IV. *Experimental Researches in Electricity.—Twenty-seventh Series.* By MICHAEL FARADAY, *Esq., D.C.L., F.R.S., Fullerian Prof. Chem. Royal Institution, Foreign Associate of the Acad. Sciences, Paris, Ord. Boruss. Pour le Mérite, Eq., Memb. Royal and Imp. Acadd. of Sciences, Petersburgh, Florence, Copenhagen, Berlin, Göttingen, Modena, Stockholm, Munich, Bruxelles, Vienna, Bologna, &c. &c.*

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§ 33. *On Atmospheric Magnetism—continued.*

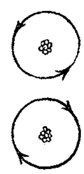
¶ ii. *Experimental inquiry into the laws of atmospheric magnetic action, and their application to particular cases.*

2969. BELIEVING that experiment may do much for the development of the general principles of atmospheric magnetism, and produce rapidly a body of facts on which philosophers may proceed hereafter to raise a superstructure, I endeavoured to find some means of representing practically the action of the atmosphere, when heated by the sun, upon the terrestrial magnetic curves. The object was to obtain some central arrangement of force which should deflect these curves or lines as they are deflected in a diamagnetic conductor or globe of hot air (2877.), and then apply the results obtained by such an arrangement as a partial test to the various cases supplied by the magnetic observatories scattered over the earth. At first I endeavoured, for the sake of convenience, to attain this desired end by means of a horseshoe magnet, employing the lines which passed from pole to pole to disturb and rearrange the earth's force; but the comparative weakness of the terrestrial force near the magnet, and the great prominence of the poles of the latter, gave rise to many inconveniences, which soon caused me to reject that method and have recourse to a ring-helix and voltaic apparatus. Considering the new use to which this helix is to be applied, the interest of the results, and the instruction that may be drawn from them, I shall be excused for being somewhat elementary in the description of its character and action.

2970. The helix consisted of about 12 feet of covered copper wire formed into a ring having about twenty-five convolutions, and being $1\frac{1}{2}$ inch in external diameter. The continuations of the wire were twisted together so as to neutralize any magnetic effect which they could produce, and were long enough to reach to a voltaic arrangement, and yet allow free motion of the helix. The requisite amount of magnetic power in the helix may be judged of by the following considerations:—Suppose a declination needle freely suspended; and then the *helix* placed at a distance in the prolongation of the needle with its axis in a line with the latter, and with that side towards the needle which will at small distances cause repulsion. The needle will point, in the magnetic meridian, with a certain amount of force; but as the helix is brought near it will point with less force, and within a certain distance will no longer point in the magnetic meridian, but either on one or the other side of it. There is a given distance within which the needle, when in the magnetic meridian, is in a position of unstable equilibrium, but beyond which it has a position of stable equilibrium, the distance varying with the strength of the exciting electric current. The power of the helix should be such, that when end on to the needle the latter has a position of stable equilibrium in the meridian. One pair of plates is quite sufficient to make the helix as magnetic as is needful for distances varying from 4 to 24 inches. When a needle is properly arranged with either a magnet or a helix to the north or south of it as above described, if the magnet or helix be moved west the near end of the needle will move east, and contrariwise.

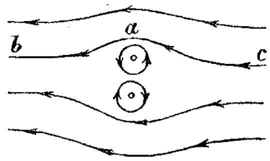
2971. As is well known, such a helix has a system of magnetic lines, which, passing through its axis, then open out and turning round on the outside re-enters again at the axis, the circles of magnetic force being everywhere perpendicular to the electric current traversing the convolutions of the helix; and now I had, at a moment's notice, a source of lines of magnetic power exactly of the kind required to produce, in association with those of the earth, a disposition of the forces coinciding either with those of paramagnetic or diamagnetic polarization (2865. 2877.).

Fig. 17.



2972. For let fig. 17 represent a section parallel to the axis of the ring-helix, then the two circles may represent the disposition of the magnetic force in that section, and the arrow-heads may serve to indicate that magnetic direction which belongs to lines of force issuing out of the north end of a magnet. If such a system be suddenly produced in the midst of the earth's lines, it acts upon them according to the position of the helix in relation to the direction of the earth's power. Choosing the two positions in which the axis of the helix is parallel to the natural direction of the power, as shown by a free needle, at the place of observation, then two contrary effects are produced, which, as regards the lines exterior to the helix system, correspond to the polarity of paramagnetic and diamagnetic conductors. If, for instance, the helix is so placed that the polarity of its magnetic lines, exterior to and in the plane of the ring, accords with that of the earth's force, as in fig. 18, then the earth's lines are deflected as represented, and a magnetic needle placed at *a*, which had taken up its position by the earth's influence, will not tend to alter its position as the helix approaches it, though it will be acted on with more power. In other parts of the line, *b a c*, it will alter its position, standing as a tangent to the curvature, and therefore will be deflected sometimes one way and sometimes another, as it is carried along the line (or through the neighbouring lines), in place of remaining parallel to itself, as it would do if the electro-magnetic helix were away.

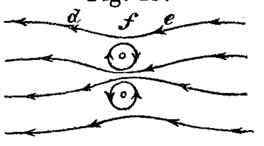
Fig. 18.



2973. On the other hand, if the helix were turned round into the second position

(2972.), then the effect upon the direction of the neighbouring lines of force would be as in fig. 19. Needles placed at *d* and *e* would again be deflected from the natural position given to them by the earth, but they would be deflected in a contrary direction to that which would be taken if they were in corresponding situations under the former arrangement. This figure and state of things represents the paramagnetic disposition of the forces, as the former did the diamagnetic condition.

Fig. 19.



2974. It is not pretended that the whole of these arrangements of forces are like those of the cases of paramagnetic and diamagnetic conductors. Independent systems are here introduced into the midst of the earth's magnetic power, and the central part of each arrangement must therefore be excepted; there are also attractions inwards and repulsions outwards, when the needle is at *a* and *f*, which do not take place in the cases of mere magnetic conduction. But external to these helix systems, the arrangement imposed upon the lines of force from the earth is in accordance with that produced by diamagnetic and paramagnetic conductors, and at distances from 2 inches to 2 or 3 feet; the lines of force thus altered, and those contorted by the sun and atmosphere in the great field of nature, are comparable in their direction, and may be considered as representing each other.

2975. In order to obtain a simple result of the action of such a centre of force on the magnetic lines of the earth, I adjusted a rod in the direction of the dipping-needle, and also a plane at the foot of it parallel to the magnetic equator at London. Then suspending a small magnet, half an inch long, from cocoon-silk, so that when hanging it should be parallel to the magnetic equator, it was adjusted so as to be near to the plane at the foot of the rod representing dip. The ring-helix (2970.) was then associated with the voltaic pair, so that contact could be completed at any moment, and being always retained parallel to itself and to the plane of the magnetic equator, could be brought into the vicinity of the needle on all sides, above or below, and its action upon it observed. As the object was to represent the sun's action, the current was so sent through the helix that its upper face would repel the north end of a magnetic needle; for then a magnet, outside of and in the plane of the ring, would not tend to have its position changed, and the disposition of the forces of the earth under the influence of the helix was as in fig. 18, or like that of a diamagnetic conductor.

2976. In making observations of this kind, and especially if the ring-helix is purposely retained at a considerable distance from the needle, it is better not to connect the helix permanently with the battery and then carry it towards and by the needle, but rather to choose the place where the helix action is to be observed, and when the helix is there to make contact with the battery; the motion and direction of the needle is then easily observed; or if it still, through reason of distance, be feeble, making and breaking contact a few times isochronously with the vibrations of the needle soon raises the effect to any degree required.

2977. There are certain positions in respect of the needle as a centre which must be clearly comprehended. The magnetic axis is a line through the centre of the free regular needle parallel to the direction of the earth's lines of force, whatever that may be, at the place where the experiments may be made. The magnetic equator plane is a plane passing through the centre of the needle perpendicular to the magnetic axis. The plane of the magnetic meridian is that plane which coincides with the magnetic axis, and also with the direction in which the declination needle points. This position always occurs with the magnets that are employed for observation, being a consequence of the method in which they are supported; it would not be taken by a needle placed at right angles on its mechanical axis, the latter being in the magnetic axis.

2978. When the ring-helix, situated as before explained (2975.), was anywhere in the plane of the *magnetic meridian*, it exerted no action on the declination needle tending to change its position. When the helix was anywhere in the plane of the magnetic equator, it exerted no action on the needle to make it change its direction. These are the only places in which the helix does not affect the position of the needle.

2979. These two planes of no variation divide the space around the magnet into four quadrants, and the helix being in any one of these, affects the needle, altering its declination. The deflection of the line of force for two neighbouring quadrants is in the contrary direction, so that as the helix passes from the neutral line into one or the other quadrant, the declination of the needle changes.

2980. If the helix be above or below the magnetic equator and be carried round the magnetic axis travelling along a line of latitude, then the needle makes *one* large oscillation to the right, and another to the left during the circuit. Supposing that the experiment commences with the helix above the equator, and in the plane of the magnetic meridian north of the needle, if it then proceeds by west to south and on by east to its original position the north end of the needle will first go westward; will then stop and return eastward, passing the mean position, and will finally return westward and settle in its first or original direction. All the time the helix is to magnetic east of the needle it will cause the same deflection, and also as long as it is in the west; the deflection will be more or less, but not change in direction as regards the neutral place. The position of the helix north or south of the needle is of no consequence as to the direction of the declination, provided it remain on the same side of the magnetic meridian, though it is to the amount. If the helix be below the magnetic equator the direction of the declination is reversed, but then again it does not change whilst the helix remains east or west of the needle and its plane of mean declination.

2981. If we carry the helix round the needle in a plane perpendicular to the planes of the magnetic equator and meridian, so as to traverse in succession the four quadrants, then the needle makes *two* to and fro vibrations (instead of one) during the circuit. Thus, beginning with the helix in the neutral position over the needle and going round by west and below, and then upwards on the east side to its first position, the north end of the needle will first pass westward, then eastward, then westward, after that eastward, and finally westward to its original or neutral position.

2982. As the helix is carried from the neutral planes (2978.) into any of the quadrants, the power of affecting the declination of the needle is first developed, and then increases every way, from the edges of the quadrant until it attains its maximum force at the middle. Hence the maximum deflection east or west is when the helix is in the middle of each quadrant. Therefore, when the helix is carried from the middle of one quadrant to the middle of the next, only *one motion* in the needle appears; as for instance, an increasing westerly declination, though the direction of the declination in relation to the mean position has been reversed in that time, and there was a moment when the needle had no extra declination, but was *in* that mean position. So also as the helix moves over one quadrant from one neutral plane to another, though the declination of the needle produced by it has not changed in direction, but has been, for instance, all the time west, still the needle will have exhibited two motions, going first west during the increase of the power, and then east whilst it is diminishing; and hence it is that though there are *four* departures of the needle from and return to the neutral or mean position, whilst the helix circumscribes it in an east and west vertical plane (2981.), there are only *two* complete journeys of the needle.

2983. The amount of the deflection diminishes as the distance of the helix from the needle increases; and the contrary.

2984. Two other needles were slung (2975.) very oblique to the magnetic axis, one with its north end upwards and the other with its north end downwards, and these were submitted to the action of the helix as the former had been (2978.). They were affected exactly in the same manner, showing no difference; *i. e.* a given end always moved the same way for the same change in position of the helix. If the helix was very near, then one pole was a little more influenced than the other in certain positions; but its removal further off took away that difference (which is easily accounted for (2970.)) and produced pure results. The place of the helix above or below the prolongation of the line of the needle made *no difference*, provided it was in the same place as regarded the magnetic equator of the earth's lines of force passing through the needle.

2985. For the purpose of establishing the nature of the action which such a helix, always in the given or diamagnetic position (2975.), would exert upon the *inclination*, a small dipping-needle was submitted to its action and the following results obtained. The needle could move in the plane passing through the magnetic meridian of London.

2986. There was no deflection of the needle when the helix was in the plane of the magnetic equator, or in a plane perpendicular to that containing the mechanical axis of the needle. In every other position it affected it; so that these two planes divided the sphere of action into four segments, as before.

2987. As the helix passes from one quadrant to another, the direction in which the needle is deflected changes as before (2982.). If the helix is in the upper north segment or the lower south segment, the upper or south end of the needle is deflected towards the south; if the helix be in the upper south or lower north segments, the upper or south end of the needle is deflected towards the north. If the helix be carried round the needle in the direction of the plane of motion, which in this case is that of the magnetic meridian, the end of the needle starting from a mean or unaffected position will move first one way, as for instance, north and then south; north again and south again, and finally north to regain its place of rest: so that there are two extreme deflections of the end in each direction, as before, in the case of the declination magnet (2982.).

2988. In other words, when the helix was anywhere below the magnetic equator, the *lower* or north end of the needle tended to point outwards from it or outside of it, being as it were *repelled* by the axis of the helix, but *drawn* by the outer curved lines of force, fig. 20 (2992.). Or if the helix were above the equator, then the *upper* or south end of the needle went outwards from the helix, moving exactly in the same direction in relation to the helix as the lower pole did before.

2989. The support of the needle was turned round 90°, which therefore removed the plane in which the needle could move 90° from the magnetic meridian. This carried the plane of no action on the needle 90° round, so that it now coincided with the magnetic meridian; and the plane, which, standing east and west, was before neutral, was no longer a plane of indifference, but in fact passed at the middle of the segments through the places of strongest action.

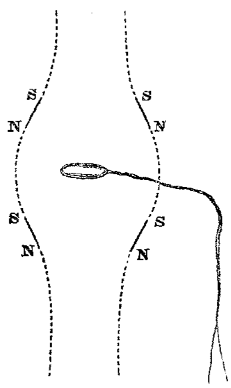
2990. Here, with *inclination*, as before with *declination*, it is not the direction in which the needle stands that determines what action the helix may have upon it; for it may be loaded or otherwise restrained, as all horizontal needles are; but it is the *direction* of the lines of force at the needle which, with the helix, governs all. The helix may be above or below the prolongation of the needle indifferently; for if it still continues on the same side of the line of force, under the influence of which the needle acts, then the end of the needle moves in the same direction, though it may travel towards the helix in one instance and from it in another.

2991. I suspended a needle so that it was free to move in every direction, and now I obtained the simple natural effect of the helix, or a diamagnetic globe (2877.) on a given line of force, and it is well to have it in mind. For, though we are obliged for the sake of practical observation to divide the position into two parts, declination and inclination, yet the results in each case are much better compared and remembered when the simple law of change in the whole line of force is ready in the mind for reference. The equatorial plane and the magnetic axis are now the only parts in which the helix can be without affecting the position of the needle;

the first gives places (for the helix) with a stable position for the needle, and the second such as have either stable or unstable positions, according to the helix distance.

2992. If the helix be out of the plane and axis, then the end of the needle nearest to it leans from it as if repelled. If the helix be carried round in a circle of latitude, the end of the needle moves round before it just like the upper end of the needles at Hobarton and Toronto, in respect of the sun, during the midday hours. Instead of moving the helix round the needle, we may carry the needle into different positions as regards the helix, and then fig. 20 will represent the result. A result exceedingly simple, and in perfect accordance with the diamagnetic disposition of the forces produced by the helix (2972.), as the two dotted lines indicate.

Fig. 20.



2993. As an expression of the facts for use in applying them to the explanation and illustration of natural phenomena, it may be said in respect of *declination*, that the helix being above the needle in a plane having dip, and therefore above its magnetic equator, if on the east of a needle having north dip, it will send the south or upper end west, or if on the east of a needle having south dip (being of course then itself inverted (2972.)), it will cause the north or upper end to pass westward; seeming to repel the end of the free needle or part of the line of force nearest to it. In reference to the *inclination*, it may be said, that the helix being above the needle, tends to send the upper end of the needle or line of force from it. If the helix is north of the magnetic axis, it will tend to send the upper end of the needle south; if it is south, the upper end will go north. As in the case of the declination, it is as if the end of the free needle or line of force nearest to it was repelled. In fact every case is included in this result, that if the helix be diamagnetically adjusted (2975.) for a free needle, whether it is above or below the needle, or on this side or that, the nearest end of the needle will be as if repelled, provided the helix is not in a neutral position.

2994. I repeated all these experiments with the helix reversed, so as to give the effect of a paramagnetic globe of air (2865. 2973.). I need only say, that the effects were precisely the same in nature and order, only in the *reverse* direction. They will be required in the explication of the night and early morning actions, due to the cooling of the atmosphere (3003. 3010.).

