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Full Length Research Paper

Kinetic Alfven wave in the presence of parallel electric field with general loss-cone distribution function: A kinetic approach

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In past, kinetic Alfven waves are widely investigated regarding the transfer of energy from the magnetosphere to the ionosphere. These waves are supposed to be responsible for the acceleration of auroral electrons to exhibit auroral phenomena. The existence of parallel electric fields is always reported in association with the kinetic Alfven waves. In the present investigation, assuming parallel electric fields developed by different mechanism, the dispersion relation and growth/damping rate of the kinetic Alfven Wave (KAW) in the presence of parallel electric field are evaluated with general loss-cone distribution using the kinetic approach. The wave frequency ω and growth/damping rate γ_L are obtained for two regimes of propagation $k_\perp\rho_i<1$ and $k_\perp\rho_i>1$, where $k_\perp$ is perpendicular wave number and ρ_i is the ion-gyro radius. The results of the present study show that the frequency ω and growth/damping rate of wave depend upon the distribution indices, parallel electric field and $k_\perp\rho_i$. The generation of kinetic Alfven wave by the combined effect of parallel electric field and loss-cone distribution indices (J), at a particular range of $k_\perp\rho_i$ is noticed. Thus the propagation of kinetic Alfven wave and loss of the Poynting flux from plasma sheet boundary layer (PSBL) to the ionosphere can be explained more effectively on the basis of present investigation. The results of the present study show that the parallel electric field in the presence of loss-cone distribution index is an important parameter to study KAW in the PSBL. The finding of the present investigation is to report that auroral phenomena are suitably described by kinetic Alfven wave in the presence of parallel electric field and the general loss-cone distribution function.

Key words: Kinetic Alfven wave, Plasma-sheet-boundary-layer, Parallel electric field, Kinetic theory, Loss-cone distribution function.

INTRODUCTION

In past, varieties of theories have been proposed to explain the development of parallel electric field on auroral field lines. Straltsov and Marklund (2006) have stated that a comprehensive statistical study of parallel electric fields (Marklund et al., 1997) have shown that they are mostly observed in the downward magnetic field aligned current (FAC) channels where the electrons flow along the ambient magnetic field from the ionosphere. Sometimes these downward FACs were associated at high latitudes with a so called “black aurora” (Straltsov and Marklund, 2006). According to Morioka et al. (2007), the recent observations from the Polar and Fast Auroral Snapshot (FAST) satellites revealed detailed characteristics of the parallel electric fields, accelerated particle spectra and background plasma distributions around the upward field-aligned current region (Ergun et al., 2004). Ergun et al. (2004) using the satellite observations have shown that the parallel electric in the upward current region are due to double layers. Hull et al. (2003) have stated that electric fields parallel to the magnetic field play a major role in the transport of mass, momentum and energy in the auroral zone.Direct observations have revealed that the quasi stationary parallel electric fields, believed to be responsible for particle acceleration, can be of large amplitude (Ergun et al., 2001; Keiling et al., 2002). These large amplitude parallel electric fields lead

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to parallel potential drops that are localized in altitudes. According to Keiling et al. (2005), observations of large parallel electric fields from FAST satellite indicate that such fields are found in regions of strong Alfvenic activity. Recently, the Polar satellite has also observed dominant parallel electric field signatures with amplitudes up to 150 mV/m associated with the large amplitude Alfven waves in the PSBL during the substroms (Wygant et al., 2000; Straltsov and Marklund, 2006). Plasma particles in the PSBL which are imbedded with curved and converging field lines have very high anisotropies in their transverse and parallel velocity components (Keiling et al., 2005; Wygant et al., 2002; Angelopoulos et al., 2002) and therefore, considerably depart from Maxwellian distribution and have the loss-cone distribution of particles. Thus kinetic Alfven waves generated in highly anisotropic plasma sheet boundary layer and propagating towards auroral ionosphere may be suitably discussed with general distribution function. The importance of using the loss-cone distribution to study various instabilities has been previously predicted by various authors (Shukla et al., 2007, 2008). In the recent past, the growth/damping rate and propagational characteristics of kinetic Alfven waves are investigated in the presence of ion and electron beam with general loss-cone distribution function (Shukla et al., 2008). The observational evidences show that ion and electron beams along auroral field lines are the consequences of parallel electric fields which may also be developed by mirroring effects due to steep loss-cone distribution. Thus, in the present investigation, the theory is further extended incorporating the effect of parallel electric field on propagational characteristics of KAW and to examine the role of parallel electric field for auroral acceleration process This paper is to investigate the effect of static parallel electric field on the kinetic Alfven wave in the plasma sheet boundary layer using the general loss-cone distribution function. The parallel electric field considered in the present paper is external in nature (Straltsov and Marklund 2006; Wygant et al., 2002). We have examined the effect of parallel electric field on the kinetic Alfven wave using the Vlasov kinetic theory as adopted in previous investigation (Shukla et al., 2008), and taken the example to examine the modification on the propagation of KAW regarding to the magnetosphere ionosphere coupling. We have evaluated the dispersion relation and growth/damping rate for KAW in both long and short wavelength regimes that is, perpendicular wave length less than ion gyro radius and greater than ion gyro radius. Finally, a brief discussion of the results in plasma sheet boundary layer is presented incorporating the effect of parallel electric field in the presence of general loss-cone distribution function.

