X. *On Magnetic Calms and Earth-Currents.*

By Charles V. Walker, *Esq.*, *F.R.S.*, *F.R.A.S.*

Received February 3,—Read February 13, 1862.

I use the word "calm" in a purely negative sense—not storm. For many months the earth has shown few marked signs of activity. Very few notable earth-currents have attracted attention since those of 1861, January 22 to 26, referred to in the last paragraph but one of my paper "On Magnetic Storms, &c.," read February 14*.

I had not proceeded far in the discussion of the results which form the subject of that communication, without discovering that I possessed close at hand, and under my immediate control, the means of verifying the conclusions to which I had arrived as to the general direction of earth-currents; of extending the observations to periods when the earth is free of signs from extraordinary activity; and of further pursuing my inquiries.

In sections 3 and 4 of Table XII.† I grouped together a series of observations; and in fig. 5 of Plate III. gave a graphic illustration of the same; and from those data deduced the approximate Direction of Earth-Currents; and determined the azimuth of the drift to be in turn about N.E. and S.W.

I was unable to include many cases in these sections of the Table. Simultaneous observations including both limiting lines were few; I was therefore glad to have so ready at hand the means of multiplying and modifying them. The groups of observations in the Table referred to were made on eight or nine different lines of telegraph, making various angles with the magnetic meridian; and were bounded on the one hand by the London-Tonbridge line, making an angle with the magnetic meridian of 13°W., and on the other hand by the Dover-London line, making an angle of 136° E., the two lines making with each other an angle of 149°; from which it could be deduced, and was shown, that the direction in which the currents moved was included within an arc of (180°−149°=)31°; and that this arc was situated midway between the lines in question (which are those set off on fig. 5, Plate III., and numbered there, as well as in Tables XI. and XII., 23 and 26 respectively), extending from 46° to 77° E. of magnetic north, or W. of magnetic south.

The Dover-London telegraph wires pass Tonbridge, where they enter my private office, being attached to a telegraph instrument placed there. This gives me the immediate command of the Dover-London line, numbered 26—25 in Table XI. p. 130, and in figs. 1 and 5, Plate III., and which is one of the limiting or boundary lines. By cutting off the communication with Dover, that is to say, by connecting the wire with

* Philosophical Transactions, 1861, p. 113.

† Ibid. 1861, p. 131.

the earth on the Dover side of Tonbridge, I obtain the other limiting line, London-Tonbridge, Nos. 23—24; or if the wires are connected with the earth on the London side of Tonbridge, I obtain the Dover-Tonbridge line. This is not given in my Table XI., but is very nearly identical with the Ashford-Tonbridge line there given, and numbered 32—31. It makes an angle of 118° E. with the magnetic meridian, and therefore falls, as shown in fig. 1, Plate III., intermediate between the other two, and incidentally is very useful in this investigation.

The earth-currents which form the subject of the present communication are not detected by the ordinary telegraph galvanometer. I have therefore prepared a small horizontal galvanometer. The coil is $2\frac{1}{4}$ inches long, $\frac{3}{4}$ of an inch wide, and $\frac{3}{4}$ of an inch high, and is filled with silk-covered copper wire, one yard of which weighs 5 grains; it is No. 35 of the Birmingham iron-wire gauge, corresponding to a diameter of $\frac{5}{640}$ inch. It is placed in the magnetic meridian. The needle is 1 inch in length, and carries a light index projecting from the E. side of the coil. The range of the index is about 55° on either side of 0°. The whole is covered by a glass shade. Earth-currents that attract no attention on the telegraph needles, produce on this instrument a deflection of 40° or 50°. It is placed in proper connexion with one of the Dover-London wires, and can be at any instant placed in circuit by merely pressing a spring, and thrown out of circuit by removing the pressure. Possession is obtained with equal facility of the London-Tonbridge or the Dover-Tonbridge section, by inserting a brass plug in one or other of two holes made in a divided brass disc. This is all the apparatus required. It is fixed on a slab within arm's reach from my chair. At any moment, when I see by the telegraph needles that the wires are unoccupied by telegrams, I can take the three complete observations in a few seconds. The word "up" is engraved in face of the N.E. quadrant, and the word "down" in face of the S.E.

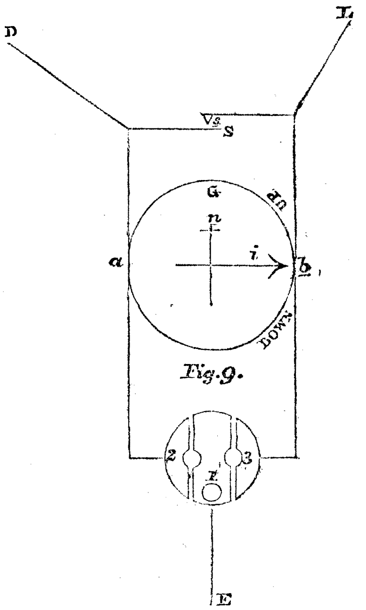


Fig. 9.

The arrangement of this miniature observatory will be readily understood from the following diagram (fig. 9).

L is the telegraph wire, entering the office from London; D the wire from Dover; S the contact spring, and *s* the stud on which it rests. When the spring and stud are in contact, the ordinary telegraph signals pass along them between D and L without being visible on the galvanometer G. The needle *n*, with its index *i*, and the circle of the galvanometer G, are given in one-third size; *a* and *b* are the terminals of the galvanometer wire. When the spring S is depressed or removed from contact with the stud *s*, as shown in the diagram, no current can pass between D and L without passing through the galvanometer G. 1, 2, and 3 show in one-third size a brass disc divided into three parts, and fixed upon a block of mahogany, insulated each from the others. The middle piece of the disc is connected by a wire with the gas- and water-pipes, and is therefore in connexion with the earth E. A brass plug is provided, which fits into the respective holes 1, 2, and 3. When in the centre hole 1, this instrument is not in action; when in the hole 2, it connects 1 and 2 together, so that the wire on the *a* or Dover side of the galvanometer is in direct communication with the earth E, and the galvanometer is in circuit between London and Tonbridge; when the plug is transferred to the hole 3, for like reasons the galvanometer is in circuit between Tonbridge and Dover. Observations on the whole line, or on either of the two sections, are readily and rapidly obtained by this arrangement.

The coil of the galvanometer is for convenience so wound, that when it is traversed by a positive current of electricity travelling *towards* London, or, to use railway language, "up" the line, the index moves in the right quadrant, or toward the word "up" engraved there; when, on the other hand, it is travelling *from* London, or "down" the line, the index moves to the left quadrant, or toward the word "down."

The following is a Table of Observations made during October 1861. They are taken in the order of the columns 1, 2, and 3. The letters *u* or *d* are entered against each observation, according as the index moves to the word "up" or "down." The time is taken at the end of the third observation. It is given in "Greenwich Mean Time," fractions of minutes being rejected; the local clock error being known by means of the "Time Signals" that come two or three times a day from Greenwich.

TABLE XIII.

Directions and Values of Earth-currents, collected at Tonbridge, 1861, October; from the London-Dover;—London-Tonbridge;—and Tonbridge-Dover lines.

