Evidence of a Phase Reversal in the Quiet Day Variation of the Magnetic Vertical Intensity at Marion Island

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Absolute observations of the geomagnetic Z component done on Marion Island on two consecutive quiet days in May 1971 showed a phase reversal in the daytime variation of this component when compared with the expected Sq variation for the latitude of the Island. The results are compared with theoretical approximations for the "island effect" and with experimental results obtained by other workers who found the "island effect" only for periods much shorter than that for which the effect is observed at Marion Island.

Absolute waarnemings van die geomagnetiese Z-komponent wat op twee agtereenvolgende stil dae in Mei 1971 te Marioneiland gemaak is, het 'n fase-omkering in die dagvariasie van dié komponent getoon, wanneer dit vergelyk word met die verwagte Sq-variasie by die breedtegraad van diè eiland. Die resultate word vergelyk met teoretiese benaderings van die „eilandeffek" en met eksperimentele resultate verkry deur ander ondersoekers, wat die „eilandeffek" slegs vind vir periodes veel korter as dié waarin die effek te Marioneiland waargeneem is.

Introduction

During May 1971, when the supply ship *RSA* visited the meteorological station at Marion Island (46,85°S, 37,87°E geographic), observations of the geomagnetic horizontal intensity (H), vertical intensity (Z), and total intensity (F), were made at a secular variation observation point on the island. The observations were made with a QHM(H), a BMZ(Z), and a proton magnetometer (F), and even though no continuous recording of the magnetic field was made, the observations were sufficiently complete on three days (May 10, 11, and 19) to give an approximation of the Sq variation at the island. Of these three days, the 19th showed disturbed magnetic conditions during the observation period, while the 10th and 11th were relatively quiet. The data obtained on the 19th were therefore excluded from the following analysis, even though they exhibited the same daily variation as was found on the 10th and 11th.

Observations were only possible during daylight, with the result that data were only obtained for the period 0730 – 1630 local mean time. This period, however, covers the main part of the Sq pattern.

