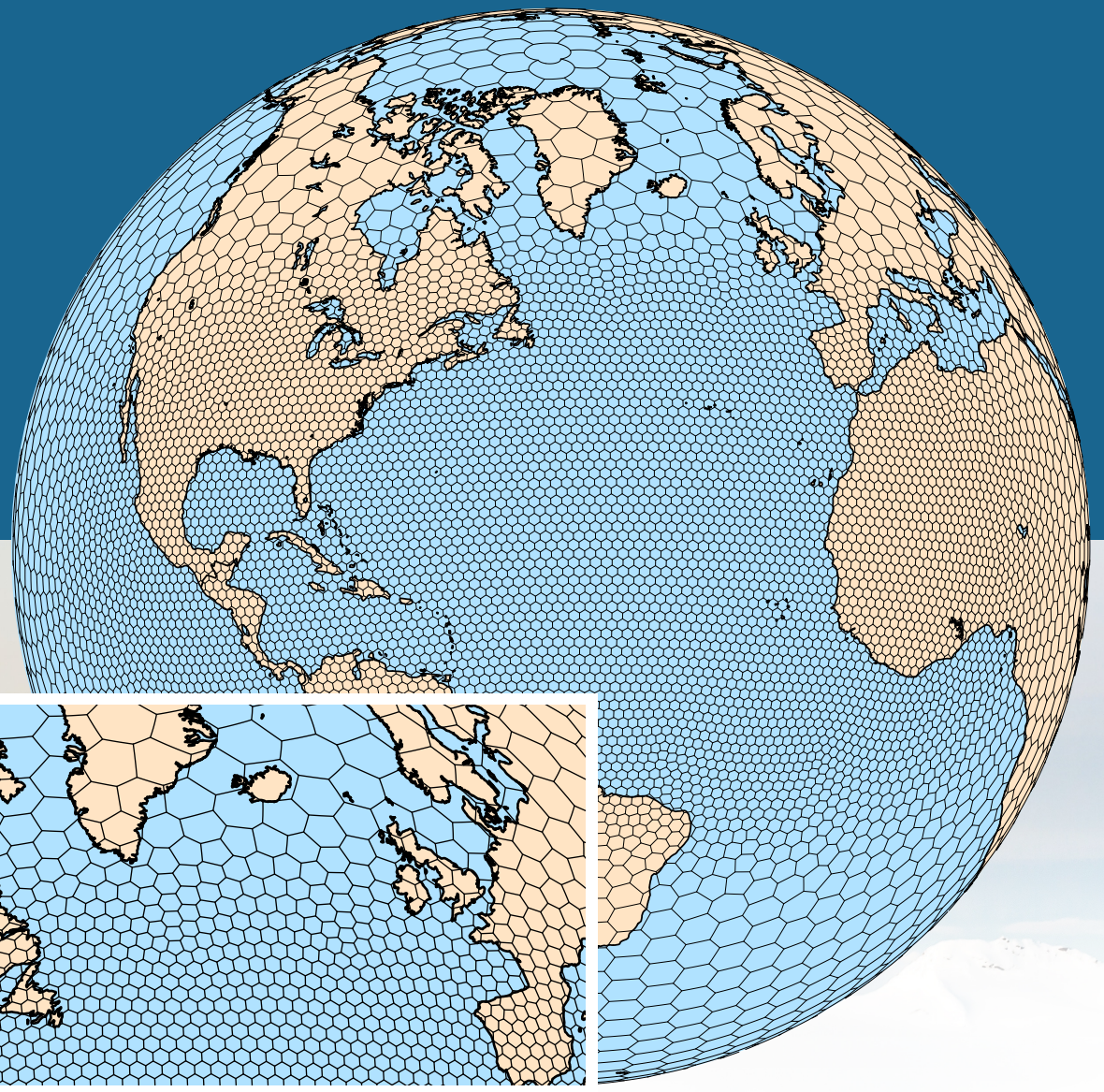
MPAS

Model for Prediction Across Scales

Based on unstructured centroidal Voronoi (hexagonal) meshes using C-grid staggering and selective grid refinement.



Collaboratively developed, primarily by NCAR and LANL/DOE

MPAS infrastructure - NCAR, LANL, others.

MPAS - Atmosphere (NCAR)

MPAS - Ocean (LANL)

MPAS – Land and Sea Ice, etc. (LANL and others)

This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

MPAS
Model for Prediction Across Scales

What is MPAS?
Freely available modeling system

MPAS Version 8.2.0 (27 June 2024)

MPAS infrastructure - NCAR, LANL, others.

Infrastructure for the Voronoi mesh and solvers (data structures; mesh generation, manipulation; operators on the mesh).

MPAS - Atmosphere (NCAR)

Nonhydrostatic atmospheric solver; pre- and post-processors

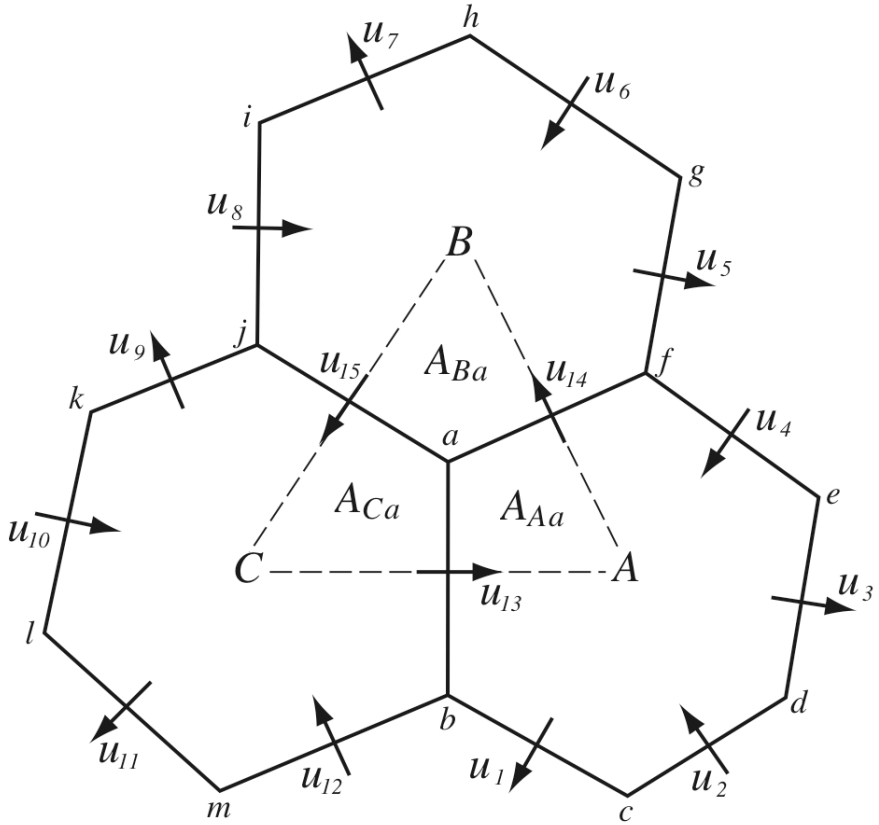
Other dynamical cores (ocean, land ice, sea ice) in the release repository are no longer supported.

MPAS
Model for Prediction Across Scales

What is MPAS?
Centroidal Voronoi Meshes

Unstructured spherical centroidal Voronoi meshes

- Mostly *hexagons*, some pentagons and 7-sided cells
- Cell centers are at cell center-of-mass (centroidal).
- Cell edges bisect lines connecting cell centers; perpendicular.
- Uniform resolution – traditional icosahedral mesh.



