SECTION I.—PHYSICS AND METEOROLOGY.

THE Council of the Royal Society are very strongly impressed with the number and importance of the desiderata in physical and meteorological science, which may wholly or in part be supplied by observations made under such highly favourable and encouraging circumstances as those afforded by the liberality of Her Majesty's Government on this and other occasions, or which may be expected from the zeal and industry of travellers, residents in foreign countries, and others whose position may give them favourable opportunities of stimulating research on the part of those in their respective departments. While they wish therefore to omit nothing in their enumeration of those objects which appear to them deserving of attentive inquiry on sound scientific grounds, and from which consequences may be drawn of real importance, either for the settlement of disputed questions, or fur the advancement of knowledge in any of its branches,—they deem it equally their duty to omit or pass lightly over several points which, although not without a certain degree of interest, may yet be regarded in the present state of science rather as matters of abstract curiosity than as affording data for strict reasoning; as well as others, which may be equally well or better elucidated by inquiries instituted at home and at leisure.

1. TERRESTRIAL MAGNETISM.

The subject of most importance, beyond all question, to which the attention of Captain James Clark Ross and his officers can be turned, —and that which must be considered as, in an emphatic manner, the great scientific object of the Expedition,—is that of Terrestrial Magnetism; and this will be considered: 1st, as gards those accessions to our knowledge which may be supplied by observations to be made during the progress of the Expedition, independently of any concert with or co-operation of other observers; and 2ndly, as regards those which depend on and require such concert; and are therefore to be considered with reference to the observations about to be carried on simultaneously in the fixed magnetic observatories established by Her Majesty's Government, and in the other similar observatories, both public and private, in Europe, India, and elsewhere, with which it is intended to open and maintain a correspondence.

Now it may be observed, that these two classes of observations naturally refer themselves to two chief branches into which the science of terrestrial magnetism in its present state subdivides itself, and which bear a certain analogy to the theories of the elliptic movements of the planets, and of their periodical and secular perturbations. The first comprehends the actual distribution of the magnetic influence over the globe, at the present epoch, in its mean or average state, when the effects of temporary fluctuations are either neglected, or eliminated by extending the observations over a sufficient time to neutralize their effects. The other comprises the history of all that is not permanent in the phenomena, whether it appear in the form of momentary, daily, monthly, or annual change and restoration, or in progressive changes not compensated by counter changes, but going on continually accumulating in one direction, so as in the course of many years to alter the mean amount of the quantities observed. These last-mentioned changes hold the same place, in the analogy above alluded to, with respect to the mean quantities and temporary fluctuations, that the secular variations in the planetary movements must be regarded as holding, with respect to their mean orbits on the one hand, and their perturbations of brief period on the other.

There is, however, this difference, that in the planetary theory all these varieties of effect have been satisfactorily traced up to a single cause, whereas in that of terrestrial magnetism this is so far from being demonstrably the case, that the contrary is not destitute of considerable probability. In fact, the great features of the magnetic curves, and their general displacements and changes of form over the whole surface of the earth, would seem to be the result of causes acting in the interior of the earth, and pervading its whole mass; while the annual and diurnal variations of the needle, with their train of subordinate periodical movements, may, and very probably do arise from, and correspond to electric currents produced by periodical variations of temperature at its surface, due to the sun's position above the horizon, or in the ecliptic, modified by local causes; while local or temporary electric discharges, due to thermic, chemical, or mechanical causes, acting in the higher regions of the atmosphere, and relieving themselves irregularly or at intervals, may serve to render account of those unceasing, and as they seem to us casual movements, which recent observations have placed in so conspicuous and interesting a light. The electrodynamic theory, which refers all magnetism to electric currents, is silent as to the causes of those currents, which may be various, and which only the analysis of their effects can teach us to regard as internal, superficial, or atmospheric.

