Update on the System for Integrated Modeling of the Atmosphere (SIMA)

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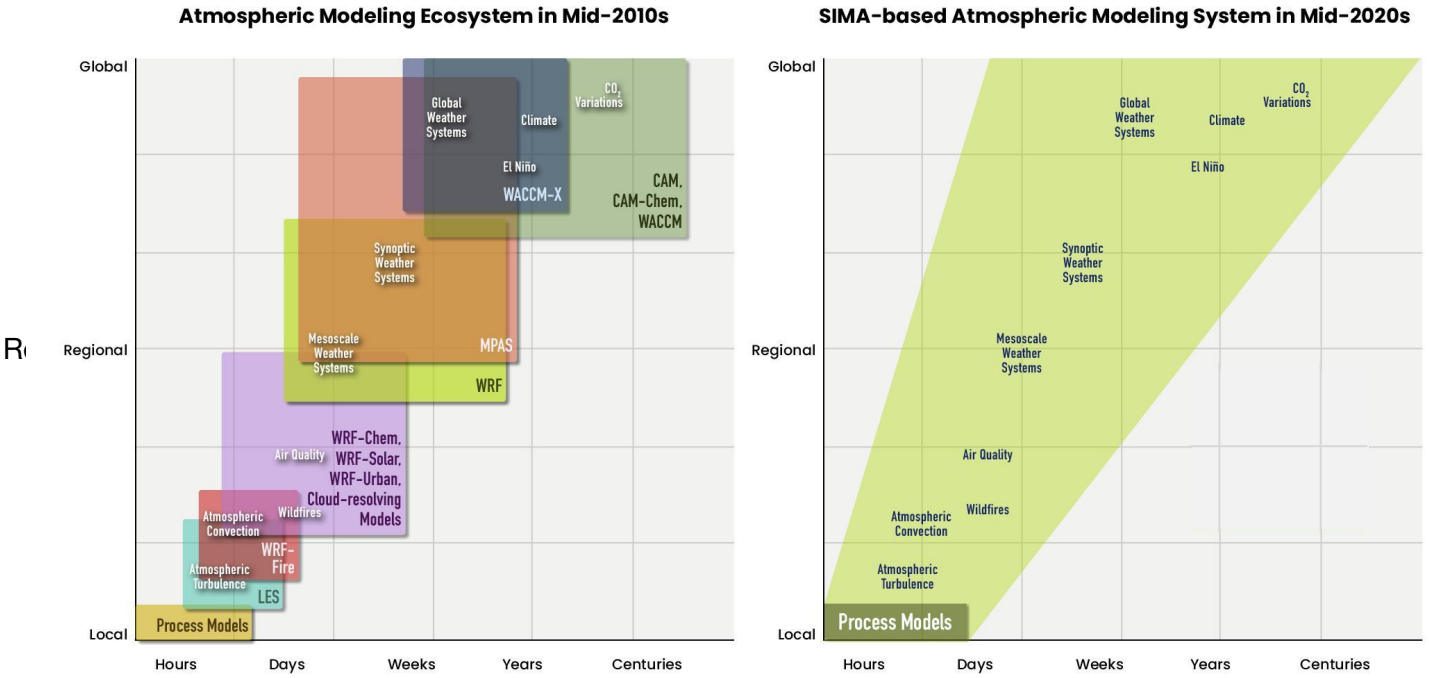
Update on the System for Integrated Modeling of the Atmosphere (SIMA)

1. ***SIMA Project's Goals***
2. *Recent Accomplishments*
3. *Ongoing Development Activities*
4. *Cross-Disciplinary Science Application Project*

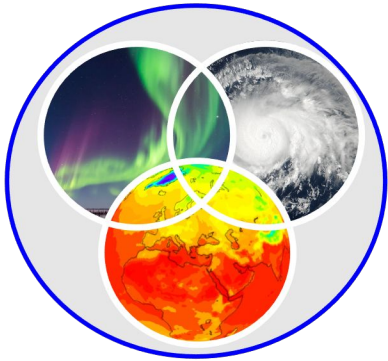
SIMA PROJECT AIMS TO UNIFY THE NCAR ATMOSPHERIC MODELING SYSTEM



NCAR atmospheric modeling ecosystem in the mid-2010s (left) and desired structure in mid-2020s (right)

MOTIVATION

SIMA will enhance frontier science simulations in climate, weather, atmospheric chemistry, geospace, and cross-discipline research with one modeling system



Examples:

How do urban centers or biomass burning or deep convection impact ***atmospheric chemistry and meteorology from local to global scales***?

