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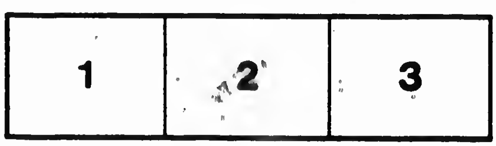

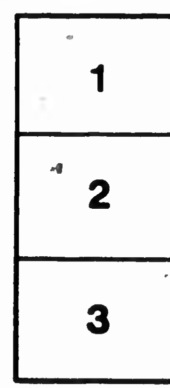

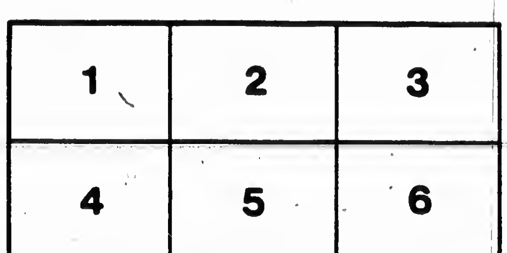

METHODS AND RESULTS

—OF—

TORONTO OBSERVATIONS

Paper read by Lieut. Andrew Gordon, R.N., Deputy Sup't Meteorological Service of Canada, before the Hamilton Association, April 13th, 1882.

The Toronto observatory was one of five which were established by the Imperial Government with a view to extending the knowledge of magnetic phenomena.

The elements on which the determination of the earth's magnetic force is based are the declination, inclination, and intensity. The declination determines the direction of the force referred to the plane of the meridian (astronomical). The inclination determines its direction in reference to the horizontal plane. If in addition to these quantities we know the measure of the intensity expressed in some absolute unit, the force will be completely determined. The absolute unit which has been adopted by English observers is for mass, the grain, for space the foot; and for time the second. The idea may be readily grasped from the following: When two south poles, distant one foot from each other, are charged to equal strength, and repel one another with a force which, if continued uniform, would produce in one second a velocity of one foot per second in a mass of one grain, each pole is said to be charged with unit magnetic force.

For the purpose of detecting and examining the more minute changes in the magnetic force a different system of elements is employed, the intensity being resolved into two portions in the plane of the magnetic meridian, one portion horizontal and the other vertical. It is readily seen that these two components may be substituted for the total intensity and the inclination, being connected with them by the relations.

$$X = R \cos I; \; Y = R \sin I$$

where X and Y are the horizontal and vertical components of the force, and R and I the intensity and inclination respectively. Variations in R and I are then expressed in terms of the variations in X and Y.

Of these elements the declination was the first to be examined, and I shall now treat briefly of it. The declination called by sailors the variation has been the subject of investigation for hundreds of years. Humboldt awards the distinction of having discovered the changes in declination to Columbus, who on the 18th September 1492 records the fact that in lat. 28° north and long 28° west or thereabouts, the direction of the needle changed from east of north to west of north. It appears however, that the heathen Chinee was aware of this fact as early as the twelfth century, for in a treatise by a Chinese philosopher at this date it is distinctly stated that the magnitised needle did not point north and south but always declined to the east of south.

It is the business of a permanent observatory to watch and record the changes which take place in the elements of magnetic force. These changes are of three kinds, called secular changes, periodic changes and disturbances.

The secular change is that which takes place from month to month and year to year, and takingthe Toronto observations of declination, the change has been from 1° 14'·8 west in 1841 to 3° 51' west at the present time; the annual increase varying in amount from 1'·8 in 1848 to 7'·5 in 1875. The necessity for careful and long continued observations is in this amply exemplified, as it must be remembered that the charts on which ships are navigated have the declination curves laid off on them, and have a fixed amount to be applied as an annual increase or decrease to the declination laid down, but this annual correction is a fluctuating quantity hence unless corrected from time to time errors would soon accumulate.

