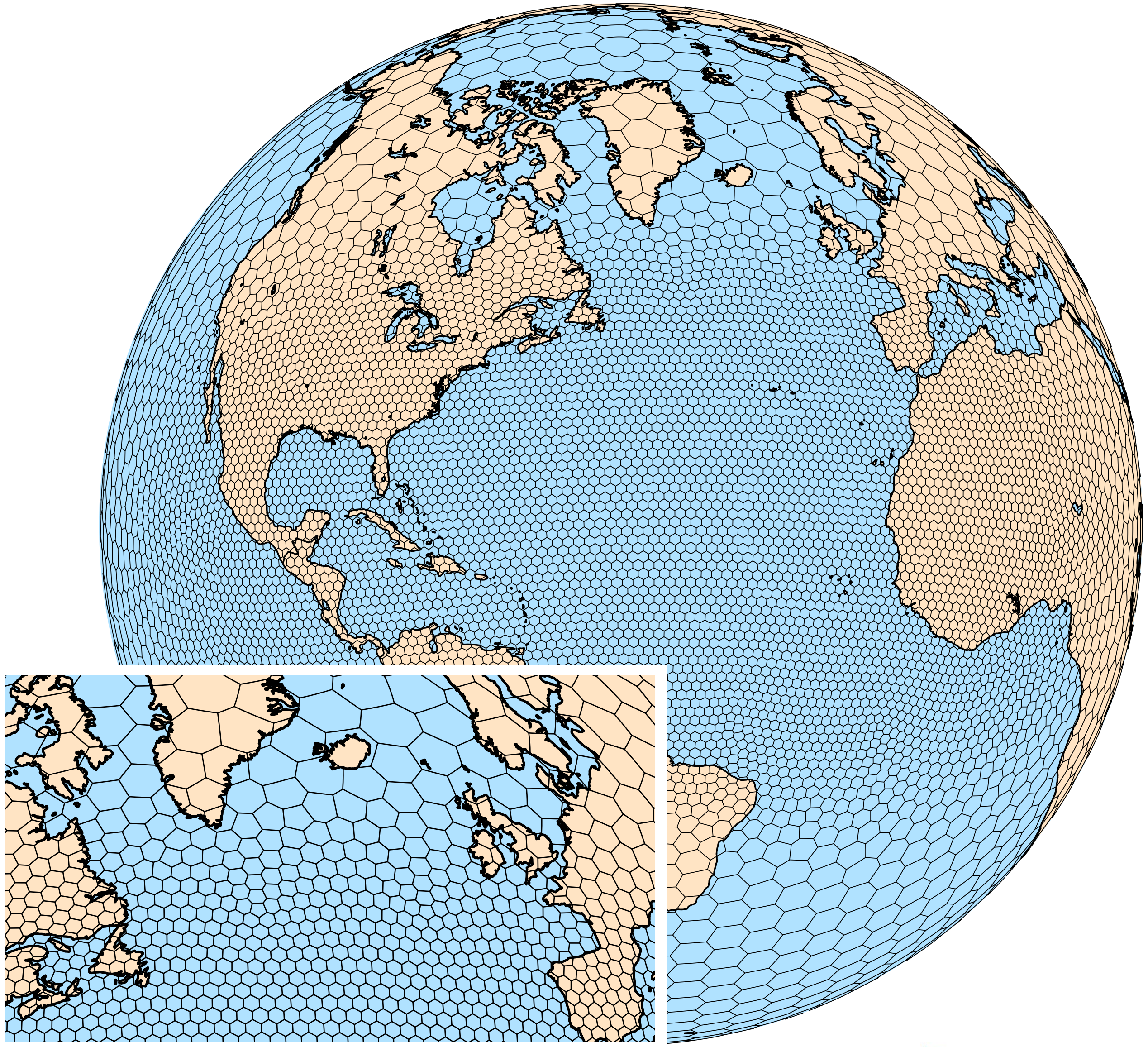
MPAS

Model for Prediction Across Scales

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



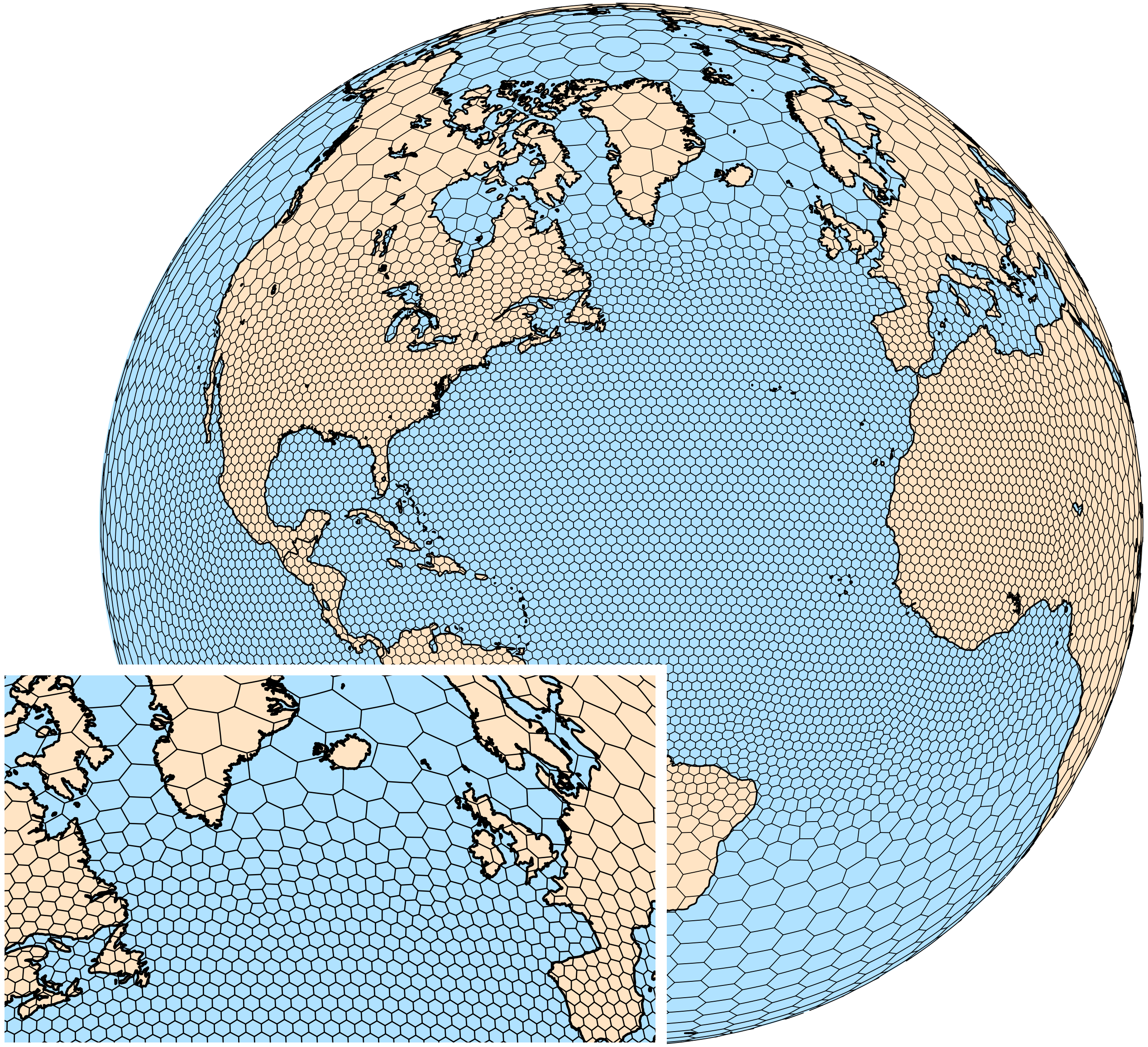
Welcome to the MPAS-A Tutorial

MPAS
Model for Prediction Across Scales

General Information

- Breaks: Cafeteria atrium (behind the auditorium stage)
- Practical sessions: Classroom (behind the FL2 reception desk)
- Bathrooms: Either side of the Auditorium going towards the cafeteria
- Lunch: Cafeteria – show the checkout person your tutorial name-badge
- Visitor WiFi network is available for your use

MPAS
Model for Prediction Across Scales



There are 5 instructors for this tutorial:

Ming Chen
Michael Duda
Bill Skamarock
Wei Wang
May Wong

Please feel free to ask questions!

