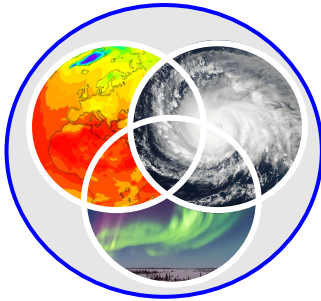
# System for Integrated Modeling of the Atmosphere (SIMA) Virtual Workshop

## Introduction

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

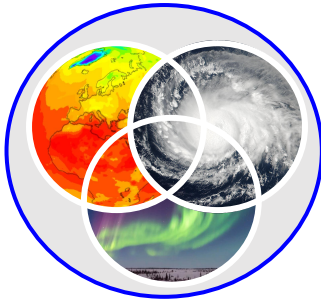
NSF

# 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

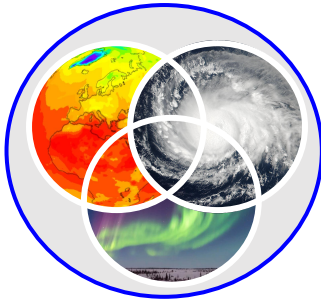
# What is SIMA?



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

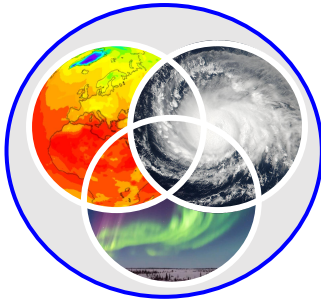
- A configurable *system or framework*, not a single *model*
- Atmospheric model *within* an Earth System Model
- A minimal set of interoperable components
  - Physical/Chemical Parameterizations, Dynamical cores
- Common *infrastructure* (software framework) and methods
  - Develop infrastructure in 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



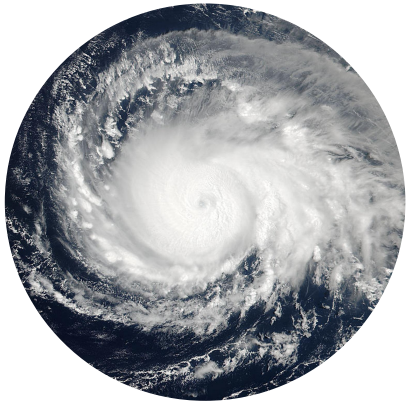
- An updated Vision Statement
- Input to the scientific objectives of SIMA and its future applications
- Identify Use-cases and workflow needs for atmospheric models
- Identify critical near-term tasks for moving SIMA forward
- Codify the discussions into a white paper for NSF/Community

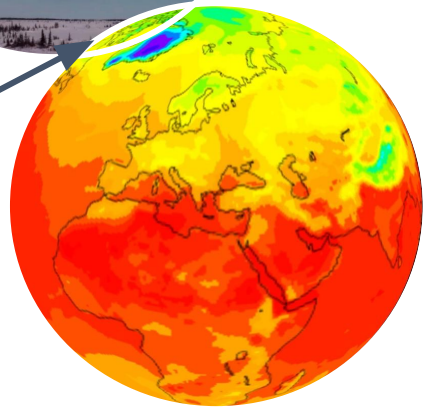
# Current Community Atmosphere Models

## Existing Applications

Weather (WRF & MPAS)

Geospace (TIE-GCM/CMIT)





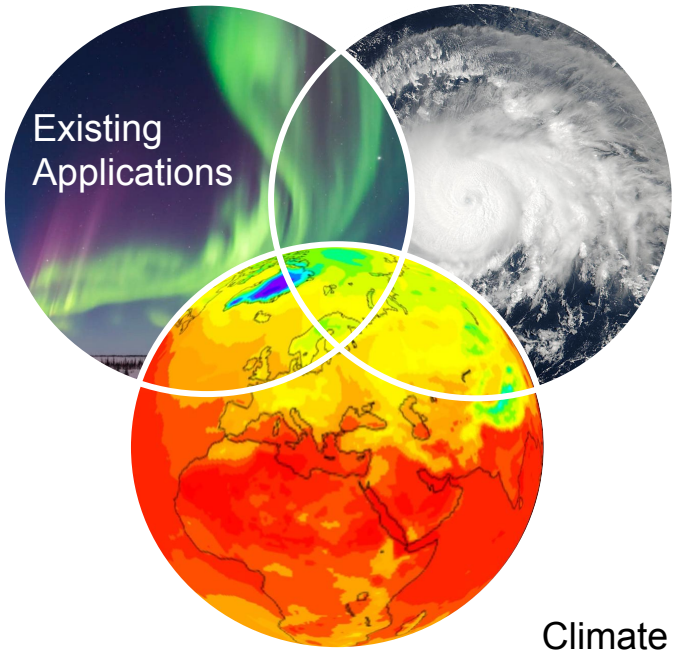
Chemistry (WRF-CHEM)

WACCM-X

Climate (CAM)
Chemistry (WACCM/CAM-CHEM)

# Current SIMA Vision

Support Existing and Frontier Atmosphere Applications *within* Earth System Models




Frontier Applications

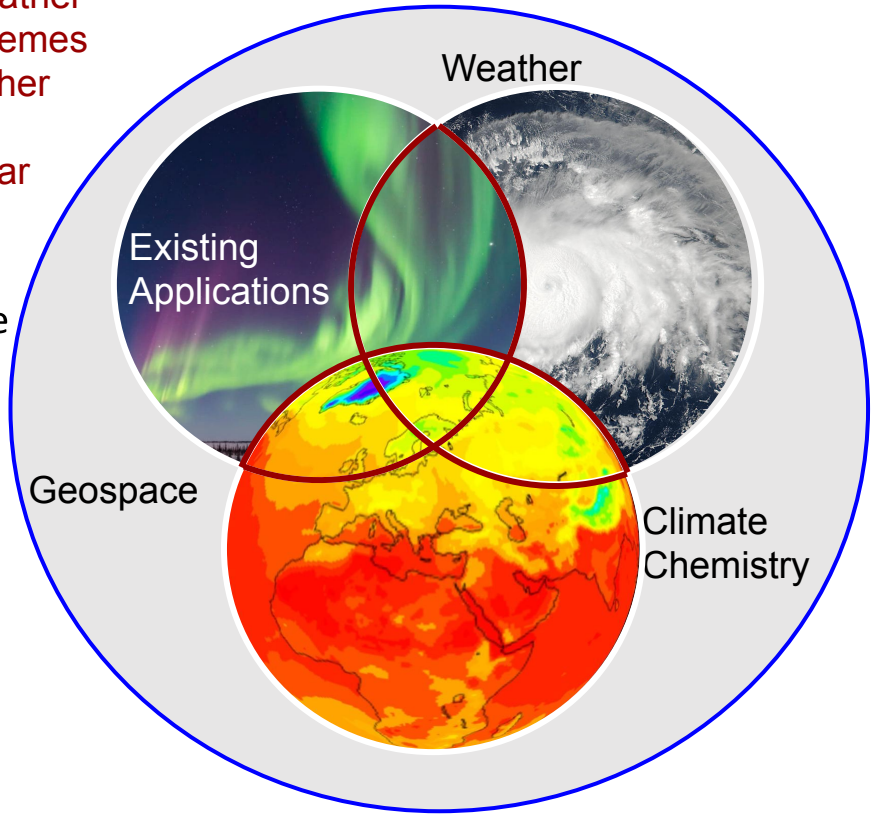
- Coupled Weather
- Climate Extremes
- Space Weather
- Air Pollution

