Model for Prediction Across Scales

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LA-UR 09-05207

Climate, Ocean and Sea-Ice Modeling Project
http://public.lanl.gov/ringler/ringler.html

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What is MPAS?

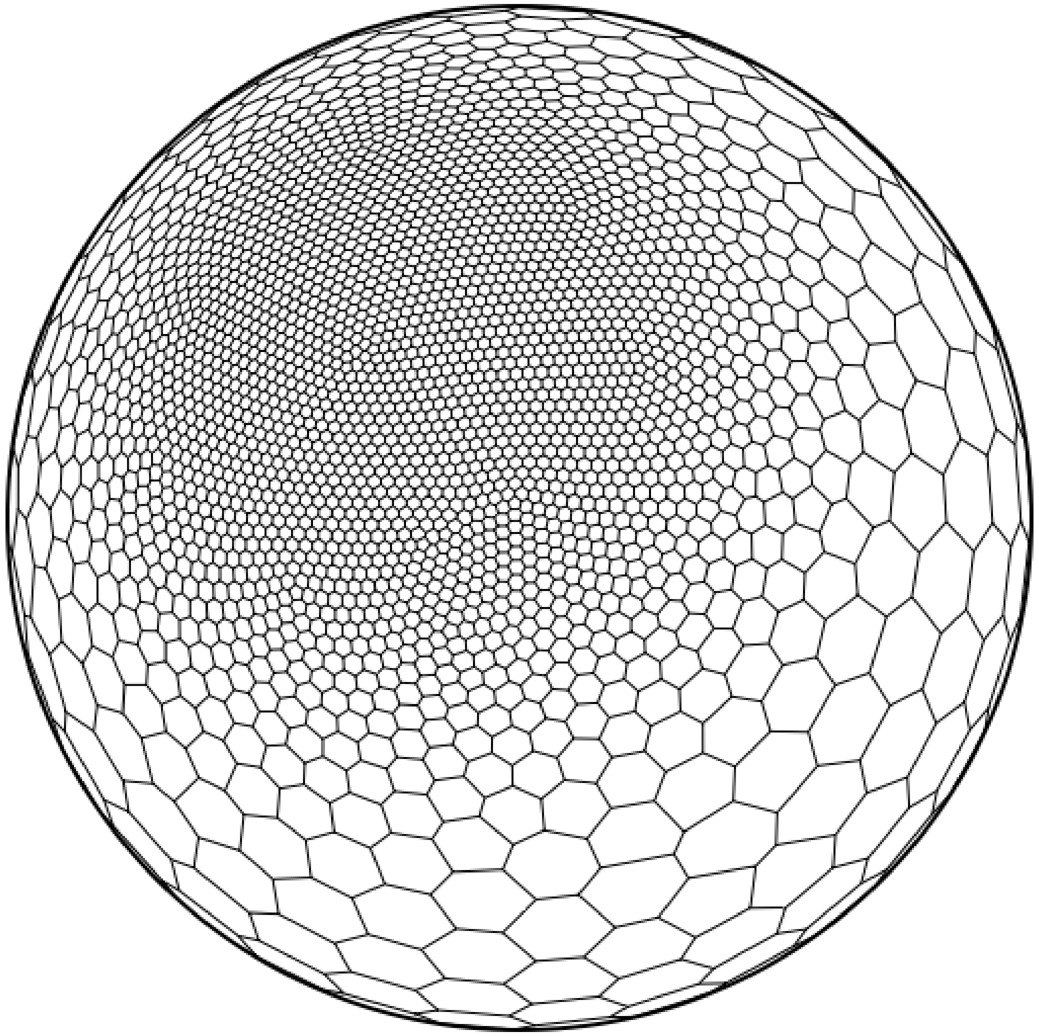
MPAS
Model for Prediction Across Scales

1. MPAS is an unstructured-grid approach to climate system modeling.

2. MPAS supports both quasi-uniform and variable resolution meshing of the sphere using quadrilaterals, triangles or Voronoi tessellations.

3. MPAS is a software framework for the rapid prototyping of single-components of climate system models (atmosphere, ocean, land ice, etc.)

4. MPAS offers the potential to explore regional-scale climate change within the context of global climate system modeling.



MPAS
Model for Prediction Across Scales

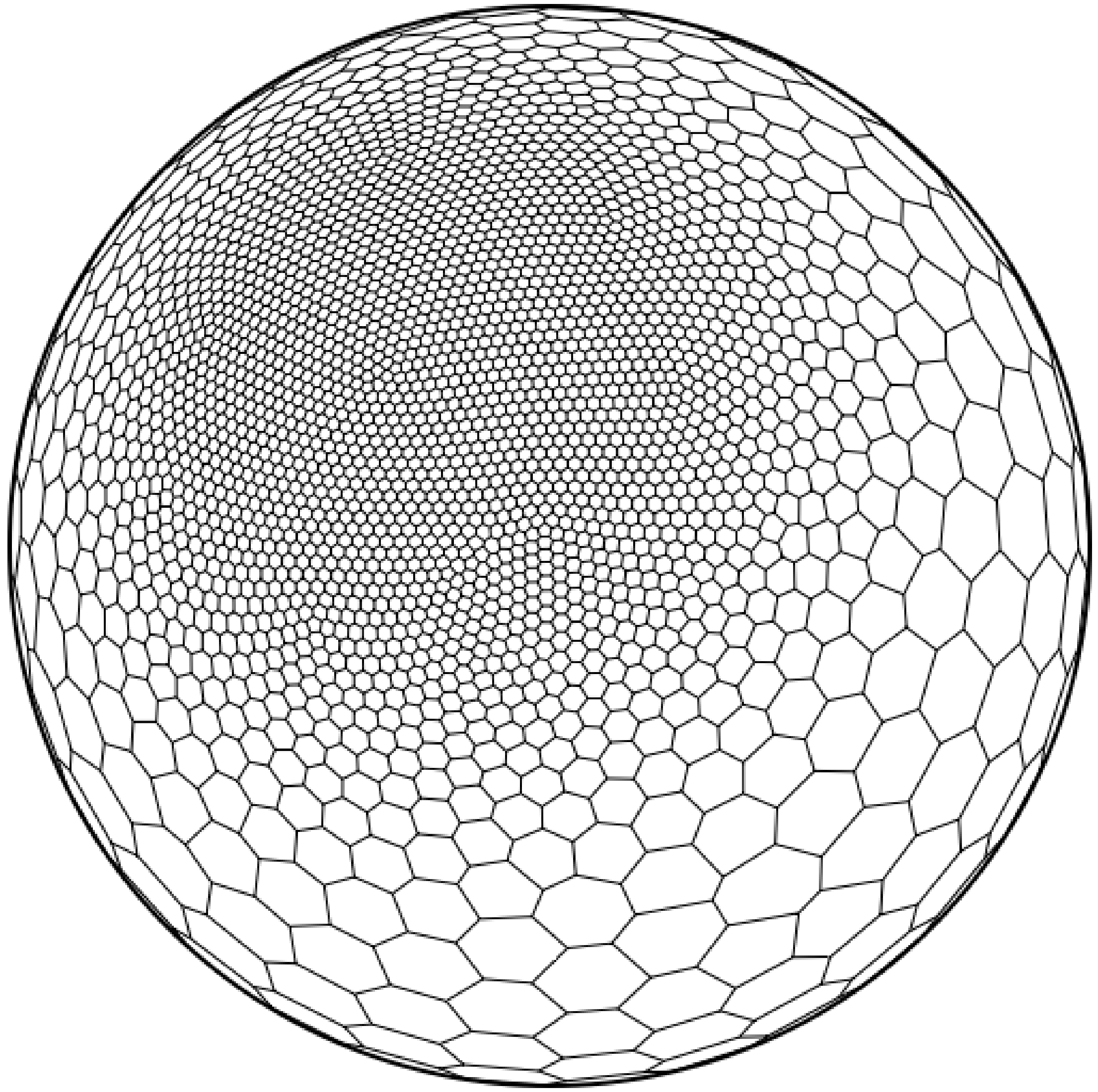
What is MPAS?

MPAS is a joint NCAR (MMM) - LANL (COSIM) model development project with MMM taking the lead on the atmosphere model and COSIM taking the lead on the ocean model.

After testing, models will be distributed through SourceForge at http://mpas.sourceforge.net/ .

Work on an MPAS land ice sheet model will likely begin this summer.

