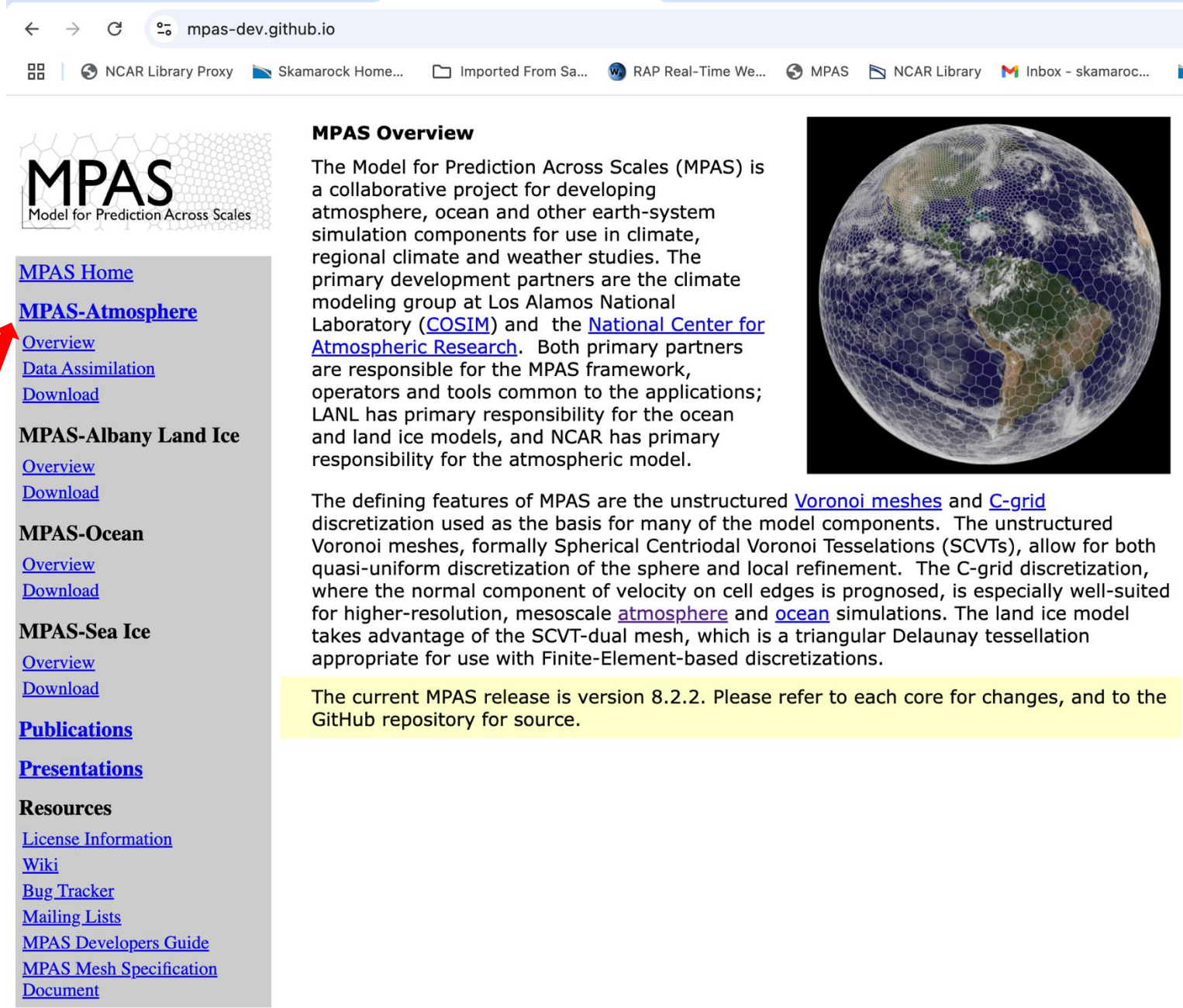
MPAS
Model for Prediction Across Scales

The Github MPAS web page

MPAS-Atmosphere



MPAS
Model for Prediction Across Scales

The new MPAS-Atmosphere web page

MPAS-Atmosphere Users Guide

https://www2.mmm.ucar.edu/projects/mpas/site/

Google Lens

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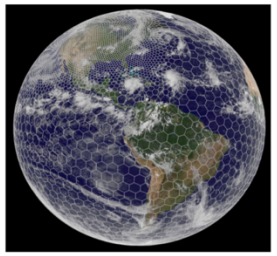

NSF | NCAR Operated by UCAR

MPAS Atmosphere

Model for Prediction Across Scales - Atmosphere

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

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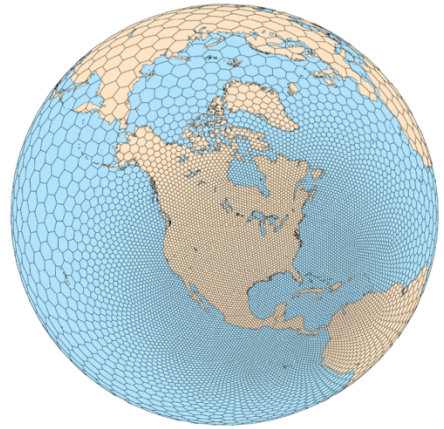
Model for Prediction Across Scales - Atmosphere

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 Code Contributor Guide
MPAS Mesh Specification
MPAS-A Tutorial Practice Guide
MPAS Data Assimilation

Access Code

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

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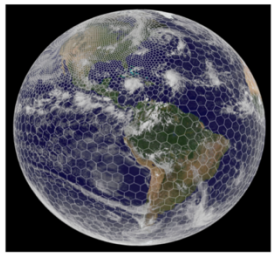

MPAS Atmosphere

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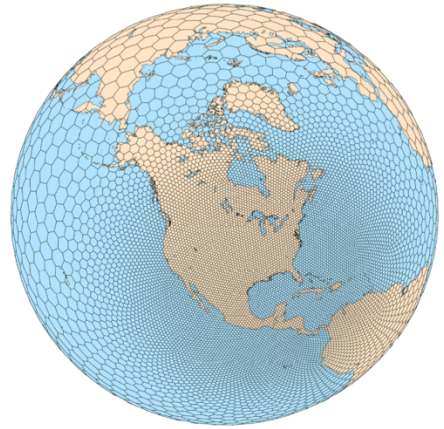

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MPAS-Atmosphere Tutorial (currently the 2024 virtual tutorial)

