GEM Focus Group: Magnetic Reconnection Modules In Global Modeling of the Magnetosphere

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1. Project Description

Global MHD models succeed in repoducing many features of the Earth's magnetosphere. However, our present computational tools fail to model fast magnetic reconnection in the high Lundquist number (or collisionless) limit. In order to achieve fast reconnection in a global MHD code, modelers usually resort to an *ad hoc* localized or current dependent resistivity. Reconnection plays a pivotal role as a driver of magnetospheric dynamics. Since the reconnection phenomena obtained in a global MHD code are sensitive to the resistivity model, it is essential that we attack the problem of how to include the physics of collisionless magnetic reconnection in global MHD codes.

In the past decade, the reconnection community has come to a consensus that reconnection can be fast if the so-called "Hall term" is included in the generalized Ohm's law. However, the inclusion of Hall physics in a global code has been achieved only recently (Tóth, 2008), and has yet to be explored in detail. Recent particle-in-cell (PIC) simulations in idealized geometries have found that in the limit of high Lundquist number, reconnecting current sheets may be subject to a super-Alfvénic plasmoid instability.(Daughton *et al.,* 2009) This instability substantially increases the rate of reconnection, possibly allowing reconnection to become fast in high Lundquist number systems, even in the absence of Hall term related effects. This instability has also been studied in detail in the context of resistive MHD studies of reconnection (Loureiro *et al., 2007,* Bhattacharjee *et al., 2009,* and Cassak *et al., 2009*). However, it has yet to be seen whether the plasmoid instability persists in more realistic, 3D systems.

Additionally, local PIC simulations of reconnection have indicated that the off-diagonal elements of the electron pressure tensor are responsible for breaking the frozen-in condition close to the reconnection site (Kuznetsova *et al.*, 2001). In addition to electron pressure agyrotropy, a recent study by Lê et al. (Lê *et al*., 2009) has found that electron pressure *anisotropy* is of key importance in determining the geometry of the dissipation region. Preliminary results suggest that the kinetic physics associated with pressure anisotropy can by captured by suitably modified equations of state for parallel and perpendicular pressure (Lê, *et al*., 2009). Fluid closures, which parameterize and encapsulate the kinetic physics associated with the pressure anisotropy and agyrotropy may be a fruitful way to more realistically model the physics of collisionless reconnection in global MHD codes, while avoiding the high computational expense of particle simulation.

We propose a GEM focus group, **Magnetic Reconnection in Global Modeling of the Magnetosphere**, to address the issues raised in the above paragraphs. This group will be a continuation of the GGCM Methods and Modules focus group. The goals of this four-year study will be to: 1) Assess the ability of global MHD to accurately model fast magnetic reconnection in the magnetosphere; 2) Address the question of how local kinetic effects may be incorporated in global simulations with realistic geometries—either by coupling to a Hall model near field nulls or by modifying the fluid closure to include pressure tensor effects; 3) Study in detail the scaling of the rate of magnetic reconnection with respect to Lundquist number in global codes with resistivity. Can secondary plasmoids be generated in global resistive simulations in the limit of the highest currently reachable simulation Lundquist numbers?

2. Relationship to other GEM focus groups

The problems addressed by our proposed focus group are directly relevant to those addressed by several existing and proposed focus groups. For example, the proposed focus group on the **Magnetosheath** (co-chairs S. Petrinec and K. Nykyri) is concerned with energy flux into the magnetosphere though the entire sheath—a considerable region of space. However our group will focus on the smallest scale processes in areas immediately around reconnection sites, which have a major influence on plasma energy flux. Our group will also complement the work of the **Plasma Entry into and within the Magnetotail** group (co-chairs A. Otto, J. Johnson, and S. Wing). Whereas these groups may focus on the larger scale properties of dayside and tail reconnection, our proposed group will focus on the kinetic scale details and the implications of the particular resistivity (or other dissipation) model employed in accurately modeling the physics of reconnection regions throughout the magnetosphere. Our group would benefit from joint sessions with these other groups.

3. Goals and deliverables

The first goal of our group will be to evaluate the ability of global MHD codes to accurately model fast reconnection in the magnetosphere. To this end, we will carry out a **Global MHD Lundquist Number Challenge** to answer the question of how reconnection in global codes scales in the limit of small uniform resistivity. Can the copious plasmoid formation seen in local simulations be achieved in global codes? Additionally we will conduct a detailed numerical study of alternative fluid closures which be able may capture the collisionless, kinetic physics of the electron dissipation region in the context of a fluid model for eventual inclusion in global models. This will address outstanding discrepancies between the current state of the art local, two-fluid and PIC simulations of magnetic reconnection, namely the presence of extended electron jets and the formation of plasmoids in kinetic simulation, which have been heretofore lacking in the two-fluid picture of reconnection.

References

Daughton, W. *et al.* (2009), Transition from collisional to kinetic regimes in large-scale reconnection layers. *Phys. Rev. Lett.* **103** 065004.

Loureiro, N. *et al.* (2007), Instability of Current Sheets and Formation of Plasmoid Chains. *Phys. Plas.* **14** 100703.

Le, A. *et al.,* (2009), Equations of state for collisionless Guide-Field Reconnection. *Phys. Rev. Lett.* **102** 085001.

Cassak, P. A. *et al.* (2009), Scaling of Sweet Parker Reconnection with secondary islands. *Phys. Plas.* **16** 120702.

Bhattacharjee, A. *et al.* (2009), Fast reconnection in high-Lundquist-number plasmas due to the plasmoid Instability. *Phys. Plas.* **16** 112102.

Tóth, G. (2008) Hall magnetohyrodynamics on block-adaptive grids, Vol. 227, Issue 14, 6967-6984.

Kuznetsova, M. *et al.* (2001), Collisionless reconnection supported by nongyrotropic pressure effects in hybrid and particle simulations, J. Geophys. Res., 106, 3799.