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Global Compressional Oscillations of the Terrestrial Magnetosphere: The Evidence and a Model

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Compressional oscillations of nearly constant frequency (period $\lesssim 8$ min) were observed from $L \simeq 5$ to $L \simeq 10$ near local noon over an interval of almost 3 hours during a dayside radial pass of the ISEE 1 spacecraft on August 12, 1982. The density fluctuations, measured by the electron density experiment, were in phase with the compressional magnetic oscillations measured by the magnetometer. We relate the observations to an analytical model of a global compressional wave reflected at the gradient of the magnetic field and plasma density near the plasmapause and standing in the outer magnetosphere. Qualitative arguments based on the model lead one to expect that conditions in the outer magnetosphere are not normally compatible with the standing wave solution, that when such a solution can be found, only the lowest eigenfrequencies will be present, and that some variation in period with local time may occur.

INTRODUCTION

Dungey [1963, 1968] pointed out that in the limit of fully axisymmetric disturbances the low-frequency oscillations of a cold plasma in a dipole field are separable into two modes called toroidal and poloidal. Attention has been directed principally to the toroidal mode oscillations, in which the electric field perturbations are radial and the velocity and magnetic field perturbations are azimuthal. In the idealized case, the magnetic shells (L shells) decouple and oscillate azimuthally independently of each other, with an L-dependent frequency. Although the ultralow-frequency (ULF) toroidal pulsations actually observed in the magnetosphere are typically not fully axisymmetric, the equations for the toroidal mode describe satisfactorily both the characteristic frequencies and the field-aligned structures of the transverse ULF waves observed in the magnetosphere [*Cummings et al.*, 1969; *Singer and Kivelson*, 1979; *Singer et al.*, 1979; *Southwood*, 1980].

The axisymmetric poloidal mode requires quite a different magnetospheric response, with an azimuthal perturbation electric field implying radial motions of the plasma. The entire magnetosphere, in the ideal case, undergoes radial expansion and compression, and magnetic field perturbations are in meridian planes with the field-aligned fluctuations in phase with density fluctuations. The frequency of such poloidal fluctuations must be L-independent.

We believe that we have identified decoupled compressional (poloidal) oscillations of the magnetosphere in data from an outbound pass of the ISEE 1 spacecraft on August 12, 1981. The pulsation period remained nearly constant ($\lesssim 8$ min) as the spacecraft moved from 4.7 R_E at 0000 UT to $\sim$9.9 R_E at 0300 UT, remaining near local noon, and magnetic perturbations were in phase with density perturbations.

The ISEE 1 data are presented in the next section. A simple model is then developed to facilitate analysis of the waves. We apply the model to the ISEE 1 data. We seek to understand why the wave has the observed period and to interpret its other characteristics. Our arguments lead us to believe that the conditions for standing compressional waves may only occasionally be satisfied in the outer magnetosphere and this may explain why global compressional waves have not previously been identified. Finally, we consider a previous account of widespread compressional ULF waves [*Higbie et al.*, 1982] which, in many ways, accords with expectations for the standing global compressional waves that we model in this paper.

DATA PRESENTATION

On August 12, 1982, ISEE 1 remained near the noon meridian as it moved from (4.6, 0.3, -1.0) at 0000 UT to (8.2, 3.8, -3.8) at 0300 UT. Positions are given in Cartesian GSE coordinates, and distances are measured in earth radii (R_E). Density fluctuations are evident in the data of the ISEE electron density experiment [*Harvey et al.*, 1978] reproduced in Figure 1. The relaxation sounder, whose data have been used here, was continuously active on the outbound pass, providing a determination of the plasma frequency and of the gyrofrequency every 16 s. We used the results of a program for automatic determination of the electron density [*Trotignon et al.*, 1982] which yields both the gyrofrequency and the plasma frequency. Erroneous determinations of both frequencies have been removed by checking that the gyrofrequency does not differ from that inferred from 1-min average magnetometer measurements by more than 7%. If this condition is not fulfilled for an individual 16-s determination, both the gyrofrequency and the plasma frequency are discarded.

