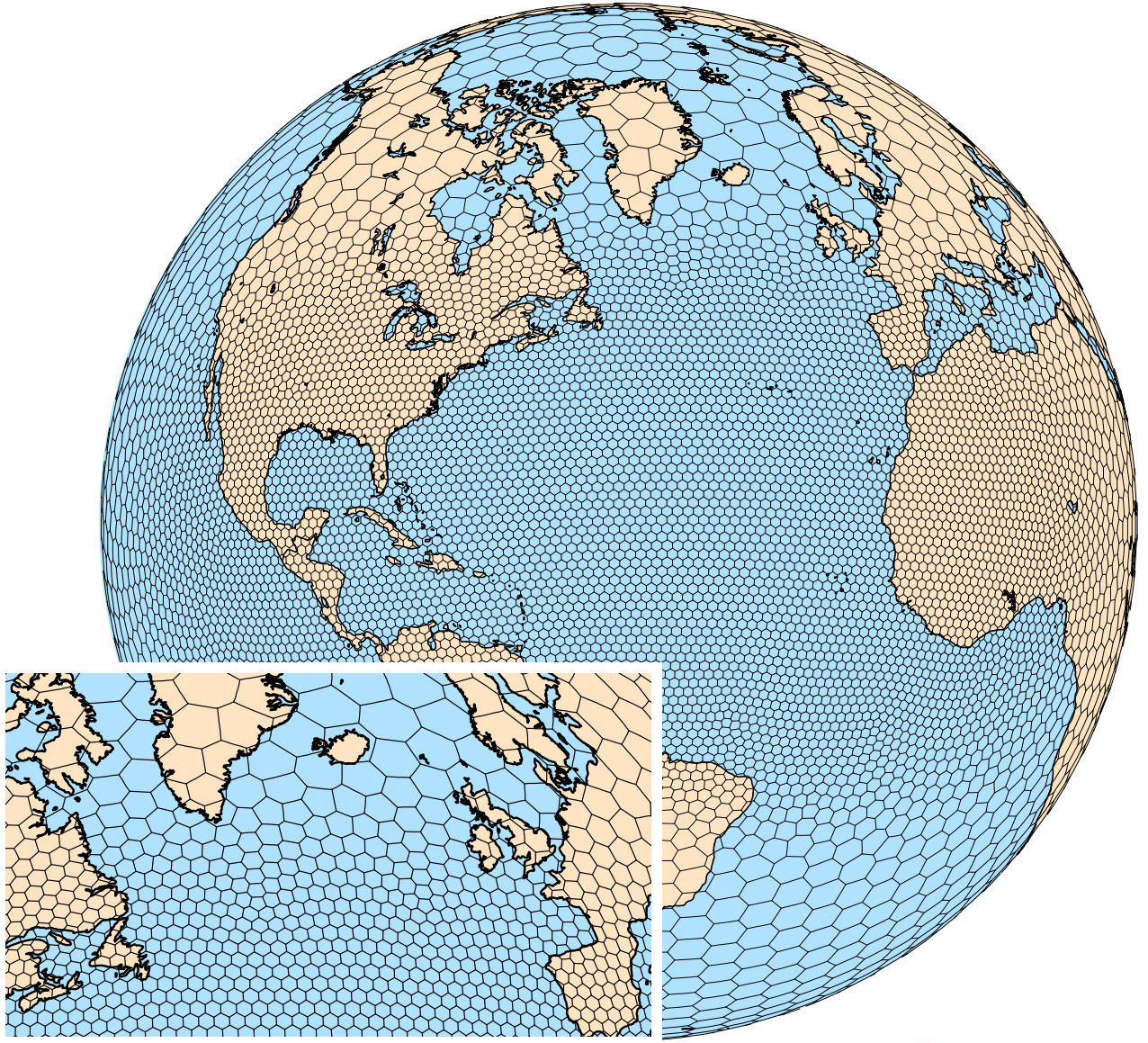
MPAS
Model for Prediction Across Scales

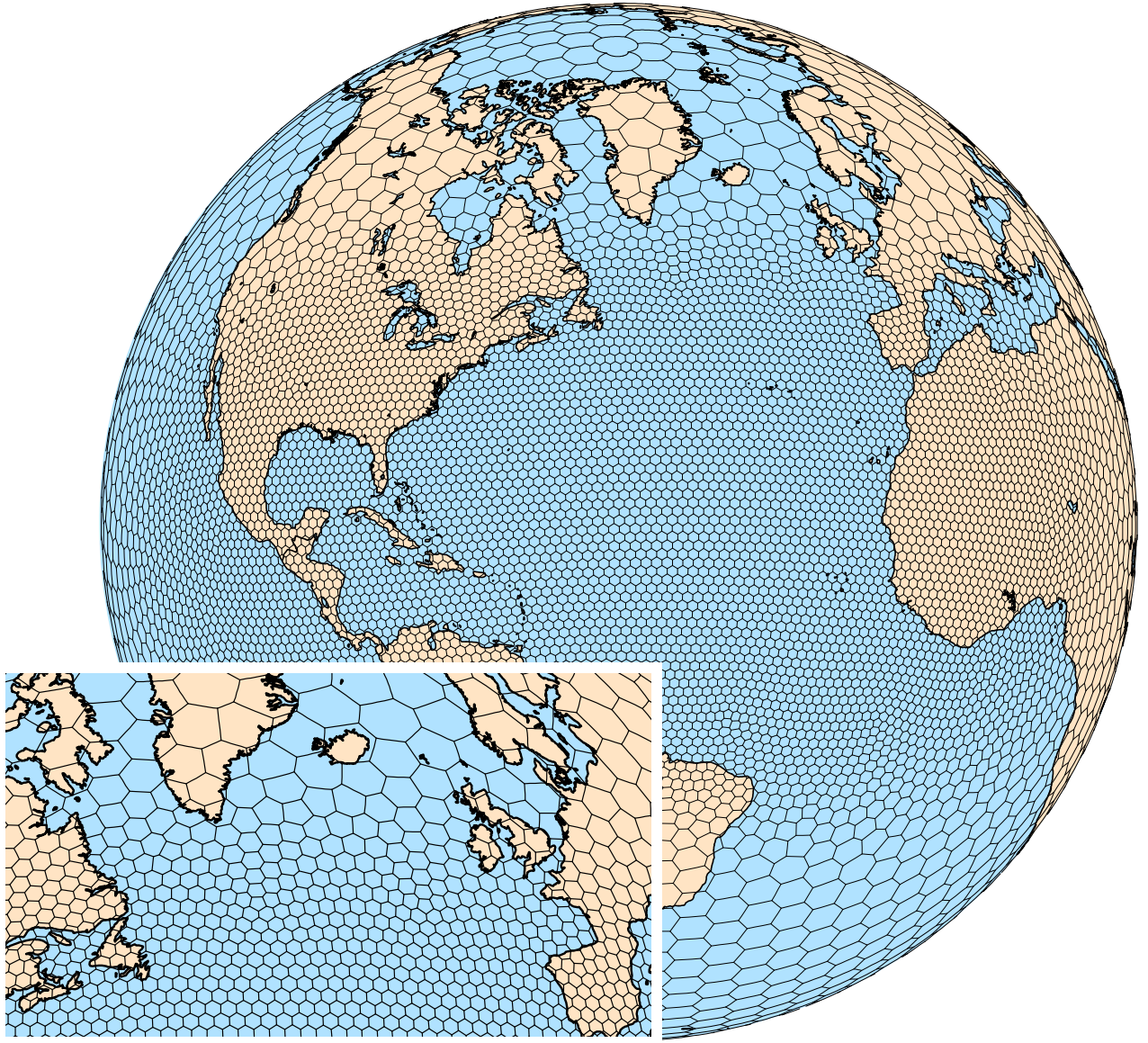
Based on unstructured centroidal Voronoi (hexagonal) meshes using C-grid staggering and selective grid refinement.