Welcome to the MPAS Tutorial

Monday 15 September:

9:15 – 09:30 Registration
9:30 – 9:45 Welcome and Introductions
9:45 – 10:05 MPAS Overview
10:05 – 10:25 MPAS-A System Requirements and Installation
10:25 – 11:20 Running MPAS, part 1: Creating ICs and running a basic global simulation
11:20 – 11:35 **Break**
11:35 – 11:45 Introduction to the practical exercises
11:45 – 12:30 Practical session
12:30 – 13:45, **Lunch**
13:45 – 14:15 Running MPAS, part 2: Variable-resolution, I/O streams, restarts, and other options
14:15 – 15:00 Practical session
15:00 – 15:15 **Break**
15:15 – 16:15 Practical session

Welcome to the MPAS Tutorial

<u>Tuesday 16 September:</u>

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

Welcome to the MPAS Tutorial

Wednesday 17 September (morning):

9:15 – 9:40 Unique aspects of MPAS code: Registry, pools, and logging
9:40 – 10:05 Adding passive tracers to MPAS-Atmosphere simulations
10:05 – 10:30 Computing new diagnostic fields in MPAS-Atmosphere simulations
10:30 – 10:45 **Break**
10:45 – 11:25 Spatial discretization, filters and transport
11:25 – 11:55 MPAS mesh generation
11:55 – 12:20 New MPAS capabilities under development, and concluding remarks
12:20 – 13:45, **Lunch**
13:45 – 15:00 Practical session
15:00 – 15:15 **Break**
15:15 – 16:15 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).

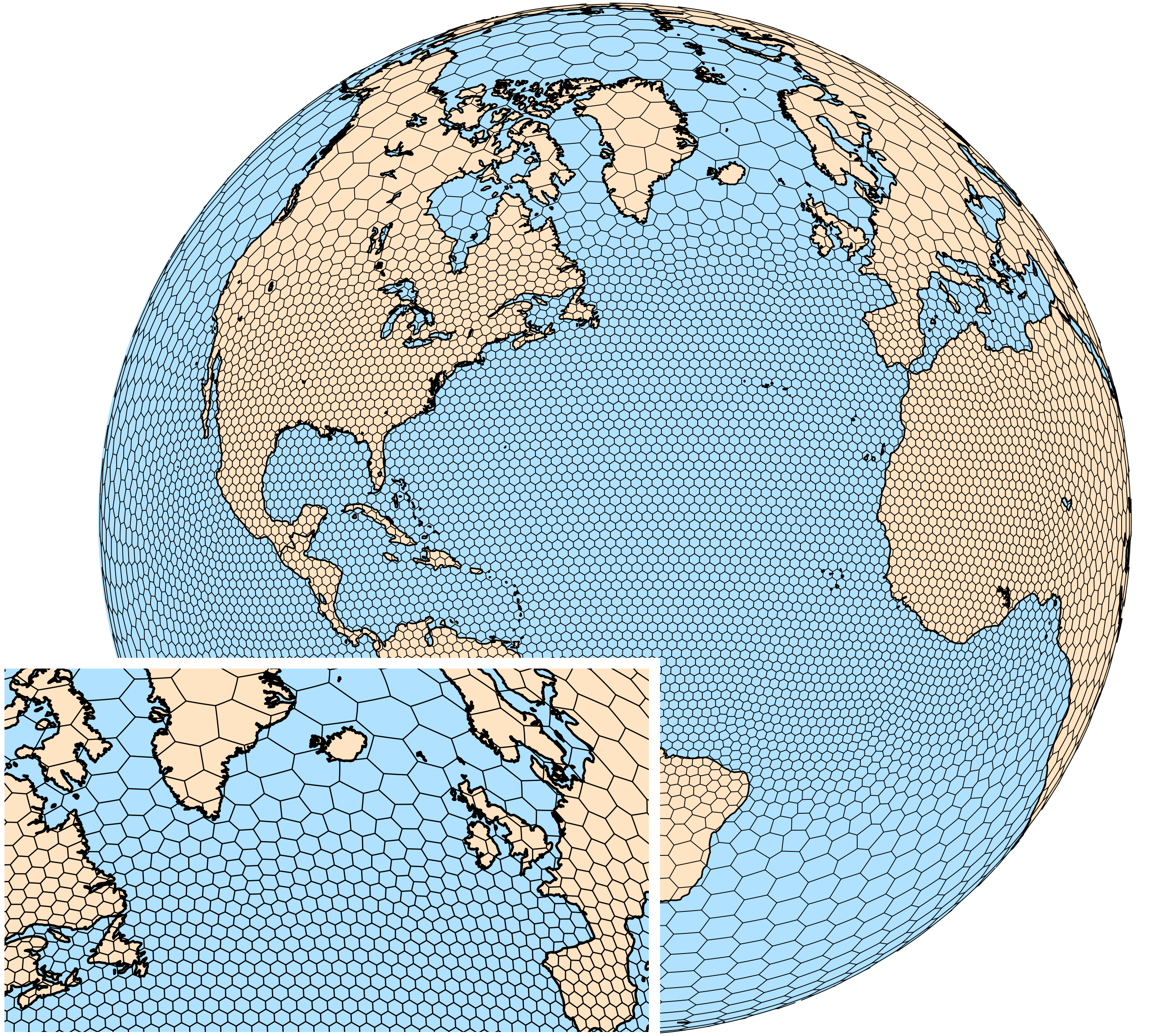
MPAS - Atmosphere (NCAR)

- 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



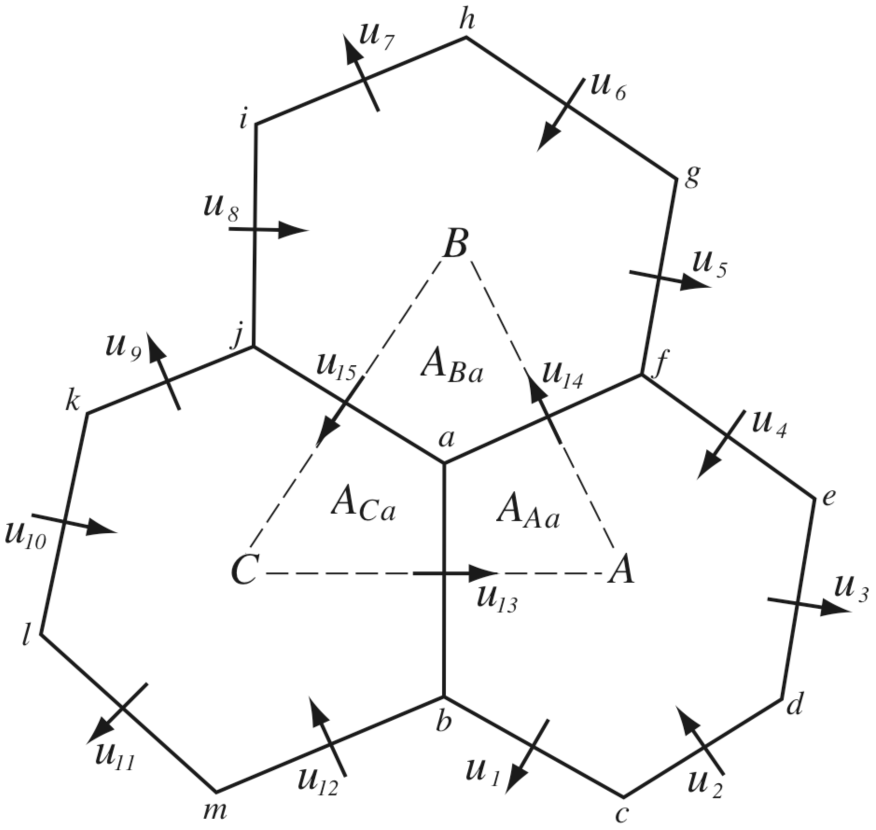
What is MPAS?
Centroidal Voronoi Meshes

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.

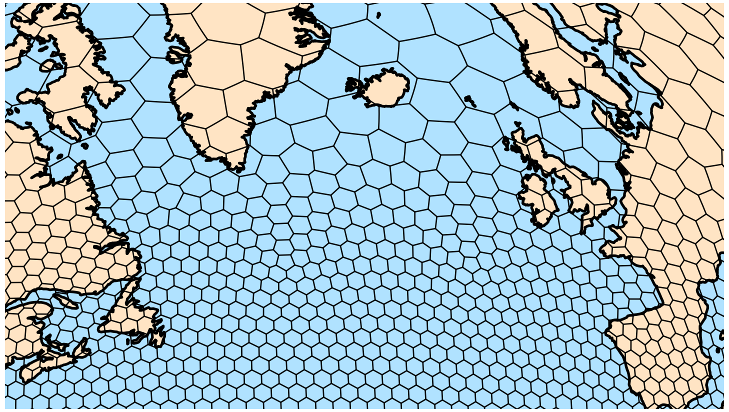
C-grid

- 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.