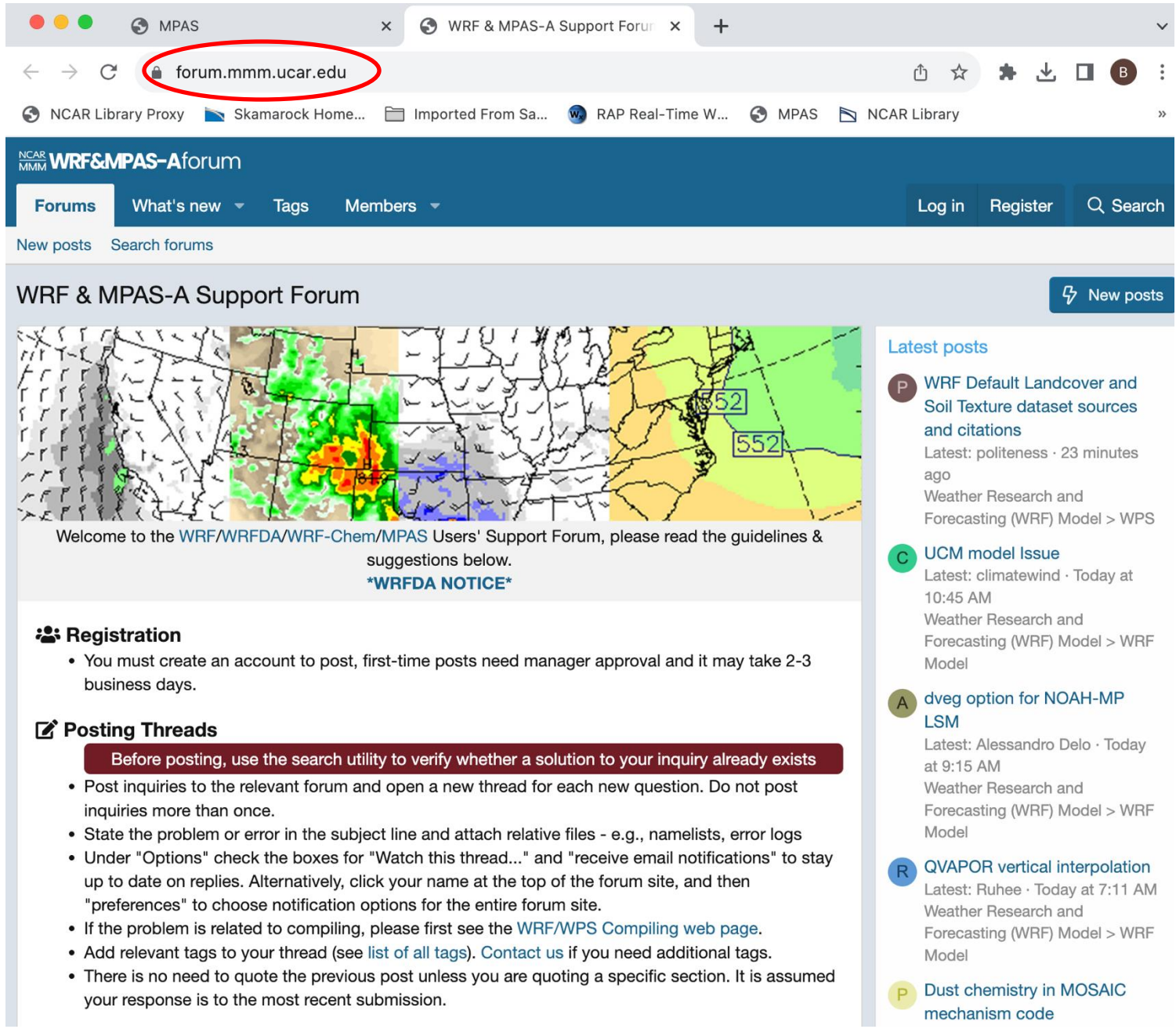
MPAS
Model for Prediction Across Scales

MPAS-Atmosphere Resources

WRF & MPAS-A Support Forum

You need to create an account to post to it.

Searchable



MPAS
Model for Prediction Across Scales

Under Development

- Large Eddy Simulation (LES) capability.
- Mesh generation, global and regional
- MPAS-Atmosphere Technical Note.
- Unified (MPAS, WRF, CM1) physics.
- NOAA physics used in the UFS and the WoFS.
- GOCART implementation
- Scalar transport in physics parameterizations (convection, boundary layer) for GOCART and chemistry.
- Earth System Model capabilities.
- GPU capability.

MPAS
Model for Prediction Across Scales

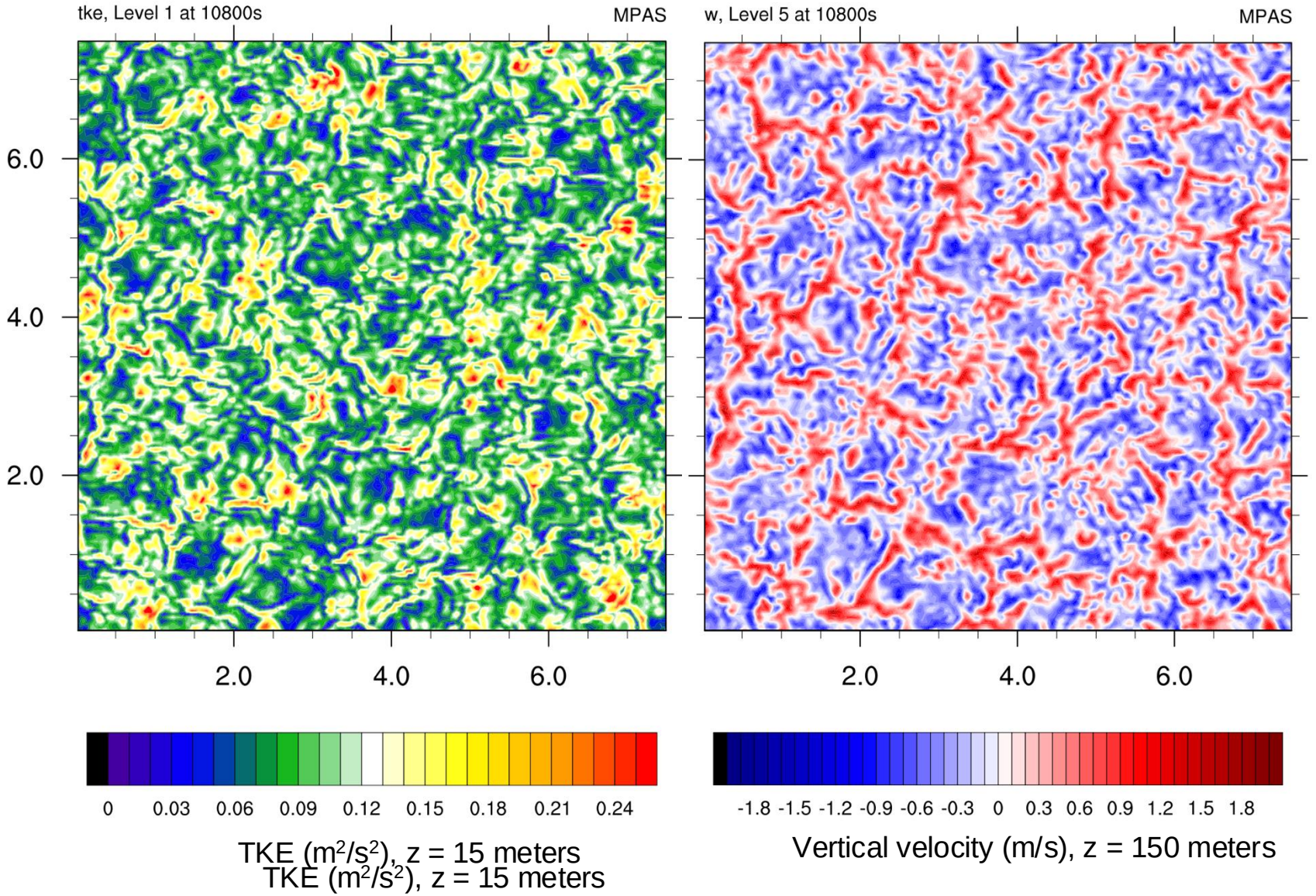
LES capabilities in MPAS

We implemented 2 LES SGS turbulence models in MPAS: 3D Smagorinsky scheme (diagnostic) and a 1.5 order TKE scheme (prognostic).

MPAS LES results look at lot like WRF and CM1 results.

Extensions for terrain need implementing.

Release expected in 2025.



