MPAS TUTORIAL

MODEL FOR PREDICTION ACROSS SCALES – ATMOSPHERE (MPAS-A) TUTORIAL

9–11 September, 2019
NCAR Foothills Lab, Boulder, CO

MPAS Tutorial Agenda
Lectures in FL2-1022 (Large Auditorium)

Monday 9 September 2019

8:45 - 9:00 Registration
9:00 - 9:20 MPAS Overview
9:20 - 9:40 Obtaining and building MPAS-Atmosphere
9:40 - 10:35 Running global MPAS, part 1: Initialization for real-data applications, initialization for idealized test cases
10:35 - 10:55 Break
10:55 - 12:00 Practice session - cloning and building MPAS, creating idealized ICs, creating static files for real-data ICs
12:00 - 1:15 Lunch
1:15 - 2:00 Practice session: creating real-data initial conditions (incl. SST update), running a global simulation
2:00 - 2:30 Mesh structure
2:30 - 3:00 Visualization/analysis tools
3:00 - 3:30 Running MPAS, part 2: Rotating meshes, streams and I/O, etc.
3:30 - 3:50 Break
3:50 - 5:00 Practice session: Running MPAS with variable-resolution meshes, visualizing output

MPAS Tutorial Agenda (continued)
Lectures in FL2-1022 (Large Auditorium)

Tuesday 10 September 2019

9:00 - 10:00 Dynamics: overview and configuration
10:00 - 10:30 Regional MPAS: overview
10:30 - 10:50 Break
10:50 - 11:20 Regional MPAS: creating a mesh and generating initial and boundary conditions
11:20 - 12:00 Practice session: Running regional MPAS
12:00 - 1:15 Lunch
1:15 - 2:00 Practice session: Running regional MPAS (continued)
2:00 - 2:30 MPAS software: Registry, pools, logging
2:30 - 2:50 How to add a passive tracer with time-varying sources and sinks
2:50 - 3:10 Break
3:10 - 5:00 Practice session: Adding a new I/O stream. adding a passive tracer

MPAS Tutorial Agenda (continued)
Lectures in FL2-1022 (Large Auditorium)

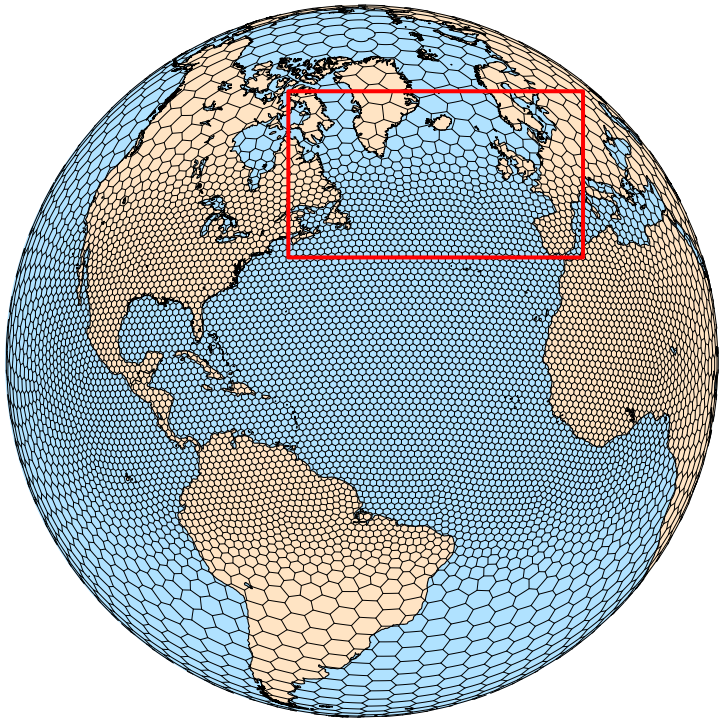
Wednesday 11 September 2019

9:00 - 9:30 Physics in MPAS
9:30 - 9:45 MPAS development - using git and GitHub
9:45 - 10:15 Diagnostics framework, and an example of adding a new accumulated diagnostic
10:15 - 10:35 Break
10:35 - 11:40 Practice session: Adding new diagnostics
11:40 - 12:00 MPAS mesh generation
12:00 - 12:15 New MPAS capabilities under development
12:15 - 1:30 Lunch
1:30 - Close Practice session: questions, help, etc.

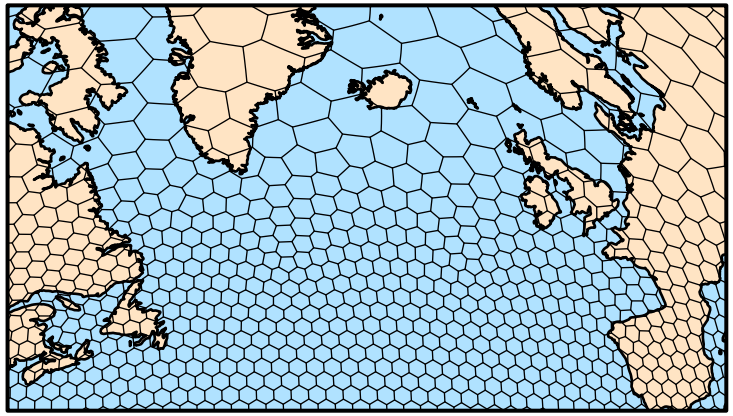
Notes: Lunch is provided in the cafeteria atrium.
Breaks (and break food/drinks) will be in the cafeteria atrium.
Practice sessions are in the room directly behind the reception desk in FL2.

MPAS

Model for Prediction Across Scales



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



Collaboratively developed, primarily by NCAR and LANL/DOE

MPAS infrastructure - NCAR, LANL, others.

MPAS - Atmosphere (NCAR)

MPAS - Ocean (LANL)

MPAS – Land and Sea Ice, etc. (LANL and others)

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NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

MPAS
Model for Prediction Across Scales

What is MPAS?
Freely available modeling system

MPAS Version 7 (8 June 2019):

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 Seaice 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

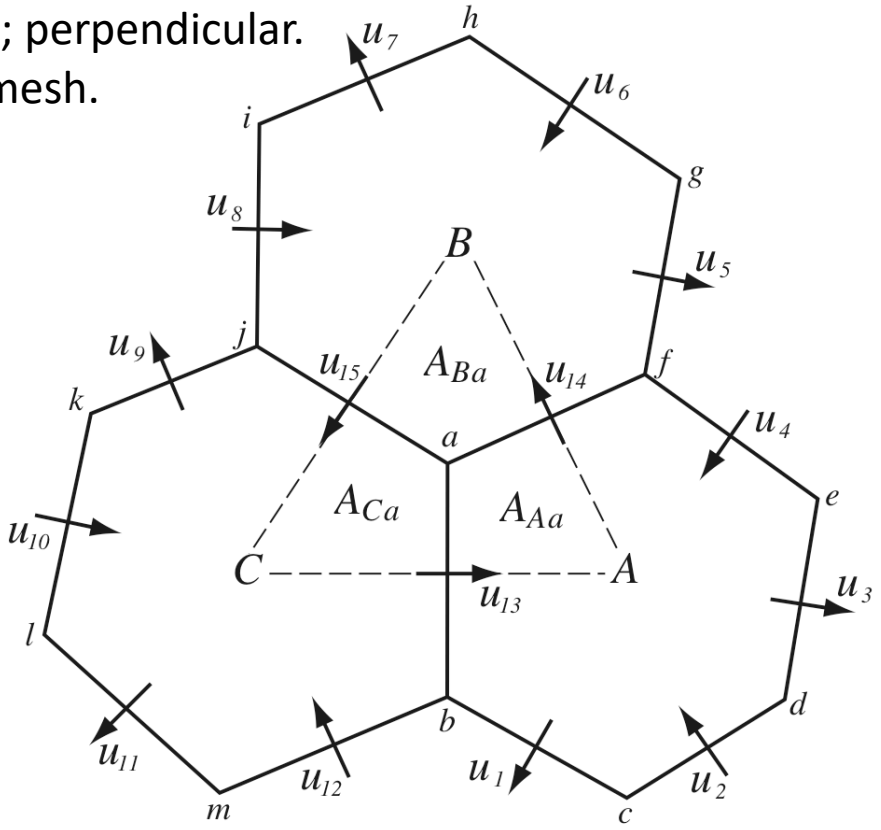
What is MPAS?
Centroidal Voronoi Meshes

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.



