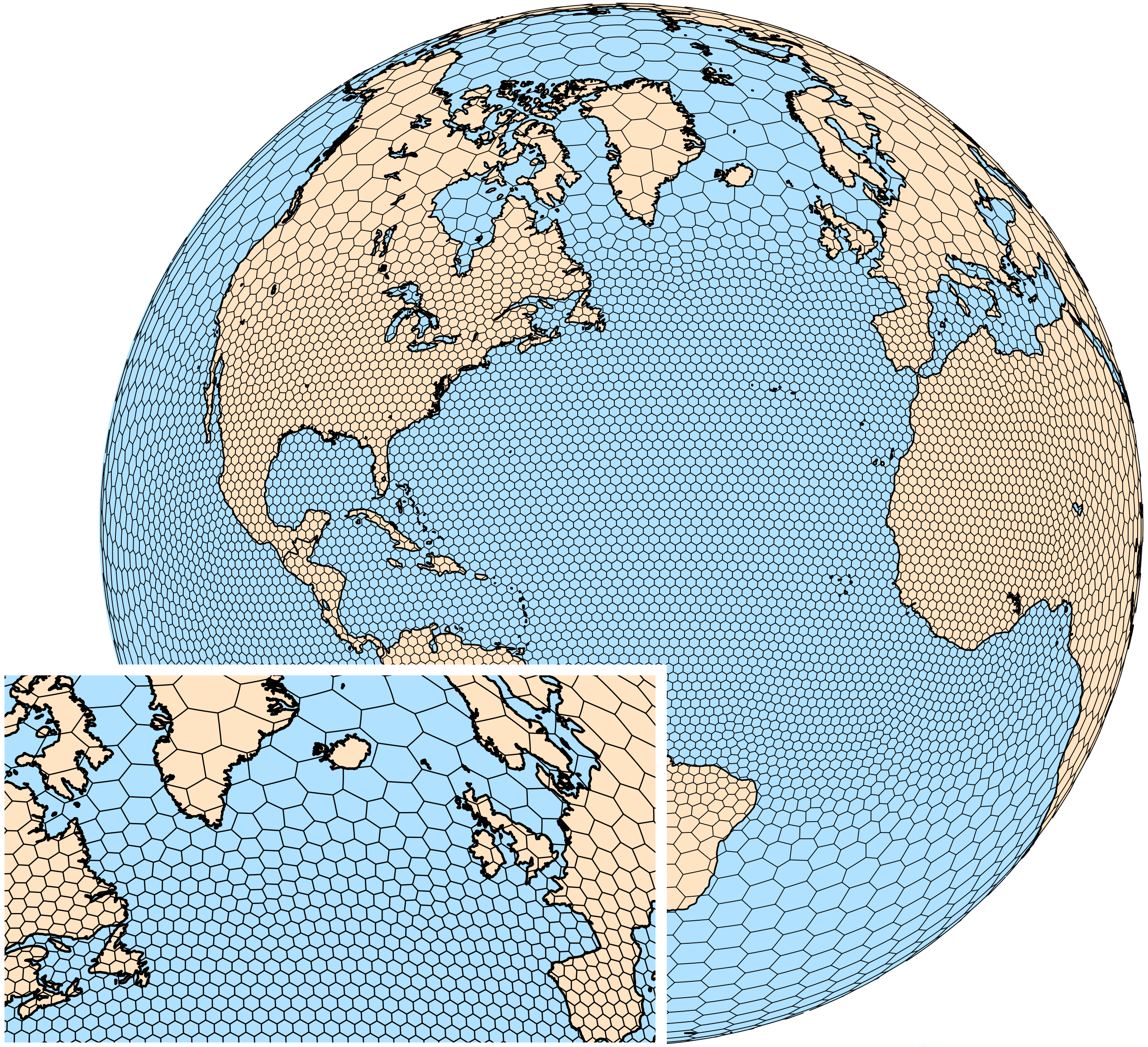
MPAS
Model for Prediction Across Scales

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

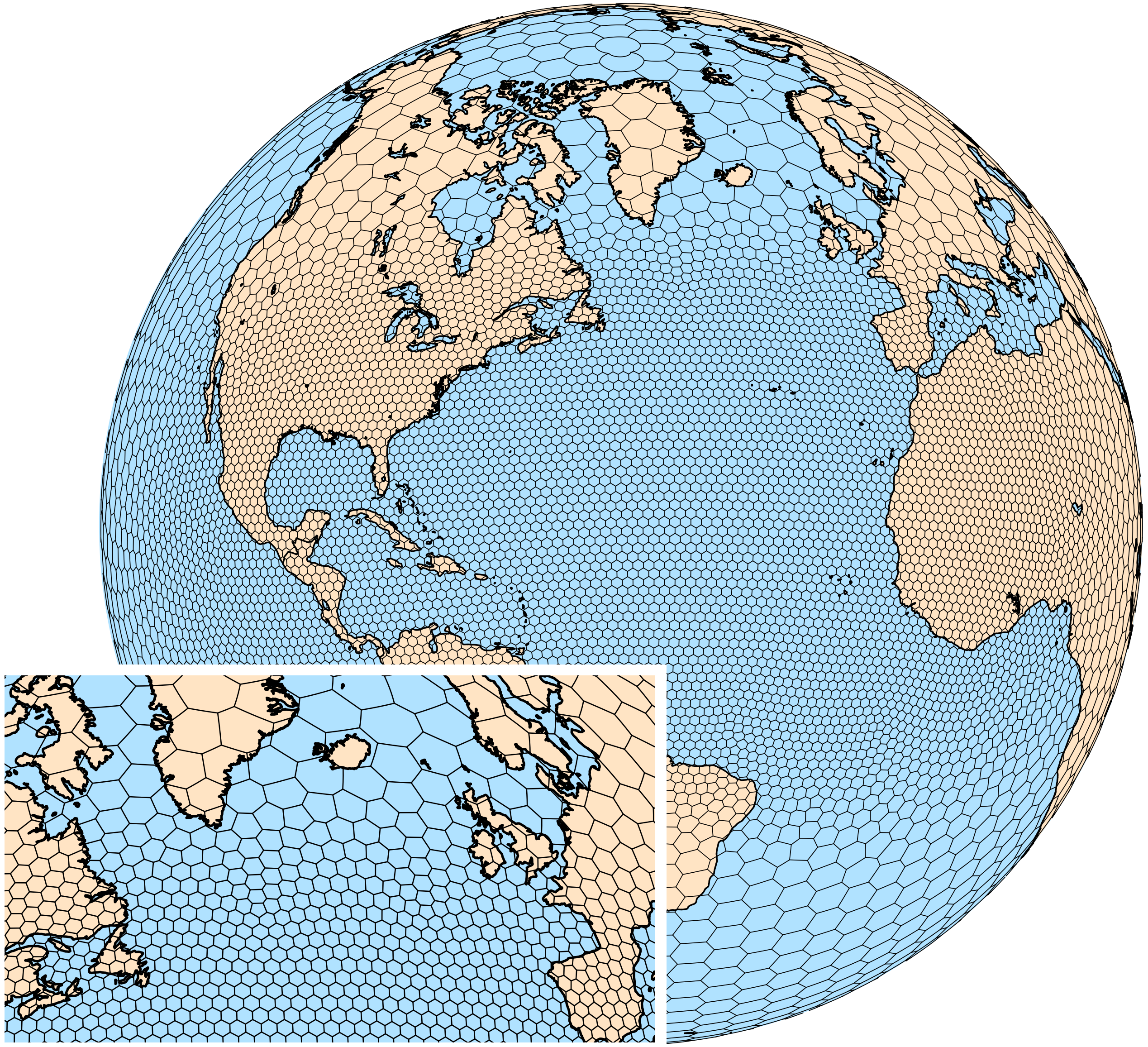


Welcome to the MPAS-A Tutorial

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

MPAS

Model for Prediction Across Scales



There are 6 instructors for this tutorial:

Ming Chen
Michael Duda
Jihyeon Jang
Bill Skamarock
Wei Wang
May Wong

Please feel free to ask questions!