METHODOLOGY

In the mathematical configuration, we consider the basic trajectories by Shukla et al. (2007, 2008) to determine the dispersion relation and damping rate, using the general distribution function of the form (Summers and Throne, 1995; Wang et al., 1998).

$$F_j = n_o F_\perp(\vec{v}_\perp) F_\parallel(v_\parallel) \tag{1}$$

where n_0 is the zeroth-order density.

$$F_\perp(\vec{v}_\perp) = \frac{v_\perp^{2J}}{\pi v_{T\perp}^{2(J+1)} J!} \exp\left[-\frac{v_\perp^2}{v_{T\perp}^2}\right] \tag{1a}$$

$$F_\parallel(v_\parallel) = \frac{1}{\pi^{1/2} v_{T\parallel ce}} \exp\left[-\frac{v_\parallel^2}{v_{T\parallel ce}^2}\right] \tag{1b}$$

$$T_{\parallel ce} = T_{\parallel e}\left[1 + \frac{ieE_\parallel}{k_\parallel\left(k_B T_{\parallel e}\right)}\right] \tag{1c}$$

J is an integer known as the loss cone index. $v_{T\parallel ce}^2 = \dfrac{2T_{\parallel ce}}{m}$ And $v_{T\perp}^2 = (J+1)^{-1}.\dfrac{2T_\perp}{m}$ are the squares of parallel and perpendicular velocities. Here, m is the mass and $T_\perp$ and $T_{\parallel ce}$ are the temperatures of charged particles perpendicular and parallel to the magnetic field B_o. The expression for $T_{\parallel ce}$ is originally derived by Pines and Schrieffer (1961) adopting the rigorous treatment of kinetic approach for collective behavior of solid state plasma. They arrived at the results where the parallel electric field $E_\parallel$ is eliminated by adopting the expression for $T_{\parallel ce}$ as expressed earlier. They have clearly mentioned that the sign of the effect depends upon both the charge of the particle and the angle between $E_\parallel$ and $\vec{k}$. Thus, it is true for the finite $k_\perp$ also. In this description, the parallel electric field $E_\parallel$ is sufficiently weak so that the drift velocity of the charged particles is much smaller than the phase velocity of the wave. The detailed description of inclusion of parallel electric field through the complex temperature ($T_{\parallel ce}$) is given in various papers (Tiwari and Varma 1991).

Dispersion relation

Adopting the same procedure as developed in Shukla et al. (2008), we evaluate the dielectric tensors perpendicular and parallel to magnetic field as:

$$\varepsilon_\perp = \frac{\omega_{pi}^2}{\omega_{ci}^2} \sum_{n=-\infty}^{\infty} \frac{D_n^J(\lambda_i)}{\lambda_i} \frac{\omega_i'^2}{\omega^2} = \frac{\omega_{pi}^2}{\omega_{ci}^2}\left(\delta_{0J} - D_0^J(\lambda_i)\right)\frac{\omega_i'^2}{\omega^2} \tag{2}$$

where, δ_{0J} =1 for J= 0 and δ_{0J} = 0 if J ≠ 0

$$\varepsilon_\parallel = C_0^J(\lambda_e)\frac{1}{\delta}\frac{m_i}{m_e}\frac{\omega_{pi}^2}{k_\parallel^2 v_{t\parallel ce}^2}\left[\left(1 + i\sqrt{\frac{\pi}{2}}\frac{\omega}{k_\parallel v_{t\parallel ce}}\right) + \frac{\sqrt{2}k_\parallel v_{De}}{\grave{\omega}_e}\right].\frac{\omega_e'}{\omega} \tag{3}$$

where

$$D_n^J(\lambda) = \int_0^\infty \left(1 - \frac{Jv_{T\perp}^2}{v_\perp^2}\right).dv_\perp^2 J_n^2\left(\frac{k_\perp v_\perp}{\omega_{cj}}\right).\frac{v_\perp^{2J}}{v_{T\perp}^{2(J+1)}.J!}\exp\left(\frac{-v_\perp^2}{v_{T\perp}^2}\right)$$

$$C_n^J(\lambda) = \int_0^\infty 2\pi\vec{v}_\perp J_n^2\left(\frac{k_\perp v_\perp}{\omega_{cj}}\right).F_\perp(\vec{v}_\perp)\,d\vec{v}_\perp$$

$\lambda_j = \frac{1}{2}(J+1)k_\perp^2\rho_j^2 = \frac{1}{2}(J+1)b_j$ and $\omega_{pj}^2 = \frac{4\pi n_j e_j^2}{m_j}$ is the plasma frequency squared, and $\omega_{cj} = \frac{e_j B_o}{m_j c}$ is the cyclotron frequency and j specifies either ion or electron, $\omega_i' = \omega - k_\parallel v_{Di}$, $\omega_e' = \omega - k_\parallel v_{De}$, v_{Dj} is the beam velocity. Here, $v_{t\parallel ce}$ is an electron thermal velocity and $\delta = \frac{n_{i0}}{n_{e0}} > 1$ is a measure of the negative charge density which signifies the presence of dust grains (Sallimullah and Rosenberg, 1999). However in the present investigation, we have assumed $\delta = 1$ to avoid dust grain effects for magnetospheric plasma. To evaluate the general dispersion relation we use Equations 2 and 3 to obtain the following equation (Shukla et al., 2008):

