GEM "Magnetospheric Response to Transient Solar Wind Features" Focus Group

Proposed Co-Chairs

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Term of Effort

5 years (2011-2015)

Abstract

We propose a new GEM focus group that will employ both observations and simulations to investigate the magnetospheric response to transient solar wind features. The goal of this focus group is to provide a fundamental physical understanding of the coupling mechanisms between transient solar wind features and the magnetospheric phenomena that they excite. This focus group encourages participation from communities interested in spacecraft observations (e.g., Cluster, Double Star, THEMIS, GOES), ground-based observations (aurora, riometer, magnetometer), and global simulations. Coordinated multi-point observations are especially encouraged. This focus group is unique in the sense that it connects phenomena in regions ranging from the distant solar wind, bow shock, magnetosheath, and magnetosphere, all the way down to the ionosphere. Thus it will attract participation from a broad community who do not normally interact. This focus group will provide support and refinement for the NASA's Radiation Belt Storm Probes (RBSP) mission (2012), as well as the Magnetospheric Multiscale (MMS) Mission (2014).

1. Topic description

The interaction of the Earth's magnetosphere with the solar wind is a fundamental problem in space plasma physics. Isolated sudden changes in the Interplanetary Magnetic Field (IMF)/solar wind conditions, e.g., coronal mass ejections (CMEs), solar energetic particles (SEPs), pressure pulses, and interplanetary shocks, provide excellent opportunities to study the complex responses of the Earth's magnetosphere and ionosphere. The interaction of transient solar wind features with the magnetosphere has several phases, including interaction with the bow shock, propagation through the magnetosheath, interaction with the magnetopause, transmission into the magnetosphere, the generation of field-aligned currents and particle precipitation, and the excitation of ionospheric responses including aurora, cosmic noise absorption, plasma convection, and magnetic field perturbations.

Studies of magnetospheric phenomena corresponding to solar wind discontinuities are tractable from at least two obvious vantage points: First, unlike other magnetospheric phenomena (e.g., substorms) the specific energy source for the solar wind discontinuity related to the magnetospheric phenomena is clearly defined. Second, they usually yield a significant and easily identifiable electromagnetic signal. Thus, there is no temporal ambiguity for the solar wind discontinuity related phenomena.

This focus group will provide an opportunity to present the latest multipoint space and ground-based observational results of the bow shock, magnetopause, polar cusp, magnetotail and the inner magnetosphere region responses to transient solar wind features. The highlights of this focus group will be the coordinated multi-point high time resolution measurements by ESA's Cluster, Chinese-ESA's Double Star, and NASA's THEMIS, and GOES spacecraft and the rich array of NSF-supported ground instrument arrays. Such constellations offer the possibility to perform sequential timing measurements of the cause and effect induced by the impact of transient solar wind features in the different magnetospheric regions. Together with global MHD and kinetic simulations (available at CCMC and in the broader community), we can address the outstanding space physics problems in geospace enumerated below.

2. Timeliness of the focus group

By analyzing measurements from the current missions (Cluster, THEMIS, GEOS), the proposed focus group will provide support and refinement for the NASA's Radiation Belt Storm Probes (RBSP) mission (2012), as well as the Magnetospheric Multiscale (MMS) Mission (2014).

The objective of NASA's Radiation Belt Storm Probes (RBSP) mission is to understand the basic principals behind relativistic particle acceleration, transport, and loss. Since transient solar wind features, e.g., CMEs and interplanetary shocks, are associated with the creation and modification of radiation belts, while smaller features may provide the compressional impulses needed for particle energization and diffusion, this focus group will provide the context for understanding these processes.

The research topics covered in this focus group are also closely related to the primary objective of NASA's future Magnetospheric Multiscale (MMS) Mission, to explore and understand magnetic reconnection, charged particle acceleration, and turbulence. For example, research on Flux Transfer Events (FTEs) will provide fundamental information about magnetic reconnection, a universal phenomenon which converts magnetic energy to heat and high speed flows. Amongst other topics, the focus group will attempt to identify triggers for transient magnetopause phenomena that modulate the flow of mass, energy, and momentum into the magnetosphere.

3. Relation to existing GEM focus groups

This cross-cutting focus group is unique in the sense that it connects regions from the solar wind, bow shock, magnetosheath, magnetosphere, all the way down to the ionosphere. Thus it impacts and will interact closely with all the existing focus groups:

- The Magnetosheath

  This focus group deals primarily with the steady state structure of the magnetosheath and will provide our focus group with the background we need to study more transient features.

- Dayside FACs and Energy Deposition

  This focus group is particularly interested in "enhanced dayside Poynting flux" events which are associated with interplanetary shocks and large in-the ecliptic IMF. They are attemping to find solar wind drivers for these events. Instead of focusing on a set of events in the ionosphere, our focus group will identify solar wind drivers and understand how they can impact the magnetosphere and the ionosphere.

