GEOMAGNETIC MICROPULSATIONS

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Summary

This paper describes simultaneous observations of geomagnetic micropulsations at three places ranging from 28° S. to 51° S. geomagnetic latitude. It is shown that there is no observable change in the micropulsation period with latitude although there is a monotonic increase in the amplitude with latitude for all periods between 10 and 100 sec. The interpretation of these results in terms of existing theories is discussed.

I. Introduction

The study of the micropulsations of the geomagnetic field has been intensified in recent years with the realization that these phenomena may provide evidence for the propagation of hydromagnetic waves in the outer atmosphere. Dungey (1954), for example, has suggested that micropulsations may be caused by standing hydromagnetic waves along the geomagnetic field lines, oscillating perpendicular to the meridian field. In the fundamental mode the period of these oscillations would increase with geomagnetic latitude as the length of the lines increased. Obayashi and Jacobs (1958) have reported that in middle and high latitudes the period of some micropulsations appears to increase with latitude and they calculated that the density of the outer atmosphere needed to support standing wave oscillations of the periods observed agreed fairly well with that obtained from the dispersion of whistling atmospherics (Storey 1953).

Dungey (1954) has suggested also that interplanetary gas, flowing over the surface of the Chapman-Ferraro boundary separating the terrestrial and interplanetary atmospheres, would generate waves in a similar way to the generation of waves on water by the wind ; propagating downwards as Alfvén waves, they would reach the ionosphere in the auroral regions. If their effects were localized, micropulsations due to this mechanism would not be observed at low and middle latitudes. However, it has recently been shown by Bomke *et al.* (1960) that magnetic disturbances caused by the Argus high altitude atomic explosions appeared to be propagated horizontally in hydromagnetic ducts between the ionosphere and a height of 2500 km. Such propagation would also be likely to spread micropulsations. In this case there would be a change in amplitude with latitude but not in period. It is relevant to this mechanism that observations at the boundary of the geomagnetic field with the Pioneer I space probe have shown the existence of large field fluctuations in this region (Sonett, Judge, and Kelso 1959).

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A third alternative has been put forward by Lehnert (1956) and Maple (1959), who, following Holmberg (1951), have suggested intra-layer hydromagnetic oscillations within the ionospheric E and F layers. The main objection to this hypothesis is that the high attenuation of hydromagnetic wave propagation under normal ionospheric conditions would appear to preclude such resonance effects (see, for example, Piddington 1959).

For the systematic study of these theories it would be necessary to record micropulsations simultaneously over large parts of the world. Nevertheless, it is clear that useful information would be obtained from a more limited investigation by comparing the amplitude and period of micropulsations recorded simultaneously at places in the same geomagnetic meridian, particularly at middle and lower latitudes where the disturbances of the auroral zone are less pronounced.

This paper presents the results of a series of observations over a range of geomagnetic latitudes extending from 28° S. to 51° S. for the period September 1959 to April 1960.

II. Observations

Micropulsations were recorded simultaneously at Townsville, Qld., Camden, N.S.W., and Hobart, Tas. These three places are at nearly the same geomagnetic longitude, but have geomagnetic latitudes of 28° S., 42° S., and 51° S. respectively. Each recorder used a 4-turn horizontal pick-up loop with an average area of 10 000 m^2. The loops were connected through galvanometer-photocell amplifiers to pen recorders with a chart speed of 6 in/hr. The frequency response of the amplifiers was flat from d.c. to $0 \cdot 15$ c/s, while the highest frequency which could be resolved by the recorders was $0 \cdot 17$ c/s. The deflection sensitivity of the three recorders for full scale deflection was normally $0 \cdot 7$, $0 \cdot 5$, and $0 \cdot 3$ γ/sec respectively, and the amplifier noise was less than $0 \cdot 005$/sec ($1\ \gamma = 10^{-5}$ gauss). Each recorder was calibrated periodically, both with a calibration loop in the same trench as the pick-up loop and with a signal generator applied to the input terminals of the amplifier. The peak-to-peak amplitude of the third highest oscillation and the average period in 5-min intervals was measured, except when the period was greater than 50 sec, when 6 cycles were used. One hundred and nine individual occurrences of micropulsations occurring on 40 days during February, March, and April 1960 were used in the analysis ; 74 of these were in the day-time and 35 at night. Records obtained during magnetically active periods ($K_p > 6$) were not used because of the difficulty of separating the many different frequency components without a spectrum analyser.

