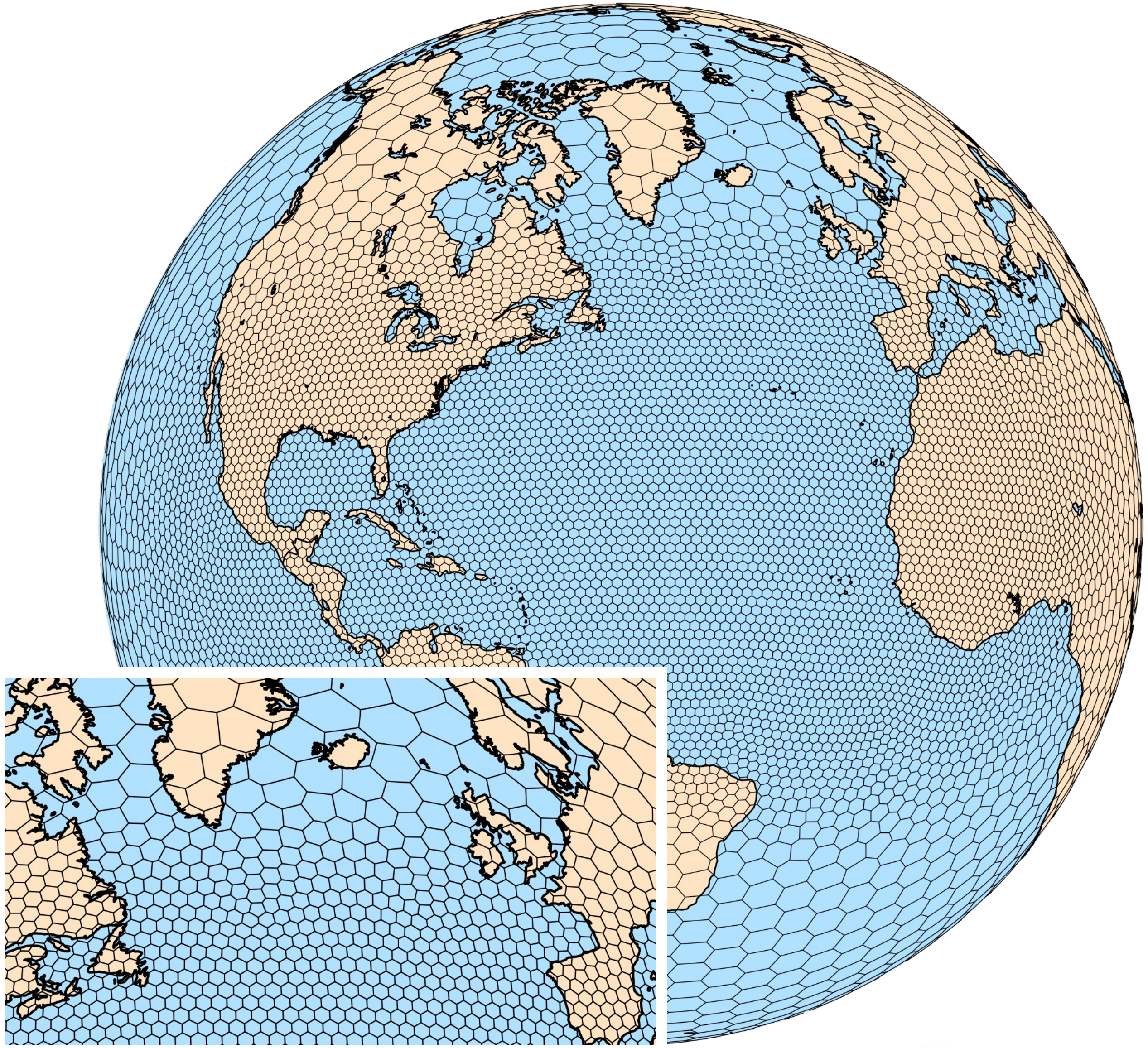
MPAS

Model for Prediction Across Scales

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

Welcome to the MPAS-A Tutorial



NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Welcome to the MPAS Tutorial

Monday 10 August 2026:

9:15 – 9:30 Registration
9:30 – 9:45 Welcome and Introductions
9:45 – 10:05 (20 mins) MPAS Overview
10:05 – 10:25 (20 mins) MPAS-A System Requirements and Installation
10:25 – 11:15 (50 mins) Running MPAS, part 1: Creating ICs and running a basic global simulation
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13:45 – 14:15 (30 mins) Running MPAS, part 2: Variable-resolution, I/O streams, restarts, and other options
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15:15 – 16:15 (60 mins) Practical session

Welcome to the MPAS Tutorial

Tuesday and Wednesday, 11 and 12 August 2026:

Morning sessions: Lectures, breaks, lunches (12:35 Tuesday, 12:10 Wednesday).
Afternoons: Practical sessions, breaks.

Lunches are in the cafeteria. Bring your workshop badge to the cafeteria. Available items are listed on the posted sheets in the tutorial areas. We have a lunch area in the atrium directly behind this auditorium.

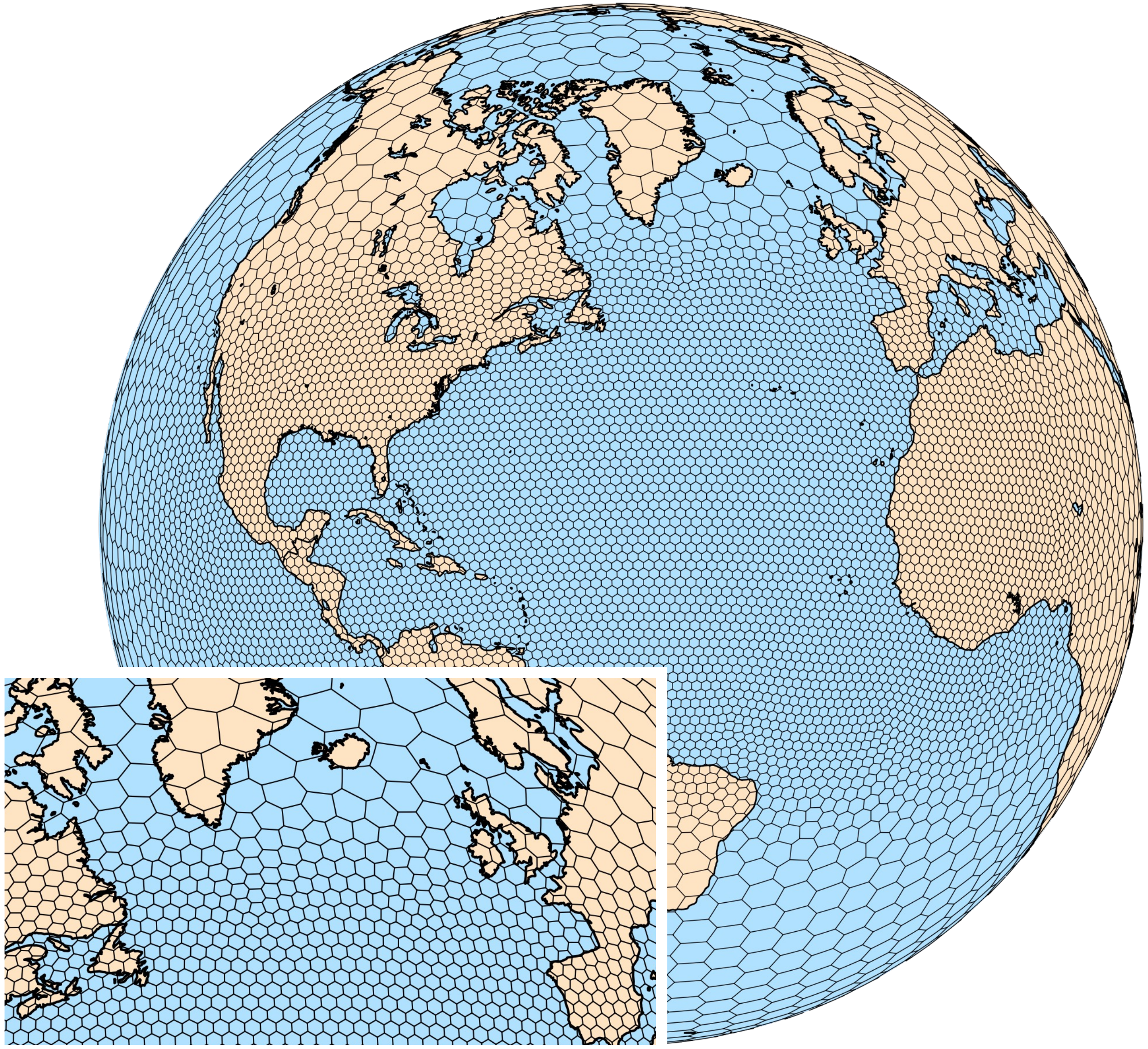
The presentation slides will be posted in links on the agenda, usually on the day following the presentations.

