MPAS

Model for Prediction Across Scales

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

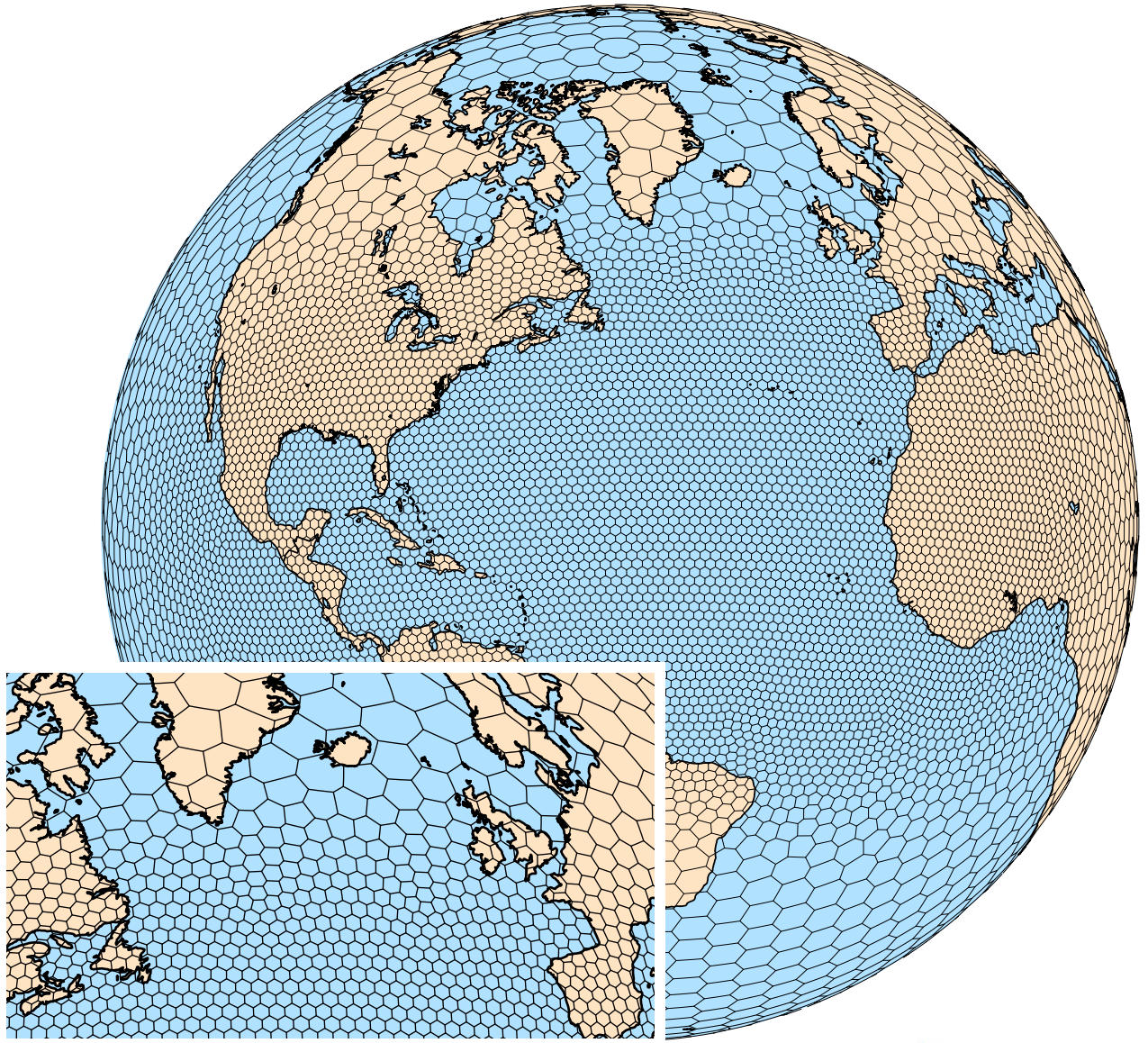
Collaboratively developed, primarily by NCAR and LANL/DOE

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, 30 September

9:00 – 9:20, Registration
9:20 - 9:30 (10 mins), Opening Remarks
9:30 – 9:50 (20 mins), MPAS Overview
9:50 – 10:10 (20 mins), Downloading and compiling MPAS-Atmosphere
10:10 – 11:05 (55 mins), Running MPAS, part 1: Creating ICs and running a basic global simulation
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12:30 – 13:30, Lunch
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14:00 – 14:45 (45 mins), Practical session
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15:00 - 16:00 (60 mins), Practical session

Welcome to the MPAS Tutorial

Tuesday, 1 October

9:00 – 9:45 (45 mins), Dynamics and dynamics configuration
9:45 – 10:30 (45 mins), Physics and physics configuration
10:30 – 10:45 (15 mins), Break
10:45 – 11:15 (30 mins), An overview of the structure of MPAS meshes
11:15 – 11:45 (30 mins), Running MPAS, part 3: Preparing limited-area meshes and LBCs
11:45 – 12:15 (30 mins), Post-processing and visualizing MPAS-Atmosphere output
12:15 – 13:30, Lunch
13:30 – 14:45 (75 mins), Practical session
14:45 – 15:00 (15 mins), Break
15:00 – 16:00 (60 mins), Practical session

Welcome to the MPAS Tutorial

Wednesday, 2 October

9:00 – 9:20 (20 mins), Unique aspects of MPAS code: Registry, pools, and logging
9:20 – 9:45 (25 mins), Adding passive tracers to MPAS-Atmosphere simulations
9:45 – 10:10 (25 mins), Computing new diagnostic fields in MPAS-Atmosphere simulations
10:1**0 – 10:25 (15 mins), Break**
10:25 – 11:05 (40 mins), Spatial discretization, filters and transport
11:05 – 11:35 (30 mins), MPAS mesh generation
11:35 – 12:00 (25 mins), New MPAS capabilities under development, and concluding remarks
12:00 – 13:30, Lunch
13:30 – 14:45 (75 mins), Practical session
14:45 – 15:00 (15 mins), Break
15:00 – 16:00 (60 mins), Practical session

