Journal of Atmospheric and Terrestrial Physics, Vol. 40, pp. 749–754.
© Pergamon Press Ltd. 1978. Printed in Northern Ireland

0021–9169/78/0601 – 0749 $02.00/0

SHORT PAPERS

MAGNETIC OBSERVATIONS AT THE TIME OF THE 23 OCTOBER 1976 SOLAR ECLIPSE IN AUSTRALIA

F.E.M. Lilley and D.V. Woods

Research School of Earth Sciences, Australian National University, Canberra, Australia.

(Received 28 February 1978)

ABSTRACT - The solar eclipse of 23 October 1976 passed across south-east Australia in the local solar afternoon. This paper records the magnetic observations of a line of ten temporary stations stretching from a region of fifty percent obscuration to the path of totality. Magnetic conditions at the time were mildly disturbed. Analyses of the data have sought an eclipse effect in the basic quiet daily variation, and also in the disturbance variations. However, no eclipse effect in the primary ionospheric currents has been clearly distinguished above spatial uneveness, due to local differential induction, in the induced secondary currents flowing in the earth.

1. INTRODUCTION

Magnetic effects accompanying solar eclipses have been sought for some eighty years, following the pioneering work by L.A. Bauer (1900, and see Harradon 1932). Introductory reviews are included in Egedal and Ambolt (1955) and Matsushita (1967), and observations have been reported by Astbury (1952), van Wijk (1955), Roy (1964), Boyd (1966), Bomke et al. (1967), Lanzerotti et al. (1971) and Stening et al. (1971). There are several relevant papers in Beynon and Brown (1956).

There appear to be a number of examples where clear magnetic effects have accompanied eclipses, of the order approximately as predicted by Chapman (1933; see also Volland 1956, 1957, and Ashour and Chapman 1965). Chapman's theory is based on eclipse shadow reducing ionospheric electrical conductivity, and so perturbing the flow of the widespread quiet daily variation (Sq) electric currents. The most convincing observations are those made near the equator, (for example Y. Kato's 1958 Suwarrow Island observations as reported in Matsushita 1967, and Bomke et al. 1967), as might be expected because the Sq current pattern has its greatest intensity in equatorial regions. In addition to the observations made during eclipses at times of magnetic calm, there have also been various observations at times of magnetic activity.

2. THE SOLAR ECLIPSE OF 23 OCTOBER 1976

The path of the eclipse across Australia is shown in Fig. 1 with the relevant observing stations marked. Daily-variation current patterns indicate that the Sq currents should be

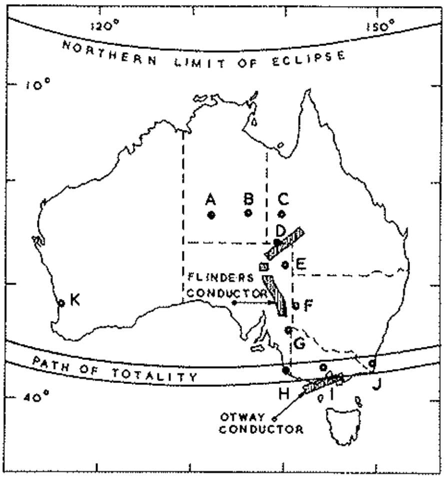

Fig. 1. The magnetic observing stations and the main known regions of electrical conductivity structure (in addition to the coasts) which give rise to anomalous natural electromagnetic induction. The northern extension of the "Flinders Conductor" is tentative. Sites: A 23°09'S, 132° 09'E; B 22°54'S, 136°07'E; C 22°55'S, 139°53'E; D 25°55'S, 139°20'E; E 28°08'S, 140°14'E; F 32° 00'S, 141°28'E; G 34°12'S, 140°42'E; H 37°35'S, 140°23'E; I 37°13'S, 144°27'E; J 36°55'S. 149° 54'E; K 31°47'S, 115°57'E. Eclipse path from Fiala and Duncombe (1975).

almost entirely north-south over Australia at the time of the eclipse, so that the simple "Chapman" eclipse effect should be sought in the east (D or Y) component of variation.

3. THE OBSERVATIONS

The stations A to J were Gough-Reitzel variometers as described by Lilley et al. (1975), recording the three components of magnetic fluctuations on film every ten seconds. They were calibrated before and after the eclipse. Four hours of data, digitized and reduced to geographic coordinates, are shown plotted for all stations in Fig. 2, which also includes observations from the West Australian observatory Gnangara.