2995. In these experiments, that the laws of deflection might appear in their simplicity, the needle was suspended in the air, and the representation of the sun's action carried round it in all directions. But in nature the air is only above the needle, and the earth as a magnet is beneath it. In the natural case also, there is the fixation of the lines in the earth (2919.), which tends, by holding them below the surface, to give them an amount of deflection *at* the surface, far beyond what they would have if they were as free to move in the earth beneath as in the space above*; and though this deflection would coincide with that produced by the helix alone, still it was important to verify its effect. I therefore took a bar magnet 30 inches long, and weak in condition, and suspended the needle above it in various parts, so as to have the effect of north or south dip to any degree, or no dip at all near the middle parts. The effect of absence of air from beneath was also in a certain degree represented; and to make this point more striking, I occasionally put masses of iron on and under the middle part of the magnet. The results with the helix were now influenced greatly in the *amount* of the deflection, but not in the direction. When the helix affected the direction of the needle, it was according to the above laws.

2996. In the consideration of natural phenomena, the magnetic axis, and also the planes of the magnetic equator and meridian, being circles or planes of no deflection, are very important. Changing as they do with every change, either of place or declination or dip, they require some ready means of illustration, and can hardly be comprehended in their effects without a model. I have prepared a globe on which, after marking the places of the observatories, I have drawn the magnetic meridians of these places as they were last estimated. I have then in another colour drawn for each place its magnetic equator, making that a great circle parallel to the equatorial plane of the dipping-needle at the place. I have also marked on the globe the mean path of the sun for each month, and by the use of adjustible pins to indicate the hours before and after noon of any given place, I have the means of ascertaining with sufficient accuracy when the sun is in any particular quadrant, or what part of the quadrant; when it passes a neutral line, and what its position in relation to the place of observation is, in a manner which no diagrams or figures could supply. I have found the globe very useful; and I accustom myself to place it always in a certain position, namely, with the axis of rotation horizontal, the north pole to my right hand, and the astronomical meridian of the place of observation towards the zenith. The observer can then regard it as from the place of the rising sun.

2997. Though we thus have the experimental conditions of a needle under an action like that resulting in nature from the presence of the sun (2920.), I do not pretend that they can be applied without modification to natural phenomena, but only that they give very important aid in the study of the latter and the rationale of their action. The atmosphere, instead of being illimitable, wraps the earth round as a garment; the influence, as it extends from the region of action, must, in respect of that portion which is conveyed through its mass (2920.), curve with its curvature, and give a result in any particular place, which only refined calculations founded upon careful observations can determine accurately. In regard to the development of the air action, it would, I think, be very interesting to ascertain, even roughly, the

* Referring to the typical globe of cold air (2874.), it is manifest that if the space below the horizontal lines *a*, *c*, &c. were occupied by matter holding the lines in it, then the deflections now represented on the lower parts would appear above the holding surfaces, and to a much greater degree, though extending downwards to a much smaller space.

daily variations of a magnet at the bottom of a deep mine, half-way up, and at the mouth of the shaft. The results might tell us much about the holding power of the earth and the depths to which the deflections of the magnetic lines of force penetrate, and might even give us a rough expression of the changes of the internal power (or the absence of such changes) when freed from those dependent upon the atmosphere.

2998. Another reason why the experimental results must not be applied too closely is as follows. If the lines of force of the earth were perfectly regular, then the change produced amongst them by the sun and air would be regular also. But as the natural system is not regular either between the tropics, as at Sister's Walk and Longford in St. Helena, or in the higher latitudes, as at Hudson's Bay, so apparent inconsistences may and must result. The probability is that the greatest irregularities in the arrangement of the earth's magnetism are in and near the surface of the earth, and that above they tend to adjust with each other into a more regular order. Still the irregularities must extend their influence very far upwards, so that the contortions of the magnetic meridians or lines of force are not likely to be effaced, or much diminished, at the region coinciding with the place of the atmosphere's effect.

2999. But though the lines are irregular in the large space affected by the sun, the result will be expansion of the whole as a system and diamagnetic polarity. The lines of force below will be affected by those above; and so, though a perfect similarity between different places is not to be expected, still the kind of change at the earth's surface is not likely to be so uncertain as it might at first appear. Therefore I believe the globe (2996.) will be found very useful in giving information regarding the probable effects at the magnetic meridian and equator, due to the place of the sun in the two chief quadrants for any given month of the year, or hour of the day.

3000. The passage of the magnetic meridian is important, and appears far more so after the experiment described (2978.) than it did on a former occasion (2942.). Being very often inclined to the astronomical meridian, it must have great influence in deciding when the daily declination changes in its direction. The place of greatest action, and its travelling north or south along a line of magnetic force according as the declination was west or east in relation to the helix as a sun, was confirmed by an experiment; and the further observation (a consequence of the former), that when the sun was equidistant from a place more north or south than itself, its action was far stronger on that side at which its path and the declination direction made an acute angle than on the other side where it was obtuse, was also confirmed. Thus if the helix, moving from east to west, were passing a place north of it having western declination, then the action was stronger on the western side of the place than on the east for equal distances of the helix from the magnet.

3001. The passage of the magnetic equator by the sun is also important, since the direction of the diurnal variation of the experimental needle is then altered; and this is of the more consequence, because by the great degree of natural declination in many places, even far north and south, this passage is thrown forward towards the astronomical meridian, either on the east side or the west, and comes into effect during the more influential hours of the sun or the cold. In all those places too where the dip is little, as at St. Helena, and in or near the sun's path, it may be important in influencing the amount of action. From the change of place of the sun between the tropics, and the variety of dip and declination at different places, the passing of the neutral planes by the sun and acting region must take place under an extreme variety of conditions; the unravelling of which I think will be much assisted by knowledge such as that which the preceding experiments and principles give. The sun may be astronomically either north or south of the needle, and yet the declination of the needle not change in direction (2980.); or if there were much mean declination, as at Greenwich, then it might be astronomically east or west of it, and yet the declination produced not change its direction. The sun region may be south of a place and yet send its upper end further south (2990.); for all will depend upon its position in relation to the magnetic meridian and the magnetic axis, which are in most cases very far removed from those that are astronomical: added to all these causes of variety, there is the fixation of the lines of force in the earth (2919.), which tends to give a further diversity to them.

3002. In the former paper I considered only the effect of air raised in temperature above the mean condition (2895.), illustrating it by the sun's effect in the middle of the day; *now* I purpose considering that which will be produced by the cold of night, which reduces the air of a given region below the mean air temperature of that place. When a portion of air is so cooled, its conduction power is increased; in conjunction with the warmer air of surrounding regions it deflects the lines of magnetic force passing through both, as indicated by the type globe (2864. 2874.), and acquires what I have called conduction polarity (paramagnetic), meaning thereby simply that the lines of force draw together in the middle of the cooled air.

3003. Theoretically, the effect of a cold region of air coming up from the east would be to make the magnetic lines of force, as they leave the earth, advance or bend towards it, because those in and about the cold air are inflected into it; and as those immediately west of the cold region move into or towards it, so those further west, being in part relieved from their tension, will also move east, and thus an effect, the reverse of that of the sun (2877. 2972.), or the same as that of the helix in the paramagnetic position (2973. 2994.), will be produced. The upper ends of needles at places having dip show this deflection of the upper part of the lines of force, because they move by, with, and in them.

3004. So as cold approaches, the lines will lean towards it until it is in the position of maximum action in the eastern quadrant; then they will return (in declination) before the cold, until both it and the line (or needle) are in the magnetic meridian; after which, as the cold travels on westward, the needle will follow it west until the cold has attained its place of maximum action in the west quadrant (2982.); and then, as the cold retreats, the needle will return east to its mean place; assuming that there is no other action for the time than that of the cold region. The upper end of the free needle, therefore, at any given place will tend *towards* the cold region, just as before it tended *from* a warm region; and as the declination is affected, so also the inclination will be. If the cold be on the magnetic meridian of a place within the tropics, as St. Helena or Singapore, it will increase the dip there, whilst at the same moment it is diminishing the dip at places south or north of it having considerable dip, a result which follows directly from the inflection of the lines of force into or towards the cold region.

3005. The chief regions of heat and cold on the same parallel of latitude, do not follow each other at equal intervals of time. It is difficult to make a judgement regarding their interval in the atmosphere above; but the maximum of cold on the earth for the twenty-four hours, is assumed by many as being seventeen hours after the preceding noon, and only seven hours from the coming noon. This brings into consideration the joint effect of hot and cold regions in deflecting the lines of force, especially during the forenoon and middle of the day. If a cold region be only three and a half hours west of a place at the same time that the warm region is three and a half hours east of it, it is very manifest that the joint effect of the two, for both act then to cause the same deflection, will be far greater than that of the heat or cold alone, or than any corresponding effect at other periods, for neither twelve hours after, nor at any other time, will there be an equivalent condition of circumstances; and so it is also for other combinations of hot and cold regions, the effect of which will vary both by position and by their extent. A free needle is held in tension by the lines, which are themselves governed by the hot and cold regions of atmosphere; it probably never occupies its mean place, but is always in the resultant of these ever-present and ever-varying causes of change.

3006. As the earth revolves under the sun, each place would have, speaking generally, a maximum and a minimum of temperature for its atmosphere in the twenty-four hours. But looking at the globe as a whole, there would be one maximum and two minima, *i. e.* there would be a maximum region somewhere beneath the sun in his path, and a minimum in each of the polar regions; which, as regards the twenty-four hours, would not be at the pole, but in some place of high latitude, and perhaps, as before, seven or eight hours before noon. These cold regions will be very seriously affected in their extent and place and power by the position of the sun between the tropics; for as he advances to one tropic the cold region there will diminish in extent and force, whilst the other will grow up in importance; and whilst they thus vary in their power of influencing the general direction of the lines of force, they will vary in their own position also, and have at different times very various relations of place to the sun in different months, and so produce very various effects. It is these differences which are made manifest to us, as I believe, in the night and morning actions at the numerous observatories scattered over the globe.

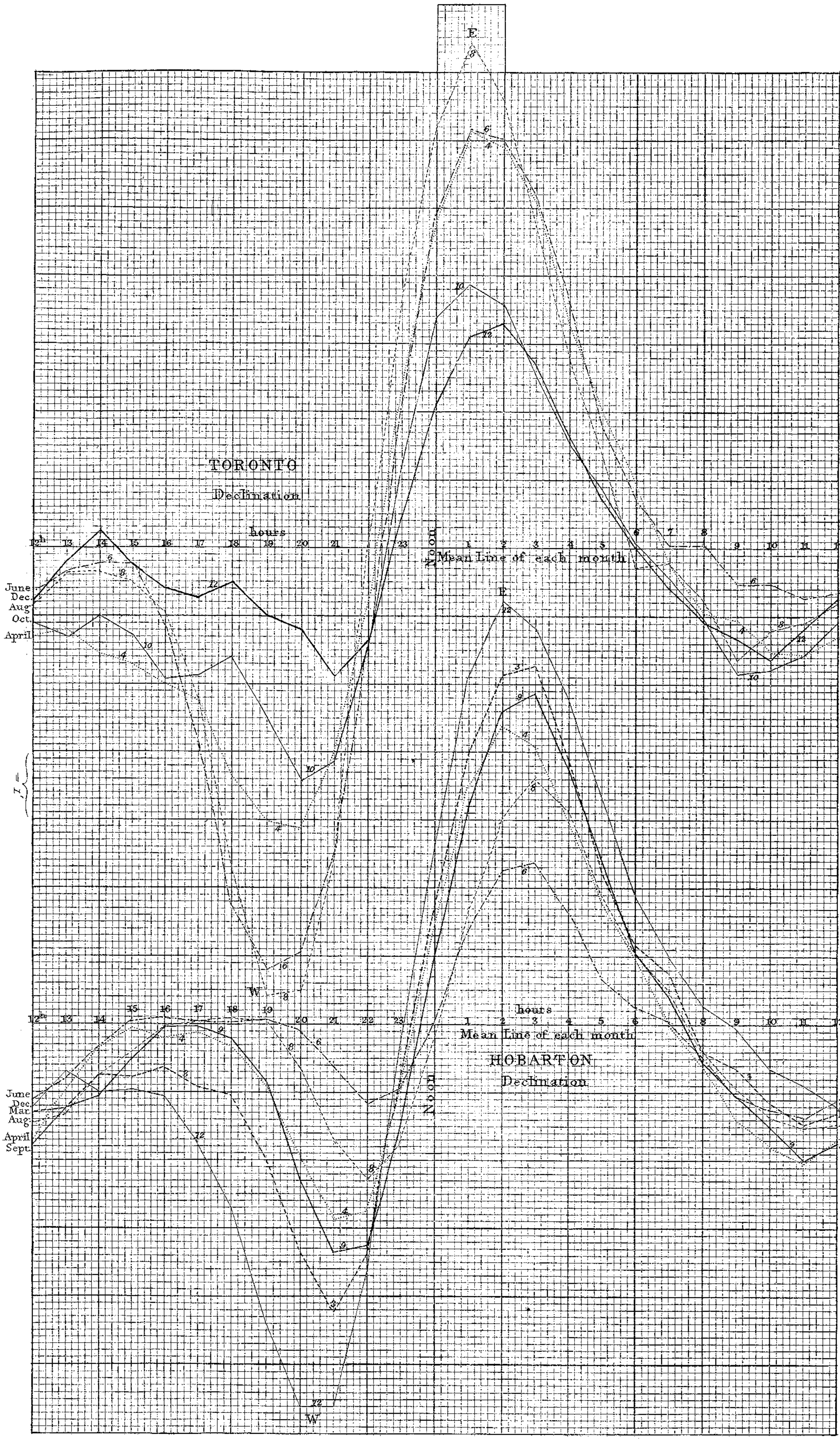
3007. I will proceed to apply these views, and the additional knowledge gained by experiment, to the localities formerly considered, and to some new ones between the tropics, for the purpose of explaining, if I can, the principles of night action; of retardation, more or less, of the effects in relation to local time; of the difference in direction of the declination variation in different months, for the same place at the same hours, as pointed out by Colonel SABINE; of the diminution of dip in one place, and increase of it at another for the same local time. In doing so, it will be necessary to refer continually to that place which may be considered, in respect of the station, as the centre of hot or cold action for the time. I will endeavour to use the word region for that purpose, meaning thereby not the whole extent of heated or warmed air, nor the centre, but the chief place of the altered portion. It is very manifest that in some days in March or September, *all* the air that is east of the meridian at 21^h or 22^h may be considered warm in comparison of that which is then west of the same meridian, and that a resultant of action, which shall be the same for all places, cannot exist.

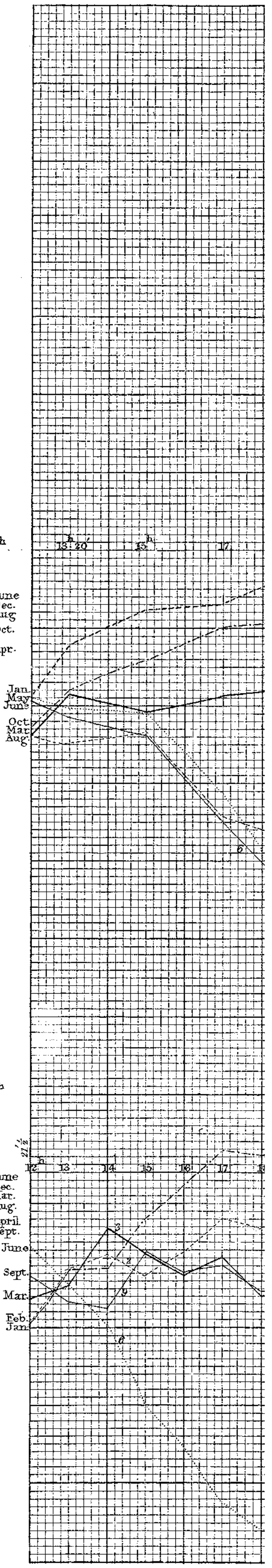
3008. We are to remember that the eastening and the westening of the upper end of the needle, of which I always speak, is produced in two ways. The needle travels as positively by the withdrawal of a direct cause of action as it does under the immediate direct action of that cause, but in the contrary direction (2982.). A westening may be the result either of the coming up of the sun on the east of the place of observation, or of its withdrawal in the west, after he has passed over the meridian and produced the great east swing.