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

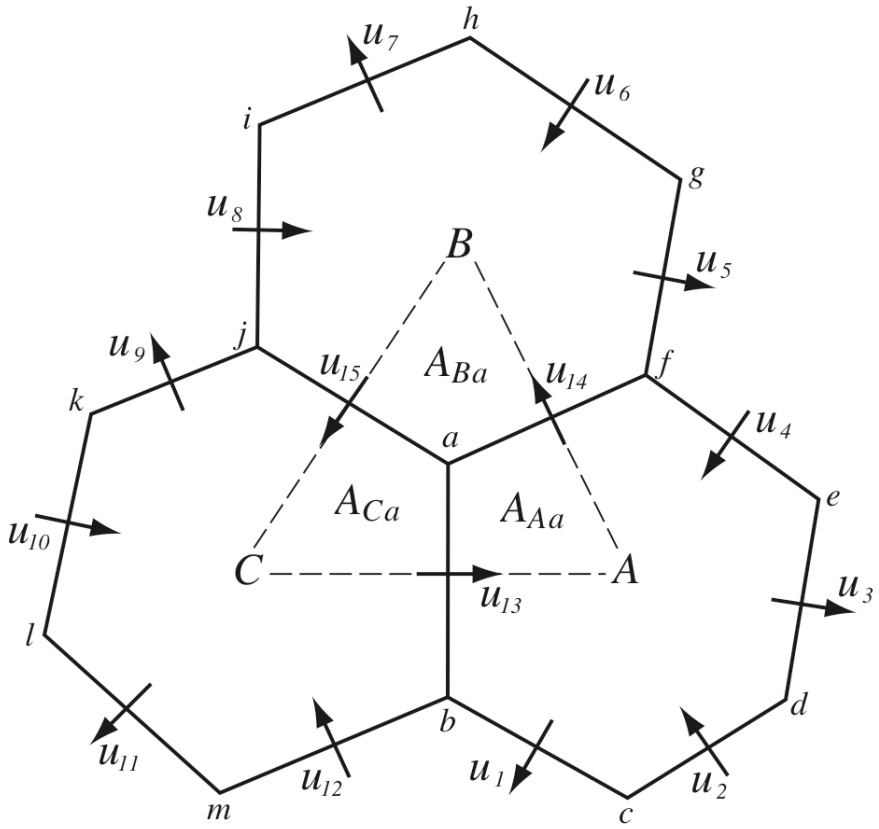
These are all stand-alone models – there is no coupler in MPAS

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.



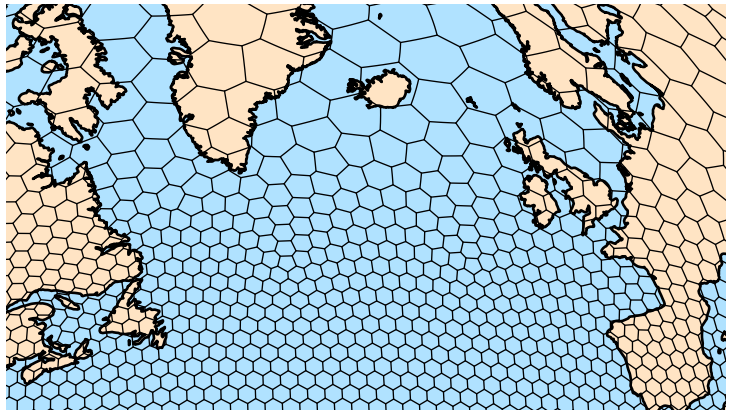
C-grid

- 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.

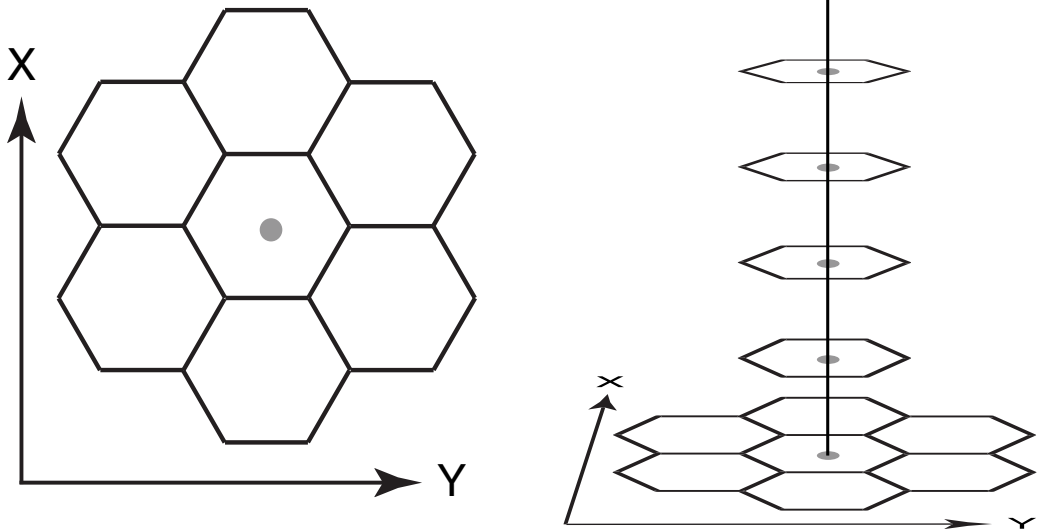
MPAS
Model for Prediction Across Scales

What is MPAS?
Centroidal Voronoi Meshes

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



The mesh is *structured* in the vertical



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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

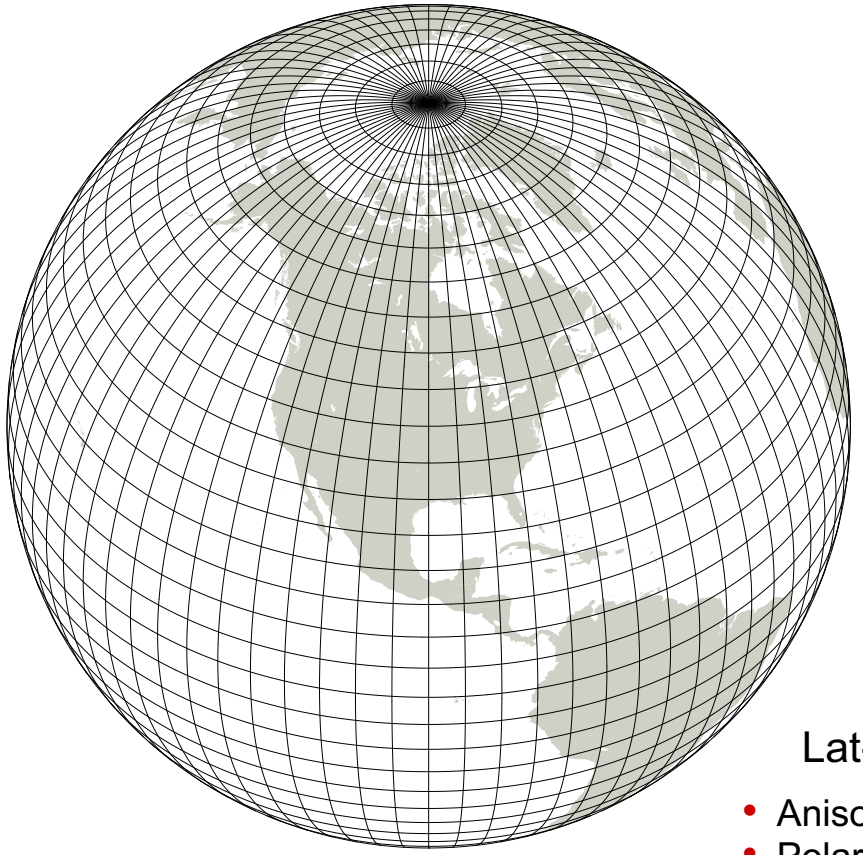
Full complement of atmospheric-model physics