How do chemistry and aerosol processes affect S2S predictability?

How do multiscale processes and interactions affect ***geospace-atmosphere coupling and space weather***?

What is the ***predictability of tropical cyclone formation*** from short (1 day) to extended range (30 days)?

How will ***extreme weather events change regionally under climate change***?

What processes in the Earth system control ***predictability in the Arctic***?

Many more – geoengineering, atmospheric rivers, ….

ADDITIONAL BENEFITS

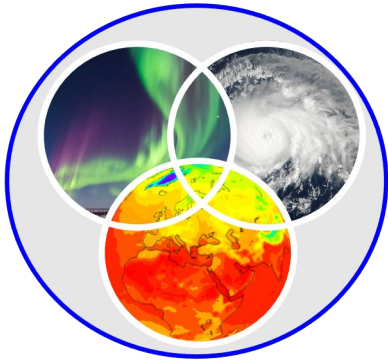
Broader range of atmospheric/geospace scientists using the same tool

- 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

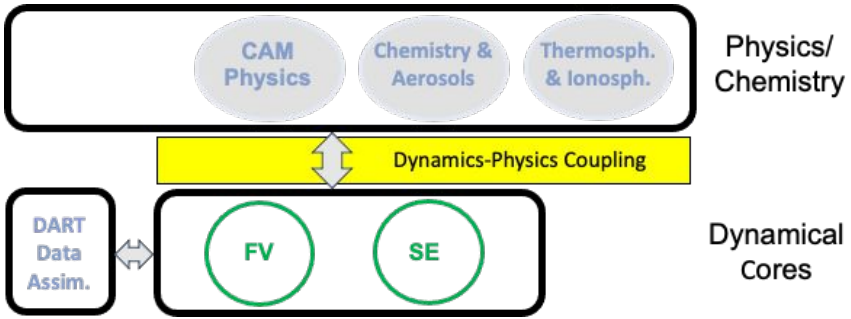
- Object-oriented structures
- Generic interfaces
- Greater runtime configuration control
- Code refactoring for GPUs or other computing architectures



ENHANCING CAM TO ACHIEVE A SINGLE MODELING SYSTEM

SIMA is enhancing CAM Capabilities for use in CESM

We started here:



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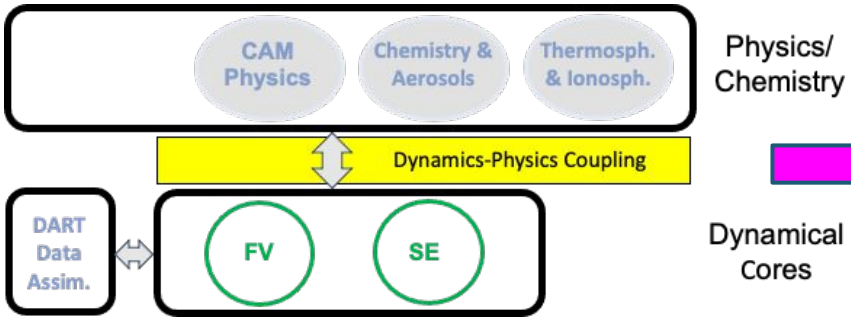
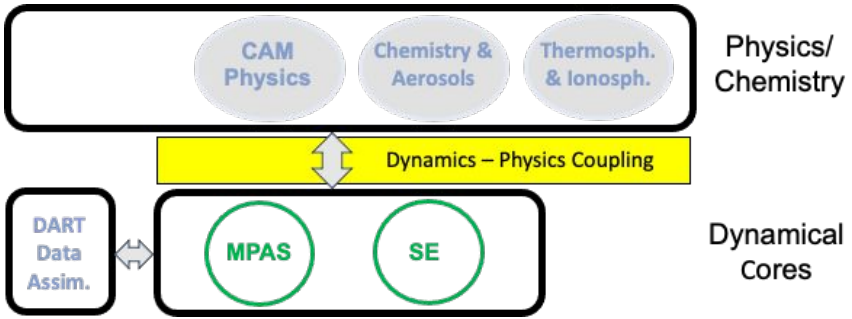


