The Antarctic Tern is not easily distinguished from some Palaearctic terns, and hitherto it has often been overlooked in South Africa. A specimen collected at Cape St. Francis on 23 July 1936 and stated to be a Common Tern, *S. hirundo*, (illustrated in Hewitt, 1937) has been identified as a juvenile Antarctic Tern (Liversidge, 1957).

Another early record, by Courtenay-Latimer (1957), is confusing and incomplete, and her report of the Antarctic Tern breeding in South Africa on Stag Island, Algoa Bay, in the winter of 1940 has been accepted by modern texts (McLachlan & Liversidge, 1970; Watson, 1975). The breeding record is open to doubt, since, apart from the apparently abnormal breeding season, adult Antarctic Terns moult while in South Africa (pers. obs.) and it is unusual for terns to breed while moulting. Elsewhere in its range the bird is strictly a summer breeder (Berruti & Harris, 1976; Hagen, 1952; Parmalee & Maxson, 1974) The record has never been subsequently verified.

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A note on the daily variation of the geomagnetic vertical intensity at Marion Island

P.R. Sutcliffe

Antarctic Geomagnetic Programme,
Magnetic Observatory of the CSIR, Hermanus.

Significant phase shifts occur in the daily variation of the geomagnetic vertical intensity at Marion Island. These phase shifts are not due to the 'island effect', as previously reported, but are brought about by the $L_2(Z)$ variation and are functions of the lunar phase angle.

Beduidende faseverskuiwings kom voor in die daaglikse variasie van die geomagnetiese vertikale intensiteit op Marion Eiland. Dié faseverskuiwings is nie te wyte aan die 'eilandeffek' soos voorheen vermeld nie, maar word teweeggebring deur die $L_2(Z)$ variasie en is 'n funksie van die maan se fasehoek.

Introduction

The daily variation of the geomagnetic vertical intensity Z at inland observatories on quiet days consists essentially of the solar quiet day variation $Sq(Z)$ plus a small perturbation due to the lunar daily variation $L(Z)$. However, the daily variation at coastal and oceanic island observatories is sometimes significantly modified by other factors. Malin (1969) reported an anomalously large value of the lunar semi-diurnal variation $L_2(Z)$ at coastal observatories and ascribed it to the generation of electric currents in the sea due to tidal movements of the conductive water across the geomagnetic field. The anomalous behaviour of the magnetic vertical intensity on oceanic islands, known as the 'island effect', has been reported by Mason (1963), Voppel (1964), and Sasai (1967).

Since an island acts as a region of low conductivity in a sheet of high conductivity, currents induced in the ocean are compelled to flow around the island; consequently the vertical component of the magnetic field produced by the induced current will be in opposite senses on opposite sides of the island. Numerous workers (Mason, 1963; Voppel, 1964; Sasai, 1967) have reported a complete reversal in sign for short-period disturbances of one hour or less, while Mason (1963) found phase shifts of up to 70° in the daily variation. Sasai (1967) concluded that the island effect, which is observed for the short-period range, vanishes at a period ranging from 8 to 24 hours. Rikitake (1970) confirmed theoretically that the phase shift is a function of the frequency of the variation. Kühn and Sutcliffe (1972) however, presented evidence of a phase reversal in $Sq(Z)$ at Marion Island (46°52′,5S, 37°50′,8E) and attributed it to the 'island effect'. In this note we show that substantial phase shifts are observed in the daily variation of Z at Marion, but that these can be explained without requiring the inconsistency of the frequency dependence of the island effect as suggested by Kühn and Sutcliffe (1972).

Data selection and analysis

The observations on which Kühn and Sutcliffe (1972) based their conclusions were made with a BMZ on 10 and 11 May 1971. Subsequently, a magnetic observatory was established on Marion Island and hourly mean values for the period 1 June 1973–31 May 1975 are available. Sutcliffe (1977) utilized these data to study Sq at Marion. He found that the range of the mean $Sq(Z)$ is anomalously small, especially during equinoctial and winter months, but found no evidence of a phase reversal.

Provided there is no significant magnetic activity present, the daily variation observed on any specific day will consist of Sq modified in a regular way, with a period of half a lunar

Table 1

List of magnetic observatories whose data were used in this paper

Name	Geographic coordinates		Geomagnetic coordinates		Position
Marion	46°52′,5S	37°50 ,8E	−49°,1	94°,8E	Island
Hermanus	34°25′,5S	19°13 ,5E	−33°,7	81°,7E	Coast
Hartebeesthoek	25°52′,9S	27°42 ,4E	−27°,0	92°,7E	Inland
Fürstenfeldbruck	48°09′,9N	11°16′,6E	48°,8	93°,3E	Inland

month, by the lunar semi-diurnal variation. In this analysis magnetic disturbance effects were excluded by discarding data for days on which any one of the 8 K_p indices was greater than 3_+. The data utilized were the hourly mean values of the geomagnetic vertical component Z. In order to bracket the dates 10 and 11 May, the available April, May and June data were used.

