

Properties of dispersive Alfvén waves and their roles in electron acceleration process in the terrestrial magnetosphere based on Plasma Distribution Solver

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Observations from the FAST satellite revealed the downward electrons in the energy range from tens of eV to a few keV in the terrestrial high latitude region [Chaston et al., 2002]. It is suggested that “Alfvénic acceleration” process by dispersive Alfvén waves is responsible for the auroral electron acceleration. Alfvénic acceleration has also attracted attention as the electron acceleration mechanism in Jupiter [e.g., Mauk et al., 2017; Saur et al., 2018], and the importance of Alfvénic acceleration in the auroral acceleration process in magnetized planets is increasing. While Alfvénic acceleration occurring in the terrestrial environment has been studied for decades [e.g., Chaston et al., 2002; Watt et al., 2006], physical processes controlling the characteristic energy and pitch angle distributions have been still unclear.

For the study of the efficiency and energy dependence of Alfvénic acceleration, understanding of the characteristics of dispersive Alfvén waves is essential. In the present study, we quantitatively examine the characteristics of dispersive Alfvén waves and their spatial variation in the magnetosphere by using originally developed “Plasma Distribution Solver”, which calculates the plasma and pressure distributions along a magnetic field line. We use results from three different conditions; Case 1 ($L=4$, $N_{e_eq}=240 \text{ cm}^{-3}$), Case 2 ($L=4$, $N_{e_eq}=24 \text{ cm}^{-3}$), and Case 3 ($L=15$, $N_{e_eq}=12 \text{ cm}^{-3}$), where N_{e_eq} is the electron number density at the magnetic equator, and the background magnetic field is assumed to be a dipole field. First, the ratio of the plasma pressure to the magnetic pressure (plasma β) is calculated to determine whether kinetic or inertial Alfvén wave dispersion relation should be used at each position along a magnetic field line. As a result, the characteristics of kinetic Alfvén waves appears in the Case 1 in the region below 20 degrees of the magnetic latitude, and the kinetic Alfvén wave region extends up to about 30 and 50 degrees of magnetic latitude in Cases 2 and 3, respectively.

Next, with the aim of considering the effect of Alfvénic acceleration on high-energy electrons, we investigate the relationship between the Larmor radius of energetic electrons and the perpendicular wavelength of dispersive Alfvén waves, referring to the discussion in Chaston et al. (2004). Chaston et al. studied the relationship between the wavelength of the dispersive Alfvén wave and the spatial scale of the cyclotron motion of ions, and showed that stochastic acceleration can occur when the wavelength perpendicular to the background magnetic field is smaller than the ion Larmor radius. In Case 1, the Larmor radius of electrons at 100 keV is larger than that thermal ions at the magnetic equator, and the effect of kinetic Alfvén waves is expected to be significant. On the other hand, the Larmor radius of 100 keV electrons is smaller than that of thermal ions, suggests limited effect of kinetic Alfvén waves in Case 2. In Case 3, the effect of kinetic/inertial Alfvén waves is expected for 100 keV electrons in the region of 20-60 degrees magnetic latitude. In this presentation, we also discuss the energy dependence of the electron acceleration process with the results obtained by the Plasma Distribution Solver.

Keywords: Terrestrial magnetosphere, Alfvén waves, Alfvénic acceleration, dispersive Alfvén waves, electron acceleration mechanism, numerical experiment

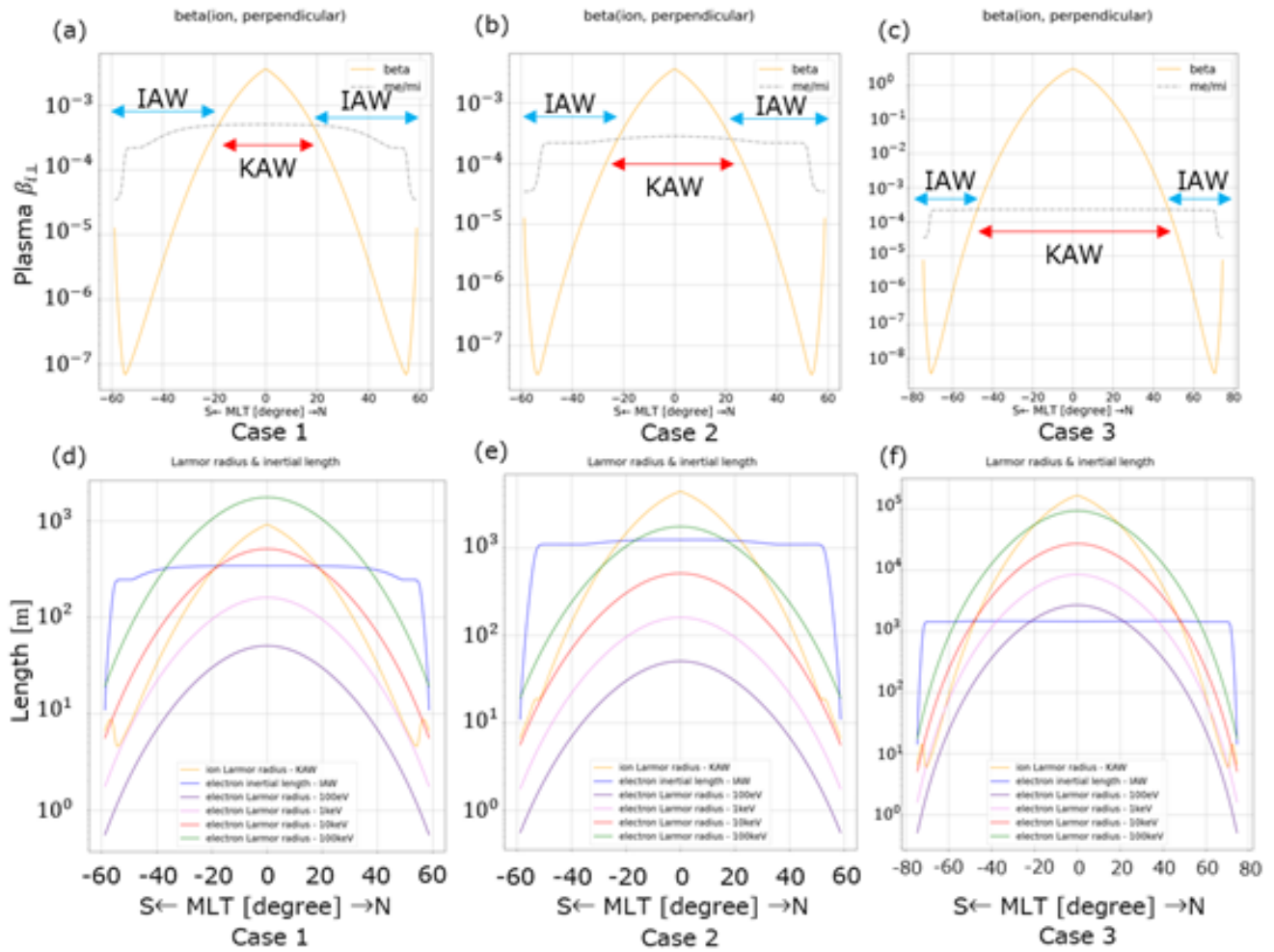


Fig. 1

(a) Plasma $\beta_{i\perp}$ profile for Case 1, (b) Profile of Case 2, (c) Profile for Case 3,

(d) Characteristic lengths profile for Case 1, (e) Profile of Case 2, (f) Profile for Case 3

IAW: inertial Alfvén wave, KAW: kinetic Alfvén wave