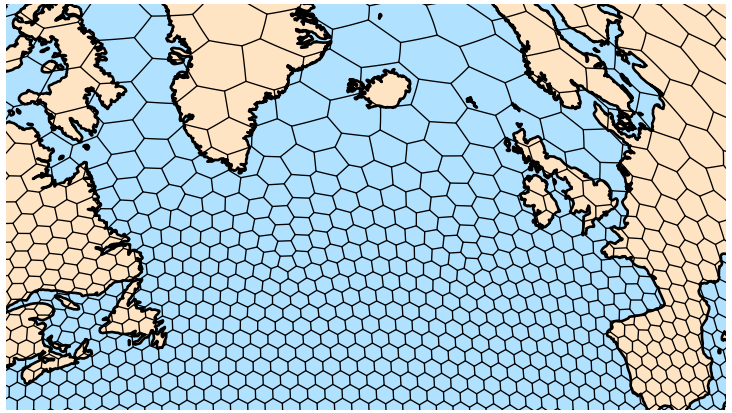
C-grid

- Solve for normal velocities on cell edges.
- Gradient operators in the horizontal momentum equations are 2nd-order accurate.
- Velocity divergence is 2nd-order accurate for edge-centered velocities.
- Reconstruction of full velocity requires care.

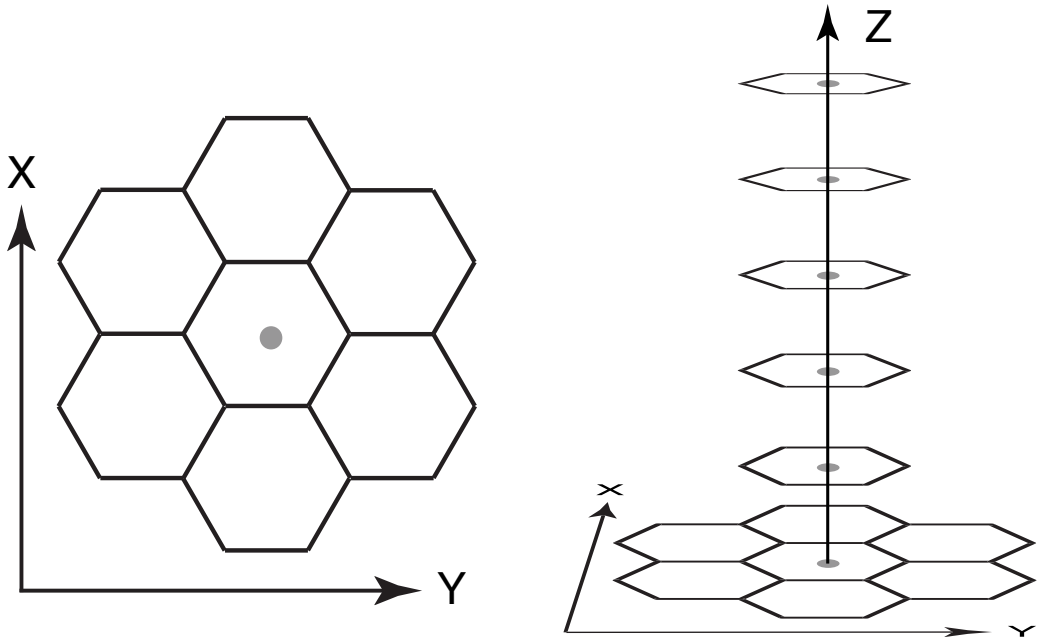
MPAS
Model for Prediction Across Scales

What is MPAS?
Centroidal Voronoi Meshes

The 2D (horizontal) mesh is *unstructured* there is no global coordinate



The mesh is *structured* in the vertical



MPAS
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MPAS Nonhydrostatic Atmospheric Solver

Fully Compressible Nonhydrostatic Equations

- Prognostic equations for coupled variables.
- Generalized height coordinate.
- Horizontally vector invariant eqn set.
- Continuity equation for dry air mass.
- Thermodynamic equation for coupled potential temperature.

Time integration as in Advanced Research WRF

- Split-explicit Runge-Kutta, with extensions

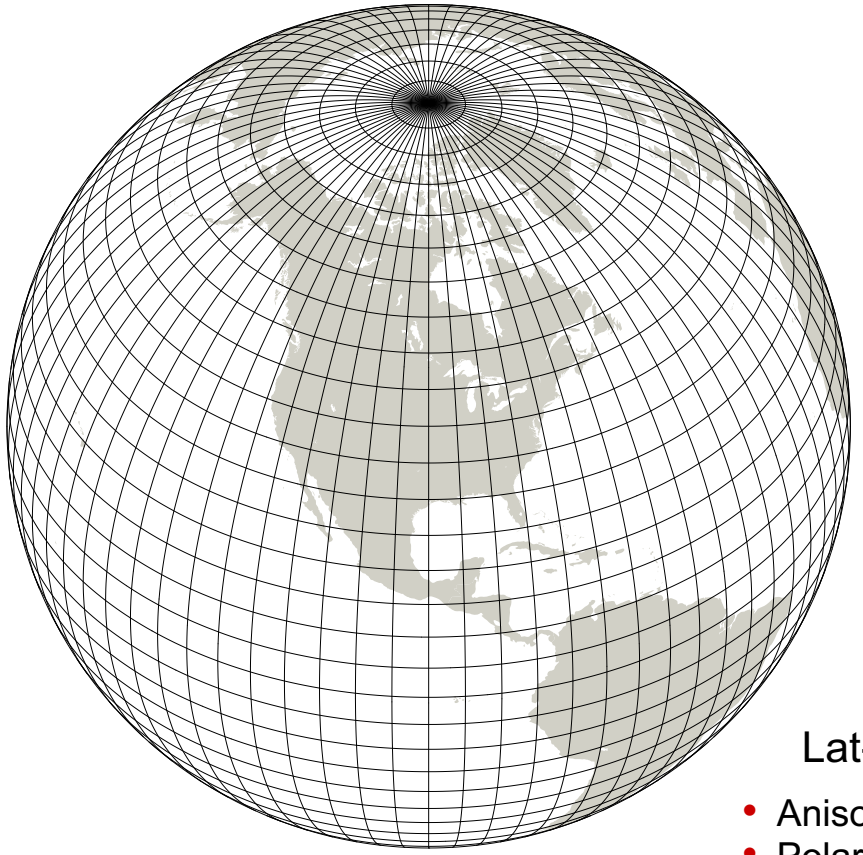
Full complement of atmospheric-model physics

MPAS-Atmosphere can be configured for both global and regional applications.

MPAS
Model for Prediction Across Scales

Why MPAS?

