7	-0.1	+0.5	-1.1	-1.1	-1.6	-0.5
9	-46	-12	+24	-40	-33	+11	-22	+3	-4	+5.9	+2.2	-6.7	-0.2	-3.7	-0.7	+1.2	+2.7	+0.7	+0.7	-0.9	-1.2	-1.3	+1.2	-0.4
10	-35	-25	+18	-50	-23	-6	-37	+9	-13	+4.7	+4.0	0.0	+0.7	+3.8	-0.3	+1.0	+2.5	+0.8	-1.5	-1.2	-1.3	-1.4	+0.7	-0.2
II	-23	-35	+12	-23	-11	-22	-49	+14	-12	-3.3	+5.2	+2.0	+4.1	+3.2	+1.1	-0.7	+1.5	+1.0	+2.2	+1.4	-1.3	-1.5	+0.1	+0.2
12	-12	-43	+7	-21	+3	-36	-59	+15	-31	+1.9	+5.4	+3.3	+4.7	+2.3	+1.6	+0.4	+0.6	+1.2	+2.8	+1.6	-0.6	-1.5	-0.6	+0.9

TABLE III.

Diurnal Variation of the Smoothed Values of the Horizontal Component of Magnetic Force Directed Along the Meridians and Parallels of Disturbance for Eight Selected Stations.

[Unity = 0.00001 C. G. S.]

Mean Geoffingen Time	KINGUA FJORD		JAN MAYEN		SODANKYLÄ		GREENWICH		TIFLIS		ZI-KA-WEI		BATAVIA		CAPE HOORN	
	X's	Y's	X's	Y's	X's	Y's	X's	Y's	X's	Y's	X's	Y's	X's	Y's	X's	Y's
1a	+5	-49	-31	-3	-52	-10	-08	+48	+41	+25	0.0	0.0	+32	+0.9	-1.4	-1.2
2	+12	-43	-46	+3	-44	-9	-05	+48	+3.9	+15	-0.5	-0.5	+3.4	0.0	-1.4	-1.9
3	+16	-33	-53	+2	-33	-9	-01	+5.3	+3.6	+0.3	-0.9	-0.7	+3.3	-1.1	-1.2	-2.4
4	+20	-24	-68	+3	-21	-7	-07	+5.5	+3.2	-1.3	-1.2	-0.9	+2.9	-1.5	+0.8	-3.1
5	+22	-17	-83	+15	-11	-5	-23	+4.7	+2.7	-3.2	-1.3	-1.0	+2.3	-1.1	+0.1	-3.5
6	+24	-13	-52	+19	-2	-2	-33	+2.3	+2.0	-3.5	-1.3	-1.1	+1.4	-0.7	+0.7	-3.7
7	+26	-8	-37	+19	0	0	-4.9	+0.1	+1.0	-1.4	-1.2	-1.2	+0.3	-0.2	+1.3	-3.7
8	+26	-4	-23	+19	0	+2	-4.5	-1.6	+0.2	-0.1	-1.1	-1.1	-1.2	+0.3	+1.7	-3.3
9	+25	+2	-12	+18	+2	+7	-4.3	-2.4	-1.8	+0.7	-1.0	-0.9	-2.2	+0.7	+2.0	-2.5
10	+22	+10	+1	+17	+5	+8	-4.3	-2.9	-3.7	+1.0	-0.9	-0.7	-2.6	+0.9	+2.2	-1.2
11	+21	+18	+24	+26	+13	+9	-4.1	-2.8	-4.3	+1.0	-0.8	-0.5	-2.9	+1.0	+1.9	+0.6
Noon	+15	+27	+35	+26	+21	+8	-3.8	-1.9	-4.3	+0.2	-0.7	-0.4	-3.0	+0.8	+1.4	+2.4
1p	+12	+35	+50	+28	+32	+8	-3.4	-0.9	-4.0	-1.3	-0.5	-0.3	-3.1	+0.2	+0.8	+4.0
2	+7	+44	+62	+25	+41	+8	-2.2	-1.5	-3.3	-2.2	-0.4	-0.4	-3.1	-0.4	+0.2	+4.6
3	+1	+54	+73	+20	+52	+8	0.0	-3.7	-2.0	-1.4	-0.2	-0.4	-3.0	-0.7	-0.1	-4.1
4	-5	+61	+78	+9	+61	+11	+2.1	-4.0	-1.5	-0.2	0.0	-0.1	-2.4	-1.0	-0.3	+3.3
5	-15	+59	+72	0	+52	+6	+4.1	-3.7	-1.3	+0.9	+0.2	+0.3	-2.0	-0.9	-0.5	+2.5
6	-35	+33	+50	-16	+38	+1	+7.2	-1.7	-1.2	+1.7	+0.8	+0.8	-1.4	-0.5	-0.6	+2.1
7	-38	+6	+25	-35	+19	-4	+7.8	+0.6	-1.1	+2.4	+1.4	+1.4	-0.8	0.0	-0.8	+1.8
8	-55	-11	+6	-45	-5	-7	+6.3	+2.5	-1.0	+2.9	+1.6	+2.1	-0.1	+0.5	-1.1	+1.6
9	-47	-21	+12	-50	-21	-6	+4.8	+4.1	-0.9	+3.6	+1.5	+2.6	+0.7	+0.9	+1.3	+1.2
10	-39	-32	-26	-47	-38	-8	+3.1	+5.4	-0.1	+3.8	-1.3	+2.4	+1.5	+1.2	-1.4	+0.7
11	-30	-39	-11	-23	-51	-8	+1.4	+6.0	+3.4	+5.9	+0.9	+1.4	+2.2	+1.4	-1.5	+0.1
12	-20	-44	-19	-11	-60	-11	0.0	+5.7	+4.1	+3.3	+0.5	+0.6	+2.8	+1.6	-1.5	-0.6