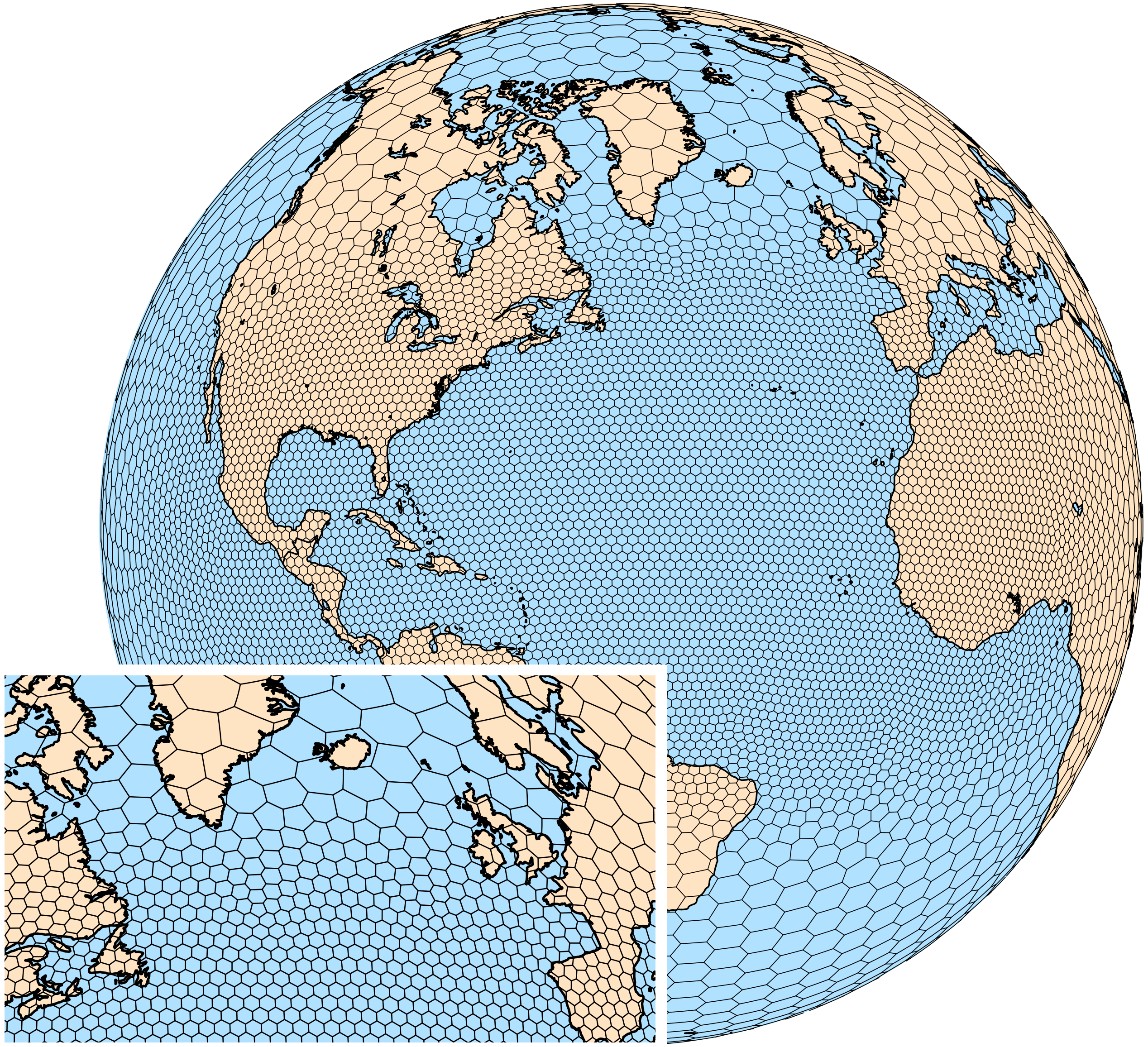
MPAS

Model for Prediction Across Scales

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

Monday 12 January 2026:

9:30 – 9:50 MPAS Overview
9:50 – 10:10 MPAS-A System Requirements and Installation
10:10 – 11:05 Running MPAS, part 1: Creating ICs and running a basic global simulation
11:05 – 11:20 **Break**
11:20 – 11:30 Introduction to the practical exercises
11:30 – 12:15 Practical session
12:15 – 13:30, **Break**
13:30 – 14:00 Running MPAS, part 2: Variable-resolution, I/O streams, restarts, and other options
14:00 – 14:45 Practical session
14:45 – 15:00 Break
15:00 – 16:00 Practical session

Welcome to the MPAS Tutorial

<u>Tuesday 13 January 2026:</u>

9:00 – 9:45 Dynamics and dynamics configuration
9:45 – 10:30 Physics introduction and configuration in MPAS
10:30 – 10:45 **Break**
10:45 – 11:15 Am overview of the structure of MPAS meshes
11:15 – 11:45 Running MPAS, part 3: Preparing limited-area meshes and running regional simulations
11:45 – 12:15 Post-processing and visualizing MPAS-Atmosphere output
12:15 – 13:30, **Break**
13:30 – 14:45 Practical session
14:45 – 15:00 **Break**
15:00 – 16:00 Practical session

Welcome to the MPAS Tutorial

Wednesday 14 January 2026:

9:00 – 9:25 Unique aspects of MPAS code: Registry, pools, and logging
9:25 – 9:50 Adding passive tracers to MPAS-Atmosphere simulations
9:50 – 10:15 Computing new diagnostic fields in MPAS-Atmosphere simulations
10:15 – 10:30 **Break**
10:30 – 11:10 Spatial discretization, filters and transport
11:10 – 11:40 MPAS mesh generation
11:40 – 12:05 New MPAS capabilities under development, and concluding remarks
12:05 – 13:30, **Break**
13:30 – 14:45 Practical session
14:45 – 15:00 **Break**
15:00 – 16:00 Practical session

MPAS
Model for Prediction Across Scales

MPAS Version 8.3.0 (2 June 2025), 8.3.1:

MPAS infrastructure - NCAR, LANL, others.

- Infrastructure for the Voronoi mesh and solvers (data structures; mesh generation, manipulation; operators on the mesh).

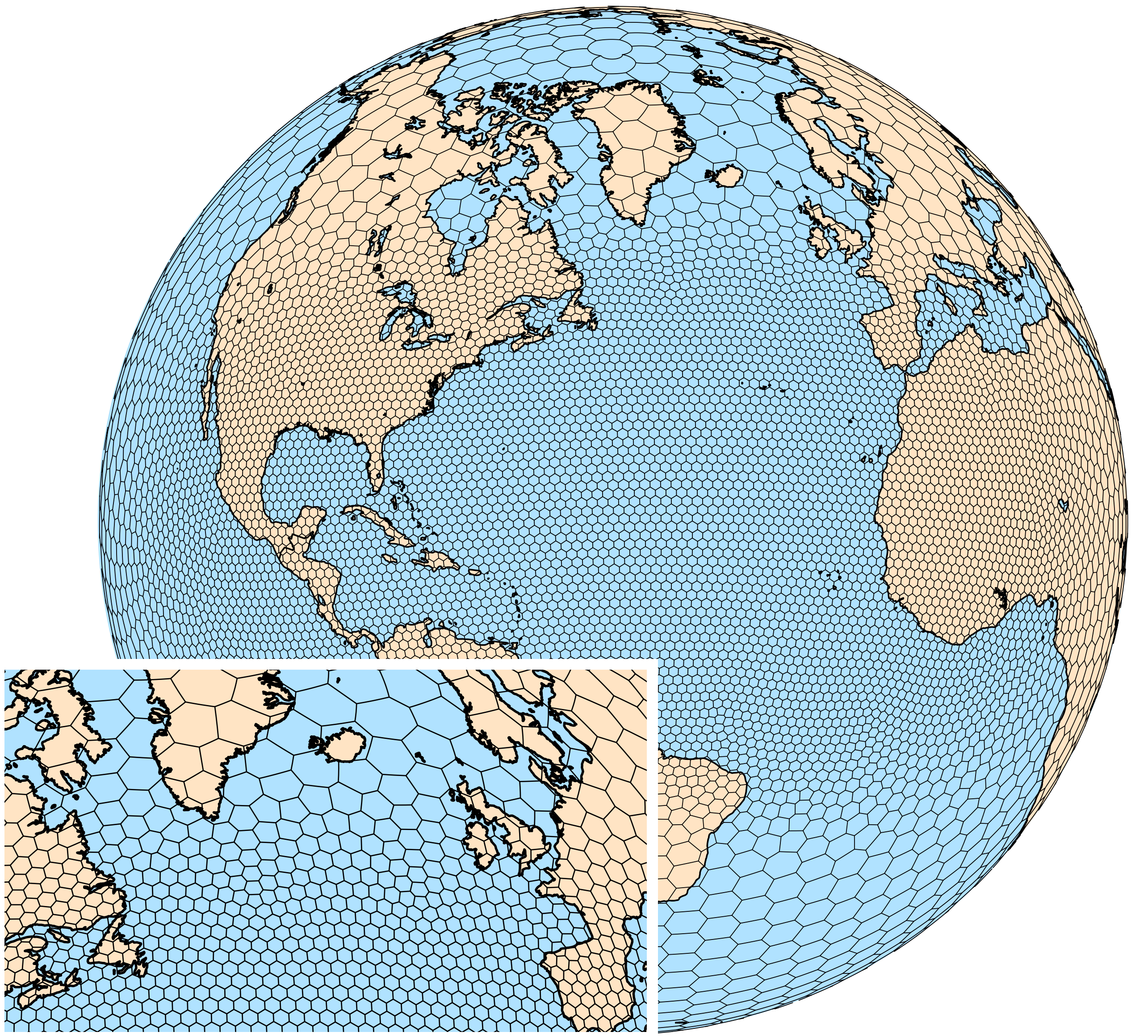
MPAS - Atmosphere (NCAR)

- 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
Model for Prediction Across Scales

