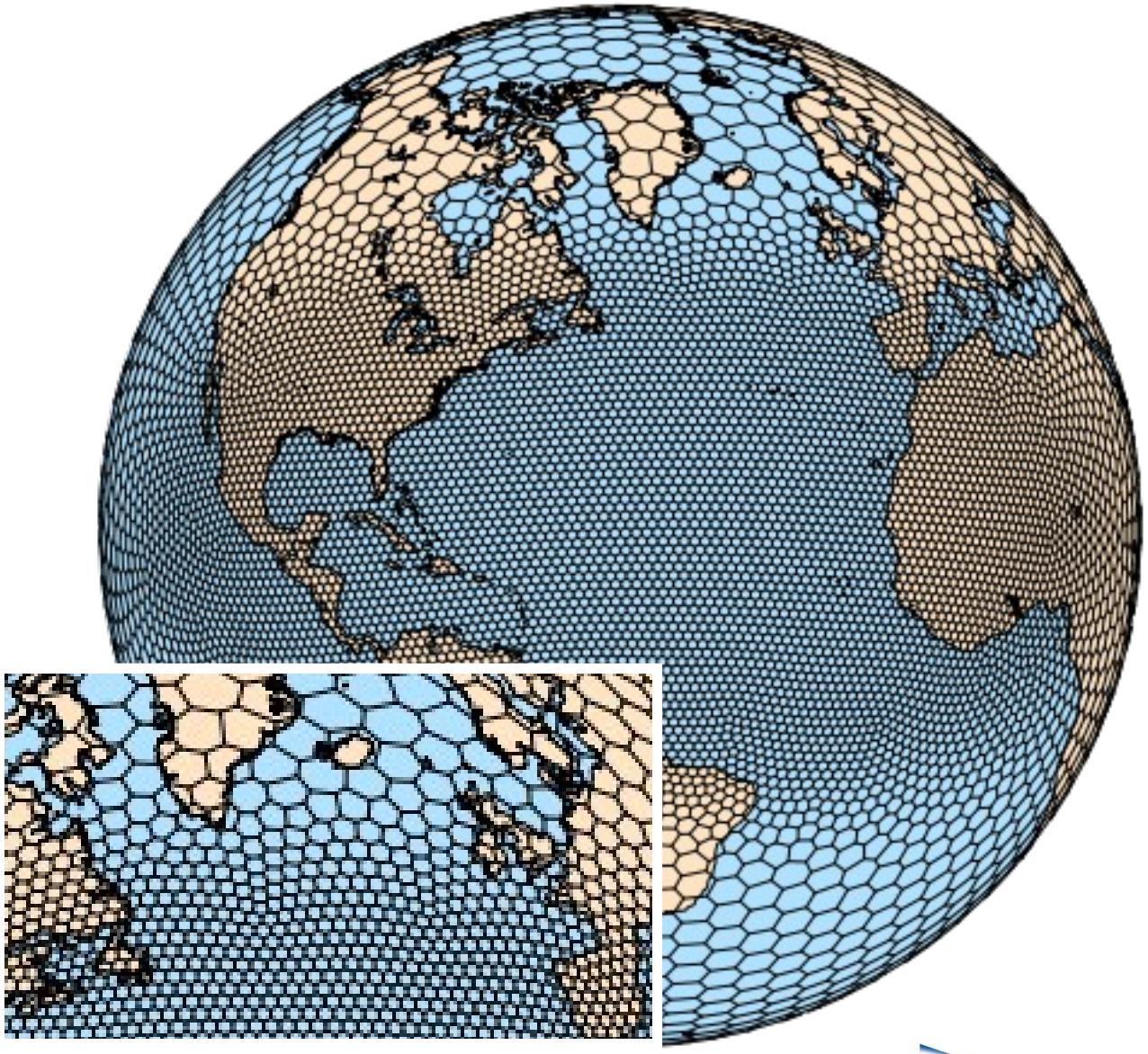
MPAS

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)



Welcome to the MPAS Tutorial

Monday, 12 August
08:30-09:00 Registration
09:00-09:30 Overview of the MONAN program (A)
09:30-10:00 Opening Remarks by the host Institution (A)
10:00-10:20 MPAS Overview (A)
10:20-10:30 Break
10:30-10:50 Downloading and compiling MPAS-Atmosphere (A)
10:50-11:35 Dynamics and dynamics configuration (A)
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14:55-15:05 Introduction to the practical exercises (A)
15:05-16:00 Practical session (TR)
16:00-16:10 Break
16:10-17:00 Practical session (TR)

Welcome to the MPAS Tutorial

Tuesday, 13 August

09:00-09:30 An overview of the structure of MPAS meshes (A)
09:30-10:00 Running MPAS, part 3: Preparing limited-area meshes and LBCs (A)
10:00-10:30 Post-processing and visualizing MPAS-Atmosphere output (A)
10:30-10:40 Break
10:40-11:20 Spatial discretization, filters and transport (A)
11:20-11:40 Unique aspects of MPAS code: Registry, pools, and logging (A)
11:40-12:00 Adding passive tracers to MPAS-Atmosphere simulations (A)
12:00-13:30 Lunch
13:30-14:00 Computing new diagnostic fields in MPAS-Atmosphere simulations (A)
14:00-15:30 Practical session (TR)
15:30-15:40 Break
15:40-17:00 Practical session (TR)

Welcome to the MPAS Tutorial

Wednesday, 14 August

09:00-09:30 MPAS mesh generation (A)
09:30-09:55 New MPAS capabilities under development, and concluding remarks (A)
09:55-10:45 Practical session (TR)
10:45-10:55 Break
10:55-12:00 Practical session (TR)
12:00-13:30 Lunch
13:45-14:10 MONAN 1.0.0 overview and future plans (A)
14:10-14:30 Overview of MONAN implementation (A)
14:30-16:00 MONAN Regional Model Training (TR)
16:00-16:15 Break
16:15-17:00 MONAN Regional Model Training (TR)
17:00-17:10 Registering MONAN workshop group photograph

MPAS
Model for Prediction Across Scales

What is MPAS?
Freely available modeling system

MPAS Version 8.2.1 (7 August 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

MPAS - Ocean (LANL)