3009. *St. Petersburgh* has a mean declination of 6° 10′ W., and a dip of 70° 30′ N.; therefore, though the magnetic and astronomical meridians are not very oblique to each other, still the sun or warm region reaches the former from 20′ to 40′ before the latter, and hence the time of the great sun-swing, which is from 20 to 1 o'clock, is made earlier than it otherwise would be. The magnetic equator of the needle (2977.) forms an angle of about 40° with the earth's equator, and being thus tilted, it disposes the two quadrants chiefly concerned in the daily variation (2979.), so, that in the St. Petersburgh summer the warmest region is not only far nearer to the needle, but passes through the strongest places of action of the quadrants, whereas in winter it is further off, and also in much weaker positions. Hence a cause, as I believe, of the great difference in the amount of variation of declination, and also in its character: in November, December and January, it is from 4′·47 to 4′·65 only, whilst in June it is 11′·52*. See the Tables, p. 82, and the Curves, Plate II.

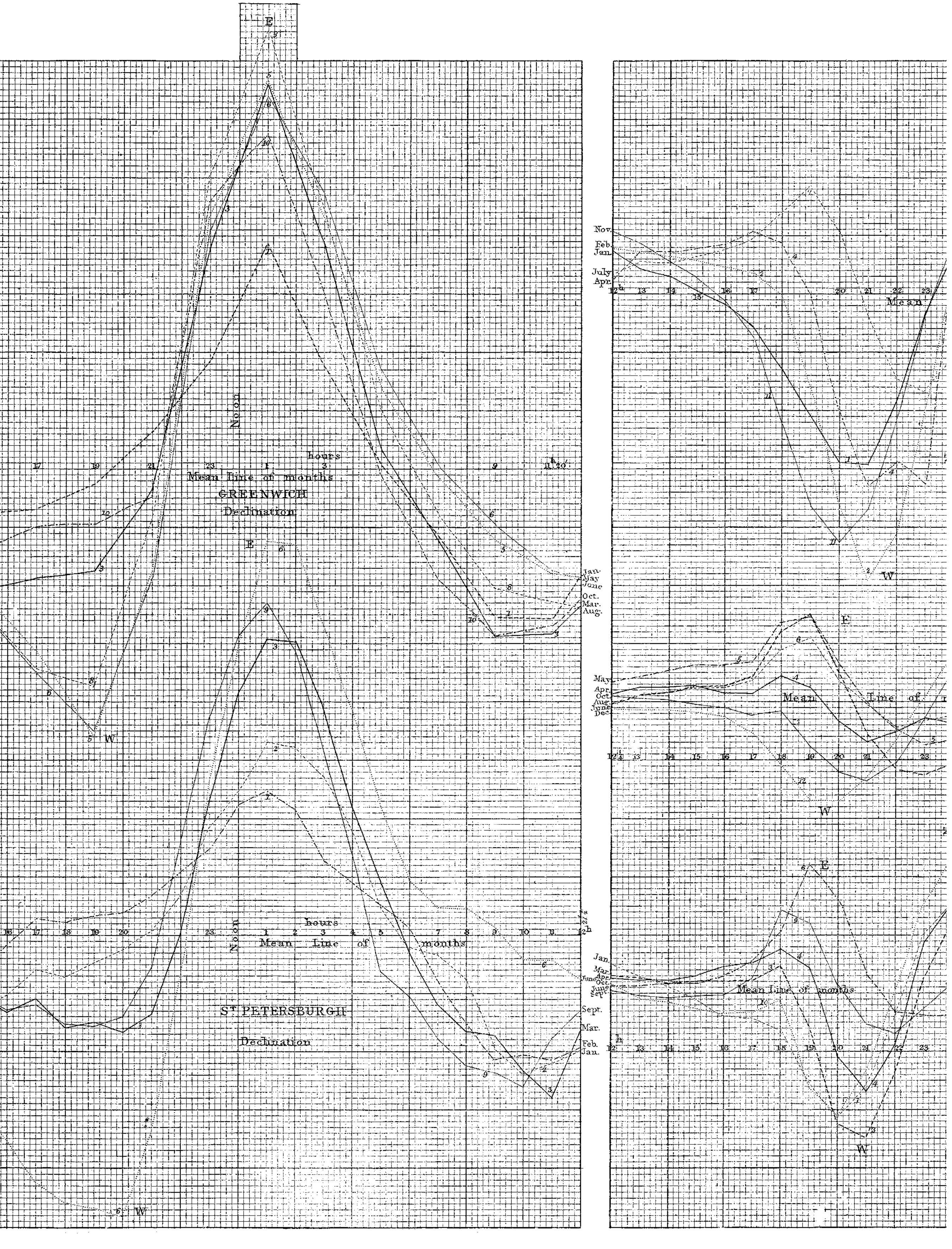
3010. In December or January, being St. Petersburgh winter, the sun-swing east

* The eastening and westening of a free dipping-needle are not properly represented by the movements of a horizontal needle, inasmuch as at places with different dip the angle is read off on planes differently inclined to the dip itself, and in high latitudes the effect is greatly exaggerated. But though different places may not be compared without a correction, the variations for the same place as St. Petersburgh are comparable and proportionate.

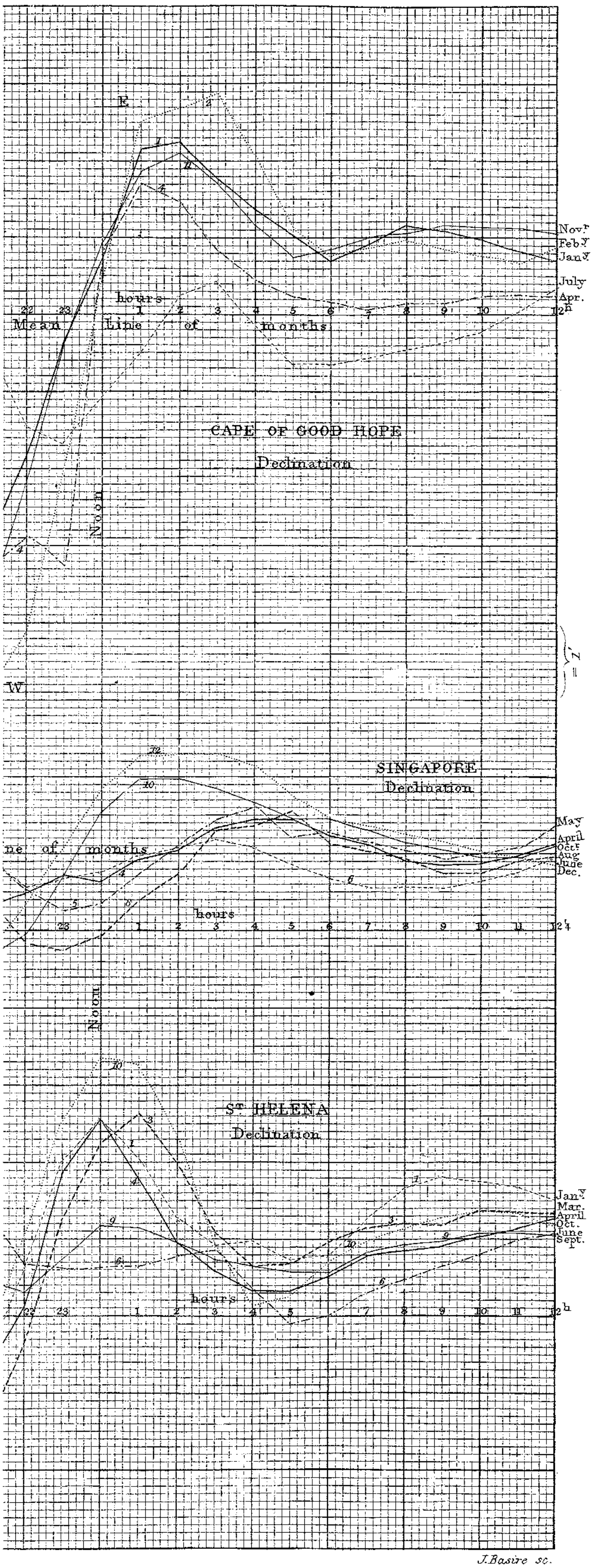




Eastern positions of the upper end of a free Needle are i



...le are indicated when the curves are above the Mean Line of the months, and Western positions when below.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almost disappears. It is over by 1 o'clock*, after which the upper end of the needle follows the sun until 9^h, having passed its mean position at 5^h. It then stops, after which it moves east until 16^h or 17^h; then again stops, or nearly so, until 21^h, and then the sun-swing comes on, carrying it to extreme east. So here there are two very important points to explain, namely, why the needle moves eastward after 9^h, and why it does not travel westward from 13^h to 20^h, but, on the contrary, is travelling eastwards or standing still: the explanation, according to my view, is as follows:—St. Petersburgh is a place in which, from its position, the upper cold, consequent upon the daily withdrawal of the sun, would produce a paramagnetic action (2994. 3003.). This action, as the sun set, would begin to appear on the east, and I conclude that at 9^h–11^h the cold region coming up from the east, not on the latitude of the sun's path, which is far to the south, but probably near to that of St. Petersburgh itself, is able at 9–11 o'clock, during which the needle is stationary, to counteract any remaining tendency westward, and after that to draw the line of force and the needle end eastward until 17 o'clock, and to hold it there, after which the sun sends it eastward in the great swing. That the cold, considering its probable position, may well direct the needle end eastward till 17^h, and the sun region not send it westward from 17^h to 20^h or 21^h, is seen, I think, to be a very natural consequence of the probable position of the two regions between these hours. For letting the sun (whose place we know) represent the warm region at 17^h, he is then in the eastern quadrant below the horizon, so that if he could affect the needle through or round the earth (2995.), it would be to easten it, and it continues in that quadrant until 19^h. Then at 19^h, when he enters the quadrant, in which he begins to exert a westening action on the sun, he is in such a position as respects the needle at St. Petersburgh (as is seen by a line drawn over the surface of the globe (2996.) and compared with the magnetic meridian and dip), and in so inefficient a part of the quadrant (2982.), and also so far off, that it has no power to send the needle westward, but only in association with the retreating cold region to hold it there, until at 21^h, or thereabout, the sun-swing from west to east occurs as in other cases. After this the needle follows the sun from 1 o'clock, being, as the hours advance, gradually arrested and taken up by the cold region of the next twenty-four hours, as already described.

3011. I have considered the cold eastening as continued until as late as 17^h, which would imply probably that until that hour the cold region was east of St. Petersburgh. It is very difficult to speak, even in a general manner, of the places or times of things so little identified as yet, as the warm and cold regions in the upper atmosphere; but referring to the temperatures on the earth at St. Petersburgh, I may point out, that the extreme cold is, in the month of January, as late as 19 and 20 o'clock, and *five hours* later than it is in the summer months. I may also point out here, for use in the summer months, that the maximum heat varies three hours in the *opposite direction*; so

* The St. Petersburgh observations are at $21\frac{1}{2}$ minutes after each hour; but I mention the hour without the minutes as sufficient for a general statement.

that whilst from the highest to the lowest temperature in the day is only eleven hours in summer, it is nineteen hours in winter, as may be seen by the Temperature Table, p. 83. As the day comes on, therefore, in January the highest temperature is only five hours after the lowest, which accords generally with the assumed cause of the effects on the needle*.

3012. As I am endeavouring to make St. Petersburgh a general case of night action for the explanation of corresponding effects at other places, so I may notice that the night action must contain a portion of sun effect which combines with that of the cold. The action of the sun is known by observation to be very extended; in the case of St. Petersburgh, the sun, when at the southern tropic and on the meridian, is between 80° and 90° from the station, and yet we see by the observations and curves how large an effect he produces (3009.). Wherever the sun may be, he is by his motion causing changes which are felt simultaneously over the whole globe; and at 9 and 10 o'clock he is in an effectual part of that quadrant which would send the needle eastward if the earth were replaced by air, and in the representative experiments with a helix (2995.) does so send it eastward when a magnet is interposed. The night action ought therefore to be greatest in winter, as it is, because the cold is then most intense, and also because the action of the distant sun coincides with it. It is very probable that many of the curious contortions of the night action which appear in the curves of Hobarton, Toronto and elsewhere, may depend upon the manner in which, at different hours, these two causes (probably with others) combine together.

3013. Though the declination varies little or nothing between 17^h and 21^h, no westening then appearing (3010.), still I should expect a marked action on the inclination at that time, and conclude that it will be on the increase; but I have not been able to obtain a table of the daily variation of inclination.

3014. In the month of February the same remarks apply; but as the sun is now coming from the southern signs and drawing nearer to St. Petersburgh its power is increasing, and this is shown by making the cold eastening for 15^h, 16^h and 17^h less in extent than before by more than half a minute (of a degree), and by absolutely overcoming it and making a return westwards between 17^h and 18^h, before the swing to the east comes on. In March the effect is still more striking; the paramagnetic eastening is arrested at 14^h, and the following diamagnetic westening extends to 20^h; then follows the swing. In April the westening by the warm region is as early as 13^h and continues to 20^h, being very strong. It is interesting to look at the Table of Temperatures for these months, even as they are obtained at the earth's surface. As the months

* In relation to the cold of the upper atmosphere and the occurrence of its maximum (at certain levels at least), not at midnight but hours after, how often do we in this country see a clear bright night, and then just before the sun rises, the formation of a veil of clouds high up, and, upon his appearing, their dissolution and passing away! In these cases the clouds show the time of greatest cold above by their formation, and by their dissolution its quick reversion and change into increasing warmth.

come on the eastening from the cold ceases sooner and sooner, being in January and April 17^h and 13^h respectively. The minimum of temperature also retreats, being for the same month 20^h and 16^h. On the contrary, the maximum of heat *advances* from the winter to the summer months, being also greatly increased; and the effect on the sun-swing is seen both in the *advanced* time of change and the *increased* amount of variation.

3015. In May and June the night or cold eastening has disappeared, or is shown only by a little hesitation; and from midnight the coming on of the sun region sets the needle end west. If we look at the globe (2996.), we should be led to expect that it would do this. The sun is then in the northern tropic nearly, wheeling round St. Petersburgh and comparatively near to it; and a free dipping-needle would in twenty-four hours make one revolution in the same direction as the sun region, but at the opposite end of the line, joining the two together. If the needle were at the astronomical pole of the earth, having great dip, it would describe almost a circle with nearly uniform motion; but being really much nearer to the warm region in one part of the uniform daily course of the latter than another, the radius vector joining it with the region then makes a much greater angle in a given time than when it is further off, and hence the greater rapidity of the motion between 20^h and 1^h, and the production of what I have familiarly called the sun-swing from west to east.

3016. It will be seen from the Table of Curves (Plate II.), that we have at St. Petersburgh a fine example of that kind of result which Colonel Sabine called attention to so strongly in his paper upon the St. Helena phenomena*; and those occurring at Hobarton, Toronto and elsewhere; namely, a declination variation in *different* directions for the same hours in different months. Thus, in the present case, the needle end goes eastward for the hours 13^h to 20^h in October, November, December, January and February, whilst it goes west for the same hours in April, May, June, July and August: March and September curves fall midway. But this difference is now I hope by the hypothesis accounted for (3010. 3015.), and I trust that equally satisfactory reasons will appear for St. Helena (3045.) and other places (3022. 3039. 3065.).

3017. The paramagnetic character of the eastening effect by cold in the winter months after 10 o'clock, would probably be illustrated by inclination observations for the same time; for if the cold region passes to the south of St. Petersburgh the inclination will be decreased by the paramagnetic action, but increased by the diamagnetic resultant; and the manner in which these two elements of direction, *i. e.* inclination and declination, are combined at any given moment, is very important to the full elucidation of the magnetic effect of the atmosphere. I have not been able to give these data for St. Petersburgh. The total force variations would also help greatly to clear up the subject. Indeed it is not fair to endeavour to explain the results of the assigned cause by taking only one element of three into consideration. What we require ultimately to know, is all the changes of a free needle in position and in respect

* Philosophical Transactions, 1847, p. 51.

of power. All are important, and all should be considered at once. I presume that the theory of the variations cannot advance very far without their joint consideration.

3018. *Greenwich* presents a fine case of the night episode, and the different directions of the magnetic variation for the same hours in different months. In these respects it is very much like St. Petersburgh, but has great additional interest, because of the large western declination*, and the effect produced by it on the places of the active quadrants (2979. 3000.), and the times of the variation phenomena. On setting up its position on the globe (2996.), it will be seen that the equatorial plane is not likely to be much concerned in the midday action, and that the sun or warm region passes nearly across the middle of the two chief quadrants in summer; which with its nearness at the same time, ought to make the midday swing to east very great. In winter it is further off and in much weaker parts of the quadrant, so that the swing ought to be far less, and such is the case. The greatest summer variation is 11'·30, and the least winter variation only 5'·88. In April, May, June, July and August, the great west declination of the south or upper end of the needle is at $19^h\ 20'$, and the chief east position at $1^h\ 20'$. The latter position remains the same all the year round, but the extreme westening is in the other seven (cold) months at $9^h\ 20'$ and $11^h\ 20'$†, or verging towards midnight; it then surpassing the morning west deflection. Thus the sun's effect in summer, in weakening the cold night effect (3005.), is very evident; and so also is the manner in which the night action grows up, until very prominent, in the winter months, through the strengthening of the cold action (3006.), when the sun is towards the southern tropic and in the weaker parts of the segments. The assumed principles of this action have been already given in the case of St. Petersburgh (3010. &c.).