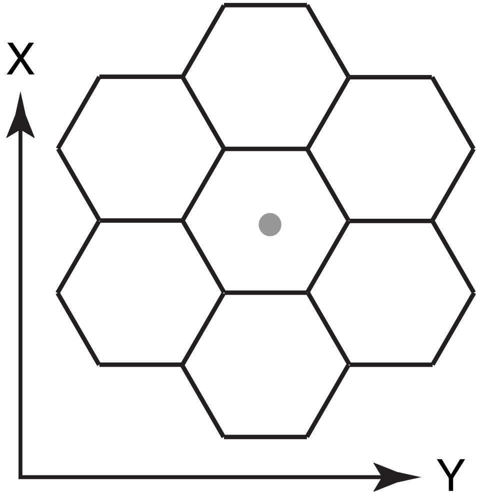


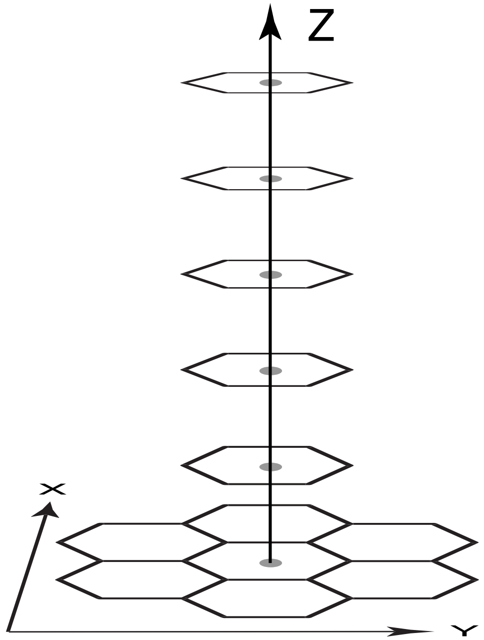
What is MPAS? *Centroidal Voronoi Meshes*

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

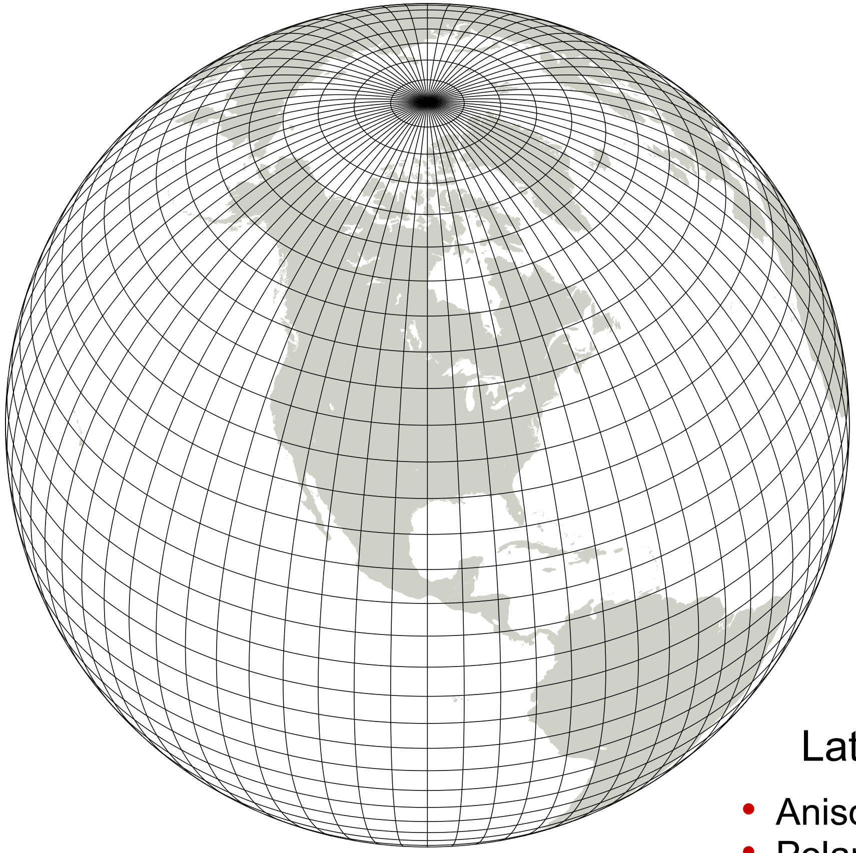
- Split-explicit Runge-Kutta, with extensions

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

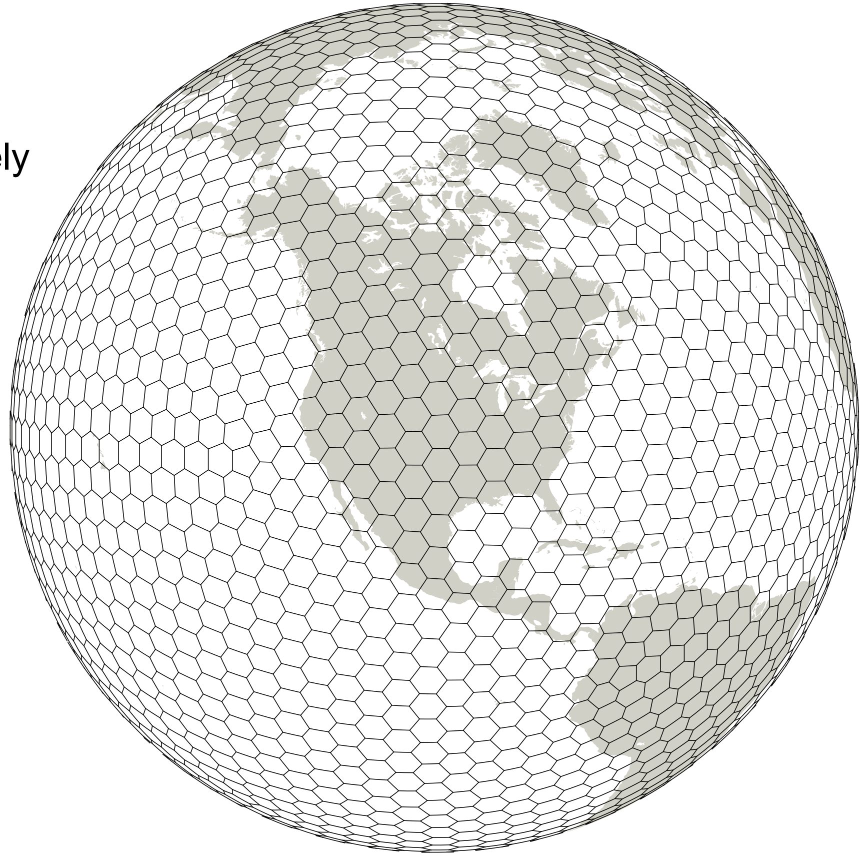
Lat-Lon global grid

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

MPAS

Unstructured Voronoi (hexagonal) grid

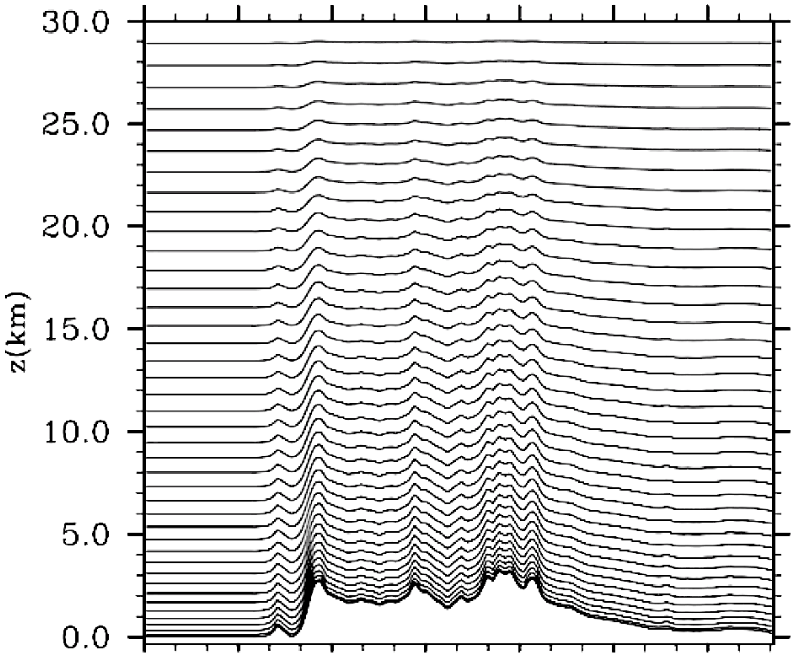
- Good scaling on massively parallel computers
- No pole problems