The days selected for analysis were divided into 12 groups according to the lunar phase angle ν which increases from 0 to 11 twice per lunation. It is given by:

$$\nu = 23{,}3827 + 29684{,}4748T + 0{,}000112T^2 \qquad (1)$$

but must be reduced by 12 during the interval from full moon to new moon, and where T denotes the time in Julian centuries measured from midday 31 December 1899. After removal of the non-periodic trend using the method suggested by Parkinson (1971), the mean variation for each group was determined and expressed as a finite Fourier series

$$S(t) = S_0 + \sum_{n=1}^{4} S_n \sin(nt + \alpha_n) \qquad (2)$$

where S_0 = mean of 24 hourly values,
S_n = amplitude of harmonic component n,
α_n = phase angle of harmonic component n.

The amplitudes and phase angles obtained for each of the 12 groups were used in Equation 2 to synthesise 24 values of S at hourly intervals. The mean value for each hour determined from these 12 groups is independent of lunar variation, thus these 24 mean values together constitute the Sq variation. A Fourier analysis was made of this mean curve in order to obtain harmonic components independent of lunar effects.

Results

The amplitudes and phase angles of the diurnal and semi-diurnal waves of the Marion Z daily variation for the 12 lunar phases are presented in Figs 1*a* and *b* respectively in the form of harmonic dials (Chapman and Bartels, 1940); the vector end-points are represented by circles and numbered according to lunar phase angle ν. The end-point of the vector representing the Sq variation is indicated by the triangle. Fig. 1*a* shows that the Sq variation is the dominant component of the diurnal wave. The random distribution of the vector end-points can probably be ascribed to magnetic activity and seasonal effects since the diurnal wave of $Sq(Z)$ is particularly sensitive to such effects (Sutcliffe, 1977). However, from Fig. 1*b* we see that the situation for the semi-diurnal wave is quite different. The end-points of the semi-diurnal wave vectors lie in a circle, the centre of which is slightly displaced from the origin. This displacement of 0,6 nT represents the Sq semi-diurnal wave vector and is significantly smaller than the 2,4 nT mean amplitude of the $L_2(Z)$ vectors.

In order to compare the semi-diurnal component of the daily variation observed at Marion with that commonly encountered, we make use of the magnetic observatories listed in Table 1. Note that Fürstenfeldbruck lies close to the conjugate point of Marion. Data from these observatories were analysed in a manner similar to that described above for Marion. Harmonic dials depicting the semi-diurnal variations at Hermanus, Hartebeesthoek and Fürstenfeldbruck are presented in Figs 2*a*, *b* and *c* respectively. We see that Sq is the dominant component of the semi-diurnal wave at all three observatories in contrast to the case at Marion. At Hermanus, a coastal observatory, a regular motion of the vector end-point in unison with lunar phase angle ν is evident, although this motion is not as smooth as that at Marion. At Hartebeesthoek and Fürstenfeldbruck, both inland observatories, the vectors appear to be randomly distributed about the Sq vector with no regular lunar variation discernable. The random component of the distribution can probably be ascribed to the day-to-day variability of Sq (Schlapp, 1968) and small magnetic disturbances which were not excluded by the method of data selection.

The times at which the semi-diurnal waves attain their maximum values twice a day can be read from the harmonic dials. From Fig. 2 we see that at Fürstenfeldbruck these times remain constant within half an hour, while at Hartebeesthoek and Hermanus the variations in times do not exceed $1\frac{1}{2}$ and $2\frac{1}{2}$ hours respectively. At Marion, however, the times at which the maxima occur vary with the full 12-hour period of the wave in unison with the lunar phase angle ν.

We now consider how $L_2(Z)$ affected the daily variation of

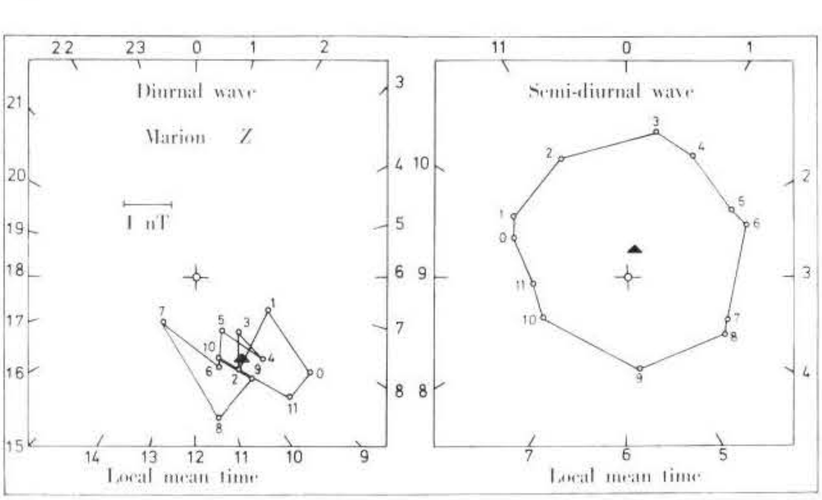

Fig. 1. Harmonic dials for the diurnal and semi-diurnal waves of the daily variation of Z at Marion Island during the 12 lunar phases. Vector end-points are represented by circles and numbered according to lunar phase angle. The triangle indicates the end-point of the $Sq(Z)$ vector component.

