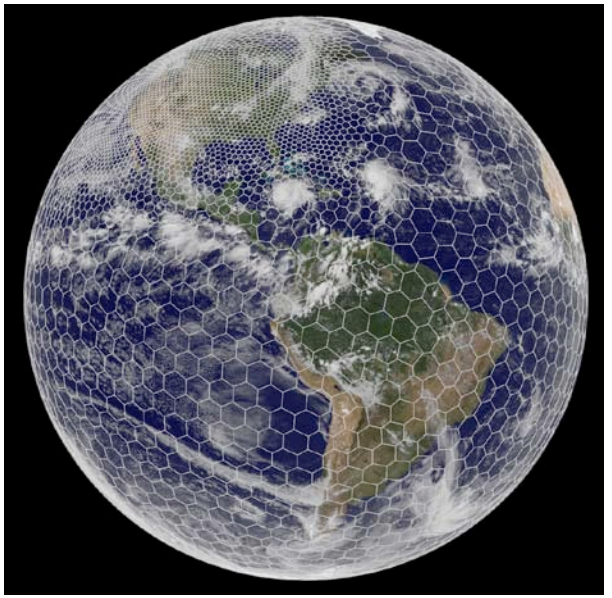
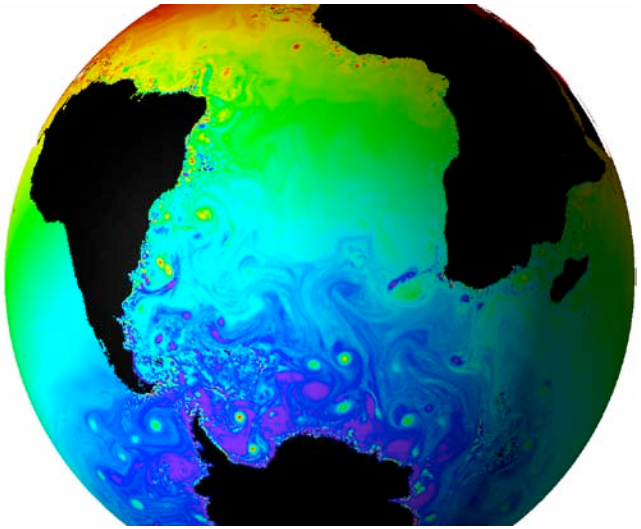
MPAS
Model for Prediction Across Scales

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



Jointly developed, primarily by NCAR and LANL/DOE



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

Project leads: Todd Ringler (LANL)
Bill Skamarock (NCAR)

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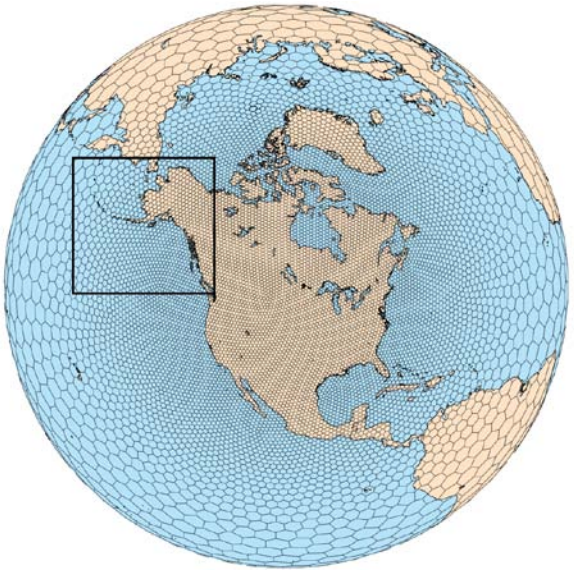
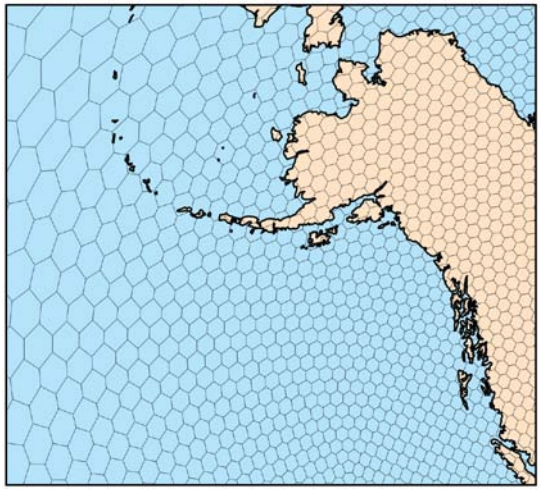
MPAS
Model for Prediction Across Scales

MPAS-Atmosphere



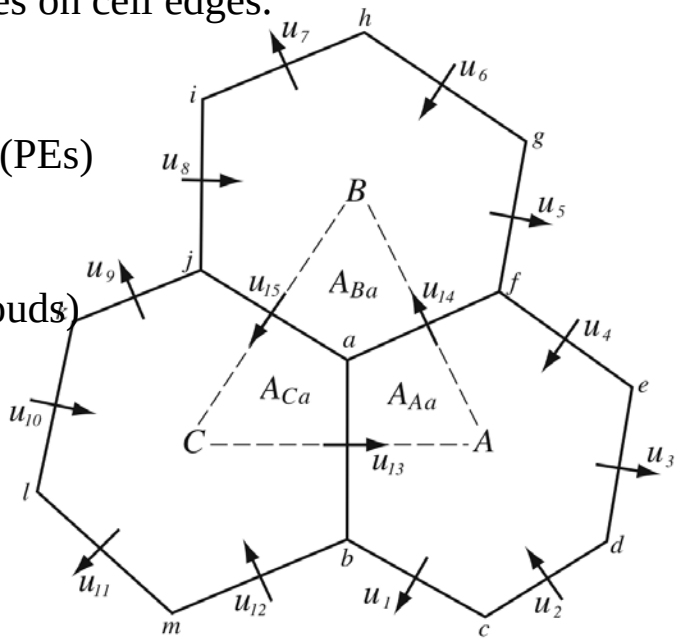


Unstructured spherical centroidal Voronoi meshes

Mostly *hexagons*, some pentagons and 7-sided cells.
Cell centers are at cell center-of-mass.
Lines connecting cell centers intersect cell edges at right angles.
Lines connecting cell centers are bisected by cell edge.
Mesh generation uses a density function.
Uniform resolution – traditional icosahedral mesh.

C-grid

Solve for normal velocities on cell edges.



Solvers

(1) hydrostatic equations (PEs)
(2) Fully compressible nonhydrostatic equations (explicit simulation of clouds)

Solver Technology

Integration schemes are similar to WRF.

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MPAS: Current Status

Atmosphere (MPAS-A)

Hydrostatic solver (MPAS-AH):

Implemented in a CESM/CAM branch (2010-2011).

APE and AMIP simulations with uniform and variable meshes.

Nonhydrostatic solver (MPAS-ANH):

Will replace MPAS-AH in CESM/CAM in 2013 (MPAS-CAM port is underway).

NWP testing on uniform and variable-resolution meshes is underway outside CESM/CAM

Testing within cycling DA system (DART) has begun.

Year-long free forecasts are being produced for comparison with WRF-NRCM.

Physics - WRF-NRCM, NCEP GFS/CFS (port in progress), CESM/CAM.

Parallelization - MPI only at present.

MPAS-ANH port: currently addressing

– *vestiges of a hardwired pressure vertical coordinate in physics*

– *PIO performance issues for dense unstructured meshes*

We expect to complete the initial port in the next few months.