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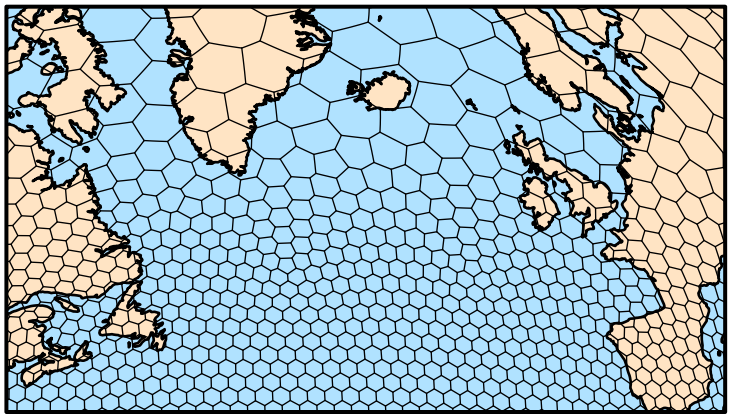
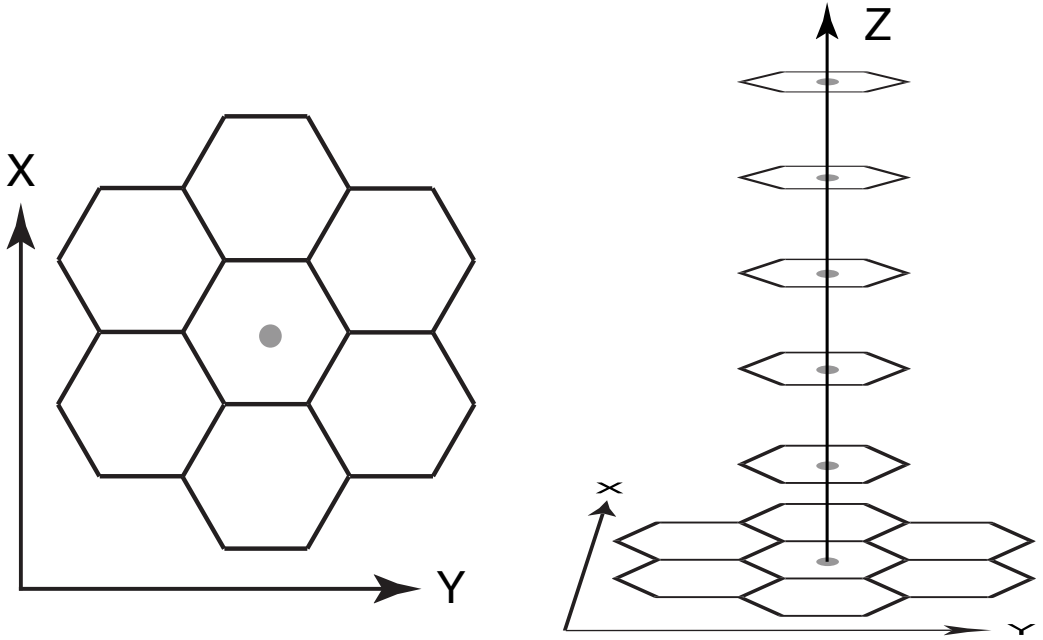
What is MPAS?
Centroidal Voronoi Meshes

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



The mesh is *structured* in the vertical



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MPAS Nonhydrostatic Atmospheric Solver

Fully Compressible Nonhydrostatic Equations

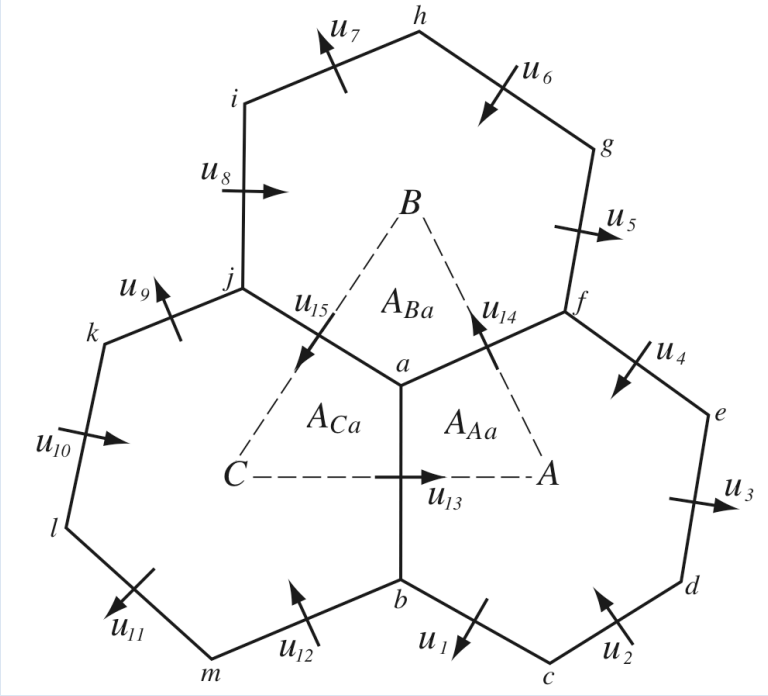
- Prognostic equations for coupled variables.
- Generalized height coordinate.
- Horizontally vector invariant eqn set.
- Continuity equation for dry air mass.
- Thermodynamic equation for coupled potential temperature.

Time integration as in Advanced Research WRF

- Split-explicit Runge-Kutta (3rd order)

Full complement of atmospheric-model physics

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



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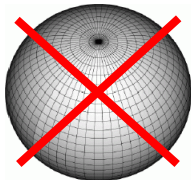
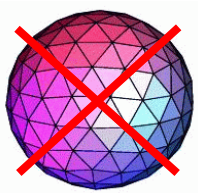
MPAS Development



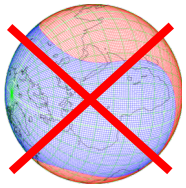
2005 Global lat-lon (WRF) problematic.

2006 Triangles - problems with divergence.



2007 Yin-Yang: local conservation past 1st-order accuracy?
Cubed-sphere: Corner point problems?

2008 Hex grid: C-grid problem solved for perfect hex mesh.
C-grid problem solved for general Voronoi mesh.

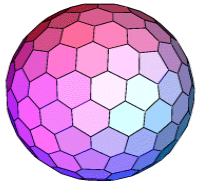


2009 Unstructured-mesh MPAS SW eqns. solver.
MPAS hydrostatic eqns. solver.

2010 MPAS nonhydrostatic eqns. solver.

2011 Hydrostatic MPAS in CAM/CESM.
WRF-NRCM physics in MPAS.

2012 DART data assimilation.



2013 3km global mesh tests on Yellowstone.
MPAS V1.0 release (atmosphere, ocean)
MPAS-Atmosphere real-time TC forecast testing.