The diurnal or first periodic range in declination has at Toronto an amplitude of from eight to ten minutes of arc, the needle moving rapidly from an extreme easterly position about 7 to 9 a.m., to an extreme westerly one at 2 p.m., returning though with a minor curve westwards, and generally remaining to the east of the mean position all night. The other elements have also a regular daily fluctuation.

Disturbances are sudden and irregular fluctuations of the magnet, some of which seem to be comparatively local, whilst others are practically universal; changes of a similar character and almost similar amounts occurring at Zika Wei, in China; at Toronto; at Kew, in Great Briton; and at Melbourne, Australia, at almost the same inrtant of time. Of the causes of these irregular movements, or as they were christened by Baron Humboldt, magnetic storms, little can at present be said that is not conjecture. This much may however, be safely asserted, that all the greater disturbances when their mean effects are taken for a sufficient period of time, have a character of periodicity. This was first suggested by General Sabine in his comments on the observations at the Toronto observatory for the years 1841, 1842, and further comparisons have elicited the fact that the disturbances (speaking of the declination) are more frequent at the equinoxes than at the solstices, and occur most frequently at night the proportion of those occuring at night, to those in the day being approximately ::8 : 5 These disturbances have also a regular period approximately eleven years, a maximum occurring between 1848 and 1853, with 1843 and 1856 as the years of minimum disturbance increasing again to a maximum in 1860. Such regular fluctuations in the amount of disturbance preclude the idea that these differences are accidental.

Additional evidence of the existence of this eleven year period may be found in M. Arago's observations taken in the year 1821 to 1830, showing minimum daily range in 1823 and maximum in 1829. 1882-3 is also expected to be year of maximum disturbance, and accordingly we have already had a disturbance far greater than has been observed for many years.

The progressive increase in the range of the diurnal variation concurrently with an increase in the number and values of disturbed observations at places widely apart, suggests the idea that they proceed from some common cause, and though we cannot at present say by what physical agency these disturbancies are produced, still since we find that variations like the regular diurnal variations have also a diurnal law, and since the sun is at least a primary source of all magnetic variations which depend on local time it is natural to inquire whether the sun has any periodical variation having a coincident epoch.

Now, Mons. Schwabe's investigations extending from 1826 onwards seem to show an affection of the solar atmosphere, whose periods of maxima and minima exactly coincide with those of the magnetic disturbances and the extent of the diurnal range of the needle. In Humbold's cosmos will be found a table containing the results of M. Schwabe's observations of sun spots from 1826 to 1850, and in Walker's treatise on terrestrial magnetism the same table extended up to 1864, and from this we find that the following are the minima years: 1833, 1843, 1856 and 1866.

Another singular point is on record which adds to the weight of proof that the condition of the sun's outer envelope bears its counterpart in the magnetic condition of the earth. It was witnessed on September 1, 1859, by Mr. Carrington at Redhill, England, while observing the sun's disc. He was taking observations of the forms and positions of the solar spots, the sun's image being projected on a plate of glass, coated with distemper of a pale straw color, at a distance, and under a power which presented a picture of about 11 inches in diameter. Suddenly within the area of the largest group there broke out two patches of intensely bright white light. The outburst after increasing for some seconds rapidly died away, the whole duration of the phenomenon being not more than five minutes. In this interval the two patches had traversed a space of about 35,000 miles. On visiting the observatory at Kew a few days later he found that at the instant when he had observed the phenomenon the three magnetic elements were simultaneously disturbed, the time of duration of the disturbance being about ten minutes.

The above incident taken with the almost exact coincidence between the periods and turning points in three classes of phenomena so widely different as the magnetic disturbances, the diurnal range and the frequency of the solar spots, leaves, I think, little doubt that the coincidence is not accidental but causal.

Professor Balfour Stewart, of Owen's college, Manchester, has lately been investigating the observations of temperature taken at the Toronto observatory with a view to determining the existence of a thermometric period similar to the sun spot period. His results are published in appendix G, to the report of the committee to advise on the methods of carrying on observations in solar physics. I shall now quote from the concluding portion of Professor Stewart's report:

"In the course of this paper I have given evidence which tends to show that there are in all probability solar variations of short period, and that these are connected with variations in the temperature range. Toronto was chosen as a station from which accurate information, with regard to temperature, was to be obtained, and also as one which, being in America, may be supposed to be influenced more directly and immediately by solar changes than an equally good station in Europe."