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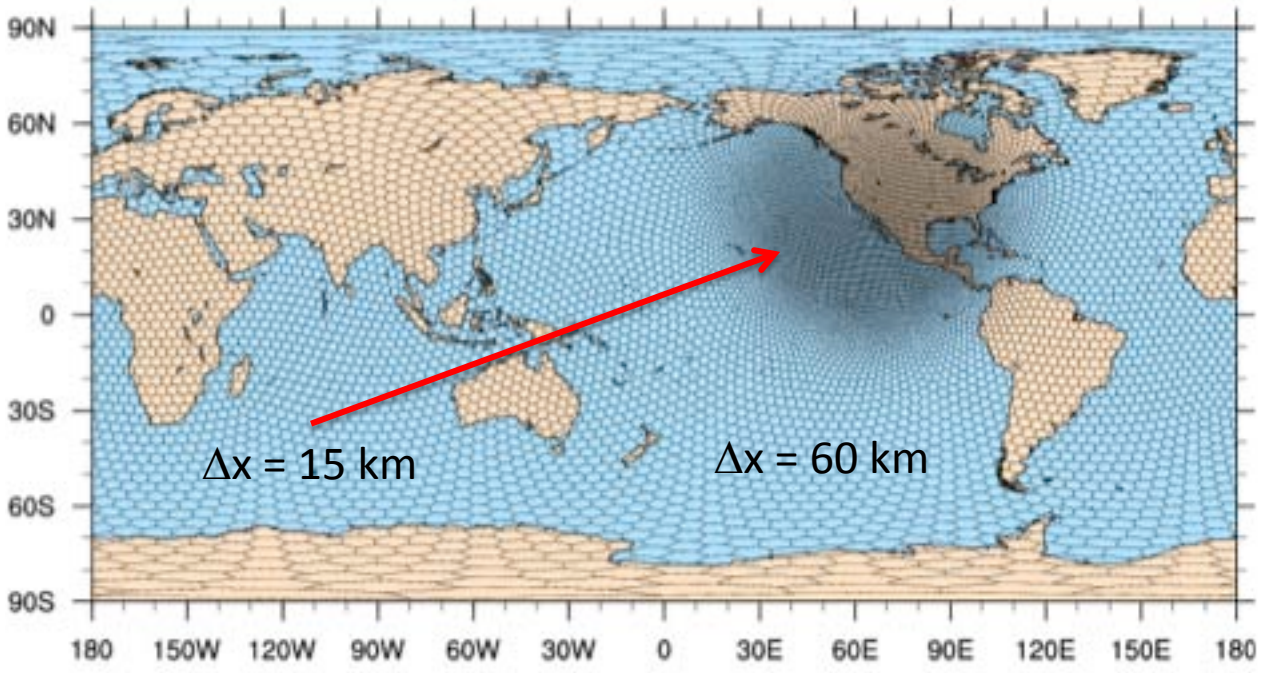
MPAS-A Forecast Tests

Current MPAS Physics:	WSM6 cloud microphysics Kain_Fritsch or Tiedtke convection Monin-Obukhov surface layer YSU pbl, Noah land-surface RRTMG lw and sw or CAM radiation.

MPAS mesh (4x finer than below), 41 levels



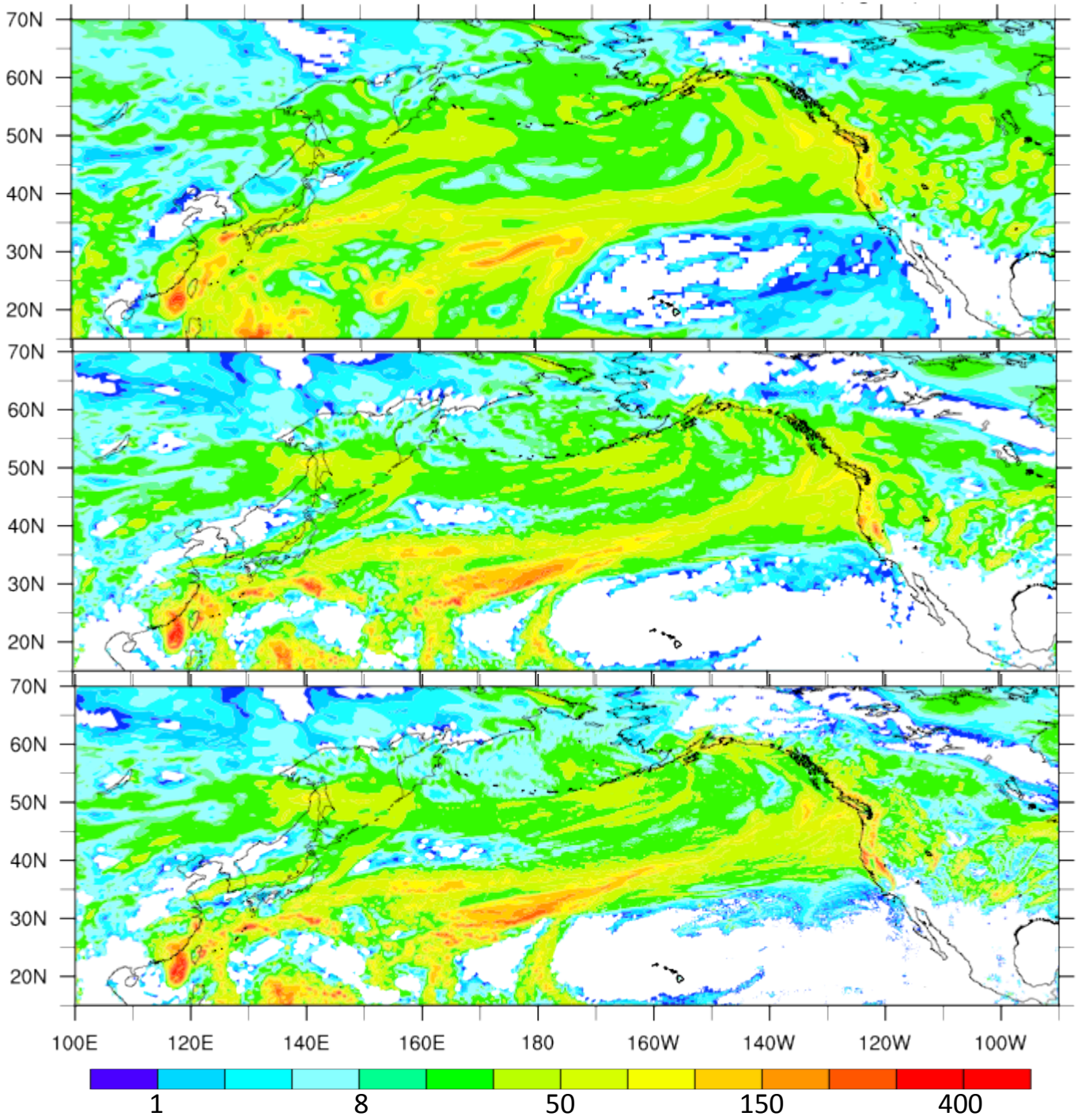
Eastern Pacific refinement

26 October 2010
5 day accumulated
precipitation (mm)

CFSR (~ 40 km)

MPAS-A (60 km)
uniform resolution
Smagorinsky

MPAS-A (60-15 km)
variable resolution
Eastern Pacific ref.
Smagorinsky,
(Δx^2 scaling)



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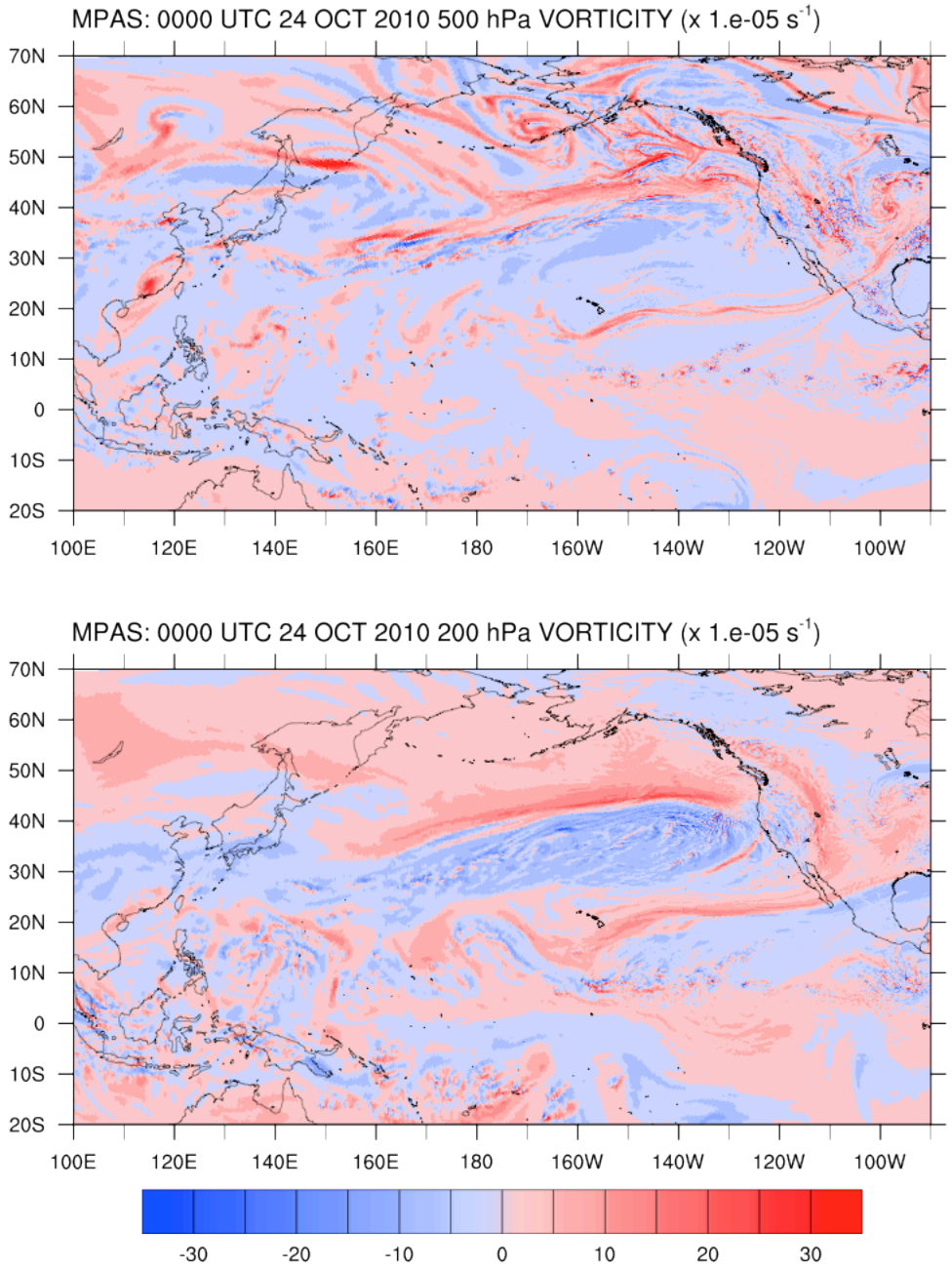
MPAS-A (60 – 15 km mesh)
Eastern Pacific refinement
21 October initialization

