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REPORT ON OBSERVATIONS OF ATMOSPHERIC ELECTRICITY AND TERRESTRIAL MAGNETISM MADE AT KEW, STONYHURST AND ESKDALEMUIR OBSERVATORIES ON THE OCCASION OF THE SOLAR ECLIPSE, APRIL 8, 1921,

COMPRISING

REPORT ON OBSERVATIONS AT KEW AND STONYHURST OBSERVATORIES

By C. CHREE, Sc.D., LL.D., F.R.S.;

AND

REPORT ON OBSERVATIONS AT ESKDALEMUIR OBSERVATORY AND A COMPARISON OF THE RESULTS OBTAINED AT KEW, STONYHURST AND ESKDALEMUIR OBSERVATORIES

By H. W. L. ABSALOM, B.Sc., A.R.C.S., D.I.C., and
E. TAYLOR, M.A., B.Sc.

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REPORT ON OBSERVATIONS OF ATMOSPHERIC ELECTRICITY AND TERRESTRIAL MAGNETISM MADE AT KEW, STONYHURST AND ESKDALEMUIR OBSERVATORIES ON THE OCCASION OF THE SOLAR ECLIPSE, APRIL 8TH 1921.

The following table gives the times and magnitude of the eclipse at the astronomical observatories nearest to Kew, Stonyhurst and Eskdalemuir.

	Eclipse began.	Greatest phase.	Eclipse ended.	Magnitude.
	h. m.	h. m.	h. m.	
Greenwich - - -	7 35	8 47	10 5	0·88
Durham - - - -	7 41	8 52	10 9	0·93
Edinburgh - - -	7 42	8 53	10 9	0·95

OBSERVATIONS AT KEW AND STONYHURST OBSERVATORIES

BY C. CHREE, SC.D., LL.D., F.R.S.

Atmospheric Electricity.—The pre-arranged electrical programme at Kew Observatory was to take readings of the air-earth current (with the Wilson apparatus) and of the ionic charges (with the Ebert apparatus) throughout the whole time of the eclipse on 8th April, and during the same hours on 7th and 9th April. Comparative results were aimed at from a day of eclipse and adjacent days of no-eclipse. The programme was carried out on 7th and 8th April, but on the 9th the weather was unpropitious. To make up for the 9th, shorter series of observations, corresponding with the time of maximum phase, were made on 11th, 12th and 13th April. At the start on 11th April, the readings with the Wilson apparatus were irregular, and these and the corresponding potential gradient observations are not included in Table I.

The cycle of observations with the Wilson apparatus consisted of—

(A) a determination of the charge produced on the plate (at zero potential);

(B) the loss of this charge in five minutes, representing the integral for that time of the air-earth current.

The complete cycle occupied about six minutes. This determined the times given in Table I. The mean of the 5-minute exposures of the Wilson plate may not have come exactly at the times

7h. 33m., 7h. 39m., etc., in the table. Sometimes the readings took a little longer than usual, the tendency being for the cycle slightly to exceed six minutes.

The usual practice (at Kew Observatory) is to derive from the Wilson apparatus merely the conductivity, the absolute values of the potential gradient at the time being derived from the electrograms of the Kelvin water-dropper. This renders an exact calibration of the Wilson scale unnecessary. On the present occasion the values of the potential gradient for 6-minute intervals, 0m. to 6m., 6m. to 12m., after each hour, were first got out as usual from the electrograms, read to the nearest 5 volts. The question then suggested itself whether, as the water-dropper is at some little distance from the spot where the eclipse observations were taken, it would not be better to derive the potentials from the series (A) readings of the Wilson apparatus. The scale value of the instrument was accordingly determined for each day by comparing the sum of the (A) readings with the sum of the corresponding potentials derived from the electrograms. The scale values thus found on the 7th, 8th and 12th, were practically identical. The potential gradients derived from the readings of the Wilson apparatus are those given in the table. The agreement between them and the corresponding electrogram readings was generally good. As an example, we give in the order of occurrence the two sets of results for 8th April:

Kelvin -	594	637	637	623	594	566	552	594	623	665	665	693	651	594
Wilson -	640	659	651	623	589	563	552	597	642	651	662	699	659	614
Kelvin	651	594	580	608	651	693	651	552	538	566	538	509	509 v/m	
Wilson -	625	597	572	606	685	696	617	526	518	555	555	498	481 „	

As the Kelvin result is a mean from a 6-minute interval, while the Wilson result represents an instantaneous value, and 0·1 division on the Wilson represented approximately 4·2 volts, the accordance is as good as could reasonably be expected.

To make the eclipse and non-eclipse results as parallel as possible, one Ebert apparatus was used throughout for the positive charges, and a second Ebert apparatus for the negative charges. The apparatus used for measuring the negative charges was, unfortunately, discharged accidentally a little after 9h. on the 8th. Some time elapsed before it could be recharged, and the subsequent observations may be less satisfactory than the others. The Ebert apparatus were both read at intervals answering to the passage of 400 litres of air. This took only about 5 minutes. Thus occasionally two readings fell in one of the 6-minute intervals used in Table I. A few natural leakage experiments—each covering 5 minutes—were interspersed, otherwise the number of such redundant observations would have been greater.

The meteorological conditions were unfortunately not the same on 8th April as on any other day. There was an absence of cloud, so that but for the eclipse the conditions would have been unusually homogeneous. The 7th was also a fine morning,

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but sunlight was constantly varying owing to the passage of clouds, and the wind was also somewhat variable.

It must be remembered that the accuracy to be expected from individual observations of the air-earth current or of the ionic charges is not high. The air-earth current during five minutes is usually represented by a change of less than one small division in the Wilson reading. The estimates for successive 5-minute periods are, however, absolutely independent. Thus if there is a sequence of high values or of low values of the air-earth current, the chances are we have to do with a natural phenomenon.

In the case of the Ebert apparatus an error of estimation in one reading affects in different directions two successive estimates of the ionic charges. Thus when a high and a low value immediately follow one another, the phenomenon is at least as likely to represent an infirmity of the observer as a vicissitude of nature.

The regular diurnal variation of potential gradient on fine April days at Kew is well known. There is a (secondary) maximum between 8h. and 9h., the range between 7h. and 10h. being about 30 volts. So far as the sequence of changes shown in Table I. during the eclipse hours is concerned, the 8th behaved more like a normal day than the 7th or 13th. Towards the central part of the eclipse the results on the 8th show considerable resemblance to those of the 12th. The only outstanding feature of the potential gradient on the 8th was its high value. The mean value for the 60 minutes centering at 9h. is measured on each day for publication in the *Geophysical Journal*. This value was higher on 8th April than on any other day of the month and 2·2 times the average. The value of 8th April was in fact exceeded on only six earlier days of the year, the nearest in point of date being 3rd March. There is normally a big drop of potential gradient in April, as compared with January and February, or even March. Thus the phenomenon calls for notice. At the same time the high value was present at the very commencement of the eclipse, and the mean value between 8h. 30m. and 9h. 30m. on the 12th was but little less than that on the 8th.

