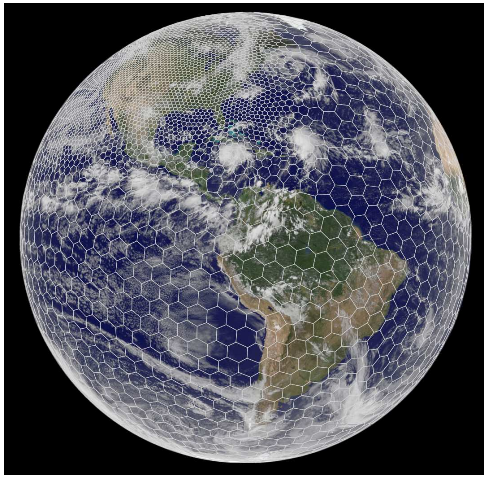
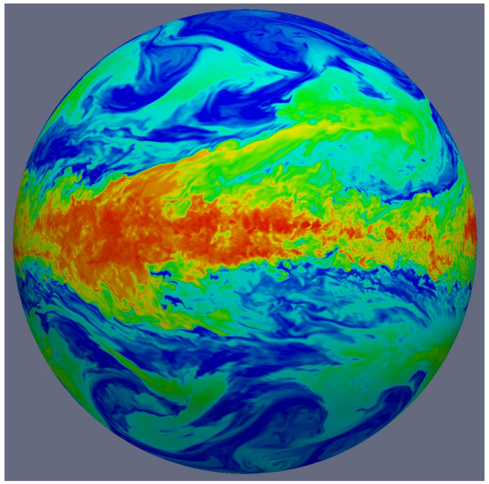
A Nonhydrostatic Atmospheric Model for Prediction Across Scales (MPAS): *Tests on Variable-Resolution Meshes*

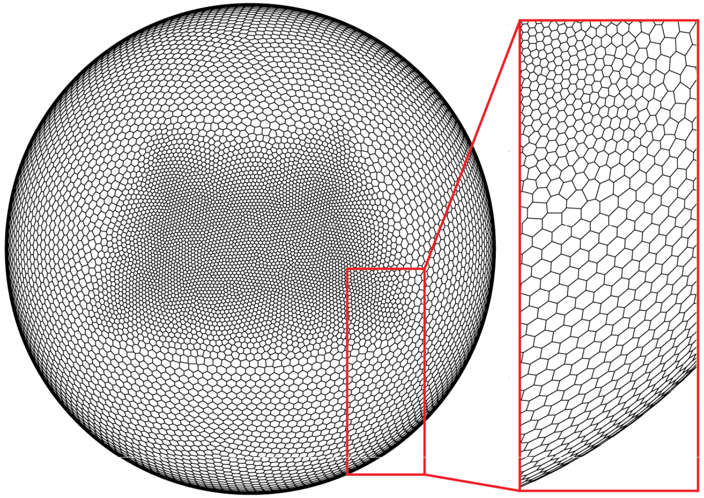




Based on unstructured centroidal Voronoi (hexagonal) meshes using C-grid staggering and selective grid refinement.

Bill Skamarock, Joe Klemp, Michael Duda,
Sang-Hun Park and Laura Fowler NCAR
Todd Ringler Los Alamos National Lab (LANL)
John Thuburn Exeter University
Max Gunzburger Florida State University
Lili Ju University of South Carolina

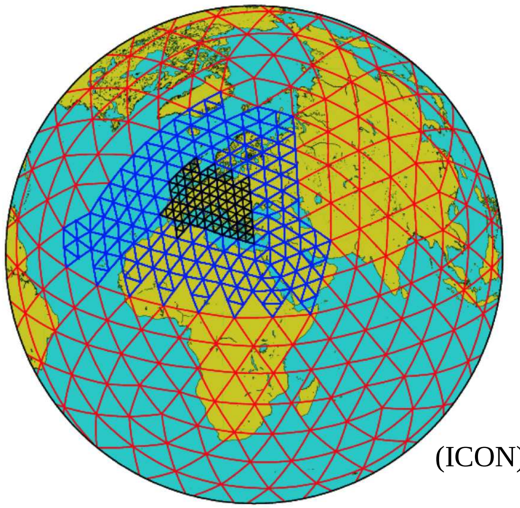
Approaches toVariable Resolution Global Modeling



MPAS (centroidal Voronoi mesh)

FIG. 6. The 353- × 415-point grid used for the VORTEX case with a 240- × 323-point uniform resolution (0.04°) window. For clarity every third point in each direction is plotted.

(GEM, Yeh et al MWR 2002)



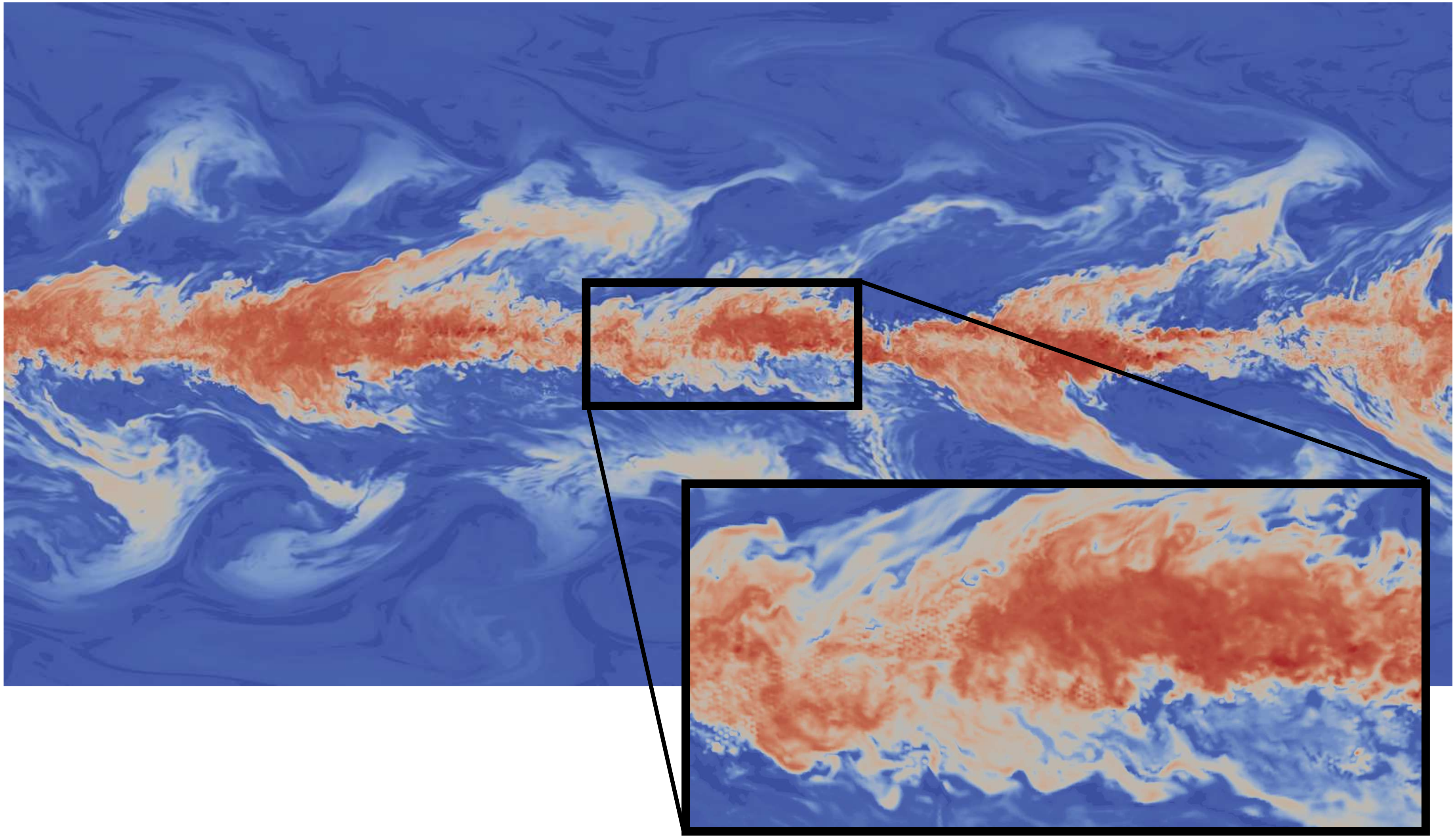
(ICON)