$$\begin{vmatrix} \varepsilon_\perp - \frac{c^2 k_\parallel}{\omega^2} & \frac{c^2 k_\parallel}{\omega^2} \\ \frac{c^2 k_\parallel}{\omega^2} & \varepsilon_\parallel - \frac{c^2 k_\perp^2}{\omega^2} \end{vmatrix} = 0 \qquad (4)$$

where $k_\parallel$ and $k_\perp$, refer to wave vector components along and across B. $\varepsilon_\parallel$ and $\varepsilon_\perp$ refer to the dielectric tensor elements along and across the external magnetic field, respectively.

Hence, the general dispersion relation of the KAW in the presence of parallel electric field is obtained as:

$$\left[A\left(\frac{\omega_i'^2}{\omega^2}.\frac{\omega_e'}{\omega}\right) + B\left(\frac{\omega_i'^2}{\omega^2}.\frac{\omega_e'^2}{\omega}\right) + C_1\left(\frac{\omega_i'^2}{\omega^2}.\frac{1}{\omega}\right) - D\left(\frac{\omega_e'}{\omega}\right) - F\left(\frac{\omega_e'^2}{\omega}\right) - G\left(\frac{1}{\omega}\right) - H\left(\frac{\omega_i'^2}{\omega^2}\right)\right] = 0 \qquad (5)$$

where,

$$A_1 = \frac{\omega_{pi}^2}{\omega_{ci}^2}\left(\delta_{0J} - D_0^J(\lambda_i)\right).\frac{m_i}{m_e}.\frac{\omega_{pi}^2}{k_\parallel^2 v_{t\parallel e}^2}.\left(\frac{a}{1+a^2}\right)$$

$$B_1 = \frac{\omega_{pi}^2}{\omega_{ci}^2}\left(\delta_{0J} - D_0^J(\lambda_i)\right).\frac{m_i}{m_e}.\frac{\omega_{pi}^2}{k_\parallel^3 v_{t\parallel e}^3}.\left(\frac{\sqrt{\pi}}{2}.\cos\left(\frac{3}{2}\theta\right)\right)$$

$$C_2 = \frac{\omega_{pi}^2}{\omega_{ci}^2}\left(\delta_{0J} - D_0^J(\lambda_i)\right).\frac{m_i}{m_e}.\frac{\omega_{pi}^2}{k_\parallel^3 v_{t\parallel e}^3}.\sqrt{2}.k_\parallel v_{De}\left(\frac{a}{1+a^2}\right)$$

$$D_1 = c^2 k_\parallel^2 \frac{m_i}{m_e}.\frac{\omega_{pi}^2}{k_\parallel^2 v_{t\parallel e}^2}.\left(\frac{a}{1+a^2}\right)$$

$$F_1 = c^2 k_\parallel^2 \frac{m_i}{m_e}\frac{\omega_{pi}^2}{k_\parallel^3 v_{t\parallel e}^3}.\left(\frac{\sqrt{\pi}}{2}.R^{-3/2}\cos\left(\frac{3}{2}\theta\right)\right)$$

$$G_1 = c^2 k_\parallel^2 \frac{m_i}{m_e}.\frac{\omega_{pi}^2}{k_\parallel^2 v_{t\parallel e}^2}.\left(\frac{a}{1+a^2}\right)\sqrt{2}.k_\parallel v_{De}$$

$$A = \frac{\omega_{pi}^2}{\omega_{ci}^2}\left(\delta_{0J} - D_0^J(\lambda_i)\right).\frac{m_i}{m_e}.\frac{\omega_{pi}^2}{k_\parallel^2 v_{t\parallel e}^2}.\left(\frac{1}{1+a^2}\right)$$

$$B = \frac{\omega_{pi}^2}{\omega_{ci}^2}\left(\delta_{0J} - D_0^J(\lambda_i)\right).\frac{m_i}{m_e}.\frac{\omega_{pi}^2}{k_\parallel^3 v_{t\parallel e}^3}.\left(\frac{\sqrt{\pi}}{2}.R^{-3/2}\sin\left(\frac{3}{2}\theta\right)\right)$$

$$C_1 = \frac{\omega_{pi}^2}{\omega_{ci}^2}\left(\delta_{0J} - D_0^J(\lambda_i)\right).\frac{m_i}{m_e}.\frac{\omega_{pi}^2}{k_\parallel^2 v_{t\parallel e}^2}.\sqrt{2}.k_\parallel v_{De}\left(\frac{1}{1+a^2}\right)$$

$$D = c^2 k_\parallel^2 \frac{m_i}{m_e}.\frac{\omega_{pi}^2}{k_\parallel^2 v_{t\parallel e}^2}.\left(\frac{1}{1+a^2}\right)$$

$$F = c^2 k_\parallel^2 \frac{m_i}{m_e}\frac{\omega_{pi}^2}{k_\parallel^3 v_{t\parallel e}^3}.\left(\frac{\sqrt{\pi}}{2}.R^{-3/2}\sin\left(\frac{3}{2}\theta\right)\right)$$