Welcome to the MPAS-A Tutorial

MPAS

Model for Prediction Across Scales



There are 4 instructors for this tutorial:

Ming Chen
Michael Duda
Bill Skamarock
May Wong

Please feel free to ask questions!

Welcome to the MPAS Tutorial

Monday, 23 June:

8:30 – 09:00 Registration
09:00 – 9:30 Welcome and Introductions
9:30 – 9:50 (20 mins), MPAS Overview
9:50 – 10:10 (20 mins), MPAS-A System Requirements and Installation
10:10 – 11:05 (55 mins), Running MPAS, part 1: Creating ICs and running a basic global simulation
11:05 – 11:20 (15 mins), **Break**
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15:15 – 15:45 (30 mins), Running MPAS, part 2: Variable-resolution, I/O streams, restarts, and other options
15:45 – 17:30 (105 mins), Practical session

Welcome to the MPAS Tutorial

Tuesday, 24 June:

9:00 – 9:30 (30 mins), An overview of the structure of MPAS meshes
9:30 – 10:00 (30 mins), Running MPAS, part 3: Preparing limited-area meshes and LBCs
10:00 – 10:30 (30 mins), Post-processing and visualizing MPAS-Atmosphere output
10:30 – 10:45 (15 mins), **Break**
10:45 – 11:25 (40 mins), Spatial discretization, filters and transport
11:25 – 11:50 (25 mins), Unique aspects of MPAS code: Registry, pools, and logging
11:50 – 12:15 (25 mins), Adding passive tracers to MPAS-Atmosphere simulations
12:15 – 13:30, **Lunch**
13:30 – 13:55 (25 mins), Computing new diagnostic fields in MPAS-Atmosphere simulations
13:55 – 15:20 (85 mins), Practical session
15:20 – 15:35 (15 mins), **Break**
15:35 – 17:00 (85 mins), Practical session

Welcome to the MPAS Tutorial

Wednesday, 25 June (morning):

9:00 – 9:30 (30 mins), MPAS mesh generation
9:30 – 9:55 (25 mins), New MPAS capabilities under development, and concluding remarks
9:55 – 10:45 (50 mins), Practical session
10:45 – 11:00 (15 mins), **Break**
11:00 – 12:00 (60 mins), Practical session
12:00 – 13:00, **Lunch**

— MPAS-JEDI course —

MPAS
Model for Prediction Across Scales

What is MPAS?
Freely available modeling system

MPAS Version 8.3.0 (2 June 2025):

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

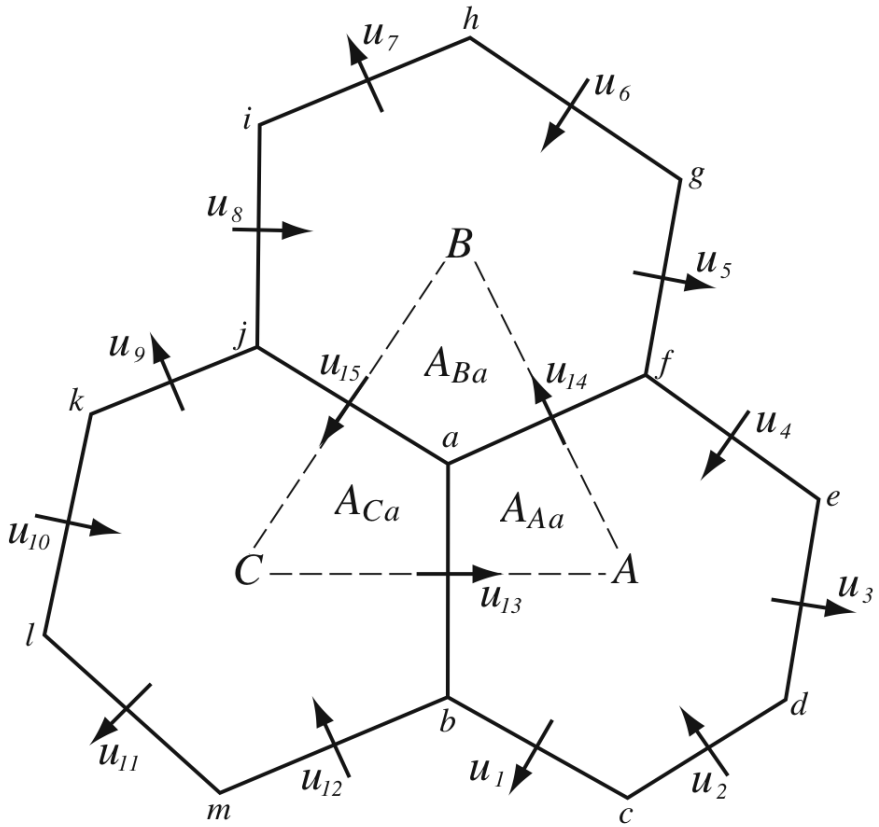
These are all stand-alone models – there is no coupler in MPAS

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.



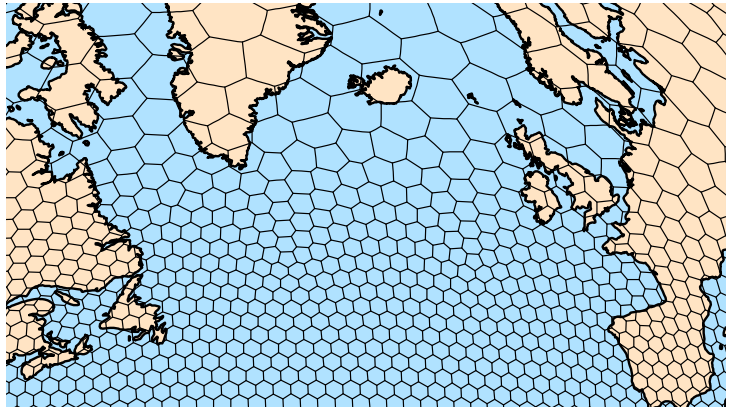
C-grid

- 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.