Variable-resolution centroidal Voronoi meshes:

- *Allow for a smooth transition in resolution.*
- *Are conforming.*
- *Mesh cells are nearly isotropic.*
- *Are flexible – they do not rely on a functional transformation of a uniform, regular mesh.*

APE, 30 km: Snapshot of water vapor @ 450 hPa.
(Todd Ringler, Art Mirin)

MPAS hydrostatic solver
Climate model physics (CAM3.5)
Ocean everywhere, specified SST,
Perpetual equinox (March 21)

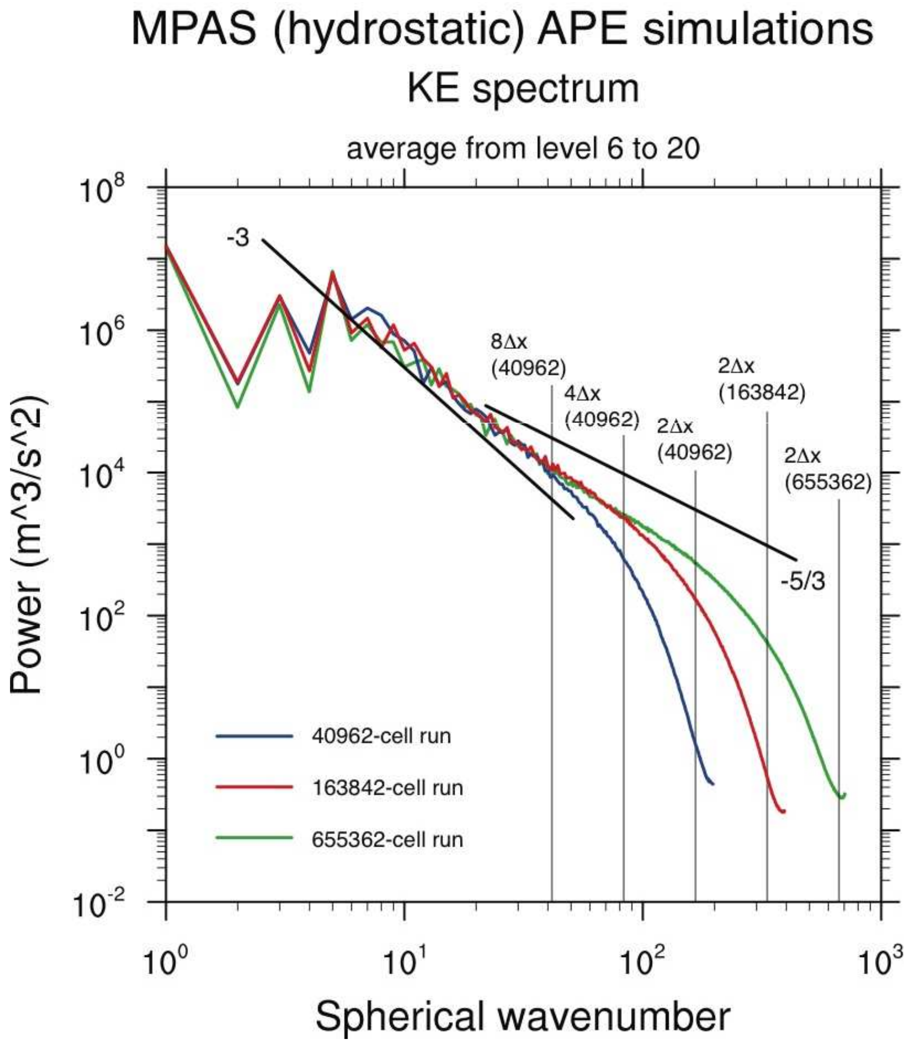


MPAS Aqua-planet (APE) Simulations

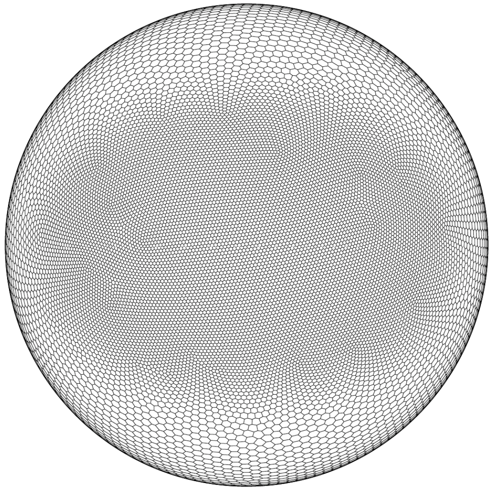
MPAS hydrostatic solver
Climate model physics (CAM3.5)
Ocean everywhere, specified SST,
Perpetual equinox (March 21)

Mesh (cell-center) spacing
~ 120 km (40962 cell)
~ 60 km (163842 cell)
~ 30 km (644362 cell)

<u>Results</u>
Mesoscale transition is captured on finer meshes.
Model filtering noticeable at around 8 Δx



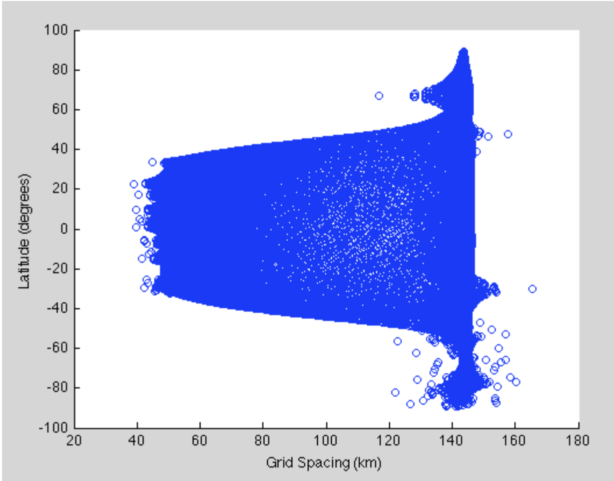
Variable-Resolution Mesh Aquaplanet Simulations



Hydrostatic version of the MPAS core using the CESM physics; 4x refinement
(Todd Ringler, LANL; Art Mirin, LLNL)

Coarse version of the mesh
Actual mesh cell spacing: 140 - 40 km

Nominal grid resolution (measured by average distance to neighbors) as a function of latitude.



