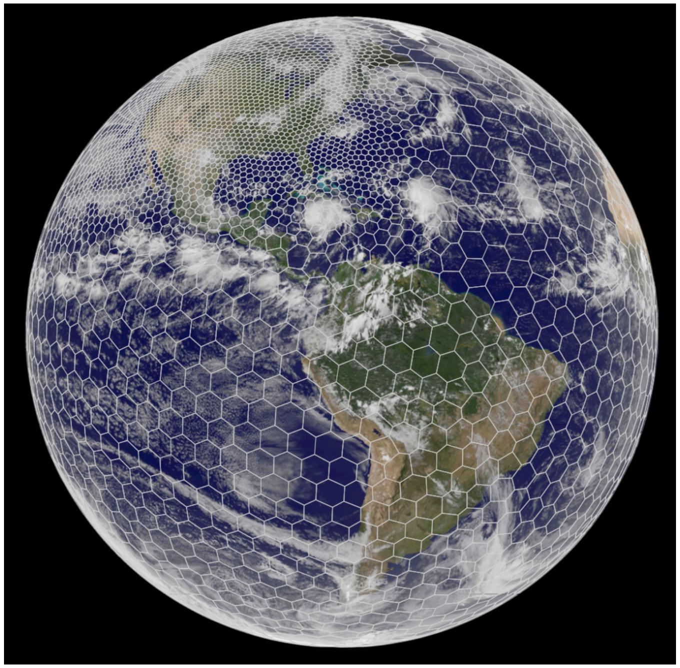
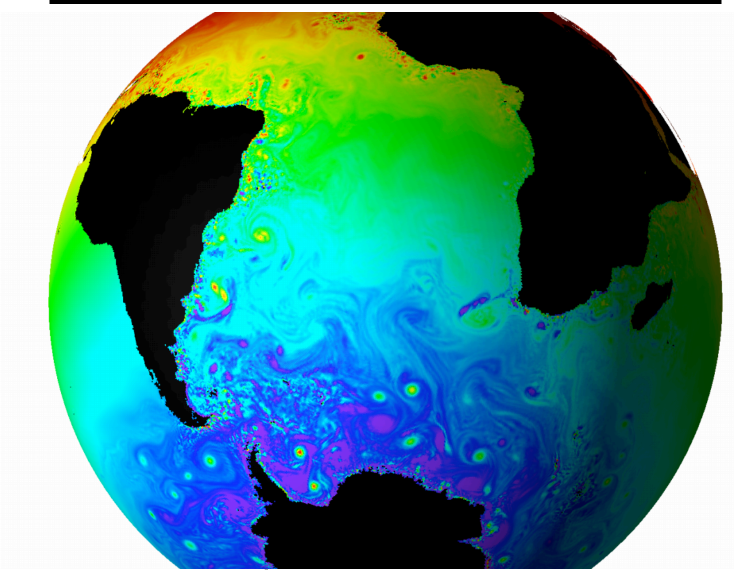
Beyond WRF: MPAS
A Global Nonhydrostatic Atmospheric Model





MPAS: Model for Prediction Across Scales

Based on Voronoi Tesselations (hexagons)

Jointly developed, primarily by NCAR and LANL for weather, regional climate and climate applications.

MPAS infrastructure - NCAR, LANL, others.

MPAS - <u>A</u>tmosphere (NCAR)

MPAS - <u>O</u>cean (LANL)

MPAS - <u>I</u>ce, etc.

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Michael Duda, Sang-Hun Park,
Laura Fowler *NCAR/NSF*

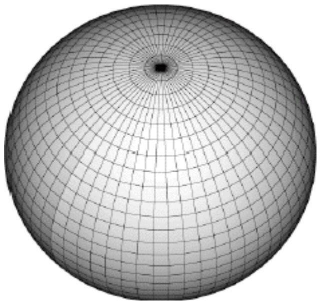
Todd Ringler *LANL/DOE*

John Thuburn *Exeter University*

Max Gunzburger *Florida State University*

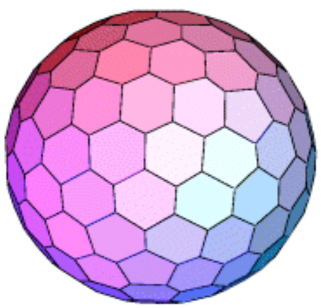
Lili Ju *University of South Carolina*

Why Voronoi Tesselations (Hexagons)?



lat-long
grid (WRF)

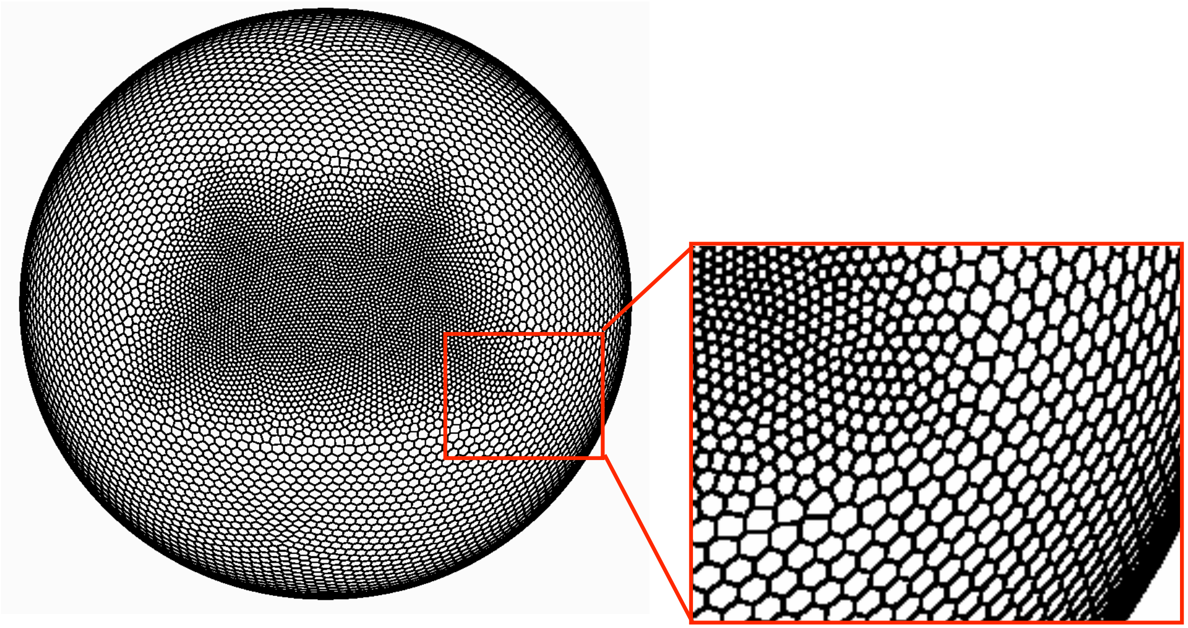
Lat-long grid issues:
gridlines converge at the poles, needs polar filtering - loss of monotonic/PD transport, does not scale on MPP architectures.



hexagonal
grid (MPAS)

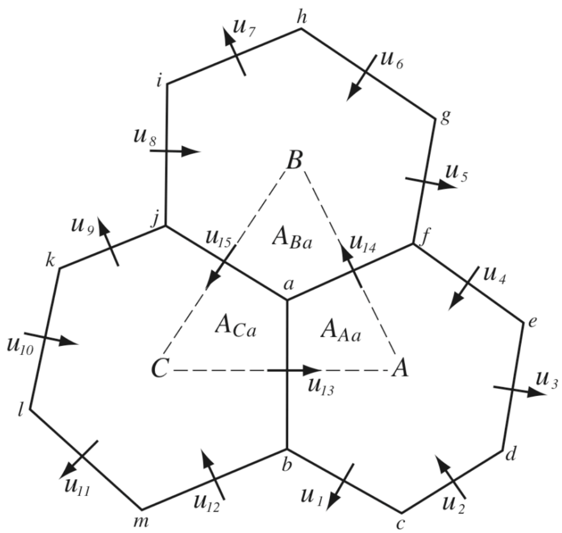
Advantages over lat-long grid:
No poles, scales well on MPP architectures, monotonic/PD conservative transport, flexible local refinement (variable resolution grids).
Possible issues: unstructured grid solver (efficiency), irregular grid (high-order schemes need development).