Coordinated effort of Implementation of MPAS dycore into CAM:



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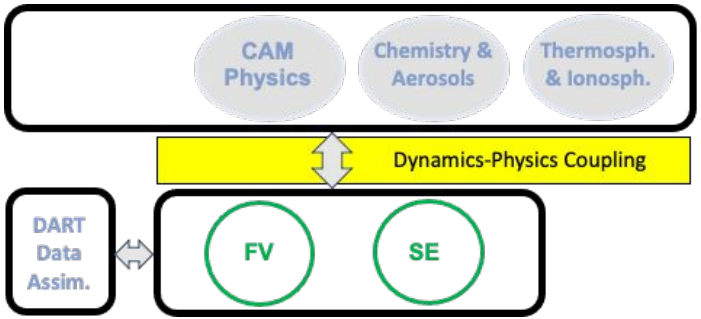

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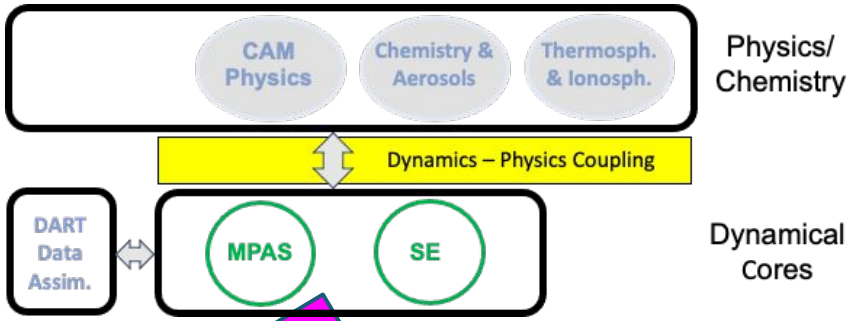
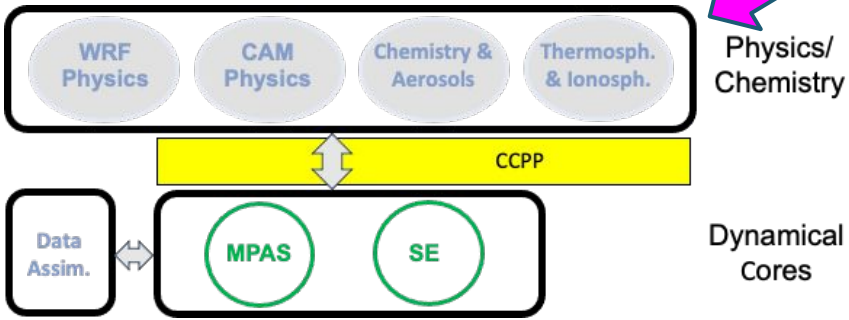


Have begun work on a CCPP compliant CAM, which will allow for WRF/MPAS physics to be ported into CAM

CAM-SIMA



These enhancements and new capabilities of CAM are bringing us toward the SIMA vision

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RECENT ACCOMPLISHMENTS OF ONGOING ACTIVITIES

Simulations Providing Insights on Effects of Grid Scale

a. Arctic 0.25° regionally refined simulations
b. GAMERA-WACCM-X 0.25° versus 1° simulations

Projects are a joint CESM and SIMA activity funded by the National Science Foundation

Core SIMA Development Efforts

a. CAM-MPAS tests with CAM6 physics variants in convection simulations
b. CAM-MPAS with full chemistry test simulations

