VI. *A Comparison of the most notable Disturbances of the Magnetic Declination in* 1858 *and* 1859 *at Kew and at Nertschinsk; preceded by a brief Retrospective View of the Progress of the Investigation into the Laws and Causes of the Magnetic Disturbances.*

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Before I proceed to the particular subject of this paper as noticed in its title, it may perhaps be desirable to take a brief retrospective view of the advances which have been made from time to time in our knowledge of the phenomena of the magnetic disturbances since they became the subjects of systematic investigation; and more especially since the publication of the Report of the Royal Society in 1840, and the establishment of magnetic observatories adopting and pursuing the methods of inquiry founded upon the instructions contained in that Report.

The observations of the German Magnetical Association, conducted by MM. Gauss and Weber, which was the immediate precursor of the British observatories, commenced in 1834 and terminated in 1841, the first year of the British Observatories. It was itself preceded by an earlier German Association, formed in 1828 under the auspices of Baron Alexander von Humboldt, having for its object to make a series of strictly synchronous observations of the magnetic declination at concerted times at widely separated localities, for the purpose of inquiring into the nature and investigating the laws, if laws should be found to reveal themselves, of the apparently casual and irregular fluctuations of the magnetic needle which had then recently begun to attract the notice of scientific men, as natural phenomena proceeding from and indicating some hitherto unknown agency, and as such well meriting systematic investigation.

Berlin was the centre of the first German Association, as Göttingen was of the second. In 1829 and 1830 the Berlin Association had correspondents in very distant parts of the European continent, such, for example, as St. Petersburg, Kasan, and Nicolaieff, by whom the direction of the declination magnet was observed with great care and precision at hourly intervals of absolute time for forty-four successive hours at eight concerted periods of the year; and to the continuance of these *term-observations*, as they were called, there were added in March 1834 similar observations at Göttingen, but made with greater frequency, viz. at intervals of ten minutes. The intercomparison of the *hourly* observations revealed the general fact that very considerable fluctuations, still happening however on days that were apparently casual and irregular, were synchronous at all the stations of observation; whilst the *ten-minutely* observations at Göttingen, which had no parallels elsewhere, showed numerous intermediate fluctuations of similar

character. In order to bring to the test of positive evidence the question whether these intermediate fluctuations were also general, or were of merely local origin, *five-minutely* observations were now appointed at all the stations; and the result of four such term-days, in May, June, August, and September 1834, was to establish conclusively, that almost all the numerous and apparently irregular movements observed at Göttingen occurred also at the other places; and although with varied relative magnitudes, yet with an agreement which did not admit of mistake. The Göttingen Association now took the lead in the inquiry, the number of terms in the year being fixed at six, each of twenty-four hours' duration, with intervals of five minutes between the observations. The number of associated stations appears to have been about twenty, distributed generally over the continent of Europe. Besides the increased frequency of the observations, improvements were introduced in the apparatus used in the observations of the declination; and the bifilar magnetometer, devised by M. GAUSS for a corresponding record of the variations in the intensity of the horizontal component of the magnetic force, was employed at a few stations where the activity was greatest. The Göttingen Association continued its terms with regularity until 1841, stimulated by the great advantage which it possessed in the discussion of the results from time to time by MM. GAUSS and WEBER in the well-known publication entitled "Resultate aus der Beobachtungen des magnetischen Vereins." The conclusions already noticed as having been obtained in 1834 were confirmed by the careful examination and discussion to which the observations of each recurring term-day were subjected. The disturbing action was found to be frequently so considerable in amount, that partial and even total obliteration of the regular diurnal movements was a very common occurrence; and to be of such general prevalence, not only in the larger but also in most of the smaller oscillations, over the greater part of Europe, as to cause it to be viewed as in a very high degree improbable that the disturbances could have either a local or an atmospherical origin. No connexion or correspondence whatsoever was discoverable between the indications of the magnetical and meteorological instruments; nor had the state of the weather any perceptible influence. It happened very frequently that either an extremely quiescent state of the needle or a very regular and uniform progress was preserved during the prevalence of the most violent atmospherical storm; and as with wind-storms, so with thunder-storms, even when close at hand they exercised no perceptible influence on the magnetic instruments*.

* As a *magnetical* question, the supposition of an atmospherical origin of the disturbances may be considered to have been disposed of by the conclusions of the Göttingen Association. There remained, however, a problem which might be interesting to *meteorologists*. It was possible to suppose that, although the magnetic disturbances did not originate in the atmosphere, their presence, or possibly that of their producing cause, might occasion some atmospherical condition (which might be indicated either by the meteorological instruments or by some peculiar state of the weather), affecting simultaneously all parts of the globe on the particular days when the magnetic instruments were disturbed. The simultaneous observations of both classes of phenomena at the widely distributed stations of the British Colonial Observatories were well calculated to bring into view any such general atmospheric condition or affection if it existed; but the most careful collation of the simultaneous records of many years has failed to reveal any such correspondence.

The variations in the proportional magnitude of the disturbances in different localities, even when the similarity was otherwise unequivocal, had in one respect the appearance of a systematic indication, a decrease being shown in the energy of the disturbing force as its action was traced and followed from north to south. Hence the probability was inferred (so far as it might be safe to draw such conclusions from experiments which embraced comparatively but a small portion of the earth's surface) that the great focus or foci from whence the most powerful disturbances in the northern hemisphere emanated might be situated, and might possibly be sought with success, in parts of the globe to the north, or to the north-west, of the European continent. But even admitting this supposition to be well founded, so many of the phenomena still remained unexplained, that in the 'Resultate' for 1836, p. 99, M. GAUSS took occasion to express his matured conviction that "we are compelled to admit that on the same day and at the same hour various forces are contemporaneously in action, which are probably quite independent of one another and have very different sources, and that the effects of these various forces are intermixed in very dissimilar proportions at various places of observation relatively to the position and distance of these latter; or these effects may pass one into the other, one beginning to act before the other has ceased. The disentanglement of the complications which thus occur in the phenomena at every individual station will undoubtedly prove very difficult. Nevertheless we may confidently hope that these difficulties will not always remain insuperable, when the simultaneous observations shall be much more widely extended. It will be a triumph of science should we at some future time succeed in arranging the manifold intricacies of the phenomena, in separating the individual forces of which they are the compound result, and in assigning the source and measure of each."

The term-days of the Göttingen Association were limited to the observation of a single element, viz. the declination, with the exception of a few stations at which the bifilar magnetometer was occasionally employed. Instrumental means had not as yet been devised for observing the disturbances of the inclination and the total magnetic force, either directly, or by means of their theoretical equivalents, the horizontal and vertical components of the force. We find it indeed expressly admitted by M. GAUSS that it could not be doubted that the Inclination and Force are subject to disturbances similar to those observed in the Declination, but that the time had not yet arrived for including the three elements in the circle of combined inquiry: adding, "that as soon as the means of observation should be so far perfected that we could recognize with certainty, follow with ease, and measure with accuracy the variations, and especially the rapidly varying changes of the dip and total force, these variations would have the same claim on the united activity of inquirers, as the variations of the declination possessed during the period of the Göttingen Association."

We come now to the epoch when the inquiry was taken up and its further prosecution carried on by our own country. The two German Associations had prepared the way for the more extended and more complete organization which, on the recommenda-

tion of the British Association for the Advancement of Science, assembled at Newcastle in September 1838, and concurred in by the President and Council of the Royal Society in the spring of 1839, the inquiry subsequently received under the sanction and with the warm support of the Ministry of which Lord MELBOURNE was the principal member, and the succeeding Administration of which Sir ROBERT PEEL was the first minister. The field of research was no longer limited to a single continent, but included the most widely separated localities on the globe. Stations were selected in both hemispheres, and in the tropics, on continents and on islands, the selection being guided either by diversity of geographical circumstances, or by magnetical relations of prominent interest. The objects of investigation were also enlarged, so as to include not alone the transient and irregular fluctuations which had occupied the chief attention of the German Associations, but also "the actual distribution of the magnetic influence over the globe at the present epoch in its mean or average state, together with all that is not permanent in the phenomena, whether it appear in the form of momentary, daily, monthly, semiannual or annual change and restoration, or in progressive changes, possibly not compensated by counter-changes, or possibly receiving compensation, either in whole or in part, in cycles of unknown relation and unknown period." Suitable instruments, which in many respects were novel in construction, were provided for the observation of each of the three magnetic elements in this scheme of comprehensive research; and a report, prepared with much deliberation and care by a special committee of the Royal Society, was printed for the instruction and guidance of those who should be employed in conducting the magnetic surveys by sea and land, and of those who should direct or superintend the investigations to be carried out at the stationary magnetic establishments.