MPAS
Model for Prediction Across Scales

There are 7 instructors for this tutorial:

Ming Chen
Michael Duda
Jihyeon Jang
Abby Jaye
Bill Skamarock
Wei Wang
May Wong

Please feel free to ask questions!



MPAS

Model for Prediction Across Scales

MPAS Version 8.4.2 (August 2026)

MPAS infrastructure - NCAR, LANL, others.

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

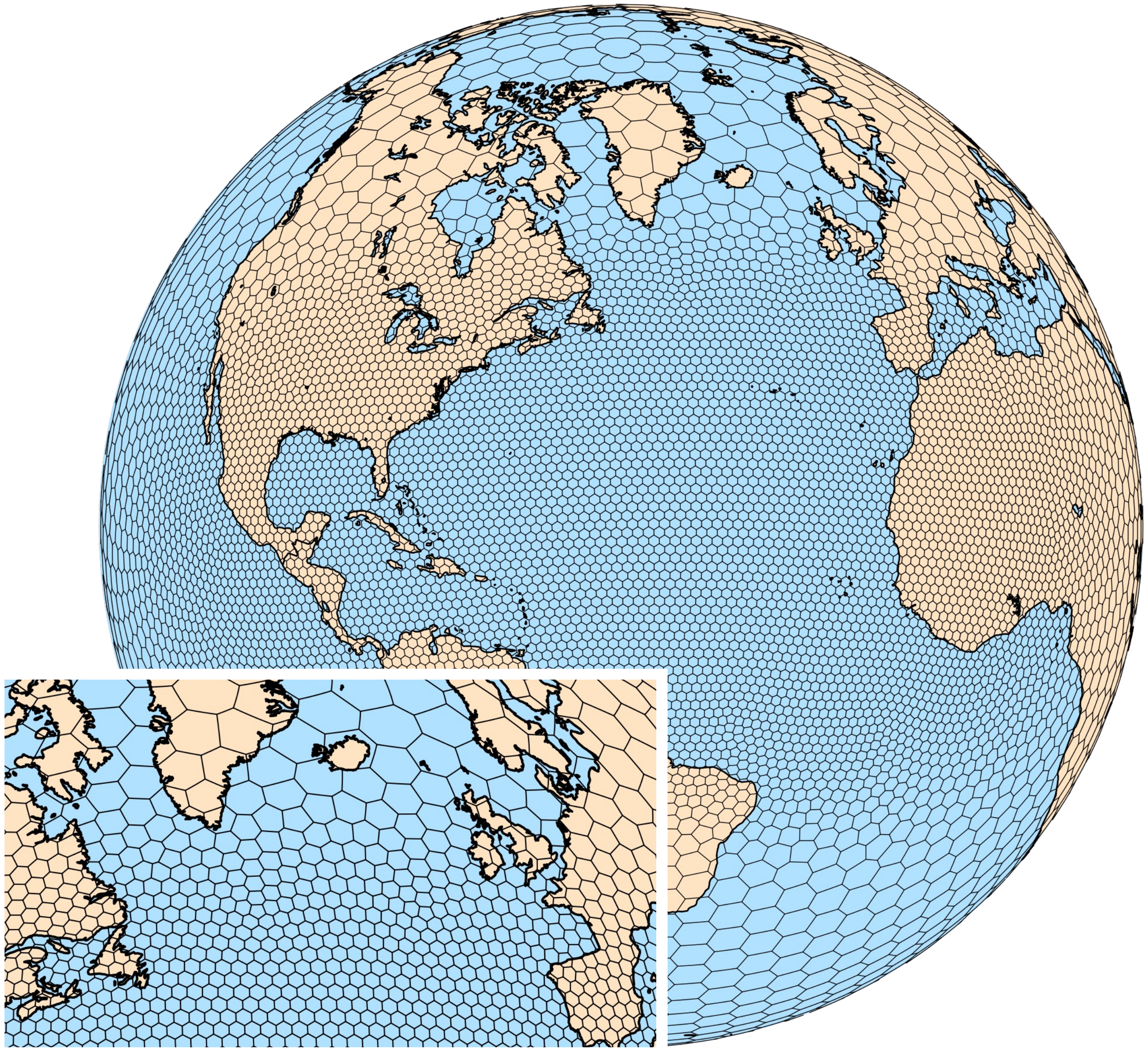
MPAS - Atmosphere (NCAR)

- Nonhydrostatic atmospheric solver; pre- and post-processors

MPAS - Ocean (LANL)

MPAS – Albany Land Ice, and Sea ice models (LANL and others)

These are all stand-alone models
There is no coupler in MPAS



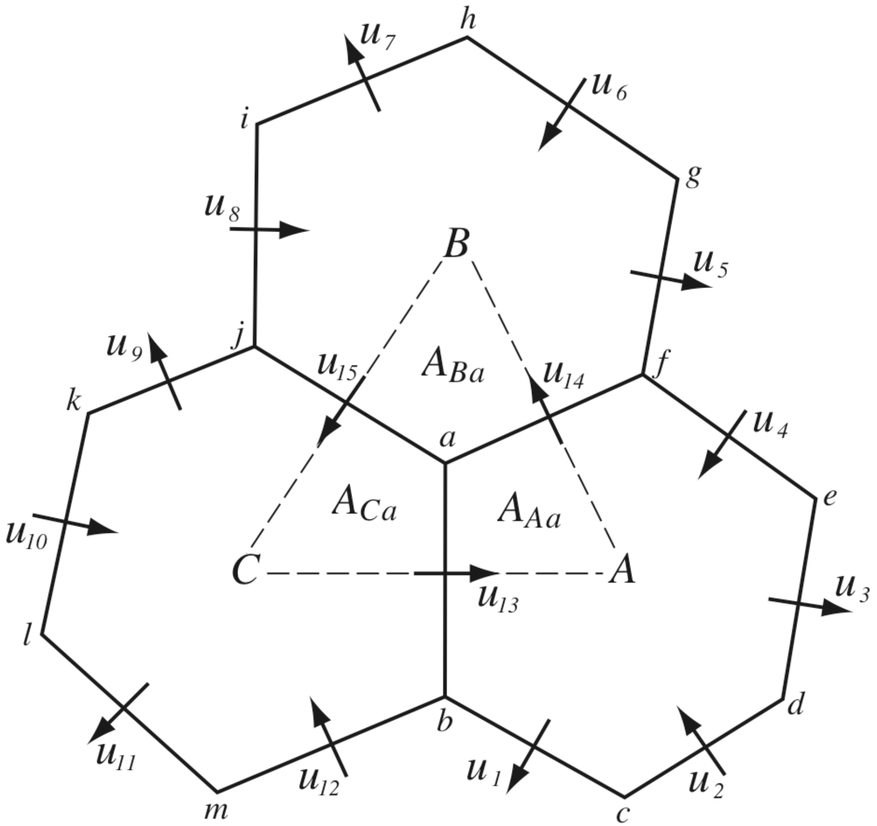
What is MPAS?
Centroidal Voronoi Meshes

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.