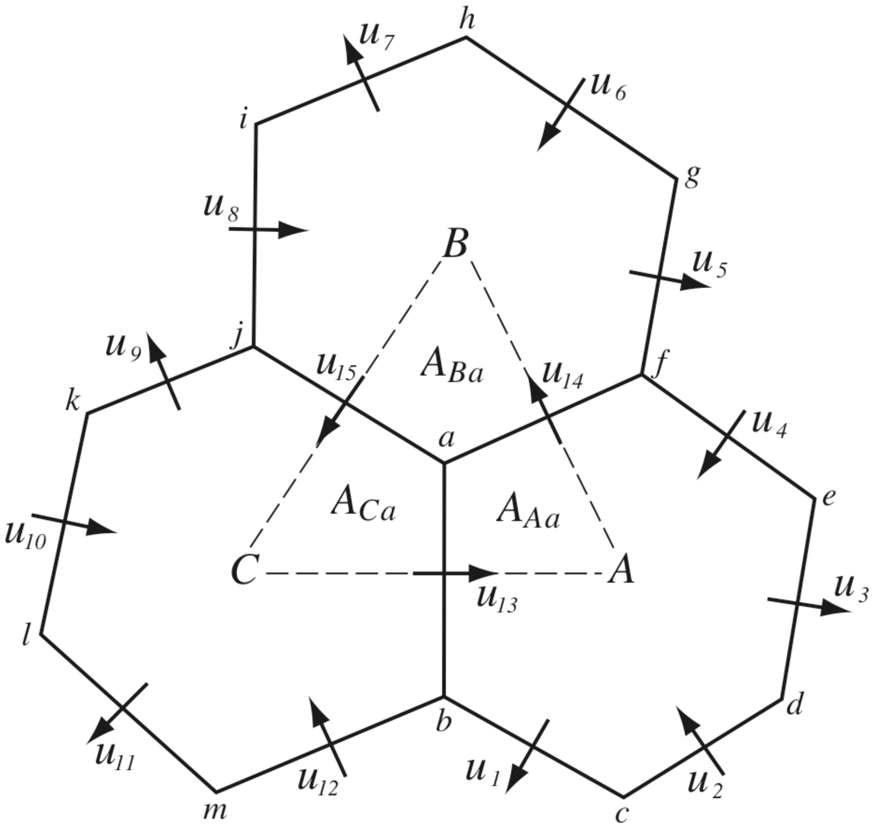
What is MPAS?
Centroidal Voronoi Meshes

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.

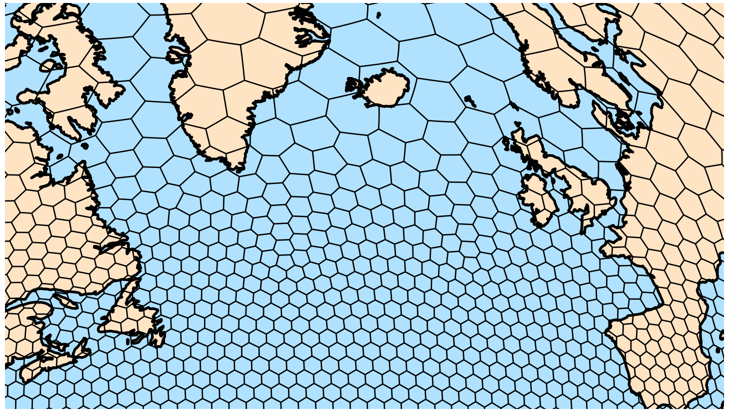
C-grid

- 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.

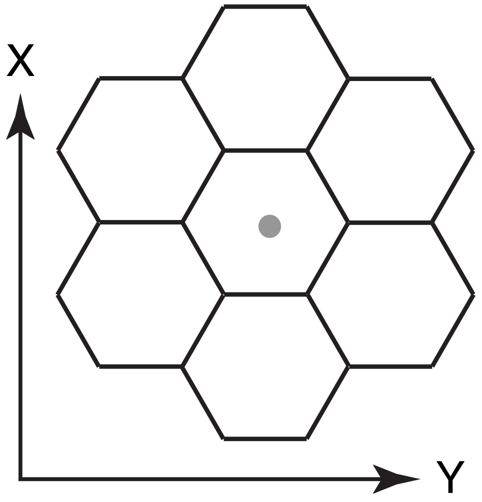


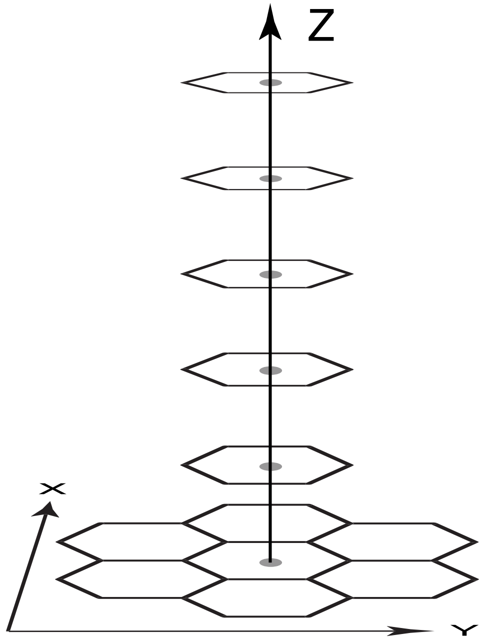
What is MPAS?
Centroidal Voronoi Meshes

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



The mesh is
structured in the
vertical





MPAS Nonhydrostatic Atmospheric Solver

MPAS
Model for Prediction Across Scales

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

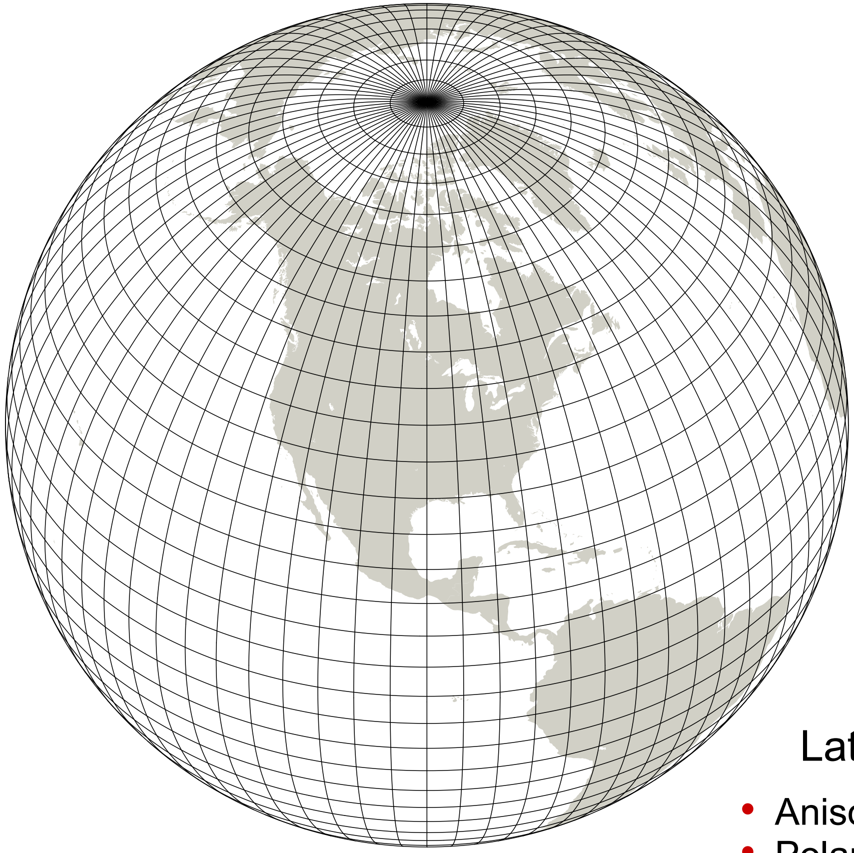
Full complement of atmospheric-model physics

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

MPAS
Model for Prediction Across Scales

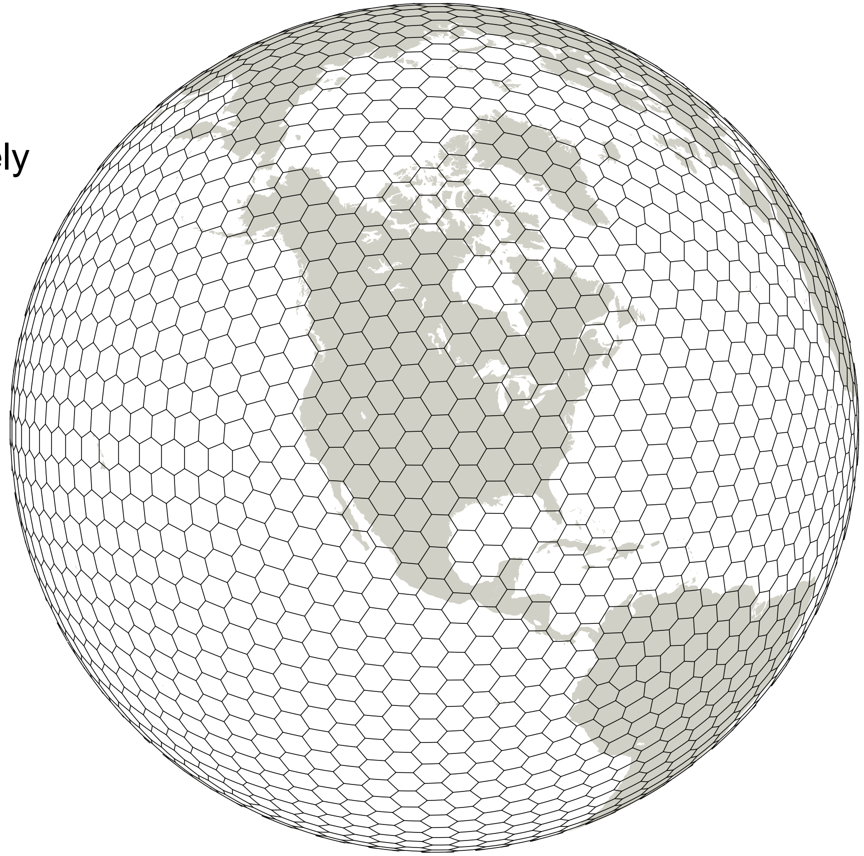
Why MPAS?