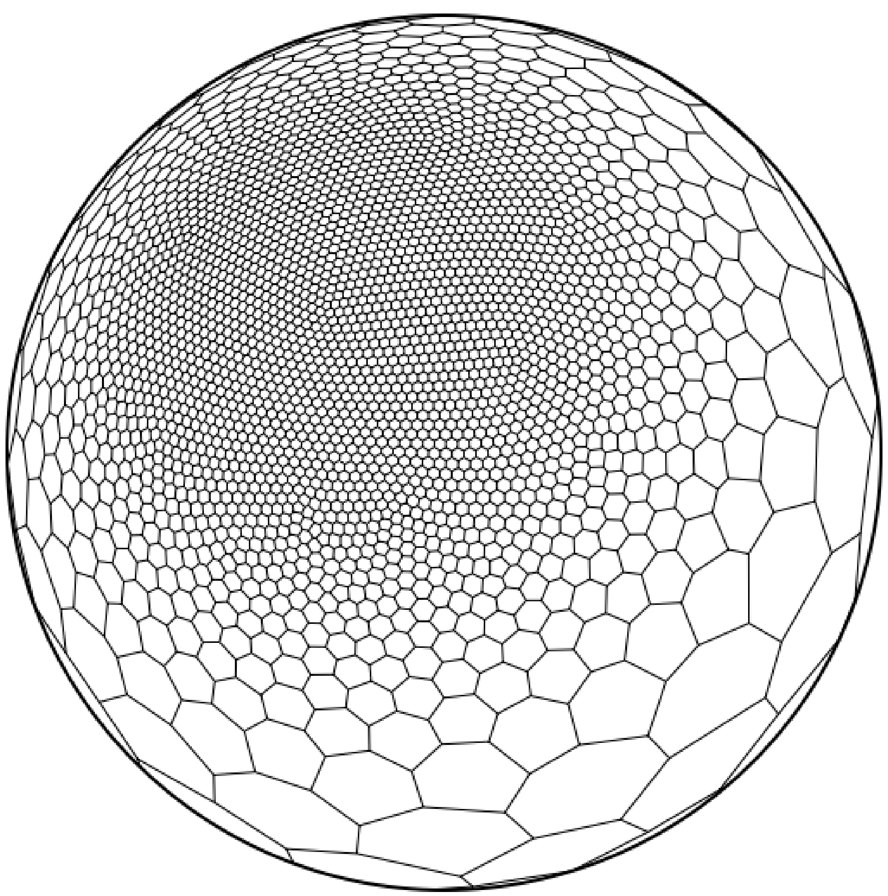
Regular project updates are given to NCAR CCSM working group members to facilitate the inclusion of MPAS-developed models in the CCSM framework.

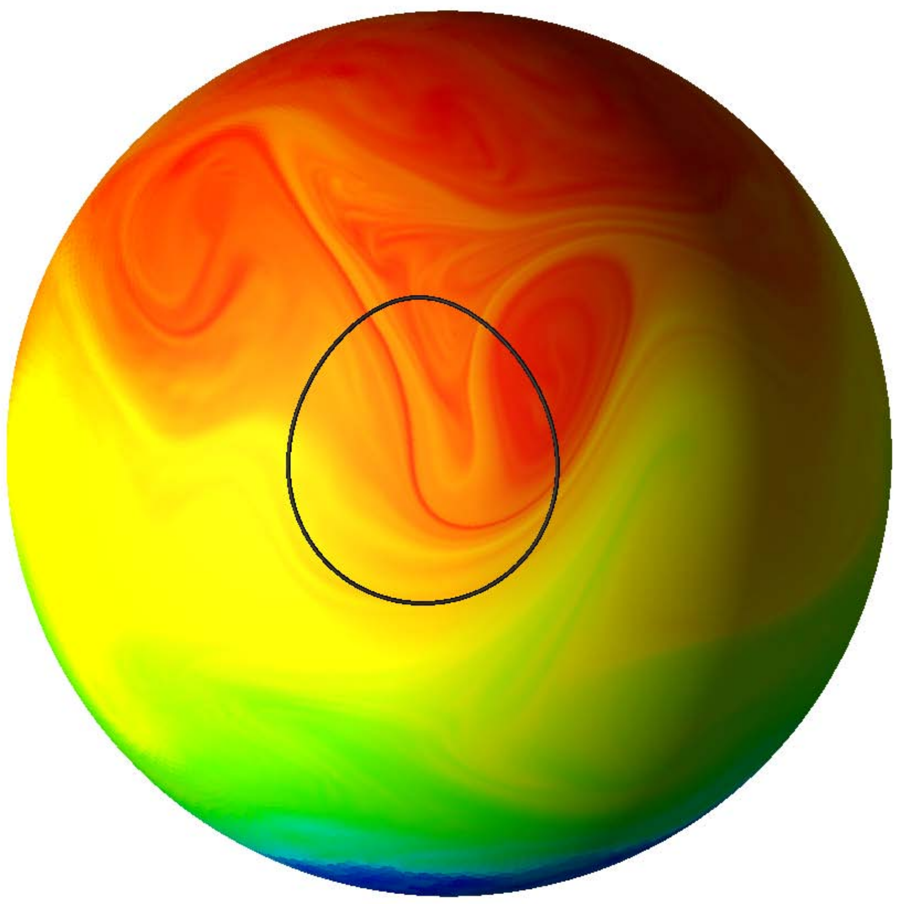


MPAS is built on top of a finite-volume technique.

The finite-volume approach is a generalization of the Arakawa and Lamb (1981) energy and potential enstrophy conserving scheme.

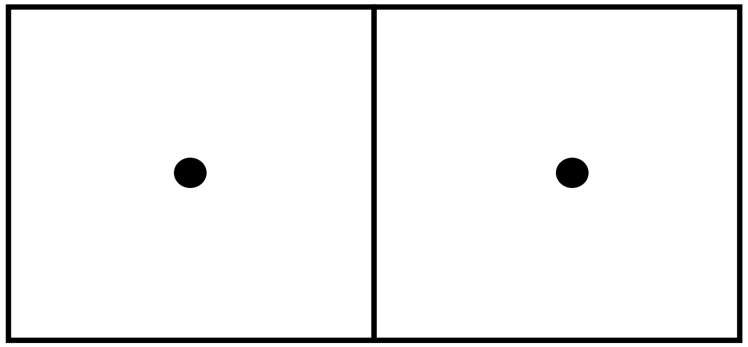
In the shallow-water system, our approach conserves energy and potential vorticity while dissipating potential enstrophy (without dissipating e



