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XI. *Note on an Extension of the Comparison of Magnetic Disturbances with Magnetic Effects inferred from observed Terrestrial Galvanic Currents; and Discussion of the Magnetic Effects inferred from Galvanic Currents on days of Tranquil Magnetism.*

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IN a communication to the Royal Society, which was honoured by publication in the Philosophical Transactions for 1868, I described the methods and gave the results of comparing the Magnetic Disturbances which might be expected as consequent on the Terrestrial Galvanic Currents recorded by the self-registering galvanometers of the Royal Observatory of Greenwich, with the Magnetic Disturbances actually registered by the self-registering magnetometers. The comparison was limited to seventeen days (1865, October 5 and 31; 1866, October 4; 1867, April 4, 5, 7, 8, 9, 11, May 4, 14, 28, 31, June 1, 2, 7, 24), various days having been omitted in consequence of a doubt on the uniformity of the clock-movement of the registering-barrel, which afterwards proved to be unfounded. The results of the comparison were exhibited in curves, engraved copies of which are given in the volume of publication. I expressed my opinion that it was impossible to doubt the general causal connexion of the Galvanic Currents with the Magnetic Disturbances, but that some points yet remained to be cleared up.

As soon as circumstances permitted, I undertook the examination of the whole of the Earth-currents recorded during the establishment of the Croydon and Dartford Wires (namely from 1865 April 1 to 1867 December 31), as far as they should appear to bear upon this and similar questions. For this purpose the days of observation were divided by Mr. GLAISHER into three groups. Group No. 1 contained days of considerable magnetic disturbance (or days of considerable galvanic disturbance, which are always the same), including, besides the seventeen days above-mentioned, the thirty-six days of the following list:—1865, April 15, 16, 17, 18, 19, May 14, 17, July 7, 15, August 14, 19, 26, September 8, 16, 28, October 4, 6, 10, 12, 14, November 1; 1866, August 11, 23, September 8, 9, 12, 13, 17, 18, 25, October 6, 7, 10, 30, November 26; 1867, February 8; making in all fifty-three days of considerable magnetic disturbance. Group No. 2 consisted of days of moderate magnetic disturbance, and of these no further notice was taken. Group No. 3 contained the days of tranquil magnetism, and the discussion of these will form the principal part of the present Memoir.

The comparisons of the additional thirty-six disturbed days were made in every respect by the same process as those of the seventeen days in the former paper; the operations of every kind were directed, as before, by Mr. GLAISHER; and the results are exhibited in the same way, in curves, drawn with great care by Mr. WILLIAM CARPENTER NASH, Assistant in the Magnetical and Meteorological Department of the Royal Observatory. While submitting these curves to the examination of the Royal Society, as presenting to the Society the evidence on which conclusions as to the relation between the galvanic currents and the magnetic disturbances must rest, I remark that the class and completeness of the evidence which they afford appear to be precisely similar to those offered by the curves appended to the First Memoir, and that the necessity for multiplying copies of them is not, perhaps, very pressing.

The conclusions arrived at in the former investigation were these:—

1. The general agreement of the curves, especially in the bold inequalities, is very striking; particularly in the curves relating to Northerly Force.

2. The small irregularities in the curves of galvanic origin are more numerous than those in the curves of magnetic origin.

3. The irregularities in the curves of galvanic origin usually precede, in time, those of magnetic origin, especially as regards Westerly Force.

4. The proportions of the magnitudes of rise and fall in the curves often differ sensibly, especially as regards Westerly Force.

5. The Northerly Force appears, on these days of magnetic storms, to be increased; whereas general experience leads us to expect that it would be diminished.

These conclusions are all supported by examination of the curves formed from the new investigations; I am still unable to suggest any explanation of the 2nd, 3rd, and 4th, and I still offer them as subjects worthy of the most careful inquiry. In considering the possibility of explaining any of them by instrumental causes, it appeared to me that the only one, for the effects of which there could be any opening, is, fault in the Declination-Magnetometer. By the courtesy of the Committee of the Kew Observatory, I was permitted to compare the Greenwich Declination-Photograms with the Kew Declination-Photograms, and I found them absolutely identical. I therefore abandon the expectation of explaining the conclusions as the effect of instrumental error.

On the 5th conclusion, much light will be thrown by the examination of the phenomena of days of tranquil magnetism.

I now proceed with the discussion of the curves exhibited by the Earth-current Photograms on days of tranquil magnetism. No comparison was made here between the results of the Earth-current Curves and the Magnetometer Curves; my object being merely to examine the laws, as regards diurnal inequality, of the Terrestrial Galvanic Currents, or rather of the Northerly and Westerly Magnetic Forces which those currents might be expected to produce.