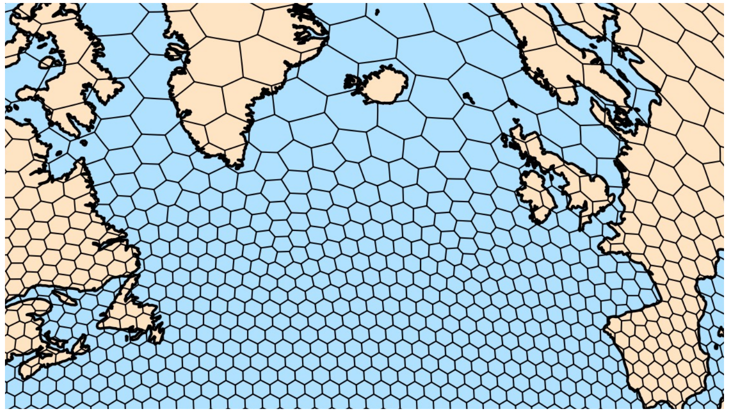


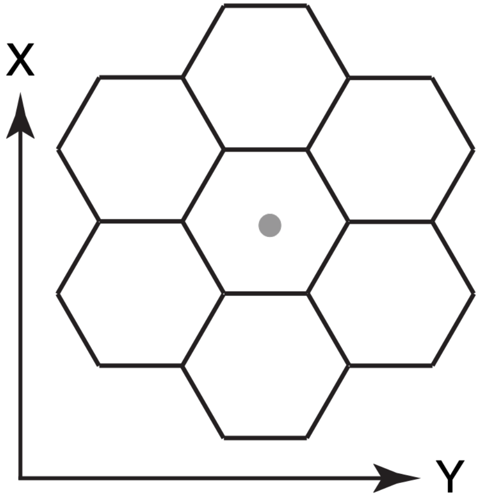
MPAS
Model for Prediction Across Scales

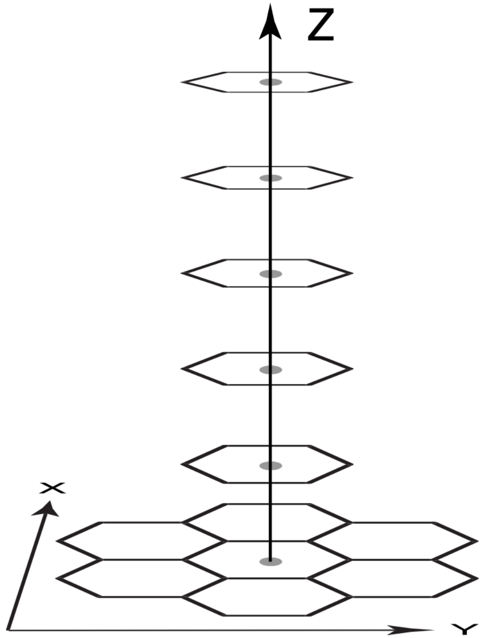
What is MPAS?
Centroidal Voronoi Meshes

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

The mesh is
structured in the
vertical







MPAS 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

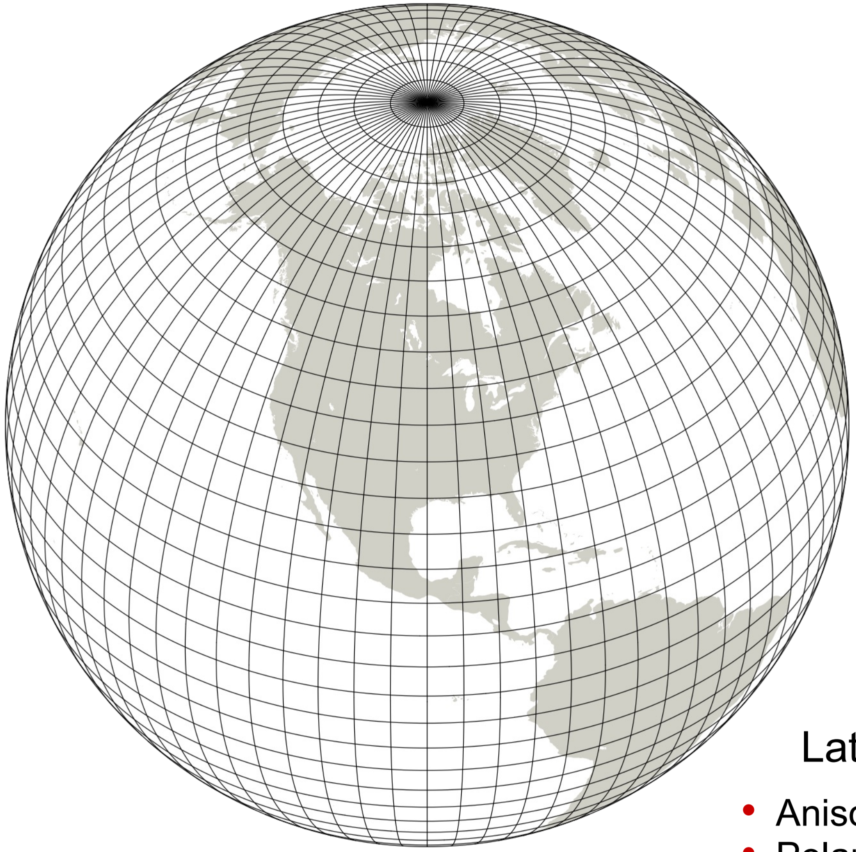
Full complement of atmospheric-model physics

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

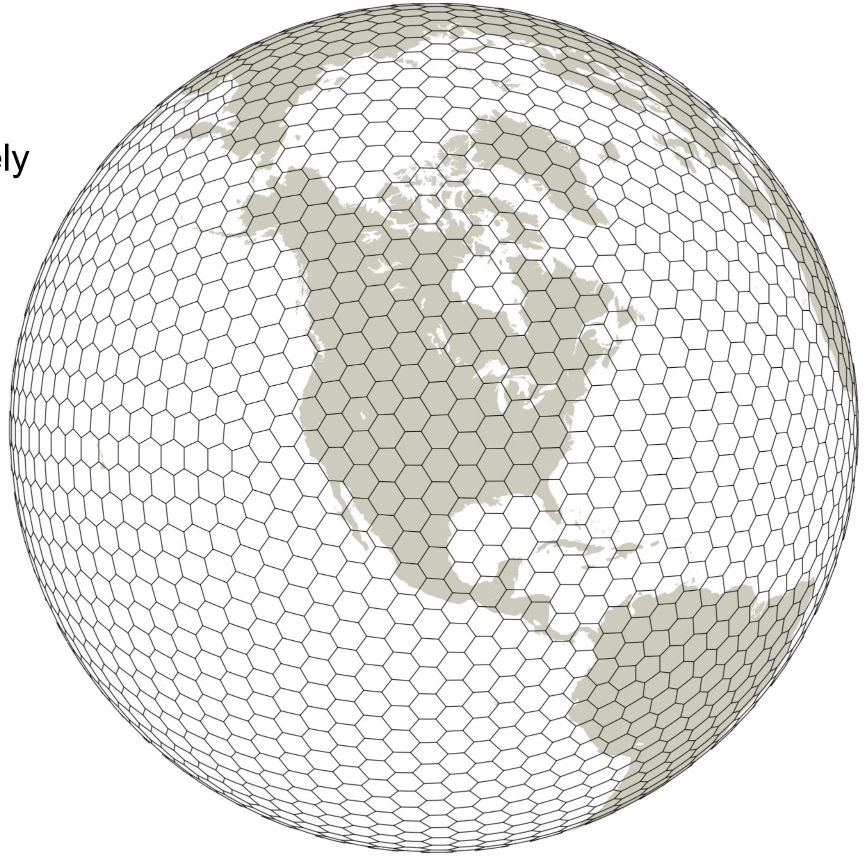


WRF
Lat-Lon global grid

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

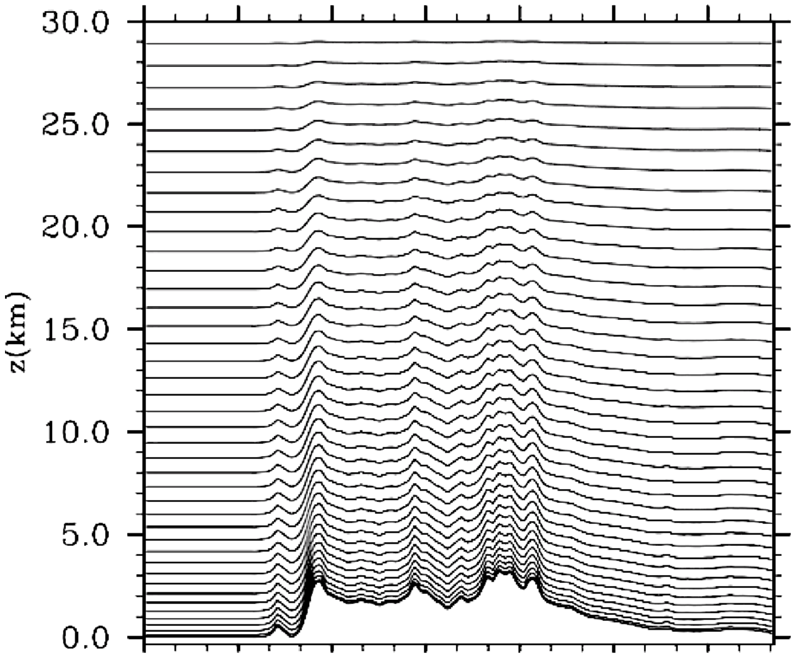
MPAS
Unstructured Voronoi (hexagonal) grid

- Good scaling on massively parallel computers
- No pole problems

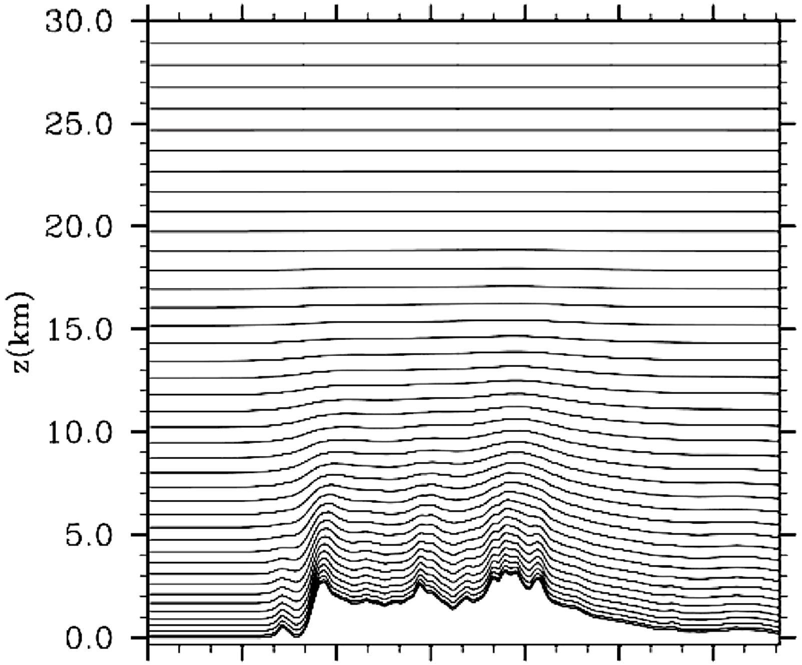


Why MPAS?