The present communication having reference to one branch only of one department of this extensive inquiry, viz. to that which relates to the *magnetic disturbances*, its notices are strictly limited to what may be necessary for placing before the Society as briefly as possible the successive steps which have advanced our knowledge of these phenomena, in respect to their diversities and mutual relations, their connexion with the general phenomena of terrestrial magnetism, and their probable cosmical origin.

The simultaneity of the days on which magnetic disturbances take place had already been shown by the term-days of the Göttingen Association to be coextensive with its sphere of operation, viz. the greater part of the continent of Europe. The wider extension of the British system, embracing stations in all quarters of the globe, now caused the fact of the simultaneity of disturbance to be recognized as a general feature common to the whole of our planet; whilst the evidence of diversity in the action of individual forces, even in the most clear cases of synchronous disturbance, was even more distinctly manifested than in the previous more limited experience. Thus the comparison of the term-days in 1840, 1841, and 1842 observed at different stations on the continents of Europe and America, and collated in the first volume of the Observations at the Toronto Observatory, published in 1845, gave occasion to the following general conclusion:—"The correspondence so strikingly manifested in the fluctuations in America, and which

has its counterpart in the correspondence shown by the term-observations at the different stations in Europe, is not found to prevail in anything like the same degree between the curves of the two continents when they are exhibited in comparison. Nevertheless indications are not wanting of participation in disturbances having a common cause. .... The character of the term-day, in respect to the degree of disturbance by which the magnetometers are affected, may always be derived alike, whether we view the European or the American curves; and instances are not infrequent of individual perturbations common to both continents, having their culminating points at the same individual instant. There are sometimes disturbances in the same direction in both continents and sometimes in opposite directions. On the other hand, there are perturbations, and occasionally of considerable magnitude, on the one continent, of which no trace is visible in the observations on the other."

These facts were in full accordance with the conclusions which had been derived by the eminent geometrician of Göttingen from the observations of the Association formed under his auspices. They were further confirmed by a still more extensive and searching comparison, the means for which were furnished by a practice adopted at the British Colonial Magnetic Observatories shortly after their operations had commenced, of summoning the whole observing staff of the Observatory whenever in the course of the hourly observations of the magnetometers (maintained without intermission except on Sundays) they were perceived to be under the influence of an unusual disturbance; and thus the movements of each of the magnetometers were recorded at as short intervals as circumstances would permit, until the disturbance appeared to have subsided. These records were received at the Headquarter Office at Woolwich from Toronto, St. Helena, the Cape of Good Hope, and Van Diemen Island, as well as from the Expedition employed under Sir JAMES ROSS in the Magnetic Survey of the Antarctic regions, whenever the ships were sufficiently long in port to admit of the magnetometers being established and observed. The comparison of the records showed that magnetic disturbances prevailed, almost invariably, on the same days and at the same hours, in all these very various parts of the globe. The observations themselves were subsequently published in two parts; Part I. in 1843, containing the observations in 1840 and 1841, and Part II. in 1851, containing those in 1842, 1843, and 1844; together with the corresponding values of the declination and of the horizontal force in Part I., and of the declination, horizontal and vertical forces, and of their theoretical equivalents, the Inclination and the Total Force, in Part II.; accompanied by the normal values of the elements at the different stations in the months in which the disturbances occurred, and their absolute values at each of the stations. Abundant evidence is to be found in these publications that fluctuations of the most marked character are strictly synchronous in the northern and southern hemispheres, as well as in Europe and America; whilst at stations remote from each other the disturbance of the one element may differ widely in amount, and occasionally may be even reversed in direction. Not unfrequently also a disturbance showing itself at the same instant at distant stations is found to affect one

element at one station and another element at another station,—all confirmatory of the conclusions arrived at by M. GAUSS, and of the opinions of those who, antecedently to the establishment of the British Colonial Observatories, had anticipated that *the distinctive characters of the disturbances at individual stations would require to be studied, as the first step in a systematic inquiry into their causes, sources, and mutual relations.*

The hourly observations made at the Colonial observatories were received at Woolwich in the form of monthly tables, in which the days of the month were arranged in successive horizontal lines, and the hourly observations in twenty-four vertical columns; an additional column at the side showed the mean of each day, and an additional line at the bottom of the Table the mean of each hour in the month. Even a very superficial examination of these Tables at any one station sufficed to show that certain hours were more affected by disturbance than others. These hours were not the same at different stations; and no distinct relation could be traced at any station between the hours of principal disturbance and those of the well-recognized horary fluctuation due to the regular solar-diurnal variation. It was obvious therefore that the horizontal line at the bottom of each monthly table, which showed the mean values at the several hours (or what might be termed the diurnal inequality), did in fact represent two variations, viz. 1st, the regular solar-diurnal variation, and 2nd, a diurnal variation due to the disturbances; the two having every appearance of proceeding either from distinct causes or from distinct actions of the same original cause. The means of separating them *perfectly* from each other did not readily present themselves, but to do so *approximately*, and with an approximation quite sufficient for many practical purposes, was merely a work of labour. The very feature which marked certain of the observations as disturbed, viz. the magnitude of their discordance with the other records standing in the same column with themselves, or (as more readily seen) the magnitude of their differences from the mean value at the same month and hour at the foot of the page, appeared to supply a ready means (in the absence of any more exact criterion) of distinguishing the observations which were most affected by disturbance. It was soon found that by assuming for each element and for each station a certain amount of difference from the monthly mean at the same hour as the *indication of disturbance*, the records in each month might be separated into two portions, of which the smaller, containing the disturbed observations, might be set apart for an examination of the laws of disturbance; whilst the larger portion, from which the disturbances had been thus eliminated, would become more available for obtaining a correct knowledge and analysis of the progressive and regular variations than when they were mixed up with the casual and transitory affections.

By maintaining these assumed discriminating or separating values (forming the criteria whereby each observation was assigned either to the disturbed or to the undisturbed category), *constant at each station*, the laws of disturbance in different months and different years, if such laws existed, might be studied with convenience and security; and by so adjusting the values adopted at the different stations as to cause the number of the disturbed observations at each station to bear nearly an equal proportion to the

whole body, an advance might be made towards an approximate estimate of the degree in which the disturbing action prevailed in different parts of the globe. In the practical application of this scheme of first or primary analysis it was found that, provided the selected separating value at each station were such as to place in the category of disturbed observations a proportion equivalent to between one and two tenths of the whole body of the observations, small alterations within these limits occasioned no significant alterations in the derived diurnal progression either of the disturbed or of the (for the most part) undisturbed observations.

The monthly records of a single year at any one of the observatories sufficed to manifest an order and sequence in the ratios of the aggregate amounts of disturbance in each of the twenty-four hours to the mean amount in the twenty-four hours taken as unity, which placed beyond a doubt the fact that, casual and irregular as the disturbances might appear in respect to the particular times of their occurrence when viewed in single days, they were in their *mean effects* strictly periodical phenomena; exhibiting, by the character of their periodical variations, *a dependence on the sun as their primary source.* To this important fact the disturbances of each of the magnetic elements, the Declination, the Inclination, and the Intensity of the magnetic force, bore concurrent testimony, although the hours of maximum and minimum of their respective diurnal progressions were dissimilar; confirming in that particular the inference of the existence of distinct periodical laws in the disturbances of each of the elements.