Although a superficial inspection of the simultaneous records showed many occasions when there was an apparent large increase in period with latitude, closer examination showed that in all cases this was due to the superimposition of micropulsations of different periods but of different amplitudes at the three places. In general, those of longer period were stronger (compared with those of shorter period) at Hobart than at Townsville. This was shown clearly on occasions when bursts of relatively pure oscillations of different periods were recorded in succession. The periods were then always observed to be the same at all stations within the limits of measurement, which were estimated to be

± 5 per cent. On the other hand, the change in amplitude was often pronounced, particularly for the longer periods. Figure 1 shows sample records of micropulsations at Townsville, Camden, and Hobart on April 13, 1960. The two bursts of micropulsations at A and B on these records had periods of 30 and 17 sec respectively. The relatively greater amplitude of the shorter micropulsations at Townsville should be noted. Figure 2 shows the average amplitudes of simultaneous micropulsations of different periods at the three places and Table 1, the average ratios of their amplitudes at Hobart and Townsville.

TABLE 1

THE RATIO BETWEEN MICROPULSATION AMPLITUDES AT HOBART AND TOWNSVILLE

Period range (sec) ..	10–20	20–30	30–45	45–60	60–100
$\dfrac{\text{Amplitude at Hobart}}{\text{Amplitude at Townsville}}$	$1\cdot75\pm0\cdot8$	$1\cdot75\pm0\cdot5$	$4\cdot0\pm1\cdot5$	$4\cdot1\pm1\cdot25$	$4\cdot0\pm1\cdot4$
No. of observations ..	28	24	14	17	26

III. Discussion

It is clear from the observations that the variation of period with latitude was very small between 28° S. and 51° S. To see how this result compared with the predictions of the standing-wave theory, the fundamental period of oscillation of the geomagnetic field lines was calculated using recent data on the density of the outer atmosphere. For a line of length l, passing through a fully ionized medium of mass density ρ, the period is

$$T=\int_0^l \frac{2\mathrm{d}s}{V(s)},$$

where ds is the line element and $V(s)$ the Alfvén velocity,

$$V(s)=H(s)(4\pi\rho(s)^{-\frac{1}{2}}. \quad \text{(Dungey 1954)}$$

$H(s)$ is the magnetic field intensity. In the lower parts of the outer atmosphere the density of neutral atoms is not negligible and it is necessary to modify the expression for the velocity. Piddington (1959) has shown that the propagation constant is then

$$K=H^{-1}(4\pi\rho)^{+\frac{1}{2}}(\omega/2\tau)^{\frac{1}{2}}(1-i),$$

which describes waves travelling with velocity

$$H(4\pi\rho)^{-\frac{1}{2}}(2\omega\tau)^{\frac{1}{2}}$$

and with attenuation

$$k=H^{-1}(4\pi\rho)(\omega/2\tau)^{\frac{1}{2}}.$$

τ is the period needed to accelerate neutral atoms to the same velocity as the ions (see Piddington 1957, Appendix I).

