Development of WACCM-X as the SIMA Geospace Component

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National Center for Atmospheric Research

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Outline

What is SIMA: Motivation and Project Goal

WACCM-X: SIMA-Geospace Component.

Current Developments.

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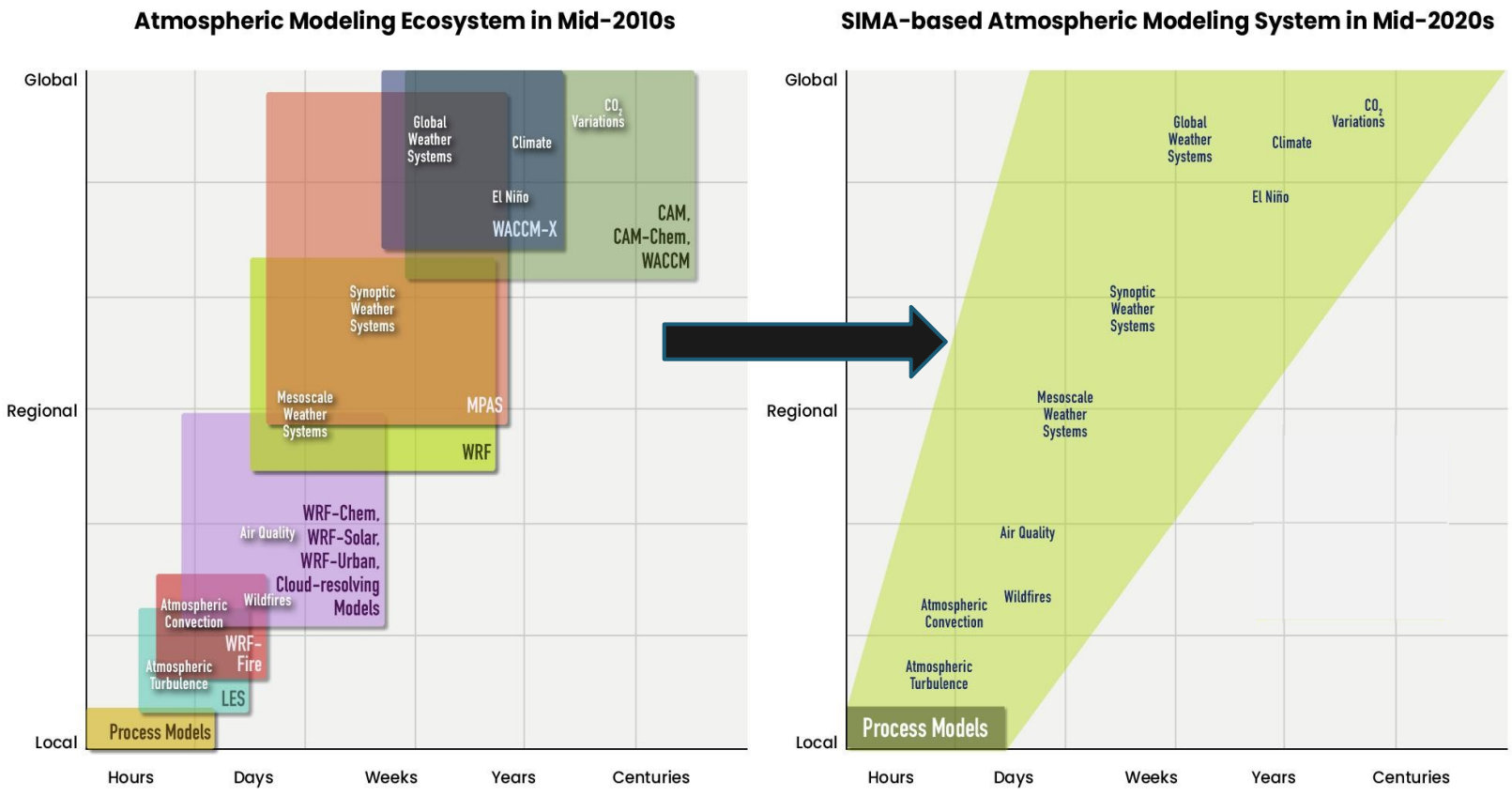
SIMA PROJECT AIMS TO UNIFY THE NCAR ATMOSPHERIC MODELING SYSTEM