It is not merely for the use of the navigator that charts, giving a general view of the lines of Magnetic Declination, Inclination, and Intensity, are necessary. Such charts, could they really be depended on, and were they in any degree complete, would be of the most eminent use to the theoretical inquirer, not only as general directions in the choice of empirical formulæ, but as powerful instruments for facilitating numerical investigation, by the choice they afford of data favourably arranged; and above all, as affording decidedly the best means of comparing any given theory with observation. In fact, upon the whole, the readiest, and beyond comparison the fairest and most effectual mode of testing the numerical applicability of a theory of terrestrial magnetism, would be, not servilely to calculate its results for given localities, however numerous, and thereby load its apparent errors with the real errors, both of observation and of local magnetism; but to compare the totality of the lines in our charts with the corresponding lines, as they result from the formulæ to be tested, when their general agreement or disagreement will not only show how far the latter truly represent the facts, but will furnish distinct indications of the modifications they require.

Unfortunately for the progress of our theories, however, we are yet very far from possessing charts even of that one element, the Declination, most useful to the navigator, which satisfy these requisites; while as respects the others (the Inclination and Intensity the most lamentable deficiencies occur, especially in the Antarctic regions. To make good these deficiencies by the continual practice of every mode of observation appropriate to the circumstances in which the observer is placed throughout the voyage, will be one of the great objects to which attention must be directed. And first—

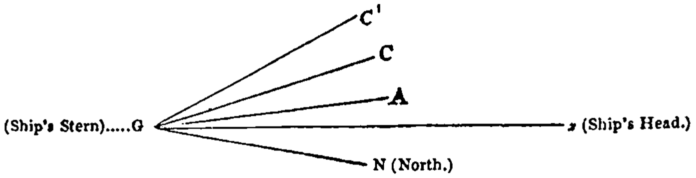
At sea.—We are not to expect from magnetic observations made at sea the precision of which they are susceptible on land. Nevertheless, it has been ascertained that not only the Declination, but the Inclination and Intensity can be observed, in moderate circumstances of weather and sea, with sufficient correctness, to afford most useful and valuable information, if patience be bestowed, and proper precautions adopted. The total intensity, it is ascertained, can be measured with some considerable degree of certainty by the adoption of a statical method of observation recently devised by Mr. Fox, whose instrument will be a part of the apparatus provided. And when it is recollected that but for such observations the whole of that portion of the globe which is covered by the ocean must remain for ever a blank in our charts, it will be needless further to insist on the necessity of making a daily series of magnetic observations, in all the three particulars above-mentioned, whenever weather and sea will permit, an essential feature in the business of the voyage, in both ships. Magnetic observations at sea will, of course, be affected by the ship's magnetism, and this must be eliminated to obtain results of any service. To this end,

First. Every series of observations made on board should be accompanied with a notice of the direction by compass of the ship's head at the time.

Secondly. Previous to sailing, a very careful series of the apparent deviations, as shown by two compasses permanently fixed, (the one as usual, the other in a convenient position, considerably more forward in the ship,) in every position of the ship's head, as compared with the real position of the ship, should be made and recorded, with a view to attempt procuring the constants of the ship's action according to M. Poisson's theory*; and this process should be repeated on one or more convenient occasions during the voyage; and, generally, while at anchor, every opportunity should be taken of swinging round the ship's head to the four cardinal points, and executing in each position a complete series of the usual observations.

Thirdly. Wherever magnetic instruments are landed and observations made on *terra firma*, or on ice, the opportunity should be

* Note on M. Poisson's theory of the deviation produced in the direction of the compass by the iron of the ship.



Let G x be the axis of the ship, x lying towards the ship's head.
G the centre of gravity of the compass.
G N the meridian, N the north.

Let A be the *south pole* of the dipping needle, that is the extremity of the needle which dips *beneath* the horizontal plane in our hemisphere, let C be the projection of the point A upon a horizontal plane, so that G C is the magnetic meridian. Let the angle A G C $= \theta$, θ varying from $-90°$ to $+90°$, being positive when the south pole A is *beneath* the horizontal plane, and negative in the contrary case.

Let C G N $= \psi$, this angle (*variation*) which is the azimuth of the vertical plane C G A may extend from $-180°$ to $+180°$, and is to be considered *positive* or *negative* according as the line G C falls to the *west* or to the *east* of the line G N, or this angle may be considered to vary from 0 to 360°, going from north to south through *west* and returning from south to north by *east*.

Let G C′ be the direction of a horizontal needle, so that C′ G C is the *local attraction*.

