WACCM Extension to the Thermosphere/Ionosphere and plans for the Magnetosphere

Hanli Liu
Stan Solomon
Mike Wiltberger

High Altitude Observatory
National Center for Atmospheric Research
WACCM-X Development Status

- Thermospheric extension and preliminary validation are done (reported in last WG meeting and draft manuscript to be submitted soon).

- Electron/ion energy equations for WACCM-X are being developed.

- Electron/ion transport (ambipolar diffusion, field aligned transport) development will follow once the energy equations are done.

- Parameterized IGW and generation of QBO being tested on WACCM. Will implement in WACCM-X and study impact on thermosphere variability.

- Inter-model comparison between WACCM-X and NOAA WAM.
Electron / Ion Energy Equations

- Important for ionosphere/thermosphere energetics, and for ambipolar diffusion and other ion transport calculations.

- The module currently under development is time-dependent iterative solver, which is an improvement over TIME-GCM.
Electron / Ion Energy Equations

- Lack of electron and ion heating may account for the cooler thermosphere in the current WACCM-X.

Midnight temperature maximum
Coupled Magnetosphere-Ionosphere-Thermosphere Model

\[ \nabla \cdot (\Sigma_H + \Sigma_p) \nabla \Phi = J_{ll} - J_w \]

- Particle precipitation: \( F_e, E_0 \)
- Electric Potential: \( \Phi_{tot} \)
- Conductivities: \( \Sigma_p, \Sigma_h \)
- Winds: \( J_w \)

TIE-GCM

GSWM
Code Coupling Technology

• Complex codes with very different spatial and temporal domains, such as WACCM and LFM, are difficult to integrate into a single executable.

• Require efficient, flexible, model coupling in a parallel environment
  – Efficient transmission of information among codes
  – Interpolation of data between grids
  – Translation of physical variables between codes
  – Control mechanisms to synchronize execution and interaction
  – Minimal modifications to existing code base

• Intercomm
  – Developed by Alan Sussman et al. at the University of Maryland
  – Enables separate executables on different processors to exchange data
  – Solution to the MxN problem in coupling parallel codes
  – Addresses control and timing issues
CMIT Implementation in Intercomm

LFM
Magnetohydrodynamics
$\Delta x_{LFM} = O(10^{-2})$

MIX
Magnetosphere-Ionosphere Coupler/Solver
$\Delta x_{MIX} = O(10^{-1})$

TIEGCM
Ionosphere
$\Delta x_{TIEGCM} = O(10^{2})$
The Earth System Modeling Framework (ESMF) now includes an interface module enabling to exchange data with Intercomm.

Bob Oemke of the ESMF development group conducted a demonstration project to show how this works, using CAM and TIME-GCM.
Plan for Magnetosphere-Ionosphere-Atmosphere Coupling

• Continue to maintain and develop LFM-MIX as a stand-alone model
• Use Intercomm to couple to TIE-GCM, WACCM, CCSM, ESM, etc.
• Extend grid interpolations, solvers, etc., as necessary in the MIX module
• Maintain ESMF compatibility