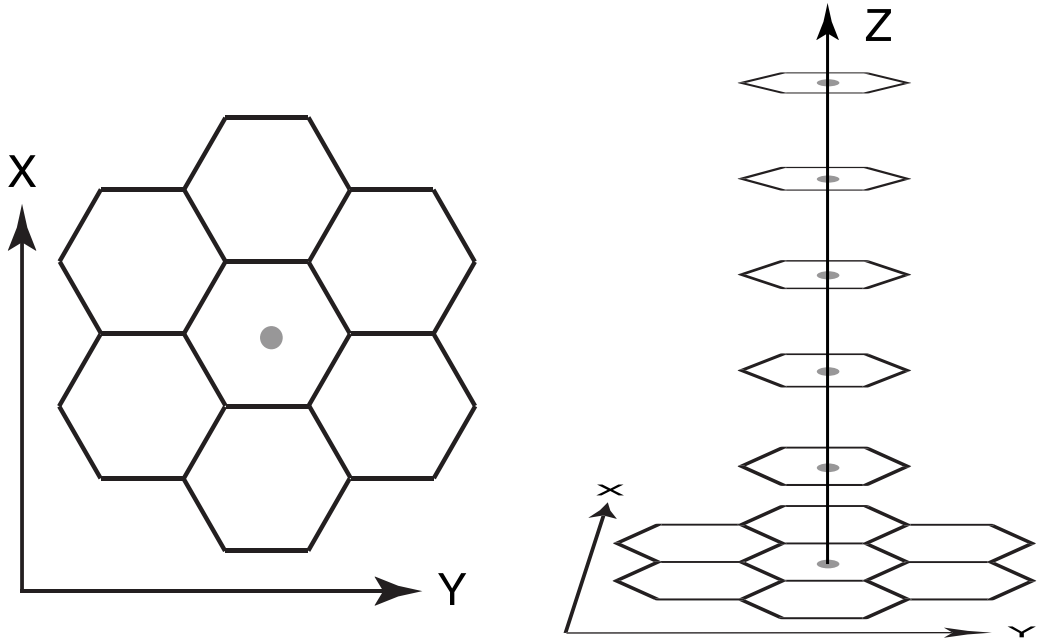
MPAS
Model for Prediction Across Scales

What is MPAS?
Centroidal Voronoi Meshes

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



The mesh is
structured in the
vertical



MPAS
Model for Prediction Across Scales

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

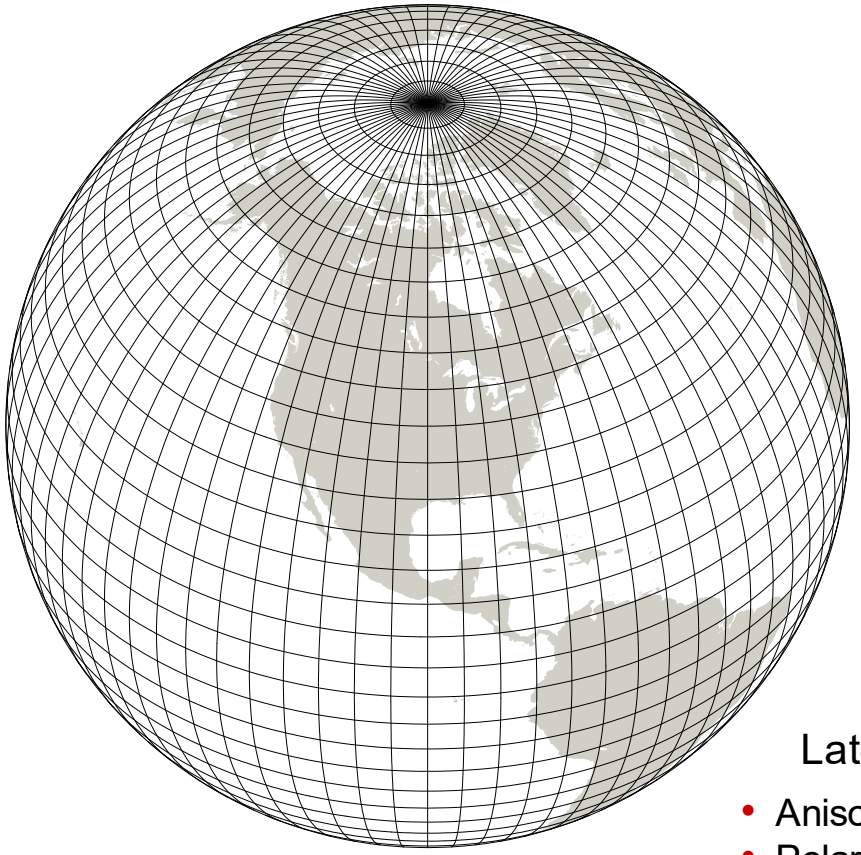
Full complement of atmospheric-model physics

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

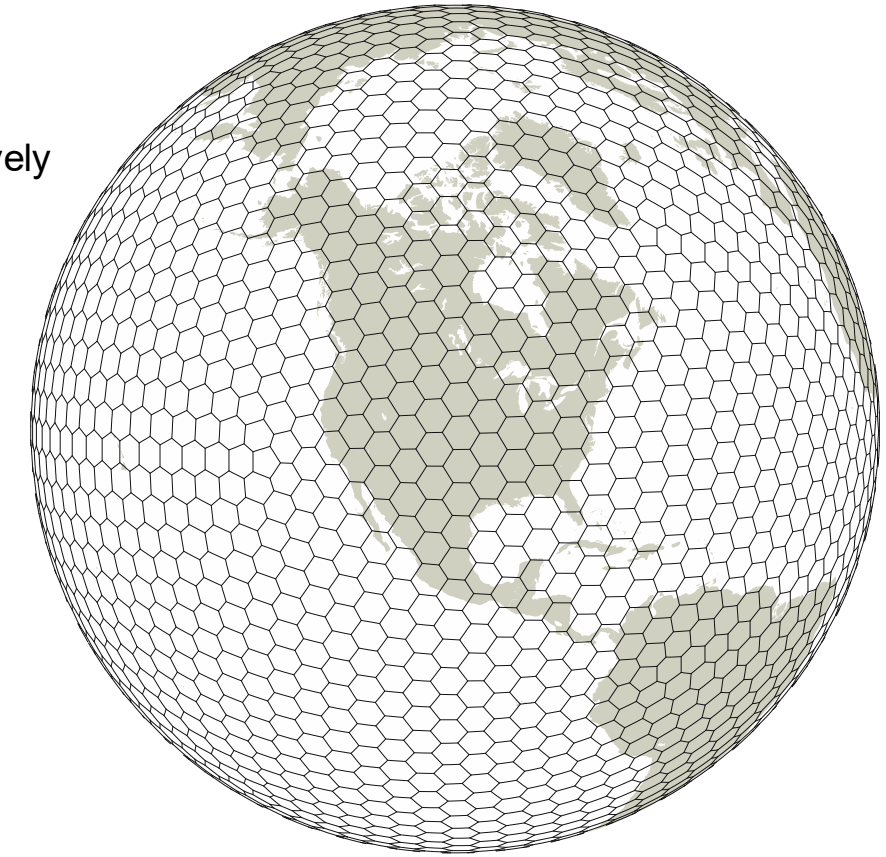


WRF
Lat-Lon global grid

- 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



MPAS
Model for Prediction Across Scales

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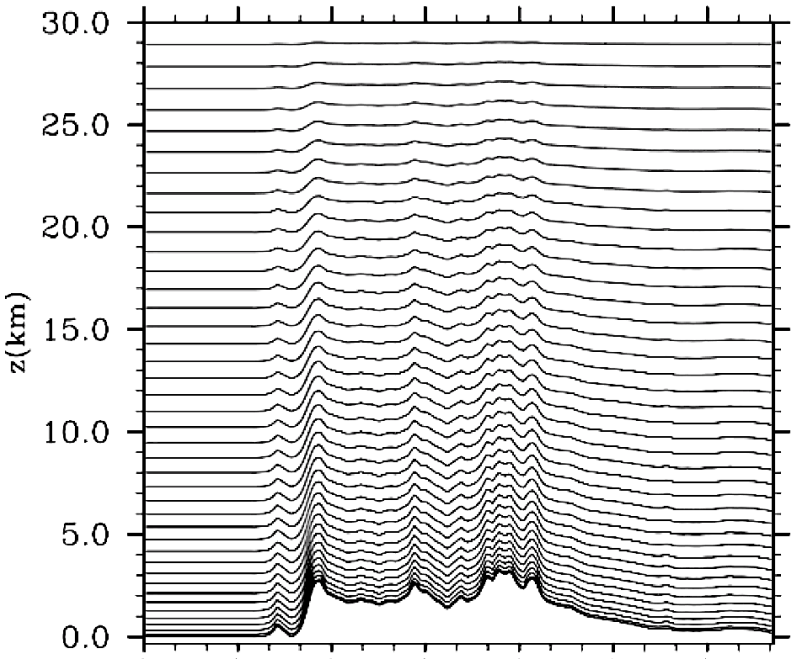
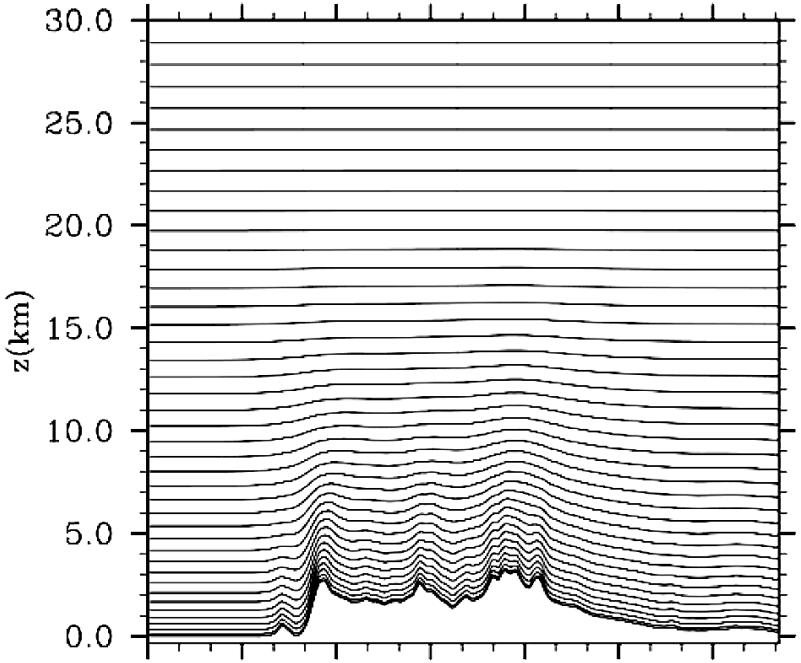