- Radiation Belts and Wave Modeling

  This focus group is dedicated to identifying and quantifying sources of relativistic particle acceleration, transport, and loss mechanisms. Our focus group endeavors to investigate the role played by transient solar wind features, e.g., CMEs and interplanetary shocks, but also smaller scale structures generated in the foreshock, in these processes. We will work with the Radiation Belts and Wave Modeling focus group to determine which solar wind features are most effective in energizing radiation belt particles.

- Space Radiation Climatology

  The objective of this focus group is to model the space environment in the inner magnetosphere on long time scales mainly through data assimilation and statistical techniques. Our focus group will focus on short time scales. Combining results from both focus groups will provide a much better understanding of the dynamics in the inner magnetosphere.

- Near Earth Magnetosphere: Plasma, Fields and Coupling

  This focus group aims to improve our understanding and modeling of electric and magnetic fields and plasma in the inner magnetosphere. Our focus group endeavors to investigate how the inner magnetosphere responds to transient solar wind features, e.g. the time scale required for inner magnetospheric features to respond to abrupt variations in solar wind features.

- Diffuse Auroral Precipitation

  Since some of the dayside diffuse auroras are caused by the impingement of interplanetary shocks, our focus group will work with the Diffuse Auroral Precipitation group to enhance understanding of the mechanisms responsible for diffuse shock aurora.

- Plasmasphere-Magnetosphere Interactions

  The plasmaspheric dynamics is highly affected by transient solar wind features such as CMEs and shocks. Our focus group will work with the Plasmasphere-Magnetosphere Interactions focus group to better understand the processes involved.

4. Goals and deliverables

The goal of this focus group is to provide a fundamental physical understanding of the coupling mechanisms between transient solar wind features and the magnetospheric phenomena excited by the transient solar wind features. In particular, this focus group aims to understand the transient features upstream from the bow shock and in the magnetosheath. We also seek to understand whether transient solar wind features can trigger magnetic activity, excite waves (e.g., ULF and VLF), and accelerate particles in the magnetosphere. This focus group will involve multiple spacecraft observations (e.g., Cluster, Double Star, THEMIS, GEOS), ground-based observations (aurora, riometer, magnetometer), as well as computer simulations. We will validate and improve models via comparison with observations. Here we note that global hybrid code kinetic models have recently been developed, and that it has recently become possible to request high time and spatial resolution MHD runs from the CCMC. These are precisely the tools needed to test existing hypotheses.

Deliverables:

- End-to-end understanding and determining which transient solar wind features are effective in triggering geomagnetic activity, aurora brightening or waves in the magnetosphere, and information on the means by which they do this.

- Characterization of electromagnetic perturbations in the magnetosphere driven by solar wind features and a determination concerning their significance in radiation belt particle acceleration and diffusion.
- Global distributions (maps) of the magnetospheric/ionospheric responses to different solar wind/IMF transient changes.
- Improved understanding of transient features occurring and/or generated near the bow shock.
- Validated and improved models through comparison with observations.

5. The Research Area with which it will be associated

Dayside, including boundary layers and plasma/energy entry (Primary association)

IMS: Inner Magnetosphere and Storms

MIC: Magnetosphere - ionosphere coupling, aurora

GGCM: Global General Circulation Modeling

6. Expected activities, questions, and challenges

The specific science questions and challenges that our focus group will address include:

- What are the physical differences and relationships between hot flow anomaly, foreshock cavities, and density holes upstream from the bow shock? How do they evolve with time and transition through the magnetosheath? Do they play an important role in solar wind-magnetosphere coupling?
- Is there any relation between transient solar wind features and FTEs at the dayside magnetopause?
- Can transient solar wind features trigger geomagnetic activity? Which transient solar wind feature(s) trigger geomagnetic activity? And to what extent? What fraction of magnetospheric events is triggered by transient features?
- What are the characteristics of shock auroras? Can other transient solar wind features also trigger aurora brightenings? How do transient solar wind features propagate through the magnetosphere? How do they modify magnetospheric particle populations?
- What is the spatial distribution (in longitude and latitude) of magnetospheric phenomena excited by transient solar wind features? What is the lifetime of these excited magnetospheric phenomena?
- Is there a transient solar wind feature(s) responsible for energetic particle acceleration in the magnetosphere, especially the MeV electrons in the radiation belt? What is the particle acceleration mechanism? What conditions favor this acceleration?
- Are transient solar wind feature(s) responsible for magnetospheric ULF and VLF wave excitation? Do these waves play an important role in accelerating or decelerating the radiation belt electrons?
- How does the ionosphere respond to transient solar wind features?