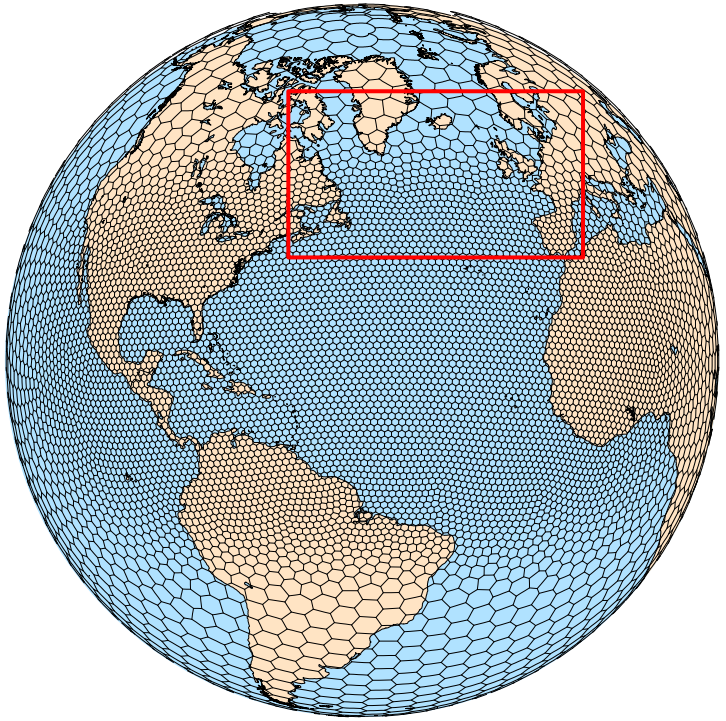
Status of CAM-MPAS Development

The Effects of Vertical Resolution in CAM-MPAS

Sang-Hun Park
William Skamarock
Peter Lauritzen
Michael Duda
Brian Eaton

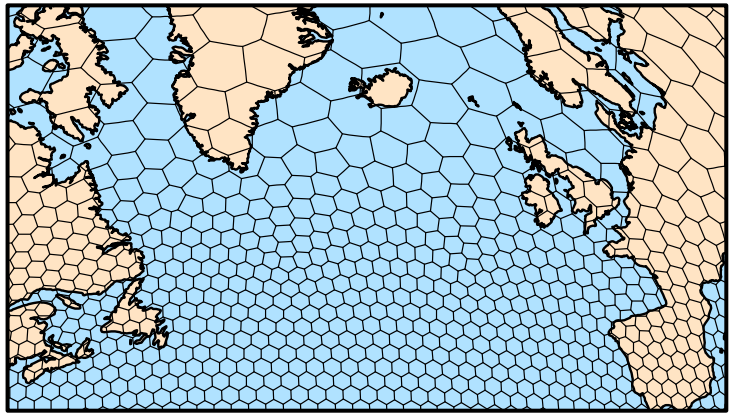
Global Nonhydrostatic Atmospheric Simulation with MPAS



MPAS
Model for Prediction Across Scales

- Bill Skamarock, Joe Klemp, Michael Duda, Laura Fowler, Sang-Hun Park
- National Center for Atmospheric Research

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



Collaboratively developed, primarily by NCAR and LANL/DOE

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

Los Alamos NATIONAL LABORATORY EST. 1943

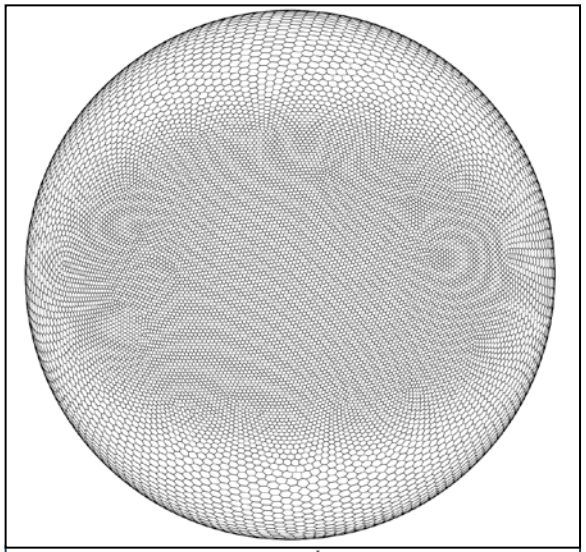
U.S. DEPARTMENT OF ENERGY | Office of Science

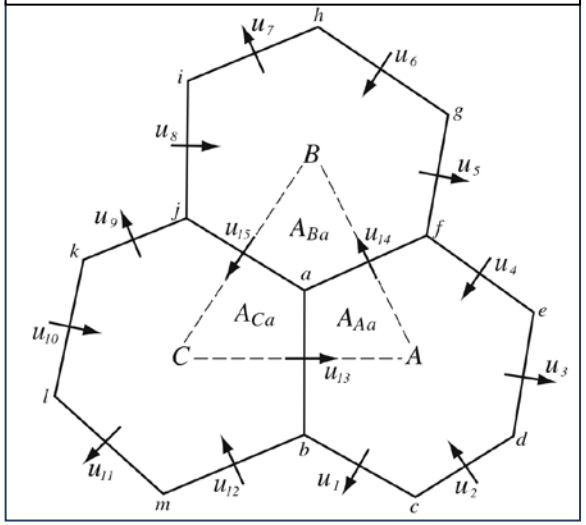
NSF

NESL

What is MPAS?