WRF
Pressure-based
terrain-following sigma
vertical coordinate



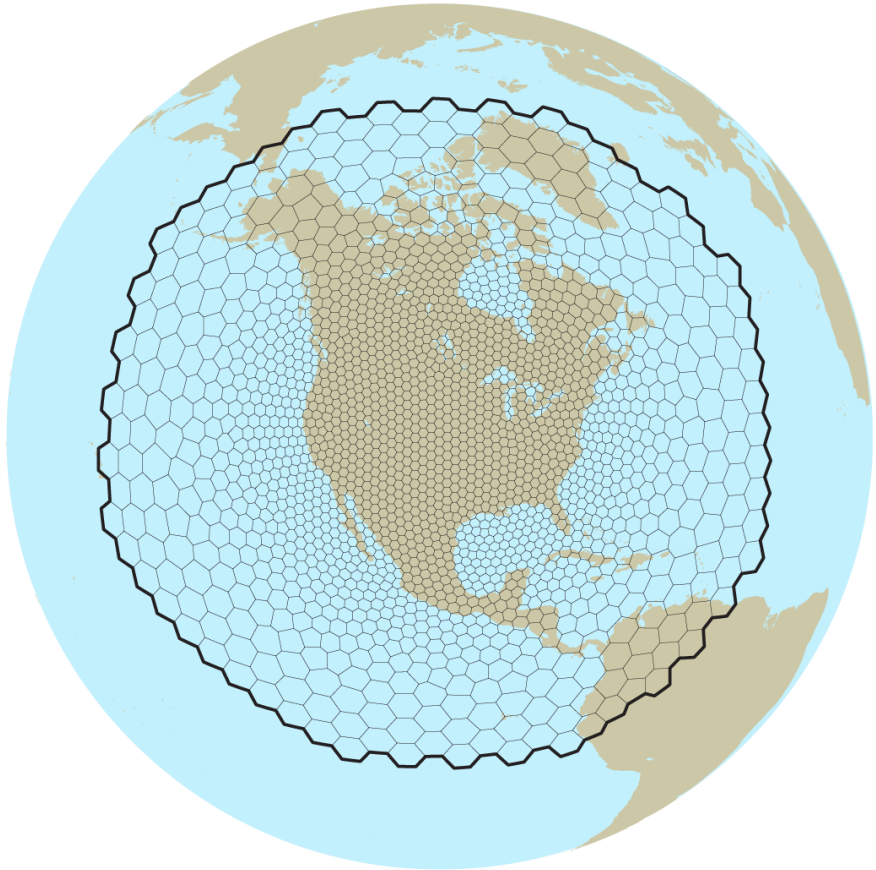
MPAS
Height-based hybrid smoothed
terrain-following vertical
coordinate

MPAS
Model for Prediction Across Scales

Regional MPAS

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
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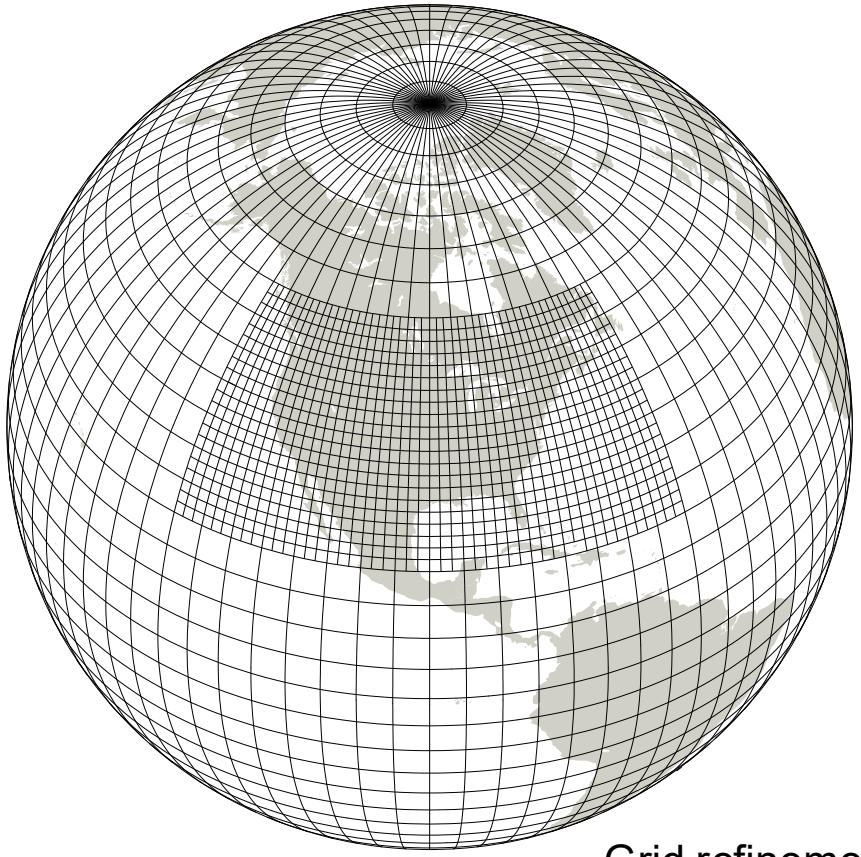
Why MPAS?