# System for Integrated Modeling-Atmosphere (SIMA)

*SIMA is composed of common atmospheric model components & infrastructure*

SIMA Frontier Applications

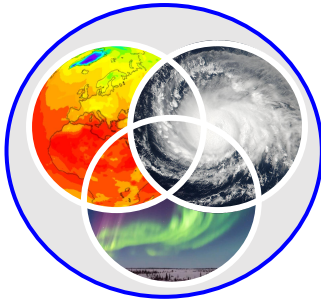
- Coupled Weather
- Climate Extremes
- Space Weather
- Air Pollution
- Coupled Polar




**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?

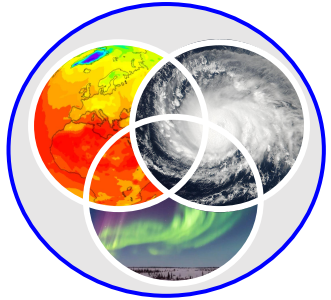
WRF/MPAS/CESM-CAM will be supported for several more years

*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

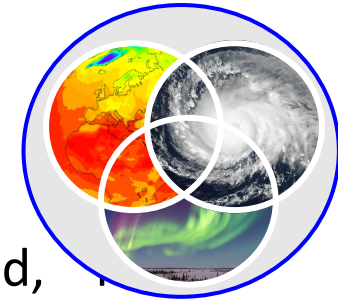


Prediction (initialized, assimilation) is implicit in many of these applications

| ***Frontier*** | ***Target Application*** | ***Configuration*** |
|---|---|---|
| Weather | Tropical Cyclones | 3km refined mesh, coupled ocean, initialized |
| Climate | Hydrologic Extremes | 10km refined mesh hydrostatic climate simulations, 3km refined mesh non-hydrostatic initialized |
| Polar | Coupled Arctic System | 10km hydrostatic coupled Arctic refined mesh |
| Geospace | Space Weather | 25km global atmosphere to the ionosphere |
| Chemistry | Regional Air Quality | 10km hydrostatic refined mesh with chemistry |

What are we missing?

# SIMA Initial Examples



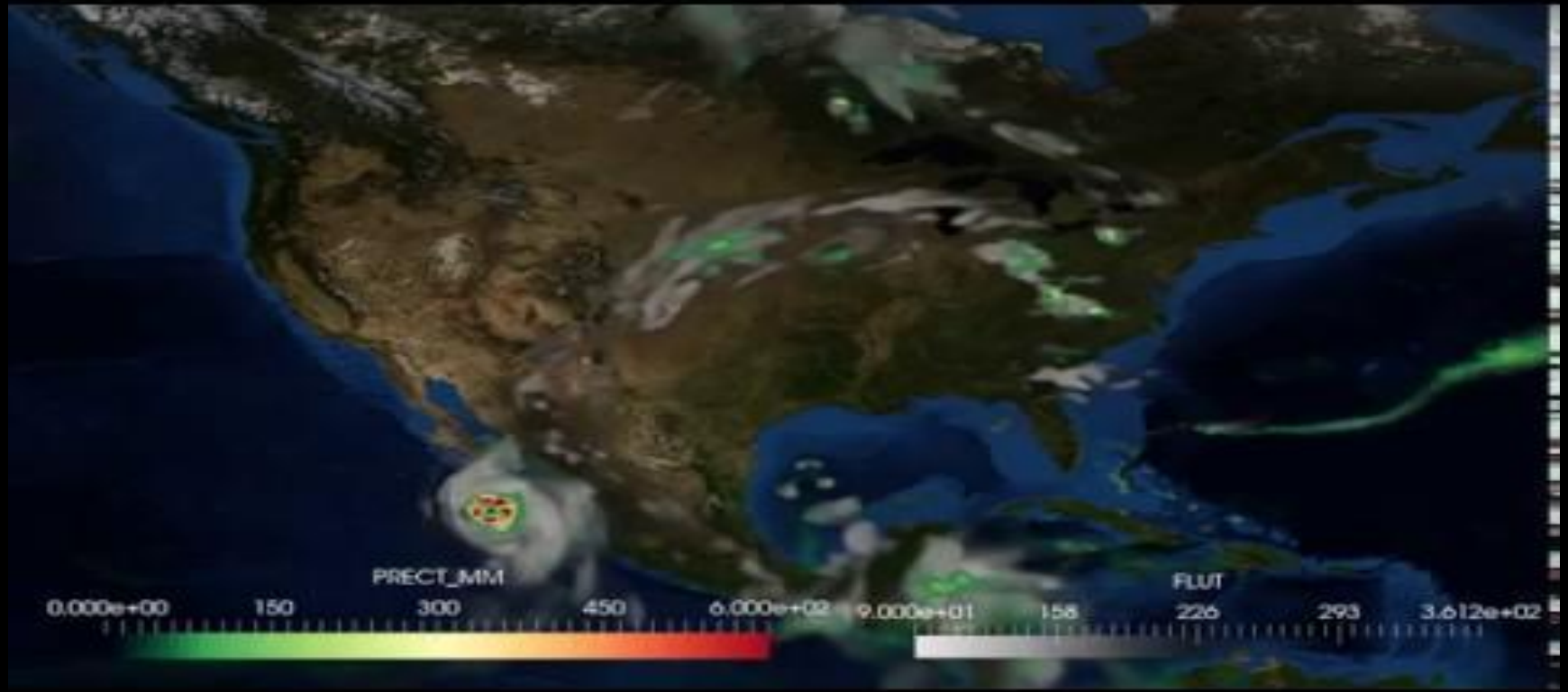
We can do parts of the frontier applications now: but not integrated, or flexible. Not available to the community.