Hydrostatic ocean solver, pre- and post-processors

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

Land ice and sea-ice models, pre- and post-processors

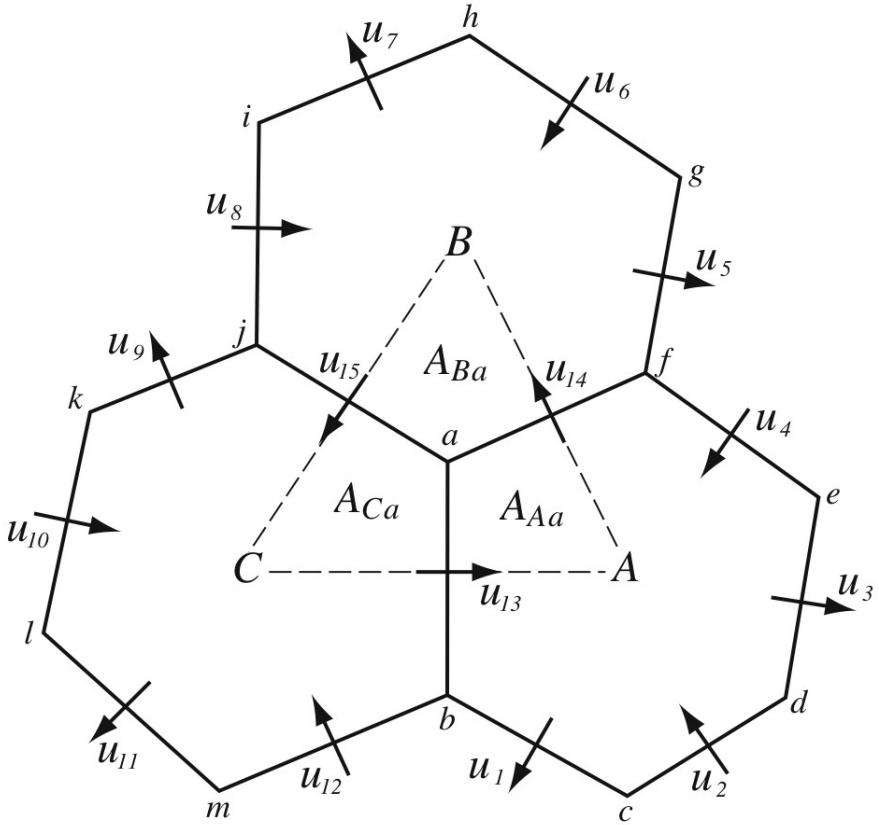
These are all stand-alone models – there is no coupler in MPAS

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.

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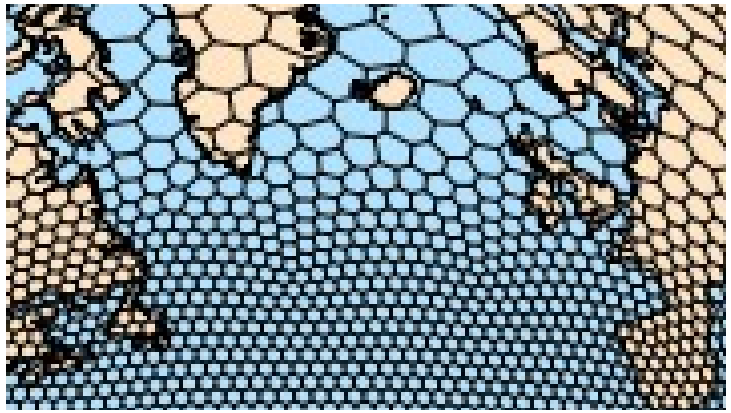
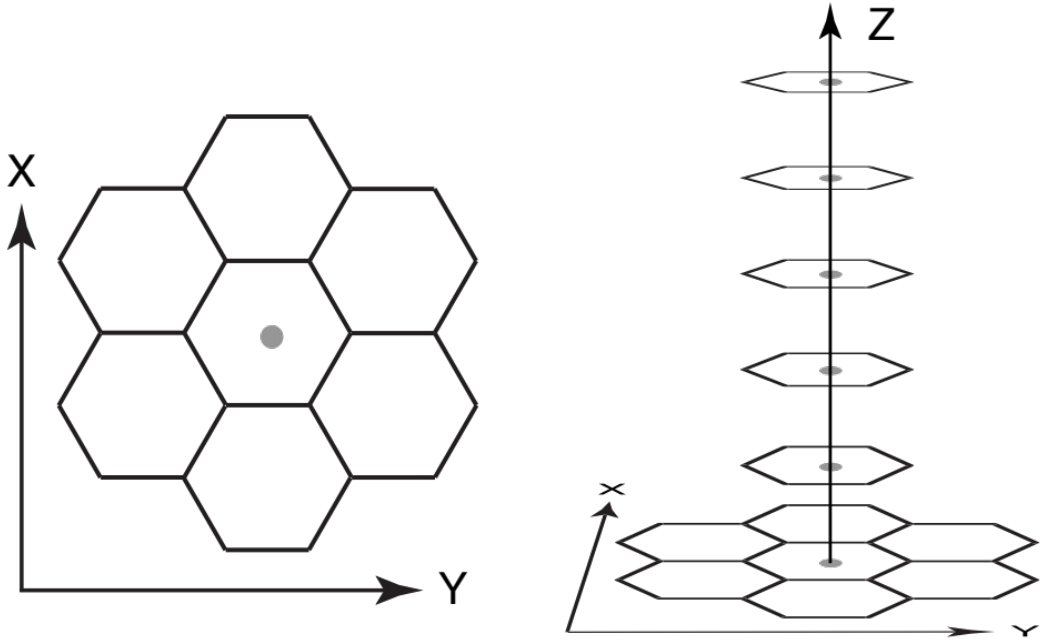
Model for Prediction Across Scales

What is MPAS?
Centroidal Voronoi Meshes

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



The mesh is *structured* in the vertical



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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.

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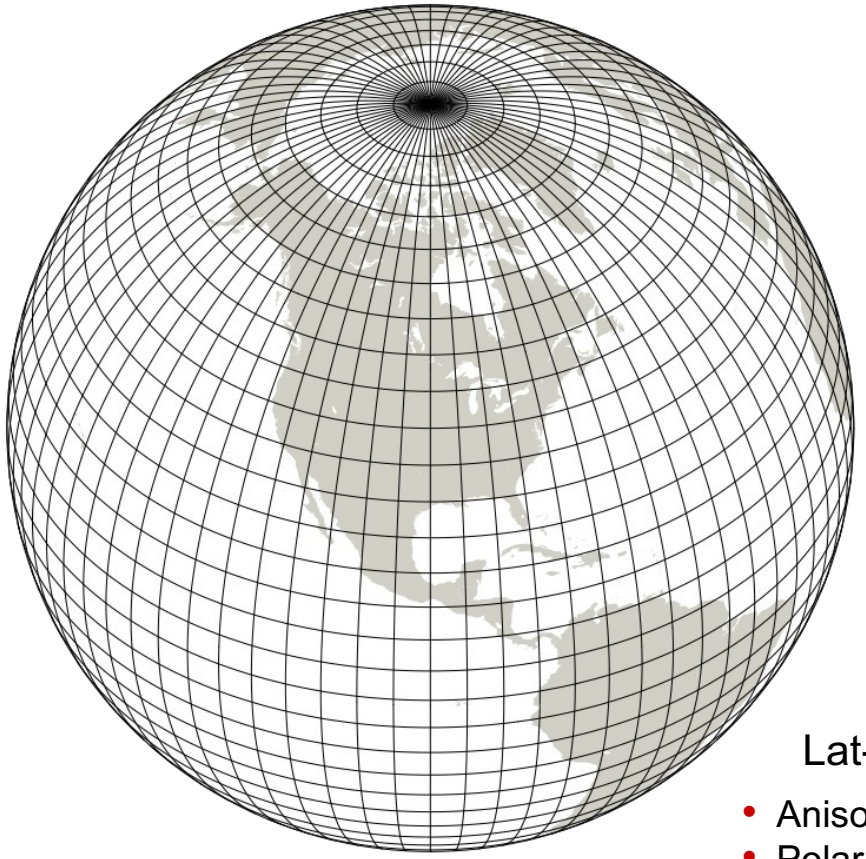
Model for Prediction Across Scales

Why MPAS?