Variable-Resolution Mesh Aquaplanet Simulations

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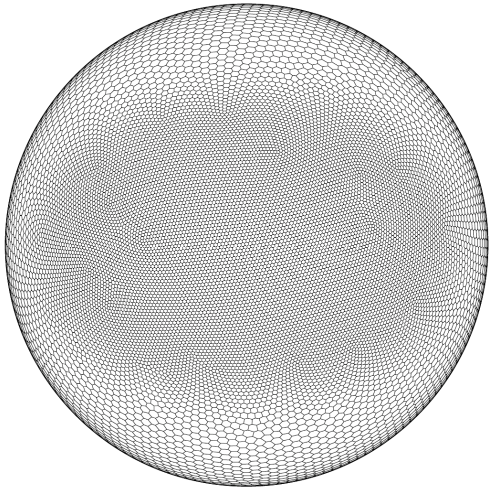
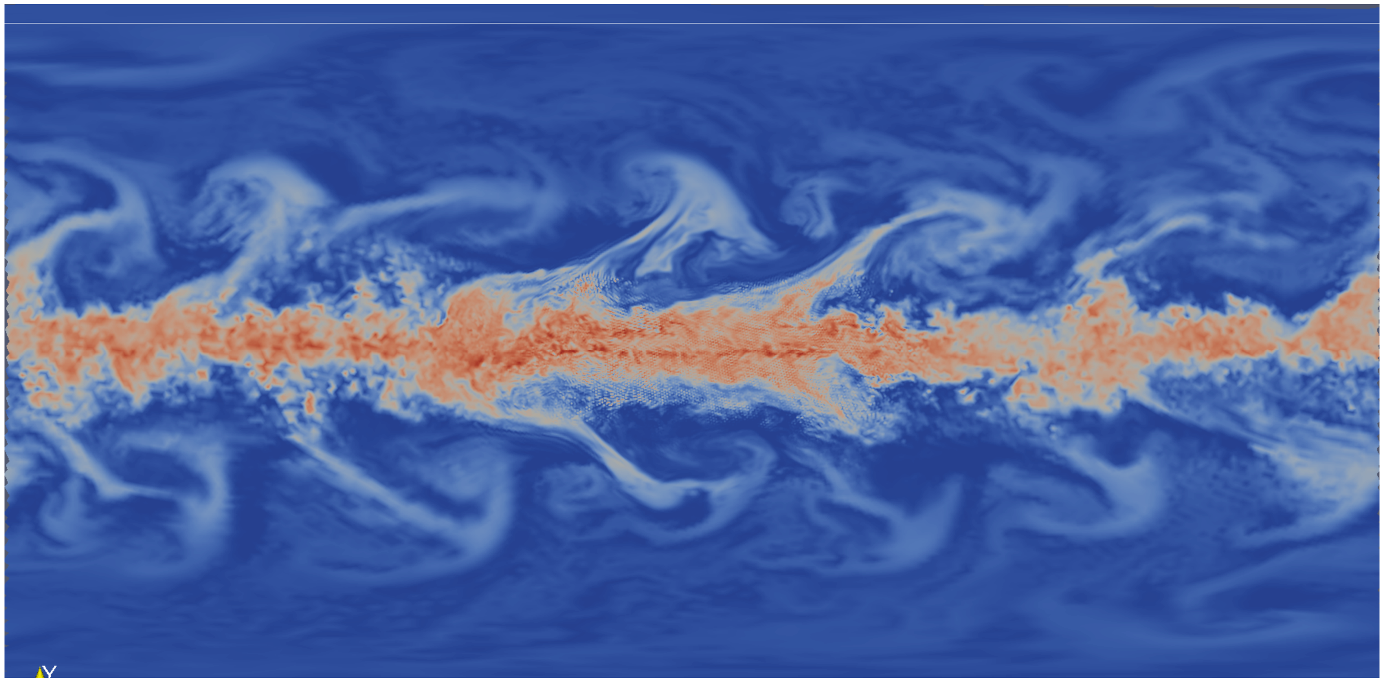
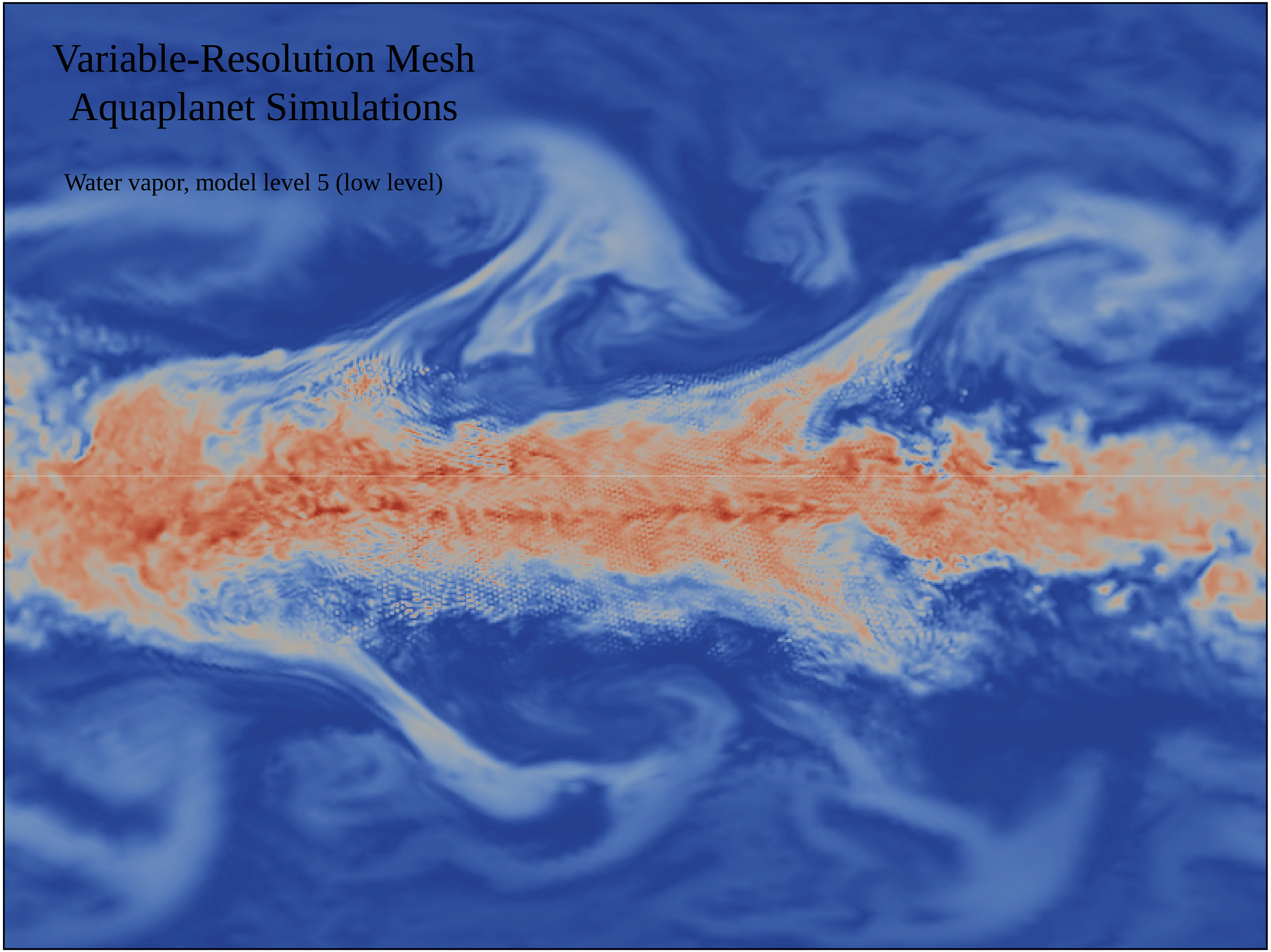


