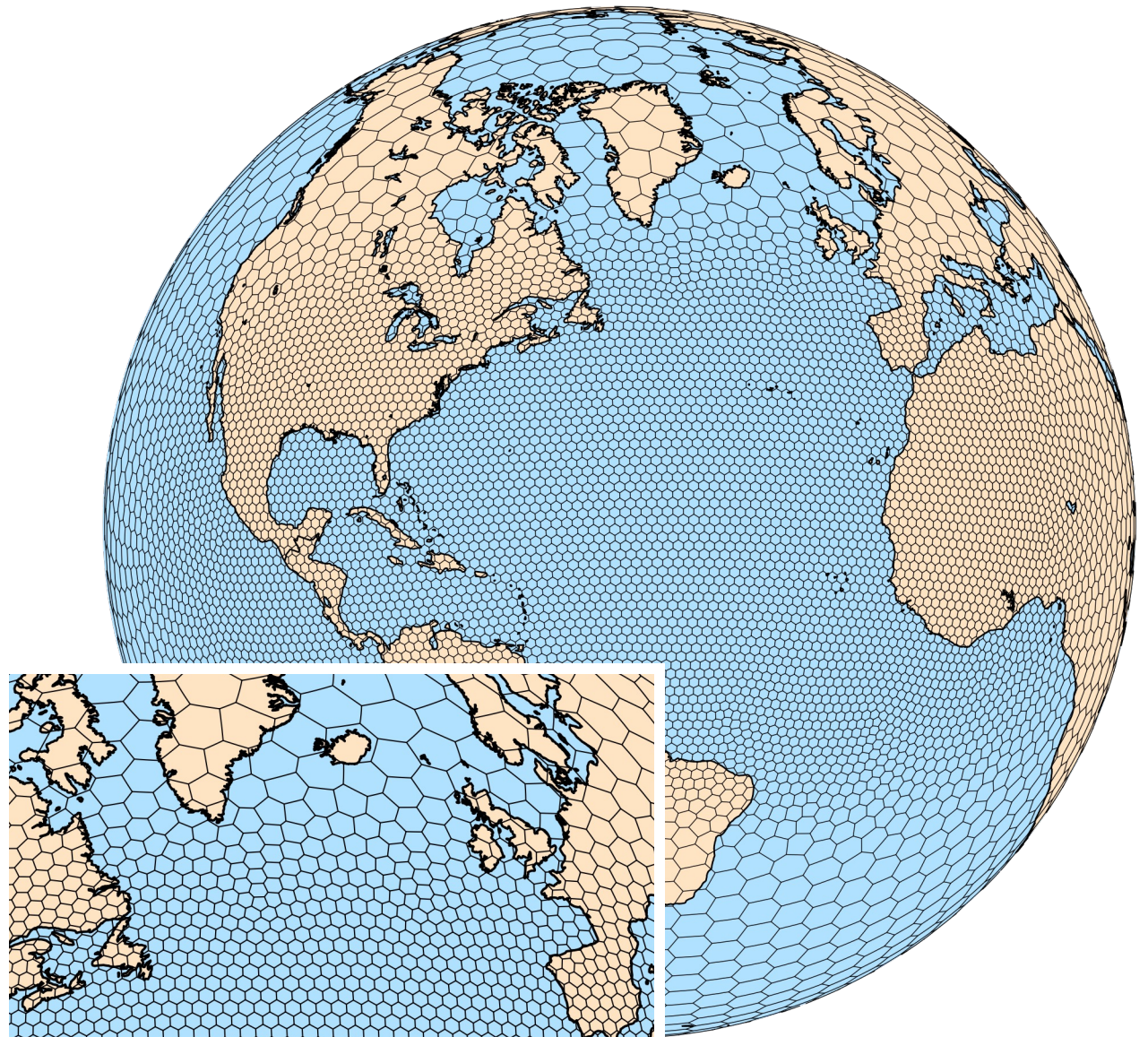


MPAS

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 Tutorial, 10-12 August 2026

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
11:15	–	11:30 (15 mins)	Break
11:30	–	11:40 (10 mins)	Introduction to the practical exercises
11:40	–	12:30 (50 mins)	Practical session
12:30	–	13:45 (75 mins)	Lunch
13:45	–	14:15 (30 mins)	Running MPAS, part 2: Variable-resolution, I/O streams, restarts, and other options
14:15	–	15:00 (45 mins)	Practical session
15:00	–	15:15 (15 mins)	Break
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.



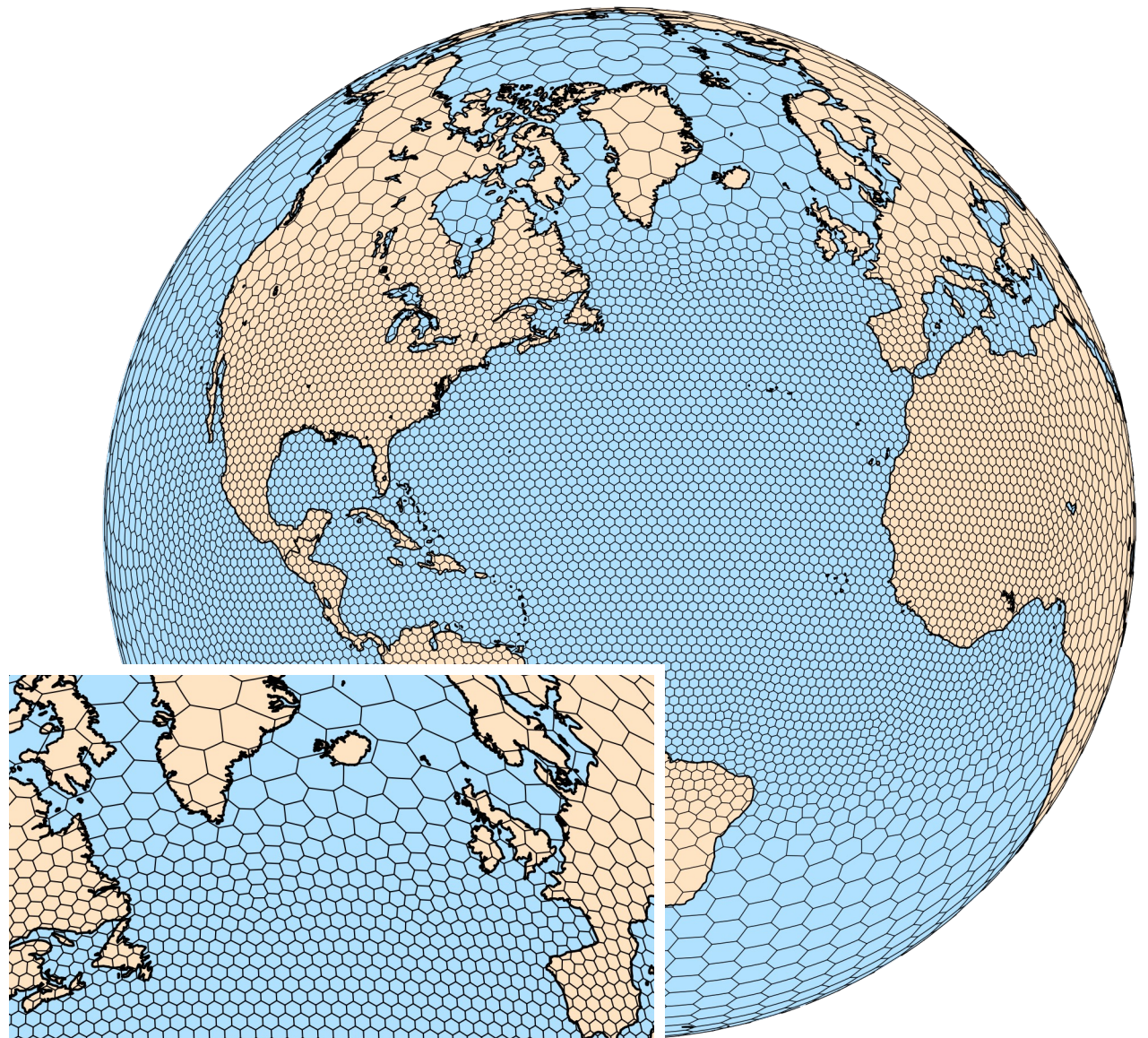
MPAS

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).