Similar results have been obtained from a comparison with the temperature ranges at Kew and Utrecht, as well as in the magnetic declination ranges at Kew, Prague and Trevandrum.

Evidence has also been adduced to show that the phase of a given meteorological inequality is not the same at different stations, but that the maximum or any other salient point reaches Kew about eight days after it has appeared in Toronto, and Utrecht about a day and a half after it has appeared at Kew.

A similar progress from west to east, but only quicker, is suspected in what may be called magnetic weather.

In conclusion Professor Stewart says the evidence tends not only to show that solar variations of short period exist, but to render it possible, if not probable, that they are the cause of temperature range periods of similar length, in such a way that a maximum amount of spots corresponds to a maximum and not a minimum temperature range, or in other words denotes, in all probability, an accession of solar energy and not a diminution thereof.

The fact, then, may be admitted as established that there are fluctuations in the meteorological and magnetical conditions of the earth, which have epochs coincident with disturbances in the solar atmosphere and that the major period is approximately eleven years. It has also been determined that both magnetical and meteorological weather travel from west to east. The magnetic weather (as we may call it) preceding the meteorological, and it remains for continued careful observation and study to develop results which may be of the greatest practical utility, for if the laws which govern the relations between magnetism, solar spots and terrestrial meteorology were once established, the magnetic needle would take its place as one of the instruments to be carefully watched in making weather predictions, extending over comparatively longer periods than we are at present able to attempt.

I shall now endeavor to describe the magnetic instrumental appliances in use at the Toronto observatory.

Besides the instrument used for making the absolute determinations, we have two sets of differential instruments, one for noting the changes by direct eye observation, and the other recording by aid of photography, the changes which take place in the magnetic elements.

The changes in declination are measured by means of a magnet enclosed in a box and suspended by a thread of unspun silk. The magnet carries a mirror which reflects a finely divided scale fixed some distance off, the scale being read by means of a telescope which is securely fastened to a stone pillar. In this way small changes in azemuth of four or five seconds of arc can be immediately detected.

The changes in the horizontal component of the force are measured by an instrument invented by M. Gauss many years ago. In this instrument the magnet is suspended by two threads separated by an arbitrary interval, the circle to which the upper ends of the thread are attached is then turned until the torsion of the threads compels the magnet to take up a position as nearly as possible at right angles to the magnetic meridian, any increase of force will then pull the marked end of the magnet towards the north; whilst if the force decrease, the torsion of the threads pulls the marked end southwards again. As in the declinometer the needle carries a mirror which reflects the fixed scale by means of which the amount of change is measured.

Changes in the vertical component of the force are measured by a magnet suspended by means of knife edges on agate planes and therefore only free to move in the vertical plane, this needle is mechanically balanced so that at the normal force the magnet shall be as nearly as possible horizontal an increase of force will cause the north end of the magnet to dip, the angle through which it moves being measured by means of micrometers.

The photographic instruments are placed in an underground chamber with a view of exposing them as little as possible to change of temperature. As in the instrument used for direct reading, each instrument has attached to it a small mirror and immediately below a fixed mirror is attached to the slate bed on which the instruments are placed. The light from a gas jet passes through a slit into a collimating tube the image of the slit passes then through a lense and is thrown on to the two mirrors and by them reflected through a semi cylindrical lense which focusses the light into two bright points which are projected on cylinders carrying sensitised paper and fed forward by clock work. The spot from the fixed mirror gives a straight or base line, and that from the mirror attached to the magnet exhibiting the direction and amount of the movements of the needle. It is to the continuous record thus obtained by photography that we must look to obtain the information necessary to establish the laws of change in the magnetic elements, and on the occasion of violent magnetic storms they give us the means of comparing the most minute changes as well as the greatest, which on these occasions seem to take place at the same instant of absolute time.