It was necessary that the process to be employed should be precisely equivalent to that used on the days of magnetic disturbance; but there was advantage in changing the form. For, where every individual disturbance was to be depicted, it was necessary to measure every individual ordinate by two different scales; here, where the mean of results for the same nominal hour on numerous days was to be used, it was better to measure the ordinate (whether of the curve or of the zero formed by breaking connexions) by one scale (a scale of inches was in fact used); to take the means of all corresponding to the same hour; and then to multiply the means by the two factors obtained from the theory explained in the former paper. This being done for the two Galvanic Curves, the results were combined in the way explained in the former paper to exhibit the Inferred Northerly Force and the Inferred Westerly Force.

The general multiplier of the geometrical factors used in the former investigation was determined tentatively, to satisfy this condition, that on the whole the magnitudes of the sudden changes of the large ordinates of the curves representing Inferred Northerly Force and Inferred Westerly Force should be sensibly equal to the similar magnitudes in the curves given by the Magnetometers. Considering it as proved that the great disturbances are really produced by the galvanic currents, it is evident that we have thus a fairly accurate scale for converting galvanic indications into magnetic forces (referred, as is done all through, to the total horizontal magnetic force as unit), which will also apply accurately to the days of tranquil magnetism. Also, the zero-indications being formed in the same way for the disturbed and the tranquil days, any error which we may discover in the zeros for tranquil days, or in the references of the ordinates to those zeros, will apply to the zeros or references of disturbed days.

I now proceed with the numerical treatment of the observations of the tranquil days.

The readings in inch-measures of the galvanic ordinates for each nominal hour being grouped by months, and, where there were observations in the same months in different years, the different years being combined, the means were taken, and were converted into Magnetic Forces by the following formulæ:—

In the scale of Horizontal-Force Photograms, 0·01 of Horizontal Force is represented by 2·3565 inches (Introduction to Greenwich Magnetical and Meteorological Observations, 1866 and 1867); and for the graduation of "Scale E for Dartford," the value $\frac{1}{e}\times$graduation of Horizontal-Force Photogram (Phil. Trans. 1868, p. 470), or $\frac{2\cdot3565 \text{ inches}}{0\cdot68259\times0\cdot5437}$ (p. 469) must be used. This number reduced gives for Scale E for Dartford,

$$0\cdot01 \text{ of Horizontal Force}=6\cdot350 \text{ inches.}$$

Similarly, for Scale F for Croydon,

$$0\cdot01 \text{ of Horizontal Force}=7\cdot768 \text{ inches.}$$

For Scale G for Dartford,

$$0\cdot01 \text{ of Horizontal Force}=5\cdot471 \text{ inches.}$$

For Scale H for Croydon,

$$0\cdot01 \text{ of Horizontal Force}=4\cdot901 \text{ inches.}$$

With these elements, Tables were prepared for converting inch-measures into measures of Horizontal Force. In the original adaptation to base-lines below the photographic curves, the measures with E and F, both used negatively, were to be added, to form

Northerly Magnetic Tendency; and the measures with G taken positively and H taken negatively were to be added, to form Westerly Magnetic Tendency. In the present operations, in which all measures were taken from the photographic base-lines, which reversed the direction of measure for Croydon, E was to be applied to the complement of actual measure of ordinate to 5 inches, and F, G, H to the actual measures of ordinates. I have entered into these minutiæ with the view of facilitating any future reference to the calculations* preserved in the Royal Observatory.

The reading for the zero of each curve (or the indication when the galvanic communications are broken) is found by taking the mean of a group of such zeros, as far as there appears to be no probability of instrumental change; and these readings are treated in the same way as those for the ordinates of the curves. Subtracting these mean zeros from the mean monthly ordinates at each nominal hour, the first Tables of Hourly indications of the Magnetic Effect of Galvanic Currents are formed. It is important to observe that all the numbers have the positive sign.

It will be remarked that, in a few instances, the register has been defective at one or two hours; in those cases it has been thought best still to use the registered hours, though imperfect in number, in the formation of means. The number of days employed to form the means for different hours is thus somewhat variable, as is indicated by the list at the bottom of the Tables. The "Means for the whole day" will appear again, in a following Table, and will explain an important difficulty.

* In the original calculations, by a mistake, E was applied to the actual measures of ordinates, and F, G, H to the complements of measure to 5 inches. The error was corrected by changing the signs of all the ultimate results.

TABLE I.

