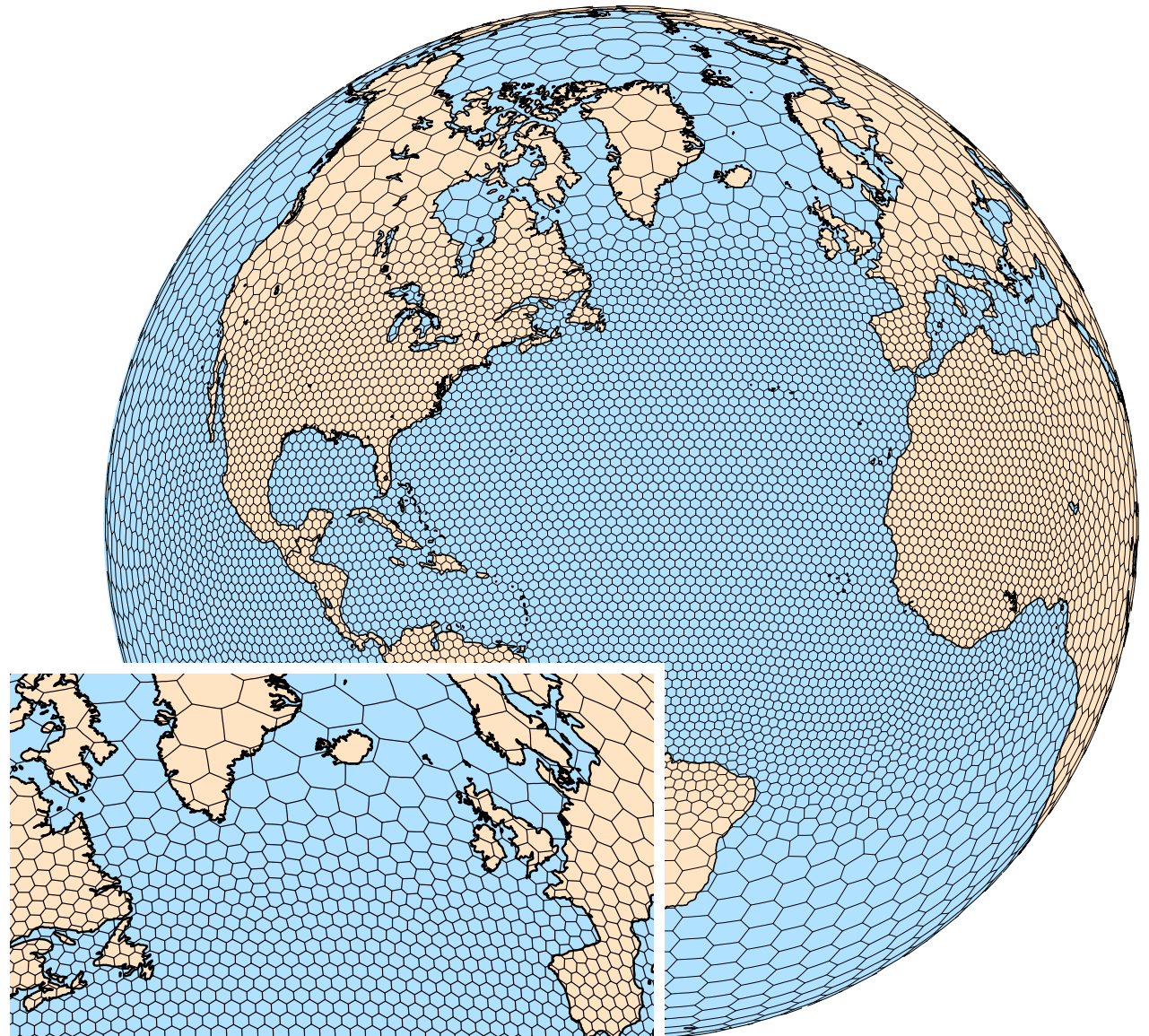


MPAS

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



Welcome to the MPAS Tutorial

There are 5 instructors for this tutorial:

Ming Chen
Michael Duda
Bill Skamarock
Wei Wang
May Wong

Please feel free to ask questions

During the lectures – raise your *virtual* hand or put your question in the chat.
We will give you instructions about how we will interact during the Practical Sessions.

Please keep your microphone muted if you are not speaking

Welcome to the MPAS Tutorial

Please note that all times are US Mountain Daylight Time (UTC-6)

Monday, 07 April 2025:

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

11:05 – 11:20 (15 mins), Break

11:20 – 11:30 (10 mins), Introduction to the practical exercises

11:30 – 12:30 (60 mins), Practical session

12:30 – 13:30, Lunch

13:30 – 14:00 (30 mins), Running MPAS, part 2: Variable-resolution, I/O streams, restarts, and other options

14:00 – 16:00 (120 mins), Practical session

Welcome to the MPAS Tutorial

Tuesday, 8 April 2025:

9:00 – 9:45 (45 mins), Dynamics and dynamics configuration

9:45 – 10:15 (30 mins), An overview of the structure of MPAS meshes

10:15 – 10:30 (15 mins), Break

10:30 – 11:15 (30 mins), Physics and physics configuration

11:15 – 11:45 (30 mins), Post-processing and visualizing MPAS-Atmosphere output

11:45 – 12:15 (30 mins), Running MPAS, part 3: Preparing limited-area meshes and LBCs

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, 9 April 2025:

9:00 – 9:20 (20 mins), Unique aspects of MPAS code: Registry, pools, and logging

9:20 – 9:50 (30 mins), Adding passive tracers to MPAS-Atmosphere simulations

9:50 – 10:20 (30 mins), Computing new diagnostic fields in MPAS-Atmosphere simulations

10:20 – 10:35 (15 mins), Break

10:35 – 11:15 (40 mins), Spatial discretization, filters and transport

11:15 – 11:35 (20 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

What is MPAS?

Freely available modeling system

MPAS Version 8.2.2 (20 September 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

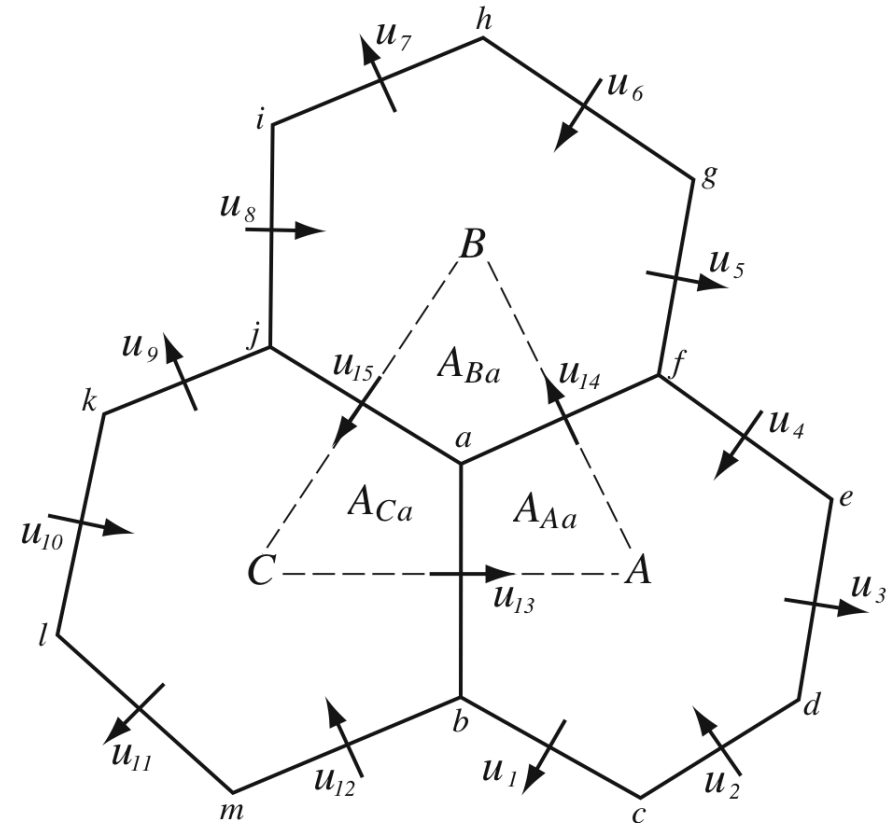
What is MPAS? Centroidal Voronoi Meshes

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.

