Project Details

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Program Element: Focused Science Topic

Topic: Understanding the Response of Magnetospheric Plasma Populations to Solar Wind Structures

Project Title:
Quantifying Wave-Induced Relativistic Electron Flux Variations in Earth's Radiation Belts Driven by Solar Wind Structures

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Summary:
Science Goals and Objectives
The relativistic electron fluxes in Earth s radiation belts are subject to various source and loss processes which are ultimately controlled by solar wind structures. The solar wind activities drive global variations of the magnetosphere and generate electromagnetic waves, which cause the enhancement and decay of energetic electrons in the inner magnetosphere. While the importance of resonant wave-particle interaction has been demonstrated in recent studies, the linkage with solar wind structures and the appropriate way of incorporating global plasma wave distribution into radiation belt simulation are not quantitatively addressed yet. The objective of this proposal is to quantify the radiation belt electron acceleration and loss due to solar wind impacts using numerical simulations with state-of-the-art global plasma wave distributions as inputs. More specifically:
1. Apply the machine learning technique to reconstruct the global distribution and evolution of whistler mode waves (chorus, hiss, magnetosonic wave), electromagnetic ion cyclotron (EMIC) wave and ultra-low-frequency (ULF) wave in Earth's magnetosphere using solar wind parameters as inputs;
2. Use the global wave distributions reconstructed by the machine learning technique as inputs to a physics-based radiation belt model to analyze relativistic electron acceleration following strong solar wind activities, quantify the simulation uncertainties and compare with the simulation using empirical wave models as inputs;
3. Model the gradual transport and decay of relativistic electrons in the magnetosphere during the quiescent solar wind period using the same method as Objective 2.

Methodology
The machine learning technique has been developed to predict various plasma quantities including total plasma density and plasma wave amplitude in Earth's magnetosphere using controlling indices. We will extend this technique to predict the global distribution of whistler mode waves (chorus, hiss, magnetosonic wave), EMIC and ULF waves using solar wind parameters. The solar wind parameters are available from the OMNI data, and the dataset of various plasma waves and electron density are available from the THEMIS and Van Allen Probes measurements. We will use the Van Allen Probes observation of energetic electrons to analyze the radiation belt electron flux variations. After identifying typical events showing the electron response to the solar wind drivers, we will simulate the radiation belt flux evolution using the global plasma wave distribution predicted by the machine learning technique. The UCLA 3D diffusion code has been developed and fully validated for simulating the electron evolution due to resonant wave-particle interactions. For comparison, we will also perform the radiation belt simulation using the empirical plasma wave model, which is available from the recent satellite statistics. The simulation results will be validated against the satellite observations using validation metrics.

Proposed Contributions to the Focused Science Team Effort
This proposal directly addresses the Focused Science Topic 3 of NASA Living With a Star program, i.e., 'Understanding the Response of Magnetospheric Plasma Populations to Solar Wind Structures', and is highly relevant to the scientific objective 2, i.e., 'Understand how the Earth and planetary systems respond to dynamic external and internal drivers'. The communities of radiation belt research and space weather prediction will benefit from the proposed studies because this proposal demonstrates a feasible and state-of-the-art method in radiation belt modeling using upstream solar wind conditions as inputs, capable of quantifying and predicting radiation belt environment. Upon the completion of the proposed studies, we will provide extensive modeling efforts of Earth's radiation environment prediction with improved accuracy, contributing to the future space weather forecast.

Publication References:

no references