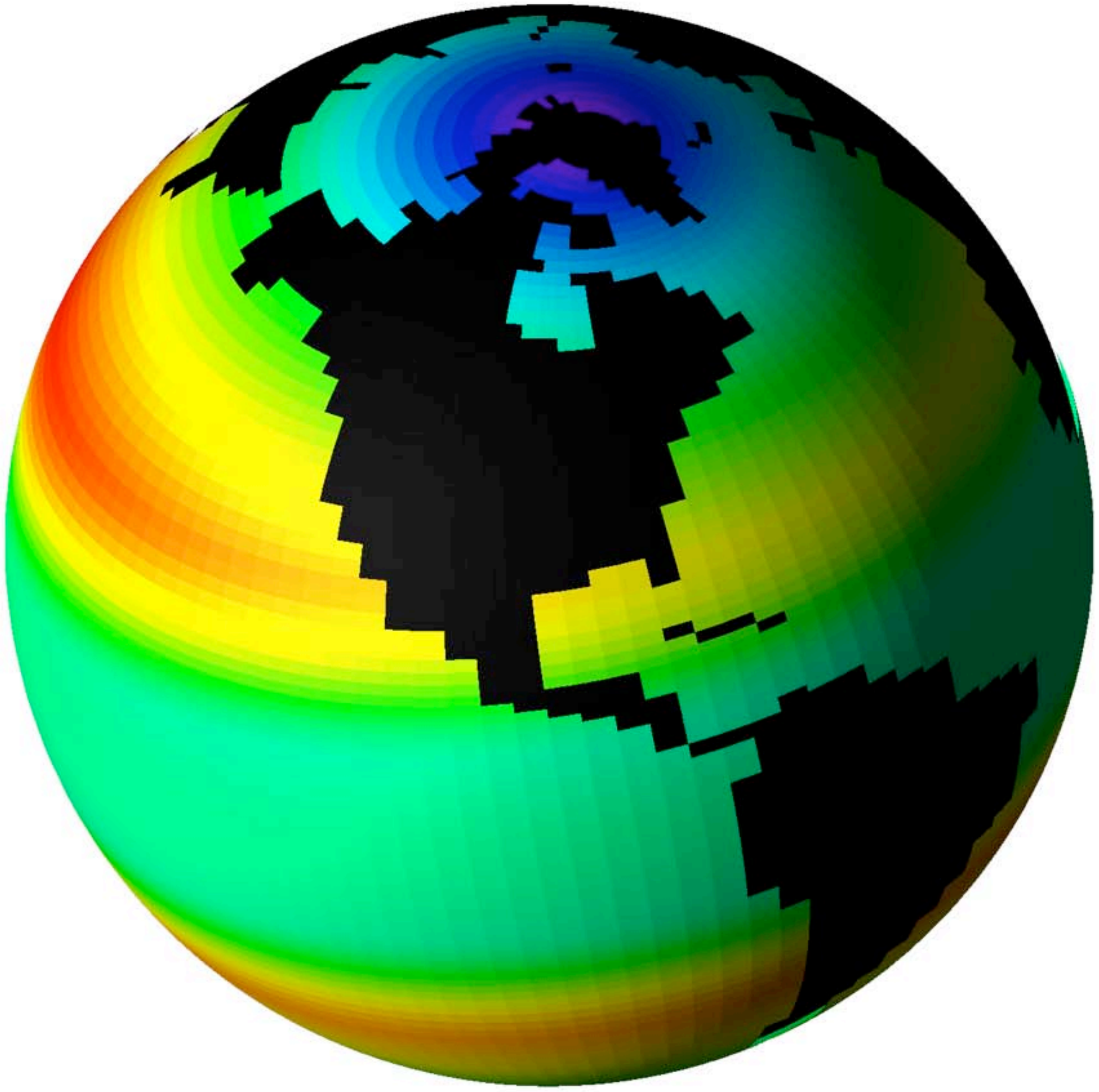


MPAS supports the POP stretched lat-lon grids

The finite-volume technique can be used with any conforming mesh that is locally orthogonal.

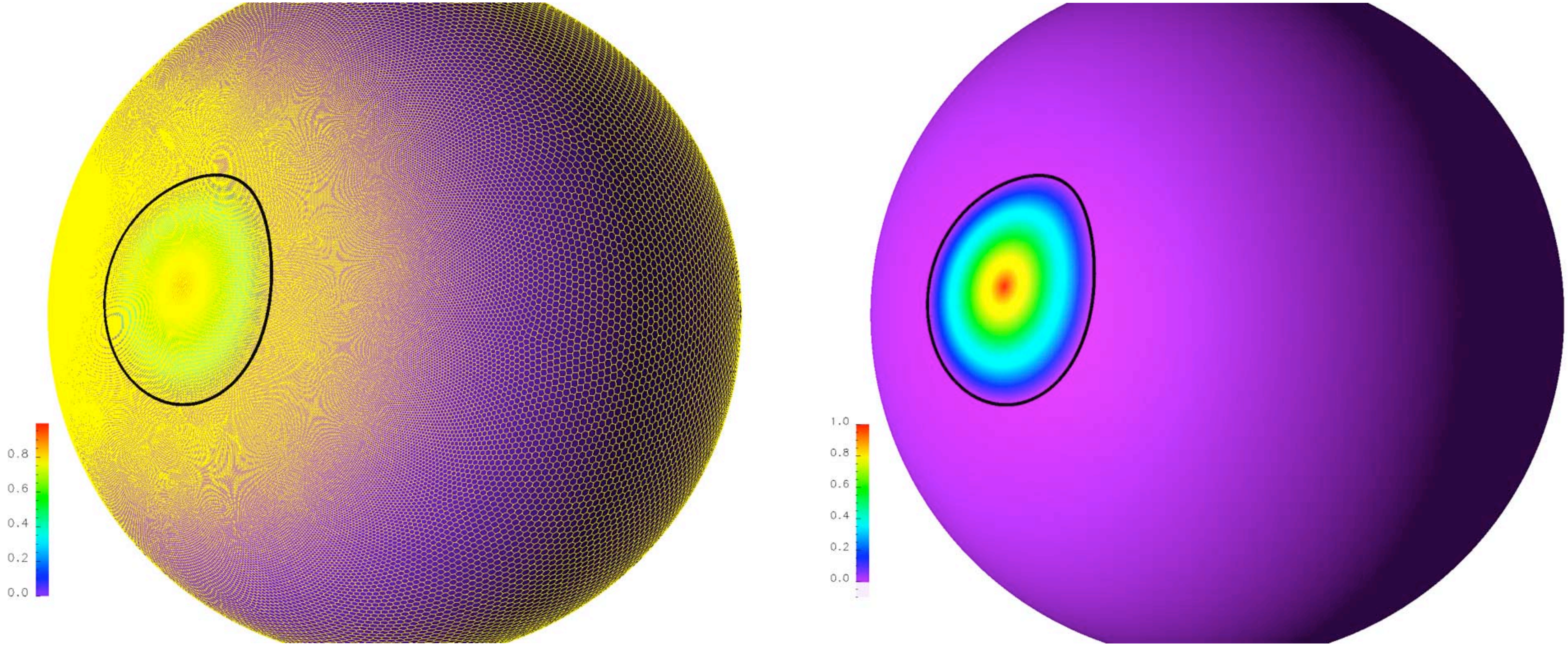


The translation from POP to MPAS maps the structured (i,j) data fields to a one-dimension vector.



This POP-MPAS connection allows to compare and contrast
the POP and MPAS solutions.

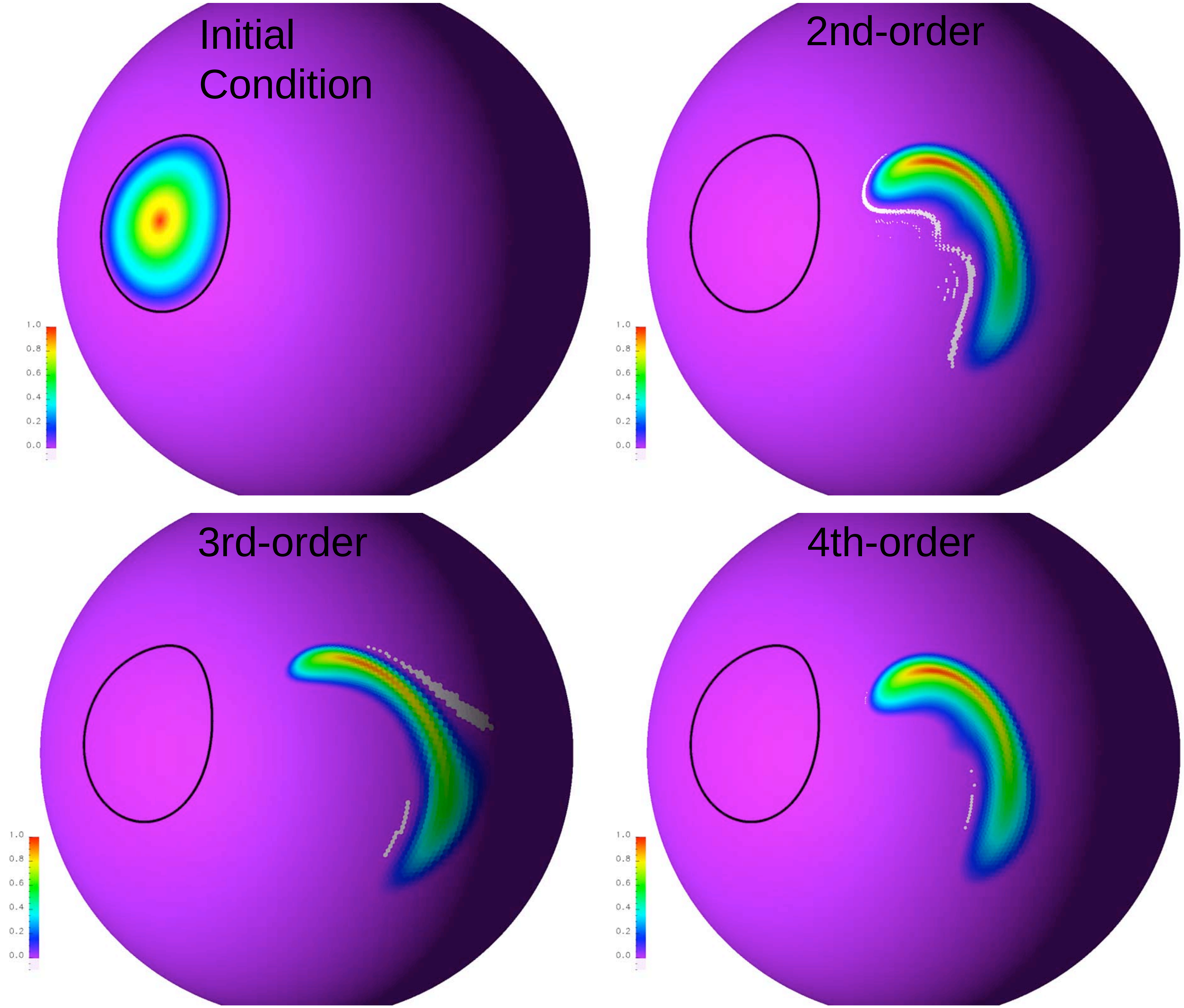
MPAS will have access to several different high-order tracer transport algorithms, each with their appropriate flux-limiter.