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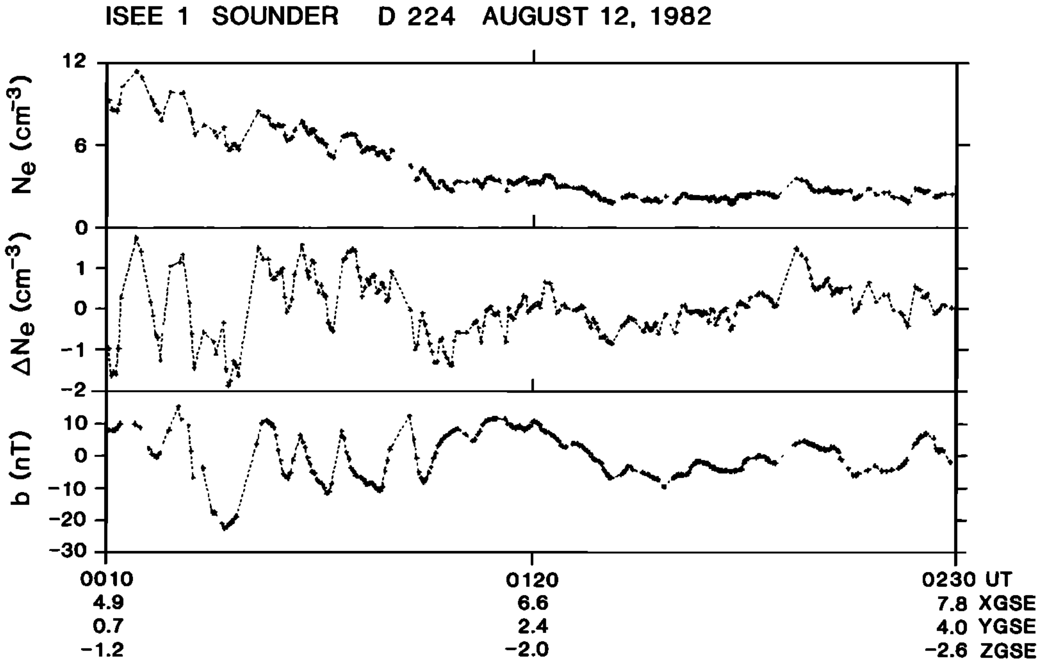

Fig. 1. Time evolution of the electron density and magnetic field modulus. From top to bottom: electron density, detrended electron density, and detrended modulus of the magnetic field. The in-phase low-frequency pulsations of the density and magnetic field are clearly seen. The period does not depend on orbital position.

The plasma frequency determination that we used is obtained from the alignment of the f_q frequencies (the frequencies of obliquely propagating electrostatic electron cyclotron waves, closely related to Bernstein waves) and therefore represents the density of the coldest component of a non-Maxwellian plasma [see *Belmont*, 1981; *Etcheto et al.*, 1983]. Consequently, the total density may be underestimated, but this should not influence the study of density fluctuations due to compressional waves, since a possible warm component of the plasma should experience the same fluctuations. As a matter of fact, the strongest resonance, believed to correspond to the plasma frequency of the total electron population, undergoes similar variations.

After clearing the data as explained above, we averaged over 48 s, sliding 24 s between successive averages. Thus, wherever all the data have been retained, we have averages over three measurements of both the plasma frequency and the gyrofrequency every 24 s.

At the top of Figure 1 the electron density obtained this way during the first 2.5 hours of the day is presented on a linear scale. A dotted line has been plotted between data points (linear interpolation). In order to remove the trend of the data resulting from the displacement of the satellite on its orbit, a polynomial of third degree was adjusted to the data by a least squares fit method and subtracted from the measurements in order to keep only the fluctuations around the mean variation. The results, plotted on an enlarged, linear scale, are shown in the middle frame of Figure 1 for the density fluctuations and in the bottom frame for the magnetic field deduced from the gyrofrequency fluctuations. Both quantities fluctuate approximately in phase, with an amplitude that is larger during the first hour than at the end of the period, but with no obvious dependence on the position of the satellite in the magnetosphere. (The GSE coordinates of the spacecraft are indicated at the the bottom of this figure, and radial distance, magnetic latitude, and local time are provided in Figure 2.) A scatter plot (not shown) of the density fluctuations versus the magnetic field fluctuations during the period 0130 to 0220 UT was made using 24-s averages. A straight line was fitted to the data (with a correlation coefficient of 0.7) leading to Δn (cm^{-3})/ΔB (γ) = 0.11. This value can be checked using Figure 1, for example at approximately 0050, and looks reasonable also at that time.

