GEM Focus Group Proposal on
"Quantitative Assessment of Radiation Belt Modeling"

1. Topic Description

Understanding the dynamics of energetic particles in Earth's radiation belts is of interest both scientifically and practically. Over the past few decades, various physical processes have been identified as potential mechanisms for the acceleration, transport, and loss of radiation belt particles. These processes, which have been mainly developed separately in the past, are now mature enough to be combined and assessed as a whole in accounting for the observed radiation belt dynamics. Furthermore, this assessment can now be performed quantitatively, owing to the unprecedented high-quality wave and particle measurements in radiation belts from multiple spacecraft, and the greatly enhanced fidelity in radiation belt modeling. Motivated by these facts, this new Focus Group (FG) on "Quantitative Assessment of Radiation Belt Modeling" will bring together the current state-of-art models for the acceleration, transport, and loss processes in radiation belts, develop event-specific and global wave, plasma, and magnetic field models to drive these radiation belt models, and finally combine all these components to achieve a quantitative assessment of the relative importance of acceleration, transport, and loss processes in radiation belts by validating against contemporary radiation belt measurements.

2. Timeliness of the Focus Group

The timeliness of this Focus Group is highlighted by:

- Ongoing and upcoming space missions which provide extensive measurements for waves and particles in radiation belts, e.g., the recently launched Van Allen Probes, THEMIS, BARREL, CubeSat, and the upcoming Japanese ERG mission, and the long-term data from NOAA/GOES, POES, LANL/GEO, GPS, Cluster, etc.

- Newly discovered physical processes in radiation belt studies which require quantitative assessment of their relative importance, e.g., drift orbit bifurcation, nonlinear wave-particle interactions, and non-resonant scattering.

- Recently developed comprehensive radiation belt models which can be used to test the relative importance of individual acceleration, transport, and loss mechanism, e.g., 3D diffusion models, convection-diffusion models, stochastic differential equation (SDE) codes, and test particle simulations.

- New event-specific and global wave, plasma, and magnetic field models that can be directly applied to radiation belt modeling, e.g., data-driven dynamic global VLF wave model based on low-altitude particle observations, self-consistent magnetic field model (3D equilibrium magnetic field model), and the coupled LFM-RCM model which can provide event-specific and global distribution of ULF waves.

3. Relation to Existing GEM Focus Groups

This newly proposed FG is strongly connected to the following existing GEM FGs:

- *Radiation Belts and Wave Modeling (2010-2014)*: Based on the wave and radiation belt models developed by the RBWM FG (which is ending in 2014), this new FG will combine the established modeling efforts and focus on quantitative assessment of the relative importance of the acceleration, transport, and loss processes.

- *Scientific Magnetic Mapping and Techniques (2011-2015)*: We will work with the mapping FG to provide event-specific and global magnetic field models for radiation belt modeling, as well as exploring the mapping techniques between low- and high-altitude measurements in radiation belts.

- *Tail-Inner Magnetosphere Interactions (2012-2016)*: We will work with the TIMI FG to specify the particles convected or injected from the tail, which serve as source particles for wave generations in radiation belts and as seed population for energetic particles.

- *Storm-Time Inner Magnetosphere-Ionosphere Convection (2013-2017)*: Since wave-driven energetic electron precipitation from the radiation belts will modify the ionospheric conductivity, which in turn modifies the convection electric field driving transport of source and seed electrons, the results from this FG will provide important constraints to the SIMIC FG.

- *Metrics and Validation (2011-2015)*: We will suggest coordinating sessions with the Metrics and Validation FG to perform detailed model-data comparison to quantitatively assess the radiation belt modeling.

We have also coordinated with other proposing focus groups and plan on synergistic activities, and joint sessions where relevant, if they are selected.

4. Goals and Deliverables

The goal of this FG is to combine the various radiation belt acceleration, transport, and loss processes and quantitatively assess their relative importance to radiation belt dynamics, as well as determining the specific conditions under which each process is dominant.