As Table I. shows, the air-earth current on 8th April was persistently low for some time on either side of the epoch of maximum eclipse. The mean value between 8h. 30m. and 9h. is markedly lower on that day than on the 9th, 12th or 13th. The phenomenon cannot be said to be absolutely unique, because a similar state of matters is observable on the 13th from 8h. 51m. to 9h. 3m. But the depression lasted shorter on the 13th, and might more reasonably have been associated with a change in the meteorological conditions.

The irregularities in the ionic charges appeal to the eye. It may be inferred, however, with some assurance, that there was no falling off in the ionic charges either positive or negative as obscuration increased. From 8h. 30m. to 9h. the charges of both signs had a higher mean value on the 8th than on any of the other days. Considerably higher values were, however, observed near 10h. on the 7th, and the values observed on the 7th between 7h. 30m. and 8h. were also higher.

The most prominent electrical phenomenon during the eclipse was the low value of the air-earth current at the time of maximum phase. As the corresponding ionic charges were high rather than low, and the potential gradient was exceptionally high, there was presumably a marked reduction in the mobility of the ions. Whether this was or was not a direct consequence of the eclipse is a matter of opinion.

Descriptions of the results of similar electrical observations in this country have been published by Messrs. G. M. B. Dobson* and E. H. Nichols,† dealing respectively with the eclipses of 17th April 1912 and 21st August 1914. In both cases the electrical conductivity, the air-earth current and the ionic charges seemed depressed during the eclipse, while the potential gradient appeared to be enhanced on the one occasion and depressed on the other. The one respect in which there seems agreement is the low value of the air-earth current (and conductivity).

Messrs. Dobson and Nichols both give references to foreign observations. More recent results will be found in various numbers of *Terrestrial Magnetism*, especially pp. 96 and 97 of Vol. 24, dealing with observations made during the solar eclipse of 8th June 1918, at Lakim within the belt of totality. On that occasion the electrical conductivity was *enhanced* about totality, and the potential gradient depressed.

Terrestrial Magnetism.—Magnetic observations were taken with declinometers at various R.A.F. stations, including Lympne, Calshot, Holyhead and Howden. The Chaldæan Society, who borrowed a declinometer, observed in North Uist (Hebrides), and Mr. Lindsay Galloway observed with an instrument of his own pattern at Campbelton. At most of these stations observations were taken at 1-minute intervals during the eclipse on 8th April, and during the same hours of two other days, usually the 7th and 9th. Only one Kew pattern magnetometer was available, and the other instruments were of inferior accuracy.

Observations have been made on the occasions of previous eclipses with superior instruments at a number of stations, largely on the initiative of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, and unambiguous results have not, so far as I can judge, yet been obtained. Thus the only reasonable chance of success for the field observations on the present occasion was the occurrence of absolutely quiet conditions from 7th to 9th April, with a close agreement between

* *Q.J.R. Meteor. Soc.* Vol. 39, 1913, p. 227.
† *Phil. Mag.* Vol. 32, 1916, p. 291.

the variations observed on the 7th and 9th. As it turned out, luck was against the enterprise. The variations observed on the 7th and 9th during the eclipse hours differed as much between themselves as they differed from the observations on the 8th. It also appeared that the observational uncertainties in the field were greater than had been anticipated. After careful consideration, it was decided to confine the discussion to Observatory results.

Thanks to the kindness of the Rev. A. L. Cortie, S.J., it has been possible to include horizontal force (H) results from Stonyhurst as well as Kew. The action of the Stonyhurst declination magnetograph was, however, unsatisfactory, so the declination (D) results are confined to Kew Observatory. During the busy hours of the day artificial disturbances introduce undue uncertainty into instantaneous values of the magnetic elements at Kew, but they do not sensibly prejudice the 10-minute mean values which are utilised in Table II. The measurements were not limited to the eclipse hours, but extended from 6h. to 12h. G.M.T. The Stonyhurst curves were measured at Kew in the same way as the Kew curves, the scale values being supplied by the Rev. A. L. Cortie.

By $8-\frac{1}{2}(7+9)$ in Table II. is meant the algebraical excess of westerly declination, or horizontal force, on 8th April as compared with the mean of the corresponding values on 7th and 9th April; while 7—9 means the algebraical excess of the element on 7th April over 9th April. It will be convenient to discuss the H results first.

On the average April day in England H falls continuously from 6h. to a minimum occurring between 10h. and 11h. On individual days the fall has often minor oscillations superposed on it. Thus small irregularities naturally appeared in the 10-minute means on all three days, but the fall to the minimum was as regular as usual, the minimum appearing at Kew about 10h. 25m. on the 7th and 9th, and about 10h. 55m. on the 8th. The times of the minima at Stonyhurst were 10h. 25m. on the 7th, 10h. 45m. on the 8th, and 10h. 15m. on the 9th. Thus at both places the H minimum occurred distinctly later on the 8th than on the adjacent days. The most prominent feature, however, as the following figures show, was the greater range observed on the 8th.

—	7 h. 35 m. to 10 h. 5 m.		6 h. to 12 h.	
	At Kew.	At Stonyhurst.	At Kew.	At Stonyhurst.
	γ	γ	γ	γ
Range on 7th -	23	23	36	42
„ „ 8th -	45	43	57	52
„ „ 9th -	15	17	25	24

As Table II. shows, *H* was higher on the 8th than on the mean of the 7th and 9th when the eclipse began, and lower when the eclipse ended. But the excess had existed to a like extent for $1\frac{1}{2}$ hours before the eclipse began, and the deficiency continued and even slightly increased during two hours after the eclipse. Thus the phenomena during the eclipse hours present no prominent feature differentiating them from the preceding and following hours.

Again, it will be noticed that while the Kew and Stonyhurst phenomena are generally very similar, the difference between the 8th and the mean of the adjacent days appears to be, if anything, least at Stonyhurst though the eclipse phase there was the larger. Also, especially during the earlier hours, the difference between the values of *H* on the 7th and 9th followed a very similar progression to the difference between the 8th and the mean of the 7th and 9th, the resemblance of Stonyhurst to Kew being again striking.

Except near midwinter the principal minimum in *D* (*i.e.*, the extreme easterly position) occurs in the morning, being later in the equinoctial months than near midsummer. On the average April day it occurs at Kew about 8h. On 7th and 9th April the minimum occurred about 8h. 30m.—the values for 8h. 25m. and 8h. 35m. being identical. On 8th April it occurred at 8h. 5m., and so somewhat *earlier*. The values of the three minima were almost identical, viz., 14° 17·2′ on the 7th, 14° 17·3′ on the 8th and 14° 16·9′ on the 9th. After the minimum there is on the average day a swing to the west for 5 or 6 hours. The ranges from 10-minute means were as follows :—

	7 h. 35 m. to 10 h. 5 m.	6 h. to 12 h.
	′	′
Range on 7th - - - - -	1·7	7·2
„ „ 8th - - - - -	3·0	10·7
„ „ 9th - - - - -	2·3	10·9

Thus with *D*, as with *H*, the range during the eclipse hours was *greater* on the 8th than on either of the adjacent days.