- 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

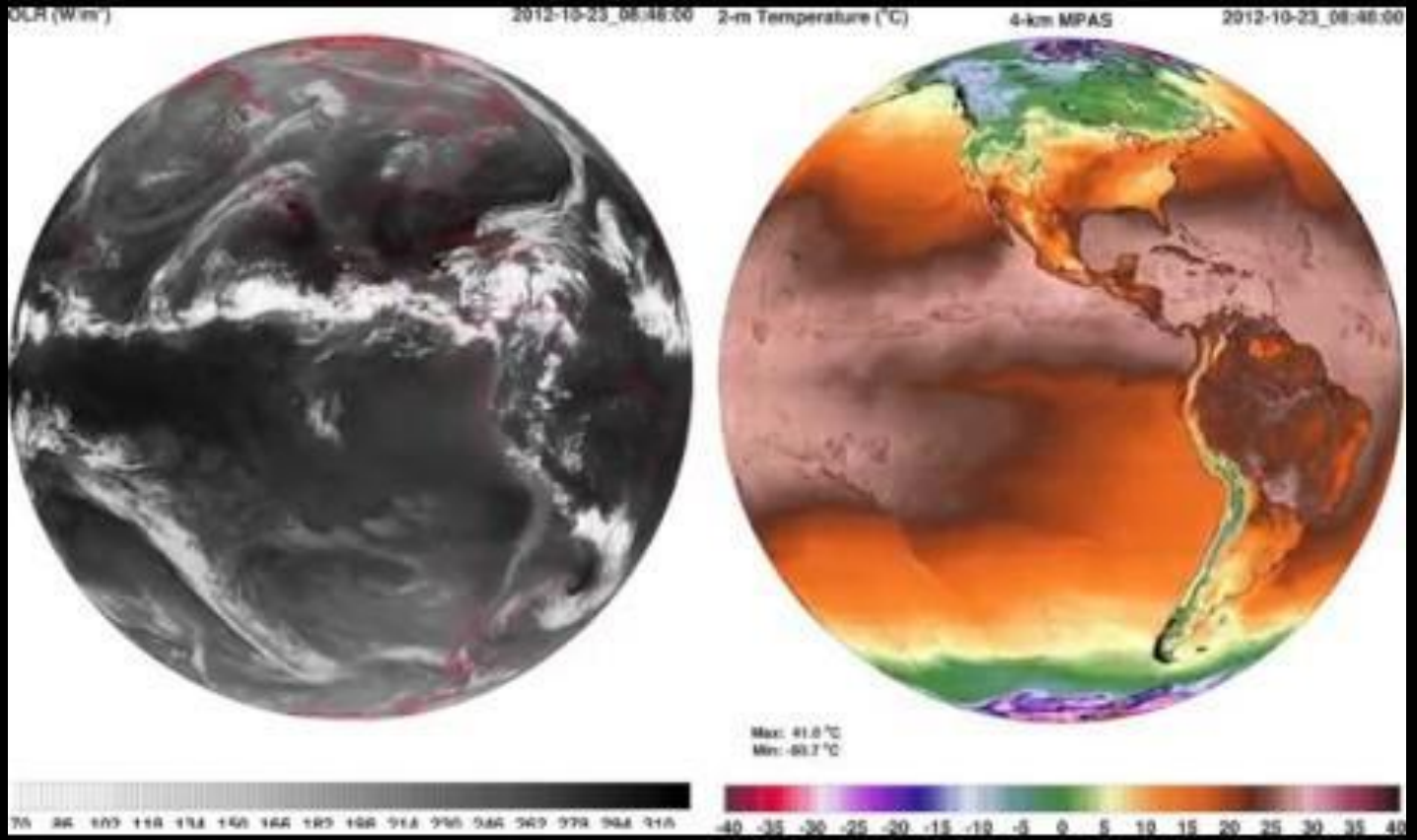
Gettelman, Callaghan (CGD), Zarzycki (PSU), Clyne (CISL)



# MPAS 4km Global Simulations

Falko Judt, MMM

Outgoing Longwave Radiation (OLR)