MPAS GRID :: Centroidal Voronoi Meshes





Unstructured spherical centroidal Voronoi meshes

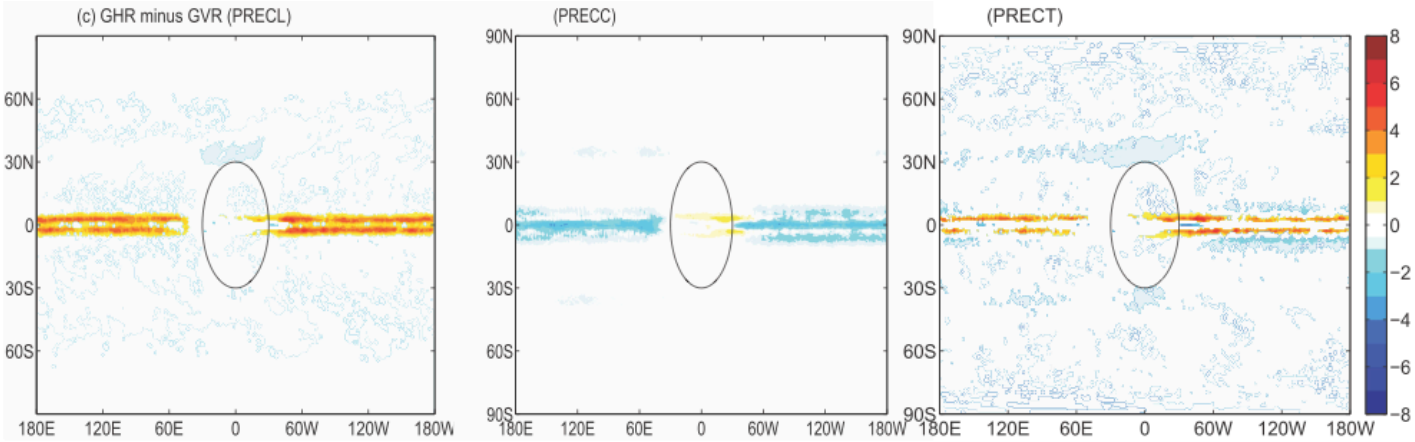
- Cell centers are at cell center-of-mass (centroidal).
- Cell edges bisect and are orthogonal to the lines connecting cell centers.
- Uniform resolution – traditional icosahedral mesh.
- Mostly *hexagons*, some pentagons and 7-sided cells

C-grid

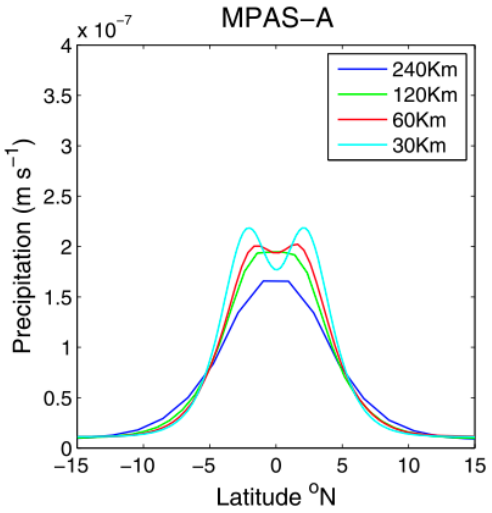
- Solve for normal velocities on cell edges.
- Gradient operators in the horizontal momentum equations are 2nd-order accurate.
- Velocity divergence is 2nd-order accurate for edge-centered velocities.
- Reconstruction of full velocity requires care.

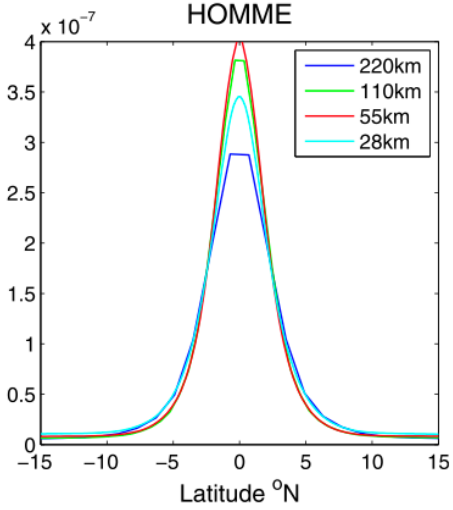
CAM-MPAS history

- Scientific Results only with hydrostatic core so far

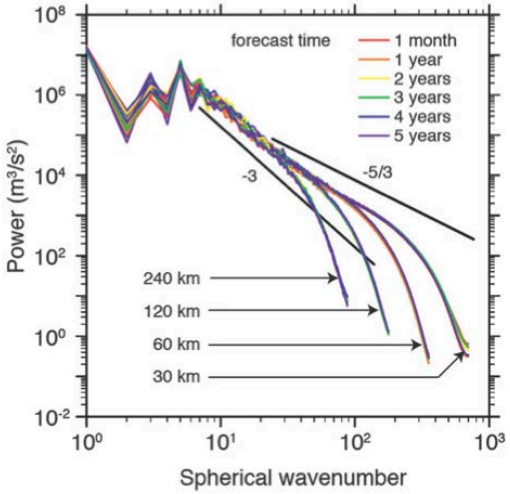


(Hagos et al., 2013)





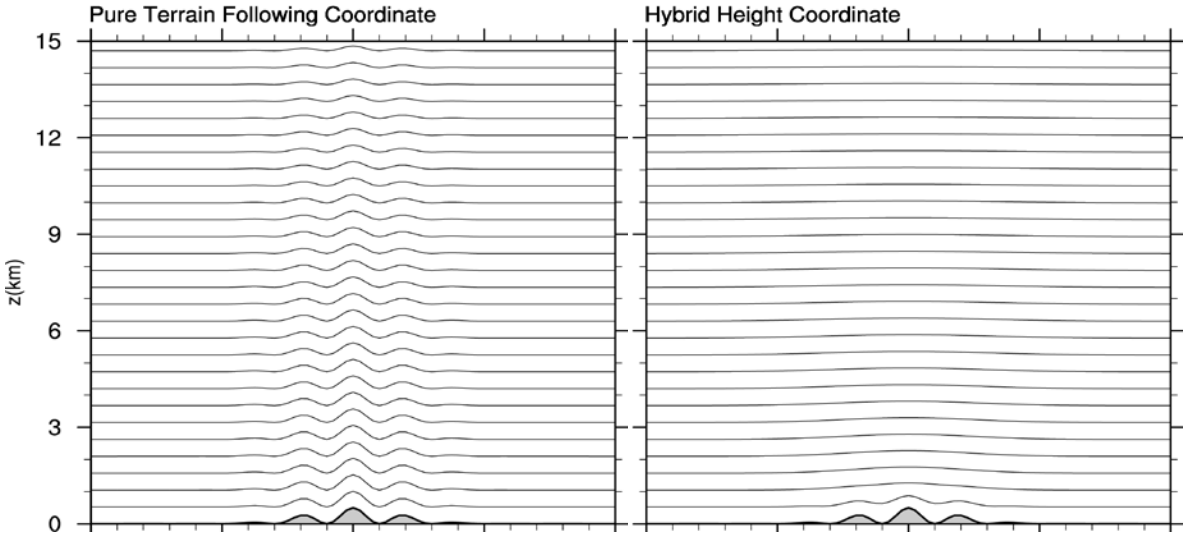
(Landu et al., 2014)