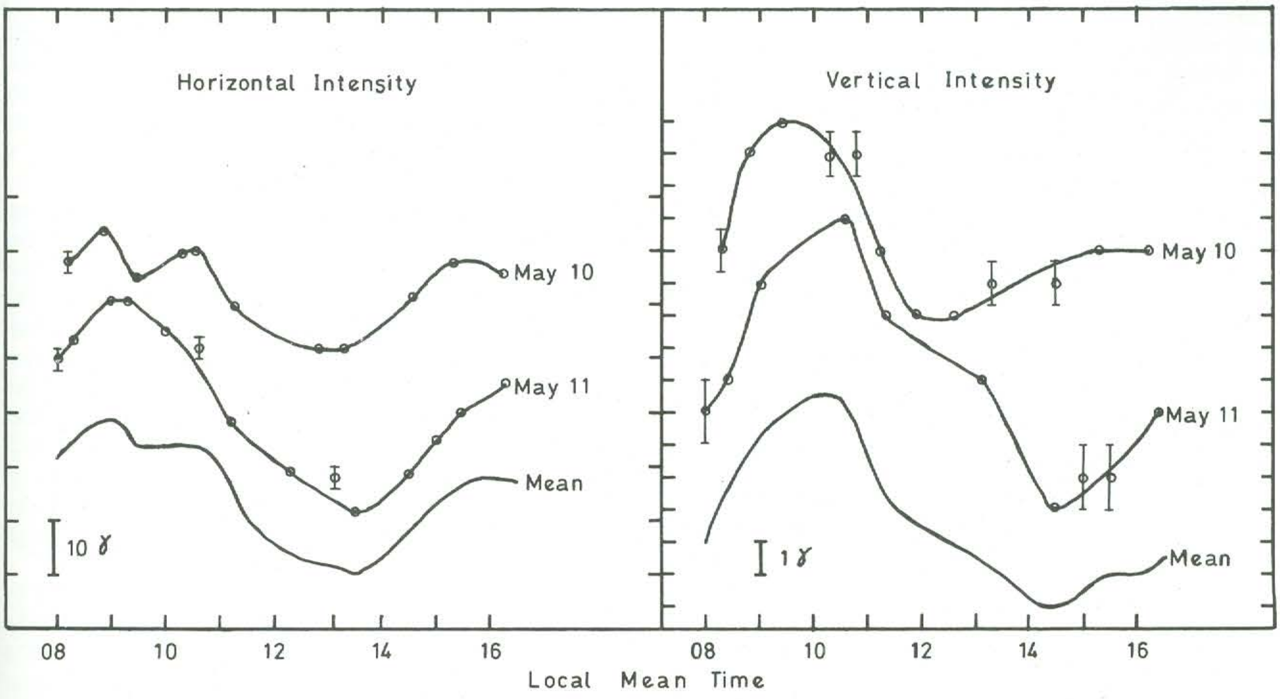

Fig. 1. Temporal variation of horizontal and vertical intensity at Marion Island.

*Seconded to the Antarctic Programme by the Council for Scientific and Industrial Research

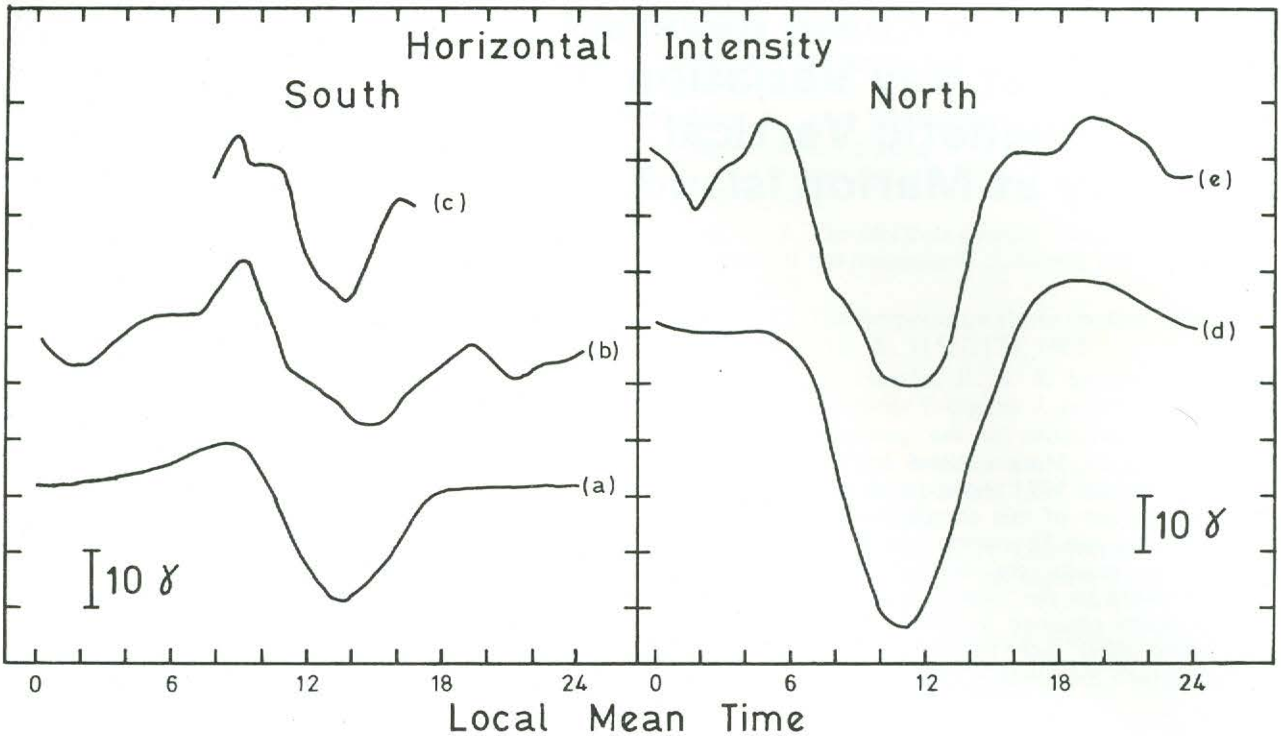

Fig. 2. Daily variation of horizontal intensity at Hermanus (b), Marion Island (c), and Rude Skov (e). Curves (a) and (d) show the expected variation in the southern and northern hemispheres respectively.