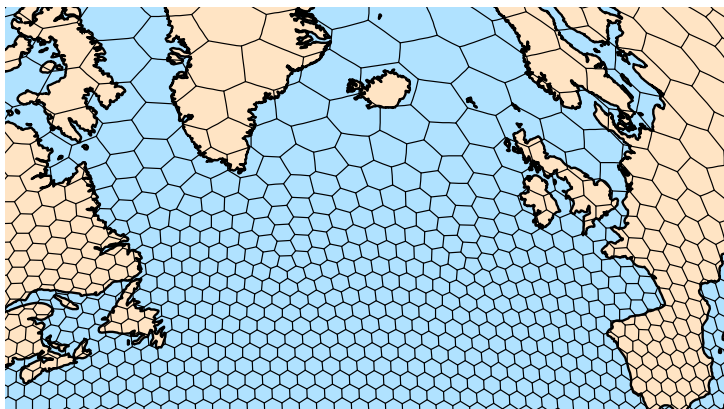
C-grid

- 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.

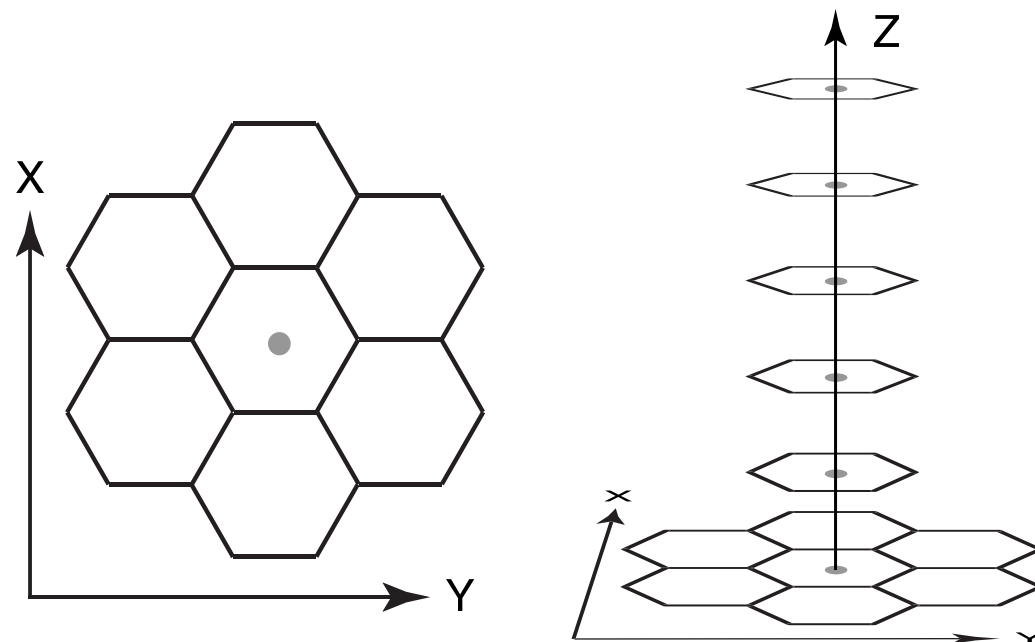


What is MPAS? Centroidal Voronoi Meshes

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

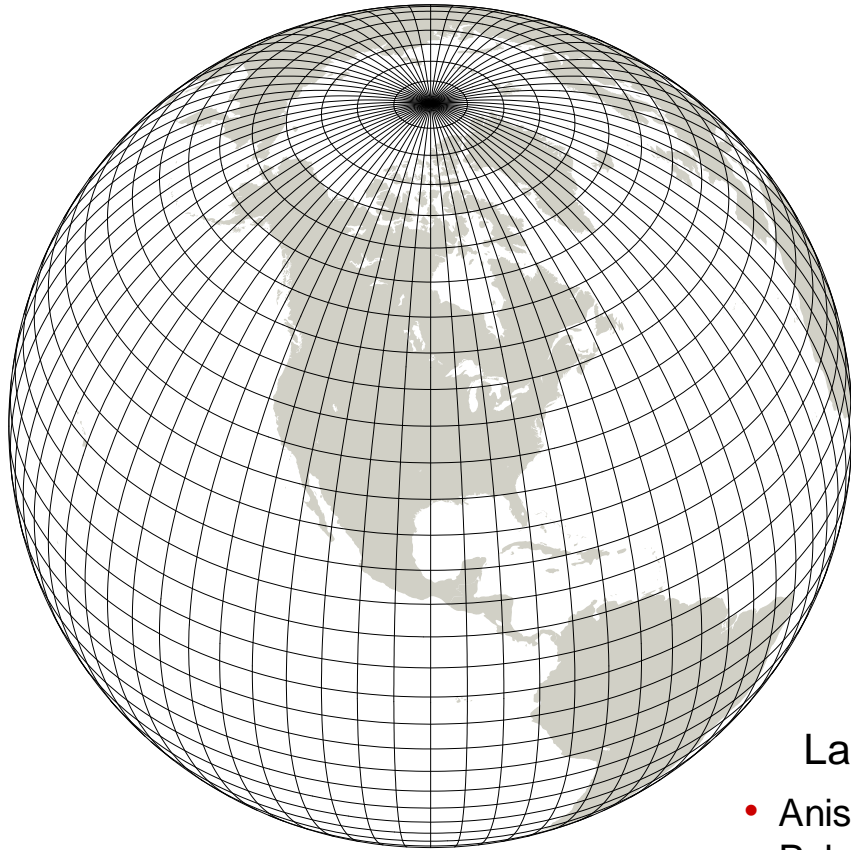
- Split-explicit Runge-Kutta, with extensions

Full complement of atmospheric-model physics

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

Why MPAS?

