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

Monday, 30 July 2018

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 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 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)

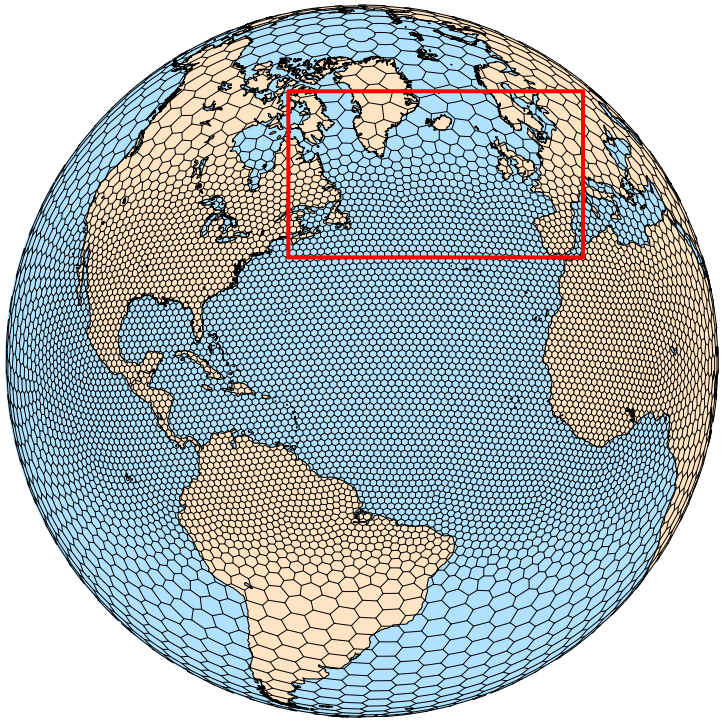
Tuesday, 31 July 2018

9:00 - 10:00 Dynamics and physics
10:00 - 10:30 MPAS software: Registry, pools, logging
10:30 - 10:50 Break
10:50 - 11:20 Practice session: Adding a new I/O stream, visualization
11:20 - 11:40 How to add passive tracer with time-varying sources and sinks
11:40 - 12:00 Diagnostics framework, and an example of adding a new accumulated diagnostic
12:00 - 1:15 Lunch
1:15 - 1:30 MPAS development - using git and GitHub
1:30 - 2:15 MPAS mesh generation, new MPAS capabilities under development
2:15 - 2:35 Break
2:35 - 4:30 Practice session: Adding a passive tracer, adding new diagnostics, other topics

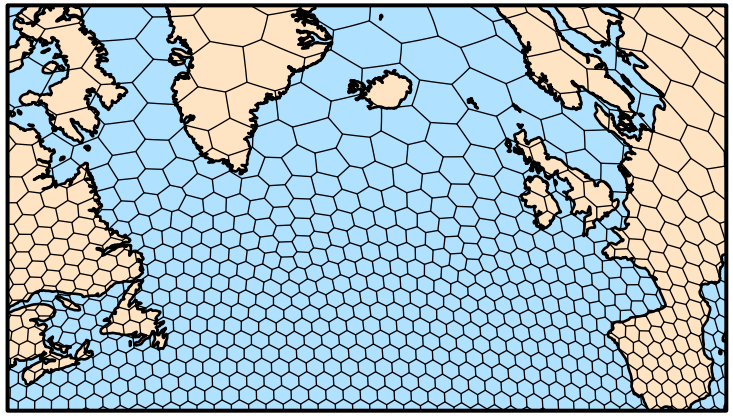
Notes: You are on your own for lunch.
Practice sessions are in the room directly behind the reception desk in FL2.

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 6.1 (11 May 2018):