Significant differences between WRF and MPAS



WRF

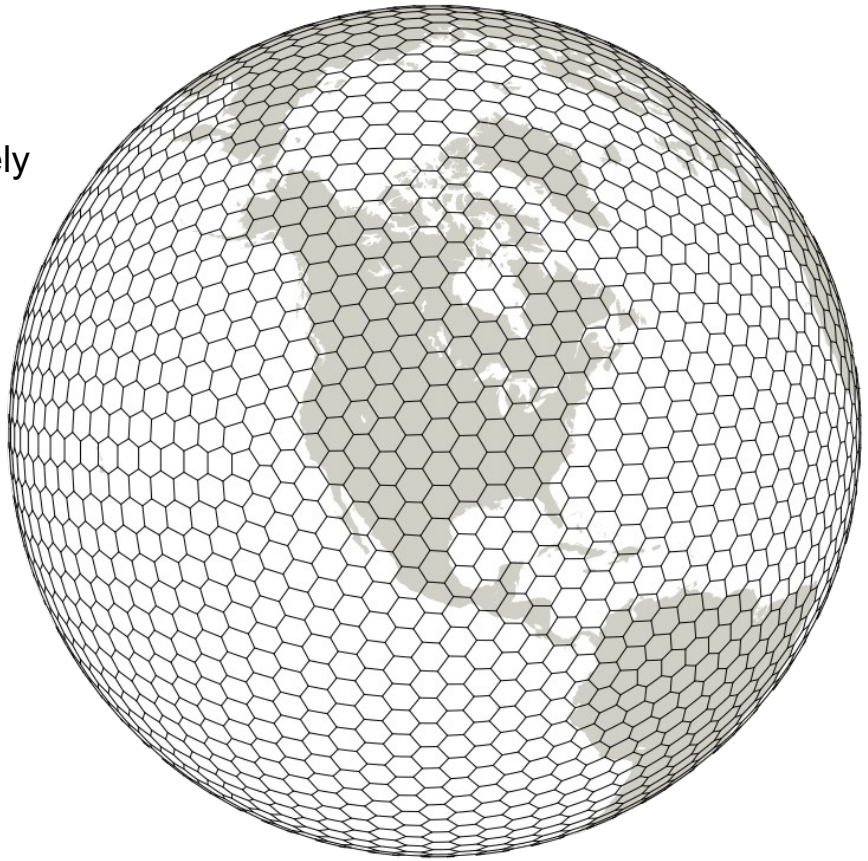
Lat-Lon global grid

- 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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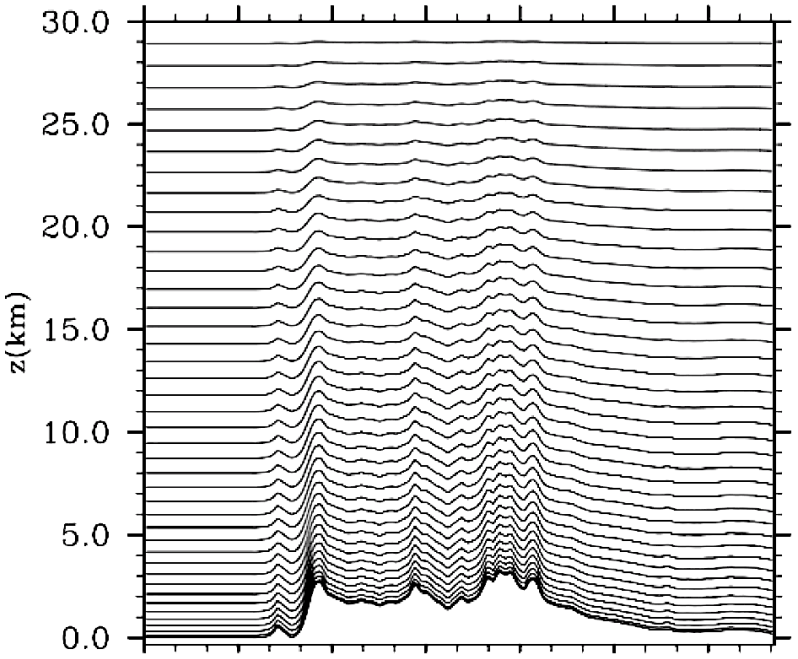
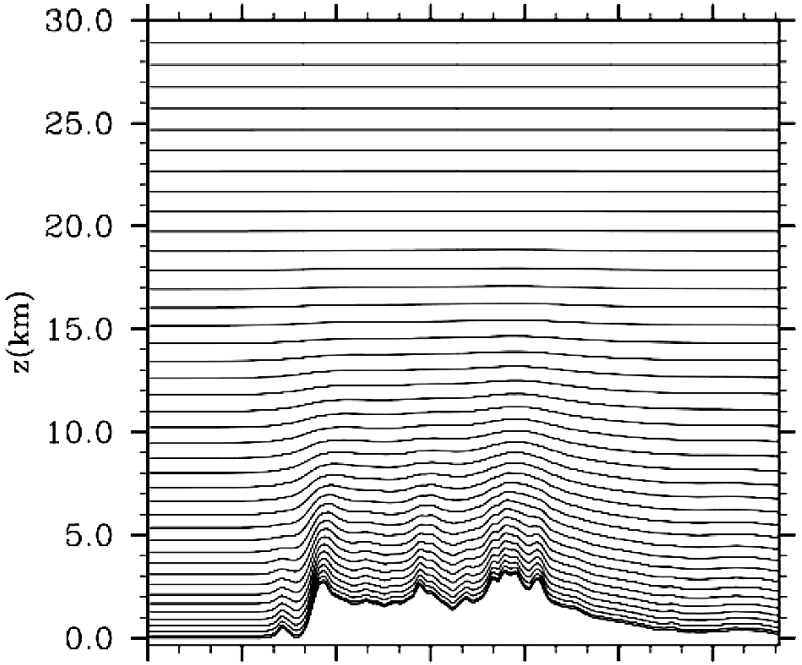


WRF
Pressure-based terrain-following sigma vertical coordinate



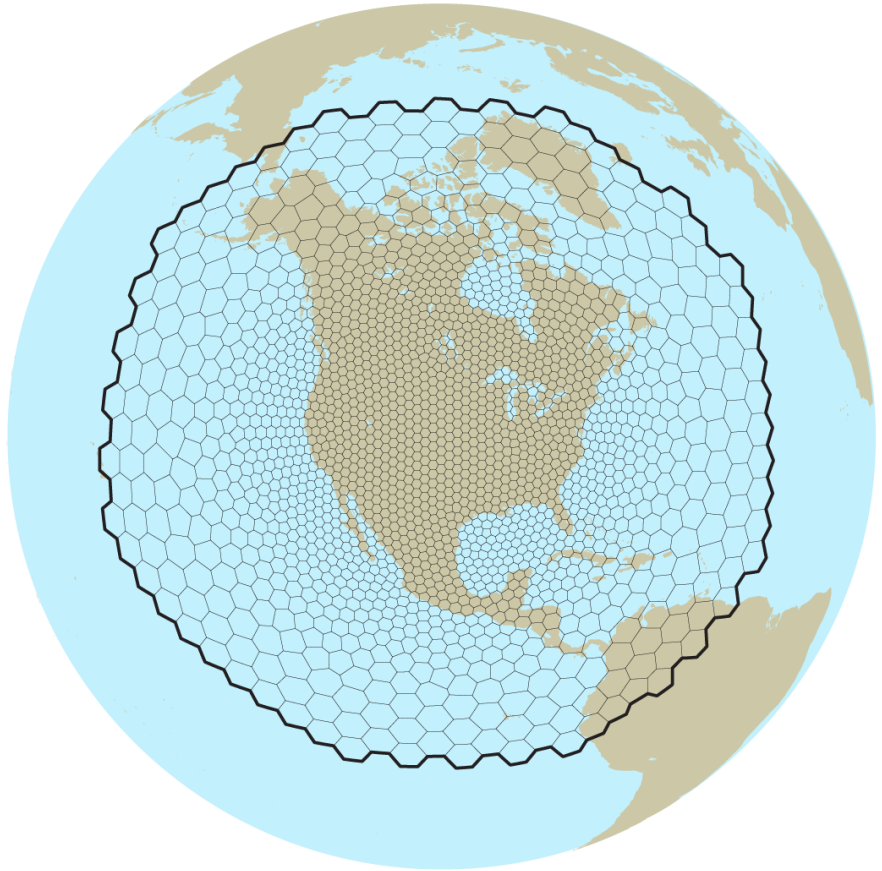
MPAS
Height-based hybrid smoothed terrain-following vertical coordinate

