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DIURNAL VARIATIONS OF THE SIZE OF THE MAGNETOSPHERE

By

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Abstract

Diurnal variations of the size of the magnetosphere are estimated from simple consideration on the pressure balance at the subsolar point of the magnetosphere. Associated geomagnetic variations on the surface of the earth are calculated.

1. Introduction

Ness *et al.* [1964] pointed out that the position of the magnetospheric boundary must be sensitive to the geomagnetic latitude of its subsolar point, θ_s. Since the magnetic pressure at the subsolar point of the magnetopause is determined by θ_s and R_s, the distance from the earth's center to the subsolar point of the magnetopause, R_s is required to vary by the change of θ_s in order to provide a constant pressure which should be balanced by the solar wind pressure. Using a factor $(1+3\sin^2\theta_s)^{1/6}$ they normalized magnetopause distances from the earth's center which were observed at various positions of the magnetospheric boundary during the flight of IMP-1 satellite. The same normalizing factor was used by Patel and Dessler [1966] to investigate relations between geomagnetic activity and the size of the magnetosphere. Their results show that at most 12% change of R_s is caused by the variation of θ_s.

If it is assumed that R_s can be accepted as a measure of the size of the magnetosphere, diurnal and seasonal variations of the geomagnetic field intensity might be caused at the surface of the earth by the change of θ_s. This is the main subject of this paper.

2. Results

The boundary condition which should be satisfied at the subsolar point of magnetopause is

$$\frac{B_t^2}{8\pi}=2\rho v_s^2 \tag{1}$$

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where ρ and v_s are mass density and velocity of the solar wind and B_t is the magnetic field intensity tangential to the magnetospheric boundary. The field B_t can be approximately replaced by twice of the dipole magnetic field intensity

$$B_t=2B_0\left(\frac{R_s}{R_0}\right)^3(1+3\sin^2\theta_s)^{1/2}, \tag{2}$$

where B_0 is magnetic field intensity at the earth's equator and R_0 is earth's radius. From (1) and (2), the relation

$$R_s=R_0\frac{B_0(1+3\sin^2\theta_s)^{1/6}}{4\pi\rho v_s^2}, \tag{3}$$

is obtained, which shows that R_s increases with increase of θ_s. Since the rotational axis of the earth makes an angle of about 66.5° to the ecliptic plane and the geomagnetic dipole axis is tilted about 11.5° from the rotational axis, the angle θ_s makes diurnal and seasonal variations. It varies diurnally from (23.5+11.5)°N to (23.5−11.5)°N in the June solstice, from 11.5°N to 11.5°S in the equinox and from (23.5−11.5)°S to (23.5+11.5)°S in December solstice and shown by the dotted line in Fig. 1.

Diurnal variations of R_s due to diurnal variation of θ_s are calculated from Eq. (3) and presented in Fig. 1 by solid line. In the June solstice, θ_s takes its

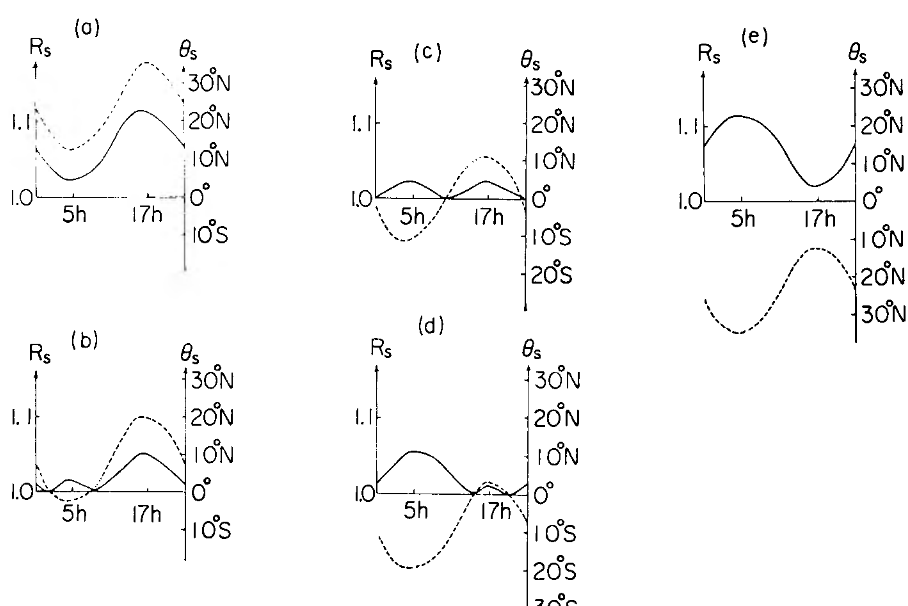

Fig. 1. Solid line; diurnal variation of θ_s (geomagnetic latitude of the subsolar point of the magnetopause). Dotted line; diurnal variation of R_s (geocentric distance to the subsolar point of the magnetopause).
(a); June solstice, (c); spring or autumnal equinox, (e); December solstice, (b): intermedeate state between (a) and (c), (d); intermedeate state between (c) and (e).

