CORRELATION BETWEEN SPORADIC *E* IONIZATION AND THE STRENGTH OF THE HORIZONTAL COMPONENT OF THE EARTH'S MAGNETIC FIELD

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Summary

By analysis of geomagnetic and ionospheric data recorded at Brisbane it has been found that the horizontal component of the Earth's magnetic field is decreased in strength by a few gammas during the appearance on ionograms of short-duration echoes, normally interpreted as coming from isolated patches of E_s ionization.

I. Introduction

The possibility of the existence of some definite relationship between the occurrence of an isolated patch of E_s ionization at a given place and a disturbance of the geomagnetic field at that place was indicated by Hojo and Yonezawa (1953), who found that the magnetic declination showed a small change a few hours after the appearance of an intense E_s layer. At Brisbane (geomagnetic latitude 36 °S.) both ionograms and records of variations of the strength of the horizontal component H are regularly made at the same site and it was decided to investigate whether any local relationship existed between the occurrence of short-duration E_s echoes and variations in H. In this connection, " short-duration " is taken to mean echoes which occur only for periods of the order of a few hours, with a maximum upper limit of 10 hours.

II. Equipment

Both " sweep-frequency " 1 to 16 Mc/s ($h'f$), and " fixed-frequency " 2·28 and 3·84 Mc/s ($h't$) ionospheric records were used in the analysis, but $h'f$ ionograms were mainly used as they gave the most information. The type of E_s was not taken into account, the only criterion being that the patches of E_s gave echoes of short duration, isolated in time from any other E_s echoes.

The magnetic records were made using a " flux-gate " type magnetometer recording on paper chart moving at 25 mm/hr and with a recording sensitivity of 4 gammas/mm.

III. Results

Variations in the value of H, measured from the average value of each separate 10-hr period, were plotted, for 5 hr on either side of the centre of the period (called the " central time ") for which isolated patches of E_s were visible on the ionograms, and the average of all such plots was found for each month. A typical example is shown in Figure 1. For almost every month, no matter

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what the season, it was found that the magnetic field strength was decreased by a few gammas for a period of a few hours, with the maximum decrease usually occurring at the central time of the E_s patch.

The average of all the monthly graphs was then found, and the result is shown in Figure 2. This figure is derived from 15 complete months of recording selected from the period between October 1957 and July 1959, and includes 250 separate cases. The vertical lines on the curve represent the magnitude (plus and minus) of the standard deviation of the mean of the values of H at each

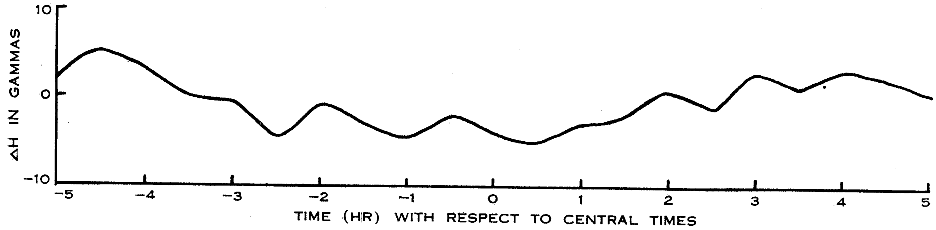

Fig. 1.—Average over 1 month (December 1959) of variations in H over 10-hr periods centred on central times of occurrence of short-duration E_s echoes on local ionograms.

half hour. The accuracy of the mean is greatest at the centre of the figure, and decreases towards the edges since the various curves involved in the averaging process have depressions of different durations and initial and final slopes, so that the spread of points increases considerably towards the start and finish of the average curve.

It will be seen that the decrease in H reaches a value of 7 gammas at the centre of the depression, and since the standard deviation of the values plotted is only of the order of 1 gamma, the depression is highly significant.

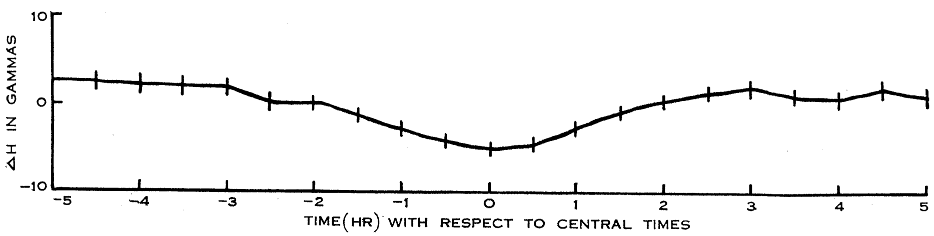

Fig. 2.—Average over the whole 15 complete months included in the analysis (between October 1957 and July 1959) of variations in H over 10-hr periods centred on central times of occurrence of E_s echoes on local ionograms.