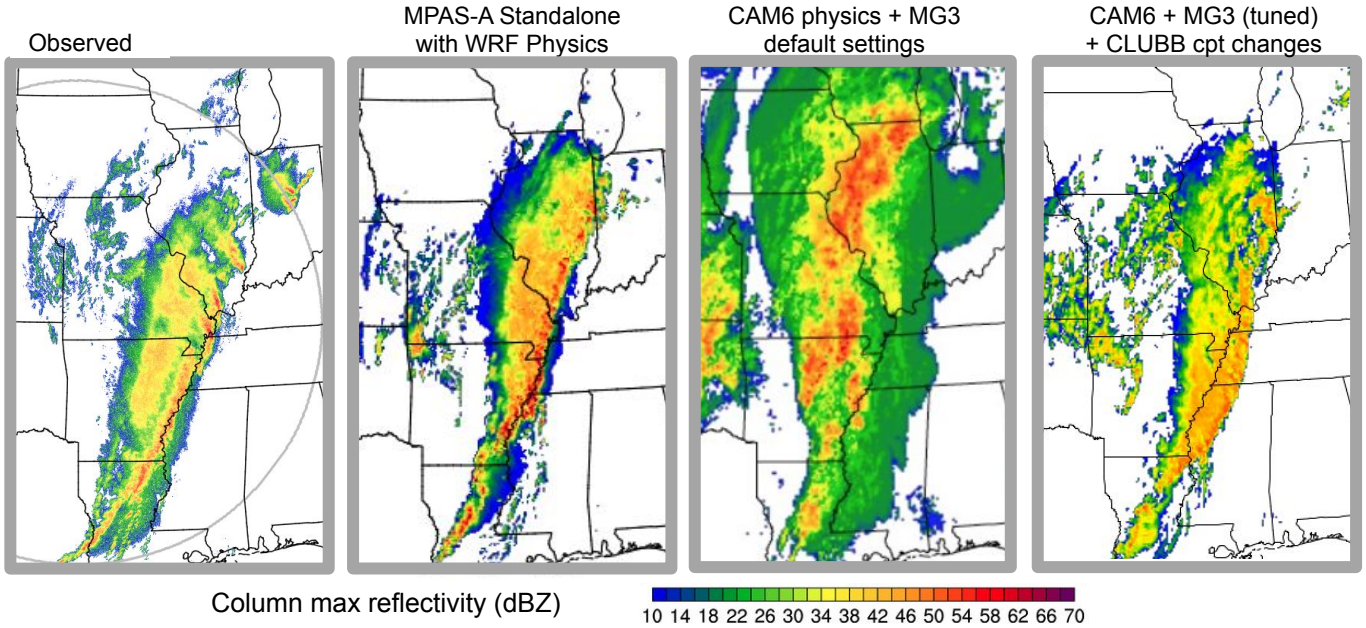
Recent tests show improved storms and that running chemistry is viable

CAM-MPAS Tests with CAM6 Physics Variants in Convection Simulations

MPAS 60-3 km mesh, 58 levels, 43 km top cell spacing (c.i. 8 km, 4 km inner contour)