MPAS
Model for Prediction Across Scales

Regional MPAS

Why is there a regional version of MPAS given we have WRF?

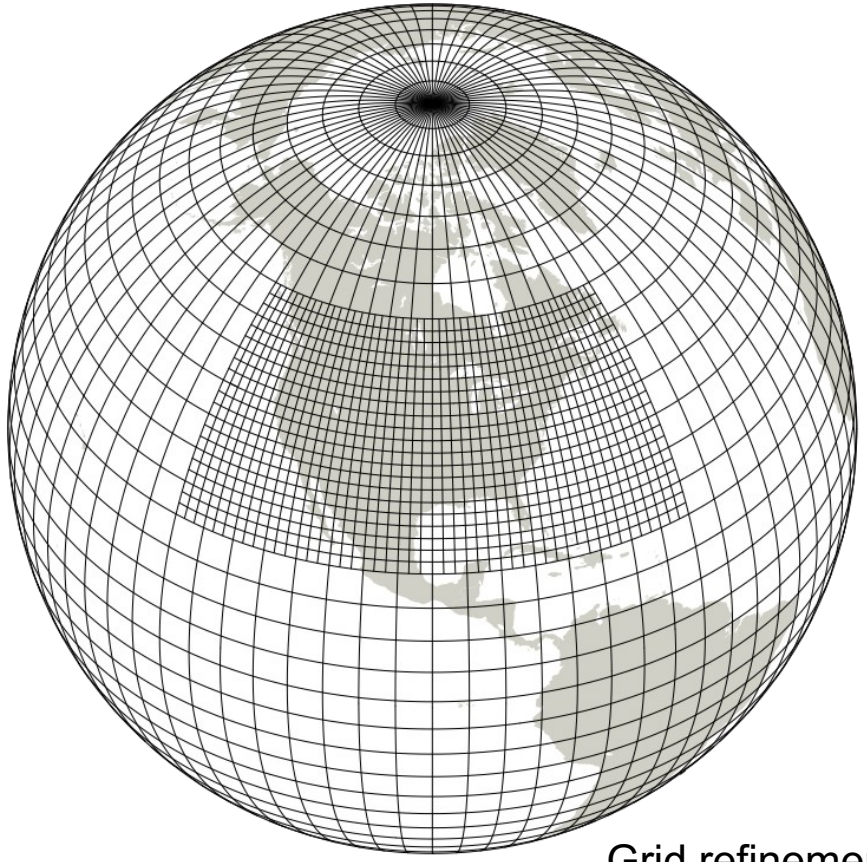
- Provide a consistent (equations, mesh) regional solver to complement global MPAS.
- Allow for more efficient (less costly) testing of MPAS at high resolutions.
- Leverage MPAS development for next-generation architectures to regional applications.
- Enable regional atmospheric applications within MPAS-enabled 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 we would like users to transition to MPAS if their applications allow.*



MPAS
Model for Prediction Across Scales

Why MPAS?

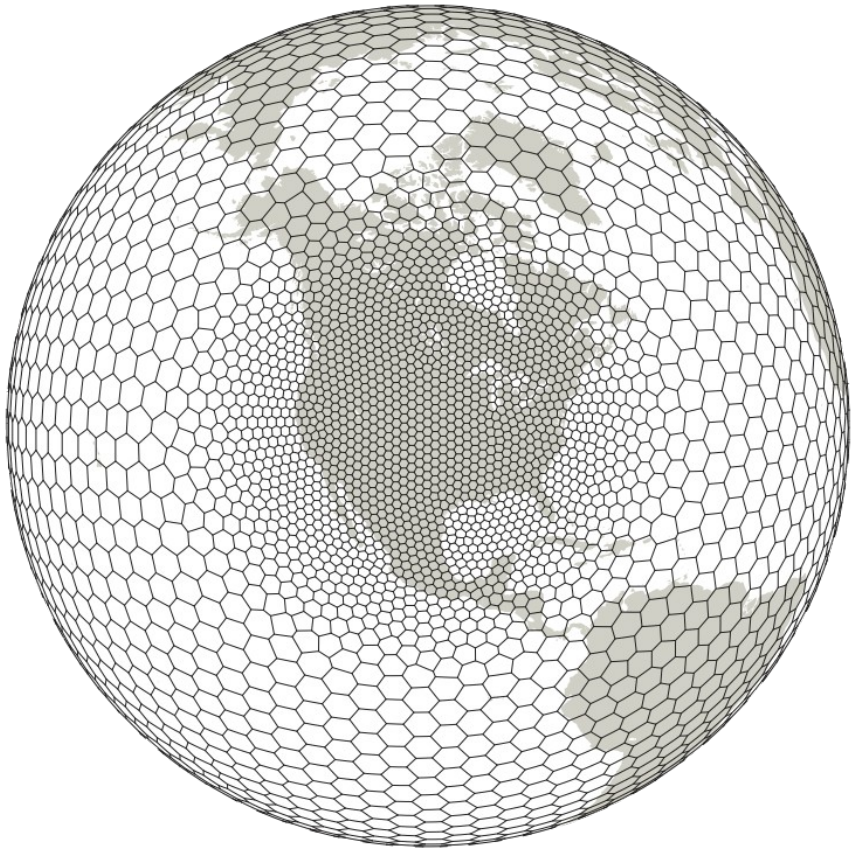
Significant differences between WRF and MPAS