TKE (m²/s²), z = 15 meters

SAS LES test case, horizontal cross sections of turbulent kinetic energy and vertical velocity

MPAS
Model for Prediction Across Scales

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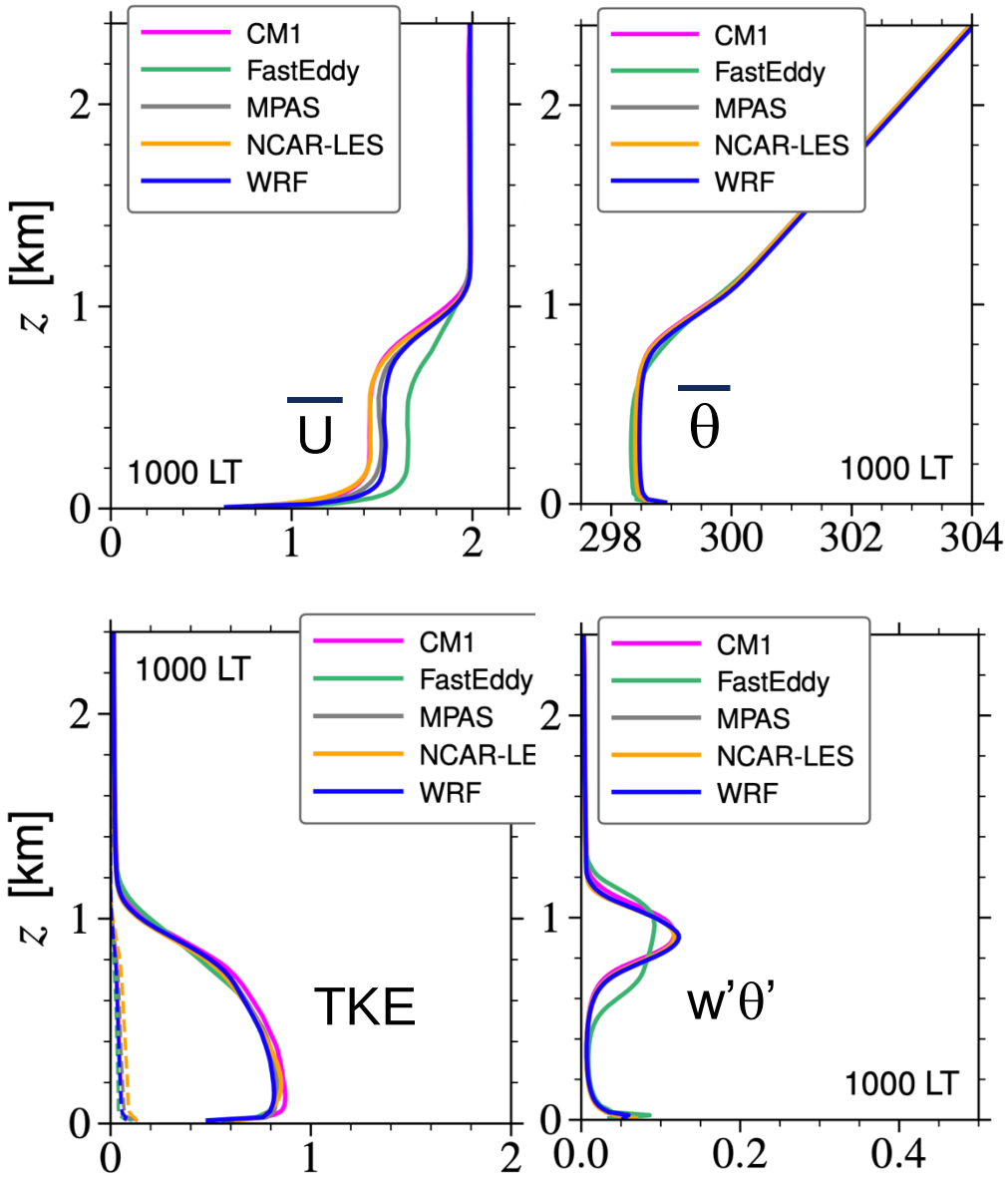


SAS LES test case

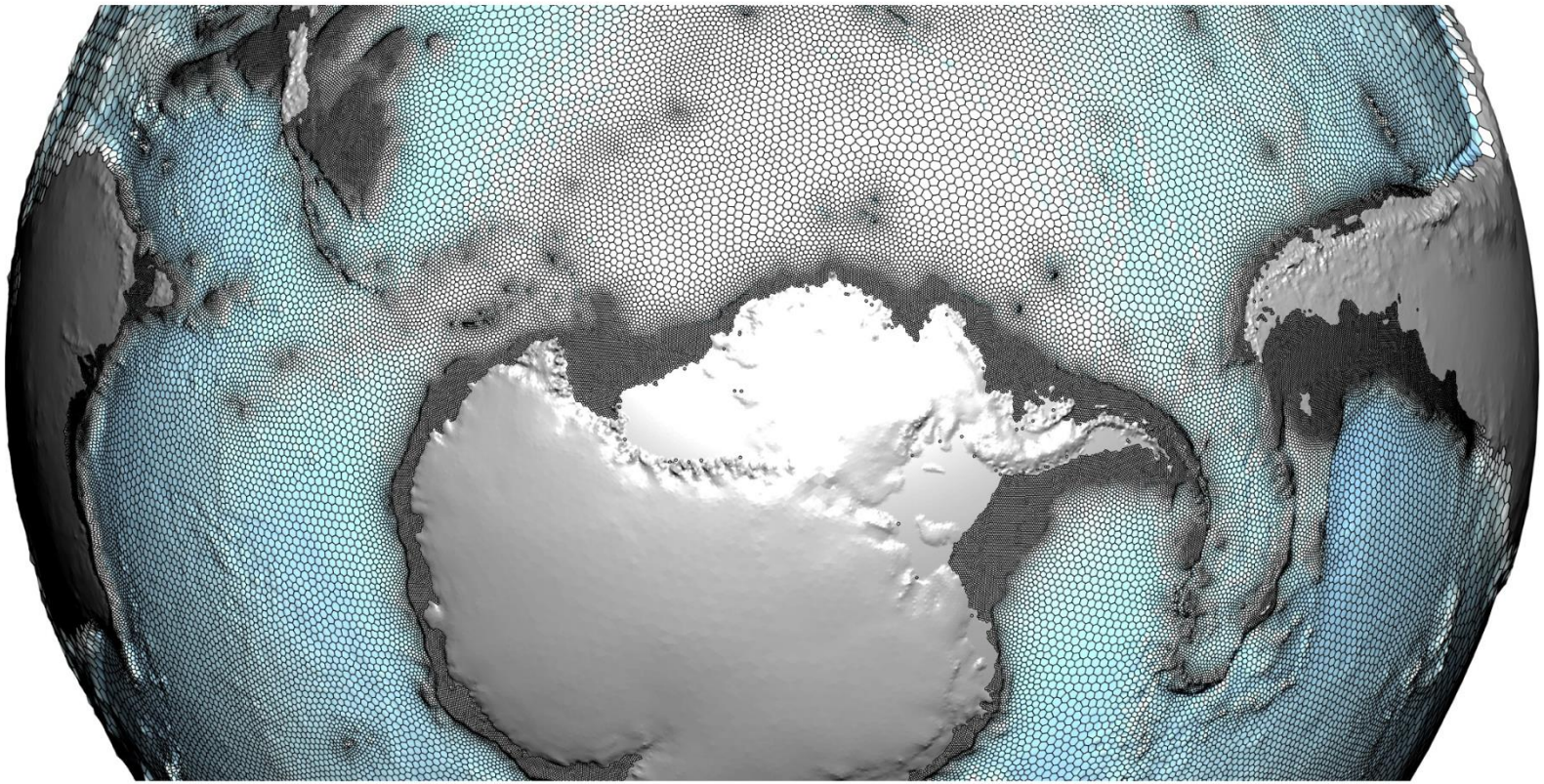
Mesh Generation

JIGSAW(GEO): potentially much faster (10x?) variable-resolution mesh creation.