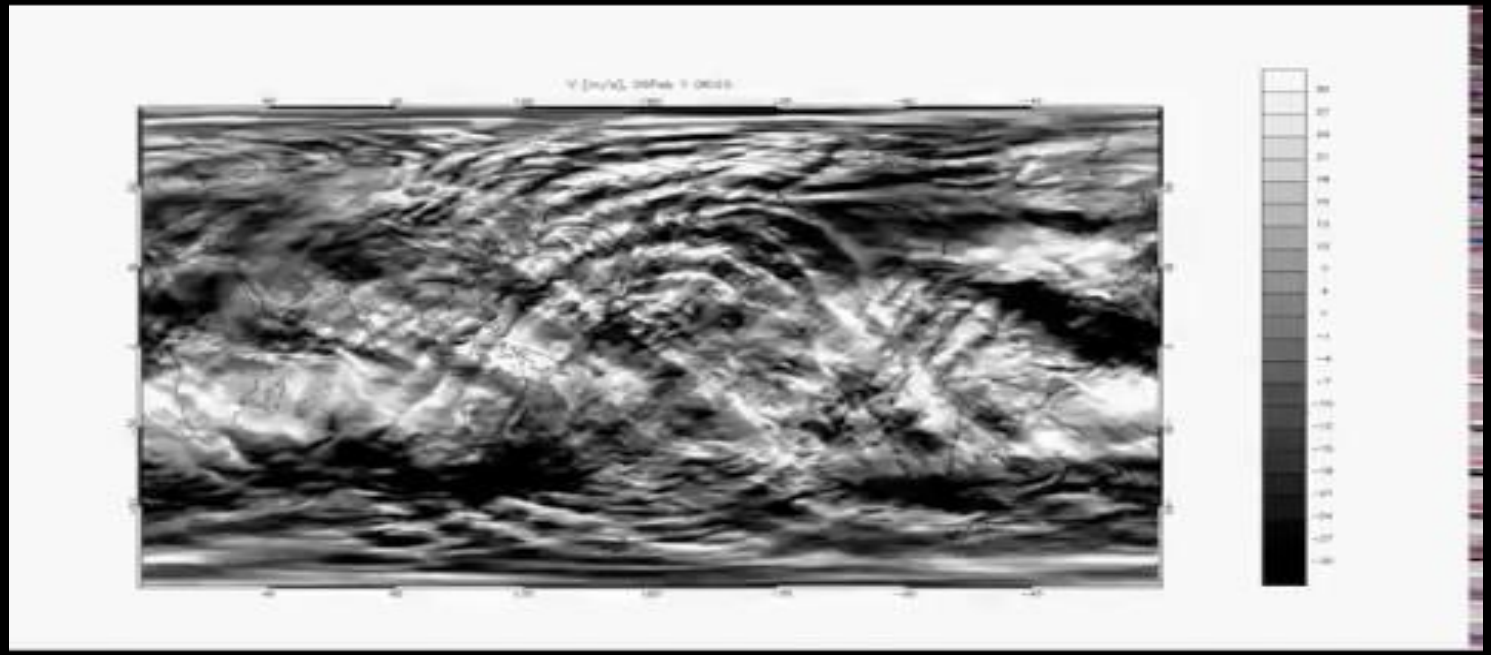

Surface Temperature

# WACCM Meridional Wind at ~110km

# Space Weather Modulated by Terrestrial Weather

H. Liu, HAO

Gravity waves in a 25km simulation that force the upper atmosphere



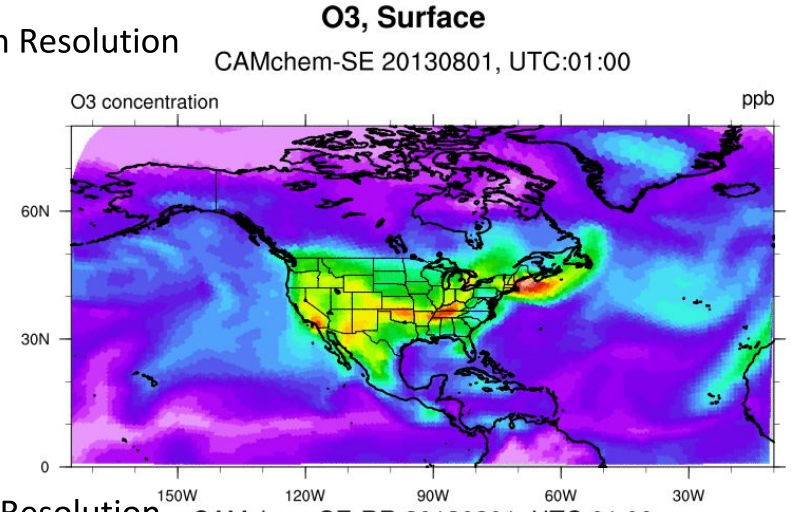
# Surface Ozone: Refined Mesh with Chemistry

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

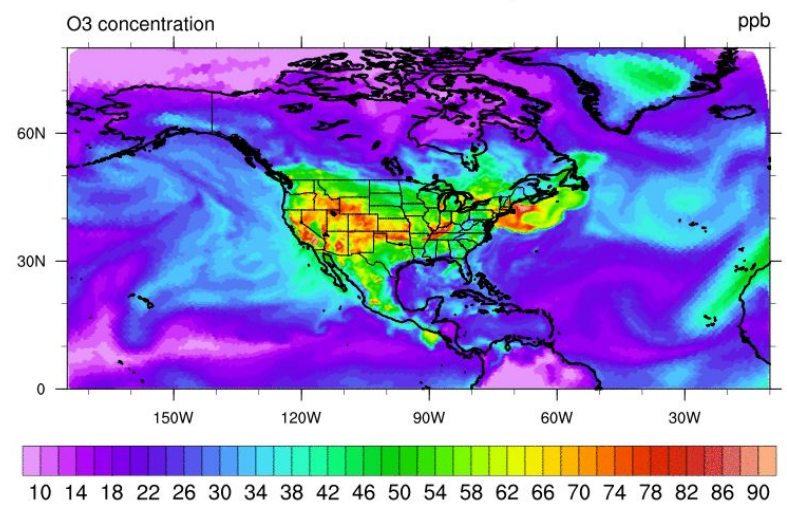
Animation illustrates how there are better defined filaments of $O_3$ in the refined simulation.

Lacey, Schwantes & Tilmes, ACOM

100 km Resolution



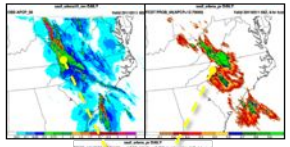

14 km Resolution



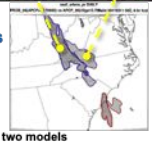
# Unifying Diagnostics

MET
Model Evaluation Tools

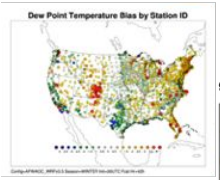
Object Based and Spatial Methods



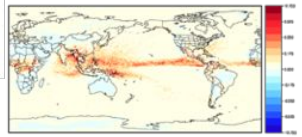
Geographical Representation of Errors



Bad forecast or Good forecast with displacement error?

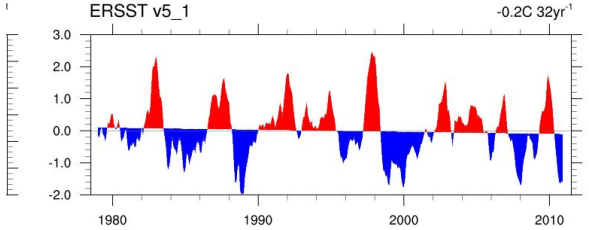


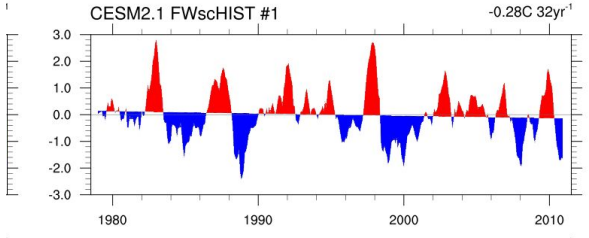

90th Percentile of difference between two models



## Climate Variability
(Phillips, CGD)

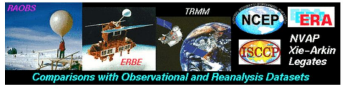
NCAR | UCAR
CGD's Climate Analysis Section
Climate Variability Diagnostics Package




## Weather
(Jensen, RAL)

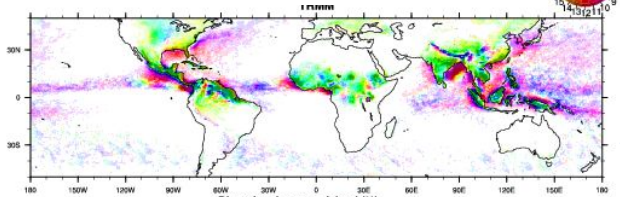
AMWG Diagnostics Package
cam6013_sd56_aerocom