The low-resolution magnetometer data (courtesy of C. T. Russell) are shown in Figure 2 [*Russell*, 1978]. A cubic fit to the average field has been subtracted to reveal the fluctuations clearly. The fluctuations peak near 0030 UT close to $L = 6$, and the signal is phase-shifted at its maximum. Power spectral analysis of the entire interval shows a peak at a period of 7.6 ± 1.0 min. Spectra for subintervals revealed no statistically significant departure from this value (differences less than 1.2 min). A second peak at 3.8 min was identified in the spectrum

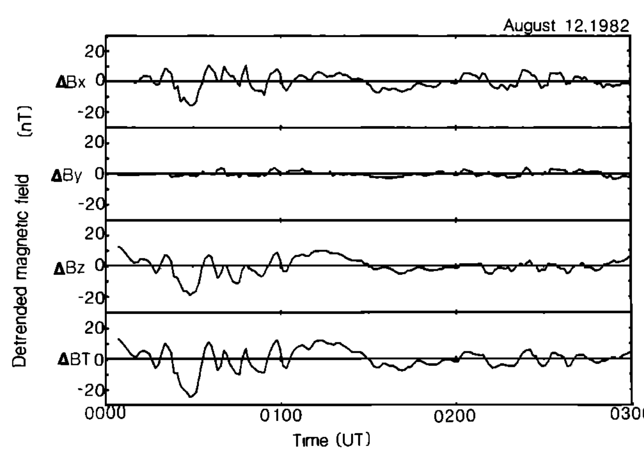

Fig. 2. Magnetic field components and magnitude from the ISEE 1 magnetometer. The z axis is parallel to the local dipole field, y is positive eastward, and $\hat{y} \times \hat{z} = \hat{x}$. Sixty-four-second averages have been detrended.

for the entire interval but could not be verified reliably for subintervals. Fluctuations are predominantly field aligned (b_z), but oscillations with amplitude $\sim b_z/3$ are also present in the radial component (b_x). The radial fluctuations also contain higher-frequency signals. Oscillations diminish in amplitude near the end of the data segment ($L \simeq 10$), but the magnetopause crossing does not occur until 0440 UT, by which time the spacecraft has moved to (9.4, 6.5, −3.6). Standard mapping yields a subsolar position of 12 R_E.

No exceptional signatures were identified in data from the ISEE 3 spacecraft upstream of the bow shock in the solar wind. Dynamic pressure ranged from 2.5×10^{-8} to 10^{-8} dyn/cm^2, and the magnetic field (amplitude near 10 nT) had a positive (northward) B_z component during most of the interval. Power spectral analysis was used to determine if the solar wind was driving the magnetospheric pulsations. A power spectrum of the solar wind field magnitude from August 11, 1982, at 2300 UT to August 12, 1984, at 0300 UT peaks at 1.5 mHz (11.1 min) and 3 mHz (5.5 min) but shows no peak near 2.2 mHz (7.5 min). Consequently, the solar wind does not appear to have been the source of the observed pulsations.

MODEL OF THE PULSATIONS

The global compressional mode satisfies the equation [*Dungey*, 1963, 1968]

$$\left[\frac{\omega^2}{r}\mu_0\rho + rB^2(\mathbf{B}\cdot\nabla)\frac{1}{r^2B^2}(\mathbf{B}\cdot\nabla)\right](rE_\phi) = -i\omega B^2(\mathbf{B}\times\nabla)_\phi\left(\frac{\mathbf{B}\cdot\mathbf{b}}{B^2}\right)$$

$$i\omega\mathbf{B}\cdot\mathbf{b} = \frac{1}{r}(\mathbf{B}\times\nabla)_\phi(rE_\phi) \qquad (1)$$