https://github.com/dengwirda/jigsaw-geo-python

Darren Engwirda

`JIGSAW(GEO): Mesh generation for geoscientific modelling`



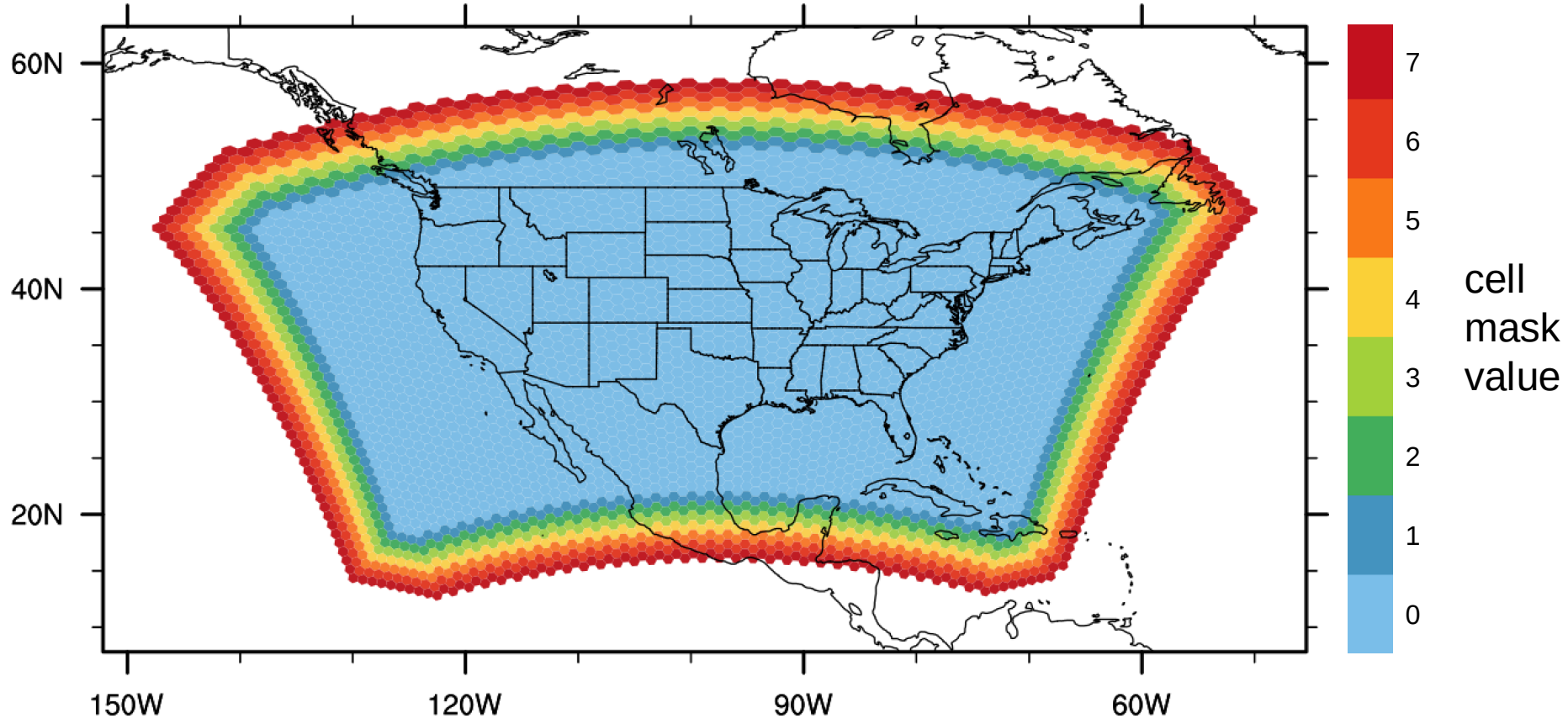
MPAS
Model for Prediction Across Scales

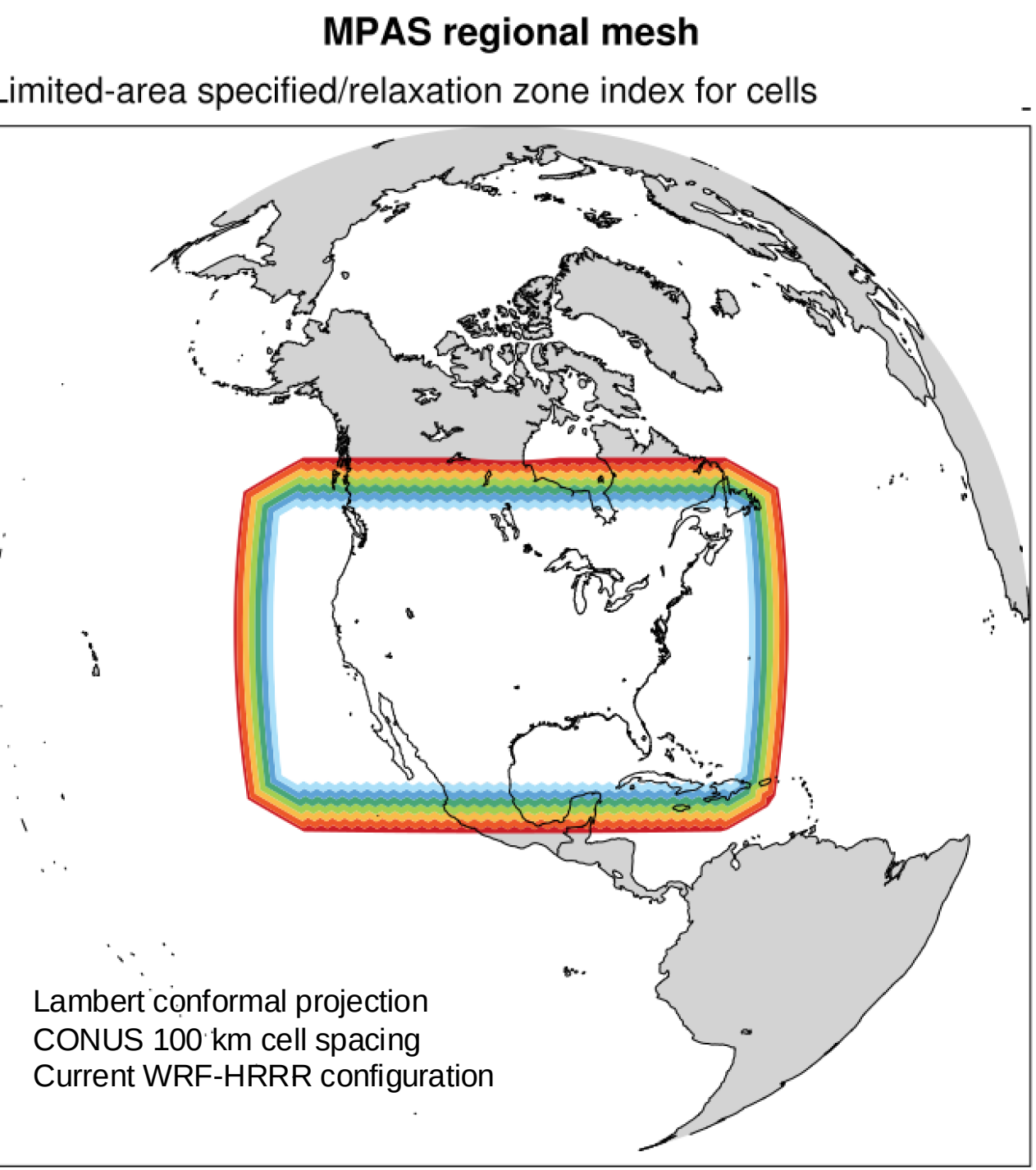
Available on Github

https://github.com/MPAS-Dev/MPAS-Tools.git

MPAS-Tools/mesh_tools/hex_projection