(Rauscher et al., 2013)

CAM-MPAS

- Scientific Results only with hydrostatic core so far
- MPAS hydrostatic vs. non-hydrstatic
  - Different equation set
  - Vertical coordinate (hybrid height)



  - In hydrostatic version, no more bug-fix

CAM-MPAS

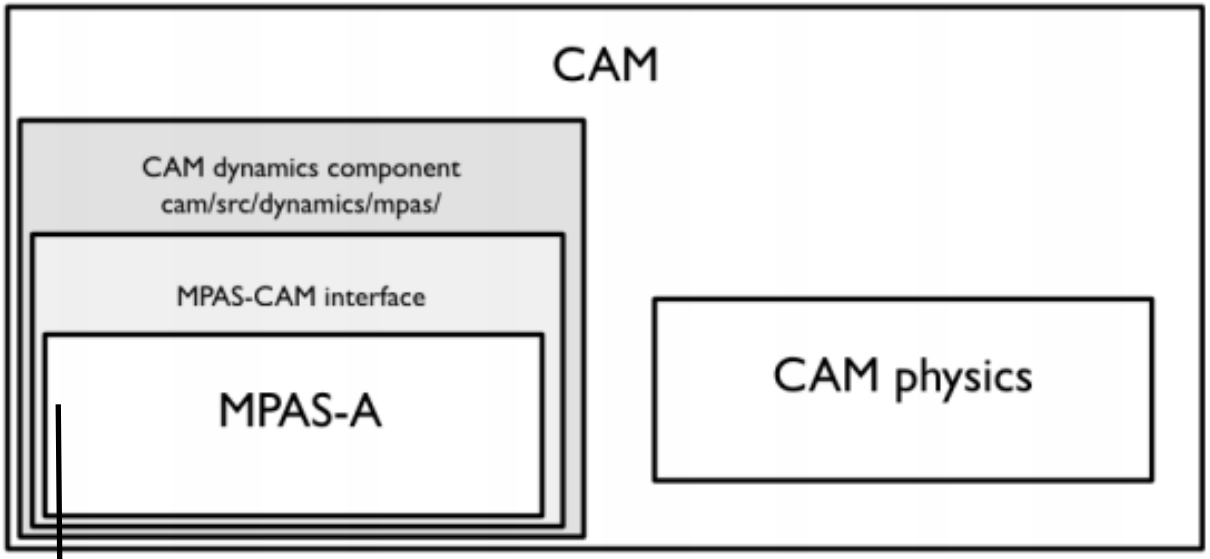
- History with non-hydrostatic MPAS

✓ Held-Suarez test (2014.2)

✓ Aqua-Planet Simulations (2014.6)

✓ AMIP Simulation (2015.1)

- CAM-MPAS framework



✓ Additional requirement files (not generated by automatically!)

- namelist.input
- Graph files for partitioning of meshes

CAM-MPAS configuration

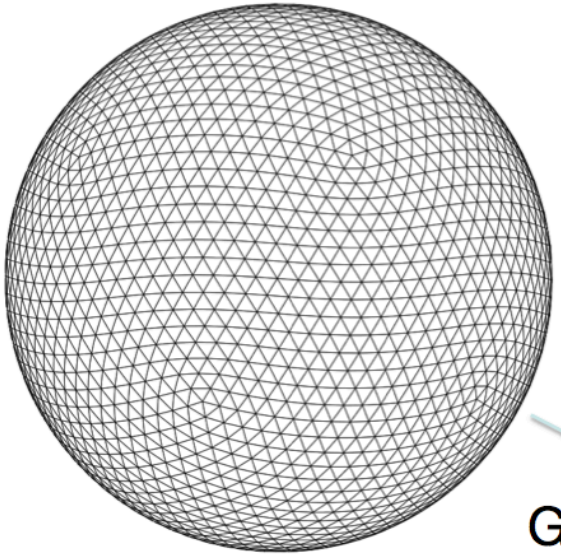
- **namelist.input**

```
&nhyd_model
 ...
   config_dt = 450.0                  :: dynamic time-step (no explicit definition in "atm_in")
   config_start_time = '0001-01-01_00:00:00'
 ...                                  :: start-time (should be defined for mpas-output)
   config_len_disp = 120000.0         :: actual mesh-size (for the smallest grid)
   config_visc4_2dsmag = 0.05
 ...                                  :: hyper diffusion coefficient

&damping
   config_zd = 32000.0                :: starting level for vertical damping option
   config_xnutr = 0.2                 :: damping coefficient
/
 ...
&restart
   config_do_restart = .true.         :: false for 'starup' run
/                                        true for 'continue' or 'branch' run
```

For more options, see MPAS tutorial
:: http://mpas-dev.github.io

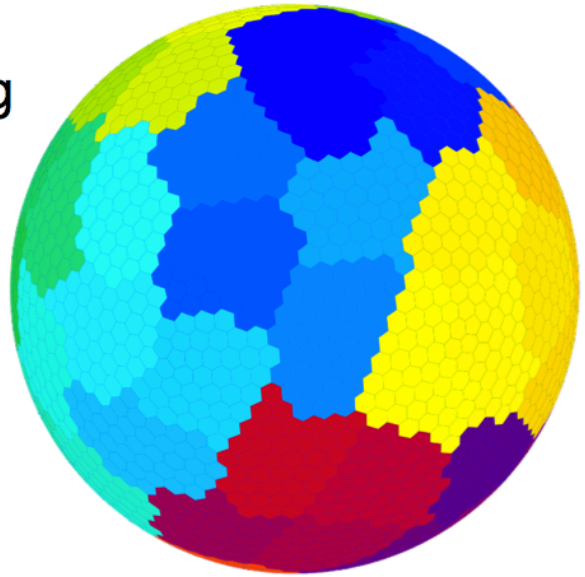
MPAS parallel decomposition



The *dual* mesh of a Voronoi tessellation is a Delaunay triangulation – essentially the connectivity graph of the cells