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

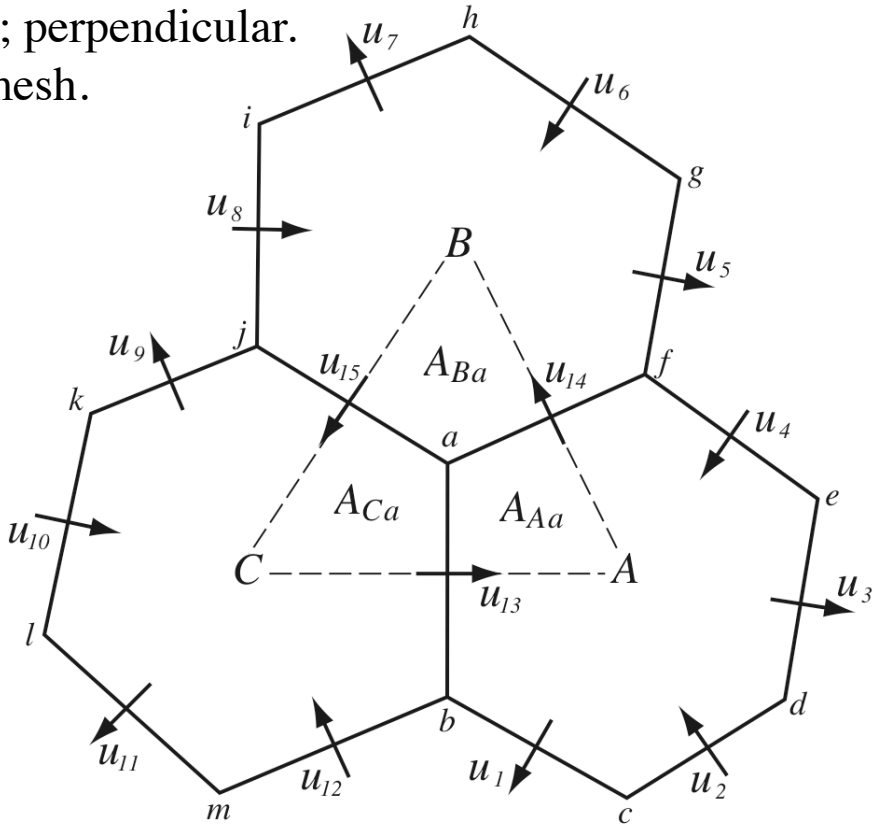
What is MPAS?
Centroidal Voronoi Meshes

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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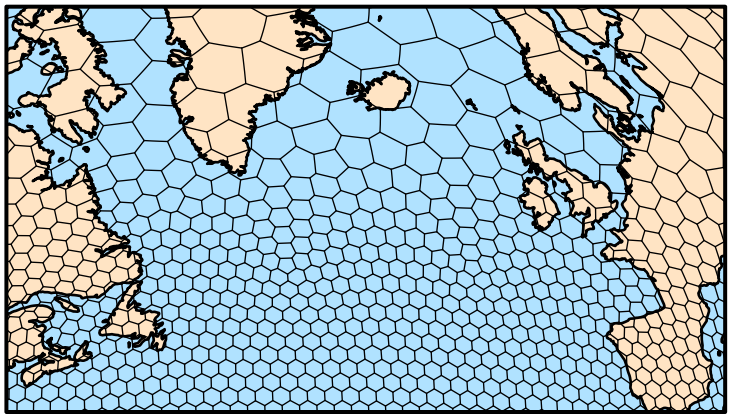
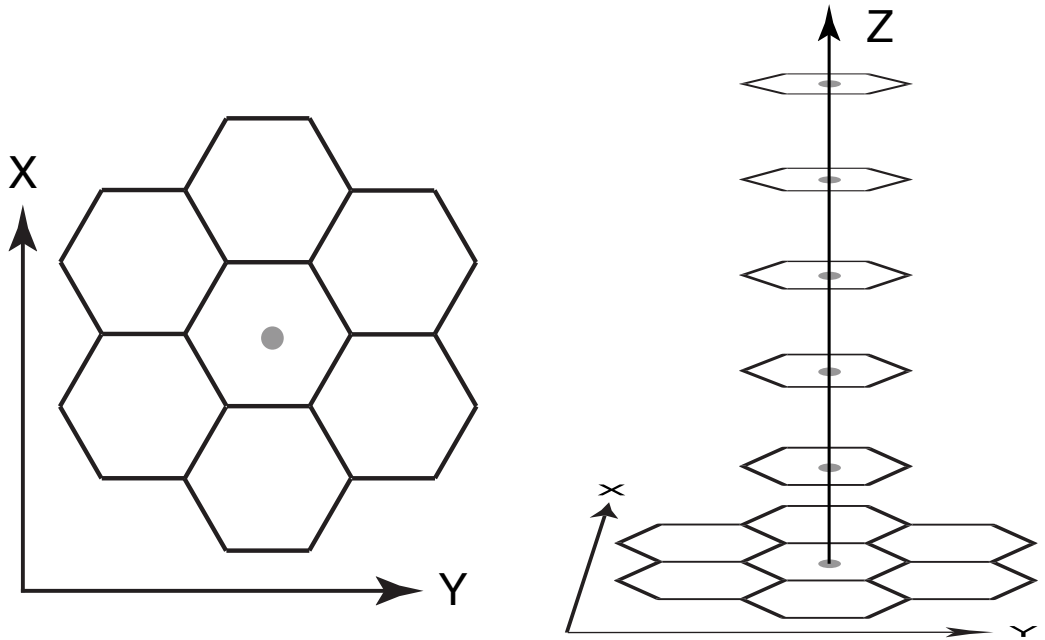
What is MPAS?
Centroidal Voronoi Meshes

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



The mesh is *structured* in the vertical



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Model for Prediction Across Scales

MPAS Nonhydrostatic Atmospheric Solver

Fully Compressible Nonhydrostatic Equations

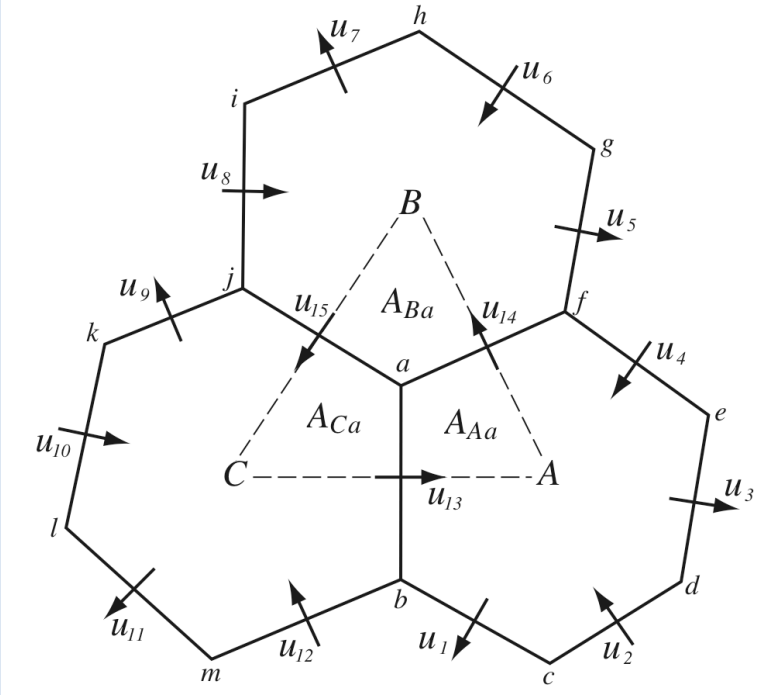
- Prognostic equations for coupled variables.
- Generalized height coordinate.
- Horizontally vector invariant eqn set.
- Continuity equation for dry air mass.
- Thermodynamic equation for coupled potential temperature.

Time integration as in Advanced Research WRF

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

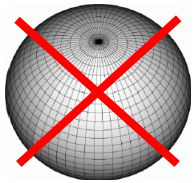
Full complement of atmospheric-model physics

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

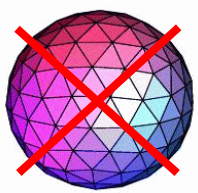


MPAS
Model for Prediction Across Scales

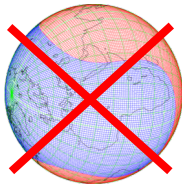
MPAS Development



2005	Global lat-lon (WRF) problematic.
2006	Triangles - problems with divergence.

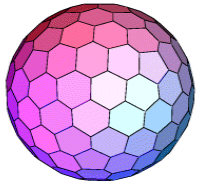


2007	Yin-Yang: local conservation past 1st-order accuracy? Cubed-sphere: Corner point problems?
2008	Hex grid: C-grid problem solved for perfect hex mesh. C-grid problem solved for general Voronoi mesh.



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.

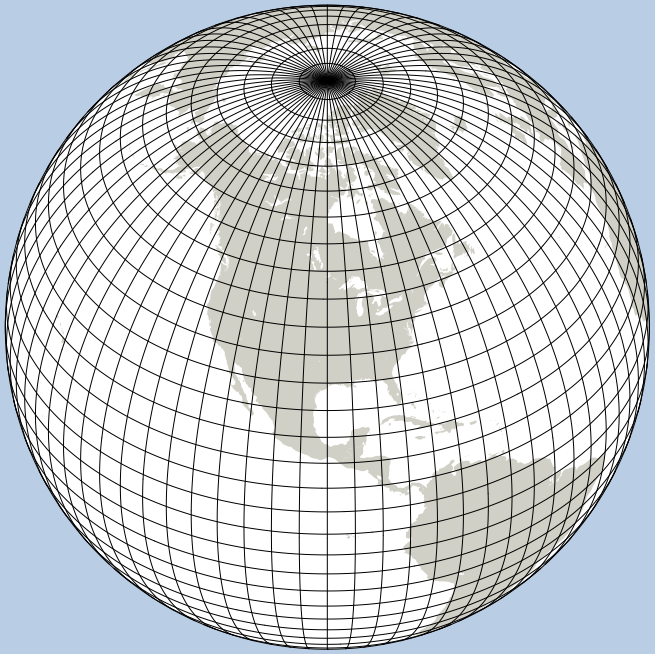


2013	3km global mesh tests on Yellowstone. MPAS V1.0 release (atmosphere, ocean) MPAS-Atmosphere real-time TC forecast testing.
2014	Scale-aware physics testing begins.

MPAS
Model for Prediction Across Scales

Why MPAS?