$$G = c^2 k_\parallel^2 \frac{m_i}{m_e}.\frac{\omega_{pi}^2}{k_\parallel^2 v_{t\parallel e}^2}.\left(\frac{1}{1+a^2}\right)\sqrt{2}.k_\parallel v_{De}$$

$$H = c^2 k_\perp^2 \frac{\omega_{pi}^2}{\omega_{ci}^2}\left(\delta_{0J} - D_0^J(\lambda_i)\right)$$

where, $a = \frac{eE_\parallel}{k_\parallel T_{\parallel e}}$, $R = \left(1+a^2\right)^{1/2}$, $\theta = \tan^{-1}(a)$ and $V_A^2 = c^2.\frac{\omega_{ci}^2}{\omega_{pi}^2}$ is the square of Alfven velocity. We recover the result of Shukla et al. (2008) if the parallel electric field is zero.

Growth/Damping rate

We assumed $\omega \to \omega_r + i\gamma_L$ with $\gamma_L < \omega$, to obtain the growth/damping rate

$$\gamma_L = -\frac{\left[A_1\left(\frac{\omega_i'^2}{\omega}.\frac{\omega_e^{`}}{\omega}\right) - B_1\left(\left(\frac{\omega_i'^2}{\omega^2}.\frac{\omega_e'^2}{\omega}\right)\right) + C_2\left(\frac{\omega_i'^2}{\omega^2}.\frac{1}{\omega}\right) - D_1\left(\frac{\omega_e'}{\omega}\right) + F_1\left(\frac{\omega_i'^2}{\omega}\right) - G_1\left(\frac{1}{\omega}\right)\right]}{\partial/\partial\omega\left[A\left(\frac{\omega_i'^2}{\omega^2}.\frac{\omega_e'}{\omega}\right) + B\left(\frac{\omega_i'^2}{\omega^2}.\frac{\omega_e'^2}{\omega}\right) + C_1\left(\frac{\omega_i'^2}{\omega^2}.\frac{1}{\omega}\right) - D\left(\frac{\omega_e'}{\omega}\right) - F\left(\frac{\omega_e'^2}{\omega}\right) - G\left(\frac{1}{\omega}\right) - H\left(\frac{\omega_i'^2}{\omega^2}\right)\right]} \qquad (6)$$

where,

$$A_1 = \frac{\omega_{pi}^2}{\omega_{ci}^2}\left(\delta_{0J} - D_0^J(\lambda_i)\right).\frac{m_i}{m_e}.\frac{\omega_{pi}^2}{k_\parallel^2 v_{t\parallel e}^2}.\left(\frac{a}{1+a^2}\right)$$

$$B_1 = \frac{\omega_{pi}^2}{\omega_{ci}^2}\left(\delta_{0J} - D_0^J(\lambda_i)\right).\frac{m_i}{m_e}.\frac{\omega_{pi}^2}{k_\parallel^3 v_{t\parallel e}^3}.\left(\frac{\sqrt{\pi}}{2}.\cos\left(\frac{3}{2}\theta\right)\right)$$

$$C_2 = \frac{\omega_{pi}^2}{\omega_{ci}^2}\left(\delta_{0J} - D_0^J(\lambda_i)\right).\frac{m_i}{m_e}.\frac{\omega_{pi}^2}{k_\parallel^3 v_{t\parallel e}^3}.\sqrt{2}.k_\parallel v_{De}\left(\frac{a}{1+a^2}\right)$$

$$D_1 = c^2 k_\parallel^2 \frac{m_i}{m_e}.\frac{\omega_{pi}^2}{k_\parallel^2 v_{t\parallel e}^2}.\left(\frac{a}{1+a^2}\right)$$

$$F_1 = c^2 k_\parallel^2 \frac{m_i}{m_e}\frac{\omega_{pi}^2}{k_\parallel^3 v_{t\parallel e}^3}.\left(\frac{\sqrt{\pi}}{2}.R^{-3/2}\cos\left(\frac{3}{2}\theta\right)\right)$$

$$G_1 = c^2 k_\parallel^2 \frac{m_i}{m_e}.\frac{\omega_{pi}^2}{k_\parallel^2 v_{t\parallel e}^2}.\left(\frac{a}{1+a^2}\right)\sqrt{2}.k_\parallel v_{De}$$

