(1) The diurnal ranges of the magnetic elements of declination and horizontal force are subject to a periodical variation, the duration of which is equal to that of the known eleven-year sun-spot period.

(2) The epochs of minimum and maximum of magnetic and sun-spot effect are nearly coincident, the magnetic epochs on the whole occurring somewhat later than the corresponding sun-spot epochs. The variations of duration in different periods appear to be similar for both phenomena.

(3) The occasional more sudden outbursts of magnetic and sun-spot energy, extending sometimes over periods of several months, appear to occur nearly simultaneously, and progress collaterally.

71. *Disturbance-Diurnal Variation of Force Components.*—We may derive the following conclusions from the results obtained by Sabine for the observatories of Toronto, Kew, and St Helena. For each element there are two categories, namely, those disturbances which tend to increase and those which tend to diminish the element in question.

(1) At Toronto the disturbances increasing both elements of force well represent single progressions with maxima occurring for both about 4 or 5 hours local time. Again the disturbances decreasing both elements represent fairly well single progressions with maxima occurring for both at about 14 or 15 hours local time.

(2) At Kew the disturbances increasing both elements represent well single progressions with maxima occurring for both about 5 hours local time. On the other hand, the disturbances decreasing the horizontal force represent signs of a double progression and those decreasing the vertical force signs of a single progression, the maximum for the latter falling between the two maxima for the former, and occurring at 14 hours local time.

(3) There is not the same close correspondence between the progress of the disturbances which tend to increase both elements nor between the progress of those which tend to decrease both elements at St Helena as there is for the other stations, nor is there the same likeness between the numbers for St Helena and those of Toronto or Kew as there is between the numbers of Toronto and those of Kew.

72. The fact that the disturbance-diurnal variations of the two force elements at Kew are very like each other while neither of them is very like the corresponding declination variation (§ 54) receives confirmation from a visual inspection of the Kew curves. In the *Philosophical Transactions* for 1862 Stewart thus describes the result of an inspection of the disturbances of these curves for the years 1858, 1859, 1860 (disturbance years):—

"There are twenty-two cases in which the declination is raised or lowered along with the horizontal force, and only seven cases of an opposite description. Also there are twenty-two cases in which the declination is raised or lowered along with the vertical force, and only eleven cases of an opposite description. Finally, there are thirty-one cases in which both forces are raised or lowered together, and only two cases of an opposite description. There is therefore a decided tendency in the curves of all the elements to be raised or lowered simultaneously, but this tendency is stronger between the horizontal and vertical force curves than between either of these and the declination. It may at the same time be affirmed that with the exception of the disturbance of August to September 1859 there is no very prominent case in which the three elements do not rise or fall together."

73. *Peaks and Hollows.*—These are certain small but abrupt magnetic changes which from the fact that they generally fall within the separating value are not usually regarded as disturbances. These changes can only be brought to light where there is a continuous record of magnetic phenomena such as that derived from self-recording magnetographs. They were first studied at the Kew Observatory by Stewart (*Phil. Trans.*, 1862). We have seen that more than one type of force must be concerned in producing magnetic disturbances. This is confirmed by the appearance of the Kew records, from which it may be seen that no disturbance of any magnitude is due to the action of a single force varying merely in amount but not in direction. For if there were only one type of force the distance at any moment of a point in the curve of one of the elements from its normal position should bear throughout a disturbance an invariable proportion to the distance of a corresponding point in the curve of another of the elements from its normal; but this is by no means the case.

But even if several independent forces are at work it may be thought unlikely that at the same moment a sudden change should take place in all; there is thus a probability that sudden changes of force, as exhibited in peaks and hollows, are changes in one of the elementary forces concerned. Even if the change is not a very abrupt one, provided that we confine ourselves to such peaks and hollows as present a similar appearance for all the curves, we may suppose that we are observing changes in one only of the elementary disturbing forces; for it is unlikely that two or more independent forces, changing independently, should produce similar appearances in all of the three curves.

Assuming it as probable that similarity of appearance in the curve variations of the three elements denotes a simplicity in the disturbing force, Stewart has discussed all such peaks and hollows at Kew extending over the first two years of their production, and has obtained a result which is embodied in the following table:—

TABLE XVIII.—*Hourly Ratios and Frequency of the Kew Peaks and Hollows, the Vertical Force Disturbance being taken as Unity.*[1]

Hour.	Declination.	Hor. Force.	Number of Observations.	Hour.	Declination.	Hor. Force.	Number of Observations.
0– 1	2·14	2·06	7	12–13	1·76	2·68	3
1– 2	1·97	2·18	7	13–14	2·00	2·04	3
2– 3	1·86	1·99	11	14–15	2·10	2·14	5
3– 4	1·81	2·05	7	15–16	2·65	2·11	10
4– 5	1·38	1·73	4	16–17	3·48	2·16	15
5– 6	1·57	1·71	1	17–18	3·80	2·14	22
6– 7			0	18–19	3·94	2·18	28
7– 8	1·82	1·91	2	19–20	3·97	2·25	21
8– 9	1·60	2·20	1	20–21	3·41	2·21	23
9–10			0	21–22	3·26	2·30	16
10–11	1·33	3·16	1	22–23	2·79	2·00	10
11–12	1·30	2·32	3	23–24	2·30	2·04	13

74. It will be seen from this table that the ratio between simultaneous peaks and hollows of the two components of the force is very nearly constant, the horizontal force disturbance being about double that of the vertical force, so far as size on the curve is concerned. It will also be seen that there is a very marked diurnal range in the ratio which the declination peak or hollow bears to that of the vertical force, this ratio being greatest about 7 A.M. About this hour we have also most peaks and hollows, while in the evening and early morning hours there is so great an absence of these phenomena that the ratios are doubtful.

75. A preliminary comparison between the peaks and hollows at Lisbon and at Kew has been made by Capello and Stewart (*Proc. Roy. Soc.*, January 28, 1864) with the following conclusions.

(1) The Kew peaks and hollows are simultaneously produced at Lisbon in all the elements, but to a smaller extent than at Kew.

(2) The direction is the same at both stations for the declination and horizontal force peaks and hollows, but it is reversed in the case of the vertical force, so that a sudden small increase of vertical force at Kew corresponds to a diminution of the same at Lisbon.

It would be manifestly impossible to discuss with any advantage the nature and origin of these peculiar changes until more extensive observations of them have been made. As the peak and hollow force is probably of a simple nature, a further knowledge of its character may be of much importance to the theory of terrestrial magnetism.

It is interesting to remark that we have in peaks and hollows the same close relation between the variations of the two force elements that we find in the larger disturbances.