Significant differences between WRF and MPAS

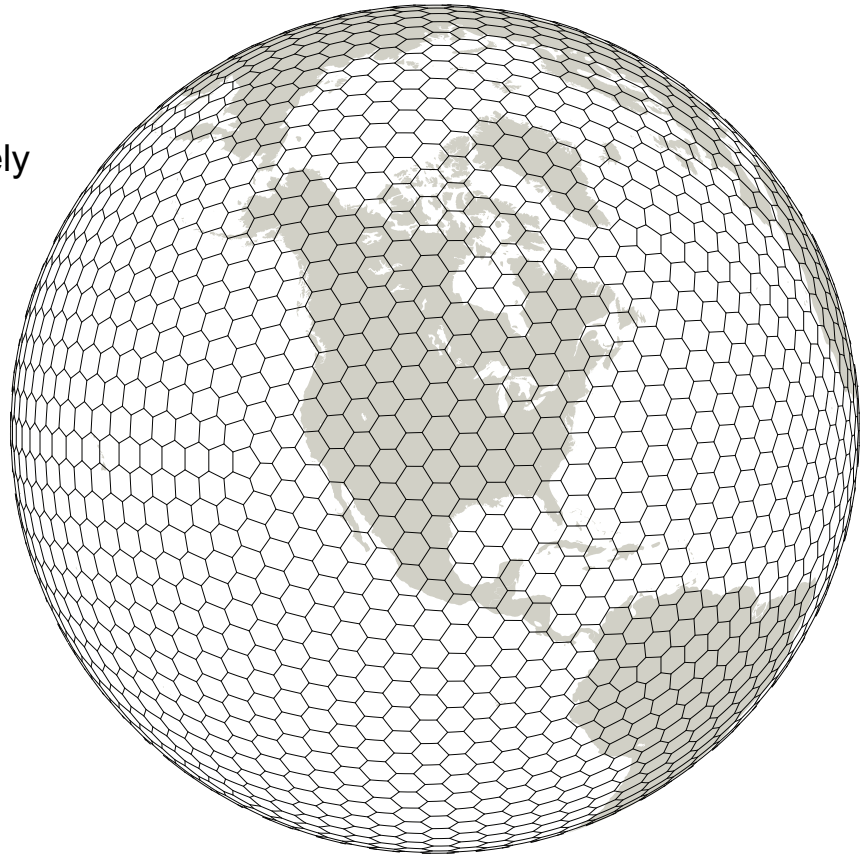


WRF
Lat-Lon global grid

- Anisotropic grid cells
- Polar filtering required
- Poor scaling on massively parallel computers

MPAS
Unstructured Voronoi (hexagonal) grid

- Good scaling on massively parallel computers
- No pole problems



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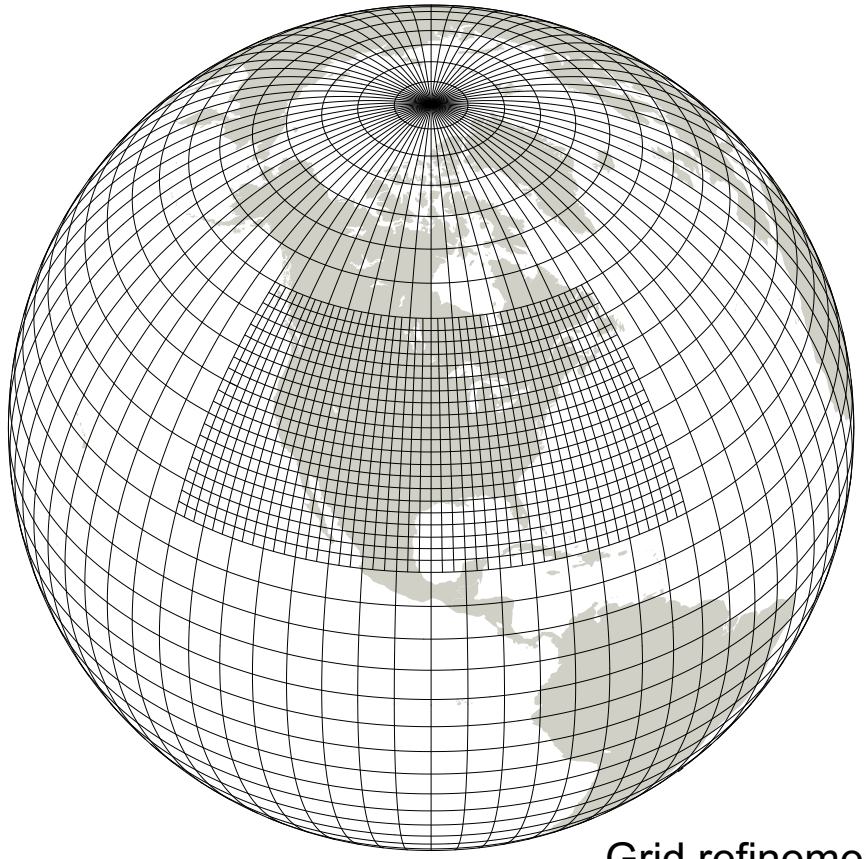
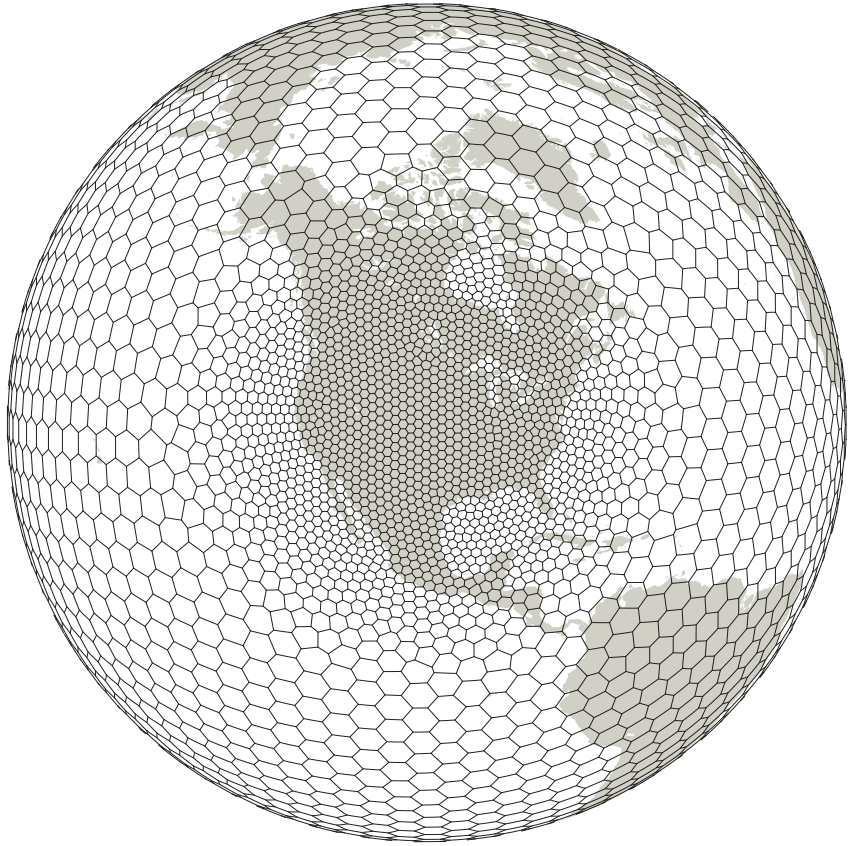


MPAS

Smooth grid refinement on a conformal mesh

- Increased accuracy and flexibility for variable resolution applications
- No abrupt mesh transitions.