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

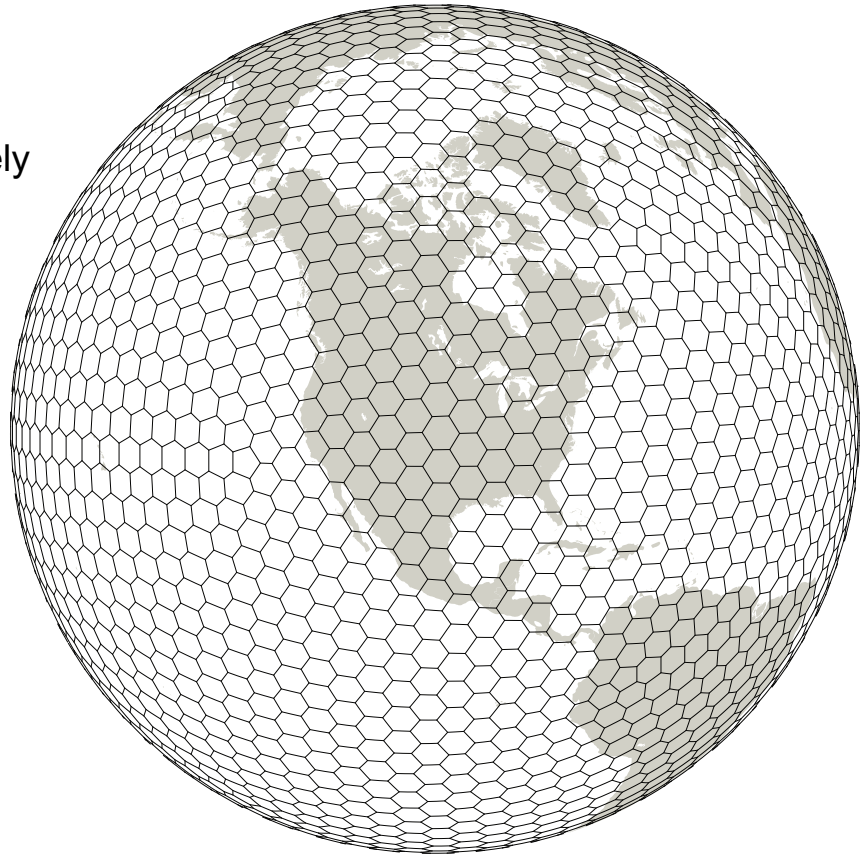


WRF
Lat-Lon global grid

- 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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Model for Prediction Across Scales

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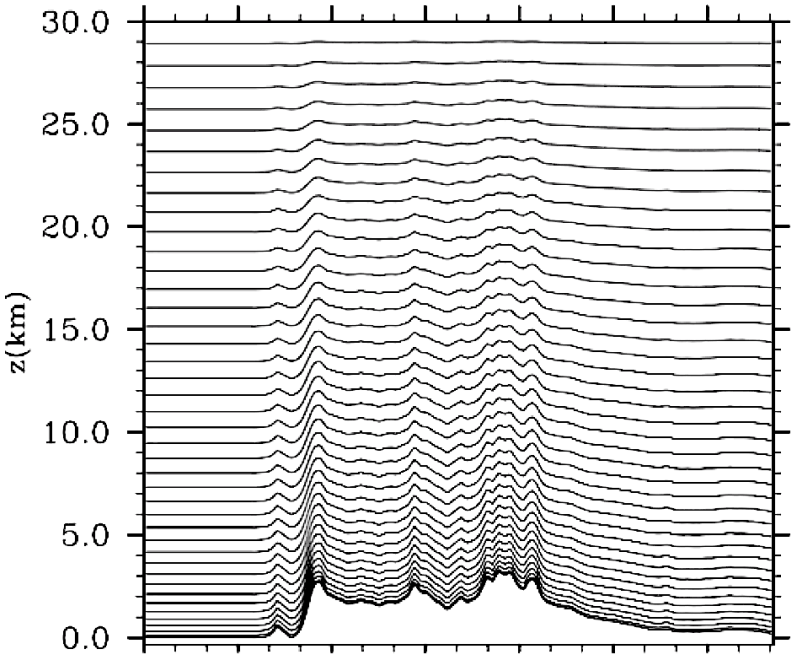
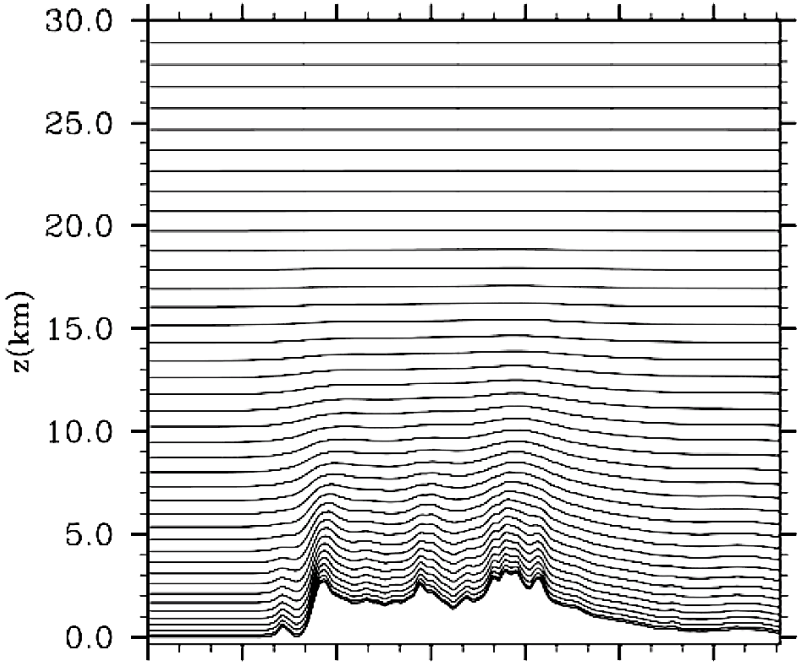


WRF
Pressure-based
terrain-following sigma
vertical coordinate



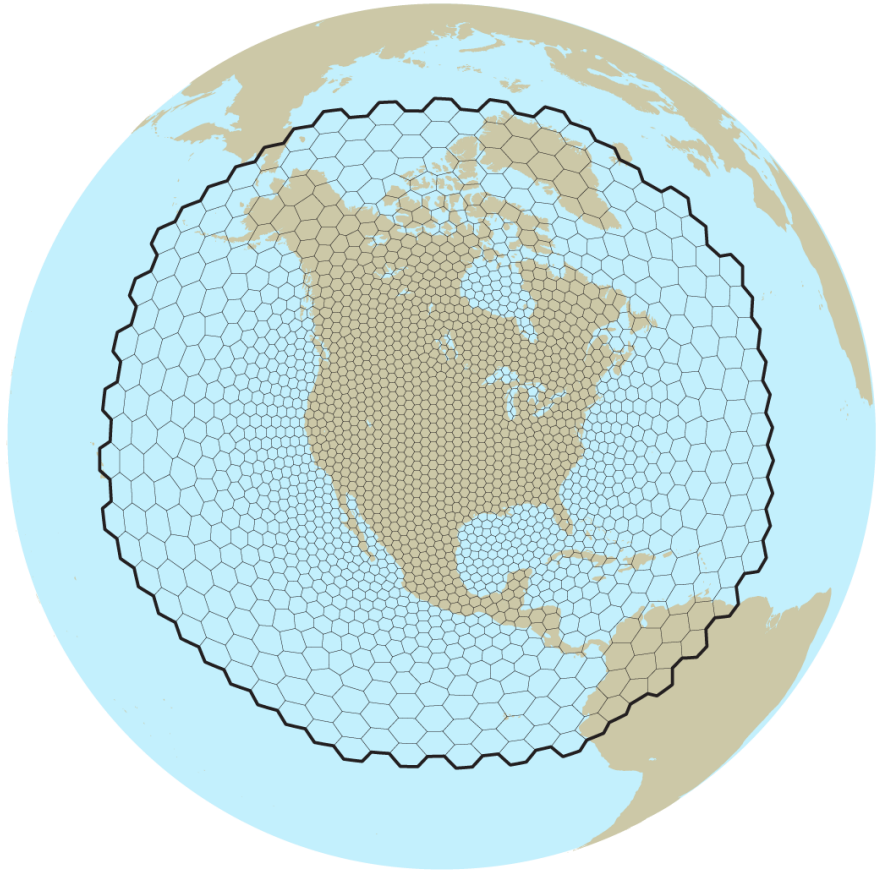
MPAS
Height-based hybrid smoothed
terrain-following vertical
coordinate

