Structure of Electron Distributions in the Near-Earth Seed Region as Transported from the Earth's Outer Magnetosphere

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Abstract

The kinetic modeling of electrons on global magnetospheric scales is discussed. At the present time, self-consistent global particle in cell simulations with realistic parameters is not feasible computationally and thus to model electron transport from the Earth's outer magnetosphere into the near-Earth plasma sheet an alternative approach is taken whereby individual electron trajectories are traced in global magnetospheric field models. Although in the majority of the magnetosphere electrons follow adiabatic motion, near weak magnetic field regions (i.e., reconnection regions), motion can be non-adiabatic. To include these effects, a guiding center code following individual electron trajectories is used in most regions of space, however, if motion begins to become non-adiabatic, the trajectory tracing equation switches to the full Lorentz force equation. Details concerning the model and results concerning electron transport and acceleration in the magnetosphere will be discussed.

1. INTRODUCTION

As electrons are transported from the Earth's outer magnetosphere they can be accelerated to energies of the order of keV when they reach the seed region located at about 10 R_E radially from the Earth in the equatorial plane. As these seed electrons move closer to the Earth wave-particle interactions can cause further acceleration up to relativistic (MeV) energies. This process occurs mainly during the recovery phase of magnetic storms, when relativistic electron fluxes are usually observed to be enhanced over pre-storm values in the inner magnetosphere near geosynchronous orbit.

How the seed region is populated with moderately energetic electrons (~ keV) is important in the entire sequence of events that leads to the formation of high energy (~ MeV) electrons that damage satellites during magnetic storms in the inner magnetosphere. This is because most theories of electron energization to MeV energies near geosynchronous orbit require a moderately energized electron population in the near-Earth plasma sheet seed region. As these electrons are transported closer towards the Earth they are most likely accelerated by some type of wave-particle interaction achieving MeV energies.

In this project, the formation of the seed region electron population from the outer magnetosphere is considered.

2. APPRAOCH

The approach is to follow electrons in a model of the Earth's global magnetic and electric field configuration taken from empirical and/or MHD simulations. Electrons are launched in the outer magnetosphere and their non-interacting trajectories are traced as they are transported through the magnetosphere. Electron trajectories are followed using a three dimensional guiding center set of equations, but in certain regions (i.e., reconnection regions or neutral sheets) if the electron motion is non-adiabatic, full particle motion equations (Lorentz force equation) are used. In the majority of the magnetosphere, guiding center equations are appropriate for electrons, thus making the problem computationally feasible.

The particle trajectory tracing code that follows guiding center motion and full particle motion is used with the three dimensional empirical magnetic field model developed by *Tsyganenko* [1], refereed to hereafter as the

T89 model. Eventually this will be generalized to use results from the BATS-R-US MHD code from the University of Michigan. Electrons are followed on a global scale from the outer magnetosphere as they are transported towards the near-Earth seed region. Electron position and velocity information is collected onto virtual detectors located at a variety of spatial positions during the course of the run for analysis. Distribution functions are calculated as well as moments over the distribution such as density and temperature. These results are used to understand the physics of electron energization and transport, and will be compared with relevant satellite data. Electron entry points, energization regions, and general transport properties from the outer magnetosphere to the seed region are examined in order to understand how an energetic electron population is formed in the inner magnetosphere.

3. PRELIMINARY RESULTS

Runs have been carried out using the three dimensional T89 magnetic field model, along with an applied convection electric field model whereby magnetic field lines are treated as equipotentials and are mapped out along field lines from the ionosphere. A 60 kV potential drop was used across the polar cap. About 20,000 electrons were launched with an initial temperature of 100 eV from various locations in the open field line deep magnetotail. As the electrons convected earthward, some crossed into the closed field line region and interacted with a magnetic neutral line located at about 100 R_E in the nightside magnetotail. The following figure shows electron phase space diagrams at different locations in the magnetotail:

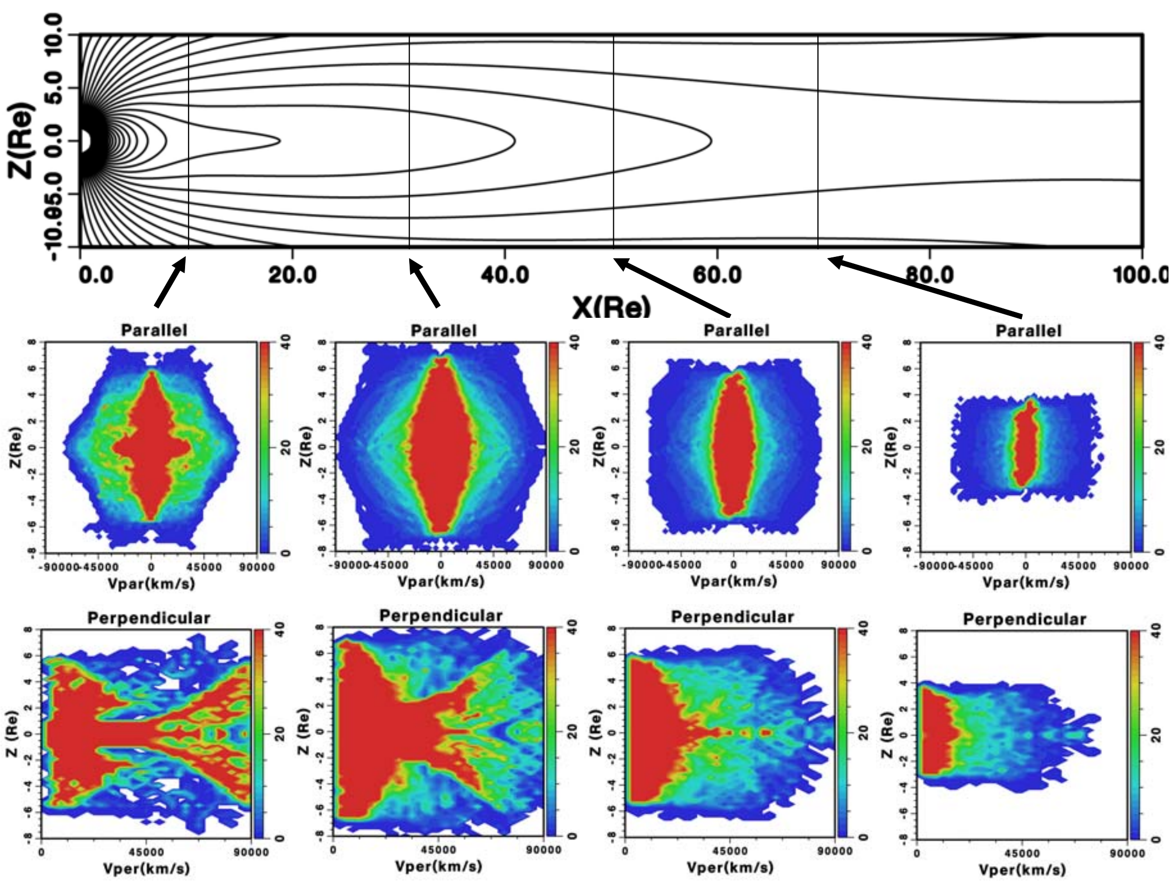

Fig. 1. The top panel of this figure shows magnetic field lines from the T89 magnetic field model and different locations of the virtual detectors (vertical lines in the system). The lower panels show the velocity phase space in both the parallel and perpendicular directions (respectively) at four different locations in the magnetotail as indicated in the top panel.

The results indicate that a combination of adiabatic compression and non-adiabatic acceleration occurred for electrons as they were transported earthward and in the seed region temperatures of the order of 1 to 2 keV were found. The next figure shows the electron temperature profile as a function of distance in the magnetotail.

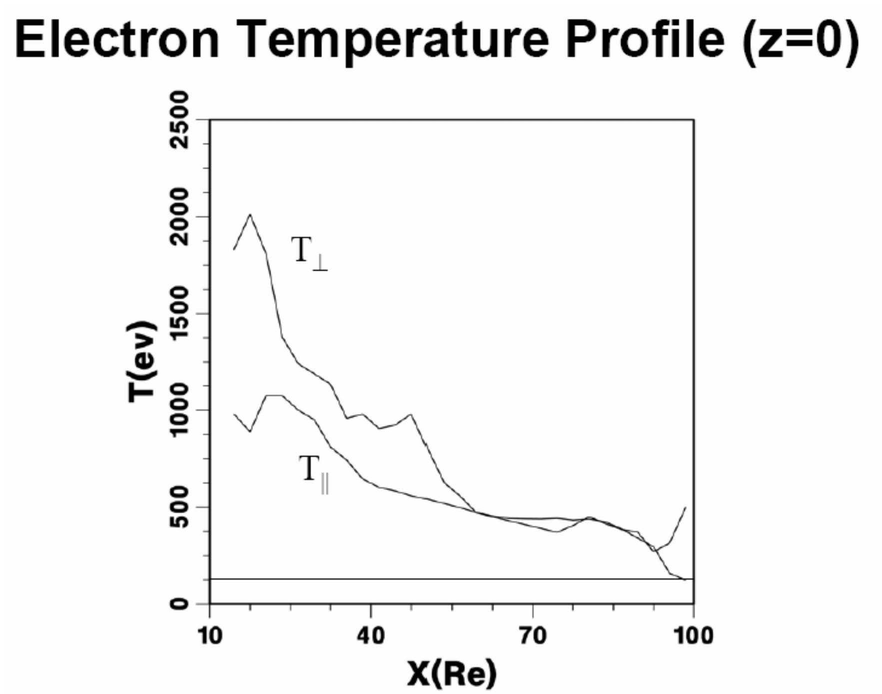

Fig. 2. This figure shows the parallel and perpendicular electron temperature in the equatorial plane versus position in the magnetotail.

It can be seen in Fig. 2 that near the seed region just beyond 10 R_E, a temperature anisotropy develops such that $T_\perp \sim 2T_\parallel$, due to heating of the electron distribution function that occurs primarily in the transverse direction. Plasma instabilities may develop due to the temperature anisotropy in the near-Earth plasma sheet region which could further affect the electron distribution function.

4. CONCLUSIONS

The large scale kinetic modeling of electrons in magnetospheric field models has yielded interesting results concerning global transport from the outer to the inner magnetosphere. Implications of the electron distributions in terms of instabilities and further near-Earth (< 10 R_E) transport will be explored in the future. Although the large scale kinetic approach has its limitations, in particular the lack of self-consistency, at the present time it is the only way to study electron kinetic particle effects over global scales since full particle in cell simulations are not computationally feasible without a serious compromise in the parameters.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

[1] N.A. Tsyganenko, "A magnetospheric magnetic field model with a warped tail current", Planet. Space Sci., vol. 37, pp. 5, 1989.