The range between 6h. and 12h. was practically the same on the 8th and 9th. At 6h. declination was more easterly on the 8th than on either the 7th or 9th. From 7h. 15m. to 7h. 45m. the value on the 8th was intermediate between the values on the 7th and 9th. Subsequent to 8h. 15m. *D* was more westerly on the 8th than on either of the other days, and this was more especially true of the last hour of the eclipse from 9h. 5m. to 10h. 5m. Thus it would be correct to say that during the whole of the eclipse, *D* changes showed a westerly tendency on the 8th as compared with the two adjacent days, and during the hour immediately following the eclipse the difference between the three days showed a slight diminution. As against this, however, the westerly tendency on the 8th as compared with the 7th, or as compared with the mean of the 7th and 9th, developed again after 11h. and at 11h. 35m. the excess in westerly declination on the 8th was greater than at any time during the eclipse. Also the time when the values of D in the three days lay nearest together was from 7h. 45m. to 9h. 5m., and so synchronised with the maximum phase. As in the case of H, the difference between the 8th and the mean of the adjacent days was decided, but it existed before the eclipse began, and continued after the eclipse ended.

The force equivalent of a 1′ change of D at Kew is $5 \cdot 3\gamma$. Thus if we multiply the declination figures in Table II. by $5 \cdot 3$, we get what may be regarded as the disturbing forces perpendicular to the normal magnetic meridian, the position of which for the morning of 8th April may be taken as 14° 20′ W. The H figures in Table II. give the corresponding disturbing forces in the magnetic meridian. The data for $8-\frac{1}{2}(7+9)$ can thus be used to draw a vector diagram for the forces which account for the difference between the 8th and the mean of the two adjacent days, the axis of H being in the magnetic meridian, and the axis of D perpendicular to it. The $+^{ve}$ direction in the one case is to magnetic north, in the other case to magnetic west. The vector diagram so drawn from 6h. to 12h. (*c.f.* Fig. 6) is of an irregular somewhat dumb-bell shape, the handle part representing in the main the eclipse hours. The values of ΔH and ΔD (the H and D differences) being opposite in sign except at 8h. 15m., when both are small, we can deduce the general orientation of the dumb-bell, and also of the eclipse hours portion, from the values of the angle $\tan^{-1}(\Sigma\Delta D/\Sigma\Delta H)$, where $\Sigma\Delta D$ and $\Sigma\Delta H$ represent the numerical sums of the entries under D and H in Table II., the former being multiplied by $5 \cdot 3$. Omitting in either case the entries under 8h. 15m., we get—

from 6h. to 12h. $\tan^{-1}(\Sigma\Delta D/\Sigma\Delta H)=\tan^{-1}(-184/427)=-23° \, 18'$;

,, 7h. 35m. to 10h. 5m. $=\tan^{-1}(-66/154)=-23° \, 12'$.

These directions are practically identical, and represent approximately 9° east of true north (or 9° west of true south). This does not seem to have any obvious relationship to the eclipse.

The eclipse included a turning point in both H and D, a minimum in the one case, an easterly extreme in the other. In the one element the turning point was later on the day of eclipse than on the adjacent days, but in the other element it was earlier. There was a decided difference between the diurnal variations from the 8th and that from the two adjacent days, but this difference was of the same order as the difference between the diurnal variations on the 7th and 9th. Causes other than the eclipse must have been responsible for the difference between the 7th and 9th, and the differences between the 8th and the mean of the 7th and 9th were not peculiar to the eclipse hours, nor of such a kind as to suggest that any special influence was at work during the eclipse hours.

The changes during the eclipse hours were decidedly *greater* on the day of eclipse than on the adjacent days. Thus if there is a general tendency for magnetic changes natural to the hour to be reduced during an eclipse, this tendency must have been more than neutralised by some other cause during the eclipse of 8th April 1921.

Much information about magnetic phenomena during eclipses has appeared during the last two years in *Terrestrial Magnetism*. Some conclusions drawn by the Editor, Dr. L. A. Bauer, from the eclipse of 29th May 1919, will be found in Vol. 25, p. 97.

OBSERVATIONS AT ESKDALEMUIR OBSERVATORY AND A COMPARISON OF THE RESULTS OBTAINED AT KEW, STONYHURST AND ESKDALEMUIR.

BY H. W. L. ABSALOM, B.SC., A.R.C.S., D.I.C. AND E. TAYLOR, M.A., B.SC.

Atmospheric Electricity.—During the eclipse period, quick run electrograms of the Kelvin water dropper were obtained and observations were made of ionic charges using a single Ebert apparatus.

The ordinary electrograms were tabulated for the 7th and 9th during the corresponding period. The times of tabulation were chosen to correspond with the Kew times, *i.e.*, 6-minute means were read, beginning at 7h. 30m. The mean curve ordinates were first read in millimeters, (Scale Value=5·91 volts per mm.) and converted to volts in the open using a multiplier (37·4) derived from absolute observations of potential gradient. The difference in the errors involved in reading the ordinary and quick run curves will not affect a general comparison of the three days under notice.

The eclipse was accompanied by calm, cloudless weather. The corresponding period on the 7th was misty and overcast, with a light north wind : that on the 9th was cloudy, with varying amount of sunshine and moderate NNE wind.

A disturbing factor on all three days was the presence in the atmosphere of smoke haze from moor fires in the neighbourhood. This disturbing element and the lack of parallel Ebert observations on the 7th and 9th discount the value of the Ebert eclipse results. These results, however, for other reasons seem to be of little value. They are few in number owing to the time taken in charging the single instrument alternatively positive and negative, allowing an interval for the steady state to be reached after each charge. Unfortunately the instrument was behaving unsatisfactorily. The observer at the time attributes eccentricities observed in charging and leaking rates to impaired conducting power of the fibres and to some sort of elastic fatigue in them or stickiness at their junction. In his opinion the observations are not reliable.

Figure 1 shows curves of potential gradient at Eskdalemuir for 7th, 8th and 9th, and at Kew for the 7th and 8th. On the 7th and 8th the mean potential gradient over the eclipse period was higher at Kew than at Eskdalemuir by 268 and 270 volts per metre respectively. These differences were subtracted from the Kew readings, so that corresponding curves have the same mean axis. An obvious feature of the curves is the high value of the potential gradient on the 8th compared with values on the 7th and 9th. The 9h. value on the 8th was exceeded on