The vertical lines through each point on the curve indicate the magnitude (plus and minus) of the standard deviation of the mean of all the values of H used.

Since the Sq variation of H at Brisbane varies from day to day, and also since it reverses its sense from summer to winter, depending on whether the central position of the dynamo current system is north or south of the recording station, it was found necessary to eliminate from the investigation all E_s occurrences whose central times lay between 0700 and 1200 h local time. Typical Sq curves for winter and summer are shown in Figure 3 ; in winter the maximum increase in H is about 30 gammas, while in summer the maximum decrease is about 100 gammas.

A separate analysis showed that the duration of the E_s patch, and the length of time for which the magnetic field was diminished roughly correspond with each other in each individual month. The duration of E_s patches was found to be longer in summer than in winter; thus for the period November to February it was 4 hr, whereas for the period May to July it was $2\frac{1}{2}$ hr. Likewise the average E_s duration for all months—3–4 hr—agrees fairly well with duration of the average depression in H shown in Figure 2.

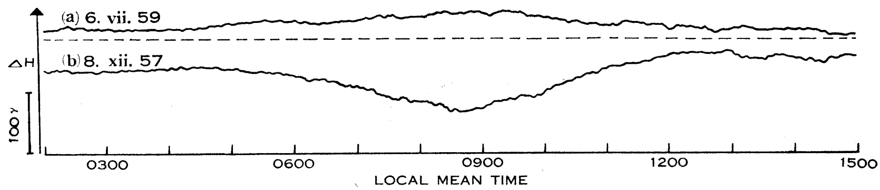

Fig. 3.—Typical Sq curves for H at Brisbane.
(a) In winter; (b) in summer.

In compiling the information presented in Figure 2, the length of each of the periods for which the short-duration E_s echoes were visible on the ionograms was not taken into account—the figure was produced merely by making the central times of the various E_s echo-periods coincide. Then since the durations of the E_s echoes varied from one case to another, the times of start and finish of the associated depressions in H would be blurred out over the left-hand and right-hand halves of the figure respectively, so that Figure 2 thus does not

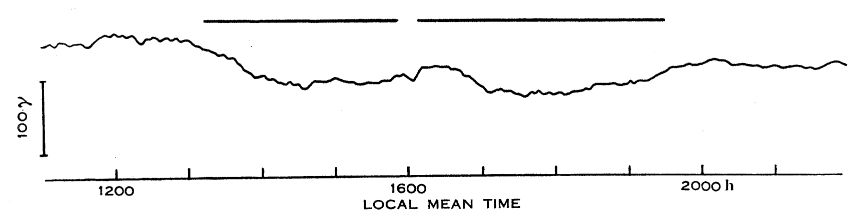

Fig. 4.—Example of apparently good correlation between a depression in H and the occurrence of short-duration E_s echoes—the range of times over which the latter were visible is indicated by the horizontal straight lines.

indicate the behaviour at start and finish of the individual echo periods. Furthermore, it was noted that while obvious correlation in individual cases between E_s occurrences and depressions in H was rare, it did occur occasionally and on such occasions the records suggested that the variation in H associated with the short-duration E_s echoes consisted of a depression occurring within about 30 min of the time the E_s echoes first appeared, and a recovery to normal within about 30 min of their disappearance, there being a relatively constant (diminished) value in between. An example is shown in Figure 4. To check this point further, the value of H was read on a number of occasions half an hour before and half an hour after each patch appeared, and was compared with the value at the actual time of appearance. A similar comparison was made for the time of disappearance of the patch. The average results for 150 representative cases (spread throughout the whole period of the investigation) are plotted in Figures 5 (*a*) and 5 (*b*) respectively. The figures show a decrease of 3 gammas occurring in the hour centred on the time of appearance of the E_s patch, and a corresponding 3 gammas increase in the hour of disappearance.

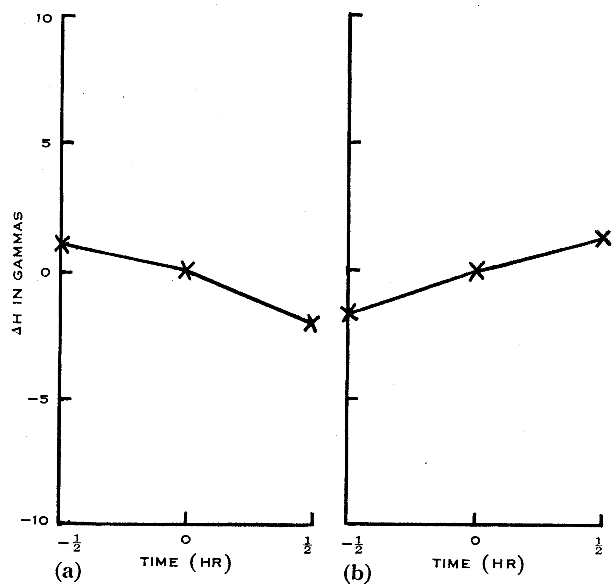

Fig. 5.—Average variations in H within ± 30 min of times of commencement and ending of short-duration E_s echoes. (*a*) Commencement times of E_s echoes coincident; (*b*) termination times of E_s echoes coincident.