Date.	Time.	Column 1.	Column 2.	Column 3.	Date.	Time.	Column 1.	Column 2.	Column 3.
		Dover-London ....*u.* London-Dover ....*d.*	Tonbridge-London ...*u.* London-Tonbridge ...*d.*	Dover-Tonbridge .....*u.* Tonbridge-Dover .....*d.*			Dover-London ....*u.* London-Dover ....*d.*	Tonbridge-London ...*u.* London-Tonbridge ...*d.*	Dover-Tonbridge .....*u.* Tonbridge-Dover ...
1861.	h m	°	°	°	1861.	h m	°	°	°
Oct. 1.	9.31 A.M.	16 *u*	6 *d*	14 *u*	Oct. 4.	12.26 P.M.	40 *u*	55 *u*	50 *u*
	11.42 A.M.	15 *u*	35 *d*	30 *u*		4.50 P.M.	10 *d*	20 *d*	2 *d*
	2.20 P.M.	4 *u*	36 *d*		Oct. 5.	7.44 A.M.	35 *d*	50 *d*	45 *d*
	2.35 P.M.	3 *u*	28 *d*	7 *u*	Oct. 8.	11 A.M.	20 *d*	10 *d*	31 *d*
Oct. 2.	9.34 A.M.	9 *u*	4 *d*	11 *u*		12.56 P.M.	20 *u*	15 *u*	15 *u*
	12.24 P.M.	23 *u*	26 *d*	42 *u*		1.47 P.M.	45 *u*	10 *d*	50 *u*
	2.15 P.M.	17 *u*	35 *d*	20 *u*		3.12 P.M.	48 *u*	50 *d*	55 *u*
	2.47 P.M.	0	0	0	Oct. 9.	6.20 A.M.	12 *u*	20 *d*	25 *u*
	3.20 P.M.	6 *u*	28 *d*	18 *u*		9.20 A.M.	35 *d*	25 *u*	35 *d*
	3.35 P.M.	0	5 *d*	0	Oct. 10.	6.58 A.M.	10 *u*	15 *d*	20 *u*
Oct. 3.	7.2 A.M.	35 *d*	5 *d*	20 *d*		3.14 P.M.	30 *u*	50 *d*	50 *u*
	11.44 A.M.	32 *u*	14 *d*	38 *u*		10.0 P.M.	55 *d*	5 *u*	10 *d*
	5.20 P.M.	19 *d*	3 *d*	20 *d*	Oct. 11.	6.25 A.M.	55 *u*	50 *d*	55 *u*
	10.12 P.M.	20 *u*	0	20 *u*		9.6 A.M.	55 *d*	35 *u*	50 *d*
Oct. 4.	6.25 A.M.	33 *d*	3 *u*	45 *d*		10.25 A.M.	0	30 *u*	0
	12.24 P.M.	35 *u*	29 *d*	50 *u*	Oct. 12.	7.8 A.M.	5 *u*	40 *d*	40 *u*

TABLE XIII. (continued).

Date.	Time.	Column 1.	Column 2.	Column 3.	Date.	Time.	Column 1.	Column 2.	Column 3.
		Dover-London ....u. London-Dover ....d.	Tonbridge-London ...u. London-Tonbridge ...d.	Dover-Tonbridge ......u. Tonbridge-Dover ......d.			Dover-London ....u. London-Dover ....d.	Tonbridge-London ...u. London-Tonbridge ...d.	Dover-Tonbridge ......u. Tonbridge-Dover ......d.
1861.	h m				1861.	h m			
Oct. 12.	9.10 A.M.	20° *d*	20° *u*	40° *d*	Oct. 24.	7.41 A.M.	20° *d*	20° *u*	20° *u*
Oct. 14.	11.59 A.M.	10 *d*	10 *d*	10 *d*		7.47 A.M.	10 *d*	20 *d*	5 *u*
	12.52 P.M.	25 *u*	30 *d*	35 *u*		7.54 A.M.	15 *u*	22 *d*	35 *u*
	2.16 P.M.	10 *u*	12 *d*	11 *d*		9.20 A.M.	45 *d*	25 *u*	50 *d*
	2.45 P.M.	5 *u*	25 *d*	15 *u*		9.37 A.M.	55 *d*	45 *u*	55 *d*
Oct. 15.	11.34 A.M.	20 *u*	40 *d*	32 *u*		10.25 A.M.	30 *d*	15 *u*	43 *d*
	12.19 P.M.	18 *u*	16 *d*	25 *u*		11.24 A.M.	0	12 *d*	8 *u*
	1.23 P.M.	8 *u*	30 *d*	20 *u*		11.47 A.M.	13 *d*	25 *u*	38 *d*
	2.30 P.M.	2 *u*	15 *d*	7 *u*		12.29 P.M.	0	15 *d*	0
	3.25 P.M.	10 *d*	4 *u*	15 *d*		2.40 P.M.	22 *u*	55 *u*	15 *u*
	7.16 P.M.	20 *u* & *d*	5 *u*	40 to 60 *d*		2.44 P.M.	55 *u*	50 *u*	50 *u*
Oct. 16.	6.37 A.M.	10 *d*	5 *u*	35 *d*		3.32 P.M.	55 *u*	13 *d*	55 *u*
	7.44 A.M.	5 *d*	35 *u*	35 *d*		4.23 P.M.	7 *u*	35 *u*	0
	12.18 P.M.	40 *u*	50 *d*	45 *u*		5.3 P.M.	3 *d*	32 *u*	40 *d*
Oct. 17.	10.52 A.M.	23 *u*	10 *d*	30 *u*	Oct. 25.	6.14 A.M.	15 *d*	5 *u*	30 *d*
	11.25 A.M.	20 *u*	25 *d*	38 *u*		6.42 A.M.	50 *d*	20 *u*	55 *d*
	11.43 A.M.	26 *u*	26 *d*	40 *u*		10.21 A.M.	15 *d*	15 *u*	20 *d*
	2.13 P.M.	20 *u*	18 *d*	35 *u*		10.29 A.M.	40 *d*	10 *u*	33 *d*
	3.41 P.M.	10 *u*	20 *d*	15 *u*		11.10 A.M.	16 *d*	13 *u*	30 *d*
	5.6 P.M.	10 *d*	15 *d*	0		4.50 P.M.	20 *u*	20 *d*	30 *u*
Oct. 18.	6.35 A.M.	30 *d*	0	35 *d*		9.25 P.M.	25 *d*	15 *u*	40 *d*
	7.17 A.M.	35 *d*	25 *u*	45 *d*	Oct. 26.	6.10 A.M.	20 *u*	25 *d*	30 *u*
	8.36 A.M.	35 *d*	30 *u*	32 *d*		7.32 A.M.	20 *d*	35 *u*	20 *d*
	10.58 A.M.	14 *u*	10 *d*	28 *u*		7.44 A.M.	25 *d*	40 *u*	40 *d*
	11.37 A.M.	24 *u*	10 *d*	34 *u*		8.50 A.M.	0	5 *d*	0
	12.30 P.M.	40 *u*	30 *d*	48 *u*		10.54 A.M.	21 *d*	15 *u*	40 *d*
	12.57 P.M.	22 *u*	15 *d*	30 *u*		12.19 P.M.	0	10 *u*	0
	1.36 P.M.	20 *u*	25 *d*	40 *u*		12.57 P.M.	0	0	0
	2.44 P.M.	22 *u*	18 *d*	34 *u*		1.10 P.M.	20 *u*	20 *d*	26 *u*
	3.39 P.M.	15 *u*	12 *d*	16 *u*		1.26 P.M.	0	8 *u*	0
Oct. 19.	7.12 A.M.	25 *d*	10 *u*	38 *d*		4.1 P.M.	0	5 *d*	0
	12.1 P.M.	12 *u*	40 *d*	45 *u*		9.45 P.M.	0	10 *d*	0
Oct. 21.	7.7 A.M.	5 *d*	0	35 *d*		10.45 P.M.	10 *d*	10 *d*	10 *d*
	10.10 A.M.	28 *d*	15 *u*	32 *d*	Oct. 28.	7.15 A.M.	0	15 *u*	0
	1.24 P.M.	50 *u*	22 *d*			10.19 A.M.	0	20 *d*	8 *u*
	1.42 P.M.	50 *u*	10 *d*	50 *u*		10.35 A.M.	23 *d*	15 *u*	32 *d*
	2.21 P.M.	55 *u*	23 *d*	52 *u*		11.2 A.M.	5 *d*	24 *d*	0
	2.56 P.M.	43 *u*	15 *d*	47 *u*		11.18 A.M.	16 *d*	18 *d*	12 *d*
	3.35 P.M.	45 *u*	22 *d*	50 *u*		11.37 A.M.	20 *d*	10 *u*	35 *d*
Oct. 22.	6.15 A.M.	0	5 *d*	2 *u*		12.13 P.M.	20 *d*	4 *u*	27 *d*
	7.15 A.M.	5 *d*	0	25 *d*		12.57 P.M.	23 *d*	0	26 *d*
	7.57 P.M.	5 *d*	0	5 *d*		1.9 P.M.	30 *d*	14 *u*	40 *d*
Oct. 23.	6.13 A.M.	0	5 *u*	0		2.50 P.M.	10 *d*	3 *u*	14 *d*
	7.0 A.M.	5 *d*	0	0		3.21 P.M.	8 *u*	40 *d*	28 *u*
	7.31 A.M.	5 *d*	10 *u*	30 *d*					
	10.13 A.M.	18 *d*	35 *u*	32 *d*		10.10 P.M.	20 *u*	15 *d*	15 *u*
	1.1 P.M.	16 *u*	16 *d*	38 *u*		10.20 P.M.	5 *d*	10 *d*	10 *d*
	1.45 P.M.	40 *u*	0	45 *u*		10.30 P.M.	5 *d*	10 *d*	5 *d*
	3.9 P.M.	45 *u*	0	50 *u*		19.40 P.M.	5 *u*	25 *d*	20 *u*
Oct. 24.	6.20 A.M.	0	7 *d*	7 *u*		10.50 P.M.	15 *d*	5 *u*	5 to 20 *d*
	7.5 A.M.	0	0	2 *u*		11.0 P.M.	20 *d*	5 to 15 *u*	20 *d*

