MAGNETIC STORMS, AURORÆ AND SOLAR PHENOMENA.

THE attention of the whole civilised world has this year been directed to the importance of finding a connection between terrestrial and solar variations, but the phenomena recorded last Saturday in the nature of a great magnetic storm and a brilliant aurora borealis have perhaps brought home to many the desirability of pursuing such investigations which may help us to be forewarned, and therefore forearmed.

The enormous development of the telegraph, telephone, cable, and other applications of electricity since the date of the last great magnetic storm has caused the disturbance to be more generally observed than was previously perhaps the case.

Practically the world's whole telegraph system was upset, and information from this country, France, the United States and other lands shows that for several hours communication was almost completely interrupted.

According to the *Daily Mail* the London telegraphic department characterised the storm as the most extraordinary ever experienced. Messages dispatched on Saturday from Russia, Spain, Switzerland, France, Germany, Belgium, and other countries, which would ordinarily have been received an hour or less after transmission, were still slowly coming through on Sunday morning. Mr. Gavey, the electrician-in-chief to the Post Office, in an interview with a *St. James's Gazette* representative, said the storm was the most severe that had been experienced for the last twelve years. The effects of it were first felt at St. Martin's-le-Grand at 6.45 a.m. on Saturday, and they continued until five in the afternoon. It was eight o'clock before the storm had completely disappeared.

The New York correspondent of the *Daily Telegraph* states that the magnetic disturbance was felt practically everywhere in the United States, affecting the great cable companies for a time, while the telegraph wires in all directions from Chicago felt the effect; the long distance telephones were similarly troubled. The disturbance lasted eight hours, and at its climax "there were 675 volts of electricity—enough to kill a man—in the wires, without any batteries being connected to them." During the magnetic storm which occurred in 1871 the Eastern Telegraph Company showed that there was an earth current of 170 volts on their Suez-Aden line.

The *Times* correspondent in Paris states that according to a Press communication from the French Under-Secretary of State for Posts and Telegraphs the magnetic phenomenon extended in all directions, but with somewhat less intensity towards the north-west; the telegraph office was from nine o'clock in the morning deprived of communication with the greater part of the French towns and the adjoining districts. It was subsequently also cut off from communication with America, Spain, Portugal, Italy, Algeria, Tunis, and places beyond those countries. At 4.40 p.m. communication was re-established; it was again interrupted at 5.30 p.m., but a little after sunset almost all communications were found to be restored.

It is interesting to note that the effect of a magnetic storm on a telegraphic system may be modified in two, if not more, ways, and this was done in the case of our own Post Office. One method, as stated by Mr. Gavey, is to join two wires, thus forming a loop, and in this way eliminate the earth from the circuit. The other means is to employ condensers; these, when connected up with the circuit, stop a continuous current such as is set up by magnetic disturbances.

In several regions the magnetic disturbance was accompanied by a display of the aurora. In New York on Saturday morning the northern sky was described as "a dazzling display of light and colour"; it was first seen in the city at two o'clock, but faded away at four. In Ireland and Scotland during Saturday evening the aurora was also observed.

A message from the Sydney correspondent of the *Times* states that a beautiful Aurora Australis was seen there on Saturday night, the streamers reaching nearly to the zenith.

Earthquakes also seem to have been recorded as well. On Friday and Saturday two undulating shocks were felt at Benevento and Avellino, in Italy, the first lasting two seconds, and the other a minute.

In Essex several distinct earthquake shocks were felt at Saffron Walden. At midnight on Saturday one shock is stated to have lasted five minutes. These were repeated at 5.50 and 9.30 on Sunday morning. At Debenham, four miles distant, shocks were felt on Monday sufficiently strong to cause small articles to fall to the ground.

Tuesday's *Daily Mail* publishes a telegram from Simla (dated November 2) in which it is stated that terrible earthquakes occurred at Turshiz, near Turbati-haideri, in Persia. Unfortunately, the time of occurrence was not mentioned, and up to the moment of writing (Tuesday evening) the news has not been corroborated.