Here ω is the angular frequency of the assumed time variation (perturbations proportional to $e^{-i\omega t}$), $\mu_0 = 4\pi \times 10^{-7}$, ρ is the mass density, $\mathbf{B}$ is the background (time stationary) magnetic field, and E_ϕ and $\mathbf{b}$ are the wave electric and magnetic fields, respectively. The equation is written in cylindrical coordinates (r, ϕ, z) centered about the axis of symmetry of $\mathbf{B}$, and there is no dependence on the azimuthal angle ϕ. In magnetospheric applications a good first approximation is to assume that lines of force are anchored in the ionosphere, where $E_\phi = 0$. The solutions then are standing waves along the field lines, characterized by wave numbers $k_\parallel$ inversely proportional to the length of the field lines between northern and southern ionospheres. The remaining dependences on spatial derivatives in (1) and the boundary conditions determine the radial variation of phase and amplitude of the oscillations. The solution of (1) is complicated by the curvature of the background field, although that curvature is not critical to understanding the physical process. Consequently, we introduce an axially symmetric model in which we retain the principal features of (1) but ignore field curvature as well as dependence of density on distance from the equator. We anticipate results that are qualitatively correct and satisfactory for rough quantitative estimates, but we do not expect exact quantitative agreement with observations.

Our model is illustrated schematically in Figure 3. Model parameters vary only with the distance from the symmetry axis. In terms of $x = r/R_E$, the distance in earth radii from the symmetry axis, we take $\mathbf{B} = \hat{z}B(x)$ and $\rho = \rho(x)$. The radial variation of the dipole field is approximated by requiring $B(x) = B_0(x_0/x)^3$. For $L \gg 1$ the length of a dipole field line between ionospheres is approximately 2.4 LR_E. We approximate this feature of the dipole field by placing the ionospheric boundaries at $z = \pm 1.2x$. In the outer magnetosphere we assume $\rho = \rho_0(x_0/x)^4$, a dependence on distance which accords well with the observations we are analyzing for distances greater than 5 R_E. The equations corresponding to (1) then become [e.g. *Southwood and Hughes*, 1983]

$$(\omega^2/A^2 - k_\parallel{}^2)(x^2\xi_x B) + \frac{d^2}{dx^2}(x^2\xi_x B) = 0 \qquad (2)$$

$$xb_z + \frac{d}{dx}(x\xi_x B) = 0 \qquad (3)$$

Here it has been assumed that the variation along z is represented by a superposition of solutions $\exp(\pm ik_\parallel z)$ with $k_\parallel$ real such that $E_\phi = 0$ in the "ionosphere," an assumption that neglects losses in the ionospheres. This means $k_\parallel = \nu\pi/2.4x \equiv \nu k_0(x_0/x)$ if the νth harmonic of the field-aligned wave structure is assumed. The variable ξ_x is the displacement of the field line in the x direction and for the frozen-in fields that have been assumed, $E_\phi = -i\omega\xi_x B$. We have also introduced the Alfvén velocity

$$A(x) = B(x)/(\mu_0\rho)^{1/2} = A_0(x_0/x) \qquad (4)$$

whose dependence on x is determined by previous assumptions for B and ρ.

Equation (2) is of the form

$$\frac{d^2f}{dx^2} + \Omega^2(x)f = 0 \qquad (5)$$

and as $\Omega(x)$ varies slowly with x in the outer magnetosphere, the equation lends itself to solution by the WKB approximation [e.g., *Budden*, 1961]. Oscillatory solutions require

$$\Omega^2 = (\omega^2/A_0{}^2)(x/x_0)^2 - \nu^2k_0{}^2(x_0/x)^2 > 0$$

Elsewhere the solutions are evanescent.

The solutions then are oscillatory for $x > x_1 = x_0(\nu k_0A_0/\omega)^{1/2}$ and evanescent for smaller values of x. The WKB solution of (2) for $x > x_1$ is of the form

$$x^2\xi_x B = (\Omega_0/\Omega)^{1/2}\exp\left[\pm i\int_{x_1}^{x} dx'\Omega\right] \qquad (6)$$

where the phase integral has been expressed in terms of x. Since x_1 is a turning point where the wave is reflected, we can obtain a standing wave structure if the phase integral taken to the magnetopause is $n\pi/2$ with n an integer. The density increases steeply at the magnetopause, which therefore approximates a high-density reflector (giving a "fixed-end" boundary). The inner reflection point may be approximated as a constant-pressure surface giving a "free-end" boundary with n odd or a perfectly reflecting boundary with n even, depending on the steepness of the density gradient.