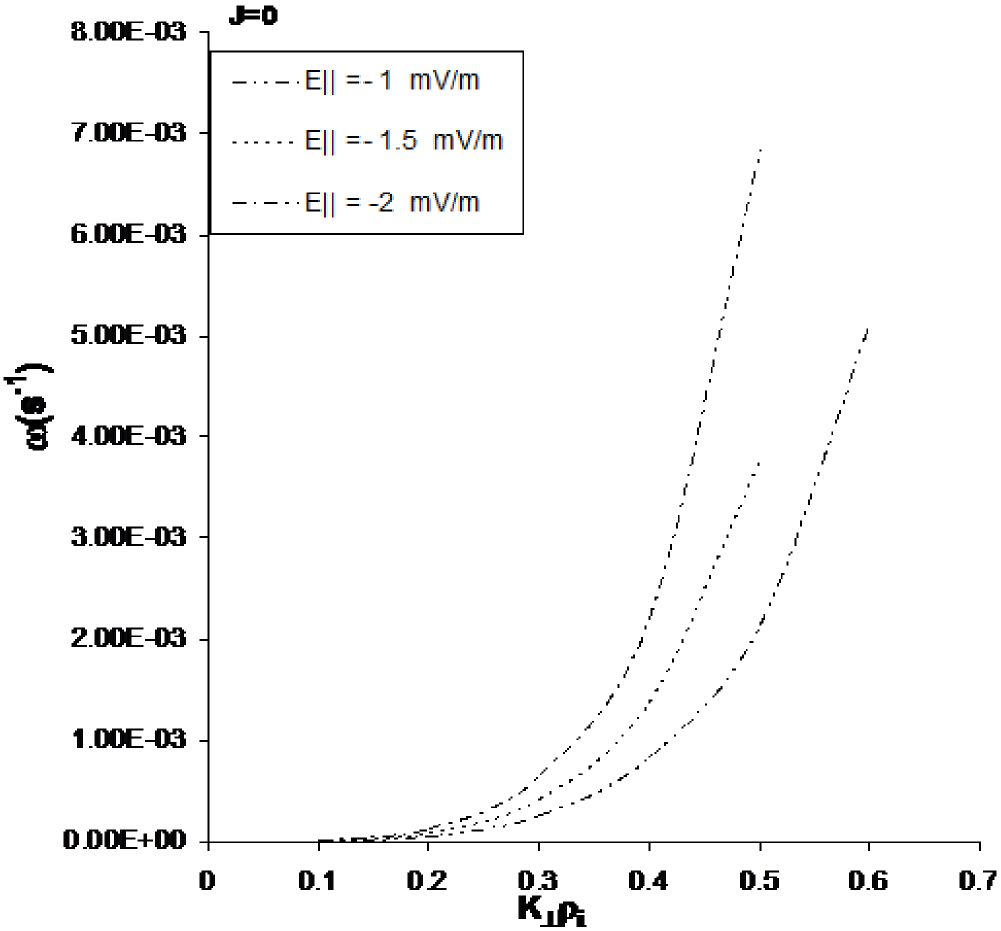

Figure 1. Variation of wave frequency $\omega(s^{-1})$ with perpendicular wave number $(k_\perp\rho_i)$ for different values of upward parallel electric field $(E_{||})$ and for distribution index J=0.

We can also easily show that for J=0, 1, 2….n, general dispersion relation and growth/damping rate can be obtained using recurrence relations (Shukla et al., 2008). We have considered both the smaller and larger wavelengths limit for ions.

RESULTS AND DISCUSSION

In the numerical calculation of the growth/damping rate and dispersion relation, we have used the following parameters for the plasma sheet boundary layer (Wygant et al., 2002; Shukla et al., 2007, 2008). $B_0 = 400nT$, $n_0 = 1\ cm^{-3}$, $T_{||e} = 10keV$, $k_{||}=1.0 \times 10^{-10}\ cm^{-1}$, $E_{||} = 0\text{-}100\ mV/m$. Equations 5 and 6 have been evaluated numerically using the Matlab software to solve the dispersion relation for wave frequency $\omega(s^{-1})$ and growth/damping rate (γ_L). Figure 1 shows the variation of wave frequency $\omega(s^{-1})$ with perpendicular wave number $(k_\perp\rho_i)$ for both $b_i<1$ and $b_i>1$ at different values of upward (negative) parallel electric field $(E_{||})$ and for distribution index J=0. Frequency is increasing with higher electric field at lower wave number $(k\perp\rho_i)$. It is also noticed that for J =0, that is, for the bi-Maxwellian distribution function, the wave frequency increases with the perpendicular wave number, which is a characteristics of KAW. In this figure, ion beam velocity is fixed that is, $k_{||}V_{Di} = -0.04$. It is assumed that the ion beam is directed from the ionosphere towards the magnetotail and therefore it is negative. In this study, electron beam velocity is also taken at fixed value that is, $k_{||}V_{De} = 0.06$. Our results are consistent with those reported by Cranmer and Van-Ballegooijen (2003) (Figure 2a) as the frequency increases with $k\perp$ for Maxwellian distribution function. Figure 2 shows the corresponding damping rate for the different value of upward parallel electric field and bi-Maxwellian distribution function of particles that is, J =0. Damping rate (γ_L/ω) is enhanced with parallel electric field and perpendicular wave number $(k\perp\rho_i)$. The damping in the wave may be due to the transfer of energy from the wave to the particles through the wave particle interaction. Thus, upward electric fields accelerate electrons downward and ions upward through the kinetic Alfven waves as the waves are attenuated imparting its energy to the particles. The upward electric fields also enhance