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

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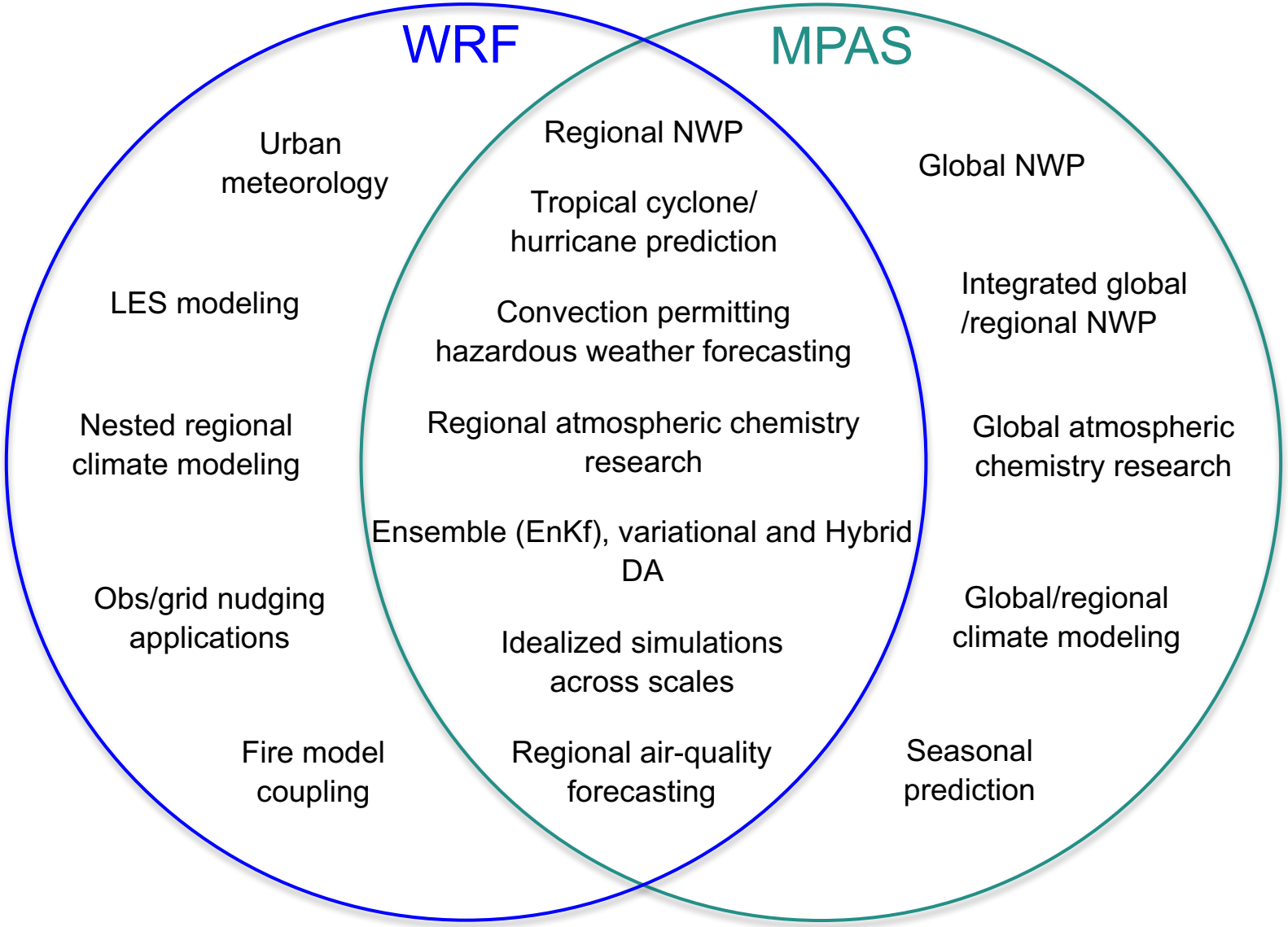

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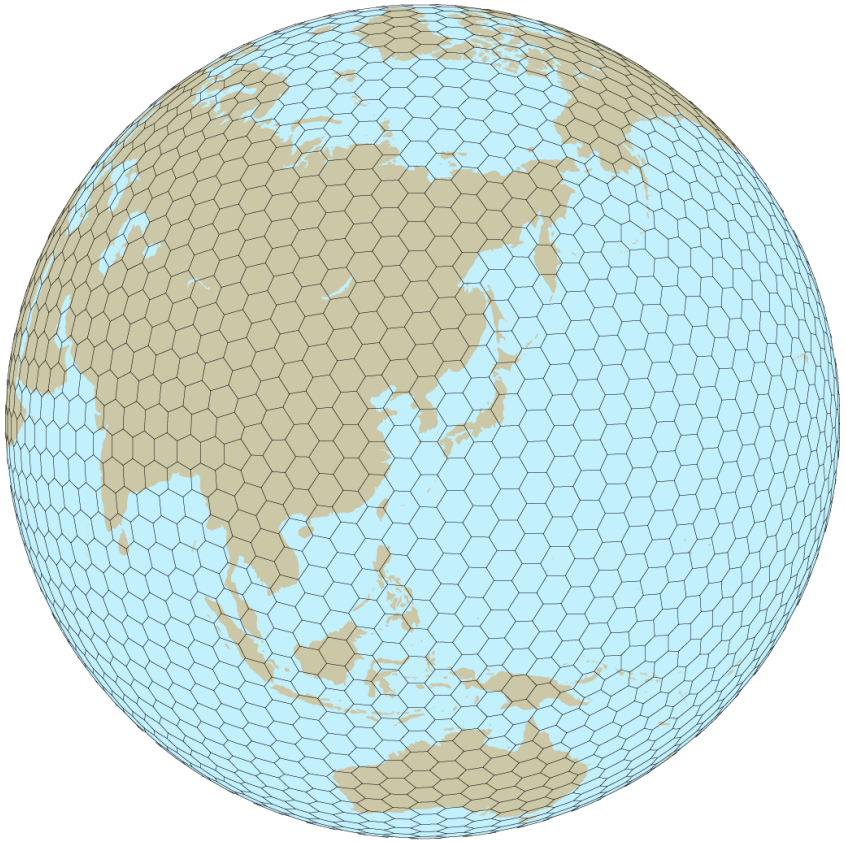
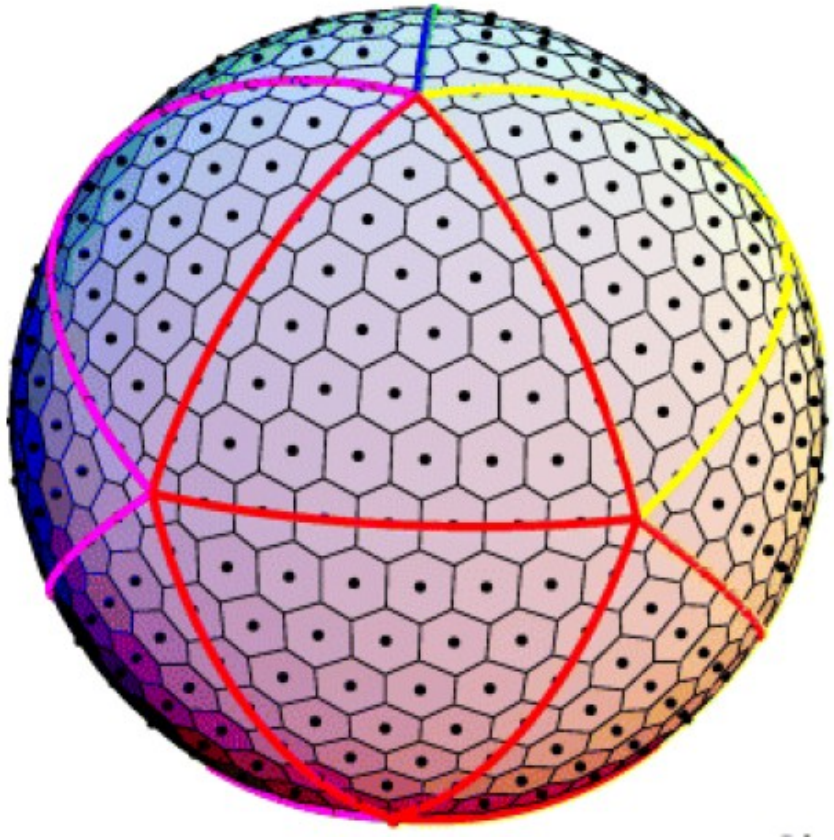