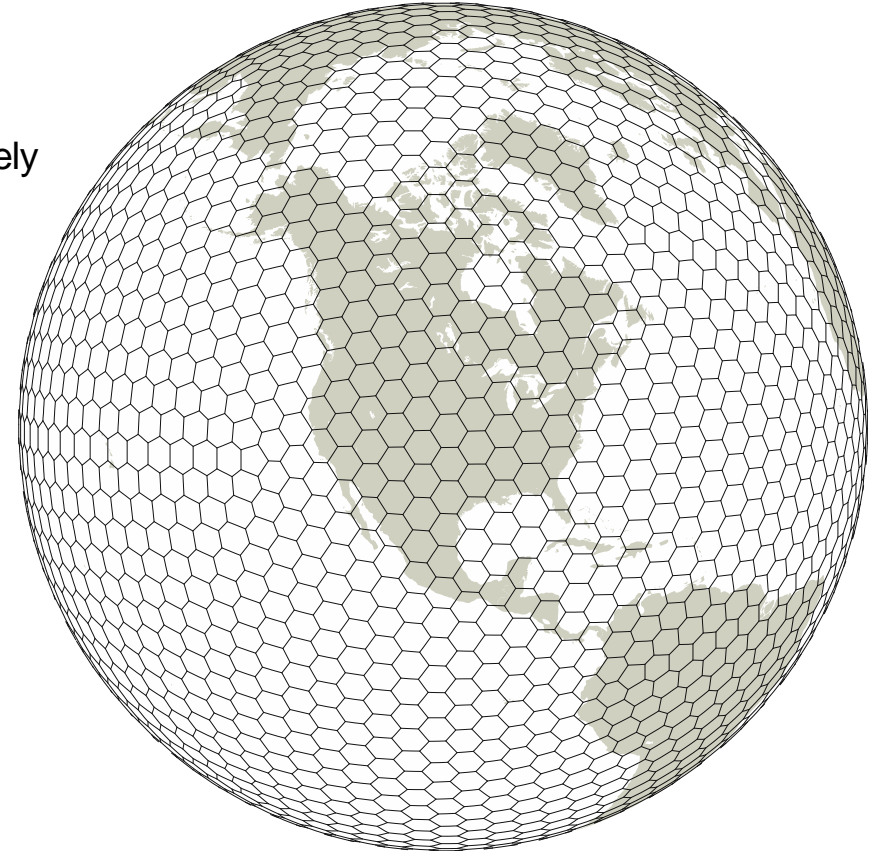
Significant differences between WRF and MPAS



WRF
Lat-Lon global grid

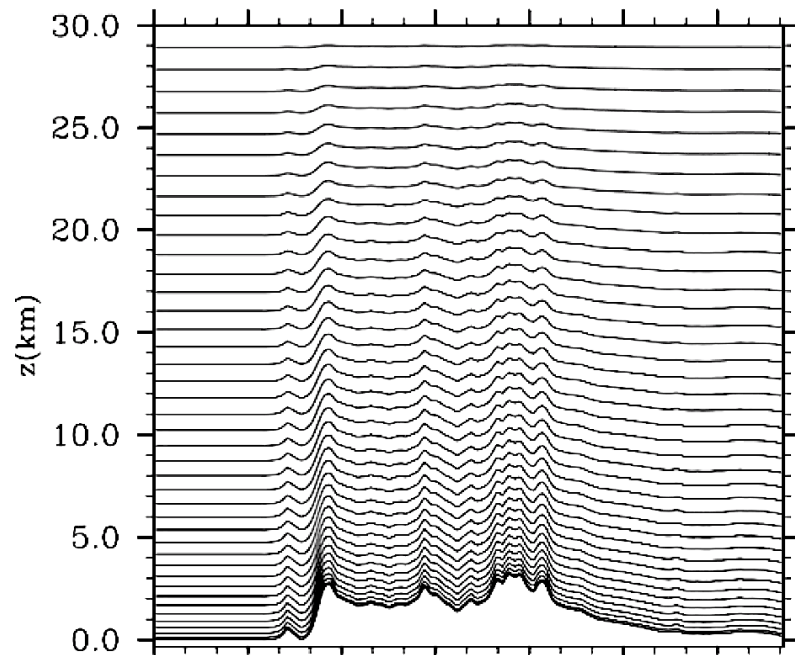
- Anisotropic grid cells
- Polar filtering required
- Poor scaling on massively parallel computers

- MPAS
Unstructured Voronoi
(hexagonal) grid
- Good scaling on massively parallel computers
 - No pole problems

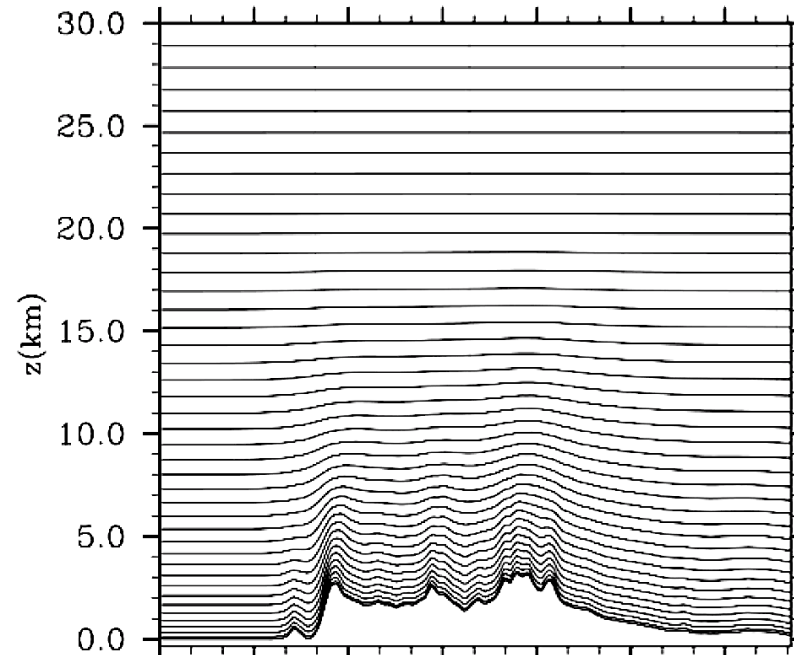


Why MPAS?