TABLE XIII. (continued).

Date.	Time.	Column 1.	Column 2.	Column 3.	Date.	Time.	Column 1.	Column 2.	Column 3.
		Dover-London ....*u*. London-Dover ....*d*.	Tonbridge-London ...*u*. London-Tonbridge ...*d*.	Dover-Tonbridge ......*u*. Tonbridge-Dover ......*d*.			Dover-London ....*u*. London-Dover ....*d*.	Tonbridge-London ...*u*. London-Tonbridge ...*d*.	Dover-Tonbridge ......*u*. Tonbridge-Dover ......*d*.
1861.	h m				1861.	h m			
Oct. 28.	11.10 P.M.	0°	10° *d*	3° *u*	Oct. 29.	4.43 A.M.	10° *d*	0° to 5° *u*	12° *d*
	11.20 P.M.	15 *u*	18 *d*	20 *u*		4.53 A.M.	10 *d*	0 to 5 *u*	15 *d*
	11.30 P.M.	5 *u*		5 *u*		5.0 A.M.	8 *d*	0 to 10 *u*	14 *d*
	11.40 P.M.	36 *d*	42 *u*	52 *d*		5.10 A.M.	8 *d*	8 *u*	18 *d*
	11.50 P.M.	25 *d*	22 *u*	35 *d*		5.20 A.M.	4 *d*	0 to 10 *u*	5 *d*
	12.0 P.M.	18 *d*	0	20 *d*		5.30 A.M.	0	0 to 15 *u*	0
Oct. 29.	12.10 A.M.	22 *d*	22 *d*	22 *d*		5.40 A.M.	4 *d*	0 to 4 *u*	5 *d*
	12.20 A.M.	10 *d*	0	15 *d*		5.50 A.M.	0	10 *u*	2 *d*
	12.30 A.M.	18 *d*	8 *d*	20 *d*		6.0 A.M.	0	5 *u* to 5 *d*	0
	12.40 A.M.	22 *d*	8 *u*	36 *d*		6.10 A.M.	0	0 to 5 *u*	0
	12.50 A.M.	10 *d*	7 *d*	13 *d*		6.20 A.M.	0	5 *d*	0
	1.0 A.M.	10 *d*	5 *d*	12 *d*		6.30 A.M.	0	0	0
	1.10 A.M.	15 *d*	6 *d*	20 *d*		6.40 A.M.	5 *u*	0	8 *u*
	1.20 A.M.	12 *d*	8 *d*	20 *d*		6.50 A.M.	5 *u*	10 *d*	25 *u*
	1.30 A.M.	18 *d*	6 *d*	20 *d*		7.7 A.M.	10 *u*	7 *u*	10 *u*
	1.40 A.M.	12 *d*	5 *d*	19 *d*					
	1.50 A.M.	15 *d*	5 *d*	21 *d*		7.30 A.M.	15 *u*	0	20 *u*
	2.0 A.M.	18 *d*	10 *u*	13 *d*		7.47 A.M.	15 *u*	0	15 *u*
	2.10 A.M.	18 *d*	0	20 *d*		10.5 A.M.	10 *u*	0 to 20 *d*	16 *u*
	2.20 A.M.	23 *d*	19 *u*	13 *d*		12.2 P.M.	8 *u*	40 *d*	28 *u*
	2.30 A.M.	18 *d*		20 *d*		12.25 P.M.	0	10 *d*	0
	2.40 A.M.	10 *d*	15 *u*	12 *d*		3.13 P.M.	10 *d*	12 *u*	16 *d*
	2.50 A.M.	5 *d*	0	10 *d*		3.29 P.M.	10 *d*	12 *u*	18 *d*
	3.0 A.M.	15 *d*	10 *d*	15 *d*	Oct. 30.	6.10 A.M.	0	10 *u*	10 *d*
	3.10 A.M.	13 *d*	5 *d*	19 *d*		6.30 A.M.	0	10 *u*	5 *d*
	3.20 A.M.	13 *d*	0	16 *d*		6.41 A.M.	0	20 *u*	8 *d*
	3.30 A.M.	15 *d*	0	20 *d*		7.42 A.M.	0	15 *u*	5 *d*
	3.40 A.M.	12 *d*	4 *d*	5 *d*		9.20 A.M.	17 *u*	1 to 10 *d*	20 *u*
	3.50 A.M.	10 *d*	0	12 *d*	Oct. 31.	6.12 A.M.	10 *d*	10 *u*	20 *d*
	4.0 A.M.	12 *d*	2 *d*	19 *d*		6.30 A.M.	0	10 *u*	0
	4.10 A.M.	14 *d*	10 *u*	20 *d*		9.43 A.M.	18 *u*	8 *u* to 12 *d*	21 *u*
	4.20 A.M.	10 *d*	5 *u*	20 *d*		11.59 A.M.	14 *u*	42 *d*	38 *u*
	4.30 A.M.	9 *d*	0 to 5 *u*	11 *d*		6.54 P.M.	0	0 to 15 *u*	4 *d*

Column 1, *u* is the direction 26—25 of Table XI.* and Plate III. figs. 1 & 5.
,, *d* ,, 25—26 ,, ,, ,,
Column 2, *u* ,, 24—23 ,, ,, ,,
,, *d* ,, 23—24 ,, ,, ,,
Column 3, *u* ,, 32—31 ,, ,, fig. 1.
,, *d* ,, 31—32 ,, ,, ,,

When column 1 contains an entry of an "up" current *u*, and column 2 of a "down"

* Philosophical Transactions, 1861, p. 130.

current *d*, we have the result of which a few cases were collected and given in Table XII. section 3, and shown graphically in Plate III. fig. 5. The result is further confirmed when the entry in column 3 corresponds in direction with that in column 1.