Significant differences between WRF and MPAS



MPAS
Unstructured Voronoi (hexagonal) grid

- Good scaling on massively parallel computers
- No pole problems

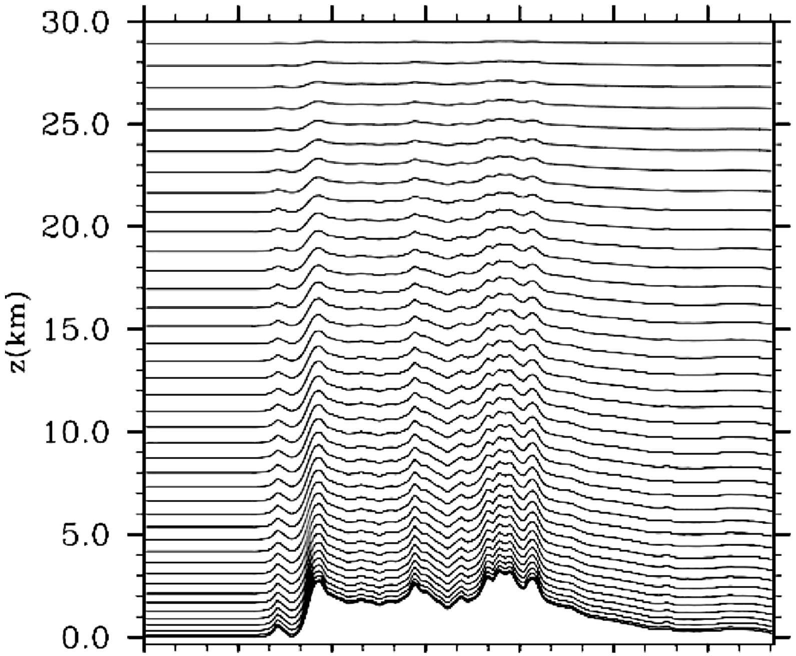


WRF
Lat-Lon global grid

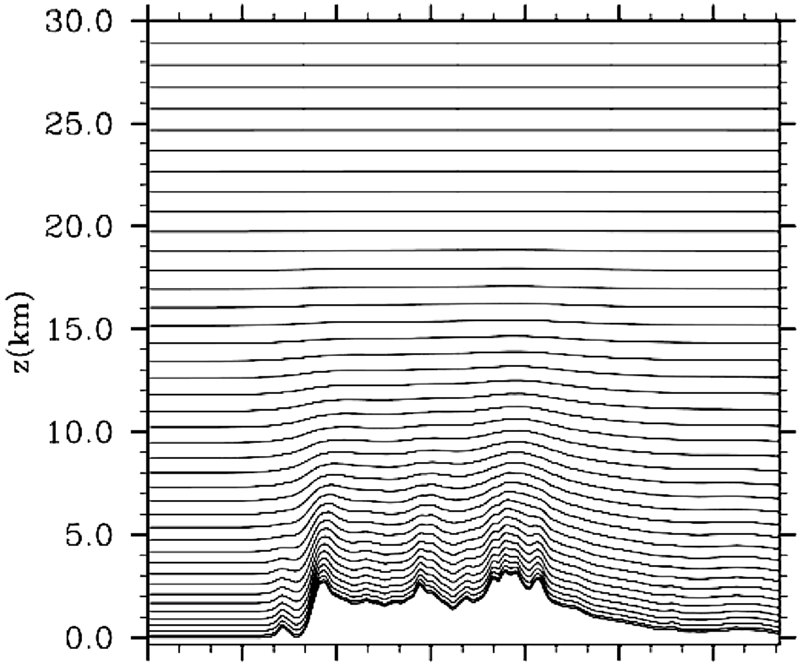
- Anisotropic grid cells
- Polar filtering required
- Poor scaling on massively parallel computers

Why MPAS?

Significant differences between WRF and MPAS



WRF
Pressure-based terrain-following sigma vertical coordinate



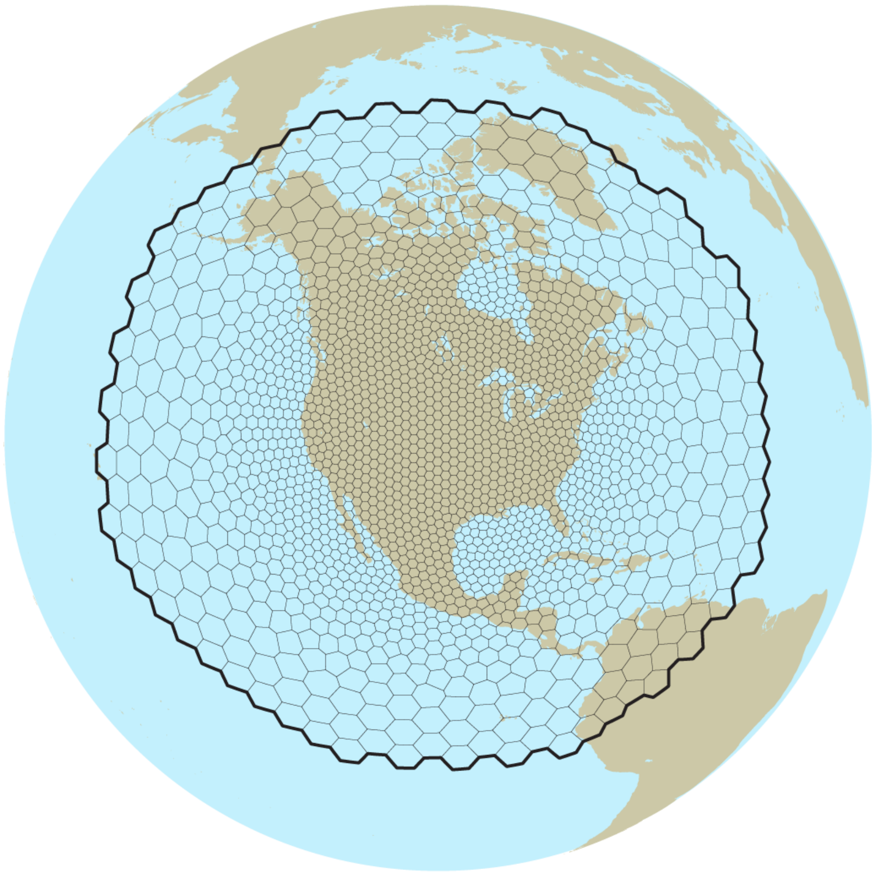
MPAS
Height-based hybrid smoothed terrain-following vertical coordinate

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.

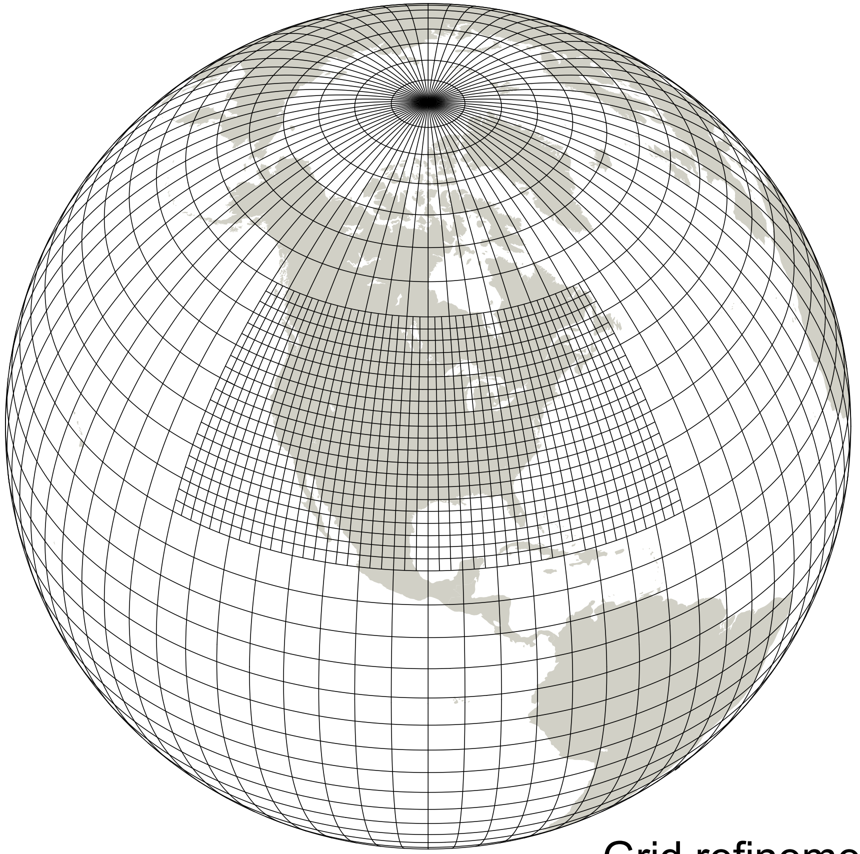
- Leverage MPAS development for next-generation architectures to regional applications (e.g. GPUs).
- Enable regional atmospheric applications within MPAS-enabled coupled modeling systems.
- Employ variable resolution in regional applications to reduce LBC errors.