4. ANALYSIS OF THE RECORDS

4.1 X-traces. The X-traces show mild activity about the time of the eclipse, superimposed on the daily variation.

4.2 Y-traces. The Y-traces for stations A to J show mainly quiet daily variation, with appropriate phase shifts for local solar-time differences between the stations A, B, C and H, I, J, which lie along west-east paths. There is on all Y-traces a rapid depression commencing at about 0711 UT, and on most traces a minimum at about 0638 UT superimposed on the smoothly decreasing daily variation.

The coincidence of this latter event with eclipse totality in south-east Australia led the authors initially to conclude that the event might have been a simple eclipse effect (Lilley and Woods 1977, see also Scheepers, 1978). The amplitude of the event decreases with increasing distance northward from the path of totality, but its simultaneous occurrence at all stations is evidence against it being a simple "Chapman" eclipse effect, which would be expected to move west to east at the same rate as the eclipse shadow, with approximately six minutes difference between stations A and C, and H and J.

The Y-record for station K (Gnangara) is more disturbed than for stations A to J, and also reflects the different time of the local solar day at this western station. The 0638 UT event is missing, but there are some other disturbances which correlate with the general pattern of X-disturbance.

4.3 Z-traces. The change in character of the Z-trace from station to station demonstrates the differences in geomagnetic induction which occur across the Australian continent. Figure 1 shows the main electrical conductivity structures found so far for Australia, the effects of which, together with the coastal contrasts, can be seen in the vertical component data of Fig. 2. The coast effects, particularly strong at stations H,J and K, have been studied and described elsewhere (Parkinson 1959, Bennett and Lilley 1974, Lilley and Parker 1976). The mid-continental Z reversal for the 0711 UT event, evident between stations C and E may be due to a northward extension of the "Flinders conductor" (Gough et al. 1974) the response of which can be seen at stations F and G.

Because the vertical component of variation reflects local electrical conductivity structure of the earth so strongly, it does not provide promising data in a search for eclipse effects.

5. DIFFERENCING BETWEEN RECORDS

With a timing accuracy of seconds for the records A to J, accurate differencing between them has been possible. These differences are shown plotted in Fig. 3. A number of points are relevant, (restricting remarks now to the horizontal components X and Y only).

5.1 Y-differences along H, I, J, and A, B, C. The "Chapman" eclipse effect would be sought first in the Y-differences H-I and I-J, which should both show the same crude time-derivative of the effect, with a phase difference between them corresponding to the speed of the eclipse along the line H to J. In fact the characteristics of the H-I and I-J differences are not similar, and can be seen instead to have some correlation with the basic X-variations of Fig. 2. This indicates that the H-I and I-J differences may be dominated by local induction in the "Otway" conductor of southern Victoria (Lilley 1976) shown on Fig. 1, and any "Chapman" eclipse effect in them obscured.

The differences between the other west-east stations, A-B and B-C, are less affected by local differential induction. These two difference traces however, appear too disturbed to demonstrate a time-derivative of the Chapman effect, expected to be weakened in such a region of partial eclipse.

5.2 X-differences along the line C to H. It has been noted that for reasons of the north-south alignment of the Sq currents, a quiet-day eclipse effect would be sought in the Y-variation component. The minor activity on the X-records of Fig. 2, however, indicates east-west disturbance currents which could themselves be affected by lowered ionospheric conductivity in an eclipse shadow.

The more southerly stations in the line C to H might then be expected to show relatively lessened activity about the time of the eclipse, which should be evident in the X-differences of Fig.3 as a peak in a modulated form of the basic X-activity as the eclipse passes over. No such effect has been discerned, however, beyond the tendency (evident on Fig. 2) of station H to respond more strongly to the major X reduction between about 0625 and 0711 UT. This characteristic may reflect source current distribution or local induction, and has little justification for being linked with the eclipse.