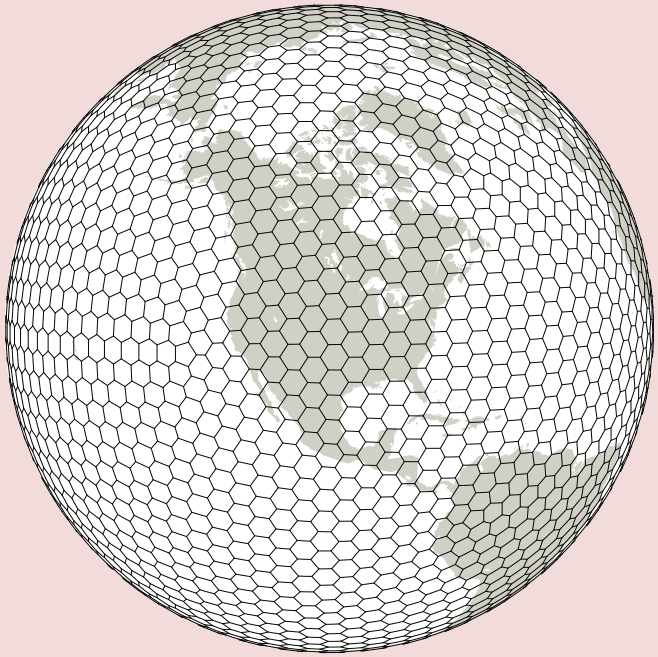
Significant differences between WRF and MPAS



WRF

Lat-Lon global grid

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



MPAS

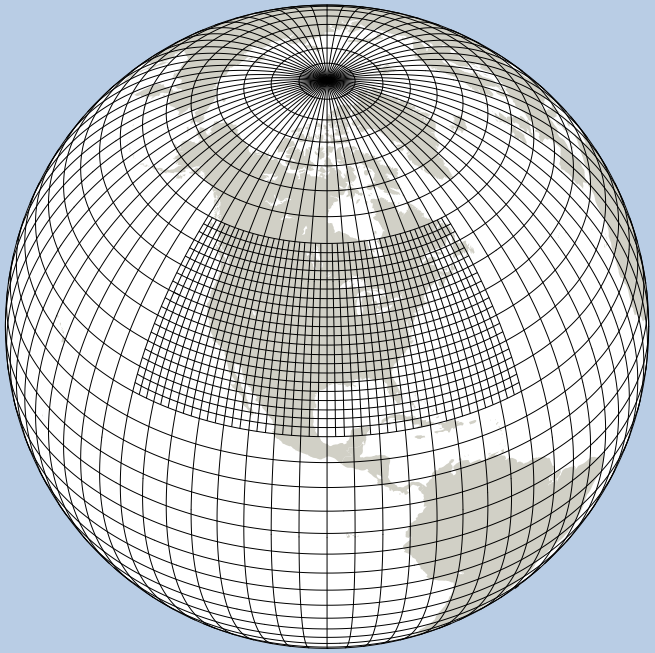
Unstructured Voronoi (hexagonal) grid

- Good scaling on massively parallel computers
- No pole problems

MPAS
Model for Prediction Across Scales

Why MPAS?

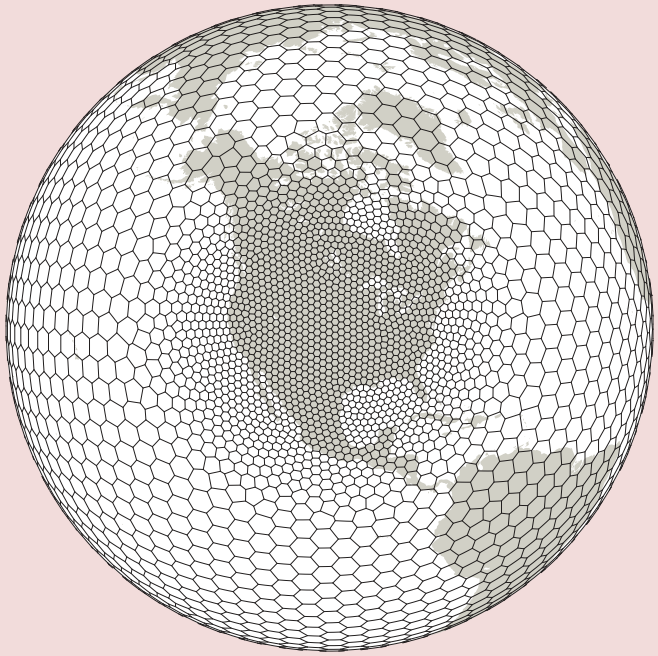
Significant differences between WRF and MPAS