It is believed too that during violent disturbances a certain change of type is produced in the peak and hollow force, and more especially is this remarkable in the great disturbance in August and September 1859, where the declination would seem to march in the opposite direction from the two components of the force. We have seen that the same peculiarity characterized on this occasion the larger and more apparent magnetic changes. We shall afterwards refer to a circumstance which may perhaps throw light upon this peculiarity (§ 93), meanwhile we conclude by again remarking that during comparative magnetic calms the peak and hollow force shows signs of remaining constant in type, and that it is therefore of great importance that the directors of observatories possessing self-recording magnetographs should take united action to observe this force.

76. *Other Inequalities of the Disturbance-Diurnal Variation of the Force Components.*—Sabine has shown that disturbances of the force components present a distribution over the various months of the year very similar on the whole to that which is exhibited by disturbances of declination. He has likewise shown that disturbances of the force components present a distribution over various years similar to that exhibited by disturbances of declination. Finally, we may probably conclude that disturbances of the force components are smallest at those portions of the earth's surface where disturbances of the declination are smallest, and largest at those portions where such disturbances are largest.

77. *Annual and Semiannual Variation of Horizontal Force and Dip.*—Broun (*Trans. Roy. Soc. Edin.* for 1861) has discussed the results obtained by Sabine at his magnetical stations, and has shown that differential and absolute observations agree in telling us that the horizontal force is smallest at the equinoxes and greatest at the solstices. Whipple has recently obtained the same result from the Kew observations.

We have deduced the following table (XIX.) from the various absolute determinations that have been made at sundry places. In it the annual and semiannual variations of declination, horizontal force, and dip are exhibited, "increase" denoting a push to the west, and "decrease" a push to the east. The method of obtaining these has already been indicated in §§ 66, 67.

[1] We ought to mention that, with the exception of the one occasion already alluded to, a peak of one element always corresponds to a peak of another element, and a hollow of one element to a hollow of another.

Station.	Effect on Declination.		Effect on Horizontal Force.		Effect on Dip.	
	At Equinoxes compared to Solstices.	At June Solstice compared to December Solstice.	At Equinoxes compared to Solstices.	At June Solstice compared to December Solstice.	At Equinoxes compared to Solstices.	At June Solstice compared to December Solstice.
Makerstoun or Kew	Increase.	Decrease.	Decrease.	Inappreciable.	Increase.	Decrease.
Toronto	Increase.	Decrease.	Decrease.	Increase.	Inappreciable.	Decrease.
Cape of Good Hope	Increase.	Decrease.	Decrease.	Increase.		
Hobart Town	Decrease.	Decrease.	Decrease.	Decrease.	Decrease.	Decrease.
Trevandrum	Decrease.	Increase.				
Bombay	Undecided.	Increase.				
St Helena	Undecided.	Decrease.				

78. In discussing the results of this table we shall assume that the sun acts, and in all probability acts indirectly, upon the magnetic system of the earth. This point will afterwards be further examined. Meanwhile, assuming this indirect action of the sun, and assuming, to fix our thoughts, that it is in close alliance with the convection system of the earth's atmosphere, we can readily imagine that such solar action would act most strongly on the earth's magnetic poles at the solstices, and that in the June solstice the pole or poles in the northern hemisphere and in the December solstice those in the southern hemisphere would be most affected. Now a strong action of this kind upon either magnetic pole may well be presumed to increase the general magnetism of the earth, or at least that portion of it which is most readily affected by external action, that is to say, the induction system. Again, if the solar magnetic influence is connected with the convection currents of the earth, we can readily imagine that the influence in the northern hemisphere where there is much land should exceed that in the southern hemisphere where there is much water.

If these views be reasonable we might expect two things to follow:—(1) the earth's induction system should be stronger at the solstices than at the equinoxes, and (2) it should be more especially strong at the June solstice, when the sun acts in the northern hemisphere. We must bear in mind, however, that so vast is the earth that a stimulus applied to its particles most susceptible of magnetism may not be instantaneously propagated throughout its mass, but that time may enter as an element of the question, in which case, inasmuch as the action of the sun at the June solstice is in the northern hemisphere, a station near the south pole may not fully partake of the magnetic effects of this action.

79. An hypothesis of this nature would appear to be consistent with the results of Table XIX.

In the first place, if the earth should become stronger as a magnet in one or in both of its magnetic systems this would show itself by an increase of horizontal force at least in all such stations as those at which absolute observations are made. An influence which increases the horizontal force at these various stations is therefore naturally regarded, and was regarded by Broun, as one increasing the strength of one or both of the magnetic systems of the earth—whether of one or of both will presently appear. We may therefore assume from our observations that one or both of the earth's magnetic systems are strongest at the solstices.

In the next place we may imagine that the changes of declination and dip which the table exhibits as occurring at the solstices are the very changes which would be wrought in these elements by an increase of power in the earth. For we see very well that an increase of horizontal force at the various stations may be regarded as denoting an increase of the earth's magnetic power. We cannot, however, see with equal facility what changes would be produced in the declination and dip by an increase in power of one or both of the magnetic systems; but we may well imagine that such changes of these elements as are found to accompany an increase of horizontal force are those that denote an increase of the earth's power.

We have thus ascertained the probable nature of those changes of the three elements which denote an increase of power. Now it will be noticed from the table that the effect at the June as compared with that at the December solstice is of the opposite nature to the effect at the equinoxes as compared with the solstices,—that is to say, the earth is more powerfully affected in June than in December, the only well-established exception to this being Hobart Town in the far south. But, assuming that time is an element in the development of this preponderating influence acting in the north, it is easy to see why Hobart Town should not exhibit its full effect.

It remains to determine from the observations themselves which of the magnetic systems it is that exhibits these oscillations. Analogy would of course point to the induction system, but it is desirable to determine this from the observations themselves.

In § 54, when discussing the disturbance-diurnal variation of declination, it was found that Toronto and Kew may be regarded as on one side of the Siberian pole, while Peking, Nertchinsk, and Bombay are on the other. Now, if it be this pole that is influenced by the oscillations under discussion, we might expect that the influence on declination at Toronto and Kew should be the opposite of that at Trevandrum and Bombay. We find by the table that this is the case, and we are thus inclined to attribute these changes to the Siberian instead of the American pole. It would thus appear that the observations of Table XIX. bear out the provisional working hypothesis which we have ventured to introduce. It is quite possible that these remarks may not stand the test of more complete inquiry, but they are here introduced rather as denoting a method of looking at the subject which ought we think to be pursued than as embodying conclusions of a final nature.

