System for Integrated Modeling of the Atmosphere (SIMA) Virtual Workshop

Introduction
Outline

● What SIMA is and a quick history
● Workshop purpose
● Rationale and Current Vision
● SIMA Science
  ○ Frontier Science Goals
  ○ Examples
  ○ Progress to date
  ○ Relationship to Existing Models
● Summary and Workshop charge
● Further information
What is SIMA?

SIMA is the effort to unify NCAR-based community atmosphere modeling across Weather, Climate, Chemistry, Geospace

- A configurable *system or framework*, not a single *model*
- Atmospheric model *within* an Earth System Model
- A minimal set of interoperable components
  - Physical/Chemical Parameterizations, Dynamical cores
- Common *infrastructure* (software framework) and methods
  - Develop infrastructure in current community models
  - Requires changes to things outside of the atmosphere (CIME, Data Assimilation, etc)
- *Community* working together towards frontier applications
  - Applications flow from diverse science goals
  - Exchanging knowledge and tools (diagnostics, best practices, evaluation)
History of SIMA

- Unification of weather and climate modeling activities was a recommendation to NCAR from the 2016 Science Visit Teams, mandated by NSF
- Internal discussion started in 2018
- Over 50 NCAR staff involved in discussions in 2018-2019
- Socialization of SIMA concept at NSF, CESM, WRF, MUSICA and CEDAR workshops
- Feasibility study (aka SIMA v0) started in late Summer 2019
- Now: NSF would now like community input as we near end of v0
SIMA Workshop Objectives/Outcomes

- An updated Vision Statement
- Input to the scientific objectives of SIMA and its future applications
- Identify Use-cases and workflow needs for atmospheric models
- Identify critical near-term tasks for moving SIMA forward
- Codify the discussions into a white paper for NSF/Community
Current Community Atmosphere Models

Existing Applications

Geospace (TIE-GCM/CMIT)

Weather (WRF & MPAS)

Chemistry (WRF-CHEM)

WACCM-X

Climate (CAM)
Chemistry (WACCM/CAM-CHEM)
Current SIMA Vision
Support Existing and Frontier Atmosphere Applications within Earth System Models

- Geospace
- Weather Chemistry
- Existing Applications

Frontier Applications
- Coupled Weather
- Climate Extremes
- Space Weather
- Air Pollution
System for Integrated Modeling-Atmosphere (SIMA)

SIMA is composed of common atmospheric model components & infrastructure

SIMA Frontier Applications
- Coupled Weather
- Climate Extremes
- Space Weather
- Air Pollution
- Coupled Polar

Current SIMA Vision
- Encompass Climate, Weather, Chemistry & Geospace
- Prediction (Initialized and Forecast) capabilities
- Complement & extend existing applications (CESM/WRF/MPAS)
- Shared infrastructure for efficiency
- Minimal set of components
- ‘Center Wide’ project including education, observations, computation
SIMA Benefits for Existing Models

What if I am happy with the models I use now?

WRF/MPAS/CESM-CAM will be supported for several more years

**SIMA Benefits:**

- Better modeling across scales
  - Non-hydrostatic dynamics for global models
  - Conservative physics that works globally
  - Community assimilation tools
- More complete and integrated hierarchy of models
- More robust software infrastructure
- Easier to use and configure (*please take the survey*)
- Modular code, community standards for existing applications
- Enhanced cross scale evaluation tools and tutorials
Sample Frontier Applications
Developed with community input, 3-5 year targets

Prediction (initialized, assimilation) is implicit in many of these applications

<table>
<thead>
<tr>
<th>Frontier</th>
<th>Target Application</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather</td>
<td>Tropical Cyclones</td>
<td>3km refined mesh, coupled ocean, initialized</td>
</tr>
<tr>
<td>Climate</td>
<td>Hydrologic Extremes</td>
<td>10km refined mesh hydrostatic climate simulations, 3km refined mesh non-hydrostatic initialized</td>
</tr>
<tr>
<td>Polar</td>
<td>Coupled Arctic System</td>
<td>10km hydrostatic coupled Arctic refined mesh</td>
</tr>
<tr>
<td>Geospace</td>
<td>Space Weather</td>
<td>25km global atmosphere to the ionosphere</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Regional Air Quality</td>
<td>10km hydrostatic refined mesh with chemistry</td>
</tr>
</tbody>
</table>

What are we missing?
SIMA Initial Examples

We can do parts of the frontier applications now: but not integrated, or flexible. Not available to the community.

- Climate: Refined Mesh CESM 12km regional climate simulation
- Weather: Global MPAS cloud permitting simulations
- Geospace: Gravity wave impact on the upper atmosphere, ¼° simulation
- Chemistry: Refined Mesh CAM-Chem 12km regional air quality simulation
- Diagnostics: Unifying evaluation. Advancing evaluation with observations
- Building a Hierarchy of atmosphere models

Difficult to bring these together. None of these are fully coupled yet. But we are making progress and are close to our ‘Frontiers’. Want to do this in the same system for the community (e.g. Hierarchy).
CESM2-14km refined mesh regional climate simulations
Gettelman, Callaghan (CGD), Zarzycki (PSU), Clyne (CISL)
MPAS 4km Global Simulations

Outgoing Longwave Radiation (OLR)

Surface Temperature

2012-10-23 08:48:00

2-m Temperature (°C)

Max: 61.0 °C
Min: -63.7 °C

4-km MPAS
WACCM Meridional Wind at ~110km
Space Weather Modulated by Terrestrial Weather

Gravity waves in a 25km simulation that force the upper atmosphere
Surface Ozone: Refined Mesh with Chemistry

Surface ozone for 3 days in August comparing uniform 100km to refined 14 km grid over CONUS.

