Beyond WRF: MPAS
A Global Nonhydrostatic Atmospheric Model

**MPAS: Model for Prediction Across Scales**
Based on Voronoi Tessellations (hexagons)

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

MPAS infrastructure - NCAR, LANL, others.
MPAS - Atmosphere (NCAR)
MPAS - Ocean (LANL)
MPAS - Ice, etc.

Bill Skamarock, Joe Klemp,
Michael Duda, Sang-Hun Park,
Laura Fowler  
Todd Ringler  
John Thuburn  
Max Gunzburger  
Lili Ju

NCAR/NSF  
LANL/DOE  
Exeter University  
Florida State University  
University of South Carolina
Why Voronoi Tessellations (Hexagons)?

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

**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
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Dynamical Core Development

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

**Atmospheric solvers:** 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.

**Test Suite**
*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.
Jablownowski and Williamson (2006) baroclinic wave test case, day 9

~120 km cell spacing

$\Delta t = 900$ s

$\Delta \tau = 150$ s

26 levels

Vertically-stretched grid.

MPAS nonhydrostatic core
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

WRF Workshop June 2010
~ 60 km cell-center spacing

~ 240 km cell-center spacing

~ 120 km cell-center spacing

(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

WRF Workshop June 2010
Supercell simulations, reference cloud model and MPAS
500 m grid, horizontal cross sections, solution at 2 hours

(from Sang-Hun Park)
Supercell simulations, reference cloud model and MPAS
500 m grid, solution at 2 hours, vertical cross sections

(from Sang-Hun Park)
Beyond WRF: MPAS - Summary

3D Solvers
- 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.

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

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