80. *Effect of the State of the Sun's Surface upon the Absolute Magnetism of the Earth.*—We have now to consider whether the state of the sun's surface permanently influences the magnetism of the earth. It will at once be seen that any such action will apparently manifest itself as an oscillation in the secular change. We must, however, carefully guard ourselves against prematurely concluding that it implies a variation in the amount of true secular change. There may be two distinct things—true secular change due to one cause, and action depending on sun-spots due to another. These, from the nature of the case, are necessarily mixed up together in the yearly changes which we examine; it does not, however, follow that there is any real identity between them. We shall now give one example of the method to be pursued in the attempt to detect a solar influence of this nature. Let us turn to Table III., and take the declination yearly values at Toronto from 1856 to 1871. Subtracting the value for 1856 from that for 1871, we find that the westerly declination had increased in fifteen years 51′·6, that is to say, at the mean rate of 3′·44 per annum. Again, the average declination for the sixteen years 1856–71 is 2° 20′·8 corresponding to the epoch at the commencement of the year 1864. Taking the average value and epoch, and also the average yearly increase above given, we are able to construct the following table (XX.), in which calculated and observed values at Toronto are compared together:—

	Observed.	Calculated.	Difference.
	° ′	° ′	′
1856	1 56·30	1 55·00	+1·30
1857	2 0·50	1 58·44	+2·06
1858	2 4·50	2 1·88	+2·62
1859	2 7·40	2 5·32	+2·08
1860	2 10·60	2 8·76	+1·84
1861	2 14·40	2 12·20	+2·20
1862	2 15·70	2 15·64	+0·06
1863	2 19·10	2 19·08	+0·02
1864	2 21·90	2 22·52	−0·62
1865	2 24·80	2 25·96	−1·16
1866	2 27·60	2 29·40	−1·80
1867	2 29·80	2 32·84	−3·04
1868	2 33·20	2 36·28	−3·08
1869	2 37·10	2 39·72	−2·62
1870	2 41·90	2 43·16	−1·26
1871	2 47·90	2 46·60	+1·30

It may be gathered from this table that the years which correspond to minimum sun-spots have in the last column a greater negative or lower positive sign than those which correspond to maximum sun-spots, and hence we may conclude that at Toronto the tendency of many sun-spots is to increase the westerly declination.

81. Performing a similar operation for all those cases in which we have a sufficiently extensive series of observations to work upon, we obtain the following table:—

TABLE XXI.—*Effect of Numerous Sun-Spots on the Values of Magnetic Elements.*

Station.	Declination.	Horizontal Force.	Dip.
Kew	Increase.	Inappreciable.	Increase.
Toronto	Increase.	Increase.	Increase.
Hobart Town	Increase (?).	Uncertain.	Increase.
Cape of Good Hope	Decrease.		
Trevandrum	Increase.		

82. We have good grounds for supposing that the sun is most powerful when there are numerous spots on his surface, and therefore the above table represents a state of things which we may imagine to be caused in one way or another by increased solar power. Now the most natural hypothesis is to imagine that an increase of spots acts in producing an increase of disturbances, and that for those stations at which the disturbances tend on the whole to affect the elements in a definite direction there will be left behind a permanent effect in this direction. A comparison of Table XXI. with Table XII. will, however, show that this explanation is not valid. For instance, at Toronto and Kew disturbances tend rather to diminish

than to increase the westerly declination, while the effect of numerous sun-spots is to increase it. Again, at the Cape the tendency of disturbances is to increase the westerly declination, while that of numerous sun-spots is to decrease it. At Trevandrum again (if we judge of it by Bombay) the effect of disturbances will be to increase the easterly declination, while that of sun-spots is to decrease it. Again, it is believed that at Kew and Toronto the supposed disturbance effect on the dip agrees in character with the sun-spot effect. On the whole, therefore, there is no definite relation between the two effects.

Now if we take Hobart Town, the Cape, and Trevandrum in the above table, we find from Table XIX. that these stations seem to indicate that the magnetic state of the earth is most powerful at times of maximum sun-spots. Kew and Toronto, however, so far as declination and dip are concerned, appear to go the other way. If, however, we suppose that during the several years of maximum sun-spots the American pole as well as the Siberian is affected, and that on such occasions of long continuance the former has more influence than the latter, we shall be able to reconcile our results with the hypothesis of increased solar action. We can understand too that time must be an important element in any influence communicated to the American pole, and that, although such influence might be apparent at Toronto and Kew, which are comparatively near the pole, it would not be apparent at the other stations of Table XXI. We shall recur to this subject when discussing secular change.

Various Phenomena connected with the Sun and with Terrestrial Magnetism.

83. *Closeness in Time between Solar Changes and Magnetic Disturbances.*—Loomis (*American Journal of Science*, vol. 1.) has registered the extent of sun-spots for the six days preceding and following each of the great magnetic disturbances at Greenwich, and has compared these values with that for the very day of the disturbance. In this manner he has treated all the days of great magnetic disturbance at Greenwich for a period of twenty-three years, with the exception of those cases in which very few observations of sun-spots were made. The cases of disturbance thus treated amount to one hundred and thirty-five, and the following result has been obtained:—

Table XXII.—*Extent of Spotted Solar Surface.*

	Days before Storm.						Storm.	Days after Storm.					
	6	5	4	3	2	1		1	2	3	4	5	6
Mean of 135 Days.	47·9	50·1	54·8	53·5	52·3	48·9	57·9	49·0	45·1	49·3	45·6	45·2	45·3

From this result Loomis draws the following conclusions:—(1) great disturbances of the earth's magnetism are accompanied by unusual disturbances of the sun's surface on the very day of the magnetic storm; (2) the great disturbance of the sun's surface which accompanies a terrestrial magnetic storm is generally heralded by a smaller disturbance three or four days previous, succeeded by a comparative calm which immediately precedes the magnetic storm.

84. There is one instance on record of a sudden solar change which was practically simultaneous with a magnetic disturbance.[1] On September 1, 1859, a little before noon, R. C. Carrington was observing by means of a telescope a large sun-spot, when, to quote his own words—

"Within the area of the great north group (the size of which had previously excited general remark) two patches of intensely bright and white light broke out. . . . I noted down the time by the chronometer, and, seeing the outburst to be very rapidly on the increase, and being somewhat flurried by the surprise, I hastily ran to call some one to witness the exhibition with me, and on returning within sixty seconds was mortified to find that it was already much changed and enfeebled. Very shortly afterwards the last trace was gone; and, although I maintained a strict watch for nearly an hour, no recurrence took place. . . . The instant of the first outburst was not fifteen seconds different from $11^h\ 18^m$ Greenwich mean time, and $11^h\ 23^m$ was taken for the time of disappearance. In this lapse of five minutes, the two patches of light traversed a space of about 35,000 miles. . . . It was impossible, on first witnessing an appearance so similar to a sudden conflagration, not to expect a considerable result in the way of alteration of the details of the group in which it occurred; and I was certainly surprised, on referring to the sketch which I had carefully and satisfactorily finished before the occurrence, at finding myself unable to recognize any change whatever as having taken place. The impression left upon me is that the phenomenon took place at an elevation considerably above the general surface of the sun, and accordingly altogether above and over the great group in which it was seen projected.