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

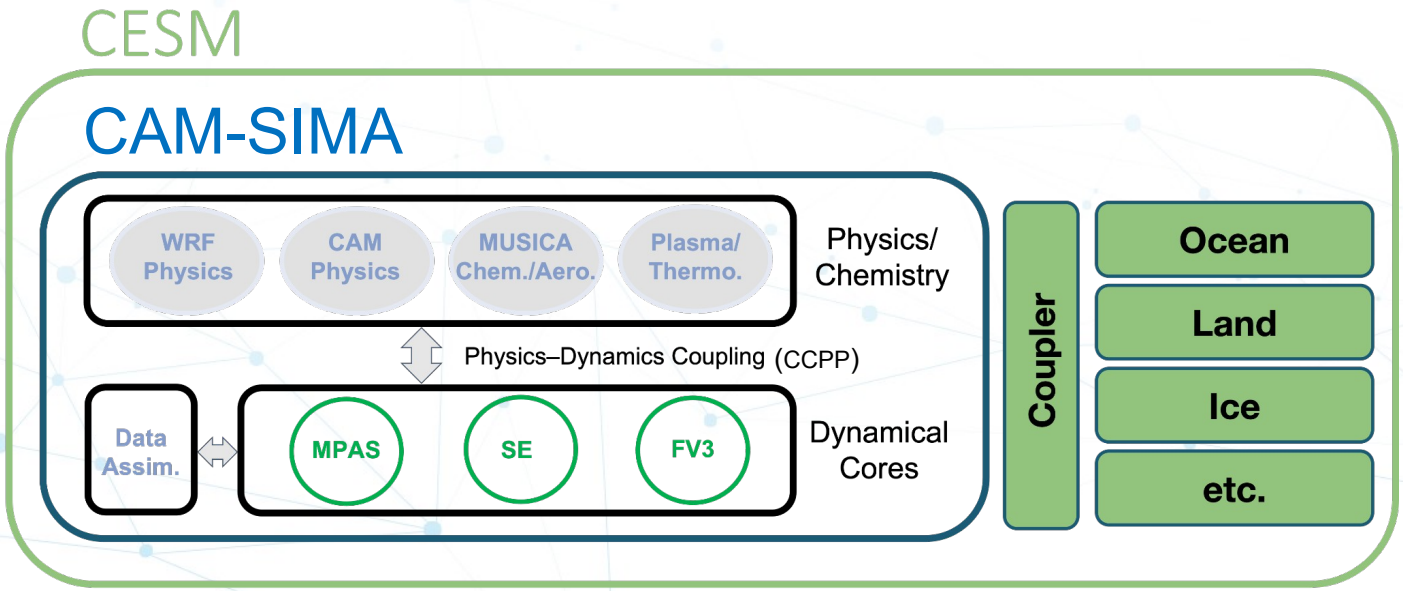
Centralized and efficient model development, maintenance, and support