Significant differences between WRF and MPAS



WRF

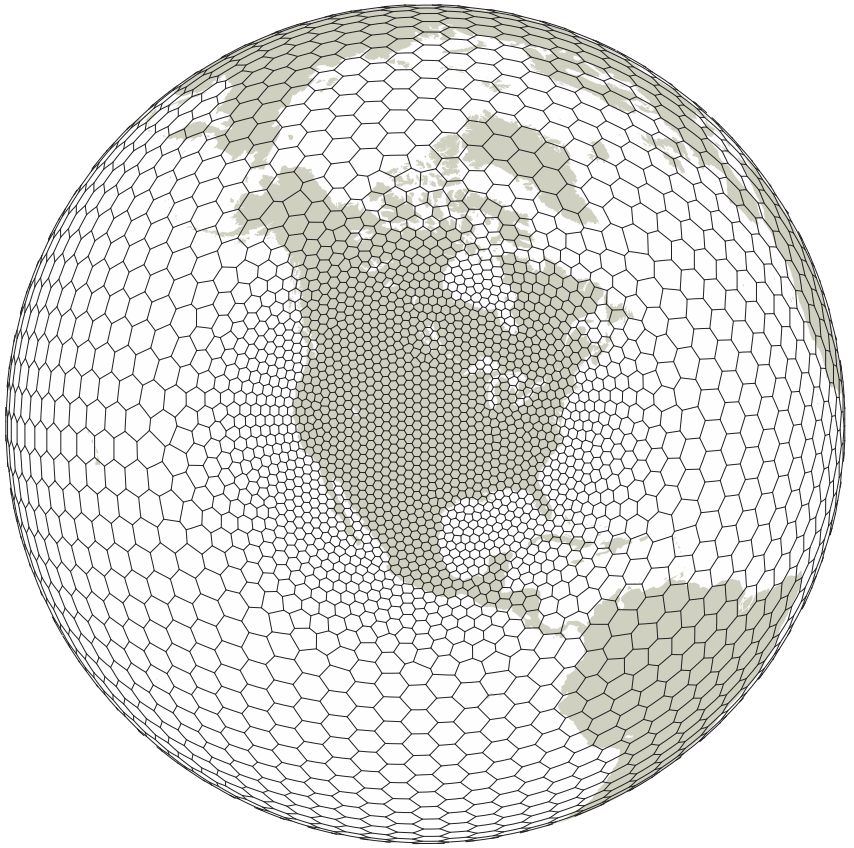
Grid refinement through domain nesting

- Flow distortions at nest boundaries

MPAS

Smooth grid refinement on a conformal mesh

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



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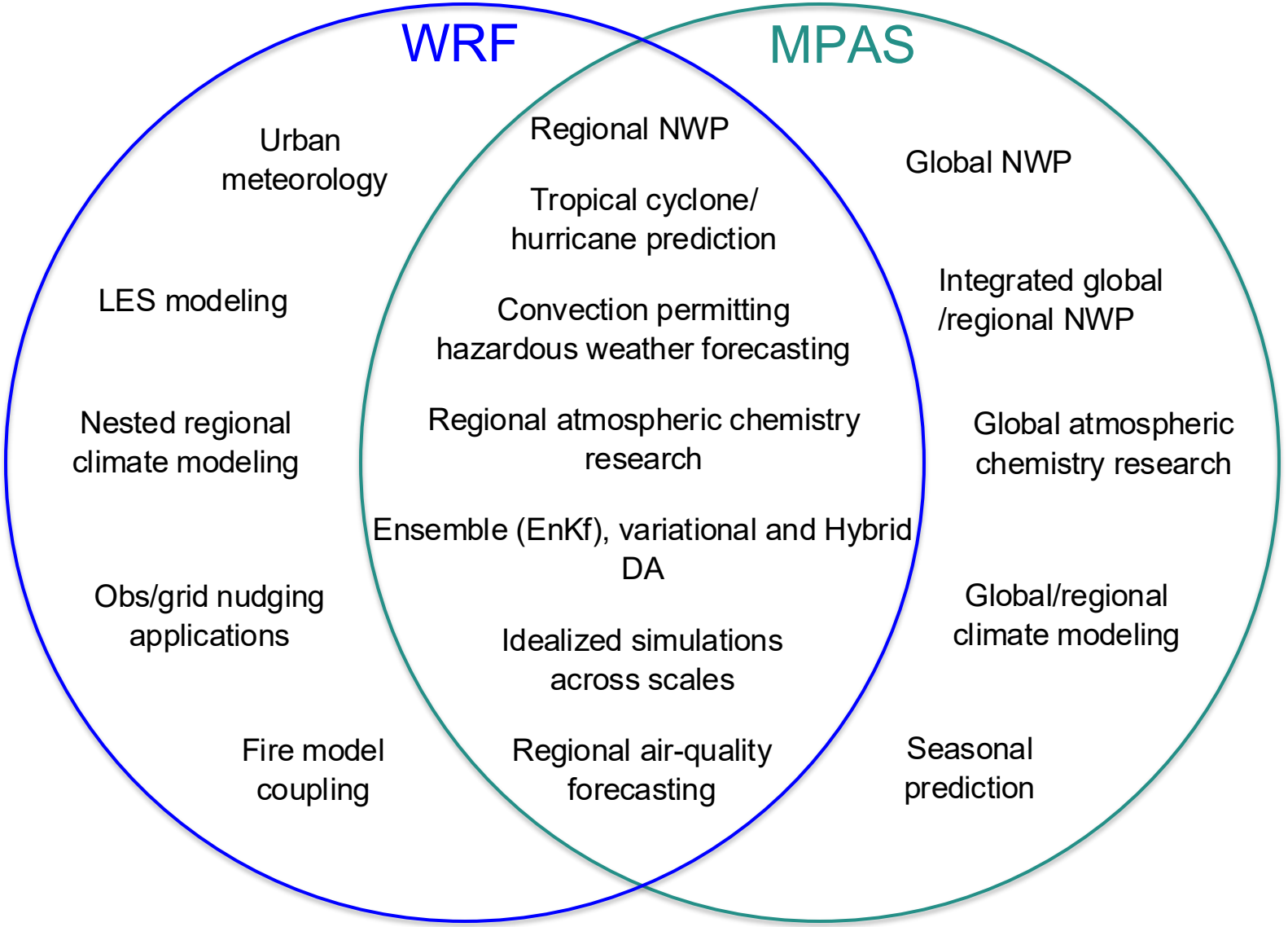

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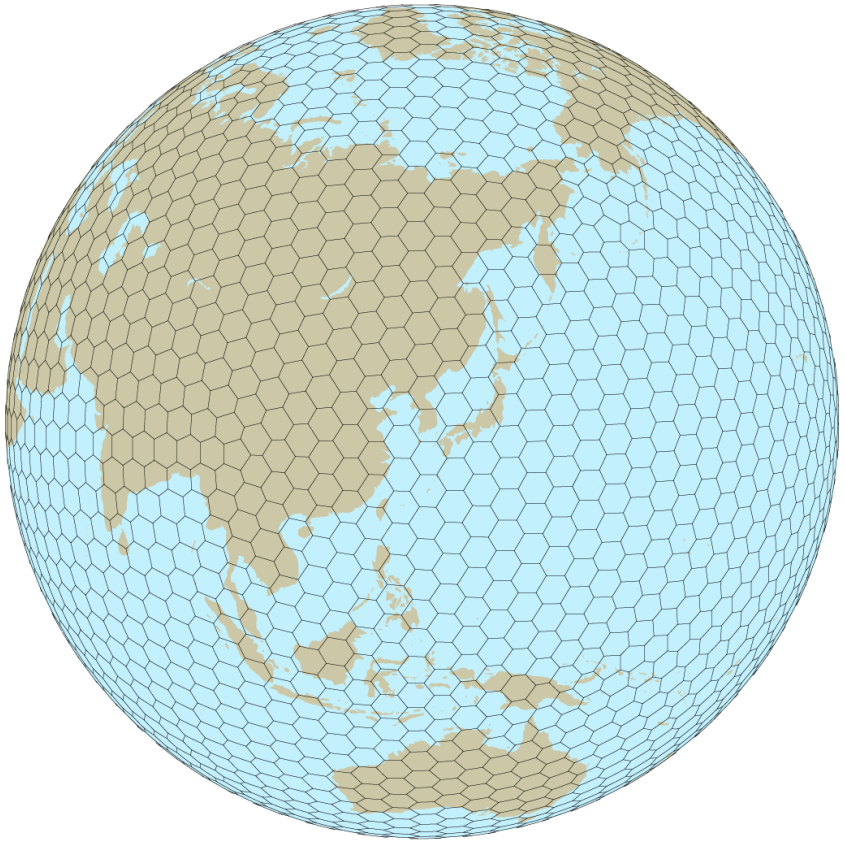
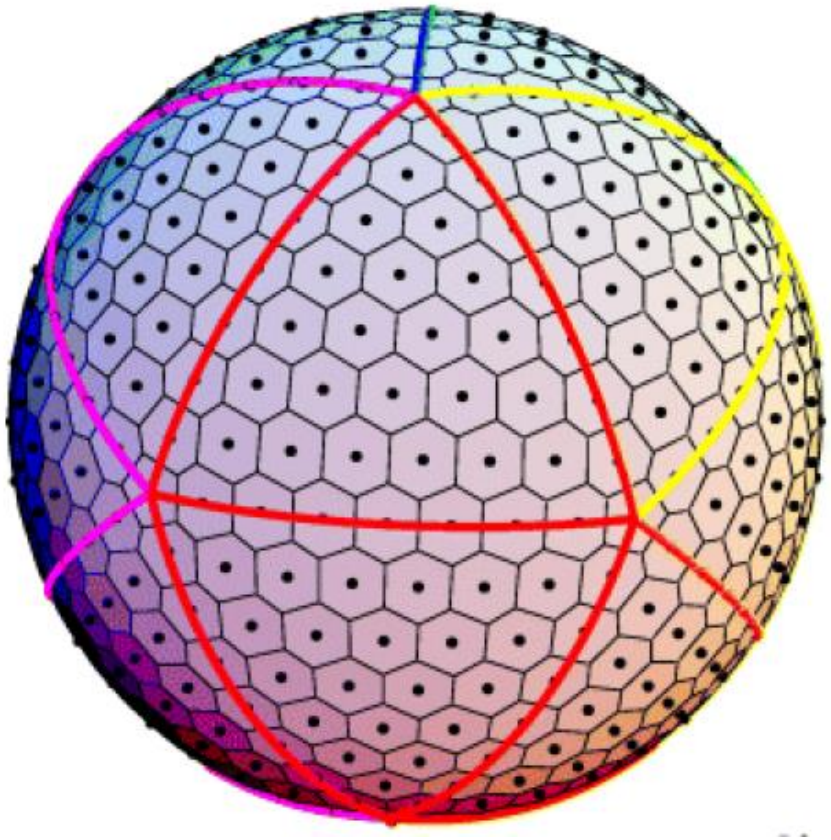