Parallel decomposition of an MPAS mesh then becomes a graph partitioning problem: ***equally distribute nodes among partitions (give each process equal work) while minimizing the edge cut (minimizing parallel communication)***

Graph partitioning



We use the Metis package for parallel graph decomposition

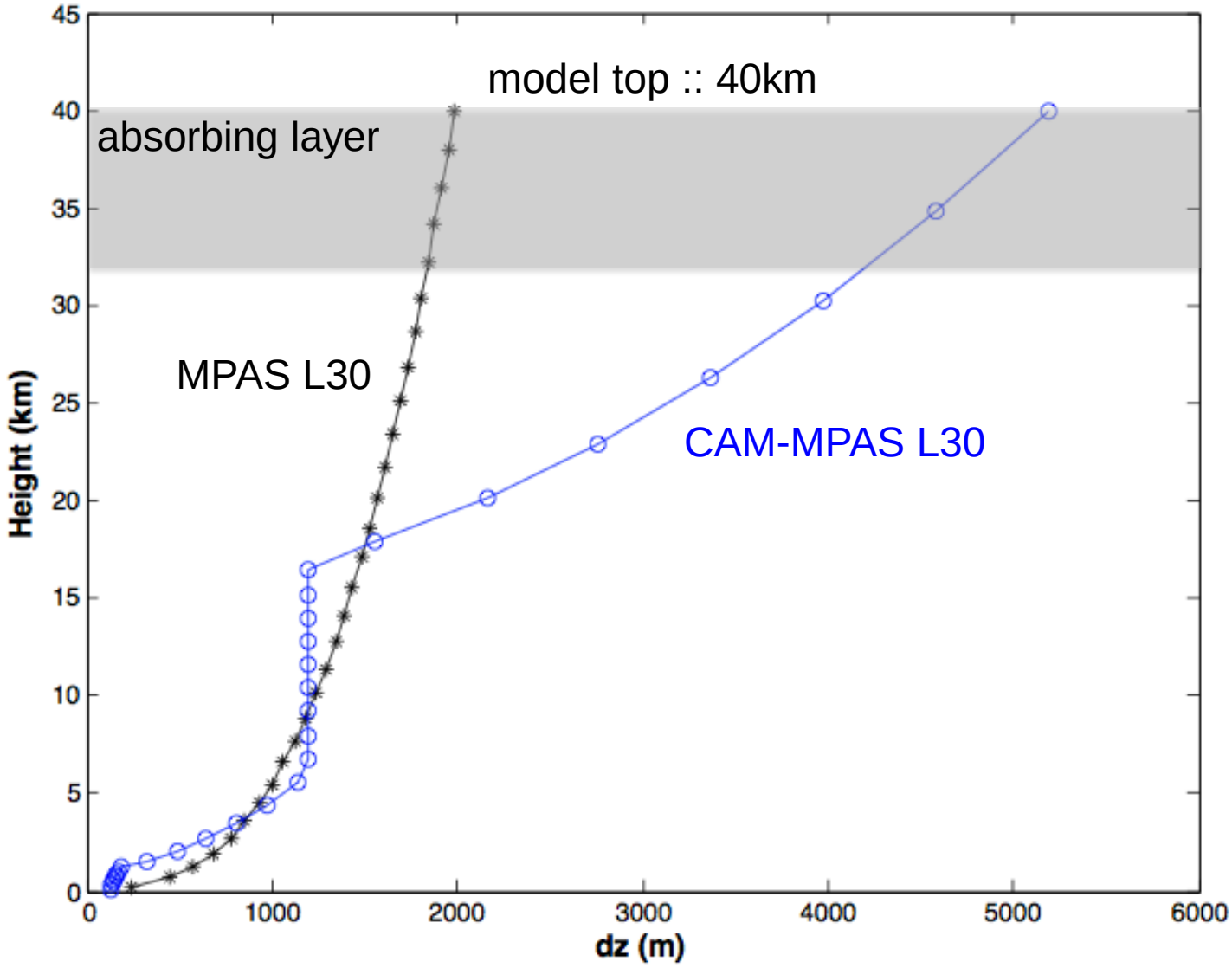
- Currently done as a pre-processing step, but could be done "on-line"