WRF

Grid refinement through domain nesting

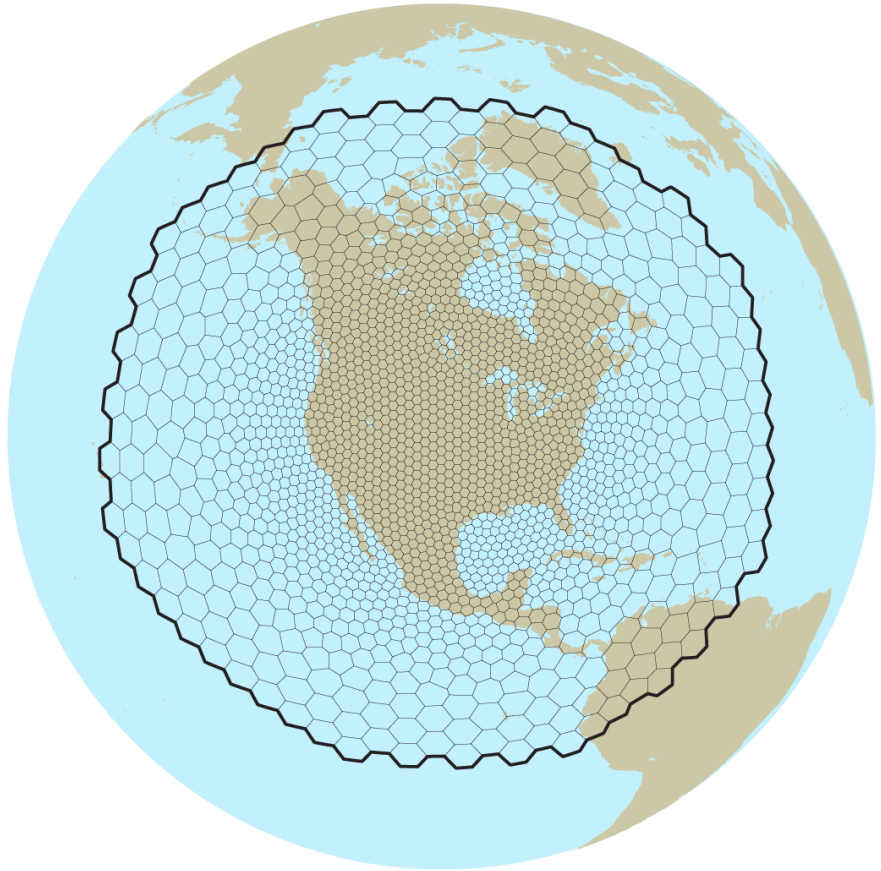
- Flow distortions at nest boundaries

MPAS
Model for Prediction Across Scales

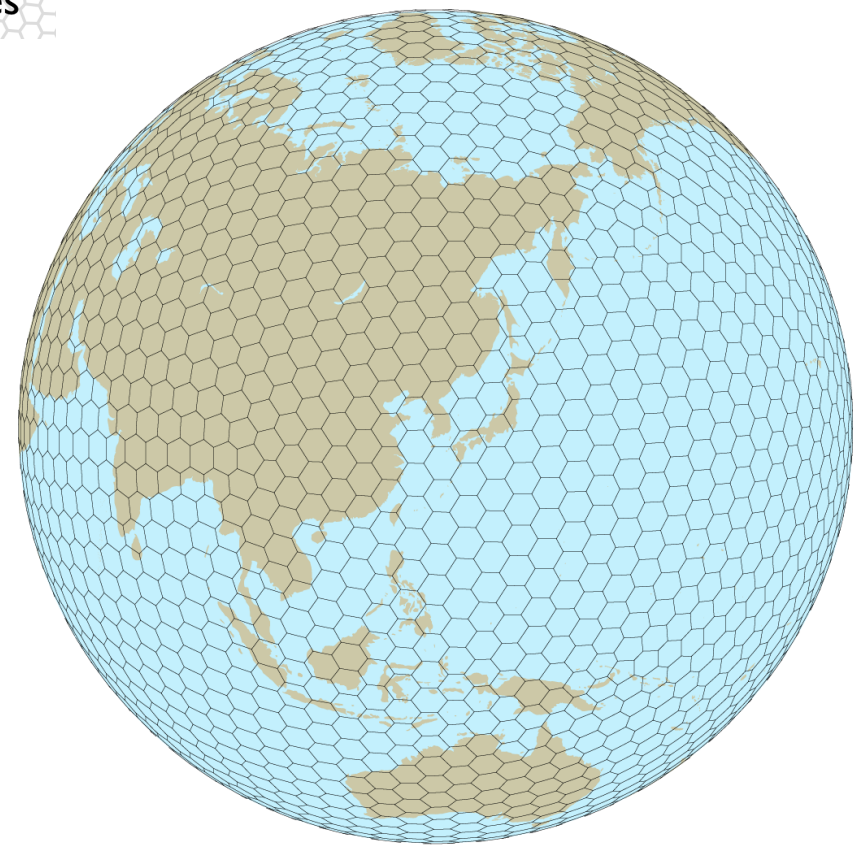
Regional MPAS

Advantages of regional MPAS

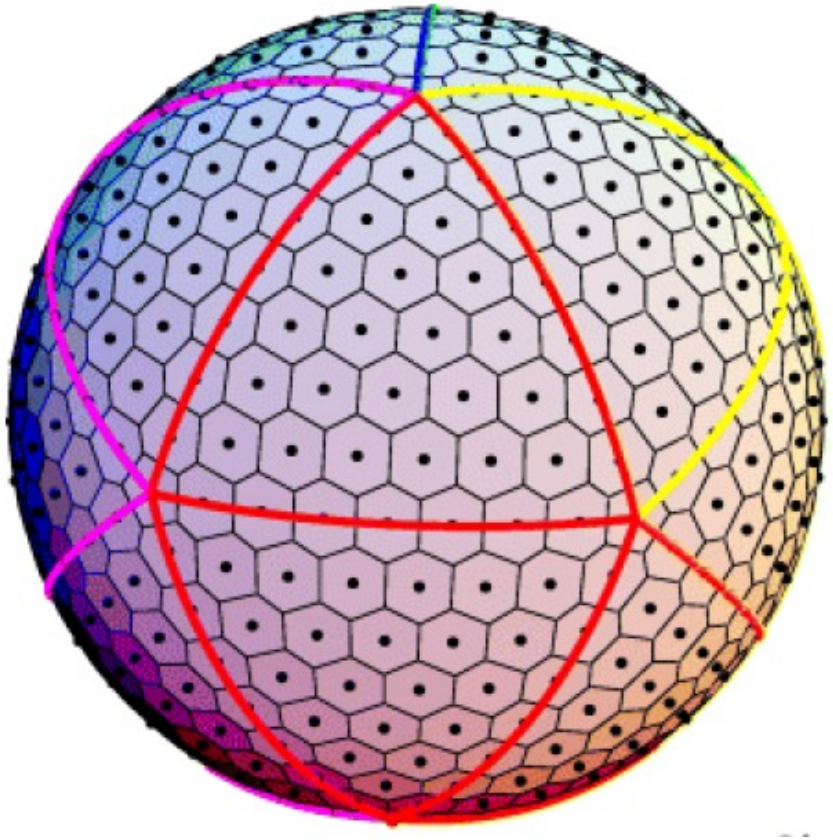
- Provide a consistent (equations, mesh) regional solver to complement global MPAS.
- Leverage MPAS development for next-generation architectures to regional applications.
- Enable regional atmospheric applications within MPAS-enabled coupled modeling systems (e.g. CESM).
- Employ variable resolution in regional applications to reduce LBC errors.
- *We are no longer developing WRF at NCAR, and users should consider transitioning to MPAS if their applications allow.*



MPAS
Model for Prediction Across Scales



Global Quasi-Uniform Mesh (SCVT)