MPAS
Model for Prediction Across Scales

Regional MPAS

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

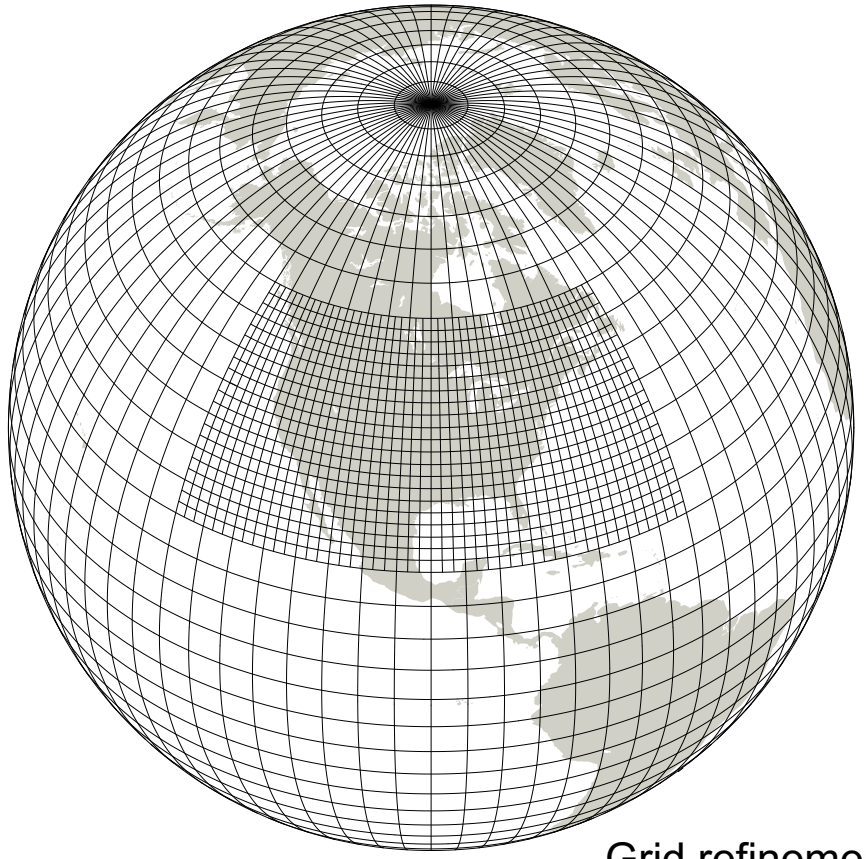
- Provide a consistent (equations, mesh) regional solver to complement global MPAS.
- Allow for more efficient (less costly) testing of MPAS at high resolutions.
- Leverage MPAS development for next-generation architectures to regional applications.
- Enable regional atmospheric applications within MPAS-enabled 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?

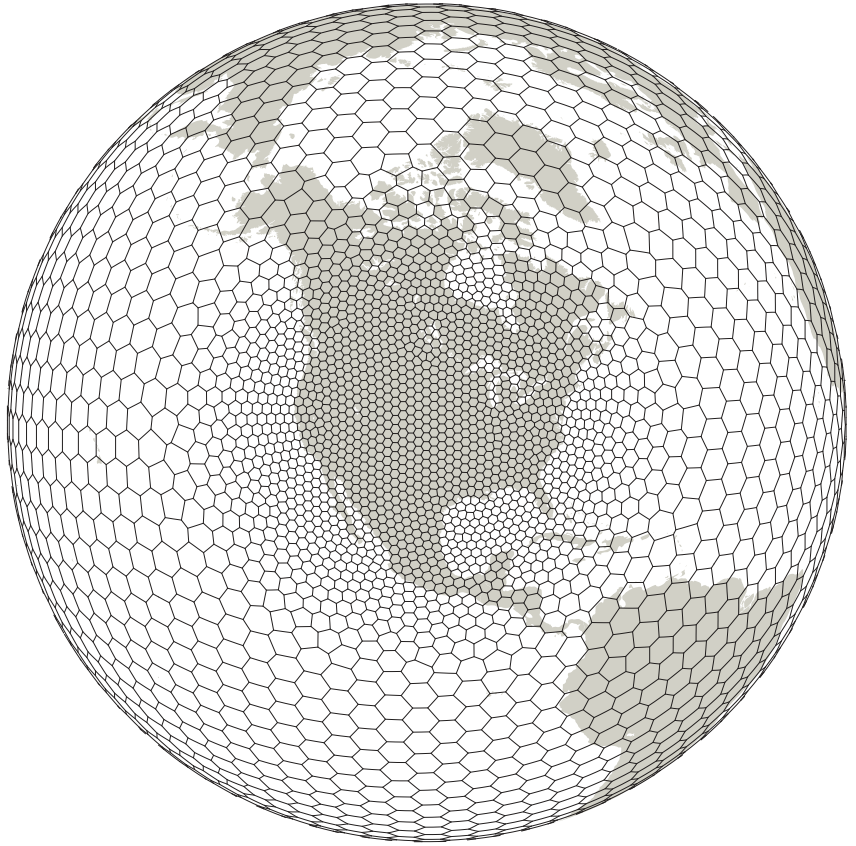
Significant differences between WRF and MPAS