2014 Scale-aware physics testing begins.

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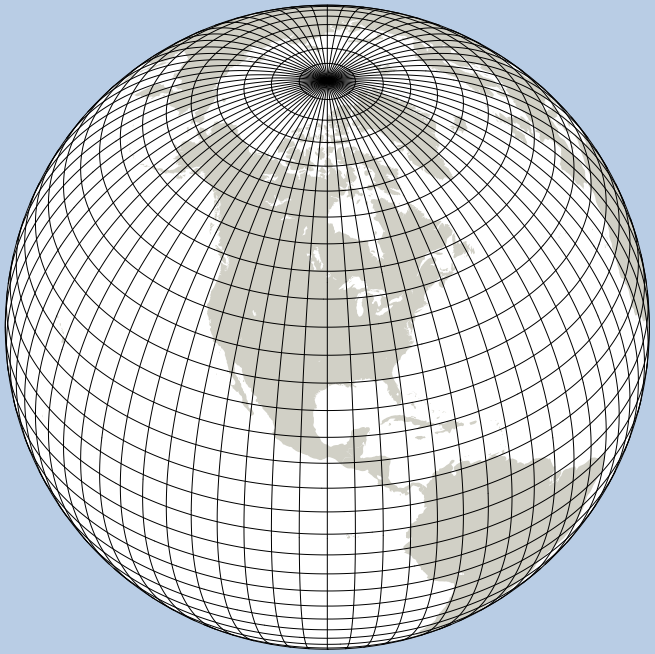
Model for Prediction Across Scales

Why MPAS?

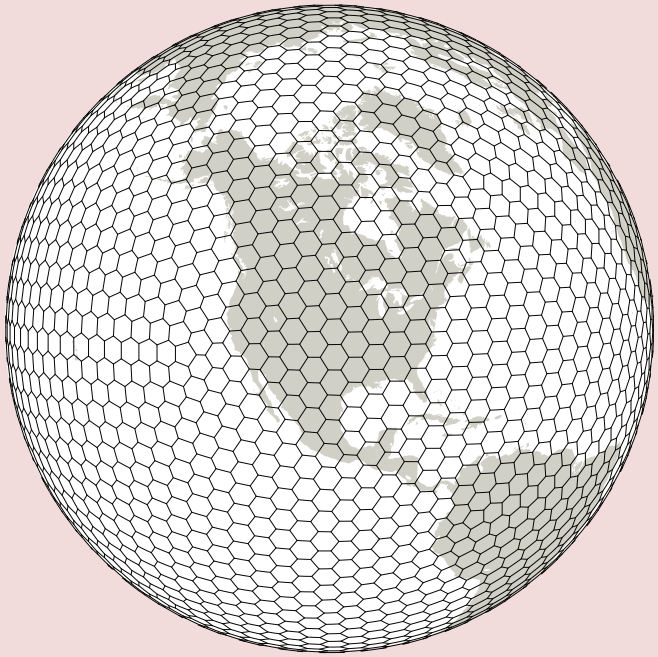
Significant differences between WRF and MPAS



WRF

Lat-Lon global grid

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



MPAS

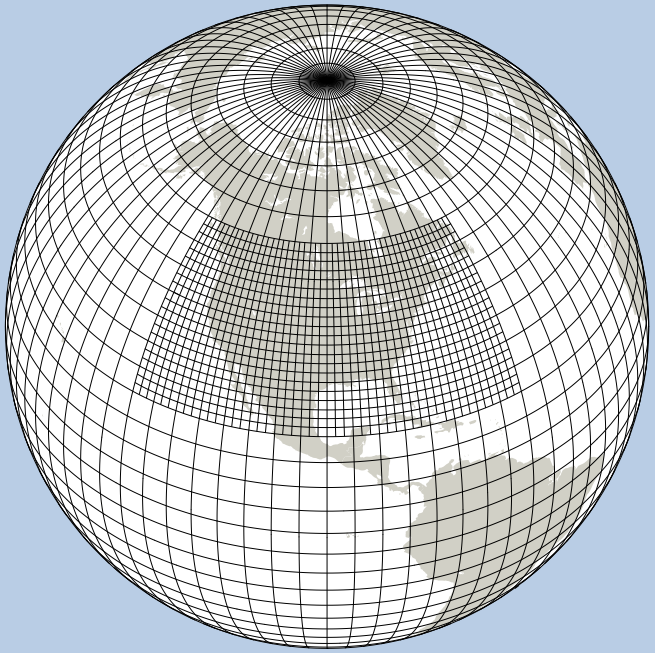
Unstructured Voronoi (hexagonal) grid

- Good scaling on massively parallel computers
- No pole problems

MPAS
Model for Prediction Across Scales

Why MPAS?

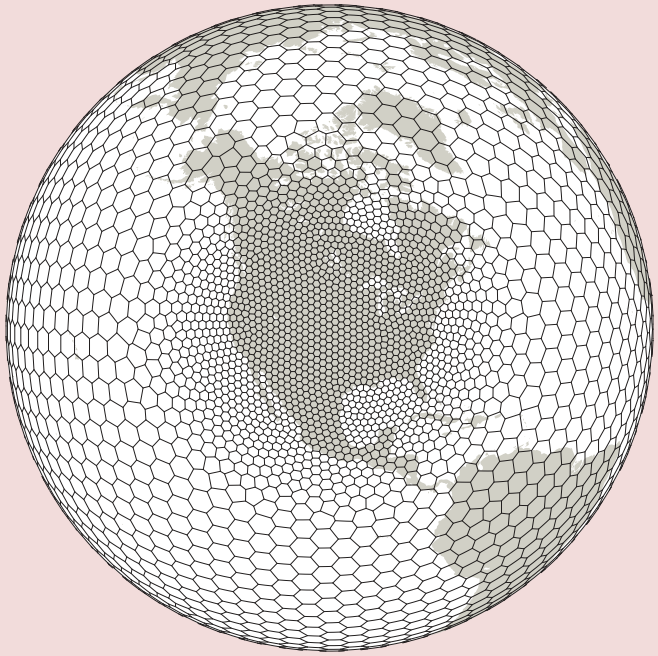
Significant differences between WRF and MPAS



