Introduction/Motivation

As an example of how to develop a comprehensive model of the Sun-Earth system, we are designing the coupling of the Low-Field Model (LFM) and the Rice Convection Model (RCM). This involves creating a 3-D global model that couples to both the magnetosphere and the ionosphere in a realistic manner.

Magnetic field can solve for the electric field by coupling to the ionosphere through field-aligned curvature drifts. The model cannot specify the magnetic field and needs an extra energy dependent velocity coming from the gradient and curvature.

Comparison of physical Models

LFM

Uses time-dependent MHD. Solves self-consistent model for the global magnetosphere

\[
\frac{\partial \mathbf{B}}{\partial t} = -\nabla \times \mathbf{E}
\]

where \(\mathbf{E} = \nabla \times \mathbf{B} - \mathbf{J} \times \mathbf{B} + \mathbf{E}_{\text{grav}} + \mathbf{E}_{\text{therm}} + \mathbf{E}_{\text{charge}}
\]

This is essentially a source-term coupling scheme, where \(T\) is the exchange coupling time (1 minute) and \(\mathbf{B}\) is the LFM timestep.

In the linear magnetosphere, the system is in the slow-flow regime. Where the MHD-equations reduce to

\[
\frac{\partial \mathbf{B}}{\partial t} = -\nabla \times \mathbf{J}
\]

RCM:

The RCM is based on the bounce-averaged motions of particles in the same slow-flow regime. There is a strong similarity to the slow-flow MHD.

Problems and Solutions, Continued

Basic Scheme is stable but does not give physically realistic results:

- High speed source from ion layer (or high latitudes)
- Increase in total energy
- Apparent chaotic field motion
- High speed outflow in equator toward terminator

There is an extra energy dependent velocity coming from the gradient and curvature drifts. The model can only specify the magnetic field and needs boundary conditions for the electric field and plasma, but within its domain can solve for the electric field by coupling to the space-time through field-aligned currents.

Problems with the Rice RCM friction code effort appear to be related to insufficient feedback of RCM grid mapped to the equatorial plane. The "cuts" on the night side move rapidly. Two-dimensional approach allows very low diffusion transport. Probably not problem: does not have known deficiencies on scale of MHD code.

Effects of Resolution

LOW

Rice MHD code

- Pressure is constant in equatorial plane
- Grid mapping the RCM grid mapped to the equatorial plane
- Time-averaging smoothed out some temporal structure
- LFM-RCM Coupling and Effects of Improved LFM Spatial Resolution

HIGH

Rice MHD code

- Pressure is constant in equatorial plane
- Grid mapping the RCM grid mapped to the equatorial plane

Methodology

Given correspondence between MHD and drift equations, why not?

Use MHD to get electric and magnetic fields and boundary conditions on planes for RCM-

"Low-Field Model (LFM) and RCM

The code is not a static, time-evolving model and needs to address several important physical questions such as:

- The slow evolution of the magnetospheric field as it passes through any current systems.
- The time dependent nature of the magnetospheric field.
- The time-dependent nature of the ionospheric field.

These models can only specify the magnetic field and needs an extra energy dependent velocity coming from the gradient and curvature.

MHD equations reduce to:

\[
\frac{\partial \mathbf{E}}{\partial t} + \nabla \times \mathbf{B} = \mathbf{E}_{\text{grav}} + \mathbf{E}_{\text{therm}} + \mathbf{E}_{\text{charge}}
\]

Where \(\mathbf{E}_{\text{grav}}\) is

\[
\mathbf{E}_{\text{grav}} = -\nabla \phi
\]

\(\phi\) is the gravitational potential.

\(\mathbf{E}_{\text{therm}}\) is

\[
\mathbf{E}_{\text{therm}} = -\nabla T
\]

\(T\) is the temperature.

\(\mathbf{E}_{\text{charge}}\) is

\[
\mathbf{E}_{\text{charge}} = \frac{1}{c} \nabla \times \mathbf{B}
\]

where \(c\) is the speed of light.

Problems with the Rice RCM friction code effort appear to be related to insufficient feedback of RCM grid mapped to the equatorial plane. The "cuts" on the night side move rapidly. Two-dimensional approach allows very low diffusion transport. Probably not problem: does not have known deficiencies on scale of MHD code.

Conclusions from resolution:

- Results are promising but:
- all require further testing over long simulation periods to determine whether really physical
- pressure distribution is somewhat unknown.