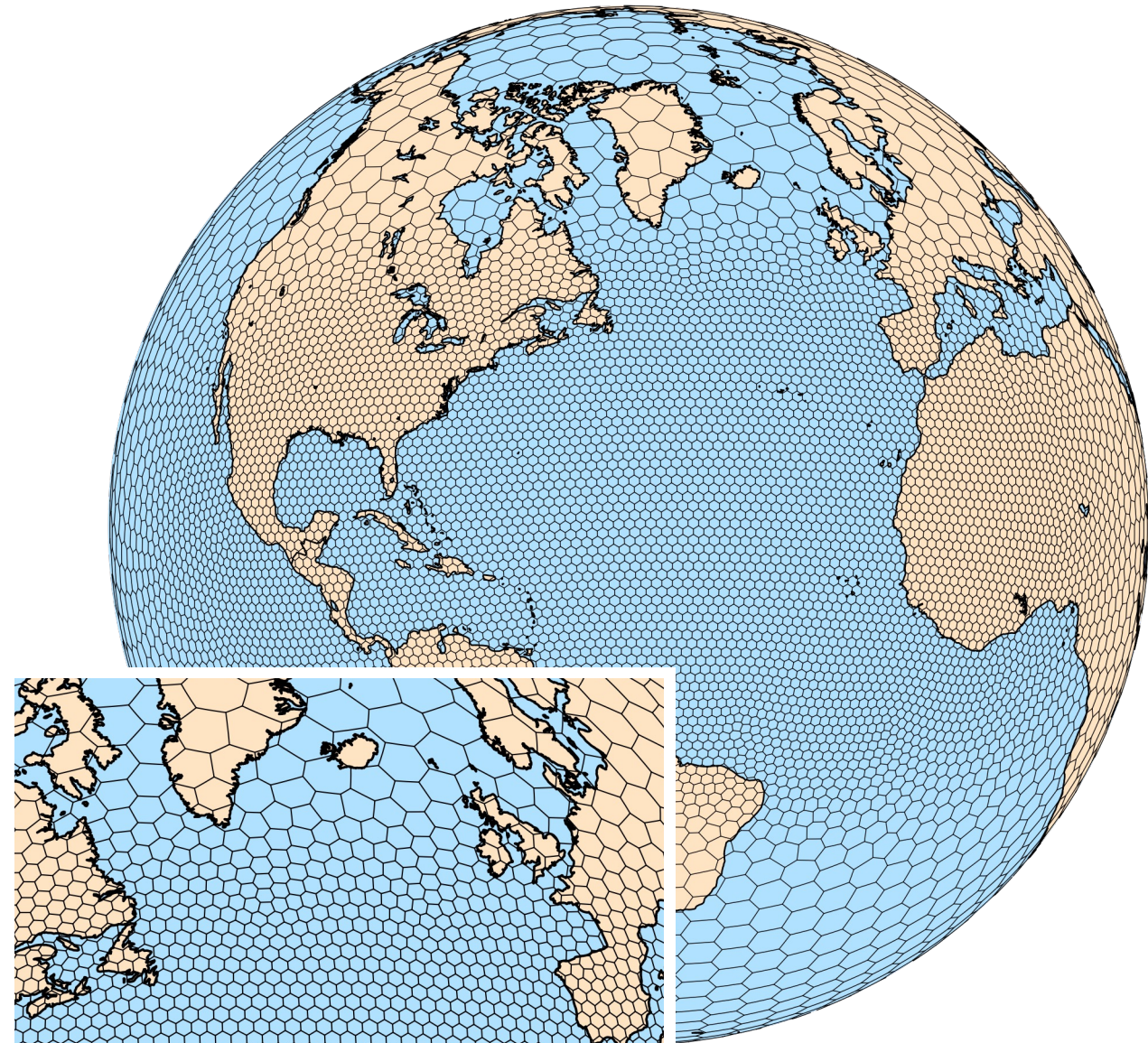
MPAS - Atmosphere (NCAR)

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*



— MPAS Tutorial, 10-12 August 2026

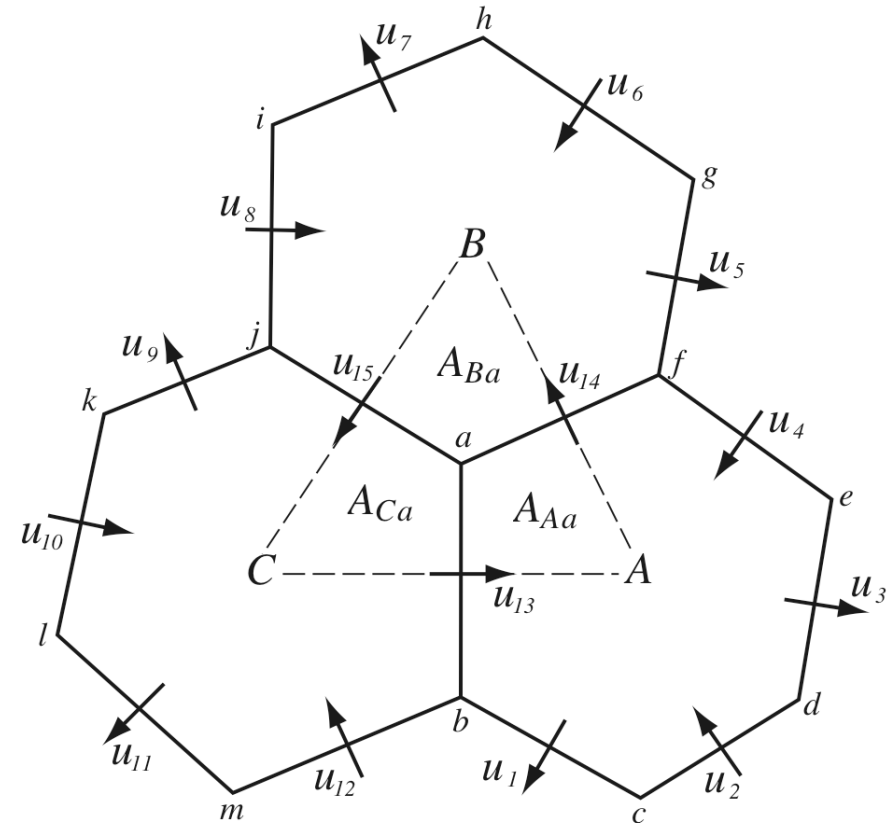
What is MPAS? Centroidal Voronoi Meshes

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.

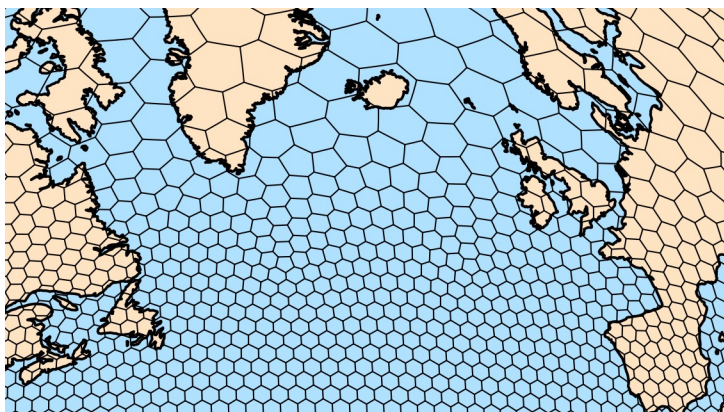
C-grid

- 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.

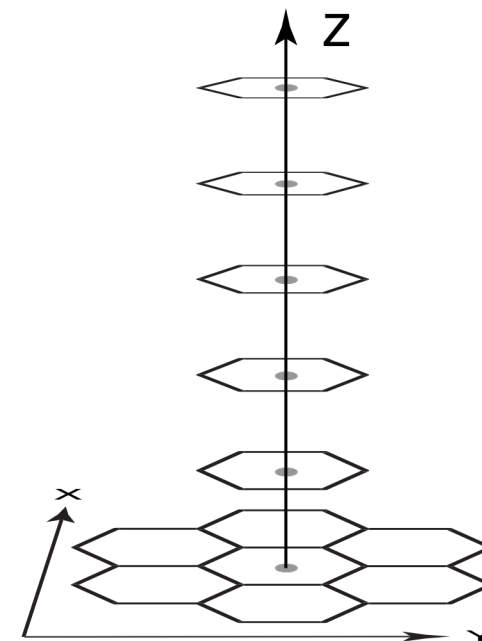
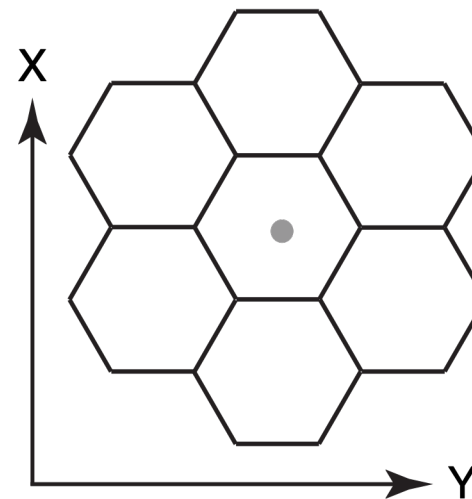