Let x G C′ $= \zeta$ C′ G C $= \delta$ x G C $= \zeta - \delta$.
N G C′ $= \psi'$ $\delta = \psi' - \psi$.

Let ω be the azimuth of the principal section of the ship reckoned from G N towards the *west*,

x G N $= \omega$ $\psi' - \omega = \zeta$ $\psi - \omega = \zeta - \delta$

M. Poisson arrives at the following equation, *Conn. de Temps*, 1841, p. 146, and *Mem. de l'Institut*, tom. xvi. p. 529.

$$\left.\begin{array}{l}[A'\cos\theta\cos(\psi-\omega)+B\cos\theta\sin(\psi-\omega)+C\sin\theta]\sin\zeta \\ \quad=[D\cos\theta\cos(\psi-\omega)+E'\cos\theta\sin(\psi-\omega)+F\sin\theta]\cos\zeta\end{array}\right\} \quad (1.)$$

A′, B, C, D, E′, F are constants, if therefore

$$\frac{B}{A'}=c,\ \frac{C}{A'}=a,\ \frac{D}{A'}=d,\ \frac{E'}{A}=b, \text{ and } \frac{F}{A'}=e$$

$$\cos(\zeta-\delta)\sin\zeta+c\sin(\zeta-\delta)\sin\zeta+a\tan\theta\cos\zeta,$$
$$=d\cos(\zeta-\delta)\cos\zeta+b\sin(\zeta-\delta)\cos\zeta+e\tan\theta\cos\zeta.$$

in which equation a, b, c, d, e are constants, which must be determined from observations at some one place, and which continue invariable as long as the position of the iron in the ship remains unaltered. In order to do this the local attractions corresponding to every azimuth of the ship's head must be obtained and may be inserted in a table, or at least they must be found in sufficient number to afford any others by interpolation. The manner of obtaining such data from obseized of going through the regular series on ship-board with more than usual diligence and care, so as to establish by actual experiment in the only unexceptionable manner the nature and amount of the corrections due to the ship's action for that particular geographical position, and by the assemblage of all such observations to afford data for concluding them in general.

Fourthly. No change possible to be avoided should be made in the

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servation is described in the small code of instructions which accompanies Mr. Barlow's plate, and is also given in the Nautical Magazine.

$\psi =$ $\theta =$

Direction of ship's head. ω. x G N.	Local attraction. δ. C′ G C.	Observed. ζ. x G C′.	$\zeta - \delta$. x G C.

N.B. *This Table to be filled up from observation.*

If $\zeta = 0$,

$$-\sin\delta_1 = \frac{d\cos\delta_1 + e\tan\theta}{b}$$

if $\zeta = 180°$

$$-\sin\delta_2 = \frac{-d\cos\delta_2 + e\tan\theta}{b}$$

if $\zeta = 90°$

$$-\sin\delta_3 = c\cos\delta_3 + a\tan\delta$$

if $\zeta = 270°$

$$\sin\delta_4 = -c\cos\delta_4 + a\tan\theta$$

from these four equations, if $d = m\,b$, $e = n\,b$, a, c, m and n may easily be found, and b may be then obtained from any other known deviation.

By solving equation (1.) with respect to tan ζ, the angle ζ may be found corresponding to the angle $\zeta - \delta$,

$$\tan\zeta = \frac{d\cos(\zeta - \delta) + b\sin(\zeta - \delta) + e\tan\theta}{\cos(\zeta - \delta) + c\sin(\zeta - \delta) + a\tan\theta}.$$

Afterwards, by interpolation or reversion, the angle $\zeta - \delta$ may be obtained corresponding to the *observed angle* ζ, and a table of double entry formed, giving the *local attraction* for every value of ζ, the *arguments* of the table being the *observed angle* ζ and the *dip*. This table, according to the theory of M. Poisson, ought to continue available in all quarters of the globe so long as the disposition of the masses of iron in the ship remains unaltered.

If when the ship's head is on the magnetic north and south, no effects arise from local attraction, as was the case in the experiments of Captain Flinders, $\delta_1 = 0$, $\delta_2 = 0$, and hence $d = 0$, $e = 0$.