Results from one high-order transport scheme.

Snapshot at Day 5.
Limiter turned off.

Conservative Transport Schemes for Spherical Geodesic Grid: High-Order Reconstructions for Forward In-Time Schemes. W. Skamarock and M. Menchaca, 2010, MWR submitted.

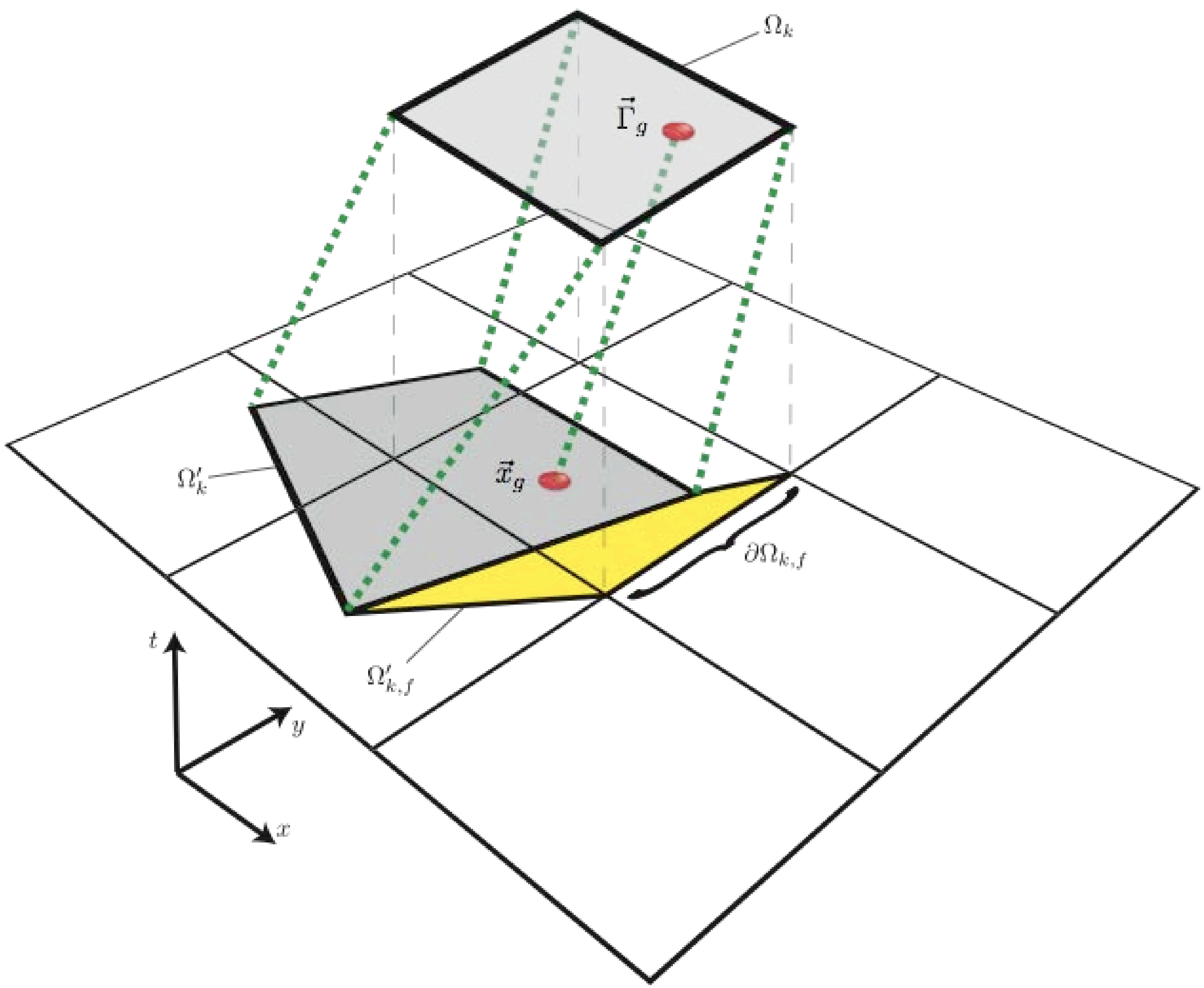


MPAS will have access to a high-order extension of Prather's method-of-moments transport algorithm.

The Characteristic Discontinuous Galerkin (CGD) method takes advantage of the Lagrangian nature of transport while maintaining a static mesh. (Lowrie, 2010)

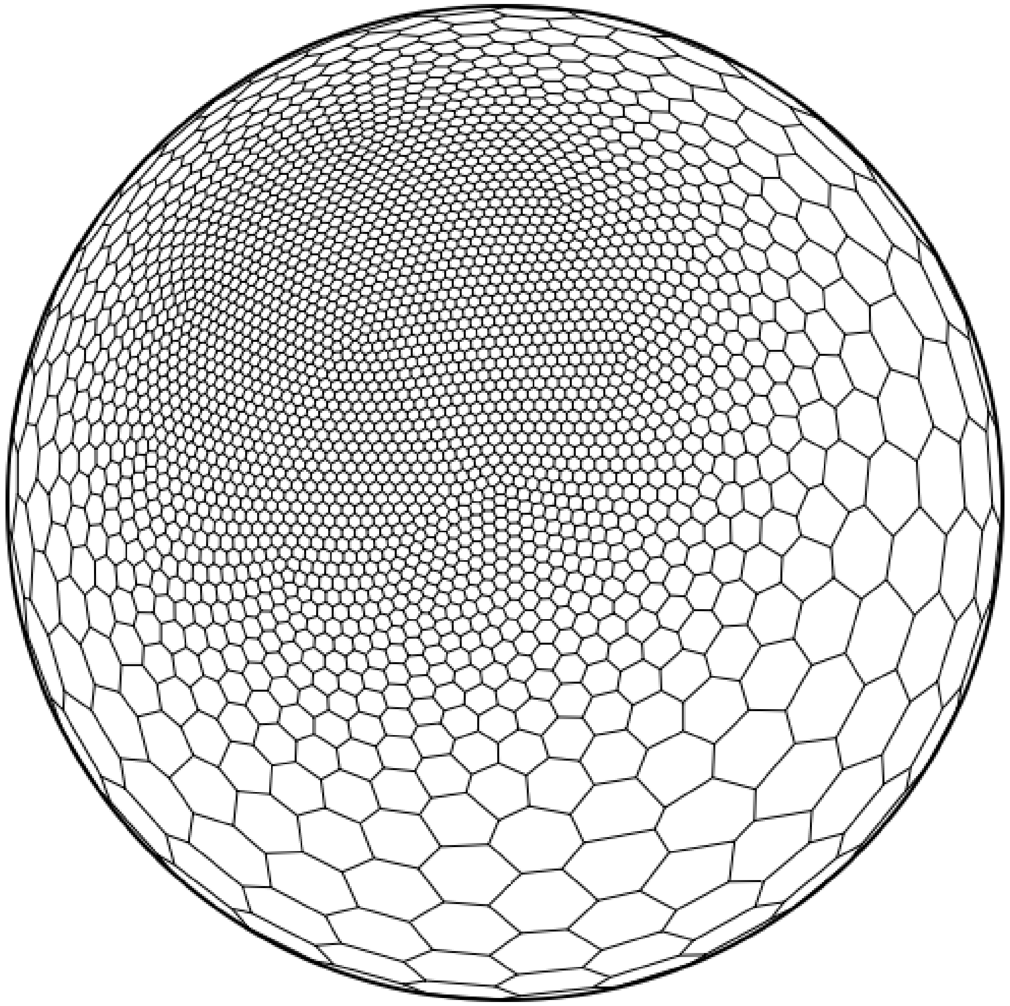
The method has been extended to arbitrary convex polygons and to arbitrary order of accuracy. (Buonoi, Lowrie and Ringler 2010).

The method has also illuminated the connection between CDG and Prather's Method-of-Moments.