Significant differences between WRF and MPAS



WRF
Pressure-based
terrain-following sigma
vertical coordinate

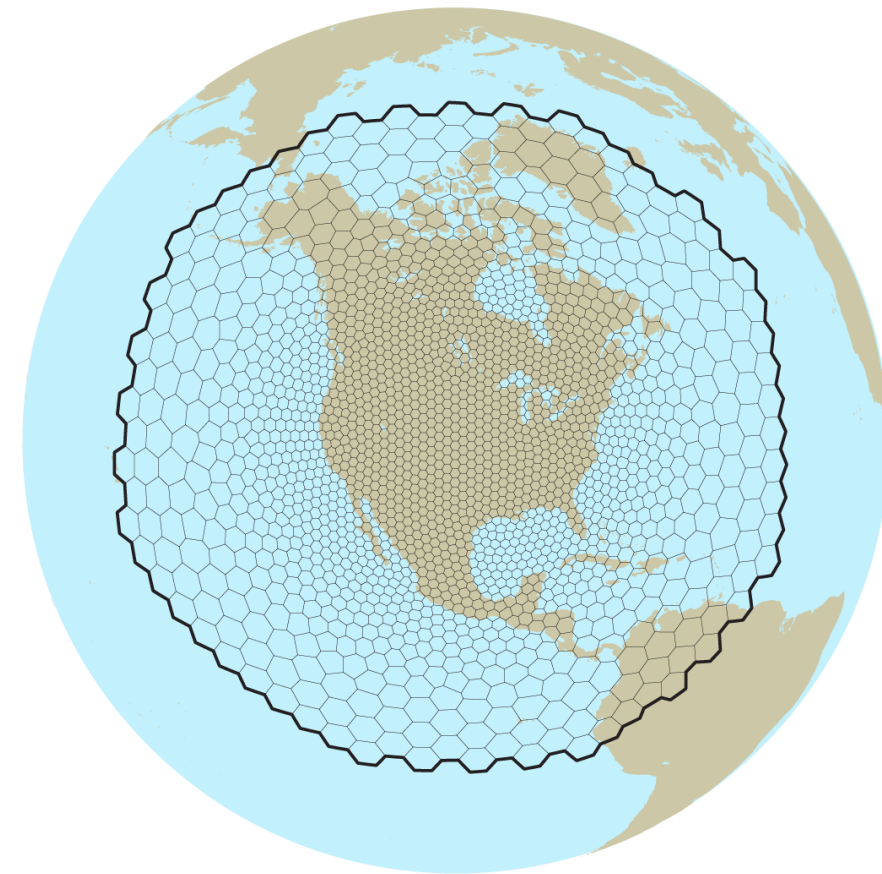


MPAS
Height-based hybrid smoothed
terrain-following vertical
coordinate

Regional MPAS

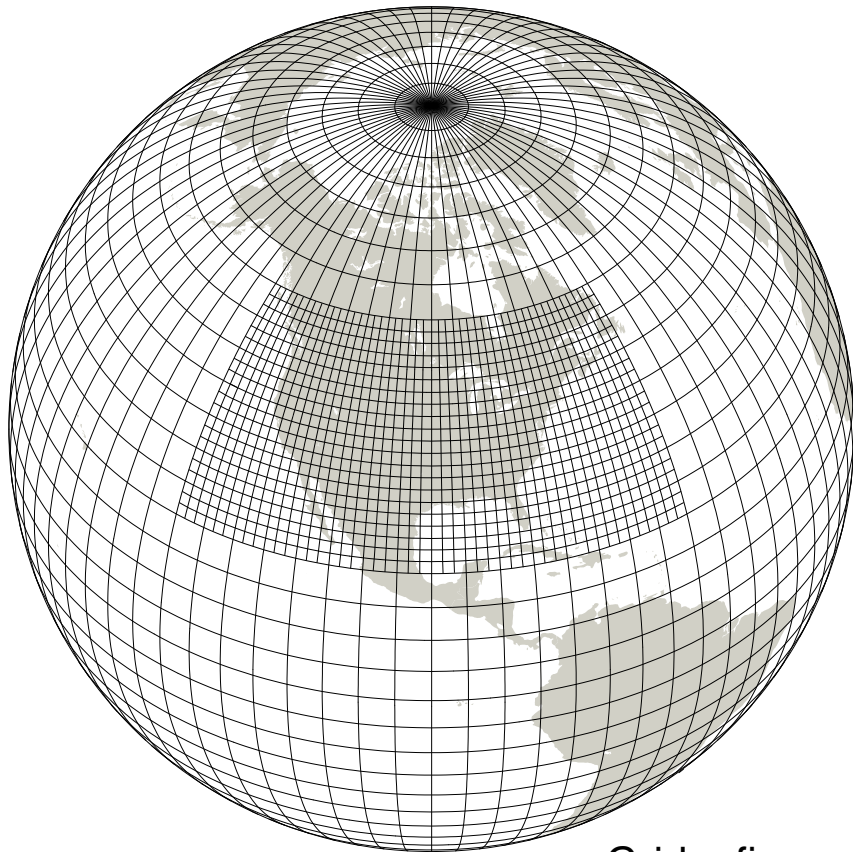
Why is there a regional version of MPAS given we have WRF?

- 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 NSF NCAR/MMM, and we would like users to transition to MPAS if their applications allow.*



Why MPAS?