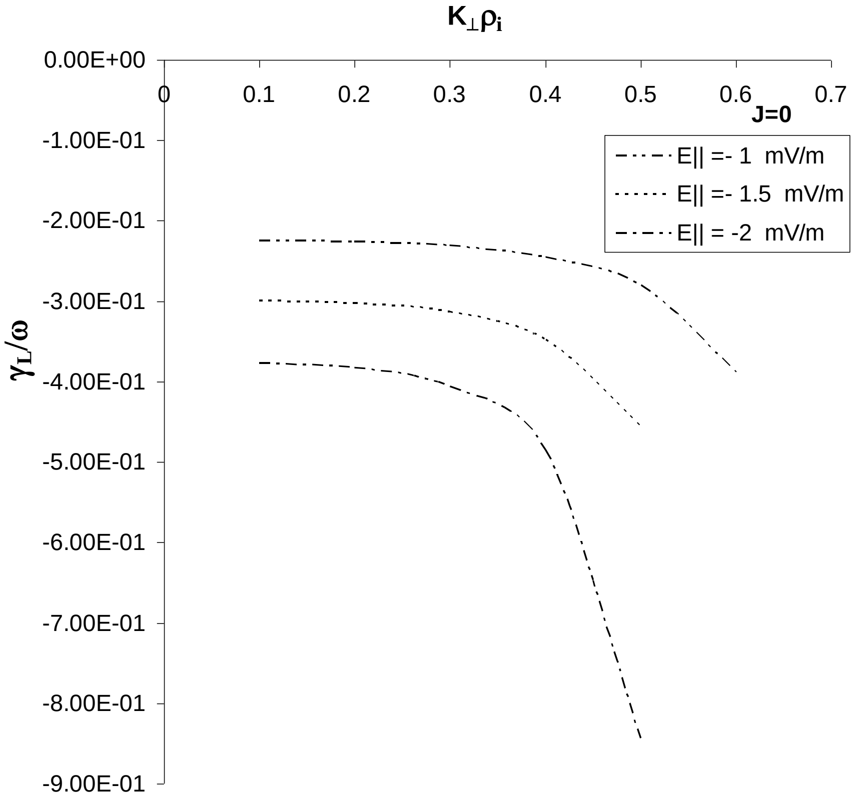

Figure 2. Variation of growth/damping rate γ_L/ω with perpendicular wave number ($k_{\perp}\rho_i$) for different values of upward parallel electric field ($E_{||}$) and for distribution index J=0.

the wave frequency of kinetic Alfven waves; therefore, the magnitude of electric fields should also be taken into account for the measurement of the kinetic Alfven wave frequency. Figure 3a, b and c shows the variation of wave frequency for different values of downward parallel electric field in the presence of the loss-cone distribution index. It is observed that in the presence of the loss-cone distribution, the frequency of the wave increases as compared to that for bi-Maxwellian distribution J=0 (Figure 3a) and $k_{\perp}\rho_i$ values are higher suggesting that as the Alfven wave propagates from the PSBL to the ionosphere, it becomes kinetic. This is consistent with the observed characteristic of KAWs (Keiling et al., 2005). Keiling et al. (2005) have analyzed the KAWs observed by the Polar satellite in the PSBL and have reported that for the highest frequency, peak E to B ratio (that is Alfven speed) was larger than for the lower frequency waves, which is consistent with a transition towards kinetic Alfven waves. It is also noticed that the downward electric fields are more effective to enhance the wave frequency as compared to the upward electric fields for the same plasma parameters. For J = 0 and when parallel electric field is zero, wave frequency is highly decreasing at lower value of ($k_{\perp}\rho_i$) and it increases again with higher perpendicular wave number. With higher downward parallel electric field, the frequency is highly increasing, attains a peak with perpendicular wave number ($k_{\perp}\rho_i$) and thereafter increases with $k_{\perp}\rho_i$. However, in the presence of the loss-cone distribution, the effect of parallel electric field with ion beam velocity is to reduce the wave frequency. This may be due to the mirroring effect of higher mirror ratio (Shukla et al., 2008). Thus, downward parallel electric fields also determine the wave frequency that may be for consideration of measurements. Figure 4a, b and c shows the variation of growth/damping rate of KAW for different values of downward parallel electric field in the presence of the loss cone distribution. For bi-Maxwellian distribution J = 0 and parallel electric field $E_{||}$=0 mV/m, Figure 4a shows the growth rate at all the shown values of perpendicular wave number. This may be due to excitation of kinetic Alfven wave by the ion beam (Voitenko, 1998). Whereas, at higher downward electric field, the wave is predominantly damped and wave energy is converted by accelerating ions and electrons. With higher perpendicular wave number, the growth rate is increasing. With higher downward electric field, the damping rate is increasing with higher distribution indices. This may be in accordance with the decreasing width of the loss-cone. The increase in the damping of the wave may be due to Landau damping of