Mesh of perfect hexagons projected to the sphere. Lambert conformal projection



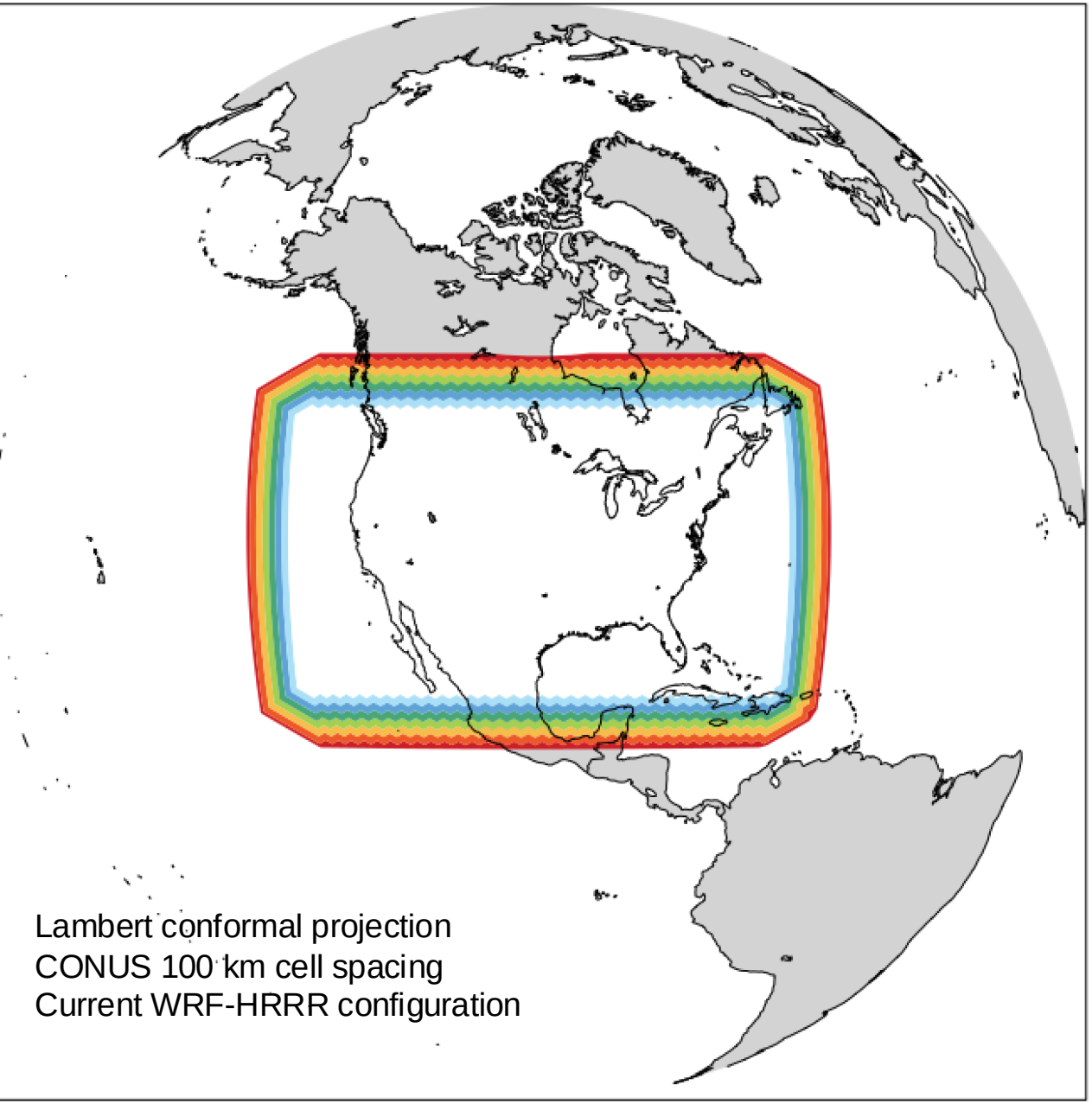


Regional Mesh Generation

Project perfect hexagons on an (xy) Cartesian plane to the sphere using standard projections

MPAS regional mesh

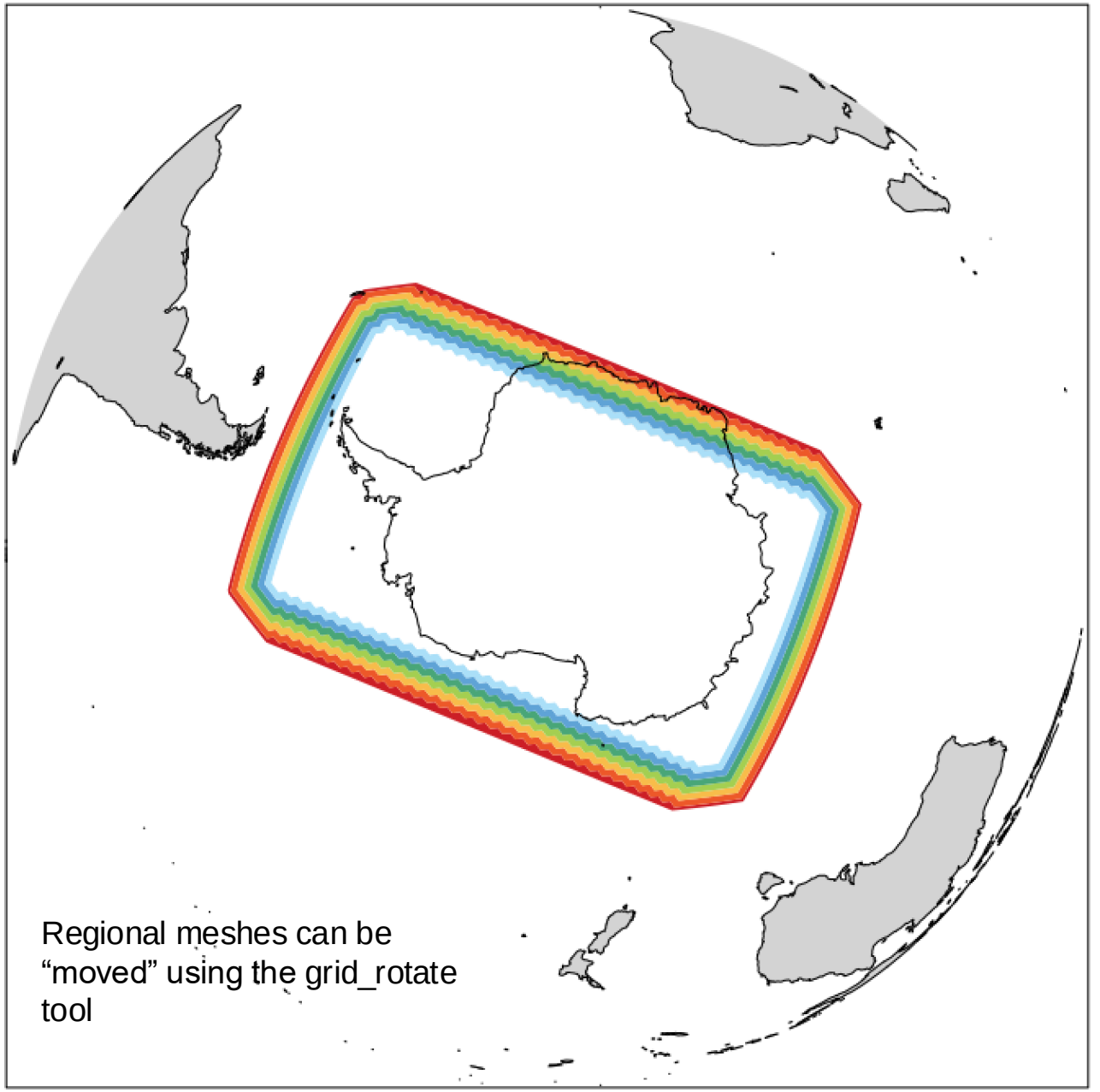
Limited-area specified/relaxation zone index for cells