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FIG 1. POTENTIAL GRADIENT

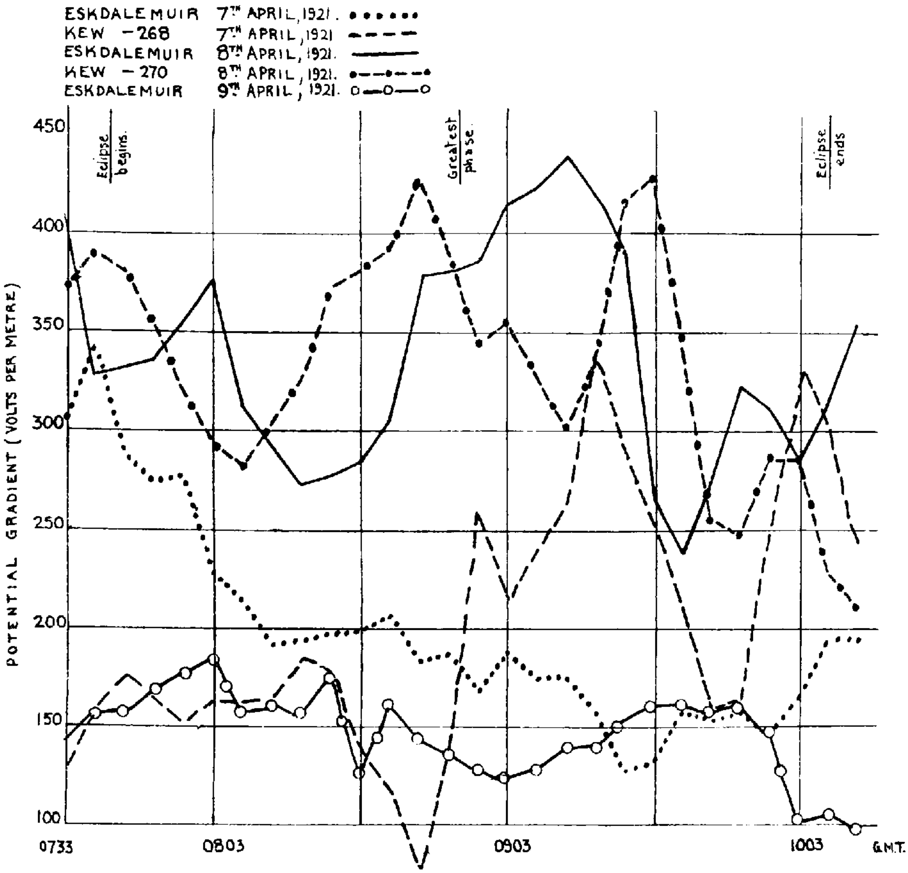
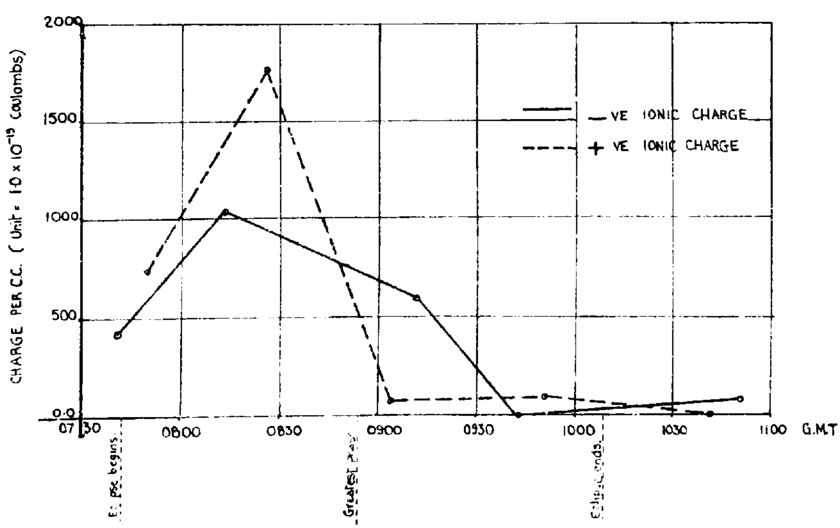


FIG. 2. ATMOSPHERIC ELECTRIC CHARGE AT ESKDALEMUIR ON APRIL 8TH.



K161C. H&SP 6227. 3700A. 10215/227. 625. 11/24.

FIG. 3 ESKDALEMUIR H 6h. to 13h. G.M.T. APRIL 7, 8, 9 1921.

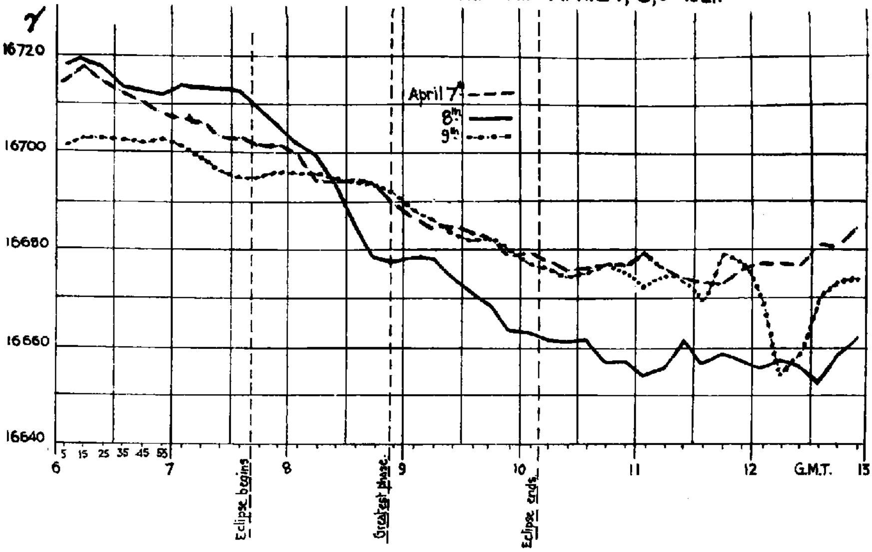


FIG. 4. ESKDALEMUIR D 6h. to 12h. G.M.T. APRIL 7, 8, 9 1921.

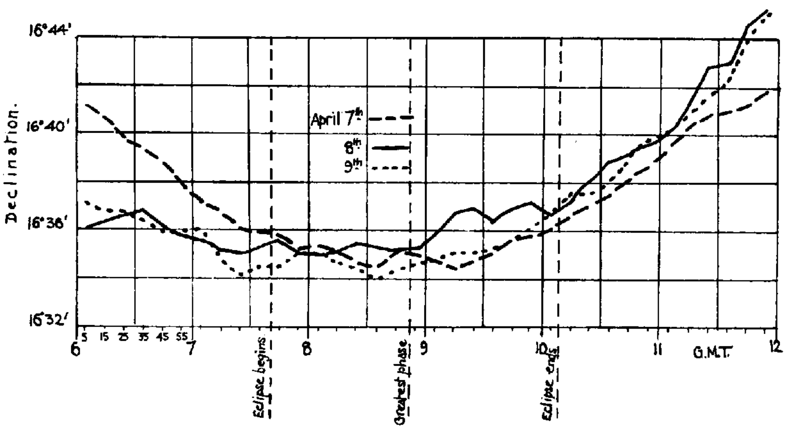
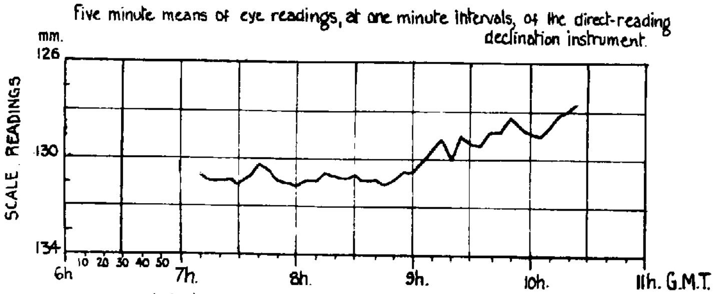


FIG. 4A ESKDALEMUIR D ON APRIL 8TH 1921.