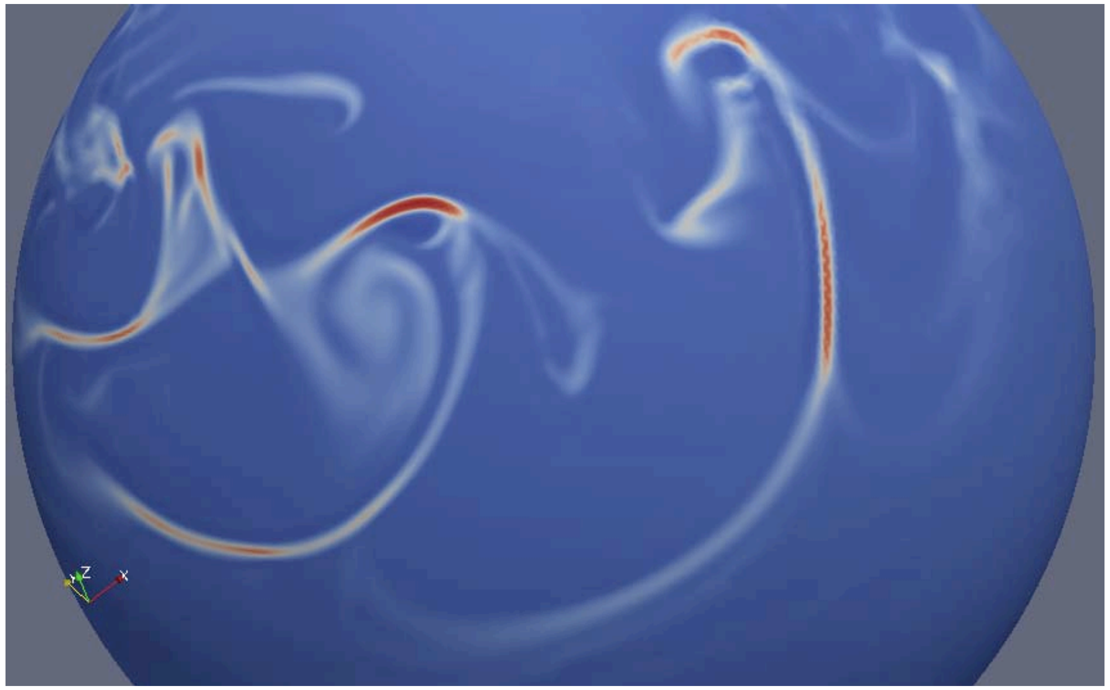


MPAS Project Status: Atmosphere

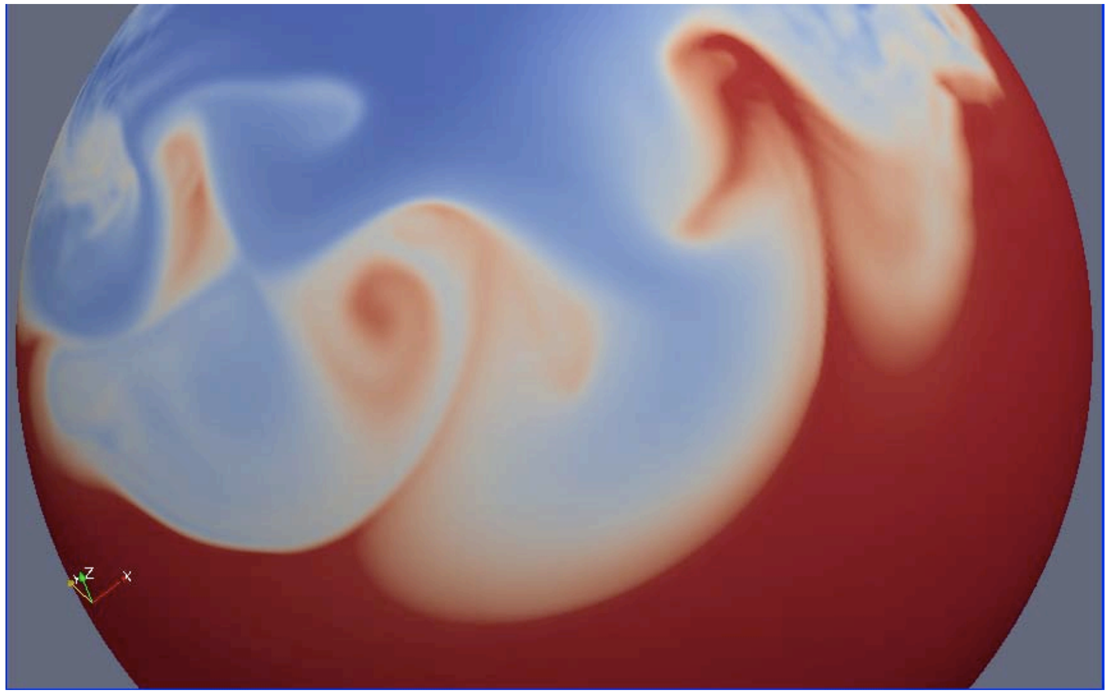
Baroclinic Instability (i.e. weather systems) Test Case using a multi-resolution mesh. Relative vorticity and potential temperature at day 10.



Relative Vorticity



Potential Temperature



MPAS Project Status: Ocean Summary

What we committed to complete by this meeting:

1. Running MPAS with POP stretched lat-lon meshes with real-world topography with a z-level vertical coordinate.

2. We have started the (2nd) evaluation of the barotropic-baroclinic splitting.

3. Code runs on 1 to 4096+ processors on a variety of platforms (MacBook Air, Lobo, Coyote, Ranger, Jaguar)

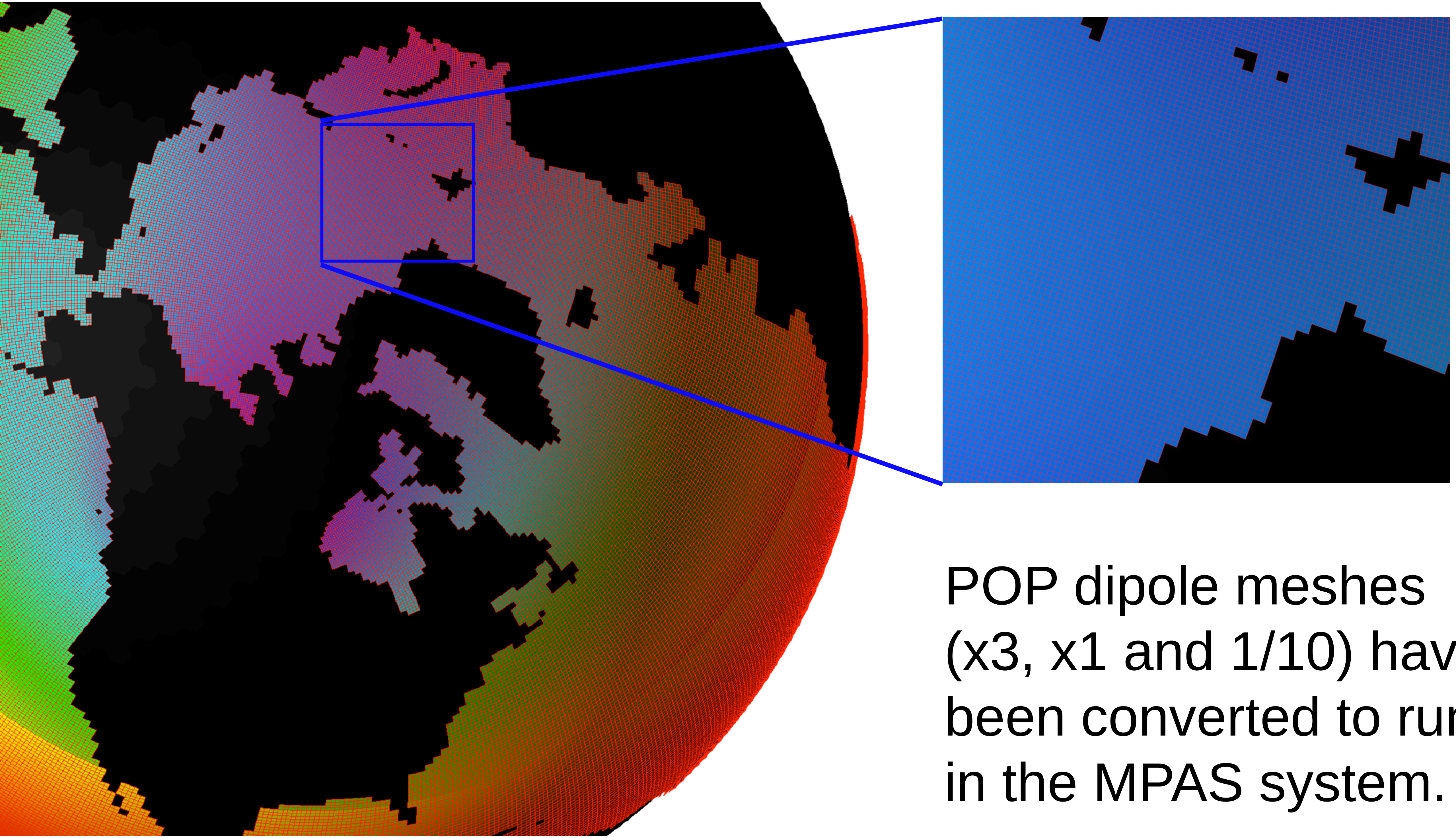
What we have completed beyond this commitment:

1. Ocean model runs in pure isopycnal mode.

2. We have tested and are implementing a high-order advection scheme (Skamarock)

3. Running ocean model with quasi-uniform and variable resolution Voronoi tessellations

MPAS Project Status: Ocean
Quads: POP-to-MPAS conversion



POP dipole meshes (x3, x1 and 1/10) have been converted to run in the MPAS system.