The bearing of this result upon the methods by which magnetical investigations could most successfully be prosecuted was important. It had been remarked at a very early date, viz. in the 1st volume of the Toronto Observations, published in 1845, p. xv, that "if the disturbances took place without any systematic prevalence at certain hours rather than at others, and with no systematic inequality in regard to direction and amount, their influence would be limited to a lengthening of the time required for obtaining accurate mean values of the solar-diurnal variation; but that if systematic inequalities were found to prevail in those respects, it was obvious that no duration of the observations would eliminate their influence; and the diurnal inequality obtained from the whole body of the observations, whatever might be the duration it represented, must include the effects of two distinct phenomena, viz. of the disturbances, and of the diurnal variation properly so called; these two phenomena having possibly distinct causes, or at least distinct laws." The conclusion could no longer be doubted, therefore, that the first step in the systematic treatment of a body of observations, whether for the purpose of studying the laws of the disturbances, or for obtaining a correct knowledge of the more regular periodical variations, must be to separate the observations into two portions, one of which should include the more significant disturbances, and the other should contain the remainder of the observations, from which the disturbances had been for the most part eliminated. Our present concern is with the treatment of the disturbed portion only; the periodical variations of more regular occurrence are discussed elsewhere.

And here it becomes proper to recall the instructions regarding the casual and transitory variations contained in the Report of the Royal Society referred to in page 230, in which we find this conclusion to have been in great measure anticipated,—the importance of treating the laws and mutual relations of the disturbances as a distinct subject of investigation clearly recognized,—and the probable results of such investigation not obscurely indicated. In pages 2 and 3 of that Report it is stated that "the investigation of the laws, extent, and mutual relations of the casual and transitory variations is become essential to the successful prosecution of magnetic discovery.... because the theory of those transitory changes is in itself one of the most interesting and important points to which the attention of magnetic observers can be turned, *as they are no doubt intimately connected with the general causes of terrestrial magnetism, and will probably lead us to a much more perfect knowledge of those causes than we now possess.*" In the opinion thus expressed, being myself one of the Committee by whom the Report was drawn up, I fully concurred; and having been appointed by Her Majesty's Government to superintend the observations made at the British Colonial Observatories, and to coordinate and publish the results, it is alike my duty and my desire to show that the methods pursued have been in strict conformity with the spirit of those instructions, whilst the conclusions derived will be seen to be in full accordance with the anticipations expressed therein*.

* The importance which M. Gauss attached to the further and full investigation of the magnetic disturbances was not less than that expressed in the Report of the Royal Society. Having had occasion, at the request of the President and Council of the Royal Society, to visit Berlin and Göttingen in conjunction with Dr. Lloyd in the autumn of 1839, when the British Colonial Observatories were in contemplation, I transcribe the following notice of M. Gauss's opinions from a copy which I have retained of a letter to Baron Alexander von Humboldt, written from Elberfeld on the 24th of October 1839, since it is more to the purpose than anything which I could now write from recollection:—"The conferences with M. Gauss did not close till late on Monday night: we left Göttingen early on Tuesday morning, and this is our first stoppage. We found M. Gauss's attention resting principally on that part of our proposed system of observation which is directed to the determination of the laws of the periodical fluctuations, and of the mode of action of the causes which produce them. Fully satisfied with the hourly observations as an almost certain means of attaining these objects, he was only desirous, for the full solution of the problem, that the number of stations should be increased so as to comprise the greatest practicable extent of latitude; care being also taken that there should be one or two parallels in which there should be stations in meridians widely apart. The relative importance of different localities in reference to the *secular changes* does not yet appear to have received M. Gauss's attention. The bearing of the stations on the periodical fluctuations was the chief and almost the only consideration on which he *dwelt*. We may hope that, in respect to the secular changes, the results obtained at the nineteen contemplated stations, so extensively distributed on the surface of the globe, will at least serve to test the validity of physical theories, though they may not include those points which a more advanced knowledge might indicate as most suitable for suggesting the true theory. Barnaoul and Yakutsk appear well situated to throw light on the easterly progression of the maximum of force in the Siberian quarter, which is by some believed to be more rapid than the progression, also easterly, of the maximum in the American quarter; forming in their combined effect a double system of translation in the lines to which the changes of Declination and Inclination in the northern hemisphere, ever since they were observed, appear to have been conformable. Our solicitude was strongly expressed to learn from M. Gauss if there were any stations, exclusive of those chosen for the fixed observatories, at which a new determination of the three

The Report anticipates, as the probable result of the researches then about to be instituted, the establishment of an intimate connexion between the casual and transitory variations and the "general causes of terrestrial magnetism." Whatever these may be, our best inferences in regard to them must be based upon the knowledge we possess of the actual distribution of the magnetic influence upon the surface of the globe. In regard to this distribution, the Report refers throughout to two works as containing the embodiment of the totality of the known phenomena, viz. 1, a memoir, published two years antecedently (1838) in the Transactions of the British Association for the Advancement of Science, entitled "On the Variations of the Magnetic Intensity in different parts of the Earth's Surface," in which the results of recent researches in almost all the accessible parts of the globe were brought together and coordinated, and their bearing on earlier systematic views discussed; and 2, M. GAUSS's 'Allgemeine Theorie des Erdmagnetismus,' published in 1839, being the year preceding that in which the Report of the Royal Society was published*. These two works are referred to throughout the Report as supplying, the first the observational, and the second the theoretical bases of the Instructions drawn up for the guidance of those who were to conduct, and of those who were willing to take part in the proposed magnetic researches by sea and by land. In both works, the facts which had been ascertained were found to be in accordance with (and so far confirmatory of) the theory which we owe to the combined industry and sagacity of our illustrious countryman and Fellow, HALLEY, of the existence of a *double* system of magnetic attraction on the surface of the globe, the direction and intensity of the magnetic force being at all points the resultant effects of the two separate systems. In both works, the localities to which the resultant Poles, or Points of greatest force (in the northern hemisphere), were traced, were nearly the same, viz. one in the northern part of the American continent, and the other in the northern part of the Europæo-Asiatic continent. To have determined their *precise* geographical positions, it would have been requisite that the observations from which they were derived should have corresponded, or nearly so, to one and the same epoch, inasmuch as one of the magnetic systems is regarded as subject to a movement of translation in a geographical sense, giving rise to the phenomena of secular change. But the approximation in the conclusions from two such extensive and laborious coordinations as those which have been named, was fully sufficient to establish that the general causes of terrestrial magnetism referred to must be such as would produce the phenomena of a double system. Now, combining the expectation expressed in the Report,

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magnetic elements was particularly desirable towards a revision of his theory. It appears that of the seven parallels of latitude which he has employed to give the basis of his numerical calculation, the most southern is in 20° S. latitude. Observations carried round a parallel in a high southern latitude are consequently the principal desideratum. This is precisely what we have reason to hope will be accomplished by the Antarctic Expedition."

* An English translation by Mrs. SABINE of M. GAUSS's "Allgemeine Theorie" was published in 1839 in Taylor's Scientific Memoirs, vol. ii. Art. V.