Recently have done tests with the MG3 cloud physics scheme

1-day forecast,
ERA5 initialization 0 UTC 26 April 2017

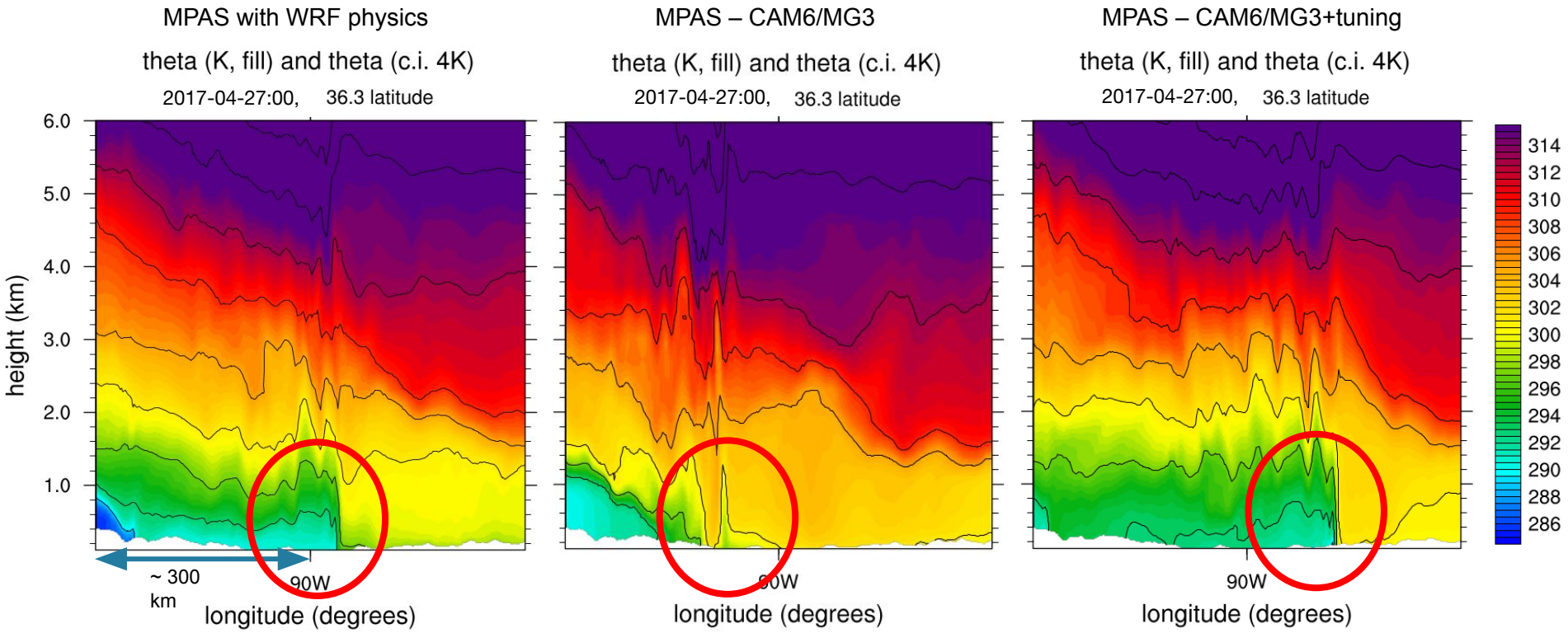


W. Skamarock, J. Hurrell, et al.,

Project is a joint Earthworks and SIMA activity funded by the National Science Foundation

Improvements through tuning cloud physics scheme and not using cloud fraction estimation from CLUBB

Convection Test Case: Squall Line in the Central US



Tuned cloud physics and CLUBB cpt changes produces a much more realistic cold pool

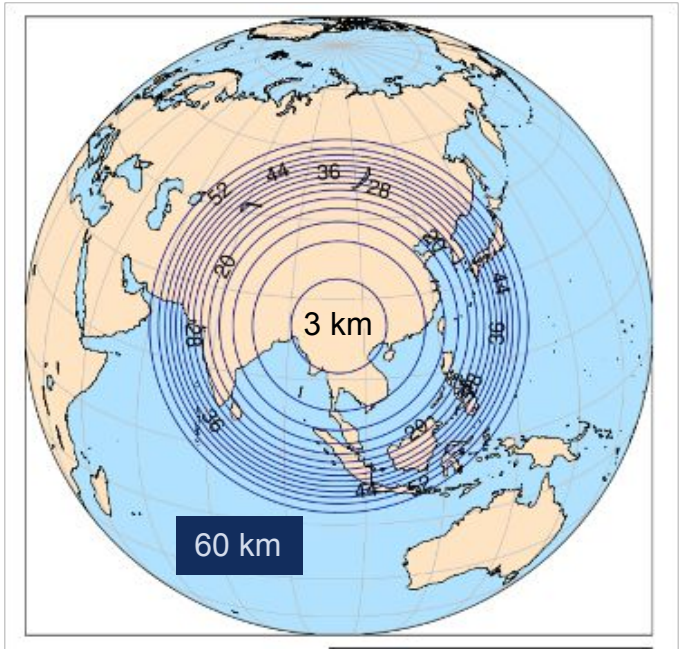
Tests of CAM-MPAS with full chemistry

Asian Summer Monsoon

- Grid mesh centered over SE Asia
- 60 - 3 km grid mesh (840,000 columns)
- Troposphere-Stratosphere (TS1) chemistry (168 trace gases & aerosols)