Hour. Greenwich Mean Solar Time.	Magnetic Tendencies to the North, inferred from the Monthly Means of Galvanic Currents at every hour of the day, expressed in terms of the Total Horizontal Magnetic Force.											
	1866 and 1867.	1867.		1865 and 1867.	1866 and 1867.		1865, 1866, and 1867.					
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
0	+0·00046	+0·00056	+0·00069	+0·00062	+0·00050	+0·00044	+0·00053	+0·00063	+0·00062	+0·00047	+0·00035	+0·00038
1	46	69	74	56	51	49	55	65	59	50	40	39
2	48	70	76	56	56	51	57	65	61	51	42	39
3	50	73	77	56	47	49	52	63	60	45	44	40
4	50	70	77	56	50	51	54	65	57	49	48	40
5	46	72	76	58	53	50	57	66	59	51	47	42
6	47	72	69	55	51	49	60	62	62	47	41	39
7	43	65	77	52	46	44	56	59	54	49	34	35
8	42	60	68	49	39	44	48	52	52	40	35	34
9	38	48	67	39	34	34	41	48	45	47	34	35
10	36	48	67	41	34	30	30	45	46	38	36	34
11	35	48	68	38	32	34	30	47	46	41	36	34
12	30	52	64	42	33	35	30	42	46	37	34	34
13	43	55	61	43	37	33	35	48	48	38	39	38
14	44	59	62	45	36	35	37	49	48	39	40	41
15	45	61	65	44	37	35	39	49	50	42	42	42
16	57	59	64	43	37	35	38	52	54	45	42	42
17	55	60	66	43	35	33	37	49	51	43	42	44
18	50	58	66	39	34	31	36	43	46	41	40	42
19	50	57	61	34	29	26	32	38	39	36	36	41
20	42	53	57	30	27	27	29	35	35	34	29	38
21	39	48	53	31	29	28	29	37	35	30	29	34
22	35	51	59	41	33	30	38	45	44	38	33	35
23	32	53	63	50	45	34	52	57	58	45	35	36
Means for the whole day...	+0·00044	+0·00059	+0·00067	+0·00046	+0·00040	+0·00038	+0·00043	+0·00052	+0·00051	+0·00043	+0·00038	+0·00038
Number of Measures employed in forming the Means for each Hour.												
Dartford Line...	36 to 40	21 to 23	24 to 28	38 to 45	34 to 41	55 to 58	54 to 58	46 to 51	47 to 50	40 to 49	32 to 38	56 to 58
Croydon Line...	35 to 40	20 to 23	26 to 28	39 to 47	49 to 54	53 to 57	53 to 61	44 to 60	45 to 52	43 to 57	53 to 67	58 to 63

TABLE II.

Hour. Greenwich Mean Solar Time.	Magnetic Tendencies to the West, inferred from the Monthly Means of Galvanic Currents at every hour of the day, expressed in terms of the Total Horizontal Magnetic Force.											
	1866 and 1867.	1867.		1865 and 1867.	1866 and 1867.		1865, 1866, and 1867.					
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
0	+0·00141	+0·00158	+0·00163	+0·00131	+0·00127	+0·00104	+0·00122	+0·00135	+0·00131	+0·00119	+0·00122	+0·00131
1	142	172	164	129	130	111	123	138	128	118	134	133
2	138	166	161	121	132	109	122	132	122	116	133	130
3	141	166	156	118	119	104	112	127	120	103	133	131
4	139	160	154	120	125	106	113	129	114	110	132	134
5	136	164	155	120	126	103	116	128	117	111	132	136
6	139	165	141	120	122	100	118	123	115	103	127	129
7	132	152	153	112	111	93	113	116	99	102	115	122
8	128	139	143	112	104	92	102	110	94	94	117	120
9	123	123	139	94	93	78	90	99	89	101	111	122
10	123	123	139	95	93	75	75	95	90	91	117	123
11	116	124	145	91	90	79	77	95	90	97	115	122
12	110	125	140	94	92	81	75	88	90	97	115	123
13	131	130	135	93	95	80	80	96	98	95	123	127
14	133	138	136	97	94	82	84	99	96	97	123	130
15	138	144	140	93	96	84	86	99	97	102	123	131
16	147	140	136	98	96	83	86	104	105	104	126	134
17	147	142	138	94	94	81	81	102	102	105	125	136
18	143	141	139	85	91	77	81	98	95	104	124	136
19	141	140	132	79	86	71	79	93	85	97	120	133
20	129	132	126	72	84	71	77	89	85	95	112	130
21	130	126	125	80	90	78	82	93	88	90	113	126
22	126	135	136	97	99	84	96	107	103	105	116	130
23	123	142	144	111	119	93	115	123	122	119	120	128
Means for the whole day...	+0·00133	+0·00144	+0·00143	+0·00102	+0·00105	+0·00088	+0·00096	+0·00109	+0·00103	+0·00103	+0·00122	+0·00129
Number of Measures employed in forming the Means for each Hour.												
Dartford Line...	36 to 40	21 to 23	24 to 28	38 to 45	34 to 41	55 to 58	54 to 58	46 to 51	47 to 50	40 to 49	32 to 38	56 to 58
Croydon Line...	35 to 40	20 to 23	26 to 28	39 to 47	49 to 54	53 to 57	53 to 61	44 to 60	45 to 52	43 to 57	53 to 67	58 to 63

On constructing curves of each month, with the northerly and westerly tendencies for coordinates, it appeared desirable to eliminate some of the irregularities by a systematic process. The numbers in each ordinate, for any month, being arranged in order, and extended as necessary by repetition of the first terms of the series, the means of adjacent numbers were taken to form a second series; the means of adjacent numbers of the second series to form a third series, and so on. This operation was repeated six times. It will be proper to examine the effect of this process upon periodical terms of different orders.