Plots Created
Fri Aug 31 13:29:20 MDT 2018

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

NOAA
Model Diagnostics Task Force (MDTF)
Diagnostics Package

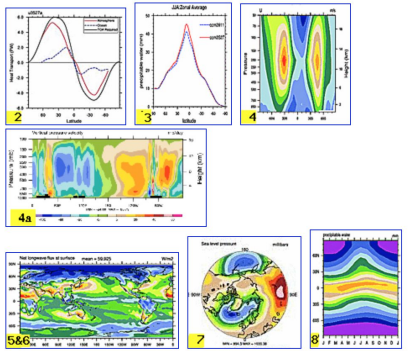



## Atmos Processes
(Coleman, Chen, CGD)

Set Description
1 Tables of ANN, DJF, JJA, global and regional means and RMSE.
2 Line plots of annual implied northward transports.
3 Line plots of DJF, JJA and ANN zonal means
4 Vertical contour plots of DJF, JJA and ANN zonal means
4a Vertical (XZ) contour plots of DJF, JJA and ANN meridional means
5 Horizontal contour plots of DJF, JJA and ANN means
6 Horizontal vector plots of DJF, JJA and ANN means
7 Polar contour and vector plots of DJF, JJA and ANN means
8 Annual cycle contour plots of zonal means
9 Horizontal contour plots of DJF-JJA differences
10 Annual cycle line plots of global means
11 Pacific annual cycle, Scatter plot plots
12 Vertical profile plots from 17 selected stations
13 Cloud simulators plots
14 Taylor Diagram plots
15 Annual Cycle at Select Stations plots
16 Budget Terms at Select Stations plots

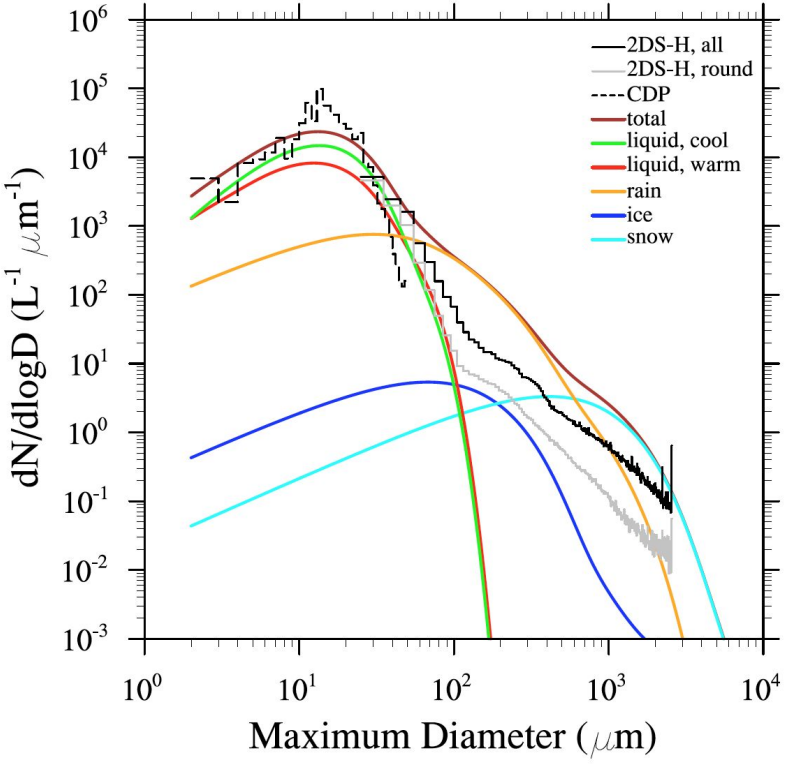
WACCM Set Description
1 Vertical contour plots of DJF, MAM, JJA, SON and ANN zonal means (vertical log scale)

*Click on Plot Type*



# 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



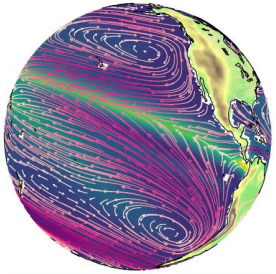


C. Bardeen, ACOM

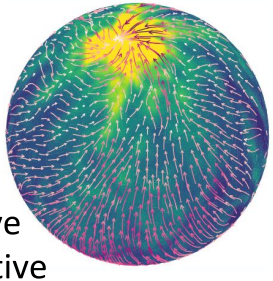
# SIMA Model Hierarchy

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).



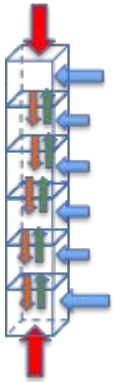
Earth (Coupled)



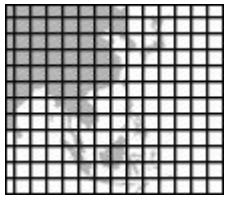
Radiative Convective Equilibrium (RCE)

Complexity

Single Column

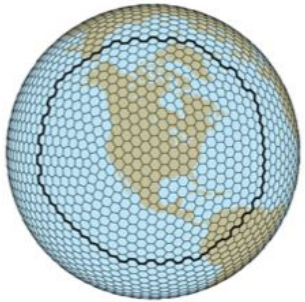


Large Eddy Simulation (LES)