Conforming, Variable-Resolution Meshes



SCVTs
Spherical Centroidal
Voronoi Tessellations

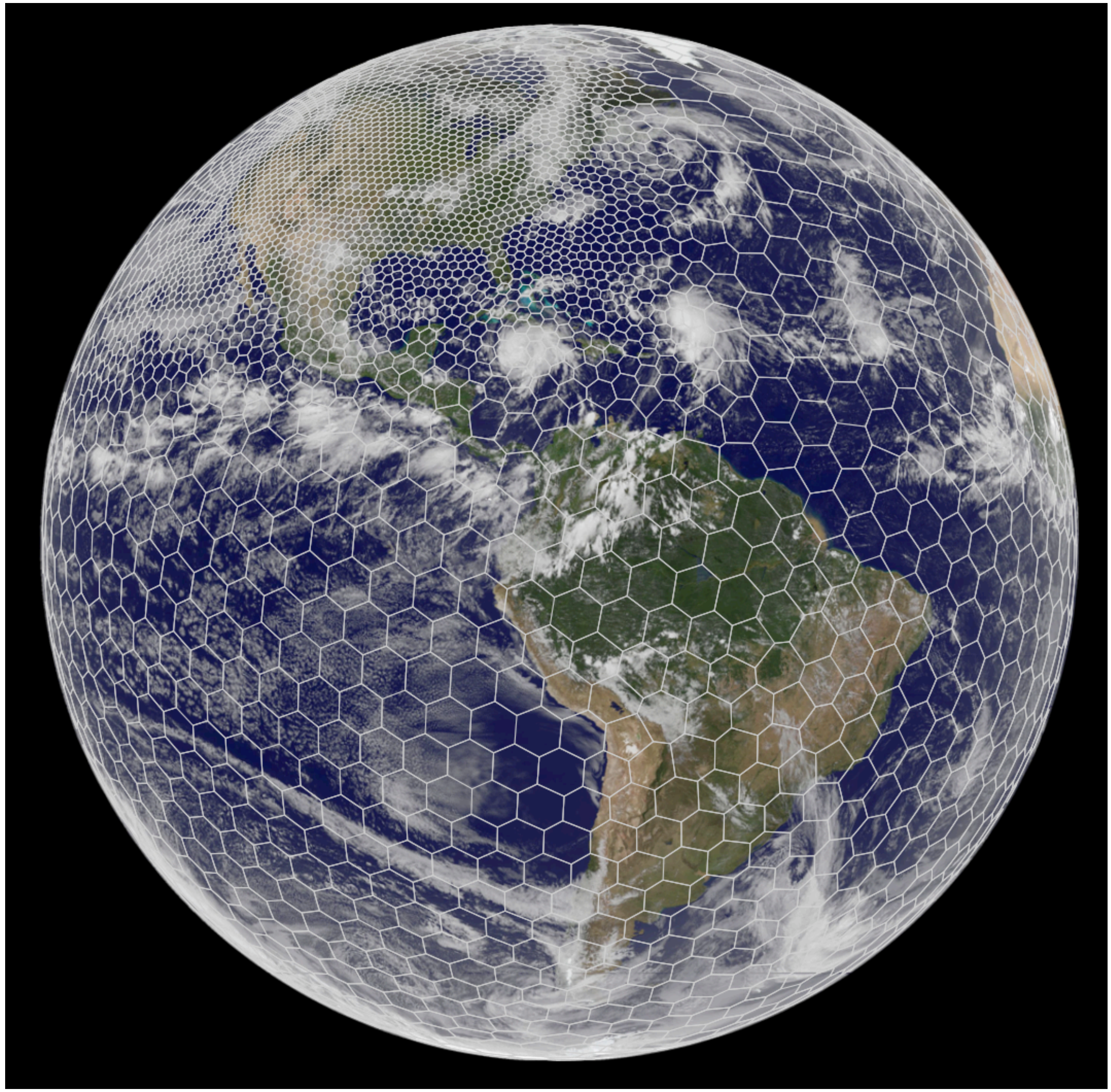
(Michael Duda, MMM)



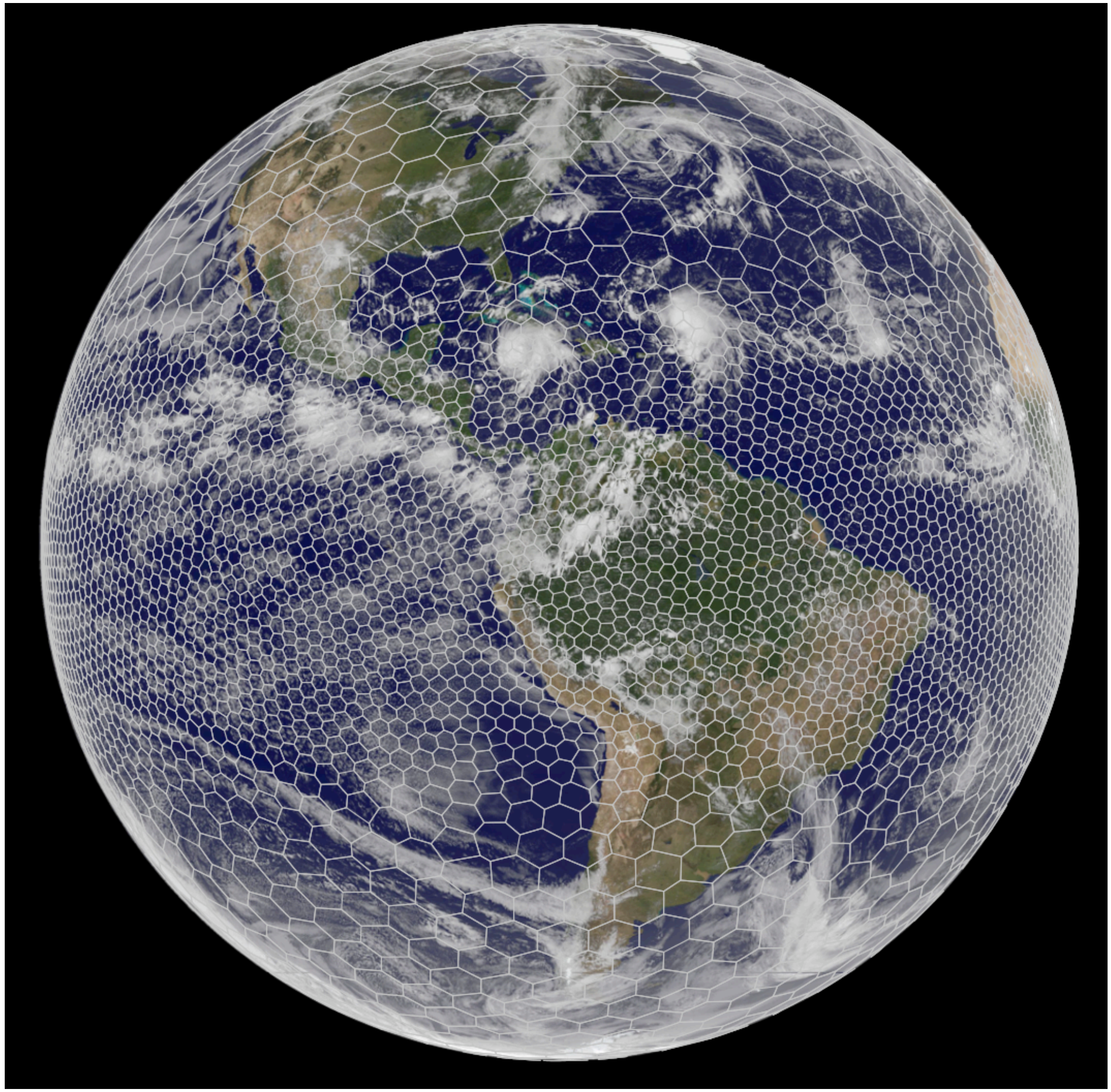
Cell center is cell center-of-mass

Edges of dual grid intersect edges of primary grid at right angles.