MPAS
Model for Prediction Across Scales

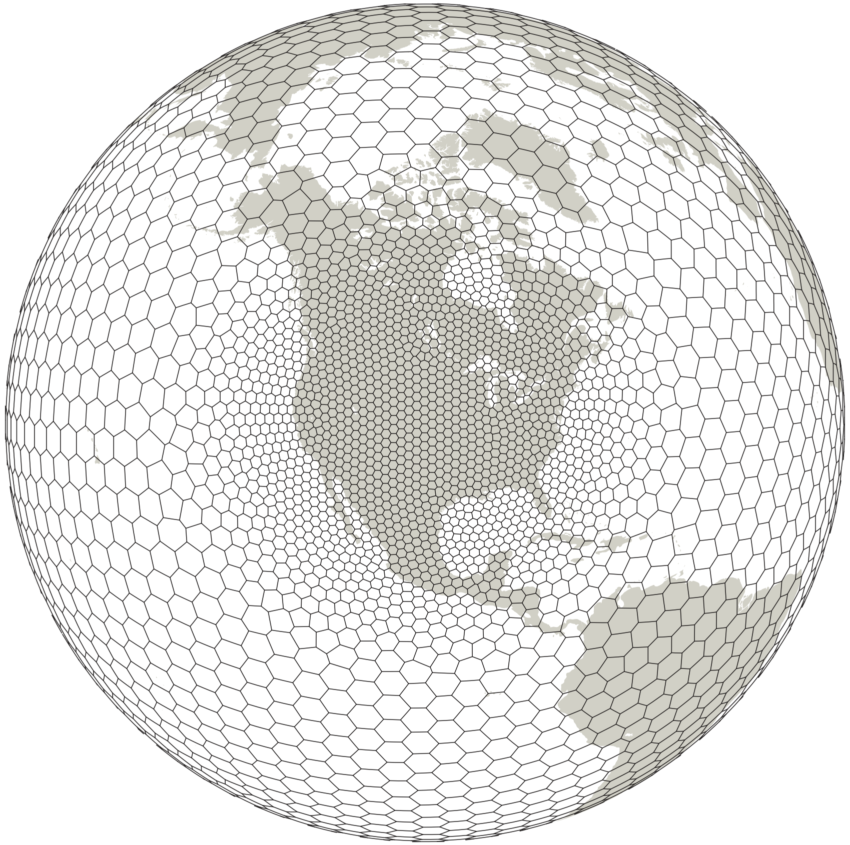
Why MPAS?

Significant differences between WRF and MPAS



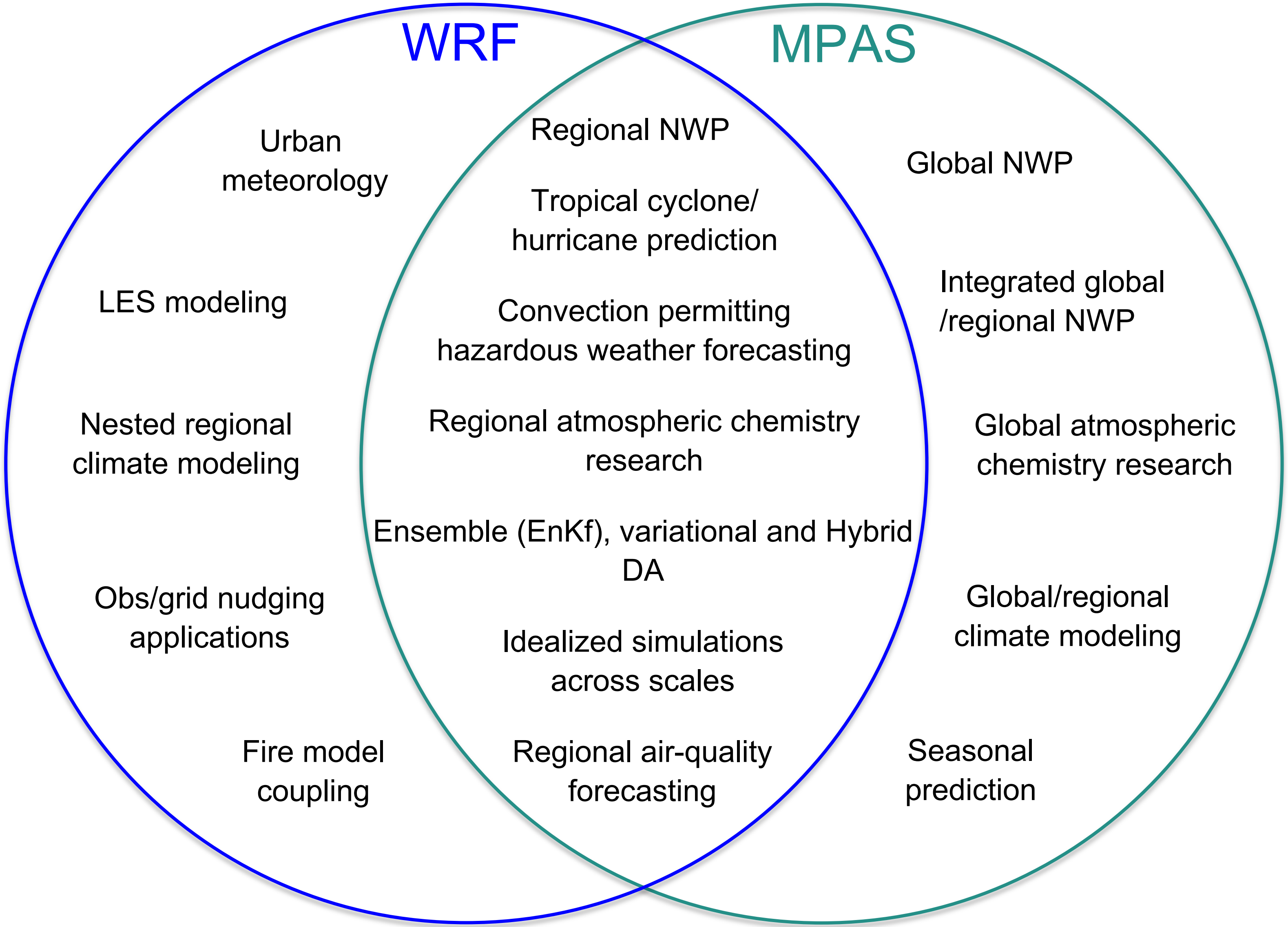
MPAS
Smooth grid refinement
on a conformal mesh

