The final report on the project

"Cusp Dynamics-Particle Acceleration by Alfvén waves"

Award Number: NAG5-11924

PI: Yi-Jiun Su; Co-Is: Robert E. Ergun and Scott A. Parker

Successful results were obtained from this research project. This investigation answered and/or made progresses on each of the four important questions that were proposed: (1) How do Alfvén waves propagate on dayside open field lines? (2) How are precipitating electrons influenced by propagating Alfvén waves? (3) How are various cusp electron distributions generated? (4) How are Alfvén waves modified by electrons?

During the first year of this investigation, the input parameters, such as density and temperature altitude profiles, of the gyrofluid code on the cusp field lines were constructed based on 3-point satellite observations. The initial gyrofluid result was presented at the GEM meeting by Dr. Samuel Jones.

During the process of collecting data, a clear relationship between Alfvén waves and ion outflows was found in the polar cap boundary acceleration region. This region includes the dayside cusp and near midnight polar cap boundary; both of which map to the reconnection regions on the dayside magnetopause and nightside magnetotail, respectively. Two characteristics suggestive of the Alfvén auroral regions are the strong wave power and the small current density. Although it can be observed at any activity level, a higher ion energy flux is observed concurrent with a higher AE index. Results indicate that the energy fluxes of ion outflows and the estimated Alfvén wave power are higher in the Alfvén region when compared with those in the static upward current region. Moreover, the ion energy flux was observed to increase with an increasing estimated Alfvén power indicating that ionospheric ion outflows are directly or indirectly energized by Alfvén waves. The estimated Alfvén Poynting flux is approximately an order of magnitude higher than the corresponding ion energy flux, suggesting that the Alfvén power is partially dissipated into the ionosphere, used in accelerating electrons by wave-particle interaction, or converted to other wave power due to wave-wave interactions.

In the second year of this investigation, a linear one-dimensional gyrofluid simulation with finite-gyroradius and electron inertial effects was applied on a dayside auroral field line to determine the propagation characteristics of Alfvén waves with small perpendicular wavelengths. A paper on the computational method adopted for the inclusion of electron inertia without advancing the electron flow was published in the Journal of Computational Physics [*Jones and Parker,* 2003]. A test particle scheme was developed by the PI including gravitational and mirror forces. Test particles were used to study the behaviors of both magnetosheath (100 eV) and background electrons (2 eV) under the influence of dispersive Alfvén waves obtained from the gyrofluid code. Although the test particle approach is not self-consistent, the gyrofluid/test-particle simulation was able to reproduce many of the features observed by low altitude satellites.

Energy-time dispersion is generated by precipitating magnetosheath electron due to an inertial Alfvén wave in the acceleration region. Pitch-angle dispersion, where the highest energy electrons appear at narrow pitch angles along the field line evolving to large pitch angles with time, is obtained as a result of the inclusion of the mirror force. With an increasing O^+ scale-height, we are able to reproduce the low-energy field-aligned electron bursts that are often observed in the dayside auroral region. In the acceleration region, the parallel electric field must maintain at a magnitude substantial enough (~0.2 mV/m) to accelerate the background electrons. The majority of the electrons are trapped within the wave and gain energy to tens-hundreds eV, while some electrons travel in front of the wave with parallel velocities of a factor of two of the Alfvén speed. In this study, we were able to successfully reproduce both the electron energy-time dispersion, pitch-angle dispersion, and the low-energy field-aligned electron burst observed by the FAST satellite. Scientific results from this portion of the study were presented at several international meeting, and were published in the Journal of Geophysics Research [*Su et al.*, 2004]. A Ph.D. dissertation resulting from this investigation by Dr. Samuel Jones is published by the University of Colorado at Boulder in May, 2004 [*Jones,* 2004].

While conducting this research, we found that the gyrofluid code developed by Dr. Jones to answer questions about the Earth's aurora could be modified and adapted to the Jovian environment in order to study Alfvén wave propagation. Dr. Jones successfully included the displacement current term in the code to avoid the problem of the Alfvén speed exceeding the speed of light. With reasonable density profiles obtained from observations and results from an existing 1-D Vlasov code, we are able to simulate a large amplitude Alfvén wave propagating along the Jupiter-Io flux tube. Initial results show that the majority of the wave energy is unable to reach the Jovian ionosphere without wave breaking, phase mixing, or other nonlinear processes occurring, however, small wavelength/high frequency waves are able to reach the Jupiter's ionosphere. Additionally, the ionospheric Alfvén resonator well-known in the Earth's upper ionosphere was obtained from our simulations in the Jovian environment. The frequency of the ionospheric Alfvén resonator depends greatly on the ionospheric density and the plasma scale height, and is comparable to the observed reoccurring frequency of S-bursts. Hence, we suggest the Alfvén resonator as a possible driver explaining multiple occurrences of S-bursts. Preliminary results from this study will be submitted for publication at the conclusion of the current funding.

Meeting

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