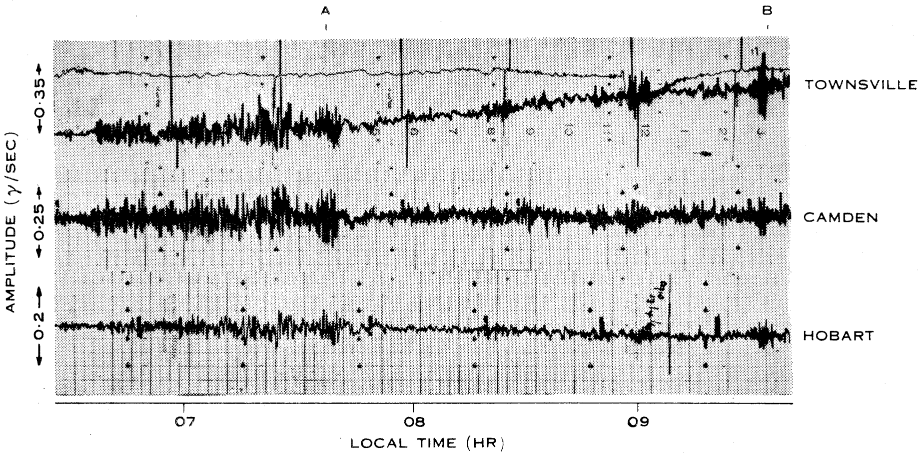

Fig. 1.—Records of micropulsations at Townsville, Camden, and Hobart on April 13, 1960. The individual oscillations were resolved on the original records.

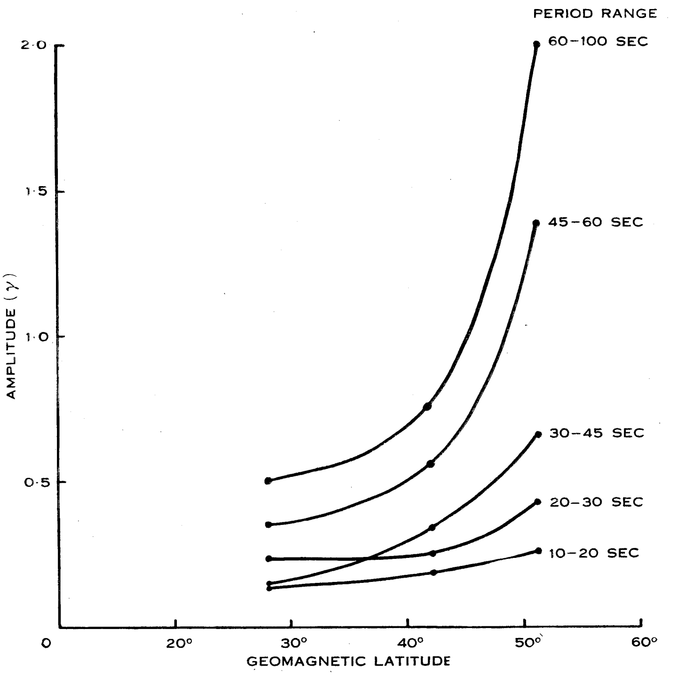

Fig. 2.—The observed variation in amplitude with geomagnetic latitude of micropulsations with different periods.

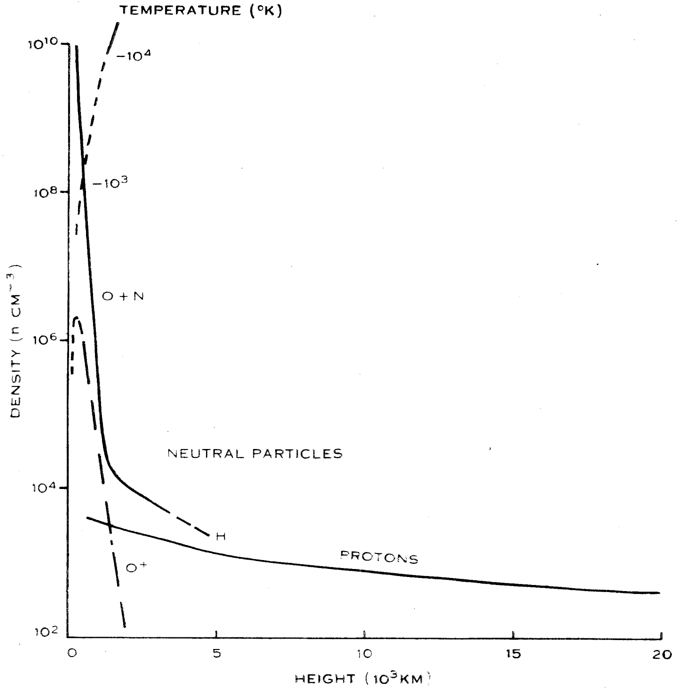

Fig. 3.—Assumed model of the outer atmosphere.