Significant differences between WRF and MPAS



WRF
Pressure-based terrain-following sigma vertical coordinate

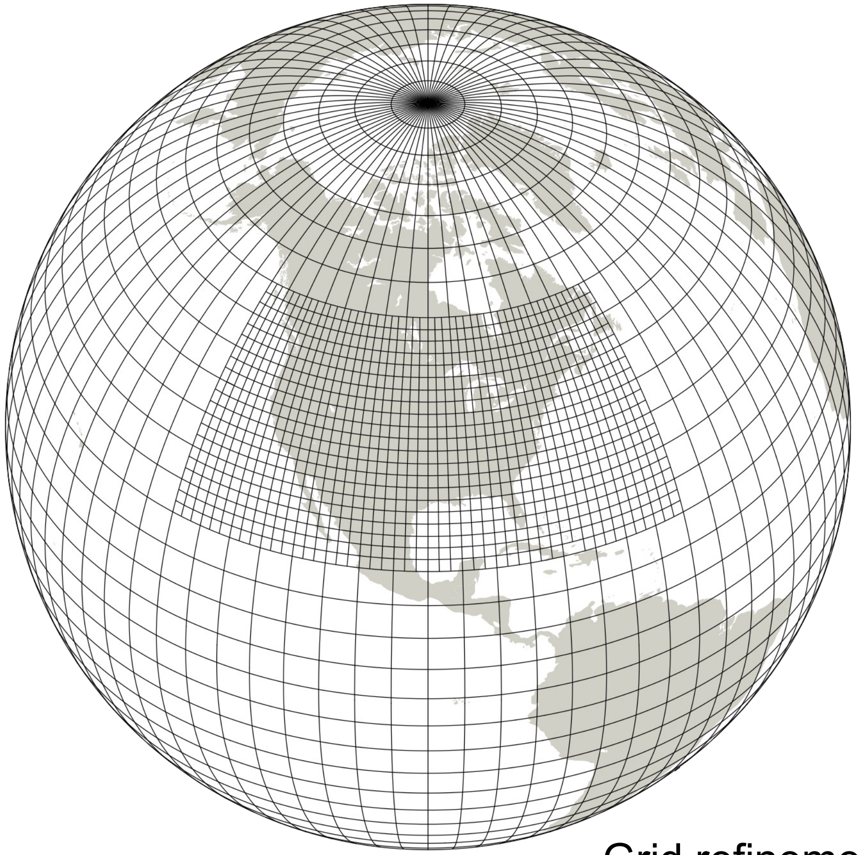


MPAS
Height-based hybrid smoothed terrain-following vertical coordinate

MPAS
Model for Prediction Across Scales

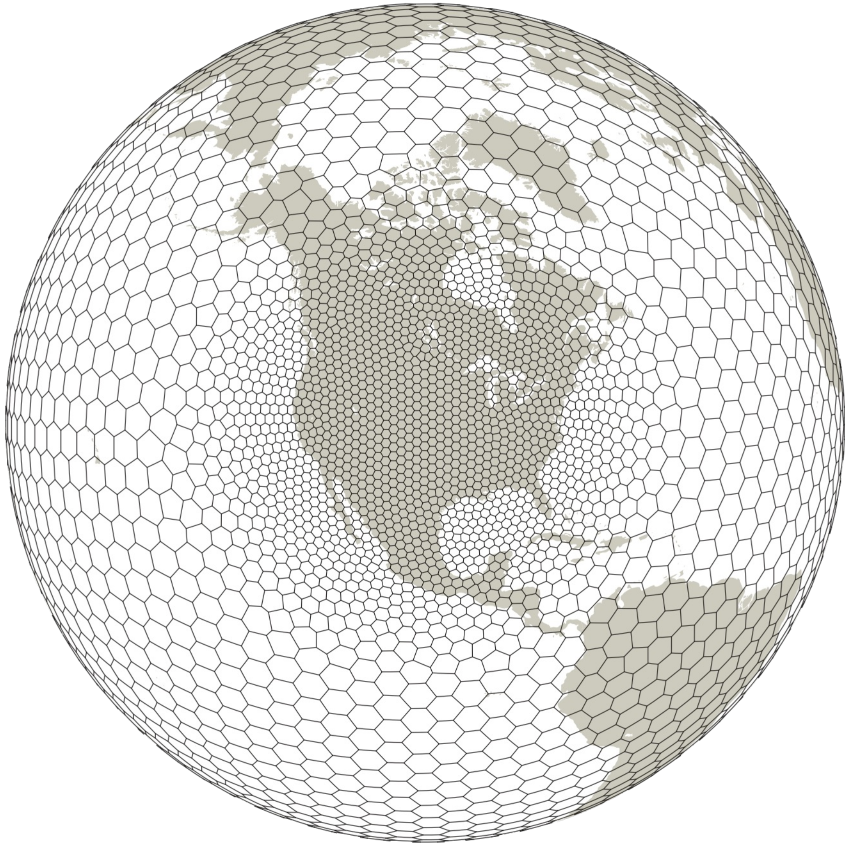
Why MPAS?

Significant differences between WRF and MPAS



MPAS
Smooth grid refinement on a conformal mesh

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



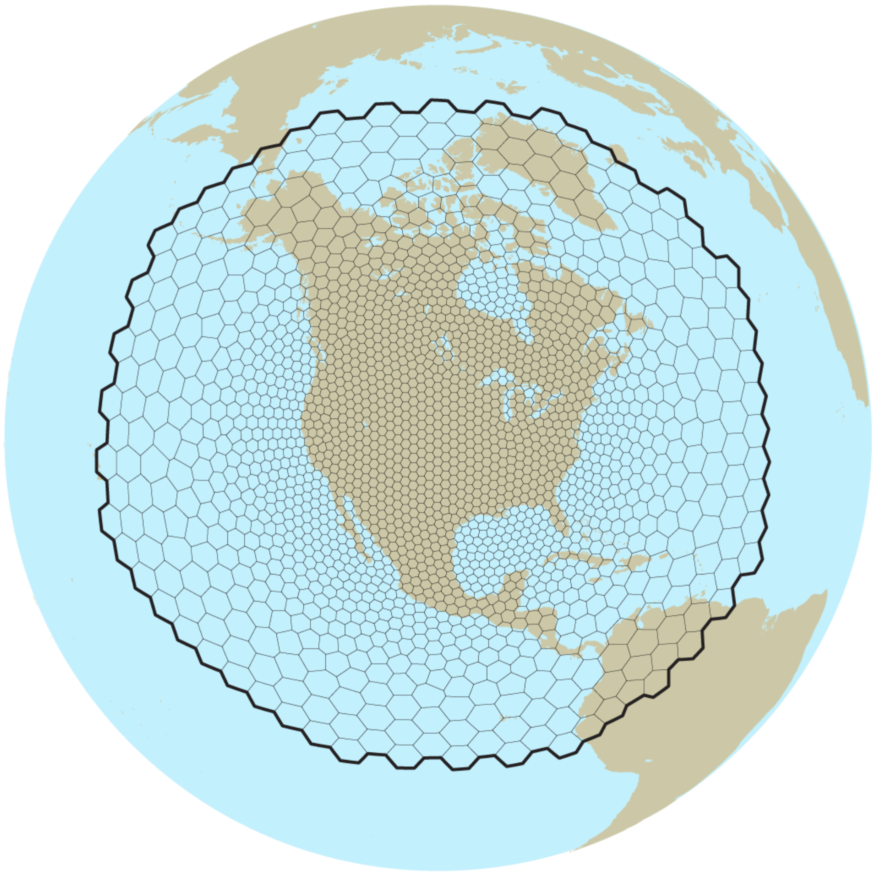
WRF
Grid refinement through domain nesting