Significant differences between WRF and MPAS

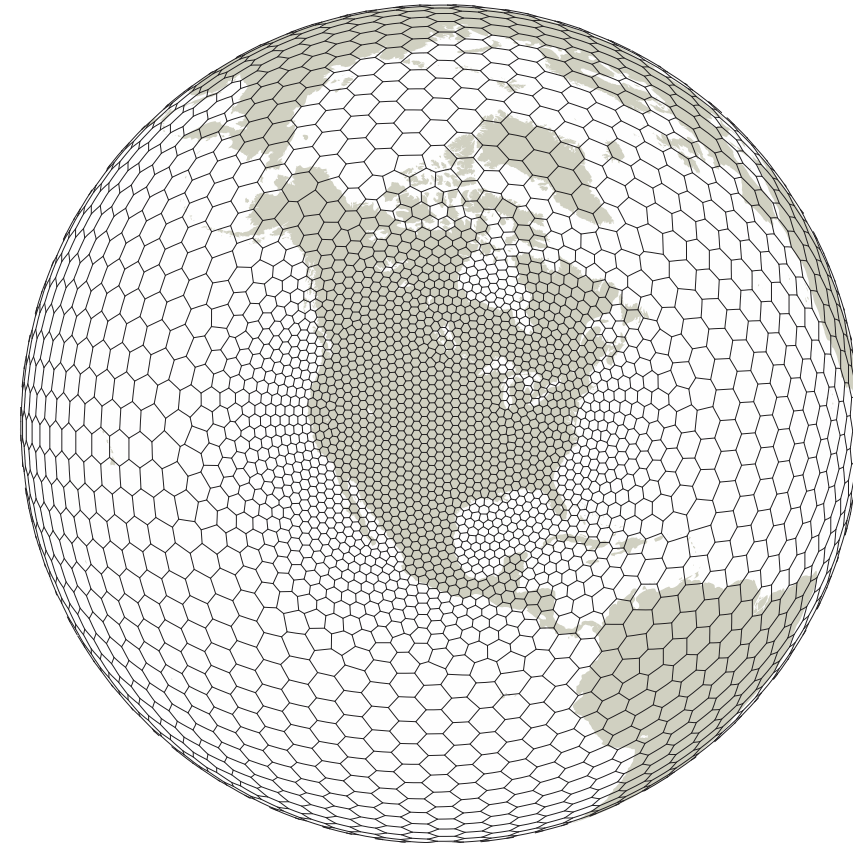


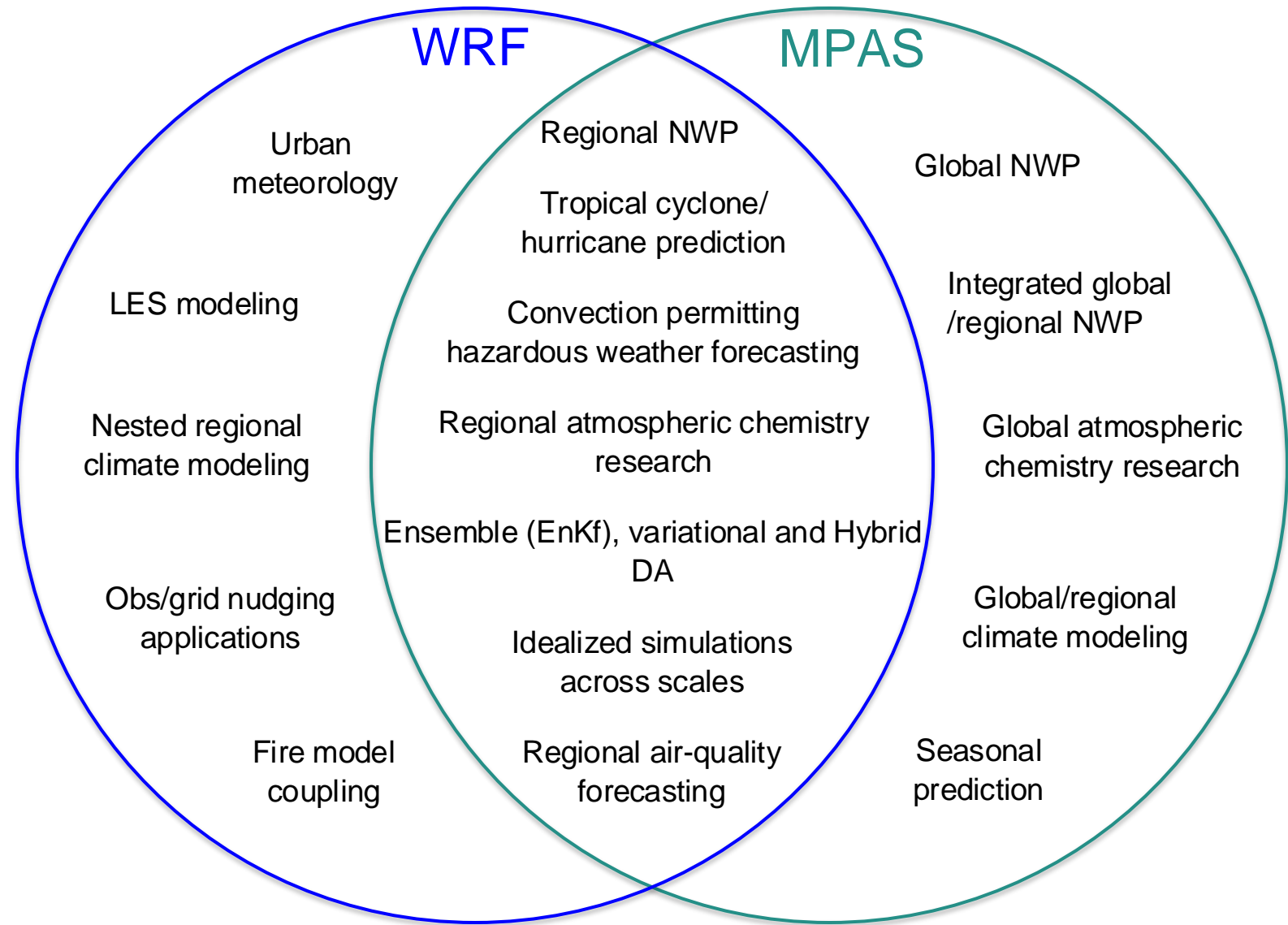
WRF

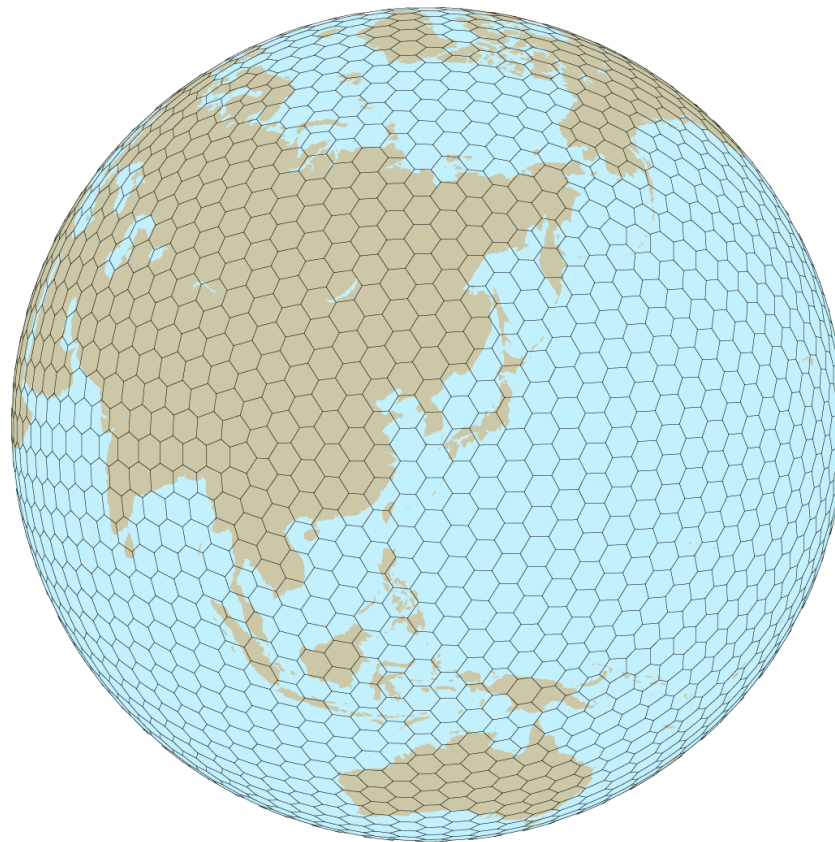
Grid refinement through domain nesting

- Flow distortions at nest boundaries

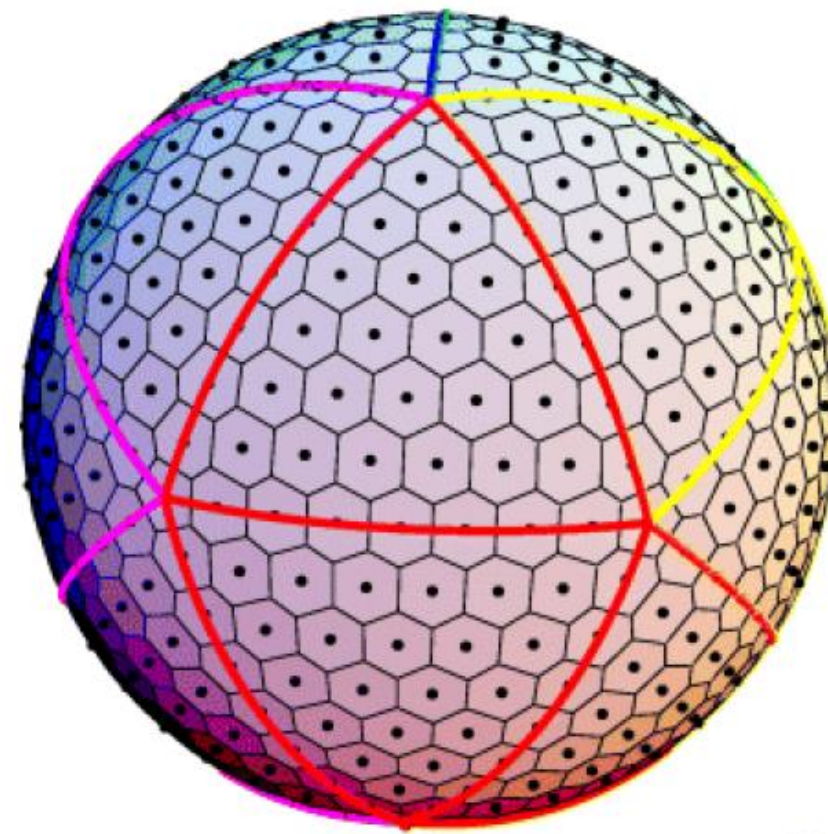
- MPAS
- Smooth grid refinement on a conformal mesh
- Increased accuracy and flexibility for variable resolution applications
 - No abrupt mesh transitions.