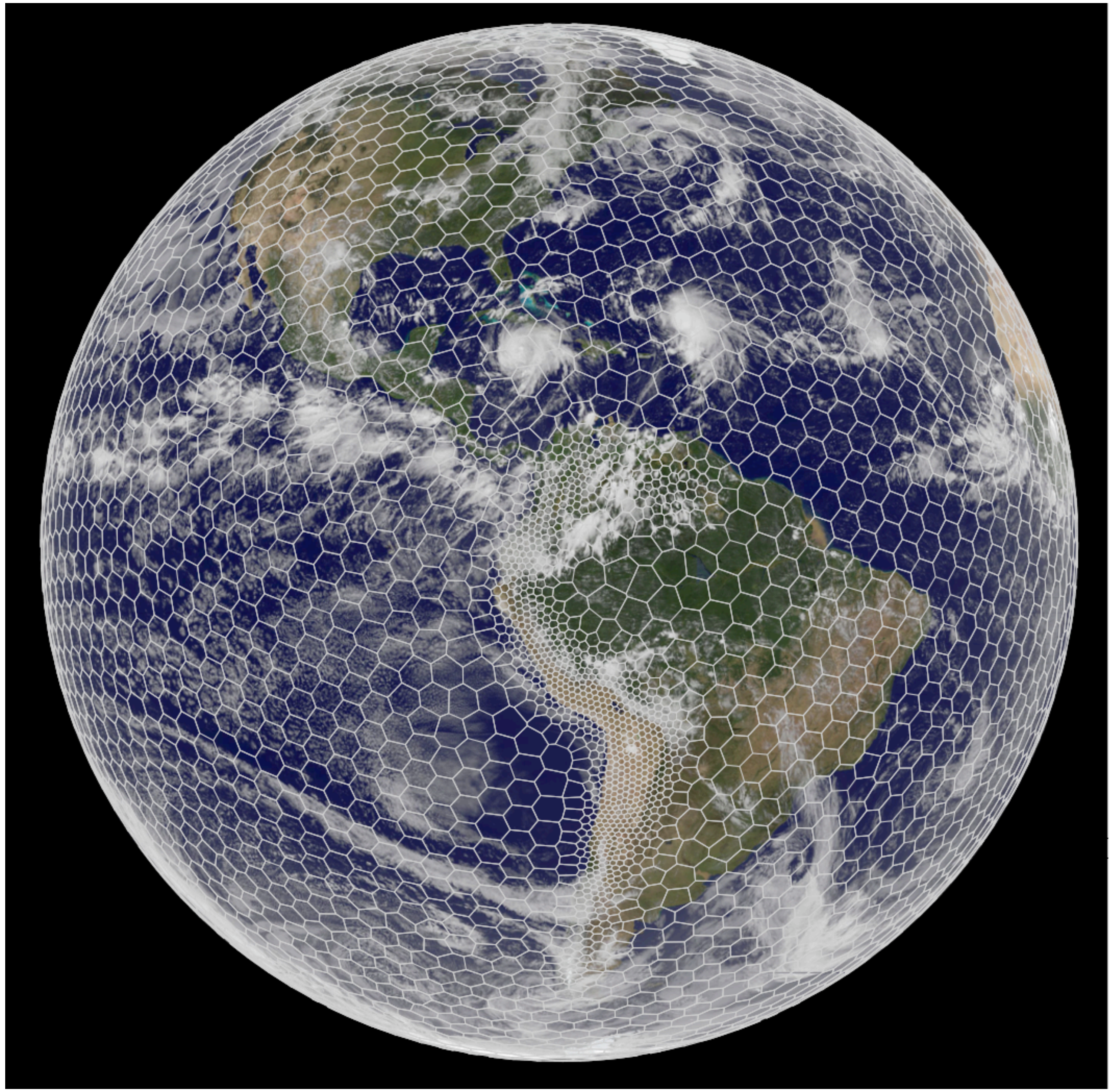
North American refinement



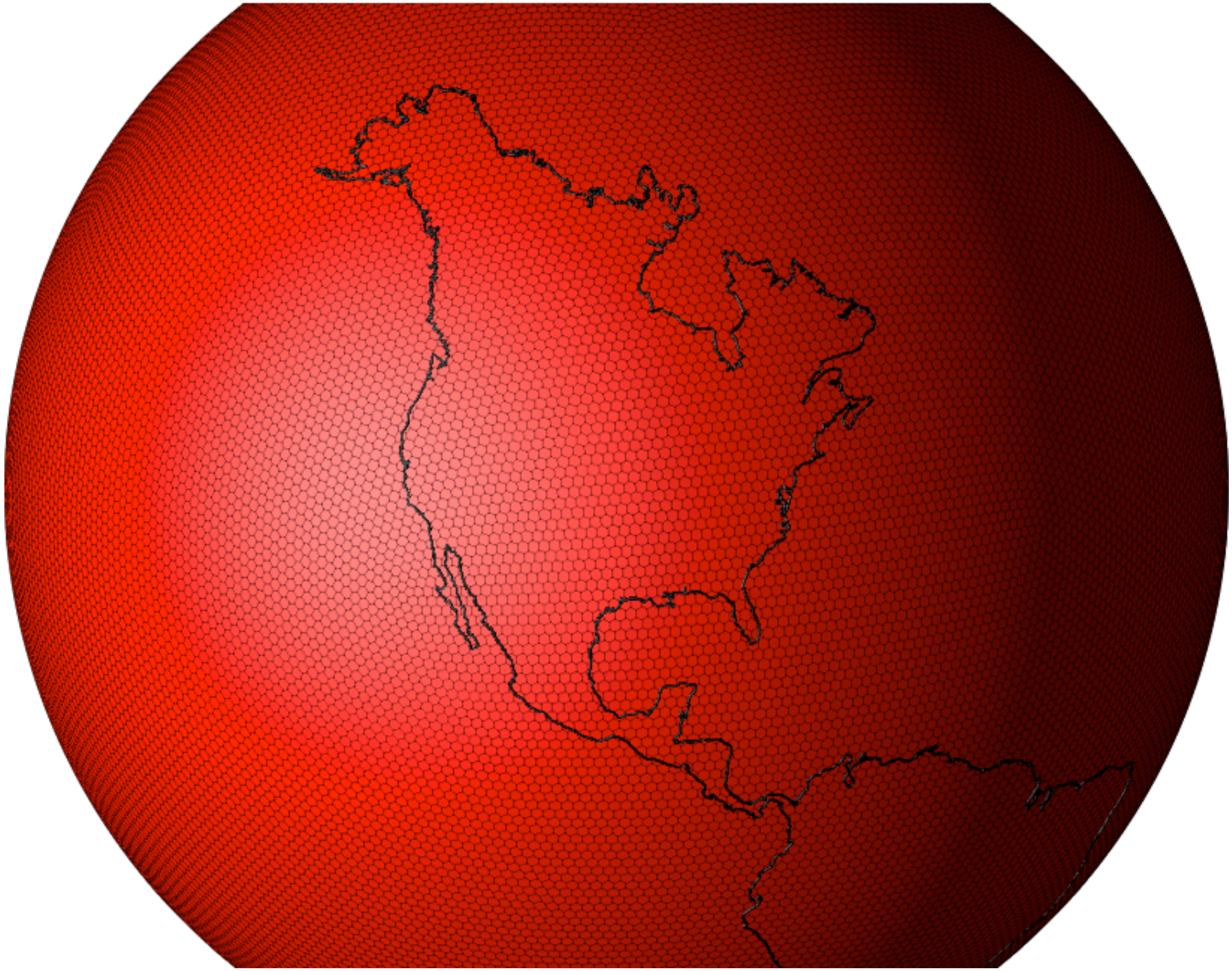
Refinement for equatorial convection



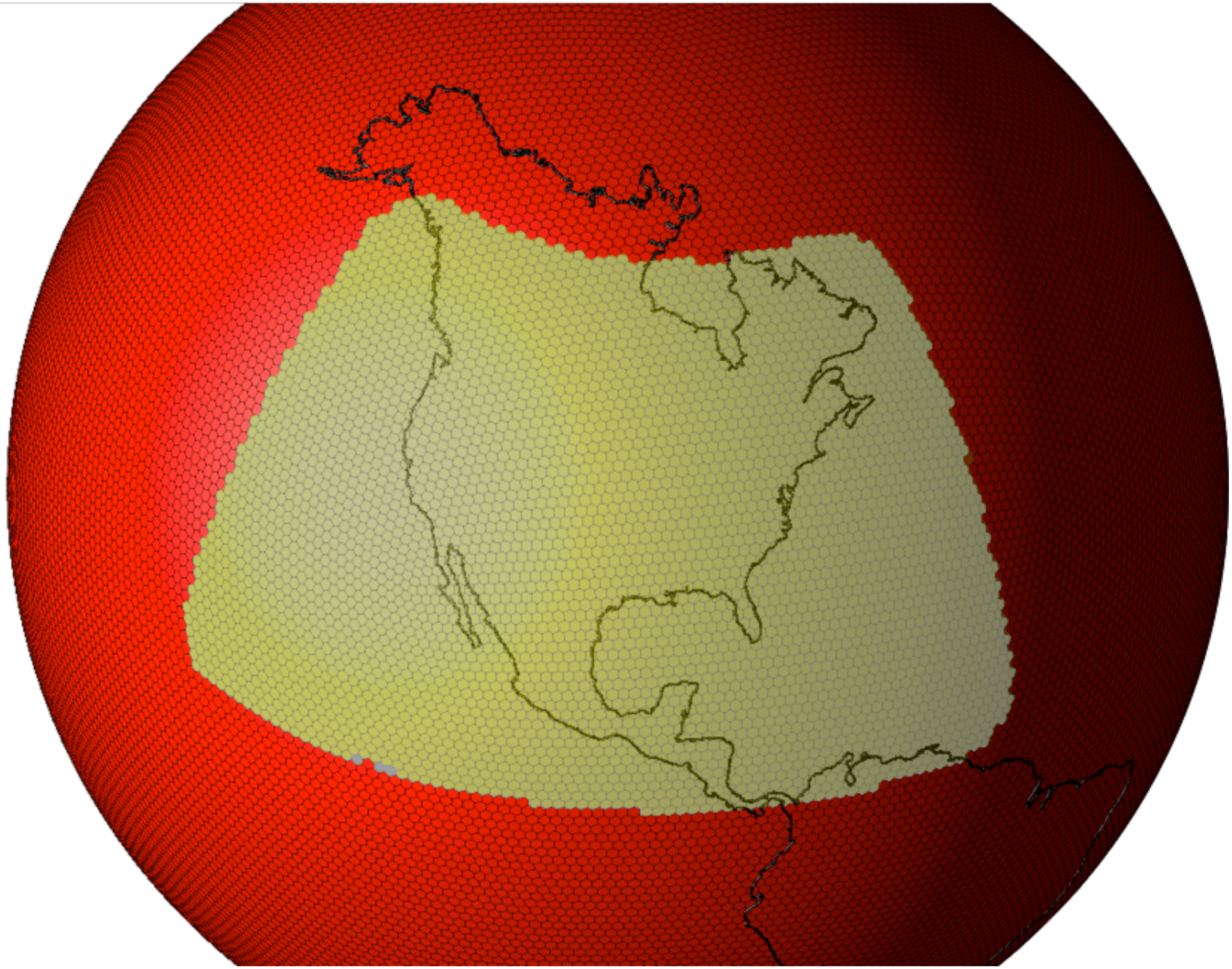
Refinement around the Andes



Nested, Conforming, Variable-Resolution Meshes

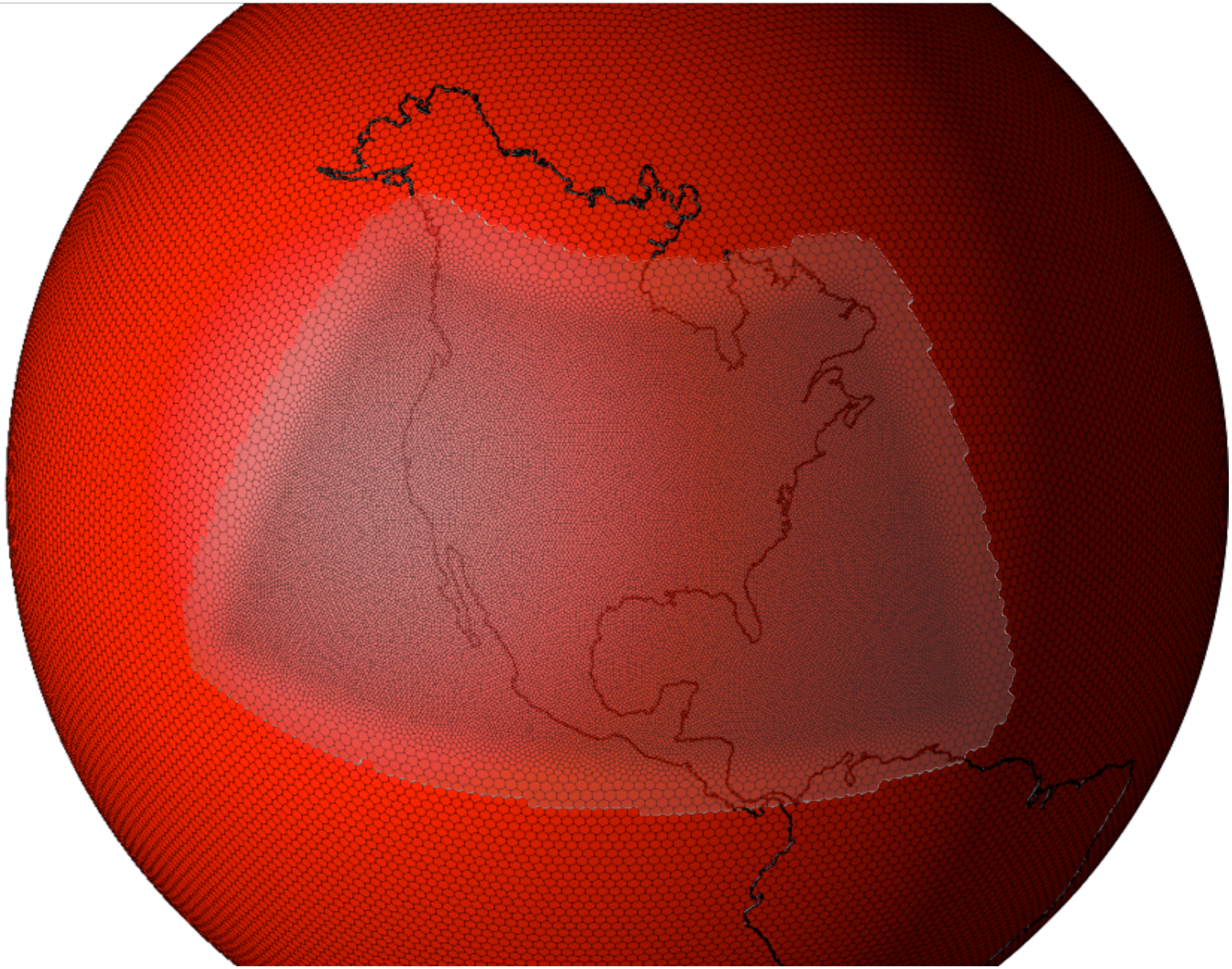


Nested, Conforming, Variable-Resolution Meshes



Nested, Conforming, Variable-Resolution Meshes

Nested, Conforming, Variable-Resolution Meshes



Dynamical Core Development

<u>SW solver:</u> Williamson et al (JCP 1992) test suite - results are similar to other icosahedral-grid models. Initial tests with variable resolution meshes.

