Project Details

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Topic: Characterization of the Earth's Radiation Environment

Project Title:
Data-constrained predictive model of radiation belt dynamics

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Summary:
During intervals of increased geomagnetic activity, the intensities of relativistic electrons trapped in Earth s radiation belts vary by orders of magnitude. Elevated levels of electron radiation can damage and disable satellites. To mitigate hazardous radiation effects it is necessary to quantify and predict radiation belt enhancement events. While many individual mechanisms of electron acceleration and loss have been identified, the net effect of all processes acting in concert is not understood because no unified physics-based model exists in which all of these effects are included.

The primary goal of this proposal is to provide a data-constrained modeling capability for prediction of the near-Earth radiation environment including its dynamic variability in response to different solar wind driving. Our model incorporates all key electron acceleration and loss mechanisms by combining a self-consistent description of global electromagnetic fields, that drive convection and radial transport, with an empirical specification of high-frequency plasma waves, that produce local acceleration and loss. Global evolution of radiation belt intensities is calculated with a test-particle approached, with time-dependent initial conditions specified by an empirical model based on a combination of statistics and near-realtime spacecraft measurement. Such global data-driven specification of radiation belt intensities over the full rage of spatiotemporal scales is timely and possible due to new unprecedented datasets (Van Allen Probes and THEMIS), recent progress in modeling capabilities, and the growth of computational power.

Armed with a global data-driven model, the proposed science investigation will enhance our understanding of the fundamental processes that sculpt the near-Earth radiation environment during coronal mass injection (CME) storms and during high solar speed (HSS) streams by addressing the following outstanding science questions:

1. What are the relative roles of global convection and transient mesoscale injections in the buildup of the radiation belt seed population?

2. What are the parameters of interplanetary shocks that produce new relativistic electron populations in the slot region and in the inner radiation belt?

3. What are the relative contributions of direct injections and diffusive radial transport to the buildup of radiation belt intensities?

4. How do radial transport and local wave-particle interactions compete in the buildup of radiation belt intensities?

5.What are the relative roles of atmospheric precipitation and magnetopause losses in depleting radiation belt intensities?

Proposed Contribution to the Focus Team Effort

The proposed research is directly relevant to Focused Science Topic (2) Characterization of the Earth s Radiation Environment . We will bring a unique set of modeling capabilities unified in a validated data-driven framework for specification and prediction of the near-Earth radiation environment. We will also collaborate with the rest of the Team who may develop new data streams or models (empirical or physics-based) of wave-particle interactions for inclusion in our global coupled framework.

Interactions with User Communities

Most disruptive effects of radiation belt electrons on orbiting spacecraft are associated with internal charging and discharging.

Internal charging occurs during intense radiation belt events when relativistic electrons penetrate the shielding of the spacecraft deep enough to accumulate in dielectric components. Global distribution of radiation belt intensities, produced by our model, can be used to compute the internal current charging, and then converted to the anomaly probability for a spacecraft at a given orbit. Such tool would be useful to spacecraft operators for designing sensible mitigation strategies to avoid descriptive effects of internal charging.

Publication References:

no references