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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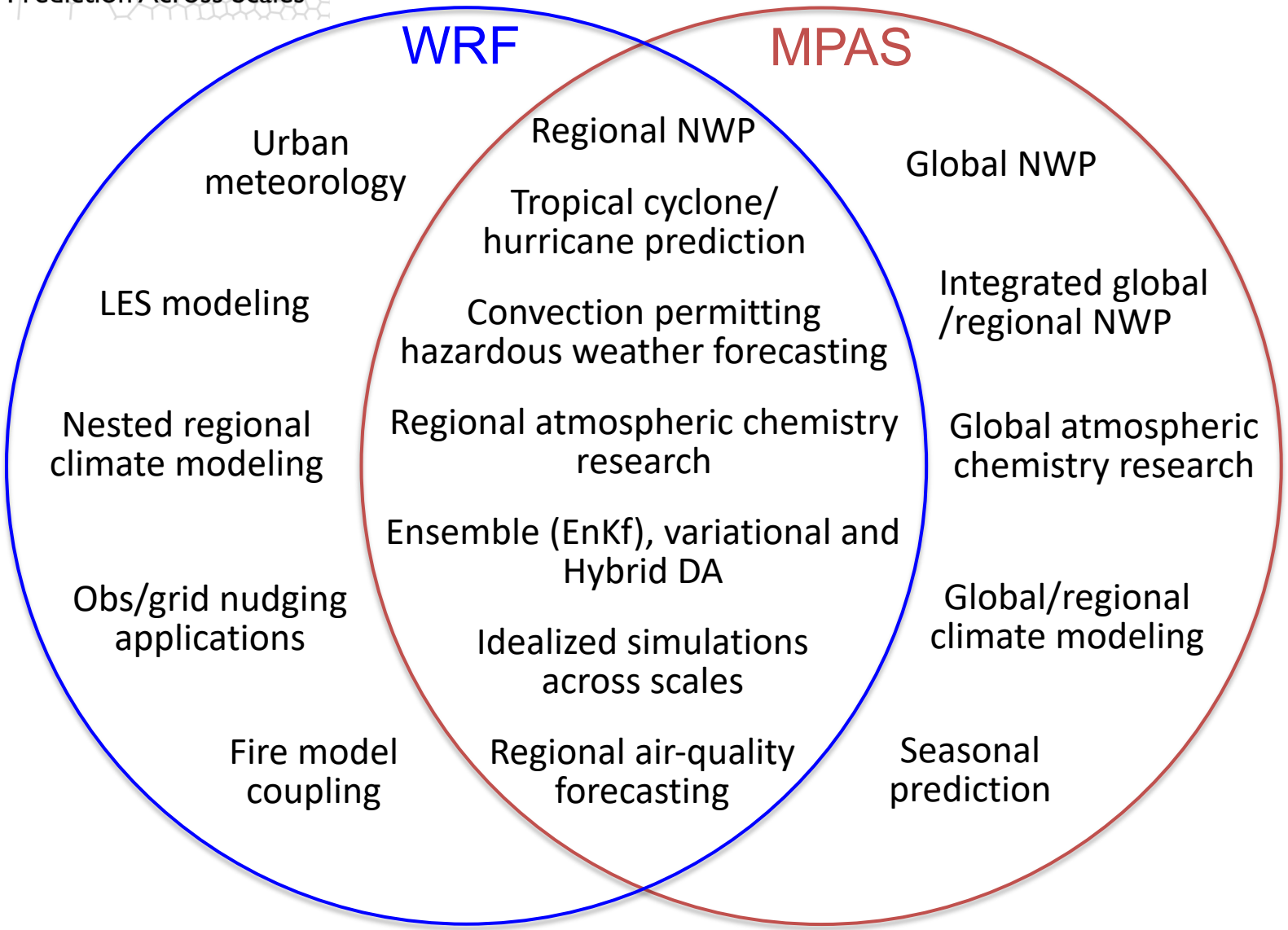
MPAS and WRF Applications



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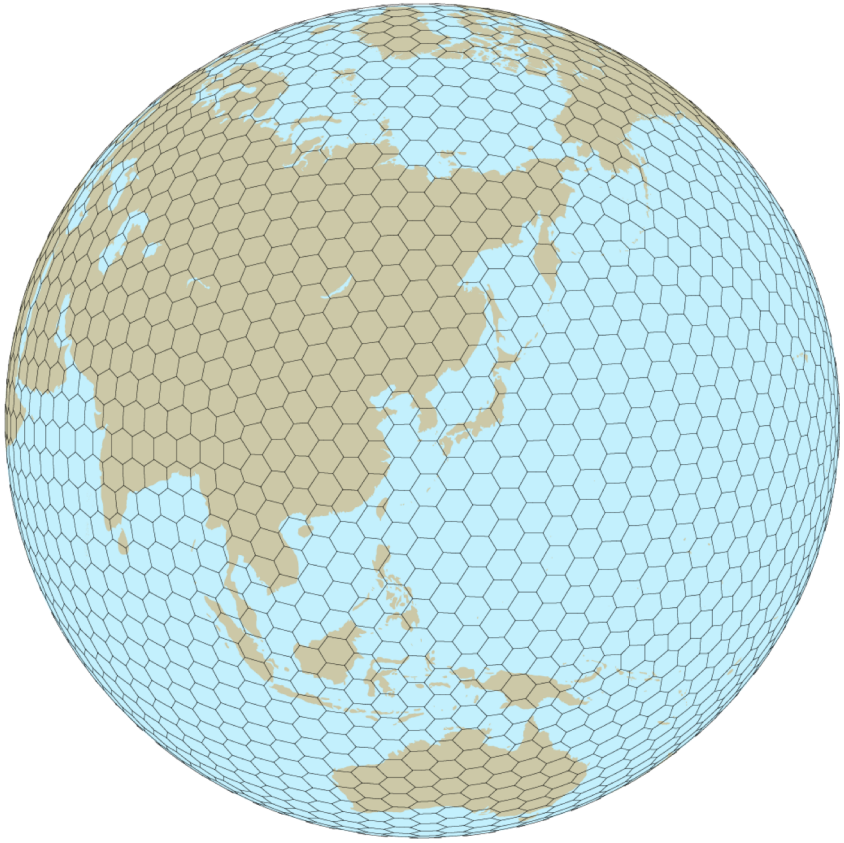
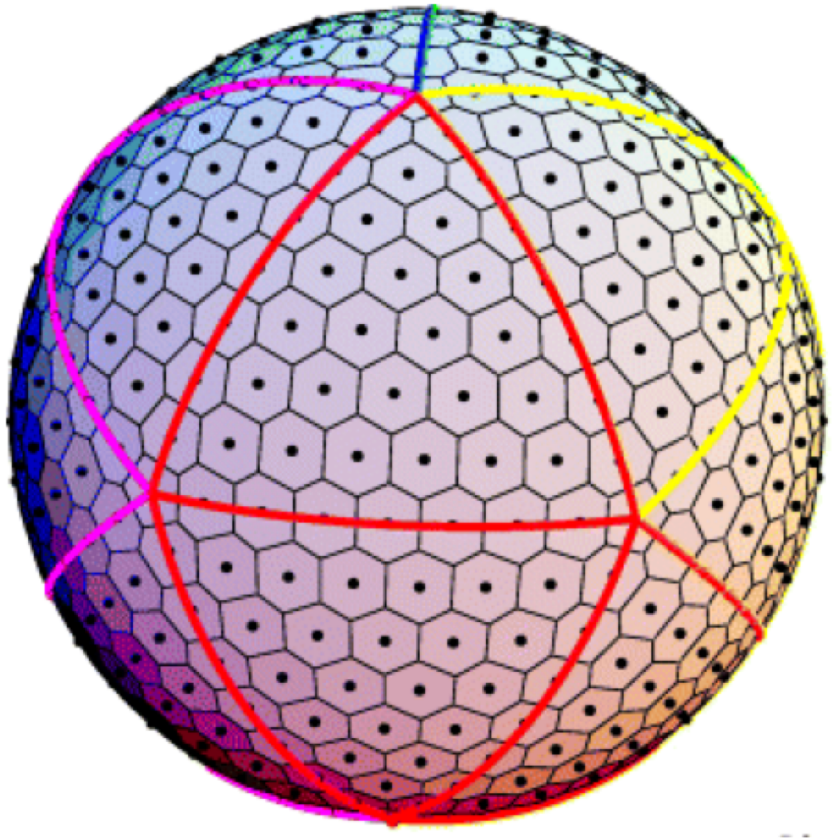
Global Meshes



Global Quasi-Uniform Mesh
(SCVT)