- Flow distortions at nest boundaries

Regional MPAS

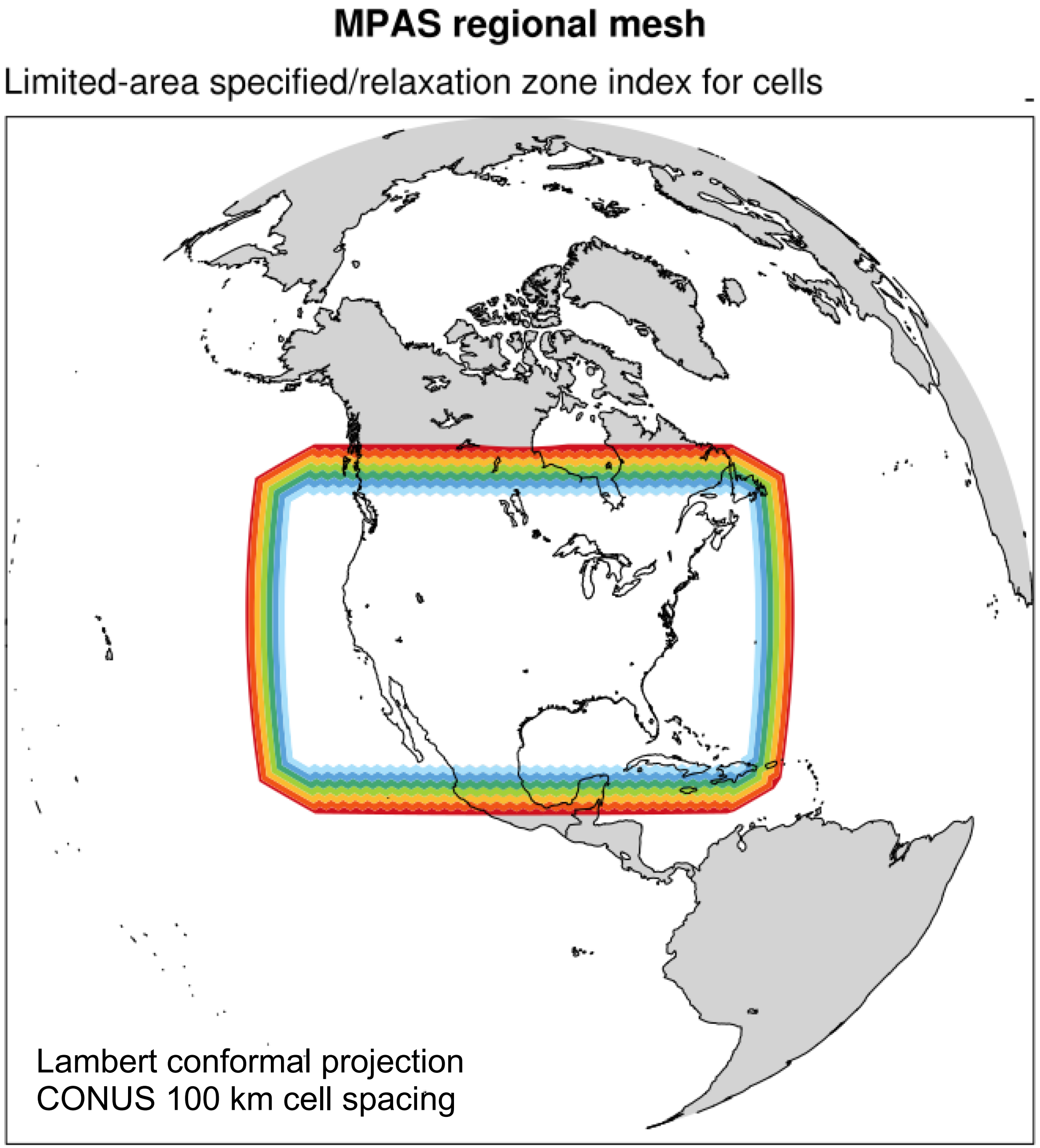
We are no longer developing WRF at NSF NCAR/MMM, and we would like users to transition to MPAS if their applications allow.

- Leverage MPAS development for next-generation architectures to regional applications (e.g. GPUs).
- Enable regional atmospheric applications within MPAS-enabled coupled modeling systems.
- Employ variable resolution in regional applications to reduce LBC errors.



MPAS
Model for Prediction Across Scales

Regional MPAS



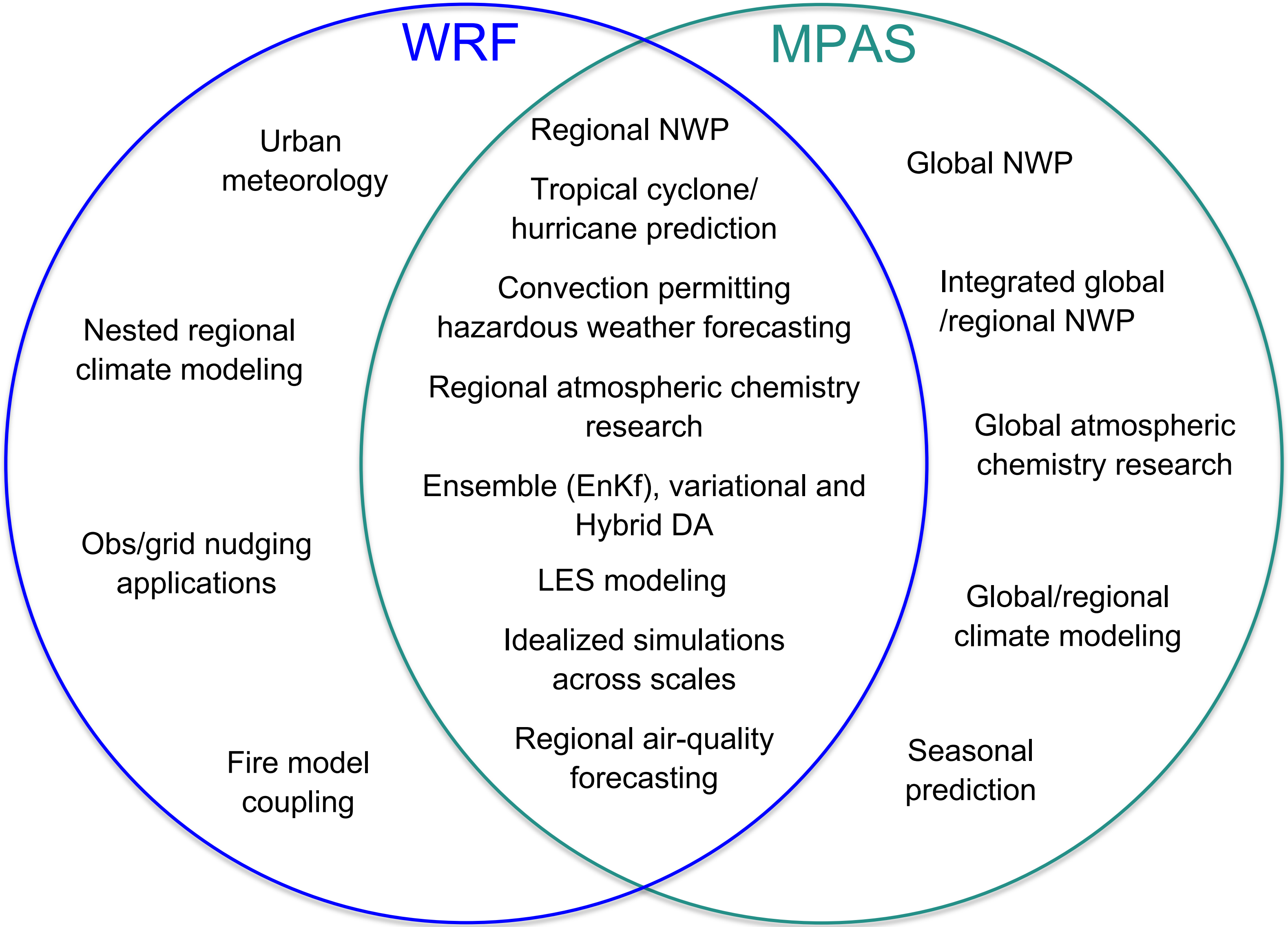
Regional Mesh Generation:
WRF-like meshes

Project perfect hexagons on an (*x*,*y*) Cartesian plane to the sphere using standard projections

Note:

- The mesh is unstructured
- The hexagons on the sphere are not perfect – the areas and lengths vary in physical space as dictated by the projection.