East-Pac mesh (Δx = 60-15 km)
Smagorinsky, Δx^2 scaling;
background $K_4 = 1 \times 10^{11}\ m^4 s^{-1}$
(15 km mesh value, Δx^4 scaling)



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MPAS-A simulations on Yellowstone

Global, uniform resolution.

6 simulations using average cell-center spacings:

60, 30, 15, 7.5 (2 - with and without convective param) and 3 km.

Cells in a horizontal plane: 163,842 (60 km), 655,362 (30 km),
2,621,442 (15 km), 10,485,762 (7.5 km) and 65,536,002 (3 km).

41 vertical levels, WRF-NRCM physics, prescribed SSTs.

Hindcast periods:

Completed:

23 October – 2 November 2010 (60, 30, 15 – (2 conv params))

23 October – 31 October (7.5 meshes, convective param on/off)

23 October – 29 October 2010 (3 km mesh)

In progress:

27 August – 1 September 2010, active TC period (3 km - almost complete)

Next up:

15 January – 4 February 2009, MJO event (begin later this month)

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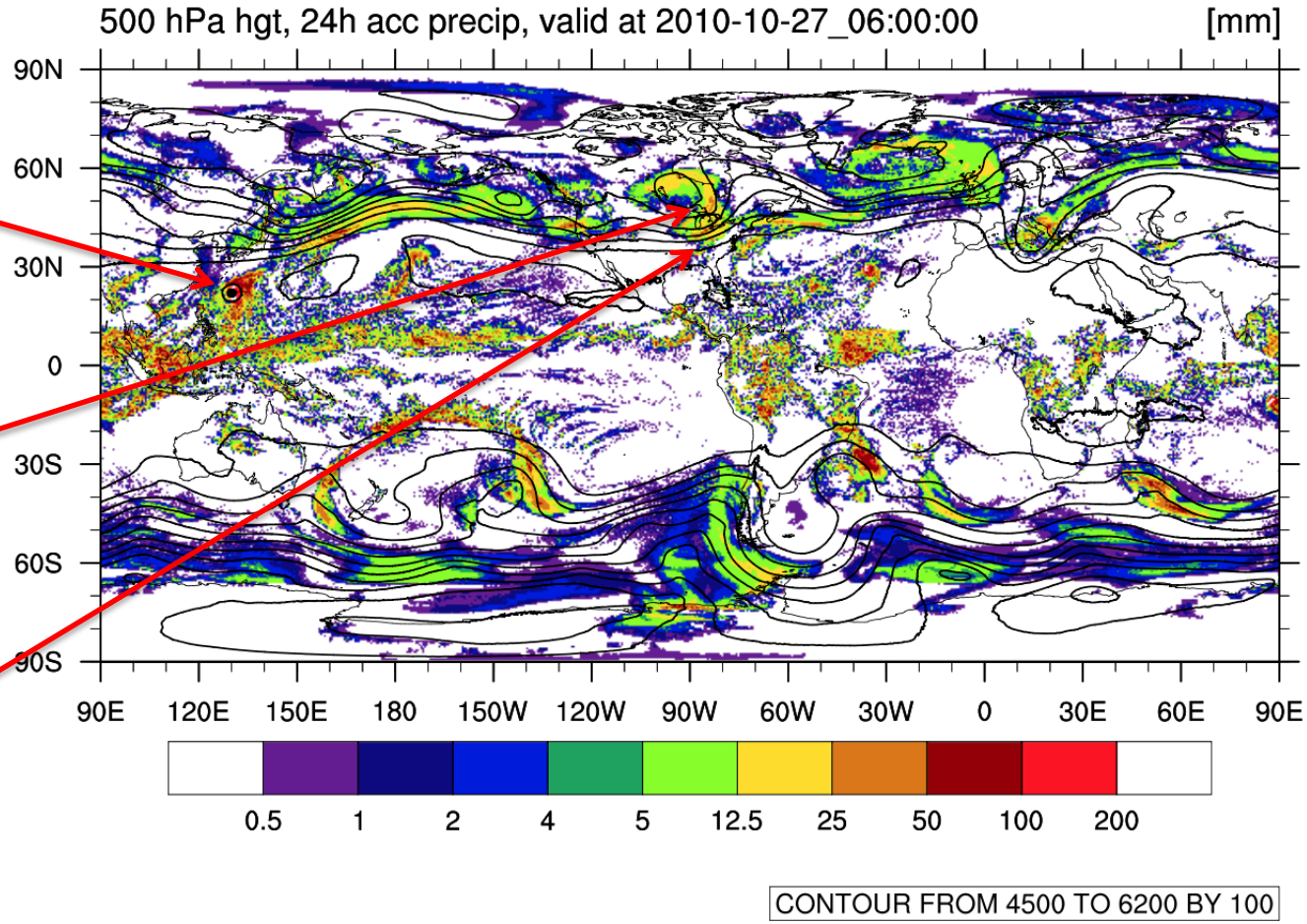
Model for Prediction Across Scales

3 km global MPAS-A simulation 2010-10-23 init

Tropical cyclone Chaba (cat 3)

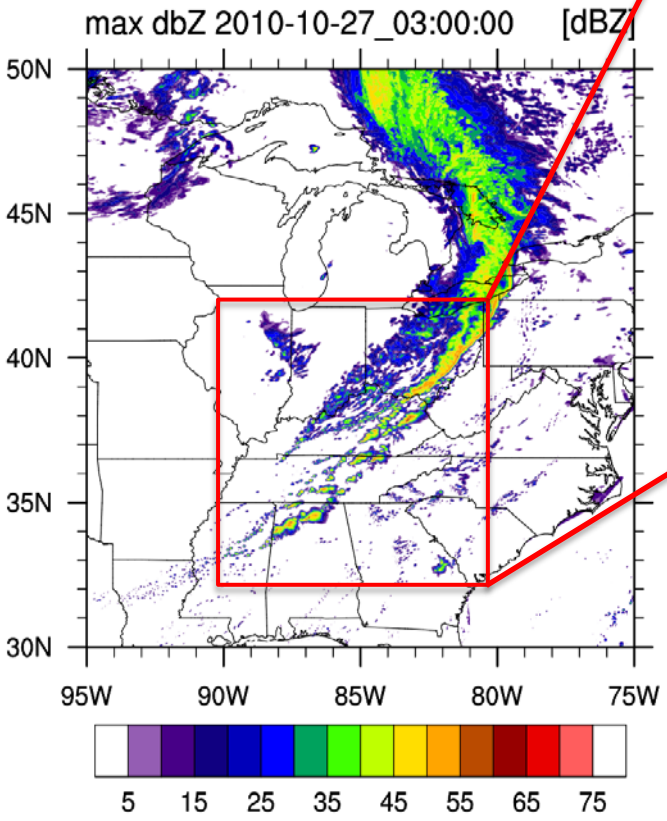
Observed extratropical cyclone with the lowest recorded surface pressure in North America