of the probability of a connexion subsisting between the magnetic disturbances and the more general phenomena of the earth's magnetism, with M. GAUSS'S inference from the Göttingen researches, that the source or sources ("point or points of apparent origin") from whence the disturbing action in the northern hemisphere proceeds must necessarily be sought in the north, or in the north-west, of the European continent, it seemed reasonable to infer hypothetically that a connexion might be found between the "points of origin" of the disturbances,—if these could be more precisely ascertained and their separate effects distinguished apart,—and the poles or points of the two magnetic systems, of which we have the resultants in the centres of the two isodynamic lemniscate-loops. The *first* analysis of the disturbances had shown the disturbances to be strictly periodical phenomena in their mean effects, and had traced them directly to the sun as their *primary source*, inasmuch as they were found to be governed everywhere by laws depending upon the solar hours. Those who are familiar with the theory by which the transmission of light from the sun to the earth is explained, will have little difficulty in admitting a similar explanation of the mode by which magnetic influences may be conveyed from the sun to the earth. The analogy has been directly recognized and reasoned upon in the explanation of magnetic phenomena by Professor CHALLIS in recent papers. It is when the influences reach the earth that the modes of their reception, distribution, and transmission may be less clearly apprehended; but these are within our own proper terrestrial domain and sphere of research, and are therefore more particularly the subjects to which our investigations may be most usefully directed. We have here to guide us the simple analogy of a magnetic impulse imparted to a bar already magnetized; the impulse is at once distributed throughout the bar; the poles or points of greatest force being affected in the greatest degree, and the effects diminishing as the middle of the bar is approached. We may conceive that in like manner a magnetic impulse communicated from without might, in either hemisphere or in both simultaneously, be received by and produce its principal effect on the poles or points of greatest force belonging to the hemisphere, either augmenting or diminishing, as the case may be, the mean or ordinary magnetism of each, and thenceforward acting generally and conjointly throughout the hemisphere according to laws which are or may be capable of determination by suitable means. The possibility of tracing a certain locality, or localities, on the globe as a "point or points of origin" where the magnetic influences being received might thenceforward distribute themselves according to the laws of magnetic propagation, had already been entertained by M. GAUSS. In the first analysis of the disturbances at the British Colonial Observatories, referred to in p. 233, those of each element were treated simply in their *aggregate* effects, as might be conceived to be suitable on the supposition of their proceeding from a *single source* only. The result was sufficient to manifest their strictly periodical character, and to refer them to the sun as their *primary* source; but it was at the same time obvious that this first analysis could by no means be regarded as a final one, inasmuch as in every case there was exhibited a plurality of maxima and minima in the diurnal progression;

giving reason to infer that, by subjecting the disturbances to a more searching analysis, systematic progressions indicative of two or more distinct sources of disturbance in each hemisphere might be made to disclose themselves.

It had been found, moreover, that at every station where the examination had been made the disturbances of the declination were occasionally deflections to the East, and occasionally deflections to the West, from the mean position of the magnet; and those of the Dip, and of the total Force, occasionally increasing and occasionally decreasing the mean values. The aggregate amounts of disturbance in each element were now therefore separated into distinct categories, and the ratios of disturbance at the several hours in each category to the mean hourly ratios were determined by a process similar to that adopted in the analysis of the aggregate values. The results fully justified the labour expended in this proceeding; each category presented progressions still more systematic and of much greater simplicity than had appeared in the preceding investigation previous to which the categories had not been separated; giving great probability to the inference that at every station a similar process would manifest that there were at least two, and probably only two, distinct sources in each hemisphere, to which disturbances occurring simultaneously might be ascribed; and that by an increase in the number of stations, particularly if they were judiciously selected, the geographical localities in which the greater part at least of the disturbances originated, might be approximately traced. Confining ourselves, for brevity, to the illustration afforded by a single element, viz. the Declination, it was found that at all stations, in all parts of the globe, the disturbances of the declination resolved themselves into two distinct and dissimilar categories; the same two distinct and dissimilar forms of diurnal progression being everywhere reproduced with little other variation than that of the particular hours of maxima and minima; but having this additional important peculiarity, that the particular form of the curve of the diurnal progression which characterized the Easterly Deflection at certain stations marked the Westerly Deflection at certain other stations, and *vice versâ*. It was also found that at some stations the Easterly Deflections greatly preponderated over the Westerly, whilst at other stations the Westerly were predominant. An attentive consideration of the facts elicited by this extensive though somewhat laborious investigation strengthened the previously prevailing impression, that the progressive increase of our knowledge of these remarkable phenomena would lead, in both hemispheres, to the establishment of a connexion—if not to the identification—of the terrestrial sources of the casual and transitory disturbances with the foci, as they are sometimes called, of the two magnetic systems of the globe.

Proceeding from these premises, it appeared desirable to examine whether, if two stations were taken in a suitable and nearly similar latitude, one of which might be on the eastern and the other on the western side of one of the supposed points of terrestrial origin, and if a sufficient comparison were made of the disturbances simultaneously observed at the two stations, the category of easterly deflections at the one station might not be found to correspond in the form of the curve, and possibly also in the hours of

maxima and minima taken in absolute time, with the category of westerly disturbances at the other station. To test this by experiment, it was desirable to select stations, in suitable localities, where trustworthy observations could be relied on, inasmuch as the experiment would be somewhat of a crucial nature. The Russian stations on the eastern side of Siberia and at Pekin, where hourly observations of the declination had been made for some years, seemed the most favourably situated for supplying a station on the eastern side of the Europæo-Asiatic focus, whilst Kew might furnish a corresponding station on the western side, as soon as its photographic records should be sufficiently advanced. For the Asiatic station Pekin was selected in the first instance, although its latitude being about 12° south of Kew, might seem to render it a rather less eligible station of comparison than one of the eastern-Siberian stations; but there was at that time an idea, originated by Sir CHARLES TREVELYAN at the Treasury, that Pekin might become a station of a British magnetic observatory, and in that view it was desirable to know what had already been accomplished there. The first thing to be done was to ascertain by a careful scrutiny the degree of reliance to be placed on the observations, these having been made, under the Russian superintendent of the Pekin Observatory, by Chinese observers; and a decisive test was at once adopted. It consisted in rewriting in *lunar* hours the monthly Tables which record the observations taken at *solar* hours, and deriving from the Tables so rewritten the lunar-diurnal variation. If this very small variation be shown consistently in different years by the observations thus transposed from the original record, the observations are entitled to be regarded as good. The Pekin hourly observations, from 1852 to 1855 inclusive, as printed in the volumes of the 'Observatoire Physique Central de Russie,' having been thus tested, were found to be quite trustworthy. The lunar-diurnal variation derived from them in each of the four years is shown in Table CXX., p. cxiv of the second volume of the St. Helena Observations, having been included in that volume for reasons stated in page cxxxvi. The aggregate values of the easterly and of the westerly portions of the disturbance-diurnal variation at Pekin, as well as the ratios of disturbance at the several hours, are printed in Table CXVIII. (p. cxi) of the same volume. The corresponding results obtained by the Kew photograms between January 1858 and December 1862 are given in a paper in the Philosophical Transactions for 1863, Art. XII., Table II., and in the same paper (Philosophical Transactions, 1863, Art. XII., p. 282) the comparison is made of the Kew and Pekin disturbance-deflections, showing that the *conical form and single maximum* which characterize the *easterly* deflections at Kew, characterize the *westerly* deflections at Pekin at approximately the same hours of absolute time.

In confirmation of this result a second comparison was made between the results at Kew and those obtained from the hourly observations at Nertschinsk in Eastern Siberia from 1851 to 1857, printed also in the 'Annales de l'Observatoire Physique Central de Russie.' Nertschinsk is almost identically in the same latitude as Kew, whilst in longitude it scarcely differs from Pekin. Here also the observations, having been submitted to the same test in respect of accuracy, were found to be equally trustworthy;

and the comparison of the disturbance-deflections showed a still more perfect accord between the curve representing the easterly deflections at Kew and the westerly at Nertschinsk at approximately the same absolute hours.

To this it should be added that at each of these stations, as at all others, the forms of the easterly and westerly deflection-curves are so distinct that they cannot be mistaken for one another: the difference is well shown in figs. 1 and 2 of plate 1 in the "Reade Lecture delivered in the Senate House of the University of Cambridge in May 1862:" the curves there represented are those of the east and of the west deflections at Kew and at Hobarton (in Tasmania); and on the same page the westerly curve at Nertschinsk, shown in fig. 3, is seen to accord with the easterly curve at Kew, fig. 1. In Plate XIII. accompanying the discussion of the Kew observations (Phil. Trans. 1863, Art. XII.), the easterly curve at Kew and the westerly at Nertschinsk are also shown in figs. 1 and 5; these figures represent the ratios derived from the aggregate values of the respective disturbance-deflections at Kew from 1858 to 1862, five years, and at Nertschinsk from 1851 to 1857, seven years. My purpose on the present occasion is to show the correspondence between these deflections (the easterly at Kew and the westerly at Nertschinsk) in what may appear to some a more impressive manner, viz. a direct comparison of nearly synchronous disturbances in absolute time in the easterly and westerly disturbances at the two stations, Kew and Nertschinsk, on the most notable occasions of disturbance in the years 1858 and 1859. I am limited to these two years because the photographic record at Kew did not commence until January 1858, whilst the hourly observations at Nertschinsk for 1860 and the succeeding years have not yet reached England.