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

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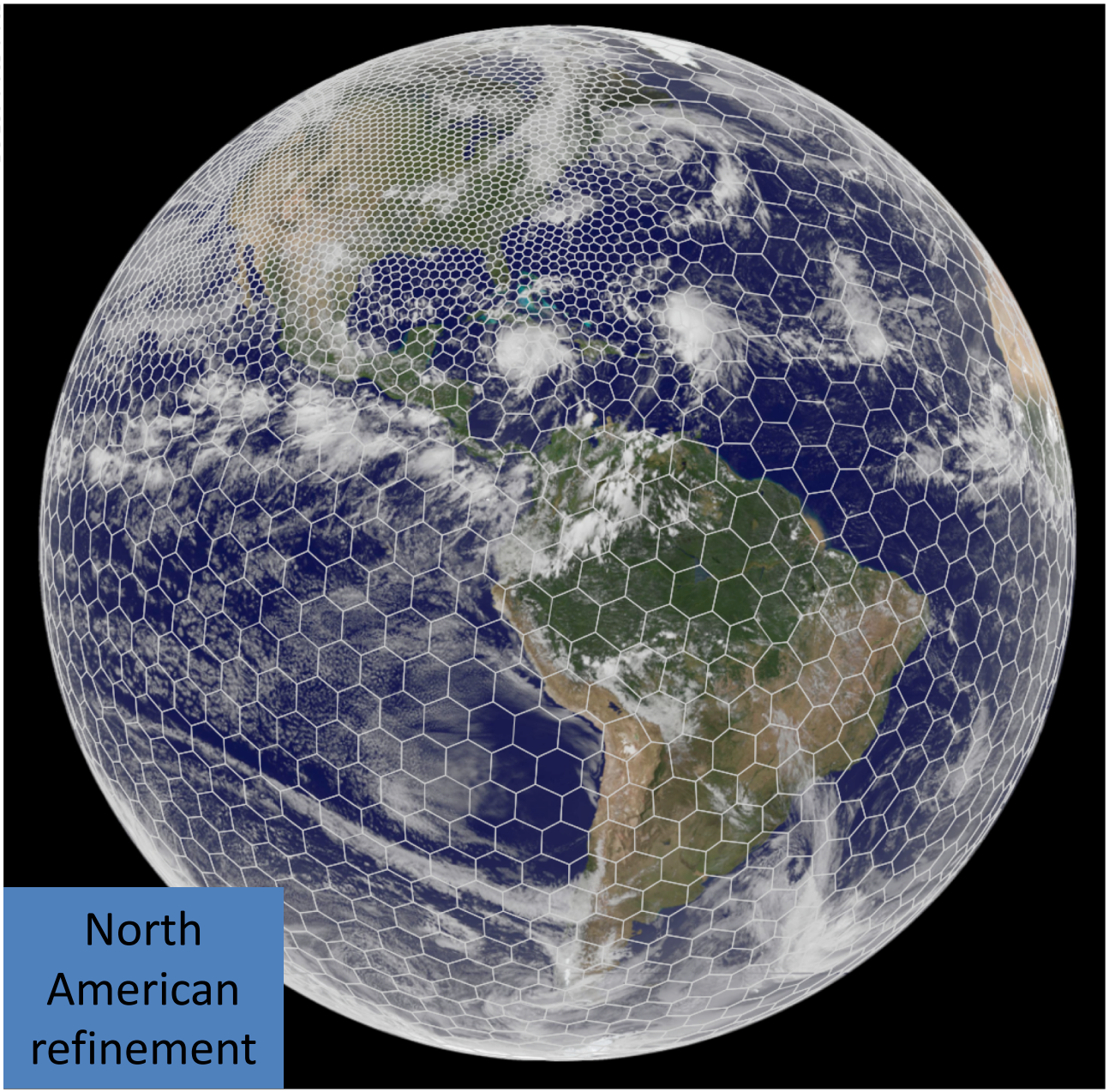
Model for Prediction Across Scales

Mesh generation

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



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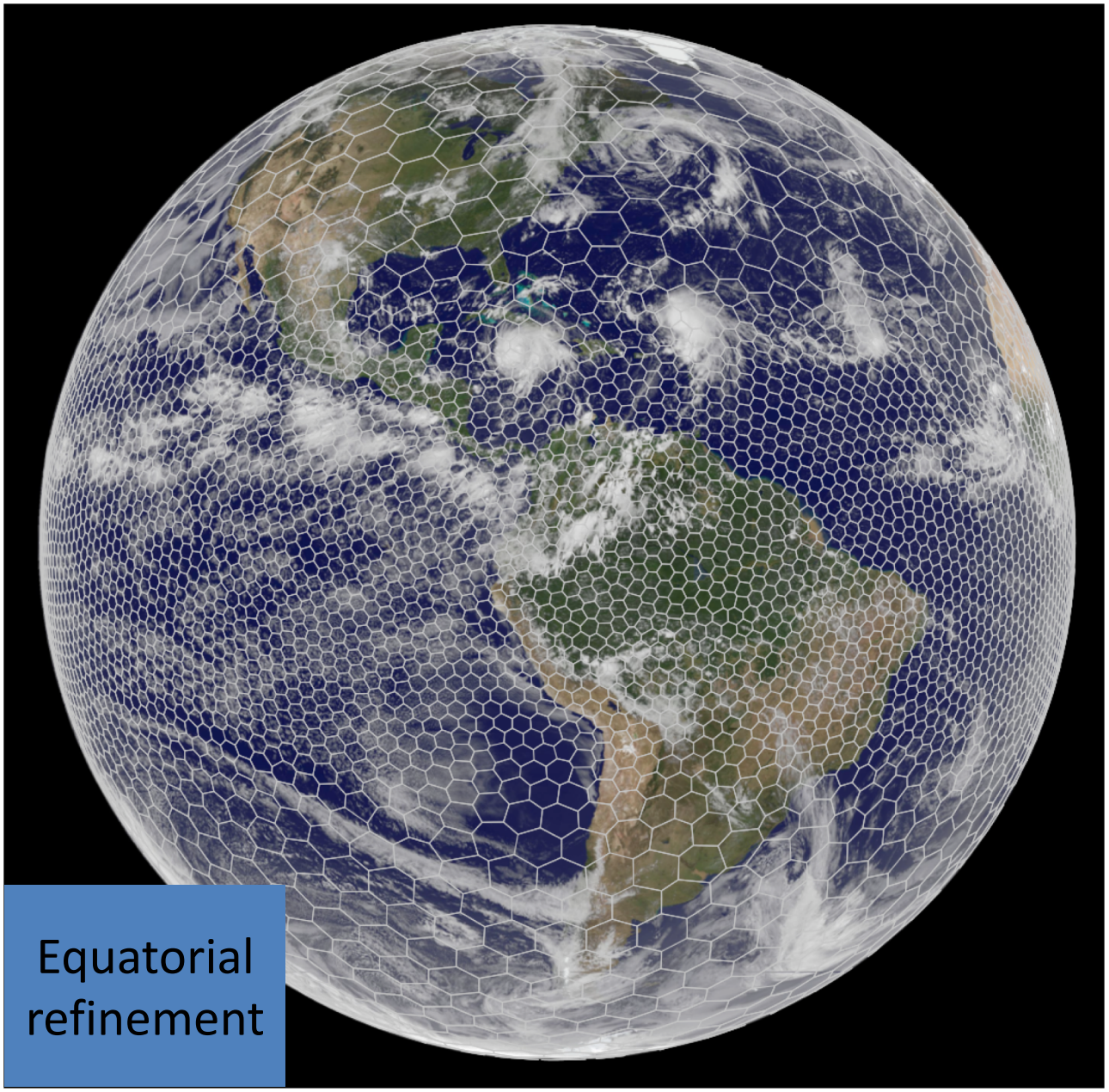