The inequalities which we seek being essentially periodical with respect to one day, the expression for the inequality at the pth hour may be expressed in the form

$$\left\{\begin{matrix}+a_1 \text{ cosine} \\ +b_1 \text{ sine}\end{matrix}\right\} p\times 15^\circ + \left\{\begin{matrix}+a_2 \text{ cosine} \\ +b_2 \text{ sine}\end{matrix}\right\} 2p\times 15^\circ + \left\{\begin{matrix}+a_3 \text{ cosine} \\ +b_3 \text{ sine}\end{matrix}\right\} 3p\times 15^\circ + \&c.$$

$$+\left\{\begin{matrix}+a_n \text{ cosine} \\ +b_n \text{ sine}\end{matrix}\right\} np\times 15^\circ.$$

Confining our attention to the cosine of the general term; three successive terms in the series for hours, for the $p-1$ hour, the p hour, and the $p+1$ hour, will be

$$a_n \text{ cosine } \{np\times 15^\circ - n\times 15^\circ\}$$
$$a_n \text{ cosine } \{np\times 15^\circ\}$$
$$a_n \text{ cosine } \{np\times 15^\circ + n\times 15^\circ\};$$

then, taking the means of the adjacent terms, and again taking their means, we arrive by this double operation at the expression

$$a_n . (\text{cosine } \{n\times 7^\circ\ 30'\})^2 \times \text{ cosine } \{np\times 15^\circ\}.$$

And, repeating the operation six times, we obtain

$$a_n . (\text{cosine } \{n\times 7^\circ\ 30'\})^6 \times \text{ cosine } \{np\times 15^\circ\}.$$

The argument $np\times 15^\circ$ remains unaltered; but the coefficient is diminished, not much for $n=1$, but very much when n is large, as for instance, $=8$; which makes

$$(\text{cosine } \{n\times 7^\circ\ 30'\})^6 = \tfrac{1}{64}.$$

It appears therefore that the effect of this process is, practically to annihilate the advanced terms of the series, and to diminish the earlier terms in different degrees. And, when we have formed a smoothed series by the process described, and resolve it into terms depending on the arguments $p\times 15^\circ$, $2p\times 15^\circ$, $3p\times 15^\circ$, &c., we must, in order to find the terms of the same kind in the original or unsmoothed series, multiply the terms found by the following factors:

The first, by $(\text{secant } 7^\circ\ 30')^6$;
The second, by $(\text{secant } 15^\circ)^6$;
The third, by $(\text{secant } 22^\circ\ 30')^6$;

and so on. And the effects of these ought, if possible, to be introduced into the curves which we may form, using the smoothed terms for ordinates; an introduction, however, which will not in practice be easy.

The two following Tables are formed by smoothing the numbers in Tables I. and II., by the process described above.

Table III.

Magnetic Tendencies to the North, formed by smoothing the numbers of Table I.
The unit is 0·00001 of Total Horizontal Magnetic Force, and the sign is everywhere positive.

Hour. Greenwich Mean Solar Time.	1866 and 1867.	1867.		1865 and 1867.	1866 and 1867.		1865, 1866, and 1867.					
	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.
0	42	59	68	55	48	42	52	60	58	47	37	37
1	45	65	72	57	51	47	54	63	60	48	39	39
2	48	69	75	57	51	49	55	64	60	49	42	39
3	49	71	76	56	51	50	55	64	59	49	44	40
4	48	71	76	56	51	50	55	64	59	49	45	40
5	47	71	75	56	51	49	56	64	59	49	44	40
6	46	69	73	54	49	47	56	61	58	48	41	38
7	44	64	72	51	45	45	53	57	55	46	37	37
8	41	58	70	47	40	41	47	53	51	45	35	35
9	39	53	68	43	36	37	41	49	48	43	35	35
10	37	50	67	41	34	34	35	47	47	41	35	34
11	35	50	66	41	34	33	32	46	46	39	36	35
12	37	52	65	41	34	34	32	46	47	39	37	36
13	40	55	63	43	35	34	34	47	48	39	38	38
14	44	58	63	44	36	35	36	48	49	40	40	40
15	48	59	64	44	37	35	37	49	50	42	41	41
16	52	59	65	43	36	34	37	49	51	43	41	42
17	53	59	65	41	35	33	37	47	49	42	41	42
18	51	58	63	38	33	30	35	43	45	40	39	42
19	47	56	61	35	31	29	33	40	41	37	35	40
20	43	53	58	33	29	28	32	38	39	35	32	38
21	39	51	57	36	31	29	34	41	40	35	31	36
22	37	52	59	42	36	32	40	47	46	38	33	36
23	38	55	64	49	42	37	47	54	53	43	35	37

Table IV.