Station	Disturbance Latitude	Disturbance Longitude
Kingua Fjord	78° N	64° W
Jan Mayen	71 N	21 E
Sodankylä	62 N	43 E
Greenwich	52 N	6 E
Tiflis	35 N	46 E
Zi-ka-wei	20 N	124 E
Batavia	18 S	101 E
Cape Hoorn	45 S	78 W

The components x'_s and y'_s , computed for this new system of co-ordinates from the smoothed values of x_s and y_s , are tabulated in Table III. The deviation of the new north, the north of disturbance, from the geographical north amounts at

Kingua Fjord	9° W	Tiflis	11½ W
Jan Mayen	35 W	Zi-ka-wei	6 E
Sodankylä	24 W	Batavia	1 E
Greenwich	18 W	Cape Hoorn	2 W

The vector diagrams reproduced in the first plate are constructed by means of these components x'_s and y'_s .

For reference the geographical N, E, S, and W directions have been added.

In the map (second plate, left hand side) the value of the vertical component z_s as well as the horizontal vector (x'_s , y'_s) at 12^h m. t. of Greenwich = 12^h 40^m m. t. of Göttingen has been inscribed at the place of each station and from that point the successive hourly values along the parallel of the station at distances of 15° from W to E. Further the lines of equal vertical intensity have been drawn and thus the field of force has been constructed.

The arrows indicate merely the direction of the horizontal vector, their length not representing the magnitude which varies too greatly for the Arctic and tropical stations to make this practical.

In the case of the vector nearly vanishing, the arrow has been replaced by a small circle, the direction being very doubtful in this instance.

The map makes it evident, that the lines of equal vertical intensity inclose various foci, of which two may be said to be double. The eastern Arctic one, which shows two maxima over 50 γ ($\gamma=0.00001$ C. G. S.) owes this feature perhaps to the fact that for these regions the field depends on the values of two stations, Kingua Fjord and Jan Mayen, differing much in longitude. It

Daily Field of Disturbing Force. Horizontal Vectors and Lines of equal Vertical Component.

JUNE - JULY

Mercators projection, Axis 79°N, 78°W - 79°S, 102°E

Vertical component - Unity 0.00001 C.G.S.

for comp directed to zenith.
• • • • •

seems not improbable that only a single focus exists, which, however, suffers some change during the daily rotation.

The two western foci on the parallel of Greenwich owe their existence to the values of this station only; notwithstanding it seems better to consider both as the two centers of a double focus.

From the foci in southern latitudes the eastern one is partly shown on the map, but the western one is only indicated; the existence, however, of two Antarctic foci, corresponding to the Arctic ones, may safely be accepted.

Considering the directions of the arrows it is obvious, that they point with great regularity towards the positive foci and radiate from the negative ones.

As the Arctic foci can better be represented on a map in stereographic projection, such a map has been constructed and reproduced in the plate (right-hand side). The two foci of the horizontal vectors of the Arctic stations and their circular path, discussed above, have been introduced as well as the pole of disturbance, the north end of the magnetic axis of the Earth and the magnetic pole, in order to make it apparent, how much nearer the pole of disturbance is situated to the former than to the latter.

The positive and the negative focus of horizontal vectors are situated close to the region where the vertical component shows a maximum and a minimum, respectively; the positive one lies between the two maxima, the negative following the minimum.

ON THE CAUSE OF THE DIURNAL FIELD OF DISTURBANCE.

The current view of geophysicists on the fields of force causing the diurnal variation and disturbance is, that they are generated by electric currents flowing above and below the Earth's surface.

If we suppose a current ring to exist outside the Earth in a plane parallel to its surface, then the lines of equal vertical magnetic force on the surface will be concentric with the projection of that ring. In case the ring moves in its own plane, the course of the lines of equal vertical force in regard to the moving projection of the ring will deviate from their original course, in consequence of currents induced in the Earth's crust, in proportion to the rate of motion and the conductivity of the crust.

In case the path of the primary current is not a ring and we are dealing with a system of currents inclosing various centra, the lines of flow will be less and less concentric with those of equal vertical force, the more intricate the system.