Global Quasi-Uniform Mesh (SCVT)

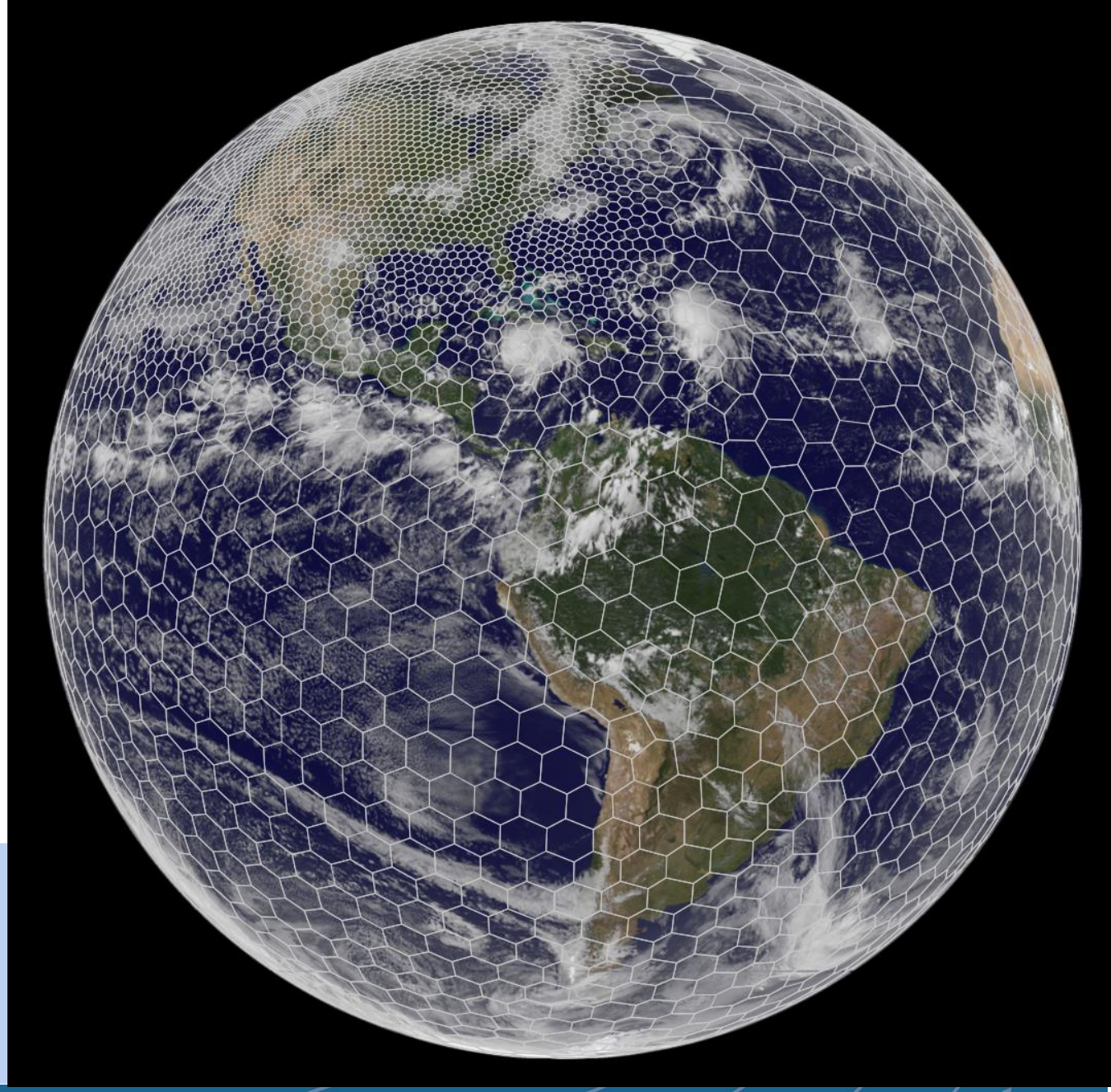


Many models use an icsoahedral mesh (NICAM, BUGS, FIM, NIM, OLAM, etc.)

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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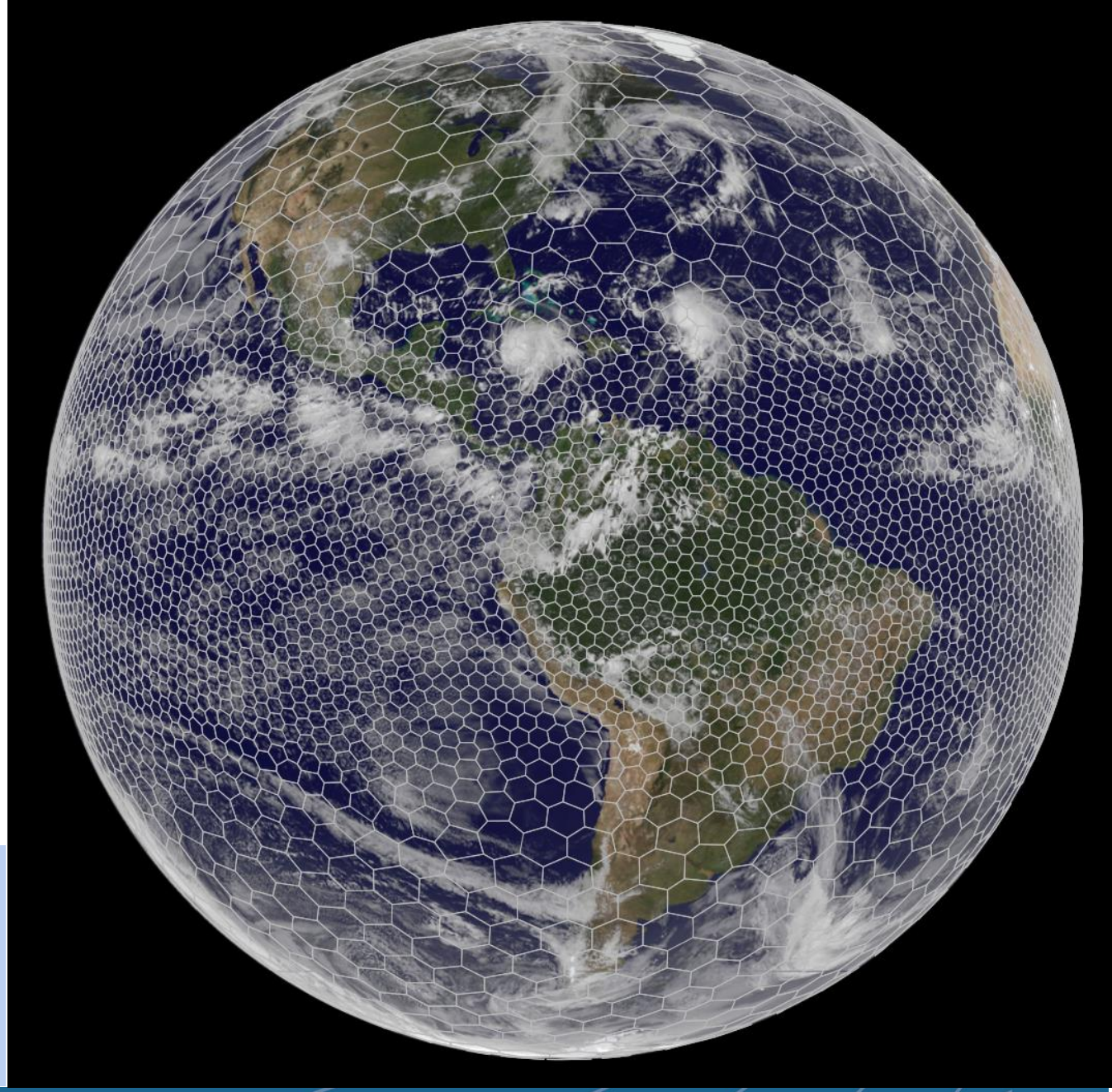
Equatorial refinement