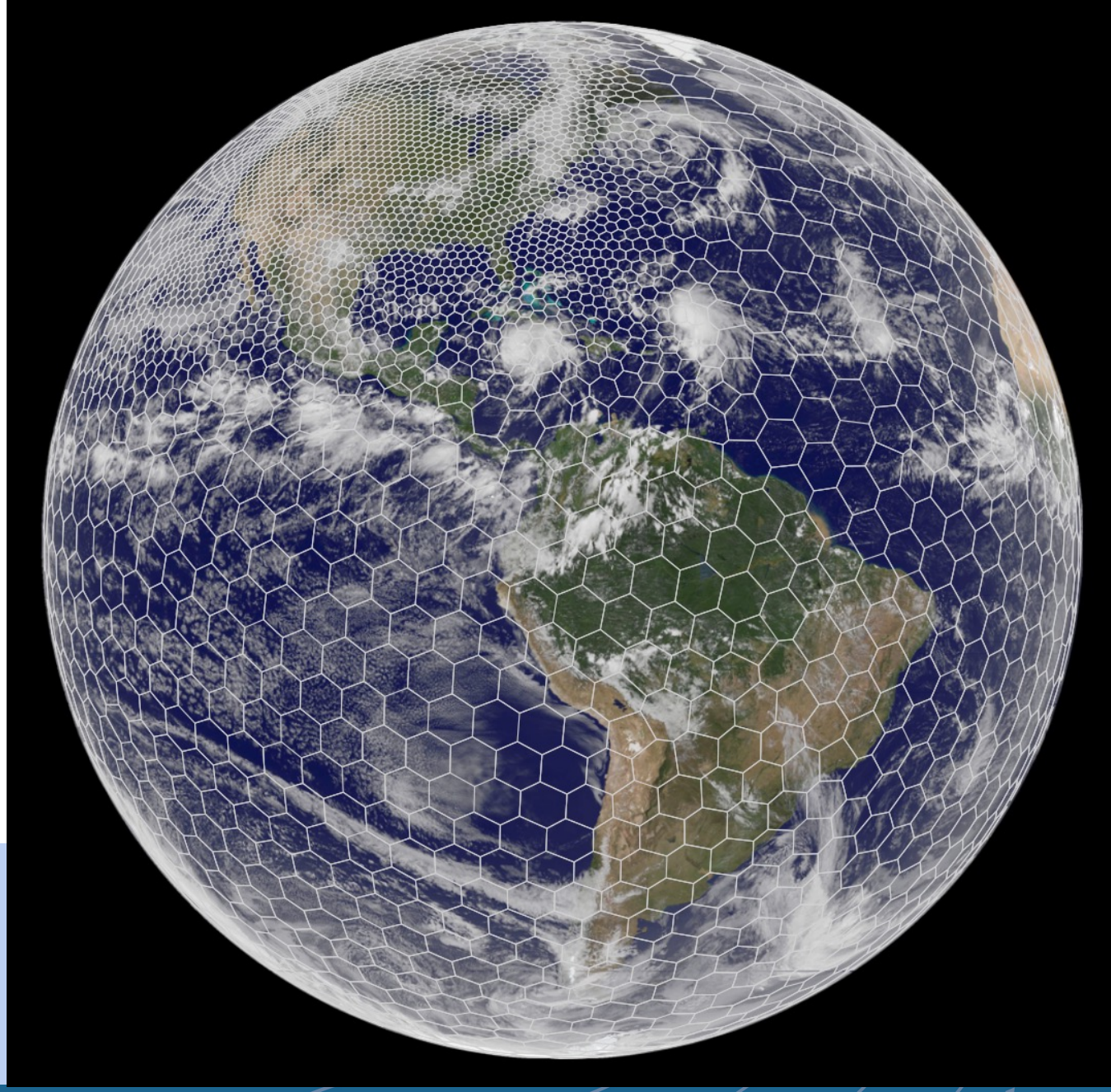


Many models use an icsoahedral mesh (NICAM, BUGS, FIM, NIM, OLAM, etc.)