Magnetic Tendencies to the West, formed by smoothing the numbers of Table II.
The unit is 0·00001 of Total Horizontal Magnetic Force, and the sign is everywhere positive.

Hour. Greenwich Mean Solar Time.	1866 and 1867.	1867.		1865 and 1867.	1866 and 1867.		1865, 1866, and 1867.					
	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.
0	135	156	155	121	123	101	117	129	124	117	125	131
1	139	163	160	124	127	106	120	133	125	116	129	131
2	140	166	160	123	127	107	119	132	123	113	132	131
3	139	165	157	121	125	106	116	130	120	110	133	132
4	139	163	154	120	124	105	115	128	117	109	132	133
5	137	162	151	119	123	102	115	126	114	107	129	132
6	135	158	149	117	119	99	114	121	109	105	125	129
7	132	150	147	113	111	94	109	116	103	101	120	125
8	128	139	144	107	104	88	101	109	96	98	116	122
9	125	130	142	100	97	83	91	102	92	97	115	122
10	121	125	141	95	93	79	82	97	91	96	115	122
11	119	125	141	93	92	79	78	95	91	96	116	123
12	120	127	139	93	93	80	78	94	93	96	118	125
13	126	131	138	94	94	81	80	95	95	97	120	127
14	133	136	137	95	95	82	83	98	97	99	123	129
15	139	140	137	95	95	83	85	100	99	101	124	132
16	143	141	138	94	95	82	85	103	100	103	125	133
17	144	141	137	91	93	80	83	105	99	103	124	135
18	142	140	134	86	91	77	81	102	94	101	122	134
19	138	137	132	81	88	74	80	96	90	99	119	133
20	133	134	130	80	89	75	81	94	92	96	116	130
21	129	133	131	86	94	79	87	99	95	99	115	129
22	129	137	137	97	103	85	98	109	105	105	117	129
23	131	146	147	111	114	94	109	120	117	113	120	129

The next step of treatment was, to resolve the series of terms for each month into a diurnal, a semidiurnal, and a tertio-diurnal series. With such numbers as we have here before us, I have found the following process very convenient. I take the numbers for the Westerly Inequality in January as an example.

Arrange the numbers in two columns, 0^h to 11^h and 12^h to 23^h, side by side, take the difference of corresponding numbers for double diurnal, and the sum (when corrected by subtracting its mean) for double semidiurnal. For convenience, the numbers may be left in the double form. Half the mean above-mentioned will be the true mean of the twenty-four hours.

Hours.		Westerly Tendencies.		Differences for double diurnal.		Sums for double semidiurnal.	
						Uncorrected.	Corrected.
0	12	35	20	+15	−15	55	−11
1	13	39	26	+13	−13	65	− 1
2	14	40	33	+ 7	− 7	73	+ 7
3	15	39	39	0	0	78	+12
4	16	39	43	− 4	+ 4	82	+16
5	17	37	44	− 7	+ 7	81	+15
6	18	35	42	− 7	+ 7	77	+11
7	19	32	38	− 6	+ 6	70	+ 4
8	20	28	33	− 5	+ 5	61	− 5
9	21	25	29	− 4	+ 4	54	−12
10	22	21	29	− 8	+ 8	50	−16
11	23	19	31	−12	+12	50	−16
				Mean		66	
				Half, or mean of the 24 hours		33	

The tertio-diurnal term will contribute no part to the semidiurnal, but it will contribute a part to the diurnal. To find its value, arrange the diurnal terms (which I shall now call 'uncorrected') in three columns of eight hours each; take the means of the corresponding numbers, which will be the tertio-diurnal terms, and apply them negatively to correct the diurnal terms.

Hours.			Uncorrected double diurnal.			Sums.	Means or double tertio-diurnal.	Corrected double diurnal.		
0	8	16	+15	− 5	+ 4	+14	+5	+10	−10	− 1
1	9	17	+13	− 4	+ 7	+16	+5	+ 8	− 9	+ 2
2	10	18	+ 7	− 8	+ 7	+ 6	+2	+ 5	−10	+ 5
3	11	19	0	−12	+ 6	− 6	−2	+ 2	−10	+ 8
4	12	20	− 4	−15	+ 5	−14	−5	+ 1	−10	+10
5	13	21	− 7	−13	+ 4	−16	−5	− 2	− 8	+ 9
6	14	22	− 7	− 7	+ 8	− 6	−2	− 5	− 5	+10
7	15	23	− 6	0	+12	+ 6	+2	− 8	− 2	+10

A quarto-diurnal series would readily be formed from the semidiurnal series by the same process by which we have formed the semidiurnal from the original numbers; and the semidiurnal would be corrected as in the operation for correcting the diurnal. But the numbers would be small, and would scarcely repay the trifling trouble.