MPAS

Smooth grid refinement on a conformal mesh

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

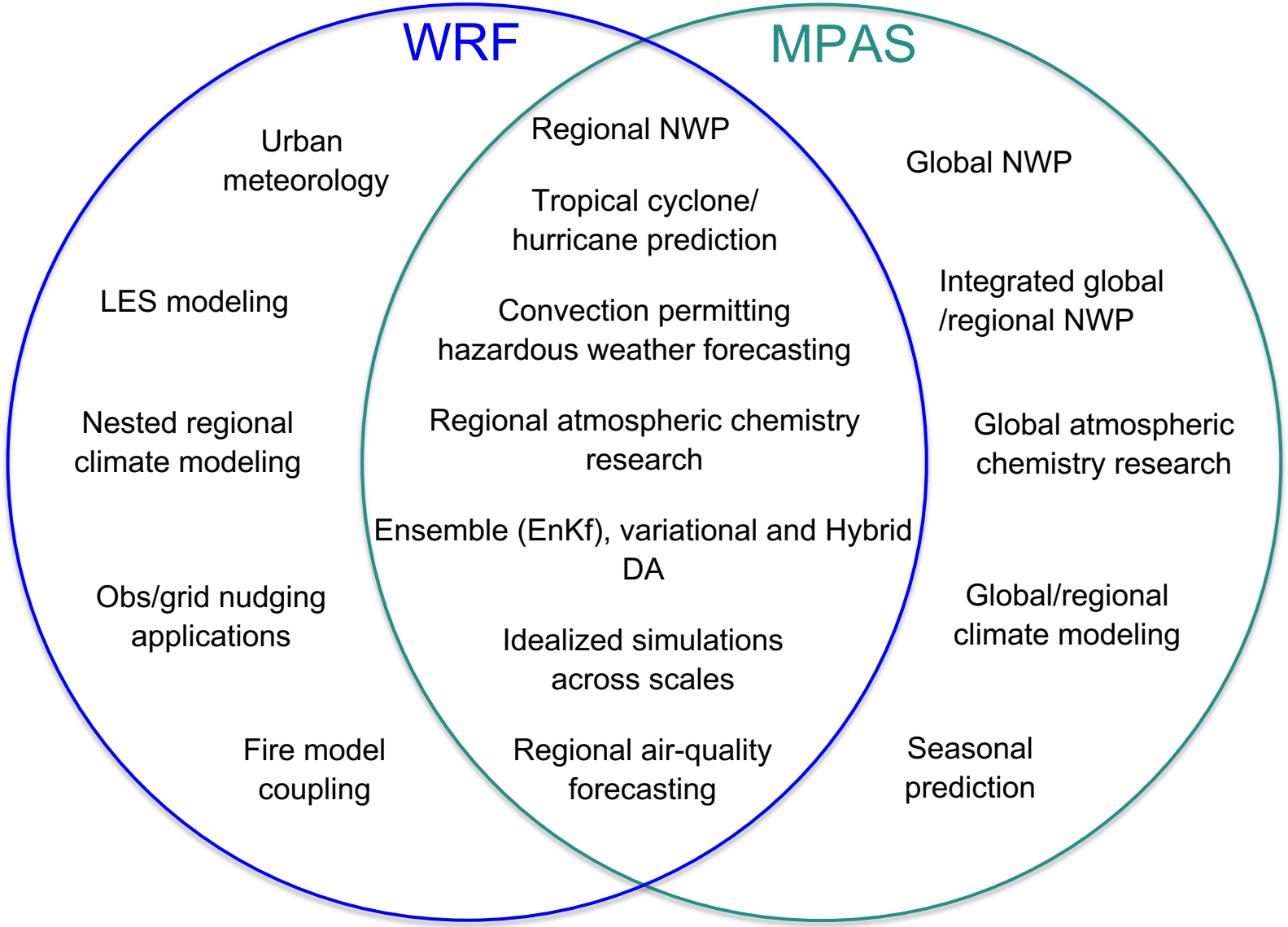


WRF

Grid refinement through domain nesting

- Flow distortions at nest boundaries

MPAS
Model for Prediction Across Scales



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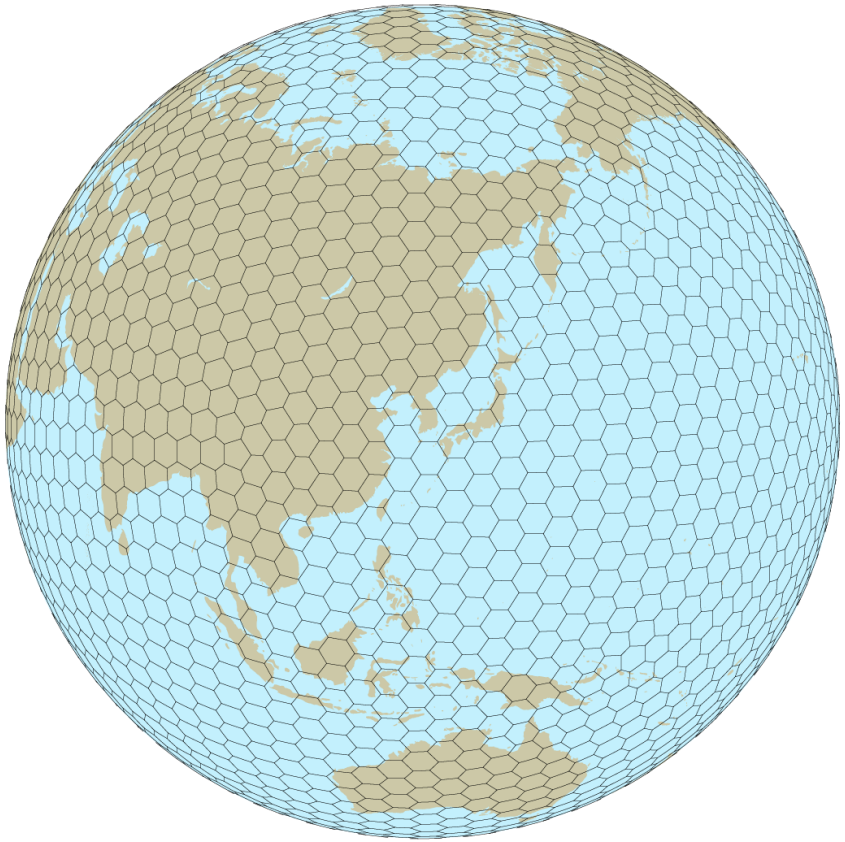
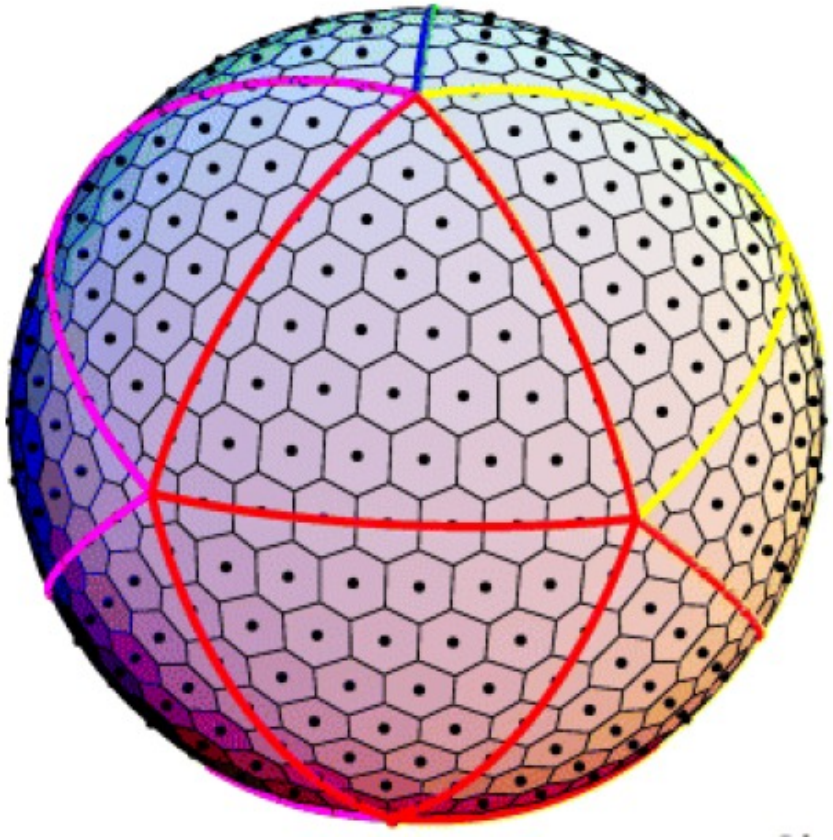