Opportunity to modernize underlying software

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

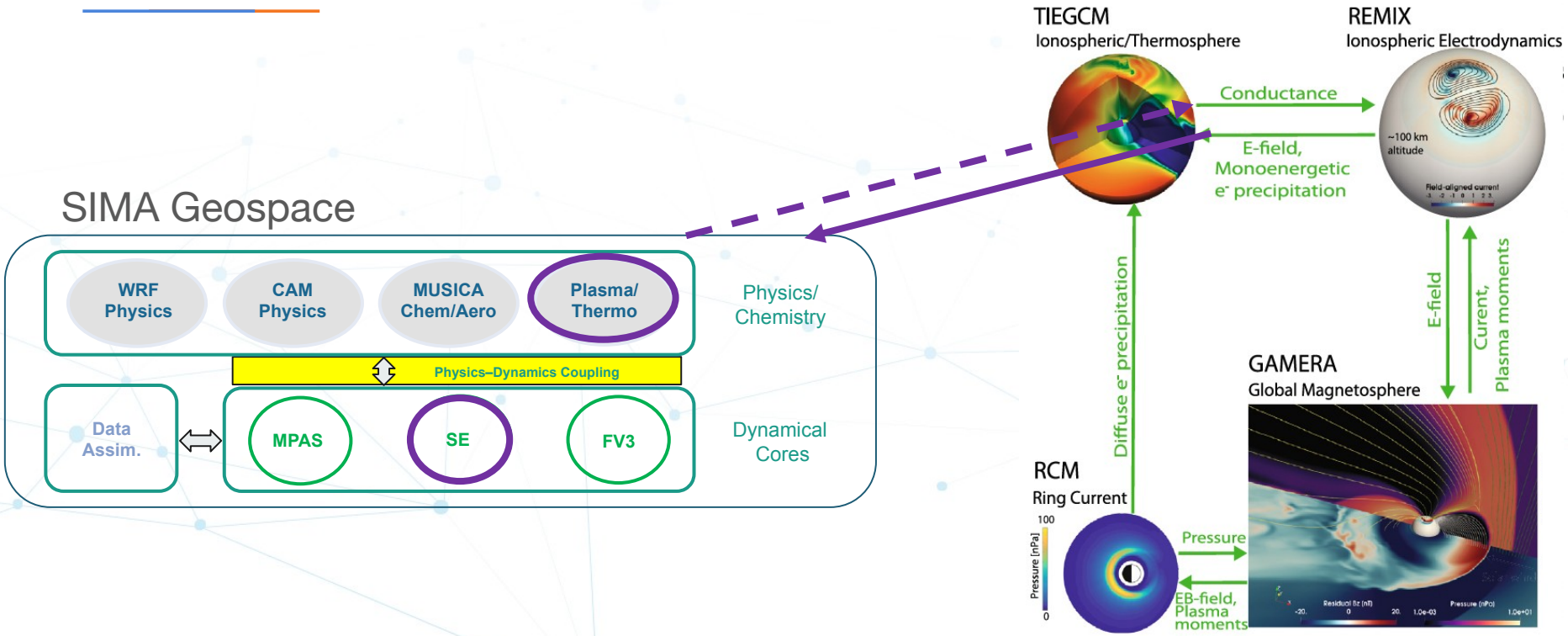
GOAL

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



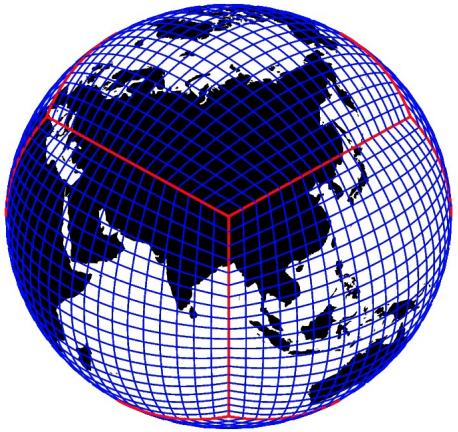
Multiscale Atmosphere-Geospace Environment (MAGE) Mode