According to the results obtained in this paper we may suppose as a first approximation, that the daily field of disturbing force is generated by the existence of a system of current rings inclosing eight foci. As the horizontal vectors point to the foci of maximum component, directed to the zenith, this system of currents, according to Ampère's rule, must be situated chiefly outside the Earth.

When a current ring moves centrally over a place, the influence of current induced in the Earth is such, that the extreme value of the vertical component for that place occurs after the moment the center passes, the horizontal component vanishing before this moment. From the representation of the field for the Arctic cap, we may conclude, that the negative focus and the minimum (-47γ) of vertical component are related in a contrary way, the latter preceding the former. For the positive region of vertical component the double focus makes any result ambiguous. In how far this may be understood as an objection to the hypothesis of electric currents is quite uncertain.

Schuster remarks that the course of the equipotential lines of his field of diurnal variation will deviate only slightly from the lines of electric flow, which may be supposed to be the cause of the production of the field. Hence we are allowed to compare directly the lines of equal vertical force drawn here for the field of disturbance, with the equipotential lines of the field of diurnal variation as it has been constructed by von Bezold¹ based on Schuster's calculations.

The most striking difference may be said to be, that the areas of positive and negative potential of diurnal variation are approximately bisected by the meridians of noon and midnight whereas the areas of upward and downward disturbing force are approximately bisected by the line of separation of day and night.

Finally it is to be remarked, that the foci of the Northern Hemisphere are strongest in the summer; a computation for Jan Meyer gives a considerable reduction for winter.

It is indeed desirable to extend the investigation of the diurnal variation field over the polar regions, but in these regions, though the use of quiet days may have great advantage, as shown by Lüdeling in the paper quoted above, the phenomena still remain

¹*Sitzungsberichte der Akademie zu Berlin*, 1897, p. 271. Tafel III.

See *T. M.*, Vol. IV, p. 48, or Vol. III, p. III.

rather intricate. Besides a day selected in the usual way as a quiet one is not to be considered as entirely free from disturbance.

To prove this 26 couples of successive days for the summer months have been chosen out of the days selected by Wild as quiet ones for Petersburg-Pawlowsk. They are:

1873 June 7—8	1886 Aug. 22—23	1896 July 23—24
" 22—23	1887 June 14—15	1897 Aug. 27—28
1877 June 2—3	Aug. 11—12	1898 July 17/18—18/19
" 3—4	1888 July 13—14	1899 June 6/7—7/8
1882 July 14—15	Aug. 10—11	July 28—29
1883 June 4—5	1890 Aug. 30—31	Aug. 11—12
July 21—22	1891 June 12—13	" 15/16—16/17
" 22—23	1893 Aug. 27—28	" 18—19
" 28—29	1895 June 25—26	

The differences of corresponding hourly values of H and D have been taken for each couple and the mean difference for each hour has been calculated. By means of the latter the diagram of the horizontal differential vector has been constructed, which proved to be quite regular and to rotate clockwise, i. e., in the same direction, which is preponderant in the daily diagram of the disturbing vector. This points to the existence of disturbing vectors during such days as are considered to be undisturbed.

These hourly values, mentioned above, expressed in 0.00001 C. G. S. are:

Hour	1	2	3	4	5	6	7	8	9	10	11	Noon
HdD	0.1	0.8	-0.4	-1.1	0.3	0.7	0.1	1.3	2.1	2.5	0.8	1.2
dH	-2.0	-1.2	-1.1	-0.5	-1.6	-2.9	-2.1	-1.1	0.9	2.5	0.5	0.9

Hour	1	2	3	4	5	6	7	8	9	10	11	Midnight
HdD	-0.7	-1.2	-1.7	-1.3	-2.4	-5.1	-1.1	-1.4	-0.7	-0.1	2.2	1.0
dH	1.8	1.4	1.6	2.2	0.3	0.2	-0.6	-4.1	0.1	-1.2	-1.4	-0.9

Dr. Fritsche, in his paper on the diurnal variation of the magnetic elements,¹ has extended the computation of the potential function over the polar regions, but I think his results for these parts of the globe are not trustworthy. He makes use of the data for Arctic stations calculated for all days, taking the average diurnal variation for these stations, divided into two groups, viz., Polhem,

¹Die tägliche Periode der erdmagnetischen Elemente. *St. Petersburg*, 1902.

Cape Thordsen, Ssagastyr, Karmakul, Point Barrow, and Jan Mayen, Bossekop, Kingua Fjord, Fort Rae. From what has been found in this paper with regard to the disturbing phenomenon, it is evident that the diurnal variation derived in the manner stated is different for Arctic and for non-Arctic stations, the result from the former stations deviating strongly from what is understood to be the true solar-diurnal variation. No doubt the great differences in the elements observed at Arctic stations from those calculated by Fritsche are due to his data having been derived without excluding days of disturbances.