The numbers thus found ought to be multiplied by 0·5; and then the diurnal numbers ought to be multiplied by $(\text{secant } 7^\circ\ 30')^6$, the semidiurnal numbers by $(\text{secant } 15^\circ)^6$, the tertio-diurnal numbers by $(\text{secant } 22^\circ\ 30')^6$.

The following Tables exhibit all the results.

TABLE V.—Diurnal Magnetic Inequality in North Direction, inferred from Galvanic Earth-Currents. The unit is 0·00001 of Total Horizontal Magnetic Force.

Hours.	1866 and 1867. January.	1867. February.	1867. March.	1865 and 1867. April.	1866 and 1867. May.	1866 and 1867. June.	1865 to 1867. July.	1865 to 1867. August.	1865 to 1867. September.	1865 to 1867. October.	1865 to 1867. November.	1865 to 1867. December.
Mean of the Inequality for the twenty-four hours.												
	+44	+59	+67	+46	+40	+38	+43	+52	+51	+43	+38	+38
Simple Diurnal Inequality (to be multiplied by 0·526).												
0	+ 3	+ 7	+ 2	+ 9	+11	+ 6	+14	+ 9	+ 6	+ 4	0	+ 1
1	+ 1	+10	+ 6	+12	+14	+11	+17	+14	+ 9	+ 6	0	0
2	+ 1	+12	+ 9	+14	+16	+14	+21	+17	+11	+ 8	+ 1	− 1
3	+ 1	+12	+11	+16	+17	+17	+24	+18	+13	+ 9	+ 2	− 1
4	− 2	+12	+12	+18	+18	+18	+24	+20	+13	+10	+ 4	− 2
5	− 2	+12	+13	+17	+18	+18	+22	+19	+13	+10	+ 4	− 1
6	− 2	+10	+13	+15	+15	+17	+19	+17	+13	+ 9	+ 3	− 4
7	− 3	+ 8	+12	+12	+11	+14	+14	+14	+10	+ 7	+ 3	− 3
8	− 4	+ 5	+11	+ 9	+ 8	+11	+ 9	+10	+ 7	+ 6	+ 3	− 3
9	− 4	+ 2	+ 8	+ 5	+ 3	+ 6	+ 4	+ 6	+ 5	+ 5	+ 3	− 2
10	− 3	− 1	+ 5	0	− 1	+ 2	− 3	+ 1	+ 1	+ 2	+ 1	− 2
11	− 3	− 5	+ 1	− 4	− 5	− 2	− 9	− 5	− 3	− 2	0	− 2
12	− 3	− 7	− 2	− 9	−11	− 6	−14	− 9	− 6	− 4	0	− 1
13	− 1	−10	− 6	−12	−14	−11	−17	−14	− 9	− 6	0	0
14	− 1	−12	− 9	−14	−16	−14	−21	−17	−11	− 8	− 1	+ 1
15	− 1	−12	−11	−16	−17	−17	−24	−18	−13	− 9	− 2	+ 1
16	+ 2	−12	−12	−18	−18	−18	−24	−20	−13	−10	− 4	+ 2
17	+ 2	−12	−13	−17	−18	−18	−22	−19	−13	−10	− 4	+ 1
18	+ 2	−10	−13	−15	−15	−17	−19	−17	−13	− 9	− 3	+ 4
19	+ 3	− 8	−12	−12	−11	−14	−14	−14	−10	− 7	− 3	+ 3
20	+ 4	− 5	−11	− 9	− 8	−11	− 9	−10	− 7	− 6	− 3	+ 3
21	+ 4	− 2	− 8	− 5	− 3	− 6	− 4	− 6	− 5	− 5	− 3	+ 2
22	+ 3	+ 1	− 5	0	+ 1	− 2	+ 3	− 1	− 1	− 2	− 1	+ 2
23	+ 3	+ 5	− 1	+ 4	+ 5	+ 2	+ 9	+ 5	+ 3	+ 2	0	+ 2
Semidiurnal Inequality (to be multiplied by 0·616).												
0 12	− 9	− 7	− 1	+ 4	+ 2	0	− 1	+ 3	+ 3	0	+ 2	− 3
1 13	− 3	+ 2	+ 1	+ 8	+ 6	+ 5	+ 3	+ 7	+ 6	+ 1	+ 1	+ 1
2 14	+ 4	+ 9	+ 4	+ 9	+ 7	+ 8	+ 6	+ 9	+ 7	+ 3	+ 6	+ 3
3 15	+ 9	+12	+ 6	+ 8	+ 8	+ 9	+ 7	+10	+ 7	+ 5	+ 9	+ 5
4 16	+12	+12	+ 7	+ 7	+ 7	+ 8	+ 7	+10	+ 8	+ 6	+10	+ 6
5 17	+12	+12	+ 6	+ 5	+ 6	+ 6	+ 8	+ 8	+ 6	+ 5	+ 9	+ 6
6 18	+ 9	+ 9	+ 2	0	+ 2	+ 1	+ 6	+ 1	+ 1	+ 2	+ 4	+ 4
7 19	+ 3	+ 2	− 1	− 6	− 4	− 2	+ 1	− 6	− 6	− 3	− 4	+ 1
8 20	− 4	− 7	− 6	−12	−11	− 7	− 6	−12	−12	− 6	− 9	− 3
9 21	−10	−14	− 9	−13	−13	−10	−10	−13	−14	− 8	−10	− 5
10 22	−14	−16	− 8	− 9	−10	−10	−10	− 9	− 9	− 7	− 8	− 6
11 23	−15	−13	− 4	− 2	− 4	− 6	− 6	− 3	− 3	− 4	− 5	− 4
Tertio-diurnal Inequality (to be multiplied by 0·804).												
0 8 16	+ 2	0	+ 1	+ 5	+ 3	+ 2	+ 6	+ 5	+ 5	+ 4	0	0
1 9 17	+ 4	0	+ 3	+ 2	+ 2	+ 2	+ 3	+ 2	+ 3	+ 3	+ 1	+ 1
2 10 18	+ 3	− 1	+ 3	− 1	− 1	0	− 2	− 1	0	+ 1	+ 1	0
3 11 19	0	0	+ 1	− 4	− 3	− 2	− 6	− 3	− 4	− 2	+ 1	0
4 12 20	− 2	0	− 1	− 5	− 3	− 2	− 6	− 5	− 5	− 4	0	0
5 13 21	− 4	0	− 3	− 2	− 2	− 2	− 3	− 2	− 3	− 3	− 1	− 1
6 14 22	− 3	+ 1	− 3	+ 1	+ 1	0	+ 2	+ 1	0	− 1	− 1	0
7 15 23	0	0	− 1	+ 4	+ 3	+ 2	+ 6	+ 3	+ 4	+ 2	− 1	0