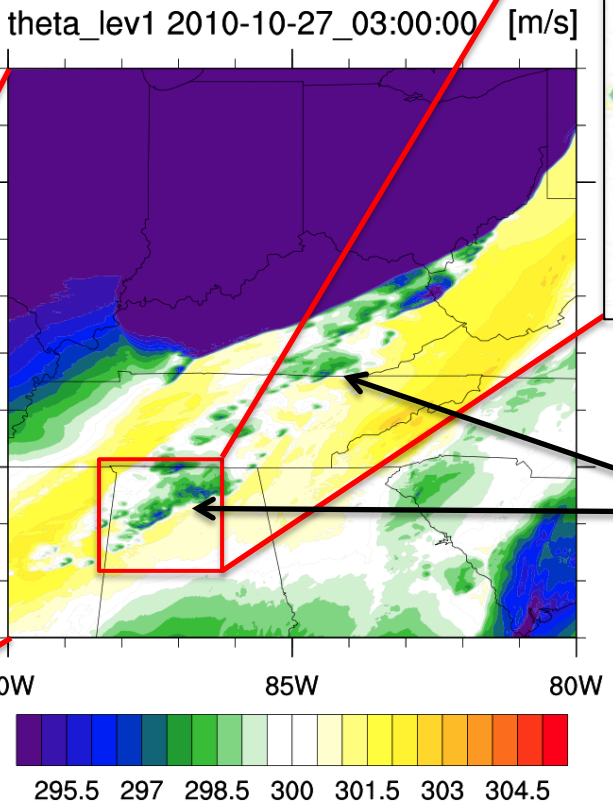
Isolated tornadic storms observed in warm sector ahead of the cold front

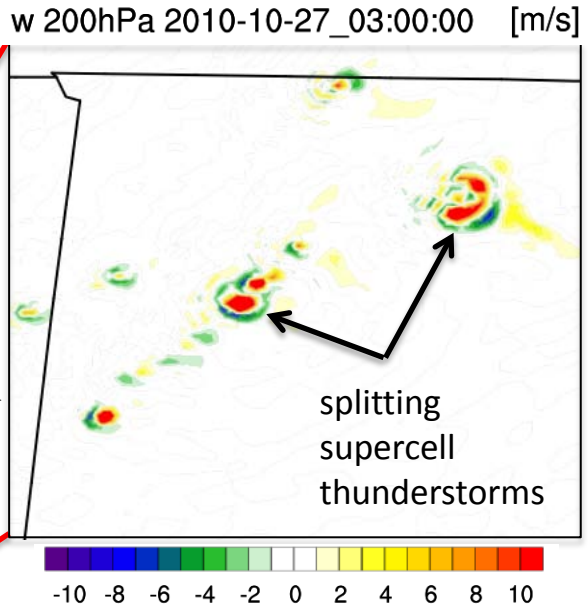


MPAS
Model for Prediction Across Scales

3 km global MPAS-A simulation
2010-10-23 init





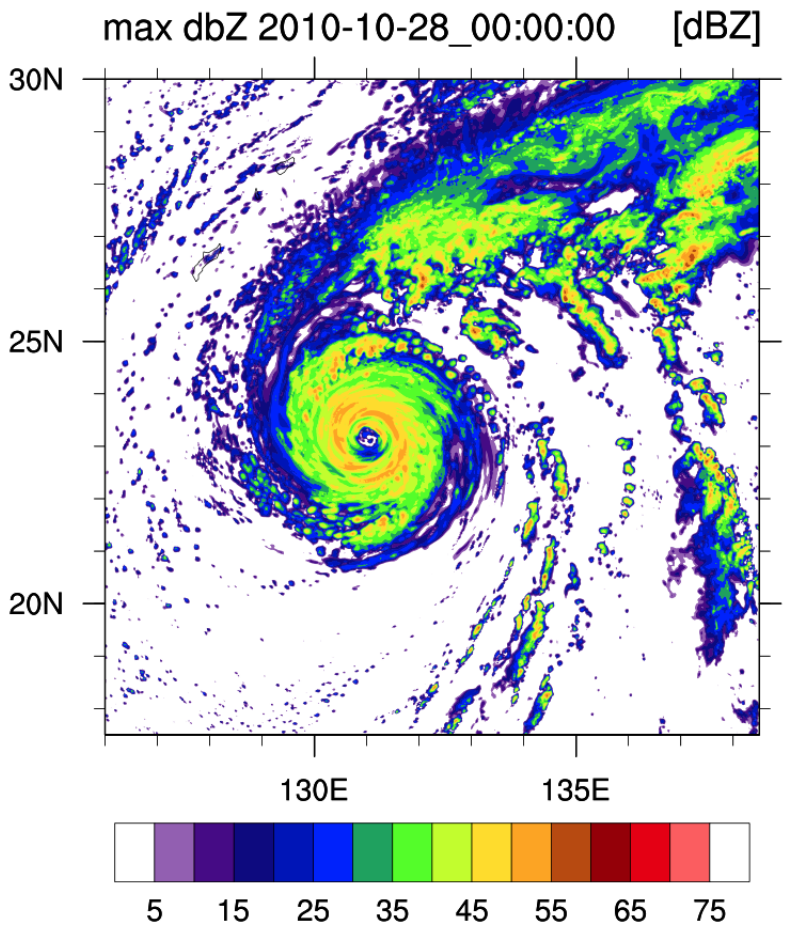


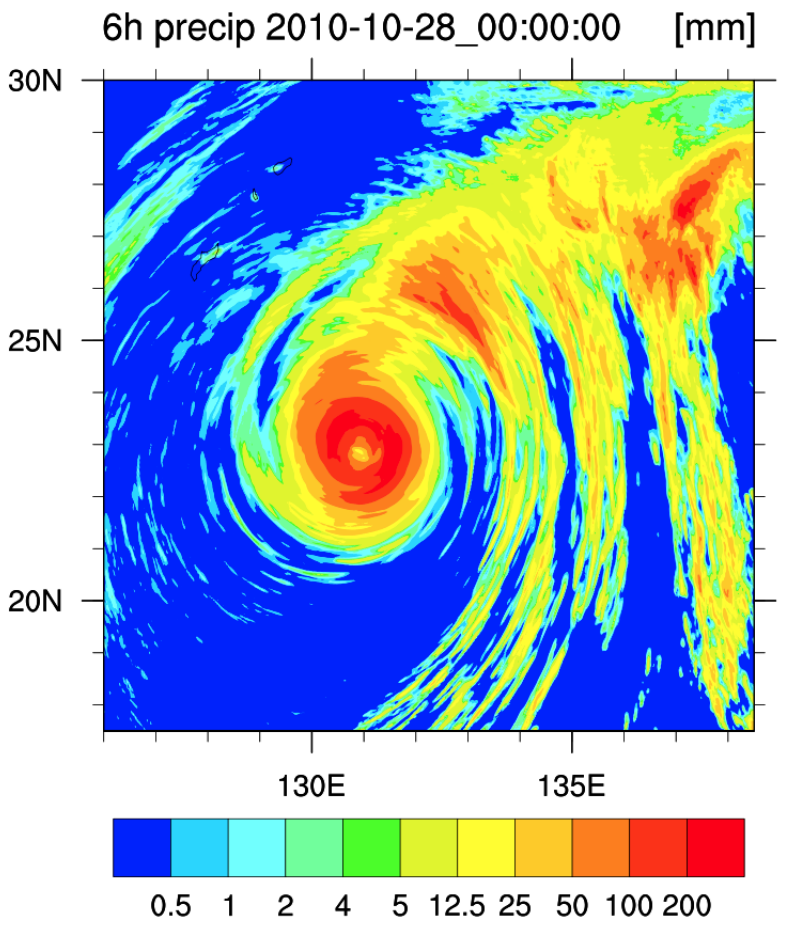
Cold-pools from isolated storms ahead of the cold front