In a communication to the writer from Stonyhurst Father Cortie writes:—"We had a magnificent magnetic storm on Saturday and Sunday, the biggest ever recorded here. The declination magnet swung through 2° 46′. The spot of light for the horizontal force travelled several times right off the pages on the drum."

From the above brief summary of the information to hand it will be gathered that we have experienced a storm of quite considerable magnitude, not perhaps the worst that has ever been recorded, but at any rate a "great" disturbance.

Two important questions now arise. What is the cause of these sudden magnetic phenomena? Can they be predicted?

The first of these questions is one which is answered differently by different investigators. Some think that there exists a common cause external to the sun, while others are agreed that the storms originate from the sun itself; there are also many who go more into detail and are inclined to favour the view that they are caused by sunspots.

In the last mentioned case then it is natural to conclude that when there is a large spot we should experience a magnetic storm, and when there are no spots storms should be absent. This, however, is not the case. The true explanation must account for the three possibilities of the appearance of these storms.

(1) A large spot *with accompanying* magnetic disturbance and auroræ.

(2) A larger spot *with no accompanying* magnetic disturbance and auroræ.

(3) No great apparent solar activity, but magnetic disturbance and auroræ.

Since sunspots cannot be held to satisfy these necessary conditions, are there other solar disturbances which can be utilised? Yes, there are the prominences which were first seen projecting beyond the dark limb of the moon during total solar eclipses. Up to the year 1868 these were the only opportunities when such solar appendages could be observed, but during that year a method was discovered by Sir Norman Lockyer and Dr. Janssen by which they could be seen on the sun's limb at any time without the necessity of waiting for these brief opportunities. It was not, however, until the year 1870 that regular observations of the limb of the sun showing these indications of solar activity were commenced, but, thanks to the magnificent work of Respighi, Tacchini, Ricco, and Mascari, we have practically a continuous record of them up to the present time.

The question then arises, are these prominences in any way related to the occurrence of magnetic storms? Before answering this, a few preliminary remarks may be made.

In the first place the number of spots on the sun is nearly always insignificant compared to the number of prominences. Prominences are, therefore, of greater relative importance than spots.

While sunspots are restricted to practically a narrow zone (±5° to ±35°) on each side of the solar equator, prominences can and do occur all over the sun's disc. Again, the general trend of the spot circulation is from the higher to the lower latitude, while in the case of prominence the reverse happens. In some years we have a great number of prominences near the solar equator, while in other years they are observed also in great numbers near the solar poles. A glance at some curves recently published in this Journal (vol. lxviii. p. 257 July 16) will shown not only the general drift

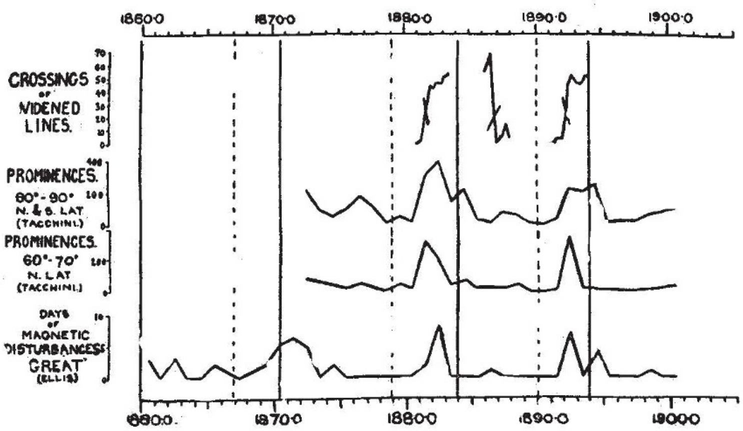

FIG. 1.—Comparison showing days of "great" magnetic disturbance, polar prominences and crossings of widened lines. (The continuous and broken vertical lines indicate the epochs of sun-spot maxima and minima respectively.)