Global Quasi-Uniform Mesh (SCVT)

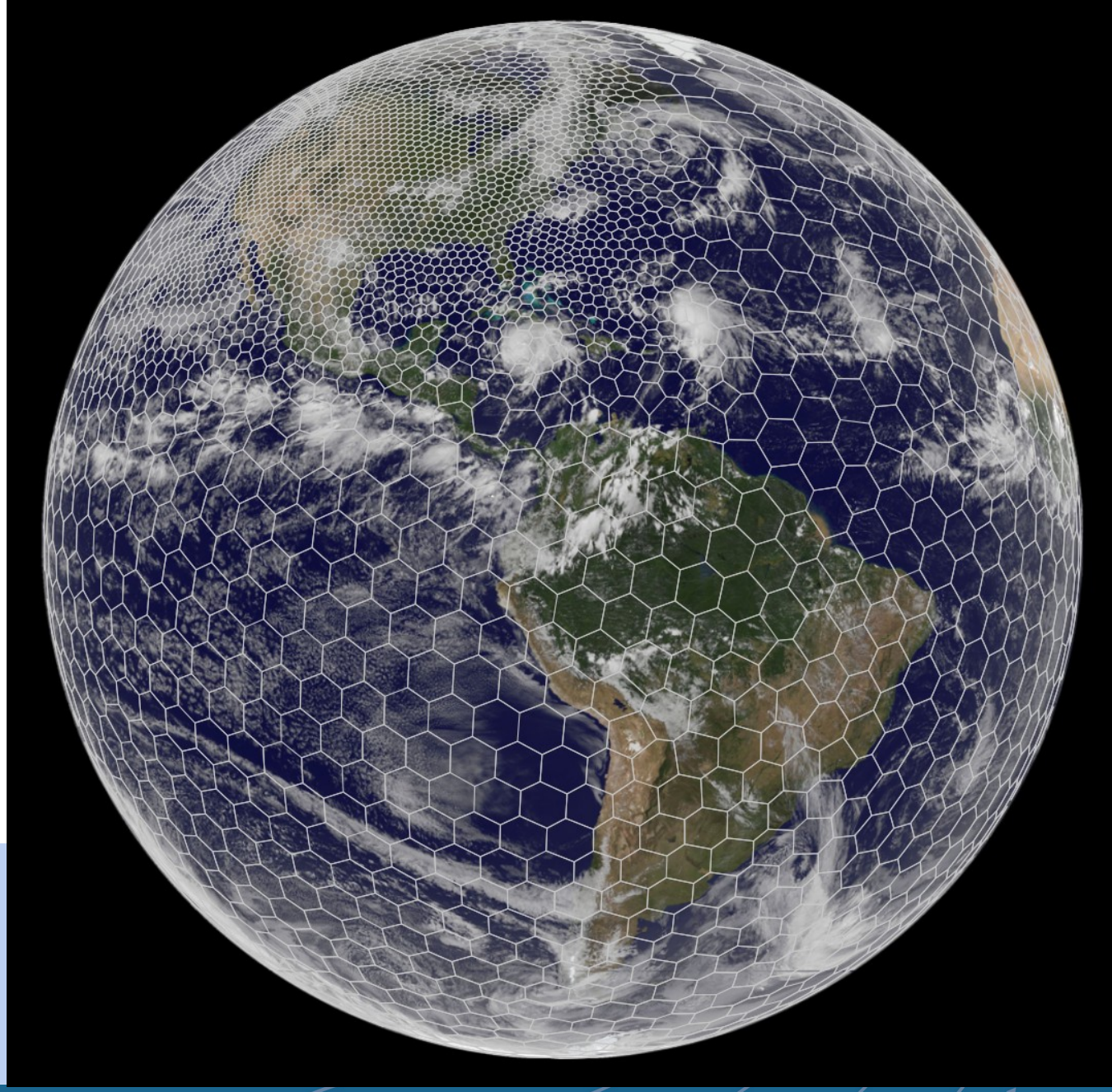


Many models use an icsoahedral mesh (NICAM, BUGS, FIM, NIM, OLAM, etc.)

MPAS
Model for Prediction Across Scales

Mesh generation

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



North American refinement

MPAS
Model for Prediction Across Scales

Mesh generation

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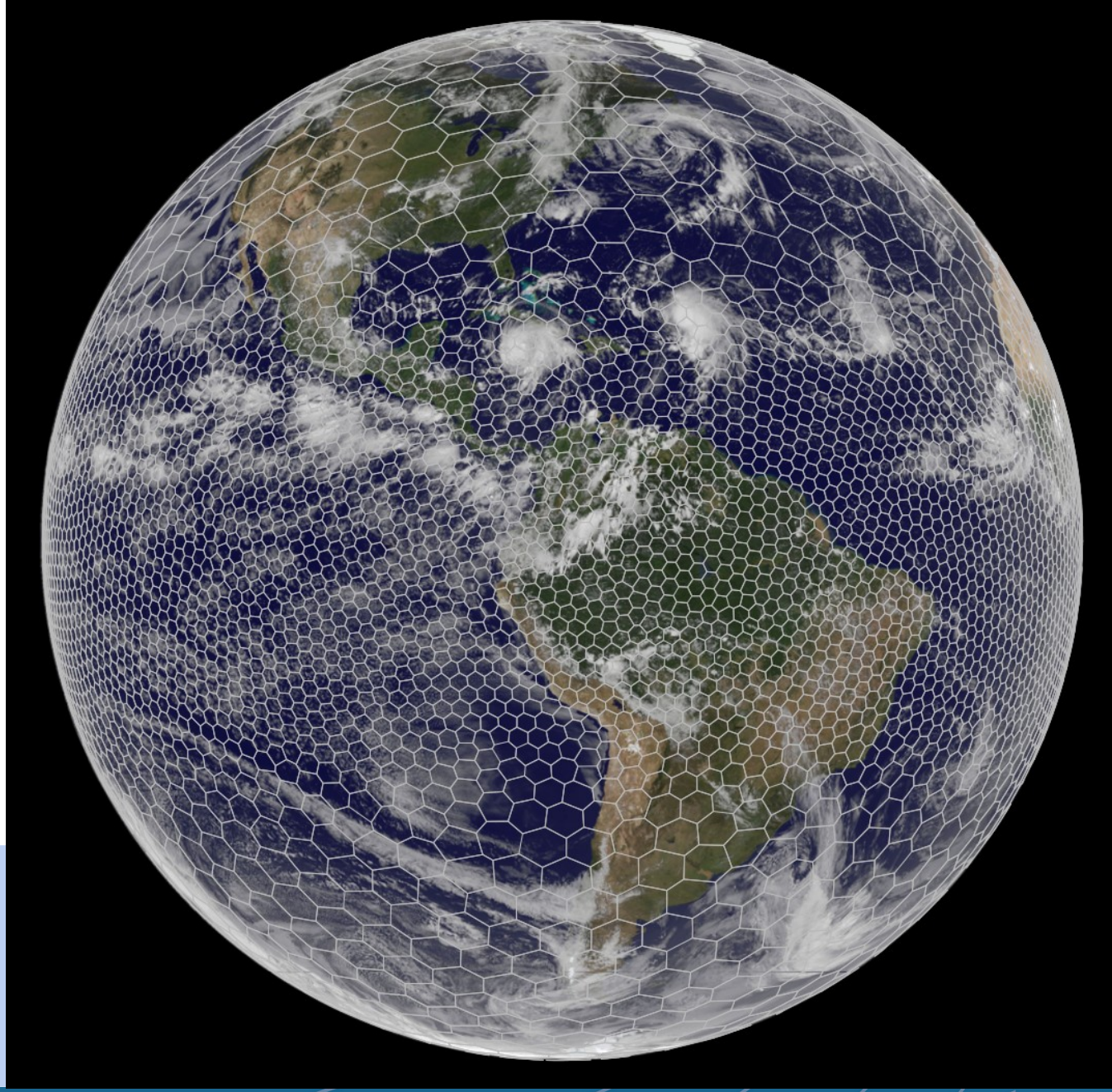