MPAS
Model for Prediction Across Scales

3 km global MPAS-A simulation
2010-10-23 init

Typhoon Chaba





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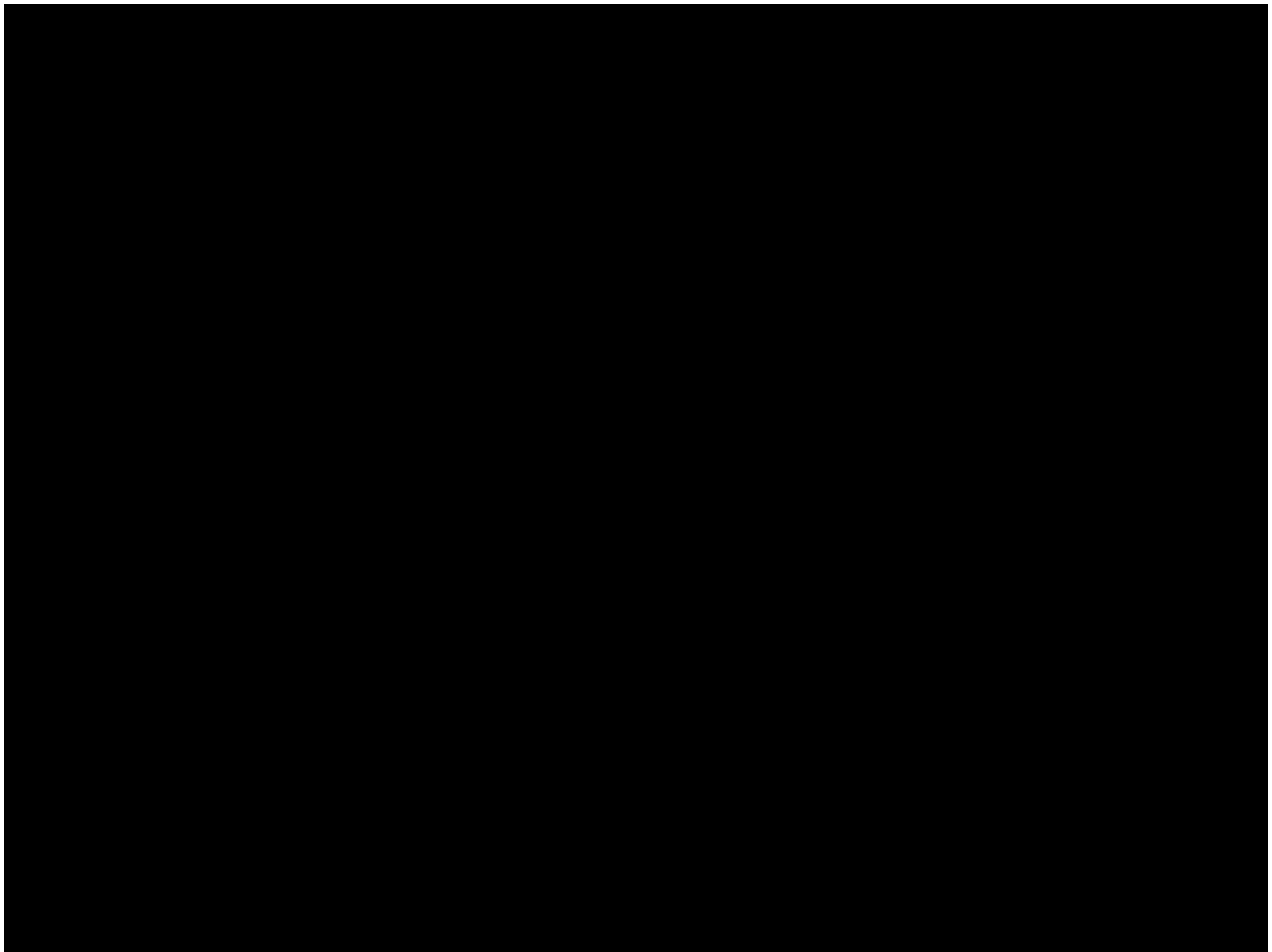
MPAS 3km global simulations, 23 Oct – 2 Nov 2010

Western Pacific Warm Pool; 25 October 12 UTC – 27 October 12 UTC

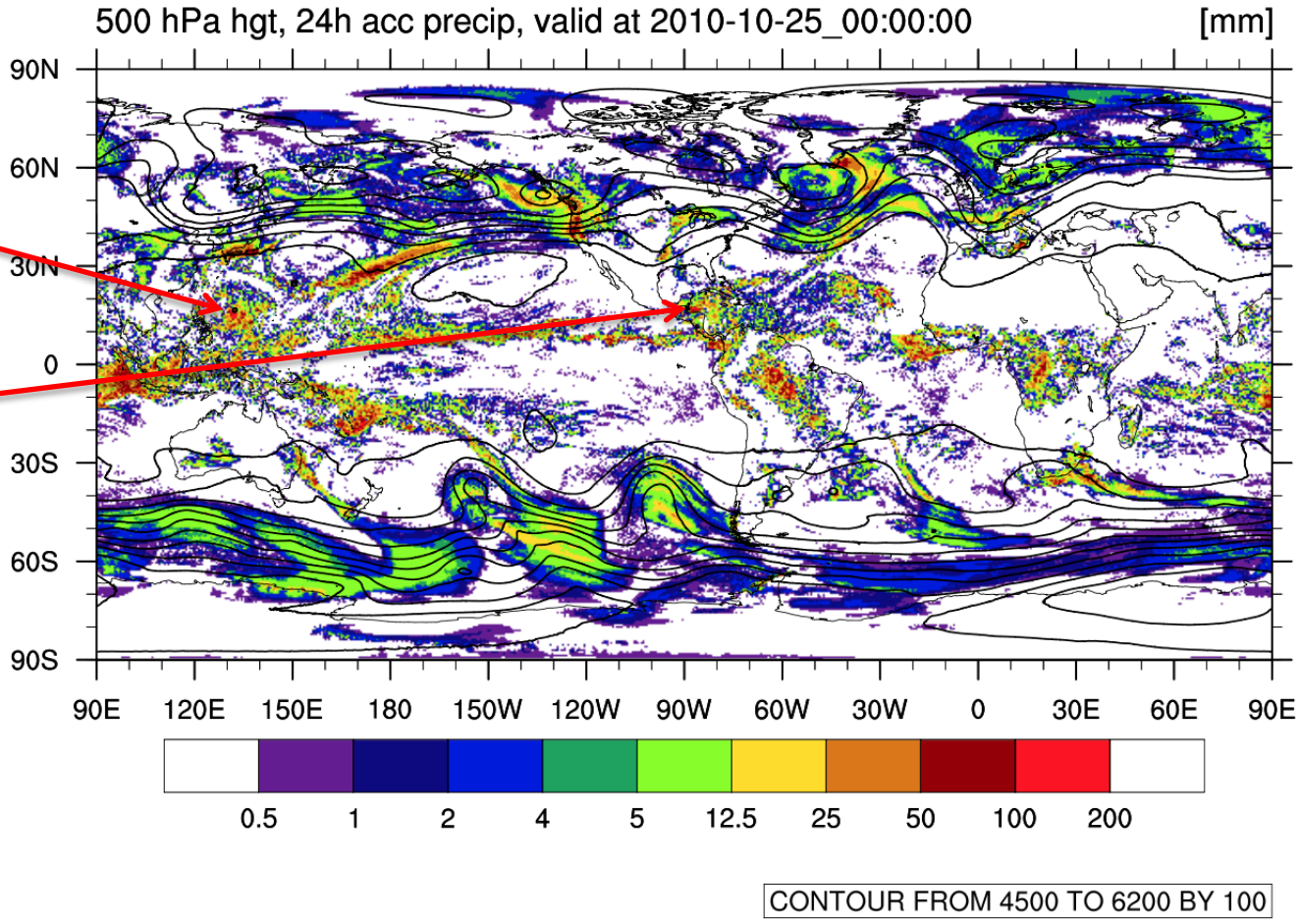


MPAS
Model for Prediction Across Scales

3 km global MPAS simulation 2010-10-23 init

Tropical cyclone Chaba (cat 3)