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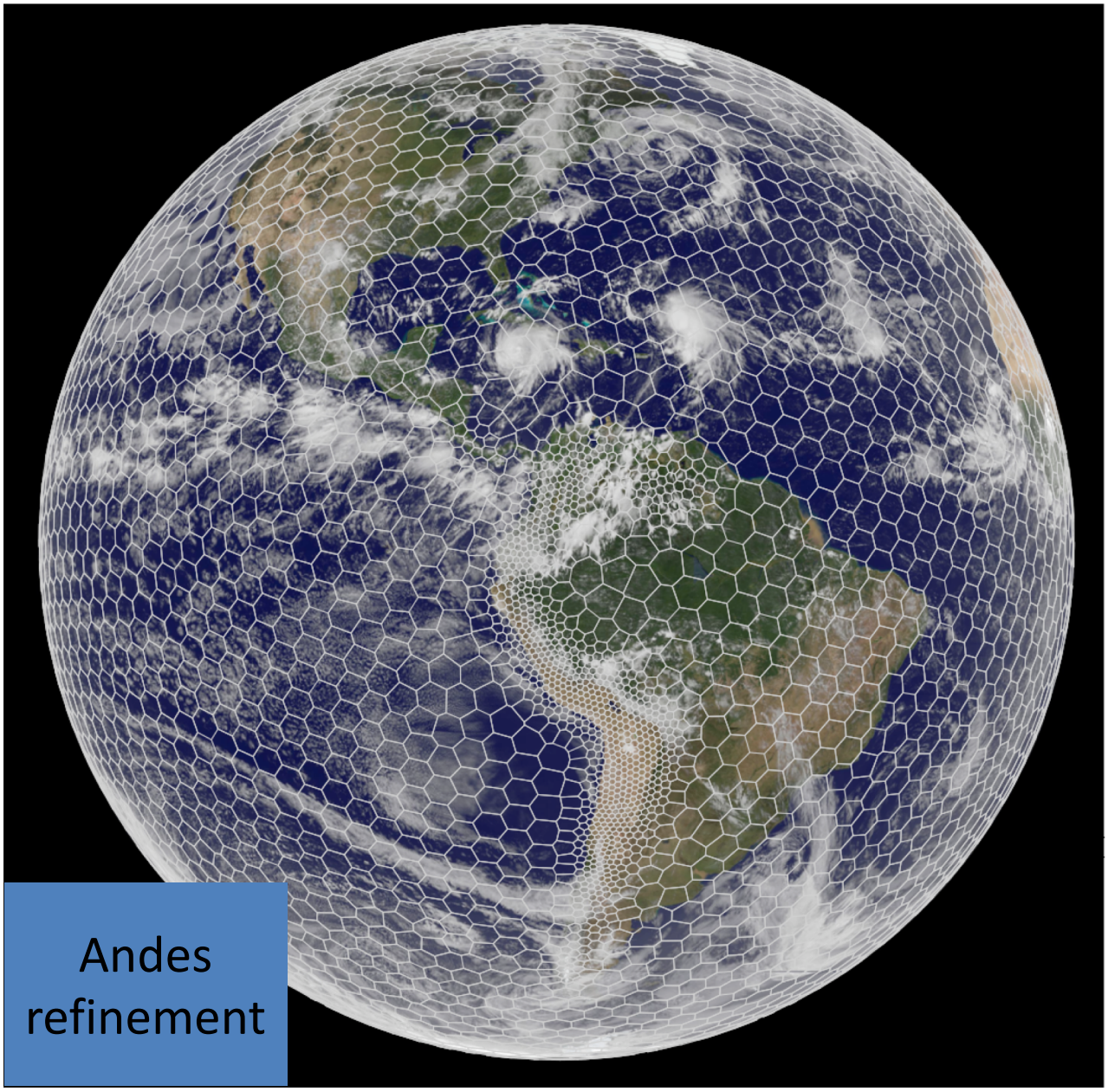


MPAS-Atmosphere Forecast Experiments

MPAS Home Page

MPAS forecast results page

The MPAS group in MMM/NCAR periodically performs forecast experiments, and here are the links to current and past experiments, and the MPAS-A model and mesh configurations for these experiments.

Ongoing forecasts:

Past experiments:

mid-2017 - 2 November 2018: Ongoing global forecasts using a 15 km global mesh

1 November 2016 - mid-2017: Global forecasts using a 60-15 km mesh centered over North America

25 April - 31 May 2017 Spring Forecast Experiment, 15-3 km mesh centered over North America

1 July - 31 October 2016 TC forecast experiment, 60-15 km mesh centered over the Western Pacific basin, and selected forecasts with the mesh centered over the Atlantic basin and Eastern Pacific basin

25 April - 31 May 2016 Spring Forecast Experiment, 15-3 km mesh centered over North America

1 July - 31 October 2015 TC forecast experiment, 60-15 km mesh centered over the Western Pacific basin, and selected forecasts with the mesh centered over the Atlantic basin and Easter Pacific basin

25 April - 11 July 2015 Spring Forecast Experiment, 15-3 km mesh centered over North America, includes forecasts for the PECAN field program

http://www2.mmm.ucar.edu/imagearchive/mpas/images.php

MPAS 15km Forecasts

Initialized: 00 UTC Thu 19 Jul 2018

Surface/Precip | Upper-Air | Plot Domain | Meshes

0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87 90 93 96 99 102 105 108 111 114 117 120 123 126 129 132 135 138 141 144 147 150 153 156 159 162 165 168 171

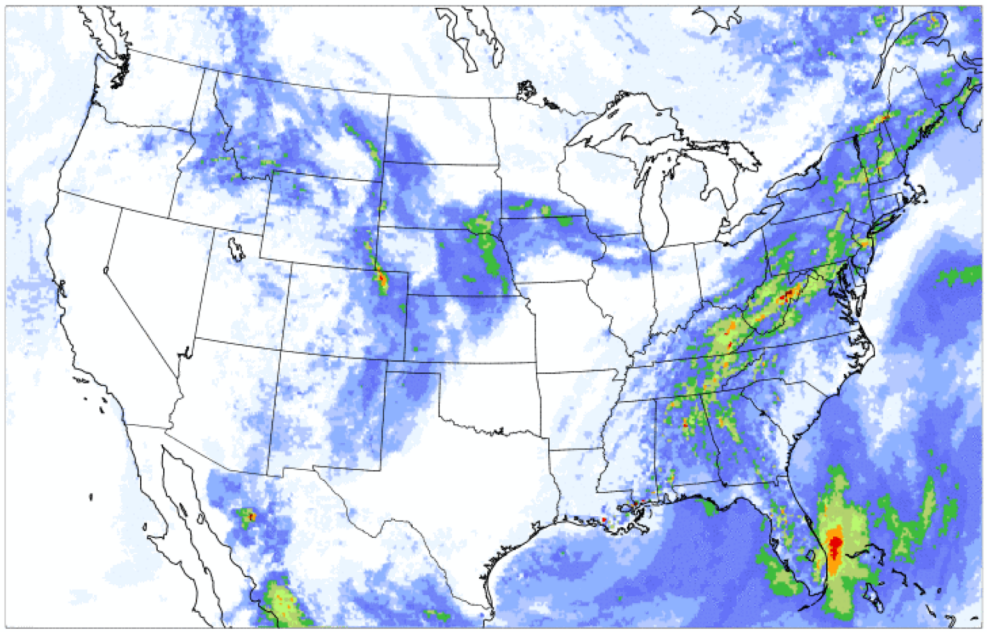
174 177 180 183 186 189 **192** 195 198 201 204 207 210 213 216 219 222 225 228 231 234 237 240