If the iron is symmetrically situate about the axis of the ship, then according to M. Poisson $c = 0$, $d = 0$, $e = 0$.

disposition of considerable masses of iron in the ships during the whole voyage; but if such change be necessary, it should be noted.

Fifthly. When crossing the magnetic line of no dip it would be desirable to go through the observation for the dip with the instrument successively placed in a series of different magnetic azimuths, by which the influence of the ship's magnetism in a vertical direction will be placed in evidence.

On land, or on ice.—As the completeness and excellence of the instruments with which the Expedition will be furnished will authorise the utmost confidence in the results obtained by Captain Ross's well-known scrupulosity and exactness in their use, the redetermination of the magnetic elements at points where they are already considered as ascertained, will be scarcely less desirable than their original determination at stations where they have never before been observed. This is the more to be insisted on, as lapse of time changes these elements in some cases with considerable rapidity; and it is therefore of great consequence that observations to be compared should be as nearly cotemporary as possible, and that data should be obtained for eliminating the effects of secular variations during short intervals of time, so as to enable us to reduce the observations of a series to a common epoch.

On the other hand it cannot be too strongly recommended, studiously to seek every opportunity of landing on points (magnetically speaking) unknown, and determining the elements of those points

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$$\cos(\zeta - \delta)\sin\zeta + a\tan\theta\sin\zeta = b\sin(\zeta - \delta)\cos\zeta. \quad \ldots \quad (2.)$$

Conn. de Temps, p. 150.

$$\tan\zeta = \frac{b\sin(\zeta - \delta)}{\cos(\zeta - \delta) + a\tan\theta}.$$

$$\sin\delta = \frac{\sin\zeta\left\{(b-1)\cos\zeta - a\tan\theta\right\}}{1 + (b-1)\cos^2\zeta} \text{ nearly.}$$

If δ' is the *local attraction*, ζ' the magnetic bearing of any compass in any other distant part of the ship, or of the same compass after the disposition of the iron has been changed,

$$\cos(\zeta' - \delta')\sin\zeta' + a'\tan\theta\sin\zeta' = b'\sin(\zeta' - \delta')\cos\zeta'$$

but $\zeta' - \delta' = \zeta - \delta$

hence $\cos(\zeta - \delta)\sin\zeta + a'\tan\theta\sin\zeta' = b'\sin(\zeta - \delta)\cos\zeta'$

eliminating $\tan\theta$

$$\tan(\zeta - \delta) = \frac{(a' - a)\sin\zeta'\sin\zeta}{a' b\sin\zeta'\cos\zeta - a b'\sin\zeta\cos\zeta'}.$$

From this equation it may be possible to compute a table of double entry, giving the local attraction without knowing the dip, the arguments of the table being the *observed angles* ζ of two compasses situate in different parts of the vessel. This table ought to continue available so long as the disposition of the masses of iron remains unaltered. The two compasses must of course be so distant as to have no sensible effect upon each other.

The theory of Mr. Barlow's plate, according to M. Poisson, depends upon the practicability of so disposing the iron in the vessel as to give to the constants a and b in equation (2.) the particular values $a = 0$, $b = 1$.

with all possible precision. Nor should it be neglected, whenever the slightest room for doubt subsists, to determine at the same time the geographical position of the stations of observation in latitude and longitude. When the observations are made on ice, it is needless to remark that this will be universally necessary.

With this general recommendation it will be unnecessary to enumerate particular localities. In fact, it is impossible to accumulate too many. Nor can it be doubted that in the course of antarctic exploration, many hitherto undiscovered points of land will be encountered, each of which will, of course, become available as a magnetic station, according to its accessibility and convenience.

There are certain points in the regions about to be traversed in this voyage which offer great and especial interest in a magnetic point of view. These are, first, the south magnetic pole (or poles), intending thereby the point or points in which the horizontal intensity vanishes and the needle tends vertically downwards; and secondly, the points of maximum intensity, which, to prevent the confusion arising from a double use of the word poles, we may provisionally term magnetic *foci*.