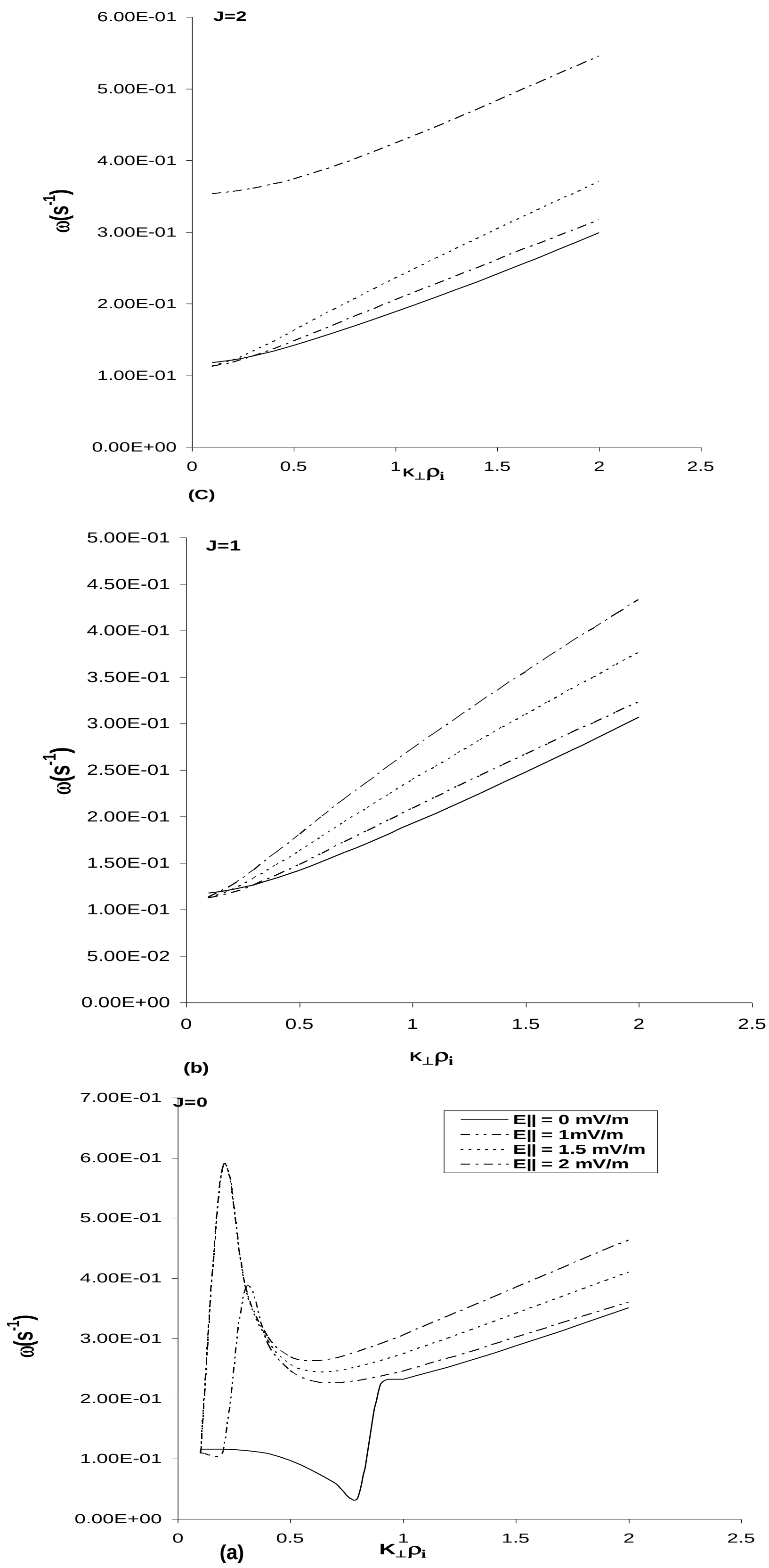

Figure 3. Variation of wave frequency $\omega(s^{-1})$ with perpendicular wave number ($k_{\perp}\rho_i$) for different values of downward parallel electric field ($E_{||}$) and for distribution index; a: J=0, b: J=1 and c: J=2.