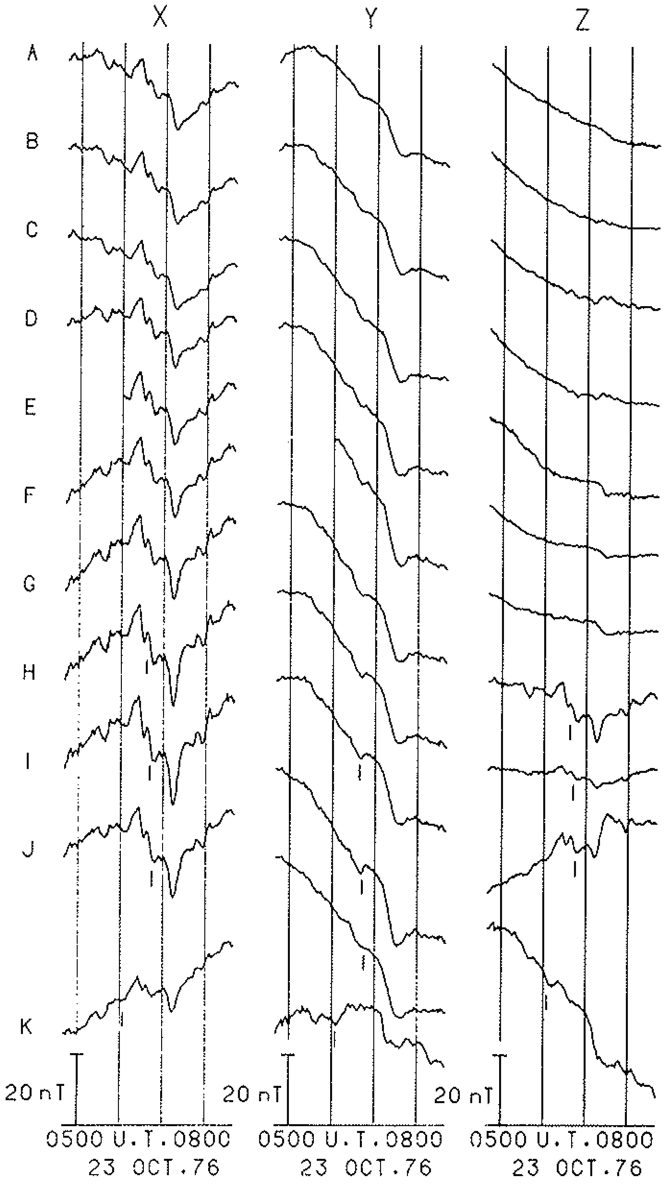

Fig. 2. Reduced magnetic variometer records for the four hours 0440 to 0840 UT 23 October 1976, plotted from data points at 1 min. intervals. The time of mid-eclipse totality on the ground is marked with vertical bars for stations H, I and J. For station K the bars mark the time of the nearest approach of ground totality.

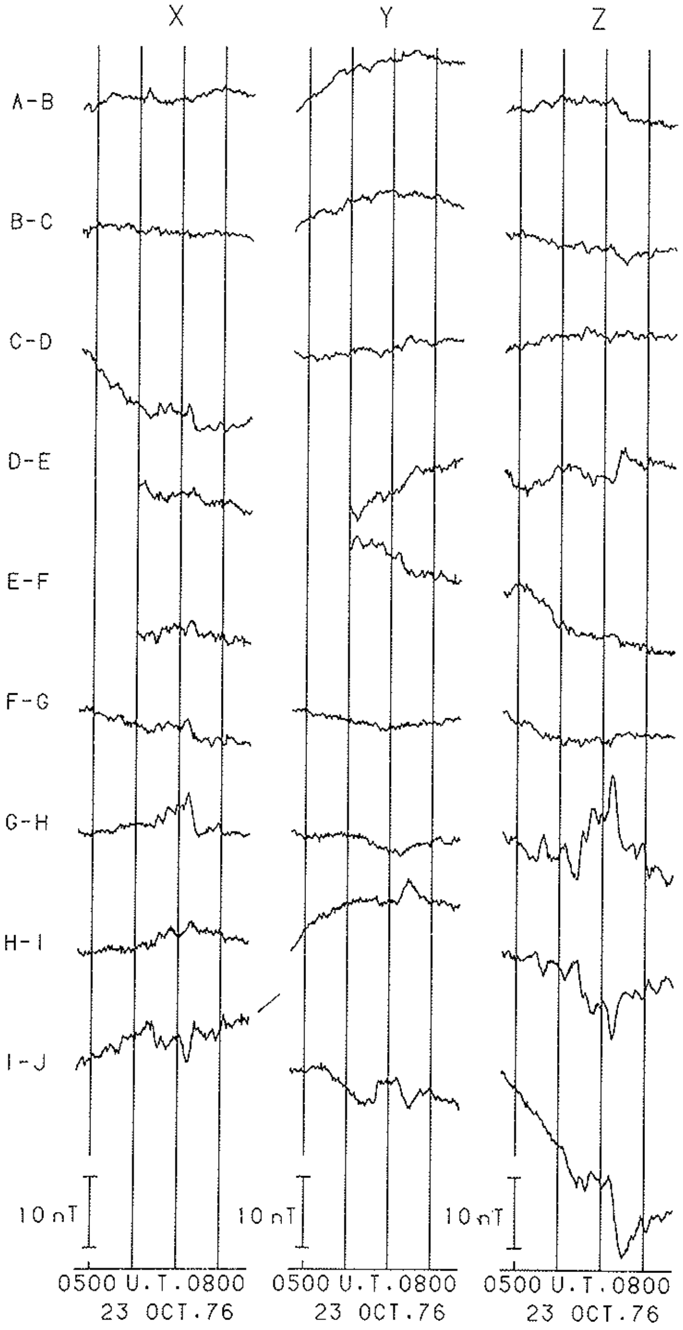

Fig. 3. Differences between the records of adjacent variometers from Fig. 2.