It is not to be supposed that Captain Ross, having already signalized himself by attaining the northern magnetic pole, should require any exhortation to induce him to use his endeavours to reach the southern. On the contrary, it might better become us to suggest for his consideration, that no scientific datum of this description, nor any attempt to attain very high southern latitudes, can be deemed important enough to be made a ground for exposing to *extraordinary* risk the lives of brave and valuable men. The magnetic pole, though not attained, will yet be pointed to by distinct and unequivocal indications; viz. by the approximation of the dip to 90°; and by the convergence of the magnetic meridians on all sides towards it. If such convergence be observed over any considerable region, the place of the pole may thence be deduced, though its locality may be inaccessible.

M. Gauss, from theoretical considerations, has recently assigned a probable position in lon. 146° E., lat. 66° S., to the southern magnetic pole, denying the existence of two poles of the same name, in either hemisphere, which, as he justly remarks, would entail the necessity of admitting also a third point, having some of the chief characters of such a pole intermediate between them. That this is so, may be made obvious without following out his somewhat intricate demonstration, by simply considering, that if a needle be transported from one such pole to another of the same name, it will *begin* to deviate from perpendicularity *towards* the pole it has quitted, and will end in attaining perpendicularity again, after pointing in the latter part of its progress obliquely *towards the pole to which it is moving*, a sequence of things impossible without an intermediate passage through the perpendicular direction.

It is not improbable that the point indicated by M. Gauss will prove accessible; at all events it cannot but be approachable sufficiently near to test by the convergence of meridians the truth of the indication; and as his theory gives within very moderate limits of error the true place of the northern pole, and otherwise represents the magnetic elements in every explored region with considerable approximation, it is but reasonable to recommend this as a distinct point to be decided in Captain Ross's voyages. Should the decision be in the negative, i. e. should none of the indications characterizing the near vicinity of the magnetic pole occur in that region, it will be to be sought; and a knowledge of its real locality will be one of the distinct scientific results which may be confidently hoped from this Expedition, and which can only be attained by circumnavigating the antarctic pole compass in hand.

The actual attainment of a *focus* of maximum intensity is rendered difficult by the want of some distinct character by which it can be known, previous to trial, in which direction to proceed, when after increasing to a certain point the intensity begins again to diminish. The best rule to be given, would be (supposing circumstances would permit it) on perceiving the intensity to have become nearly stationary in its amount, to turn short and pursue a course at right angles to that just before followed, when a change could not fail to occur, and indicate by its direction towards which side the focus in question were situated.

Another, and as it would appear, a better mode of conducting such a research, would be, when in the presumed neighbourhood of a focus of maximum intensity, to run down two parallels of latitude or two arcs of meridians separated by an interval of moderate extent, observing all the way in each, by which observations, when compared, the concavities of the isodynamic lines would become apparent, and perpendiculars to the chords, intersecting in or near the foci, might be drawn.

Two foci or points of maximum *total* intensity are indicated by the general course of the lines in Major Sabine's chart in the Southern Hemisphere, one about long. 140° E., lat. 47° S., the other more obscurely in long. 235° E., lat. 60° S., or thereabouts. Both these points are certainly accessible; and as the course of the Expedition will lead not far from each of them, they might be visited with advantage by a course calculated to lead directly across the isodynamic ovals surrounding them.

Pursuing the course of the isodynamic lines in the chart above mentioned, it appears that one of the two points of *minimum* total intensity, which must exist, if that chart be correct, may be looked for nearly about lat. 25° S., long. 12° W., and that the intensity at that point is probably the least which occurs over the whole globe. Now this point does not lie much out of the direct course usually pursued by vessels going to the Cape. It would therefore appear desirable to pass directly over it, were it only for the sake of determining by direct measure the least magnetic intensity at present existing on the earth, an element not unlikely to prove of importance in the further progress of theoretical investigation. Excellent opportunities will be afforded for the investigation of all these points, and for making out the true form of the isodynamic ovals of the South Atlantic, both in beating up for St. Helena, and in the passage from thence to the Cape; in the course of which, the point of least intensity will, almost of necessity, have to be crossed, or at least approached very near.

Nor is the theoretical line indicated by Gauss as dividing the northern and southern regions, in which free magnetism may be regarded as superficially distributed, undeserving of attention. That line cuts the equator in 6° east longitude, being inclined thereto (supposing it a great circle) 15°, by which quantity it recedes from the equator northward in going towards the west of the point of intersection. Observations made at points lying in the course of this line may hereafter prove to possess a value not at present contemplated.