The standing wave condition determines the eigenfrequencies from

$$\int_{x_1}^{x_2} dx'\Omega = \nu k_0x_0I(x_2, x_1) = n\pi/2 \qquad (7)$$

Here x_2 is the magnetopause distance, and both Ω and x_1 depend on n and ν. The integral in (7) is

$$I(x_2, x_1) = \tfrac{1}{2}\{[(x_2/x_1)^4 - 1]^{1/2} + \sin^{-1}[(x_1/x_2)^2] - \pi/2\} \qquad (8)$$

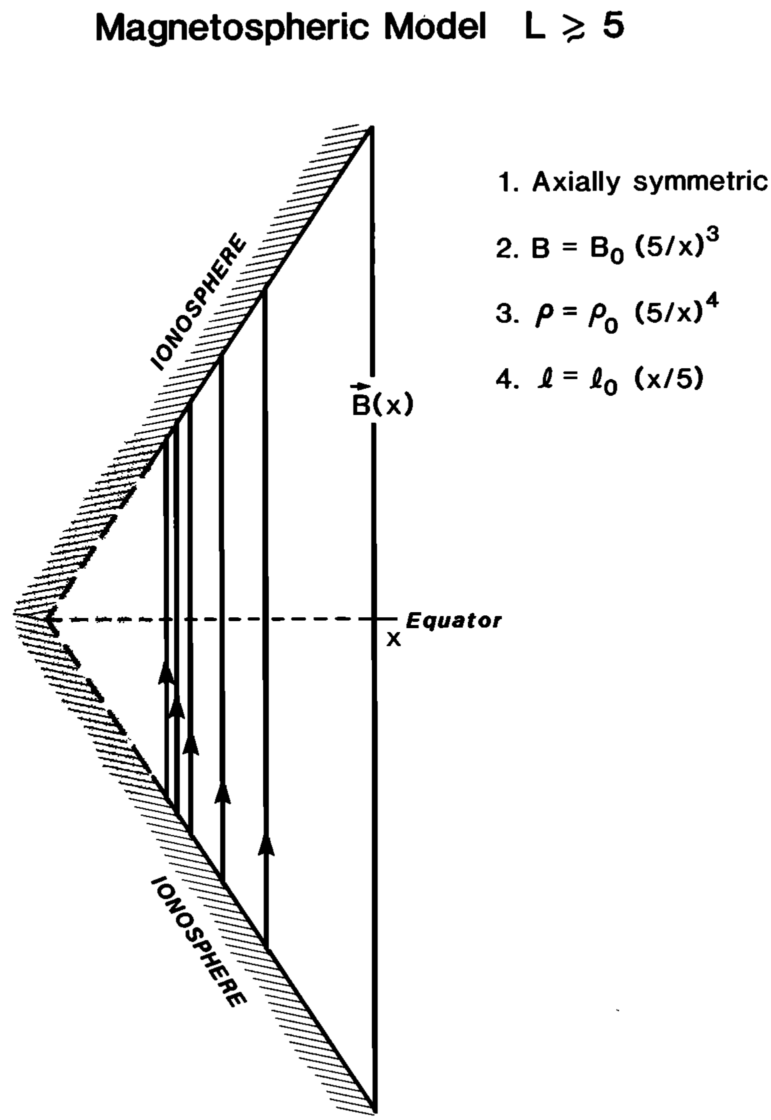

Fig. 3. Schematic of model used for calculation, with l = length of field line = $l_0(x/5)$.

With $k_0x_0 = \pi/2.4$, we can solve (7), obtaining values given in Table 1. For the observed magnetopause position at $x = 12$, the table provides the location of the inner boundary of the standing compressional mode. Only the low harmonics are reflected well outside the plasmapause, where the assumed density model applies.