<u>Atmospheric solvers:</u> Conservative (flux-form) equations. Hydrostatic solver (pressure coordinate), nonhydrostatic solver (height coordinate), both solver work on the sphere, on doubly-periodic Cartesian (3D; *x,y,z*) domains, and 2D (*x,z*) planes.

<u>Test Suite</u>
Global: J&W baroclinic wave simulations on the sphere.
2D (x,z) plane: IG waves, mountain waves, density currents, squall lines.
3D planes: Squall-lines and supercells.

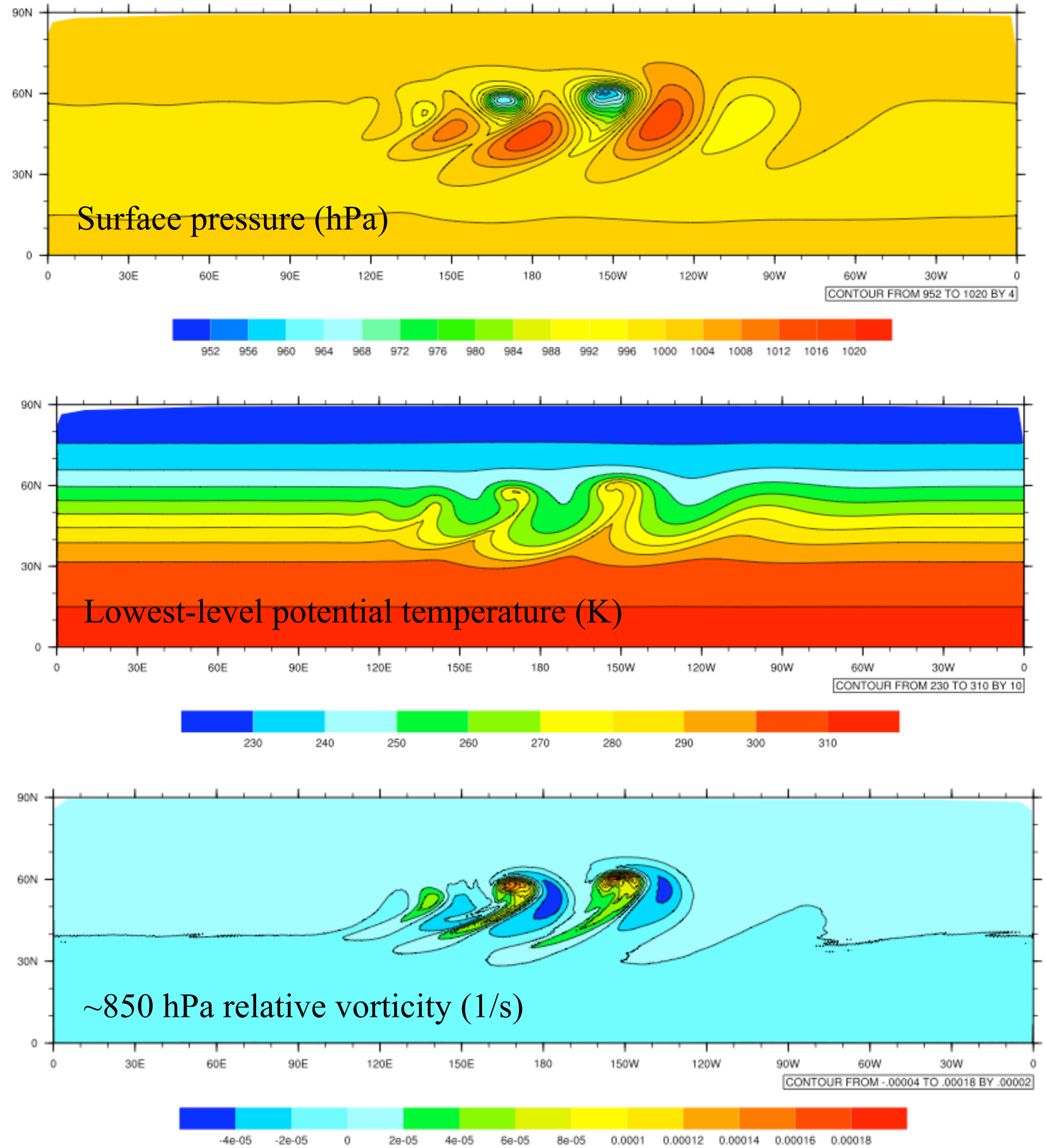
MPAS nonhydrostatic core

Jablownowski and Williamson (2006) baroclinic wave test case, day 9

~120 km cell spacing

Δt = 900 s
Δτ = 150 s
26 levels

Vertically-stretched grid.