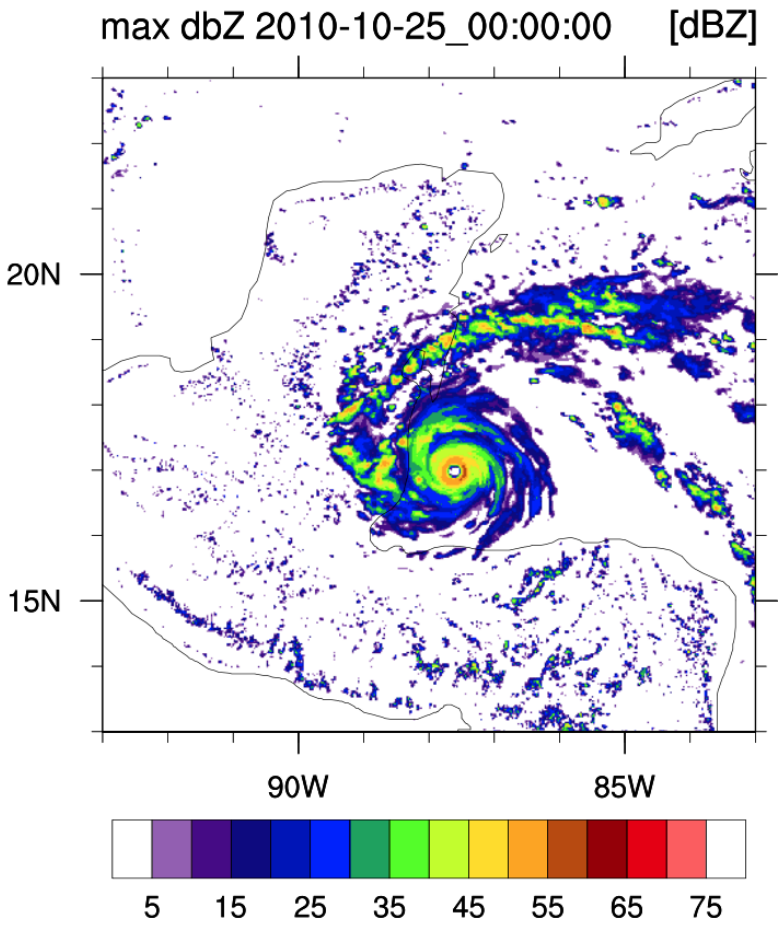
Tropical cyclone Richard (cat 2)

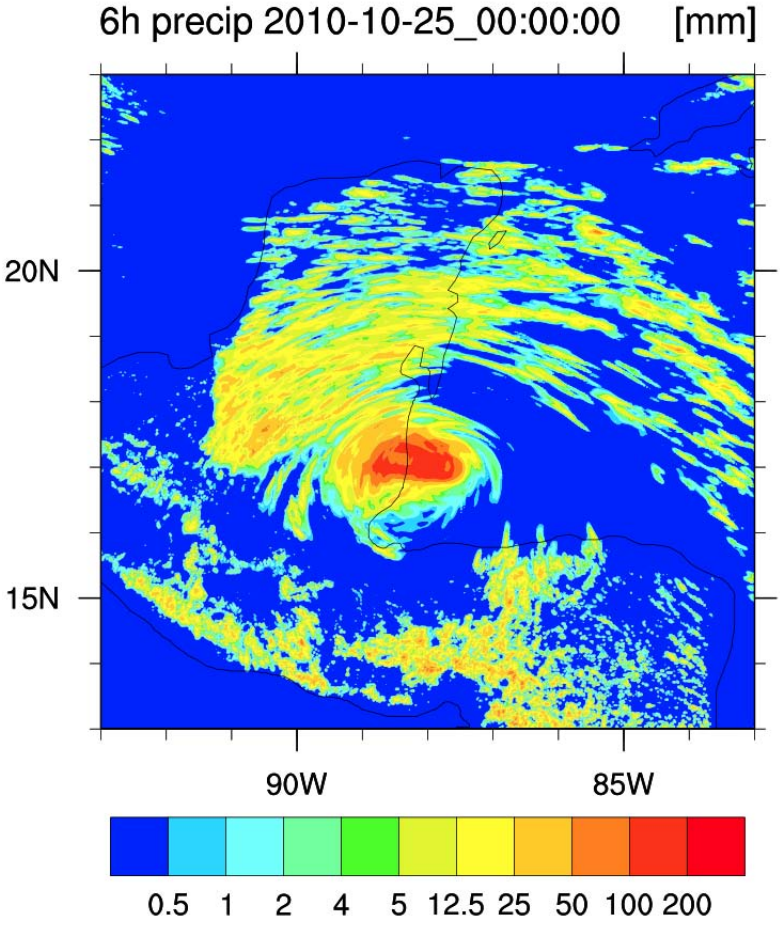


MPAS
Model for Prediction Across Scales

3 km global MPAS simulation 2010-10-23 init

Hurricane Richard





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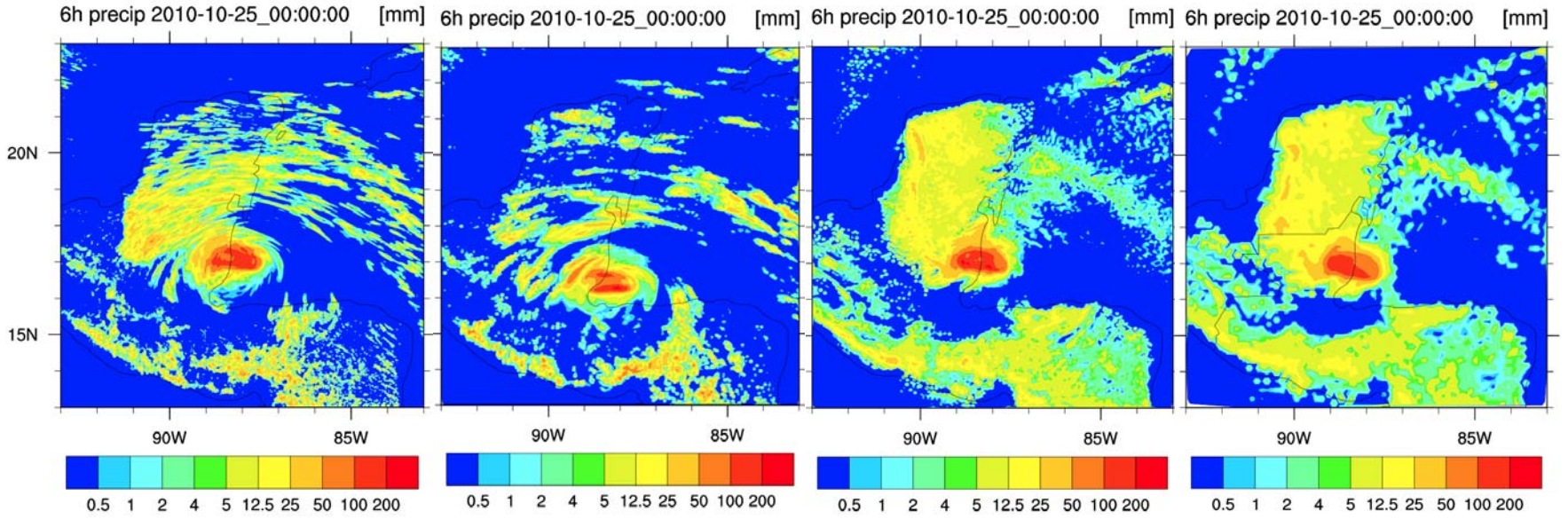
MPAS global simulations, TC Richard