Emissions: CAMS 0.1deg emissions inventory

Case study: 23-28 August 2019



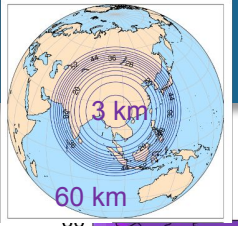
Preliminary Results are reasonable

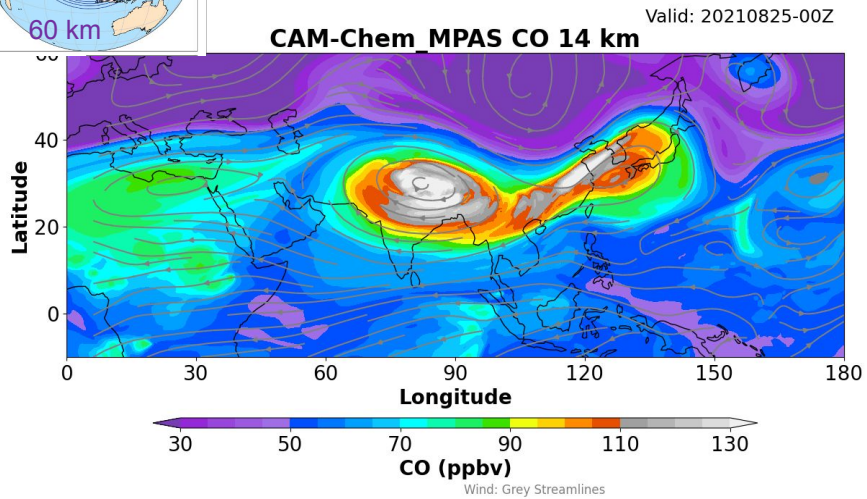
Next Steps:

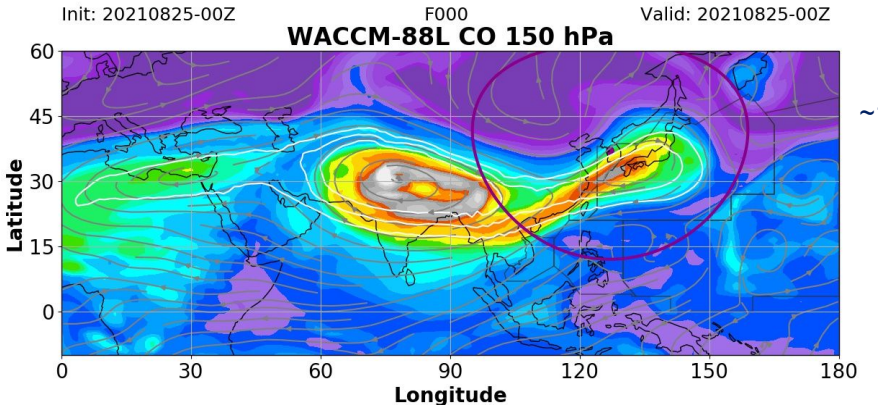
- Further comparisons with CAM-MPAS-chemistry on a uniform grid
- Test computational aspects

