Inner Magnetosphere Cross-Energy/Population Interactions (IMCEPI)

Topic Description

This focus group aims to improve physical knowledge and modeling of the inner magnetosphere, particularly the ring current interactions and feedback with other populations in the magnetosphere (e.g., plasmasphere, radiation belt, and ionosphere). Gaps still exist in the self-consistent modeling of ring current dynamics due to complex cross-energy interactions with the radiation belts, plasmasphere, and ionosphere. While the plasmasphere and radiation belts do not contribute significantly to the inner magnetosphere current systems or directly drive electric shielding and thus are often neglected or treated crudely in ring current modeling, they still play a very important role as a driver of the dynamics of the inner magnetosphere. The plasmasphere influences the plasma wave environment that controls pitch-angle scattering rates and subsequent precipitation losses of ring current and radiation belt particles. In addition to directly altering the phase space density in the inner magnetosphere, the precipitation also enhances ionospheric conductivity and outflow rate, which modifies the inner magnetospheric electric field and composition and in turn influences the magnetic field via the modified current systems. In recent years, efforts have been made to include/improve self-consistency between the plasma and fields, and we believe the time is right to turn out focus to what has been viewed as "second order effects" in the ring current modeling community, and has certainly suffered from a paucity of in-situ equatorial inner magnetospheric measurements.

Existing kinetic models (e.g., RAM-SCB, RCM, RCM-E, CRCM, HEIDI) use oversimplified scattering rates due to wave-particle interactions. These models can use electric fields more-or-less self-consistently obtained from an ionospheric potential solver that often still treats the conductivity non-self-consistently. Moreover, the inner magnetosphere ion composition is usually specified based on empirical models, not on first-principle physics, and therefore cannot provide event-specific influence or outcomes. These sample issues are the consequences of overlooking the proper connection with other populations or regimes. Therefore, to further our knowledge of the ring current dynamics and the nonlinear feedback process with other populations, we desire comprehensive models that tie the ring current to other regions in a self-consistent approach. Such a desire requires the modeling capability that takes into account physical mechanisms in different regimes as well as the interactions in between.

This focus group will foster interactions among observations, simulations, and modeling. The broad scientific goals of this focus group are, through implementation of physics in the existing models, to contribute to the physics-based understanding of (1) the mechanisms responsible for the ring current growth and decay, (2) the interactions with particles in other regions, e.g., the radiation belts and plasmasphere, and (3) the nonlinear feedback mechanisms. The main deliverable will the development of more comprehensive, full physics circulation modules, consistent with the goal of GEM program.

Timeliness of the Focus Group

Our focus group is timely for the following reasons:

- The Van Allen Probes provide extensive simultaneous high-resolution near-equatorial particle measurements over a wide energy range as well as plasma wave measurements from different inner magnetospheric components (e.g., plasmasphere, ring current and radiation

belt). This enables our capability to monitor cross-energy interactions between different populations in the inner magnetosphere. In addition, the Cluster and THEMIS missions also cover a wide energy range and hence provide a great opportunity for multi-point simultaneous investigation of the inner magnetosphere.

- The recently ended "*Near Earth Magnetosphere: Fields, Plasma, and Coupling*" focus group (2007-2012) improved modeling capabilities in self-consistently coupling plasma with electromagnetic fields (e.g., RAM-SCB, RCM, RCM-E, CRCM, HEIDI). Now it is time to move forward and continue to improve modeling capabilities by stimulating the development of more comprehensive, full-physics models that could account for self-consistent cross-energy/population coupling processes. Some GGCM modules (e.g., SWMF, OpenGGCM, LFM) have already been developed to include one or more inner-magnetospheric modules, providing a necessary and important base.

- The "*Plasmasphere-Magnetosphere Interaction (PMI)*" focus group (2008-2013), which investigated the cold plasma population and evolution, has just ended. Our focus group would build on what was learned and apply that to couple the plasmasphere with higher energy populations, therefore continue the investigation of plasmaspheric dynamics.

Fit/Relevance to Existing GEM Focus Group

The group is intended to fill a niche within GEM that is not addressed by any active focus group but will work with and leverage results from existing GEM efforts.

- *Tail-Inner Magnetosphere Interactions (2012-2016)*

This focus group endeavors to investigate the physical mechanisms of tail transport modes into the inner magnetosphere while excluding the discussion on variations in the inner magnetosphere. We will use the results from this focus group as tail drivers for modeling ring current dynamics and subsequent interactions with other inner magnetosphere populations.

- *Storm-time Inner Magnetosphere-Ionosphere Convection (2013-2017)*

This focus group aims to understand the coupled inner magnetosphere-ionosphere system, emphasizing the convection link. Our focus group will be complimentary to the SIMIC focus group by investigating the inner magnetosphere cross-population interactions that can alter the inner magnetosphere-ionosphere electrodynamics.

- *Radiation Belt and Wave Modeling (2010-2014)*

The wave-particle interaction is one important physical mechanism in the ring current and plasmasphere. We will work with the RBWM focus group to constrain physical models improved/developed under our focus group.

- *The Ionospheric Source of Magnetospheric Plasma-measuring, modeling and merging into the GEM GGCM (2011-2015)*

The merging of ionospheric sources into the GGCM will provide tools for better understanding the effects of heavy ions on the ring current and radiation belt dynamics, which is one of the goals of our focus group.