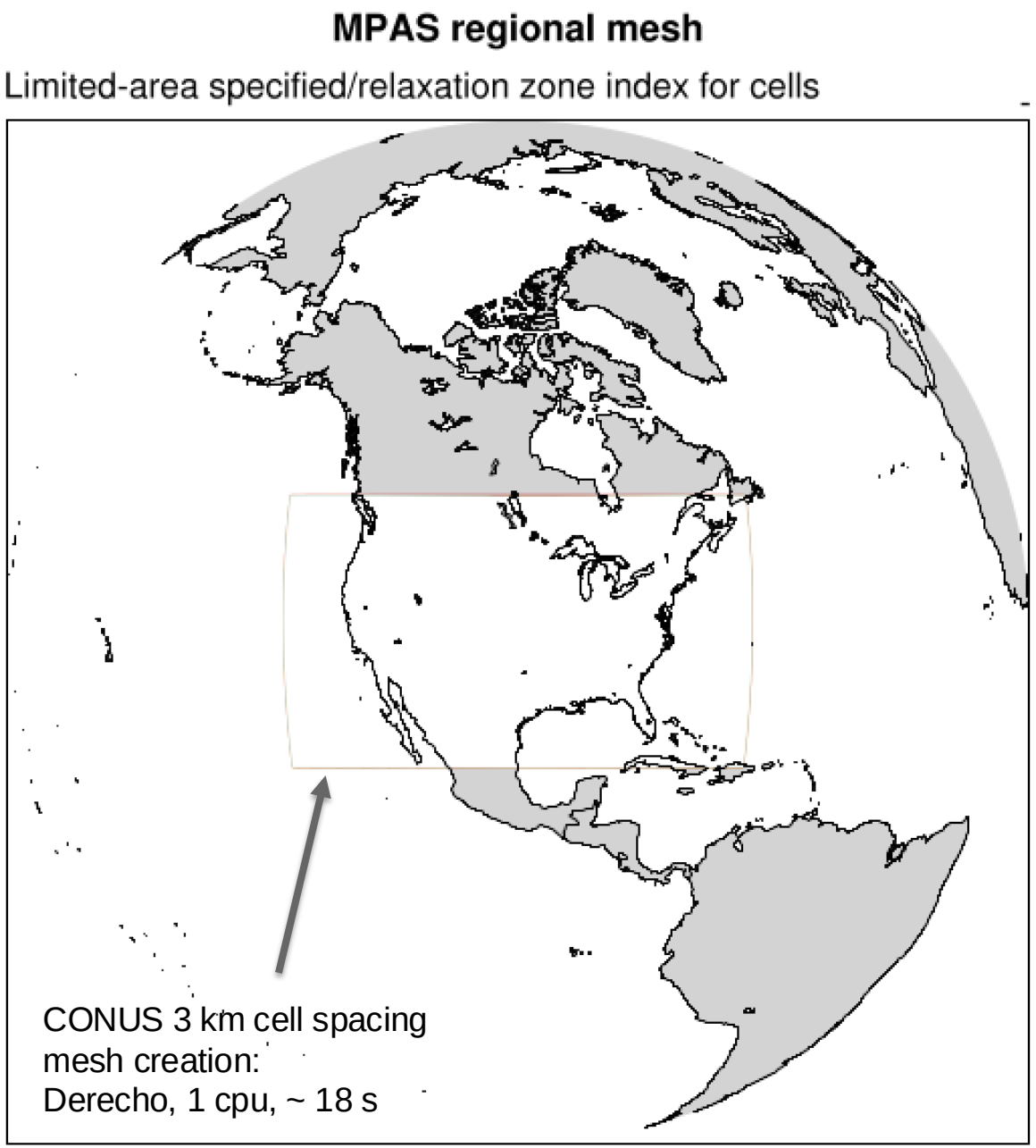
Lambert conformal projection
CONUS 100 km cell spacing
Current WRF-HRRR configuration

MPAS regional mesh

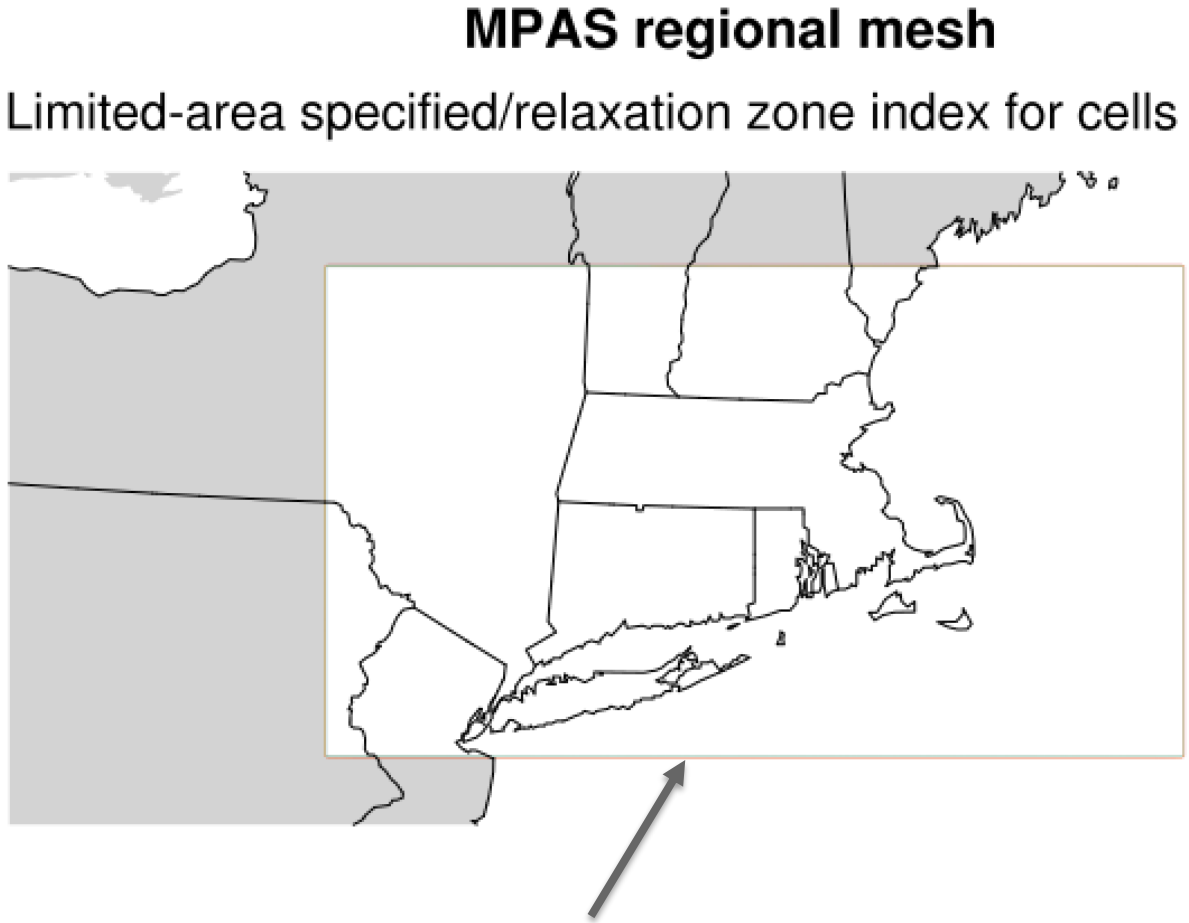
Limited-area specified/relaxation zone index for cells