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

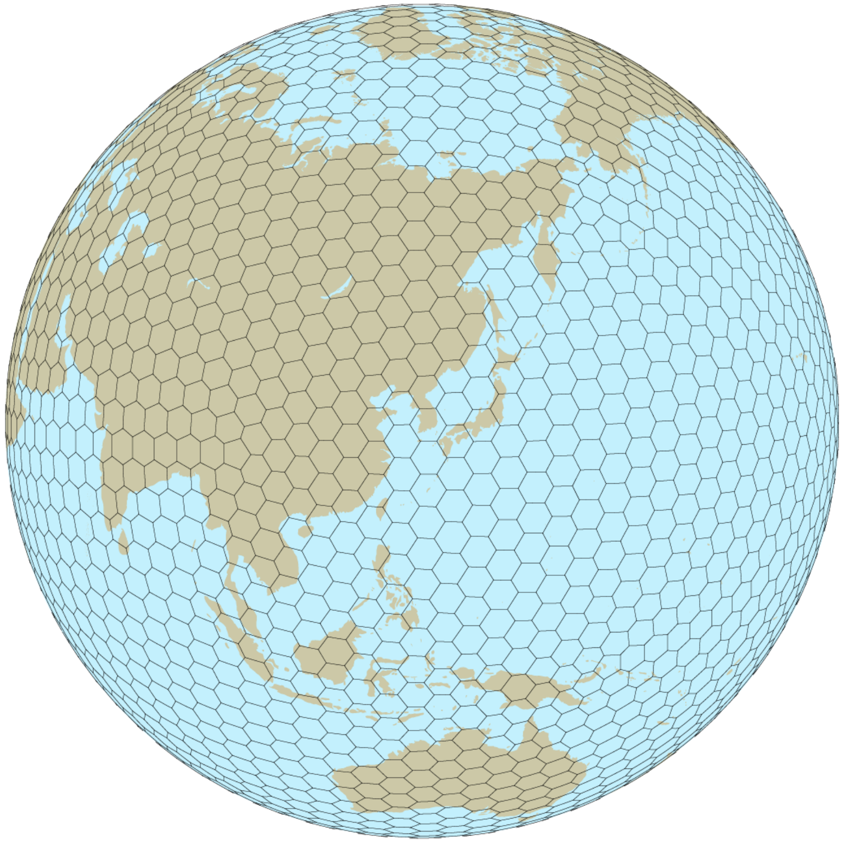


WRF
Grid refinement through domain nesting

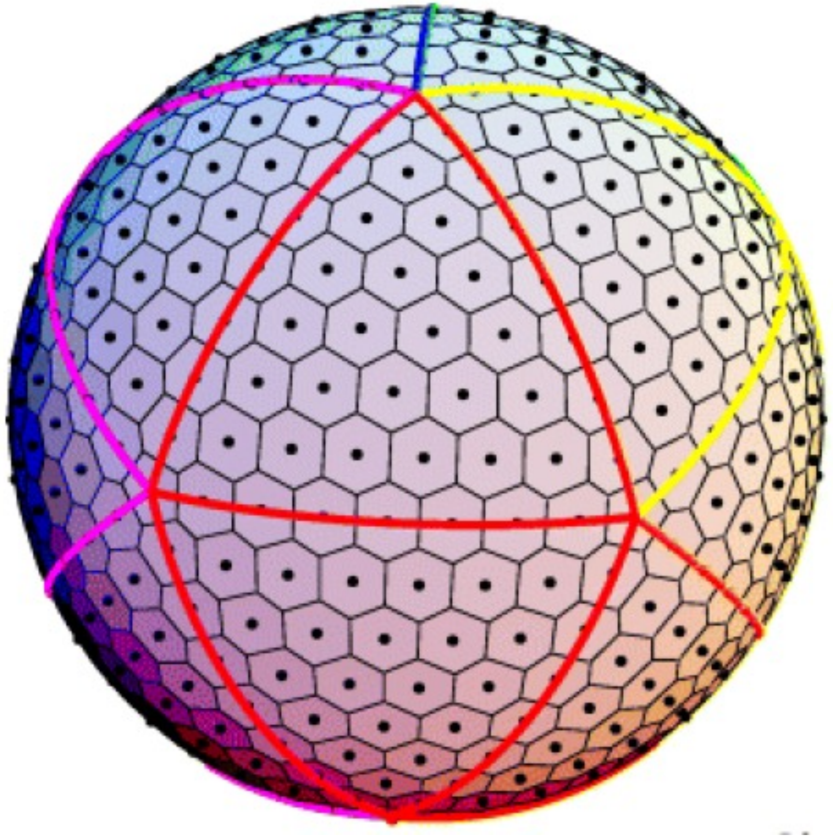
- Flow distortions at nest boundaries


WRF
MPAS
Urban meteorology
LES modeling
Nested regional climate modeling
Obs/grid nudging applications
Fire model coupling
Regional NWP
Tropical cyclone/ hurricane prediction
Convection permitting hazardous weather forecasting
Regional atmospheric chemistry research
Ensemble (EnKf), variational and Hybrid DA
Idealized simulations across scales
Regional air-quality forecasting
Global NWP
Integrated global /regional NWP
Global atmospheric chemistry research
Global/regional climate modeling
Seasonal prediction

MPAS
Model for Prediction Across Scales



Global Quasi-Uniform
Mesh (SCVT)



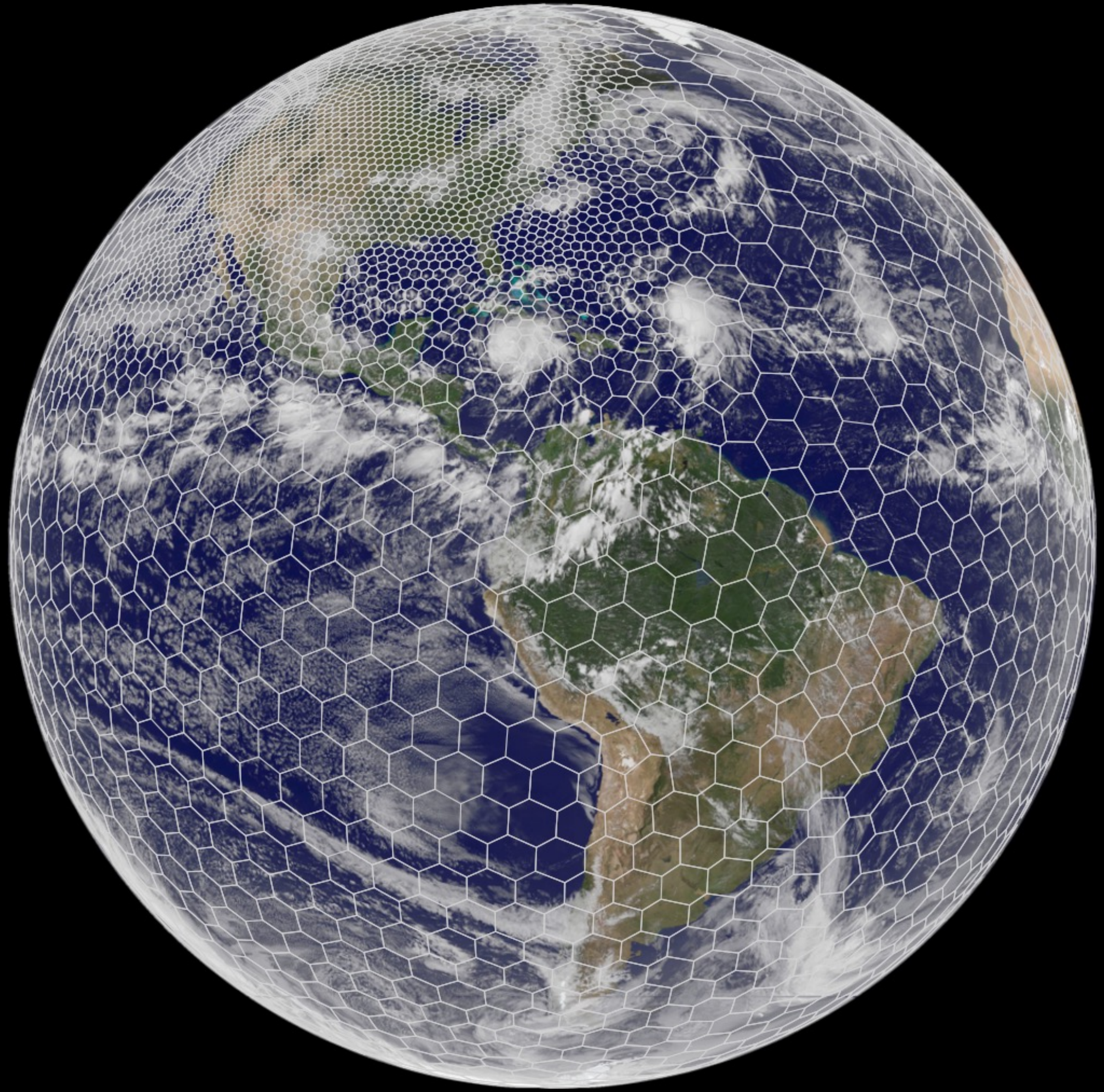
Many models use an icsoahedral mesh
(NICAM, BUGS, FIM, NIM, OLAM, etc.)

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

Lloyd's method
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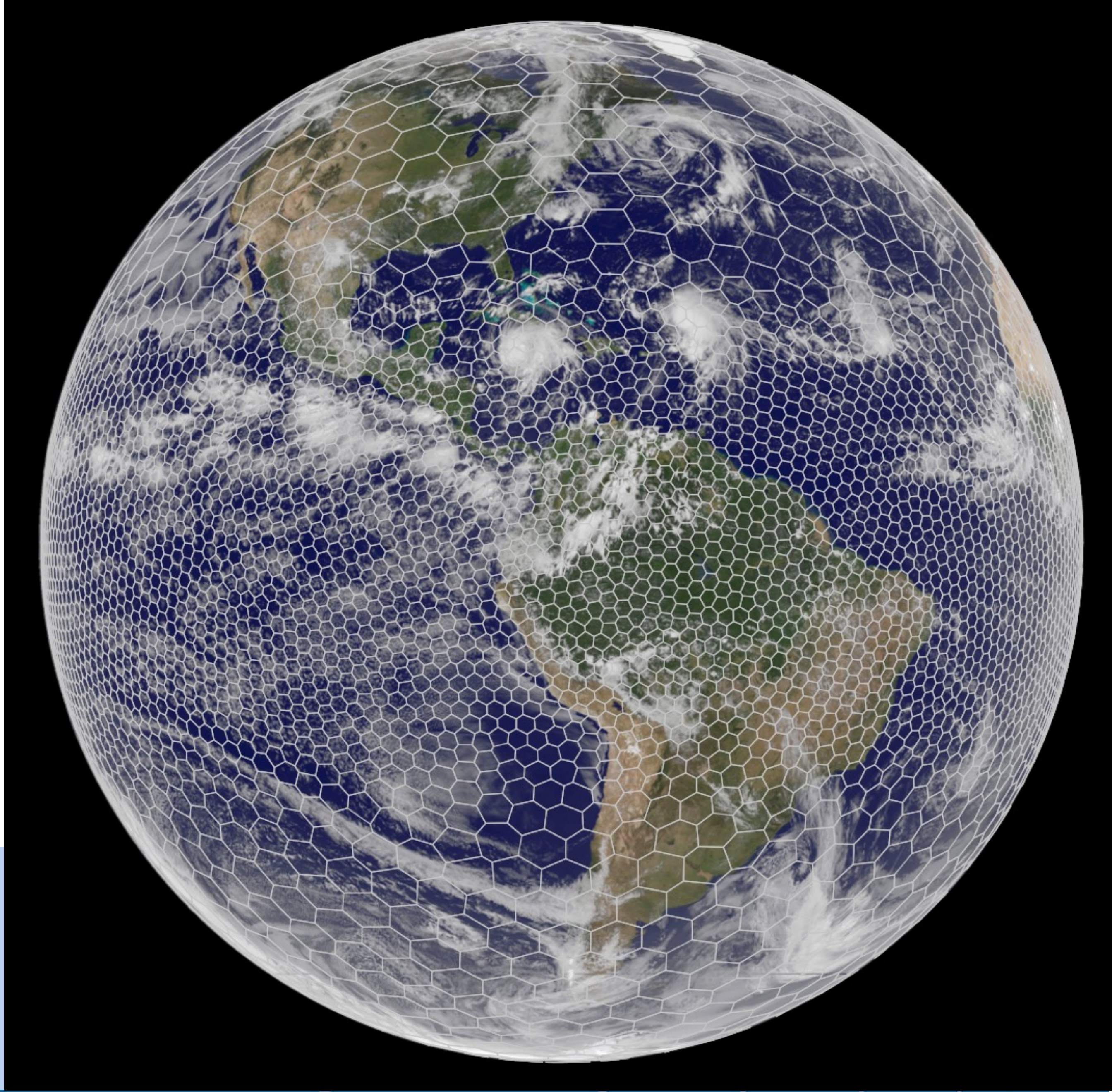