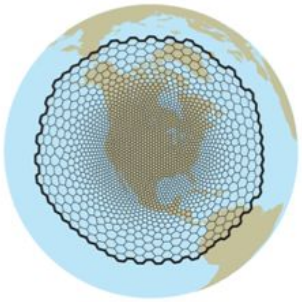


Mesoscale Model

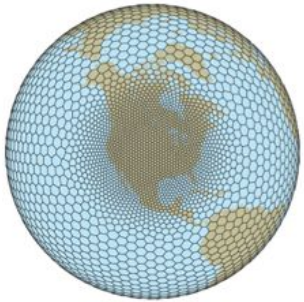
Global Models



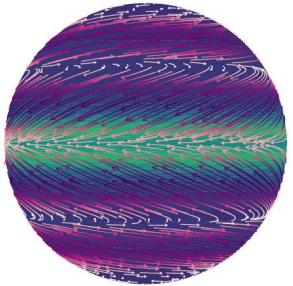
**UNIFORM**



**REGIONAL**



**VARIABLE**



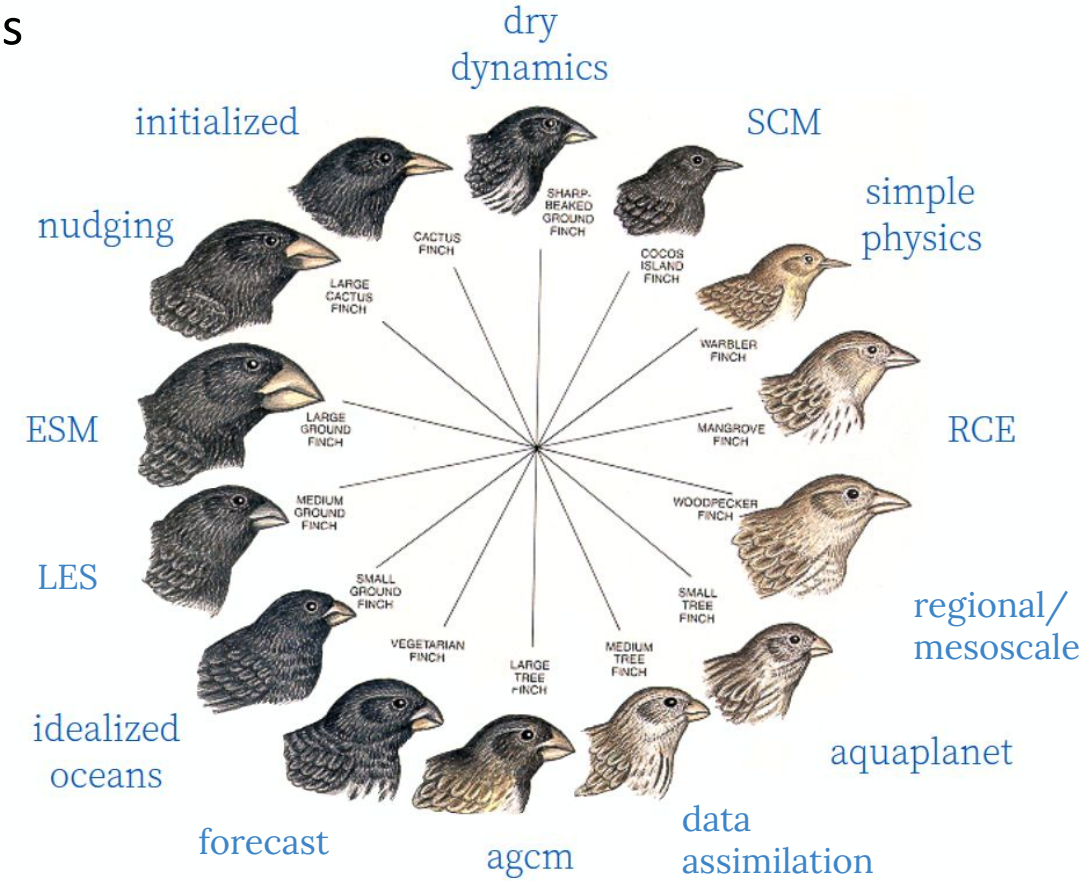
Aquaplanet

# SIMA Model Hierarchy

## Different Tools for Different Jobs

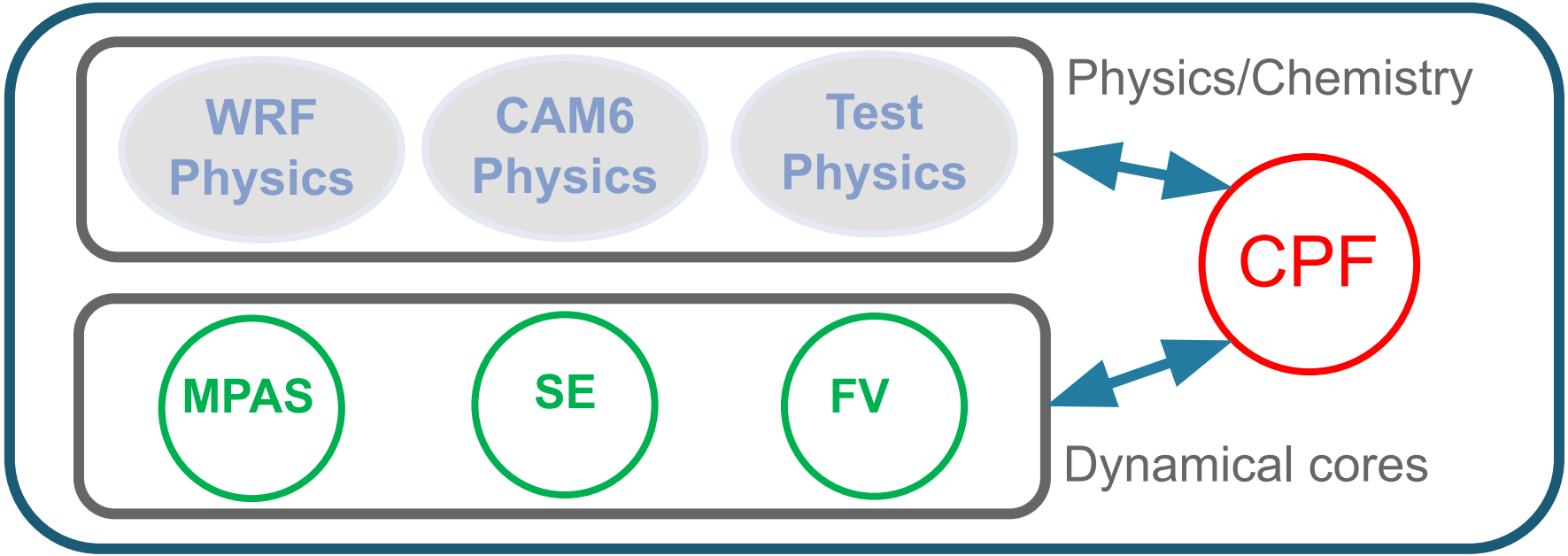
SIMA is a system for different types of atmosphere modeling, allowing independent research using the right tool.

