GEM Proposal for a Focus Group on "The Magnetosheath"

FG Co-chairs: Steven Petrinec and Katariina Nykyri

FG term: 3 year term; with possible proposal during the third year to extend to another 2 years

Description of the Topic and Relevance to Dayside Research Area

This is a formal request to the GEM Steering Committee to start a new, dedicated Focus Group (FG) on "The Magnetosheath". The main objective of this Focus Group is to provide a better understanding of the characteristics and processes of the magnetosheath. This topic is of fundamental importance for understanding the immediate environment within which the magnetosphere is embedded. A clear understanding of this region of space is crucial for determining how the shocked solar wind directly interacts with and transports plasma energy flux into the magnetosphere. This topic is especially timely because 1) A significant number of missions are actively sampling the magnetosheath *in situ* (the THEMIS suite, the Cluster suite, Double Star, and Geotail) and remotely (IBEX), and 2) Detailed knowledge of the magnetosheath properties are needed for the planning of future missions (notably, for maximizing the probable encounters of the magnetopause reconnection X-line by the MMS suite). This focus group will foster participation from the theory, modeling and experimentalist communities which study the solar wind, bow shock, the magnetosheath, and the magnetopause. Because the Focus Group concerns the properties and physics of the shocked solar wind plasma from the bow shock to the magnetopause, it is most closely related to the 'Dayside' Research Area. However, since the magnetosheath region extends over a considerable spatial region, it is also related to the 'GGCM' and 'Tail' Research Areas.

Scientific Rationale

Although the plasma of the magnetosphere interacts with the solar wind via the magnetosheath, the magnetosheath region is paid scant attention; often being viewed as simply sub-magnetosonic solar wind. However, the magnetosheath is a much more complex region. Firstly, the boundary locations which define the magnetosheath region are not completely understood, especially during non-nominal circumstances; e.g., the bow shock location during very low solar wind Mach number, the magnetopause during times of very large solar wind pressure and/or large solar wind magnetic field intensity, and the behavior of the boundaries during dynamic solar wind conditions. Secondly, the self-consistent understanding of large scale plasma moment variations as a function of distance from the geophysical boundaries (the bow shock and magnetopause) and distance downtail has not progressed significantly from the early hydrodynamic simulations of Spreiter. In addition, magnetic field models in most cases do not yet accurately model the intensities and draping characteristics within the magnetosheath. Finally, factors controlling plasma wave mode instabilities, growth rates, and the existence of slow and intermediate standing shock waves within the magnetosheath are rather poorly understood (e.g., the slow mode shock location and stability, and plasma depletion layer close to the magnetopause); yet strongly affect the transport of plasma and magnetic flux into the magnetosphere. These characteristics are also strongly influenced by whether the magnetosheath regions map to the quasi-parallel or quasi-perpendicular bow shock.

With so many active and well-instrumented missions sampling the magnetosheath, and with active solar wind monitors to provide upstream information, this is an excellent time to exploit the observational data sets to perform a variety of multi-point conjunction studies. The spatial variation of magnetosheath plasma characteristics can be well-determined in a statistical manner. In addition, the time evolution of the plasma distribution functions, moments, and magnetic field can truly be addressed by *in situ* observations at multiple locations along streamlines within the magnetosheath. Dawn/dusk asymmetries in the plasma moments as a function of solar wind conditions need to be examined in detail, during both steady times and as solar wind discontinuities propagate through the magnetosheath. The dawn-dusk asymmetry in some magnetosheath plasma moments may be responsible for generating asymmetries in magnetosphere directly or indirectly; building on recent modeling efforts in FG3. For example, the cold population ions in the plasma sheet are hotter on the dawn side than on the dusk side plasma sheet. The 'direct' impact can be explained if the dawn-flank magnetosheath is statistically hotter than the dusk-side flank. The indirect impact may be explained by physical processes at the flank magnetopause that are affected by magnetosheath properties. A comprehensive understanding of magnetosheath plasma characteristics such as Mach numbers, electron/ion temperature ratios, plasma beta, and plasma wave and turbulence properties are also desperately needed. Magnetosheath plasma beta in particular plays an important role in the growth of waves in the magnetosheath, as well as the reconnection rate at the magnetopause (anisotropies in plasma beta, as well as the ion and electron beta parameters need to be better understood). The magnetosheath Alfvén Mach number is important for determining the spatial extent of the reconnection X-line and onset dynamics of the Kelvin-Helmholtz Instability. *In situ* magnetosheath observations and derived empirical models will then be used as inputs for the wide variety of models available (MHD, hybrid, and kinetic), both for validation of the models, and for placing the observations within a global context. The final result will be a far more complete understanding of the physics of the magnetosheath, including transport, heating, and turbulence processes within the magnetosheath, and into the magnetosphere.

Primary Objectives and Expected Activities of the FG:

1. To produce more comprehensive models of large scale magnetosheath flow and field patterns, and geometry of the magnetosheath region
2. To improve understanding of magnetosheath plasma instabilities and wave particle interactions: Spatial distribution and characteristics
3. To develop a better understanding of the effects on magnetospheric dynamics due to processes occurring in the magnetosheath and due to characteristic magnetosheath properties

Each of these represents a session topic, and associated challenge to the modeling community

Deliverables

1. Data sets and new empirical relations, for validating and constraining the GGCM models
2. Improved, self-consistent analytic models which well-describe the macroscopic plasma properties and magnetic field of the magnetosheath.
3. Empirical and analytic models describing the characteristics of plasma instabilities, including standing and traveling wave fronts within the magnetosheath

Specific Science Questions that the FG activities will help to solve with *in situ* case studies, statistical studies and numerical simulations:

<u>Structure:</u>

1. What is the large scale magnetosheath plasma and magnetic field structure during various IMF orientations and solar wind conditions?
2. Is the IMF Parker-Spiral (PS) vs. Ortho-Parker Spiral (OPS) orientation the determining factor generating dawn-dusk asymmetries on magnetosheath and plasma sheet plasma properties by affecting the location of the quasi-parallel bow-shock and resulting wave-particle interactions? Is the dawn (dusk) flank statistically hotter during PS (OPS) orientation?
3. How do ion and electron distribution functions evolve downstream from the quasi-parallel bow shock?

<u>Impact on magnetospheric processes:</u>

4. What is the impact of magnetosheath turbulence levels (*dB* and *dV*) on magnetospheric transport processes? Does the cold, dense plasma sheet form faster when the seed turbulence level in the magnetosheath is large? Is the reconnection rate enhanced for increased magnetosheath turbulence levels?
5. How are the reconnection and Kelvin-Helmholtz instability (location and growth rates) affected by magnetosheath plasma beta and Alfvén Mach number?
6. How does the ionospheric convection change as a function of magnetosheath plasma properties?

<u>Physical processes in the magnetosheath:</u>

7. How typical is the small-scale reconnection in the magnetosheath and how effectively can this heat magnetosheath plasma?
8. What is the physical mechanism keeping the ion to electron temperature ratio close to 6 in the magnetosheath? Are there any conditions which alter this ratio?
9. Is the turbulent spectra in the magnetosheath dominated by the mirror-mode waves and does the recently observed -8/3 spectra continue to electron scales?