"It has been very gratifying to me to learn that Mr Hodgson chanced to be observing the sun at his house at Holloway on the same day, and to hear that he was a witness of what he also considered a very remarkable phenomenon."

At the very moment when Carrington observed this phenomenon the three magnetic elements at Kew were simultaneously disturbed. This disturbance occurred as nearly as possible at $11^h\ 15^m$ A.M., affecting all the elements simultaneously, and commencing quite abruptly. The first or most abrupt portion of the disturbance lasted only about three minutes for all the elements; but after that there was a more gradual change in the same direction before the curve turned. This more gradual continuation of the first sudden movement lasted about seven minutes for all the elements. This magnetic disturbance was, however, in reality a small one, and was followed by a very great disturbance which took place not many hours afterwards.

85. *Simultaneity of Changes of Horizontal Force at Various Parts of the Earth.*—We have already (§ 79) alluded to the superiority of the horizontal force in indicating by its changes what is taking place in the magnetic system of the earth. If this system be strengthened as a whole we shall no doubt find the horizontal force increased in value at our various stations, while if the earth's power be weakened as a whole we shall find the horizontal force diminished.

Broun has discussed this subject at great length in a memoir already mentioned, and has embodied his observations in numerical results from which the following table has been extracted:—

Table XXIII.—*Daily Means of Horizontal Force at Makerstoun,* (M.), *Trevandrum* (T.), *Singapore* (S.), *and Hobart Town* (H.).

1844.	M.	T.	S.	H.	1844.	M.	T.	S.	H.
March 1	21·40	07·42	16·40	16·46	March 17	21·30	11·54	19·74	19·12
" 3	18·34	05·25	14·18	13·98	" 18	20·11	07·62	17·65	17·08
" 4	16·53	06·42	14·59	14·49	" 19	21·73	08·55	16·26	13·59
" 5	11·43	04·43	12·79	10·04	" 20	22·00	07·83	17·24	16·20
" 6	13·94	01·85	10·42	9·66	" 21	23·15	09·06	18·35	17·06
" 7	12·99	04·12	12·37	9·98	" 22	22·47	08·14	18·35	19·12
" 8	16·94	03·81	13·62	11·50	" 24	22·30	09·58	18·76	18·99
" 10	19·12	04·33	14·87	14·07	" 25	23·71	10·09	18·76	19·25
" 11	17·64	05·87	14·87	13·97	" 26	25·22	09·48	20·29	20·10
" 12	18·05	06·28	15·01	14·22	" 27	22·24	10·81	18·63	19·33
" 13	23·25	09·58	17·65	16·18	" 28	22·16	07·52	17·79	16·73
" 14	23·66	10·61	18·90	17·81	" 29	–5·97	03·50	11·54	7·82
" 15	22·12	10·09	18·63	16·85	" 31	17·06	02·27	11·81	10·27

This table shows a considerable likeness between the daily changes of the horizontal force at the four stations. For instance, we have a minimum which occurs on March 5 at Makerstoun and March 6 at the other stations; we have likewise a well-defined maximum occurring at all stations on March 14, and another occurring at Trevandrum on March 25, and at the other stations on March 26. Finally we have a well-defined minimum occurring at Trevandrum on March 31, and at the other stations a day earlier.

Broun has extended a similar treatment to daily means for every hour, and fig. 38 conveys a good idea of the amount of simultaneity which obtains in the changes of such values of horizontal force at stations far apart.

86. *Recurrence of Disturbances at Intervals of about Twenty-six Days.*—Broun[2] and likewise Hornstein[3] have observed that there is a tendency in large magnetic changes to recur at intervals of about twenty-six days. At first it was natural to suppose that we have here a magnetical indication of the true time of the sun's synodical rotation, the interval between two disturbances denoting that which elapses between two presentations to the earth of a peculiarly powerful solar meridian. It seems unlikely, however, that there is a really permanent one-sidedness of this kind in our luminary; but the result of observation seems to show that for a limited period, say two or three years, certain meridians of the sun appear to be peculiarly powerful. The cause of this we shall not here discuss, but simply treat the phenomenon as a fact derived from observation. Broun in his paper above quoted (*Phil. Trans.*, 1876) makes the following remarks:—

"We have seen that when one side of the sun is presented to the earth the magnetic force of the latter is greater than when the other side is turned towards us; we may even say that the intensity is greatest for a given solar meridian; this, however, may be simply an integral effect resulting from the actions due to all the meridians. But can we suppose when a great and sudden increase or diminution of the earth's magnetic force occurs that this is produced by some change occurring on a particular solar meridian? This does not seem at all improbable.

"In order to examine the facts, all the cases were noted during the years 1844 and 1845 in which the daily mean horizontal force diminished one-thousandth of its whole value within an interval of three days; they were found to be twenty-eight in number. If we call the solar meridian presented to us on the 1st January 1844 the zero meridian (0), and consider the time of rotation to be twenty-six days, and that there are twenty-six meridians, we find that the solar meridians presented to us when these great movements occurred may be arranged in a few groups, as in the following table" [Table XXIV., p. 177].

"An examination," continues Broun, "of this table will show that nearly half of the great changes began when the eighth meridian after the zero had passed, while five began near the twelfth after, and five near the zero itself. . . . If any doubt existed as to the possibility of these being mere accidental coincidences, it would be removed, I think, by a consideration of the marked succession occurring between July 31 (No. 18) and December 11, 1845 (No. 28). . . . If we neglect the two cases of July 31 and August 26, which commence at +6 and +5 respectively, we have five cases of successive solar rotations in which the diminutions of intensity began on the +8 day. This exact recurrence at the end of twenty-six days of a marked diminution of force proves, it seems to me, that the actions are all due to the sun, whose time of rotation must be nearly twenty-six days.

"An examination will show that the sudden diminutions of terrestrial magnetic force are in nearly every case preceded by a sudden increase."

In the above extract we have given the author's exact words, but, while thinking with him that these actions are due to the sun, it does not appear to us to follow that the time of the sun's rotation

[1] *Phil. Trans.*, November 21, 1861.

[2] *Phil. Mag.*, August 1858; *Phil. Trans.*, 1876.

[3] *Vienna Acad. S.*, June 15, 1871.

must be nearly twenty-six days. This assumes that the meridian of peculiar power is fixed on the solar surface. It does not, however, seem impossible to imagine that such a meridian may have a proper motion of its own, and indeed the planetary hypothesis of the origin of sun-spots would rather lead to this conclusion. But if this be the case we shall be unable to deduce from recurrent magnetic disturbances the true value of the period of solar rotation.