When the directions recorded in columns 1, 2, and 3 are *d*, *u*, and *d* respectively, we have the results given in Table XII. section 4.

As I shall have occasion to refer incidentally to the possible influence of heat or cold, &c. over the relative values of the currents registered in the three columns of Table XIII., I have given in Table XIV. the Meteorological Register taken at Tonbridge, and kindly furnished to me by Dr. FIELDING. The barometer readings are corrected and reduced to sea-level at 32°.

TABLE XIV.—Meteorological Register taken at Tonbridge, October 1861.

	Barometer, 9 A.M.	Degree of moisture, 9 A.M.	Shade, maximum.	Shade, minimum.	Mean tempera-ture.	Wind at 9 A.M.	Pluvio-meter, 9 A.M.
	in.	°	°	°	°		
October 1.	29·827	94	70·5	55·3	62·90	S.E.	0·015
2.	29·967	88	65	48	56·50	N.	0·080
3.	30·217	93	66	52	59	N.	0·010
4.	30·223	79	65·8	48	56·75	S.E.	0·005
5.	30·089	96	66·8	55·5	61·15	S.	0·000
6.	30·227	91	61	57	59	E.	0·010
7.	30·153	97	69·8	53·5	61·55	N.E.	0·080
8.	29·975	97	71·6	57	64·30	N.	0·010
9.	29·973	94	65	48	56·50	S.W.	0·040
10.	30·045	96	67·5	51·5	59·50	N.E.	0·030
11.	29·559	88	69	49·8	59·40	S.S.W.	0·070
12.	30·039	79	62	55	58·50	S.W.	0·320
13.	30·105	79	65·8	55·6	60·70	S.W.	0·005
14.	30·133	92	70·4	47·2	58·80	E.	0·000
15.	30·181	81	68·4	48·2	58·30	E.	0·000
16.	30·265	90	57	43·2	50·10	N.	0·000
17.	30·351	74	58·6	49·2	53·90	E.	0·000
18.	30·221	80	59	42	50·50	S.E.	0·000
19.	30·065	93	60	43	51·50	E.	0·000
20.	29·933	96	62	48	55	E.	0·000
21.	29·863	80	59	50·5	54·75	E.	0·020
22.	29·881	93	60·3	48·5	54·40	S.E.	0·030
23.	30·103	89	57·4	47	52·20	S.W.	0·310
24.	30·135	84	61·3	56	58·65	S.	0·010
25.	30·167	91	62	50·5	56·25	W.S.W.	0·030
26.	30·217	84	57	43	50	N.E.	0·000
27.	30·143	80	56	46·5	51·25	E.	0·000
28.	30·143	72	53·4	43	48·20	E.	0·000
29.	30·065	74	52·2	43	47·60	E.	0·000
30.	30·983	76	53·3	43	48·15	N.	0·015
31.	30·921	89	53	44	48·50	N.	0·000

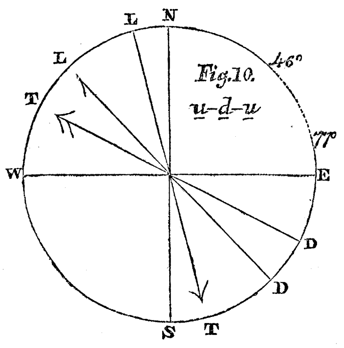
In Table XV. is given an analysis of the contents of Table XIII. Observations of a like character (as well as others to be hereafter referred to) were taken during the month of November. I have not thought it necessary to give them in detail, but have included a summary of them in this Table together with those of October.

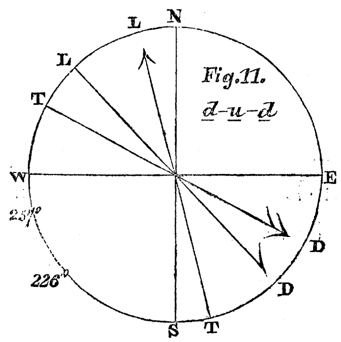
TABLE XV.—Analysis of Observations of Earth-Currents collected 1861, October and November.

	Col. 1.	Col. 2.	Col. 3.	October.	November.		
	0	0	0	3	2	5	
	u	*d*	*u*	78	37	115	
	d	*u*	*d*	83	27	110	
Normal	....	....	....	164	66		230
	u	*u*	*u*	1	10	11	
	d	*d*	*d*	25	6	31	
Abnormal	....	....	....	26	16		42
	u	*d*	*d*	1		1	
	d	*u*	*u*	1		1	
	d	*d*	*u*	1		1	
	u	*u*	*d*		1	1	
Exceptional	....	....	....	3	1		4
							276

In October there are three cases (000), and in November two, in which no deflection of the needle occurred in either of the three observations; and many individual cases are recorded. No particular stress is laid on these cases of no action. They merely indicate that the current, if any, was too small to affect the particular instrument used; a more delicate instrument might doubtless have given signs.

Of the 276 complete observations, 230, or five-sixths, are in accordance with the conclusions already arrived at—that the general direction of the drift of earth-currents is approximately N.E. or S.W. And the numbers of each kind come out nearly the same: 115 N.E. *u*, *d*, *u*;—and 110 S.W. *d*, *u*, *d*. The conditions of this group of results, which for convenience may be called *normal*, given graphically in Plate III. fig. 5, may be gathered in detail more readily from figs. 10 and 11.





N is the magnetic north; L—D, London-Dover; L—T, London-Tonbridge; T—D, Tonbridge-Dover. The respective lines of direction are further shown by the arrow-heads,—one semi-barb indicating column 1; two, column 2; three, column 3. The arrow-heads pointing upwards all apply to "up" currents *u*; those pointing downwards, to "down" currents *d*. The dotted portion of the circumference of the circle is the arc of the horizon, within which the resultant is to be found. The degrees are given reckoned from the north, eastward round the circle. Fig. 10 represents the N.E. *normal*, or *u*, *d*, *u*, in Tables XIII. and XV.; fig. 11 the S.W. *normal*, or *d*, *u*, *d*.