Eigenfrequencies tabulated in Table 1 are obtained from

$$\omega_{n,v} = vk_0A_0(x_0/x_1)^2 \tag{9}$$

To proceed quantitatively, we select $x_0 = 5$ as a reference position. We use values for the electron density from Figure 1, obtaining $n_e \simeq 12$ cm^{-3}, and with $B_0 \simeq 250$ nT we find $A_0 = 1600/(m_i/m_p)^{1/2}$ km/s. Equation (4) then represents the trend of the observations to be considered from $L \simeq 5$ to the end of the data. The average ion mass in units of the proton mass, m_i/m_p, is a quantity for which we have no measurement available at the moment.

For the lowest harmonics, (9) yields periods $143(m_i/m_p)^{1/2}$, $107(m_i/m_p)^{1/2}$, and $87(m_i/m_p)^{1/2}$, respectively. One should recall that the electron density may be underestimated and thus the model period may be underestimated. For the nominal n_e the 450-s period observed in the ISEE 1 event is obtained for the fundamental ($n = 1$) if the ion mass was $9.9m_p$. Although the composition of the thermal plasma in this event is not known, we can estimate reasonable values for m_i from average ion compositions reported by *Balsinger et al.* [1983] for low-energy ions (0.9 to 16 keV per charge). They find that up to 20% O^+ and approximately 4% He^+ are typical for quiet-time plasmas near geostationary orbit, corresponding to an average $m_i = 4.1m_p$, somewhat smaller than the $9.9m_p$ we require. In a previous study, *Singer et al.* [1979] reported transverse magnetic pulsations whose periods were 2-3 times longer than expected for standing waves on field lines. They were able to demonstrate that the average ion mass was indeed 5–9 times the proton mass by combining density measurements from the ISEE 1 plasma wave detector, the

TABLE 1. Solutions of (7) and (9) for Low Harmonics

n	v	x_1/x_2	x_1 for $x_2 = 12$	$T(s)(m_p/m_i)^{1/2}$
1	1	0.510	6.12	143
	2	0.625	7.50	107
2	1	0.398	4.78	87.2
	2	0.510	6.12	71.2
3	1	0.339	4.07	63.2
	2	0.444	5.33	54.2

TABLE 2. Periods of Low Harmonics for Magnetopause at 13 R_E

n	ν	x_1	$T(s)(m_p/m_i)^{1/2}$	$T(s)$ for $m_i/m_p = 7.2$
1	1	6.63	168	450
	2	8.12	126	338
3	1	4.41	74.1	200
	2	5.77	63.5	170

sounder and propagation experiment, and the plasma composition experiment. Their study suggests than an average $m_i > 4m_p$ may not be atypical of long-period pulsation events.

The odd n cases correspond to the free-end inner boundary conditions anticipated for a rather smooth density profile that fits the average $n_e(x)$ of Figure 1. A fixed-end inner boundary has $n = 2$ as its fundamental; an average $m_i = 27m_p$ is needed to obtain a 450-s oscillation in this case, and we regard that value as unreasonably large. As both the density profile and the observed frequency suggest free-end conditions for the inner boundary, we limit further consideration to the odd harmonics of the radial eigenvalue (n odd). We proceed with the model by adjusting the magnetopause position to $x_2 = 13$, well within uncertainties of the data. For the $n = 1$, $\nu = 1$ mode, this reduces m_i to $7.2m_p$, not an unreasonable value, and implies inner boundaries and periods given in Table 2 for $n = 1$ and $n = 3$. The estimated inner boundary at $x_1 = 6.63$ lies near but outside the position at which the peak amplitude and phase shift in b_z are actually observed (see Figure 2). Of the low-order harmonics predicted, only the lowest harmonic in n is identifiable in the total field. In the power spectra, peaks at $n = 1$, $\nu = 1$ or $n = 1$, $\nu = 2$ could not be separately identified, and both may be present. The absence of $n = 3$ oscillations may be understood qualitatively by noting that the Alfvén velocity does not continue to increase smoothly with decreasing x for $x < 4.3$ but, in fact, falls rapidly near the plasmapause as illustrated qualitatively in Figure 4*a*. In the WKB approximation used here, $Ak_\parallel$ is analogous to potential energy in a particle-scattering problem, and leakage through a potential energy in a particle-scattering problem, and leakage through a potential barrier can be calculated [e.g., *Bohm*, 1951]. The situation is illustrated schematically in Figure 4*b*, where $k_\parallel A$ is plotted assuming a density discontinuity near the plasmapause and elsewhere a variation as x^{-2}. The lowest-order harmonics correspond to states with energy levels whose turning points (only approximations to those calculated) are indicated. In this model, leakage through the barrier would be insignificant for the $n = 1$ state that lies below the minimum value of $k_\parallel A$, but would be important for higher n states.