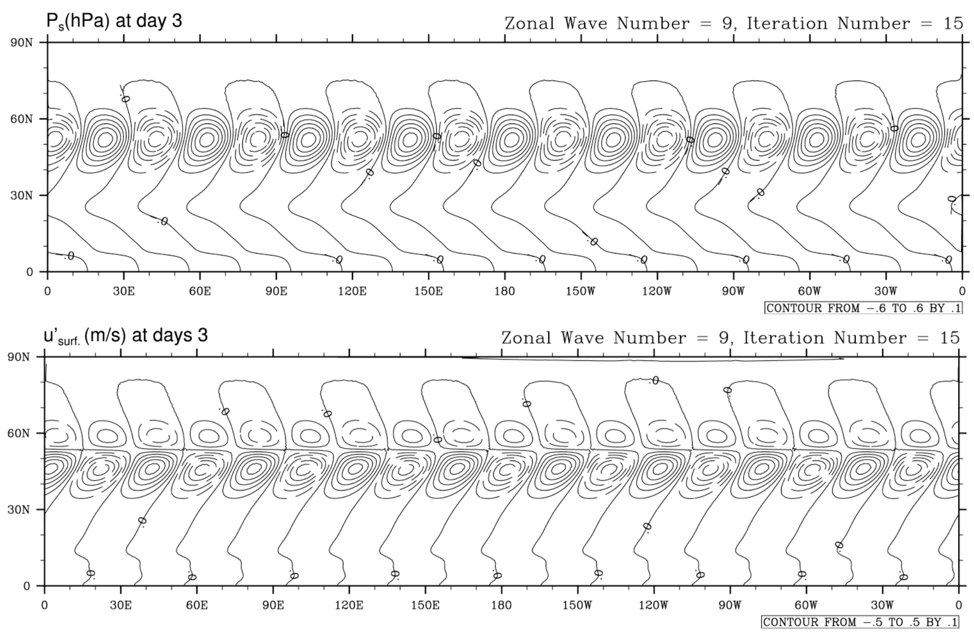


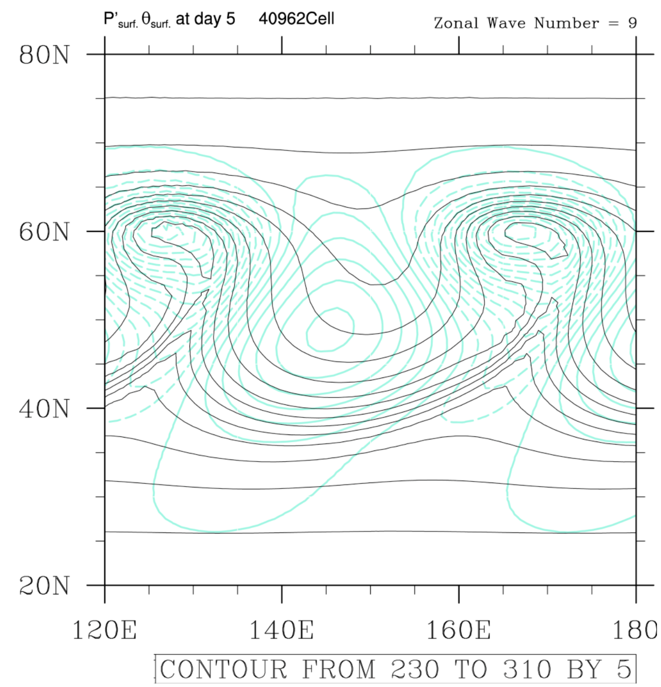
Hydrostatic MPAS core

Jablownowski and Williamson unstable jet

Normal mode solution

Most unstable mode has wavenumber 9





(from Sang-Hun Park)

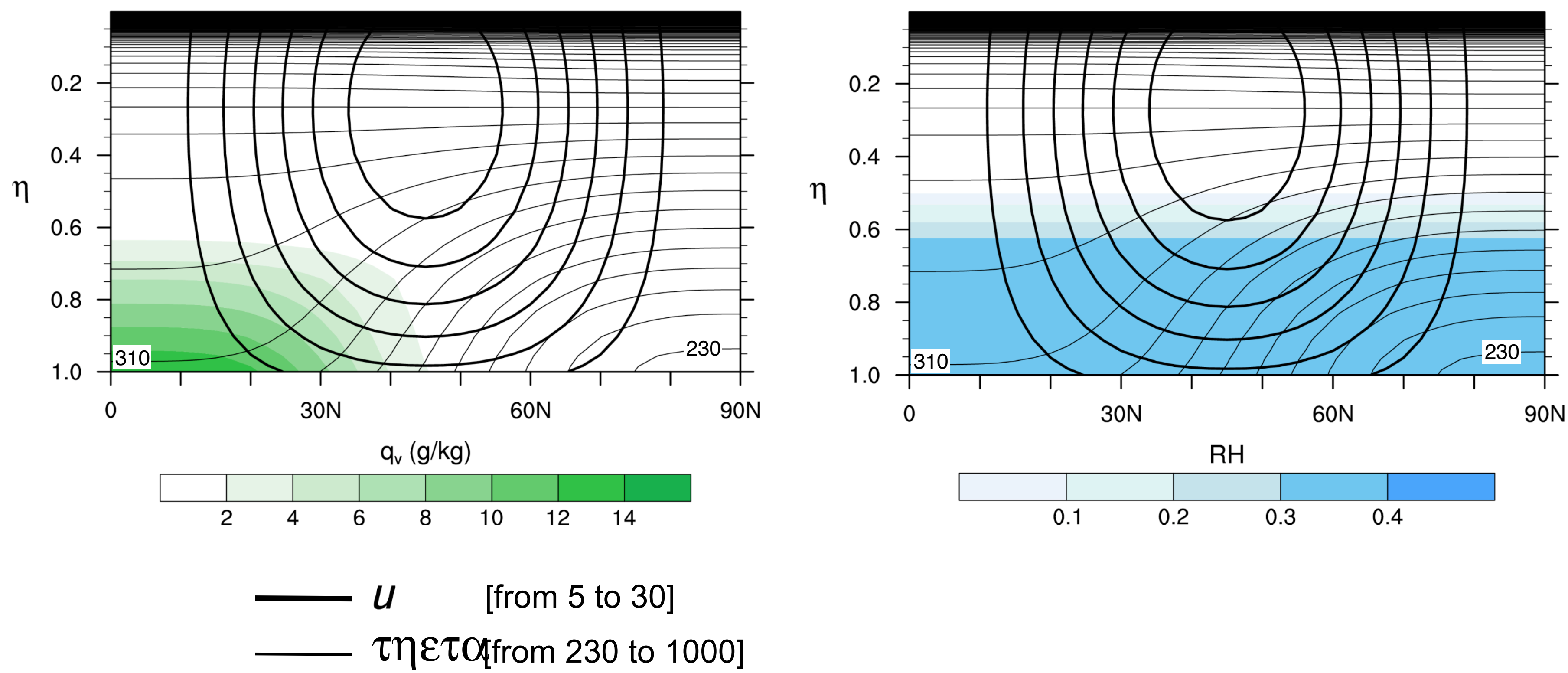
Hydrostatic MPAS core

Jablownowski and Williamson unstable jet

Moist initial state

Warm rain microphysics

Initial state zonal velocity, potential temperature and moisture



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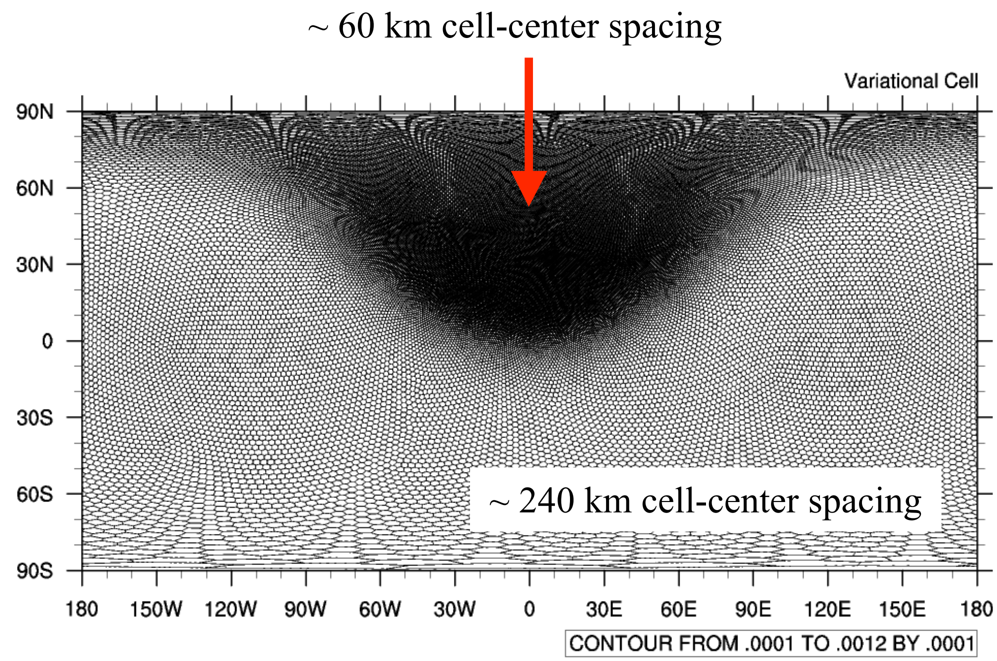
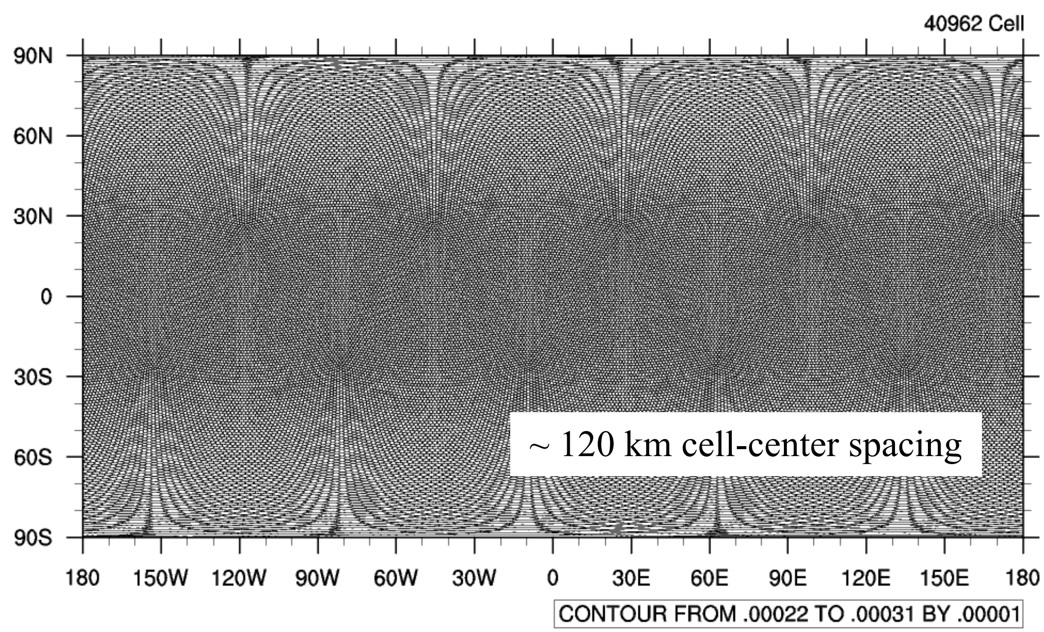
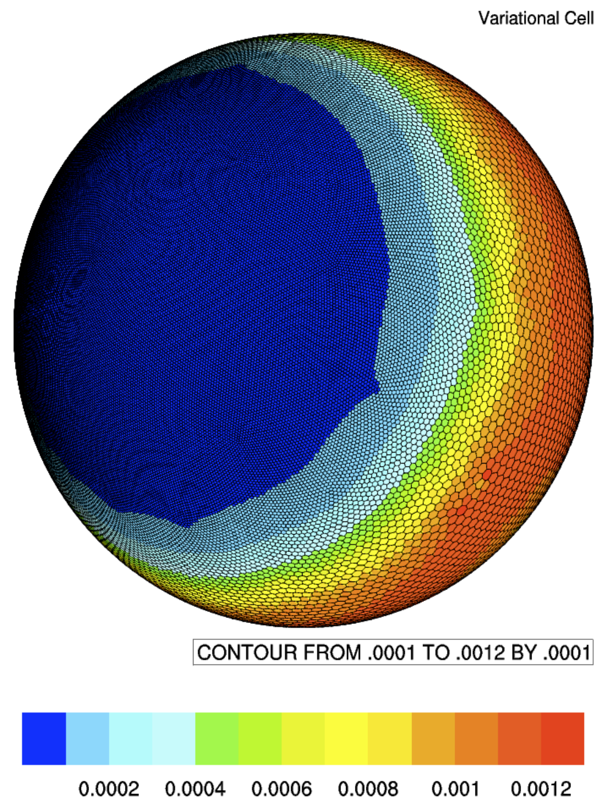