3019. The magnetic meridian is much to the east of the astronomical meridian, where the warm region passes it, especially in winter, for then the sun crosses it about 10 o'clock, and in summer about 11 o'clock. Hence the swing ought to be earlier in winter than in summer, though, because of the slower angular motion of the warm region in relation to Greenwich (3015.), it ought then to occupy a longer time; and yet, as above said (3018.), be, by reason of distance, of smaller amount. All this appears to accord remarkably with the fact. The swing begins at 17^h in the winter but not until 19^h in the summer, and ending at the same hour at both seasons, namely, 1 o'clock, is much longer in its occurrence in winter than in summer. It begins earlier, because the magnetic meridian is sooner passed than in summer; and the reason also appears why the extension in time is at the beginning rather than at the termination of the swing; for, because of the declination, the warm region is at the same hours much less east of the magnetic meridian in the morning and much further west of it

* Mean declination 22° 51' W. Mean inclination 69° N.

† See the Curves, Plate II. The observations are only for every two hours, so that no degree of nicety can be expected in assigning the time of any given change.

in the afternoon, in winter than in summer; hence the swing is thrown forward in time in winter; and though prolonged, its termination coincides with the termination in summer, as far at least as these two-hour observations can indicate.

3020. As the region precedes the sun, the degree of mean declination here ought to make the day-swing come on early, *i. e.* earlier than at Hobarton, and especially earlier than at Toronto, unless other causes of variation interfere. Now the beginning is earlier than at Toronto, but the end the same. Both the beginning and the end is an hour earlier than at Hobarton. The latter difference I believe due to the difference of mean declination: at Toronto, I think we shall find another cause influencing the time (3032.).

3021. We are to remember also that in winter the sun or warm region passes the magnetic meridian two hours before he passes the astronomical meridian; and therefore his effect in giving west position to the south or upper end of the needle ceases long before it does in summer, and perhaps even before it ceases to come nearer; and so the eastern after-effect on it ought to be greater, which it is. This eastern effect should be strengthened also, because the action of the warm region on the needle ought to be comparatively great after passing the magnetic meridian; for its path forms an obtuse angle with the meridian before the passage and an acute one afterwards (3000.), and therefore is more powerful. To all these causes of action will be added the effect for the time of the cold in the distant west (3005.).

3022. The case of difference of direction before 19^h (3016.) is very marked at Greenwich, as may be seen by looking at the Curves for the months, Plate II. The south or upper end of the needle goes west in May, June, July and August, from 12^h to 19^h, *i. e.* from midnight to five hours before noon; but in October, November, December and January, it is eastening at the same hours. Considering first a summer month, as June, the upper end of the needle is westward as the sun comes onward (as it ought to be) until 19^h, when he is almost in the middle of his passage through the east quadrant; and in respect of distance and angular relation to the magnetic meridian, the warm region is then, probably, in the place of greatest power to produce westening of the needle end*. In the next six hours the needle passes to extreme east, performing, according to the observations, a fourth of the whole swing in the first two hours, a half in the next two, and a fourth in the remaining two, the journey being no doubt with first rapidly increasing and then rapidly diminishing velocity. In this transit of the region, the sun is for about two-thirds of the time in the eastern quadrant, and one-third in the western; and his path in the latter third forms almost the base of an equilateral triangle with Greenwich, having the magnetic meridian for one side, so that all that time it is close to and therefore has strong action on the needle (3000.). The sun is at 1^h in such a position as respects this angle, that if

* It must not be forgotten, that the return from an extreme east or west position is not when the sun or warm region passes by a neutral line, or from one quadrant to another, but when it passes its point of greatest action in a quadrant (2982.).

we assume the region to be somewhat in advance of it, the latter would be in that place where it could exert its maximum eastening effect; and therefore after that, as it recedes westwards, would let the needle return from east to west, as it does, following it. The needle continues to go west, passing its *mean* place for the month about 7^h; in the meantime, before that, at a little after 6 o'clock, the sun has left the western segment by passing the magnetic equator; it has not yet set to Greenwich, and if it have any action, it will, because of the segment it is now in (2979.), still be to carry the needle end *westward*. The end in fact continues to go westward, slowly only, after 10 o'clock, gaining a little from 10^h to 15^h; and then, as the sun comes up, passing more rapidly west, as it ought to do, until 19^h, and finally making the great swing to the east as before. The whole progression here is very simple, and apparently a natural result of the assumed cause. Effects of cooling no doubt come in; but the cold region has diminished in intensity and extent (3006.), has retreated northward, and its action appears in combining with the former to produce only variations in the velocity of the change.

3023. Then for the winter, let us consider January; and, as the eastening is a maximum in all the months at 1 o'clock, after the sun's passage across the meridian, let us begin the cycle there. At 1^h the upper end of the needle is at extreme east, and the amount of the variation not half what it was in summer, the sun being now far off. The sun and warm region pass the magnetic meridian about 21^h or 22^h; and therefore, in the hours before and after that, should produce the full west to east effect. At 1 o'clock the needle returns west, following the retreating sun, and does so quickly for seven or eight hours, or up to 9^h, during which time the warm region, and also the early morning cold region, are in quadrants and positions, which, if they have any action at all like that referred to in the experiments (2975. 2995.), would then set or hold the needle end west of its mean position. Then an action of the following kind supervenes; the needle remains stationary until 11^h, after which it goes east at midnight and until 15^h; again remains stationary, or nearly so, for two hours; then eastens again, slowly at first and afterwards more rapidly, until 1^h, when it has attained its maximum eastening and the place from whence it set out.

3024. This night action is another case of the action of a cold region like that considered in respect of St. Petersburgh (3010.). It appears to me that at 11^h the immediate sun action and returns west after it, were over; that the cold region which was coming round from the east did then act by its paramagnetic condition (combined with the complementary effects of the sun's action on the other side of the globe), and set the needle eastward, as it would be competent to do (2994. 3010.) until 14^h or 15^h. In eastening, the needle does not arrive at the mean place, but is still $1'$ west of it; and the reason why it hangs there from 15^h to 17^h and then begins to go east again, more and more under the sun's action, is probably that, as the sun rises in the southern tropics, his distance and position bring the resulting distant warm region gradually into action with that of the nearer cold; that at first he stops the action of the latter, and then as he advances combines with and finally replaces it; causing the usual swing to come on, slowly at first and then quickly, from west to east by 1^h. How this would happen is well seen, both as respects the place of the sun in the southern hemisphere, and in the two magnetic segments, by reference to the globe (2996.) and the diagram of the curves of variation, Plate II.

3025. Considering another and an intermediate month as March; at 1^h the upper end of the needle is at extreme east; then until 9^h it follows the sun as before (3023.). From 9^h to 11^h it is stationary; then the paramagnetic action of cold from the east occurs, and the needle moves east until 13^h. It is then stopped, and two hours sooner than before; for the sun now appears to Greenwich as early as 6 o'clock, and in a more favourable position for effect, both as regards the magnetic meridian and the segment in which it has for the time its place; and so the needle is actually sent west for a couple of hours. It is then almost held steady until 19^h, after which the great sun-swing occurs. The holding west and yet the absence of more westening between 15^h and 19^h, is not inconsistent with the southern place of the warm region, and it is probable that at that time the *dip* is increasing; an effect which would accord very harmoniously with the condition of matters at the time.

3026. Other months are on this or that side of March in respect of their effects; the corresponding month on the opposite side of the year (September) is the same as March, except in that portion of effect which is consequent upon a month following one that is warmer or colder than itself (3053.). Greenwich therefore satisfactorily illustrates the application of the hypothesis to the case of a difference in direction for the same hour in different months (3016. 3022.); and also the occurrence of the night effect, and its transition into the very marked eastening of the early morning.

3027. The cases of *Hobarton* and *Toronto* are so similar, though in opposite hemispheres, that they may be considered together. A very important comparison of the phenomena at both places has been already made by Colonel Sabine in relation to the variations of declination, inclination, and total force*. When examined by the globe (2996.) the distribution of the quadrants is nearly alike, the sun being in two chief east and west quadrants, from about 18 to 6 o'clock, or during the day. The sun is in more influential parts of the quadrants in summer than in winter, and the effect is seen in the difference of the amount of declination variation. At Hobarton it is $12'{\cdot}05$ in summer and only $3'{\cdot}6$ in winter. At Toronto it is $14'$ in summer and $5'{\cdot}2$ in winter. The night action at both is alike in character, and has been sufficiently explained according to the hypothesis in the former cases (3010. 3024.).

3028. Colonel Sabine has given the data by which the variations of the inclination and of the total force at Hobarton and Toronto may be compared with and applied to the hypothesis; but I hesitate to enter upon them in this general view, inasmuch

* Hobarton Observations, 1850, vol. i. p. lxviii., &c.; also Philosophical Transactions, 1847, p. 55, and 1850, pp. 201, 215, &c. See the Curves, Plate II., and Tables for Toronto, pp. 80, 81.

as these and the declination variations should be closely considered and compared together at every hour for each particular place. The inclination variation at Hobarton is greatest in its summer, being then 2'·18, and least in winter, or 1'·28, as was to be expected. The great variation occurs in the daytime, as with the declination; the dip being most as the sun region passes over the meridian. The greatest dip is not at the same hour for all the months; it occurs at 23 o'clock for December, February and March, at 24 o'clock for September, at 1 o'clock for June and July; as it moves on so do the points of least dip on each side of it, so that the whole curve advances in time in the order of these months. There is also another affection of it, for the *quickest* transition is from *most* to *least* dip in some months, as December, February, and from *least* to *most* dip in other months, as June, July, September. At Toronto the dip variation, though peculiar in some points, may be said to have the same general character.

3029. For the variation of the total force at both places, I will at present only refer to Colonel SABINE's volumes, and the observations he has made thereon.

3030. There is a remarkable difference between the time of the day changes at Hobarton and Toronto, to which Colonel SABINE has called attention. It consists in the occurrence of those at the latter place, about an hour before those of the former. If this had depended upon the declination, then the change should have taken place first at Hobarton, for there the sun arrives at the magnetic meridian before he comes to the astronomical meridian, and for like hours of local time he is in a better position in the quadrant in the afternoon than at Toronto; still it is the later of the two.

3031. If the *time* of the sun-swing from west to east be considered, the middle of it ought to be somewhere near the period when the warm region is passing the magnetic meridian (2982.), and in that way supplies an approximative expression of the relative positions of the region and the sun. The swing is at Hobarton from 21 to 2 o'clock, or five hours, and the magnetic meridian is passed by the sun nearly in the middle of the time, or $23^h\ 20'$ o'clock. But according to the supposition just made, this is also the time at which the warm region ought also to pass, and so the sun and the region in this place appear to arrive at the meridian together. At *Toronto* the sun-swing is about four hours in winter, or from 21 to 1 o'clock, and five hours in summer, or from 20 to 1 o'clock. Of the latter five hours the middle is $22\frac{1}{2}$ o'clock, at which time the region ought to pass over the magnetic meridian, and as that coincides nearly with the astronomical meridian, it appears that the region is about $1\frac{1}{2}$ hour *before* the sun. By a similar comparison for winter, the region would then appear to be about an hour before the sun*.

* In referenee to the position in advance of the sun, of the resultant of those actions which set the needle end westward, we must remember that the preceding cold, being perhaps seven hours only to the west, is by its action on the general system of the curves aiding the westening of the needle, whilst the sun is in the east and even over the meridian (3005.).

3032. I am inclined to refer much of this precession of the warm region at Toronto to the geographical distribution of land and water there. The Atlantic is on the east and the continent of America on the west of the station, and as DOVE's charts and results intimate, the temperature may rise higher and sooner over the land than over the water, and so throw the warm region in respect of Toronto in advance of the time or of the sun. In the case of Hobarton the arrangement is different; and, in fact, what land there is is between the advancing sun and the station, and would tend to hold the warm air region back, and tend to cause its time to coincide with that of the sun. Even the greater difference in summer than in winter at Toronto appears to be explicable in the same manner, by reference to the relative position of the sun at the two seasons to the land and water arrangement.

3033. Though the temperature on the earth's surface is a very uncertain indication of that above (2937.), yet as far as it goes it harmonizes with this view. The maximum temperature occurs sooner after midday at Hobarton than at Toronto; in the former place it is at 2 o'clock and very regular, and the minimum at 16–19 o'clock, being earlier in summer and later in winter. At Toronto the maxima are from 2 to 4 o'clock, and the minima at 16–18 o'clock. The maxima are later in summer than in winter; the minima are as at Hobarton, being later in winter than in summer. The mean temperature is lower at Toronto than at Hobarton, being as 44°·48 and 53°·48: the range of variation is also greater, being at Toronto 43° and for Hobarton only 18°.

3034. It is probable that effects of retardation and acceleration, in respect of the passage of the local part of the warm region for a given place, may occur in many parts of the globe, and these will require to be ascertained for every locality and for the different seasons there. A place having the reverse position of Toronto would have a reversed or retarded effect; and hence it might happen that needles in the same latitude might be affected at very different local times, and yet all be regularly affected every twenty-four hours. The region would in that time make its diurnal revolution, but vary in the velocity of its different parts at different periods of its journey, and that in a different degree and order for different latitudes, and for different parts of the same parallel of latitude. Even the time during which the effect (as for instance the sun-swing) continued would probably be altered; one place holding the influence longer and another dismissing it sooner, analogous to two conditions of stable and unstable equilibrium.

3035. *Cape of Good Hope**.—This station is in longitude 18° 33′ east and latitude 33° 56′ south. The mean declination is 29° west and the dip 53° 15′ south. The amount of dip, combined with the position of the place, gives a magnetic equator, which passes nearly through the astronomical poles, and so the sun's path in every part of the year intersects it almost at right angles and at the same hour, namely, about 20′ past 7 o'clock in the morning and evening, or at 19^h 20′ and 7^h 20′. But

* See Tables, pp. 117, 118, and curves of variation, Plate II.

because of the great declination, the sun is in the astronomical meridian two hours before he arrives at the magnetic meridian in Cape winter, and half an hour or more before in Cape summer.

3036. The sun passes obliquely through both the chief quadrants and across their central parts pretty equably; but because of the western character of the mean declination he is much nearer the Cape when in the eastern than when in the western quadrant for all the months, and so the coming up effect, *i. e.* the westening before the midday swing commences, ought to be more powerful than the eastening after it is over, and such is the case. This is in beautiful and striking contrast to Greenwich, which, having the same kind of mean declination and nearly in the same degree, is on the north of the sun's path, and therefore the luminary passes its magnetic meridian before 12 o'clock, and for a time still approaches the station: the result is the reverse effect to what we have at the Cape; for the eastening effect at the end of the midday swing is more powerful than the westening effect before it, as is well seen by the curves given in Plate II.

3037. Selecting July as the month in which the effect of winter occurs at the Cape, we find that the day-swing is very feeble, as it ought to be, the sun being in the northern tropic and far away; and the swing east is at an end by 3 o'clock, when the sun has passed by about one hour over the magnetic meridian. The upper or north end of the needle then westens for two hours, following the sun until 5^h, when the luminary is low to the Cape and at its setting. After that the needle end eastens slowly until 10^h, then a little more quickly until midnight (passing the mean position at 11^h); quicker still until 16^h or 17^h, and still more quickly until 19^h, when it has attained its maximum east position. This effect I believe to be due to the cold, which in these hours is approaching from the east, and setting by its paramagnetic action (3003.) the needle end eastward. On the surface of the earth the maximum cold in this month is at 17^h or 18^h, and as far as it goes this result accords with the effect above described. At 19^h, the sun in rising not only stops the eastening but quickly drives the needle back again, and the latter very rapidly goes westward until about 23^h, at which time the sun-swing from west to east comes on, being over by 2^h or 3^h, completing the daily variation, after which the needle goes west, following the sun as before. In this sun-swing is seen the effect of an inclined magnetic meridian (3000.); for though the sun is, at the beginning, only an hour east of the astronomical meridian, he is full three hours to the east of the magnetic meridian. As the swing occupies about four hours, the warm region is probably near the magnetic meridian about half-past 12 or 1 o'clock.