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Mesh generation

Lloyd's method
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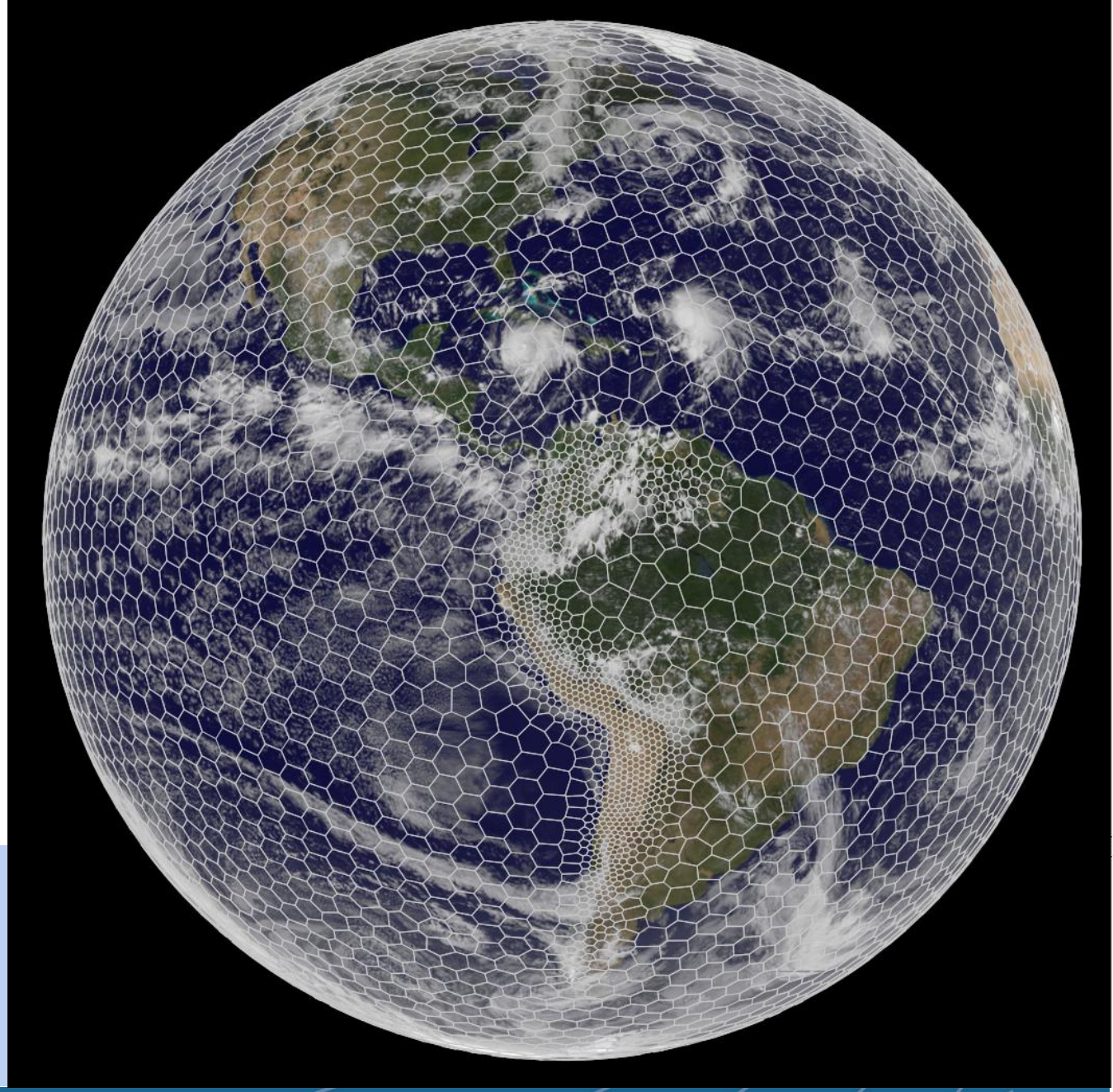
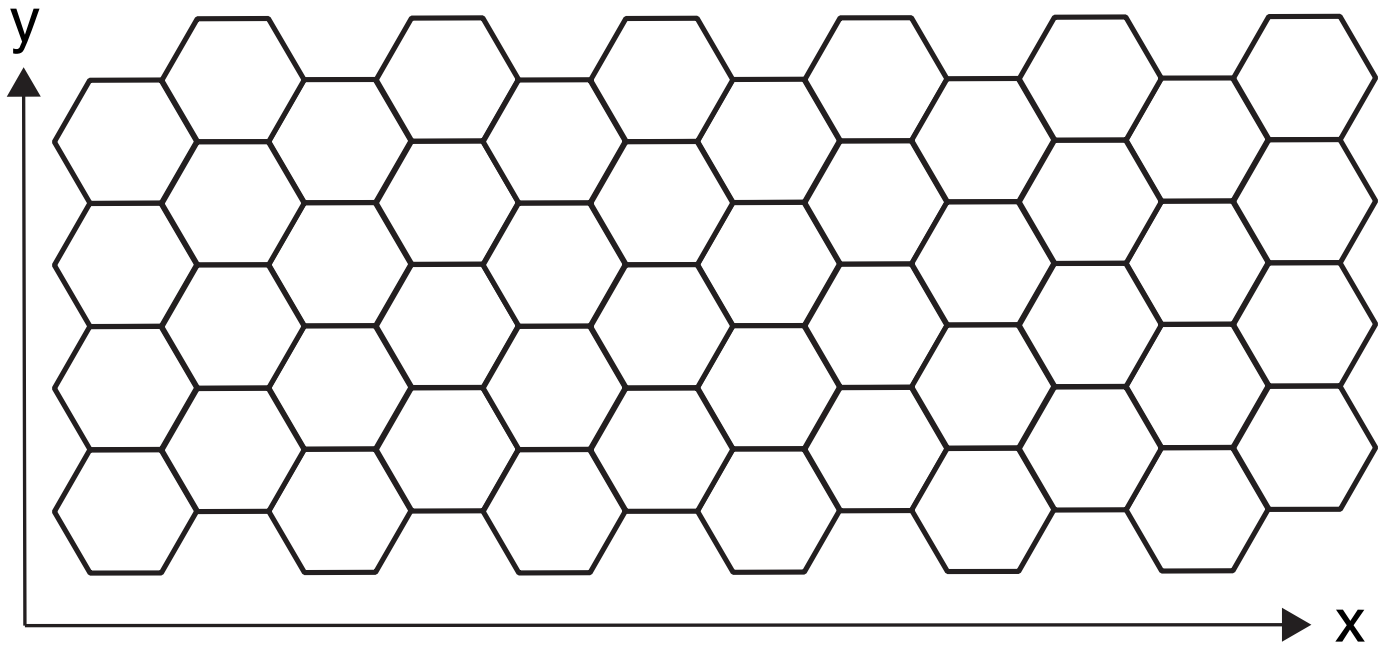