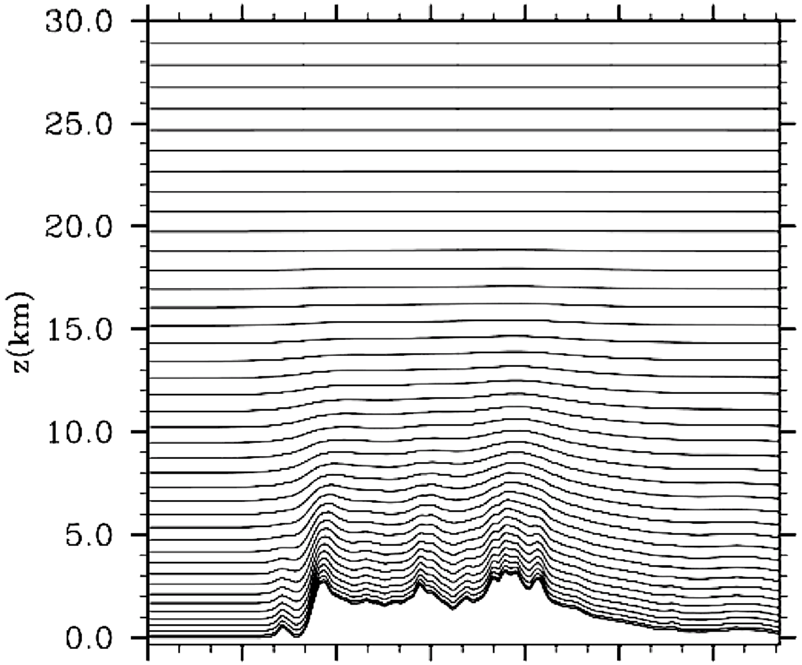
MPAS
Model for Prediction Across Scales

Why MPAS?

Significant differences between WRF and MPAS



WRF
Pressure-based terrain-following sigma vertical coordinate

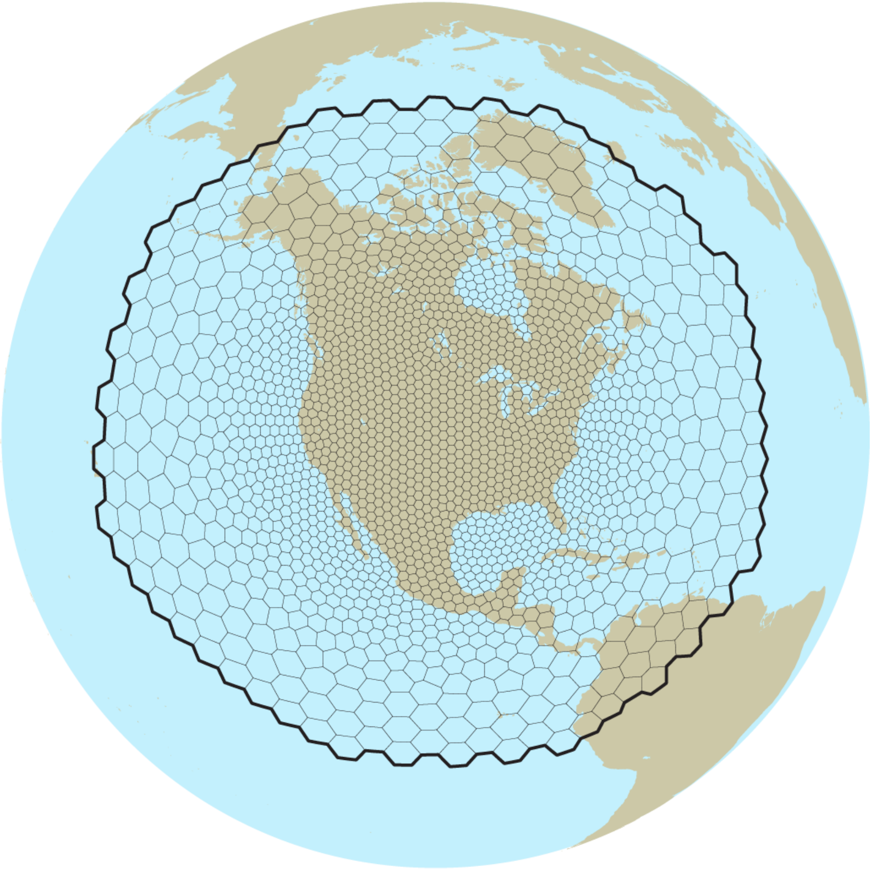


MPAS
Height-based hybrid smoothed terrain-following vertical coordinate

Regional MPAS

We are no longer developing WRF at NSF NCAR/MMM, and we would like users to transition to MPAS if their applications allow.

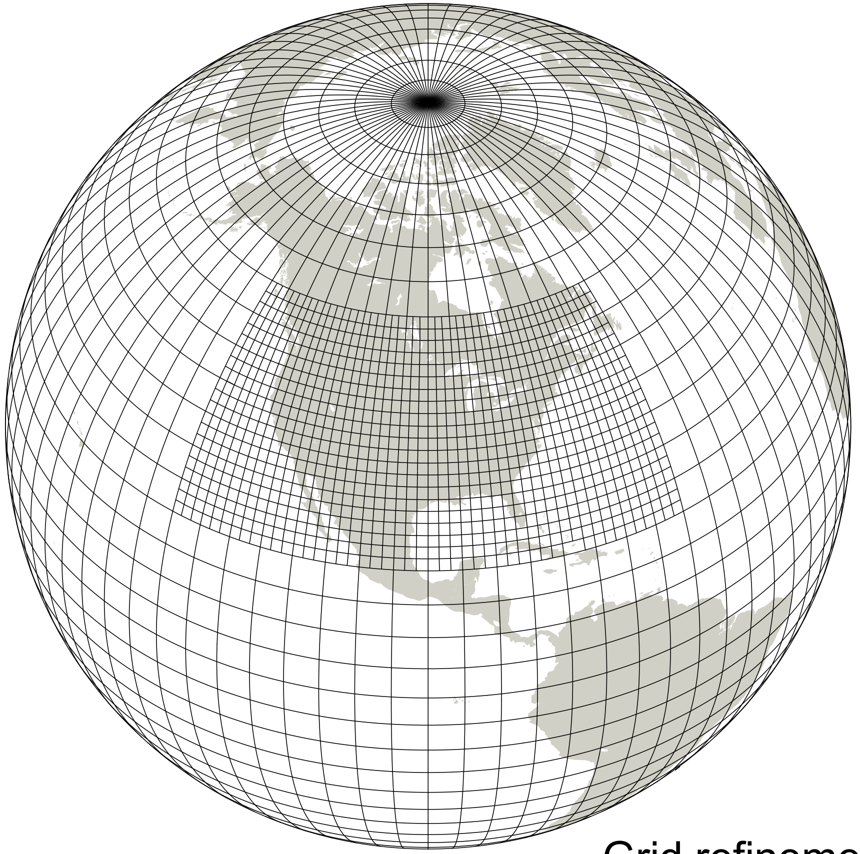
- Leverage MPAS development for next-generation architectures to regional applications (e.g. GPUs).
- Enable regional atmospheric applications within MPAS-enabled coupled modeling systems.
- Employ variable resolution in regional applications to reduce LBC errors.