MPAS
Model for Prediction Across Scales



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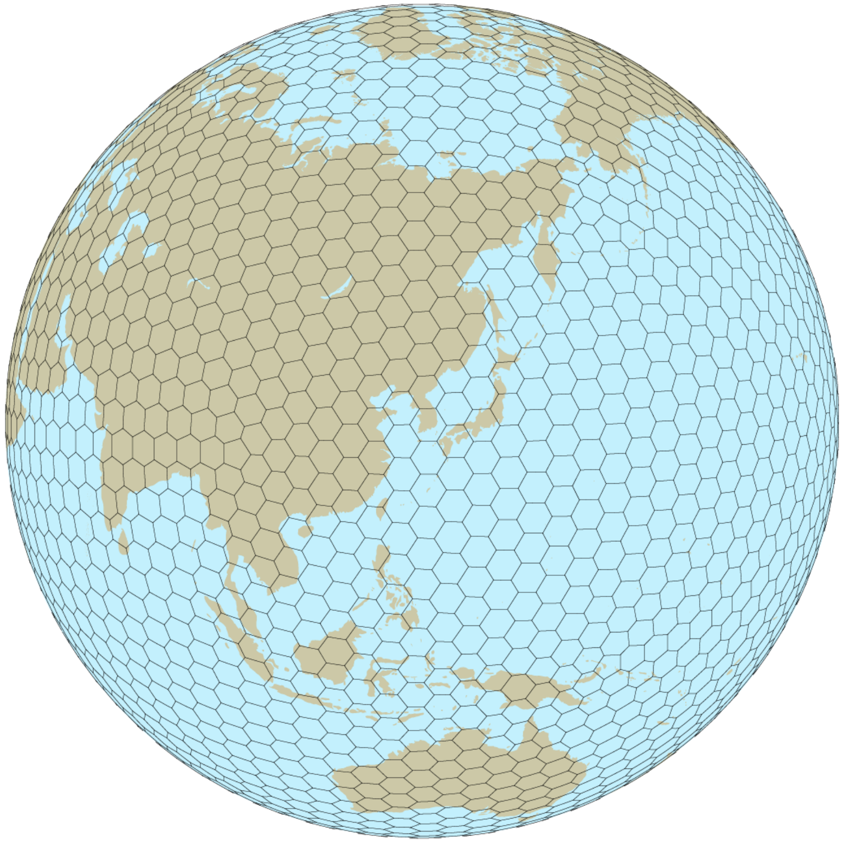
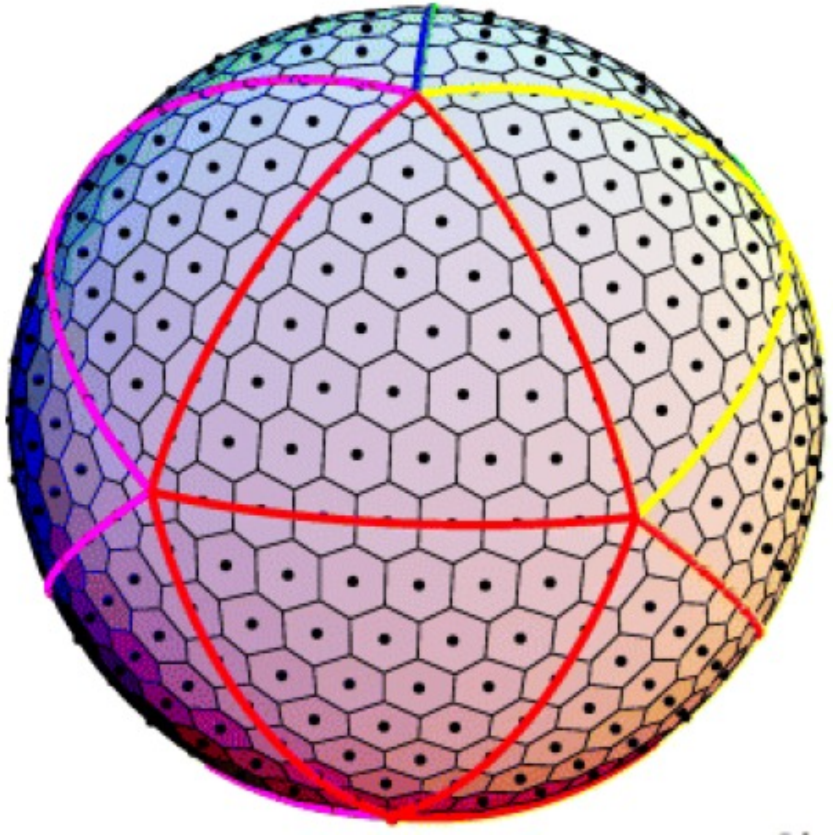


Global Quasi-Uniform
Mesh (SCVT)



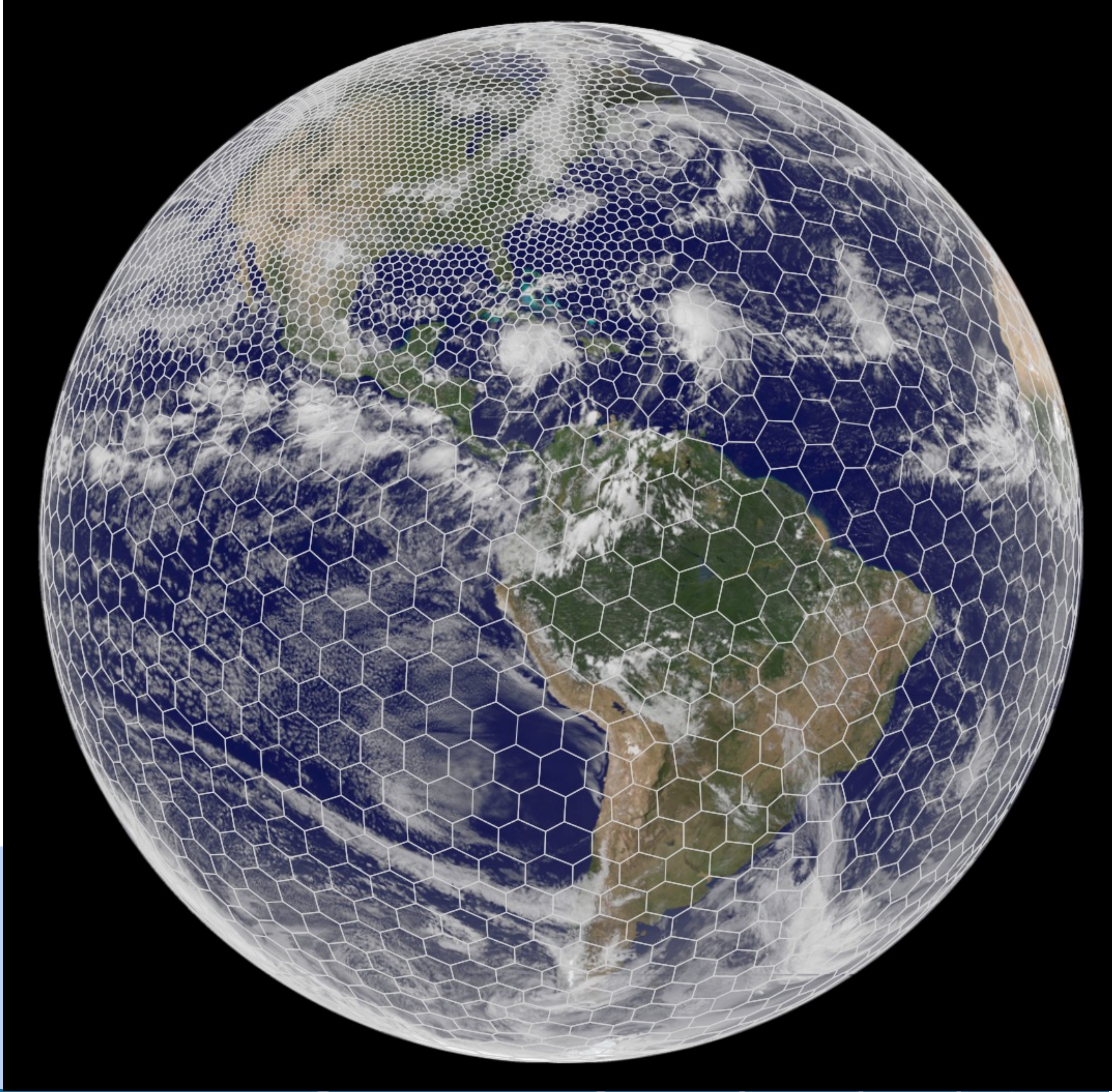
Many models use an icsoahedral mesh
(NICAM, BUGS, FIM, NIM, OLAM, etc.)

