Radiation Belt Studies using the LFM MHD code

Scot Elkington1, Anthony Chan2, Yue Fei1, and Michael Wiltberger3

1 LASP, University of Colorado, Boulder; 2 Rice University, Houston, Texas; 3 HAO/NCAR, Boulder, Colorado

Introduction

The outer zone radiation belts are comprised of energetic Electrons trapped in drift orbits encircling the Earth, lying at radial distances extending from around 2RE to 7RE or greater. This region of space is of particular significance due to the large number of spacecraft operating at these altitudes, and global society’s increasing reliance on space based technologies. As the MeV particles composing the belts represent a hazard to human activity in space, a goal of the CISM project is to provide a means for understanding and predicting changes in the radiation belts.

How well do we understand radial transport?

In this work we conduct a model-model comparison to test our understanding of the radial diffusion process during periods of enhanced geomagnetic activity. An LFM MHD simulation, driven by upstream solar wind measurements, is used to drive test particle simulations (Elkington, 2004) of the outer zone radiation belts. The results are used as a baseline for comparison in a radial diffusion study.

Radial Diffusion Coefficients

The geomagnetic storm of September 24-26, 1998 was characterized by high solar wind speeds and an order-of-magnitude increase in outer zone electron fluxes occurring over a period of less than 18 hours. The high solar wind speeds and widely-varying dynamic pressures provided a source of energy for magnetospheric ULF waves, which in turn led to efficient radial transport and adiabatic heating of the energetic electrons comprising the outer zone.

September 1998 Storm

The results of the MHD simulations are spectrally analyzed to determine the ULF wave characteristics throughout the storm. In particular, the power spectrum as a function of mode structure was determined using the method outlined in Holzworth & Mozer [1979].

Diffusion results

Simple power law: $\sigma = 0.376$

Symmetric only: $\sigma = 0.325$

Asymmetric only: $\sigma = 0.441$

Sym + Asym: $\sigma = 0.316$

Power at the frequency of a particle with first invariant corresponding to a 1MeV geosynchronous electron was extracted and applied to the diffusion coefficients.

The results of the MHD simulations are spectrally analyzed to determine the ULF wave characteristics throughout the storm. In particular, the power spectrum as a function of mode structure was determined using the method outlined in Holzworth & Mozer [1979].

Summary

We have conducted simulations of the September 24, 1998 geomagnetic storm to examine the extent to which this storm could be described in terms of radial diffusion. We find the best agreement between the MHD/particle and diffusion simulations when the full compliment of symmetric and asymmetric coefficients are used. We find it necessary to include realistic descriptions of power spectral density, including information on the global mode structure. Such simulations show the utility of the CISM modeling effort as not only a means of predicting the space weather environment, but also as a means of examining fundamental physical questions about the geospace environment.

References