Project Details

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Program Element: Focused Science Topic

Topic: Incorporating Plasma Waves in Models of the Radiation Belts and Ring Current

Project Title:
Ring Current Control of the Outer Radiation Belt: Local Wave-Particle Interactions and Large-Scale Magnetopause Losses

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Summary:
The goal of this project is to advance our quantitative understanding of storm-time variability of energetic electron fluxes in the outer electron belt by developing an improved empirical model of EMIC wave properties, incorporating it into a global 3D test-particle model of the outer belt and conducting detailed numerical simulations of storm-time dropout events in support of the RBSP and BARREL missions. We address the following science questions: (1) How do spatial and spectral properties of storm-time EMIC waves vary as function of geomagnetic activity? (2) What are the relative roles of magnetopause losses and quasi-linear resonant scattering by EMIC waves in causing permanent losses of the outer belt electrons? (3) What are a relative roles of adiabatic and non-adiabatic processes in producing dropouts of the outer belt electron fluxes?

The proposed research is highly relevant to the 2010 TR&T FST 1.2.1(d), which identifies "...the spatial distribution and properties of EMIC waves..." to be the first of the "Major uncertainties..." limiting our understanding of radiation belts and explicitly calls for "... incorporating improved models of plasma waves into our large-scale plasma and field models."

To quantify EMIC wave properties, we use high-resolution magnetic field measurements from 7 NASA missions: DE 1, AMPTE/CCE, CRRES, Polar, Cluster, THEMIS, and RBSP, which provide extensive coverage of the inner magnetosphere for four different solar cycles. Combining data from the 15 spacecraft of these missions, using our existing analysis tools, will result in a more than factor of 6 increase in statistics of storm-time EMIC waves compared to previous analysis. This will enable a detailed parameterization of wave properties including characterization as a function of storm phases.

Our global test-particle model of the outer electron belt (RB-REALM) provides a detailed description of three-dimensional particle motion including rapid magnetopause losses produced by large-scale reconfiguration of the magnetic field due to storm-time ring current and magnetopause compression, and non-diffusive radial transport due to ULF field oscillations. The model also incorporates local energization and pitch-angle scattering due to resonant wave-particle interaction, which is described as a Monte Carlo process based on analytical formulae for the pitch-angle and energy diffusion coefficients in a multi-component plasma. It will include the newly developed empirical model of EMIC waves described above, and existing parameterizations of whistler chorus and hiss.

To address science questions, two main modeling campaigns will be carried out. We first select a set of 15 minor, moderate, and large magnetic storms. For each storm, we use our RB-REALM test-particle model to compute the relative roles of the atmospheric losses due to rapid pitch-angle scattering by EMIC waves and magnetopause escape due to storm-time ring current and increases in the solar wind dynamic pressure. These simulations will quantify the balance of magnetopause and atmospheric losses as function of electron initial location, pitch angle, and energy for different phases of the storm, and will also reveal how losses are affected by the spatial extent of waves producing local acceleration and pitch-angle scattering.

The second part of the investigation provides direct support to the RBSP and BARREL missions. We will use pre-storm fluxes measured at RBSP as initial conditions and simulate storm-time evolution of the belt with RB-REALM. We will adjust model free parameters to match electron losses measured by BARREL. We will compare simulation results and observations at RBSP to determine: (a) what fraction of the observed dropout is produced by permanent losses versus adiabatic deenergization; (b) what are the relative roles of magnetopause escape and pitch-angle scattering by EMIC waves in producing radiation belt dropouts observed by RBSP.

Publication References:

Summary: no summary

Reference: Mitchell, D. G.; Lanzerotti, L. J.; Kim, C. K.; Stokes, M.; Ho, G.; Cooper, S.; Ukhorskiy, A.; Manweiler, J. W.; Jaskulek, S.; Haggerty, D. K.; Brandt, P.; Sitnov, M.; Keika, K.; Hayes, J. R.; Brown, L. E.; Gurnee, R. S.; Hutcheson, J. C.; Nelson, K. S.; Paschalidis, N.; Rossano, E.; Kerem, S.; (2013), Radiation Belt Storm Probes Ion Composition Experiment (RBSPICE), Space Science Reviews, Volume 179, Issue 1-4, pp. 263-308, doi: 10.1007/s11214-013-9965-x

Summary: no summary

Reference: Ukhorskiy, A. Y.; Sitnov, M. I.; Millan, R. M.; Kress, B. T.; Fennell, J. F.; Claudepierre, S. G.; Barnes, R. J.; (2015), Global storm time depletion of the outer electron belt, Journal of Geophysical Research: Space Physics, Volume 120, Issue 4, pp. 2543-2556, doi: 10.1002/2014JA020645