From these Tables it appears that the *prevailing* currents, or those of most frequency, are from the N.E. or S.W.; this as well in calm periods as in periods of magnetic storms. In the absence of long-continued and consecutive observations, it is not easy to form an opinion as to whether the N.E. or S.W. currents prevail more or less at one part of the day than at another; or to what extent, if at all, the directions or alternations are influenced by local meteorological changes or conditions. In 'Les Archives des Sciences Physiques,' vol. xi. pp. 110–136, is a memoir by Father SECCHI, "On the Connexion of Meteorological Phenomena and Variations of the Intensity of Terrestrial Magnetism," in which he expresses very strongly his opinion that every rupture of meteorological equilibrium produces a rupture of electrical equilibrium, which can only be re-established by means of a current which discharges itself from place to place, which current cannot fail to act upon the magnetometers. Here is a wide field for research. Although I am not engaged in investigating the *origin* of the currents, I cannot avoid expressing my opinion that the value of existing currents, if not their direction (I speak locally), may be more or less influenced by meteorological changes, especially cloud, sunshine, or temperature. The currents at calm periods are at best but feeble. The resistances of the various parts of the telegraph wire through which they pass vary with the varying temperatures, so that it is quite reasonable to expect that, even when no change is taking place in the absolute value of the current travelling in the earth, the needle of the galvanometer may move forward or backward according as sunshine or cloud, heat or cold prevail here or there in the district under examination. This opinion is sanctioned in some degree by the result of some night observations made on October 28—29. My original observations were almost wholly made by day. On the night in question observations were made every ten minutes from 10.10 P.M. to 6.50 A.M. During this period there was evidently an excess of S.W. currents; the proportion of *u*, *d*, *u* to *d*, *u*, *d* currents was 1 : 2·7, whereas the day proportion for the month was 3·7 : 2·7. Also fifteen out of the twenty-five *d*, *d*, *d* currents were collected during the night; in fact there were only ten *u*, *d*, *u* currents in the whole fifty-six night observations. From 11.40 P.M. to 5.40 A.M. the London-Dover wire collected a continuous down *d* current, varying more or less in intensity; from 5.40 to 6.30 A.M., the current was too feeble to be appreciated; at 6.40 it was found in the reverse direction *u*, and was so when the observations were interrupted at 7.47.—These remarks in passing.

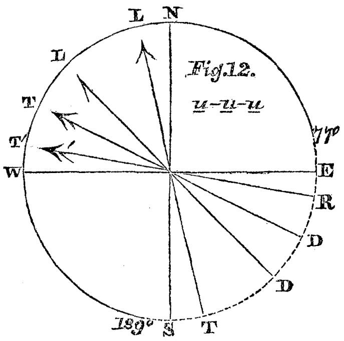
There is no consistency in the relations between two derived currents collected at the same time from the same earth-drift of electricity: this may be in great measure due, as I have hinted, to local meteorological interference, if not to the absolute differences of value in the different sections of the drift itself. I have taken at random, from the October observations, a few cases for illustration:—

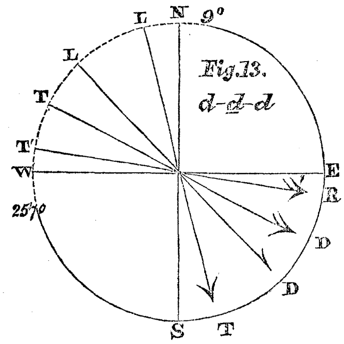
13 *u*	38 *u*
14 *u*	28 *u*
,,	31 *u*
15 *u*	15 *u*
,,	16 *u*
,,	20 *u*
,,	30 *u*
,,	35 *u*
16 *u*	14 *u*
,,	38 *u*
17 *u*	20 *u*
18 *u*	21 *u*
,,	25 *u*

The first column are Dover-London currents; the second, Dover-Tonbridge. Being read off on the same instrument, and under circumstances so favourable, they are strictly comparable. There are no relative values to be traced. For instance, 13° corresponds with 38°; 18° with 21° and 25°; 15° is coupled with various values—15°, 16°, 20°, 30°, and 35°, and so on. These illustrations may be extended at pleasure.

Since my original communication to the Royal Society, an "eighth article," by Professor LOOMIS, has appeared in the 'American Journal,' vol. xxxii., November 1861. On discussing the results accumulated in America, he infers that all the facts are consistent with the supposition of electric currents moving to and fro on the earth's surface, the average direction of which, on that continent, is from about N. 45° E. to S. 45° W., a result remarkably in accordance with the conclusions to which we have arrived by a somewhat different process for the S.E. part of England. He has also discussed, in quite another way, the magnetic disturbances in Europe; and he obtains a direction for the electric wave, connected with those disturbances, from N. 28° E. to S. 28° W. over the surface of Europe. These approximations are noteworthy.

It is plain, however, from Tables XIII. and XV., that currents from time to time flow from some point in the S.E. and in the N.W. quadrants. These directions may for the present be called *abnormal*. In the existing state of our knowledge, it is impossible to say whether they indicate the state of *transition* between the two *normal* quadrants. The cases are few in number. In October, 26 were recorded; in November, 16; or $\frac{2}{13}$ of the whole number. In December also I noticed a few. Like the *normal*, they are subdivided into two classes: *u*, *u*, *u*, 11; *d*, *d*, *d*, 31. The current was constant in the *d*, *d*, *d* direction, with a single interruption, from midnight October 28 to 1.50 A.M. October 29. Currents of this kind, as may be seen in Table XIII., are as definitely marked as the others; their values are equally large. They are expressed graphically in figs. 12 and 13.





The references and letters are the same as in figs. 10 and 11. The lines of direction are not favourable for arriving at an approximate place for the resultant. We have to seek it within the large arc of 131°, which includes respectively the whole of the S.E. or N.W. quadrant. I have the command at Tonbridge of the RamsgateHarbour-Tonbridge line, to which I shall have occasion hereafter to refer. It corresponds nearly with the Shalford-Red Hill, 34—33 of Table XI. and Plate III. fig. 1; it makes an angle with the magnetic meridian of 99°, reckoned eastward. Many observations on this line are given in Table XVI. column 3, and in all cases will be found to coincide in direction with those on the Tonbridge-Dover line. I have therefore been able to lay down this line in figs. 12 and 13. It is indicated by the letters R T′, and by three semibarbs. It reduces the arc to 112°, which, however, is still large, and which I cannot further reduce by the means at my command.

Since I wrote the note (1861, July) which appears in the 'Philosophical Transactions' for that year, Part I. p. 96, the Astronomer Royal has laid his proposition for erecting earth-current wires before the Board of Directors of the South-Eastern Railway, which has been referred to me; and it is needless to say has had my favourable report. The Directors have entertained the proposition most cordially; and have approved of the erection of the wires at cost price, and conceded the right of way and maintenance on the payment for each of a nominal sum of a few shillings annually.

The Greenwich-Dartford wire will make an angle of about 60° W. of N. (magnetic), nearly coincident with my Tonbridge-Ashford, or with the Tonbridge-Dover line of the present communication. The Greenwich-Croydon wire will make an angle of about 47° E. of N., or not far from the direction of my Ashford-Hastings line. By combining the wires at Greenwich, the Dartford-Croydon line may be obtained, which is 84° E. of N., or nearly my Ramsgate-Ashford direction. Treating these lines in the usual way, we shall have an arc of 36° or 107°. The former will be between N. and N.E., and out of the range. The latter, which however is very large, will include the range. I look forward with great interest to the completion of these wires, in order that we may see the result of uninterrupted observations, which cannot be obtained from our highly occupied telegraph wires.

I purpose erecting these wires as soon as the insulators are made; which will be constructed with great care, of a double concentric cup of ebonite, with an outer cup of French porcelain. The ebonite cups will be turned in a lathe before fitting, so as to present a perfectly smooth surface. They will be placed on the apex of our telegraph poles*.