87. *Repetitions of Magnetic Changes.*—J. B. Capello, director of the Lisbon observatory (*Proc. Roy. Soc.*, October 1868), has remarked that at periods of disturbance there are nearly synchronous movements of the declination needle during corresponding hours for two, three, or more days. He thus describes these phenomena:—

"In some cases the repetition is only in two or three parallel movements; in others there are true periods of repetition of some hours in duration. The repeated periods are not entirely similar, their phases being so modified that in some cases their identity can only be recognized by a very minute investigation. The same periods, when repeated, have not always the same total duration; nor do they recommence at the same precise hour, but sometimes earlier and sometimes later, the differences varying from a few minutes to two or three hours. We also see that the greatest number of repetitions belong to the night hours, that is to say, those hours when the movements of the needle are easterly. In the morning hours there do not appear to be any well-marked repetitions. There are twenty-four examples now given, fifteen of which show repetition on two days, eight on three days, and only one where the curve appears repeated for four days. It appears that all the facts exhibited in these examples agree with the cosmical theory; the cause (existing in the sun or in space) appears to continue sometimes during two, three, or several days without undergoing remarkable transformations. The repetition, being sometimes earlier, sometimes later, seems also to indicate that the cause possesses a proper movement; the cause persists, but only comes again into operation when the earth by its diurnal rotation is placed in a similar position or conjunction to that of the preceding days."

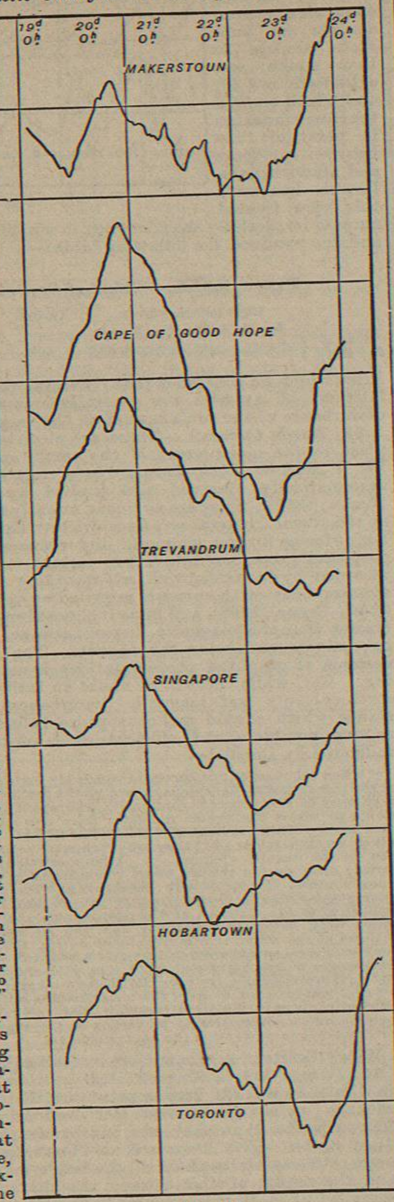

Fig. 38.

Stewart, having compared Capello's curves with the corresponding traces of the declination at Kew, found that the Lisbon disturbances are almost invariably reproduced at Kew at the same time, only to a greater extent, and also that the same amount of similarity which the various Lisbon curves exhibit is exhibited in the corresponding Kew curves. The strongest point in favour of the hypothesis is, he thinks, "not so much the repetition of a single disturbance as the repetition of a complicated disturbance in most if not all of its sinuosities." Several examples of this occur in the diagrams. It would seem that something of the above nature was suspected by Humboldt, the earliest investigator of disturbances. Humboldt was astonished to discover the frequency with which nocturnal perturbations occurred, sometimes recurring at the same hour on several successive nights (Walker's *Magnetism*, p. 80). We would make two suggestions before dismissing this subject.

Table XXIV.—*Cases in which the Earth's Magnetic Force diminished One-thousandth of its Value or more in* 1844–45 (§ 86).

No. of Case.	Date (Jan. 1. 1844=0).	Change of Force in Hundred-thousandths.	Solar Meridians. 5 to 10.	1 to 14.	–3 to +1 and others.
1	87 to 89	–360	+8 to +10		
2	110 to 116	–104		+11 to +12	
3	141 to 143	–107		+11 to +12	
4	189 to 190	–116	+7 to + 8		
5	213 to 214	–175	+5 to + 6		
6	221 to 222	–135		+13 to +14	
7	267 to 270	–115	+7 to +10		
8	273 to 274	–104		+13 to +14	
9	292 to 294	–268	+6 to + 8		
10	323 to 325	–130		+13 to +14	
11	361 to 364	–165			–3 to 0
12	373 to 375	–210	+9 to +11		
13	383 to 385	–163			(–6 to –4)
14	416 to 417	–118			0 to +1
15	467 to 469	–350			–1 to +1
16	526 to 528	–110	+6 to + 8		
17	570 to 571	–154			–2 to –1
18	577 to 580	–102	+6 to + 9		
19	603 to 604	–101	+5 to + 6		
20	606 to 607	–159	+8 to + 9		
21	632 to 633	–153	+8 to + 9		
22	646 to 648	–126			(–4 to –2)
23	658 to 659	–118	+8 to + 9		
24	668 to 670	–100			(–8 to –6)
25	684 to 687	–100	+8 to +10		
26	696 to 698	–110			(–6 to –4)
27	702 to 703	–291			–0 to +1
28	710 to 712	–122	+8 to +10		

(1) If we imagine that these changes are caused by the solar influence acting vertically on some susceptible region of the earth, then, inasmuch as they occur at the evening or early night hours, this region must lie considerably to the west.

(2) The region must also have a proper motion of its own (see Capello's remark). Is it possible that this proper motion is on the whole from west to east,—a motion which we know is pursued by meteorological weather, and in which it is imagined (§ 52) that magnetical weather as defined by us likewise participates?

88. *Comparison of Declination Changes at Stations near each other.*—Messrs Sidgreaves and Stewart (*Pro. Roy. Soc.*, October 1868) have compared together certain curves of the Kew and Stonyhurst declination magnetographs. These magnetographs are of the same pattern, and it was found that on ordinary occasions the declination traces at both stations were precisely alike. This was confirmed by placing the curves the one over the other, when they were found to coincide even in their most minute features. In times of disturbance, however, it was found that the motions exhibited by the Stonyhurst curves were greater than those at Kew, and this excess of Stonyhurst over Kew depended not so much on the absolute size of the disturbance as on its abruptness.