MPAS
Model for Prediction Across Scales

Mesh generation

Lloyd's method
(iterative)
using a user-supplied
density function



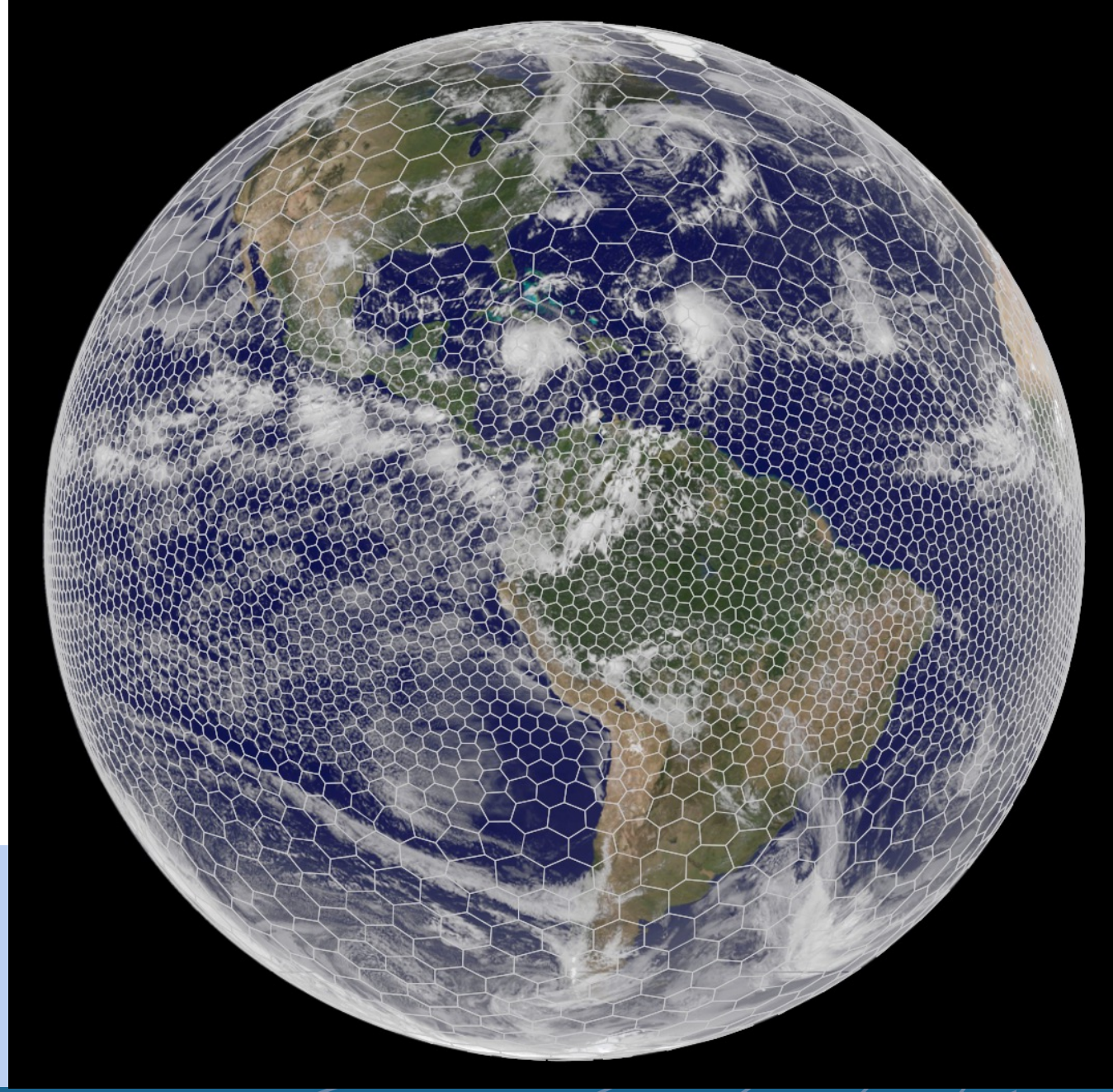
North American refinement

MPAS
Model for Prediction Across Scales

Mesh generation

Lloyd's method
(iterative)
using a user-supplied
density function

Equatorial refinement



MPAS
Model for Prediction Across Scales

Mesh generation

Lloyd's method
(iterative)
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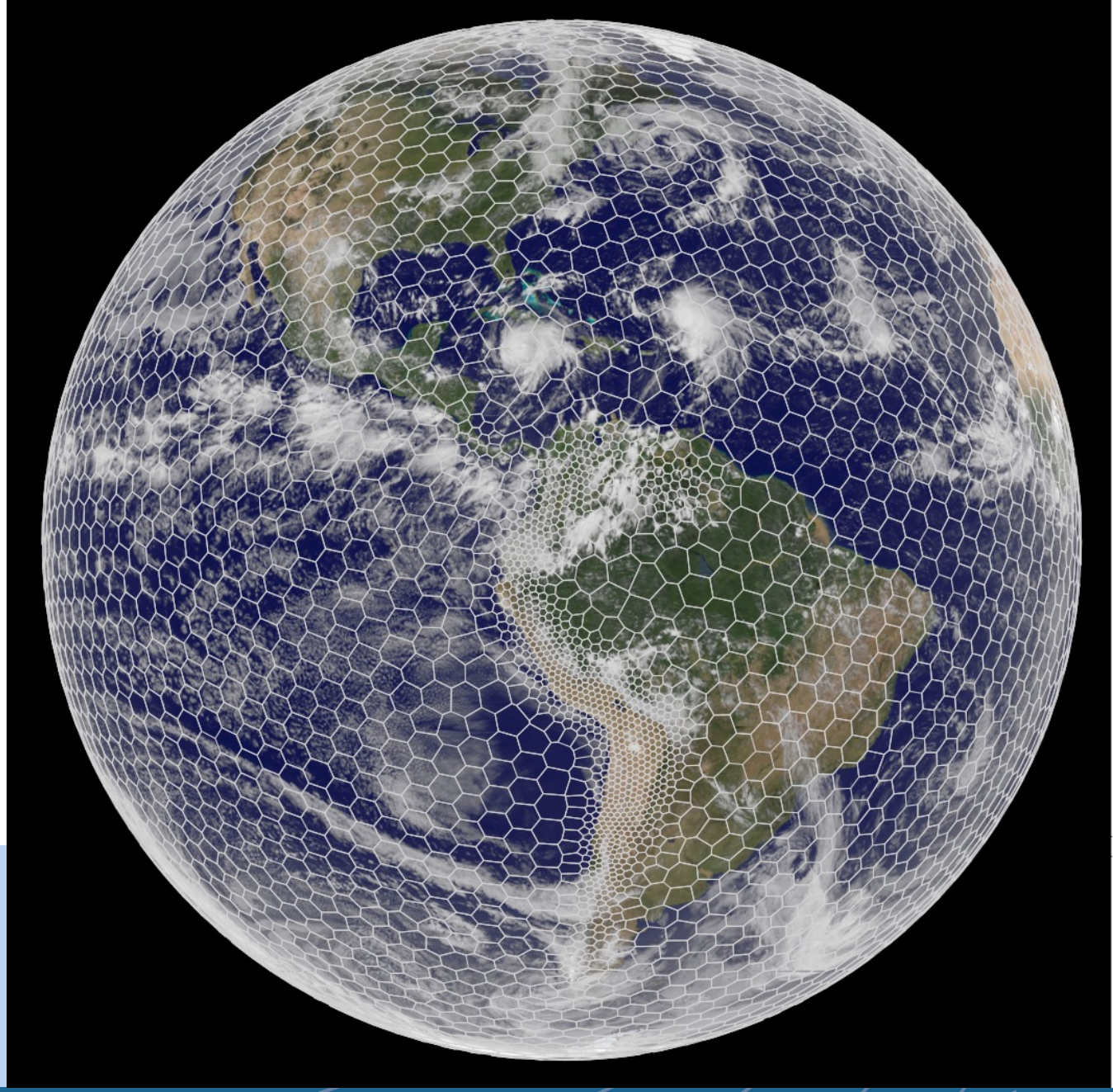
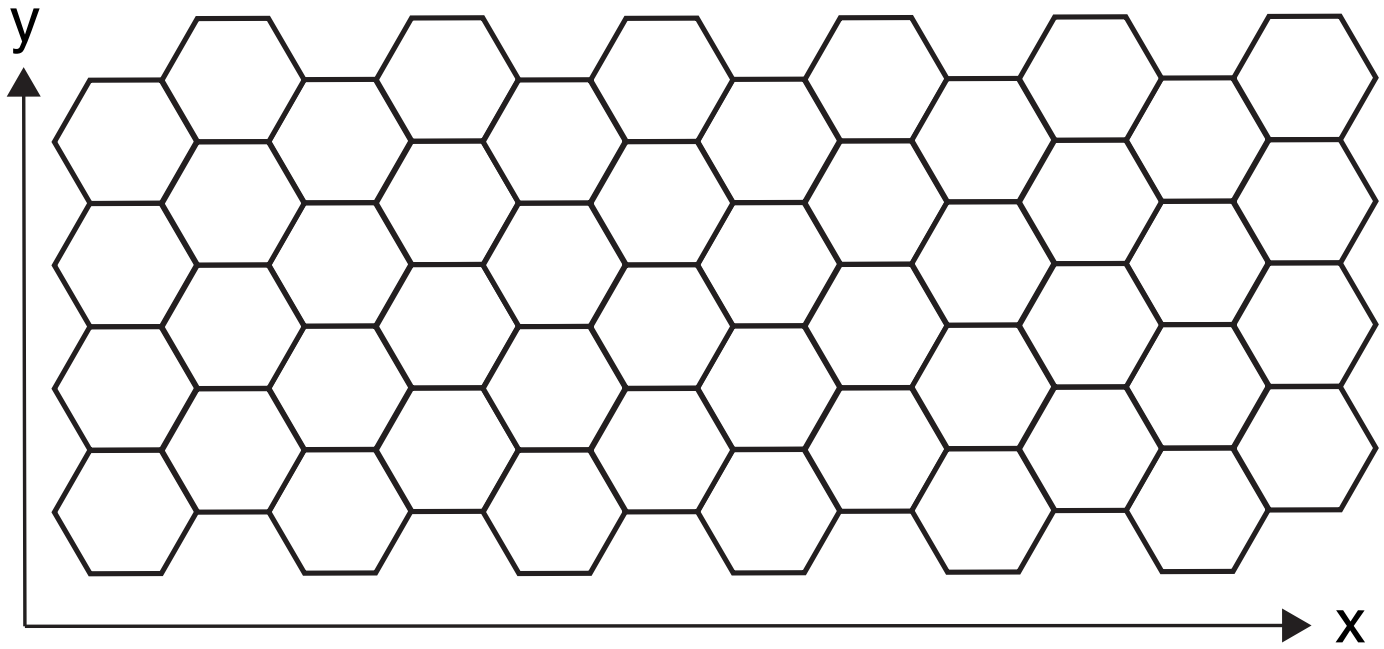