WRF

Grid refinement through domain nesting

- Flow distortions at nest boundaries



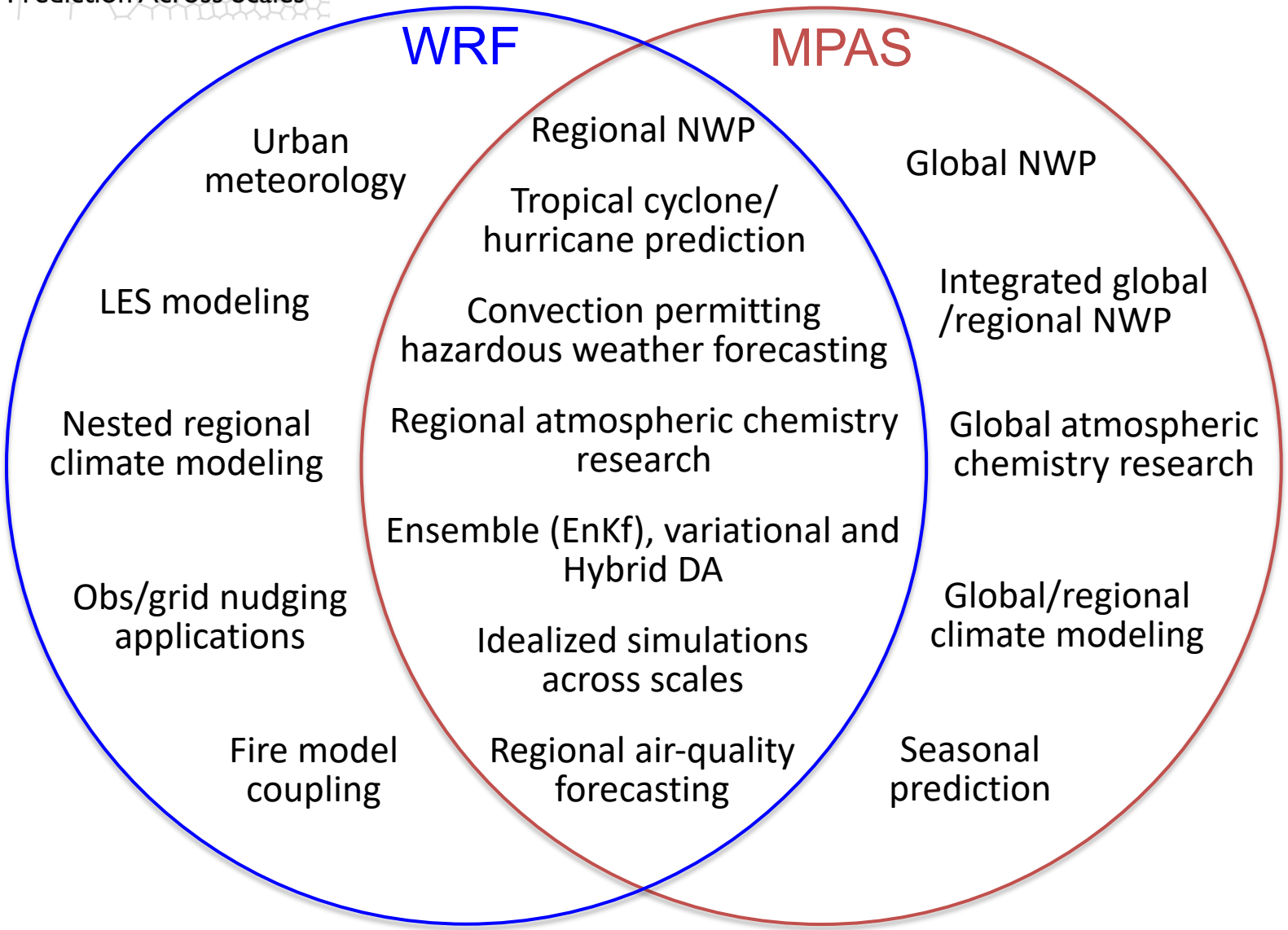
MPAS

Smooth grid refinement on a conformal mesh

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

MPAS
Model for Prediction Across Scales

MPAS and WRF Applications



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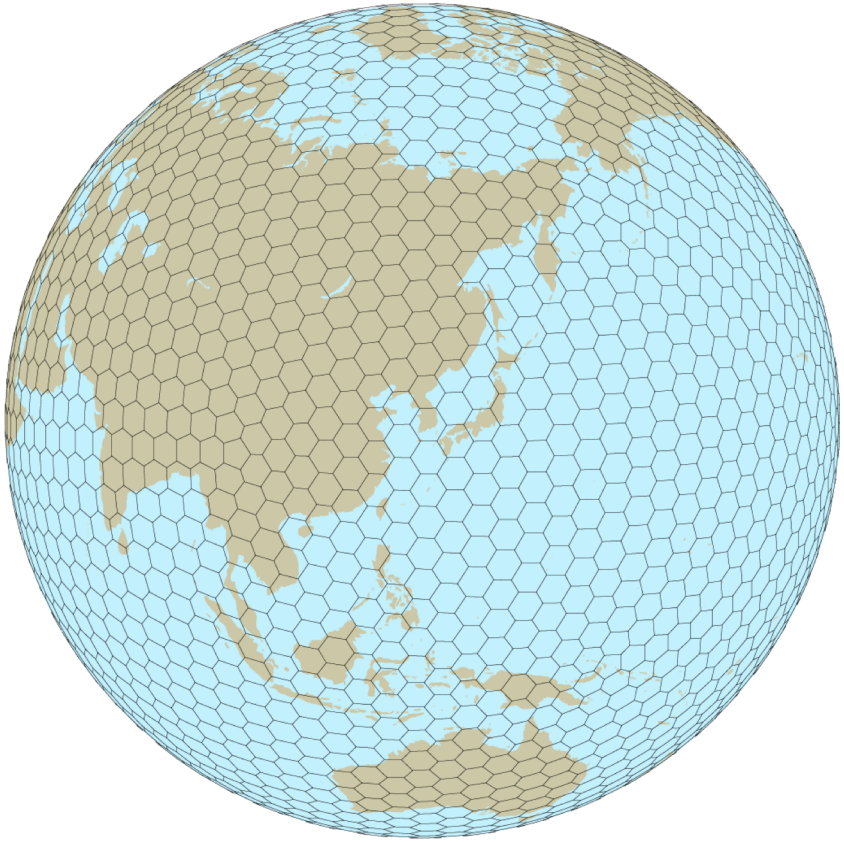
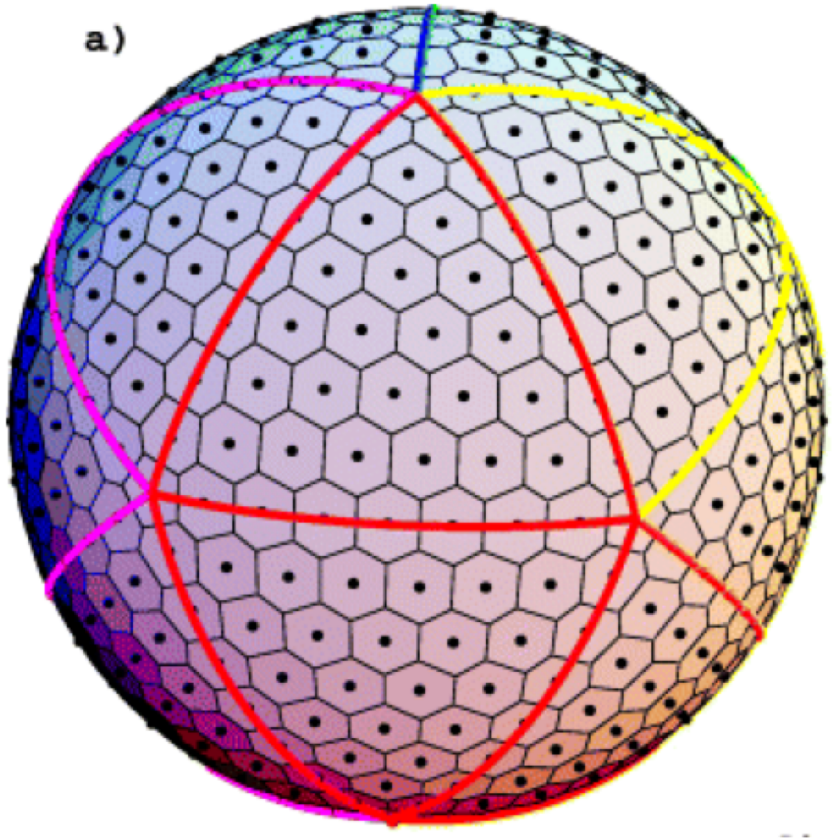
Global Meshes



Global Quasi-Uniform Mesh
(SCVT)

