Geospace Roadmap

1. Scientific Need/motivation:

Our goal is to develop a coupled numerical model of the atmosphere-ionosphere-magnetosphere system, including data assimilation, and use it to address outstanding scientific issues that constrain our ability to describe, and ultimately forecast, the geospace system:

- *the response of the ionosphere-thermosphere system to geomagnetic storms;*
- *the role of the lower atmosphere in driving ionospheric variability;*
- *the physics controlling ionospheric instabilities;*
- *the processes leading to anthropogenic global change in the upper atmosphere.*

The functional objective is to construct a *Whole Geospace Model*, an open-source community model consisting of an atmosphere-ionosphere component, a magnetospheric component, and the ability to use measured or predicted solar wind and solar irradiance inputs.

2. Current Capability:

WACCM-X is a coupled atmosphere-ionosphere model that builds on CAM4 physics, can be coupled to the CESM framework, and includes specified dynamics and development of data assimilation. It includes fully-interactive ionospheric dynamics and electrodynamics, and is capable of space weather simulations as well as climate. It can be run with empirical or modeled magnetospheric inputs. WACCM-X is currently limited to 2° resolution on the FV dycore, and 2° resolution in the ionosphere, which constrains our ability to resolve small-scale ionospheric structures and pursue frontier science concerning formation of instabilities. We can increase to 1° resolution, but in order to surmount the dependence on the hydrostatic FV dycore, the ionospheric dynamics and electrodynamics need to be able to communicate with new unstructured-grid high-resolution dycores.

3. Target Capability:

1-year goals:

- Move to the 1° FV dycore (with 1° resolution in the ionosphere) with CAM6 physics
- Develop regridding capability to enable communication between the ionosphere and the SE dycore or other unstructured grid dycores. This will enable simulation of gravity wave propagation into the ionosphere, and other high-resolution applications.
- Include major species transport (variable M, R, and Cp) in SE dycore.
- Develop assimilation capability to include ionospheric data.

3-year goals (ambitious - replace with frontier science?):

- Integrate ionospheric dynamics and electrodynamics with the new physics coupler.
- Implement deep-atmosphere non-hydrostatic dycore in WACCM-X.
- Couple magnetospheric model with the ionosphere.
- Add regional-refinement capability and scale aware gravity wave parameterization

• Extend data assimilation capability for new thermosphere-ionosphere missions.

3-year goals (incremental)

• Integrate ionospheric dynamics and electrodynamics with high-resolution dycore.
• Utilize CAM6/CESM2 framework until “singletrack” development is ready.
• Simplified coupling from magnetosphere to ionosphere using standard interface.

4. Key requirements/tasks:

• Regridding capability to/from unstructured dycore grid from/to geographic grid.
• Include major species transport (variable M, R, and Cp) in new dycore(s).
• Migrate to SE or MPAS dynamical core
• Make physics CPF compliant
• Key decision points: Having implemented a 1° model with CAM6 physics:
    - Are the new models, frameworks, and infrastructure ready for WACCM-X?
    - Are our collaborators’ magnetospheric model(s) ready for integration?

5. Tasks:

• Before decision points:
    • Merge up to CAM6 / WACCM6
    • Improve O+ high latitude filtering
    • Implement 1° FV dycore with 1° O+ transport
    • Regridding to/from SE dycore from/to latitude/longitude grid
    • Implement ionospheric data assimilation
        • Resources required (exclusive of LT scientists already working on the project):
            0.5 ACOM/HAO SE IV, 0.5 HAO PS III, 0.25 CGD SE III
• After decision points:
    • Merge up to new chemistry and/or physics modules
    • Regridding to/from arbitrary dycore from/to geographic and magnetic coordinates
    • Couple to magnetospheric MHD model
        • Resources required (exclusive of LT scientists already working on the project):
            0.5 ACOM/HAO SE IV, 0.5 HAO PS III, 0.5 CGD SE III, 2.0 HAO S I

6. Key Deliverables:

• WACCM-X 2.1 (incremental adjustments to current release)
• WACCM-X 6.0 (CAM6 physics and 1° FV dycore, option for SE dycore)
• WACCM-X XS (Whole Geospace Model in singletrack framework)