- *Metrics and Validation (2011-2015)*

Our focus group is directly related to this M&V focus group contributing to the development of more self-consistent and realistic global circulation models.

Goals and Deliverables

The goals of this proposed focus group are to provide a detailed, quantitative understanding of the coupled inner magnetosphere by including cross-energy and cross-population coupling processes. Some specific goals are:

- How do the cold plasmasphere and ring current properties influence wave-particle interactions and what are the feedback mechanisms? These questions will be addressed through efforts such as determining the relative role of various driving mechanisms on the ring current dynamics, developing empirical or numerical models of wave distributions in the inner magnetosphere, quantifying scattering rates by different types of waves, implementing loss rates in physical models, analyzing multi-spacecraft measurements, inferring cold plasma density, and correlating wave evolution to the dynamics of ring current and radiation belts.

- How do the cross-energy/population interactions alter the inner magnetospheric dynamics? To address this question, modeling efforts to couple physical models from different regions are required, including coupling the plasmasphere, radiation belts, and ring current, and constructing an ionospheric conductivity model based on particle precipitation due to magnetospheric waves. Enhanced precipitation also drives ionospheric ions into the magnetosphere, changing the content and dynamics of the ring current and radiation belts, suggesting the need to develop a self-consistent circulation link between the ionosphere and inner magnetosphere.
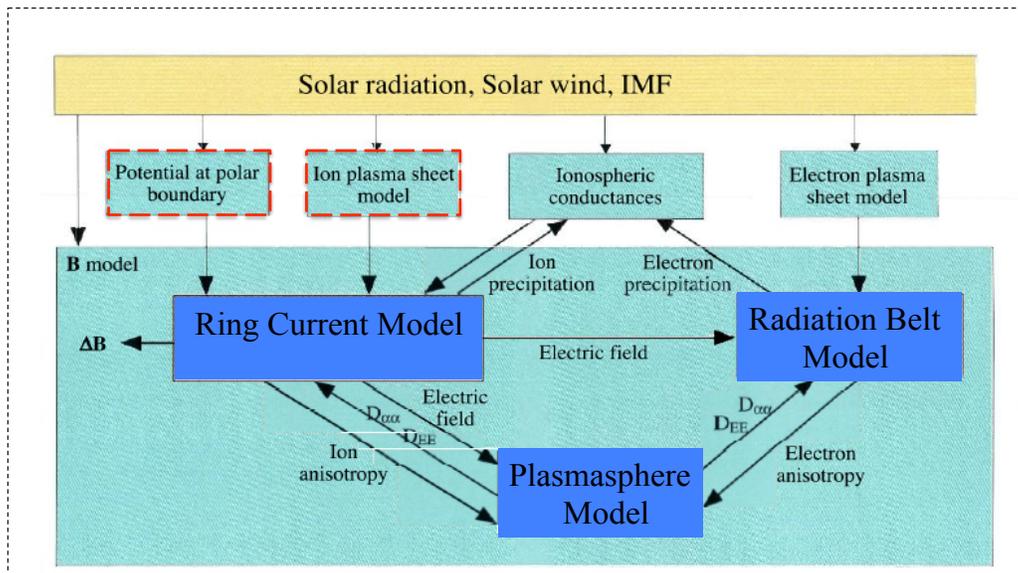

Figure 1. The coupling framework adapted from Fok et al. "Gospace Storm Processes Coupling the Ring Current, Radiation Belt and Plasmasphere", AGU/GMS, 2005. This scheme provides a general direction for the community to work together and improve the physics therein.

The main deliverable will be the development of more comprehensive, self-consistent physics-based circulation models, which is the main goal of the GEM program. They will be used for the study of ring current dynamics and interactions with the plasmasphere, radiation belts, and ionosphere. Detailed deliverables will include global wave distribution models, loss rates due to different types of waves in the ring current, plasmasphere, and radiation belts, and a dynamic module of ionospheric conductivity. **Figure 1** illustrates one designated coupling framework by Fok et al. (2005), providing a general direction for the community using various

inner magnetospheric models and magnetic field models to work together, in order to develop a comprehensive inner magnetosphere interaction model and continue to improve the physics therein.

Co-Chairs
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Research Area
Inner Magnetospheric Research Area

Term of Focus Group
Five Years (2014 -- 2018)

Expected Activities and Challenges

Below are some scheduled activities in the Focus Group: (1) A statistical study of the global distributions of various plasmas waves; (2) Kinetic model improvements in wave-particle interactions, precipitation, and ionospheric conductivity modeling; (3) Model development to couple different inner magnetosphere components; (4) Data-model comparisons with in-situ and ground-based measurement for the validation of the improved/developed models.

The challenges for modelers will be to reasonably well reproduce realistic events within different regimes. We plan to call for a series of challenges by simulating several storm events using different models with the same input, in order to improve the modeling capabilities through implementation of the physics. For example, in Year 1, we will set up a challenge study for several recent storms (e.g., those on 1 June 2013 and 2 November 2012) within the Van Allen Probes era, to compare and identify physical processes necessary for implementation in the models. In Year 2, modelers will present their capabilities with the same driving conditions and identify commonalities and discrepancies. With achievements obtained over years in both models and statistical quantities, we will repeat the challenge studies to further evaluate the model capabilities, with a potential collaboration with the Metrics and Validation Focus group.