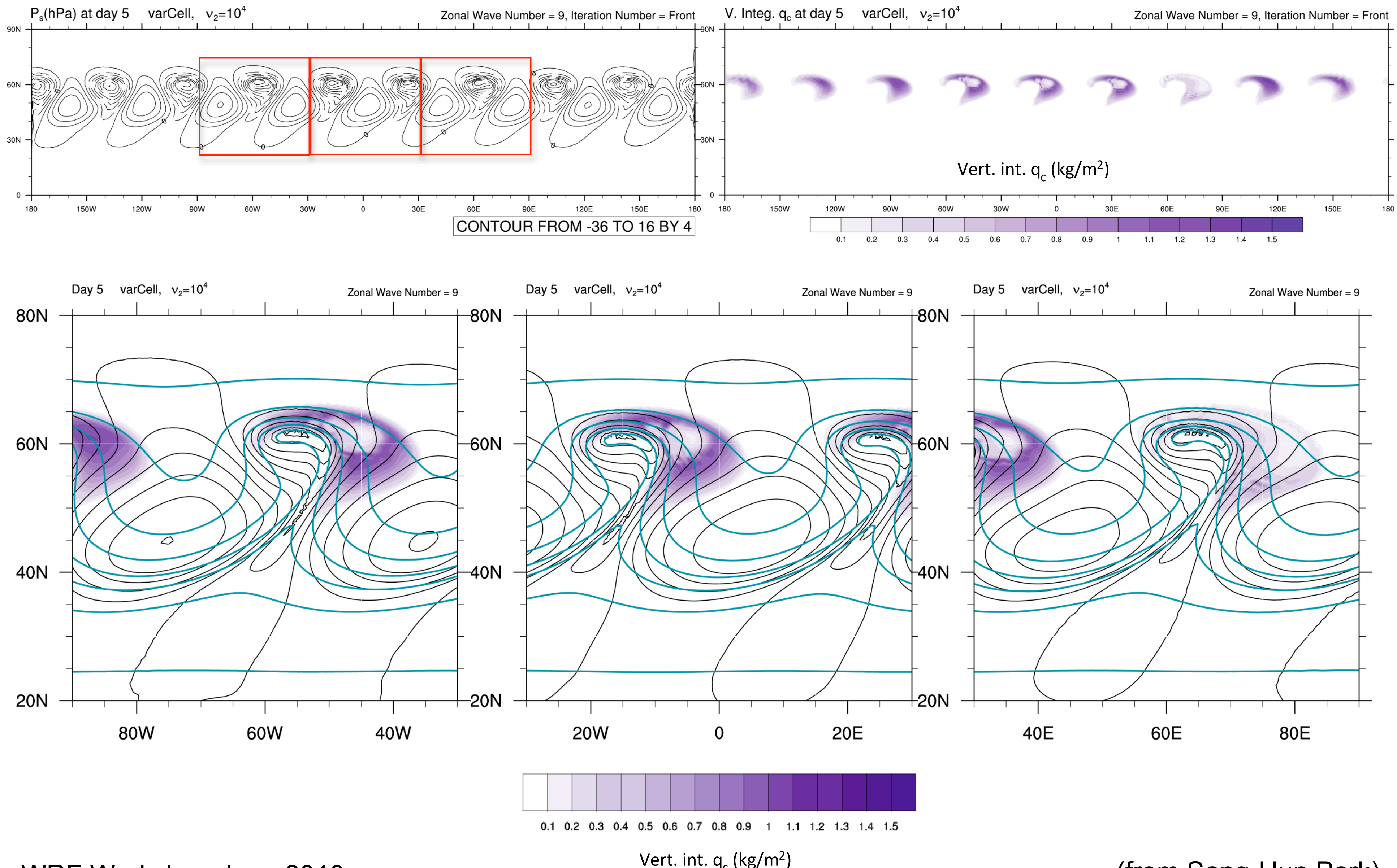




(from Sang-Hun Park)

Jablonowski and Williamson Unstable Jet, Normal-Mode Initialization

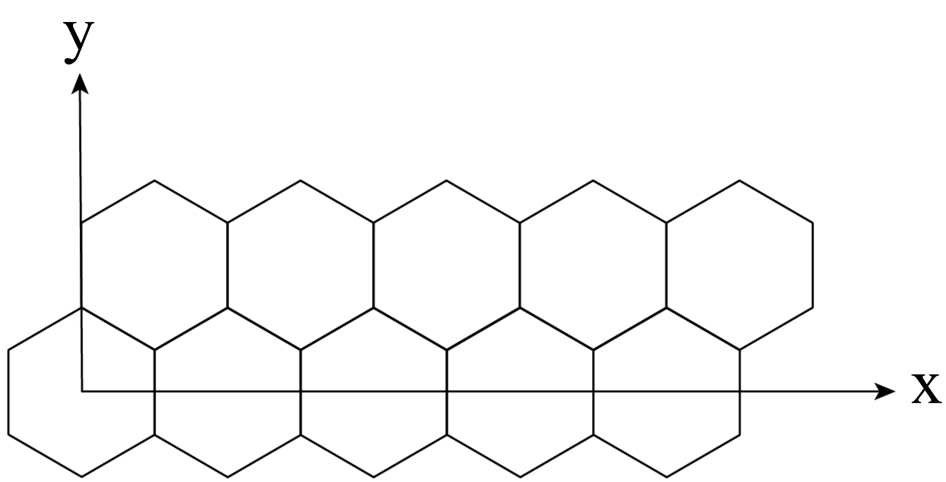
Mesh with local refinement (240-60 km cell spacing), Kessler moist physics



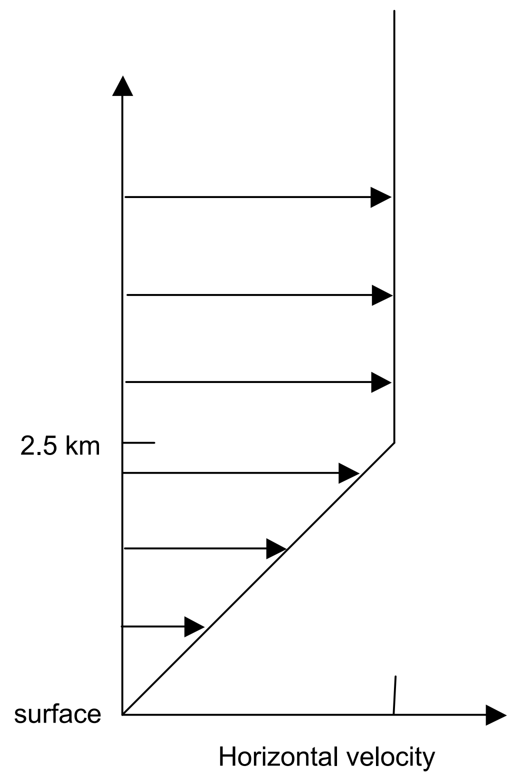
(from Sang-Hun Park)