TABLE VI.—Diurnal Magnetic Inequality in West Direction, inferred from Galvanic Earth-Currents. The unit is 0·00001 of Total Horizontal Magnetic Force.

Hours.	1866 and 1867. January.	1867. February.	1867. March.	1865 and 1867. April.	1866 and 1867. May.	1866 and 1867. June.	1865 to 1867. July.	1865 to 1867. August.	1865 to 1867. September.	1865 to 1867. October.	1865 to 1867. November.	1865 to 1867. December.
Mean of the Inequality for the twenty-four hours.												
	+133	+144	+143	+103	+105	+88	+96	+110	+103	+103	+122	+129
Simple Diurnal Inequality (to be multiplied by 0·526).												
0	+10	+25	+11	+18	+25	+17	+29	+27	+25	+15	+ 7	+7
1	+ 8	+29	+16	+25	+31	+23	+36	+31	+26	+15	+ 8	+4
2	+ 5	+30	+19	+30	+34	+26	+40	+33	+27	+14	+ 8	+2
3	+ 2	+28	+20	+34	+35	+27	+41	+35	+27	+12	+ 8	−1
4	+ 1	+26	+21	+36	+34	+27	+40	+33	+23	+12	+ 7	−1
5	− 2	+24	+20	+33	+32	+24	+36	+28	+19	+ 8	+ 6	−3
6	− 5	+18	+19	+29	+26	+21	+29	+20	+14	+ 4	+ 4	−5
7	− 8	+10	+15	+24	+18	+16	+19	+15	+ 7	− 1	+ 2	−7
8	−10	+ 1	+ 9	+17	+10	+ 9	+10	+ 7	− 2	− 4	0	−7
9	− 9	− 6	+ 5	+ 9	+ 1	+ 2	0	− 4	− 7	− 6	− 1	−7
10	−10	−12	0	0	− 8	− 5	−12	−13	−13	− 9	− 3	−7
11	−10	−18	− 6	−10	−17	−11	−21	−20	−20	−14	− 5	−7
12	−10	−25	−11	−18	−25	−17	−29	−27	−25	−15	− 7	−7
13	− 8	−29	−16	−25	−31	−23	−36	−31	−26	−15	− 8	−4
14	− 5	−30	−19	−30	−34	−26	−40	−33	−27	−14	− 8	−2
15	− 2	−28	−20	−34	−35	−27	−41	−35	−27	−12	− 8	+1
16	− 1	−26	−21	−36	−34	−27	−40	−33	−23	−12	− 7	+1
17	+ 2	−24	−20	−33	−32	−24	−36	−28	−19	− 8	− 6	+3
18	+ 5	−18	−19	−29	−26	−21	−21	−20	−14	− 4	− 4	+5
19	+ 8	−10	−15	−24	−18	−16	−19	−15	− 7	+ 1	− 2	+7
20	+10	− 1	− 9	−17	−10	− 9	−10	− 7	+ 2	+ 4	0	+7
21	+ 9	+ 6	− 5	− 9	− 1	− 2	0	+ 4	+ 7	+ 6	+ 1	+7
22	+10	+12	0	0	+ 8	+ 5	+12	+13	+13	+ 9	+ 3	+7
23	+10	+18	+ 6	+10	+17	+11	+21	+20	+20	+14	+ 5	+7
Semidiurnal Inequality (to be multiplied by 0·616).												
0 12	−11	− 4	+ 7	+ 9	+ 7	+ 4	+ 3	+ 4	+10	+ 7	− 1	−2
1 13	− 1	+ 7	+11	+13	+12	+10	+ 8	+ 9	+13	+ 7	+ 5	0
2 14	+ 7	+15	+10	+13	+13	+12	+10	+11	+13	+ 6	+11	+2
3 15	+12	+18	+ 7	+11	+11	+12	+ 9	+11	+12	+ 5	+13	+6
4 16	+16	+17	+ 5	+ 9	+10	+10	+ 8	+12	+10	+ 6	+13	+8
5 17	+15	+16	+ 1	+ 5	+ 7	+ 5	+ 6	+12	+ 6	+ 4	+ 9	+9
6 18	+11	+11	− 4	− 2	+ 1	− 1	+ 3	+ 4	− 4	0	+ 3	+5
7 19	+ 4	0	− 8	−11	−10	− 9	− 3	− 7	−14	− 6	− 5	0
8 20	− 5	−14	−13	−18	−16	−14	−10	−16	−19	−18	−12	−6
9 21	−12	−24	−14	−19	−18	−15	−14	−18	−20	−10	−14	−7
10 22	−16	−25	− 9	−13	−13	−13	−12	−13	−11	− 5	−12	−7
11 23	−16	−16	+ 1	− 1	− 3	− 4	− 5	− 4	+ 1	+ 3	− 8	−6
Tertio-diurnal Inequality (to be multiplied by 0·804).												
0 8 16	+ 5	+ 4	+ 5	+10	+ 5	+ 4	+10	+ 8	+ 6	+ 6	0	−1
1 9 17	+ 5	+ 3	+ 6	+ 5	+ 2	+ 2	+ 4	+ 7	+ 4	+ 4	+ 1	0
2 10 18	+ 2	0	+ 4	− 2	− 2	− 1	− 4	+ 1	− 1	0	+ 1	0
3 11 19	− 2	− 3	0	− 8	− 5	− 4	−10	− 5	− 6	− 3	+ 1	+1
4 12 20	− 5	− 4	− 5	−10	− 5	− 4	−10	− 8	− 6	− 6	0	+1