I have adopted the same characteristic at both stations for the days of most notable disturbance, viz. all those days in which twelve at least of the twenty-four equidistant epochs were disturbed to an amount equalling or exceeding "the separating value," viz. 3′·3 at Kew, and 3′·5 at Nertschinsk; the differences from the normals of the same month and hour at Nertschinsk being entered in the Table at the close of this paper, as those at Kew were in the Table in the Philosophical Transactions for 1863, Art. XII., p. 274, with which it may be compared. The number of days so characterized in 1858 and 1859 are at Kew forty-two, and at Nertschinsk forty-four; a great part of the disturbances being on the same days at both stations, but not invariably so, since, as is known, "a disturbance affecting one *element* at one station does not always affect the same *element* at another station." In inspecting the Summary at the close of the Table, it must be borne in mind, on the one hand, that a *very regular* progression can scarcely be looked for from disturbances occurring in the very limited space of two years; but, on the other hand, that 1858 and 1859 were years of maximum disturbance in the decennial period, and are therefore years of peculiar suitability in the case of a very limited comparison. The aggregate value of the disturbances at Nertschinsk in 1854 was 3497 minutes of arc, and in 1859 5602 minutes*.

* An inquiry into the years corresponding to the epochs of minimum of the decennial variation from 1823–

The comparison of the contemporaneous disturbances at Kew and Nertschinsk in 1858 and 1859, which are given in detail in the Table at the close, may perhaps be facilitated by the subjoined Tables I. and II., in both of which the hours are those of absolute solar time at Kew, whilst the deflections are *easterly* at Kew and *westerly* at Nertschinsk.

TABLE I.

Stations.	Kew Astronomical Hours.											
	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Kew	67	93	75	144	187	214	183	232	206	131	77	25
Nertschinsk	36	47	40	69	106	93	146	204	198	159	103	75

TABLE II.

Stations.	Kew Astronomical Hours.											
	18.	19.	20.	21.	22.	23.	0.	1.	2.	3.	4.	5.
Kew	27	34	33	8	13	12	59	40	46	33	46	27
Nertschinsk	75	79	154	88	72	63	32	46	54	20	25	16

It is seen that much the larger proportion of the disturbances at both stations occur between the hours of 6 and 17, Kew time. They exhibit a generally progressive increase of disturbance, easterly at Kew and westerly at Nertschinsk, from 6 to 13 hours, and a progressive decrease from 13 to 17 hours, also easterly at Kew and westerly at Nertschinsk. It is at these hours, viz. the hours contained in Table I., that the disturbances which produce opposite deflections at the two stations, and may therefore be supposed to proceed from a source intermediate between the stations, have their principal preponderance. In Table II. containing the hours, also of Kew time, from 18 to 5, and the deflections still easterly at Kew and westerly at Nertschinsk, we find the disturbances at both stations generally lessened in their aggregate amount, as we may suppose might be occasioned by the interference of disturbances of an opposite character proceeding from another and a more distant source. Admitting this supposition, the principal operation of the interfering cause does not take effect at the same hours of absolute time at the two stations; it appears to be chiefly influential at Kew from 18 to 23 hours, and at Nertschinsk from 0 to 5 hours.

I have thus endeavoured to trace consecutively the steps by which the probability of

1824 to 1853–1854 is to be found in the second volume of the St. Helena Observations, published in 1860, pages cxxi–cxxxvi. Assuming the period to be approximately decennial, we should now (1863–1864) be arrived at the fourth recurrence of an epoch of minimum in forty years. Appearances, as yet, seem to favour the recurrence of the minimum at the expected epoch. In 1865 and 1866 and succeeding years the disturbances should be expected to be on the increase.

a connexion subsisting between the points of terrestrial origin of the disturbances, and the Poles or Points of maximum force of the two systems which conjointly determine the distribution of the magnetic influence on the globe, has been examined, and to some extent strengthened. We have now to await the concurrent evidence which may result from a similar examination of the disturbances of the Dip and of the Total Force, which it is hoped may appear in a continuation of the papers on the results obtained at the Kew Observatory. But for the completion of the retrospective view of the progress which has been made in developing the theory of the magnetic disturbances, and in conducting us possibly to a more perfect knowledge of the general causes of terrestrial magnetism than we previously possessed, I must revert to the remark occurring in the earlier part of this paper (page 232), that the value adopted for each element and at each station to characterize what should be regarded as a disturbed observation, was purposely made a *constant amount*, with a view to an examination of the relative amount of disturbance in different months and in different years. It was in this way learnt, as is stated in the second volume of the Toronto Observations, pp. xxii and xxiii, that "1843, 1844, and 1845 were years in which the proportion of observations affected by a certain constant amount of disturbance was much smaller than the preceding years 1841 and 1842, or the following years, 1846, 1847, and 1848;" presenting thus the aspect of a *periodical variation* of which the epoch of minimum might be assigned to the years 1843 and 1844, but of which the period or cycle had yet to be learnt. The phenomena were not peculiar to a single station, but were found to correspond in localities most distant from each other: nor were they confined to one only of the magnetic elements, but were exhibited by all, each element having its own distinct instrumental means of measurement. They were therefore recognized as the indication of a magnetic affection common to the whole of our globe, constituting a periodical variation in the amount of disturbance in different years. In 1851 and 1852 the annual ratios of disturbance were found to be everywhere decidedly on the *decrease*, the epoch of maximum appearing to have taken place in 1848–1849. The evidence of the existence of a *decennial* variation appearing to be thus complete, its announcement, as a fact of which the knowledge was acquired by a process of investigation specially designed for the discovery of any such periodical variation, if one should exist, was on the point of taking place, when a fortunate incident (the receipt from M. DE HUMBOLDT of a proof-sheet of his 'Kosmos,' containing the first publication of HOFRATH SCHWABE'S Table of the variations of the solar spots from 1826 to 1850) brought to my knowledge the existence of a corresponding variation in the physical aspect of the sun, precisely similar in period and epochs to the terrestrial magnetic variation. The importance of a revelation which gave a present apparent connexion, and presented the promise of establishing a permanent connexion, between the previously isolated terrestrial magnetic phenomena and the physical affections of the central body of our system, could not well be overrated. It was not alone the cosmical character which it imparted to a single terrestrial magnetic variation otherwise unconnected and inexplicable,—but there could scarcely fail to be impressed on the

mind of every reflecting magnetician the possibility, almost amounting to probability, that the second system of the terrestrial magnetism, which by the change in its relations to geographical space seemed to be distinct and dissevered from the magnetism of the earth properly so called (*i. e.* the collective action of all the permanent magnetic particles of the earth's mass, having its seat in the earth itself), might, like the decennial variation, be in truth assignable to a cosmical origin. The movement of translation on the earth's surface of the second system, and with it the whole phenomena of the secular change, would thus be regarded as belonging to, or being part of, a cosmical variation. It has, indeed, all the characters befitting such a relation, besides appearing inexplicable on any other hypothesis: we do not, indeed, yet know the duration of this far longer period, nor are we able to trace its course by visible signs on any of the heavenly bodies, as we trace the decennial period by the changes in the magnitude and frequency of the sun-spots. We infer its existence only from the terrestrial manifestation afforded by the secular change in the magnetic elements.