3038. *January* presents a case of Cape summer. The day-swing is then from 21^h to 1^h or 2^h. After 2^h the needle upper end follows the sun westward until 6^h, and then moves a little eastward for two hours; after this it moves slowly westward again, the whole effect being as if a cold region had occurred on the east, had passed over and gone away west, and the temperature below at this time is within 2° of the minimum. This night effect of drawing the needle westward (3004.) proceeds slowly until 15^h or 16^h, being assisted by the rising temperature on the east urging the end still more rapidly west until 20^h, when having reached its maximum in that direction, it at 21^h turns back and is driven to extreme east in the sun-swing, through an amount of variation more than twice as great as that produced in July or Cape winter.

3039. I think the above is a true explanation of the reverse motion of the needle in the months of July and January, or Cape winter and summer. In winter the para-magnetic effect of cold air is on between 12^h and 19^h, remaining longer on the east side of the magnetic meridian; as it passes forward, both it and the sun region conspire at 19^h to carry the needle westward, for though they have opposite actions they are then also on opposite sides of the magnetic meridian (3005.). In the summer the cold region has much less power, occurs earlier*, soon passes over, for the summer sun is behind it, and then rather aids the sun in carrying the needle westward.

3040. Some of the other months are still more striking in summer effect. February has a swing through 8′ from west to east between 21^h and 1^h; then from 1^h to 3^h it scarcely changes; from 3^h to 6^h it follows the sun west; from 6^h to 16^h it varies but little, showing the merest trace of east effect about 8^h; and after 16^h it passes west more and more rapidly, so that by 21^h it is at a maximum west, ready to swing back as the sun region passes over. The other and intermediate months are easily traced, and found to be beautifully consistent with the same principles of the hypothesis. As is evident, in almost every case each month partakes of the character of the preceding month in some degree, though not so much in this case of the Cape as in some others (3053.). The curves of December and January are more equal.

3041. The time of the sun-swing illustrates exceedingly well the effect of the inclined magnetic meridian (3000.). In November, December and January, the swing is from 20^h to between 1^h and 2^h. In these months the sun crosses the astronomical meridian about half an hour before he arrives at the magnetic meridian. In October, February and March, the swing is later, being from 21^h to 2^h or 3^h, for the sun then passes the magnetic meridian an hour or more later than the astronomical or time meridian. In September, April and May, the swing is still later, being from 22^h to 2^h or 3^h, and the sun is still longer than before in reaching the magnetic meridian. In June, July and August, the swing is latest, being from 23^h to 3^h, and the sun is proportionately late in arriving at the magnetic meridian. What I describe as the passage of the sun is of course true of the warm region which precedes it; but I prefer referring to the visible type rather than to the invisible reality, because it ties the considerations of time more simply together.

3042. The inclination at the Cape varies singularly in the twenty-four hours, depending, I think, upon its mean degree. It is such that the warm and cold resultants of action for the Cape will sometimes be above the line of the dip and sometimes

* The minimum temperature below is three hours earlier.

below it, not only for different times of the year, but I think in some seasons, even at different times of the day. It would require much attention to unravel the whole effect. In June, July and August, when the sun and its warm region are greatly to the north of the Cape, it appears that the dip is increased as the region passes, which would give a rotation of the upper end of the needle like that at Hobarton (2909.); but in November, December, January, February, March and April, the dip diminishes at that time, and the resulting rotation of the pole is of the contrary kind, or like that at St. Helena (3057.) and Singapore (3061. 3067.).

3043. The daily variations of intensity at the Cape are remarkable. In the months October to April it is at a chief maximum at 19^h or 20^h; by noon it is reduced to a minimum as the sun passes over; gradually rises to a second maximum about 4^h or 5^h, and then, after sinking a little about 8^h or 9^h, reaches the chief maximum about 18^h or 19^h next morning. In the months from May to September the chief maximum is at 21^h or 22^h, which is followed by a minimum at 1^h or 2^h, due to the day effect. Then comes on the 5^h maximum, and after thirteen hours or more the second minimum as low almost as the former, and only three hours before the chief maximum; so that this maximum is placed between minima close on each side of it.

3044. These are exactly the months during which the upper end of the needle moves eastward in early morning up to 19^h, and that is just the hour when the minimum intensity occurs. From 18^h or 19^h to 21^h the intensity rises to a maximum, precisely as the lines of force are moving westward before the sun region, prior to their quick return east; and as they return in their quick journey so the intensity falls to a minimum again, and is at that minimum at 1^h or 2^h, just as the swing is over. Here is a very close connexion, and it is curious to see the needle end at east with minimum power at 18^h, and again also at 1^h, remembering that in that time it has swung from east to west and back to east again.

3045. *St. Helena**.—This is a station which Colonel SABINE has distinguished as of the highest interest; being near the line of least force, within the tropics, and with little magnetic inclination†. It was here also that he called attention to the striking fact, that the course of the needle is in some months in one direction, and in other months in the contrary for the same hours of the day‡. DE LA RIVE attempted to explain this fact§, but SABINE has stated that this explanation is not satisfactory¶.

3046. St. Helena being a small island in the south Atlantic ocean is removed about 1200 miles from the nearest land. The longitude is 5° 40′ west, the latitude 15° 56′ south; the mean declination 23° 30′ west, and the mean dip 22° south. Hence there are three quadrants concerned in the day action of the sun, especially when that luminary is south of the equator. The sun is south of St. Helena itself in the months

* See Tables, pp. 119, 120, and curves of variation, Plate II.

† Magnetical Observations, St. Helena, 1840 to 1843.

‡ Philosophical Transactions, 1847, p. 51.

§ Annales de Chimie et de Physique, March 1849, tome xxv. p. 310.

¶ Proceedings of the Royal Society, May 10. 1849, p. 821.

of November, December, January and February, or for nearly that time; it is north of the island for the rest of the year. At one time the sun passes the astronomical meridian before it arrives at the magnetic meridian, and at another time the contrary is the case. In addition to these peculiar circumstances, St. Helena is a place of great local differences, and also its dip is so low that the sun's day effect is almost constantly to depress and lessen it.

3047. In June and July the sun rises to St. Helena in the south-east quadrant; about an hour after it passes into the north-east quadrant, and crosses it towards the southern end, being then at mid-distance in the quadrant about one-third of the length, or nearly 60° from the southern termination. It leaves this quadrant about 1^h 20^m, crossing the magnetic meridian at that time (and consequently so long *after* passing the astronomical meridian), and entering the third or north-west quadrant traverses it obliquely towards its northern extremity. In our winter, December and January, the sun also rises to St. Helena in the south-east quadrant, as before; but it now remains in it until 22^h, being for much of the time in strong places of action; it enters the north-east quadrant to the south of St. Helena, and does not remain in it two hours, being then only in the weakest part of it; it leaves it again *before* arriving at the astronomical meridian, then enters the north-west quadrant, gliding along near to its southern side, and is within two-thirds of an hour of leaving it when it sets to St. Helena.

3048. As June presents the aspect of circumstances approaching nearest to that of a station further south, as Hobarton or the Cape, so I will consider the variations for it first. The north or upper end of the needle is then nearly at its mean place at midnight or 12^h: it advances east (slowly at first) until 16^h, and then more and more rapidly up to 19^h, when it stops and goes as quickly west until about 22^h, after which it changes but little until 3^h, when it moves *west* till 5^h, and then slowly east up to 12^h, and then onwards to 16^h and 19^h, as already said. The eastening from midnight, and before I refer to the paramagnetic action of the cold, which comes up from the east as before (3003. 3025. 3037.); the rapid increase of the eastening from 16^h to 19^h is consistent with the increasing cold of the early morning, and also with the circumstance, that the sun and its representative region are then passing from the south-east into the north-east quadrant, and must be not far from the neutral line, for that is the time of quickest transit of the needle. As the sun advances into the north-east quadrant, it first stops the eastening, as at 19^h, and then converts it into westening (3014.), which goes on consistently with all former observations until 22^h; the needle is then retained a little west of its mean position until 1^h, at which time it has not yet attained coincidence with the magnetic meridian, and after this hour it is determined east a little until 3^h. This effect, from 22^h to 3^h, I consider as the sun-swing to the east; and I think, examining the globe (2996.), its small amount in declination is quite consistent with the relative positions of St. Helena and the warm region, combined with those of the active and neutral parts of the quadrants traversed during the time. From 3^h to 5^h the needle end moves westward, following the sun; and that effect harmonizes with the idea that the previous holding of the needle in an eastern position, from 22^h to 3^h, is the sun effect: then the slow eastening from 5^h to midnight and beyond, is the cold effect coming on.

3049. Colonel SABINE has shown that the months of May, June, July and August, may be classed together, so that I will not speak of each. Whilst they show the analogies they have between themselves, they also indicate the transitions to and from the other months. Let us consider September. From 7^h, through midnight on to 16^h, the needle stands nearly at the mean. From 16^h to 18^h, the upper or north end eastens through the effect of the early morning cold. That the eastening should be fully effected an hour sooner than before (3048.) is quite consistent with the principles, for the path of the sun and its diamagnetic region is far nearer to the station than before, being now about the equator. From 18^h to 22^h it sends the end westward, in conformity with all former observations, and then comes on the sun-swing from west to east, between 22^h and 24^h, and a hold at extreme east an hour longer. The shortness in time of this transit is, I think, a beautiful point. The sun is still north of St. Helena, but is now so much nearer that he passes through the *same angle* east and west, in respect to the place of observation, in less than half the time of the former sun effect in June (3041). After this the needle end travels west from 1^h to 6^h, following the sun as on other occasions; and then from 6^h to 9^h it moves a little east by the evening cold in the east, and remains near the mean position until the greater cold before sunrise (3005. 3011.) takes it more east between 16^h and 18^h of the coming day.

3050. In looking at the curves of variation (Plate II.), it will be seen that the curve for the next month, October, is remarkable for being like in general character, and yet far removed in place from that of September; and this effect appears due to the circumstance that the sun has now arrived at the latitude of St. Helena, or nearly so. According to my supposition, there has been a feeble night effect (3010.); and at midnight the needle is at the mean position and moving slowly westward, when the greater cold which precedes the sunrise coming into action on the east, counterbalances and arrests the western progress, and even draws the needle, as before, east a little for a couple of hours, till 18^h. Even the sun region is at 16^h in that quadrant (the south-east one), that if it could act on the needle it would combine with the cold in the next or north-east quadrant in setting it eastward. By 18^h both the preceding cold region and the following sun region are so far advanced in their respective quadrants that they combine to carry the needle end west as before, until 20^h, and then comes on the swing from west to east until 24^h. Why this begins sooner, lasts longer, and is above four times the extent of the September swing, appears to be that the sun region comes up upon the latitude of St. Helena, and so acts in respect of the magnetic meridian more powerfully, and also sooner and longer: also that because of the mean declination west it arrives at equidistant points from and passes over the magnetic meridian sooner; and also from the effect of an accumulative action added to it from former months (3053.).

3051. At 1 o'clock the needle begins to turn from extreme east, *i. e.* sooner than in the former months, because the magnetic meridian is sooner passed, and follows the sun until 4^h, when it stops, and then the evening or night action due to cold appearing in the east, carries the needle back eastward till 10^h, and then as it advances in the quadrant lets the needle return back again (3004.) until between 12^h and 13^h, when the latter is in its mean position. The cold region then appears to draw it westward until 16^h, when its distance increasing it releases the needle, and lets it return east until 18 o'clock, when the latter is still west of its normal position, and then the sun region rising up, helped perhaps by the cold that immediately precedes it, which is probably now over or beyond the magnetic meridian, sets it toward the west prior to the sun-swing.

3052. In December and January the sun is south of the station. This makes no difference in the general character of the curve for these months; nor should it according to the hypothesis, except in this point, that though the sun is very near to St. Helena and has the cumulative effects of the preceding months (3050. 3053.) added to its own effect at the time, still it is in weaker parts of the quadrant, and whilst in the chief segment is almost up in the corner and near the place where the two neutral planes cross each other; hence its effect ought to be less, and so it is; for the sun-swing of November and February is larger than that of December and January. The sun-swing happens in December at the same time as for October, though in the latter month it crosses the magnetic meridian after, and in the present before midday: still there is only half an hour's difference from one to the other, and the observations are perhaps not close enough to allow one to separate its peculiar effect out of an interval of four hours. Besides, accumulative causes may interfere: the places of the December curve are altogether a little more west than those for October.

3053. The *cumulative* effect of preceding months is very important and well-shown at St. Helena (3050.). Thus, taking the September curve and comparing it with that for October or the following month, we have a great difference of a certain kind; then again comparing September with the month in which the sun is returning from the southern tropic instead of proceeding to it, and has arrived at the same position as it had in October, another striking difference appears. March is the nearest month for the second comparison. Up to 20^h its curve changes like the October curve, but the upper end of the needle is all the time about half a minute east of its place in October. At 20^h the needle in October begins to swing from west, and reaches extreme east at 24^h: in March it westens until 21^h, then returns and reaches extreme east at 1^h; so that the swing is an hour later, and during that time the end is from half a minute (of space) to a minute more west than in October. This difference I believe to be due to the cumulative effect of the months between October and March, during which time the heat has been diminishing in the northern hemisphere, and increasing in the south. Similar results in other months make it probable that the effect of the atmosphere, though induced by the sun, lags behind the luminary, considered as in his astronomical position all the year round; and that therefore in advancing to and receding from a tropic, he seems to do less in the first instance and more in the second than is due to his place for the time.

3054. But where circumstances are apparently equal, a difference also arises. Thus from March to April in one direction, and from September to October in the other, might be expected to be alike, except for a little of the lagging effect (3053.), which would appear on both sides: nevertheless March and April are in SABINE's curves *between* September and October, and near together, whilst the other two are far apart. This effect I refer to the different conditions of the two hemispheres as regards heat (DOVE). From September to October the sun is passing from a hemisphere having a mean temperature in summer 17°·4 above that of the other hemisphere for its winter; but in March and April it is departing from a hemisphere having a mean summer temperature of only 10°·7 above that of the other hemisphere for its winter (2949.); and these respective differences must tend to separate September and October, and bring together March and April, as is seen to be the case by the curve charts, Plate II.

3055. I need not go further into the declination variation of St. Helena: the lines for the other months are subject to the observations already made. Colonel SABINE's important query of the cause of difference in direction for different months (3045.), appears to me at present to be answered for this station, as well as for the other stations, in very various latitudes where it makes its appearance (3016. 3022. 3039.).

3056. The *dip* at St. Helena is a daily variation very simple in character, being a maximum at 7^h and a minimum at 22^h and 23^h, with only one progression. It proceeds to its minimum therefore in the middle of the sun-swing, *i. e.* the upper end of the needle proceeds to west, and descends from 16^h to 19^h or 20^h, during which time therefore the dip is decreasing; then it returns east until it reaches the neutral position, the dip decreasing the while still more. The needle still continues to go east to complete the sun-swing, but now the dip increases; at 24^h or 1^h the needle returns (in declination) after the sun westward, but still with increasing dip; at 5^h or 6^h the westening has almost ceased, and an hour after the dip is at its maximum.

3057. So as the sun and its region pass over they diminish the dip by depressing the upper ends of the lines of force, and as they pass away the lines rise (2926. 2937.) and the dip increases. The ellipse or curve, therefore, which represents the motion of the upper end of the needle at St. Helena, as the sun comes up from the east, is above westward and downward, and back below to east; then rising to be repeated in the next twenty-four hours. This is the reverse direction to the representative ellipse for Hobarton, having like south dip in a greater degree. But that is in perfect consistency with the hypothesis; for as the region is located above in the air, it is above the angle which the dip makes with the horizon at St. Helena, and therefore ought to depress the line of force and lessen the dip. At Hobarton, the region being in the tropical parts, is within the angle formed by the line of dip with the horizon, and therefore deflects the lines of force upwards and *increases* the dip, and so the portions of ellipse at the two places, which correspond in time and direction as to declination, have contrary variations of inclination.

3058. *Singapore**.—This is a very interesting station: being in longitude 103° 53′ E., it has only 1° 16′ N. latitude, and so is close to the equator. Its declination too is only 1° 40′ E., and its inclination 12° S. It is also near the line of weakest force round the earth. The magnetic equator of the needle is almost parallel to the earth's equator, and the quadrants (2929.) are distributed with great simplicity, the magnetic and astronomical meridian nearly coinciding. In our summer the sun passes through the east and west northern quadrants during the daytime; in our winter through the east and west southern quadrants; and in certain months through all four quadrants, following nearly the neutral line of the magnetic equator.