5 13 21	− 5	− 3	− 6	− 5	− 2	− 2	− 4	− 7	− 4	− 4	− 1	0
6 14 22	− 2	0	− 4	+ 2	+ 2	+ 1	+ 4	− 1	+ 1	0	− 1	0
7 15 23	+ 2	+ 3	0	+ 8	+ 5	+ 4	+10	+ 5	+ 6	+ 3	− 1	−1

It must be observed that the investigations of any one month are totally unconnected with the investigations of every other month. Bearing this in mind, and remarking the strong similarity in the laws of the numbers (under each division of the Table) in proceeding from month to month, with change in the magnitude of the numbers and small change in the epochs of the argument evidently depending on the season, it is impossible to doubt that these numbers are real, the true representation of a galvanic and consequent magnetic action, with remarkable diurnal variation, in the surface-materials of the earth.

In every month there is a constant term of considerable magnitude (in reference to the scale of forces before us) towards the North. Of the origin of this term we can give no certain account; but it may not improbably arise from the different oxidabilities of the terminal plates. The variations of magnitude probably depend on the changes which were made from time to time in the earth-connexions. In any case, there is no reason to doubt that the same term exists in the exhibition of forces on days of great disturbance. And, referring to the tabular values of these constant terms, and to the apparent increase of northern force in the disturbed days as measured by the scales at the sides of their diagrams, it will be seen that the magnitude of these constant terms fully explains the apparent increase in northerly force which was remarked in the discussion of the magnetic effects of earth-currents on the days of great disturbance. The last of the apparent anomalies, which exhibited itself in that discussion, is therefore entirely removed.

In every month there is a constant term of still greater magnitude towards the west. And, on referring to the diagrams applying to the days of great disturbance, it will be seen that there is in them a greater increase of force to the west, well corresponding in magnitude to that larger constant term.

The peculiarities of the law of diurnal inequality will be well seen in the diagrams attached to this paper. The general type of the curve is a double lobe, somewhat modified in one or two months, but always preserving the duplicity. It must be remembered that these curves, which are formed by use of the smoothed numbers, are slightly inaccurate in regard to the more rapid inequalities.

Neither in magnitude nor in law are these inequalities, consequent on the galvanic currents, competent to explain the ordinary diurnal inequalities of magnetism.

The discussion of the galvanic currents on the Croydon and Dartford Lines may now, perhaps, be considered as exhausted.