Coarse version of the mesh
Actual mesh cell spacing: 140 - 40 km

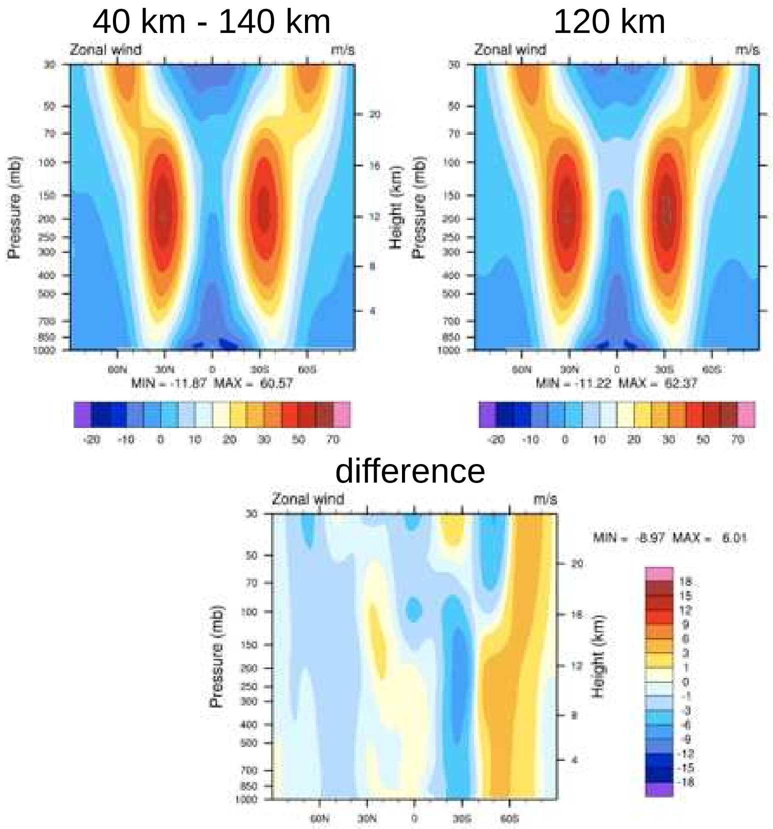
Water vapor, model level 5 (low level)



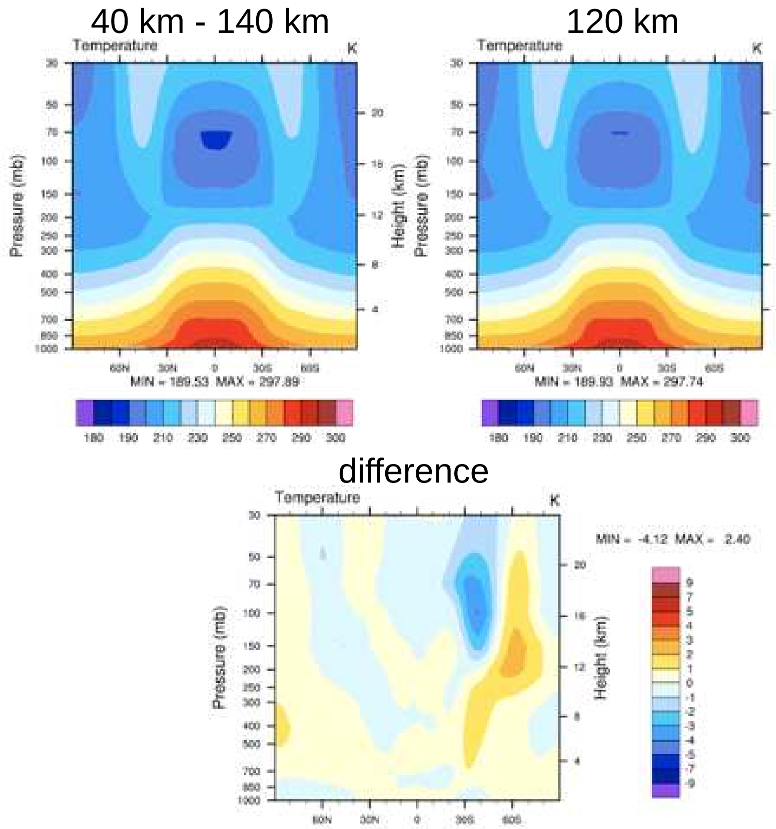

Variable-Resolution Mesh
Aquaplanet Simulations
Water vapor, model level 5 (low level)

Comparison of the multi-resolution 40 km - 140 km simulation with a global quasi-uniform 120 km simulation.

Zonally-averaged wind



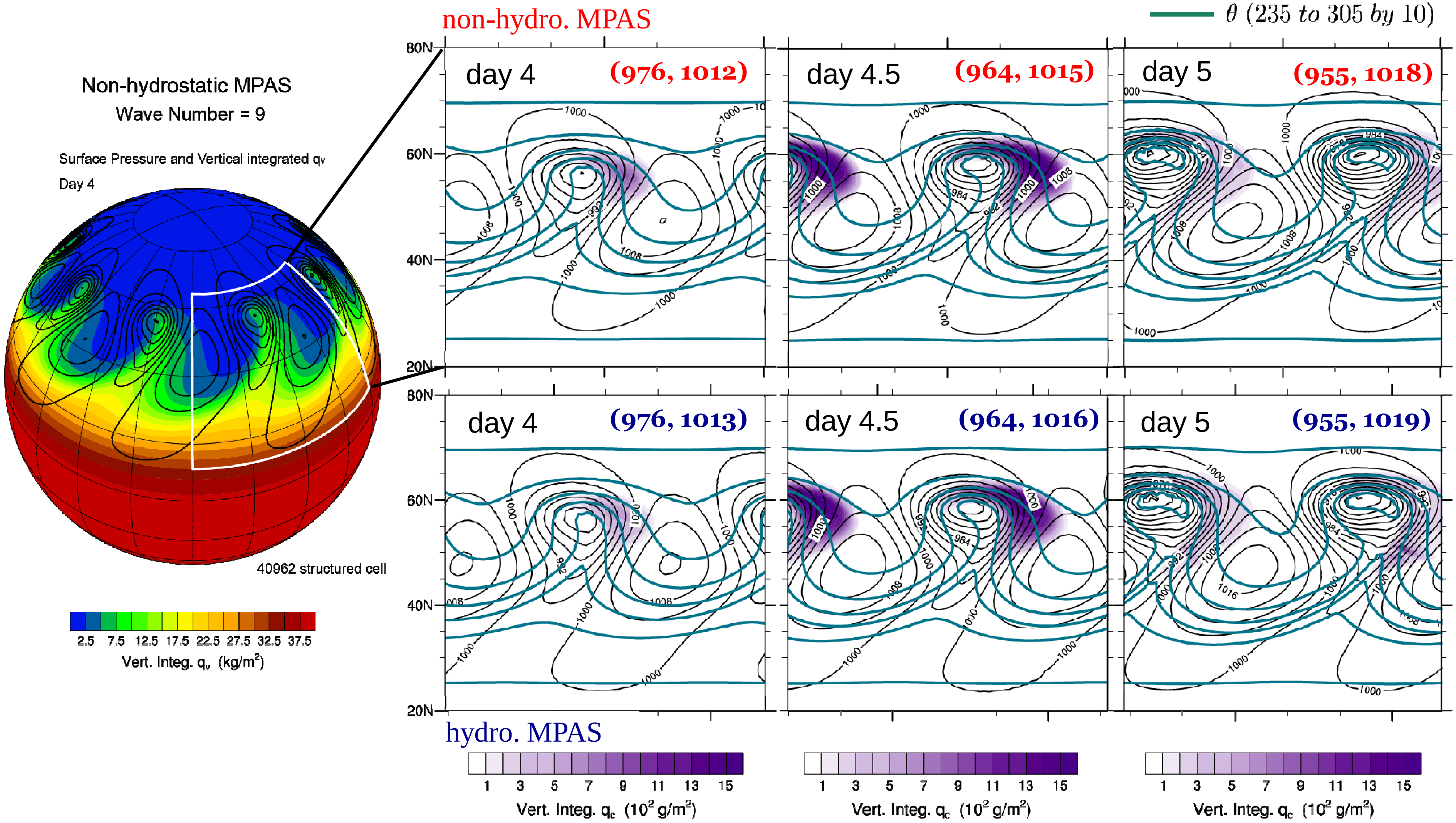
Zonally-averaged temperature



The zonal means are essentially the same.