Metis also handles weighted graph partitioning

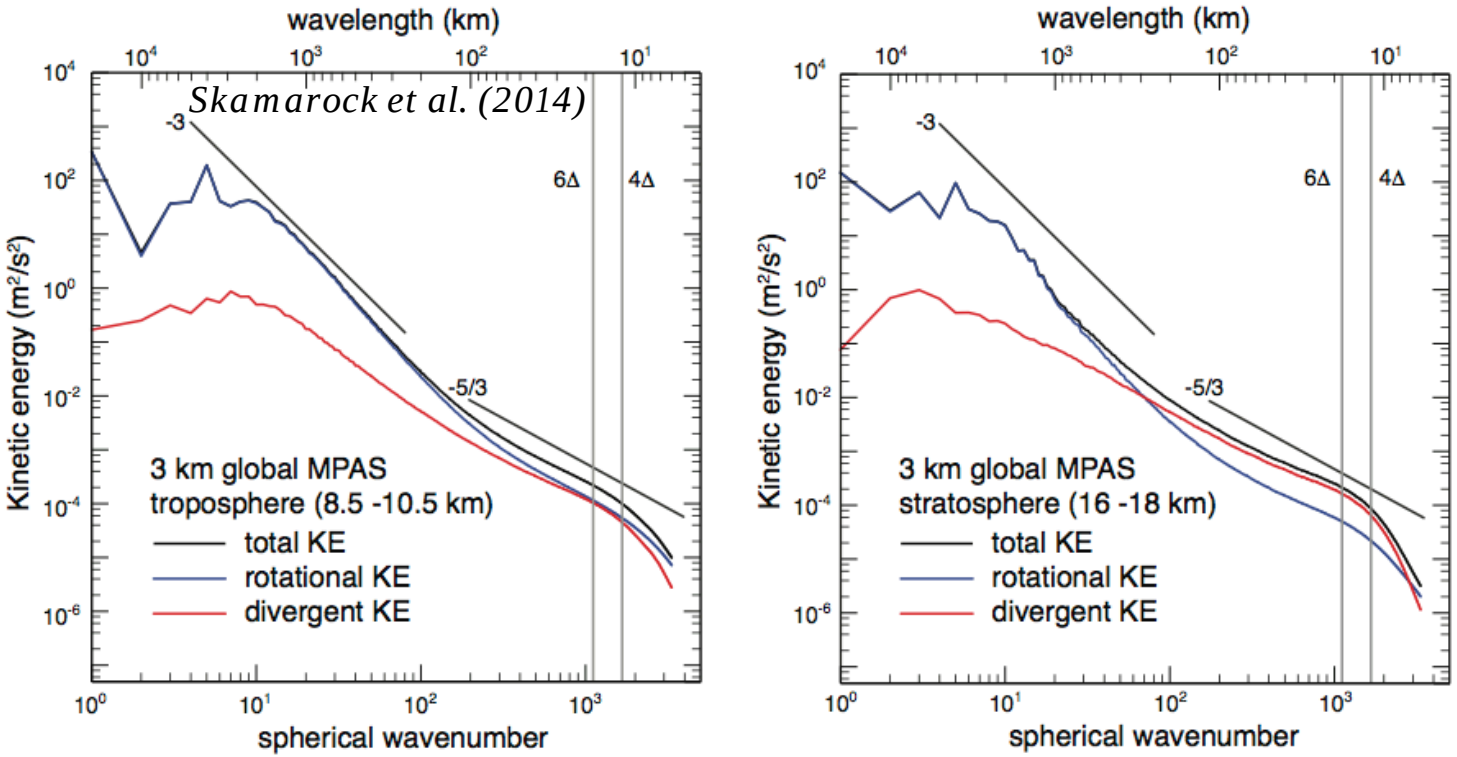
- Given *a priori* estimates for the computational costs of each grid cell, we can better balance the load among processes

From MPAS tutorial :: http://mpas-dev.github.io

CAM-MPAS vertical levels



MPAS Spectra



- MPAS diffusion :: 2D smagorinsky + hyper diffusion

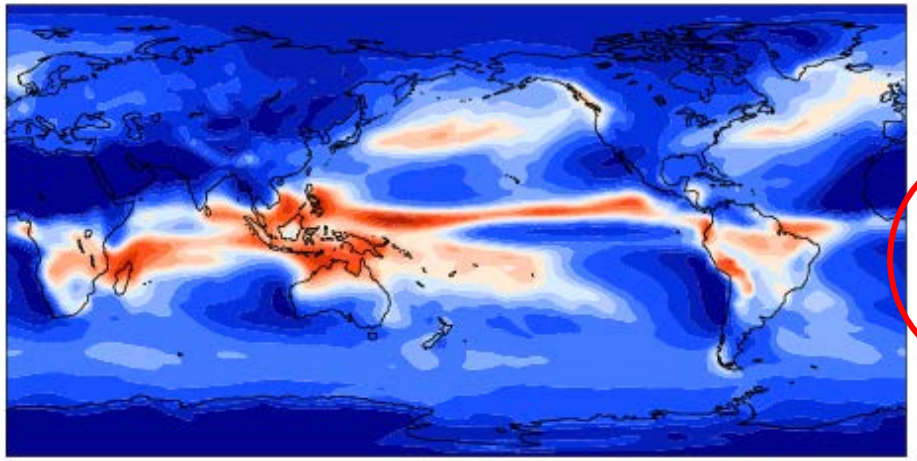
  hyper diffusion ~ $0.05 \times \triangle^3$

- units of $\nu_4[m^4/s]$

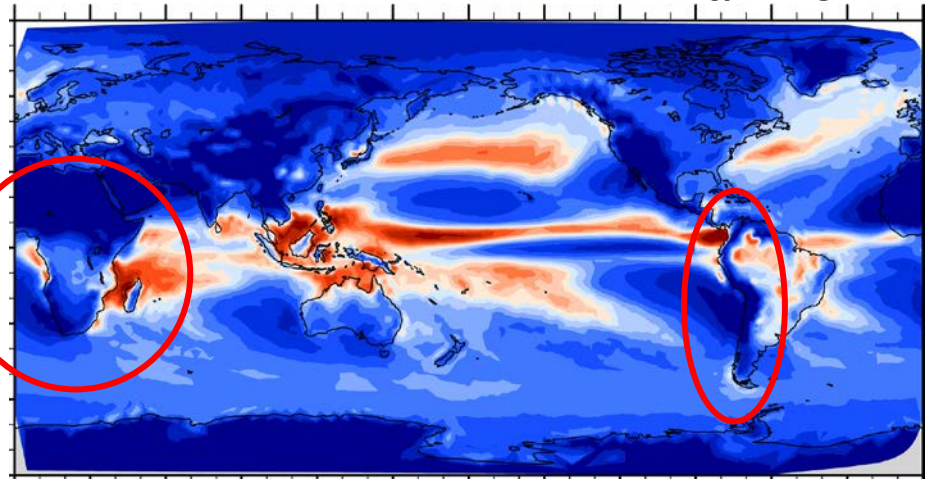
	240km	120km	60km	30km	15km
MPAS	6.5×10^{14}	8.6×10^{13}	1.1×10^{14}	1.35×10^{12}	1.7×10^{11}
CAM-SE	7.0×10^{15}	1.0×10^{15}	1.0×10^{14}	1.0×10^{13}	1.1×10^{12}