The "Terrella," by which HALLEY figured to himself a cause capable of producing phenomena of the order and regularity of those which his laborious and extensive generalization had disclosed to him, has never, I imagine, found favour as a probable physical reality. Viewed simply as an illustration of the systematic arrangement, symmetrical progression, and exceeding regularity of the *effects*, and the consequent necessity for the admission of qualities of the same order in the *causes*, of the terrestrial magnetism and its secular changes, HALLEY'S Terrella had its proper value; and it would have been well if the lesson which it inculcated had received more consideration than it has done from those who, more than a century after his publications, have attempted to explain the phenomena of the progressive magnetic change by accidental or adventitious variations in the superficial temperature of the globe or of its atmosphere, or in the occasional development or protrusion of magnetically attractive or repulsive rocks beneath its surface. The order and harmony of the facts manifested by the researches of a much earlier date had already effectually removed them from the category of partial or accidental occurrences. The symmetry of their general distribution, the counterpart to each other presented by the phenomena of the northern and southern terrestrial hemispheres, and the regularity with which the periodical changes take place, indicated a systematic causation which, obscure as it might be, was obviously anything but fortuitous. And when to the increased knowledge of the general phenomena acquired in the last and present centuries, confirming and extending the previous conclusions, was added the evidence obtained by the observations of the British Colonial Observatories, that the secular change is progressive in the *extremest sense*, that *each week* shows (and that if the means of observation were sufficiently refined it is more than probable that *each day* would show) an exact aliquot part of the annual change, the conviction became almost irresistible, that the causes which produce such remarkable effects can only have a cosmical origin.

The objections that might have impeded the reception of such an hypothesis before

we had learnt to recognize in the sun itself a source of magnetic energy,—before we had been informed by the sun-spots of the existence of periodical variations in the physical aspect, and consequently in the physical condition of that luminary,—and before we had succeeded in connecting these by their identity in period and epoch with the magnetic variations of our terrestrial sphere,—are no longer tenable. The solar origin of the variations in the magnetic phenomena of the earth's surface is indeed legitimately inferrible from their correspondence to solar hours; but in the decennial cycle, discovered in the solar spots and in the terrestrial magnetic disturbances, we have the *absolute* evidence and the *ocular* demonstration of a periodical variation common to the sun and to the earth, which in the sun is cognizable by our visual organs, and which, in the case of the earth, we know to be a magnetic variation.

We do not, as yet at least, possess a similar ocular demonstration of a connexion between the sun and the earth in the cycle of longer duration corresponding to the earth's secular magnetic change. But careful observations of the variable phenomena of the solar disk can only be said to be in their commencement; and it would be premature to assume that no visible phenomena will ever be discovered in the sun which will render the evidence of connexion as complete in the one case as in the other. But such evidence is not a necessary condition of an existing connexion; the decennial period would have been equally true (though not so readily perceived by us) if the sun-spots had been less conspicuous.

In the cosmical hypothesis here imagined, the north "pole or point of greatest attraction" (adopting HALLEY'S phraseology) of the *induced* terrestrial system at this epoch is in the north of the Europæo-Asiatic continent, whilst that of the *magnetism proper* of the globe is in the north of the American continent; the direction of the magnet "in those parts which lie adjacent to either being governed thereby, the nearest pole being always predominant over the more remote"*.

In the references made in this paper to the existence of a Theory of Terrestrial Magnetism, and to the advantage which I have myself endeavoured to derive from it in guiding experimental inquiry, I wish it to be understood that I employ the term "Theory," and regard its office in the work of inductive research, in the same light in which both were viewed by the late Professor PLAYFAIR. "In physical inquiries the work of theory and observation must go hand in hand, and ought to be carried on at the same time; more especially if the matter is very complicated, for then the clue of

* I have recalled these words of HALLEY in the text, because they show that he already recognized what has since been dwelt on by other magneticians, viz., that we must discriminate between the *true* poles or points of greatest force of the terrestrial and induced systems, and the *apparent* poles or centres of the isodynamic loops, which are the *resultants* of the double system. It is not improbable that the further observation and study of the magnetic disturbances, when those of the three elements are brought to bear together on the question, may guide us directly to a knowledge of the geographical positions of the true foci, as distinguished from the resultant foci. We have now learnt experimentally, *i. e.* by the observations of Captains MAGUIRE and M^c^CLINTOCK (Phil. Trans. 1863, p. 657), that the resultant foci are not themselves the points of origin of the disturbances.

theory is necessary to direct the observer. Though a man may begin to observe without any hypothesis, he cannot continue long without seeing some general conclusion arise; and to the nascent theory it is his business to attend, because by seeking either to verify or to disprove it, he is led to new experiments and new observations. He is led also to the very experiments and observations that are of the greatest importance; namely, to those '*Instantiæ Crucis*' that naturally present themselves for the test of every hypothesis. By the correction of his first opinion a new approximation is made to the truth, and by the repetition of the same process certainty is finally obtained. Thus Theory and Observation mutually assist one another; and the spirit of system, against which there are so many and so just complaints, appears nevertheless as the animating principle of inductive investigation. The business of sound Philosophy is, not to extinguish this spirit, but to restrain and direct its efforts."

TABLE III.—Synopsis of Forty-four days of most notable Disturbance of the Magnetic Declination at Nertschinsk in the years 1858 and 1859, to be compared with the Synopsis of the most notable disturbances of the same element in the same years at Kew (Philosophical Transactions, 1863, page 276).

Astronomical Hours.