This FG will provide a radiation belt module as a component to the global General Geospace Circulation Models (GGCM), since the radiation belt modeling is driven by inputs from the entire magnetosphere, including tail (e.g., source particles for wave generation and seed particles for energetic particles), plasmasphere (e.g., plasma density, plasmapause location, and waves generated inside the plasmasphere), ring current (e.g., excitation of EMIC waves and magnetosonic waves), dayside (e.g., magnetopause location for the last closed drift shell and solar wind driven ULF waves). The event-specific and global models for these inputs to radiation belt modeling will also be developed and provided to the community.

5. Co-chairs

Jay Albert, Air Force Research Lab (Jay.Albert@kirtland.af.mil)

Expertise: Theory and simulation of the Earth's magnetosphere, especially cyclotron-resonant wave particle interactions in the radiation belts. He has developed innovative techniques for evaluating quasi-linear pitch angle and energy diffusion coefficients, and has pioneered the treatment of cross diffusion terms in the full transport equation. He also studies nonlinear, coherent interactions, obtaining analytical estimates of transport rates suitable for use in large-scale modeling.

Wen Li, UCLA (moonli@atmos.ucla.edu)

Expertise: Analysis in wave and particle data from multiple spacecraft including THEMIS, POES/MetOp, and Van Allen Probes, and simulation of quasilinear wave-particle interactions. Most recently, she has contributed to develop a physics-based technique to construct the spatiotemporal evolution of the global chorus wave intensity using in-situ electron precipitation data measured by multiple POES satellites, which is helpful to evaluate the specific role of chorus waves in any geomagnetic storm.

Steve Morley, LANL (smorley@lanl.gov)

Expertise: Scientist at LANL working primarily with large energetic particle datasets, including LANL-GEO, GPS, RBSP, GOES. Particular expertise in radiation belt dropouts, EMIC waves, substorm dynamics and informatics. Modeling background in ionospheric convection, substorms, realtime-DREAM radiation belt and model verification/validation.

Weichao Tu, LANL (wtu@lanl.gov)

Expertise: Numerical modeling and data analysis of energetic particles in Earth's radiation belts. She has developed: a 2D drift-diffusion model to quantify the precipitation loss of outer belt electrons by simulating both the low- and high-altitude electron distributions; physical quantification of radial diffusion coefficients based on global MHD simulation and spacecraft measurements; a 3D diffusion model, DREAM3D, to comprehensively simulate the outer belt dynamics; and a test particle code to model the field line curvature scattering loss of inner belt protons.

6. GEM Research Area

Inner Magnetosphere and Storms (IMS)

7. Term of Effort

5 years (2014-2018)

8. Expected Activities, Session Topics, and Challenges

The specific session topics and related activities include:

(1) A review of current radiation belt models. We will review the important acceleration,

transport, and loss mechanisms in radiation belts and identify and coordinate the models that simulate these processes.

(2) Specification of the required model and data inputs for driving radiation belt simulations. We will specify the inputs and then collaborate with other FGs to develop event-specific and global models for various magnetospheric waves (ULF, VLF, magnetosonic, EMIC waves, etc.), seed populations, magnetic field configuration, last closed drift shell, etc.

(3) Quantitative assessment of the relative contributions of the acceleration, transport, and loss processes during radiation belt dropout events. We will comprehensively model the radiation belt dropouts by combining all the important contributing processes. By comparing against the in situ radiation belt measurements, we will quantitatively evaluate their relative importance and determine the specific conditions under which each process plays a dominant role.

(4) Quantitative assessment of the relative contributions of the acceleration, transport, and loss processes during radiation belt enhancement events. This will be addressed similarly to the last topic but focusing on the radiation belt enhancements.

(5) Quantitative assessment of the relative importance of the newly discovered physics to radiation belt dynamics. These physical processes include nonlinear wave-particle interactions, non-resonant interactions, drift-orbit bifurcation, etc. Their contributions to radiation belt dynamics will be assessed in comparison to the traditionally considered mechanisms.

The FG will organize a ‘RB dropout’ challenge and a ‘RB buildup’ challenge, focusing on modeling the radiation belt dropouts and buildups individually. We will select a few dropout/buildup events using the Van Allen Probes data, gather the data and model inputs needed to simulate these events, and organize the FG to simulate the observed dropouts/buildups using their models to quantitatively assess the relative importance of various acceleration, transport, and loss processes and ultimately identify conditions under which each process is important.