F_2000_CAM5 Case

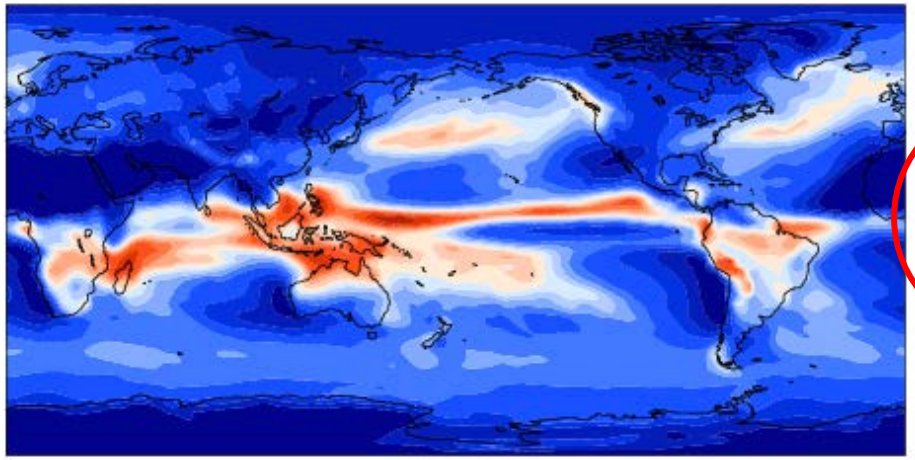
- **FV 1.9x2.5 DJF** max =16.15



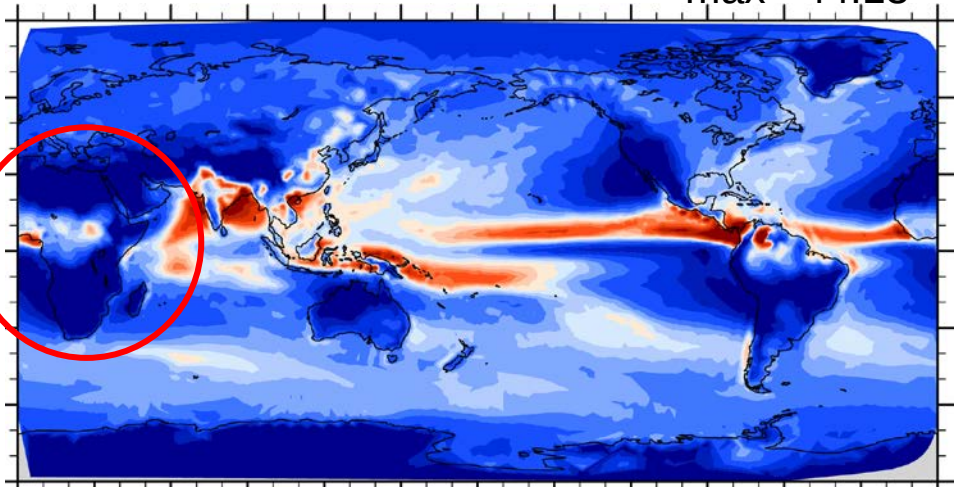
- **MP240a DJF** max =23.47



- **FV 1.9x2.5 JJA** max =35.69

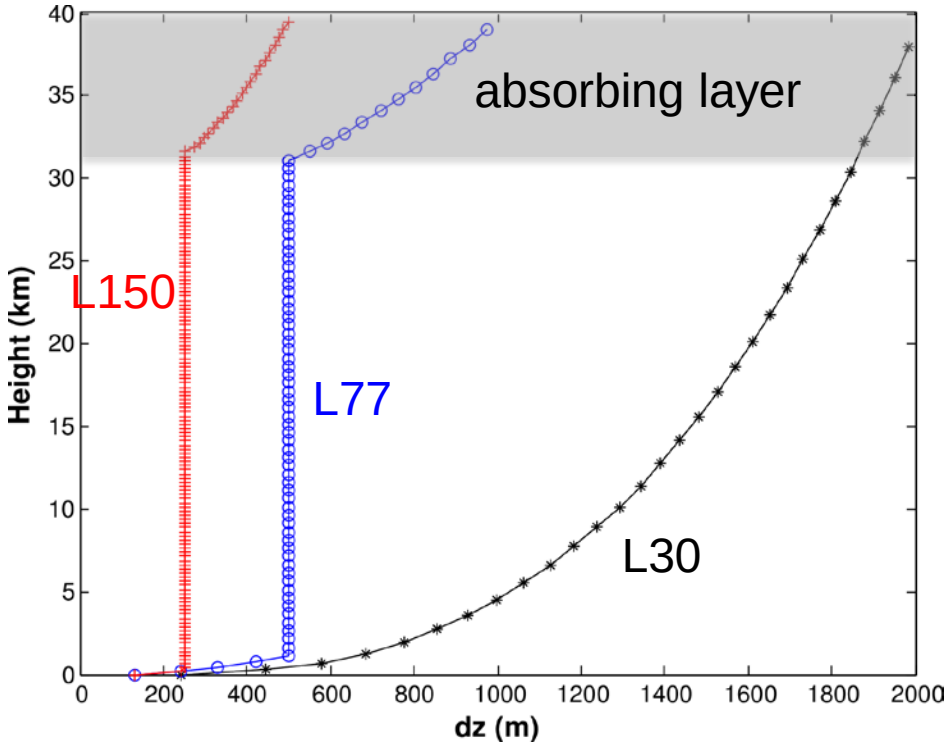


- **MP240a JJA** max =44.13