This feature of the comparison is exhibited in the following table (XXV.), in which the excess of Stonyhurst over Kew in scale divisions is compared with the abruptness of the disturbance, this element being measured by the changes occurring in unit of time:—

Group I.		Group II.		Group III.		Group IV.	
Excess (under 5).	Abruptness.	Excess (under 10).	Abruptness.	Excess (under 20).	Abruptness.	Excess (above 20).	Abruptness.
2	3·7	6	4·2	10	·5	21	7·3
2	6·4	6	2·6	10	0	25	2·9
3	4·0	8	6·3	11	7	25	10·7
0	3·1	5	3·3	10	0	20	7·0
0	3·1	8	8·7	10	·8	21	6·6
4	2·9	5	3·5	15	6·4	21	11·2
1	1·8	7	6·3	11	4·9	22	9·6
4	3·3	9	4·7	13	7·4	24	7·8
3	5·2	5	4·1				
Means 1·5	3·7	6·6	4·9	11	6·5	22	7·9

It is very desirable that further comparisons of this nature should be made.

89. *Auroral Displays.*—These are very frequent if not continuous near the magnetic poles, while in middle latitudes they are the invariable accompaniments of all considerable magnetic storms. Near the equator they hardly ever occur.

There is a considerable variety in the forms assumed by these displays, and it is possible that this may denote a corresponding variety in the cause or causes which give rise to this phenomenon.

Loomis (*Smithsonian Report* for 1865) specifies five such varieties: (1) a horizontal light like the morning aurora or break of day; (2) an arch of light which frequently extends entirely across the heavens from east to west and cuts the magnetic meridian nearly at right angles,—in the polar regions five such arches have been seen at once; (3) slender luminous beams or columns well-defined and often of a bright light; (4) the corona, the centre of which is invariably near the magnetic zenith, but not always exactly coincident with it; and (5) waves or flashes of light.

90. Auroras exhibit the same annual variation as magnetic disturbances, and are most frequent about the equinoxes—a fact first observed by Maizan. Kaemtz in his *Meteorology* gives the following table, which is applicable to European auroras.

TABLE XXVI.—*Monthly Frequency of European Auroras.*

Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
229	307	440	312	184	65	87	217	405	497	285	225

Loomis again in the memoir already quoted gives the distribution of American auroras over the various months derived from one hundred and thirteen years' observations at New Haven and Boston, twenty-five years' observations at New York, and two years' observations in Canada. His results are represented in the following table:—

TABLE XXVII.—*Monthly Frequency of American Auroras.*

	Boston and New Haven.	New York.	Canada.	Sum.
January	81	76	16	173
February	93	86	31	210
March	110	106	24	240
April	104	125	38	267
May	86	83	22	191
June	83	79	17	179
July	123	100	21	244
August	102	122	14	238
September	143	131	19	293
October	99	110	27	236
November	115	74	26	215
December	83	60	16	159

It appears from this table that American like European auroras exhibit a maximum of frequency about the equinoxes.

91. Since auroras and magnetic disturbances go together, it is natural to imagine that we should have great auroral displays in years of maximum sun-spots. This is found to be the case, and in the following table (XXVIII.) Wolf's proportional numbers denoting sun-spot frequency are compared with the number of auroras witnessed in Europe and America as compiled by Loomis. It will be seen from this table that years of maximum auroras coincide very well with years of maximum sun-spots.

	Sun-Spot Number.	Auroral Number.		Sun-Spot Number.	Auroral Number.		Sun-Spot Number.	Auroral Number.
1750	83·1	31	1794	38·0	14	1837	136·9	42
1751	52·1	30	1795	23·8	7	1838	104·1	60
1752	45·9	17	1796	15·6	8	1839	83·4	65
1753	28·9	15	1797	6·5	5	1840	61·8	80
1754	13·5	11	1798	4·6	6	1841	38·5	67
1755	9·3	10	1799	7·1	4	1842	23·0	53
1756	12·2	9	1800	15·6	6	1843	13·1	37
1757	31·9	7	1801	33·9	6	1844	19·3	39
1758	47·1	14	1802	54·7	6	1845	38·3	48
1759	54·6	16	1803	70·7	6	1846	59·6	54
1760	64·7	23	1804	71·4	14	1847	97·4	76
1761	80·2	22	1805	48·0	14	1848	124·9	72
1762	60·0	19	1806	28·4	13	1849	95·4	69
1763	48·4	16	1807	11·1	4	1850	69·8	49
1764	36·7	11	1808	7·2	2	1851	63·2	65
1765	21·4	8	1809	3·1	1	1852	52·7	67
1766	14·1	5	1810	0·0	1	1853	38·5	63
1767	35·9	9	1811	1·6	0	1854	21·0	35
1768	66·8	30	1812	4·9	1	1855	7·7	20
1769	03·4	40	1813	12·6	4	1856	5·1	11
1770	98·5	41	1814	16·2	5	1857	22·9	21
1771	86·6	24	1815	35·2	5	1858	56·2	37
1772	65·7	26	1816	46·9	5	1859	90·3	50
1773	39·7	33	1817	39·9	7	1860	94·8	48
1774	27·4	33	1818	29·7	11	1861	77·7	36
1775	8·8	22	1819	23·5	10	1862	61·0	28
1776	21·7	23	1820	16·2	8	1863	45·4	29
1777	92·0	38	1821	6·1	4	1864	45·2	33
1778	151·7	69	1822	3·9	2	1865	31·4	34
1779	123·4	70	1823	2·6	1	1866	14·7	31
1780	89·2	67	1824	8·1	1	1867	8·8	22
1781	66·5	57	1825	16·2	4	1868	36·8	32
1782	38·7	57	1826	35·0	12	1869	78·6	
1783	22·5	47	1827	51·2	17	1870	131·8	
1784	10·3	39	1828	62·1	[illegible]	1871	113·8	
1785	26·7	56	1829	67·2	25	1872	99·7	
1786	81·2	84	1830	67·0	25	1873	67·7	
1787	128·2	108	1831	50·4	20	1874	43·1	
1788	138·3	105	1832	26·3	13	1875	18·9	
1789	116·9	84	1833	9·4	11	1876	11·7	
1790	90·6	68	1834	13·3	12	1877	11·1	
1791	67·6	46	1835	59·0	15	1878	3·8	
1792	59·9	37	1836	119·3	32	1879	7·7	
1793	47·3	23						

In fig. 39 a graphical representation is given of the likeness which subsists between the progress of auroral frequency, spot frequency, and declination ranges.

92. While the results now given leave little doubt as to the fact of a connexion of some sort subsisting between sun-spots on the one hand and magnetic disturbances and auroras on the other, yet it is desirable to obtain evidence as to the closeness of the connexion between auroras and sun-spots similar to that which was exhibited in § 82, and which showed the close connexion in point of time between sun-spots and disturbances. Loomis has with this view treated auroras in precisely the same way in which he treated disturbances, and has obtained the following table:—

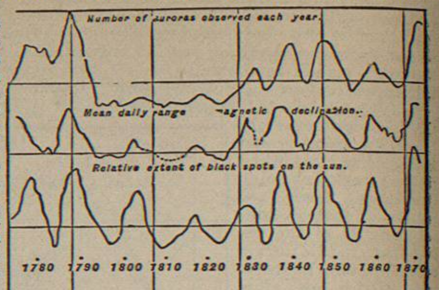

Fig. 39.