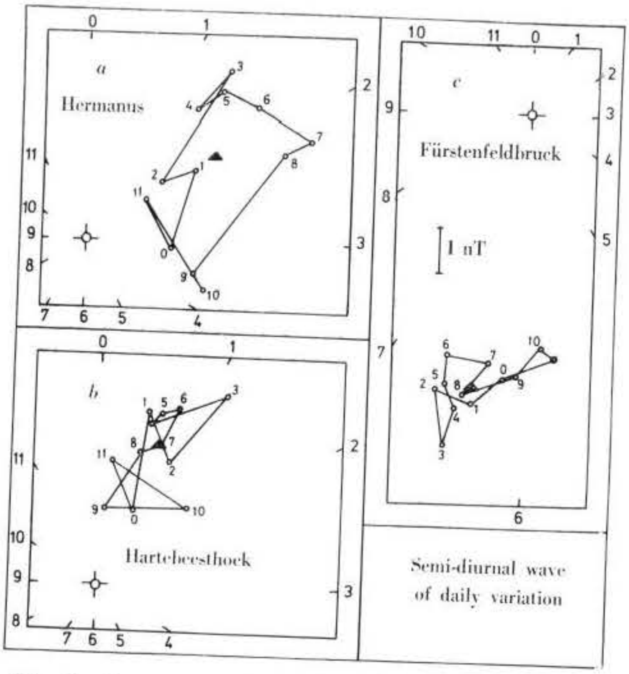

Fig. 2. Harmonic dials for the semi-diurnal waves of the daily variation of Z during the 12 lunar phases. Vector end-points are represented by circles and numbered according to lunar phase angle. The triangle indicates the end-point of the $Sq_2(Z)$ vector.

Z on 10 and 11 May 1971. According to Equation 1 the lunar phase angles were $\nu = 0$ and $\nu = 1$ respectively on these two days. In Fig. 3 the following curves, displaced vertically with respect to each other, are plotted:

(*a*) the mean synthesised daily variation for days on which $\nu = 0$ and $\nu = 1$,

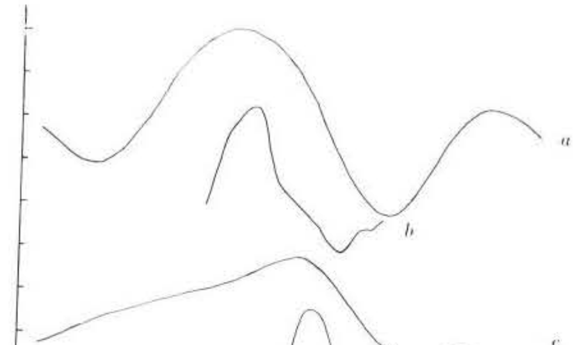

Fig. 3. The curves represent: (*a*) the mean daily variation at Marion when $\nu = 0$ and $\nu = 1$, (*b*) the mean variation at Marion on 10 and 11 May 1971, (*c*) the mean $Sq(Z)$ at Marion Island, and (*d*) the mean $Sq(Z)$ at Hermanus for the months April, May and June.

(*b*) the mean variation determined from the BMZ observations on 10 and 11 May 1971,

(*c*) the mean $Sq(Z)$ at Marion for the months April, May and June, and

(*d*) the mean $Sq(Z)$ at Hermanus for the months April, May and June.

Curve (*d*) is similar to the winter solstice $Sq(Z)$ curve for dip-latitude 50°S (Matsushita, 1967) which was used by Kühn and Sutcliffe (1972) for comparison with curve (*b*). The difference between curves (*b*) and (*d*) is clear and led them to conclude, albeit erroneously, that there was a phase reversal of $Sq(Z)$ at Marion. From Fig. 1*b* we see that during daylight hours the semi-diurnal variation, on days on which $\nu = 0$ and $\nu = 1$, attains its maximum value at approximately 0930 LT, while the maximum in $Sq_2(Z)$ occurs at 1230 LT; the effect this has on the daily variation is illustrated by the difference between curves (*a*) and (*c*). The similarity of curves (*a*) and (*b*) in Fig. 3, together with the conclusions drawn from Fig. 1*b*, demonstrate that the apparent phase shift in $Sq(Z)$ on 10 and 11 May 1971 was due to the small $Sq(Z)$ variation being modified by $L_2(Z)$.

Conclusions

There is no evidence of a significant phase shift in $Sq(Z)$ on the north-east coast of Marion Island as a result of the island effect. Nevertheless, significant phase shifts occur in the daily variation of the geomagnetic vertical intensity; these are brought about by the modification of $Sq(Z)$ by $L_2(Z)$. The shape of the daily variation is thus a function of lunar phase angle and will very nearly repeat itself twice per lunation.

The conclusions drawn in this paper are based on data for a very limited period. A detailed study of the lunar daily variation at Marion Island will be made when more data become available.

Acknowledgements

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