Regional meshes can be “moved” using the grid_rotate tool



CONUS 3 km cell spacing
mesh creation:
Derecho, 1 cpu, ~ 18 s



300 meter cell spacing
mesh creation:
Derecho, 1 cpu, ~ 18 s

An example from the draft technical note

Vertical Vorticity

The discrete vertical vorticity is evaluated at the vertices of the MPAS CVT mesh. Referring to figure 2.1, the vertical vorticity at vertex a is computed using the circulation theorum applied to the MPAS dual triangular mesh. The relative vertical vorticity at vertex a is computed as

$$\zeta_a = \frac{u_{13} \left|\overrightarrow{CA}\right| t_{13,a} + u_{14} \left|\overrightarrow{AB}\right| t_{14,a} + u_{15} \left|\overrightarrow{BC}\right| t_{15,a}}{A_a}, \tag{4.27}$$

where A_a is the area of the triangle centered at vertex a. The indicator function $t_{e,v}$ corrects for the direction of a positive velocity from the first cell center to the second in the circulation calculation. In the example (4.27), the indicator functions are all equal to 1. In contrast, the indicator functions would be equal to -1 for these same velocities contributing to the circulation about vertices b, f and j. Also note that these computations are performed on MPAS horizontal surfaces. Finally, the absolute vorticity at the vertices $\eta_a = \zeta_a + 2\Omega \sin(\phi)$, where Ω is the angular velocity of the earth's rotation and ϕ is the latitude.

MPAS code: *The vertical vorticity is computed in subroutine atm_compute_solve_diagnostics found in MPAS-Model/src/core_atmosphere/dynamics/mpas_atm_time_integration.F. The relative vertical vorticity at a vertex ζ_v is stored in the array* vorticity(level,vertex). *The indicator function $t_{e,v}$ is stored in the array* edgesOnVertex_sign(edge,vertex).
The absolute vorticity at the vertices η_v is stored in the array pv_vertex(level,vertex). *The name goes back to MPAS-A's initial implementation of a shallow water model.*

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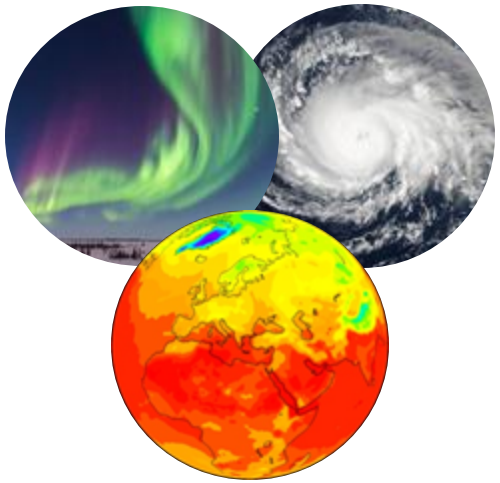
The Model for Prediction Across Scales Atmosphere

MPAS-A in Earth Systems Models



SIMA

EarthWorks

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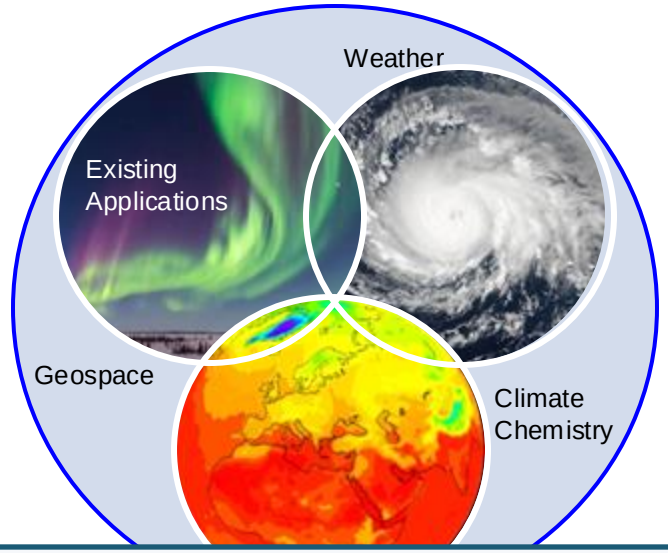
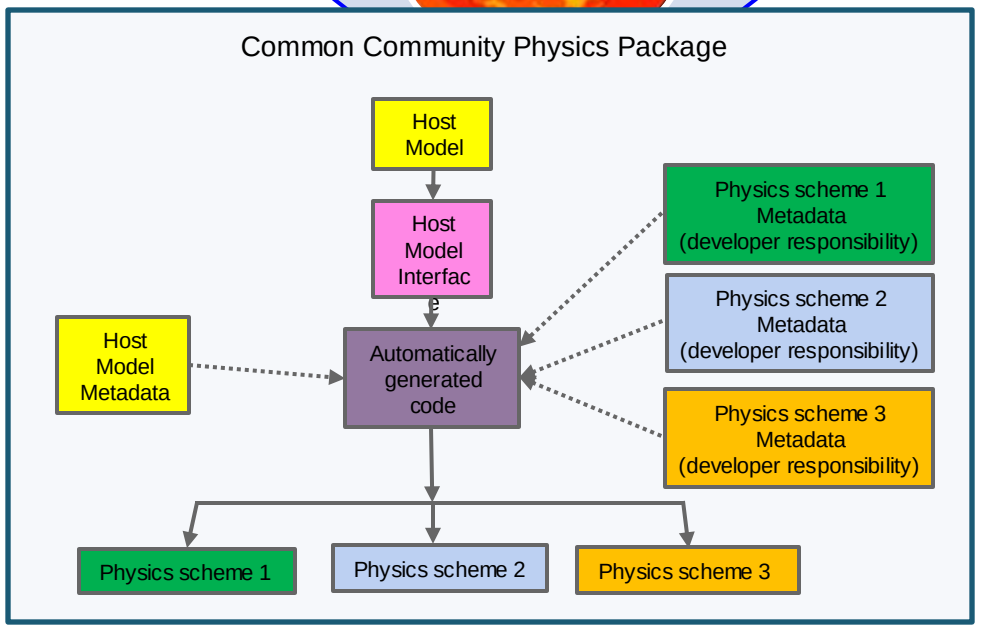
Model for Prediction Across Scales

System for Integrated Modeling of the Atmosphere (SIMA)



MPAS-Atmosphere in an Earth System Model (ESM), using CESM components. Other ESM components: ocean, land, land and sea ice, chemistry



Status:

- *MPAS-A in CESM is being tested.*
- *Only CESM/CAM physics will be available in a first release with MPAS-Atmosphere.*
- *Initial release (experimental) TBD.*