Four *exceptional cases* presented themselves among the 276 observations. Their character is given in Table XV. They are beyond the reach of the system of analysis we have adopted. Whether the general direction of the current-drift was changing at the moment of observation, and was complete in one part of the district and not so in the other, I cannot, with these very rare and isolated data, pretend to say. The results are given precisely as read off. There was no reason to suspect any interferences from artificial currents; a few more cases may throw more light on this exceptional class.

A few entries will be found in the Table XIII. as thus: 5° to 15°; 0° to 10°; 5° *u* to 5° *d*, &c. The derived currents in these cases were unstable. A few of the earlier cases that occurred were questioned, and I was disposed to reject them, the impression being that they were due to interference from strong telegraph currents entering into the observing-wire. But instances occurred in which there was no reason to suspect interferences, they are therefore placed on record.

We speak of electric *currents* in this inquiry; the word conveys the idea of length without width. The currents in question necessarily and evidently cover large areas, presenting as it were an *electric plane*. Passing on from the determination of mere direction, I was able to survey the two sides of the same plane. By reference to the map (vol. 159, Plate II.), the RamsgateHarbour-London and the Dover-Tonbridge lines are not many degrees from being parallel. They are about 20 miles apart; the former is 67 miles, and the latter 45 miles in length. I have at Ashford junction a turn-plate or switch. When desiring to make the observations on the Ramsgate-London line, I call Ashford and give the word "branch;" the reply is "yes" or "no," according as it is at liberty or not. If at liberty, the switch is turned, and I have the command of the wire from Ramsgate to London, the telegraph length of which is $97\frac{1}{2}$ miles; and then, by placing the plug in the hole 3 of fig. 9, for reasons already explained, the command is obtained of the Ramsgate-Tonbridge line.

Observations of this kind have been made from time to time; the results are given in Table XVI. The letters in this and subsequent Tables have the same references as those in Table XIII.

* I completed the two wires, and handed them over to the Astronomer Royal, June 30, 1862.

TABLE XVI.—Directions and Values of Earth-Currents collected at Tonbridge, 1861, November and December; from the Tonbridge-Dover, London-Ramsgate, and Tonbridge-Ramsgate lines.

Date.	Time.	Column 1.	Column 2.	Column 3.	Date.	Time.	Column 1.	Column 2.	Column 3.
		Dover-Tonbridge .... *u.* Tonbridge-Dover .... *d.*	Ramsgate-London .... *u.* London-Ramsgate .... *d.*	Ramsgate-Tonbridge, *u.* Tonbridge-Ramsgate, *d.*			Dover-Tonbridge .... *u.* Tonbridge-Dover .... *d.*	Ramsgate-London .... *u.* London-Ramsgate .... *d.*	Ramsgate-Tonbridge, *u.* Tonbridge-Ramsgate, *d.*
1861.	h m				1861.	h m			
Nov. 17.	12.35 P.M.	28° *u*	10° *u*	14° *u*	Dec. 3.	6.13 A.M.	18° *d*	9° *d*	9° *d*
Nov. 20.	7.34 A.M.	25 *d*	15 *d*	20 *d*	Dec. 4.	6.20 A.M.	0	5 *d*	0
Nov. 21.	7.7 A.M.	0	0	0		1.25 P.M.	40 *u*	27 *u*	32 *u*
Nov. 22.	7.1 A.M.	15 *u*	12 *u*	0	Dec. 6.	6.39 A.M.	5 *u*	0	0
Nov. 25.	3.25 P.M.	14 *u*	0	7 *u*	Dec. 7.	6.24 A.M.	25 *u*	35 *u*	42 *u*
Nov. 26.	6.35 A.M.	35 *u*	20 *u*	15 *u*	Dec. 9.	7.18 A.M.	20 *u*	0	0
	3.24 P.M.	10 *u*	15 *u*	15 *u*	Dec. 13.	6.49 A.M.	10 *u*	20 *u*	20 *u*
Nov. 27.	6.19 A.M.	10 *u*	10 *u*	15 *u*	Dec. 14.	6.35 A.M.	15 *d*	10 *d*	20 *d*
	11.47 A.M.	15 *d*	11 *d*	10 *d*	Dec. 17.	6.30 A.M.	10 *d*	5 *d*	5 *d*
	12.32 P.M.	16 *d*	0	0	Dec. 19.	6.23 A.M.	0	15 *u*	20 *u*
	2.18 P.M.	28 *d*	8 *d*	20 *d*		8.18 P.M.	55 *d*	55 *d*	55 *d*
	2.38 P.M.	26 *d*	24 *d*	29 *d*	Dec. 20.	6.30 A.M.	5 *u*(?)	15 *d*	10 *d*
Nov. 28.	6.20 A.M.	0	0	2 *u*	Dec. 21.	6.24 A.M.	10 *u*	20 *u*	30 *u*
Nov. 29.	6.33 A.M.	5 *d*	2 *d*	0	Dec. 26.	6.34 A.M.	25 *u*	20 *u*	25 *u*
	1.13 P.M.	17 *d*	23 *d*	35 *d*	Dec. 27.	6.35 A.M.	15 *u*	15 *u*	20 *u*
Nov. 30.	6.22 A.M.	10-*d*	0	5 *d*	Dec. 28.	6.23 A.M.	0	2 *u*	2 *u*
Dec. 2.	2.27 P.M.	22 *u*	7 *d*	5 *d*	Dec. 31.	6.26 A.M.	30 *d*	25 *d*	30 *d*

Column 2 gives the Ramsgate-London results, or the survey of the north side of the parallelogram; and column 1 the Dover-Tonbridge results, or survey of the south side of the parallelogram. In every instance, with a solitary exception during the two months of observation, the directions coincide; the current or drift or electric plane is at least 20 miles wide, and the behaviour of its two limits is consistent. The proportion between the values of the currents on the two sides of the plane is not constant, but is a little better maintained than that of Table XIII. before referred to. The Ramsgate-London, or 67-mile line collected by $97\frac{1}{2}$ miles of telegraph wire, gives in the majority of cases a less value than the Dover-Tonbridge, or 45-mile line, collected in $46\frac{3}{4}$ miles of wire.

Column 3 of Table XVI., already noticed, is the Ramsgate-Tonbridge line. It makes a diagonal across the plane. The directions in all cases coincide with those of the other two lines, and so give a further evidence of consistency.

Tonbridge is almost in a direct line between London and Hastings, and very nearly equidistant. Lines 21—22, and 23—24, Plate III. fig. 1, give the true readings. I have a switch or turn-plate in the Telegraph Office at the Tonbridge junction, by means of which the Tonbridge-Hastings wire can be placed at my request in connexion with the

Tonbridge-London wire. The direct line between London and Hastings is 53 miles. I have thus an opportunity of making observations on the whole of this line, or on either half, the direction of all three being the same. The results of these observations are given in Table XVII. Column 1 contains the value of currents collected on the whole line of 53 miles; column 2, those on the London half of 27 miles; and column 3, those on the Hastings half of 26 miles.

TABLE XVII.—Directions and Values of Earth-Currents collected at Tonbridge, 1861, November and December; from the London-Hastings, London-Tonbridge, and Tonbridge-Hastings lines.