3059. Hence if the line of force were free, *i. e.* if it had no hold in the earth (2919.), we should expect from the hypothesis little or no change in the needle, especially in the months when the sun was over the magnetic equator; but because there is dip, and the lines of force which govern the needle are to the south tied up in the earth (2929.), whilst they are free to move in the air and space toward the north, so there is variation both of the declination and inclination in a perfectly consistent manner; and keeping this in mind, I think we shall have no difficulty in tracing the monthly results according to the hypothesis.

3060. In the first place, the curves of day variation are so like those of St. Helena, month for month, that the account given of them there will suffice for the present occasion (3048.). The sun-swing occurs at the same period, and the effect, dependent, as I suppose, on the character of the two hemispheres, is produced (3054. 2949.). There are however striking differences in the latter part of the sun turn, and also in the night hours, from 5^h to 14^h. The amount of variation appears small; but this is chiefly due to the circumstance that the horizontal plane on which we read it, almost coincides with the free needle, and so the correction before referred to (3009. note) necessary to give the true value of the variation is here very small.

3061. Considering *June* first, as at St. Helena, the upper needle end moves east as before until 19^h, under the influence of the morning cold, after which it stops and is sun-driven west until 22^h, when it swings downwards and beneath to east by 3^h; then follows the sun west until 7^h; it then stops and returns, creeping more and more east because of the coming cold (3065.). In July the needle eastens a little more before 19^h; westens until 23^h, and then eastens until 4^h. The sun-swing is thus thrown an hour later than in June, which I believe to be connected with the accumulation of heat over the land (3054.), combined with the lagging effect of the sun (3053.). In August the needle end eastens until 19^h; more than in July, and most of all the months: it then westens strongly before the sun until 23^h, after which the sun-swing

* See Tables, pp. 121, 122, and the curves of variation, Plate II. The data for Singapore are deduced from the recent very valuable labours of Captain Elliot.

comes on and continues until 5^h, as if the warm region were behind the sun, perhaps even 2^h. The time of the swing is much prolonged, and not unnaturally, as the place is at the equator and therefore under the sun. In September the eastening is less, the westening is less, and the sun-swing is less. April is like September, except that the latter shows the effect of the previously warmed hemisphere (3053.).

3062. Then there are four months in the year, November, December, January and February, when the sun is south of Singapore, and altogether during the day in the southern quadrants (3058.). As the sun comes on from 16^h or 17^h, the upper part of the line of force moves westward (the lower being fixed in the earth) until 19 or 20 o'clock. The sun is at this time in the south-east quadrant, and it might be expected perhaps that the motion of the north or upper end of the needle should be to the east if there were any change at all. But there are two or three reasons, from the hypothesis, why this should not be. For that effect there should first of all be no dip; and in the next place, if there were no dip, the sun is so nearly in the neutral line of the magnetic equator, that the deflection, if any, would have been very small. On the other hand, the lines of force have dip to the south, and being therefore held in the earth; that travelling of the sun along the neutral line, which in its coming up would have sent the whole line of force west, and so caused no variation of declination, can now only send the northern parts, as they rise out of the earth and are carried on with the general system of lines, west, and so cause that western travelling of the needle which does occur. Besides this, though the sun be south of that neutral line and also of Singapore, there is reason to suppose that the middle or resultant of the warm region is north even of both (3063.), which would aid the westening of the needle just described.

3063. For if we recall to mind DOVE's results, they show that the northern hemisphere, as a whole, is warmer than the southern (2949.). Again, if we look at the meridian of Singapore, we shall find that there is far more continent on the north of it, to produce a higher temperature, than to the south; and even by the local tables of temperature below, we shall find that May, June, July and August are the hottest months for Singapore, and November, December, January and February the coldest; all tending to make us suppose that the warm region of the atmosphere is relatively north of the sun's place, and perhaps even of Singapore (3067.).

3064. At 20^h the sun-swing from west to east comes on, and continues until 2^h, after which the needle moves west, following the sun, until 10^h or 11^h when it is near the mean; it still goes on westening very slowly until 17^h, when the morning sun action takes it up and drives it more quickly west, until about 20^h, when the sun-swing east occurs. The curve in these months is very simple in its character; the night or cold effect appears to be but small, being indicated rather by a hesitation than by a distinct movement east.

3065. The easterly movement of the needle end in May, June, July and August, and the westerly movement in November, December, January and February, for the same hours, up to 19 o'clock, is in striking contrast; and I have attributed the difference to the effect of a cold region coming on from the east during the former months (3061.), which is absent in the latter months. In reference to this point, we have again to consider that the warm region is on the north of the equator (3063.), and that as the sun moves north and south it also will move with it, but still keeping north of it. Hence the two cold regions, which come up to the meridian in higher latitudes (3006.) before the sun, will not be in the same relation to Singapore, for the one on the south will be nearer to it than the one on the north, or at all events more powerful. So when the sun is near and at the southern tropic, the warm region probably passes *over* Singapore, at which time, therefore, whilst it is the nearest, the most powerful and most direct in position, the cold regions will be *least* in force at the station, and also least favourably disposed by position. But when the sun is at the northern tropic, then the power of the warm region is diminished, both by distance and direction, and the southern cold region grows up into importance by increased strength and closer vicinity, and so produces the eastening before 19^h.

3066. A striking difference in the direction of the night curves, from 5^h to 14^h, at St. Helena and Singapore may be observed. At the former place the needle end tends first east and then west, whilst at the latter it moves first west and then east. The difference is, I believe, due to the appearance of night cold action at St. Helena to a greater extent than at Singapore. Singapore shows that action in June, July and August, as just described (3065.), but only in a weak degree and at a late hour. At St. Helena, which is in latitude 16° S., the cold effect should, for the reasons given above (3065.), appear in more power, and hence the eastening at 6^h and after; and that this is the cause is indicated also in a degree by the tables of temperature; for whilst at Singapore the difference between the maximum and minimum in the twenty-four hours is only from 3° to 4°, at St. Helena it is from 4°·5 to 7°, and four-fifths or even five-sixths of this depression occurs by 9 o'clock: so that four or five hours before that, there was in the east a cold region coming up and producing the eastening effect recorded in the curves.

3067. The *inclination* variation at Singapore is beautifully simple, and such as might be expected from the hypothesis; the sun or warm region, when passing the meridian, always being over the lines to depress them. It is alike in all the months, being greatest at night-time and least at midday; it is nearly the same from 8^h to 18^h; then as the sun comes up it decreases quickly until 23^h or 24^h, after which, as the sun passes away, it increases nearly as quickly until 7^h or 8^h. The amount of variation is greatest when the sun is over or to the south of Singapore. It is least in June and July, when he is near the northern tropic. In December and January, when he is near the southern tropic, it is considerably more than in June and July, which again seems to show that the warm region is chiefly north of the sun (3063.).

3068. The total force variation is simple, being a maximum from 9^h to 12^h, and a minimum at 22^h or 23^h, near noon. The greatest variation is in April and October, or at the equinoxes, and the least in December and June, when the sun is at the tropics. The force is the least towards noon, when I suppose that the air above is in the worst condition of conduction, and would cause a magnet in it to show more power. But how that may affect the curves beneath on the surface of the earth, where they are compressed together, is doubtful, and the whole matter of intensity is too uncertain and has too many bearings for me to consider it usefully here.

3069. I hope soon to give further experimental data for the purpose of illustrating and testing the view of the physical cause of the magnetic variations which I have put forth, namely, those I expect to obtain by the differential balance, and others concerning the sensible influence of oxygen in causing, under different conditions, deflection of the lines of magnetic force.

Royal Institution,
November 16, 1850.

Cape of Good Hope.—Longitude 18° 30′ East. Latitude 33° 56′ South. Declination 29° 05′ West. Inclination 53° 15′ South.

Mean Diurnal variation of the Declination in each month of the years 1841 to 1846.

Increasing numbers denote a movement of the north or upper end of the magnet towards the East.

Mean time ...	Noon. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midn. 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
January	4·11	5·43	5·50	5·04	4·64	4·29	3·96	4·16	4·43	4·36	4·27	4·13	3·98	3·79	3·56	3·32	3·09	2·67	2·01	1·15	0·37	0·36	1·39	2·93	3·28
February......	5·51	7·48	8·21	7·86	7·06	6·11	5·74	5·83	5·90	5·82	5·74	5·69	5·78	5·73	5·55	5·50	5·38	5·27	4·90	3·36	1·26	0·00	0·82	2·96	4·93
March.........	5·34	6·74	7·29	6·93	6·17	5·48	5·32	5·33	5·42	5·39	5·28	5·40	5·34	5·52	5·59	5·54	5·52	5·39	4·95	3·22	1·04	0·02	1·26	3·44	4·66
April	4·07	5·00	4·76	4·21	3·75	3·53	3·42	3·39	3·44	3·45	3·51	3·56	3·53	3·98	3·96	4·07	4·17	4·32	4·15	3·29	1·32	0·00	0·39	0·06	3·30
May...........	1·83	2·49	2·81	2·92	2·50	2·15	2·17	2·31	2·33	2·30	2·45	2·41	2·64	2·83	2·87	3·10	3·24	3·36	3·80	3·91	2·31	0·68	0·00	0·62	2·42
June	0·74	1·27	1·87	1·87	1·36	1·05	1·11	1·19	1·24	1·34	1·49	1·63	1·74	2·00	2·04	2·25	2·22	2·28	2·59	3·21	2·38	0·86	0·00	0·10	1·58
July...........	0·60	1·18	1·96	2·09	1·54	1·06	1·06	1·09	1·19	1·31	1·46	1·74	2·03	2·22	2·23	2·32	2·46	2·61	3·08	3·56	2·74	1·35	0·28	0·02	1·71
August	0·62	1·52	2·50	3·23	2·93	2·22	2·27	2·34	2·46	2·56	2·49	2·64	2·77	2·91	3·01	3·32	3·45	3·63	4·35	4·98	3·65	1·74	0·36	0·00	2·71
September ...	1·58	2·64	3·22	3·27	2·94	2·57	2·64	2·73	2·75	2·76	2·82	2·84	2·91	3·05	3·06	3·19	3·22	3·36	4·33	4·10	2·43	0·84	0·00	0·49	2·65
October	4·90	5·81	5·96	5·23	4·29	3·69	3·84	4·05	4·09	4·17	4·18	4·16	4·16	4·15	3·96	3·79	3·63	3·40	2·78	1·37	0·14	0·00	1·27	3·18	3·59
November ...	5·19	6·15	6·36	5·98	5·43	4·98	5·08	5·26	5·32	5·39	5·37	5·37	5·34	5·13	4·84	4·55	4·15	3·41	2·05	0·68	0·00	0·57	2·19	3·88	4·28
December ...	4·64	5·48	5·51	5·08	4·47	4·41	4·24	4·42	4·54	4·60	4·66	4·67	4·62	4·36	4·07	3·74	3·38	2·63	1·42	0·39	0·04	0·55	2·05	3·56	3·62

Cape of Good Hope.—Mean Diurnal variation of the inclination in each month of the year, from April 1841 to June 1846.

Increasing numbers denote increasing inclination. Inclination 53° 15′ South.

Mean time ...	Noon. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midn. 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
January	0·03	0·00	0·34	0·56	0·72	1·00	1·25	1·35	1·46	1·51	1·50	1·41	1·37	1·40	1·30	1·22	1·18	1·10	0·94	0·99	0·97	0·92	0·66	0·23	0·98
February......	0·13	0·00	0·44	1·05	1·55	1·91	2·01	2·14	2·14	2·09	2·94	1·94	1·70	1·63	1·65	1·56	1·63	1·70	1·66	1·94	2·26	2·08	1·45	0·66	1·56
March.........	0·11	0·00	0·46	1·05	1·45	1·86	2·09	2·21	2·16	2·02	1·94	1·79	1·79	1·46	1·35	1·46	1·45	1·50	1·51	1·69	1·81	1·66	1·00	0·41	1·38
April	0·00	0·49	1·05	1·55	1·76	1·89	2·16	2·21	2·11	2·06	1·88	1·65	1·45	1·18	1·18	1·07	1·22	1·12	1·10	1·10	1·48	1·53	0·92	0·33	1·35
May	0·00	0·38	0·70	0·86	1·08	1·16	1·27	1·31	1·49	1·59	1·39	1·32	1·16	0·89	0·93	0·89	0·76	0·68	0·30	0·15	0·53	0·66	0·56	0·12	0·84
June	0·41	0·53	0·58	0·76	0·64	0·79	0·96	1·22	1·34	1·40	1·29	1·22	1·04	0·96	0·89	0·81	0·73	0·78	0·36	0·00	0·07	0·38	0·36	0·43	0·75
July	0·62	0·64	0·59	0·64	0·77	0·87	1·18	1·20	1·46	1·43	1·43	1·21	1·07	0·95	0·77	0·87	0·67	0·60	0·28	0·00	0·18	0·51	0·64	0·56	0·80
August	0·12	0·38	0·76	0·99	1·16	1·27	1·34	1·60	1·55	1·52	1·45	1·30	1·16	1·04	0·84	0·83	0·63	0·68	0·27	0·00	0·13	0·33	0·43	0·30	0·84
September ...	0·00	0·23	0·66	1·09	1·40	1·65	1·78	1·68	1·75	1·75	1·40	1·27	0·91	0·97	0·56	0·81	0·51	0·73	0·18	0·31	0·07	0·35	0·03	0·12	0·84
October	0·00	0·08	0·53	1·17	1·75	1·98	1·98	1·89	1·88	1·75	1·60	1·50	1·28	1·23	1·20	1·10	1·09	1·07	1·07	1·09	1·04	0·77	0·36	0·05	1·14
November ...	0·14	0·00	0·29	0·64	1·12	1·53	1·41	1·46	1·48	1·33	1·25	1·08	0·99	0·94	0·90	0·87	0·87	0·94	0·80	0·62	0·46	0·26	0·06	0·00	0·81
December ...	0·13	0·30	0·87	1·22	1·40	1·53	1·78	2·01	2·04	1·81	1·70	1·57	1·50	1·48	1·47	1·50	1·50	1·40	1·05	0·81	0·48	0·15	0·02	0·00	1·15
Hourly means	0·14	0·25	0·61	0·96	1·23	1·45	1·60	1·69	1·74	1·69	1·49	1·44	1·28	1·18	1·09	1·08	1·02	1·02	0·79	0·72	0·79	0·80	0·54	0·27	1·04

Cape of Good Hope.—Mean Diurnal variation of the Intensity in each month of the year, from April 1841 to June 1846.

Increasing numbers denote increasing intensity.

The numbers express the changes in parts of the whole Force. Approximate Total Intensity 7·5.

Mean time ...	Noon. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midn. 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00
January	000	003	018	031	041	047	048	039	036	038	040	044	045	047	049	050	052	061	071	079	078	056	028	005	042
February......	000	000	020	047	069	083	076	072	068	069	071	071	074	075	078	076	077	080	092	115	127	105	062	026	068
March.........	000	007	027	052	070	079	074	069	064	064	067	066	070	068	066	068	068	068	081	103	119	094	047	011	063
April	000	017	040	058	070	071	068	065	060	059	059	060	060	059	060	063	061	060	065	083	102	093	059	021	059
May	003	000	008	019	036	038	035	028	025	023	021	021	022	020	020	019	019	018	013	026	056	063	050	020	025
June	008	000	003	015	029	030	026	021	017	014	017	010	010	007	009	007	010	008	004	003	030	041	039	017	015
July............	009	004	005	016	032	033	026	023	018	013	010	007	007	007	008	009	008	007	000	005	027	043	041	023	016
August	028	013	007	010	028	035	029	024	019	016	017	016	016	016	017	013	013	009	000	009	044	061	064	044	023
September ...	007	000	005	015	023	028	021	017	013	012	013	012	019	015	020	014	019	008	005	018	051	057	050	023	019
October	000	009	033	057	070	064	053	047	045	047	047	049	051	055	056	056	056	060	073	088	084	060	025	005	050
November ...	000	005	021	038	049	057	048	044	043	044	044	047	050	053	056	057	052	074	090	096	082	054	022	007	047
December ...	000	003	015	029	037	035	034	030	027	026	028	031	035	036	038	042	047	060	074	076	066	042	013	000	034
Hourly means	005	005	017	032	046	050	045	040	036	035	036	036	038	038	040	040	040	043	047	058	072	064	042	017	461

Cape of Good Hope.—Mean Temperature of the Air from April 1841 to June 1846 inclusive. FAHRENHEIT's scale.