Global Quasi-Uniform
Mesh (SCVT)

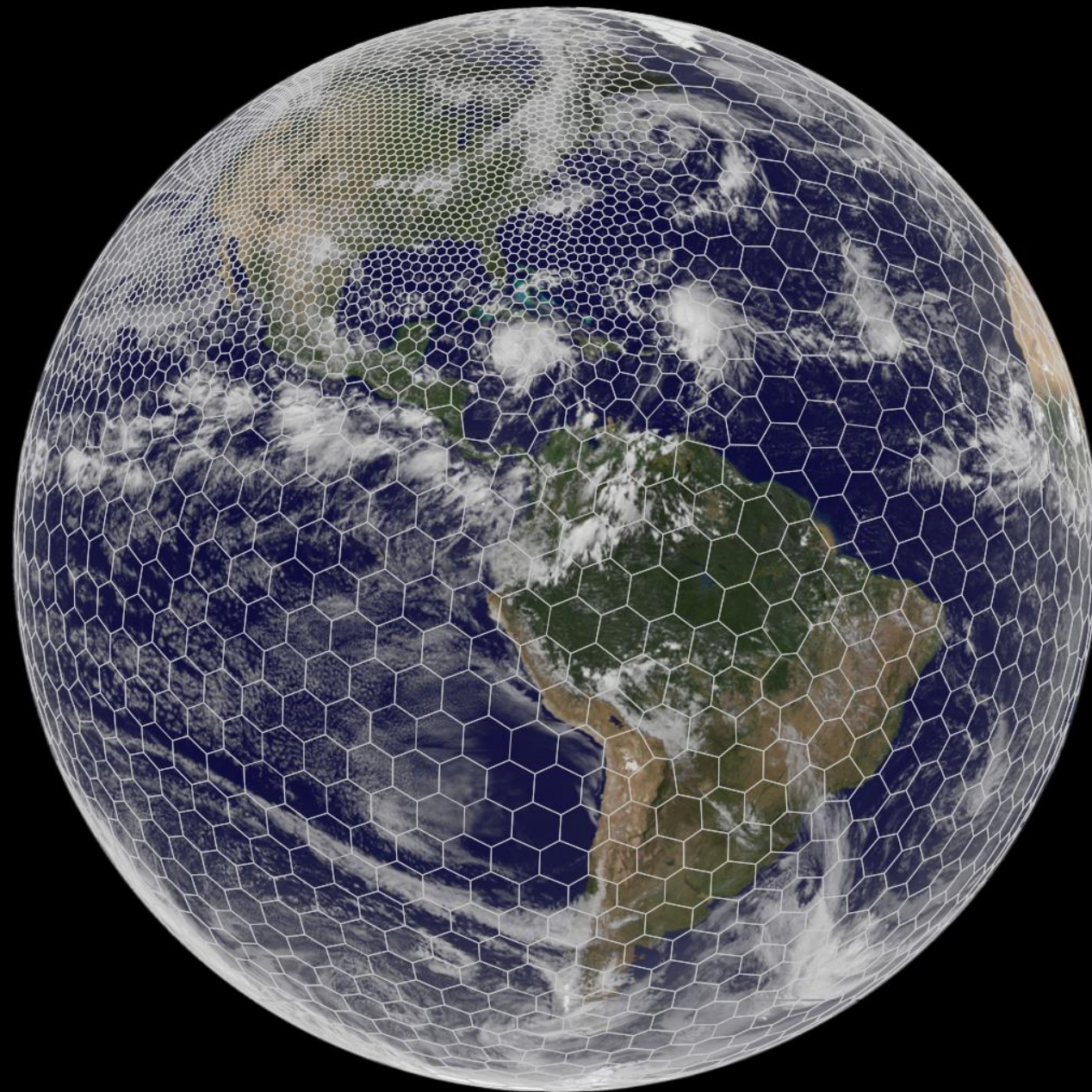


Many models use an icsoahedral mesh
(NICAM, BUGS, FIM, NIM, OLAM, etc.)