Date.	Time.	Column 1.	Column 2.	Column 3.	Date.	Time.	Column 1.	Column 2.	Column 3.
		Hastings-London .... *u.* London-Hastings .... *d.*	Tonbridge-London ... *u.* London-Tonbridge ... *d.*	Hastings-Tonbridge... *u.* Tonbridge-Hastings... *d.*			Hastings-London .... *u.* London-Hastings .... *d.*	Tonbridge-London ... *u.* London-Tonbridge ... *d.*	Hastings-Tonbridge .. *u.* Tonbridge-Hastings .. *d.*
1861.	h m				1861.	h m			
Nov. 15.	12.34 P.M.	8° *d*	18° *d*	1° *d*	Nov. 29.	6.24 A.M.	2° *u*	5° *u*	0°
	1.56 P.M.	8 *d*	24 *d*		Nov. 30.	6.17 A.M.	5 *u*	10 *u*	0
Nov. 16.	10.19 A.M.	4 *u*	44 *u*	6 *u*	Dec. 2.	11.48 A.M.	0	8 *d*	0
	10.53 A.M.	20 *d*	50 *d*	0	Dec. 3.	6.13 A.M.	5 *d*	0	5 *d*
Nov. 17.	12.35 P.M.	5 *u*	10 *u*	4 *u*	Dec. 4.	6.17 A.M.	10 *d*	15 *d*	5 *d*
Nov. 20.	7.37 A.M.	5 *d*	10 *d*	0		1.29 P.M.	0	16 *d*	1 *d*
	10.50 A.M.	7 *u*	8 *u*	4 *u*	Dec. 5.	6.24 A.M.	5 *d*	0	5 *d*
Nov. 21.	7.10 A.M.	0	5 *d*	0	Dec. 6.	6.37 A.M.	0		0
	9.35 A.M.	12 *u*	18 *u*	0	Dec. 7.	6.22 A.M.	0	5 *d*	0
	11.46 A.M.	4 *u*	6 *u*	3 *u*	Dec. 9.	7.16 A.M.	5 *d*	0	5 *d*
	12.49 P.M.	0	0	5 *u*	Dec. 13.	6.43 A.M.	0	0	0
Nov. 23.	6.22 A.M.	5 *d*	10 *d*	0	Dec. 14.	6.33 A.M.	5 *u*	10 *u*	0
	9.1 A.M.	0	10 *u*	0	Dec. 17.	6.29 A.M.	0	5 *d*	0
Nov. 25.	1.34 P.M.	6 *u*	12 *u*	4 *u*	Dec. 18.	6.20 A.M.	5 *d*	10 *d*	5 *d*
	2.47 P.M.	8 *u*	5 *u*	9 *u*	Dec. 19.	6.21 A.M.	5 *d*	10 *d*	5 *d*
	3.24 P.M.	8 *u*	23 *u*	7 *u*	Dec. 20.	6.20 A.M.	10 *d*	25 *d*	5 *d*
Nov. 26.	6.34 A.M.	0	10 *d*	0	Dec. 21.	6.22 A.M.	15 *d*	28 *d*	10 *d*
Nov. 27.	6.17 A.M.	0	0	0	Dec. 26.	6.30 A.M.	0	10 *d*	0
	12.32 P.M.	7 *d*	5 *d*	5 *d*	Dec. 27.	6.34 A.M.	0	0	0
	2.18 P.M.	0	3 *u*	0	Dec. 28.	6.21 A.M.	0	0	0
Nov. 28.	6.17 A.M.	0	5 *u*	2 *d*(?)	Dec. 31.	6.23 A.M.	0	0	0

If the value of these derived currents depended simply on the mere distance between the earth-plates or observing-stations, and their bearing each on the other, it is obvious that the values in columns 2 and 3 would be identical, or in this case nearly so. The London-Tonbridge wire-length is 41 miles; the Tonbridge-Hastings 33; so that the value on the latter length should be a little higher if anything, the resistance being less. But, with very rare exceptions, the Tonbridge-Hastings values are seen to be greatly below the Tonbridge-London. The contrast is remarkable. In some cases the differences are very conspicuous. I have made a sufficient number of observations, extended over two months, to satisfy myself that the one section is under all circumstances less active in derived currents than the other. This difference can only be attributed, as already suggested in my former communication (p. 109), to the different geological conditions of the two sections of country, a difference which may operate in two ways: either the resistance of the section may be relatively great, so that the earth-plates penetrate into a portion of the electric plane that is traversed by a current of low value, and hence the derived current is comparatively low; or the resistance of the section may be relatively small, so that, although the earth-plate may penetrate into a portion of the electric plane that is traversed by a current of higher value, yet the wire resistance, in contrast with the high conducting power of the earth section, may cause the derived current to have a relatively low value.

The London-Hastings line makes an angle of possibly 70° with the N.E. or S.W. resultant, that is with the *u*, *d*, *u* or the *d*, *u*, *d* currents; so that even with a good geological section and with a perfect knowledge of the relative resistances of its various parts, it would be no easy matter even to hint at the precise relation between the value of the current and the structure and arrangement of the strata. Mr. Robert Hunt has kindly furnished me with a geological section of the country between London and Hastings drawn by Mr. F. Drew. Between London and Tonbridge are included, London clay; Woolwich beds (sand); chalk; gault (clay); lower greensand, sand and a little limestone; clay; sand and sandstone; clay. Between Tonbridge and Hastings, sand and sandstone; clay and a little limestone. There are many faults also between Tonbridge and Hastings.

Column 1 of Table XVII. contains the values given by the whole length, from London to Hastings. They differ but little, save in one or two instances, from the Tonbridge-Hastings values; and are consequently very low in comparison with the Tonbridge-London values. These facts all indicate the very notable influence of local conditions, other than the meteorological variation already noted, over the relative value of the current in different parts of the plane.

It was a matter of considerable importance to determine with certainty whether the currents with which I was dealing were in whole, or only in part, earth-currents; whether, that is, any portion of the observed deflections of the galvanometer needle were due to electricity collected from the atmosphere by the suspended telegraph wires that were employed in these observations. To determine this I availed myself of the assistance of Ashford. After taking observations in the usual way between London and Dover, and between Tonbridge and Dover, I desired the Ashford clerk to detach the wire from his instrument and leave the end insulated. I thus had a wire of 67 miles connected with the earth at London, or one of 25 miles connected with the earth at Tonbridge, the end in either case being insulated at Ashford. It was desirable to make a considerable number of observations, at various hours of the day and under all conditions of weather, in order to test this question rigidly. The results are given in Table XVIII.

TABLE XVIII.—Observations showing, by detaching one end of the Telegraph wire from the earth, that currents collected at Tonbridge, 1861, October, November, and December, from the London-Dover and Tonbridge-Dover lines, were true and proper Earth-currents.