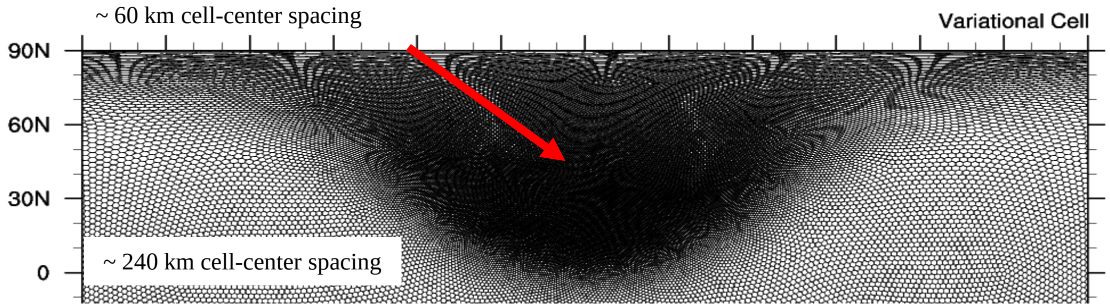
Jablonowski & Williamson Baroclinic Wave Simulation

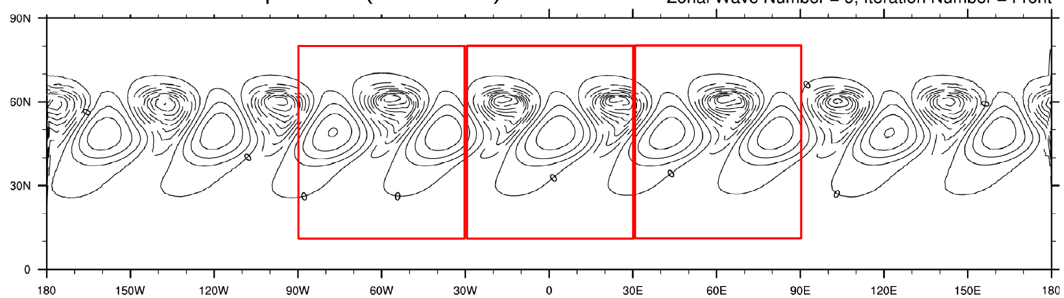
Hydrostatic and Nonhydrostatic Moist Normal Mode Solutions

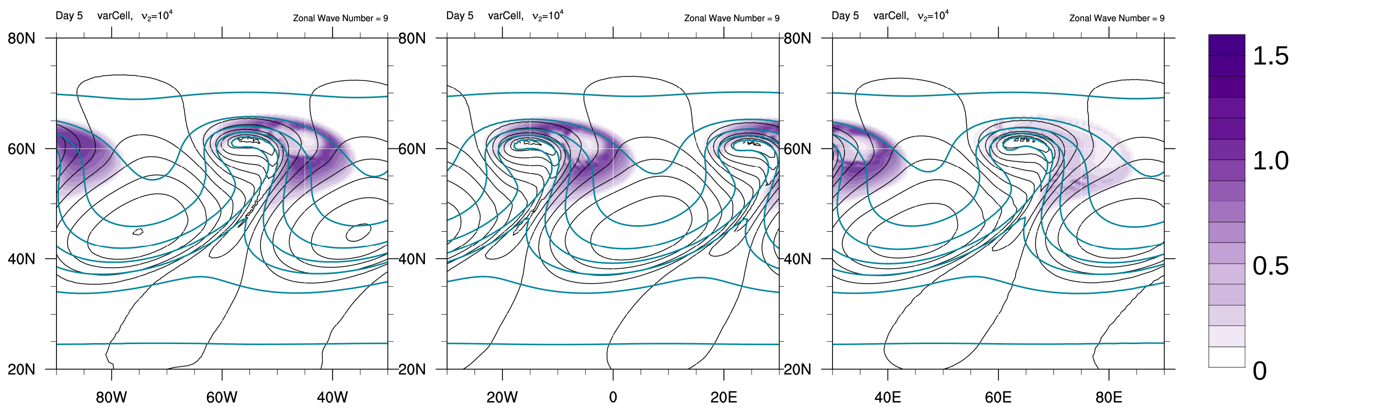


MPAS nonhydrostatic core

Global variable-resolution moist baroclinic waves





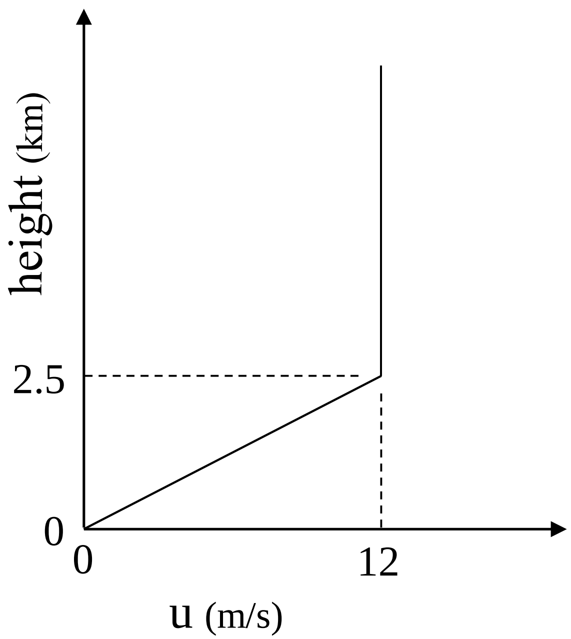


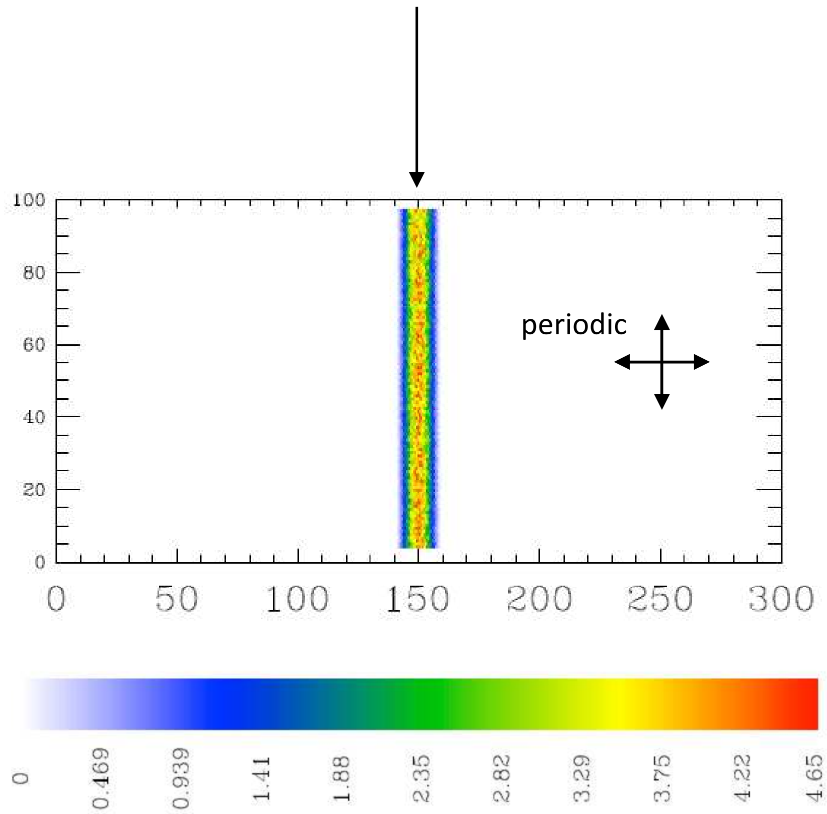
Lowest model level potential temperature (c.i. 10 K), pressure (c.i. 4 hPa)