6. CONCLUSION

A simple magnetic effect occurring as a result of the solar eclipse has not been satisfactorily demonstrated. The array of stations might have been a sufficiently powerful tool to separate out the minor activity and demonstrate whether or not a "Chapman" quiet-day effect was present, but for the "contamination" of the observations by local inhomogeneous induction.

There remains the possibility, unexplored here, that some of the magnetic activity was itself associated with the eclipse, by ionospheric mechanisms more complicated than the partial avoidance by Sq electric currents of an eclipse shadow.

Related papers on the 23 October 1976 eclipse have been published by Baulch and Butcher (1977), Hajkowicz (1977), and Waldmeier (1977).

ACKNOWLEDGEMENTS

The imminence of the eclipse and the possible interest of magnetic observations made during it was first pointed out to one of us by V.R.S. Hutton. In the planning stages, advice from W.H. Campbell, J.A. Eddy, M.W. McElhinny, A.L. Hales and S. Matsushita was much appreciated. J. Styles gave valuable assistance with the field-work, and M.N. Sloane with the data reduction and plotting. In the collation of data we thank the Bureau of Mineral Resources for the Gnangara records, and W.D. Parkinson and C. Bisdee for magnetic records from northern and southern Tasmania. We thank G.L.M. Scheepers for sending records from South Africa, and for correspondence on the effects of local induction. We also acknowledge discussions on the ionospheric effects of the eclipse with B.H. Briggs, E.C. Butcher, D.G. Cole and K.D. Cole.

REFERENCES

Astbury, N.F. 1952, Nature 170, 68.
Ashour, A.A. and Chapman, S. 1965, Geophys.J.R.astr.Soc. 10, 31.
Bauer, L.A. 1900, Terr.Mag. 5, 143.
Baulch, R.N.E. and Butcher, E.C. 1977, Nature 269, 497.
Bennett, D.J. and Lilley, F.E.M. 1974, Geophys.J.R.astr.Soc. 37, 191.
Beynon, W.J.G. and Brown, G.M. 1956, J.atmos.terr.Phys. 6, special supplement, 330pp.
Bomke, H.A., Blake, H.A., Harris, A.K., Hulse, W.H., Sheppard, D.J., Giesecke, A.A. and Pantoja, A. 1967, J.geophys.Res. 72, 5913.
Boyd, G.M. 1966, Earth planet.sci.Letts., 1, 333.
Chapman, S. 1933, Terr.Mag. 38, 175.
Egedal, J. and Ambolt, N. 1955, J.atmos.terr.Phys. 7, 40.
Fiala, A.D. and Duncombe, J.S. 1975, U.S. Naval Obs.Circ. 152, 23pp.
Gough, D.I., McElhinny, M.W. and Lilley, F.E.M. 1974, Geophys.J.R.astr.Soc. 36, 345.
Hajkowicz, L.A. 1977, Nature 266, 147.
Harradon, H.D. 1932, Terr.Mag. 37, 221.
Lanzerotti, L.J., Maclennan, C.G., Medford, L.V. and Tartaglia, N.A. 1971, J.G.R. 76, 3684.
Lilley, F.E.M. 1976, Geophys.J.R.astr.Soc. 46, 165.
Lilley, F.E.M., Burden, F.R., Boyd, G.W. and Sloane, M.N. 1975, J.Geomag.Geoelectr. 27, 75.
Lilley, F.E.M. and Parker, R.L. 1976, Geophys.J.R.astr.Soc. 44, 719.
Lilley, F.E.M. and Woods, D.V. 1977, Nature 266, 823.
Matsushita, S. 1967, in "Physics of Geomagnetic Phenomena", Academic Press, N.Y., 301.
Parkinson, W.D. 1959, Geophys.J.R.astr.Soc. 2, 1.
Roy, J.L. 1964, Canad.J.Phys. 42, 831.
Scheepers, G.L.M. 1978, Nature 271, 91.
Stening, R.J., Gupta, J.C. and van Beek, G.J. 1971, Nature Phys.Sci. 230, 22.
van Wijk, A.M. 1955, J.geophys.Res. 60, 297.
Volland, H. 1956, J.atmos.terr.Phys. 9, 131.
Volland, H. 1957, J.atmos.terr.Phys.11, 1.
Waldmeier, M. 1977, Nature, 265, 611.