Date.	Time.	Column 1.	Column 2.	Column 3.	Date.	Time.	Column 1.	Column 2.	Column 3.
		Dover-London .... *u.* London-Dover .... *d.*	Dover-Tonbridge ...... *u.* Tonbridge-Dover ...... *d.*	Columns 1 and 2 with wire off earth at Ashford.			Dover-London .... *u.* London-Dover .... *d.*	Dover-Tonbridge ...... *u.* Tonbridge-Dover ...... *d.*	Columns 1 and 2 with wire off earth at Ashford.
1861.	h m	°	°	°	1861.	h m	°	°	°
Oct. 18.	11.37 A.M.	24 *u*	34 *u*	0	Nov. 27.	11.47 A.M.	10 *d*	15 *d*	0
	1.36 P.M.	20 *u*	40 *u*	0		2.18 P.M.	17 *d*	28 *d*	0
	2.44 P.M.	22 *u*	34 *u*	0		2.38 P.M.	18 *d*	26 *d*	0
	3.39 P.M.	15 *u*	16 *u*	0	Nov. 28.	6.15 A.M.	0	0	0
Oct. 21.	10.10 A.M.	28 *d*	32 *d*	0	Nov. 29.	6.20 A.M.	0	5 *d*	0
Oct. 24.	11.47 A.M.	13 *d*	38 *d*	0	Nov. 30.	6.21 A.M.	5 *d*	10 *d*	0
	2.44 P.M.	55 *u*	50 *u*	0	Dec. 2.	11.49 A.M.	23 *u*	34 *u*	0
	4.23 P.M.	7 *u*	0	0		2.24 P.M.	15 *u*	22 *u*	0
Oct. 28.	11.18 A.M.	16 *d*	12 *d*	0	Dec. 3.	6.24 A.M.	15 *d*	18 *d*	0
	10.30 P.M.	5 *d*	5 *d*	0	Dec. 4.	6.15 A.M.	5 *d*	0	0
	11.0 P.M.	20 *d*	20 *d*	0		12.9 P.M.	20 *u*	13 *u*	0
	11.30 P.M.	5 *u*	5 *u*	0		1.24 P.M.	34 *u*	40 *u*	0
	12.0 P.M.	18 *d*	20 *d*	0		2.40 P.M.	20 *u*	16 *u*	0
Oct. 29.	0.30 A.M.	18 *d*	20 *d*	0	Dec. 5.	6.20 A.M.	0	0	0
	1.0 A.M.	10 *d*	12 *d*	0		12.34 P.M.	17 *u*	40 *u*	0
	1.30 A.M.	18 *d*	20 *d*	0	Dec. 6.	6.20 A.M.	0	0	0
	2.0 A.M.	18 *d*	13 *d*	0	Dec. 7.	6.20 A.M.	16 *u*	25 *u*	0
	2.30 A.M.	18 *d*	20 *d*	0	Dec. 9.	7.12 A.M.	15 *u*	20 *u*	0
	3.0 A.M.	15 *d*	15 *d*	0	Dec. 13.	6.40 A.M.	10 *u*	10 *u*	0
	3.30 A.M.	15 *d*	20 *d*	0	Dec. 14.	6.30 A.M.	5 *d*	15 *d*	0
	4.0 A.M.	12 *d*	19 *d*	0	Dec. 17.	6.17 A.M.	10 *d*	10 *d*	0
	4.30 A.M.	9 *d*	11 *d*	0	Dec. 18.	6.18 A.M.	15 *d*	10 *d*	0
	5.0 A.M.	8 *d*	14 *d*	0	Dec. 19.	6.20 A.M.	0	0	0
	5.30 A.M.	0	0	0	Dec. 20.	6.20 A.M.	0	5 *u*	0
	6.0 A.M.	0	0	0	Dec. 21.	6.18 A.M.	0	10 *u*	0
	6.30 A.M.	0	0	0	Dec. 26.	6.25 A.M.	20 *u*	25 *u*	0
Nov. 21.	11.46 A.M.	10 *d*	20 *d*	0	Dec. 27.	6.30 A.M.	10 *u*	15 *u*	0
Nov. 25.	1.31 P.M.	0	0	0	Dec. 28.	6.17 A.M.	0	0	0
	3.23 P.M.	16 *u*	14 *u*	0	Dec. 31.	6.19 A.M.	25 *d*	30 *d*	0
Nov. 26.	3.24 P.M.	5 *u*	10 *u*	0					

It will be seen that in no single instance was any deflection of the needle obtained when the wire was off at Ashford; so that we are right in regarding all the currents with which we have been dealing, as far as atmospheric electricity is concerned, as true and proper earth-currents.

Columns 1 and 2 are the deflections obtained on the London-Dover and Tonbridge-Dover lines in the usual way. Column 3 are the 0° resulting from repeating each of the two previous observations with the Ashford wire detached.

I have also made repeated observations on the effect of polarizing the earth-plates by the passage of a powerful current; and all with the same negative result. An observation is made, say on the Tonbridge-London line, and the deflection noted. A powerful current from the ordinary telegraph battery (a current which it would be imprudent to receive on the observing galvanometer) is transmitted for a given time, say half a minute, through the Tonbridge-London circuit, in the direction which would have produced the deflection previously observed. After this the observation is repeated. No appreciable difference has in any instance been found in the deflection. The direction remains the same; and the value unaltered. So that the currents, as far as the polarizing of the plates is concerned, may be regarded as true and proper earth-currents.

The alterations in direction of the currents and the varying values in either direction indicate that they are in nowise due to the mere electromotive force of the earth-plates employed.

I have mentioned in my former communication (pp. 94, 95) that the connexion with the earth is very frequently made by means of the fish-jointed rails. Some misgivings might arise on a first glance as to the influence of this arrangement over the results. The current collected under such circumstances, however, would be true in direction, but reduced in value. We need not enter into the discussion of this question from the fact that no such earth-connexion has been required for our present purposes.

To prevent misapprehension, I have thought it better to give a list of the earth-connexion employed at all the stations concerned in this investigation.

London	Gas-pipes; and a lightning conductor terminating in a wet pit of coke.
Tonbridge	Gas- and water-pipes.
Hastings	Gas- and water-pipes.
Ramsgate Harbour . . .	Water-pipes.
Dover	Gas-pipes.

I still continue taking observations; but they are all of the same character as those now placed on record, and merely afford further illustrations of the points that have been discussed. It would be premature to say that the subject is tolerably exhausted, as far as the means at my command are concerned; but I do not at this moment see any salient point that is within my reach. The steady daily and hourly march of these phenomena, and their relation, if any, to the like march of magnetometers, will soon be within the reach of Mr. AIRY; and we may be well assured that these and the other collateral questions will be ably discussed by him.

The results arrived at in these two communications may be briefly summed up as follows:—

1st. That currents of electricity are at all times moving in definite directions in the earth.

2nd. That their direction is not determined by local causes.

3rd. That there is no apparent difference, except in degree, between the currents collected in times of great magnetic disturbance, and those collected during the ordinary calm periods.

4th. That the prevailing directions of earth-currents, or the currents of most frequent occurrence, are approximately N.E. and S.W. respectively.

5th. That there is no marked difference in frequency, duration, or value, between the N.E. and the S.W. currents.

6th. That (at least during calm periods) there are definite currents of less frequency from some place in the S.E. and N.W. quadrants respectively.

7th. That the direction of the current in one part of a plane on the earth's surface (at least as far as the S.E. district of England is concerned) coincides with the direction in another part of the plane; and if the direction changes in one part, it changes in all parts of the plane.

8th. That the relation in value between currents in a given part of the plane and currents in another given part is not constant, but is influenced by local meteorological conditions, and varies from time to time.

9th. That the value of the current of a given length, moving in a given line of direction, is not necessarily the same as that of a current of the same length on the same line of direction produced, and that their relative value depends on the physical character of the earth interposed between the respective points of observation, and is tolerably constant.

10th. That the currents which have formed the bases of these investigations are derived currents from true and proper earth-currents, and neither in whole nor in any appreciable part have been collected from the atmosphere, nor are due either in whole or in any appreciable part to polarization imparted to earth-plates by the previous passage of earth-currents or of powerful telegraphic currents; nor are they due to any electromotive force in the earth-plates themselves.

11th. That the earth-currents in question (at least the powerful currents present at all times of great magnetic disturbance) exercise a *direct* action upon magnetometers, just as artificial currents confined to a wire exercise a direct action upon a magnet.