		h 0·2	h 1·2	h 2·2	h 3·2	h 4·2	h 5·2	h 6·2	h 7·2	h 8·2	h 9·2	h 10·2	h 11·2	h 12·2	h 13·2	h 14·2	h 15·2	.....	h 16·2	h 17·2	h 18·2	h 19·2	h 20·2	h 21·2	h 22·2	h 23·2
Kew		8·0	9·0	10·0	11·0	12·0	13·0	14·0	15·0	16·0	17·0	18·0	19·0	20·0	21·0	22·0	23·0	.....	0·0	1·0	2·0	3·0	4·0	5·0	6·0	7·0
Nertschinsk																		.....								
1858.		′		′		′		′	′	′	′	′	′	′	′			1858.								
February	16.....	.....	E. 3·9	.....	E. 2·1	E. 3·1	E. 3·1	.....	E. 3·7	.....	.....	.....	.....	W. 5·1	W. 11·3	W. 9·2	W. 7·6	Feb. 17	W. 3·2	W. 2·9	W. 2·4	.....	.....	.....	.....	.....
	17.....	.....	.....	.....	.....	.....	.....	W. 8·0	W. 5·3	W. 4·2	W. 2·7	.....	.....	.....	W. 2·0	W. 3·5	W. 2·5	18	W. 6·9	W. 5·6	W. 4·6	W. 2·2	.....	W. 2·0	W. 2·4	.....
March	13.....	W. 2·6	E. 7·1	E. 2·3	E. 2·3	.....	.....	E. 3·9	E. 4·4	.....	E. 3·3	.....	E. 2·7	W. 2·1	W. 3·1	W. 4·7	W. 6·7	Mar. 14	W. 3·9	W. 3·7	W. 4·2	W. 6·5	W. 2·6	E. 2·2	W. 6·9	W. 5·8
	14.....	.....	E. 3·2	E. 4·0	E. 2·0	E. 3·7	E. 3·6	.....	W. 2·2	W. 3·6	W. 3·7	.....	W. 5·7	W. 7·8	W. 6·0	W. 3·9	W. 2·0	15	W. 7·0	W. 9·2	W. 3·8	W. 2·2	W. 3·0	W. 6·2	W. 3·9	.....
	15.....	.....	.....	.....	.....	.....	E. 4·2	.....	W. 4·6	W. 4·8	W. 6·5	W. 7·4	W. 4·7	W. 3·8	W. 3·1	W. 4·3	W. 5·1	16	.....	.....	.....	W. 1·9	.....	E. 10·6	E. 3·2	.....
April	9.....	E. 3·1	E. 2·7	E. 9·5	E. 5·8	E. 11·7	E. 11·9	E. 15·5	E. 20·0	E. 19·1	E. 10·2	E. 2·6	W. 2·1	W. 3·3	W. 5·1	W. 7·0	W. 6·0	April 10	W. 5·3	.....	.....	.....	.....	W. 3·1	W. 3·9	W. 2·0
	10.....	W. 4·2	.....	E. 3·3	E. 3·3	E. 3·5	E. 4·1	.....	W. 4·0	E. 2·6	.....	W. 6·4	W. 7·2	W. 8·4	W. 5·6	W. 10·6	W. 7·0	11	W. 5·8	W. 4·6	W. 3·4	W. 4·7	W. 8·8	.....	.....	.....
June	24.....	.....	E. 8·6	.....	.....	.....	.....	.....	W. 6·9	.....	W. 4·4	W. 4·2	W. 10·9	W. 5·8	W. 10·3	W. 8·1	W. 5·9	June 25	.....	W. 2·0	.....	.....	W. 3·1	W. 2·2	W. 4·3	.....
July	1.....	.....	E. 3·7	.....	.....	E. 2·0	.....	.....	.....	E. 2·0	E. 3·0	E. 2·8	.....	.....	.....	.....	E. 2·6	July 2	.....	.....	W. 2·2	W. 2·3	W. 3·0	W. 2·3	W. 2·8	W. 3·1
	2.....	.....	E. 2·3	E. 2·3	.....	.....	.....	.....	.....	.....	W. 2·2	W. 3·5	W. 2·8	W. 3·3	W. 2·6	.....	.....	3	E. 3·1	.....	.....	W. 2·5	W. 3·2	W. 2·2	.....	E. 2·0
September	20.....	E. 4·8	W. 2·4	.....	.....	.....	E. 2·8	E. 4·2	E. 2·5	E. 3·0	E. 2·2	.....	W. 4·4	W. 6·4	W. 11·0	W. 6·7	W. 6·0	Sept. 21	.....	.....	.....	.....	W. 2·7	W. 3·6	W. 2·0
	22.....	.....	.....	.....	E. 2·8	E. 3·1	E. 4·4	E. 2·4	.....	.....	.....	W. 6·8	W. 2·9	W. 2·9	W. 3·1	W. 2·6	W. 2·2	23	W. 2·7	W. 3·1	.....	.....	.....	.....	.....	.....
	24.....	W. 2·4	.....	E. 3·0	E. 4·0	W. 2·9	.....	E. 2·0	E. 1·9	.....	W. 2·5	W. 4·6	W. 3·0	W. 3·9	W. 4·6	W. 2·2	.....	25	.....	W. 2·9	W. 3·9	W. 2·4	W. 3·8	E. 2·3	.....	W. 4·2
October	9.....	.....	E. 2·6	E. 2·5	.....	.....	.....	E. 3·9	E. 4·1	E. 3·4	.....	.....	W. 2·6	W. 4·3	W. 6·0	W. 3·9	W. 2·8	Oct. 10	W. 3·8	W. 2·5	W. 2·7	W. 2·8	.....	.....	.....	.....
	1859.																	1859.								
January	15.....	W. 2·0	.....	.....	E. 6·8	E. 9·8	E. 5·8	.....	W. 3·8	W. 3·0	.....	W. 2·2	W. 3·8	W. 7·3	W. 6·5	W. 5·9	W. 4·5	Jan. 16	.....	.....	.....	.....	.....	.....	W. 2·8	E. 2·1
February	9.....	.....	E. 2·2	E. 3·1	E. 2·5	E. 2·1	E. 5·7	E. 6·6	E. 4·7	.....	E. 2·1	W. 2·5	.....	W. 2·1	W. 17·1	W. 6·2	W. 2·2	Feb. 10	.....	.....	.....	.....	.....	.....	.....	.....
	23.....	.....	.....	.....	E. 5·2	E. 2·1	.....	W. 2·5	W. 3·4	W. 6·4	W. 2·3	W. 4·7	.....	E. 1·9	W. 2·0	W. 2·5	W. 3·9	24	.....	.....	W. 3·1	W. 2·2	.....	.....	.....	.....
	24.....	E. 2·4	E. 13·6	E. 6·2	E. 3·5	E. 5·5	E. 10·0	E. 3·8	E. 3·6	E. 3·2	.....	.....	.....	.....	.....	.....	W. 2·7	25	W. 1·8	W. 2·9	W. 5·0	W. 3·6	W. 2·3	W. 5·5	W. 3·3	W. 2·9

TABLE III. (continued).

