Project Details

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Topic: Characterization of the Earth's Radiation Environment

Project Title:
Effects of advective and diffusive transport of trapped energetic particles in radiation belt models

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Summary:
Science Goals and Objectives

We propose to investigate and contrast the effects of stochastic (diffusive) transport processes with transport resulting from coherent interactions of energetic particles with large scale magnetospheric disturbances. Processes affecting the dynamics of energetic particles in the inner magnetosphere may be broadly categorized as either stochastic processes, describing individually-random dynamics of an ensemble of particles interacting with a spectrum of magnetospheric waves; or coherent processes, whereby the dynamics of the particles are collectively driven in one direction in energy or space. On timescales longer than the drift period stochastic processes lead to radial diffusion, whereby particles move randomly through regions of higher or lower magnetic field strength, gaining or losing energy in accordance with the conservation of the particle's magnetic moment. The radial profile of phase space density determines whether a net increase in energy occurs resulting from a positive outward gradient or a net loss of energy from a negative gradient. Coherent processes, by contrast, result from interactions with convective or impulsive transfers of energy with a well-defined direction. Examples of key coherent processes in the inner magnetosphere include plasmasheet injections into the stable trapping region during substorms, and injections of previously-trapped particles from high L values during impulsive events induced by shocks in the solar wind.

The proposed work applies to dynamical simulations based on a Fokker-Planck framework, which traditionally describe trapped particle dynamics in terms of only diffusive motion. Specifically, we address the following science questions:

1) How do we characterize the quantitative effect of advective processes on overall radiation belt dynamics, and how does this compare to the stochastic processes that lead to radial diffusion for specific events?

2) How do we characterize the physical characteristics of the drivers of advective transport affect the efficiency of the process? Specifically, how does particle transport vary with injection front amplitude, propagation speed, azimuthal extent, and pulse width or steepness?

Methodology

This work will use state-of-the-art simulation models in combination with observations of the solar wind and radiation belts from NASA missions, with emphasis on Van Allen Probes, MMS, and THEMIS data sets. Global magnetohydrodynamic (MHD) simulations of the Earth's interactions with the solar wind will be used to drive test particle models of the radiation belts, the results of which will be used to specify the relative contribution of advective and diffusive transport in the framework of a Fokker-Planck formalism. Analytic models of advective transport will be used to parameterize and augment understanding of the physical characteristics and dependencies of the transport process for quiet, active, and extreme conditions. Simulation results will be compared in detail to measured fluxes to demonstrate the importance of each transport mechanism and quantify associated sources of uncertainty in the models.

Proposed Contributions to Focus Team Effort

The results of this effort will provide an efficient Fokker-Planck formalism for including advective transport in dynamical models

of the Earth's radiation environment. Parameterized advection and diffusion coefficients will be provided to other members of the Focus Science Team and the community at large to improve future modeling efforts and define sources of uncertainty in physical models of the radiation belts.

Publication References:

no references