MPAS Project Status: Ocean

Quads: POP to MPAS comparison

x3 comparison

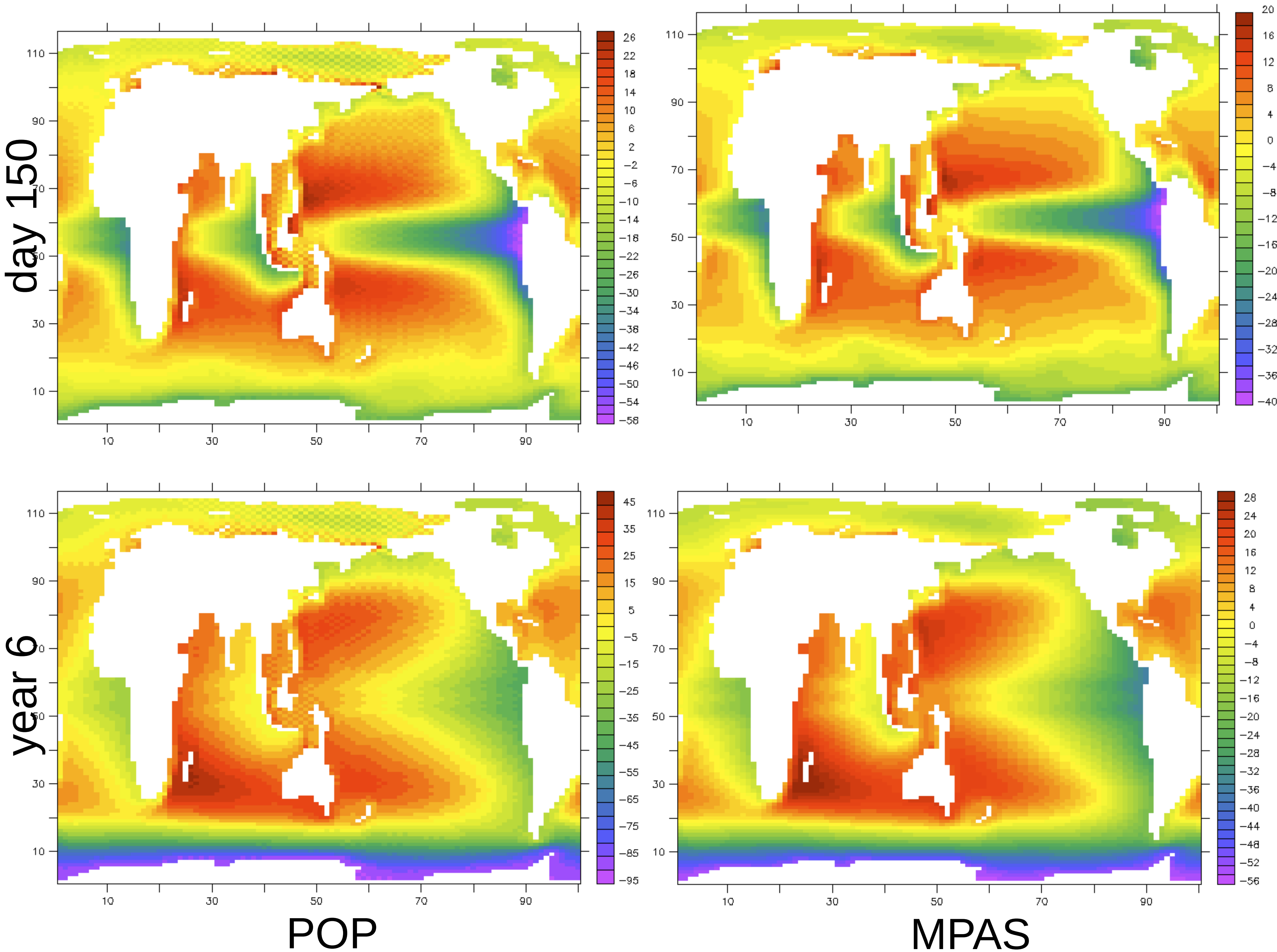
Left: POP
Right :MPAS

Top: Day 150
Bottom: Year 6

Subtropical gyres are weaker in MPAS by 30%.

We are checking parameter settings in each model to determine the source of this difference.

MPAS will not have checkerboarding.