Professor Grylls Adams has in this way investigated the great magnetic storm of the 11, 12, 13 and 14 August, 1880. This storm began at 10 hours 20 min. a. m. G.M.T. The traces showing the same instant in Europe, Asia, and America in high northern and southern latitudes, and also near the equator at Bombay, and everywhere precisely in the same way. A full report of the examinations of the records of this storm will be found in the report of the British association for 1881, being a paper on magnetic disturbances and earth currents by Professor W. Grylls Adams, F. R. S.

Professor Adams says in closing his paper on magnetic disturbances: "We know so little as yet of the causes of the changes of the sun, and this connection with terrestrial phenomena that we can hardly do more than ask what possible causes there are that could account for the effects which are observed. Can we suppose that the sun is a very powerful magnet, and that a great alteration in his magnetism accompanies the production of the bright faculæ, and the spots in his atmosphere? such a change of magnetism would affect the magnetism of the earth, although the effect would not be large unless the sun is magnetized to an intensity much greater than the earth, even allowing for the difference in the mass of the sun and earth."

As I have already mentioned, Professor Balfour Stewart has pointed out that there are similar periods of short range in the solar spots and in the fluctuations of temperature at Toronto and other stations where results have been worked up.

The conclusion which he drew from these investigations was that the sun emitted more heat at times of maximum number of spots than at minimum. In order to test directly whether this was the case he devised an instrument called an actinometer. One of these instruments of a most improved pattern has been purchased for use at the Toronto observatory.

The instrument itself consists of a large mercurial thermometer, with its bulb in the middle of a cubical chamber of brass, the chamber being so massive that its temperature will remain sensibly constant for some time. This massive chamber is lined outside with felt, and this again surrounded by polished brass plates.

A lense is attached by means of a rod to the cubical chamber, and in taking the observation the sun's rays are focussed by this lense, and projected directly on the bulb of the thermometer. In taking an observation the aperture in the cubical chamber through which the sun's rays are projected is first kept closed, and say that the time of exposure has been selected as two minutes, the thermometer is first read exactly two minutes before exposure begins. It is again read at the expiration of the two minutes, and the exposure at once made by drawing out the slide which covers the aperture. Exactly two minutes after it is again read and the exposure discontinued. Again, at the expiration of another two minutes, the thermometer is read. The comparative heating power of the sun is deduced from the formula

$$R + \frac{r\,x}{2}$$ [illegible]

where R is the amount of heat gained during exposure, and r and r' the difference between the 1st and 2d, and 3d and 4th readings respectively, which indicate the heat which the instrument is losing by radiation from itself.

The great difficulty in the way of making these direct observations is the variability of the condition of the earth's atmosphere, which forms a medium of ever varying opacity, through which we are forced to view the sun. This source of uncertainty might be reduced to a minimum if these observations were made at some great altitude, as on the top of a high mountain where the lower or grosser strata of the atmosphere would be left behind.

In Toronto we have determined to pursue the observations regularly and endeavor to allow for the effect of the condition of the atmosphere at the time of the observation by careful simultaneous observations of cloud and the hygrometric condition of the atmosphere, etc., etc.

I am strongly of opinion that, when true observations have been taken for a sufficent length of time to determine the effect of the sun's altitude, light cirrus cloud, etc., we shall be able to detect the existence of any variability in the direct heating power of the sun.

One great difficulty which we labor under in the Toronto observatory is that in connection with the meterological service, there is such a vast amount of routine and purely clerical work, as correspondence checking observations etc., that but little can be done in the way reducing the observations and endeavoring to deduce results, at present some of our results are being worked up at home by the committee of the Royal Society on Solar Physics, but it would be a great point gained if the Government would so add to the staff that some time might be devoted to the working up of our own results, especially in view of the fact that there is every reason to believe that these results would ultimately prove of great public utility.