TABLE XXIX.—*Extent of Spotted Solar Surface.*

	Days before Aurora.						Aurora.	Days after Aurora.					
	6	5	4	3	2	1		1	2	3	4	5	6
Mean of 251 Days.	50·3	52·7	51·0	51·2	53·1	53·7	60·5	54·8	52·5	53·3	51·4	53·3	50·7

From which he concludes that "auroral observations in the middle latitudes of America are generally accompanied by a maximum disturbance of the sun's surface on the very day of the aurora."

93. *Earth Currents.*—These are electrical currents which take place in the moist crust of the earth, and were first detected by W. H. Barlow (*Phil. Trans.*, 1849). At a later period they were systematically observed and studied by C. V. Walker (*Phil. Trans.*, 1862). They are now continuously recorded by photography at the Royal Observatory, Greenwich. Earth currents are particularly strong during magnetic disturbances. Sir George Airy has graphically compared together certain magnetic disturbances as recorded by the Greenwich self-recording magnetographs and the simultaneous earth currents recorded by appropriate galvanometers (*Phil. Trans.*, 1868), and finds it almost impossible to avoid the conclusion that the magnetic disturbances are produced by terrestrial galvanic currents below the magnets. The likeness between the two systems of graphical representations is unquestionably very striking. But, while there is no doubt an intimate connexion between earth currents and magnetic disturbances, there is one circumstance which should make us pause before assigning the former as the complete and efficient cause of the latter. It is thus indicated by Lloyd:[1]—

"When we examine the curves in which Mr Barlow has represented the course of the galvanometric deflexions caused by the earth currents, we observe that the regularity of that course is continually interrupted by rapid reciprocating movements in which the needle oscillates from one side to the other of the zero alternately. These movements are similar to those of the magnetometers with which we are familiar; but they are much more rapid, and bear a larger proportion to the regular changes. . . I have selected for calculation the observations made during the six hours commencing at 3 A.M. on May 29, 1848, that being a period of comparative disturbance. The sum of the changes of the galvanometer needle during that period, on the Derby and Rugby line, was equivalent to 571 divisions of the instrument—the mean daily range for the entire week being 11·4 divisions and the ratio=50. . . . The sum of the changes of the Greenwich declinometer during the same period was only 57 minutes, the mean daily range being 12·4 minutes. In like manner the sum of the changes of the horizontal force was ·0158 and the mean daily range ·0034. The ratio is accordingly the same for the two magnetic elements, and its amount is 4·6, or less than one-tenth of the corresponding ratio in the case of the galvanometrical changes. We learn therefore that the rapid changes of the earth currents are much greater in proportion to the regular daily changes than the corresponding movements of the magnetometers."

We shall return to this subject in a subsequent part of this article.

94. *Inequalities in Terrestrial Magnetism caused by the Moon.*—Kreil in 1841 was the first to point out that the moon has a small influence on the position of the declination needle, and shortly afterwards the same fact was independently discovered by John Allan Broun. The more recent observations of Sabine and of Broun, but especially those of the latter, have thrown much light upon the nature of this action. As the lunar influence is not generally large, it is necessary to free the observations from the results of other inequalities, and this has beendone by the two observers above mentioned. The results given in Table XXX. have been obtained by Sabine (see Walker's *Magnetism*).

95. Thus (1) the mean effect of the moon upon the declination needle is to cause in each lunar day a double oscillation, and Sabine has shown that the lunar influence upon the other magnetic elements is of a similar type. (2) The turning points for both hemispheres are in all cases not far removed from the lunar hours

[1] *Trans. Roy. Irish Acad.*, xxiv. 115.

TABLE XXX.—*Mean Lunar-Diurnal Variation in Declination.*

Lunar Hour.	Kew.	Toronto.	Peking.	St Helena.	Cape.	Hobart Town.
	"	"	"	"	"	"
0	− 6·2	−18·9	−4·2	+2·6	+ 8·9	+5·9
1	− 9·6	−16·5	−3·3	+0·3	+ 6·4	+8·3
2	− 8·4	− 9·5	−1·5	−2·2	+ 2·1	+8·5
3	− 2·0	− 0·1	+0·7	−4·2	− 2·6	+6·4
4	− 0·6	+ 9·2	+2·6	−5·1	− 6·5	+2·7
5	+ 4·0	+15·9	+3·7	−4·6	− 8·4	−1·6
6	+ 9·0	+18·1	+3·9	−2·9	− 7·9	−5·3
7	+11·3	+15·3	+3·0	−0·3	− 4·9	−7·3
8	+ 9·6	+ 8·2	+1·3	+2·6	− 0·3	−7·2
9	+ 4·7	− 0·4	−0·6	+4·9	+ 4·7	−4·9
10	− 0·1	−10·7	−2·2	+6·1	+ 8·6	−1·0
11	− 5·5	−17·3	−3·1	+5·9	+10·6	+3·4
12	− 9·6	−19·4	−2·9	+4·4	+ 9·9	+7·2
13	−11·3	−16·3	−1·7	+1·9	+ 6·7	+9·1
14	− 9·5	− 8·9	+0·2	−0·8	+ 1·8	+8·8
15	− 5·4	+ 1·0	+2·3	−3·1	− 3·5	+6·3
16	− 0·6	+10·8	+4·0	−4·4	− 7·9	+2·1
17	+ 5·1	+17·8	+5·0	−4·4	−10·3	−2·7
18	+ 8·5	+20·2	+4·8	−3·1	−10·1	−6·7
19	+ 9·8	+17·4	+3·5	−1·0	− 7·3	−9·1
20	+ 8·8	+10·2	+1·5	+1·5	− 2·7	−9·1
21	+ 7·4	+ 0·4	−0·8	+3·5	+ 2·4	−6·8
22	+ 2·4	− 9·3	−2·9	+4·4	+ 6·7	−2·8
23	− 1·6	−15·9	−4·1	+4·1	+ 9·2	+1·8

In this table + indicates that the north end of the magnet is to the east and − that it is to the west of its mean position.

0, 6, 12, 18. (3) In the northern stations we have a maximum westerly deflexion about the hours 0 and 12 and a maximum easterly deflexion about the hours 6 and 18, while in the southern stations the action is the reverse of this. (4) The oscillations would appear to be most decided at those stations, such as Toronto and Hobart Town, that are far removed from the equator.