Global Quasi-Uniform Mesh (SCVT)

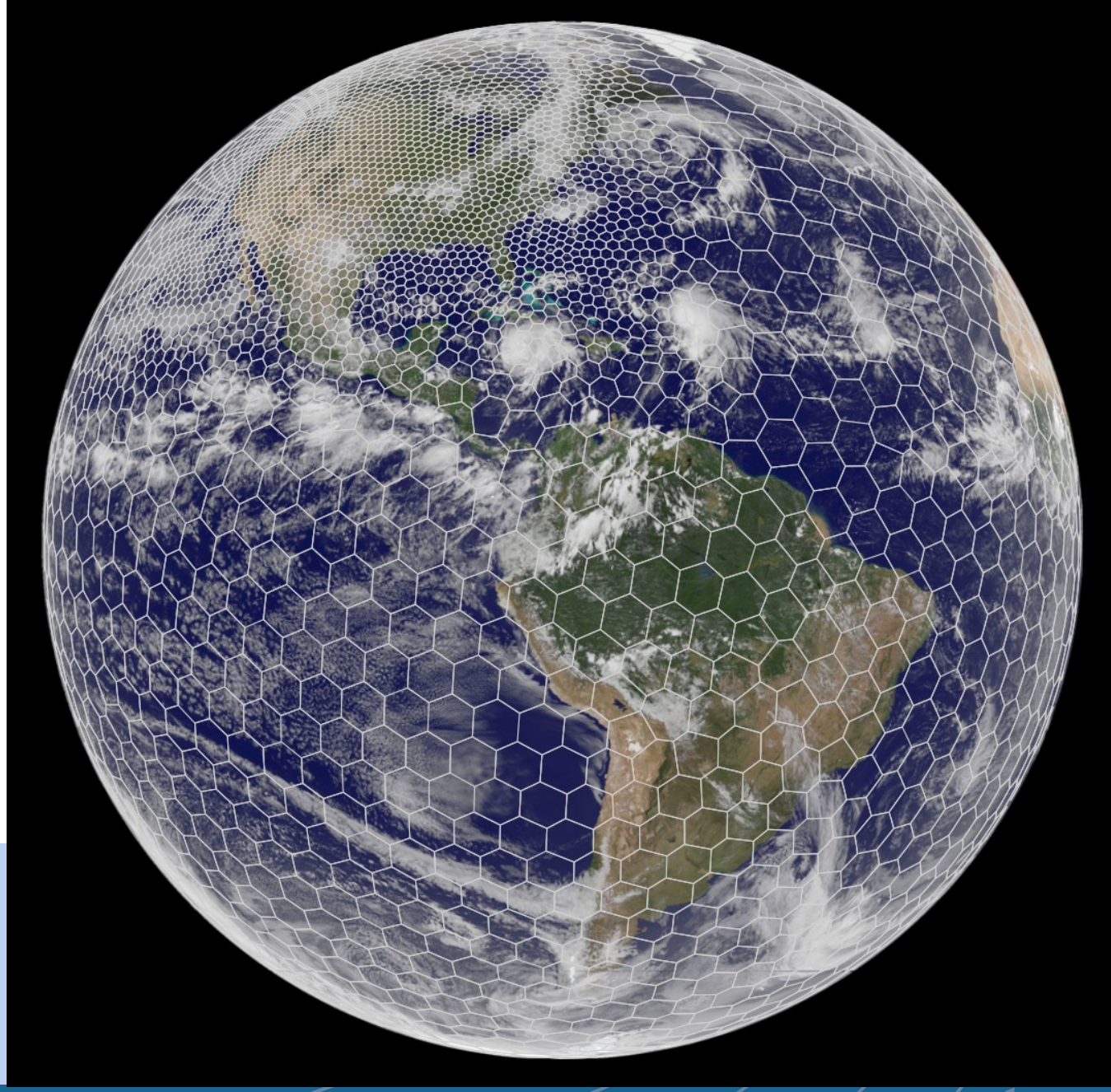


Many models use an icsoahedral mesh (NICAM, BUGS, FIM, NIM, OLAM, etc.)

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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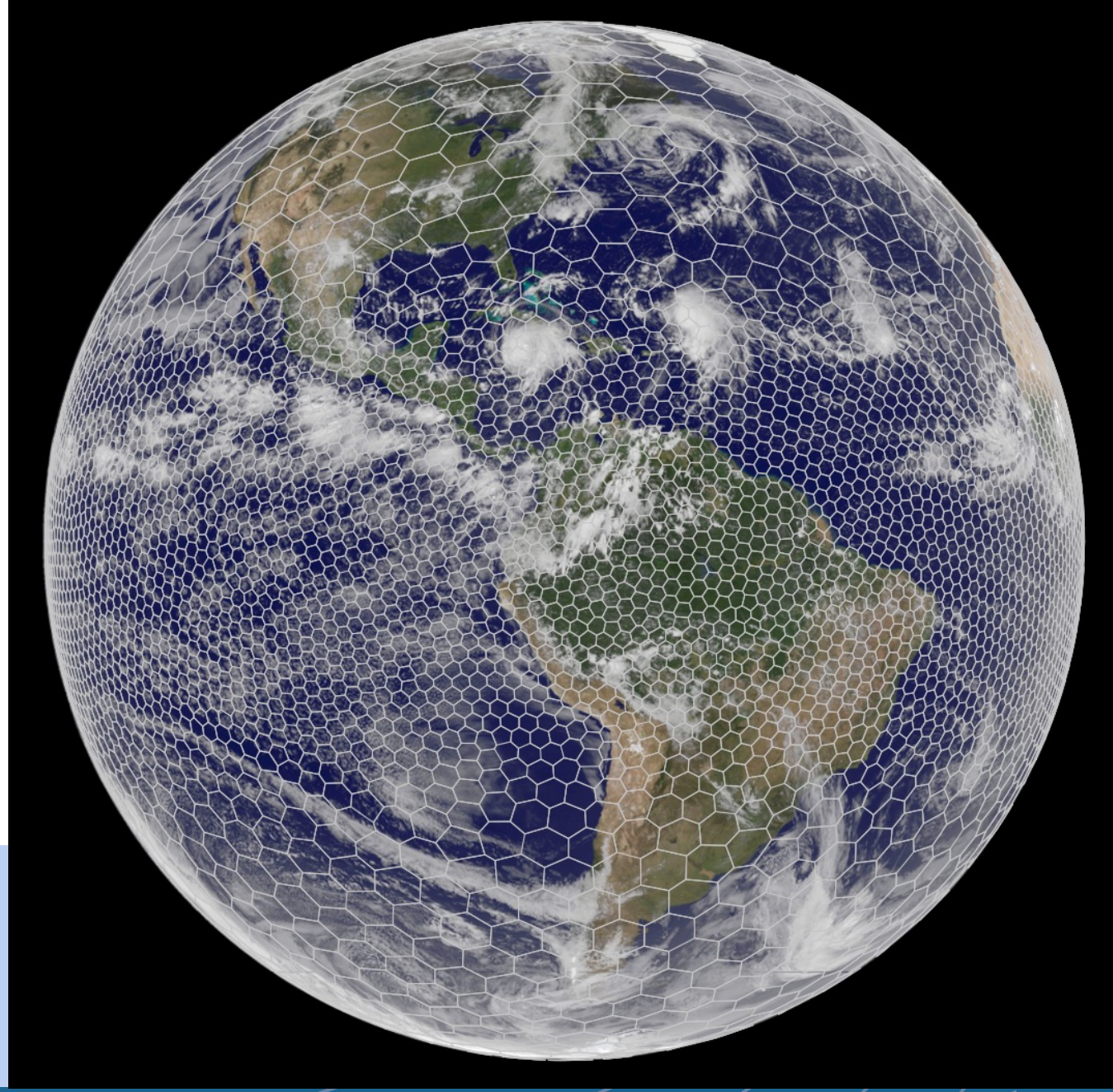