MPAS
Model for Prediction Across Scales

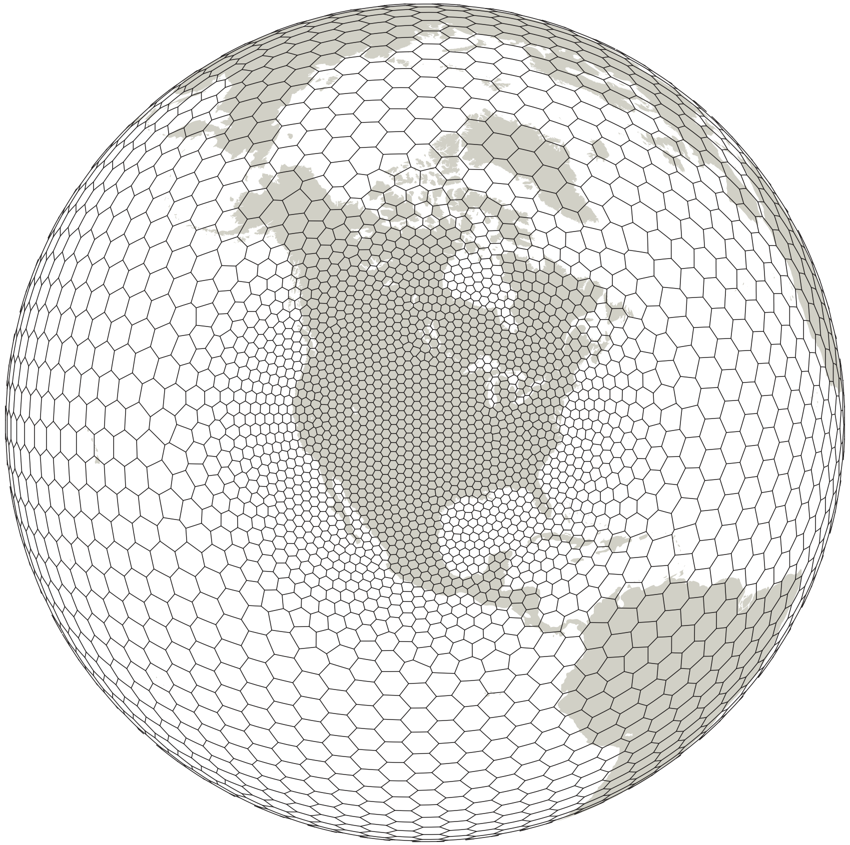
Why MPAS?

Significant differences between WRF and MPAS



MPAS
Smooth grid refinement
on a conformal mesh

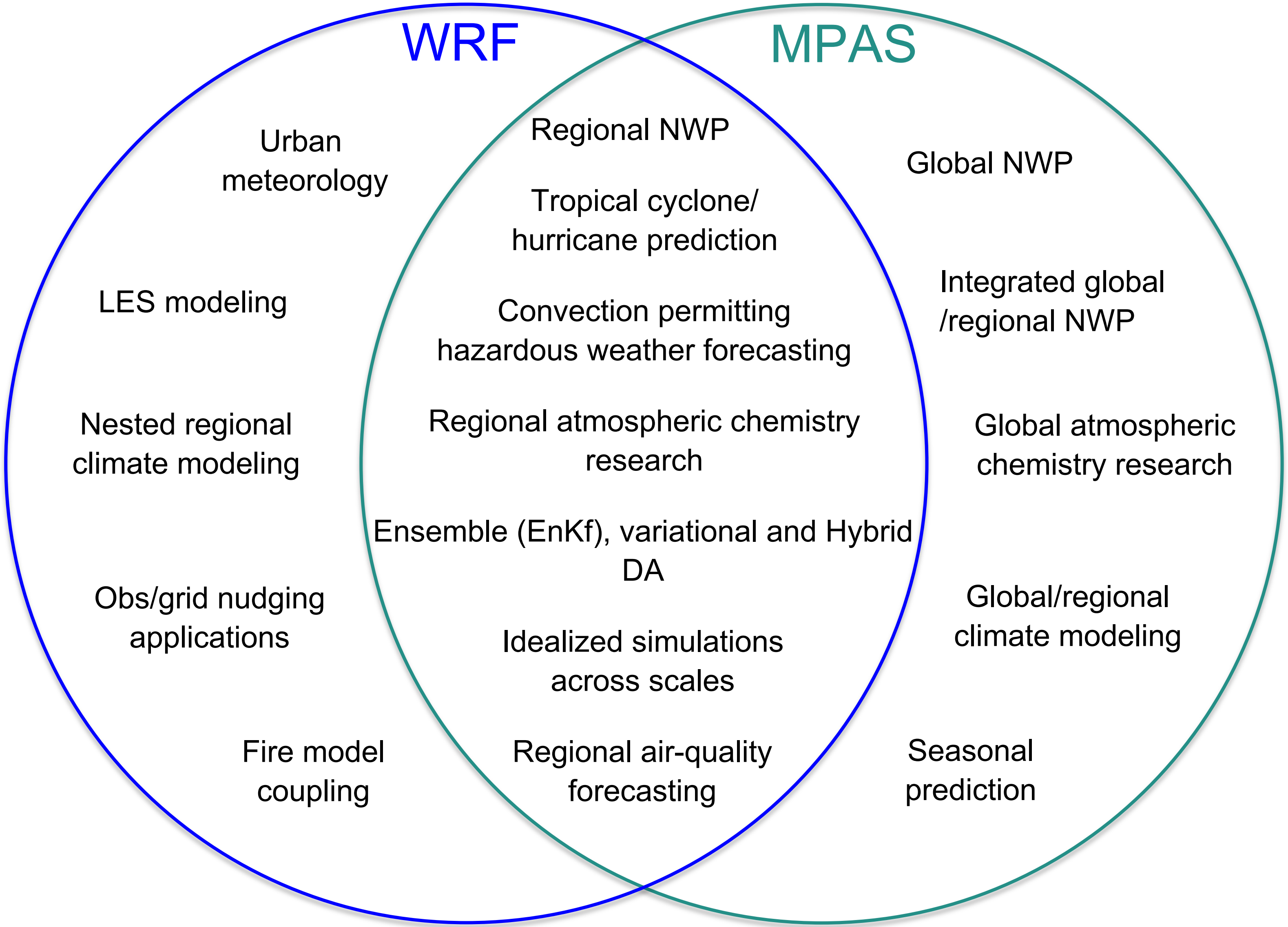
- Increased accuracy and flexibility for variable resolution applications
- No abrupt mesh transitions.