Squall-Line Tests

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



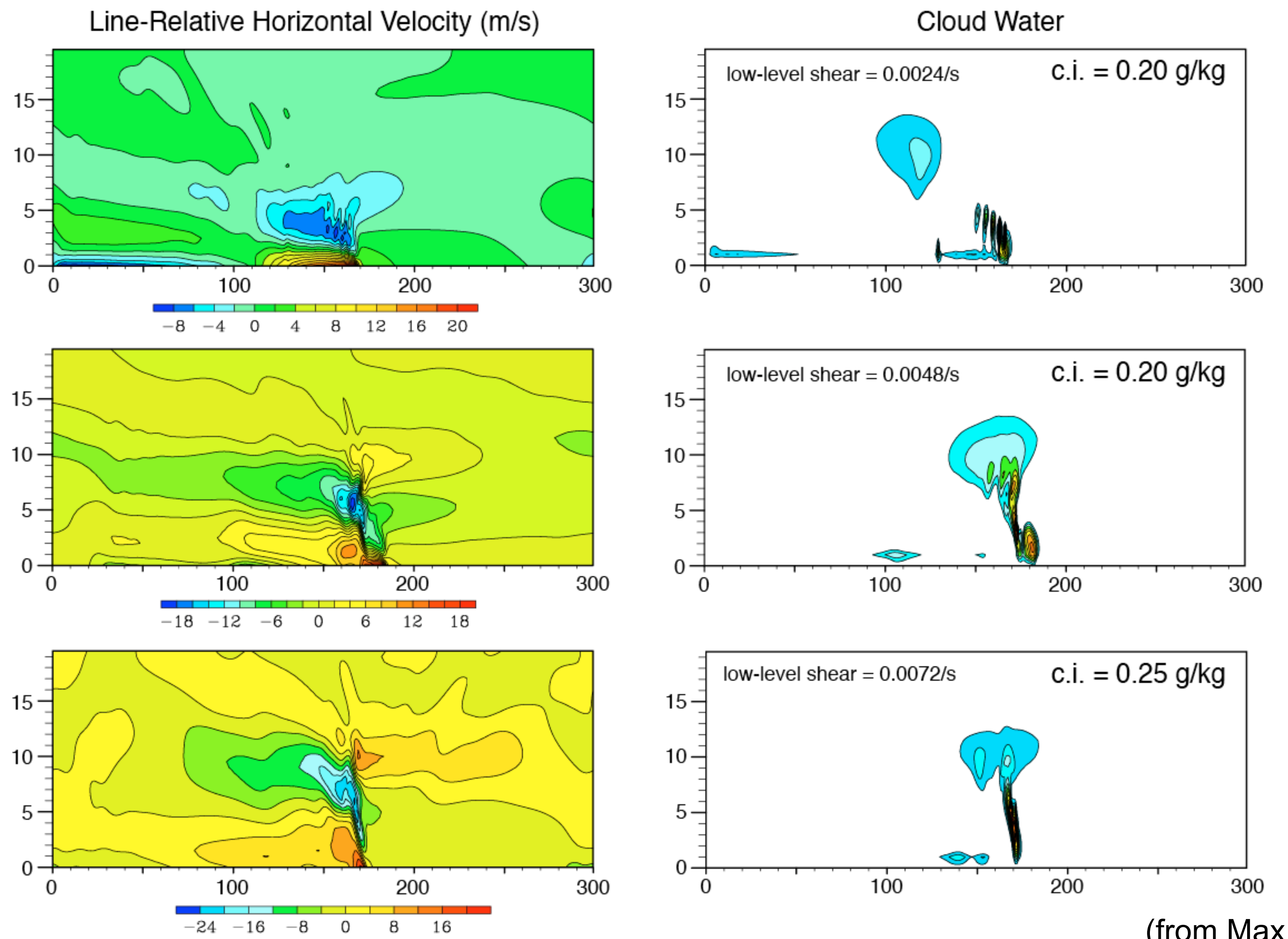
Initial tests use perfect hexagons
Periodic in x and y
2D (x,z) simulations, 2 rows (y) are used



Squall-Line Tests

Low-level shear (0-2.5 km), Weisman-Klemp sounding

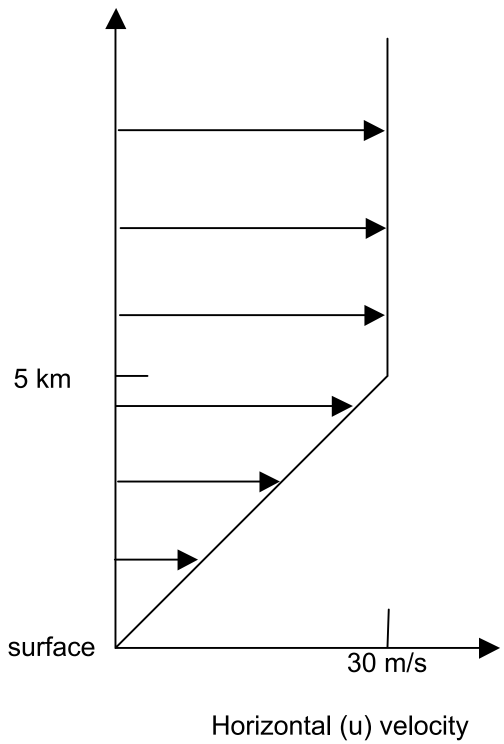
Warm-bubble perturbation, results at 3 hours



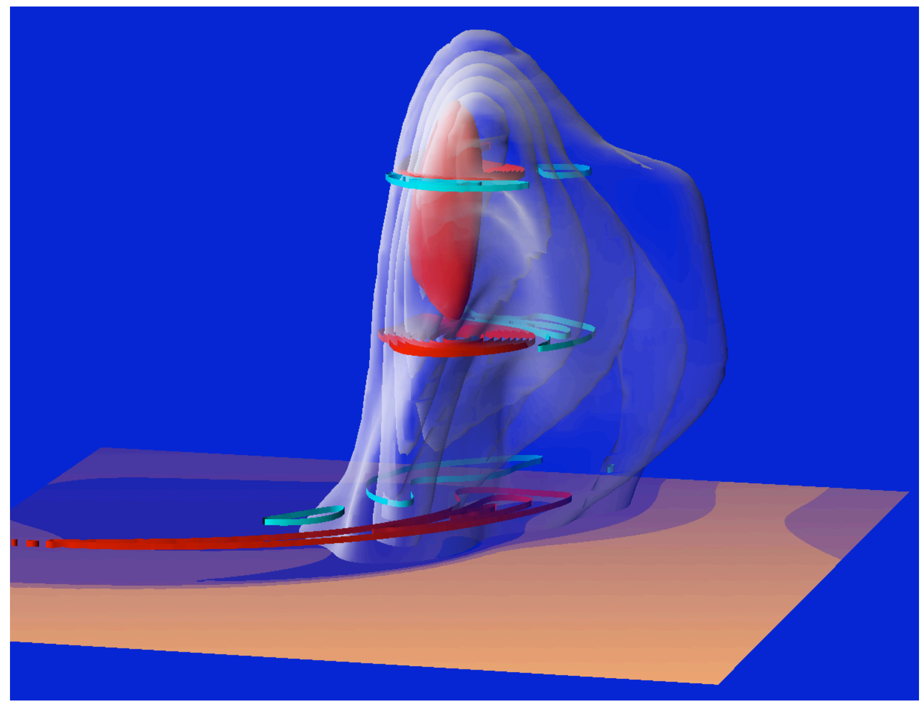
(from Max Menchaca)

Supercell Tests

Low-level shear (0-5 km, 30 m/s), Weisman-Klemp sounding,
Warm-bubble perturbation, Periodic in x and y (Lx, Ly ~ 84 km),
3D (x,y,z) simulations, δh = 500 m



Reference solution



Vertical velocity contours at 1, 5, and 10 km (c.i. = 3 m/s)