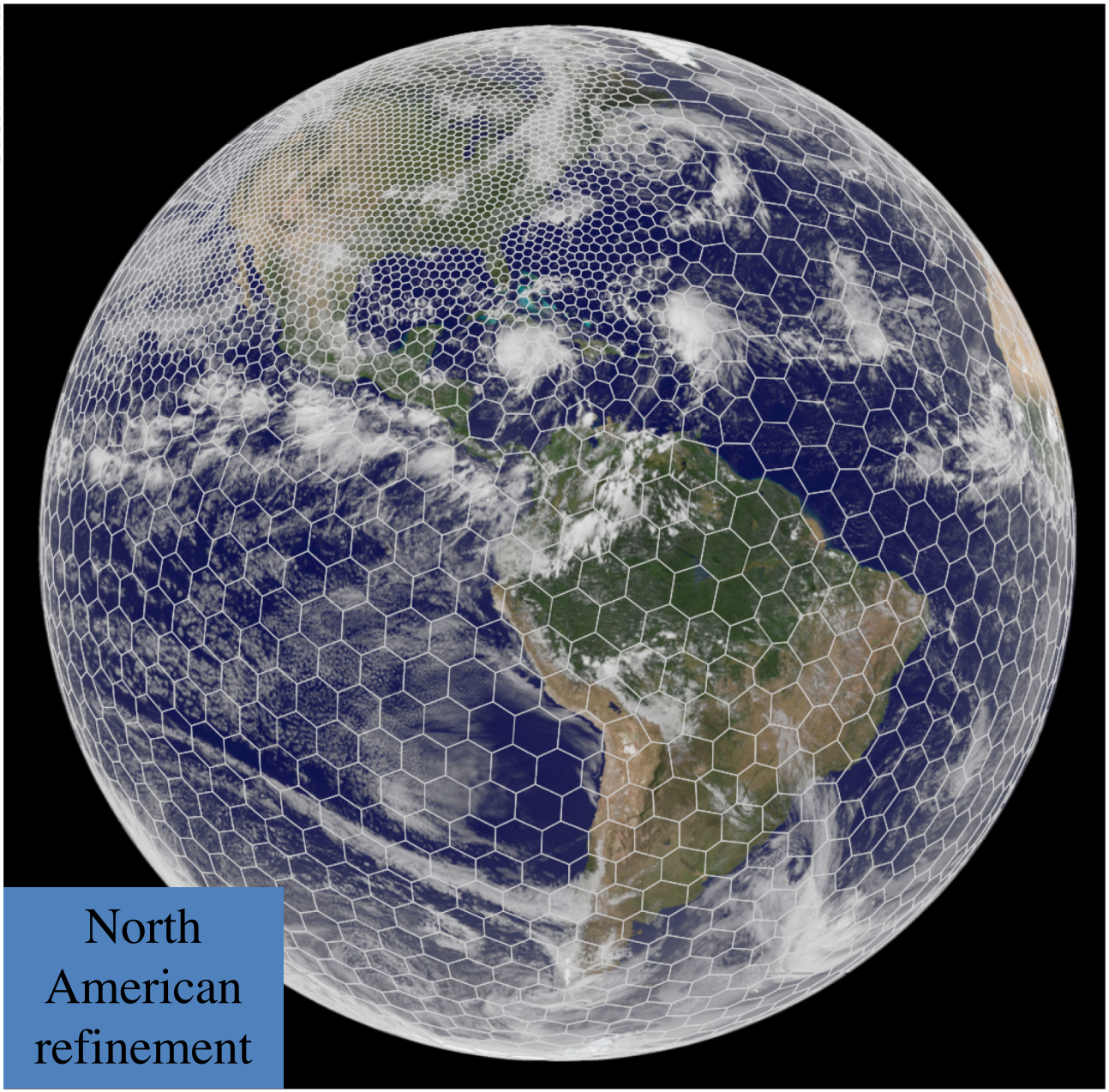


Many models use an icsoahedral mesh
(NICAM, BUGS, FIM, NIM, OLAM, etc.)

MPAS
Model for Prediction Across Scales

Mesh generation

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



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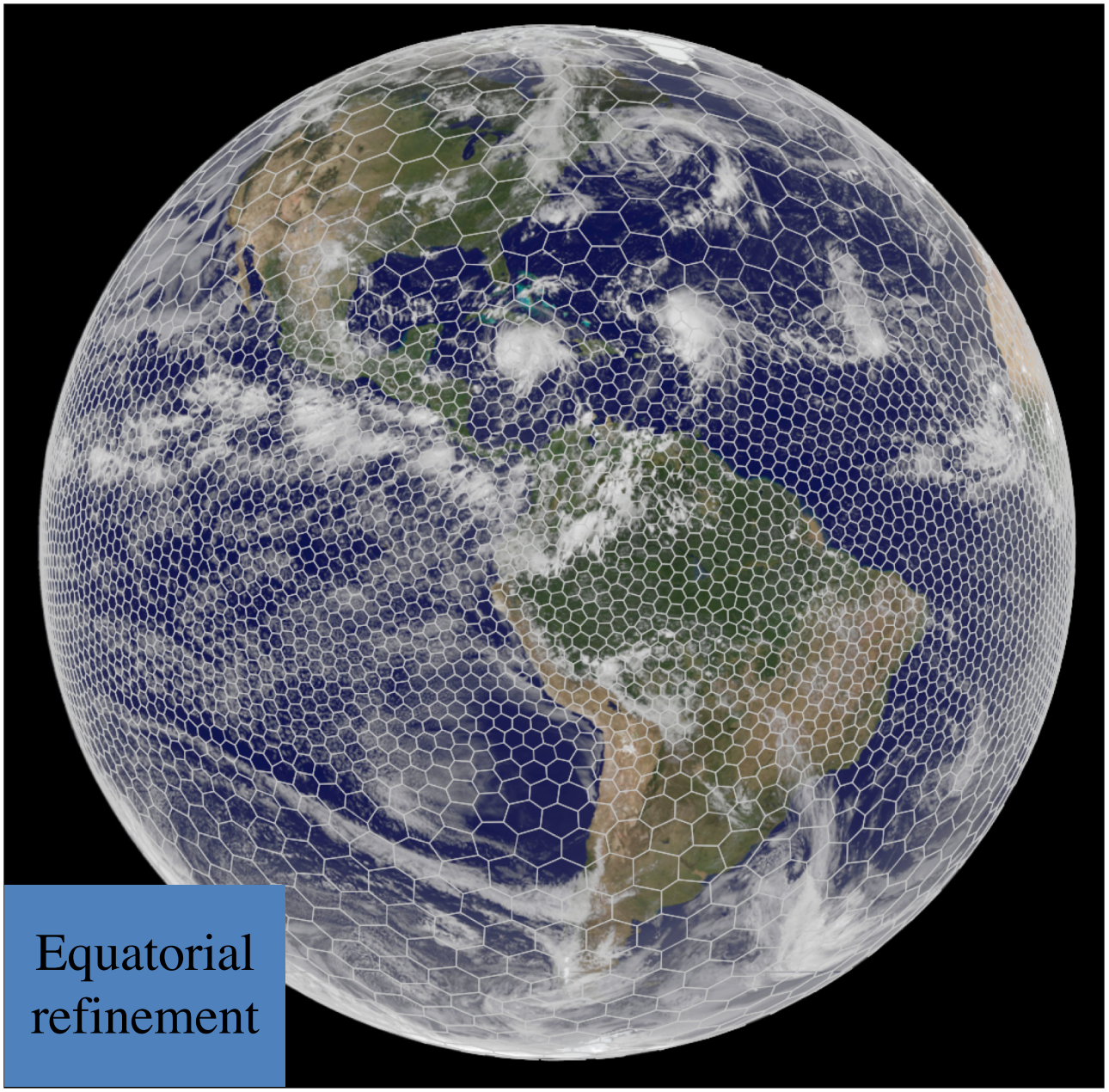