What is MPAS? Centroidal Voronoi Meshes

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

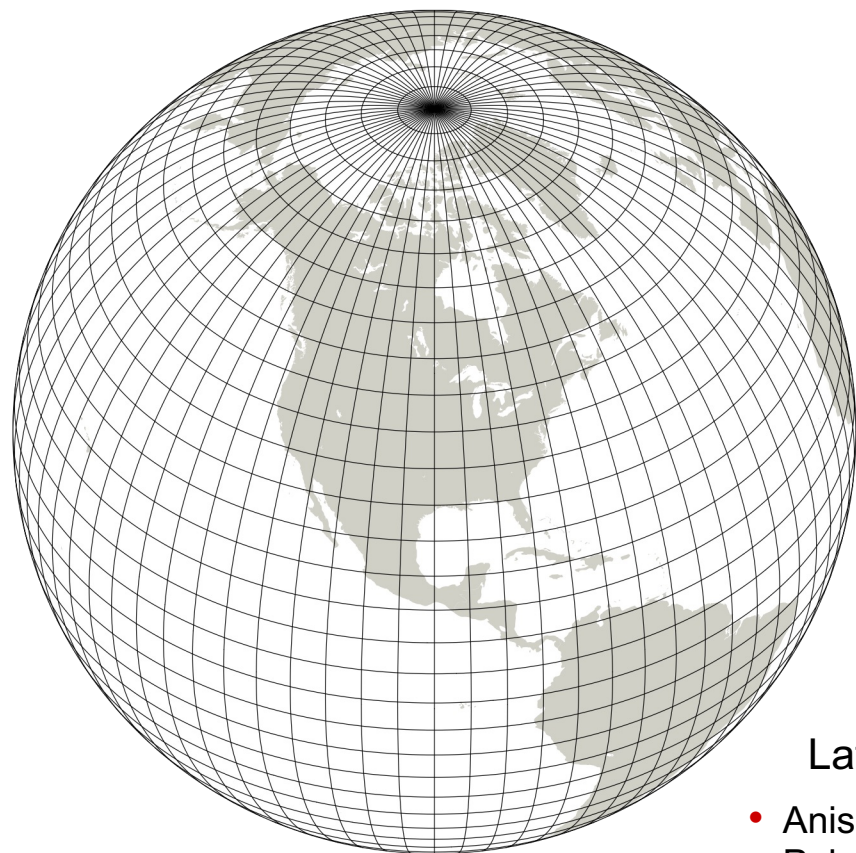
- Split-explicit Runge-Kutta, with extensions

Full complement of atmospheric-model physics

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

Why MPAS?

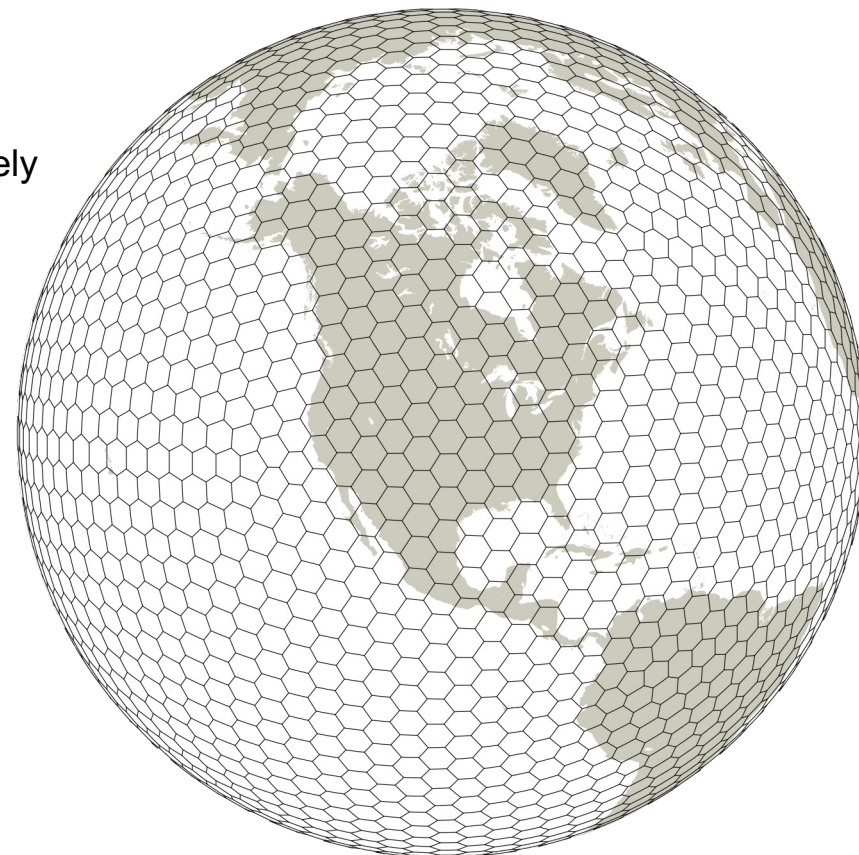
Significant differences between WRF and MPAS



WRF
Lat-Lon global grid

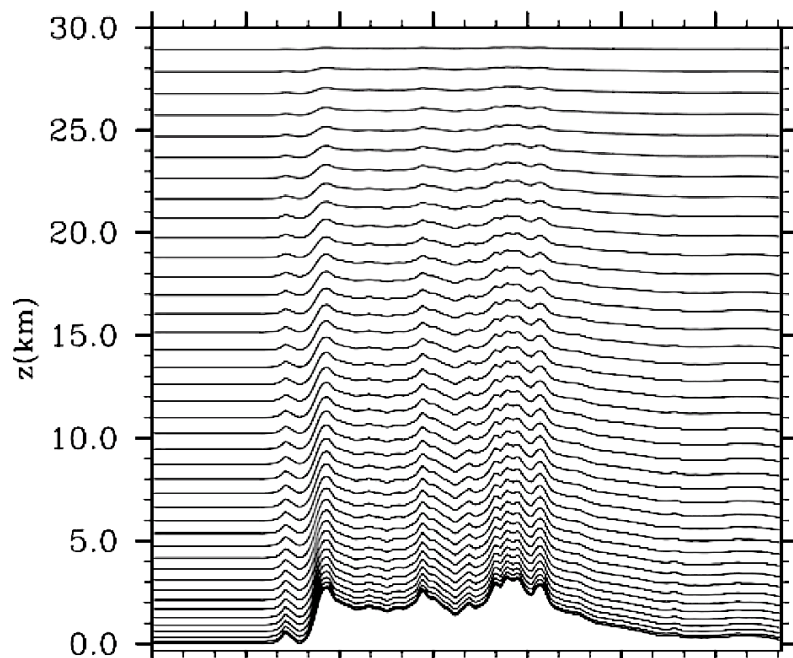
- Anisotropic grid cells
- Polar filtering required
- Poor scaling on massively parallel computers

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

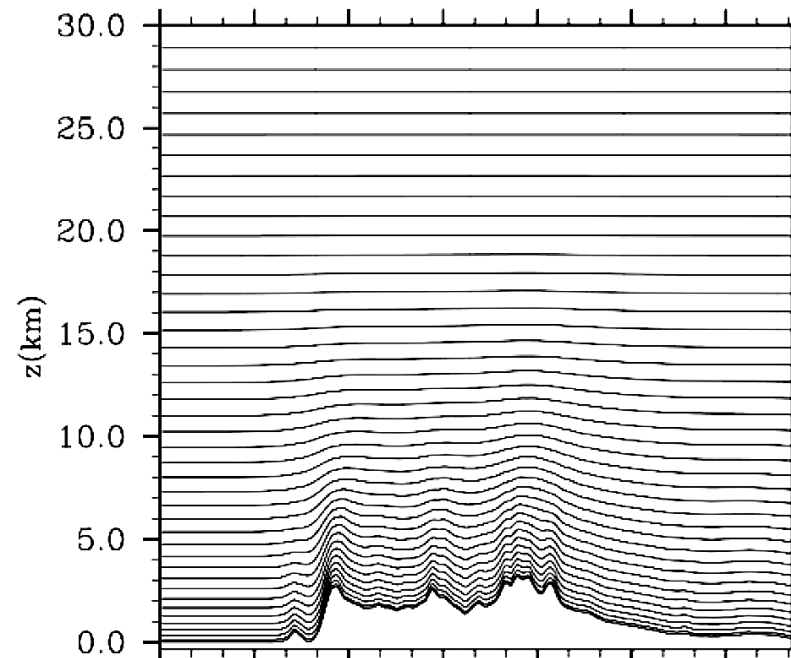


Why MPAS?