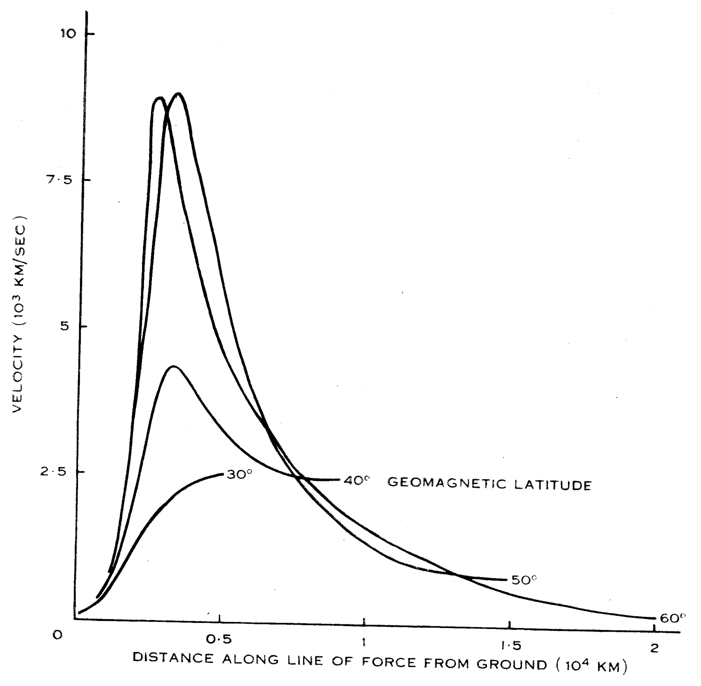

Fig. 4.—The variation of the Alfvén velocity along different geomagnetic field lines.

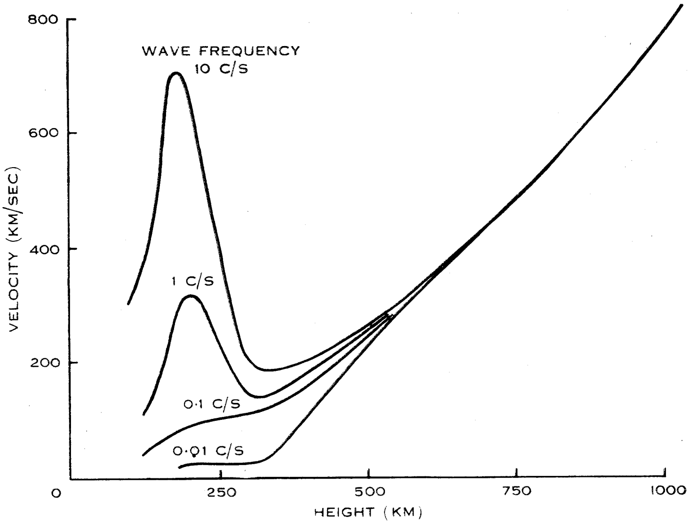

Fig. 5.—The variation of hydromagnetic wave velocity below 1000 km height when the effect of neutral atoms is taken into account.