Experimental Results

The temporal variation of the magnetic horizontal and vertical intensities on the two days (May 10 and 11) is given in Fig. 1, together with the mean variation for the two days. Each datum point on the curves for the individual days is the mean value of a series of five observations.

In Figs. 2 and 3, the mean variation of H and Z at Marion for the two days is compared with the mean daily variation for the same two days at Hermanus and at Rude Skov (which lies close to the magnetic conjugate point of Marion). Also included in these figures are curves showing the expected quiet day variation of H and Z in the northern and southern hemispheres. during the June solstice (from Fig. 8 of *Matsushita*, 1967).

These figures show that the mean daily variation of H and Z at both Hermanus and Rude Skov agrees well with the expected variation in their respective hemispheres. The data for the two days also seem to be sufficient to reproduce this expected variation. When comparing the mean variation at Marion, however, it is evident that while H is in agreement with the expected variation in the Southern hemisphere, the variation in Z is approximately 180° out of phase with what would be expected. The range of the variation in Z is also smaller by a factor of 3 when compared with that at Hermanus. These two stations are very nearly on the same dip latitude, while Hermanus lies 10° equatorward of Marion in invariant latitude.

Discussion

The anomalous behaviour of the magnetic vertical intensity on islands, the so-called "island effect", has been reported by *Parkinson* (1962), *Mason* (1963), *Voppel* (1964), *Lawrie* (1965), and *Sasai* (1967). Mason made observations at a number of points on Christmas Island and found short-period magnetic disturbances in Z at the south-east to be 180° out of phase with disturbances at the north-west of the island. When considering the quiet day variation in Z, however, he found phase differences of up to 70°. *Sasai* (1967) reported on observations made on Oshima Island. He observed the island effect on short period variations, but found no significant phase shifts in the quiet day variation, and concluded that: "... the anomaly observed for the short period range vanishes at a period ranging from 8 to 24 hours".

The island effect is explained by considering electrical currents induced in the sea by overhead ionospheric currents. The island then acts as a region of low conductivity in a sheet of high conductivity, and consequently the current flow around it is modified. This concept is illustrated in Fig. 4 for the ideal case of a circular island. It is clear from this figure that the vertical magnetic field of the induced current at point P will be 180° out of phase with that at point P′ which lies on the opposite side of the island. Points Q and Q′ are on the sides of the island perpendicular to the direction of current flow and should show no change in Z.

This explanation was formulated theoretically by *Rikitake* (1964) and by *Ashour & Chapman* (1965). Rikitake considered the highly idealized case of a round hole in a perfectly conducting sheet, while Ashour and Chapman considered the more realistic case of a conducting sheet with a circular area of different uniform conductivity. Ashour and Chapman found a reversal in the direction of the vertical magnetic field across the circular discontinuity in a direction perpendicular to the current flow, with the largest values of this vertical magnetic field at the boundary of the discontinuity.