Squall-Line Test Case: Uniform Resolution

Doubly periodic Cartesian domain,
perfect hexagons,
Δx = 1 km, Δz = 500 m,
Weisman-Klemp sounding,
moderate shear

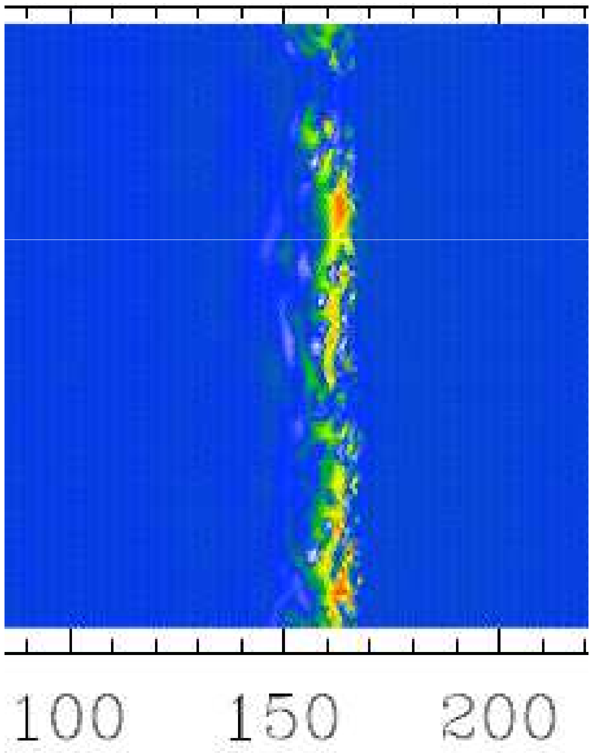
Convection triggered using a line thermal with a random perturbation



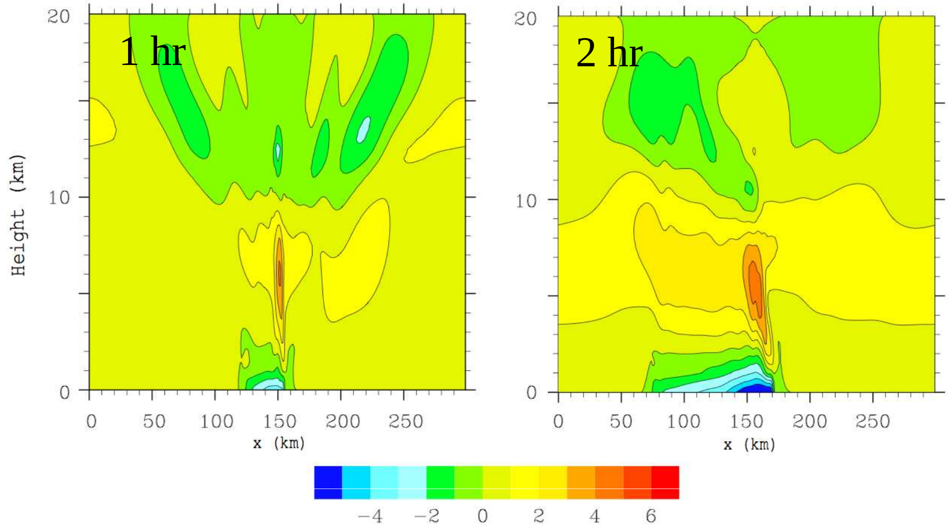


Squall-Line Test Case: Uniform Resolution

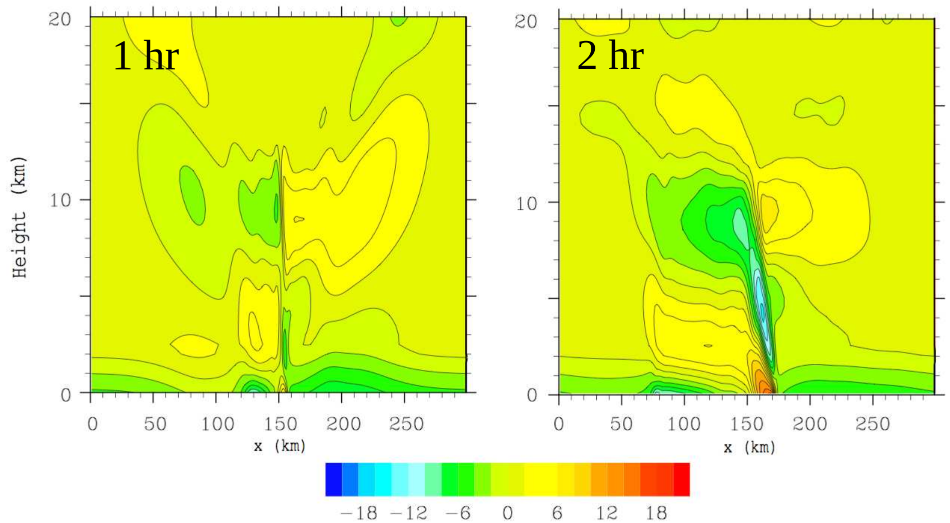
Vertical velocity
2 hr, z = 2.5 km



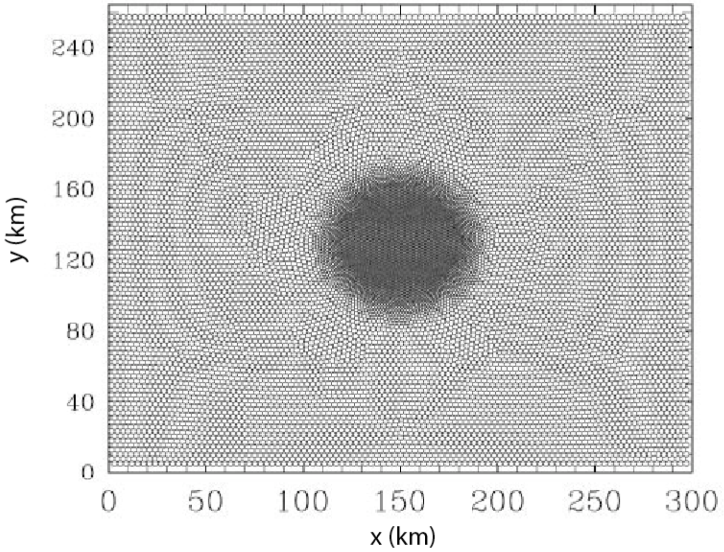
Line-average perturbation θ (K)

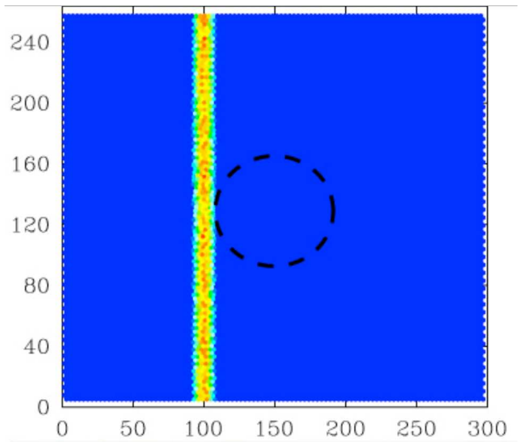


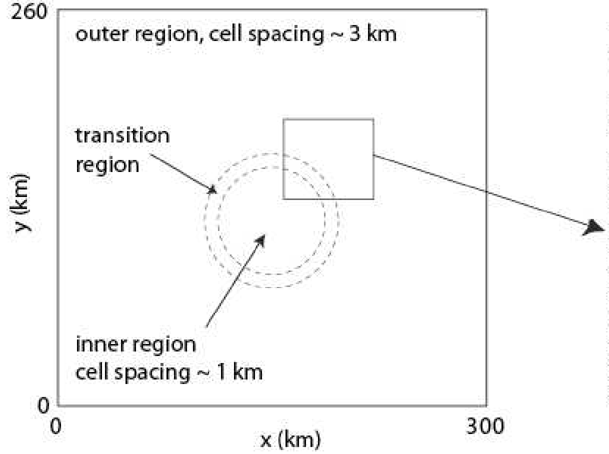
Line-average line-relative u (m/s)