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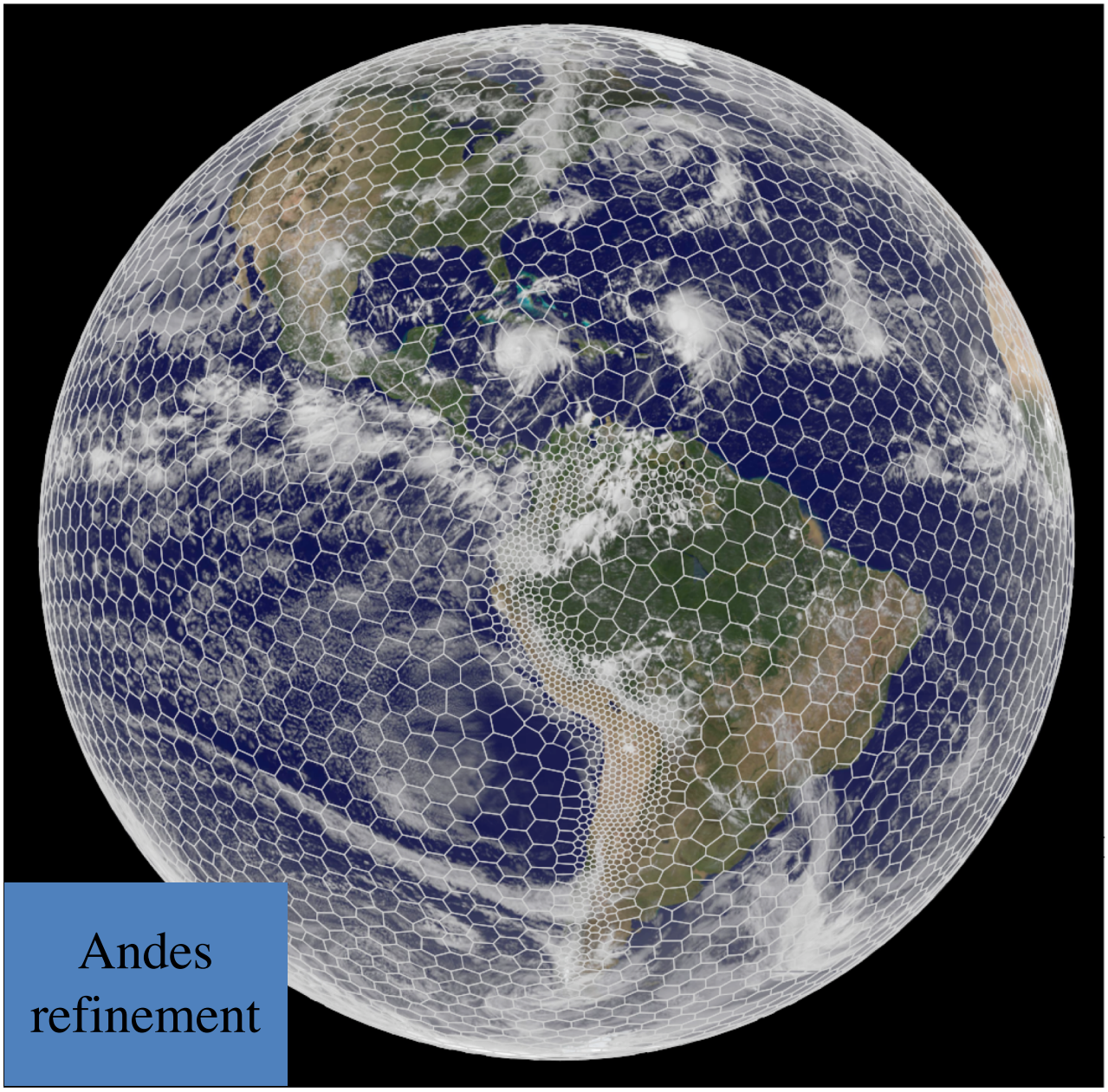


MPAS-Atmosphere Forecast Experiments

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:

mid-2017 - present: Ongoing global forecasts using a 15 km global mesh

Past experiments:

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

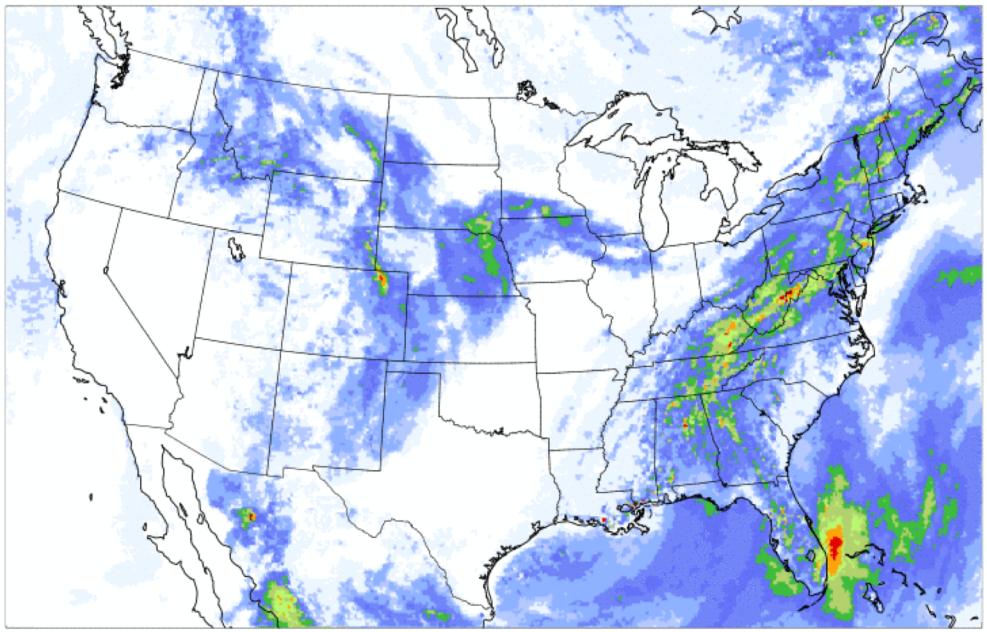
174 177 180 183 186 189 **192** 195 198 201 204 207 210 213 216 219 222 225 228 231 234 237 240

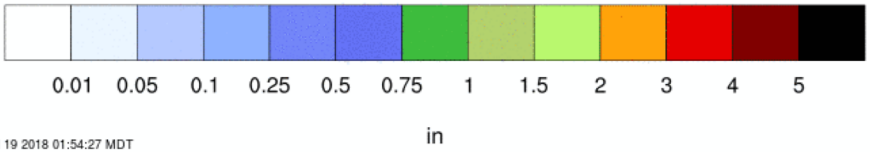
MPAS 15km 192h fcst

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

Precipitation over last 24 h

in





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created Jul 19 2018 01:54:27 MDT