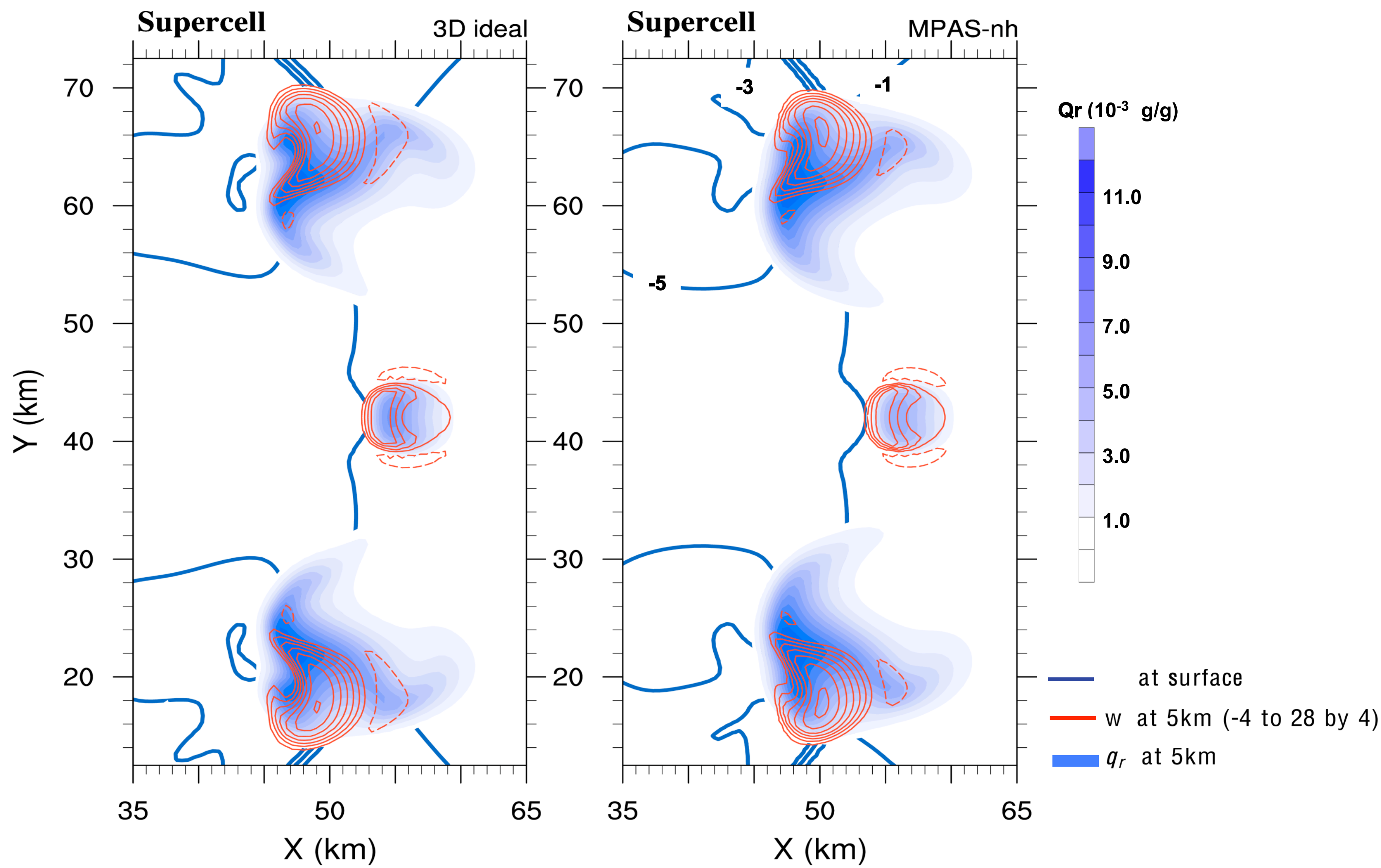
30 m/s vertical velocity surface shaded in red

Rainwater surfaces shaded as transparent shells

Perturbation surface temperature shaded on baseplane

Supercell simulations, reference cloud model and MPAS

500 m grid, horizontal cross sections, solution at 2 hours



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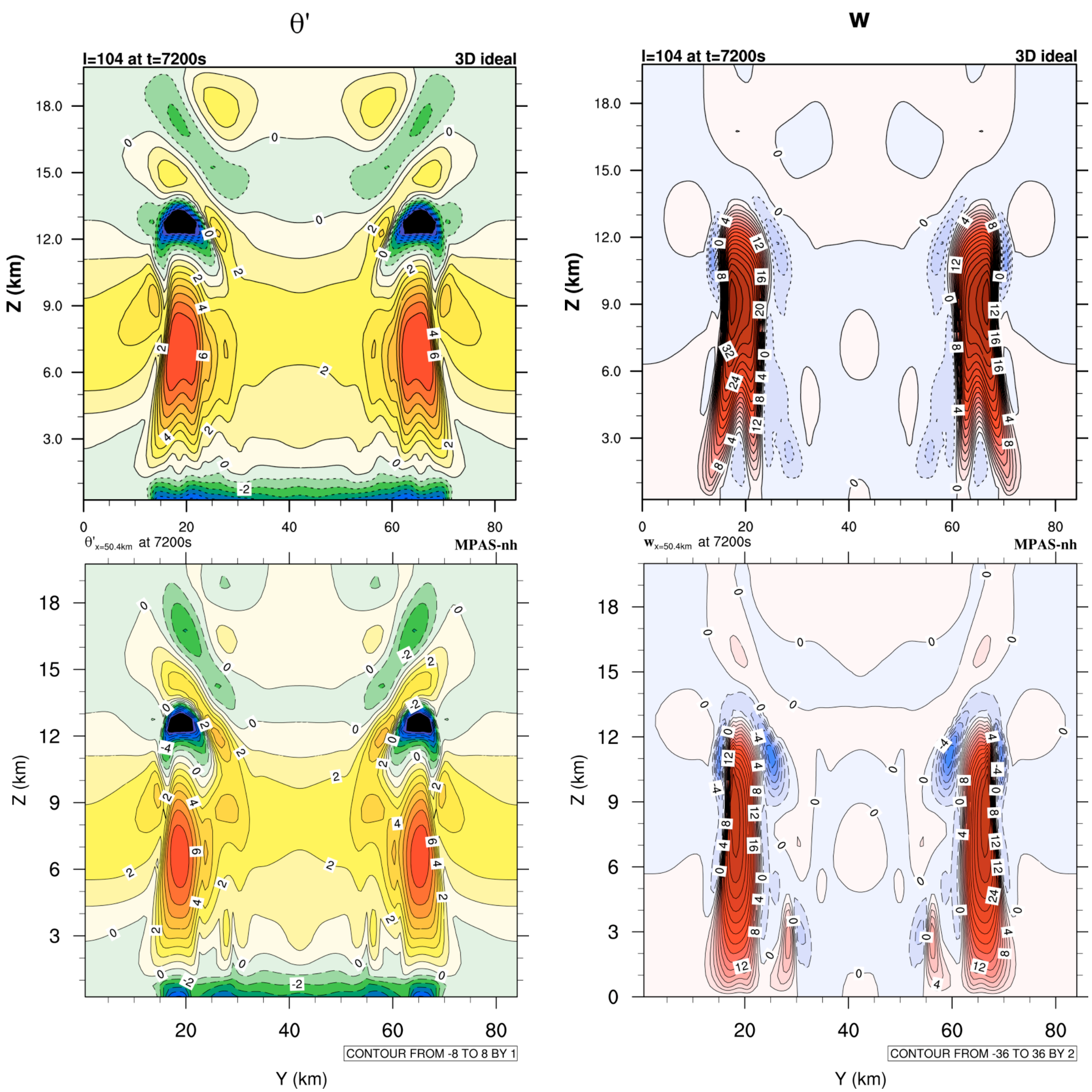
Supercell simulations, reference cloud model and MPAS

500 m grid, solution at 2 hours, vertical cross sections



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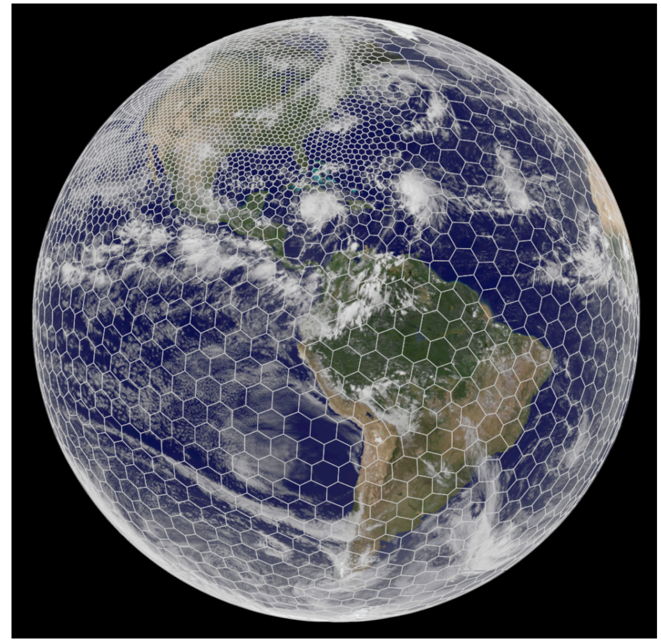
(from Sang-Hun Park)

Beyond WRF: MPAS - Summary

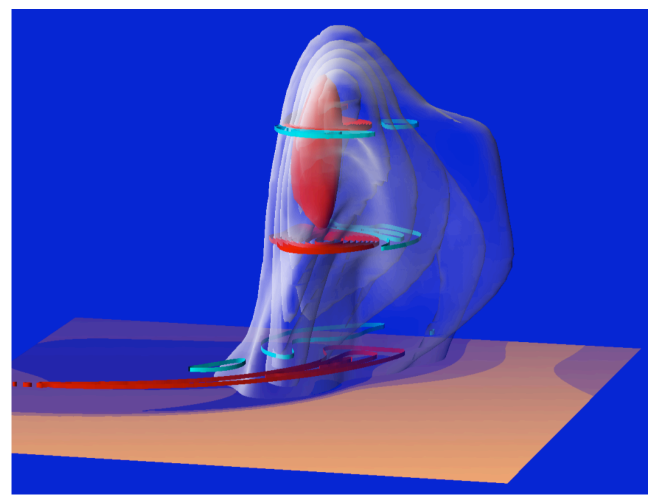


<ins>3D Solvers</ins>

- Hydrostatic 3D SVCT solver (pressure coordinate).
- Nonhydrostatic 3D SVCT solver (height coordinate).
- Both solvers work on the sphere and on 2D and 3D Cartesian domains.
- Tests results confirm viability of Voronoi C-grid discretization at large scales (global) and cloud-permitting scales for both solvers.
- Variable-resolution grid results are encouraging.

<ins>Future Development</ins>

- Weather, regional climate and climate physics suites.
- Further testing of variable resolution meshes, physics development.
- Further development and testing of higher-order transport schemes.



<ins>Expectations</ins>

- NWP testing by the end of this year.
- Friendly-user release summer 2011?