96. *Annual Variation of Lunar Effect.*—Broun has recently studied with much success the peculiarities of the lunar influence at Trevandrum, and has obtained some very unexpected results. His first result was that the nature of the lunar influence upon the declination needle at Trevandrum depends upon the time of the year, and that the southern type of lunar action predominates at Trevandrum during the winter and the northern type during the summer months. If we take the mean of the whole year, then probably the southern type will be found to predominate.

97. *Mean Lunar-Diurnal Variation during the Day and during the Night.*—Broun has shown that the action of the moon on the declination needle at Trevandrum is greater in every month of the year during the day than during the night. The following table (XXXI.) gives the day and night ranges for the various months and their ratios:—

Range.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	′	′	′	′	′	′	′	′	′	′	′	′
Day	0·85	0·47	0·49	0·41	0·24	0·36	0·40	0·39	0·31	0·23	0·41	0·69
Night	0·24	0·26	0·23	0·22	0·14	0·11	0·22	0·18	0·21	0·21	0·20	0·23
Ratio	3·6	1·8	2·1	1·8	1·6	3·2	1·9	2·1	1·5	1·1	2·1	3·0

It would appear from Broun's observations that there is a difference of type as well as a difference of range.

98. *Lunar-Diurnal Variation with Reference to the Moon's Distance.*—Both Sabine and Broun have shown that this variation is greater for perigee than for apogee. Broun has found that the mean ratio of the apogee effect to the perigee effect is as 1 to 1·24 nearly. He remarks that "the ratio of the moon's mean distance from the earth in the half orbit about apogee is to that in the half orbit about perigee nearly as 1·07 is to 1; as the cube of 1·07 is 1·23 nearly, we see that the mean ranges of the curves for the two distances are in the approximate ratios of the inverse cubes of the moon's distance from the earth, as in the theory of the tides."

99. *Lunar-Diurnal Variation with Reference to the State of the Sun's Surface.*—Kreil in a memoir presented to the Imperial Academy of Science in 1852 considers that the observations at Prague and Milan tend to show the existence of a solar period in the lunar variations. Sabine (*Phil. Trans.*, 1856) has discussed the Toronto observations and also (*Phil. Trans.*, 1857) the Hobart Town observations with the view of deciding this important point, and has come to the conclusion that there is no systematic difference in the lunar-variation corresponding to the decennial period of the solar-diurnal variation, but merely such casual fluctuations as might be reasonably expected, considering the shortness of the periods which they represent.

We have made a preliminary discussion of Broun's Trevandrum observations with the view of throwing a little more light on this subject. For this purpose we have taken the ranges of the lunar-diurnal variations recorded by him for each month of each year. We have in the first place grouped these ranges together into threes, representing quarterly results, and have then compared together these quarterly results for years of small and for years of great sun-spot frequency,—assuming the years 1854–56 and 1863–64 to represent the former, and the years 1857–62 to represent the latter. We have thus obtained the following result:—

TABLE XXXII.—*Relation between Lunar-Diurnal-Ranges of Declination at Trevandrum and Sun-Spot Frequency.*

	Great Sun-Spot Frequency.	Small Sun-Spot Frequency.
	′	′
February, March, April	0·501	0·493
May, June, July	·464	·380
August, September, October	·504	·419
November, December, January	·641	·583

It would appear from this table that such ranges are greater at years of maximum than at years of minimum sun-spot frequency. Nevertheless the proof is not conclusive, inasmuch as associated with such lunar ranges we may have remnants of solar disturbance, the tendency of which might possibly be to increase the apparent range. Now such disturbances are more frequent at times of maximum sun-spots, and it might therefore be conjectured that this tendency would be to increase the apparent lunar range at such times above the range corresponding to years of minimum sun-spots. On the whole we are not disposed to think that the evidence already adduced is sufficient to decide this question as a matter of fact either in the one direction or in the other.

100. *Variation in the Diurnal Range of Declination depending upon the Age of the Moon.*—Capello (*Annals of Lisbon Observatory*, 1876) and Stewart (*Proc. Roy. Soc.*, 1877) have separately found that the range of declination is greatest about the times of new and full moon, a result recently confirmed by C. Chambers of Bombay. The following are the results recorded by Stewart derived from 197 lunations at the Kew Observatory:—

TABLE XXXIII.—*Variation of Diurnal Range of Declination with Moon's Age,* (0) *denoting New and* (4) *Full Moon.*

Phase of lunation	(0)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Value of range	519	512	499	499	507	508	499	503

101. *Earth Currents caused by Lunar Influence.*—Mr Alexander J. S. Adams (*Nature*, March 3, 1881) has made use of a telegraph wire the ends of which were connected with the earth, the one at Cardiff and the other at London. He observed the currents on this wire every quarter of an hour from March 28 to April 26, 1879. He believes that such are earth currents, and that they have a lunar-diurnal variation. There are during the lunar day, according to this observer, four electrical maxima, two positive and two negative, each maximum being divided from the next by a zero or point of no current. His results likewise exhibit a regular retardation or lagging of the earth-current variations behind the corresponding phase of the moon to the extent of nearly three hours, but these require confirmation from further observations.

THE EFFECT OF SOLAR VARIABILITY ON THE METEOROLOGY OF THE EARTH.

102. We may learn from the preceding paragraphs that the sun exercises a more powerful influence upon the magnetism of the earth at times of maximum than at times of minimum sun-spots. It remains now to find whether a similar variability obtains in the phenomena of terrestrial meteorology. For this purpose we may divide the meteorological elements into the four divisions of pressure, rainfall, wind, and temperature, inquiring in what manner these are affected by solar inequalities.

103. *Pressure.*—In 1871 Baxendell (*Memoirs of the Lit. and Phil. Society of Manchester*, 1871–72), from an analysis of eleven years of the Radcliffe observations, Oxford, came to the conclusion that in years of maximum sun-spots the maximum barometric pressure occurred under north-east winds and the minimum under south-west, while in years of minimum sun-spots the maximum and minimum pressures took place respectively under north and south-east winds. He came likewise to the conclusion that, besides this difference in distribution of the convection currents of the earth, the forces which give rise to the movements of the atmosphere appear to be more energetic in years of maximum than in years of minimum sun-spots.

104. A study of the isobaric lines would appear to be the best method of obtaining information upon this important point. It is well known that during summer the interiors of large continents have a peculiarly low and the surrounding oceans a peculiarly high atmospheric pressure; while a disposition exactly the reverse obtains during the winter months. All this is no doubt due to solar action, and we might therefore imagine that when the sun is peculiarly powerful these peculiarities of distribution will be found to be increased in prominence, while they will be diminished at times of comparatively weak solar influence.

The distribution of pressure has been studied with much success by the Indian meteorologists, including Messrs Archibald, Blanford,