Equatorial refinement

MPAS
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Mesh generation

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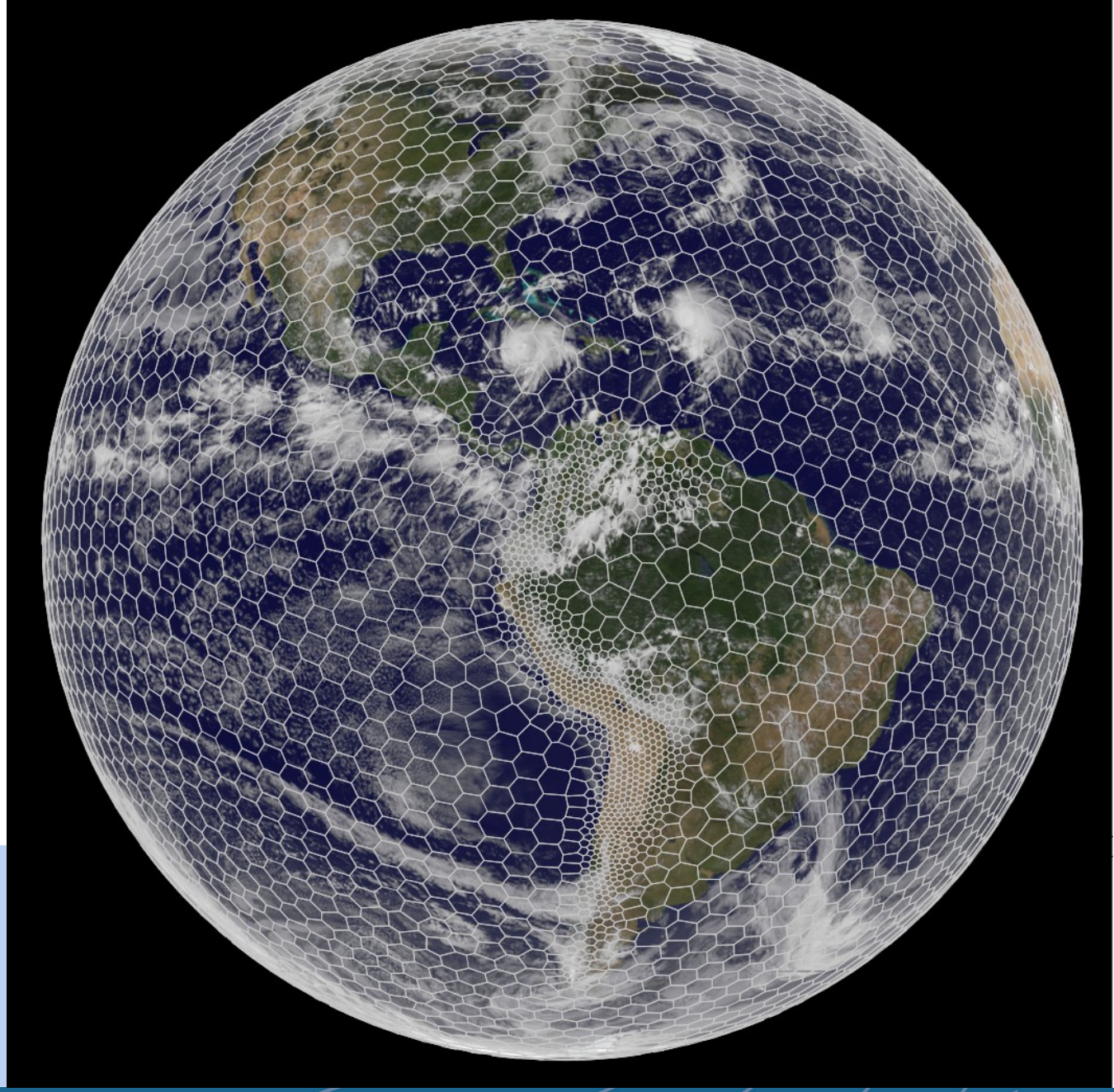