maximum value (35°N) at 16.6 hours UT, because the geomagnetic north pole lies on the longitude line of about 69°W (4.6 hours west from the zero longitude). At the same time R_s takes its maximum value which is larger by 12% than that for $\theta_s=0$ (Fig. 1a). The minimum of R_s occures at about 4.6 hours UT which is about 4% larger than that for $\theta_s=0$. Therefore diurnal variation of about 8% is expected for R_s. After the June solstice the curve of diurnal variation of R_s comes down to the base line (which shows the value of R_s for $\theta_s=0$) without any change of its shape, but as soon as its minimum touches the base line two peaks appear as shown in Fig. 1b. In the equinox two peaks take the same value and the diurnal variation of R_s is about 4% at this time (Fig. 1c). After the autumnal equinox the peak at 4.6 hours UT becomes larger (Fig. 1d) and becomes largest in the December solstice (Fig. 1e).

If the distance R_s may be accepted as a measure of the magnetospheric size in the solar side of the earth, UT variations same as for R_s is expected for the size of the magnetosphere.

Mead (1964) showed that total magnetic field variation ΔH at earth's surface due to the change of R_s is given as follows,

$$\Delta H(\text{gamma})=\frac{75000}{R_s^4}\Delta r \tag{4}$$

where Δr is change of R_s. If R_s is taken to be $10R_e$ (earth radii) as usual, Δr becomes $0.8R_e$ in the solstice and $0.4R_e$ in the equinox. From the relation (4) these values correspond to values of 6γ and 3γ of ΔH. After all we can expect the diurnal UT variations of geomagnetic field which have properties presented in Table 1.

Table 1.

	Time of maximum (UT)	Time of maximum (UT)	Amplitude
June solstice	16.6h	4.6h	6γ
Spring and autumnal equinox	4.6h 16.6h	10.6h 22.6h	3γ
December solstice	4.6h	16.6h	6γ

3. Discussion

In Eq. (2), $\boldsymbol{B}_t$, the magnetic field intensity tangential to the magnetospheric boundary, is approximately taken to be twice of the dipole magnetic field intensity. Rigorously, $\boldsymbol{B}_t$ should be the sum of the dipole magnetic field, $\boldsymbol{B}_d$, and the magnetic field due to currents flowing on the magnetopause, $\boldsymbol{B}_c$, so that

$$\boldsymbol{B}_t=\boldsymbol{B}_d+\boldsymbol{B}_c.$$

The field $\boldsymbol{B}_d$ varies with θ_s but it is not assured that B_c varies in the same way as $\boldsymbol{B}_d$. In order to know behaviour of $\boldsymbol{B}_c$, it is necessary to carry out much more complex calculation such as done by Spreiter and Briggs [1963]. Our purpose is to estimate geomagnetic response to variations of θ_s in rather simple way and the basis of the argumnent is a belief that our results would not be greatly altered by more detailed calculations.

Even if R_s could be accepted as a measure of the size of the magnetosphere, it is so only for the solar side of the magnetosphere. For the tail side it is required to take into consideration effects of such as tail currents and its peculier shape. Therefore the geomagnetic field variations derived here would be realized when a observing station is in the dayside of the earth.

Ionospheric dynamo currents would have also components varying with universal time because of tilting of the magnetic dipole axis. Geomagnetic field observed at the surface of the earth involves UT variations due to these ionospheric currents as well as those due to mechanisms mentioned above. Separation of these variations from ordinary S_q is very difficult and remains as a future problem.

4. Conclusion

From simple consideration on the pressure balance at the subsolar point of the magnetopause, it is deduced that the geomagnetic field at the dayside of the earth's surface makes UT variations with amplitude of 3–6 γ depending on seasons. More detailed calculation is needed to derive the field pattern through all of the day, but the results obtained here may be thought to be approximately correct for the dayside of the earth.

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