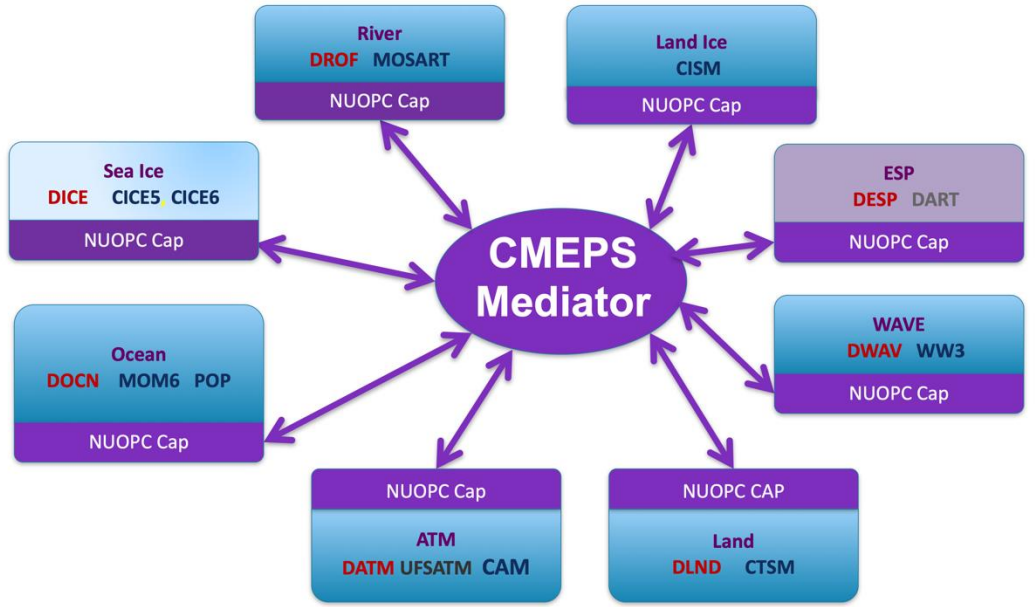
MPAS
Model for Prediction Across Scales

EarthWorks

EarthWorks is a five-year university-based project (CSU), supported by NSF/CISE, to develop a *global convection-permitting coupled model* based on the CESM with GPU capability for all components.

Earthworks consists of:

- The MPAS non-hydrostatic dynamical core, with a resolved stratosphere and CAM-ish physics
- The MPAS ocean model, developed at Los Alamos
- The MPAS sea ice model, based on CICE
- The Community Land Model (CLM)
- The Community Mediator for Earth Prediction Systems (CMEPS)



MPAS
Model for Prediction Across Scales

EarthWorks

EarthWorks is available now in a first “functional” release:
git clone https://github.com/EarthWorksOrg/EarthWorks.git

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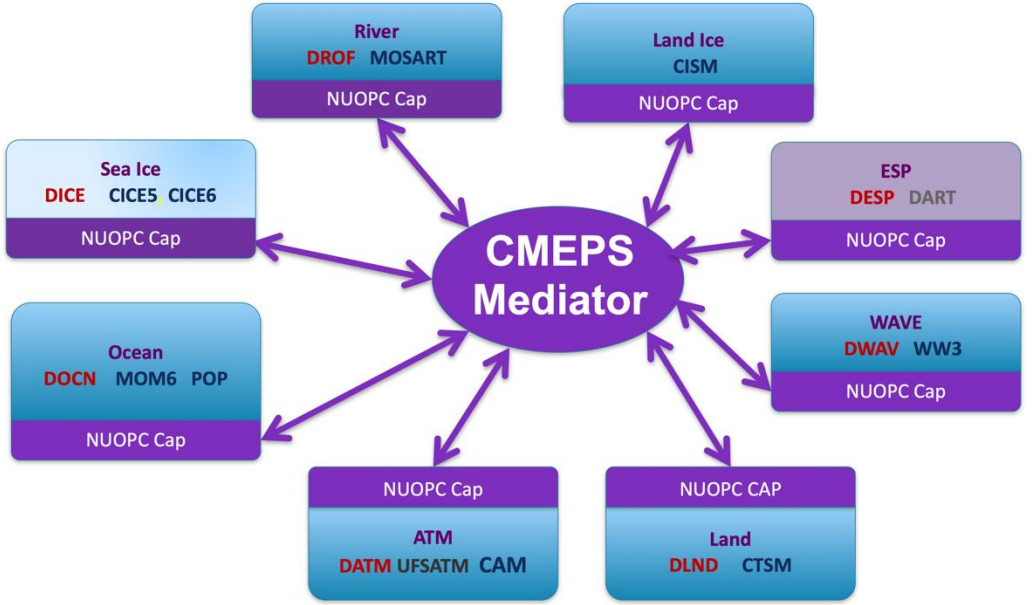

MPAS
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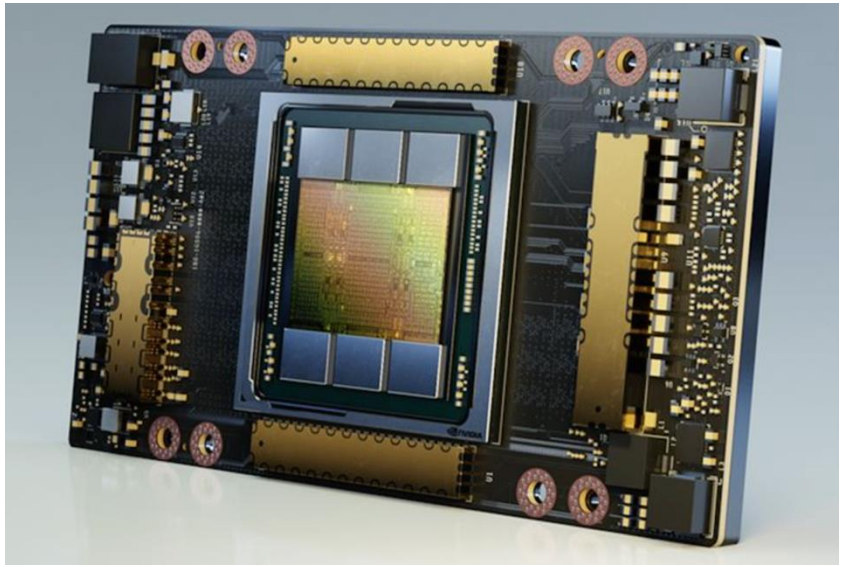
MPAS and GPUs

We released the GPU-enabled MPAS-Atmosphere in October 2020 as a branch from MPAS Version 6.1. We have a Version 7 update but it has not been released.



NVIDIA Ampere A100 GPU

GPU implementation for MPAS-Atmosphere
https://mpas-dev.github.io/atmosphere/OpenACC/index.html

What is in current GPU release:

- GPU-enabled MPAS dynamical core using OpenACC directives.
- Some GPU-enabled physics (e.g. YSU, WSM6, M-O, scale-aware nTiedtke)
- Asynchronous execution capability on heterogenous architectures - currently radiation (lagged) and NOAH land model on CPUs, all else on GPUs
- Configurations tested and validated on IBM POWER9 architectures and on AMD architectures employing NVIDIA V100 and A100 GPUs.

MPAS-Atmosphere Upcoming Releases

MPAS-Atmosphere GPU Implementation

Based on our experience with the existing separate release, we are re-implementing this capability in the main MPAS release.

- Initial (partial) GPU capability has been released and in MPAS v8.2.0 (transport in the dynamics).
- Subsequent MPAS-A releases will incrementally extend GPU capabilities in the dynamical core and physics.
- Demonstrates commitment to MPAS-A as a community model designed for next-generation computing systems
- Builds on lessons learned from past partnerships with IBM, The Weather Company, the University of Wyoming, and NVIDIA.

Above: A Derecho GPU blade with two GPU nodes, each with 1 AMD EPYC Zen3 "Milan" 64-core processor and 4 NVIDIA A100 Ampere GPUs.

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Coming Events

MPAS-WRF workshop: 3-6 June 2025 (in person (Boulder CO), plus virtual option)
https://www.mmm.ucar.edu/events/workshops/wrf-mpas

We've begun work on an MPAS NCAR Technical Note. Draft release before the MPAS-WRF workshop?

We have two NSF NCAR-based tutorials each year, NH spring (virtual) and NH fall (in person):

- April 2025 (this one).
- Fall 2025 (in person, dates TBD)

Feature and bug releases occur whenever components are ready.