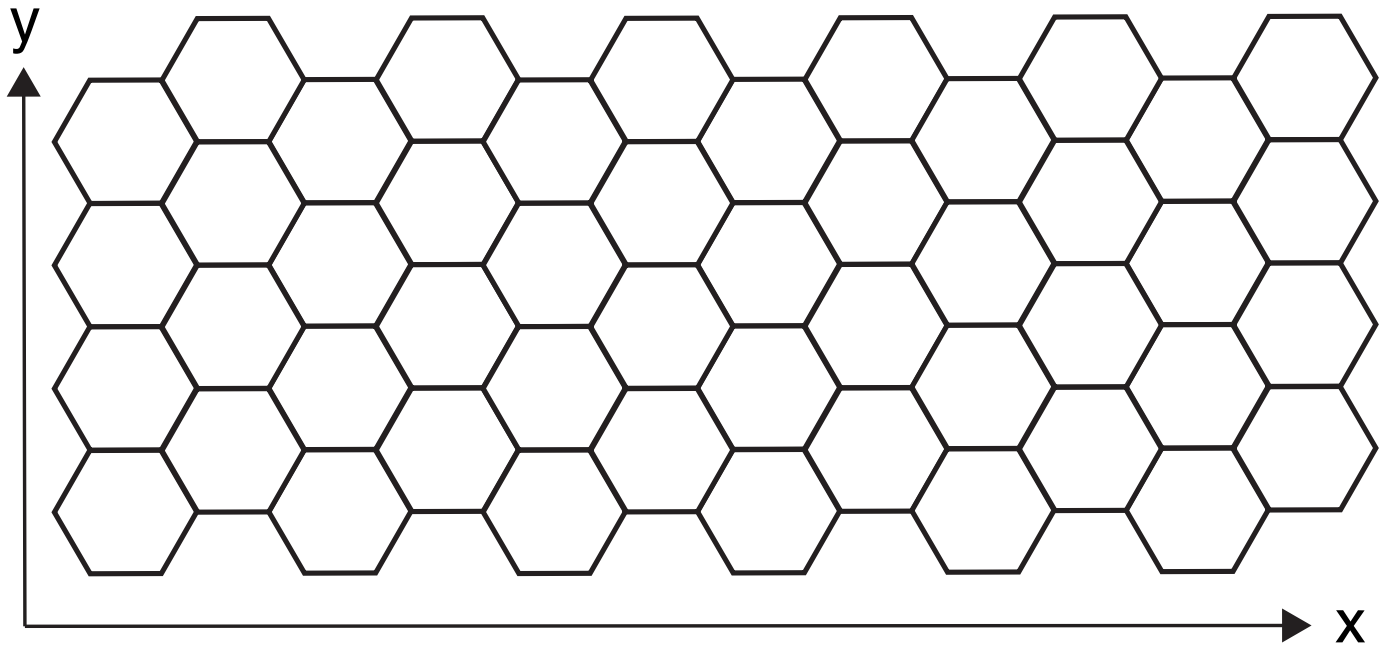
Andes refinement

Other mesh spaces



Doubly-periodic Cartesian mesh

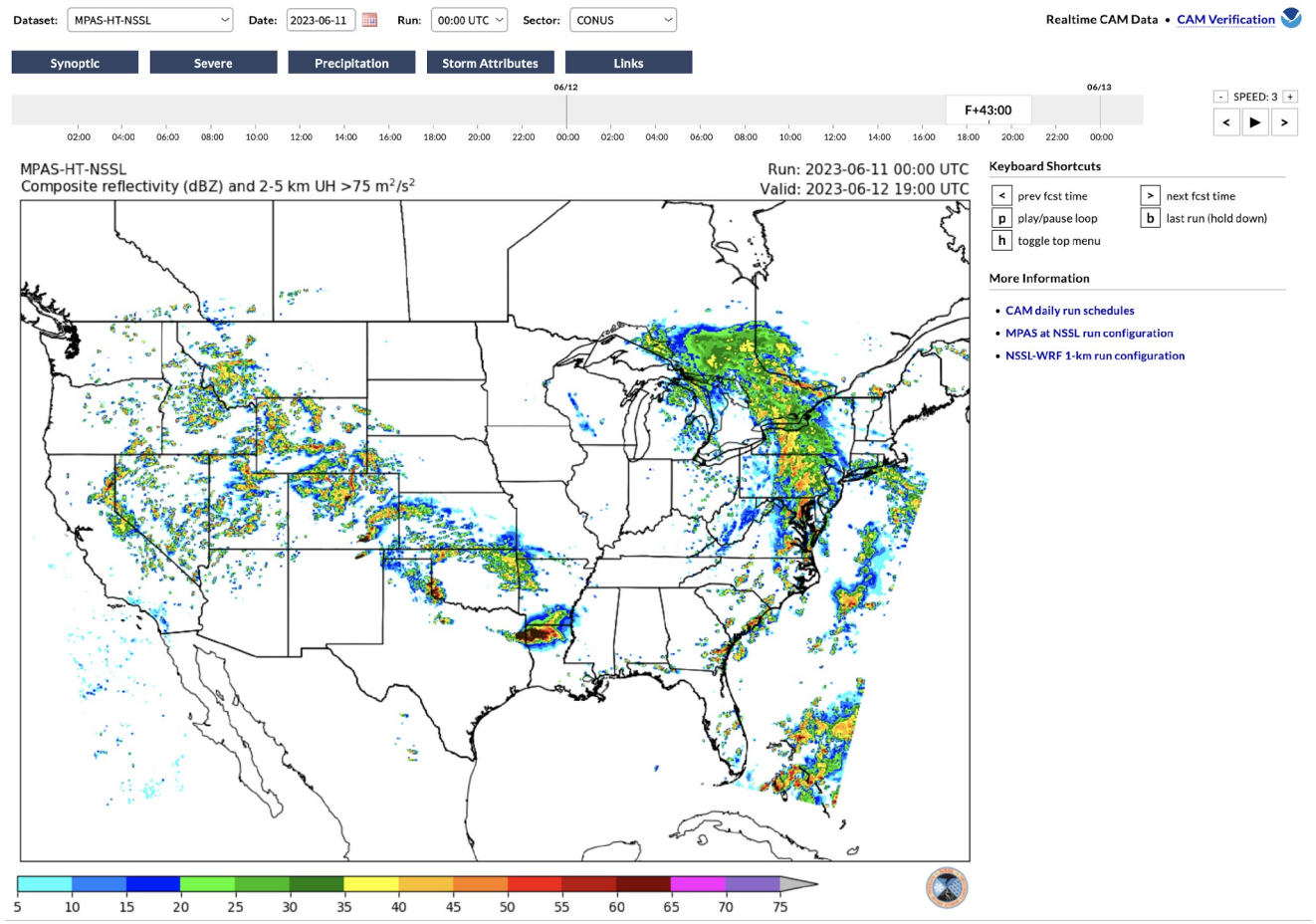
Other mesh spaces



2D (y,z) mesh in MPAS
The solution is *periodic* in y and *does not vary* in y

MPAS in a HRRR Configuration

cams.nssl.noaa.gov



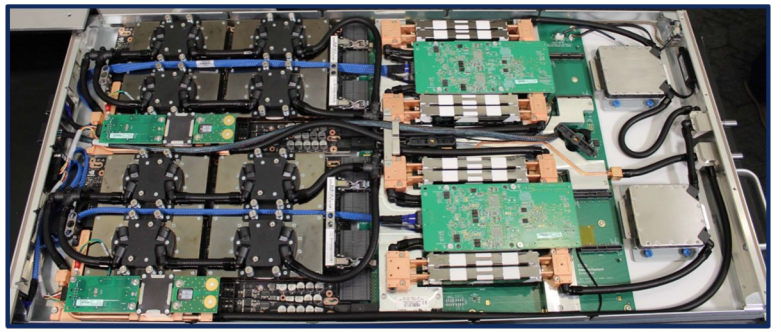
NOAA announced that MPAS-Atmosphere would be the basis of the RRFS V2. MPAS will be implemented in NOAA's UFS as part of this evolution.

MPAS and GPUs

We released the GPU-enabled MPAS-Atmosphere as a branch from MPAS Version 7.

It does not work on Derecho

We are working on a new GPU implementation for MPAS



Above: A Derecho GPU blade with two GPU nodes, each with 1 AMD EPYC Zen3 "Milan" 64-core processor and 4 NVIDIA A100 Ampere GPUs.