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



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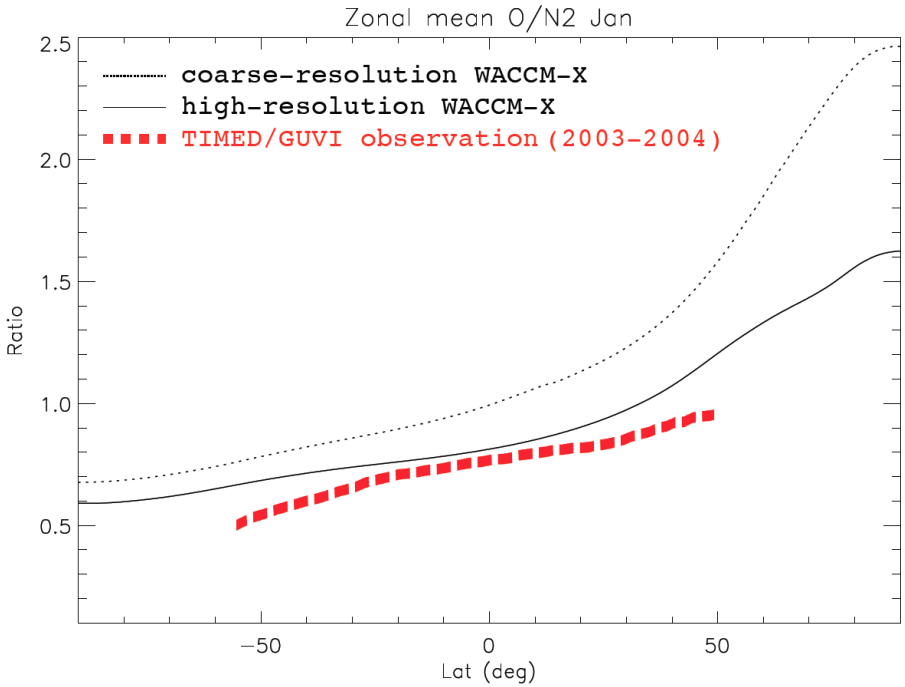
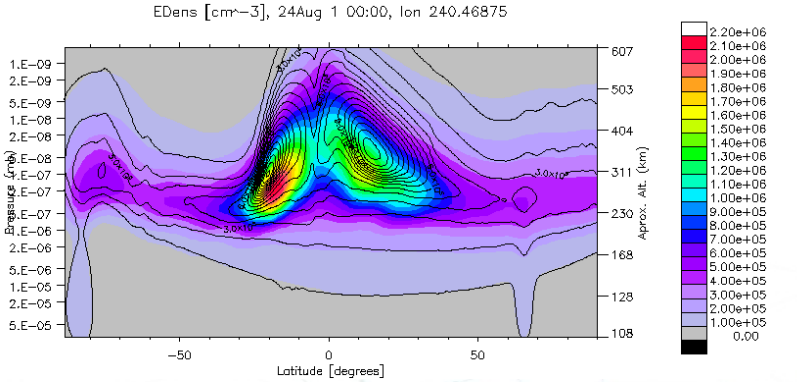
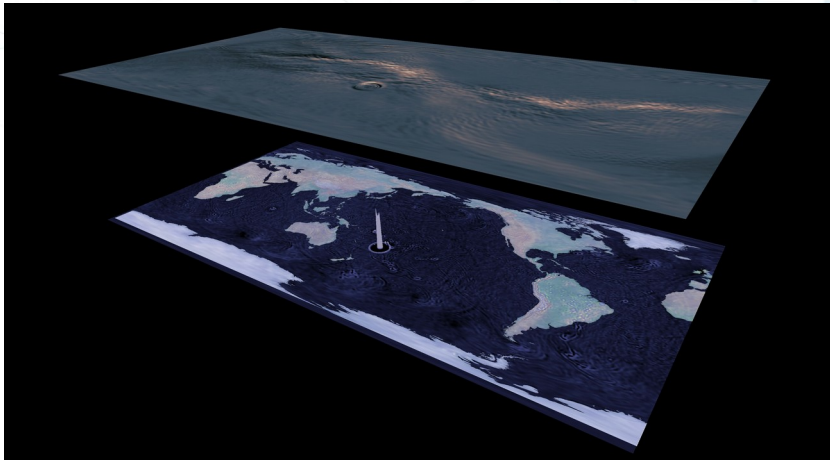
Gravity Wave Resolving

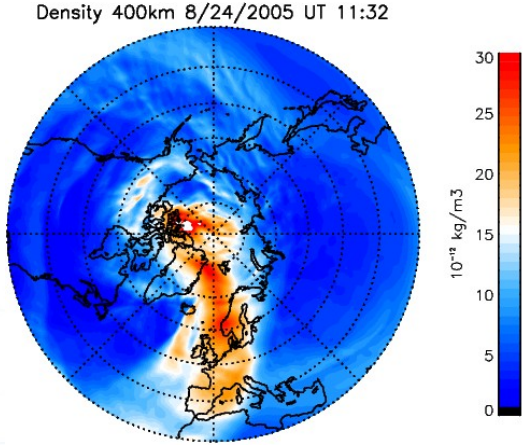
Improved thermospheric circulation, composition, and variability