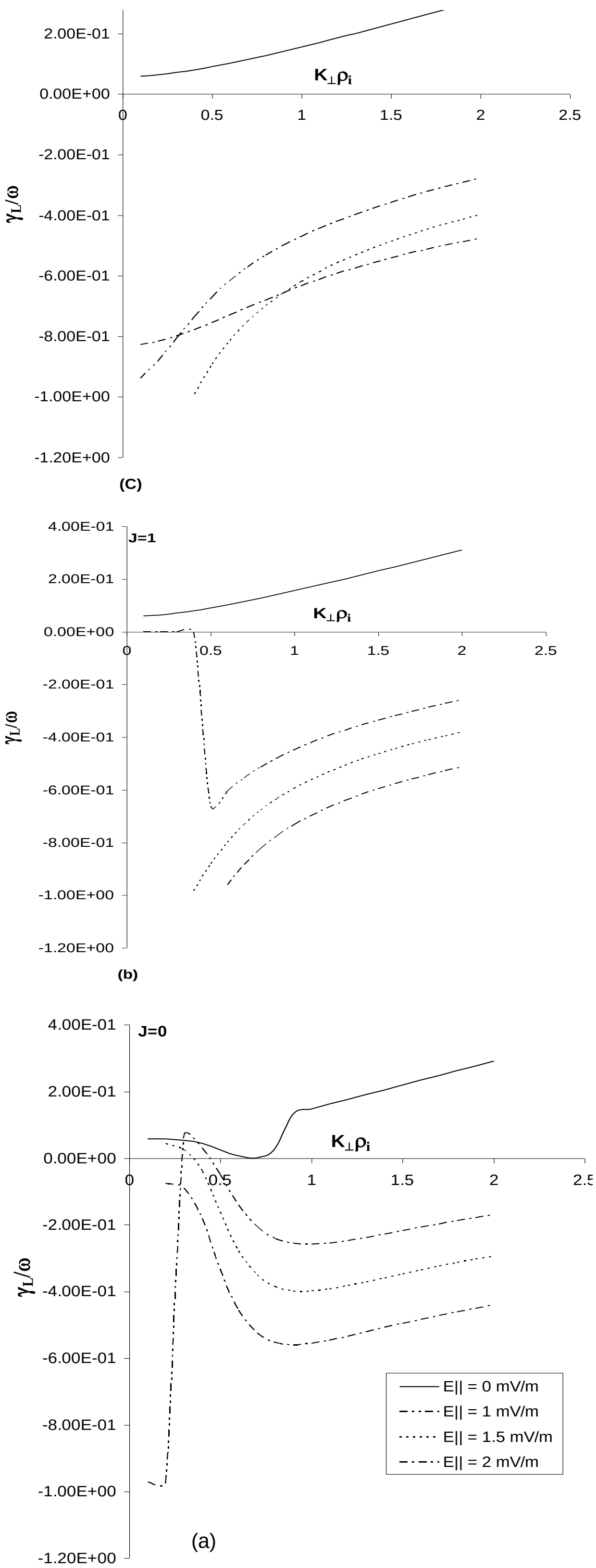

Figure 4. Variation of growth/damping rate γ_L/ω with perpendicular wave number ($k_\perp\rho_i$) for different values of downward parallel electric field ($E_{||}$) and for distribution index; a: J=0, b: J=1 and c: J=2.

of the wave. It is seen that the combined effect of general loss-cone distribution and parallel electric field with effect of ion and electron beam, is operative more effectively towards lower $k_\perp\rho_i$ contributing in the growth/damping rate of the wave. For $E_{||} = 0$, the effect of higher distribution index is to increase the growth rate due to the effects of ion beam. As compared to the case of upward parallel electric fields, the down-ward fields reduce the damping rate more effectively and may generate the kinetic Alfven wave for bi-Maxwellian distribution. Based upon Freja, Fast, Viking and Cluster observations, Marklund (2009) has reported the characteristics of the electric fields and related parameters, at altitudes below, within and above the auroral acceleration region. He pointed out that, the downward field-aligned current region plays an active role in magnetosphere-ionosphere coupling processes associated with aurora. A quasi-static electric field structure with a downward parallel electric field forms at altitude between 800 and 5000 km, accelerating ionospheric electrons upward, away from the auroral ionosphere. Accordingly, downward current region is characterized by enhanced ion heating, from the bottom to the top of the ionosphere and represents an important source for ion outflow. The ions become efficiently heated, as they spent time trapped between the downward electric field and the upward magnetic mirror force (Marklund, 2009). Marklund et al. (2001) demonstrated by data from Freja, Fast and Cluster (Marklund et al., 2001, 2004) at higher altitudes, above 1000 to 2000 km, quasi-static electric field structures with downward magnetic field-aligned component developed in the auroral return current. Marklund (2009) have also stated that the downward electric field accelerates ionospheric electrons upward away from the auroral ionosphere. The quasi-static acceleration is typically accompanied by significant wave activity and the up-going electrons display a broad energy range between a few eV up to keV energies. Strong double layers and large parallel electric fields have been observed or inferred from *in Situ* observations in both the upward and the downward FAC regions. Ergun et al., (2002) and Andersson et al. (2002) have contributed significantly to quasi-static parallel potential drops in the auroral region. The Freja and FAST observations of downward ion beams indicate that the acceleration region may at certain times be located at high altitudes above the FAST and Freja satellites (Marklund, 2009). In view of the observations as stated earlier and simultaneous observations of kinetic Alfven wave activities may explain the ion, electron heating in the downward current region, which is the presence of downward electric fields as inferred from the present study.

Conclusion

In the present analysis, we have investigated the effect of parallel electric fields on kinetic Alfven wave propagation for the auroral acceleration region. The past investigations (Shukla et al., 2008) are affected by the presence of parallel electric field to change the frequency and to alter the growth/damping rate and provide efficient mechanism of acceleration of ions and electrons along the auroral filed lines. The wave is assumed to be originated at the plasma-sheet-boundary layer and propagating towards the ionosphere. The wave frequency and growth/damping rates are mathematically evaluated and numerically analysed. The findings indicate that upward and downward of both electric fields enhances wave frequency. The damping of kinetic Alfven wave was also noticed, but in case of downward electric fields the damping rate reduces and there is possibility of excitation of waves also at certain $k_\perp \rho_i$. The applicability of study is indicated for the auroral acceleration process. The development of the kinetic approach may be used for the variety of electromagnetic waves propagation in the presence of external homogeneous electric/magnetic fields and inhomogeneous electric/magnetic field. The general distribution function in the presence of kinetic Alfven wave enhances the growth/damping rate and the frequency is likely to play crucial role in the auroral dynamics. This study can extend for the effect of ion and electron beam effect on kinetic Alfven wave in the presence of inertia effect. This study may offer on explanation for the various effects on earth at the substroms times, which have been mysteries for long periods. Further, it may also be useful to provide the knowledge of the structure of space environments for our polar satellites. The loss-cone distribution is an important factor to study KAWs in the PSBL as the distribution index alters the propagating properties of KAW.

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