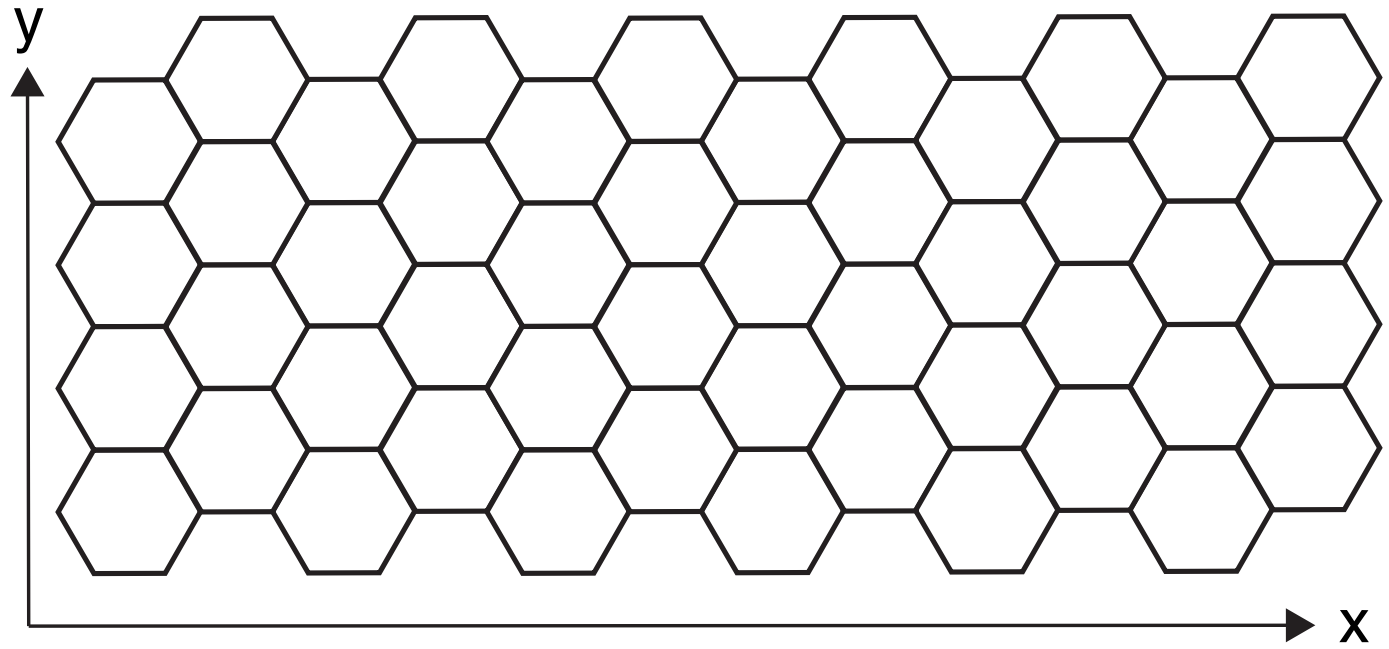
Keyboard commands: previous image [<] --- next image [>] --- hide header [**h**]

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

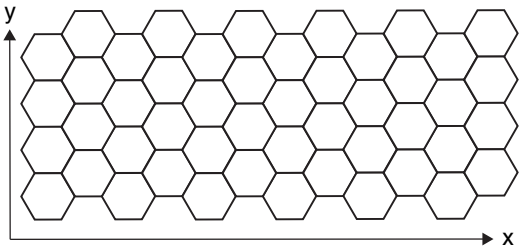
Uniform Cartesian Mesh



MPAS Nonhydrostatic Core

2D Mountain Waves - Schar Test Case

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



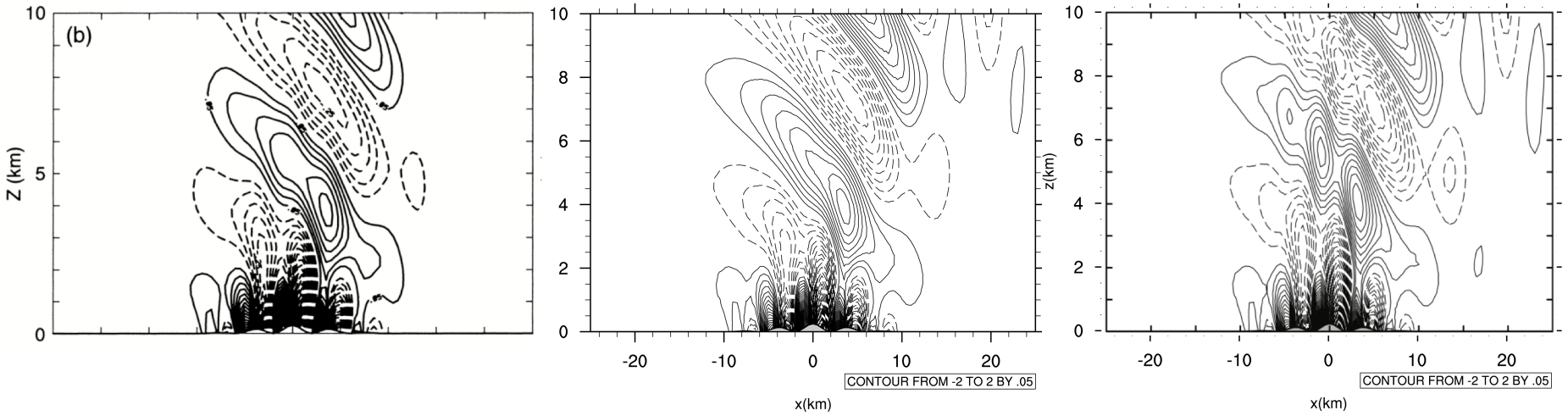
$U = 10\ ms^{-1}$ $\Delta x = 500$ m, dc = 577.35 m