	Astronomical Hours.																							
Kew	h 0·2	h 1·2	h 2·2	h 3·2	h 4·2	h 5·2	h 6·2	h 7·2	h 8·2	h 9·2	h 10·2	h 11·2	h 12·2	h 13·2	h 14·2	h 15·2	.....	h 16·2	h 17·2	h 18·2	h 19·2	h 20·2	h 21·2	h 22·2	h 23·2
Nertschinsk	8·0	9·0	10·0	11·0	12·0	13·0	14·0	15·0	16·0	17·0	18·0	19·0	20·0	21·0	22·0	23·0	.....	0·0	1·0	2·0	3·0	4·0	5·0	6·0	7·0
1859.	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	1859.	′	′	′	′	′	′	′	′
March 26.....	.....	.....	.....	.....	.....	E. 3·4	E. 2·4	E. 4·8	E. 6·2	E. 5·0	.....	.....	E. 2·7	W. 3·3	W. 2·9	W. 2·9	Mar. 27	.....	W. 3·4	W. 2·7	W. 2·6	.....	.....	.....	.....
30.....	.....	.....	.....	E. 4·2	E. 3·1	E. 5·2	W. 2·1	E. 2·0	.....	.....	E. 2·6	.....	.....	E. 1·9	.....	W. 2·3	31	W. 2·9	W. 3·4	W. 3·4	W. 2·7	W. 2·7	W. 2·3	.....	.....
April 21.....	.....	.....	W. 2·2	.....	E. 7·9	E. 3·6	E. 9·3	E. 3·2	E. 10·5	W. 6·0	W. 5·1	W. 3·9	.....	W. 12·1	W. 10·5	W. 8·1	April 22	.....	.....	W. 2·4	.....	.....	.....	.....	.....
22.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	W. 6·1	W. 3·4	.....	W. 3·1	.....	W. 2·9	.....	23	W. 7·1	W. 4·2	W. 3·3	W. 2·9	W. 2·7	W. 2·9	W. 3·4	W. 2·5
23.....	.....	E. 3·5	E. 3·7	E. 4·6	E. 3·2	.....	.....	.....	.....	.....	.....	.....	W. 6·4	W. 5·6	W. 4·1	W. 2·1	24	W. 3·4	W. 2·6	.....	W. 2·9	W. 2·5	.....	.....	.....
29.....	.....	E. 2·6	.....	.....	E. 3·8	E. 6·0	E. 10·7	E. 6·9	.....	.....	W. 7·4	W. 3·1	W. 14·7	W. 6·4	W. 11·8	W. 7·9	30	W. 2·3	.....	W. 2·4	W. 2·3	W. 3·5	W. 3·3	W. 2·4	E. 2·7
May 4.....	E. 2·2	E. 3·2	E. 4·7	E. 3·4	E. 3·0	E. 2·9	E. 2·9	E. 2·2	.....	.....	.....	.....	E. 3·4	E. 4·2	E. 5·8	E. 2·1	May 5	.....	E. 2·1	E. 2·0	.....	.....	.....	.....	E. 1·9
19.....	.....	W. 5·7	W. 3·5	.....	E. 3·1	E. 2·4	E. 8·7	E. 3·0	.....	.....	.....	.....	W. 2·9	W. 3·3	W. 2·9	W. 3·1	20	.....	.....	.....	.....	.....	W. 2·0	.....	W. 2·7
June 8.....	W. 3·1	W. 2·3	.....	W. 6·1	E. 2·2	E. 2·5	E. 2·5	E. 4·8	E. 2·5	.....	E. 4·4	.....	W. 2·6	W. 3·9	W. 3·9	W. 2·6	June 9	.....	.....	.....	.....	.....	.....	W. 5·5	W. 5·1
August 15.....	.....	.....	.....	.....	.....	E. 3·1	E. 3·0	E. 3·1	E. 2·6	E. 2·0	.....	.....	E. 2·7	E. 2·9	E. 3·0	E. 4·5	Aug. 16	E. 3·2	E. 2·8	E. 3·2	E. 2·4	.....	.....	.....	.....
28.....	W. 2·8	W. 3·8	.....	.....	E. 2·8	.....	.....	.....	E. 2·8	E. 5·0	E. 7·0	.....	E. 15·0	W. 3·6	W. 10·5	W. 9·0	29	.....	.....	.....	E. 2·3	E. 2·3	W. 3·3	W. 5·0	
29.....	E. 14·0	E. 2·3	.....	W. 8·6	W. 2·4	.....	W. 4·7	W. 6·6	W. 3·4	.....	.....	.....	.....	W. 2·7	.....	W. 2·3	30	W. 10·1	E. 15·4	W. 8·4	W. 8·8	W. 22·9	W. 7·1	W. 2·4	.....
September 2.....	W. 9·3	W. 22·6	W. 23·0	E. 54·1	W. 12·0	W. 5·3	W. 6·5	W. 9·8	W. 6·6	W. 16·5	.....	W. 4·0	W. 5·0	W. 8·8	W. 11·5	W. 5·9	Sept. 3	.....	E. 21·4	W. 4·6	E. 5·7	W. 74·8	W. 31·0	W. 13·4	W. 6·5
3.....	E. 13·2	E. 8·1	E. 3·5	E. 16·9	W. 3·1	W. 3·2	.....	.....	.....	.....	E. 4·3	E. 2·3	W. 6·2	W. 5·8	W. 4·2	W. 5·1	4	W. 8·2	W. 6·0	W. 3·7	W. 3·5	.....	E. 3·0	E. 10·7	E. 7·2
4.....	E. 5·6	E. 4·3	E. 4·0	E. 2·9	.....	.....	.....	.....	.....	.....	.....	W. 3·3	.....	E. 2·5	.....	W. 2·4	5	W. 4·8	W. 5·9	W. 3·1	W. 5·2	W. 6·7	W. 4·0	.....	E. 2·4
5.....	E. 6·7	E. 8·1	E. 6·2	E. 4·6	E. 2·6	W. 7·2	W. 7·2	.....	.....	.....	.....	E. 2·3	.....	W. 2·8	W. 3·3	W. 5·1	6	.....	.....	.....	.....	E. 2·4	.....	E. 2·4	E. 7·3
6.....	.....	.....	W. 11·5	.....	.....	.....	E. 2·0	E. 2·5	E. 3·5	E. 4·1	E. 4·9	E. 4·4	E. 2·9	.....	W. 4·2	W. 2·9	7	W. 5·4	W. 3·8	.....	.....	.....	W. 2·9	E. 7·9	E. 5·0
24.....	.....	.....	E. 2·4	.....	.....	E. 2·9	E. 6·6	E. 7·7	E. 7·6	E. 5·2	E. 4·3	.....	E. 3·3	W. 8·0	W. 3·8	.....	25	E. 3·4	E. 2·9	E. 3·1	.....	.....	.....	.....	.....
October 12.....	E. 5·2	E. 6·9	.....	E. 12·2	E. 11·5	E. 36·0	E. 23·5	E. 15·7	.....	W. 6·0	W. 15·5	W. 2·9	W. 2·4	W. 5·2	W. 6·7	W. 7·0	Oct. 13	W. 4·6	.....	.....	W. 3·3	W. 2·8	W. 3·0	.....	.....
18.....	E. 15·6	W. 2·1	W. 14·2	E. 3·0	E. 2·5	E. 2·1	.....	.....	.....	W. 8·3	W. 9·6	W. 5·7	W. 5·7	W. 6·9	W. 9·6	W. 7·3	19	W. 4·6	.....	W. 3·5	W. 3·9	W. 5·4	.....	W. 5·2	W. 8·7
19.....	.....	.....	.....	.....	.....	.....	.....	.....	W. 5·0	W. 2·7	W. 3·9	W. 3·5	W. 5·0	W. 4·7	W. 3·5	.....	20	W. 6·5	W. 3·0	W. 2·2	.....	.....	E. 2·2	E. 2·7	.....
20.....	E. 4·6	E. 3·9	.....	E. 4·3	E. 3·7	E. 7·6	.....	.....	.....	.....	W. 6·0	W. 5·5	W. 4·1	W. 5·2	W. 5·1	W. 2·4	21	.....	.....	.....	.....	.....	.....	.....	W. 3·4
November 12.....	.....	.....	.....	E. 8·8	E. 3·0	E. 2·3	E. 2·3	E. 2·9	.....	E. 3·1	W. 4·1	W. 4·4	W. 4·2	.....	W. 4·8	W. 3·2	Nov. 13	.....	.....	.....	W. 2·7	.....	.....	.....	.....
13.....	E. 9·0	W. 3·4	E. 2·9	.....	E. 4·1	.....	.....	E. 5·2	.....	.....	W. 5·3	E. 3·5	W. 8·6	W. 3·9	W. 4·7	W. 3·1	14	W. 2·5	W. 2·8	.....	W. 2·3	.....	W. 3·7	E. 2·1	W. 6·4
December 11.....	W. 5·9	W. 3·8	E. 3·3	E. 3·5	E. 2·5	E. 3·1	.....	E. 7·8	E. 6·0	.....	.....	W. 4·1	W. 4·1	W. 5·5	W. 2·5	W. 4·0	Dec. 12	.....	.....	.....	W. 2·9	.....	.....	W. 2·0	W. 2·4
13.....	.....	E. 20·7	.....	W. 5·2	W. 4·8	.....	W. 5·1	E. 2·2	W. 3·4	.....	W. 3·2	W. 4·8	W. 4·8	W. 3·8	W. 2·9	W. 3·4	14	.....	.....	.....	.....	.....	.....	.....	E. 4·7

Summary.

Easterly Deflections	1858	′ 7·9	′ 34·1	′ 26·9	′ 22·3	′ 27·1	′ 34·1	′ 32·6	′ 39·0	′ 30·1	′ 17·7	′ 5·6	′ 5·5	′	′	′	′ 2·6	1858	′ 3·1	′	′	′	′	′ 15·1	′ 3·2	′ 2·0
	1859	78·5	79·4	40·0	140·5	78·5	104·6	84·3	82·3	44·9	26·5	27·5	12·5	31·9	11·5	8·8	6·6	1859	6·6	44·6	8·3	8·1	4·7	7·5	25·8	33·3
Sums		86·4	113·5	66·9	162·8	105·6	138·7	116·9	121·3	75·0	44·2	33·1	18·0	31·9	11·5	8·8	9·2	Sums ...	9·7	44·6	8·3	8·1	4·7	22·6	29·0	35·3
Westerly Deflections	1858	9·2	2·4	.....	.....	2·9	.....	8·0	23·0	12·6	22·0	32·9	43·4	57·1	73·8	66·7	53·8	1858	38·6	36·5	27·2	27·5	27·5	20·7	27·8	17·1
	1859	23·1	43·7	54·4	19·9	22·3	15·7	28·1	23·6	27·8	47·9	72·9	49·0	89·1	127·1	130·9	105·4	1859	64·2	38·0	47·8	51·8	126·3	67·7	43·7	45·6
Sums		32·3	46·1	54·4	19·9	25·2	15·7	36·1	46·6	40·4	69·9	105·8	92·4	146·2	200·9	197·6	159·2	Sums ...	102·8	74·5	75·0	79·3	153·8	88·4	71·5	62·7

	Astronomical Hours.																							
Kew	h 0·2	h 1·2	h 2·2	h 3·2	h 4·2	h 5·2	h 6·2	h 7·2	h 8·2	h 9·2	h 10·2	h 11·2	h 12·2	h 13·2	h 14·2	h 15·2	.....	h 16·2	h 17·2	h 18·2	h 19·2	h 20·2	h 21·2	h 22·2	h 23·2
Nertschinsk	8·0	9·0	10·0	11·0	12·0	13·0	14·0	15·0	16·0	17·0	18·0	19·0	20·0	21·0	22·0	23·0	.....	0·0	1·0	2·0	3·0	4·0	5·0	6·0	7·0

Note.—No observations were made at Nertschinsk in July 1859.