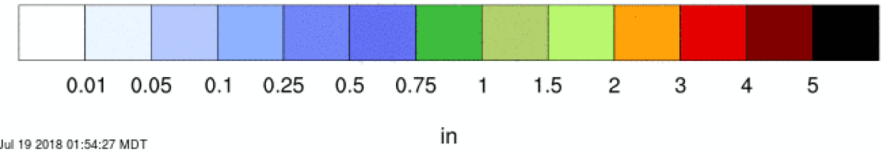
MPAS 15km 192h fcst

Init: 2018-07-19_00:00:00 UTC Valid: 2018-07-27_00:00:00 UTC

Precipitation over last 24 h

in





in

created Jul 19 2018 01:54:27 MDT

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NCAR

Forecasts sponsored by the National Science Foundation, National Center for Atmospheric Research/Mesoscale and Microscale Meteorology Laboratory, and Computational Information Systems Laboratory

about MPAS | web contact: ahijevyc@ucar.edu

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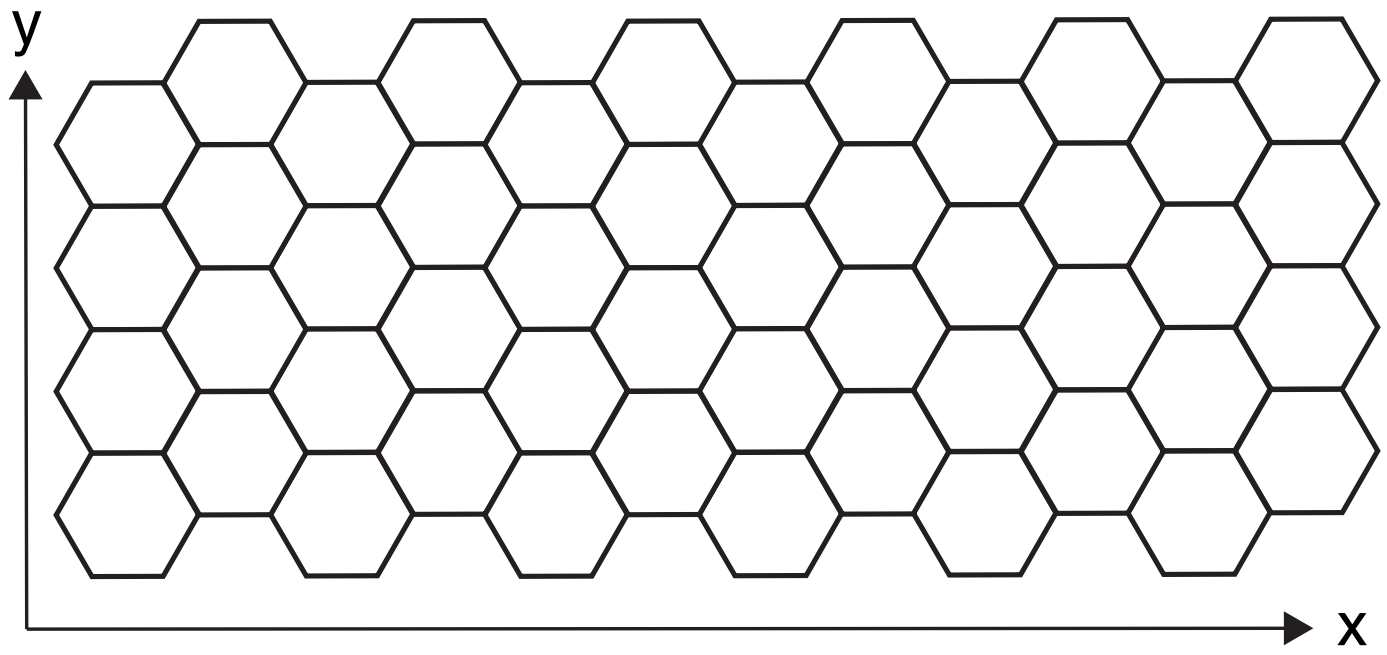
Uniform Cartesian Mesh



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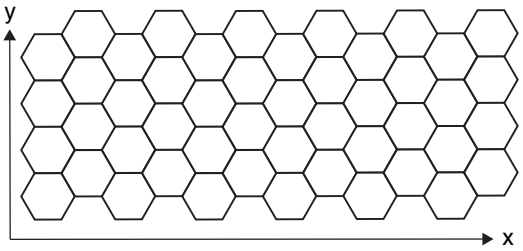
MPAS Nonhydrostatic Core

2D Mountain Waves - Schar Test Case

2D (y,z) simulations
Based on 3D doubly periodic (*x,y*) config.



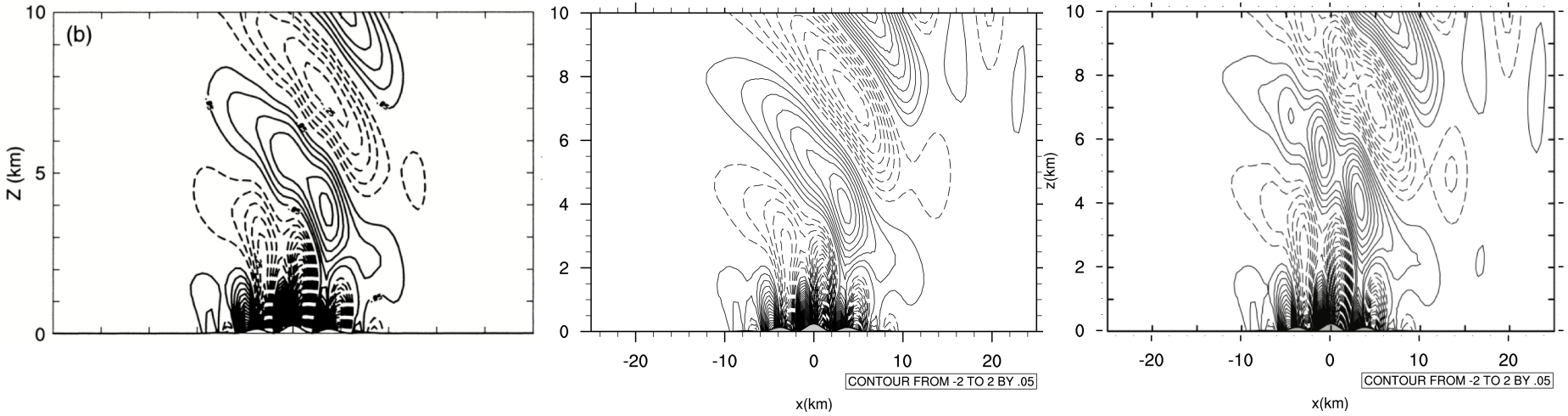
$U = 10\ ms^{-1}$ $\Delta x = 500$ m, dc = 577.35 m