Mean time ...	Noon. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midn. 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
January	73°·16	73°·30	73°·03	72°·43	71°·52	70°·30	67°·94	66°·11	65°·45	65°·01	64°·51	64°·10	63°·77	63°·54	63°·32	63°·06	62°·85	63°·18	65°·20	67°·24	68°·78	70°·05	71°·46	72°·59	67°·58
February......	74·04	74·07	73·63	72·85	71·74	70·36	68·20	66·69	66·13	65·75	65·34	64·93	64·54	64·23	64·00	63·60	63·41	63·12	64·46	66·33	67·94	69·72	71·62	73·10	67·91
March.........	71·74	72·40	72·19	71·40	69·96	68·07	65·98	64·98	64·38	63·69	63·20	62·85	62·37	62·06	61·69	61·44	61·15	60·97	61·31	63·03	65·39	67·48	69·50	71·00	65·76
April	68·39	68·94	68·90	68·06	66·56	64·22	62·69	62·13	61·54	60·98	60·46	59·87	59·53	59·27	59·00	58·80	58·40	58·28	58·17	59·49	61·82	64·14	65·95	67·35	62·62
May...........	62·32	62·55	62·43	61·74	60·49	58·99	58·08	57·41	56·81	56·39	55·85	55·48	55·37	55·21	55·05	54·81	54·59	54·32	54·04	54·44	56·42	58·48	60·09	61·29	57·61
June	58·45	58·79	58·78	58·32	57·01	55·58	54·79	54·25	53·71	53·25	52·77	52·32	52·16	51·86	51·69	51·53	51·21	50·95	50·80	50·83	52·20	54·42	56·17	57·42	54·14
July	59·15	59·66	59·65	59·21	57·77	56·13	55·15	54·47	53·83	53·34	52·86	52·37	52·08	51·72	51·42	51·19	50·96	50·83	50·51	50·88	52·67	54·94	56·87	58·28	54·41
August	58·86	59·23	59·07	58·61	57·61	55·91	55·01	54·35	53·91	53·60	53·17	52·91	52·71	52·31	52·07	51·87	51·54	51·19	51·15	51·88	53·19	55·57	57·05	58·30	54·63
September ...	61·60	61·79	61·68	60·87	59·65	58·02	56·78	56·09	55·62	55·22	54·58	54·47	54·36	53·95	53·64	53·31	53·10	53·20	53·13	54·94	56·90	58·61	59·94	60·94	56·77
October	65·48	65·71	65·46	64·66	63·38	61·56	59·51	58·68	58·05	57·51	57·14	56·74	56·70	56·33	56·11	55·88	55·64	55·63	57·14	59·08	61·00	62·75	64·07	65·04	59·97
November ...	68·00	68·03	67·63	66·98	66·19	64·82	62·49	61·12	60·38	59·99	59·52	59·12	58·82	58·43	58·00	57·69	57·48	58·14	60·55	62·50	63·96	65·27	66·50	67·50	62·46
December ...	71·02	71·23	70·84	70·21	69·63	68·23	65·69	63·94	63·19	62·64	62·07	61·59	61·18	60·82	60·49	60·17	59·91	60·83	63·41	65·80	67·17	68·42	69·62	70·42	65·35

St. Helena.—Longitude 5° 40′ West. Latitude 15° 56′ South. Declination 23° 36′ West. Inclination 21° 40′ South.

Mean Diurnal variation of the Declination for the years 1841 to 1845 inclusive.

Increasing numbers denote increasing eastening of the north or upper end of the needle. Mean Declination 23° 36′·6 West.

Mean time ...	Noon. 0h.	1h.	2h.	3h.	4h.	5h.	6h	7h.	8h.	9h.	10h.	11h.	Midn. 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
January	3′·72	3′·19	2′·41	2′·03	2′·09	1′·84	1′·92	2′·41	2′·80	2′·90	2′·86	2′·81	2′·63	2′·43	2′·23	2′·01	1′·73	1′·68	1′·50	0′·59	0′·00	0′·57	1′·75	3′·15	2′·13
February......	4·53	4·51	4·11	3·39	2·80	2·55	2·61	3·02	3·21	3·35	3·48	3·52	3·42	3·22	3·12	2·98	2·83	2·75	2·64	1·14	0·00	0·31	1·52	3·34	2·85
March.........	3·76	4·11	3·48	2·57	2·15	2·20	2·48	2·64	2·69	2·68	2·85	2·84	2·80	2·77	2·68	2·70	2·69	2·70	2·96	1·90	0·26	0·00	1·13	2·72	2·49
April	3·28	2·48	1·65	1·27	1·03	1·01	1·23	1·50	1·56	1·60	1·71	1·81	1·96	1·92	1·92	2·00	2·16	2·22	2·47	2·15	0·62	0·00	0·82	2·57	1·70
May	0·71	0·44	0·57	0·71	0·55	0·21	0·25	0·48	0·56	0·72	0·78	0·90	1·02	1·09	1·11	1·18	1·32	1·57	2·04	2·58	1·50	0·32	0·00	0·49	0·88
June	0·71	0·73	0·88	0·94	0·44	0·00	0·10	0·39	0·56	0·73	0·90	1·06	1·17	1·22	1·25	1·29	1·40	1·66	2·16	3·31	2·69	1·39	0·75	0·69	1·10
July	0·82	0·71	0·78	0·84	0·48	0·02	0·00	0·22	0·46	0·64	0·84	0·98	1·08	1·14	1·14	1·24	1·31	1·46	2·02	3·11	2·58	1·31	0·63	0·67	1·02
August	0·11	0·00	0·40	0·86	0·82	0·42	0·25	0·52	0·68	0·78	0·88	1·02	1·02	1·02	1·04	1·18	1·27	1·61	2·37	3·43	2·52	1·19	0·36	0·05	0·99
September ...	0·89	0·85	0·65	0·44	0·35	0·28	0·28	0·53	0·62	0·67	0·79	0·78	0·75	0·64	0·61	0·65	0·70	0·95	2·12	1·89	0·85	0·17	0·00	0·43	0·70
October	4·41	4·35	3·43	2·06	1·23	1·32	1·80	2·04	2·21	2·34	2·45	2·43	2·23	2·00	1·92	1·81	1·72	1·74	1·99	0·49	0·00	0·72	2·08	3·61	2·10
November ...	3·97	3·82	3·31	2·52	1·85	1·85	2·29	2·77	2·99	3·13	3·21	3·13	2·96	2·68	2·46	2·22	1·97	1·80	1·53	0·21	0·00	1·03	2·22	3·41	2·39
December ...	3·65	3·48	2·70	1·94	1·66	1·85	2·15	2·58	2·93	3·12	3·20	3·13	2·89	2·64	2·40	2·17	1·93	1·73	1·38	0·32	0·00	0·86	2·09	3·32	2·25

St. Helena.—Mean Diurnal variation of the Inclination in each month, from January 1841 to December 1845.

Increasing numbers denote increasing inclination. Mean Inclination 21° 40′ South.

Mean time ...	Noon. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midn. 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
January	0′·14	0′·46	1′·07	1′·49	2′·18	2′·53	2′·77	2′·91	2′·87	2′·83	2′·77	2′·63	2′·40	2′·23	1·99	1′·85	1′·80	1′·77	1′·65	1′·37	0′·88	0′·53	0′·00	0′·02	1′·71
February......	0·23	0·61	1·33	2·00	2·39	2·78	3·01	3·15	3·12	2·98	2·86	2·73	2·61	2·46	2·44	2·21	2·15	2·00	2·04	1·82	1·40	0·94	0·10	0·00	1·97
March.........	0·11	0·56	1·33	1·86	2·21	2·47	2·80	2·97	2·99	2·89	2·89	2·67	2·46	2·37	2·26	2·12	1·99	2·01	1·84	1·53	1·06	0·43	0·00	0·10	1·83
April	0·45	0·89	1·54	2·14	2·53	2·83	3·05	3·17	3·26	2·88	2·97	2·63	2·41	2·18	2·15	2·08	1·88	1·77	1·47	1·30	0·94	0·43	0·27	0·00	1·88
May...........	0·20	0·74	1·16	1·62	1·90	2·10	2·22	2·36	2·28	2·21	2·12	1·99	1·77	1·69	1·56	1·33	1·21	1·16	1·18	1·09	0·81	0·36	0·00	0·03	1·38
June	0·18	0·56	1·04	1·58	1·65	1·91	2·21	2·26	2·24	2·12	2·02	1·98	2·06	1·77	1·68	1·54	1·46	1·36	1·22	0·98	0·80	0·43	0·09	0·00	1·38
July	0·30	0·60	1·06	1·44	1·82	2·01	2·42	2·47	2·40	2·35	2·21	2·04	1·80	1·58	1·52	1·30	1·25	1·08	1·00	0·84	0·53	0·27	0·00	0·03	1·35
August	0·25	0·72	1·21	1·61	1·94	2·16	2·35	2·40	2·39	2·19	2·12	1·98	1·80	1·69	1·58	1·40	1·33	1·25	1·13	1·07	0·79	0·54	0·19	0·00	1·42
September ...	0·18	0·70	1·29	1·72	2·02	2·19	2·40	2·40	2·32	2·13	2·01	1·99	1·80	1·68	1·47	1·50	1·51	1·44	1·40	1·27	0·92	0·60	0·36	0·00	1·47
October	0·24	0·74	1·36	1·90	2·34	2·56	2·55	2·88	2·65	2·56	2·46	2·28	2·09	2·04	1·89	1·80	1·70	1·69	1·63	1·31	0·88	0·37	0·00	0·02	1·66
November ...	0·08	0·27	0·74	1·19	1·63	2·00	2·35	2·45	2·38	2·30	2·18	2·07	1·96	1·83	1·71	1·59	1·66	1·48	1·35	0·92	0·55	0·23	0·00	0·10	1·38
December ...	0·26	0·73	1·06	1·59	2·08	2·41	2·69	2·78	2·61	2·45	2·39	2·15	2·01	1·80	1·72	1·56	1·48	1·38	1·26	0·85	0·40	0·10	0·00	0·07	1·49
Hourly means	0·22	0·63	1·18	1·68	2·06	2·33	2·57	2·68	2·63	2·49	2·42	2·26	2·10	1·94	1·83	1·69	1·62	1·53	1·43	1·20	0·83	0·44	0·08	0·03	1·58

St. Helena.—Mean Diurnal variation of the Total Intensity in each month, from January 1841 to December 1845.

Increasing numbers denote increasing intensity.

Mean time ...	Noon. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midn. 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00
January	130	129	116	098	081	063	046	027	016	004	000	001	001	008	015	015	019	019	024	040	055	080	109	124	051
February......	117	109	092	077	063	050	029	014	007	001	002	003	004	002	000	002	002	003	009	023	046	070	095	114	039
March.........	153	147	124	096	070	055	032	020	010	000	006	004	001	016	014	018	018	021	026	040	068	102	132	149	055
April	162	150	122	088	068	042	021	010	005	001	004	000	007	014	015	016	025	024	024	031	054	090	102	150	051
May...........	163	142	115	087	065	049	036	023	016	011	004	000	008	008	011	018	019	019	025	034	048	095	132	159	054
June	141	128	101	064	063	047	028	015	006	004	001	000	002	003	004	004	004	009	013	022	042	075	110	137	043
July...........	126	117	095	073	051	042	027	015	011	002	002	000	003	005	006	011	015	018	019	024	038	068	097	116	041
August	139	126	103	077	053	038	026	013	004	001	000	000	002	005	009	015	015	016	016	018	037	068	103	131	039
September ...	143	131	105	077	056	037	026	013	004	000	003	007	011	014	018	024	022	024	023	022	038	069	101	134	046
October	135	123	105	088	070	051	030	015	007	001	000	005	011	013	019	020	019	020	017	032	058	093	123	135	050
November ...	112	111	101	090	076	055	029	018	007	000	002	009	011	011	016	017	017	017	026	048	071	087	105	112	048
December ...	116	110	105	089	071	051	027	011	004	000	000	003	003	006	008	010	011	012	024	046	064	086	107	117	045
Hourly means	136	127	107	084	066	048	030	016	008	002	002	003	006	009	011	014	015	017	021	032	052	082	110	132	047

St. Helena.—Mean Temperature of the Air from 1841 to 1845 inclusive.

Mean time ...	Noon. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midn. 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	Daily means.
January	67°·68	68°·05	67°·93	67°·79	67°·30	66°·04	64·58	63°·39	62°·93	62°·62	62°·42	62°·27	62°·06	61°·88	61°·66	61°·60	61°·49	61°·39	61°·37	61°·84	62°·79	64°·09	65°·38	66°·55	63°·98
February......	69·14	69·61	69·85	69·59	68·95	67·89	66·59	65·43	64·91	64·66	64·46	64·32	64·13	63·96	63·78	63·59	63·51	63·44	63·42	63·62	64·43	65·72	67·08	68·24	65·87
March.........	69·13	69·57	69·89	69·71	69·10	68·10	66·86	65·84	65·47	65·15	65·00	64·83	64·65	64·50	64·31	64·17	64·15	64·03	64·05	64·29	65·08	66·39	67·35	68·38	66·24
April	68·54	68·89	68·98	68·64	67·99	66·98	65·84	65·15	64·84	64·61	64·45	64·29	64 11	64·02	63·88	63·77	63·66	63·51	63·49	63·69	64·50	65·70	66·74	67·86	65·60
May	65·76	66·01	66·09	65·84	65·17	64·11	63·56	63·32	62·73	62·13	62·03	61·88	61·67	61·57	61·40	61·24	61·19	61·19	61·04	61·06	62·01	63·22	64·11	65·22	63·05
June	62·40	62·76	62·73	62·39	61·83	60·98	60·14	59·68	59·49	59·34	59·20	59·11	59·00	58·86	58·74	58·61	58·56	58·53	58·47	58·52	59·13	60·16	60·98	61·80	60·07
July...........	60·37	60·83	60·77	60·51	59·87	58·98	58·14	57·70	57·48	57·25	57·13	56·91	56·81	56·72	56·60	56·51	56·43	56·36	56 31	56·38	57·07	58·09	58·90	59·69	57·99
August	59 68	59·99	60·12	59·72	59·11	58·11	57·23	56·83	56·60	56·45	56·32	56·20	56·10	55·98	55·76	55·68	55·53	55·50	55·39	55·56	56·20	57·22	58·07	58·96	57·17
September ...	59·89	60·26	60·18	59·77	59·11	58·03	57·05	56·56	56·35	56·21	56·04	55·91	55·82	55·67	55·51	55·37	55·29	55·21	55·21	55·44	56·12	57·18	58·31	59·14	57·07
October	61·50	61·98	61·91	61·31	60·46	59·31	58·18	57·57	57·64	57·12	56·99	56·84	56·64	56·48	56·30	56·18	56·11	56·01	56·06	56·50	57·38	58·61	59·71	60·73	58·23
November ...	63·44	63·88	63·97	63·52	62·63	61·32	59·94	59·11	58·76	58·57	58·41	58·24	58·08	57·90	57·71	57·62	57·55	57·43	57·53	58·03	58·94	60·20	61·35	62·35	59·84
December ...	65·19	65·81	67·87	65·72	64·88	63·62	62·17	61·10	60·70	60·46	60·27	60·12	59·95	59·75	59·57	59·47	59·34	59·31	59·39	59·77	60·69	61·97	63·03	64·19	61·77

Singapore.—Latitude 1° 16′ North. Longitude 103° 53′ East. Declination 1° 40′ East (Approx.). Inclination 12° South (Approx.).

Mean Hourly oscillation of the Magnetic Declination for each month of the years 1843, 1844 and 1845.

Increasing numbers denote a movement of the north or upper end of the magnet towards the East.