Five minute means of eye readings, at one minute intervals, of the direct-reading declination instrument.



Westerly declination increases up the sheet.

FIG 5. DIFFERENCES 8 − ½(7+9) AND (7−9) IN H AT KEW, STONYHURST AND ESKDALEMUIR

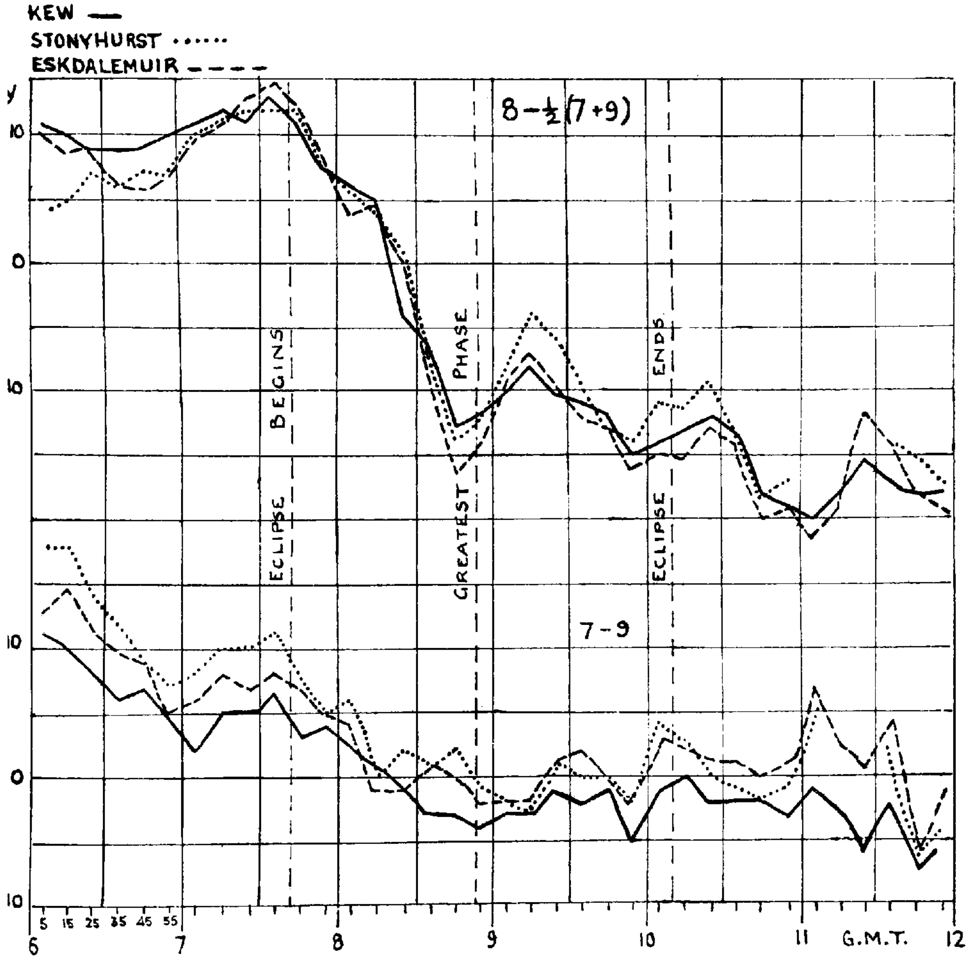
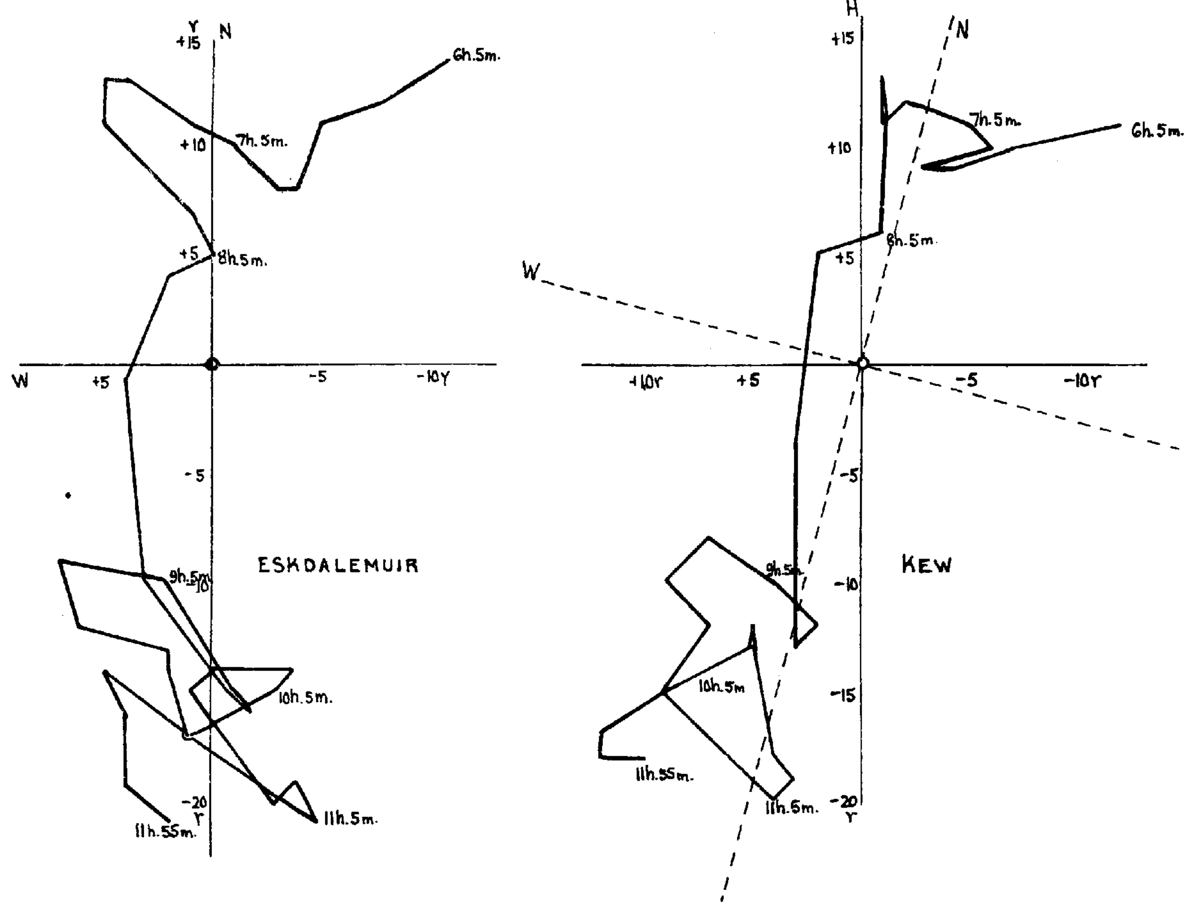


FIG.6. VECTOR DIAGRAMS OF THE DIFFERENCE $8-\frac{1}{2}(7+9)$



three previous "0a" days* of 1921. These occurred in February, when higher values are expected over this epoch.