of prominence activity, but the epochs when the prominences were present near the polar regions of the sun. The years in which they attain these high latitudes are not numerous; they are (first observations made in 1870) 1870, 1871, 1881, 1882, 1892, 1893, and 1894. Mr. William Ellis, who has made a special study of magnetic disturbances, has tabulated the number of days of "great" disturbances, that is, those recorded at Greenwich above a certain standard. These are utilised to form the following table :—

Date	Number of years	Number of days of "great" magnetic disturbances	Average per year
1870–1872 ...	3 ...	16 ...	5·33
1873–1880 ...	8 ...	2 ...	0·25
1881–1882 ...	3 ...	10 ...	3·33
1883–1891 ...	9 ...	1 ...	0·11
1892–1894 ...	3 ...	7 ...	2·33
1895–1900 ...	6 ...	2 ...	0·33

Another and perhaps more striking way of showing the coincidence of the epochs of the occurrence of days of magnetic disturbances and polar prominences is illustrated in the accompanying figure (*see* NATURE, February 19, vol. lxvii.).

The continuous and broken vertical lines indicate the epochs of maxima and minima sunspots, showing that the former tend to occur later than the peaks of the magnetic curves. In this diagram Respighi's observations of polar prominences made during the years 1870 and 1871 are not included, but their mean latitudes for each hemisphere during these years were ±70°.

It will thus be seen from the above that the occurrence of polar prominences is closely associated, at any rate in time, with great magnetic storms, and, therefore, with auroræ, which nearly always accompany them. Further, prominences fulfil the three conditions mentioned previously in this article, for they can occur when there are spots and also when there are none.

One argument used against the prominence theory is that the polar prominences are "quiet" prominences and therefore are not likely or are possibly not capable of producing such large terrestrial effects. The critic may, however, have forgotten to consider the possible and natural conclusion that the appearance of prominences in high latitudes may at least be simply an indication of greater action occurring nearer the equatorial regions with consequent greater extension of the disturbed region towards the polar zones.

That the polar regions of the sun are sometimes greatly disturbed is again emphasised by the presence of enormous streamers that are seen in those regions during some total solar eclipses. Further, these polar streamers are observed only at those times when the prominences approach high latitudes. Here again we have good cause to doubt the inability of these polar prominences as disturbing agents. Even if the prominences be not conceded to be the initial cause of magnetic storms, their gradual changes of position towards the solar poles may afford a valuable means of forecasting the epochs of magnetic disturbances.

From the facts before us let us consider the question of forecasting the years in which magnetic storms should occur. If the reader will glance at the figure accompanying this article and continue the curves on the assumption that the last sunspot minimum occurred in 1901·5 and the next maximum in 1905, he will most probably make a maximum fall between these two dates, but somewhat nearer the latter; in fact the maximum would have been placed in the middle of the year 1903. It will be noticed, however, that at the sunspot maximum of 1870 the disturbance curve reaches a maximum a year after 1870. A recent investigation has indicated that all sunspot cycles are not alike in intensity, and that the cycle commencing in 1901 may probably correspond to that which commenced in 1867. If, therefore, the coming sunspot maximum should attain the same dimensions as that reached in 1870, it seems quite possible that the magnetic disturbance curve for the present cycle should correspond to that portion commencing about 1867. If this be so, then not only should polar prominences be recorded from the years 1903 to 1906 or 1907, but during these years "great" magnetic disturbance will be liable to occur. As shown in the previous table, no less than 16 of Ellis's "great" magnetic storms occurred between 1870 and 1872; also two occurred in 1869 and one in 1868, so that if we consider the present year to correspond to 1868 there is much in store for us. It may be mentioned also that since the years 1899 and 1900 the prominences have exhibited the tendency to attain high latitudes, so that there seems every reason to suppose that magnetic storms and auroræ may be experienced during the course of the next three or four years, after which there will be a cessation for about ten or eleven years.

WILLIAM J. S. LOCKYER.