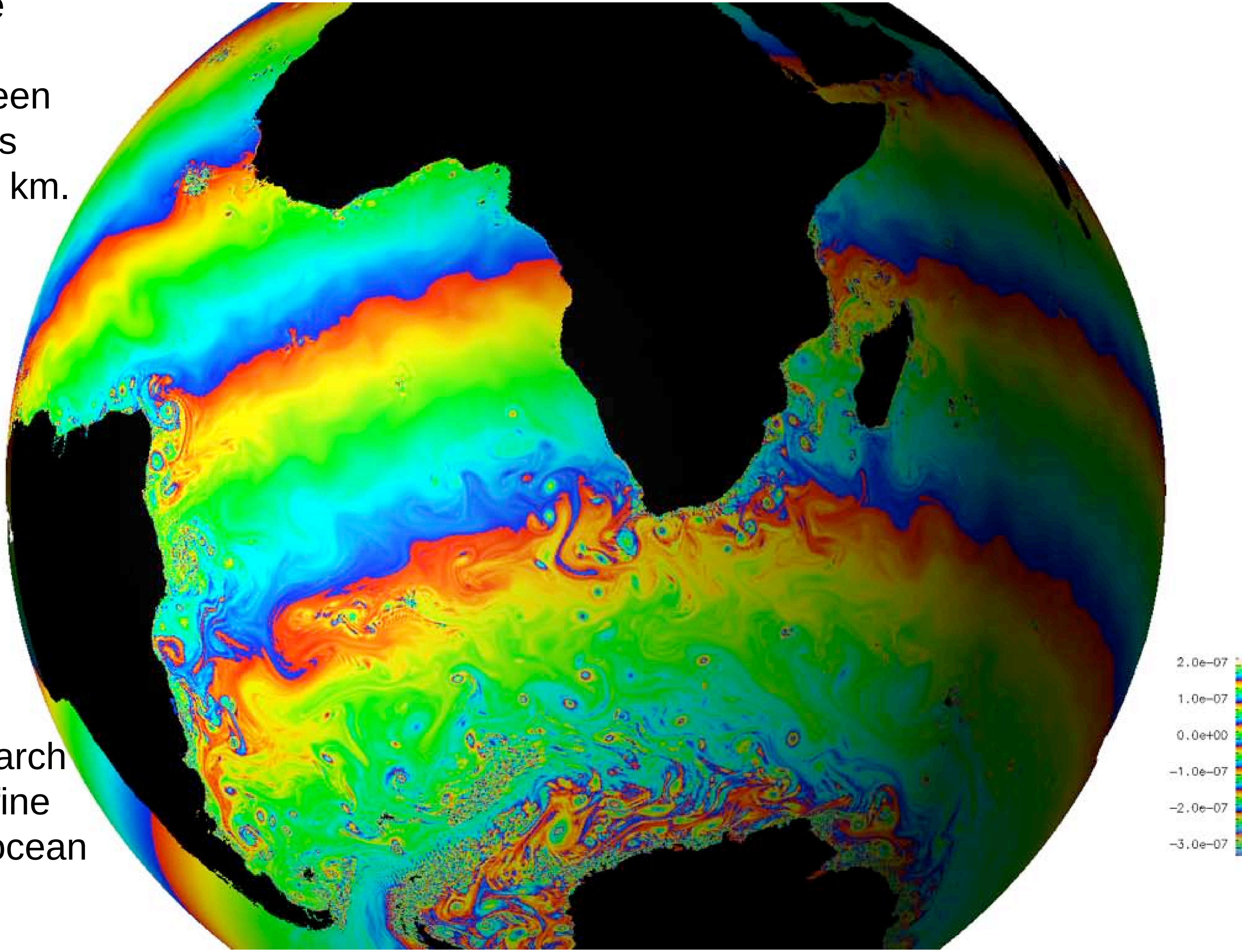


MPAS Project Status: Ocean Voronoi Tessellations

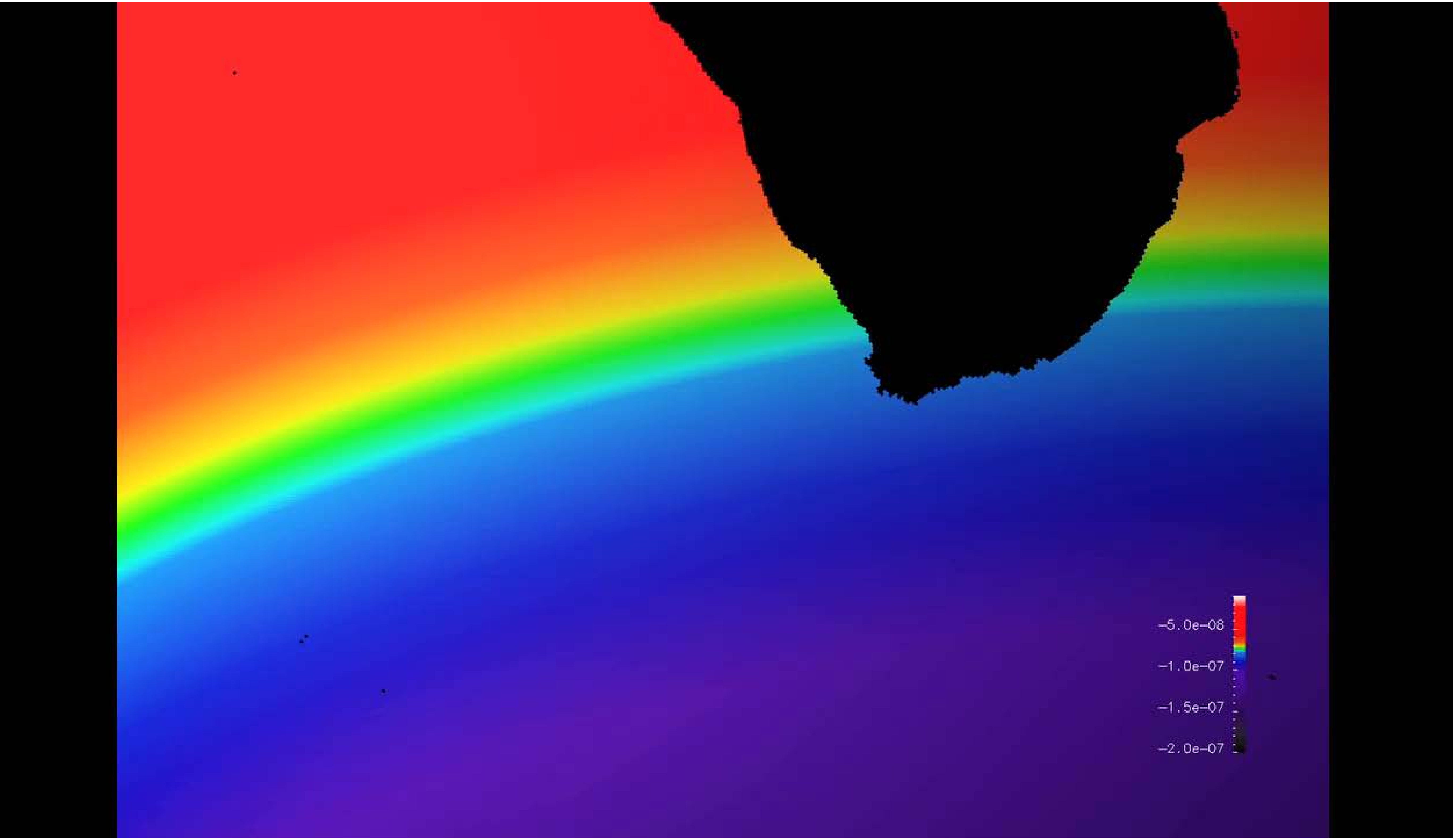
Uniform and variable resolution Voronoi tessellations have been created at resolutions between 120 and 15 km.

Right: Global 15km mesh, PV shown, single-layer, flat bottom.

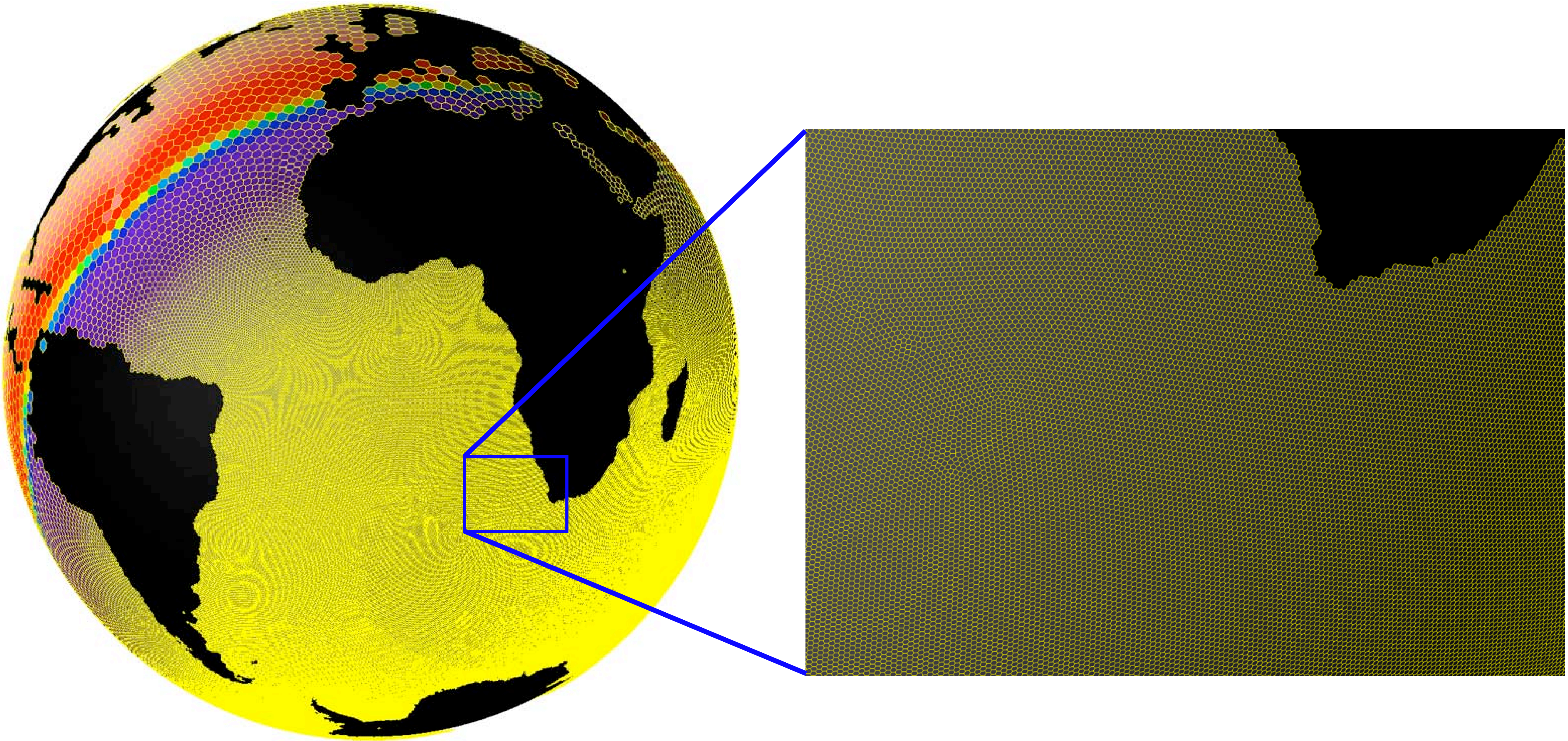
The meshes use nearest-neighbor search from ETOPO2 to define land/sea mask and ocean depth.