According to the normal diurnal inequality derived from the results for the 11 years 1911–21, the potential gradient on the average "0a" day at Eskdalemuir decreases during the eclipse period, so that the changes on the 7th were more nearly normal than those on the 8th. On the latter date a certain similarity between the pulses at Eskdalemuir and Kew could be detected but there was a varying phase difference, the changes at Eskdalemuir lagging behind those at Kew.

Figure 2 shows ten Ebert observations, five of positive and five of negative ionic charge. As already remarked, conditions were not favourable for observation with the Ebert instrument.

Terrestrial Magnetism.—Quick run records (*i.e.*, speed 12 times normal) were obtained from the magnetographs between 7h. 30m. and 11h. 15m. on each of the days 7th, 8th, 9th April. Eye readings of a direct reading instrument were taken at one minute intervals in the period 7h. 6m. to 10h. 30m., 8th April.

The magnetic character figures assigned to the three days 7th, 8th, 9th April were 0, 0, 1 respectively.

Ten-minute readings of the north and west components between 6h. and 12h. G.M.T. on each of the three days were obtained, and the results have been reduced to a form comparable with that employed in the discussion of the Kew and Stonyhurst data.

Table IV. shows, for N, W, H, and D, (1) the differences between the values on the 8th and the mean of the values on the 7th and 9th, and (2) the differences between the values on the 7th and 9th. Figs. 3 and 4 show the course of H and D on the three days, while Fig. 5 shows the differences $(8-\frac{1}{2}(7+9))$ and $(7-9)$ for H at the three observatories Kew, Stonyhurst, and Eskdalemuir.

On the average April day at Eskdalemuir, H decreases continuously from 6h. to a minimum at about 11h. G.M.T. The time of the minimum on 7th was 11h. 35m.–11h. 45m. On the 8th and 9th there were irregularities in H between 11h. and 13h., but the times of minima on these days appear to have been 12h. 35m. and 12h. 15m. respectively. Thus, the minimum of H occurred later on the 8th than on either of the adjacent days. This is in agreement with the relations noted for Kew and Stonyhurst. Also, it may be noted that the range in H was greater on the 8th than on either the 7th or 9th, both in the eclipse hours and in the longer period 6h. to 12h.

	7h. 40m.—10h. 10m.	7h. 35m.—10h. 5m.	6h. 5m.—11h. 55m.
H range on 7th	24γ	25γ	45γ
H ,, ,, 8th	48γ	50γ	65γ
H ,, ,, 9th	20γ	19γ	34γ

* "0a" denotes a day during which from midnight to midnight no negative potential was recorded, and in no hour of which did the range of potential gradient exceed 1,000 volts.

The Eskdalemuir ranges were greater than those for Kew and Stonyhurst, while the difference between the values of *H* on the 8th and the means of the values on 7th and 9th was very similar to the differences found at the latter two places. During the greater portion of the eclipse period the difference appears to have been greatest at Eskdalemuir, but this feature persisted for more than an hour after the end of the eclipse.

The eclipse hours include a minimum of *D*, the normal time of occurrence of which in this month is about 8h. In this respect conditions on the 8th were normal, for the *D* minimum was at 7h. 55m.–8h. 5m. On the 7th, the minimum was at 8h. 35m. (or 9h. 15m.), while the time of minimum on the 9th was 8h. 35m. Hence, as at Kew. the time of the *D* minimum was earlier on the 8th than on either of the adjacent days. The values of the minima on 7th, 8th, 9th were 16° 34·4′, 16° 35′, 16° 34′, respectively. Ranges in *D* during the periods under consideration were as follows :—

	7h. 40m.—10h. 10m.	7h. 35m.—10h. 5m.	6h. 5m.—11h. 55m.
D range on 7th	2′·1	1′·8	7′·5
D ,, ,, 8th	2′·1	2′·1	10′·1
D ,, ,, 9th	3′·1	2′·7	11′·0

It appears that the relation of the *D* ranges during the eclipse hours differ from those at Kew in that the range on the 8th was not greater than on either of the adjacent days. During the greater part of the eclipse period declination was more westerly than on the mean of the 7th and 9th, the westerly tendency being most pronounced during the last hour of the eclipse. As at Kew, this tendency diminished somewhat between 10h. and 11h. but increased again towards 12h.

Fig. 6 shows a vector diagram for the forces which may be held to account for the difference between 8th and the mean of the 7th and 9th—the axes of reference being geographical N–S. and W–E. The diagram is similar to that for the differences at Kew, but is somewhat more complicated in the latter part of the period.

Generally, the relations between the magnetic elements considered in the three days 7th, 8th, 9th April appear to support the conclusion arrived at in the discussion of the Kew and Stonyhurst results, viz., that if any special influence were active during the eclipse its effects were more than neutralised by some other cause.

As "quick run" magnetograph records were probably obtained by other observatories on this occasion it has been considered advisable to give details of certain oscillations or pulsations which appeared on the Eskdalemuir "quick run" records. It may be stated that at the beginning and end of the "quick run" periods there were, as might be expected, instrumental pulsations of which the periods were very approximately 14 and 11 seconds (the periods of the suspended magnets) for the north and west components respectively. The pulsations of which details are given below, were of entirely different character from the artificially produced instrumental pulsations.

April 7th.

W. Component. Evidence of very feeble pulsations between 8h. 35m. and 8h. 40m.

April 8th.

W. Component.

(*a*) between 8h. 52m. and 8h. 55·5m., 4 complete oscillations in 155 seconds. Mean period about 39 seconds. Period of one of the oscillations only 35 seconds. Double amplitude (crest to trough) about 0·6 mm. $= 3\gamma$.

(*b*) Faint pulsations between 10h. 35m. and 10h. 45m.

(*c*) Between 10h. 51·5m. and 10h. 54m., 5 complete oscillations in 110 seconds. Mean period 22 seconds. The centre oscillation was largest. Double amplitude about 0·4 or 0·5 mm. $= 2$ or $2 \cdot 5\gamma$.

(*d*) Pulsations became distinct again at 10h. 58m. and continued visible until 11h. 10m. Not so well marked as those under (*c*). Mean period 22–23 seconds. Greatest double amplitude 0·3 mm. $= 1 \cdot 5\gamma$.

N. Component.

(*a*) Between 8h. 52m. and 8h. 55m., some undulatory movement but no regular pulsations.

(*b*) Onwards from 10h. 30m., evidence of intermittent pulsation.

(*c*) Between 11h. and 11h. 10m., pulsations became more distinct. Mean period of 9 complete oscillations approximately 20 seconds. Greatest double amplitude 0·3 mm. $= 1 \cdot 5\gamma$.

April 9th.