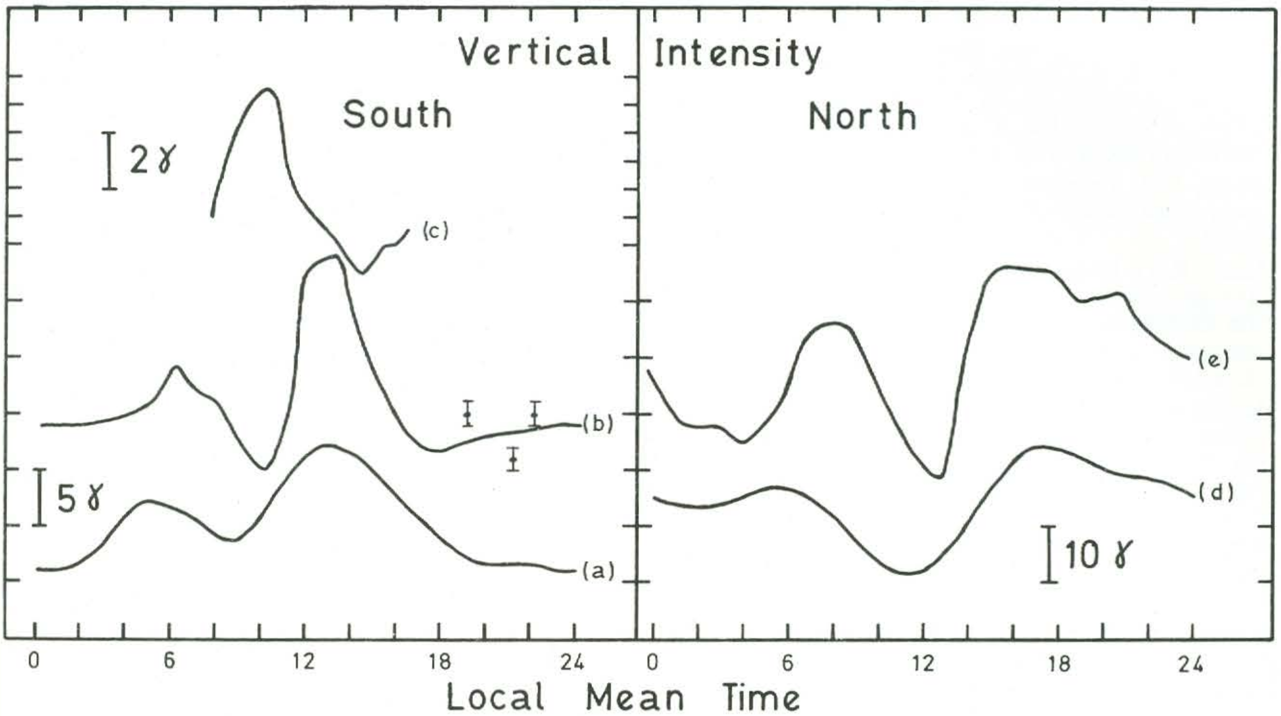

Fig. 3. Daily variation of vertical intensity at Hermanus (b), Marion Island (c), and Rude Skov (e). Curves (a) and (d) show the expected variation in the southern and northern hemispheres respectively.

Both the above papers consider only the steady-state problem by determining the effect of an existing current. *Rikitake* (1970) extended the problem to include the effects of periodic induction. He found, to a first approximation, that the magnetic field of the induced current is proportional to a quantity C, which is defined as:

$$C = \frac{2\pi}{T} KR$$

for periodic induction with period T in a sheet with conductivity K (which represents the sea), and with R the radius of the discontinuity (the island). This equation is in agreement with the observations reported by *Sasai* (1967), in that the magnetic field of long-period induction becomes small enough to be unobservable.

When the Marion observations are compared with the theoretical results mentioned above, it is clear that the phase inversion observed is in agreement with the steady state theory of *Ashour & Chapman* (1965). The induced current flows from west to east past Marion Island, which means that the quiet day variation on the north-east side of the island, where the observations were made, should be 180° out of phase with the variation expected from the inducing Sq current. It is, however, interesting that this phase inversion is observed for such a long-period variation, particularly as it is not supported by Rikitake's theoretical model, or by Sasai's experimental observations. The phase difference is also much larger than the 70° phase difference observed by *Mason* (1963).