Animation illustrates how there are better defined filaments of O$_3$ in the refined simulation.
Unifying Diagnostics

Climate Variability
(Phillips, CGD)

Weather
(Jensen, RAL)

Climate/Chemistry
(Hannay, Tilmes, CGD/ACOM)

Atmos Processes
(Coleman, Chen, CGD)
Bridging Models and Observations

- Aircraft (SOCRATES) & GCM (CAM6) size distributions over the S. Ocean
- Simulate detailed observations from EOL facility cloud probes
- Develop ‘simulators’ to simulate specific facility instruments (cloud probes, radar, lidar) in SIMA system
SIMA Model Hierarchy

SIMA:
- Scalable atmosphere model INSIDE an Earth System Model
- Testing frameworks:
  - SCM → LES → regional models → global → variable resolution global
  - ‘minimal set’ of interoperable components (clouds, chemistry, geospace, etc.)

Single Column

Large Eddy Simulation (LES)

Mesoscale Model

Global Models

UNIFORM

REGIONAL

VARIABLE

Complexity

Earth (Coupled)

Radiative Convective Equilibrium (RCE)

Aquaplanet
SIMA Model Hierarchy

Different Tools for Different Jobs

SIMA is a system for different types of atmosphere modeling, allowing independent research using the right tool.

SIMA is integrated with an Earth System Model for coupled applications.
SIMA-Weather

WRF+CAM Physics

MPAS

CPF

Physics/Chemistry

Dynamical cores
SIMA-Climate

- WRF Physics
- CPF
- Physics/Chemistry
- SE
- Dynamical cores
SIMA-Chemistry/Climate

- CAM6 Physics
- MUSICA Chem

CPF

Physics/Chemistry

SE

Dynamical cores
SIMA Progress/Timeline
Past, Present, Future

- Jan-May 2018: Organized, developed science goals, applications
- June-Aug: Develop a ‘Roadmap’, Solicit Community Feedback
- Oct-Dec: Roadmap available. More feedback (CESM/UCAR Members)

Jan-Feb 2019: SIMA Terms of Reference, CESM CAB presentation
- July 2019: SIMA version 0 reinvestment project
- Aug 2019-May 2020: SIMA Version 0 Development

June 2020: SIMA Community Workshop
- Aug 2020: SIMA Whitepaper
- Sep 2020: SIMA Version 0 Complete
- Oct 2020: SIMA Launch after Community Input (White Paper)
SIMA ‘Version 0’ Progress

● Common infrastructure
  ○ Unified physics interface (CCPP)
  ○ Common repository for weather & climate code
● Common Dynamical cores
  ○ MPAS dynamical core in coupled framework
● CIME infrastructure modifications
  ○ Better initialization, regridding, and assimilation for global models
  ○ Good scaling at high resolution (e.g. 3km atmosphere)
  ○ More robust and flexible workflows for a hierarchy of models
● Unified Chemistry (MICM/MUSICA)
● Testing & developing physical parameterizations across scales
● Couple atmosphere physics mesh and geomagnetic grid
SIMA and Existing Community Models
WRF/MPAS/CESM

- Support and extend existing applications (CAM-WACCM&X/WRF/MPAS)
- Engage and extend existing communities
- Better access to prediction (initialization, assimilation) capabilities
- Coordinate efforts for greater efficiency (Do things right. Once.)
- Larger critical mass to develop a single system
- Existing modeling groups contribute to and define SIMA goals
- Existing modeling groups determine their own configurations
  - E.g.: CESM selects a dynamical core and physical parameterizations
- Work with existing governance structures (do not duplicate management)
Summary: SIMA

- Enables frontier science across NCAR: coupling climate and Earth System Modeling to Meteorology, Chemistry, Geospace, Polar
- Is responsive to Community Science
- Expands the reach and capabilities of atmosphere modeling
- Build a unified (cross scale) community modeling system
- Integrated with existing models
Workshop Goals

• An updated Vision Statement
• Input to the scientific objectives of SIMA and its future applications
• Identify Use-cases and workflow needs for atmospheric models
• Identify critical near-term tasks for moving SIMA forward
• Codify the discussions into a white paper for NSF/Community
Workshop Questions/Feedback

Specifically, in preparing an updated vision and white paper:

• What in the SIMA vision be adjusted?
• What are the science frontiers in your research area?
• Have we identified the right applications and scope?
• What are the most important requirements/needs?
• How could we make models easier to use?
Documents

SIMA Wiki:  https://wiki.ucar.edu/display/SIMA  (Google: sima wiki ncar)

- Vision Document
- Version of this presentation

Please take the surveys (see wiki): Data for starting discussion

- SIMA Community Survey
- User Experience Survey

Questions? Bring them to the workshop