MPAS
Model for Prediction Across Scales

Mesh generation

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

North American refinement



MPAS
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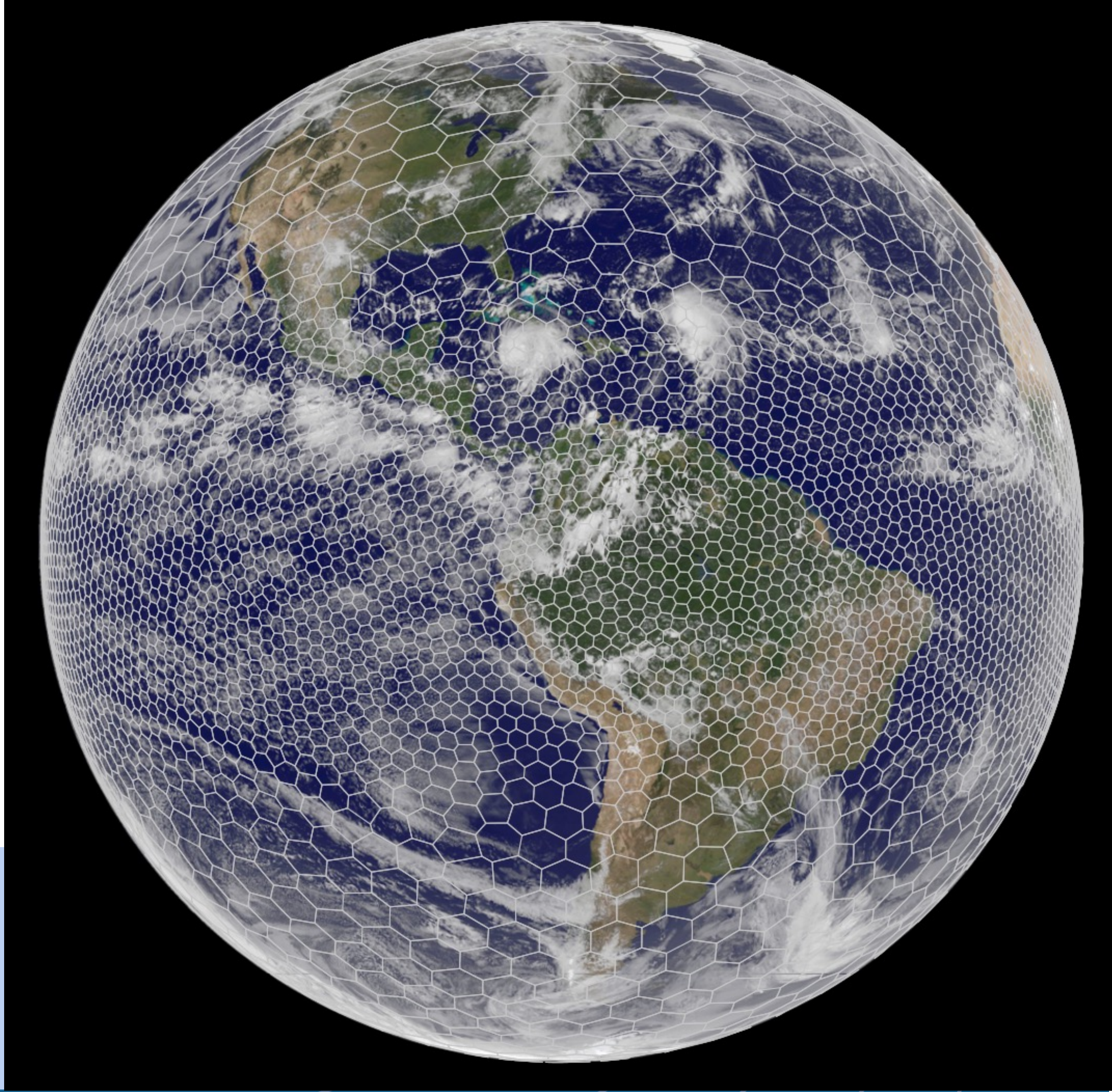


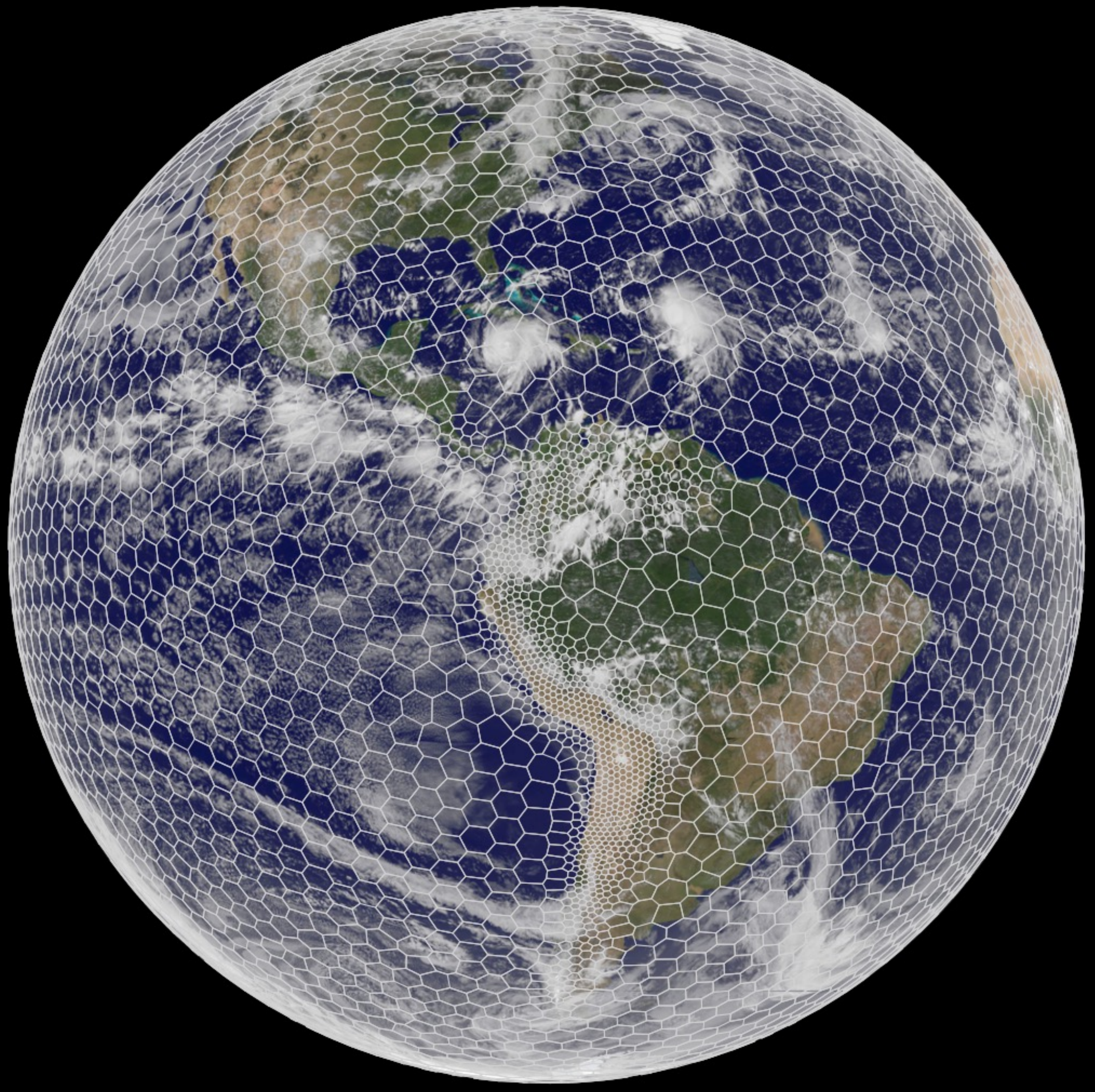
Equatorial refinement

MPAS
Model for Prediction Across Scales

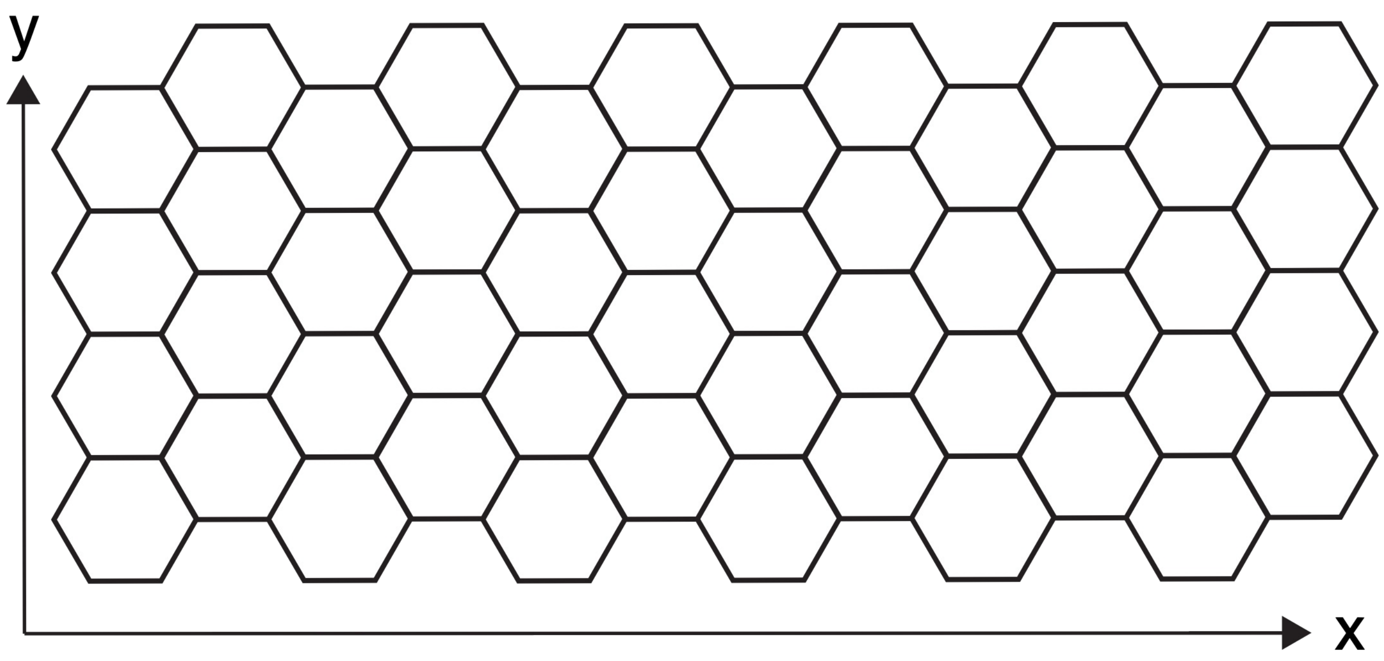
Mesh generation

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

Andes refinement



Other mesh spaces



Doubly-periodic Cartesian mesh

This mesh also allows for 2D (*x,z*) solutions when the solution is constrained to not vary in *y.*