W. Component.

Slight pulsations between 9h. 50m. and 9h. 54m., period (?) 20–25 seconds.

N. Component.

(*a*) Between 8h. 58m. and 9h. 1m., slight pulsations of period about 20 seconds.

(*b*) Occasional pulsations between 9h. 46m. and 10h. 36m. Between 9h. 51m. and 9h. 52m. there were 3 complete oscillations in 65 seconds. Mean period nearly 22 seconds. Double amplitude 0·4 mm. $= 2\gamma$.

It may be merely a coincidence that the pulsations were more clearly in evidence on the 8th than on either the 7th or 9th.

TABLE I.—ELECTRICAL OBSERVATIONS AT KEW OBSERVATORY.

Time (G.M.T.).	Potential Gradient. Volts per Metre.				Air—Earth Current. Unit 1×10^{-16} amp/cm^2.				Charges per cm^3. Unit 1×10^{-19} Coulomb. Positive Charge					Negative Charge				
	7th	8th	12th	13th	7th	8th	12th	13th	7th	8th	11th	12th	13th	7th	8th	11th	12th	13th
h. m.																		
7 33	393	640	—	—	1·11	0·73	—	—	—	430	—	—	—	—	270	—	—	—
39	427	659	—	—	0·99	0·61	—	—	553	307	—	—	—	270	216	—	—	—
45	444	651	—	—	0·74	0·48	—	—	553	492	—	—	—	378	378	—	—	—
51	—	623	—	—	0·62	0·73	—	—	430	307	—	—	—	216	162	—	—	—
57	419	589	—	—	0·99	0·85	—	—	553	246	—	—	—	270	216	—	—	—
8 3	430	563	—	—	0·99	0·48	—	—	369	492	—	—	—	270	270	—	—	—
9	430	552	—	—	0·74	0·61	—	—	430	246	—	—	—	270	270	—	—	—
15	430	—	—	—	—	—	—	—	492	369	430	—	—	324	108	216	—	—
21	453	597	—	—	1·11	0·85	—	—	246	246	184	—	—	270	270	54	—	—
27	444	642	623	263	0·87	0·85	0·89	1·27	430	492	123	184	—	162	{108, 270}	270	162	270
33	402	651	603	269	1·36	0·48	1·01	1·13	553	492	430	184	184	270	270	162	324	162
39	382	662	603	286	1·11	0·36	0·76	1·27	369	307	307	184 123	307	162	216	216	162	324
45	342	699	580	272	0·37	0·36	0·76	0·99	430	553	{430, 492}	123	184	162	432	{0, 324}	{108, 216}	216
51	408	659	603	243	1·24	0·48	0·89	0·57	307	{492, 553}	246	246	123	216	270	54	162	216
57	526	614	631	235	0·62	0·61	0·89	0·42	492	369	430	184	246	216	216	108	54	270

9 3	481	625	676	229	0·87	0·73	0·76	0·42	553	307	307	184	{246, 369}	216	270	54	108	216
9	444	597	668	207	1·36	0·73	0·76	0·84	553	553	307 {184, 430}	{492, 61}	246	270	—	162 {162, 0}	{162, 162}	{216, 216}
15	526	572	623	187	1·11	0·85	0·76	1·13	—	430		430	430	—	—		108	378
21	608	606	611	167	1·24	1·34	0·76	0·99	615	492	—	123	307	378	—	—	162	324, 216
27	558	685	589	139	1·11	0·73	0·64	0·57	430	307	—	—	{430, 615}	270	—	—	—	378
33	521	696	—	—	0·99	1·22	0·89	0·70	430	184	—	—	—	{378, 216}	—	—	—	—
39	478	617	—	—	0·74	1·09	—	—	553	492	—	—	—	378	108	—	—	—
45	427	526	—	—	0·87	1·09	—	—	861	492	—	—	—	—	216	—	—	—
51	430	518	—	—	0·99	1·09	—	—	553	246	—	—	—	378	162	—	—	—
57	515	555	—	—	1·24	1·09	—	—	676	430	—	—	—	432	270	—	—	—
10 3	603	555	—	—	1·61	1·09	—	—	799	615, 123	—	—	—	594	216	—	—	—
9	577	498	—	—	1·48	0·97	—	—	676	553	—	—	—	486	270	—	—	—
15	512	481	—	—	1·85	0·97	—	—	861	—	—	—	—	486	378	—	—	—
Means.																		
h. m. h. m.																		
7 30 to 8 0	421	632	—	—	0·89	0·68	—	—	522	356	—	—	—	284	248	—	—	—
8 0 8 30	437	589	—	—	0·93	0·70	—	—	393	369	246	—	—	259	216	180	—	—
8 30 9 0	412	657	604	261	0·94	0·46	0·86	0·88	430	461	389	174	209	205	281	144	171	238
9 0 9 30	523	617	633	186	1·14	0·88	0·74	0·79	538	418	307	258	378	284	—	95	140	278
9 30 10 0	474	582	—	—	0·97	1·12	—	—	615	369	—	—	—	356	189	—	—	—
10 0 10 15	564	511	—	—	1·65	1·01	—	—	779	430	—	—	—	522	288	—	—	—

TABLE II.—CHANGES OF MAGNETIC DECLINATION AT KEW AND OF HORIZONTAL FORCE AT KEW AND STONYHURST, from 6h. to 12h. G.M.T. on 7th, 8th and 9th April 1921.

Time G.M.T.	Kew Declination		Horizontal Force				Time G.M.T.	Kew Declination		Horizontal Force			
	8 − ½ (7+9)	7−9	8 − ½ (7 + 9)		7−9			8 − ½ (7 + 9)	7−9	8 − ½ (7 + 9)		7 − 9	
			Kew.	Stonyhurst.	Kew.	Stonyhurst.				Kew.	Stonyhurst.	Kew.	Stonyhurst.
h. m.	′	′	γ	γ	γ	γ	h. m.	′	′	γ	γ	γ	γ
6 5	−2·2	+2·8	+11	+ 4	+11	+18	9 5	0·8	0·0	−10	− 8	− 3	− 2
15	−1·4	+2·6	+10	+ 5	+10	+18	15	1·4	−0·4	− 8	− 4	− 3	− 3
25	−0·8	+2·4	+ 9	+ 7	+ 8	+14	25	1·8	−0·2	−10	− 6	− 1	+ 1
35	−0·6	+2·2	+ 9	+ 6	+ 6	+12	35	1·5	+0·1	−11	−10	− 2	+ 0
45	−0·6	+2·2	+ 9	+ 7	+ 7	+ 9	45	1·4	+0·0	−12	−13	− 1	+ 0
55	−1·1	+1·6	+10	+ 7	+ 5	+ 7	55	1·6	−0·2	−15	−14	− 5	− 2
7 5	−0·9	+0·6	+11	+10	+ 2	+ 8	10 5	1·3	−0·3	−14	−11	− 1	+ 4
15	−0·3	+1·3	+12	+11	+ 5	+10	15	1·0	−0·5	−13	−11	0	+ 3
25	−0·1	+1·6	+11	+12	+ 5	+10	25	0·9	−0·5	−12	− 9	− 2	+ 0
35	−0·1	+1·3	+13	+12	+ 6	+11	35	0·9	−0·7	−13	−13	− 2	− 1
45	−0·2	+0·9	+11	+12	+ 3	+ 7	45	0·7	−0·4	−18	−18	− 2	− 2
55	−0·2	+0·3	+ 8	+ 8	+ 4	+ 5	55	0·6	−1·0	−19	−17	− 3	− 1
8 5	−0·2	+0·4	+ 6	+ 6	+ 2	+ 6	11 5	0·8	−1·0	−20	—	− 1	5
15	+0·3	+0·2	+ 5	+ 4	+ 1	+ 0	15	1·0	−1·5	−18	—	− 3	—
25	+0·6	+0·3	− 4	+ 1	− 1	+ 2	25	1·7	−1·5	−15	—	− 6	—
35	+0·5	+0·3	− 7	− 8	− 3	+ 1	35	2·3	−1·1	−17	−14	− 2	+ 2
45	+0·5	+0·4	−13	−14	− 3	+ 2	45	2·3	−3·0	−18	−15	− 8	− 6
55	+0·4	+0·3	−12	−12	− 4	− 1	55	1·9	−3·4	−18	−17	− 6	− 4