Significant differences between WRF and MPAS



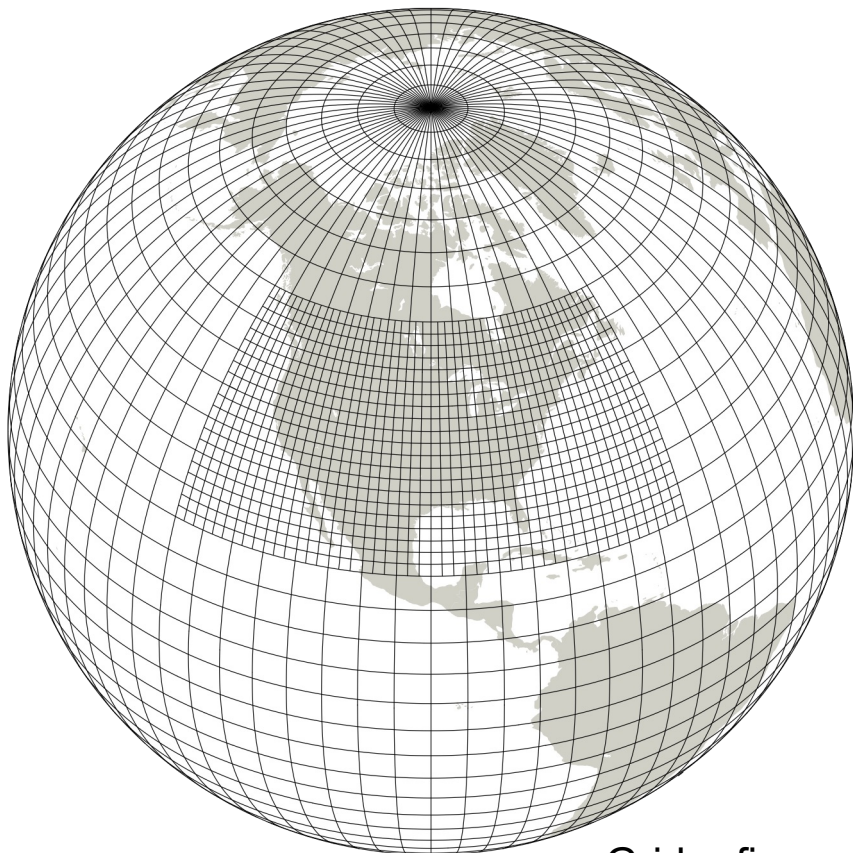
WRF
Pressure-based
terrain-following sigma
vertical coordinate



MPAS
Height-based hybrid smoothed
terrain-following vertical
coordinate

Why MPAS?

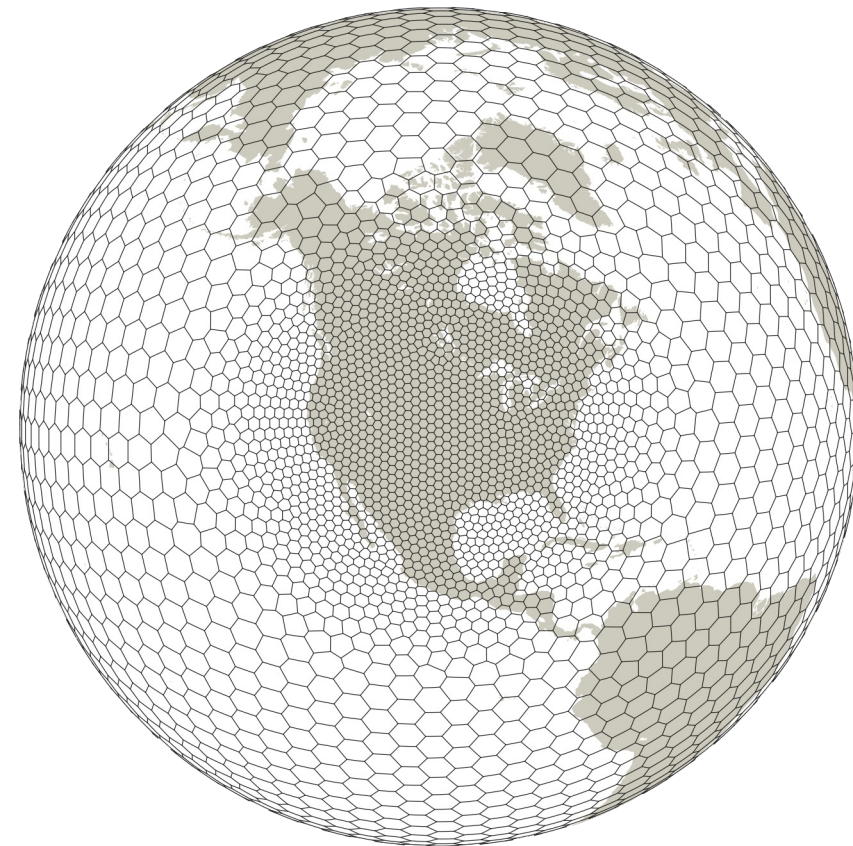
Significant differences between WRF and MPAS



WRF
Grid refinement through domain nesting

- Flow distortions at nest boundaries

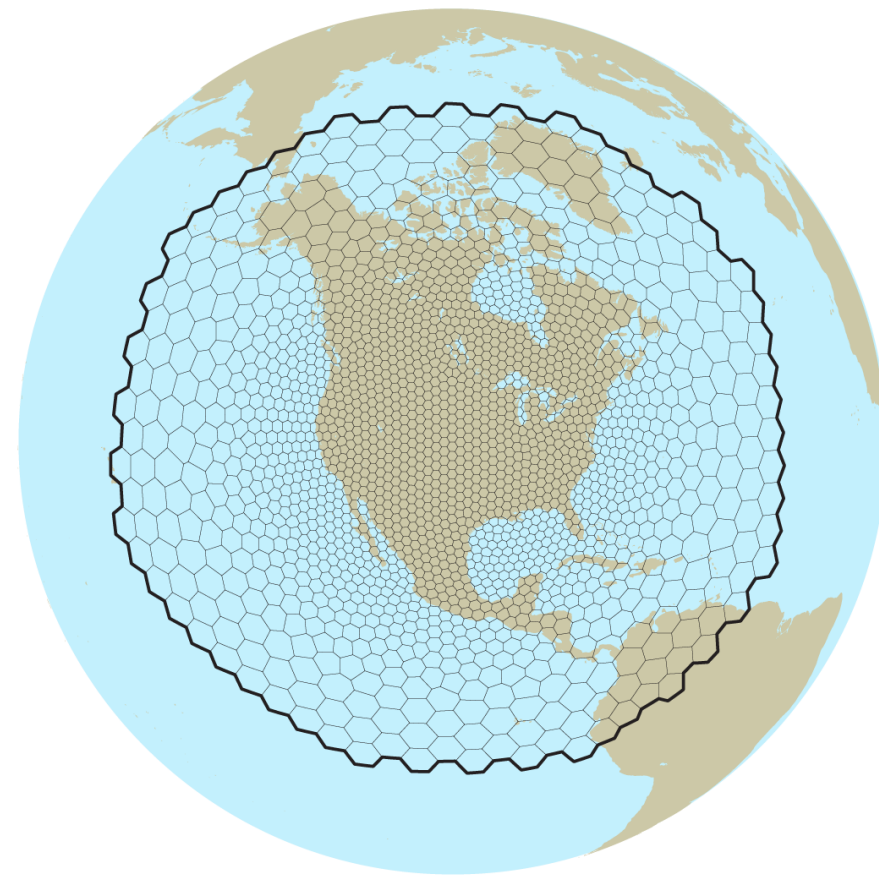
- MPAS
Smooth grid refinement
on a conformal mesh
- Increased accuracy and flexibility for variable resolution applications
 - No abrupt mesh transitions.



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.