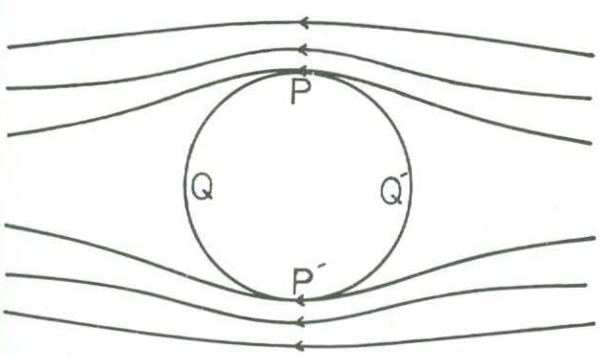

Fig. 4. Representation of the flow of electrical current in a conducting medium around a non-conducting circular discontinuity.

Conclusion

The present small number of magnetic observations obtained at Marion Island apparently show quite interesting discrepancies in the frequency dependence of the island effect. A more conclusive investigation will, however, only be possible when a more intensive magnetic survey of the island has been made, and when continuous recording of the magnetic field is done at Marion Island.

Acknowledgements

We should like to thank the South African Department of Transport for their sponsoring of the survey on Marion Island; the CSIR Magnetic Observatory at Hermanus for equipment made available for the survey; and the Rude Skov Observatory for unpublished data provided by them.

The Editor thanks S. Matsushita for his assistance in evaluating this paper.

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(Received 18 March, 1972; accepted 2 May, 1972.)

Latitude Distribution of Cosmic Rays at Sea Level from 1963 to 1970

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The latitude distribution of cosmic rays at sea level, in the region of the Cape Town Magnetic Anomaly, compares well with the distribution in the North American region when vertical cutoff rigidities computed from particle trajectories in a simulated geomagnetic field are used. From the North American latitude distribution during minimum modulation of cosmic rays in May 1965, the distributions in January of each year from 1963 through to 1970 were calculated. They were found to compare well with the survey data if uncertainties in air pressure and changes in the rigidity dependence of the modulation of cosmic rays in 1969 and 1970 were taken into consideration.

Die breedtegraadspreiding van kosmiese strale op seevlak in die gebied van die Kaapstadse Magnetiese Anomalie vergelyk goed met die spreiding oor Noord-Amerika indien vertikale afsnystyfhede, bereken met deeltjiebane in 'n gesimuleerde geomagnetiese veld, gebruik word. Uitgaande van die Noord-Amerikaanse breedtegraadspreiding gedurende minimummodulasie van kosmiese strale in Mei 1965 is die breedtegraadspreiding vir Januarie van elke jaar van 1963 tot 1970 bereken. Die waargenome breedtegraadspreiding vergelyk goed met hierdie berekende spreidings as die onsekerhede in lugdruk en die veranderinge in styfheidsafhanklikheid van die modulasie van kosmiese strale in 1969 en 1970 in aanmerking geneem word.

Introduction

The intensity of the horizontal component of the geomagnetic field reaches a local maximum in a region slightly to the south of South Africa, the region being known as the South African or Cape Town Magnetic Anomaly. This is a true geomagnetic anomaly in the sense that it cannot be explained only by a magnetic dipole. The Brazilian Magnetic Anomaly is characterized by a minimum in the total intensity of the earth's field, situated at and off the coast of Brazil. This anomaly can be explained by a magnetic dipole displaced from the centre of the earth in the direction opposite to the Brazilian region.

Since the trajectories of cosmic rays are greatly influenced by the magnetic field they traverse, the effect of the anomaly should be apparent on cosmic rays recorded on earth in the region of the South African Magnetic Anomaly. *Van der Walt et al.* (1969) have shown that the effect of the anomaly on cosmic rays recorded in the vicinity of South Africa can be explained when vertical cutoff rigidities from computer-calculated trajectories of cosmic rays in a simulated geomagnetic field are used. This is also apparent from the surveys conducted by *Kodama*

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