As a theoretical datum, the horizontal intensity has been recommended by Gauss, in preference to the total, not only as being concluded from observations susceptible of great precision, but as affording immediate facilities for calculation. As it cannot now be long before the desideratum of a chart of the horizontal intensity is supplied, the maxima and minima of this element may also deserve especial inquiry, and may be ascertained in the manner above pointed out.

The maxima of horizontal intensity are at present undetermined by any direct observation. They must of necessity, however, lie in lower magnetic latitudes than those of the total intensity, as its minima must in higher; and from such imperfect means as we have of judging, the conjectural situations of the maxima may be stated as occurring in

20° N.	80° E.	I.
7 N.	260 E.	II.
3 S.	130 E.	III.
10 S.	180 E.	IV.

Observations have been made of the horizontal intensity in the vicinities of II. and III., and are decidedly the highest which have been observed anywhere.

In general, in the choice of stations for determining the values of the three magnetic elements, it should be borne in mind, that the value of each new station is directly proportional to its remoteness from those already known. Should any doubt arise, therefore, as to the greater or less eligibility of particular points, a reference to the existing magnetic maps and charts, by showing where the known points of observation are most sparingly distributed, will decide it.

For such magnetic determinations as those above contemplated, the instruments hitherto in ordinary use, with the addition of Mr. Fox's apparatus for the statical determination of the intensity, will suffice; the number of the sea observations compensating for their possible want of exactness. The determinations which belong to the second branch of our subject,—viz. those of the secular changes, of the diurnal and other periodical variations, and of the momentary fluctuations of the magnetic forces,—require, in the present state of our knowledge, the use of those more refined instruments recently introduced, and to be presently described.

The variations to which the earth's magnetic force is subject, at a given place, may be classed under three heads, namely, 1. the *irregular* variations, or those which *apparently* observe no law; 2. the *periodical* variations, whose amount is a function of the *hour angle* of the sun, or of its *longitude*; and 3. the *secular* variations, which are either slowly progressive, or else return to their former values in periods of very great and unknown magnitude.

The recent discoveries connected with the *irregular* variations of the magnetic declination, have given to this class of changes a prominent interest. In the year 1818 M. Arago made, at the Observatory of Paris, a valuable and extensive series of observations on the declination changes; and M. Kupffer having about the same time undertaken a similar research at Cazan, a comparison of the results led to the discovery that the perturbations of the needle were *synchronous* at the two places, although these places differed from one another by more than forty-seven degrees of longitude. This seems to have been the first recognition of a phenomenon, which now, in the hands of Gauss and those who are labouring with him, appears likely to receive a full elucidation.

To pursue this phenomenon successfully, and to promote in other directions the theory of terrestrial magnetism, it was necessary to extend and vary the stations of observation, and to adopt at all a common plan. Such a system of simultaneous observations was organized by Von Humboldt in the year 1827. Magnetic stations were established at Berlin and Freyberg: and the Imperial Academy of Russia entering with zeal into the project, the chain of stations was carried over the whole of that colossal empire. Magnetic *houses* were erected at Petersburg and at Cazan; and magnetic instruments were placed, and regular observations commenced, at Moscow, at Sitka, at Nicolajeff in the Crimea, at Barnaoul and Nertschinsk in Siberia, and even at Pekin. The plan of observation was definitely organized in 1830; and simultaneous observations were made seven times in the year, at intervals of an hour for the space of forty-four hours.

In 1834 the illustrious Gauss turned his attention to the subject of terrestrial magnetism; and having contrived instruments which were capable of yielding results of an accuracy before unthought of in magnetic researches, he proceeded to inquire into the simultaneous movements of the horizontal needle at distant places. At the very outset of his inquiry he discovered the fact, that the synchronism of the perturbations was not confined (as had been hitherto imagined) to the larger and extraordinary changes; but that even the minutest deviation at one place of observation had its counterpart at the other. Gauss was thus led to organize a plan of simultaneous observations, not at intervals of an hour, but at the short intervals of five minutes. These were carried on through twenty-four hours six* times

* Recently reduced to *four*.