Regional MPAS

Regional Mesh Generation: *WRF-like* meshes

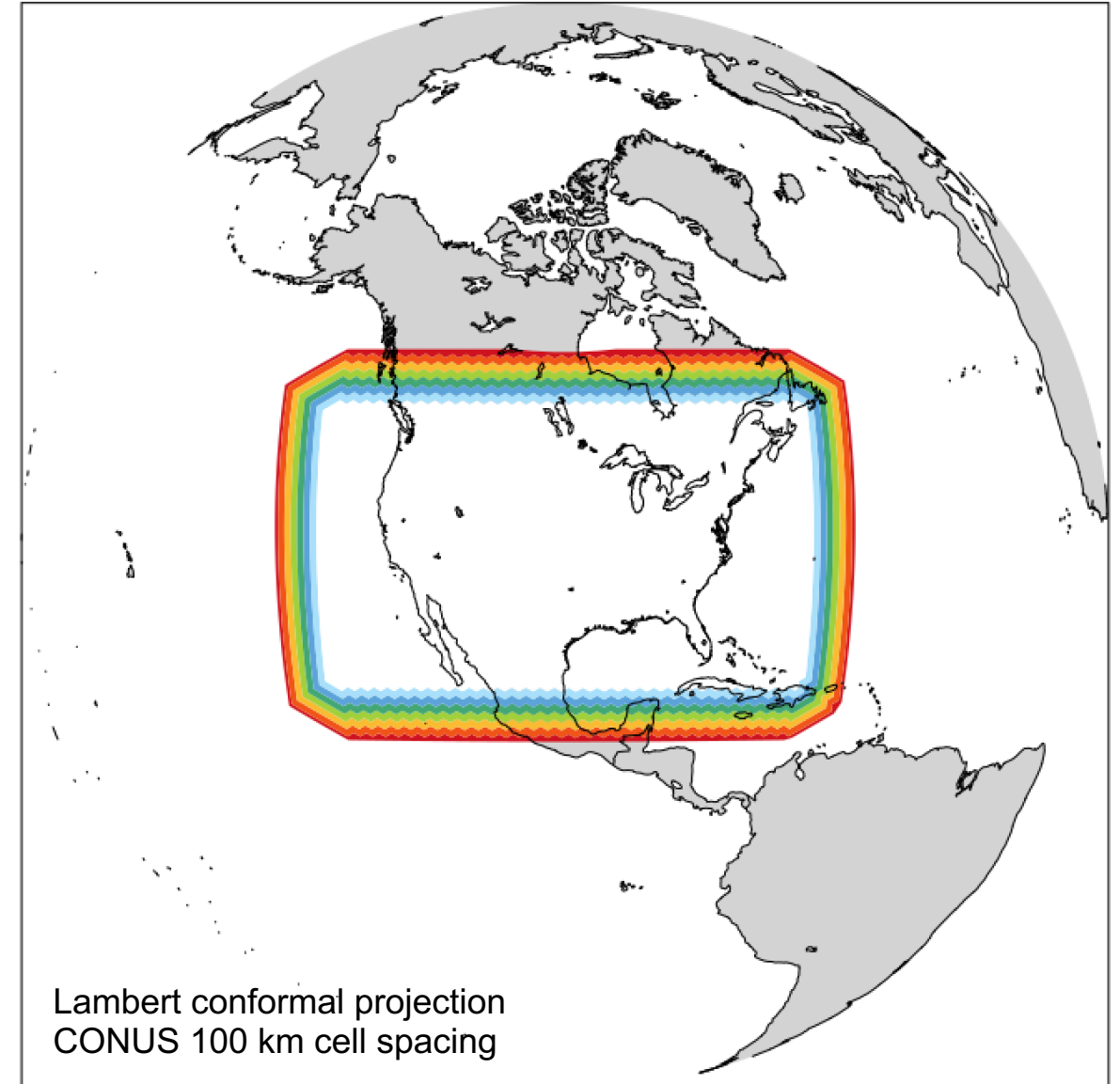
Project perfect hexagons on an (x,y) Cartesian plane to the sphere using standard projections

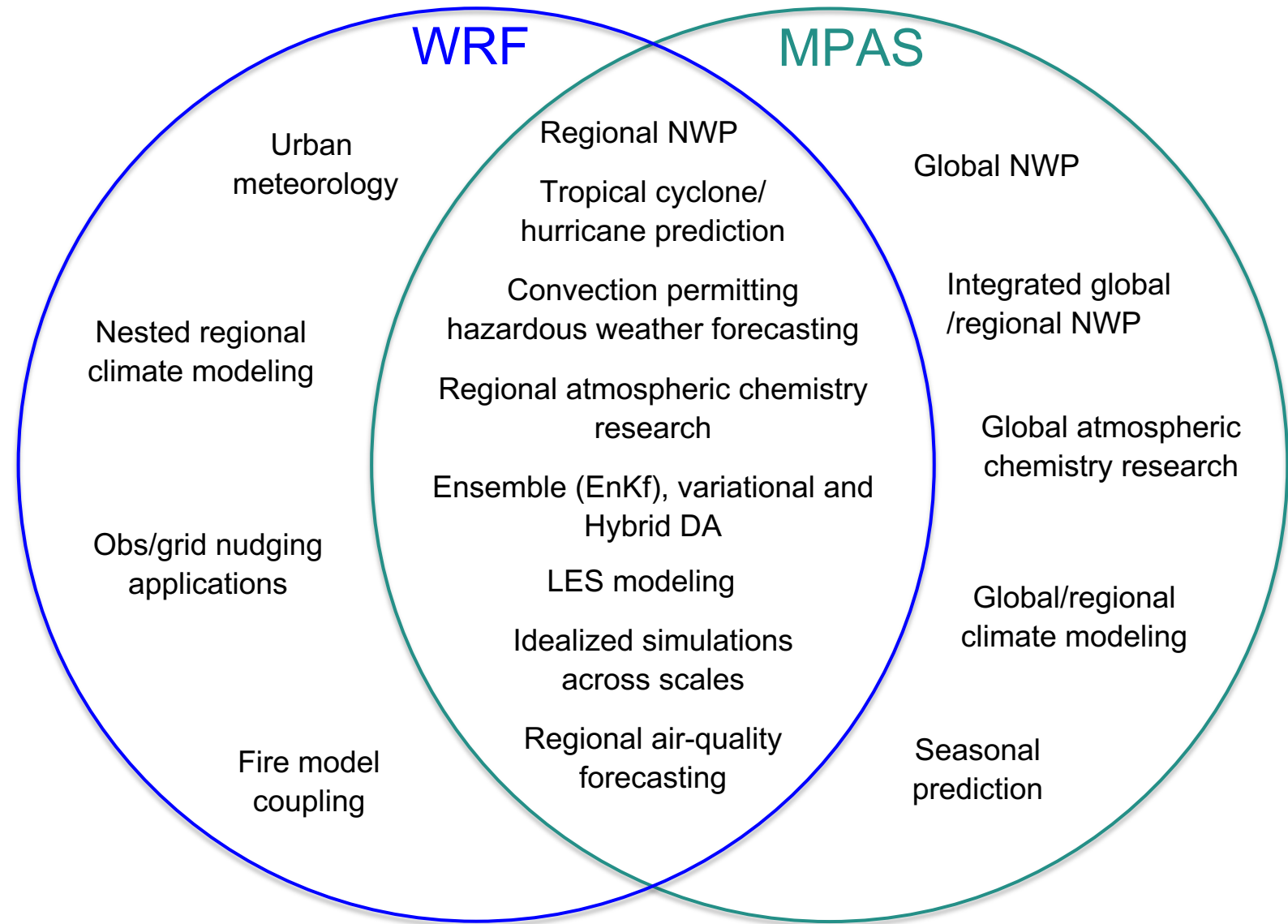
Note:

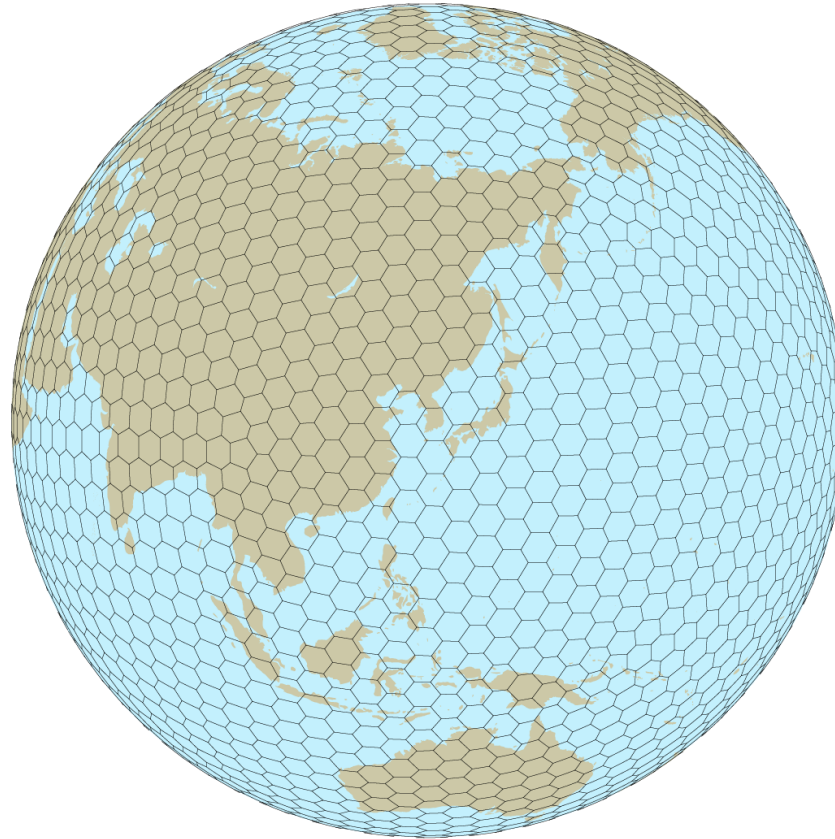
- The mesh is unstructured
- The hexagons on the sphere are not perfect – the areas and lengths vary in physical space as dictated by the projection.