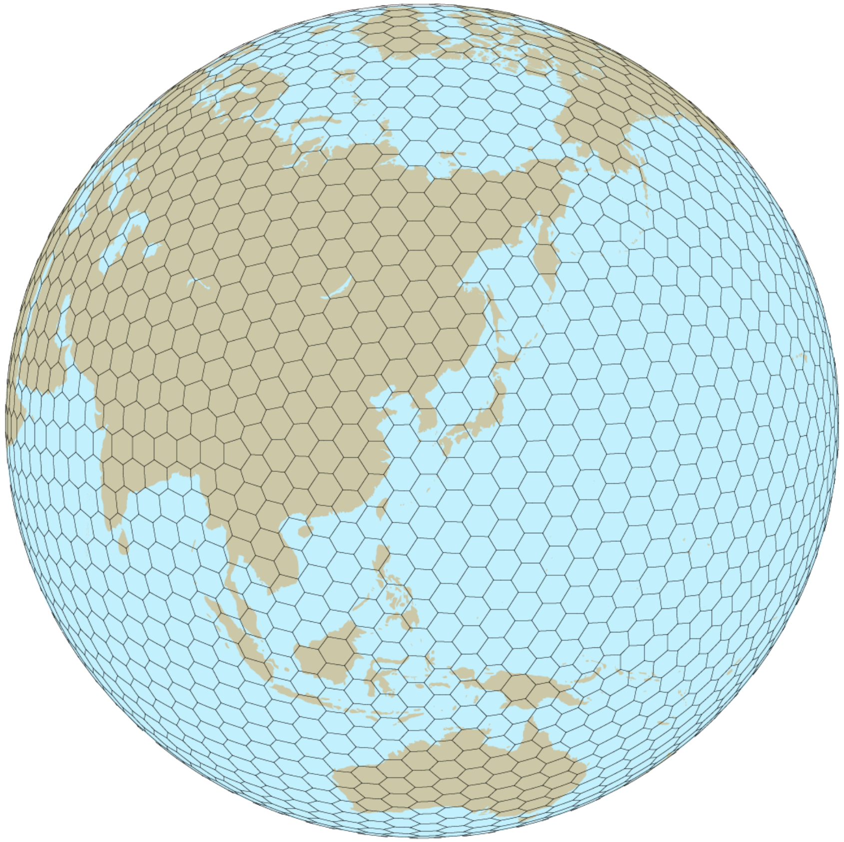


WRF
Grid refinement through domain nesting

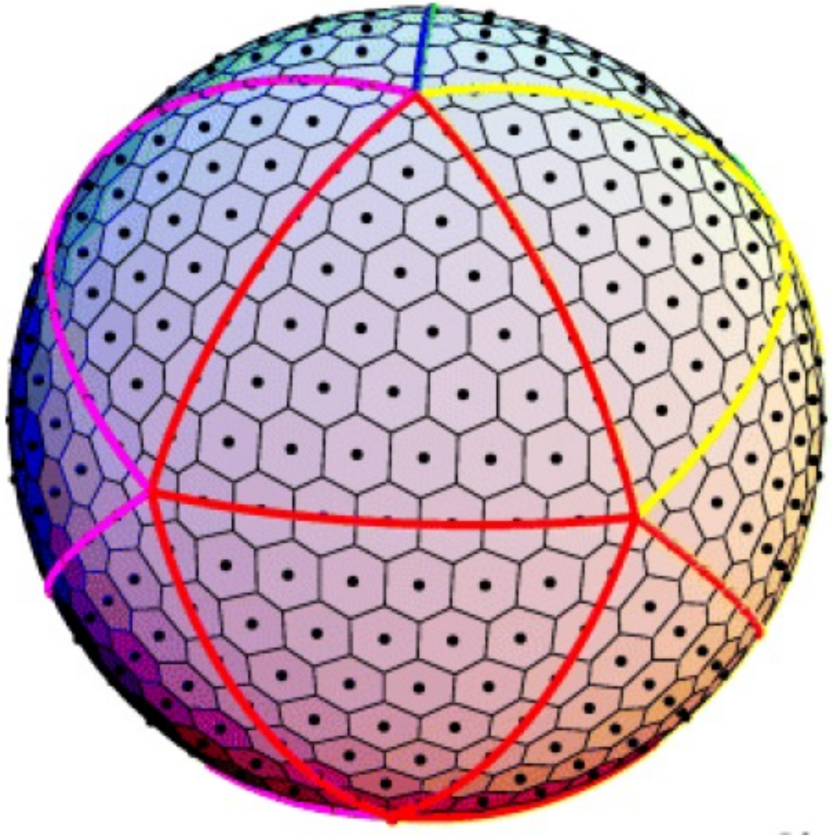
- Flow distortions at nest boundaries

MPAS
Model for Prediction Across Scales





Global Quasi-Uniform
Mesh (SCVT)

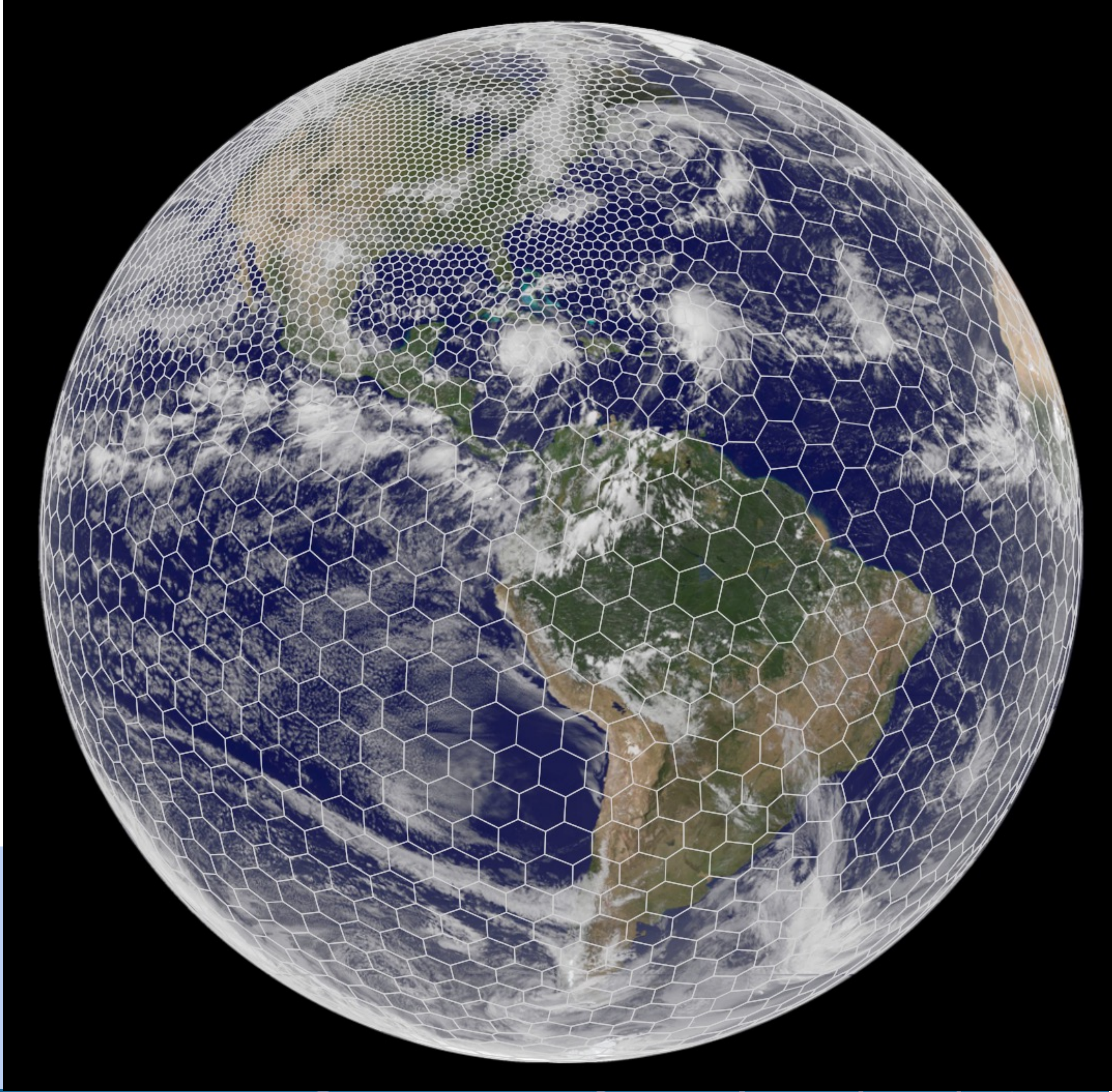


Many models use an icsoahedral mesh
(NICAM, BUGS, FIM, NIM, OLAM, etc.)