$N = .01\ s^{-1}$ $\Delta z = 300$ m

Analytic reference solution

MPAS, 4th-order advection
4th order Ω reconstruction

MPAS, 4th-order advection
2nd order Ω reconstruction



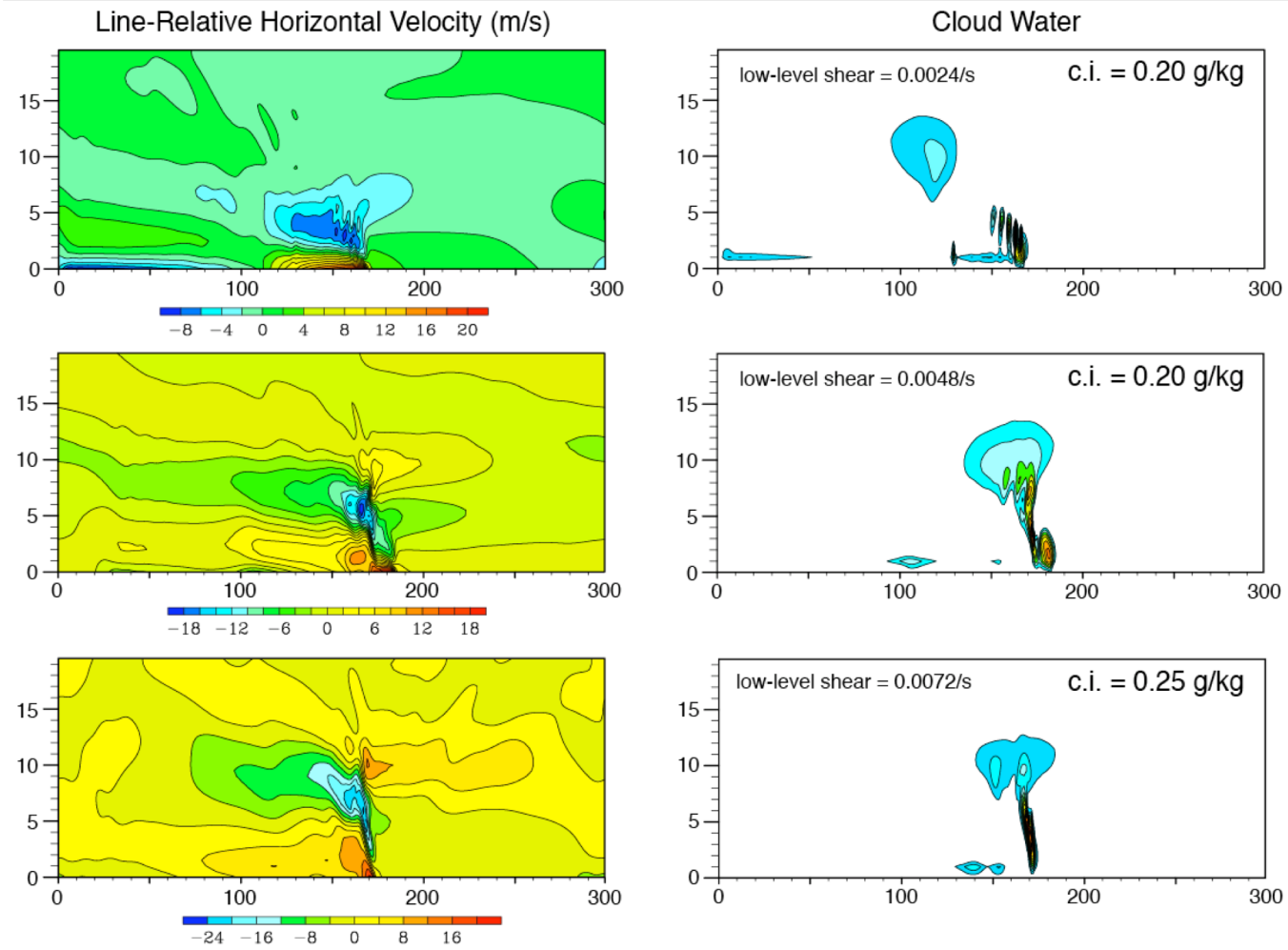
Confirms that numerical accuracy of terrain metric terms is consistent with accuracy of advection

(Klemp et al MWR 2003)

MPAS
Model for Prediction Across Scales

Squall-Line Tests

Low-level shear (0-2.5 km), Weisman-Klemp sounding
Warm-bubble perturbation, results at 3 hours



(from Max Menchaca)

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MPAS 7.0 Release

MPAS release is available at

http://mpas-dev.github.io/

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Apps | NCAR Library Proxy | Skamarock Home... | Imported From Sa... | RAP Real-Time W... | Home - Workday | MPAS | NCAR Library

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MPAS Atmosphere Public Releases

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MPAS Atmosphere 7.0 release notes

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MPAS-Atmosphere Users' Guide

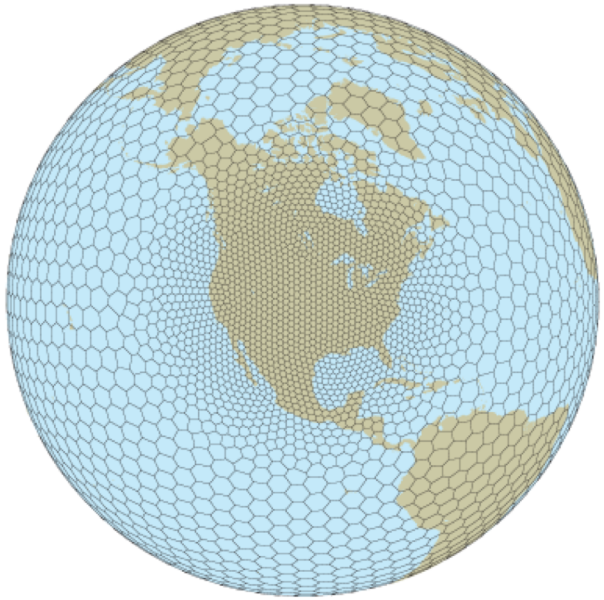
MPAS-Atmosphere tutorial presentations

MPAS-Atmosphere meshes

Configurations for idealized test cases

Sample input files for real-data simulations

Visualization and analysis tools



A variable resolution MPAS Voronoi mesh

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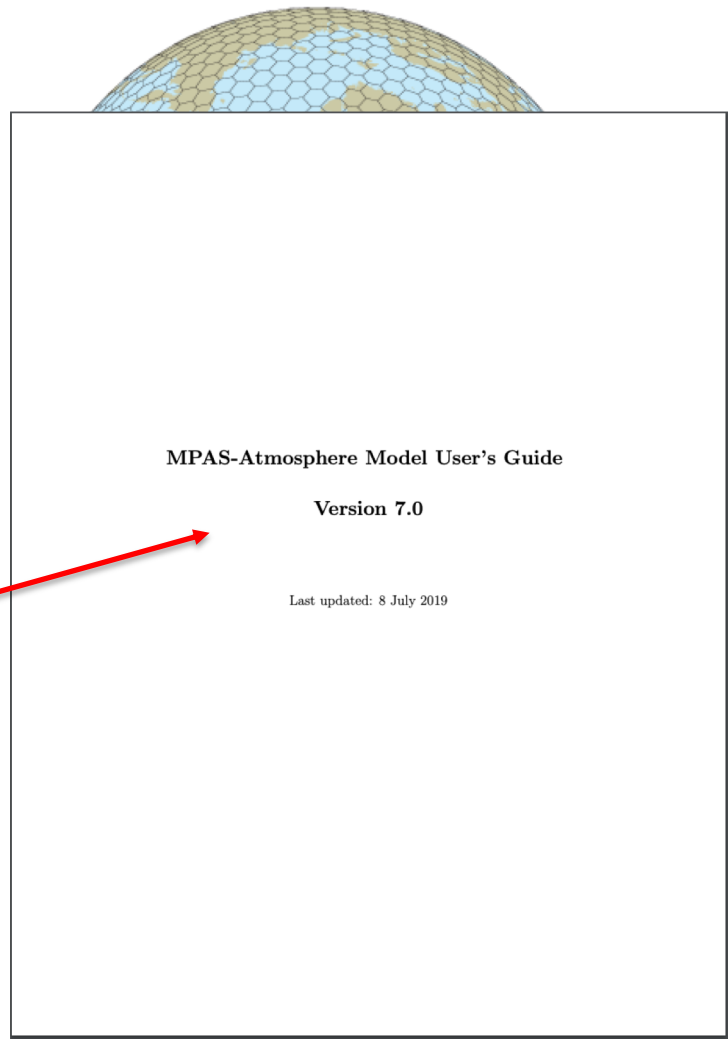

MPAS-Atmosphere Model User's Guide

Version 7.0

Last updated: 8 July 2019

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