SIMA is integrated with an Earth System Model for coupled applications

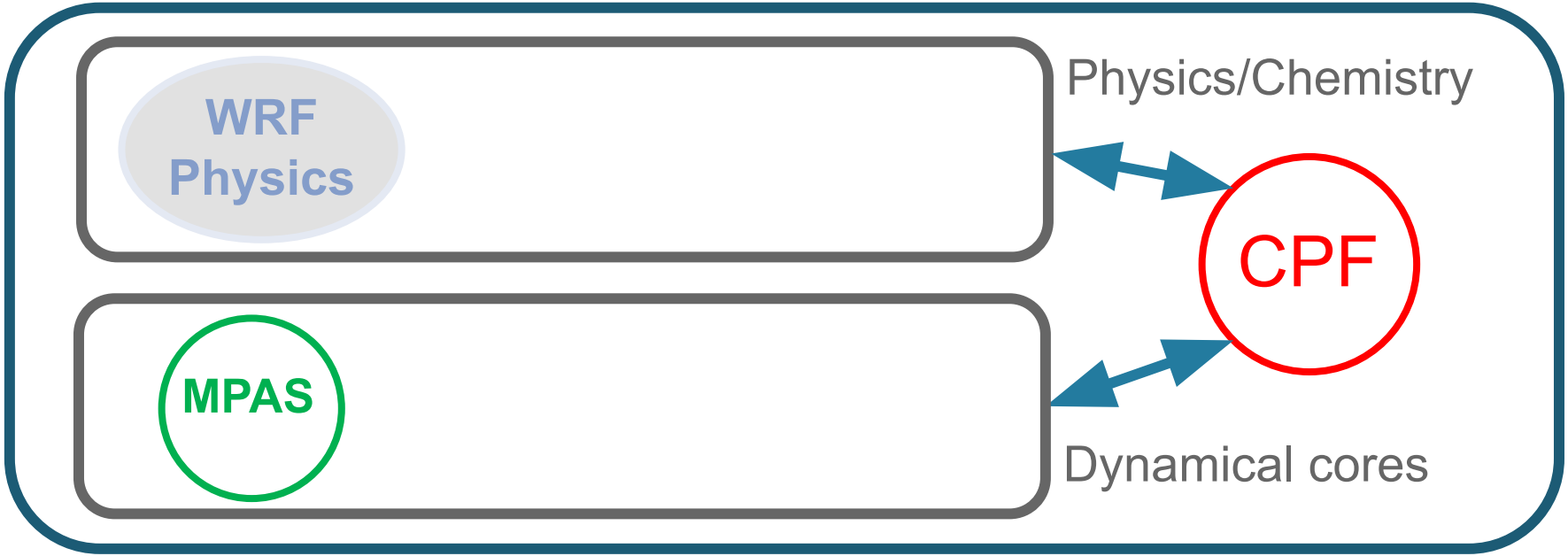



Medeiros, CGD

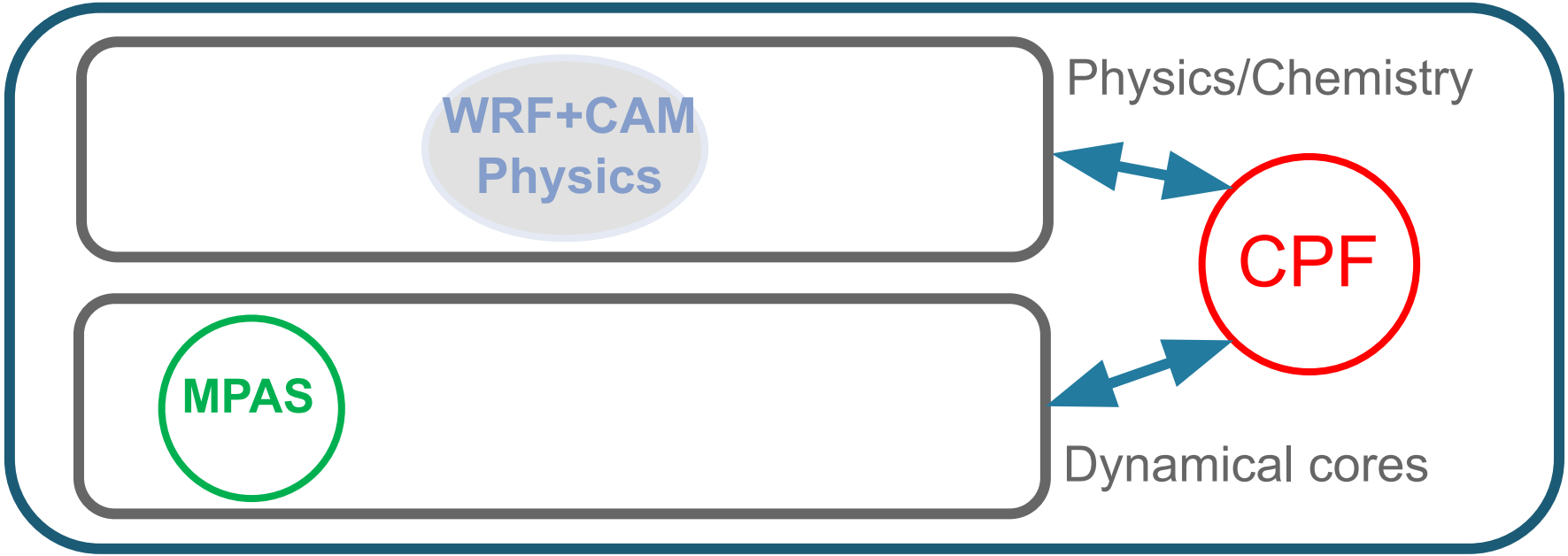
# SIMA


WRF Physics
CAM6 Physics
Test Physics
Physics/Chemistry
CPF
MPAS
SE
FV
Dynamical cores