Equatorial refinement

MPAS
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Mesh generation

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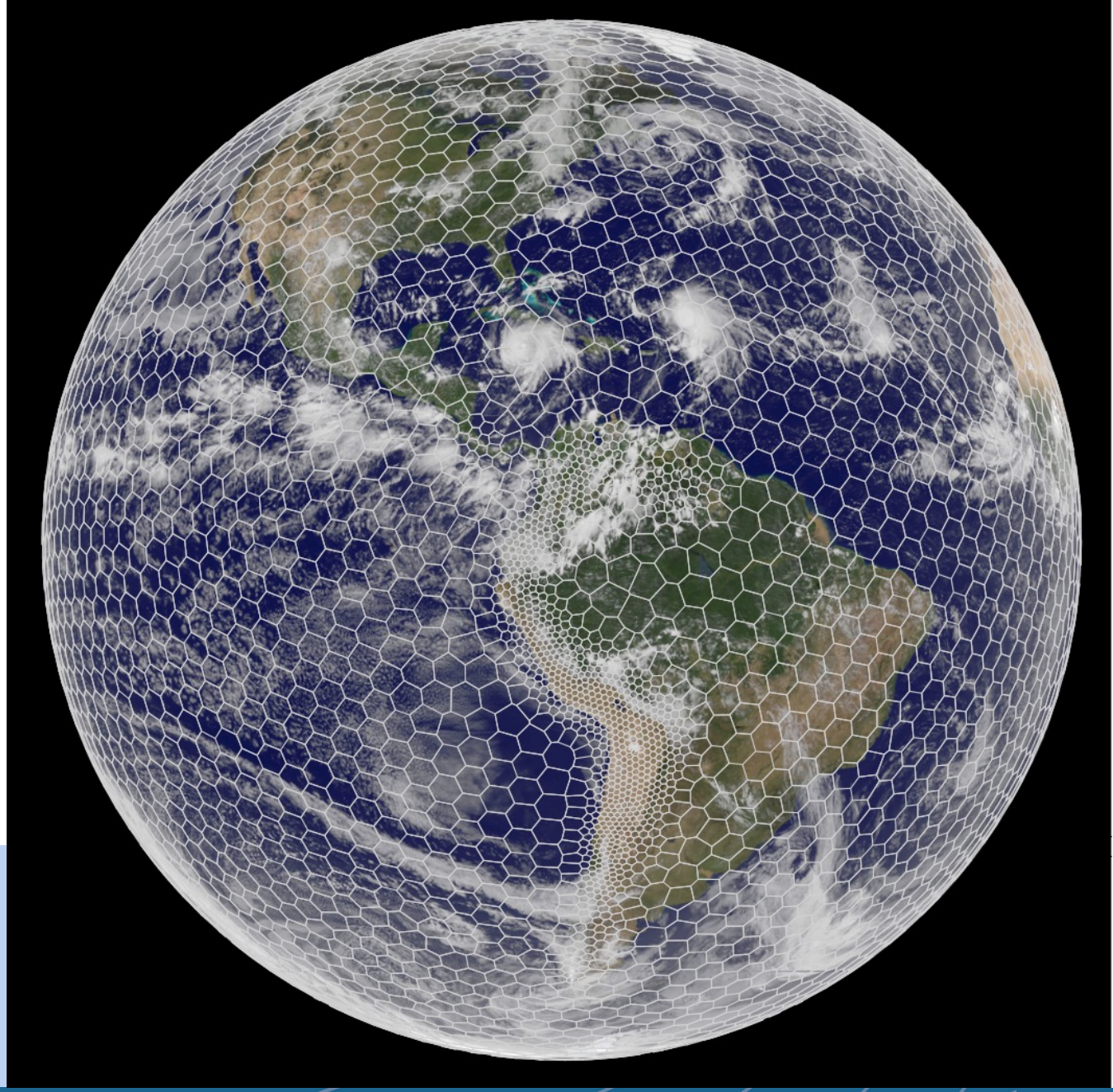
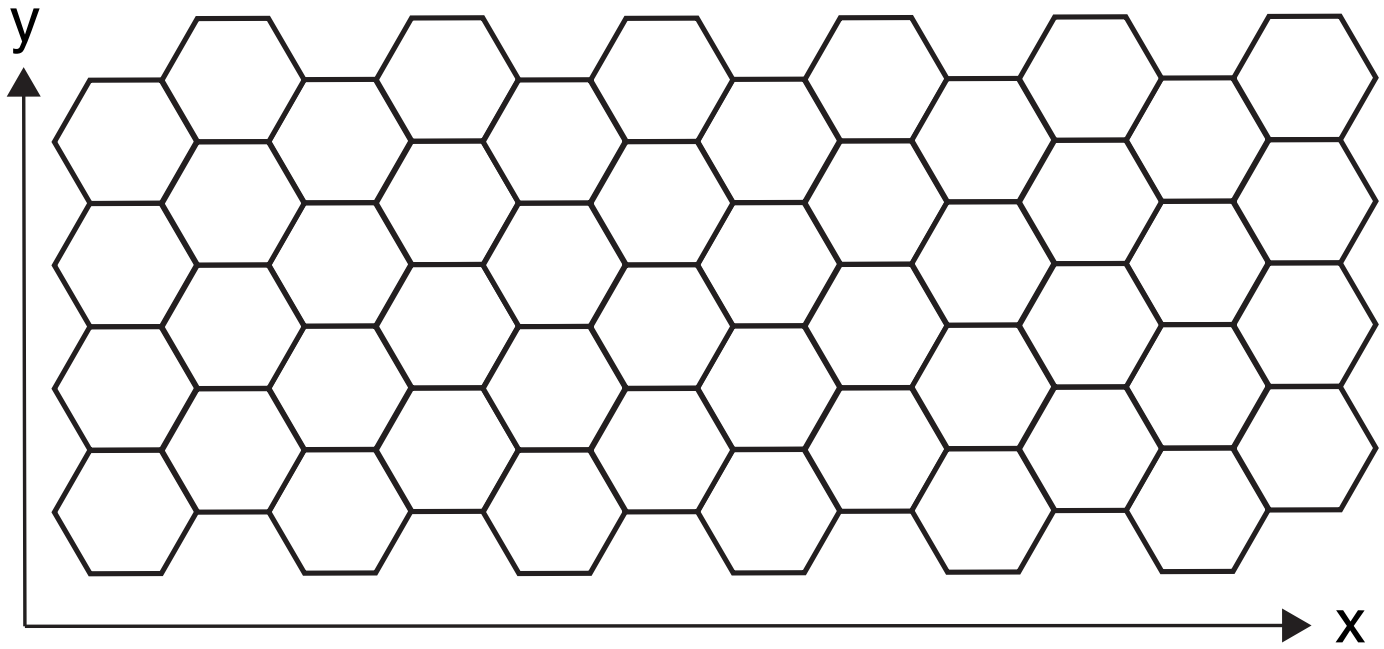