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

Analytic reference solution

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

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

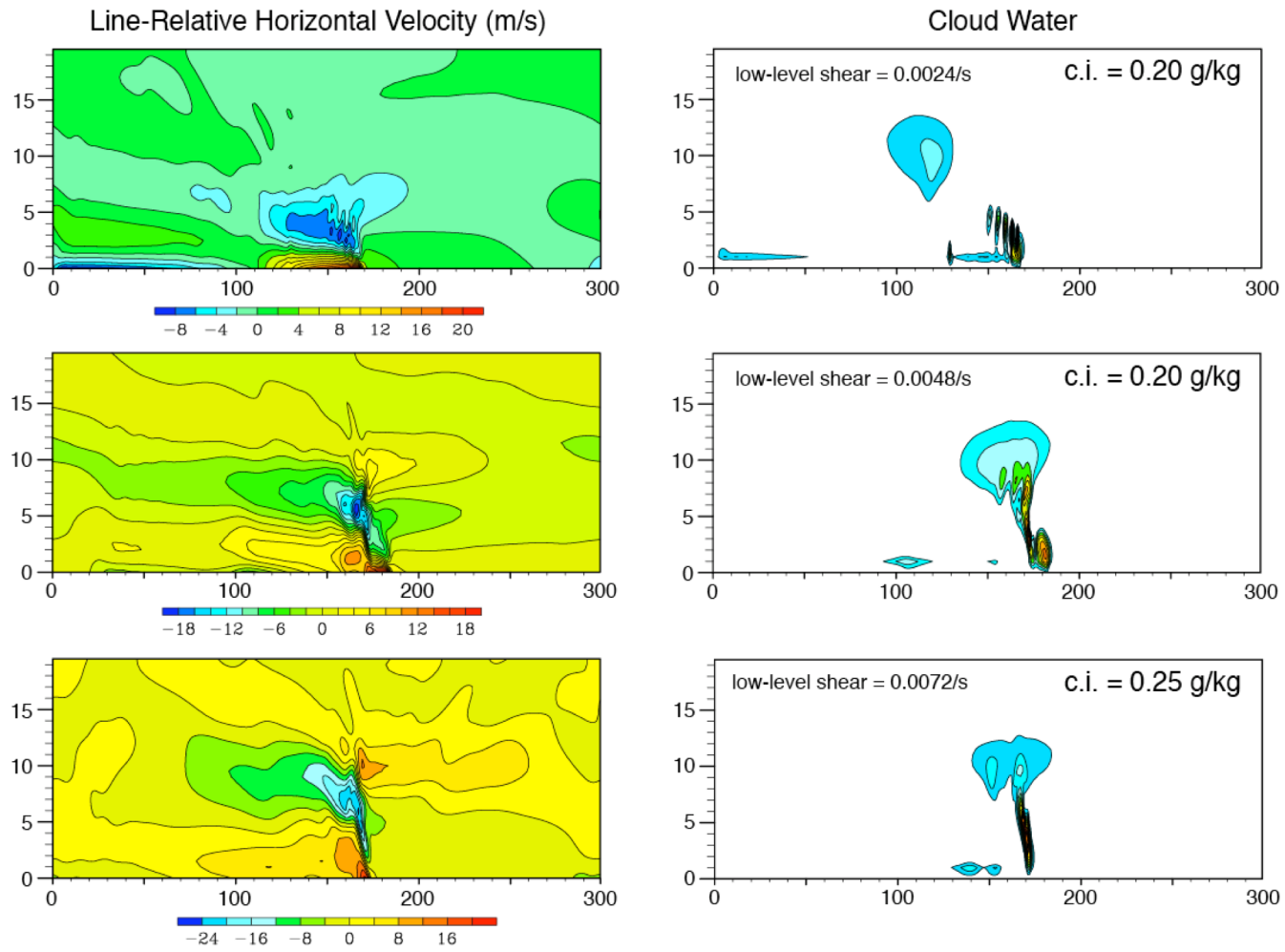


Confirms that numerical accuracy of terrain metric terms
is consistent with accuracy of advection

(Klemp et al MWR 2003)

Squall-Line Tests

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



(from Max Menchaca)

MPAS 6.1 Release

MPAS release is available at

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

MPAS
Model for Prediction Across Scales

MPAS Atmosphere Public Releases

MPAS Home

Overview
MPAS-Atmosphere
MPAS-Albany Land Ice
MPAS-Ocean
MPAS-Seaice
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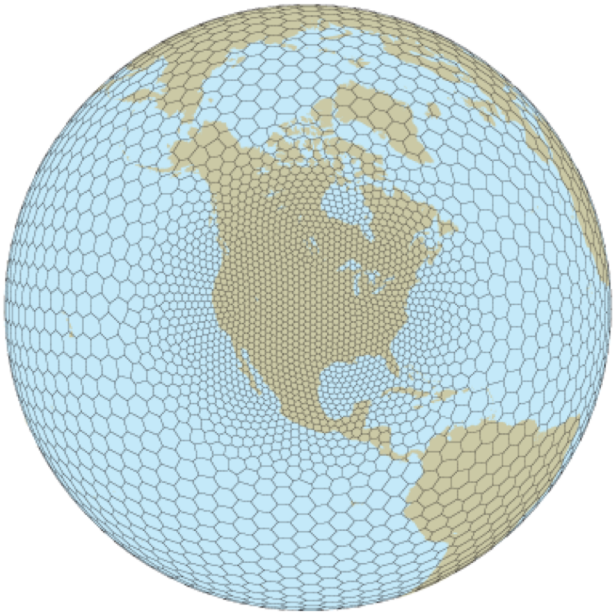
MPAS Developers Guide
MPAS Mesh Specification Document

MPAS Atmosphere 6.1 was released on 11 May 2018.

Any questions related to building and running MPAS-Atmosphere should be directed to the MPAS-Atmosphere Help forum. Posting to the forum requires a free google account. Alternatively, questions may be sent from any e-mail address to "mpas-atmosphere-help **AT** googlegroups.com". *Please note that in either case, questions and their answers will appear on the online forum.*



A variable resolution MPAS Voronoi mesh

MPAS Atmosphere 6.0 release notes

MPAS source code download

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

mpas-dev.github.io

MPAS
Model for Prediction Across Scales

MPAS Atmosphere Public Releases

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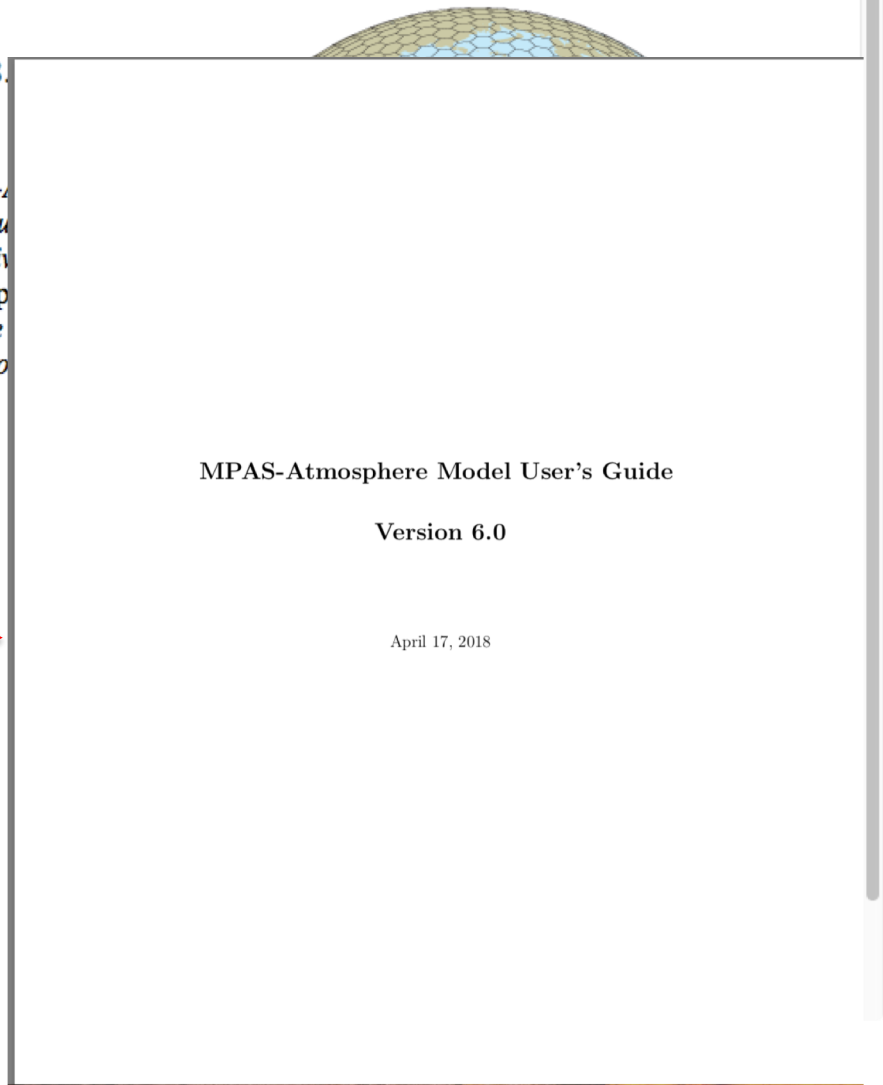

MPAS-Atmosphere Model User's Guide

Version 6.0

April 17, 2018

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