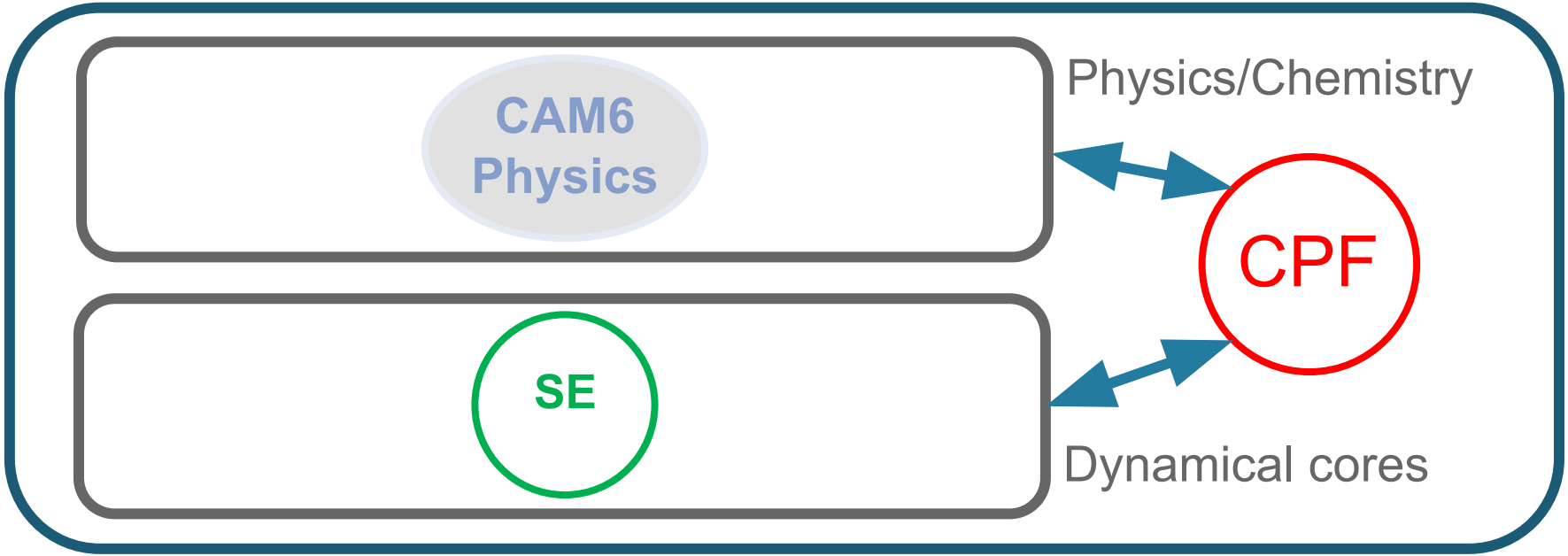
# SIMA-Weather



# SIMA-Weather

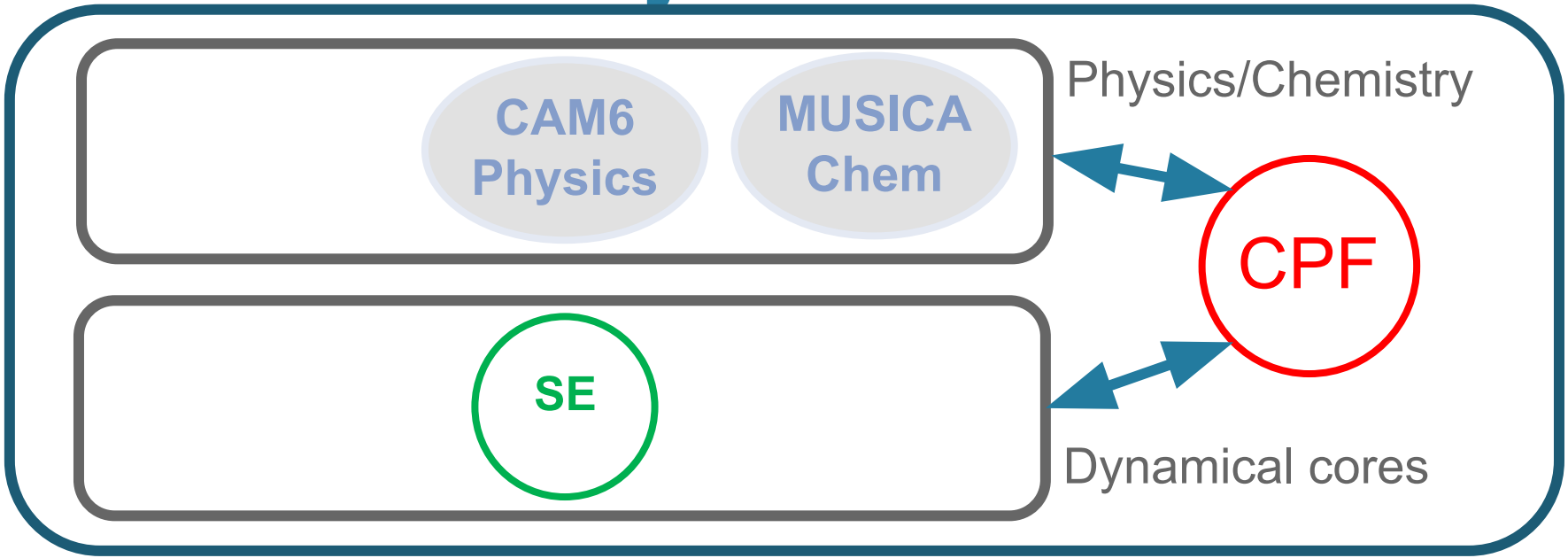


# SIMA-Climate



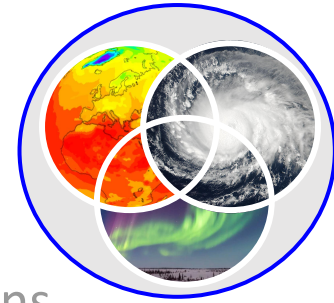
# SIMA-Climate

# SIMA-Chemistry/Climate



# SIMA Progress/Timeline

## Past, Present, Future



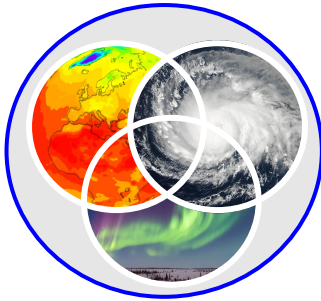
'Singletrack'

- 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)

SIMA

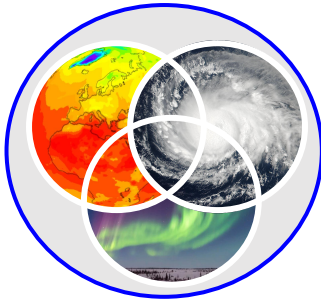
- Jan-Feb 2019: SIMA Terms of Reference, CESM CAB presentation
- July 2019: SIMA version 0 reinvestment project
- Aug 2019-May 2020: SIMA Version 0 Development
- June 2020: SIMA Community Workshop
- Aug 2020: SIMA Whitepaper
- Sep 2020: SIMA Version 0 Complete
- Oct 2020: SIMA Launch after Community Input (White Paper)

# SIMA ‘Version 0’ Progress



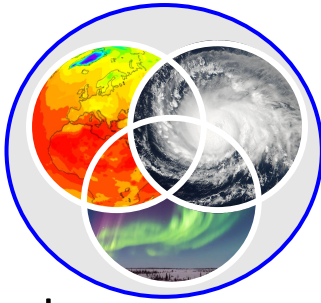
- Common infrastructure
  - Unified physics interface (CCPP)
  - Common repository for weather & climate code
- Common Dynamical cores
  - MPAS dynamical core in coupled framework
- CIME infrastructure modifications
  - Better initialization, regridding, and assimilation for global models
  - Good scaling 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



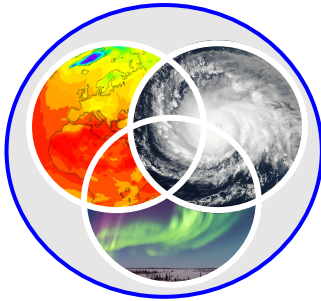
- Support and extend existing applications (CAM-WACCM&X/WRF/MPAS)
- Engage and extend existing communities
- Better access to prediction (initialization, assimilation) capabilities
- Coordinate efforts for greater efficiency (Do things right. Once.)
- Larger critical mass to develop a single system
- 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



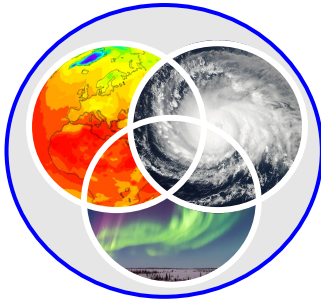
- Enables frontier science across NCAR: coupling climate and Earth System Modeling to Meteorology, Chemistry, Geospace, Polar
- Is responsive to Community Science
- Expands the reach and capabilities of atmosphere modeling
- Build a unified (cross scale) community modeling system
- Integrated with existing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