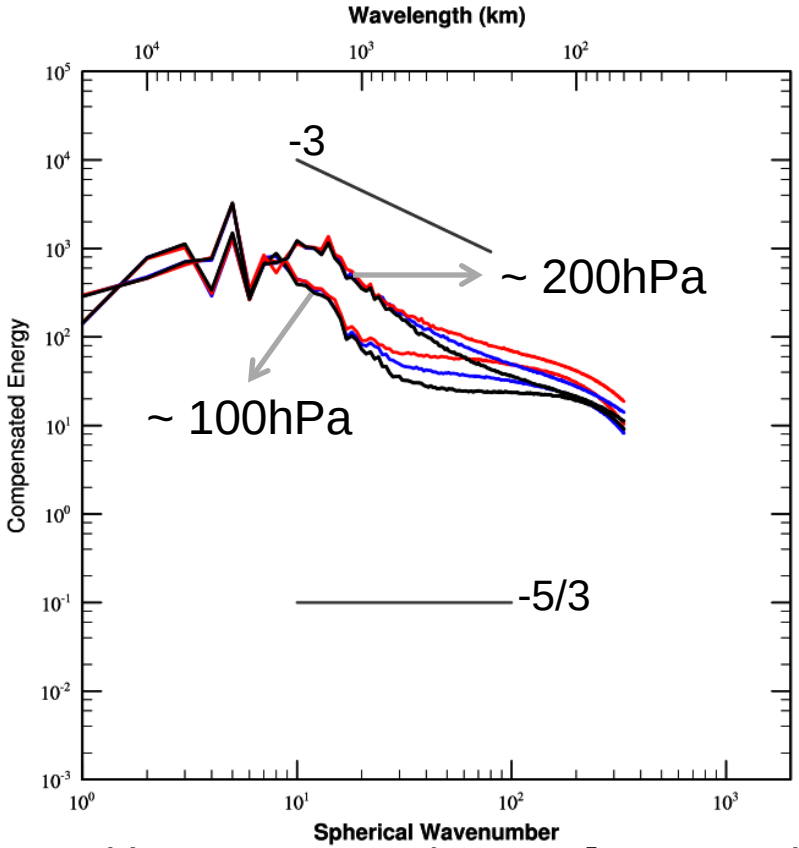


KE Spectra for MPAS

- Vertical Levels Configurations

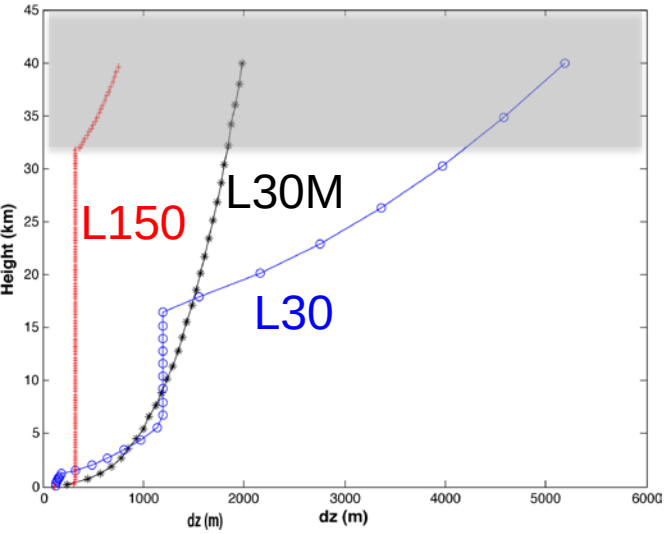


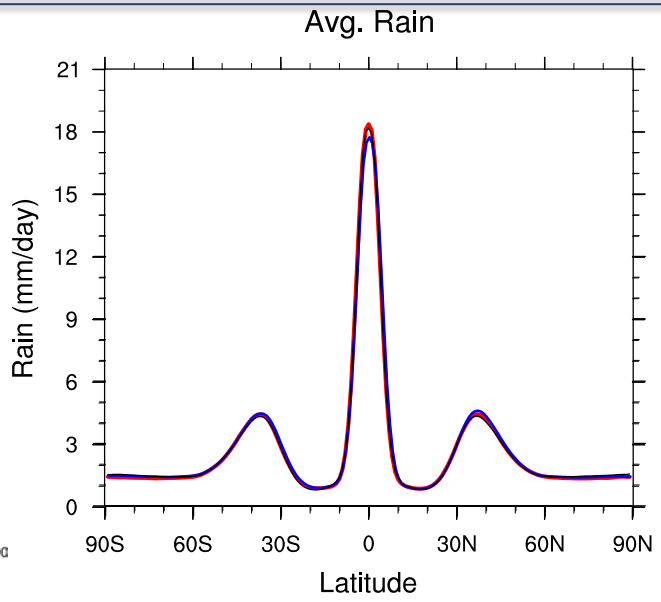
- Global 30km for 10days weather forecasting



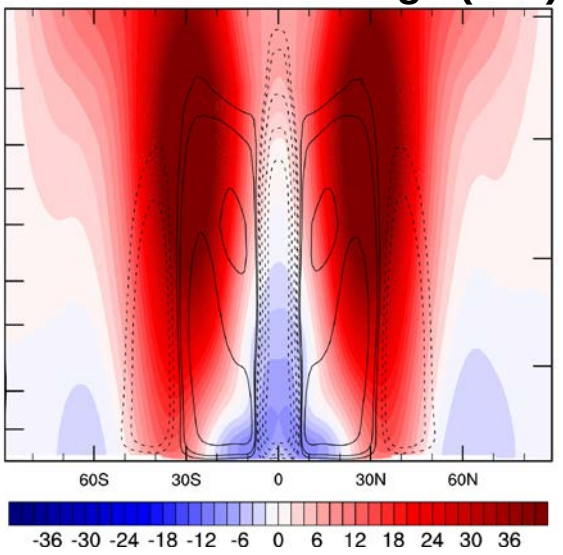
(in prep. Park et al., 2015)