Table III.—Atmospheric Electrical Potential Gradient, 7th, 8th and 9th April 1921, at Eskdalemuir.

(Six-minute means from 7h. 30m. to 10h. 18m.)

Time	Potential Gradient volts per metre.			Time	Potential Gradient volts per metre.			Time	Potential Gradient volts per metre.		
h. m.	7th	8th	9th	h. m.	7th	8th	9th	h. m.	7th	8th	9th
7 33	303	411	142	39	206	307	161	45	153	273	157
39	344	329	157	45	183	374	142	51	157	322	161
45	288	333	157	51	187	378	135	57	146	314	146
51	273	337	168	57	168	385	127	10 03	165	284	101
57	277	355	176	9 03	187	415	123	09	194	314	105
8 03	228	378	183	09	175	423	127	15	194	355	97
09	213	314	157	15	175	438	138				
15	191	292	161	21	157	419	138	Range	217	202	86
21	194	273	157	27	127	389	153	Mean	199	335	146
27	198	277	176	33	131	266	161				
33	198	284	123	39	157	236	161				

Half-hour Means.

Time	7th	8th	9th	Time	7th	8th	9th
h. m. h. m.	v/m	v/m	v/m	h. m. h. m.	v/m	v/m	v/m
7 30 to 8 0	297	353	160	9 0 to 9 30	164	417	136
8 0 to 8 30	205	307	167	9 30 to 10 0	149	282	157
8 30 to 9 0	188	346	138	10 0 to 10 18	184	318	101

Table IIIa.—Atmospheric Electric Charge, 8th April 1921, at Eskdalemuir.

(Ebert Observations.)

Time	+ve Charge coulombs per cm³.	−ve Charge coulombs per cm³.	Time	+ve Charge coulombs per cm³.	−ve Charge coulombs per cm³.
h. m. h. m.			h. m. h. m.		
7 38 – 7 44	—	421×10^{-19}	9 09 – 9 15	—	595×10^{-19}
7 47 – 7 53	742×10^{-19}	—	9 39 – 9 45	—	000
8 10 – 8 16	—	1030×10^{-19}	9 48 – 9 54	91×10^{-19}	—
8 23 – 8 29	1750×10^{-19}	—	10 36 – 10 45	000	—
9 01 – 9 08	70×10^{-19}	—	10 47 – 10 56	—	78×10^{-19}

TABLE IV.—CHANGES OF MAGNETIC DECLINATION AND HORIZONTAL FORCE AT ESKDALEMUIR, from 6h. to 12h. G.M.T. on 7th, 8th, 9th April 1921.

G.M.T.	Declination		Horizontal Force and Components						G.M.T.	Declination		Horizontal Force and Components					
			N		W		H					N		W		H	
	8 — ½ (7+9)	7—9	8 — ½(7+9)	7—9	8 — ½(7+9)	7—9	8 — ½(7+9)	7—9		8 — ½(7+9)	7—9	8 — ½(7+9)	7—9	8 — ½(7+9)	7—9	8 — ½(7+9)	7—9
h. m.	′	′	γ	γ	γ	γ	γ	γ	h. m.	′	′	γ	γ	γ	γ	γ	γ
6 5	−3·1	+4·0	+14	+7	−11	+23	+10	+13	9 5	+1·0	−0·1	−10	−1	+2	−1	−9	−2
15	−2·3	+3·8	+12	+9	−8	+22	+9	+15	15	+2·0	−0·7	−9	−1	+7	−4	−7	−2
25	−1·6	+3·0	+11	+7	−5	+18	+9	+12	25	+1·9	−0·3	−12	+2	+6	−1	−10	+1
35	−1·2	+3·0	+8	+5	−4	+17	+6	+10	35	+1·2	−0·1	−13	+1	+2	0	−12	+2
45	−1·1	+2·8	+8	+5	−3	+16	+6	+9	45	+1·3	0·0	−14	−1	+2	0	−13	−0
55	−1·1	+1·7	+8	+3	−3	+10	+7	+5	55	+1·2	−0·6	−17	−1	+1	−3	−16	−2
7 5	−0·9	+1·0	+10	+4	−1	+6	+9	+6	10 5	+0·3	−0·6	−15	+3	−3	−2	−15	+3
15	−0·6	+1·8	+11	+5	+1	+11	+11	+8	15	+0·1	−0·8	−14	+3	−4	−3	−15	+2
25	+0·5	+2·0	+13	+4	+4	+11	+13	+7	25	+0·8	−0·5	−14	+1	0	−2	−13	+1
35	+0·1	+1·5	+13	+6	+5	+9	+14	+8	35	+1·1	−0·5	−15	+1	+1	−2	−14	+1
45	+0·4	+1·3	+11	+4	+5	+8	+12	+7	45	+0·6	−0·8	−20	+1	−3	−4	−20	0
55	−0·2	+0·2	+7	+5	+1	+3	+7	+5	55	+0·4	−1·2	−19	+2	−4	−5	−19	+1
8 5	−0·2	+0·3	+5	+4	+0	+3	+4	+4	11 5	+0·3	−0·5	−21	+7	−5	−1	−21	+7
15	+0·2	+0·4	+4	−1	+2	+2	+5	−1	15	+0·8	−0·5	−19	+3	−2	−2	−19	+2
25	+0·8	0·0	−1	−1	+4	0	0	−1	25	+1·7	−0·8	−14	+1	+5	−4	−12	0
35	+1·1	+0·4	−10	0	+3	+2	−9	+1	35	+1·7	−1·3	−16	+5	+4	−5	−14	+4
45	+0·6	+0·7	−16	−1	−2	+3	−16	−0	45	+1·8	−2·7	−19	−2	+4	−14	−18	−6
55	+0·7	+0·4	−15	−3	−1	+1	−14	−2	55	+1·7	−3·1	−21	+3	+2	−15	−19	−1

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