Andes refinement

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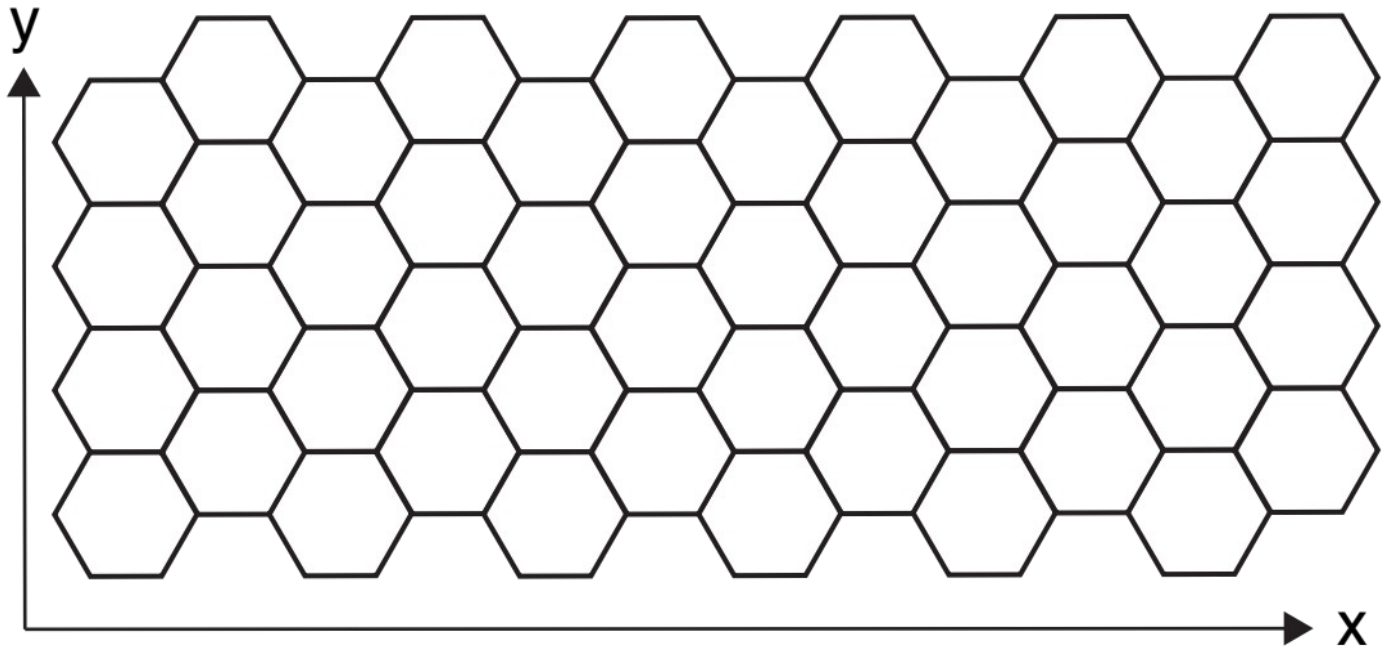
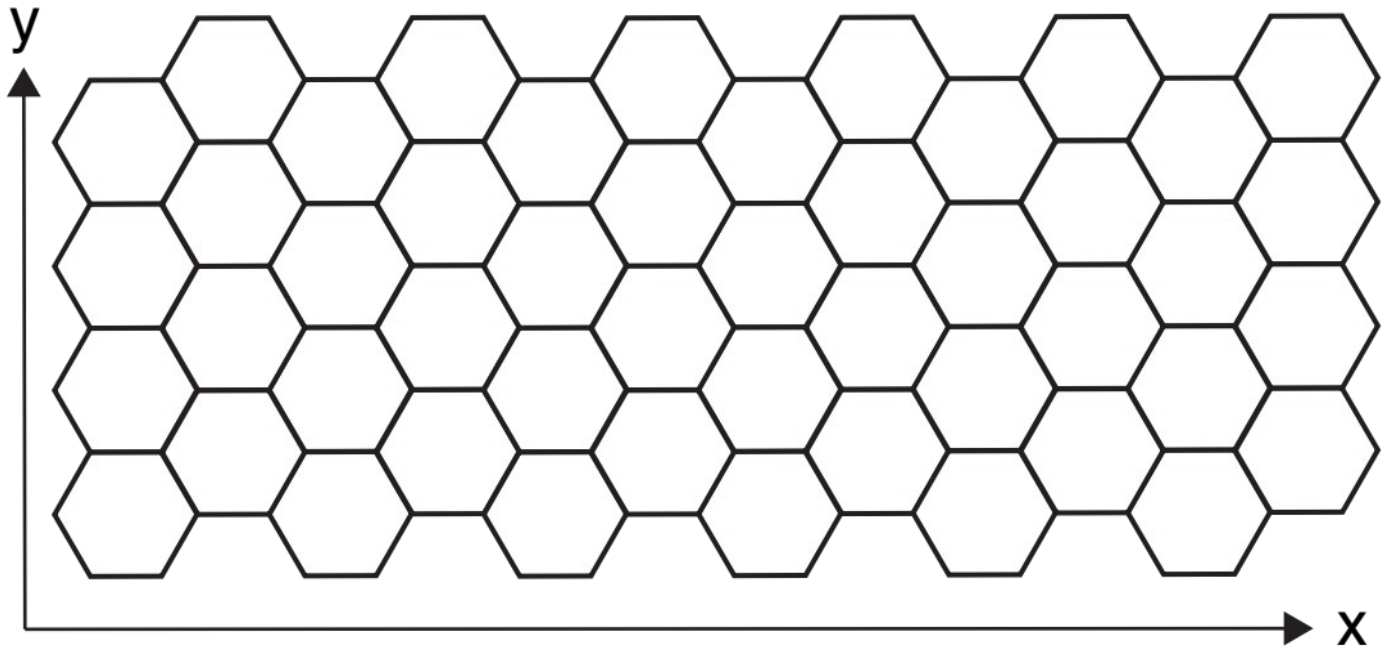
Other mesh spaces



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

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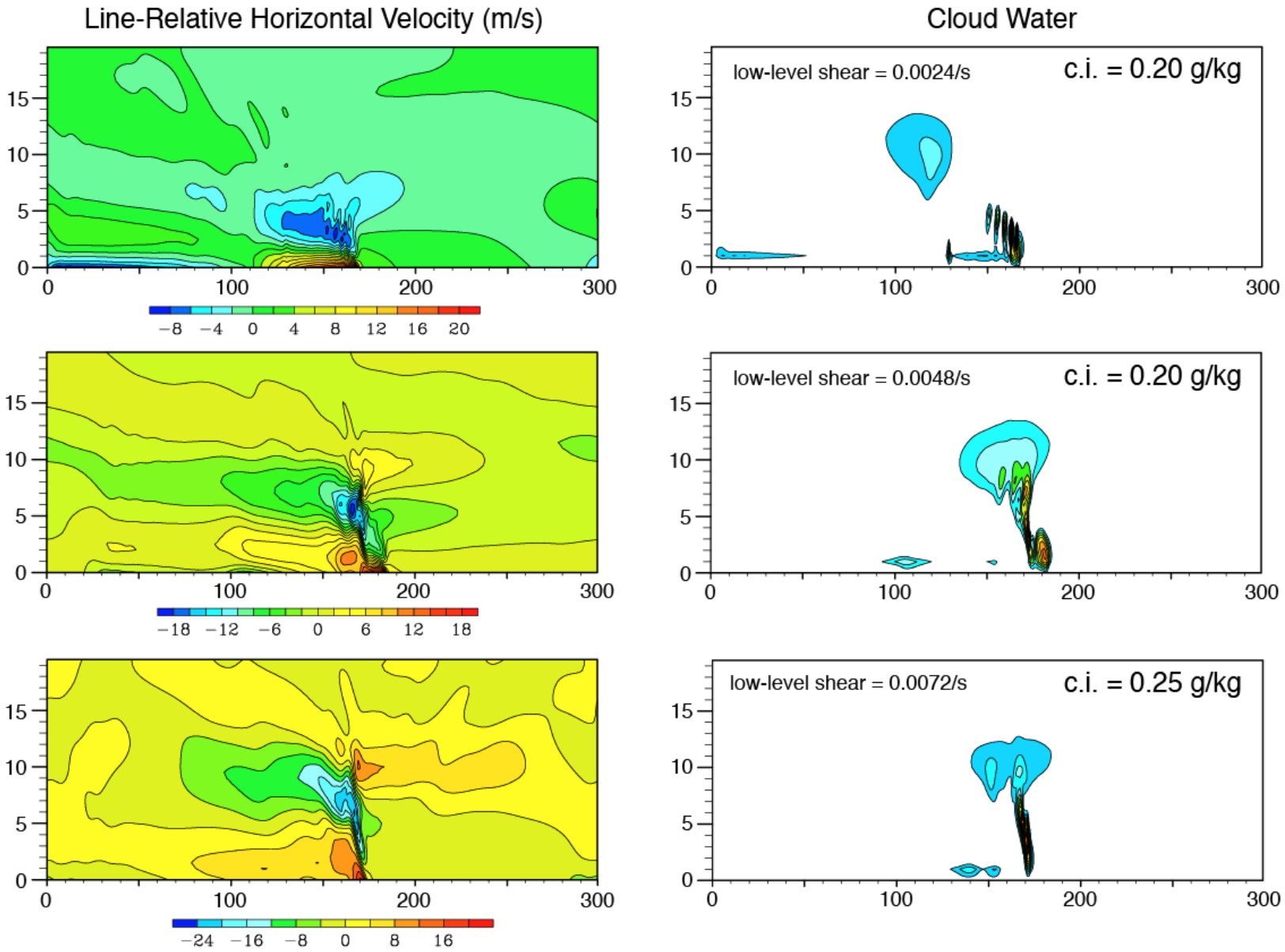
Squall-Line Tests 2D (x,z)

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



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