M. Barth, F. Vitt, W. Skamarock, W. Smith et al.

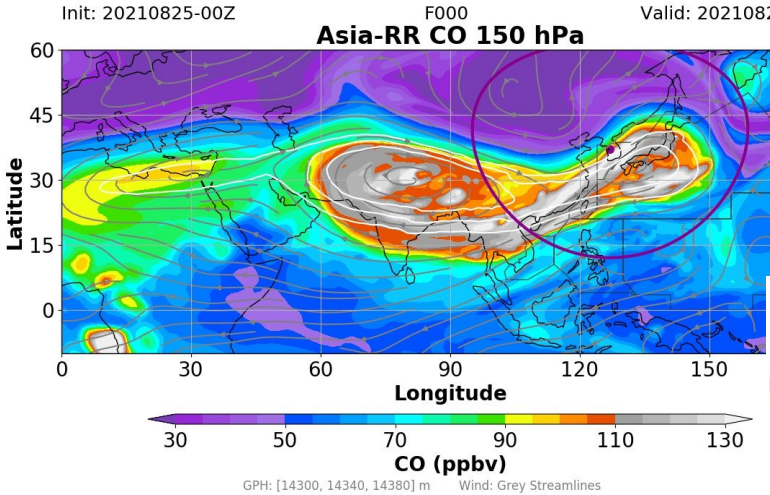
14 km CO (τ ~ 1 month)



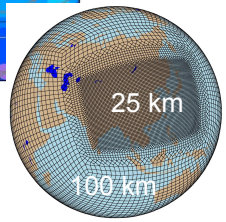




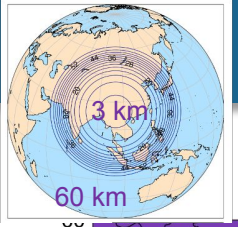
~1deg

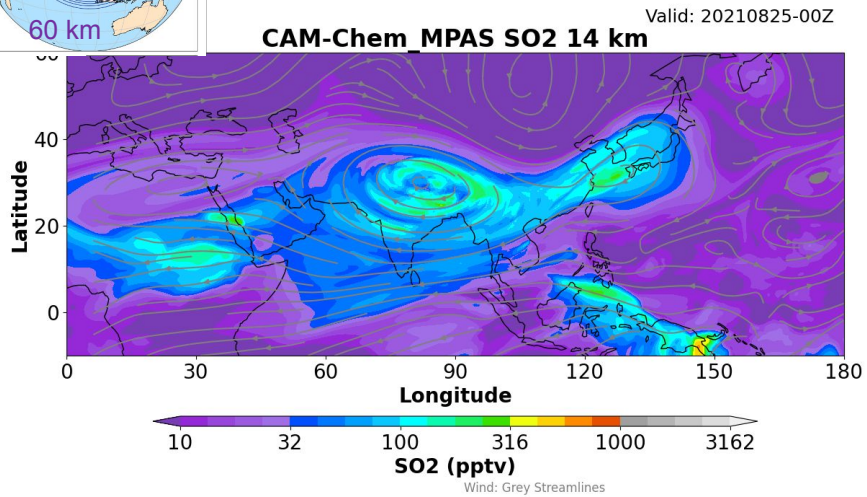


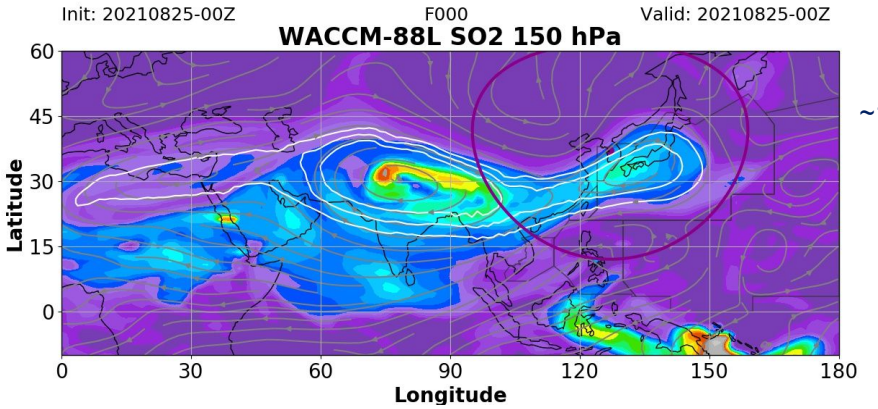
- CAM-MPAS-Chem: 60km to 3km, 32 levels, free running, daily average
- WACCM: 1deg, 88 levels, nudged, instantaneous
- MUSICAv0: 1deg to 0.25deg, 32 levels, nudged, instantaneous