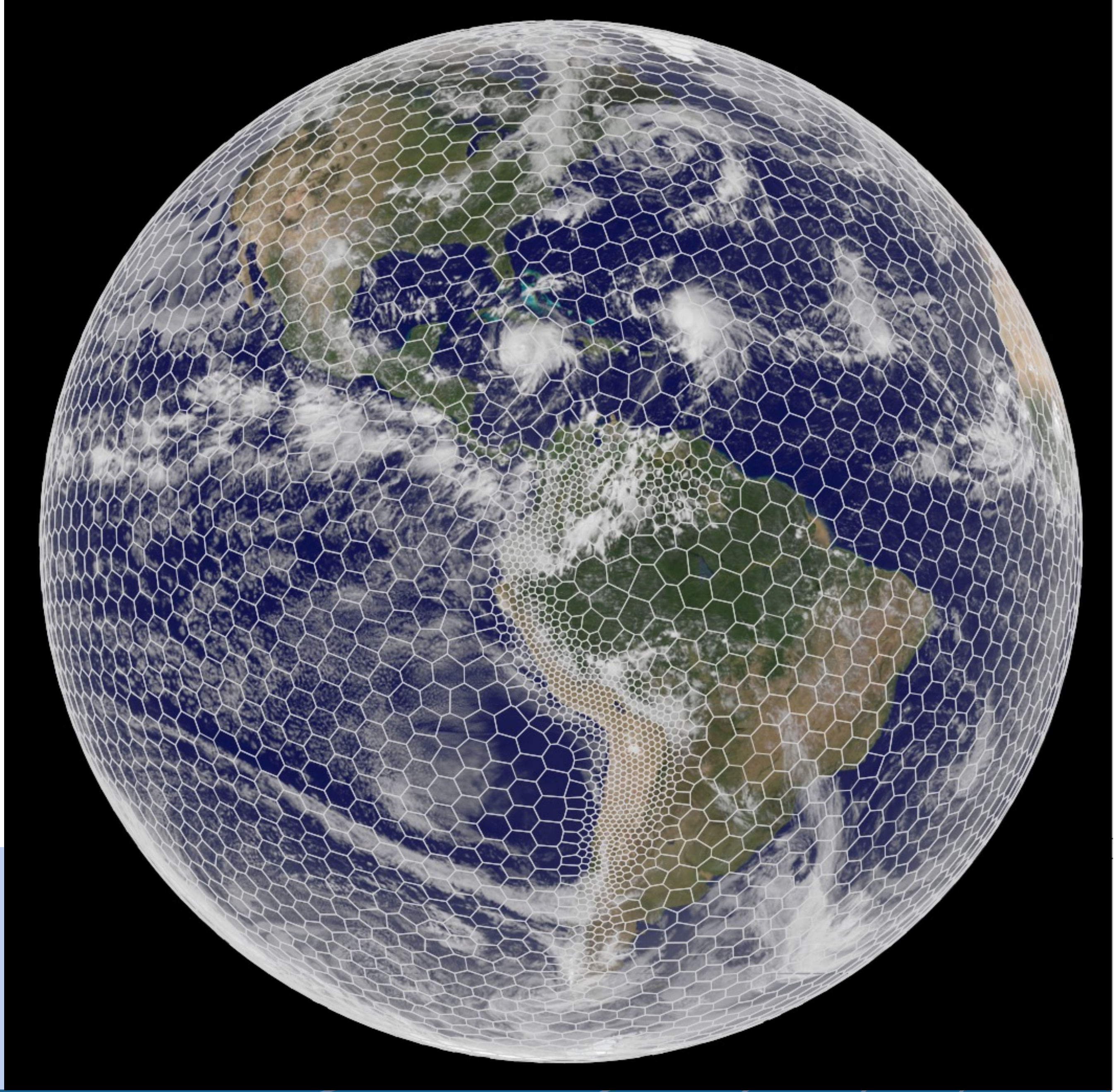
Equatorial refinement

MPAS
Model for Prediction Across Scales

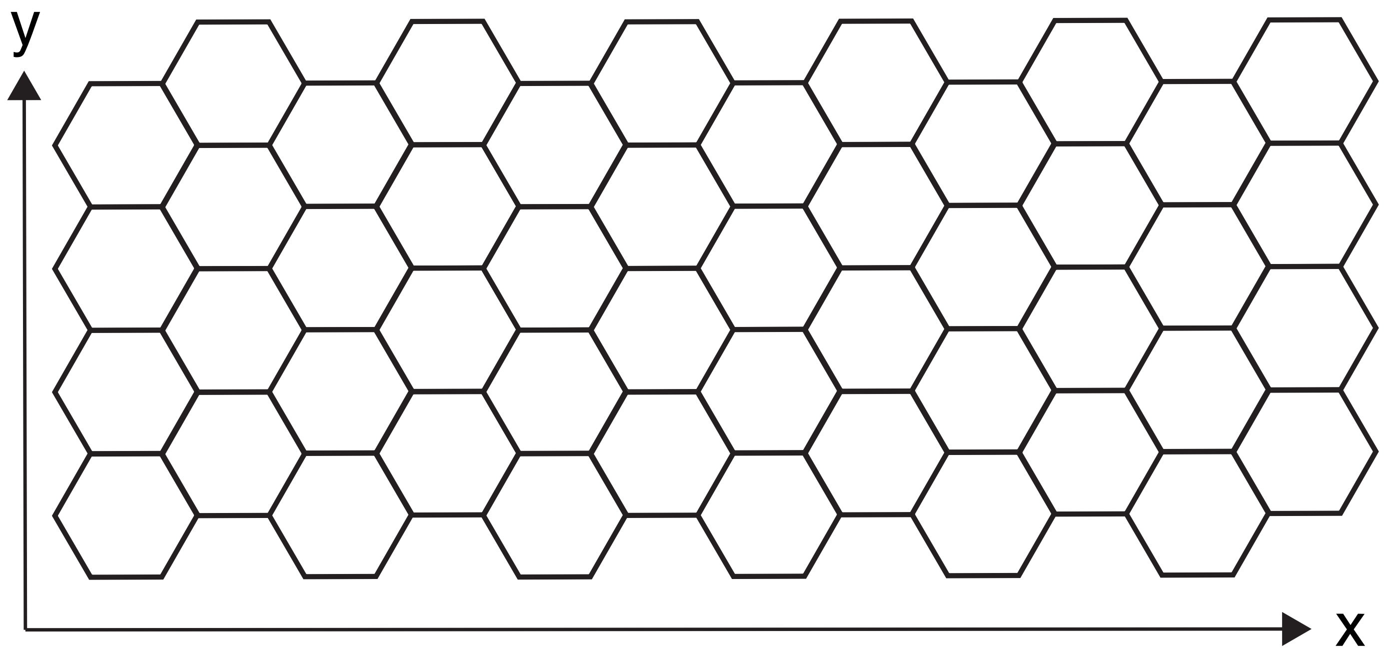
Mesh generation

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

Andes refinement

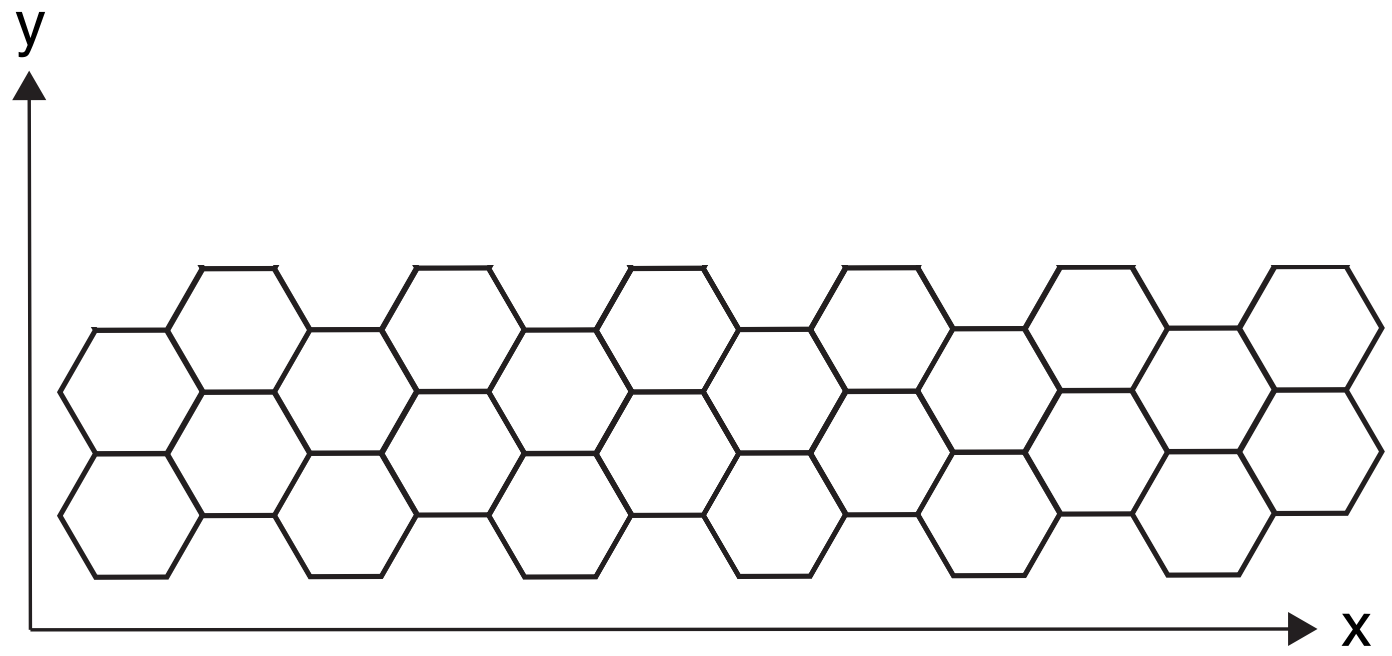


Other mesh spaces



Doubly-periodic Cartesian mesh

Other mesh spaces

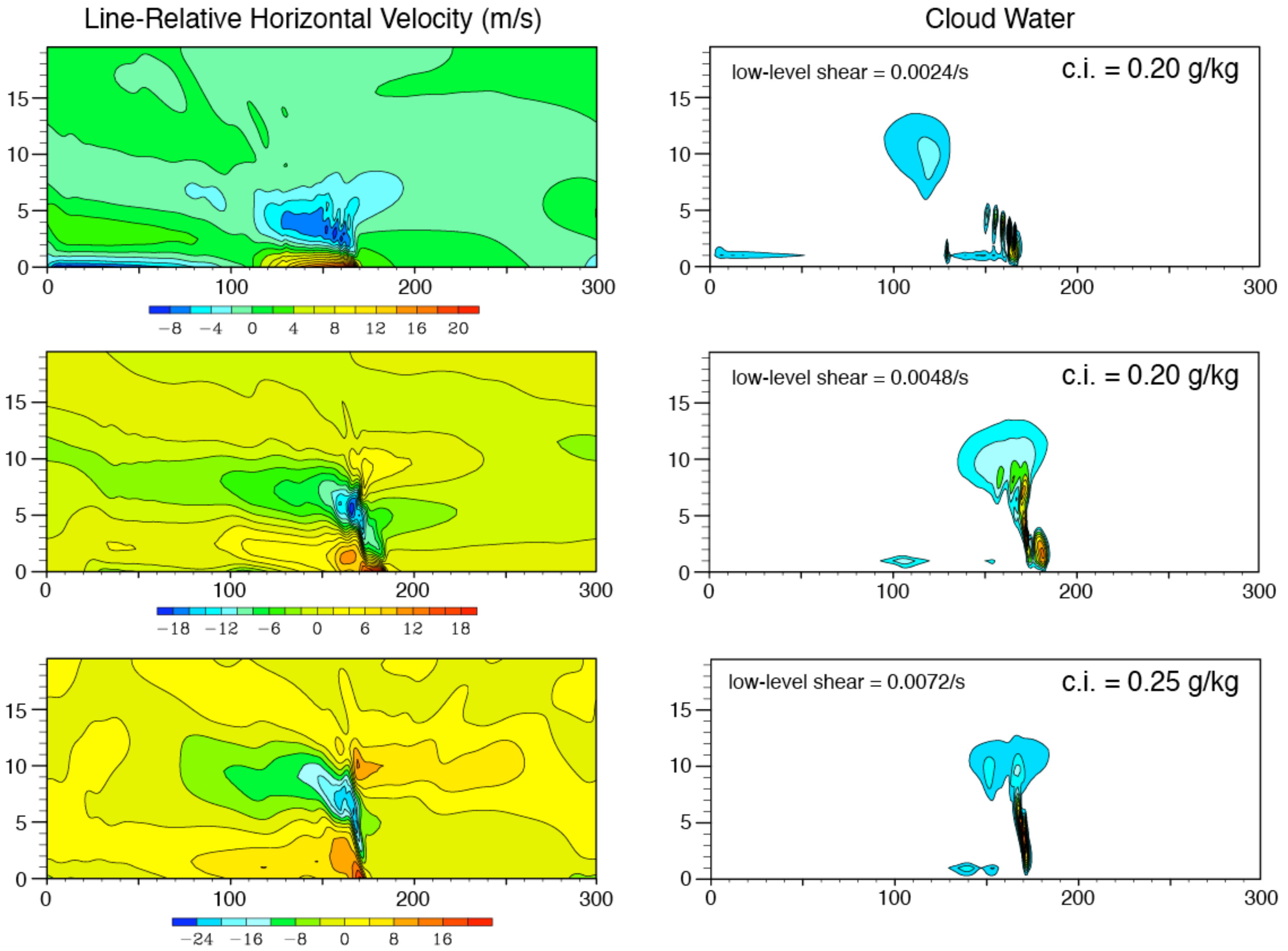