Mesh generation

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

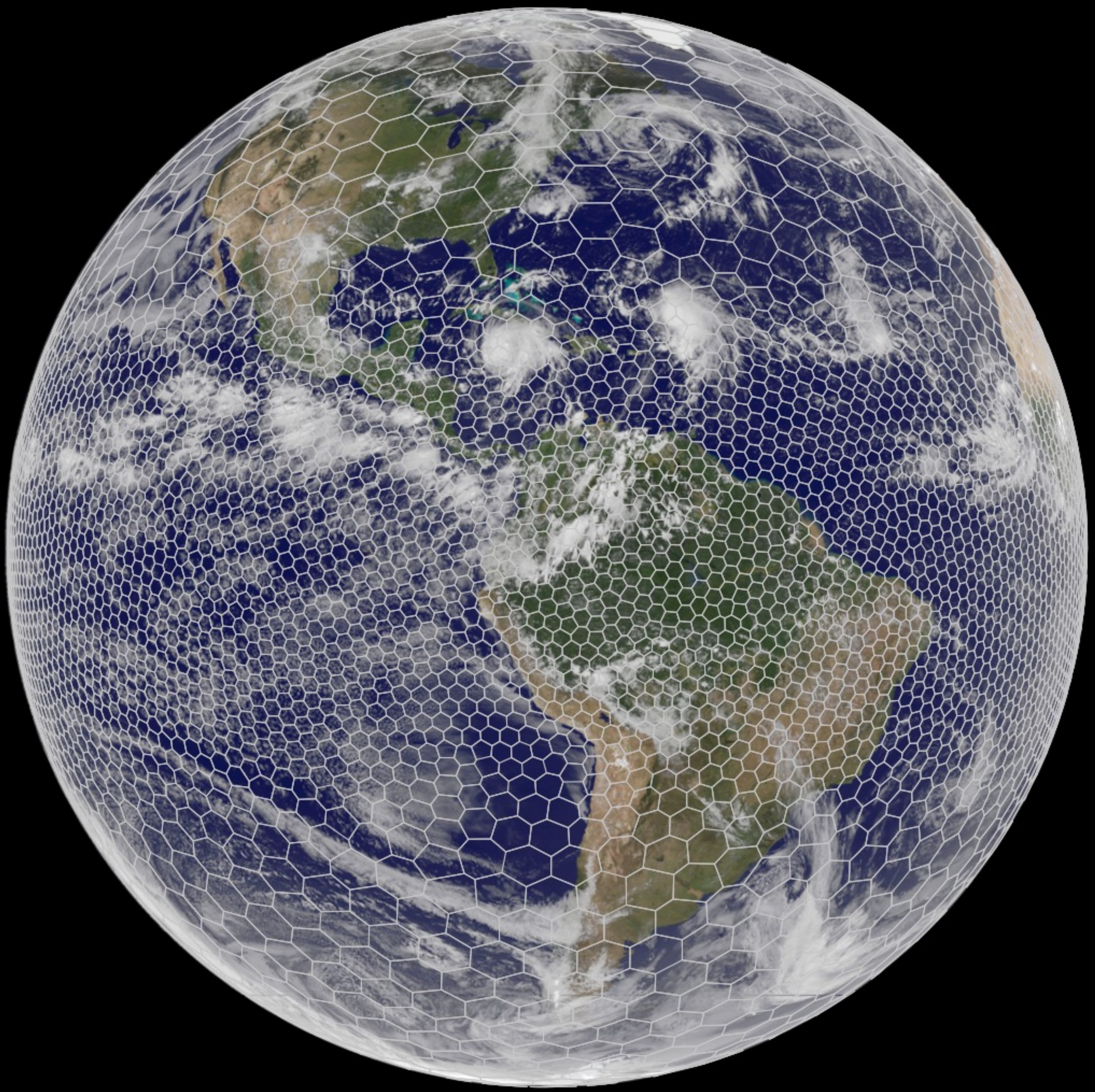
North American refinement



Mesh generation

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

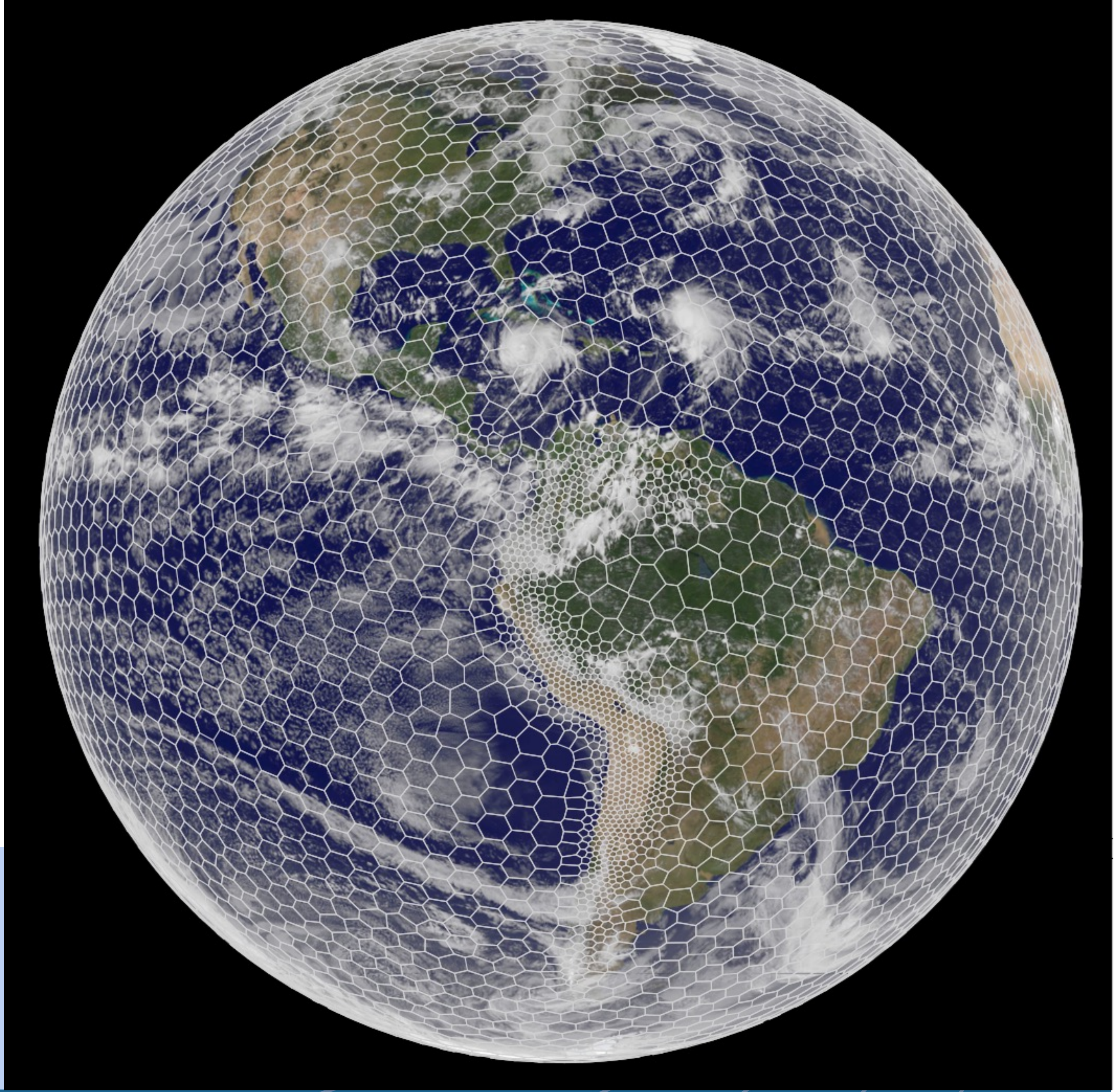
Equatorial refinement



MPAS
Model for Prediction Across Scales

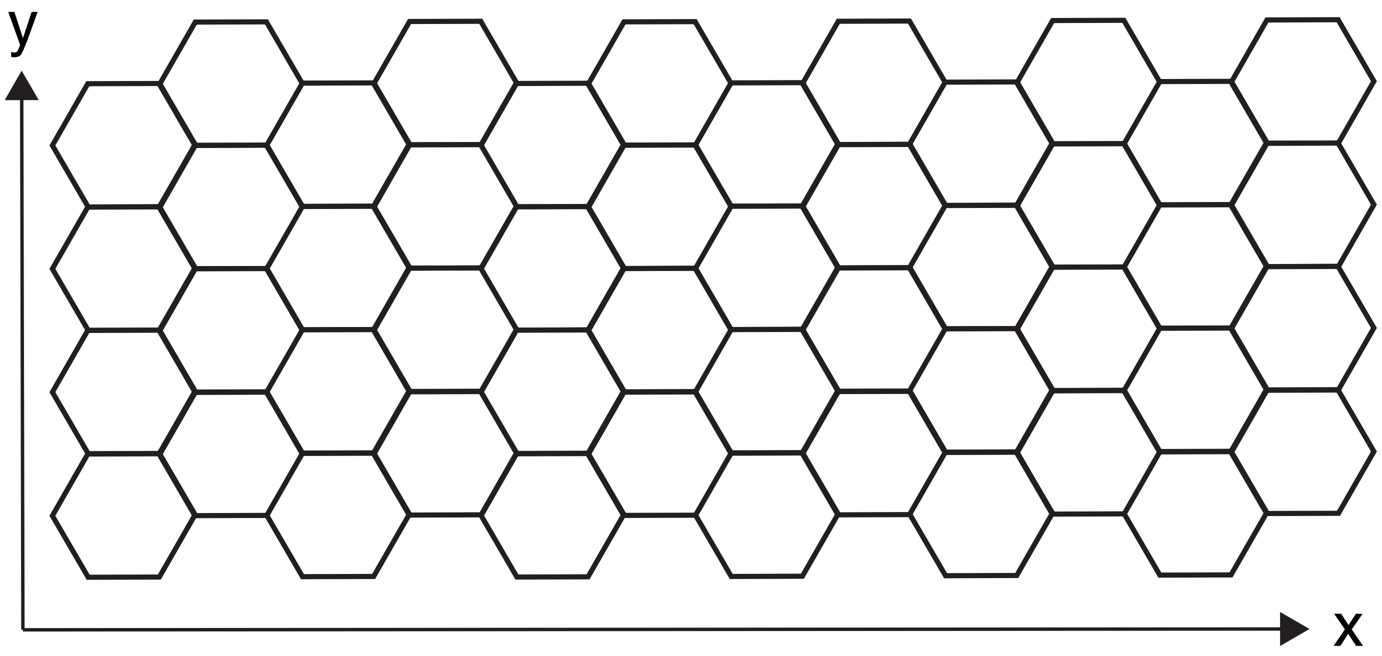
Mesh generation

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



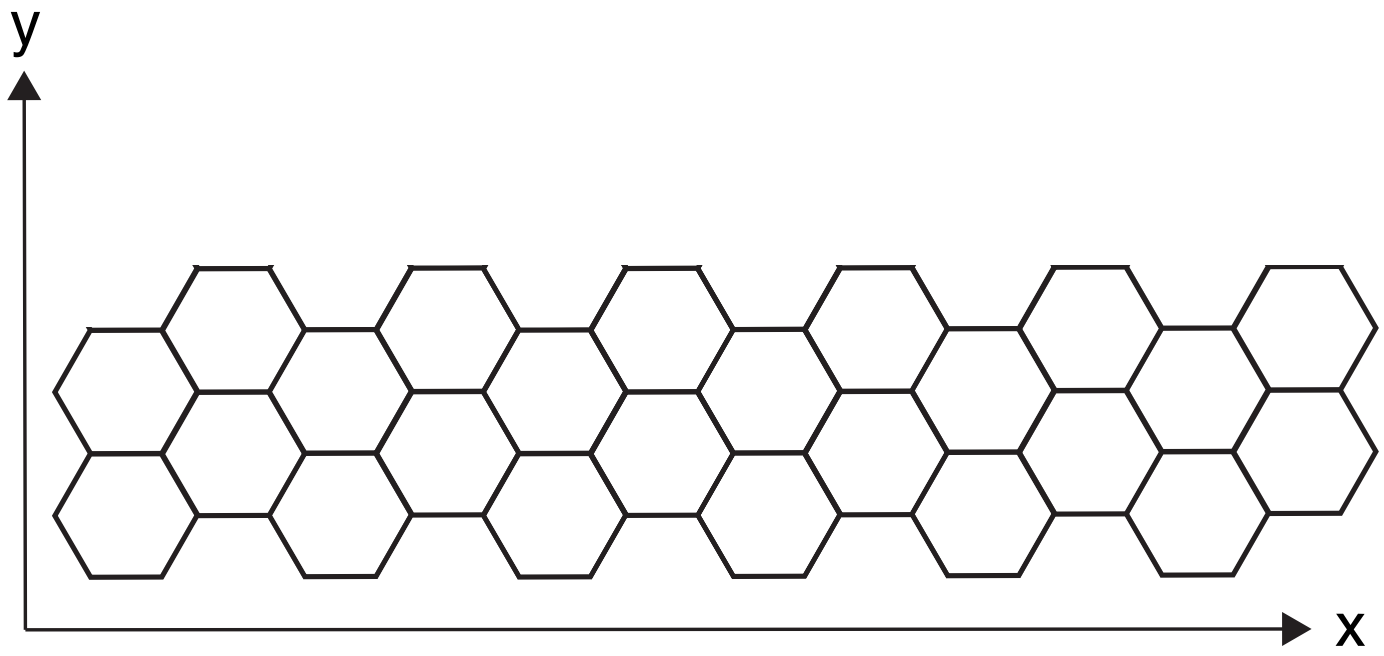
Andes refinement

Other mesh spaces



Doubly-periodic Cartesian mesh

Other mesh spaces



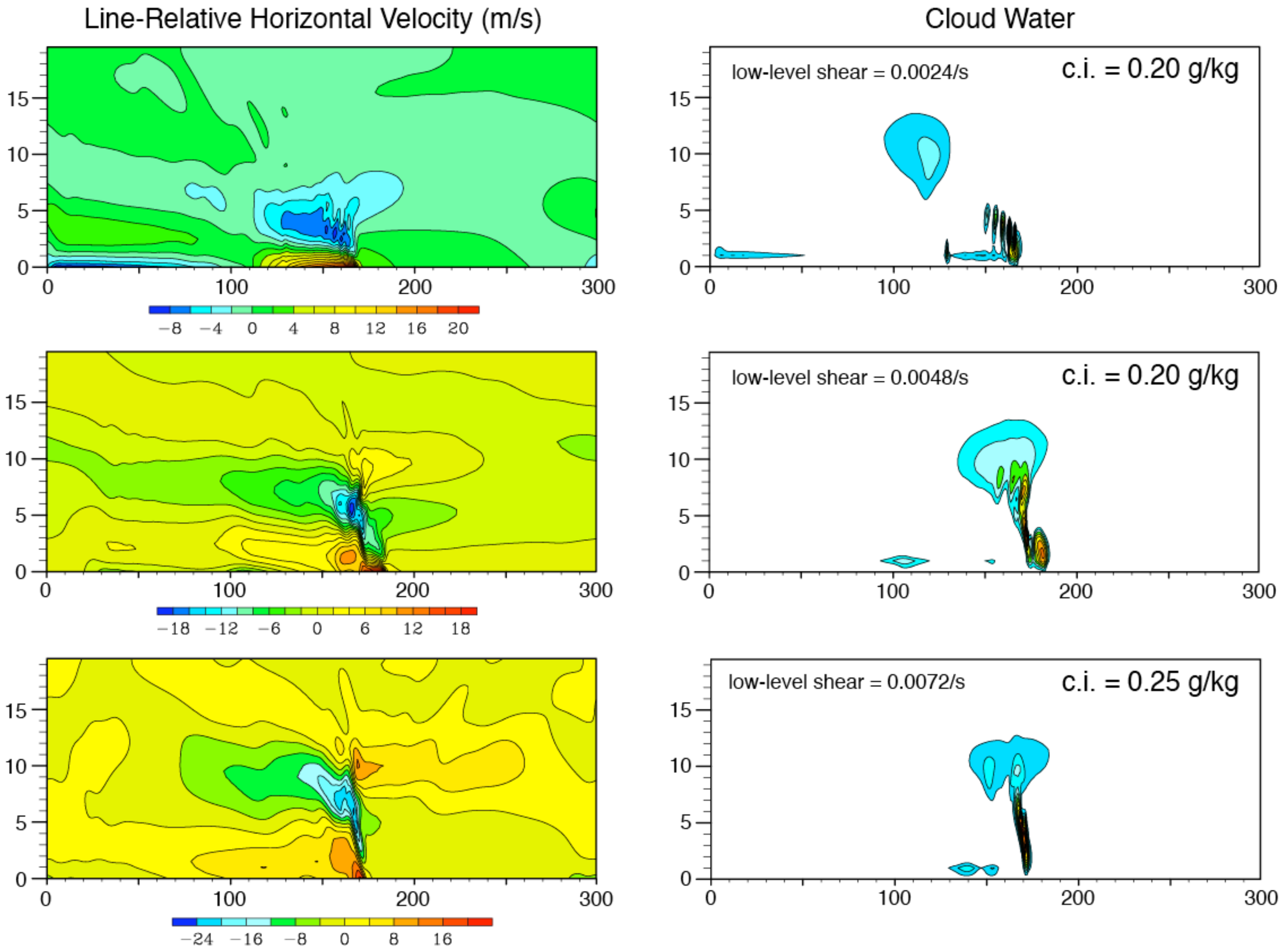
2D (y,z) mesh in MPAS
The solution does not vary in y, periodic in y

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



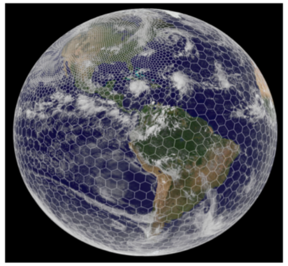
MPAS
Model for Prediction Across Scales

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