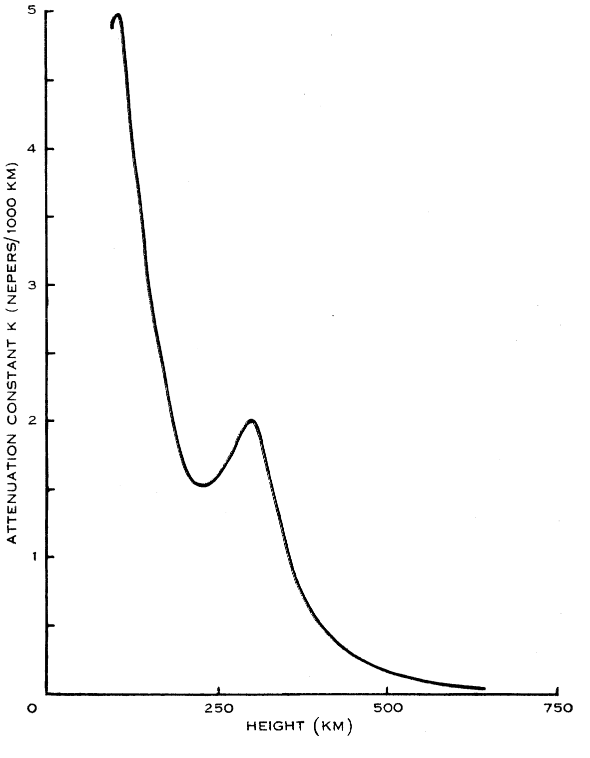

Fig. 6.—The attenuation below 1000 km height for a wave frequency of 0·01 c/s when neutral atoms are taken into account. The attenuation is proportional to (frequency)$^{\frac{1}{2}}$.

The velocity of propagation along field lines ending at different latitudes was computed assuming a dipole form for the geomagnetic field and using the model of the outer atmosphere recently proposed by Johnson (1960) (Fig. 3). Figures 4 and 5 show the velocity profiles obtained. Figure 6 shows the high attenuation for propagation within the ionosphere when neutral atoms are taken into account, and Figure 7 shows the variation of the fundamental period with latitude.

With this model the period would be 30 sec at 28° S. increasing to 55 sec at 51° S. An earlier exponential model of the outer atmosphere with greater densities between 2000 and 10 000 km heights (Obayashi and Jacobs 1958) gave periods of 45 and 70 sec at 28° S. and 51° S. respectively.

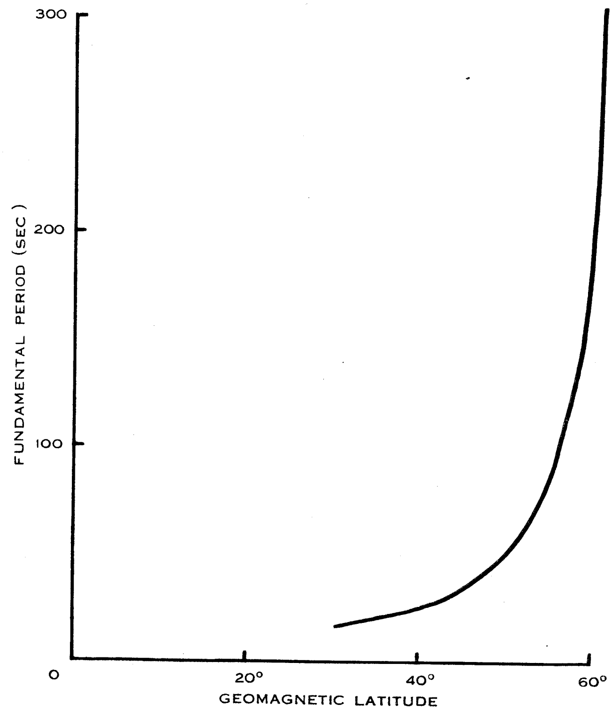

Fig. 7.—The calculated variation of the fundamental period of oscillation of geomagnetic field lines using the model of Figure 3.

The absence of any observed variation in the period over this range of latitudes would therefore appear to point to some other cause of micropulsations. The monotonically increasing amplitude with latitude, on the other hand, suggests strongly that they originate at higher latitudes and are propagated towards the equator, with greater attenuation at the longer periods. The rapid decrease in the propagation velocity of longitudinal hydromagnetic waves below 3000 km (Fig. 4) supports the idea of suitable horizontal hydromagnetic ducts such as Bomke *et al.* proposed. Although the fundamental periods of standing waves along high latitude field lines would be much greater than the periods observed, it should be noted that the considerable variation in velocity along these lines would favour the generation of many higher order oscillations with periods not integral submultiples of the fundamental.

As in the case of Dungey's hypothesis of ripples in the Chapman-Ferraro surface, micropulsations due to higher order oscillations of the longer field lines would first appear in the auroral zone. Lower latitude observations could not distinguish between these two possibilities. However, very accurate measurements of the phase difference between micropulsations at slightly different latitudes should provide information about their horizontal propagation.

IV. Acknowledgments

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V. References

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