Development of WACCM-X as the SIMA Geospace Component

Han-Li Liu, SIMA Science Co-Lead, High Altitude Observatory

Mary Barth, SIMA Science Lead, Atmospheric Chemistry Observations and Modeling

Adam Herrington, SIMA Science Co-Lead, Climate and Global Dynamics

Bill Skamarock, SIMA Science Co-Lead, Mesoscale and Microscale Meteorology

National Center for Atmospheric Research
Outline

What is SIMA: Motivation and Project Goal

WACCM-X: SIMA-Geospace Component.

Current Developments.
SIMA PROJECT AIMS TO UNIFY THE NCAR ATMOSPHERIC MODELING SYSTEM

NCAR atmospheric modeling ecosystem in the mid-2010s (left) and desired structure in mid-2020s (right)
SIMA will enhance **frontier science simulations** in climate, weather, atmospheric chemistry, geospace, and cross-discipline research with one modeling system.
Broader range of atmospheric/geospace scientists using the same tool
• Increases interdisciplinary interaction, fostering collaborations
• Benefits from diverse perspectives
• Exchange of knowledge and tools
• Accelerates scientific progress

Centralized and efficient model development, maintenance, and support

Opportunity to modernize underlying software
• Object-oriented structures
• Generic interfaces
• Greater runtime configuration control
• Code refactoring for GPUs or other computing architectures
SIMA is a framework in one modeling system allowing configurations for climate, weather, atmospheric chemistry, and geospace simulations.

MUSICA = Multiscale Infrastructure for Chemistry and Aerosols, MPAS = Model for Prediction Across Scales, SE = Spectral Element dynamical core, FV3 = Finite Volume dynamical core on cubed sphere.
Geospace and Space Weather: SIMA/WACCM-X and MAGE

SIMA Geospace

- WRF Physics
- CAM Physics
- MUSICA Chem/Aero
- Plasma/Thermo
- Physics/Chemistry
- Data Assim.
- MPAS
- SE
- FV3
- Physics-Dynamics Coupling
- Dynamical Cores
- TIEGCM Ionospheric/Thermosphere
- REMIX Ionospheric Electrodynamics
- Conductance
- E-field, Monoenergetic e⁻ precipitation
- Diffuse e⁻ precipitation
- GAMERA Global Magnetosphere
- RCM Ring Current
- E-field
- Current, Plasma moments
- Pressure
- B-field, Plasma moments

Multiscale Atmosphere-Geospace Environment (MAGE) Model
Current Developments of SIMA-Geospace

- High-resolution SIMA/WACCM-X.
- WACCM-X/GAMERA coupling.
- WACCM/WACCM-X with non-hydrostatic dynamical core MPAS-A.
SIMA WACCM-X SE with High-Resolution Capability

- Neutral dynamics and physics
  - WACCM-X Species Dependent Spectral Element Dynamical core with CSLAM transport
  - Cubed sphere grid (no polar singularity)
  - Molecular viscosity/diffusion in horizontal direction.
- Regridding between physics mesh and geomagnetic grid.
  - Interactive ionospheric dynamo, transport, and energetics.
- High resolution configuration:
  - ~25km horizontal, 0.1 scale height vertical
Gravity Wave Resolving

Improved thermospheric circulation, composition, and variability

Zonal mean O/N2 Jan

- coarse-resolution WACCM-X
- high-resolution WACCM-X
Non-hydrostatic Dynamical Core: MPAS-A in WACCM-X

- MPAS-A brings non-hydrostatic modeling capabilities to CESM.
- Centroidal Voronoi mesh
- Finite-volume, C-grid staggering
- Hybrid terrain-following height vertical coordinate

Finite Volume (FV)

Spectral Element (SE)

MPAS-A

Kamali et al. (2023)
Summary

1. SIMA will enhance frontier science simulations in climate, weather, atmospheric chemistry, geospace, and cross-discipline research with one modeling system.
2. SIMA hopes to move NCAR atmospheric modeling to a single atmospheric modeling system.
3. High resolution simulations (geospace, Arctic, convection) show improved representation of multiscale processes.
4. The Subseasonal to Seasonal, Sun to Soil cross-disciplinary science application project will establish workflows for ensemble simulations and address multiscale processes in two extreme weather events.