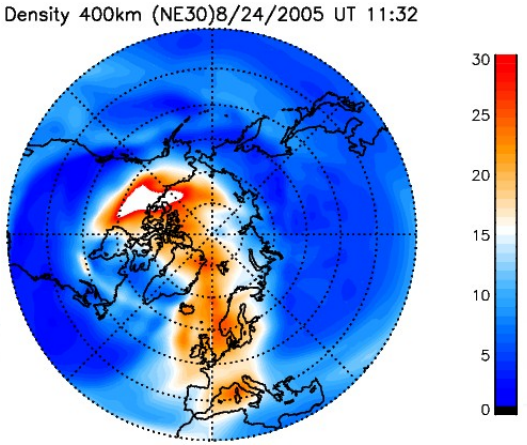


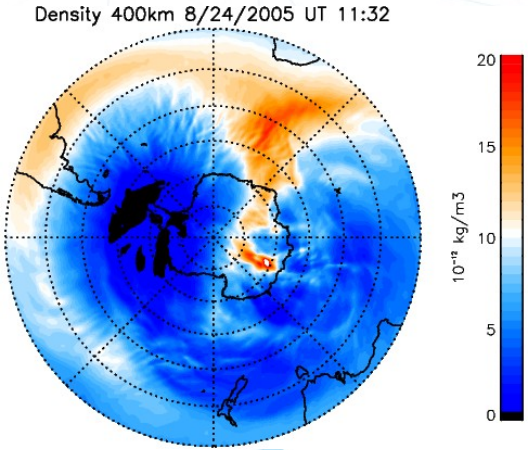


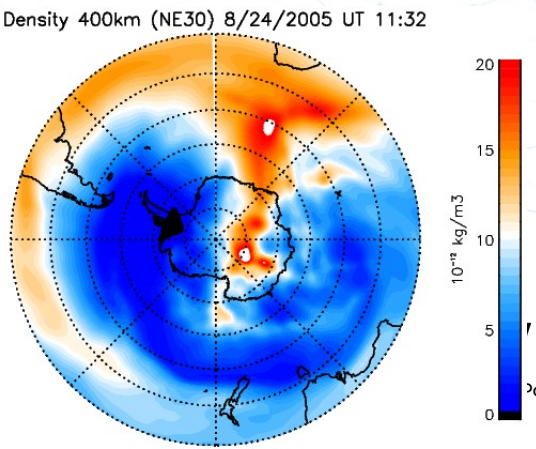


WACCM-X/GAMERA









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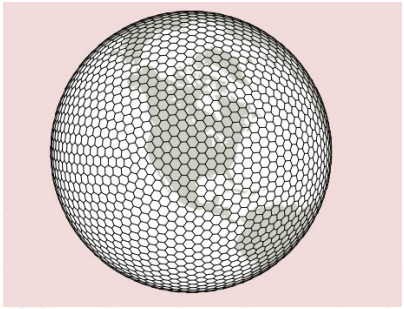
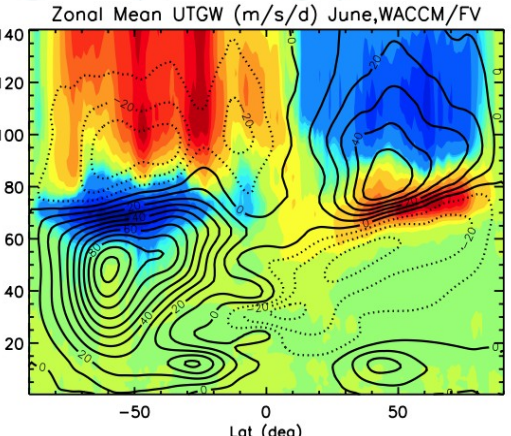
Non-hydrostatic Dynamical Core: MPAS-A in WACCM-X

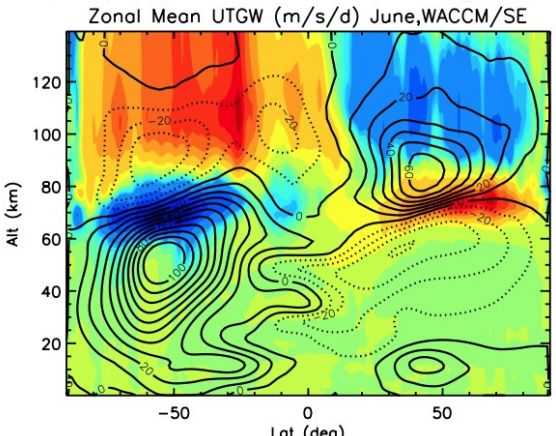
- MPAS-A brings non-hydrostatic modeling capabilities to CESM.
- Centroidal Voronoi mesh
- Finite-volume, C-grid staggering
- Hybrid terrain-following height vertical coordinate



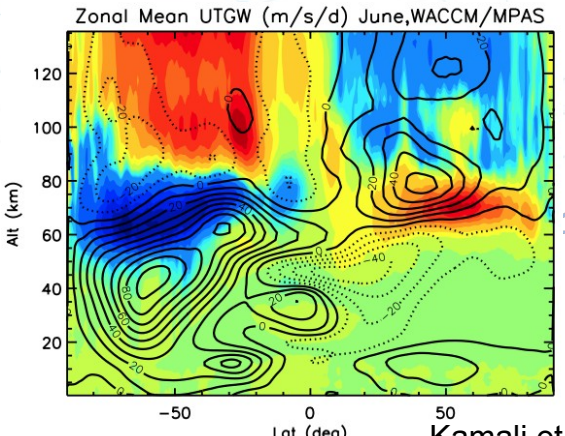
Finite Volume (FV)



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*

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