The decay in amplitude through the peak in $k_\parallel A$ near $x = 5$ may be estimated crudely using the exact solution obtained by expanding $\Omega(x)$ about its zeroes at the turning points [e.g., *Budden*, 1961]. The solution is an Airy function of argument

$$\xi = (a_{n\nu})^{1/3}(x_1 - x) \tag{10}$$

where

$$a_{n\nu} = \frac{d}{dx}(\Omega^2)_{x=x_1} = \nu^2 \frac{4k_0{}^2x_0{}^2}{x_1{}^3} = \frac{6.8}{x_1{}^3}\nu^2$$

and x_1 is a function of n and ν.

A typical e-folding distance of the evanescent solution in the region $x \lesssim x_1$ is $\xi = 1$. Thus a typical decay distance is $\Delta x_n = x_1/1.9$. For the $n = 1$ and 3 harmonics with $\nu = 1$ and $x_2 = 13$, the values of Δx_n are 3.5 R_E and 2.3 R_E, respectively. These numbers are consistent with an expectation that the $n = 3$ mode has substantial amplitude inside $x = 4.5$ and leaks into the inner cavity, possibly coupling to a bound state inside. Only the fundamental mode can be well confined in the outer magnetosphere by the effective potential profile expected. (If fixed-end boundary conditions are considered, the lowest harmonic would have $x_1 = 5.2$ and $\Delta x_2 = 2.7$ R_E and would also leak into the inner magnetosphere for our model conditions.)

The consistency of the estimated perpendicular wavelength, $\lambda_\perp = 4(x_2 - x_1) \simeq 25$ R_E, with the observed magnetic perturbations can be tested by examining the consequences of $\nabla \cdot \mathbf{b} = 0$. Perturbation amplitudes (near $z = 0$) must satisfy $k_\parallel b_z \simeq 2\pi b_\perp/\lambda_\perp$. For a nominal value of $x = 10$ one then expects the oscillation amplitudes to obey

$$b_\perp/b_z \simeq k_0x_0\lambda_\perp/2\pi x \simeq \tfrac{1}{2}$$

Because the equator is a node of $b_\perp$ and an antinode of b_z for the fundamental oscillation along z, this ratio of amplitudes is an upper limit to the ratio of perturbations expected along the near-equatorial ISEE 1 pass. As previously noted, the observed ratio is less than $\tfrac{1}{3}$ and thus is not inconsistent with the estimate based on wavelengths.

Finally, it should be stressed that (2) and (3) apply in the idealized case with azimuthal wave number $k_\phi = 0$. For non-vanishing k_ϕ the compressional mode treated here couples to the transverse mode. The "turning point" of the compressional wave is also the resonant field line of the transverse wave [*Southwood*, 1974; *Chen and Hasegawa*, 1974], and when coupling is significant, the compressional waves can be damped efficiently. The upper bound on k_ϕ imposed by the requirement that the damping be unimportant, and the consequences of mode coupling when k_ϕ is not too small to ignore, will be treated elsewhere.

OCCURRENCE EXPECTATIONS

In the previous section we have presented a model of global compressional pulsations. We argue that at least the fundamental standing mode should typically be well confined by the plasma density gradient of the outer magnetosphere. Yet we also suggest that the type of wave here reported may occur only infrequently. Why should this be the case? Note that the