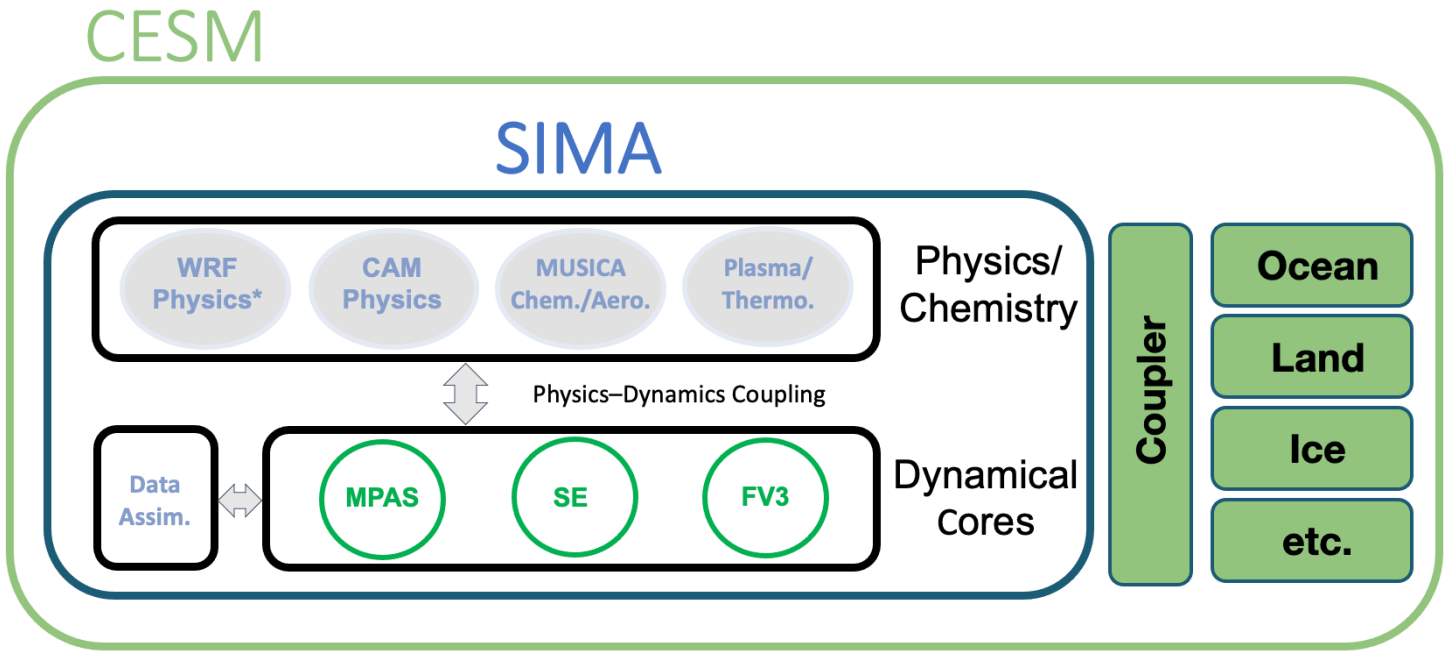
What is in current release:

- GPU-enabled MPAS dynamical core using OpenACC directives.
- Some GPU-enabled physics (e.g. YSU, WSM6, M-O, scale-aware nTiedtke)
- Asynchronous execution capability on heterogenous architectures - currently radiation (lagged) and NOAH CPUs, all else on GPUs
- Configurations tested and validated on IBM POWER9 architectures.

MPAS Earth System Model Capabilities

System For Integrated Modeling of the Atmosphere (SIMA)

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

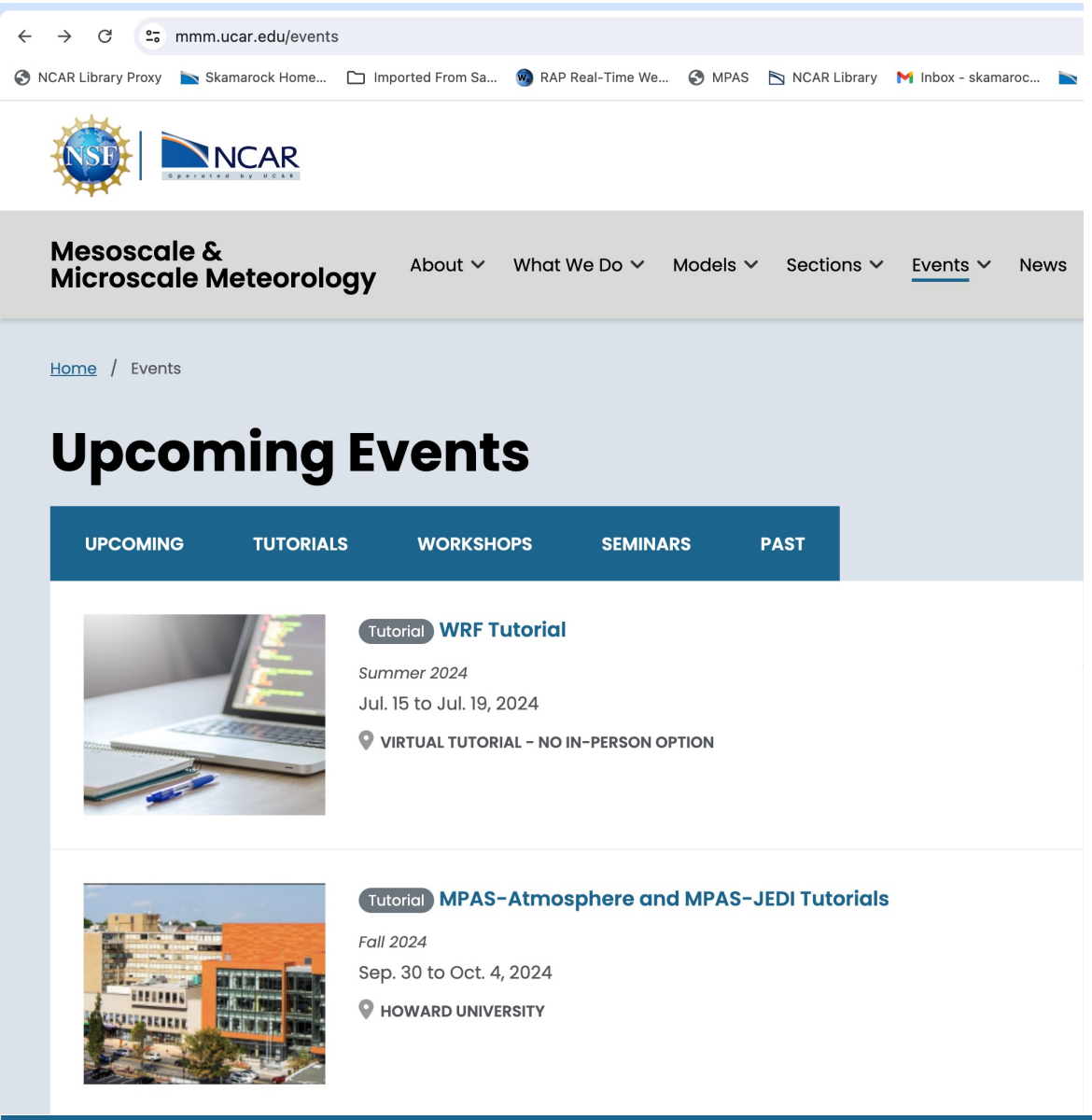


* where needed to augment CAM physics

MPAS – Atmosphere brings nonhydrostatic modelling capabilities to CESM.

https://sima.ucar.edu

Upcoming Events: MPAS Virtual Tutorial



Registration will open soon for an MPAS/MPAS-JEDI in-person tutorial that is scheduled for 30 Sept – 4 October 2024 at Howard University in Washington DC.

Registration will also open soon for an MPAS/MPAS-JEDI in-person tutorial that is scheduled for 21-24 October 2024 in Edinburgh Scotland.

There will be a virtual MPAS tutorial in the spring of 2025, dates TBD

https://www.mmm.ucar.edu/events/tutorials

There will also be a WRF email list announcements.

Upcoming Events: Joint WRF/MPAS Workshop

The Joint WRF/MPAS Workshop is scheduled for June 2025 in Boulder Colorado. Exact dates TBD.

The workshop is hybrid - both in-person and virtual attendance is encouraged.