3 km

7.5 km
no convective
parameterization

7.5 km
KF convective
parameterization

15 km
KF convective
parameterization

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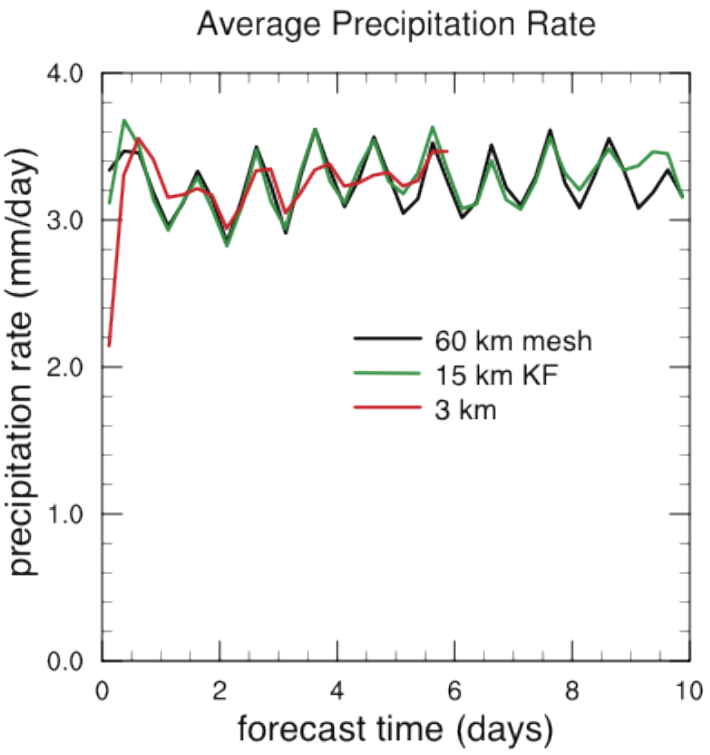
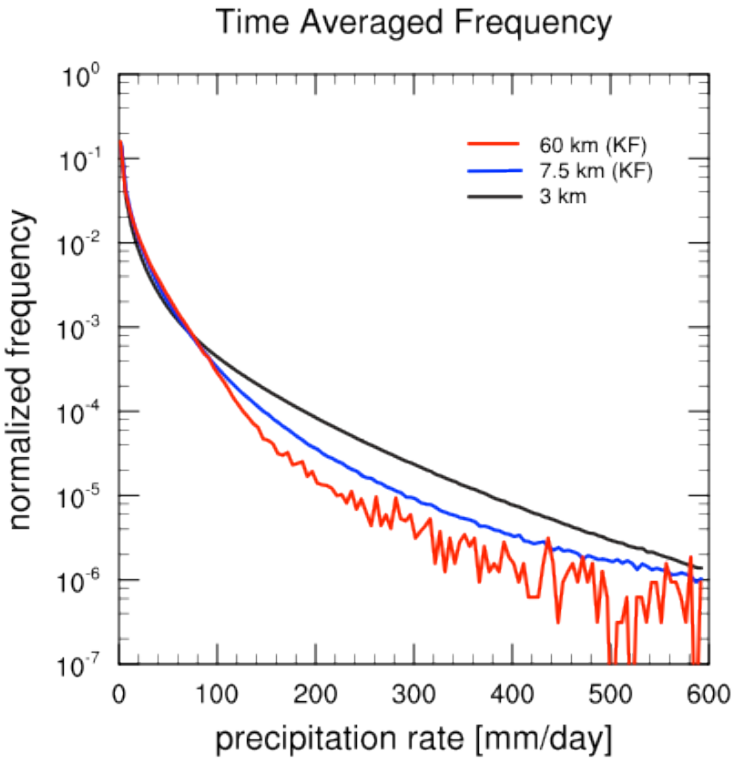
Precipitation statistics 2010-10-23 init

Averaged precipitation rates are computed for each 6-hour period in the forecast (0-6, 6-12, etc) and plotted at the midpoint of the period.

5-day time average over forecast days 2 - 6





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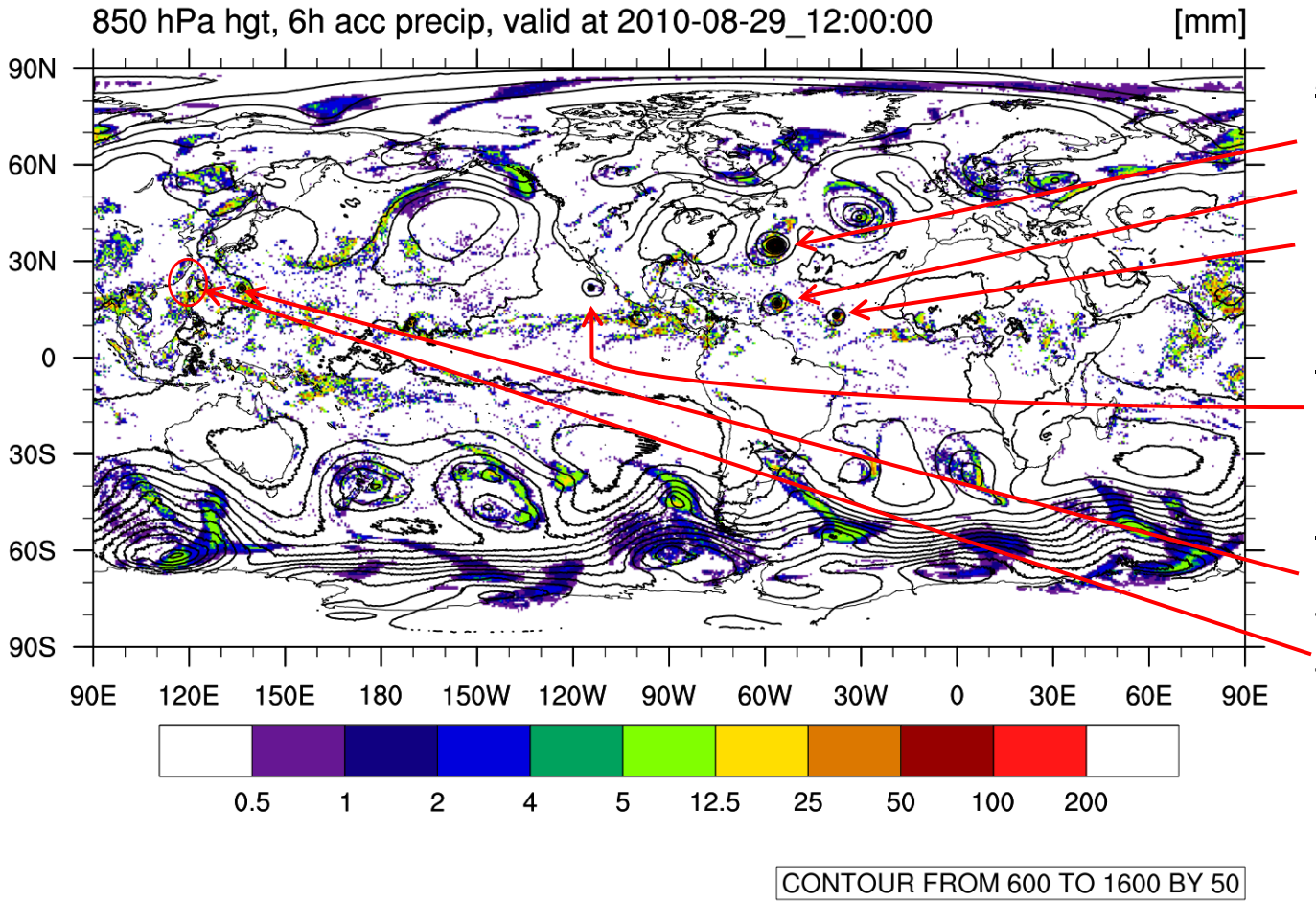
MPAS 3km global simulations, 27 Aug– 1 Sept 2010