Mesh generation

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

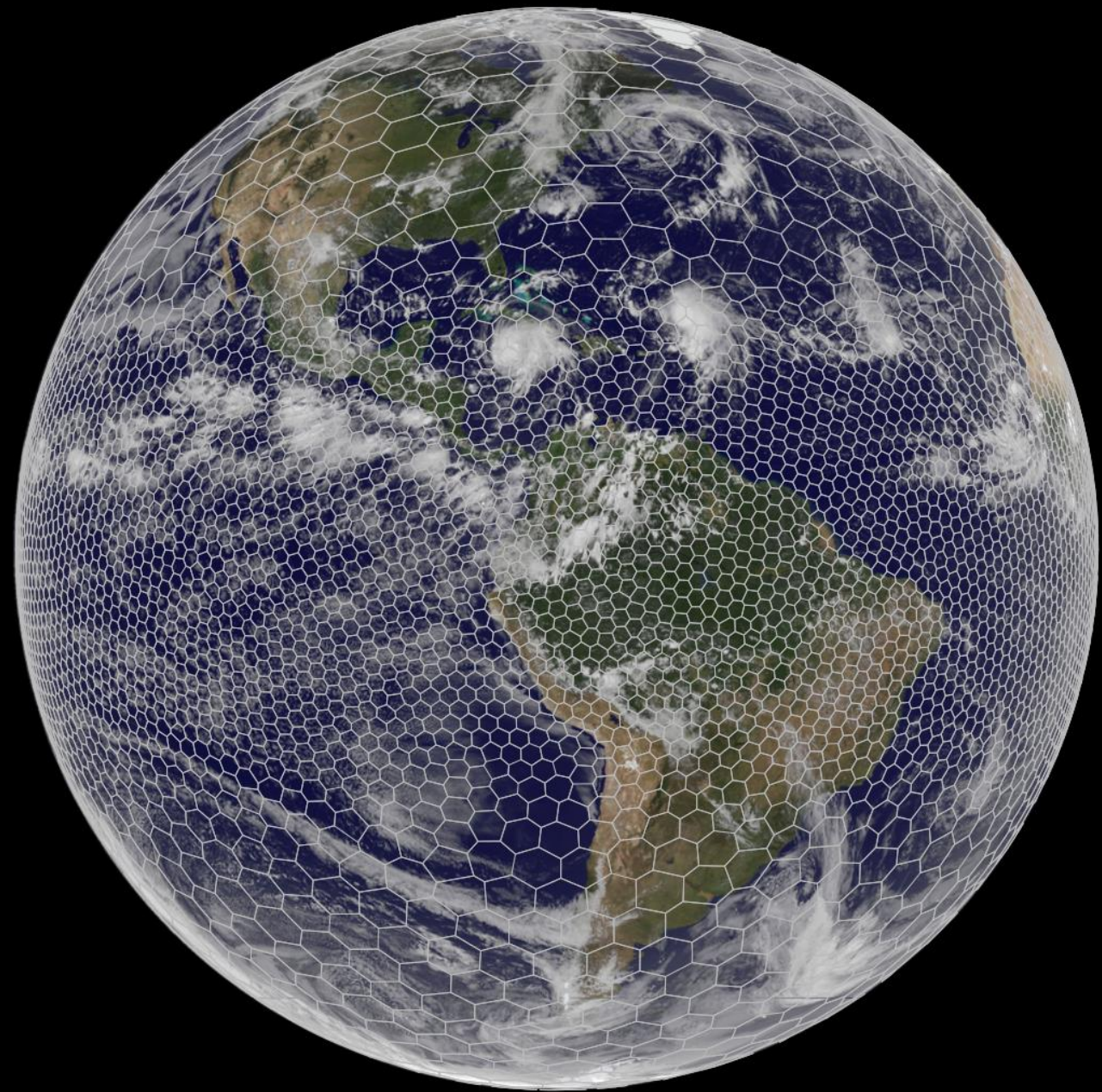
**North
American
refinement**



Mesh generation

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

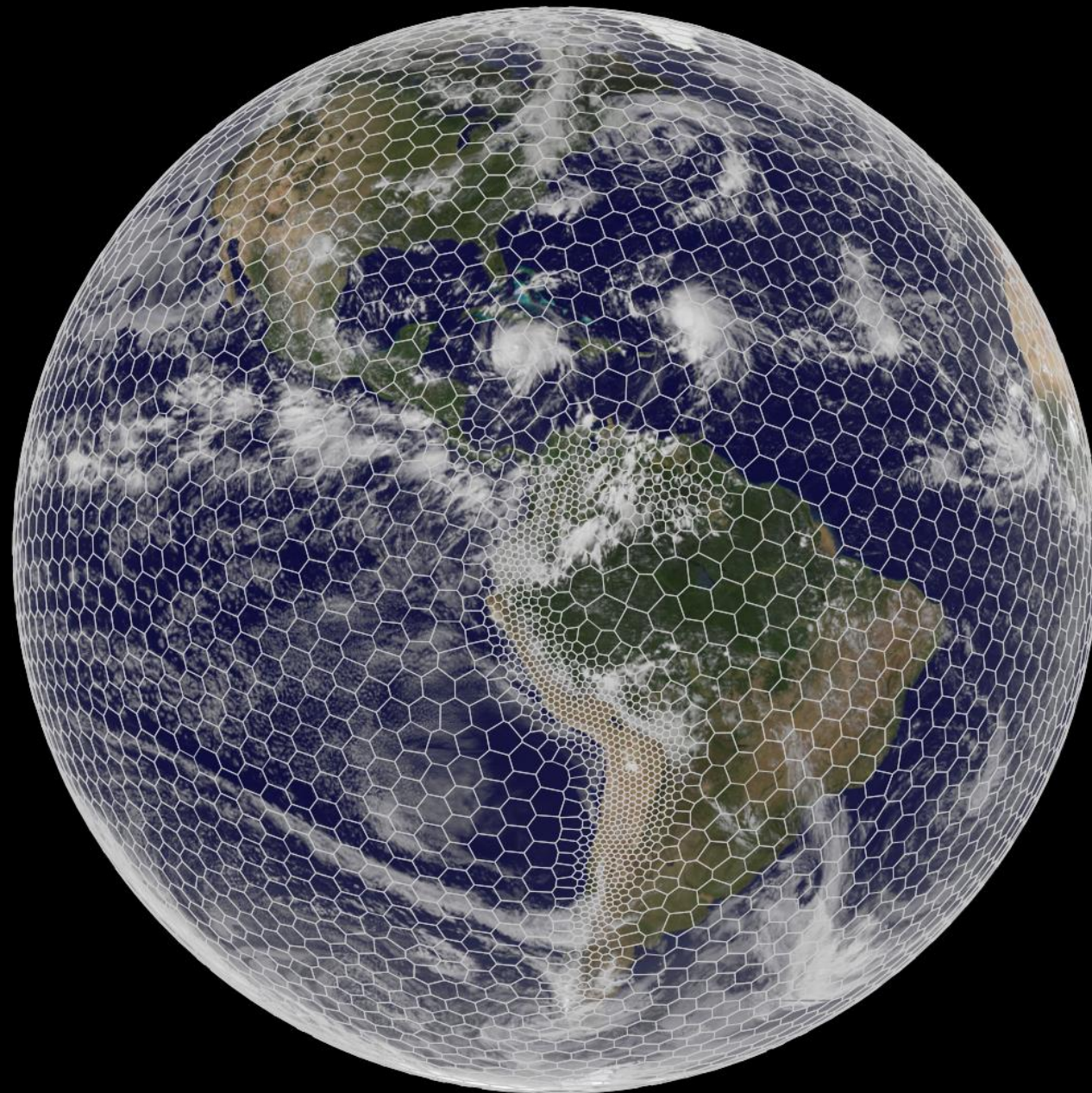
**Equatorial
refinement**



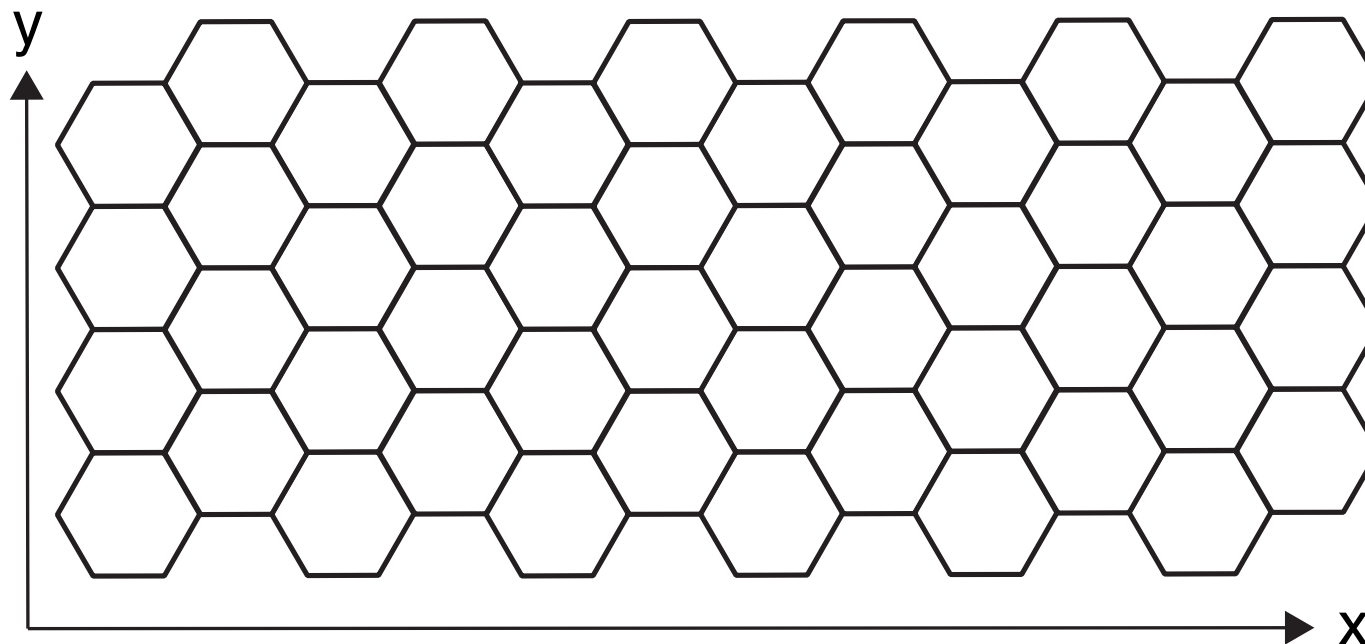
Mesh generation

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

**Andes
refinement**

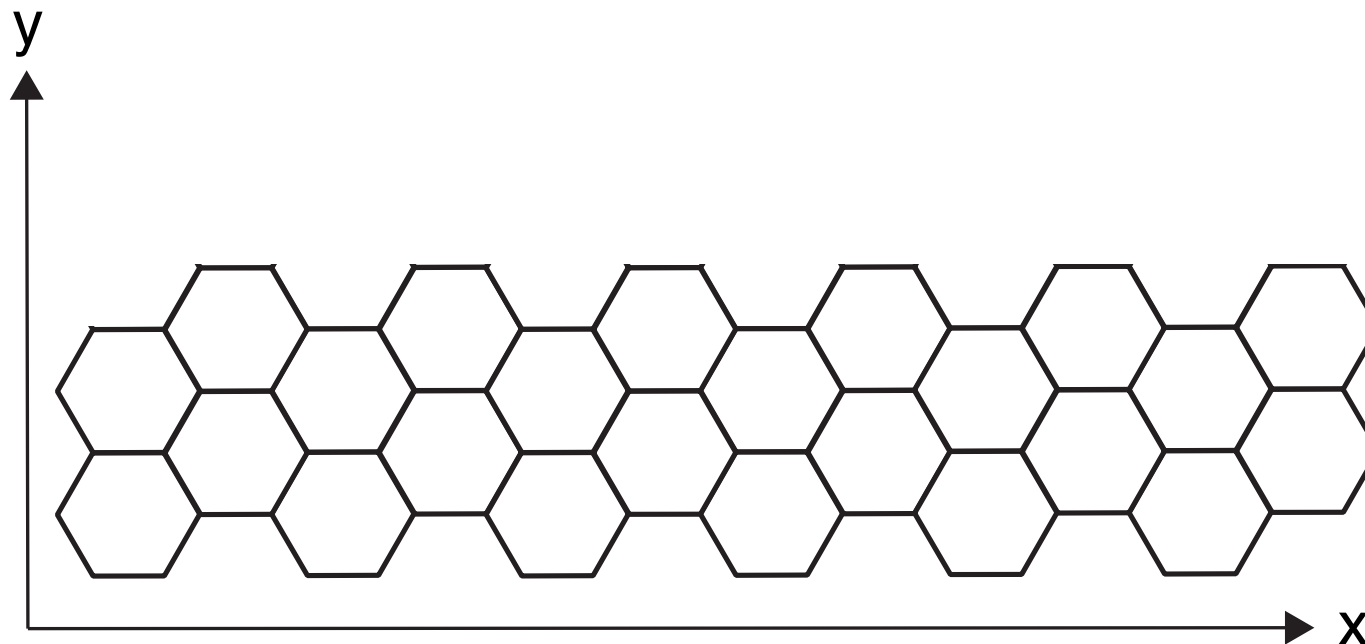


Other mesh spaces