MPAS regional mesh

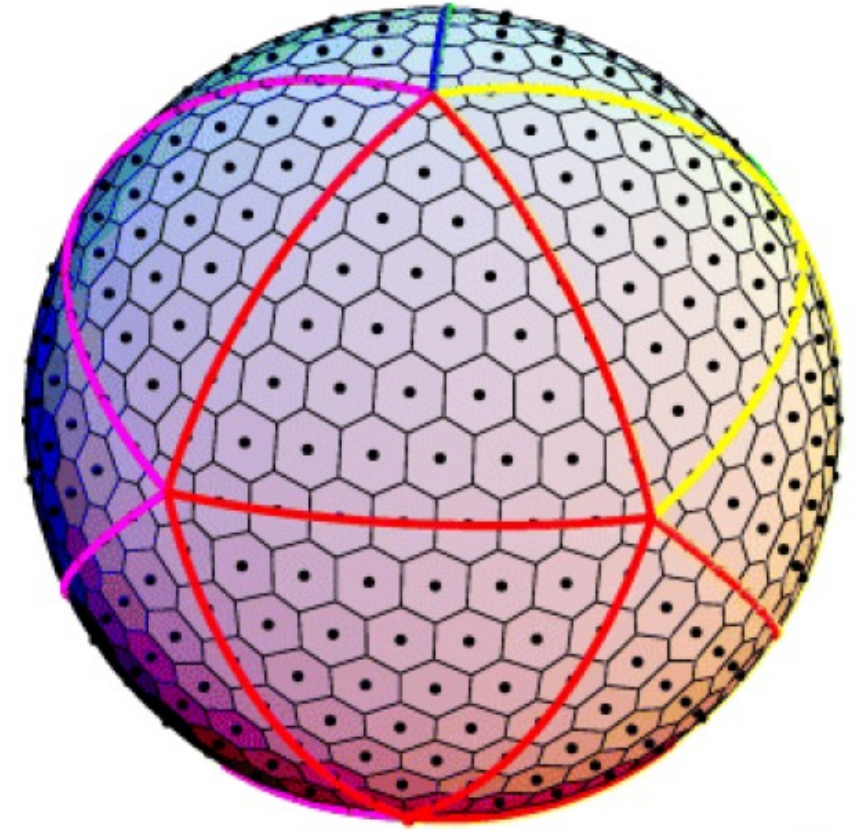
Limited-area specified/relaxation zone index for cells







Global Quasi-Uniform
Mesh (SCVT)

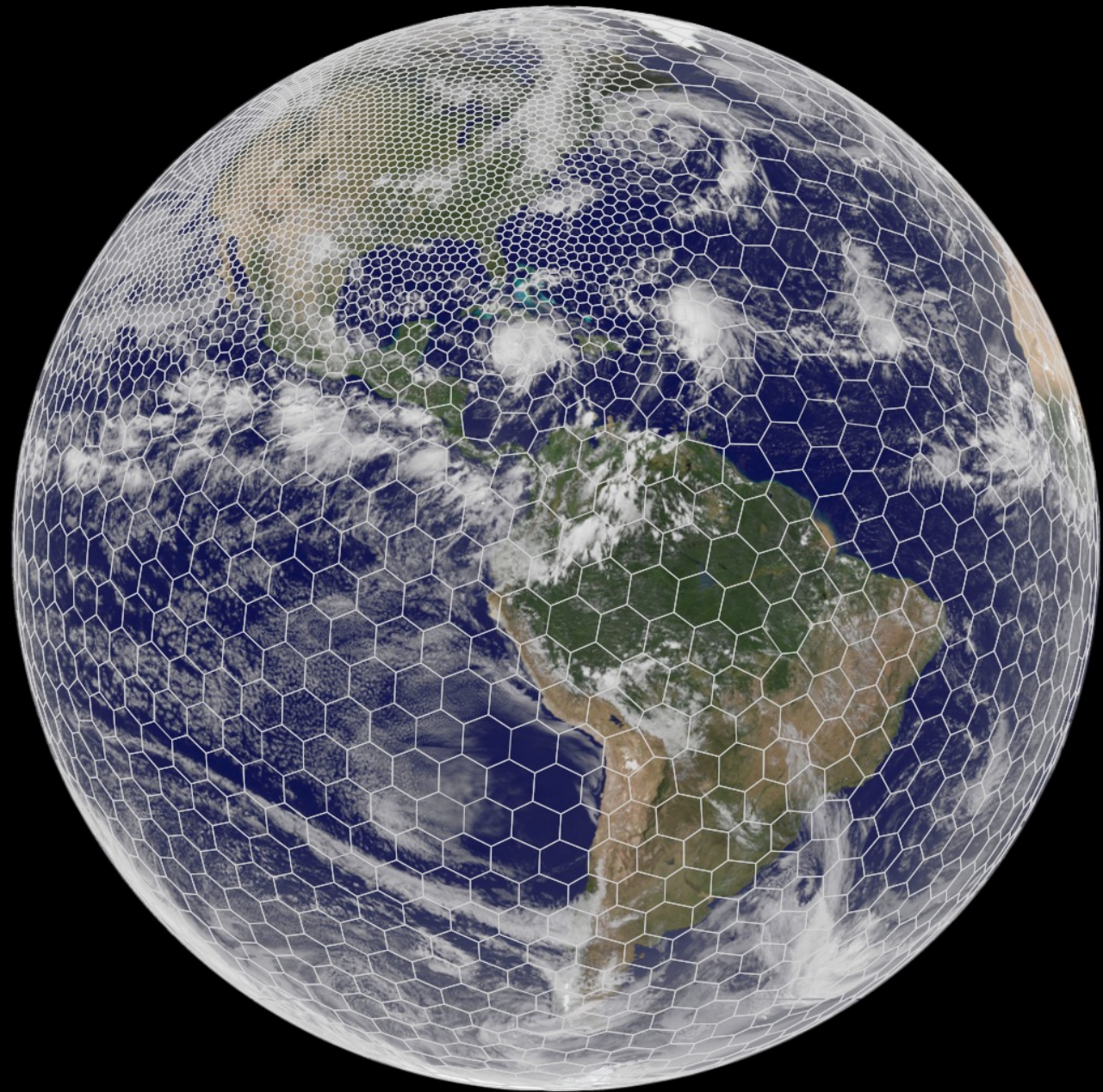


Many models use an icosahedral mesh
(NICAM, BUGS, FIM, NIM, OLAM, etc.)