IV. Possibility of Coincidental Association

Examination of ionograms made at Brisbane over a number of years showed that the probability of occurrence of isolated patches of E_s ionization was not constant throughout the portion of the day (1200–0700 h L.M.T.) included in the foregoing analysis, but exhibited a maximum between 1700 and 1800 h L.M.T. Correspondingly a plot of the average value of H (relative to some arbitrary zero) showed a well-marked depression at about 1700 h L.M.T. It was therefore necessary to investigate the possibility that the association between the appearance of E_s patches and the depression in H arose merely because both phenomena displayed regular diurnal variations with maximum amplitude at about 1700 h.

To do this, it was decided to take a number of cases of short-duration E_s echoes with their central times spread uniformly over a substantial part of the day (from 1600 to 0200 h) and find the average behaviour of H under such circumstances, thus removing any " weighting " effect due to taking the majority of cases around 1700–1800 h. Since the minimum number of cases of short-duration E_s echoes with central times in the ranges 1600–1700, 1700–1800, . . ., 0100–0200 h was 10, this determined the maximum number of cases that could be used. Accordingly 10 cases were taken with their central times in each of the ten 1-hr ranges listed above, and the average of the 100 cases thereby obtained was found. The result is shown in Figure 6 (*a*).

As a further check, a corresponding 100 cases were taken (10 per 1-hr range as above), this time when no E_s echoes were present. The average curve of the behaviour of H under these conditions is shown in Figure 6 (*b*).

It will be noted that Figure 6 (*a*) still shows a well-defined depression in H, and also that there is a significant difference between Figures 6 (*a*) and 6 (*b*). It thus appears that a real correlation exists between depressions in H and the presence of E_s patches in the vicinity, independent of time of day.

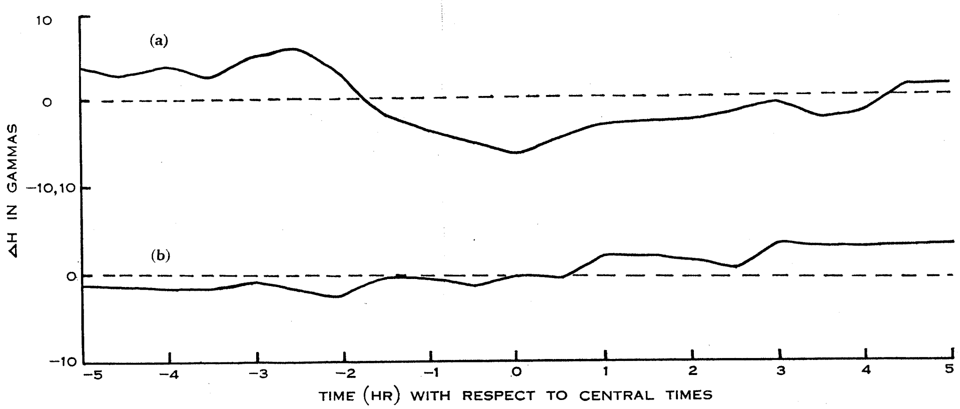

Fig. 6.—Average variation in H over 100 cases, with central times spread uniformly between 1600 and 0200 h.

(*a*) When short-duration E_s echoes were present; (*b*) when E_s echoes were absent.

V. Conclusions

Although there are a number of possible explanations of why H should show a decrease in value coincident with the presence in the vicinity of the observing station of isolated patches of E_s ionization, the lack of information about the behaviour of the E.–W. and vertical components of the geomagnetic field at the relevant times prevented any detailed analysis of the effect. A significant feature of the phenomenon is that H always decreases. It seems that the possibility of the existing overhead dynamo current being concentrated by the presence of an E_s cloud (assuming for the moment that the cloud is more highly conducting than the background), must be ruled out because the dynamo currents themselves do not always decrease H. Likewise the concept of a highly conducting cloud moving relative to the existing magnetic field pattern, and " pushing aside " the magnetic flux through which it moves, is defective because in such a process the flux would leak back into the cloud in a time much less than the periods of several hours for which H is observed to remain decreased. Bowman (1960) has shown that there often exists a close relationship between travelling ripples in the F_2 region ionization contours and the occurrence of isolated E_s clouds. Thus it may be that the magnetic disturbance described above is not primarily due to the presence of the E_s, but is rather produced by associated changes in the height of the highly conducting F_2 layer, somewhat in the manner suggested by Parker (1956).

VI. Acknowledgments

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