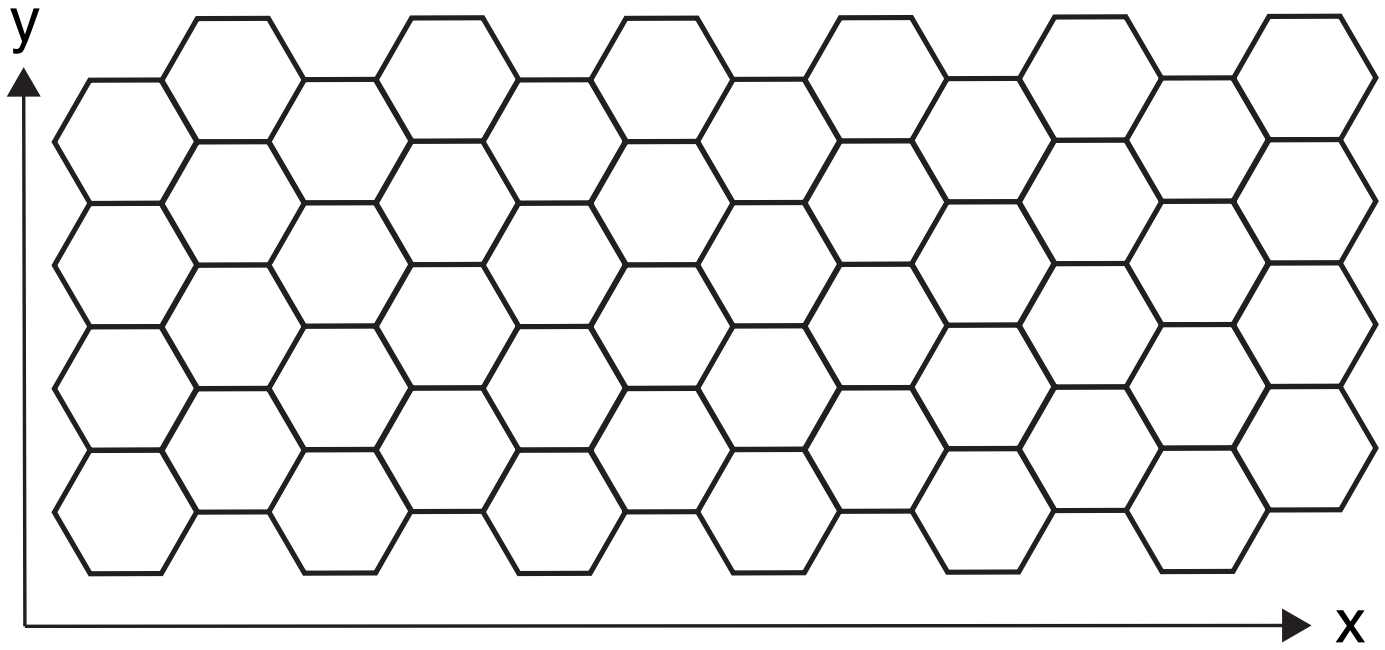
Andes refinement

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
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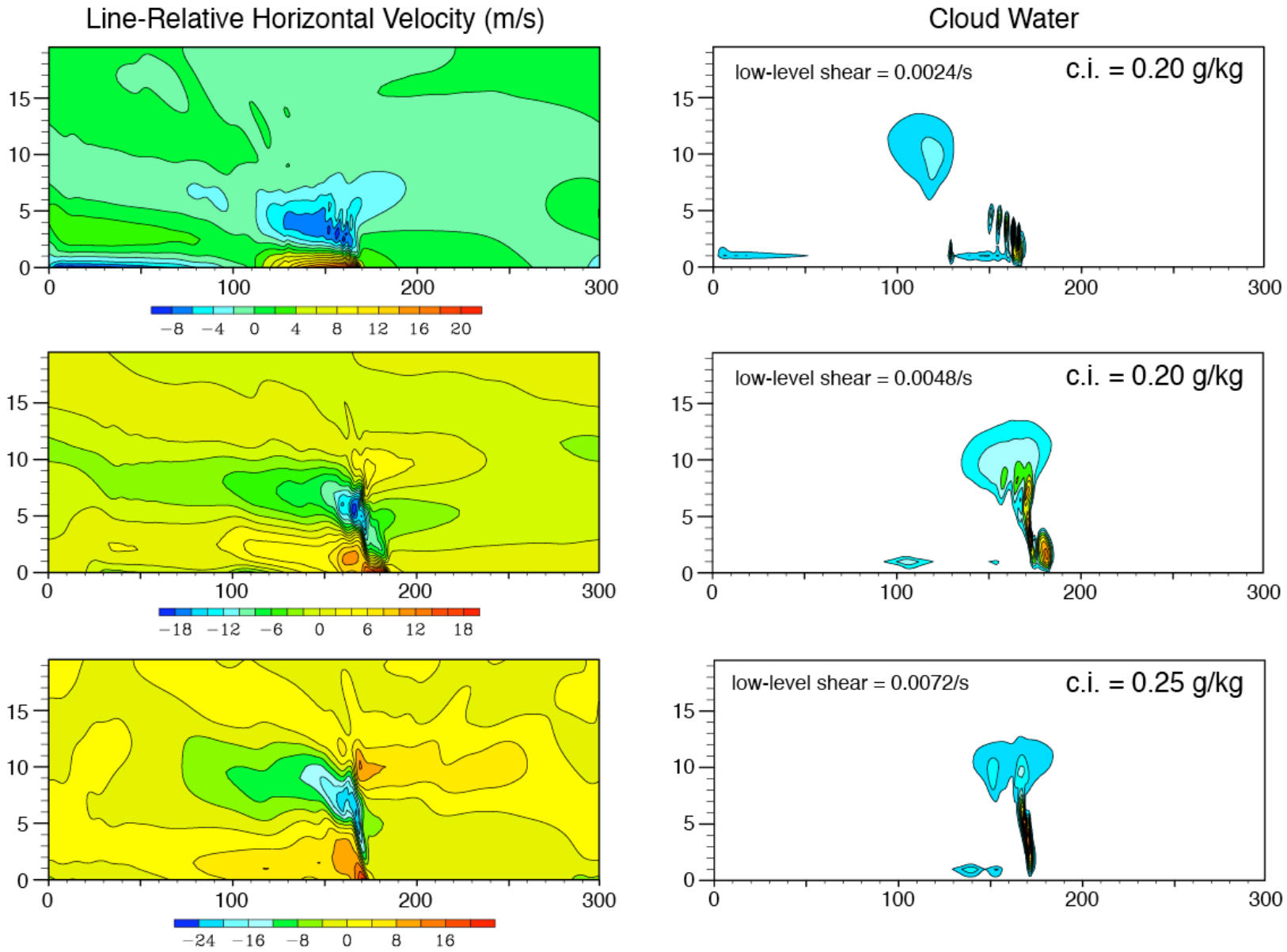
Squall-Line Tests 2D (x,z)

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



Next Up…

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