Mesh generation

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

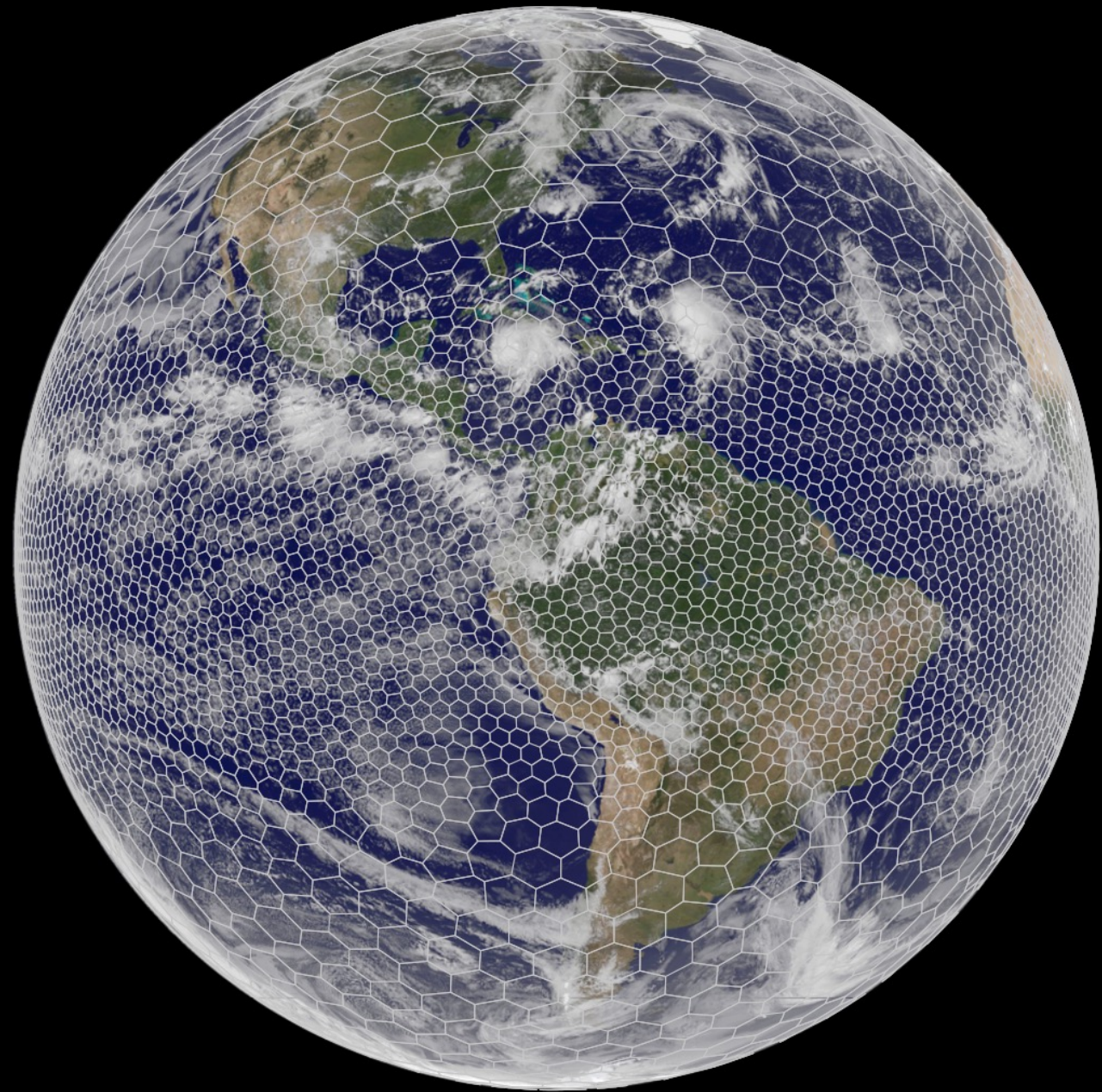
**North
American
refinement**



Mesh generation

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

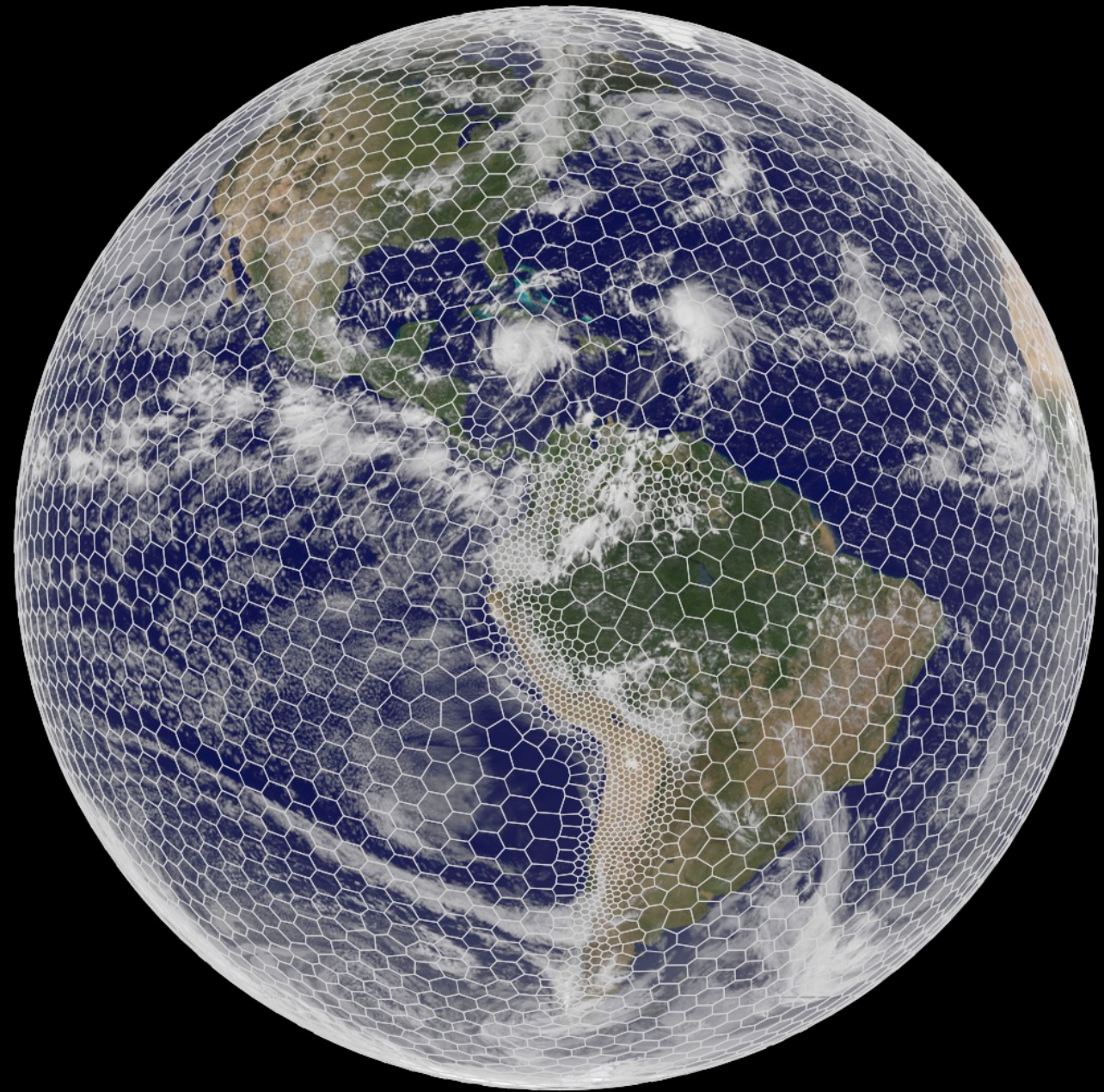
**Equatorial
refinement**



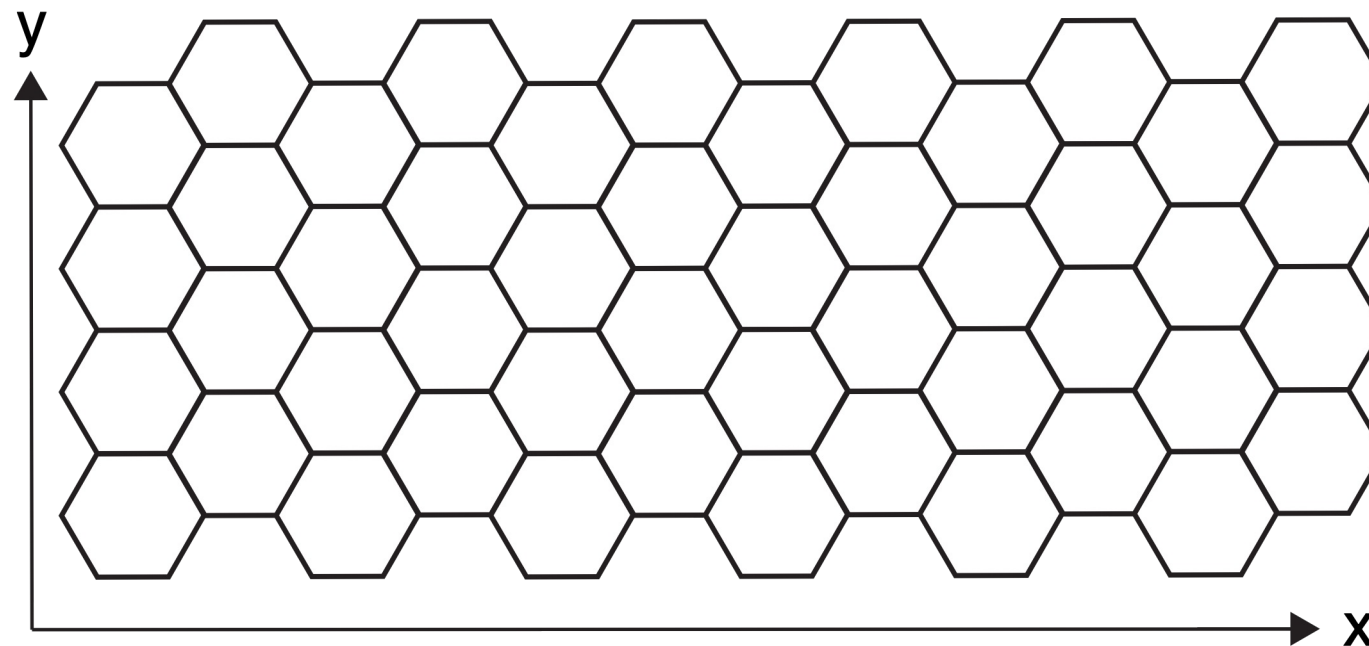
Mesh generation

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

**Andes
refinement**



Other mesh spaces

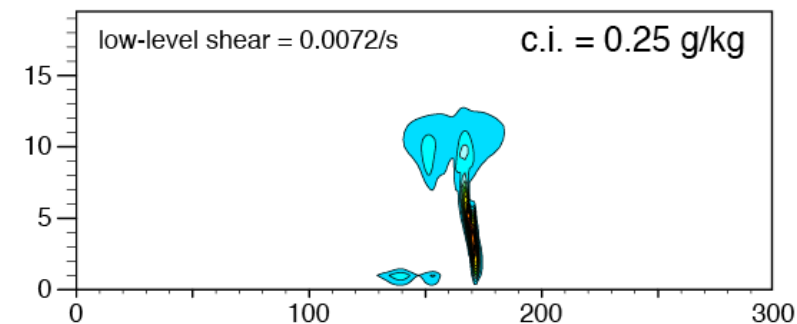
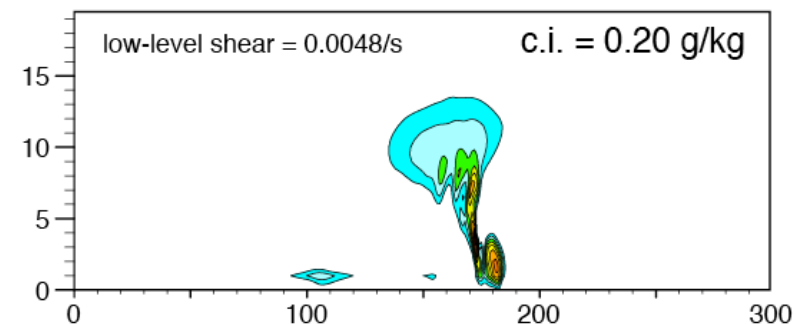
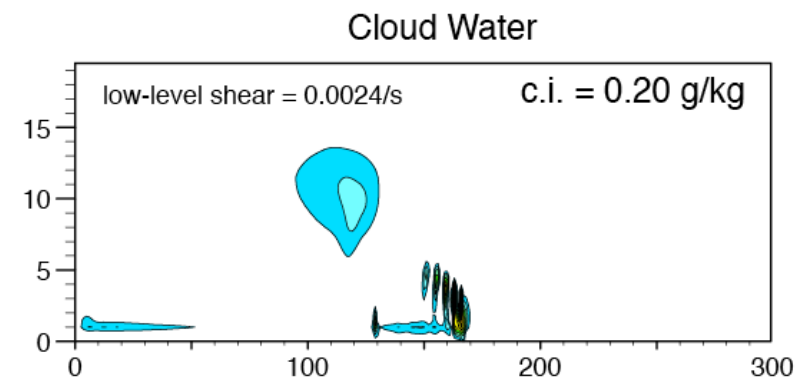
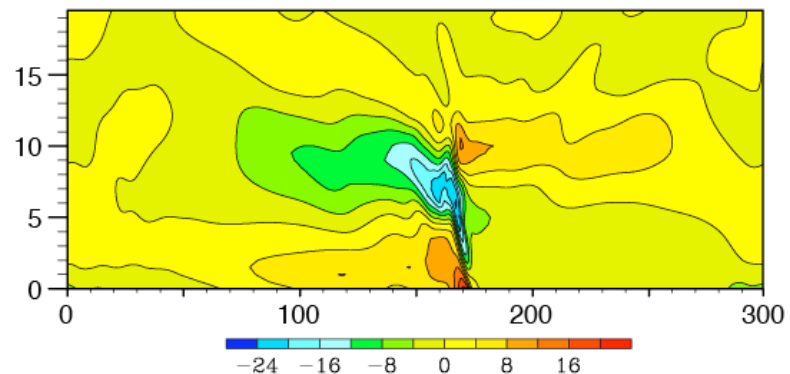
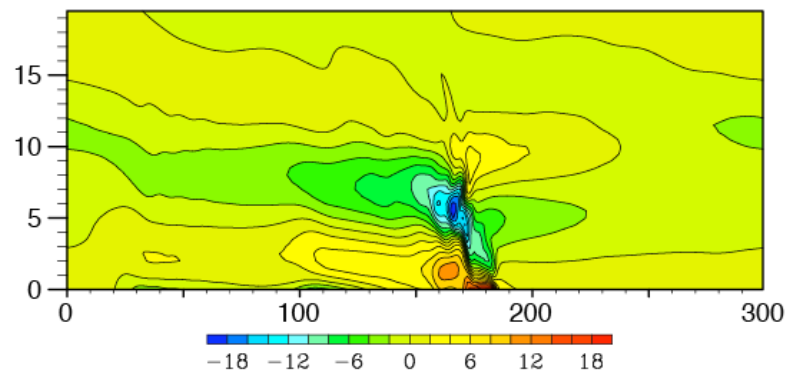
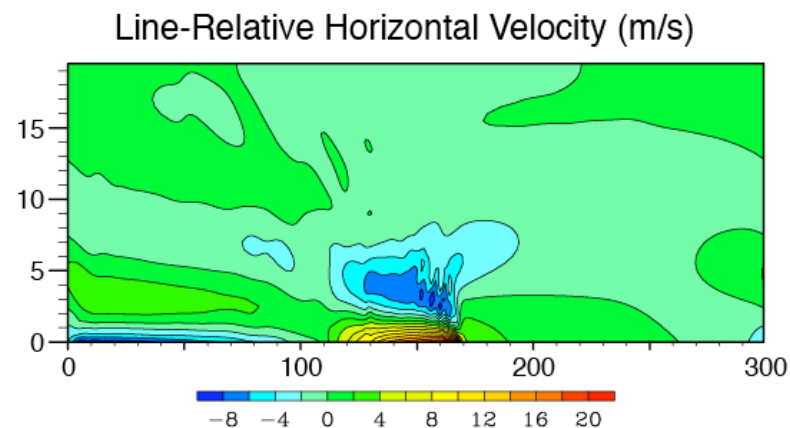


Doubly-periodic Cartesian mesh

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



MPAS

Model for Prediction Across Scales

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

www2.mmm.ucar.edu/projects/mpas/site/index.html

NCAR Library Proxy Skamarock Home... Imported From Sa... RAP Real-Time We... MPAS NCAR Library Inbox - skamaroc... All Bookmarks

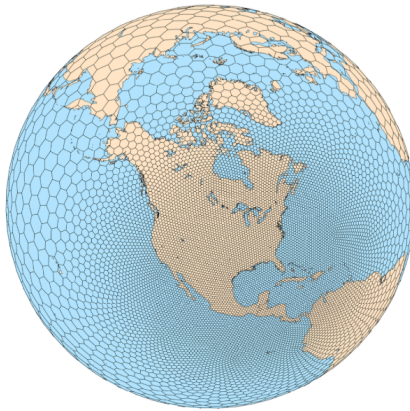
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Home / Model for Prediction Across Scales - Atmosphere

View source GitHub

Model for Prediction Across Scales - Atmosphere

The atmospheric component of MPAS uses an unstructured centroidal Voronoi mesh (grid, or tessellation) and C-grid staggering of the state variables as the basis for the horizontal discretization in the fluid-flow solver. The unstructured variable resolution meshes can be generated having smoothly-varying mesh transitions (see figure (a) below), which ameliorates many issues associated with the traditional mesh refinement strategy of one-way and two-way grid nesting where the transitions are abrupt. The flexibility of the MPAS meshes allows for applications in high-resolution numerical weather prediction (NWP) and regional climate, in addition to global uniform-resolution NWP and climate applications.



Documentation & Resources

- [Overview of MPAS-A](#)
- [MPAS-A User Guide](#)
- [MPAS-A Technical Description](#)
- [MPAS Mesh Specification](#)
- [MPAS-A Tutorial Practice Guide](#)
- [MPAS Data Assimilation](#)
- [MPAS-JEDI Tutorial Practice Guide](#)

Access Code, Data, & Meshes

Information and links to MPAS-A source code, static geographical datasets, meshes, and input files for real-data and idealized test cases

NSF | NCAR
Model for Prediction Across Scales - Atmosphere

Documentation +
Downloads +
GPU-enabled MPAS-A +
Visualization
News & Events
Publications

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Next Up...

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