Doubly-periodic Cartesian mesh

Other mesh spaces

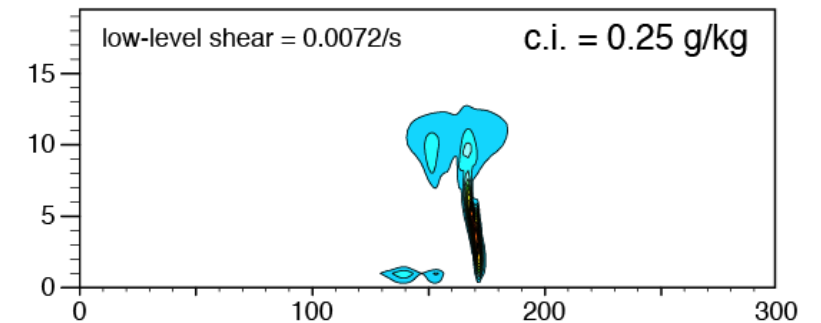
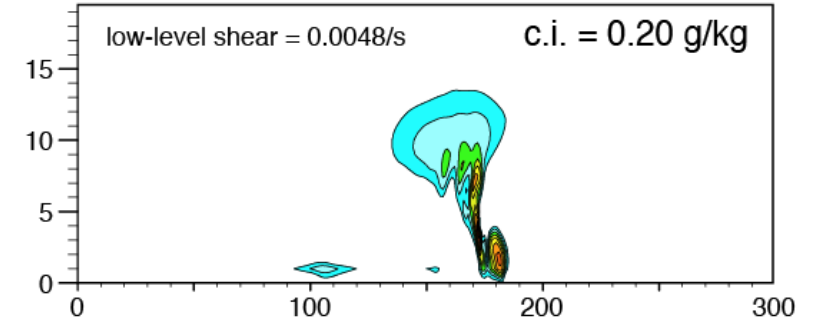
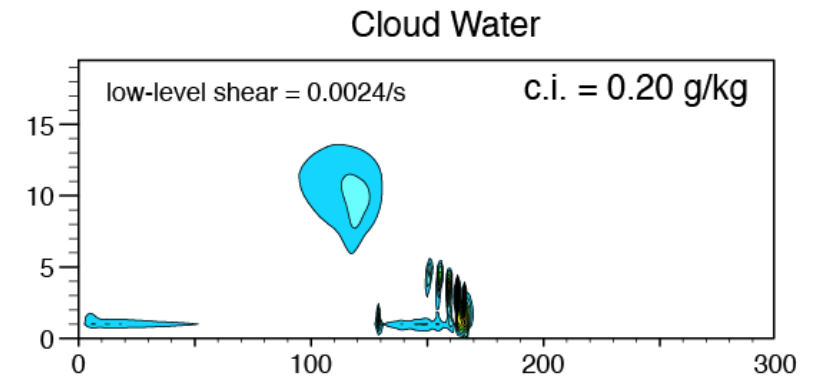
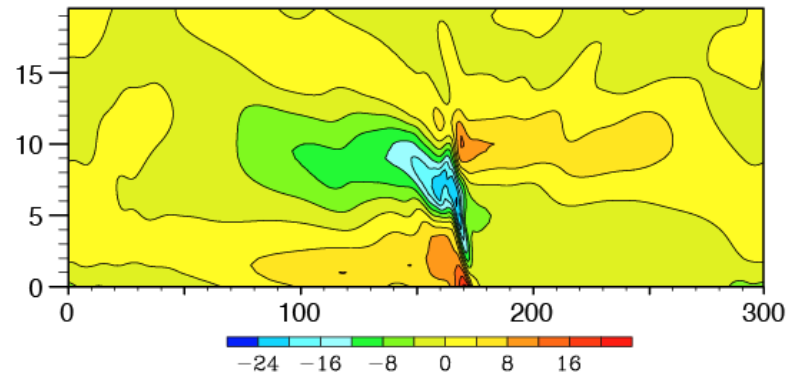
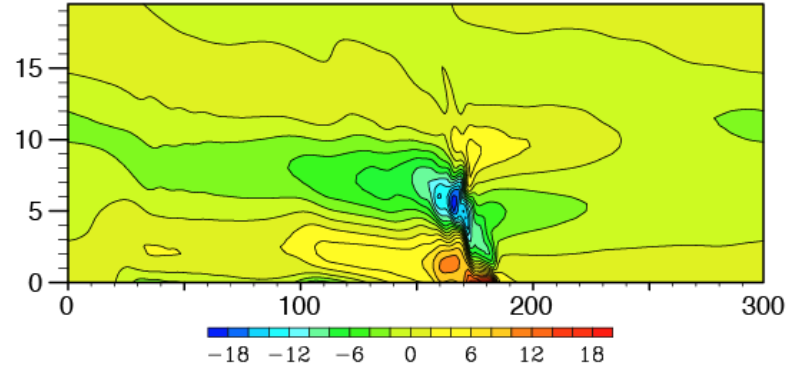
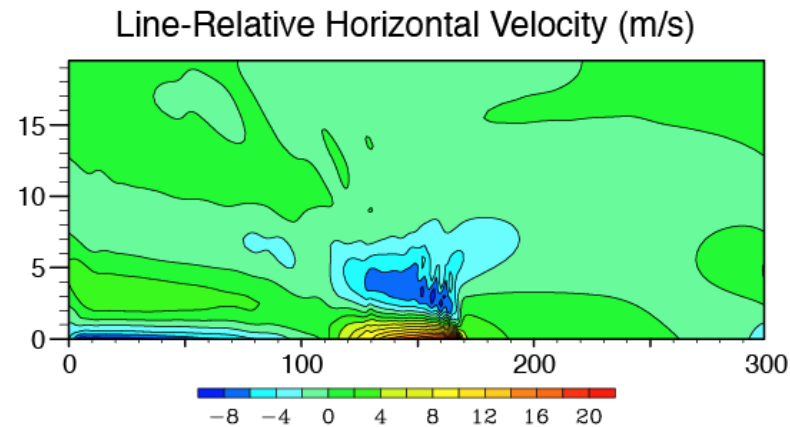


2D (y,z) mesh in MPAS

The solution does not vary in y , periodic in y

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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