MPAS
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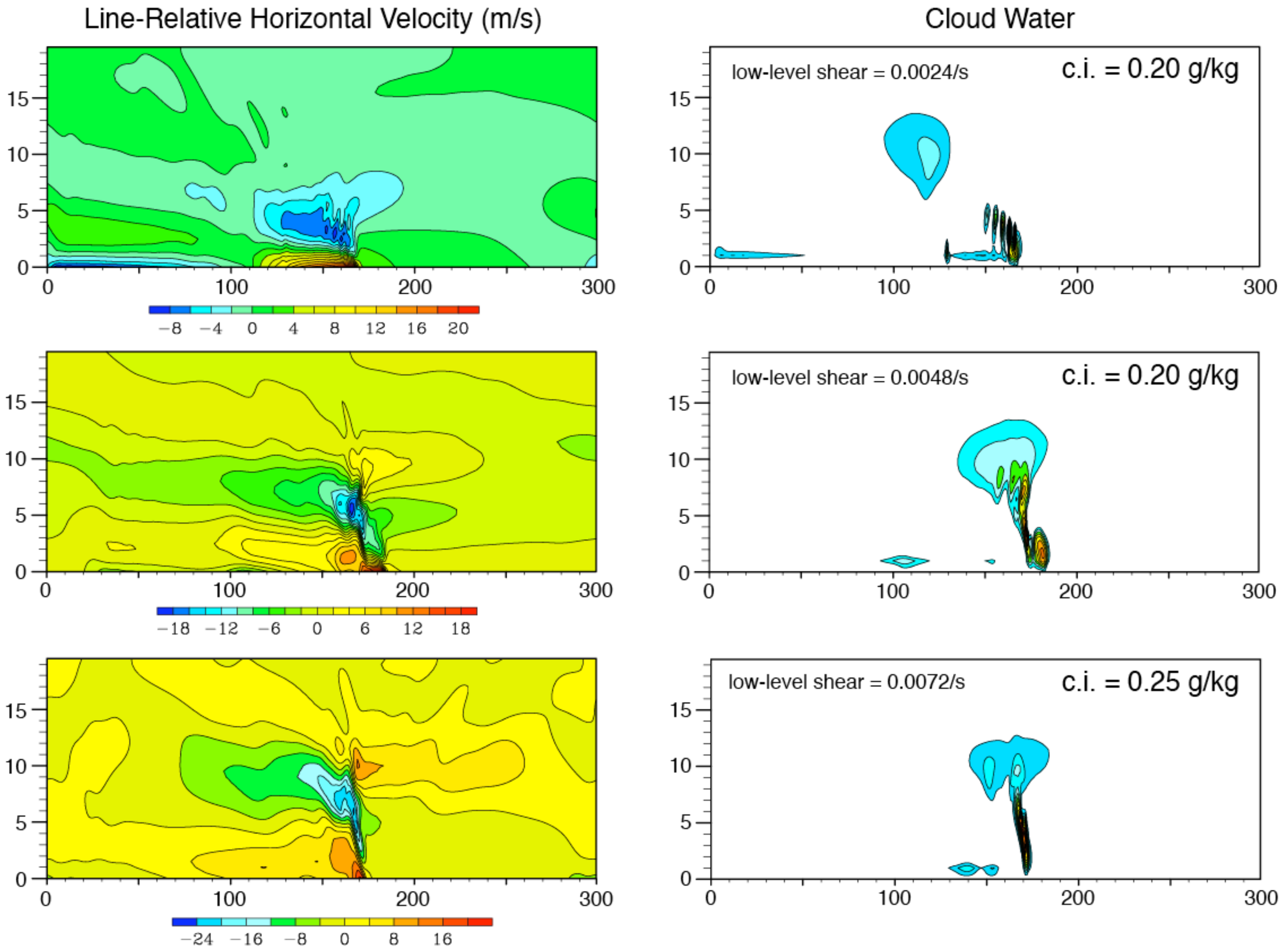
Squall-Line Tests
2D (x,z)

Low-level shear (0-2.5 km), Weisman-Klemp sounding Warm-bubble perturbation, results at 3 hours



MPAS
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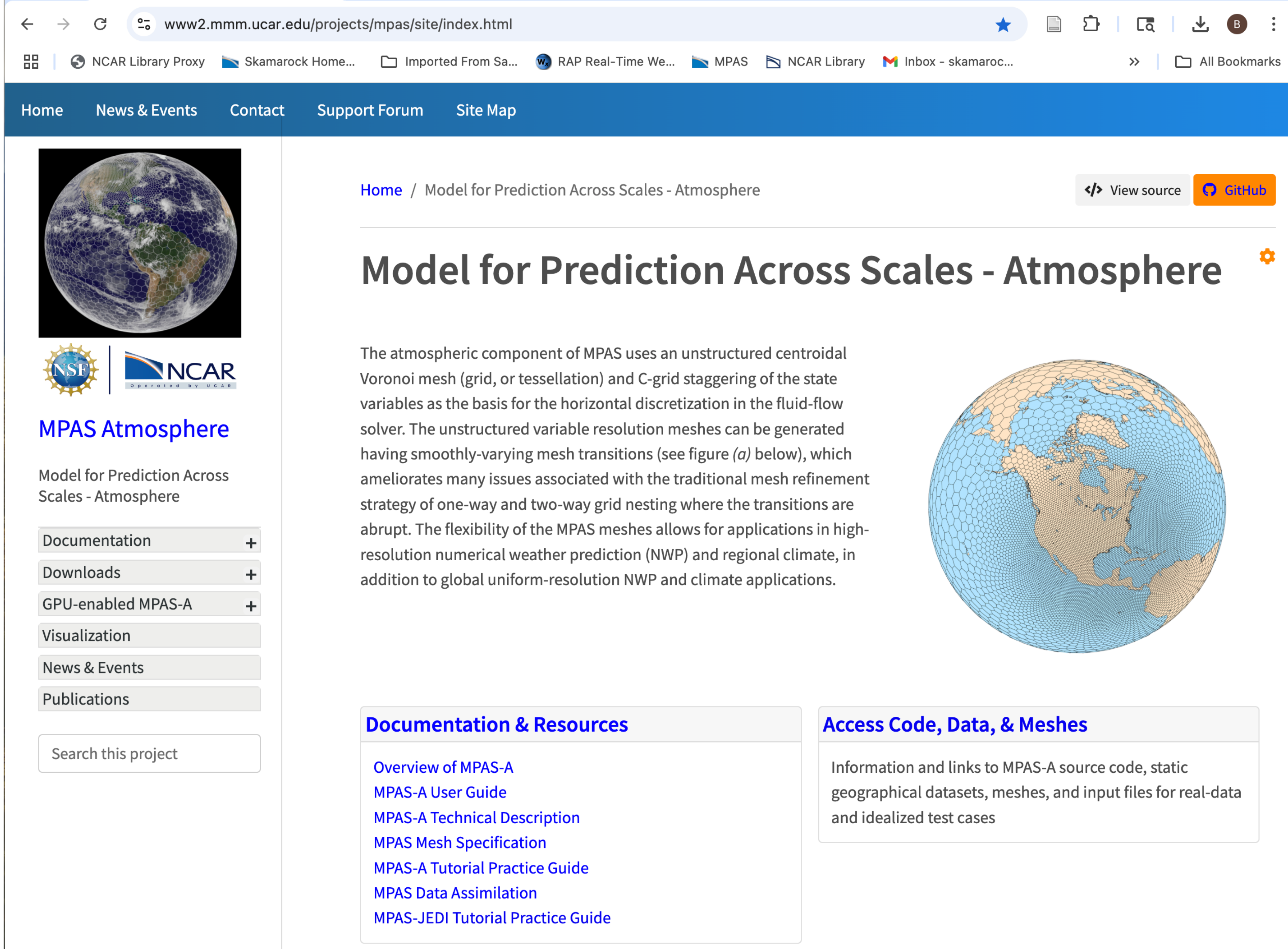
The MPAS-Atmosphere web pages provides links to a lot of information about MPAS.



Next Up…

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