14 km SO_2 (τ < 1 day)







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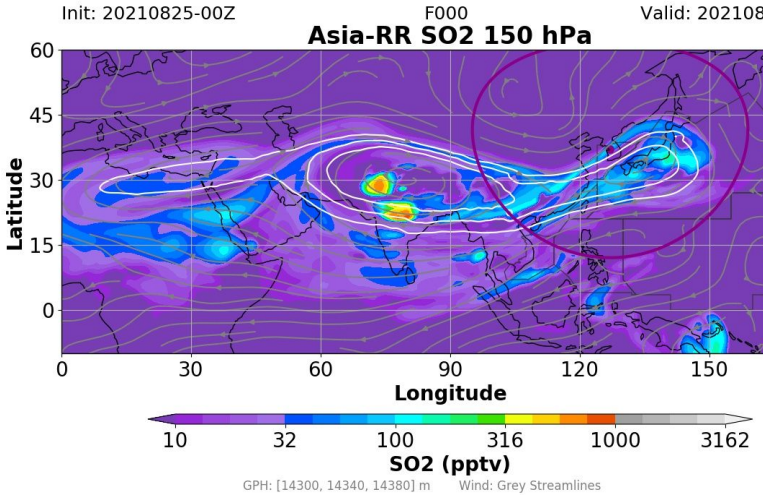

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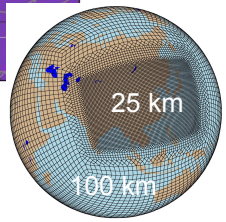

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OTHER ONGOING ACTIVITIES

Core SIMA Development Efforts

1. Capability to run global, convective-permitting grid mesh simulations
2. Develop CAM-SIMA
    a) Complete development of CCPP Framework
    b) Refactor CAM physics to be compliant with CCPP
    c) Implement Model Independent Chemistry Module (MICM) into CAM-SIMA
    d) Test WRF/MPAS CCPP-compliant physics in CAM-SIMA
3. Transform ionospheric electric dynamo module to enable GPU capability
4. Implement abstract interfaces for aerosol-physics interactions

Also: Develop multi-phase chemistry in MICM; MPAS deep atmosphere dynamical core; 2-way WACCM-X/GAMERA coupling; Online flexible regridding

CROSS-DISCIPLINARY SCIENCE APPLICATION PROJECT

Subseasonal-to-seasonal, sun-to-surface prediction system

PI: Nick Davis (ACOM)
Co-Is: A. Prein (MMM), G. Danabasoglu, I. Simpson, J. Richter, S. Yeager (CGD), N. Pedatella (HAO), J. Berner (MMM/CGD)

Science Goals:

- Evaluate role of small-scale processes on extreme weather events;
- Quantify the value of refined resolution of events, their surface impacts, and coupling to upper atmosphere

SIMA Development

- WACCM - MPAS with TSMLT chemistry and CAM6 physics;
- Elevate model lid to lower thermosphere;

Development Tasks

- Configure simulation with grid, data files
- Evaluate potential memory and start-up time issues
- Apply nudging for configuration
- Design ensemble simulations
- Advance post-processing data science
- Should be able to run coupled with ocean model

Simulations

1. Two 10-member ensemble simulations of a) cold air outbreak and b) heatwave
2. Two 5-member ensemble simulations with scrambled upstream input information
3. Key deliverable: MPAS-WACCM initialization archive

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. *Good progress on CAM-MPAS representing convection with CAM physics and on testing chemistry with CAM-MPAS*
4. *Ongoing and near-term efforts are focused on creating CAM-SIMA*
5. *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*

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Thank you!

Extra Slides

FROM CAM TO CAM-SIMA

The future – CCPP compliant – atmospheric component of CESM