2D (y,z) mesh in MPAS
The solution does not vary in y, periodic in y

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



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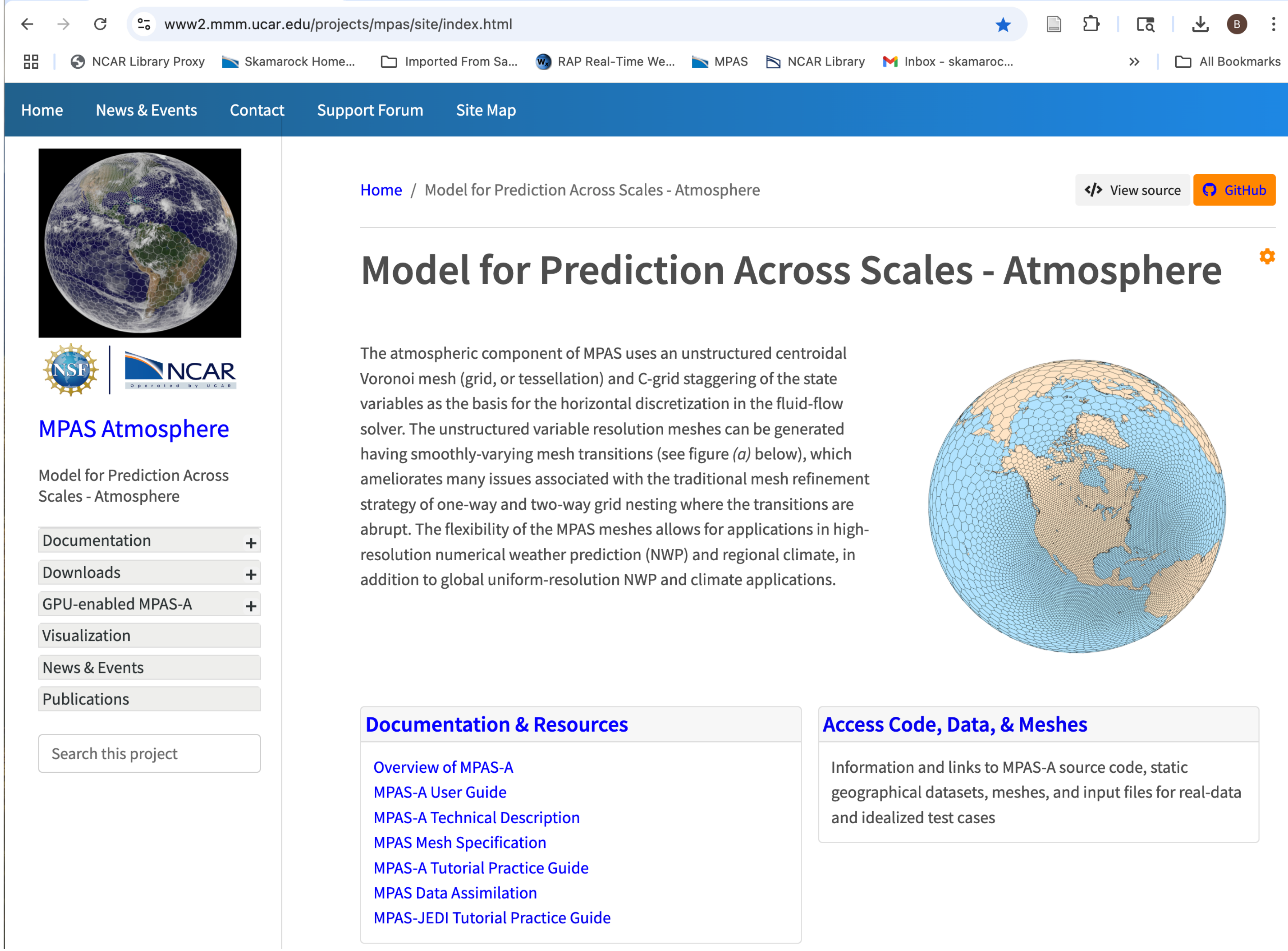
The MPAS-Atmosphere web pages provides links to a lot of information about MPAS.



Next Up…

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