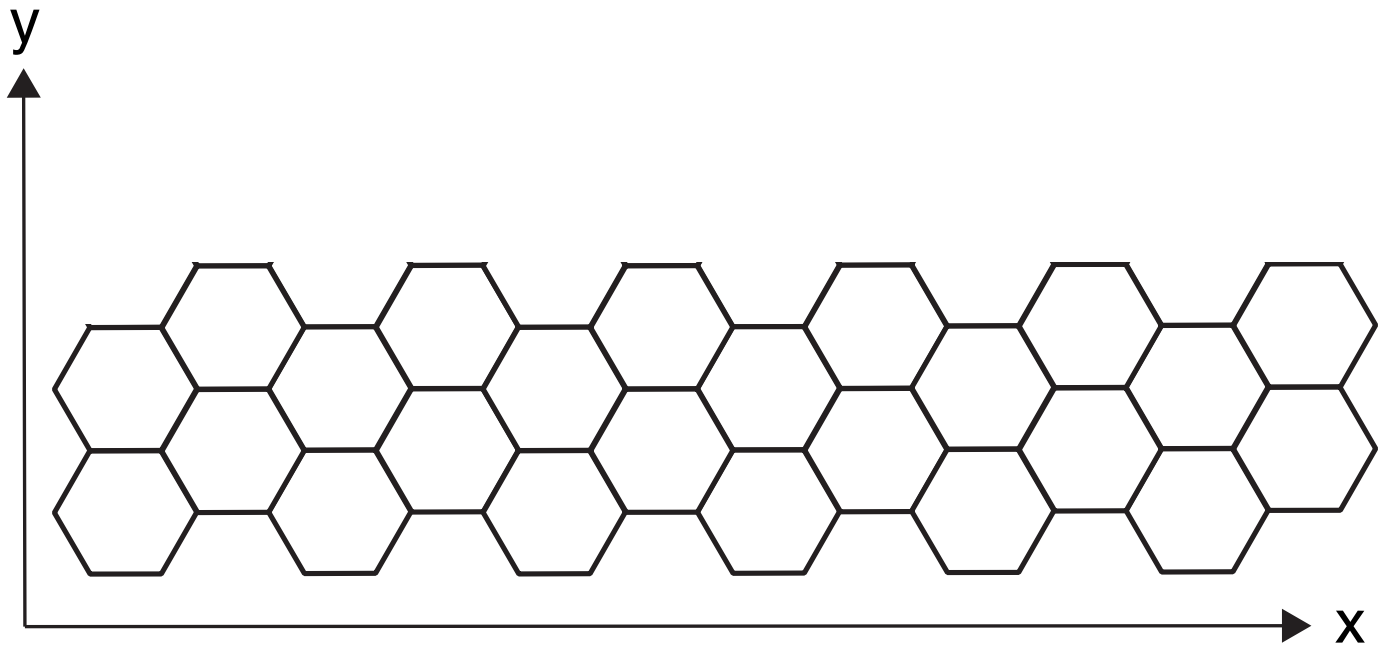
Andes refinement

Other mesh spaces



Doubly-periodic Cartesian mesh

Other mesh spaces

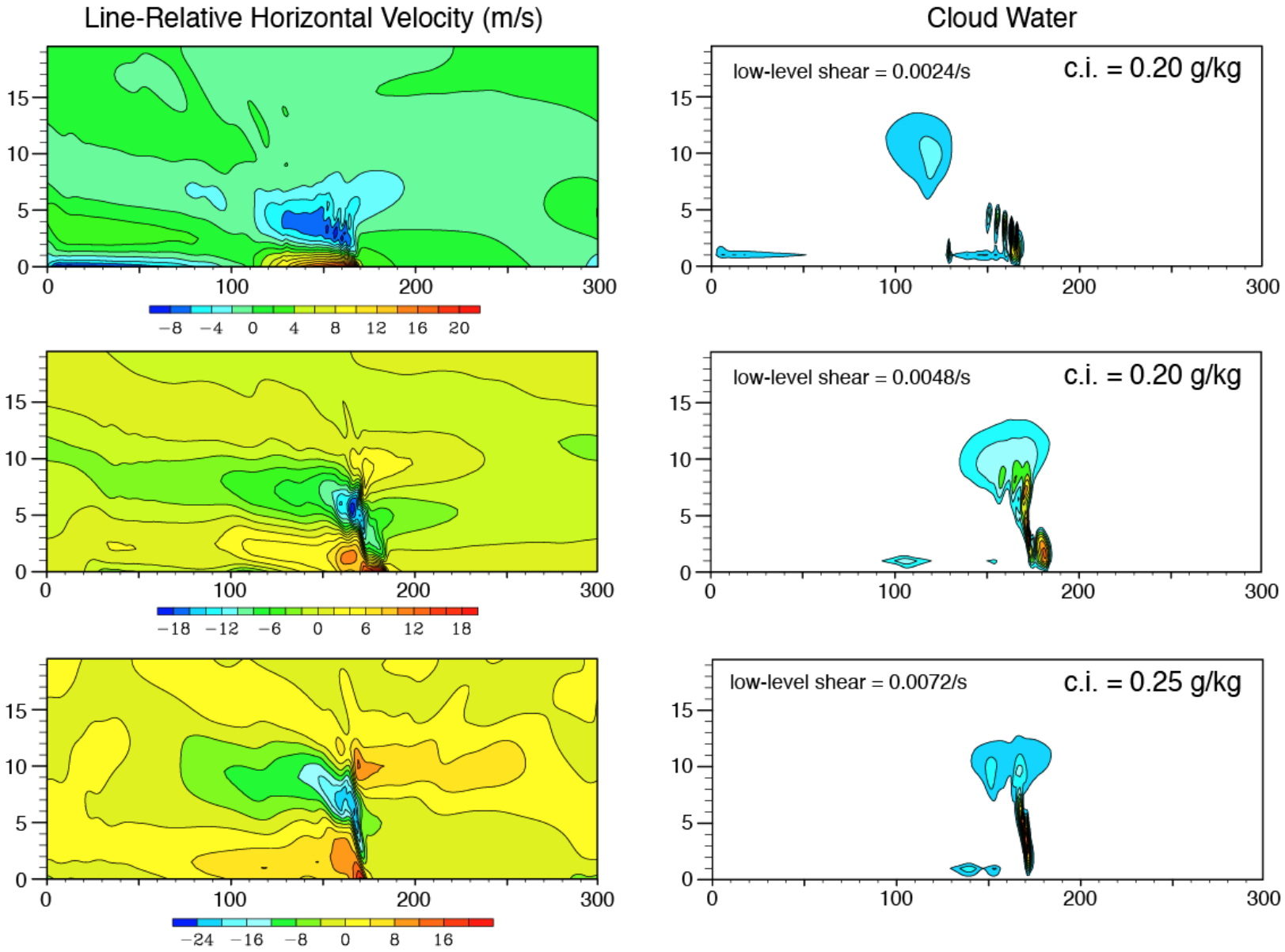


2D (y,z) mesh in MPAS
The solution does not vary in y, periodic in y

MPAS
Model for Prediction Across Scales

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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