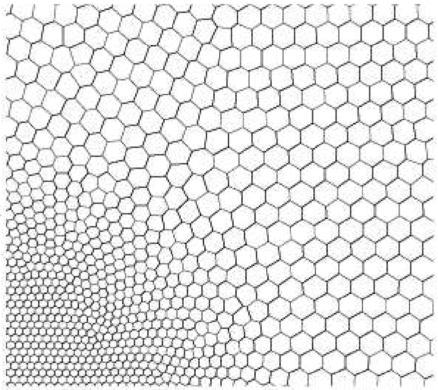


Squall-Line Test Case: Non-Uniform Mesh







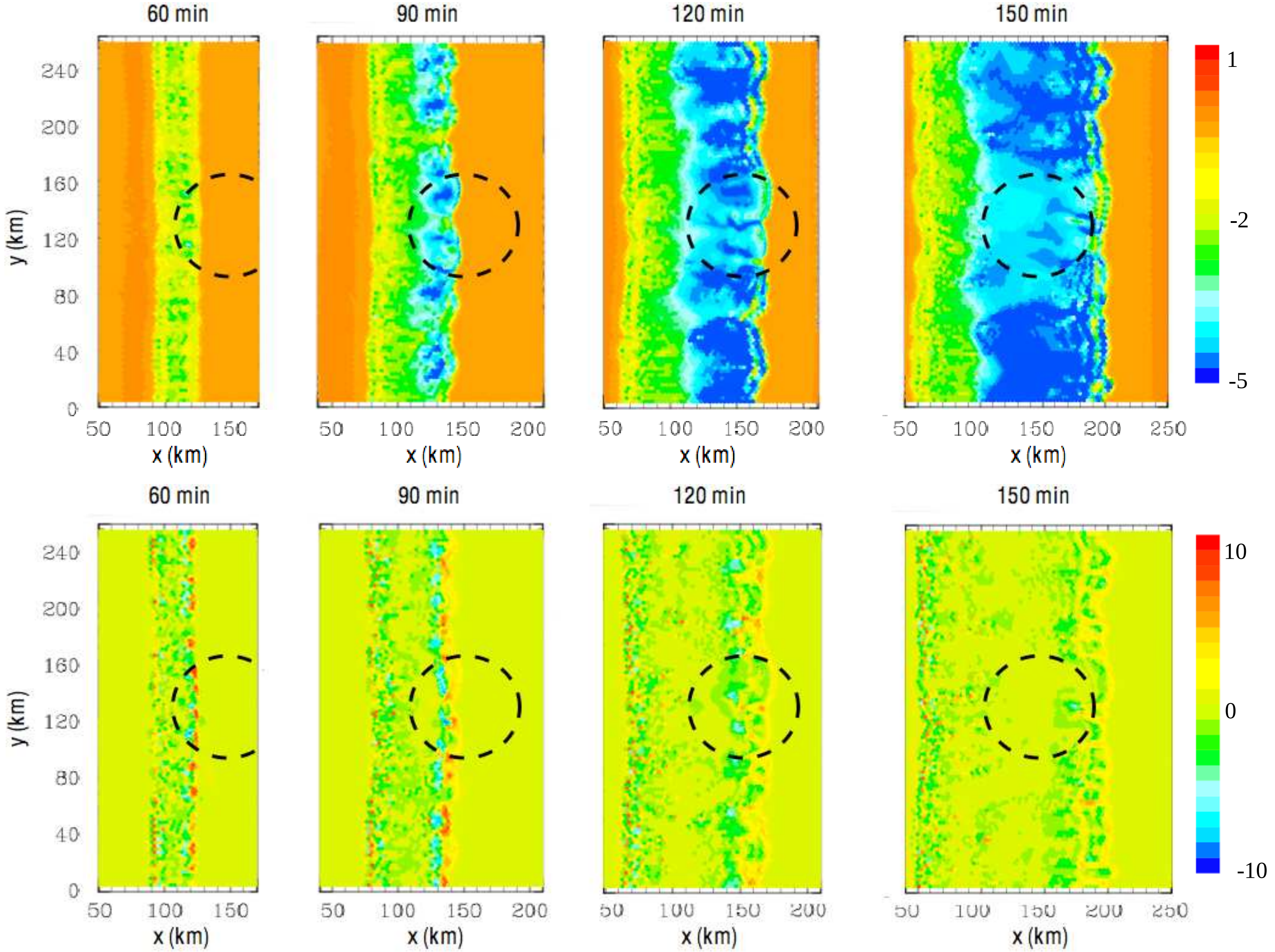


Squall-Line Test Case: Non-Uniform Mesh

Horizontal mixing using a constant physical viscosity $\nu = 500\ m^2/s$

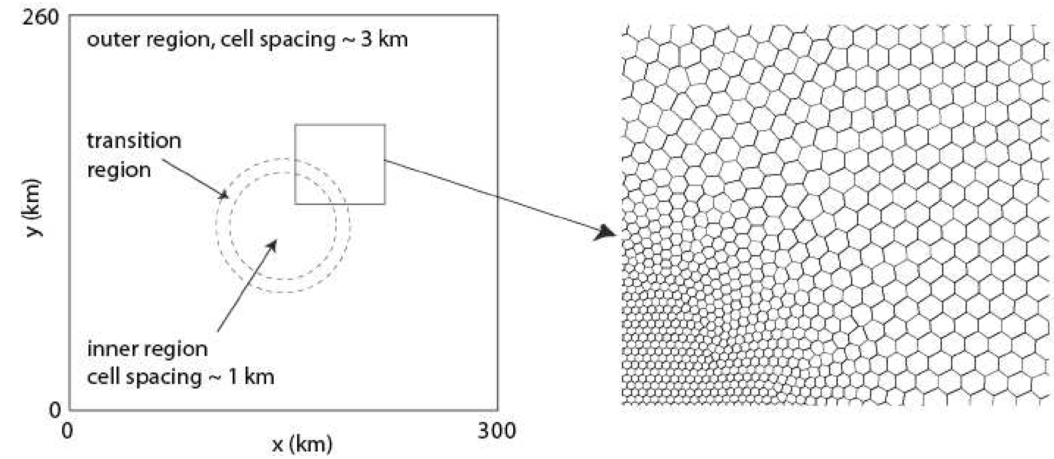
Perturbation Temperature (Level 1) (z = 500 m)

Vertical Velocity (Level 5) (z = 2.5 km)