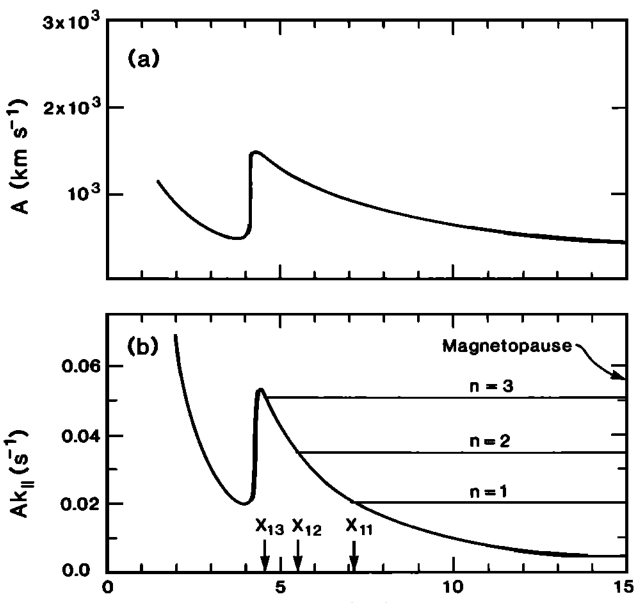

Fig. 4. (*a*) Schematic Alfvén velocity with nominal plasmapause at $x \simeq 4$. (Density is 1000 cm^{-3} at $x = 3.5$, 500 cm^{-3} at $x \simeq 4$, and 18 cm^{-3} at $x = 5$.) (*b*) Schematic effective potential $k_\parallel A$ and quasi-energy levels of low-order states: $n = 1, 2, 3$, and $\nu = 1$.

wave mode we propose requires azimuthal symmetry of the plasma conditions. We take that statement as an idealization, but we must surely require that the plasma and field remain roughly independent of azimuth over a distance at least of order $x_2 - x_1$, which in our case was $\simeq 7\ R_E$. Near geostationary orbit this corresponds to $\sim 60°$ of longitude. At times of geomagnetic disturbance or significant convective flow, plasma conditions in the outer magnetosphere vary with local time, and the global pulsations would not be expected. Quiet conditions, on the other hand, may allow the mode to appear if an appropriate excitation mechanism exists. During August 12, 1982, the conditions in the solar wind were, indeed, very steady.

During the period 0000 to 0300 UT on August 12 the two geostationary satellites GEOS 2 (geographic longitude 37°E) and GOES 2 (geographic longitude 106°W) showed no pulsation activity of the sort observed at ISEE 1. Their approximate positions in local time were 0230 to 0530 and 1700 to 2000, respectively. On the other hand, when GOES 2 was in the local time section 1300 to 1630 (that is, between 1955 and 2330 UT on August 11; there were no data before that), it observed pulsations in the same period range (5 to 8 min). Similarly, GEOS 2 observed pulsations with similar period in the region 1400 to 1630 LT (1130 to 1400 UT on August 12) with an amplitude varying in time. This pulsation event seems to be long lived (probably at least 20 hours) and localized on the dayside (about 3 hours in local time). One should note, however, that pulsations with longer periods are observed later on board GEOS 2, and it is difficult to know whether to consider these pulsations as the same wave event.

We speculate now on another possible observation of a global magnetospheric compressional wave. *Higbie et al.* [1982] report on large-amplitude compressional waves observed concurrently by multiple spacecraft in geostationary orbit on the dayside of the magnetosphere at different local times on November 14 and 15, 1979. The interval in question was extremely quiet, in accord with requirements described above. The pulsation period of 7 to 8 min is compatible with expectations from our model. One peculiarity noted by Higbie et al. was that the observed "quasi-periods" were longer and more erratic near dawn and dust than near noon. Such an observation could be explained if the proposed model were applied in separate wedges of about 6 hours in local time about noon and about dawn or dusk. Near the terminators the magnetopause is found at larger distance than near noon. The distances x_1 vary proportionally to the distance to the magnetopause, and therefore (10) implies that periods vary as the square of the distance to the magnetopause. Thus longer periods near dawn and dusk could be accounted for.

DISCUSSION

We believe that the properties of the compressional pulsations observed by ISEE 1 on August 12, 1983, are consistent with expectations for a quarter-wave fundamental standing wave of the global compressional mode. We have not addressed the questions of a driving mechanism. Kelvin-Helmholtz waves at the magnetopause (identified in connection with the *Higbie et al.* [1982] event) may well drive these waves, but interaction with ring current particles or other mechanisms must also be considered [*Southwood and Hughes*, 1983]. The model used in this paper has illustrated qualitative aspects of the solution, but a more complete treatment in a dipole geometry which also allows for losses to the ionosphere will be required for detailed quantitative investigations.

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