MPAS Project Status: Ocean
Voronoi Tessellations



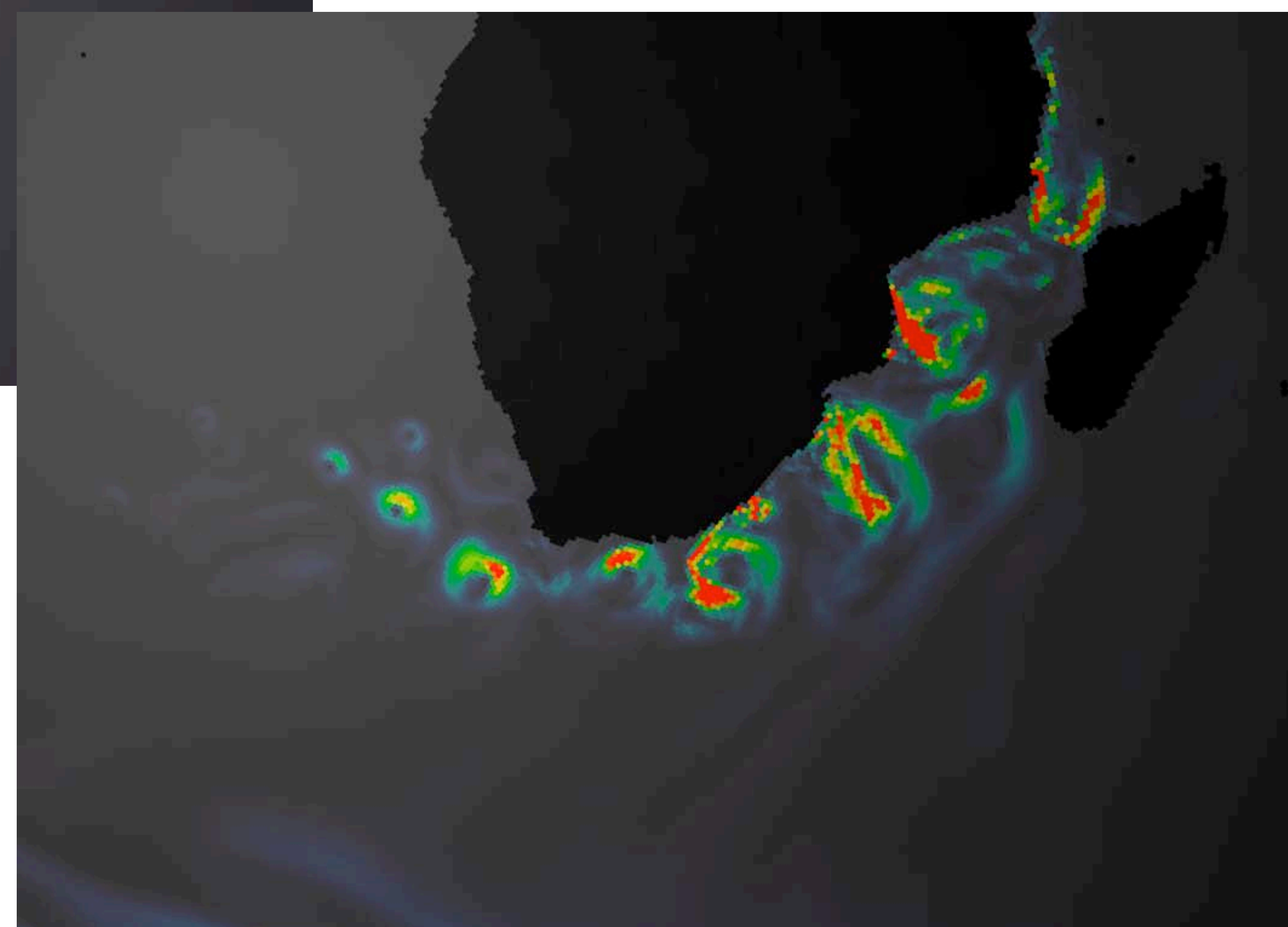
MPAS Project Status: Ocean
Variable Resolution Voronoi Tessellations



Mesh grid spacing varies by a factor of 8, ranging from 25 km to 200 km. This mesh has about 1/10 the number of nodes as the glob uniform 15 km mesh.

MPAS Project Status: Ocean

uniform mesh
1,800,000 nodes



variable resolution mesh
120,000 nodes

MPAS Ocean: Challenges Looking Forward

1. Porting POP physics to MPAS (relative risk: low)

2. Obtaining quality simulations (relative risk: low)

3. Implementing barotropic-baroclinic splitting (relative risk: low)

4. Implementing high-order vertical remapping (relative risk: medium)

5. Designing computationally efficient kernels (relative risk: high)

MPAS and Exascale

The implementation of MPAS on the next generation of heterogenous computing platforms will be a significant challenge.

LANL has developed a capacity to port “domain-specific” applications to novel architectures (i.e. RoadRunner) that we would like to leverage into this effort.

MPAS will be a major theme in the LANL (et al.) response to the DOE solicitation for co-design computing centers.

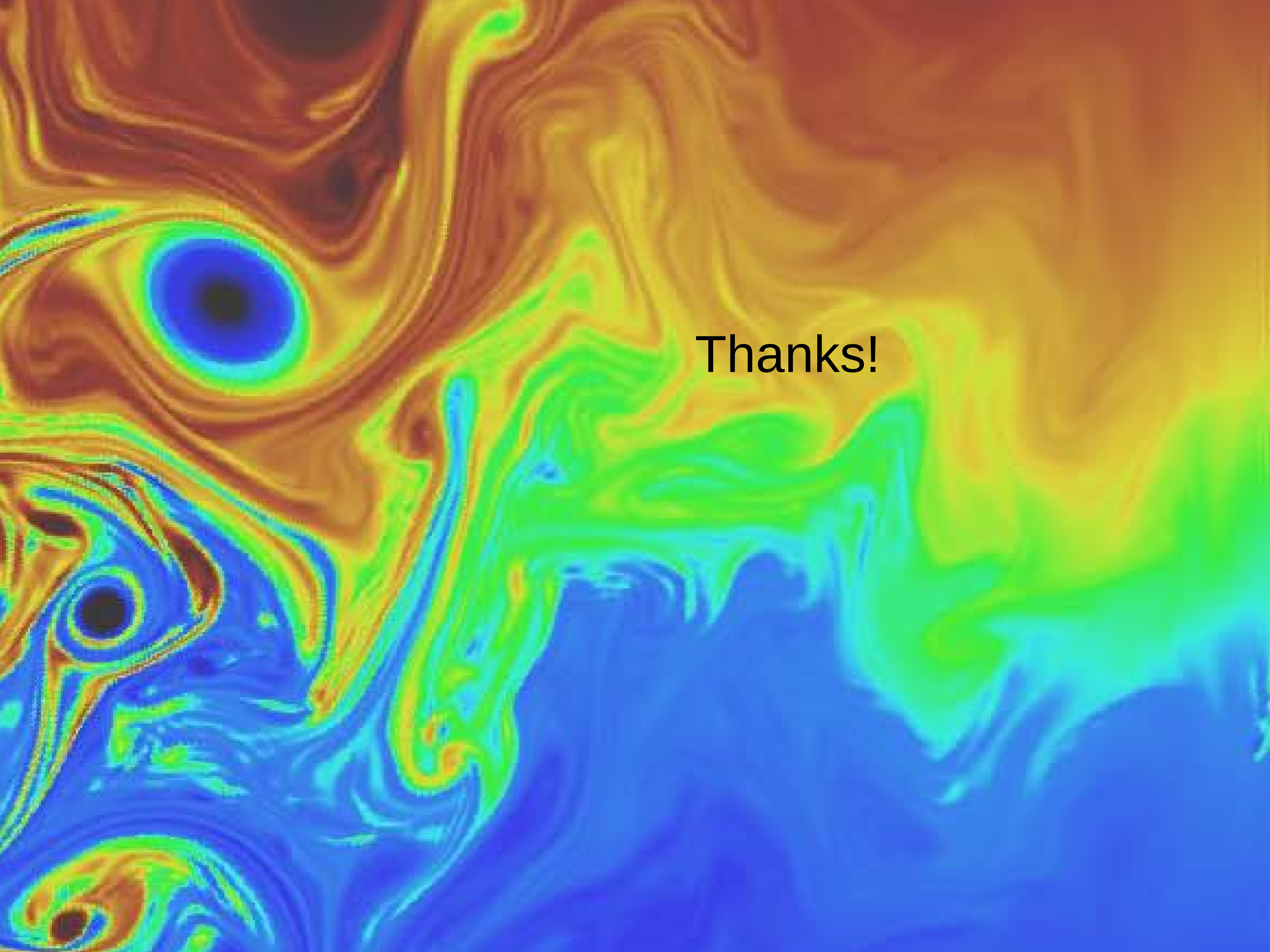
Regardless of the outcome of this DOE solicitation, COSIM is committed to designing, porting and evaluating MPAS solver kernels on heterogenous computing platforms.

(yet to be vetted) Timeline for MPAS Ocean

0 to 3 months:
1. take to a deep breath and scope resources
2. finish POP-MPAS comparison at low-resolution
3. fix a few bothersome bugs (restarts, multiple connected domains)
4. test high-order advection in limited-area (ocean) domains
5. begin implementation of barotropic-baroclinic splitting in MPAS

3 to 12 months:
1. extend del2 to del4 with variable resolution coefficients
2. evaluate global and local eddy resolving simulations (write papers)
3. implement GM and LANS-alpha closure models
4. continue to explore fully-implicit time stepping methods
5. consider the implementation of immersed boundary methods
6. set requirements and design document for coupling into CCSM
7. implement White and Adcroft method for vertical remapping.

12 to 24 months:
1. conduct fully coupled simulations
2. evaluate the quality of coupled simulations
3. consider the adoption of MPAS-O as the default CCSM ocean model.


Thanks!

References

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