Mean time ...	Noon. 0¼h.	1¼h.	2¼h.	3¼h.	4¼h.	5¼h.	6¼h.	7¼h.	8¼h.	9¼h.	10¼h.	11¼h.	Midn. 12¼h.	13¼h.	14¼h.	15¼h.	16¼h.	17¼h.	18¼h.	19¼h.	20¼h.	21¼h.	22¼h.	23¼h.	Daily means.
January	2·04	2·52	2·79	2·72	2·52	2·24	2·11	2·18	2·04	1·97	1·84	1·70	1·63	1·63	1·50	1·43	1·29	1·02	0·61	0·00	0·00	0·41	0·82	1·22	1·59
February......	2·31	2·92	3·13	3·06	2·79	2·52	2·31	2·31	2·18	2·04	1·90	1·90	1·97	1·90	1·90	1·90	1·84	1·70	1·29	0·54	0·00	0·00	0·34	1·43	1·84
March.........	1·29	1·43	1·63	1·77	1·63	1·43	1·29	1·09	0·95	0·88	0·82	0·82	0·88	0·88	0·88	0·82	0·82	0·82	0·82	0·48	0·00	0·07	0·54	1·02	0·96
April	0·34	0·61	0·75	1·02	1·16	1·16	0·95	0·82	0·61	0·54	0·61	0·68	0·82	0·95	0·95	0·95	0·88	0·82	1·16	0·95	0·34	0·00	0·20	0·41	0·70
May...........	0·07	0·48	0·82	1·16	1·36	0·95	1·02	0·88	0·75	0·68	0·75	0·82	1·09	1·16	1·29	1·36	1·36	1·43	2·11	2·24	1·43	0·68	0·27	0·00	0·75
June	0·20	0·41	0·54	0·61	0·54	0·34	0·14	0·00	0·00	0·00	0·07	0·20	0·41	0·54	0·61	0·68	0·68	0·82	1·36	1·56	0·82	0·41	0·00	0·14	0·46
July...........	0·07	0·41	0·61	0·88	1·02	0·88	0·48	0·34	0·27	0·20	0·27	0·34	0·54	0·68	0·82	0·75	0·82	1·16	1·63	1·97	1·29	0·54	0·14	0·00	0·67
August	0·20	0·68	1·02	1·56	1·63	1·84	1·43	1·29	1·09	1·02	1·02	1·16	1·22	1·36	1·43	1·50	1·50	1·70	2·52	2·79	1·77	0·75	0·14	0·00	1·27
September ...	0·48	0·88	1·36	1·63	1·63	1·56	1·50	1·29	1·16	1·09	1·02	1·09	1·16	1·22	1·29	1·29	1·36	1·43	1·97	1·77	0·75	0·20	0·00	0·20	1·14
October	1·90	2·31	2·31	2·18	1·97	1·77	1·77	1·63	1·50	1·36	1·29	1·29	1·43	1·36	1·36	1·29	1·22	1·09	1·16	0·54	0·14	0·00	0·27	1·02	1·33
November ...	2·45	2·92	2·99	2·86	2·45	2·11	1·97	1·84	1·70	1·56	1·36	1·36	1·43	1·43	1·36	1·29	1·16	1·02	0·48	0·00	0·00	0·27	0·82	1·63	1·51
December ...	2·52	2·99	2·99	2·99	2·86	2·45	2·18	2·04	1·97	1·84	1·70	1·63	1·56	1·56	1·56	1·50	1·43	1·16	0·61	0·00	0·00	0·41	1·02	1·77	1·70

Singapore.—Mean Diurnal variation of the Inclination in the several months during the years 1843, 1844 and 1845.

Increasing numbers denote increasing inclination. Approximate inclination 12° South.

Mean time ...	Noon. 0¼h.	1¼h.	2¼h.	3¼h.	4¼h.	5¼h.	6¼h.	7¼h.	8¼h.	9¼h.	10¼h.	11¼h.	Midn. 12¼h.	13¼h.	14¼h.	15¼h.	16¼h.	17¼h.	18¼h.	19¼h.	20¼h.	21¼h.	22¼h.	23¼h.	Daily means.
January	0·00	0·43	0·98	1·28	1·90	2·07	2·38	2·57	2·62	2·71	2·76	2·76	2·66	2·71	2·71	2·72	2·72	2·72	2·73	2·52	1·97	1·09	0·32	0·02	1·97
February......	0·04	0·64	1·24	1·75	2·00	2·21	2·56	2·82	2·94	3·02	3·10	3·07	3·08	3·03	2·98	2·99	2·97	2·97	3·03	2·88	2·35	1·21	0·40	0·00	2·22
March.........	0·06	0·29	0·75	1·36	1·75	1·88	2·22	2·55	2·65	2·70	2·74	2·72	2·72	2·67	2·71	2·72	2·72	2·75	2·75	2·54	1·84	0·75	0·11	0·00	1·91
April	0·28	0·82	1·54	2·09	2·47	2·71	3·04	3·00	3·27	3·36	3·41	3·49	3·43	3·40	3·33	3·29	3·29	3·27	3·15	2·92	2·18	1·15	0·28	0·00	2·46
May...........	0·00	0·32	0·80	1·17	1·62	1·96	2·29	2·34	2·42	2·43	2·42	2·20	2·38	2·40	2·42	2·46	2·52	2·51	2·25	1·87	1·25	0·49	0·03	0·00	1·69
June	0·04	0·20	0·57	0·98	1·44	1·50	2·20	2·25	2·19	2·16	2·10	2·07	2·15	2·21	2·15	2·20	2·21	2·29	2·02	1·71	1·25	0·69	0·22	0·00	1·53
July...........	0·00	0·15	0·45	0·89	1·34	1·76	2·10	2·16	2·19	2·20	2·20	2·07	2·18	2·19	2·19	2·21	2·21	2·27	2·02	1·74	1·28	0·69	0·27	0·05	1·53
August	0·12	0·34	0·69	1·01	1·35	1·68	1·99	2·32	2·21	2·27	2·26	2·28	2·26	2·20	2·18	2·22	2·21	2·22	1·93	1·68	1·30	0·62	0·14	0·00	1·56
September ...	0·41	1·00	1·60	1·94	2·11	2·32	2·58	2·69	2·78	2·82	2·85	2·84	2·85	2·79	2·74	2·75	2·75	2·79	2·66	2·39	1·66	0·79	0·15	0·00	2·09
October	0·38	1·17	1·94	2·38	2·48	2·59	2·86	3·07	3·23	3·29	3·34	3·23	3·33	3·23	3·22	3·20	3·24	3·20	3·25	2·96	2·18	1·14	0·21	0·00	2·46
November ...	0·16	0·63	1·37	1·96	2·32	2·68	2·88	2·87	3·02	3·08	3·07	3·06	3·06	3·03	3·02	2·95	3·01	3·00	3·15	2·80	2·01	1·04	0·17	0·00	2·26
December ...	0·09	0·54	1·13	1·62	1·92	2·26	2·53	2·66	2·85	2·86	2·85	2·86	2·76	2·76	2·72	2·69	2·65	2·69	2·44	2·38	1·81	1·08	0·34	0·00	2·02
Hourly means	0·13	0·54	1·09	1·54	1·89	2·14	2·47	2·61	2·70	2·74	2·76	2·72	2·74	2·72	2·70	2·70	2·71	2·72	2·62	2·37	1·76	0·89	0·22	0·01	1·98

Singapore.—Mean Diurnal variation of the Total Intensity in the several months during the years 1843, 1844, 1845.

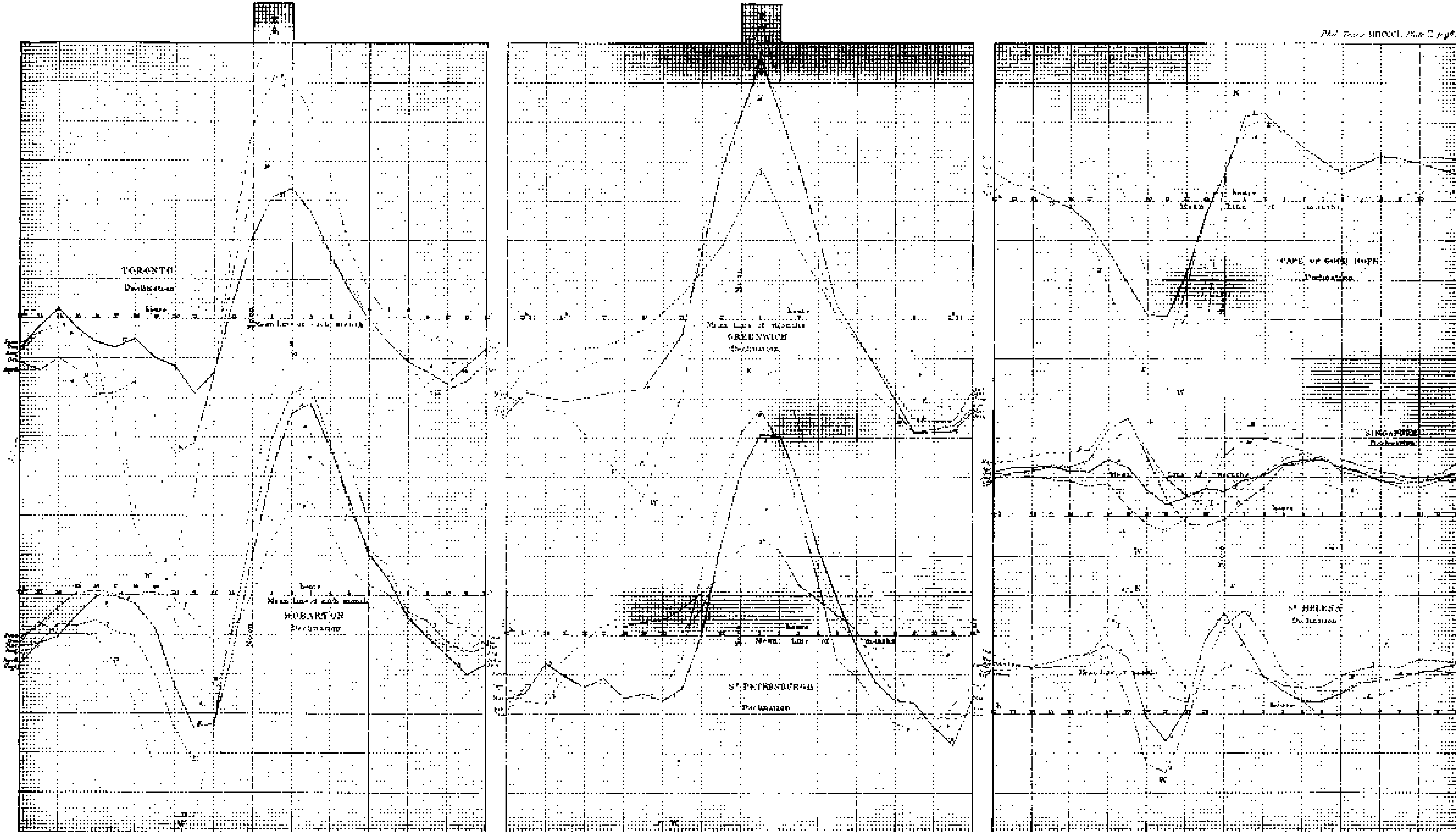
Increasing numbers indicate increase of total intensity.

The numbers express the changes in parts of the whole force. Approximate total intensity 8·21.

Mean time ...	Noon. 0¼h.	1¼h.	2¼h.	3¼h.	4¼h.	5¼h.	6¼h.	7¼h.	8¼h.	9¼h.	10¼h.	11¼h.	Midn. 12¼h.	13¼h.	14¼h.	15¼h.	16¼h.	17¼h.	18¼h.	19¼h.	20¼h.	21¼h.	22¼h.	23¼h.	Daily means.
	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00	·00
January	086	066	047	030	028	021	015	009	009	003	002	000	007	002	008	007	010	012	022	033	054	074	099	100	031
February......	099	080	061	042	027	024	013	008	004	000	000	002	000	001	005	005	009	011	014	025	049	082	103	110	032
March.........	114	085	055	035	026	020	013	007	003	001	000	002	005	008	007	009	011	012	012	027	057	087	112	122	035
April	122	094	065	040	029	020	016	011	005	003	005	002	000	004	009	011	013	015	020	043	076	110	139	137	041
May............	104	081	060	036	020	013	014	011	010	006	006	000	004	006	006	006	008	012	025	044	073	097	114	118	036
June	096	075	051	026	011	042	004	004	001	000	000	000	001	001	003	004	004	008	020	038	062	085	102	105	031
July	100	081	056	033	019	013	007	007	004	004	002	000	002	004	006	004	010	015	026	044	070	091	105	110	034
August	101	081	055	033	016	009	010	005	006	000	002	002	004	010	011	011	016	018	028	046	077	096	115	114	036
September ...	093	065	037	029	018	009	009	008	002	001	000	003	003	008	014	018	019	017	023	045	079	104	117	115	035
October	102	073	050	036	029	024	013	007	003	000	000	001	006	011	011	016	019	017	020	037	070	101	117	121	037
November ...	080	063	044	030	021	015	009	003	001	000	001	000	002	006	007	013	012	013	017	034	059	082	098	095	029
December ...	077	061	044	031	026	021	012	004	000	000	001	002	003	006	009	013	014	014	019	035	056	078	095	091	030
Hourly means	098	075	052	033	022	019	011	007	004	002	002	001	003	006	008	010	012	014	021	038	065	091	110	112	034

Singapore.—Mean Temperature of the Air observed on the Standard Thermometer inside the Observatory, during the years 1841, 1842 and 1843.

Mean time ...	Noon. 0¼h.	1¼h.	2¼h.	3¼h.	4¼h.	5¼h.	6¼h.	7¼h.	8¼h.	9¼h.	10¼h.	11¼h.	Midn. 12¼h.	13¼h.	14¼h.	15¼h.	16¼h.	17¼h.	18¼h.	19¼h.	20¼h.	21¼h.	22¼h.	23¼h.	Daily means.
January	79°·7	79°·5	80°·0	79°·5	79°·7	79°·1	79°·0	78°·4	78°·5	78°·0	78°·1	77°·5	77°·9	77°·3	77°·6	76°·9	77°·4	76°·5	77°·0	76°·3	77°·3	77°·4	78°·6	78°·8	78°·2
February......	80·7	81·6	81·2	82·1	81·2	82·1	80·2	80·6	79·7	80·2	79·2	79·6	78·6	79·0	78·3	78·6	78·2	78·2	77·7	78·2	78·0	79·4	79·6	81·8	79·8
March.........	81·4	82·1	81·7	82·3	81·6	82·0	80·9	81·5	80·5	81·2	80·1	81·0	79·9	80·6	79·4	80·3	79·1	79·9	78·7	79·8	79·4	80·6	80·6	81·5	80·7
April	81·8	81·8	82·1	81·8	81·9	81·6	81·4	81·2	81·0	80·9	80·7	80·2	80·3	80·3	79·9	80·0	79·5	79·6	79·2	79·8	79·9	80·6	81·1	81·4	80·8
May............	82·5	......	82·7	......	82·5	......	82·1	......	81·8	......	81·4	......	80·9	......	80·5	......	80·3	......	79·9	......	80·9	......	81·8	......	81·4
June	82·5	82·9	82·7	83·1	82·5	82·7	82·2	82·0	81·7	81·6	81·4	81·4	81·2	81·2	80·7	80·7	80·3	80·2	80·1	80·4	81·0	81·7	81·8	82·6	81·6
July............	82·4	83·0	82·8	83·1	82·7	82·7	82·2	82·1	81·8	81·9	81·5	81·5	81·1	81·2	80·7	80·9	80·3	80·6	80·8	80·8	80·8	81·9	81·9	82·6	81·7
August	81·7	81·9	81·9	81·9	81·8	81·8	81·4	81·3	81·0	81·2	80·8	80·8	80·4	80·3	80·1	80·1	79·8	79·8	79·5	79·8	80·2	80·8	81·2	81·6	80·9
September ...	82·1	82·6	82·4	82·3	82·2	82·1	81·7	81·6	81·5	81·2	81·0	80·8	80·5	80·3	80·1	80·0	79·7	79·7	79·4	79·4	80·3	80·9	81·4	81·8	81·0
October	81·5	81·3	81·7	81·4	81·7	81·2	81·2	80·6	80·7	80·2	80·1	79·8	79·6	79·8	79·4	79·3	79·0	79·3	78·7	79·2	79·5	80·0	80·7	80·9	80·3
November ...	81·1	81·0	81·3	80·8	81·0	80·6	80·4	80·1	80·1	79·7	79·7	79·6	79·3	79·1	78·9	78·7	78·6	78·5	78·4	78·5	79·2	79·6	80·2	80·5	79·8
December ...	81·0	81·3	81·3	81·3	80·9	80·8	80·2	80·0	79·6	79·4	79·2	79·2	79·0	79·0	78·6	78·4	78·1	78·1	77·9	78·2	78·7	79·5	80·1	80·7	79·6
Hourly means	81·5	81·7	81·8	81·8	81·6	81·5	81·1	80·9	80·7	80·5	80·3	80·1	79·9	79·8	79·5	79·4	79·2	79·1	78·9	79·1	79·6	80·2	80·7	81·3	80·4



Eastern positions of the upper end of a free Needle are indicated when the curves are above the Mean Line of the months, and Western positions when below.