Home | News & Events | Contact | Support Forum | Site Map



MPAS Atmosphere

Model for Prediction Across Scales - Atmosphere

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

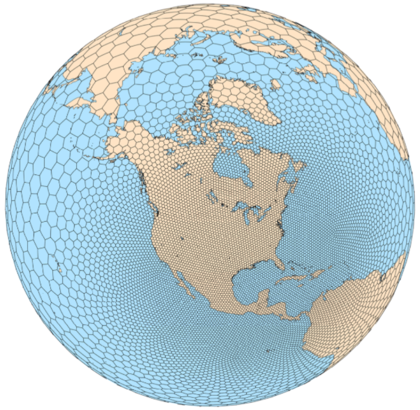
Search this project

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

Next Up…

Monday 15 September:

9:15 – 09:30 Registration
9:30 – 9:45 Welcome and Introductions
9:45 – 10:05 MPAS Overview
10:05 – 10:25 MPAS-A System Requirements and Installation
10:25 – 11:20 Running MPAS, part 1: Creating ICs and running a basic global simulation
11:20 – 11:35 **Break**
11:35 – 11:45 Introduction to the practical exercises
11:45 – 12:30 Practical session
12:30 – 13:45, **Lunch**
13:45 – 14:15 Running MPAS, part 2: Variable-resolution, I/O streams, restarts, and other options
14:15 – 15:00 Practical session
15:00 – 15:15 **Break**
15:15 – 16:15 Practical session