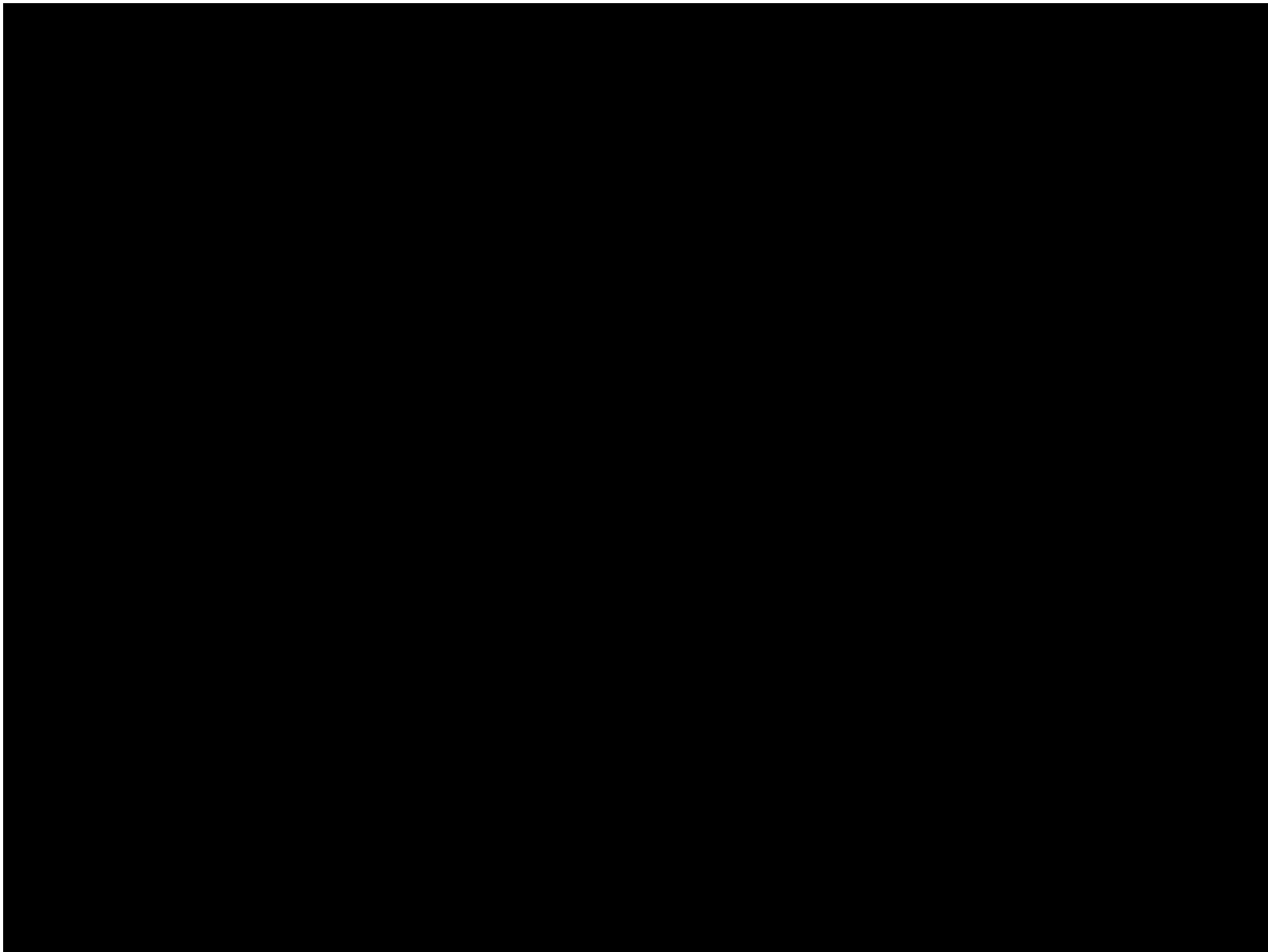
Atlantic Basin
Danielle
Earl
Fiona

Eastern Pacific
Frank (disp. 8/28)

Western Pacific
Kompasu
TS Lionrock (missing??)
TD Nantheum (missing)

MPAS
Model for Prediction Across Scales

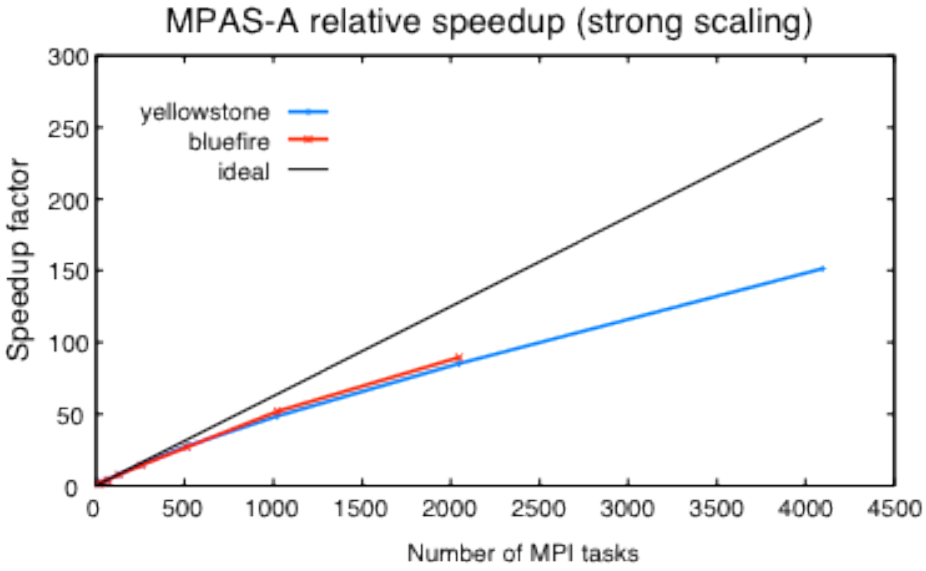
MPAS 3km global simulations, 27 Aug– 2 Sept 2010

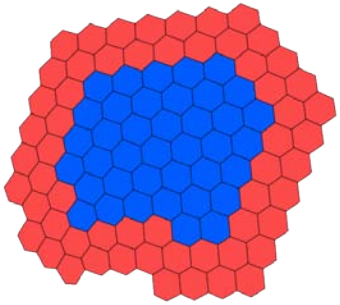


MPAS
Model for Prediction Across Scales

MPAS-Atmosphere scaling

60 km global mesh
(163,842 horizontal cells).
6 hour simulation
40 vertical levels.
8 scalars with FCT.
Full physics





Block plus two layers of halo/ghost cells

Yellowstone results

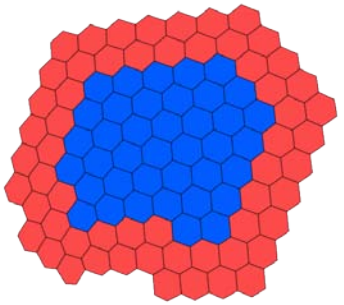
MPI tasks	Cells per task	Speedup	Efficiency
16	10240	1.00	100.00%
32	5120	1.97	98.40%
64	2560	3.90	97.49%
128	1280	7.67	95.88%
256	640	14.65	91.57%
512	320	27.56	86.12%
1024	160	48.49	75.77%
2048	80	85.21	66.57%
4096	40	151.43	59.15%

MPAS
Model for Prediction Across Scales

MPAS optimizations

Communication optimizations to be implemented:
- Aggregation of same-stencil halo communications
- Overlap computation and communication
- Switch to one-sided communication?

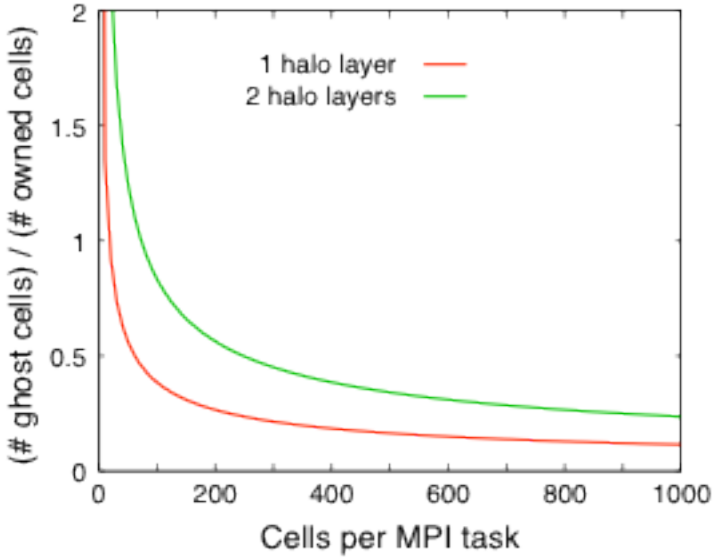
Computation optimizations to be implemented:
- Tighter loop bounds to minimize redundant computation



Block plus two layers of halo/ghost cells

For 2 halo layers, the number of ghost (halo) cells, N_G, is approximately related to the number of owned cells, N_O, by

$$N_g = \pi \left(\sqrt{\frac{N_o}{\pi}} + 2 \right)^2 - N_o$$



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Summary: MPAS-ANH/CESM/CAM plans

Complete MPAS-ANH port: currently addressing

– *vestiges of a hardwired pressure vertical coordinate in physics*

– *PIO performance for dense unstructured meshes*

We expect to complete the initial port in the next few months.

MPAS-ANH in CAM: testing (with CAM5 physics)

– *short APE simulations; AMIP tests.*

– *short (NWP) forecast tests, low O(50 km) and high (few km) resolution, uniform and variable resolution meshes.*

MPAS-ANH in CAM: begin applications testing and science

– *Variable-res mesh testing for regional climate applications (seasons – years), coupled-model testing.*

– *Process studies: convection and scale interactions; other applications*

– *Scale-aware physics development, especially for the 20-2 km gap.*

CESM/MPAS-ANH: community availability?

Further information:

MPAS-O: http://public.lanl.gov/ringler/files/multiResolutionOceanR1.pdf

MPAS-A: http://www.mmm.ucar.edu/people/skamarock/mpas_mwr_2012_final.pdf

MPAS: http://mpas.sourceforge.net/ (to be updated soon)

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