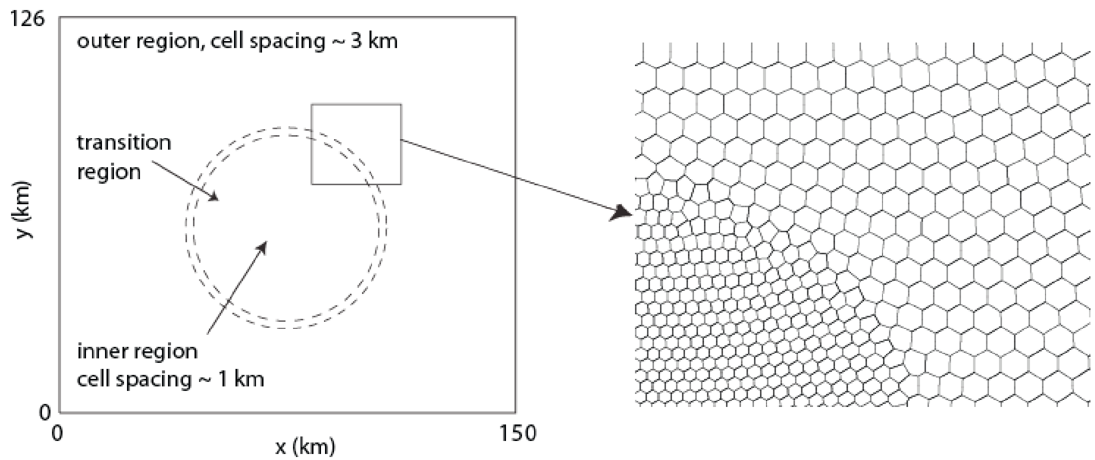


Squall-Line Test Case: Non-Uniform Mesh

Mesh with smooth transition



Mesh with abrupt transition



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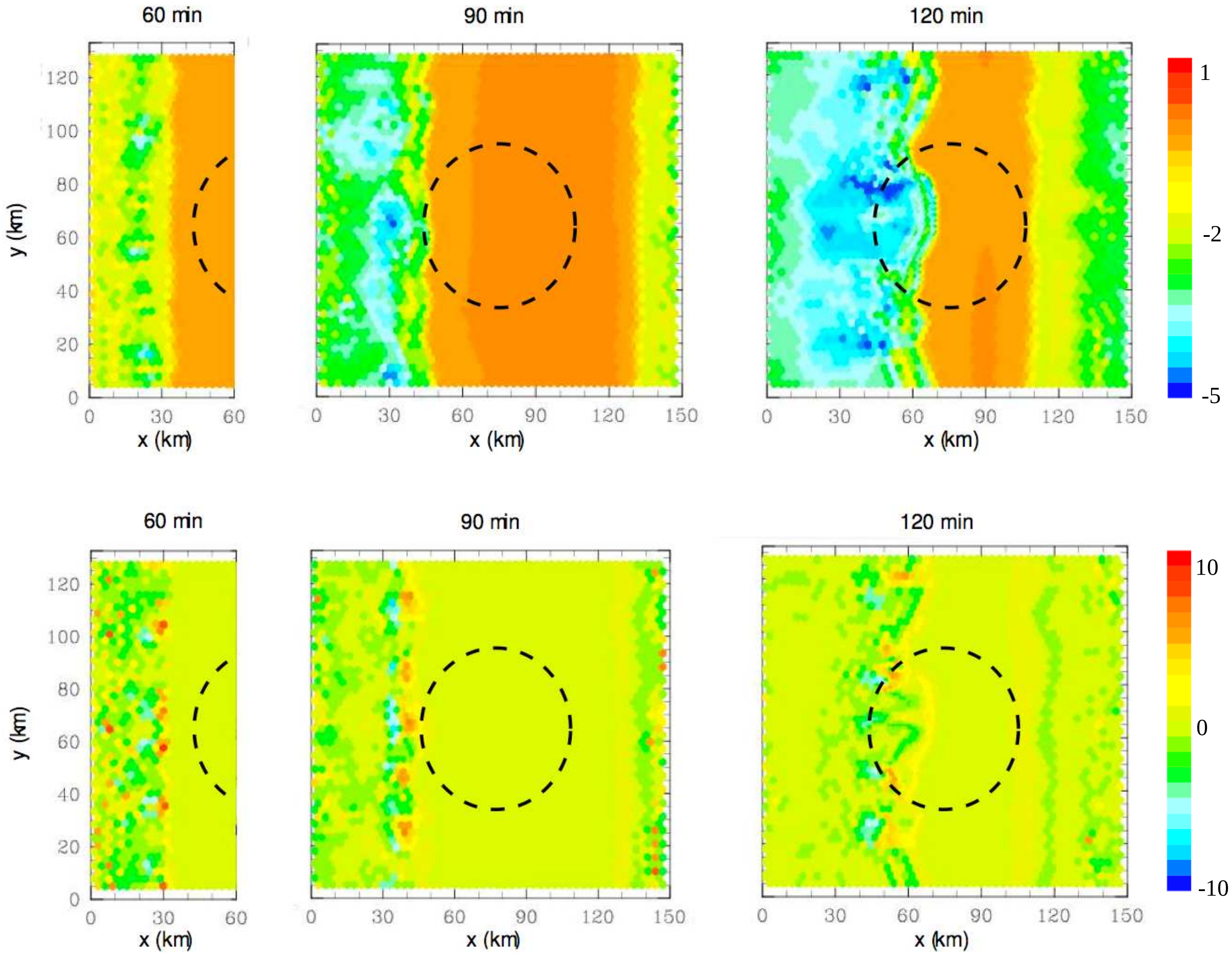
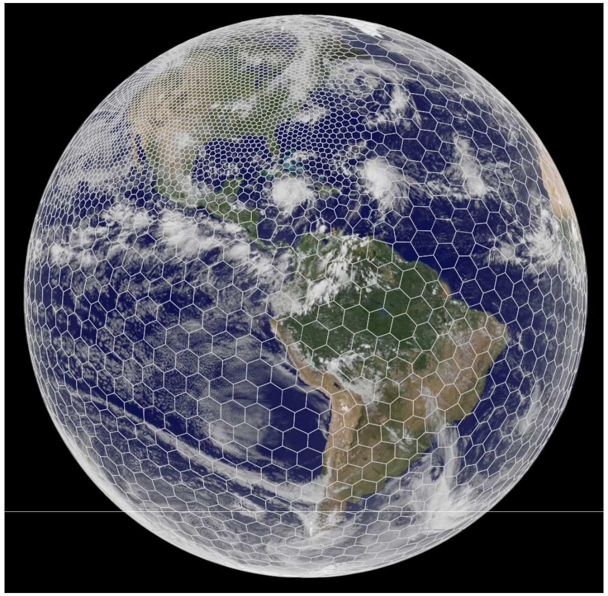
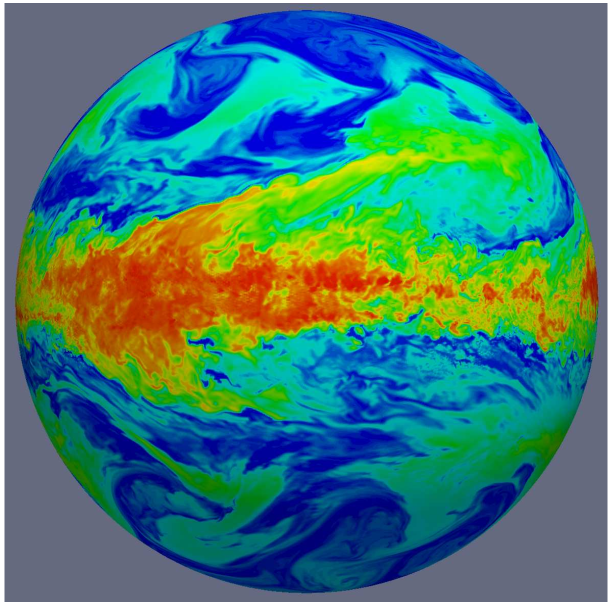


Atmospheric Modeling with MPAS
Summary



3D Solvers

- Nonhydrostatic and hydrostatic 3D SVCT solver.
- Variable-resolution grid results for the hydrostatic and nonhydrostatic solvers are encouraging.
- Both solvers work on the sphere and 2D and 3D Cartesian domains.
- Moist test results confirm viability of centroidal Voronoi C-grid discretization.
- Physics development for variable-resolution meshes is needed.



Future Development of Nonhydrostatic MPAS

- NWP testing with existing physics suite on uniform-resolution meshes.
- NWP and RCM testing on variable-resolution meshes.
  - NWP: hydrostatic to nonhydrostatic scales.
  - RCM: climate (synoptic) to mesoscale.
- Physics and filter development (esp. for variable resolution apps)