CAM-MPAS APE

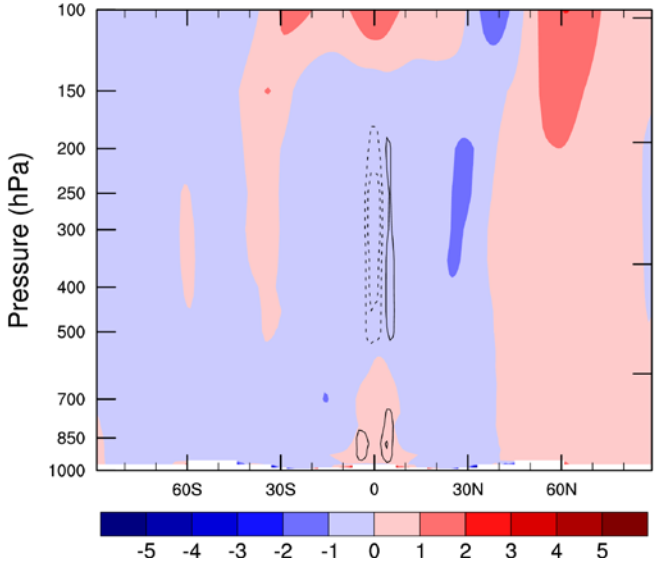




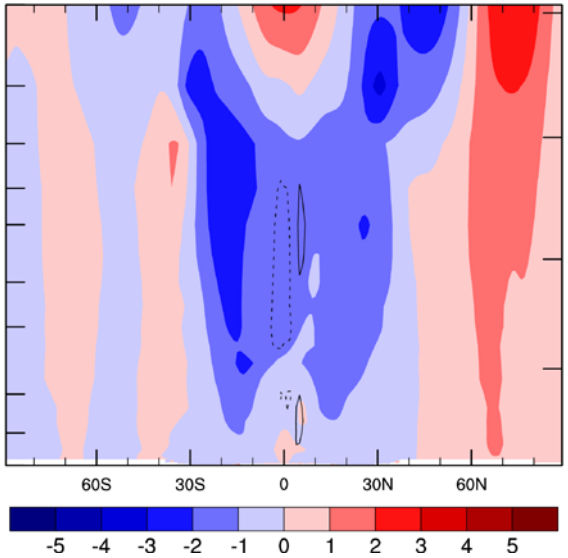
Zonal Wind + Omega (L30)



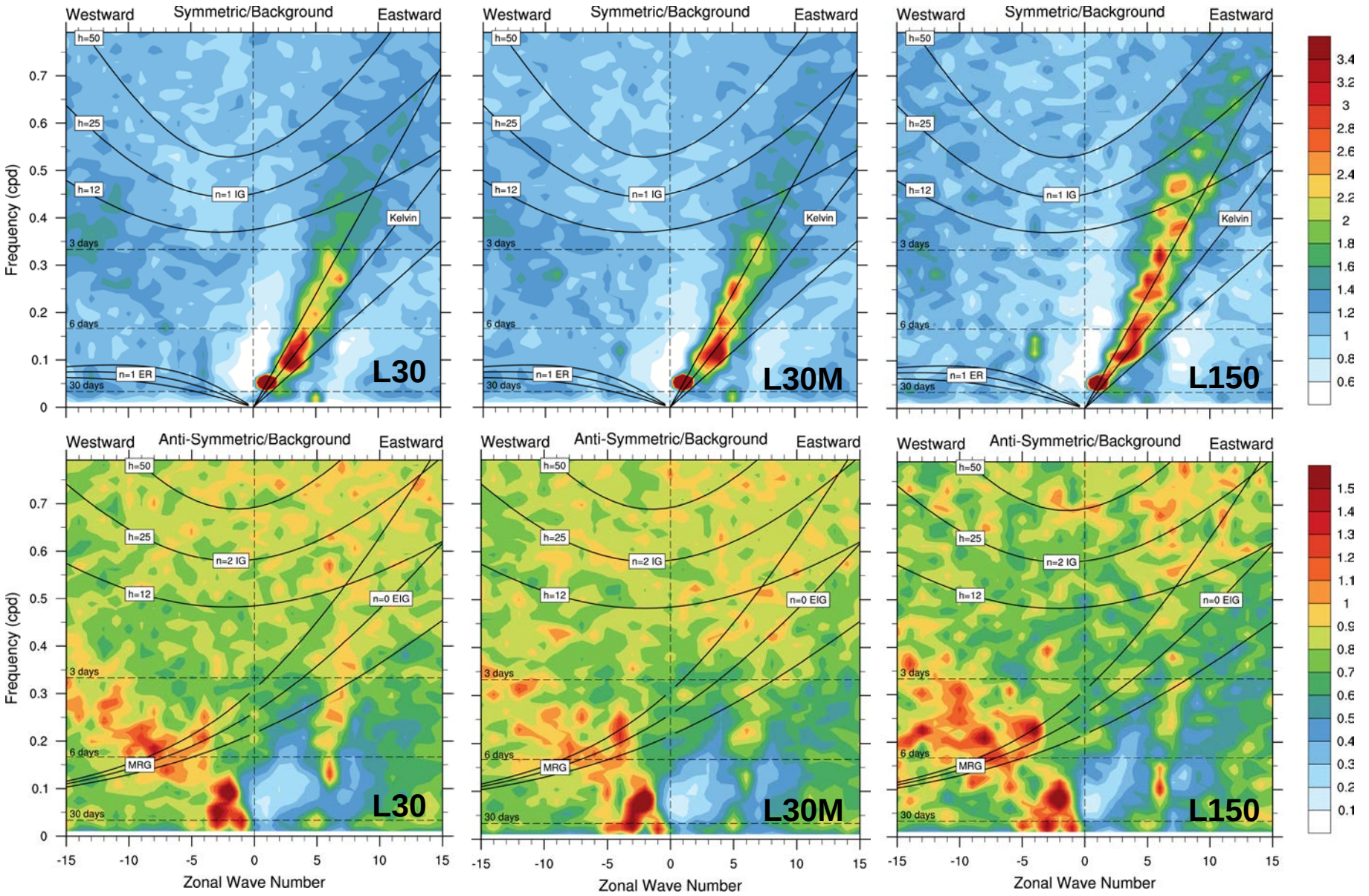
L30M - L30



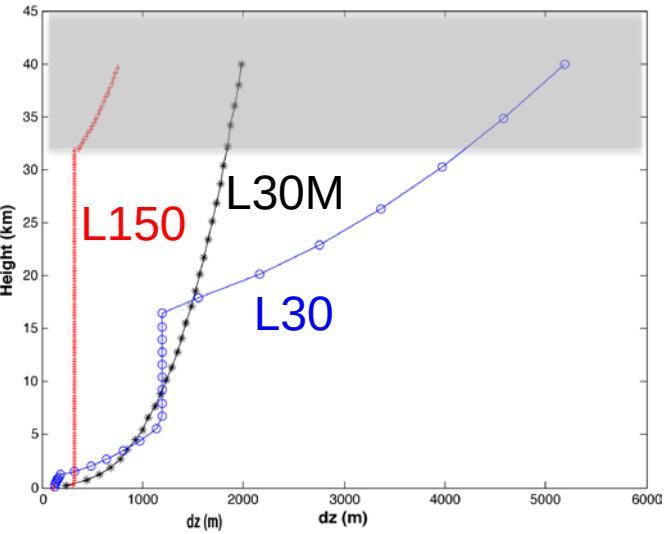
L150 - L30

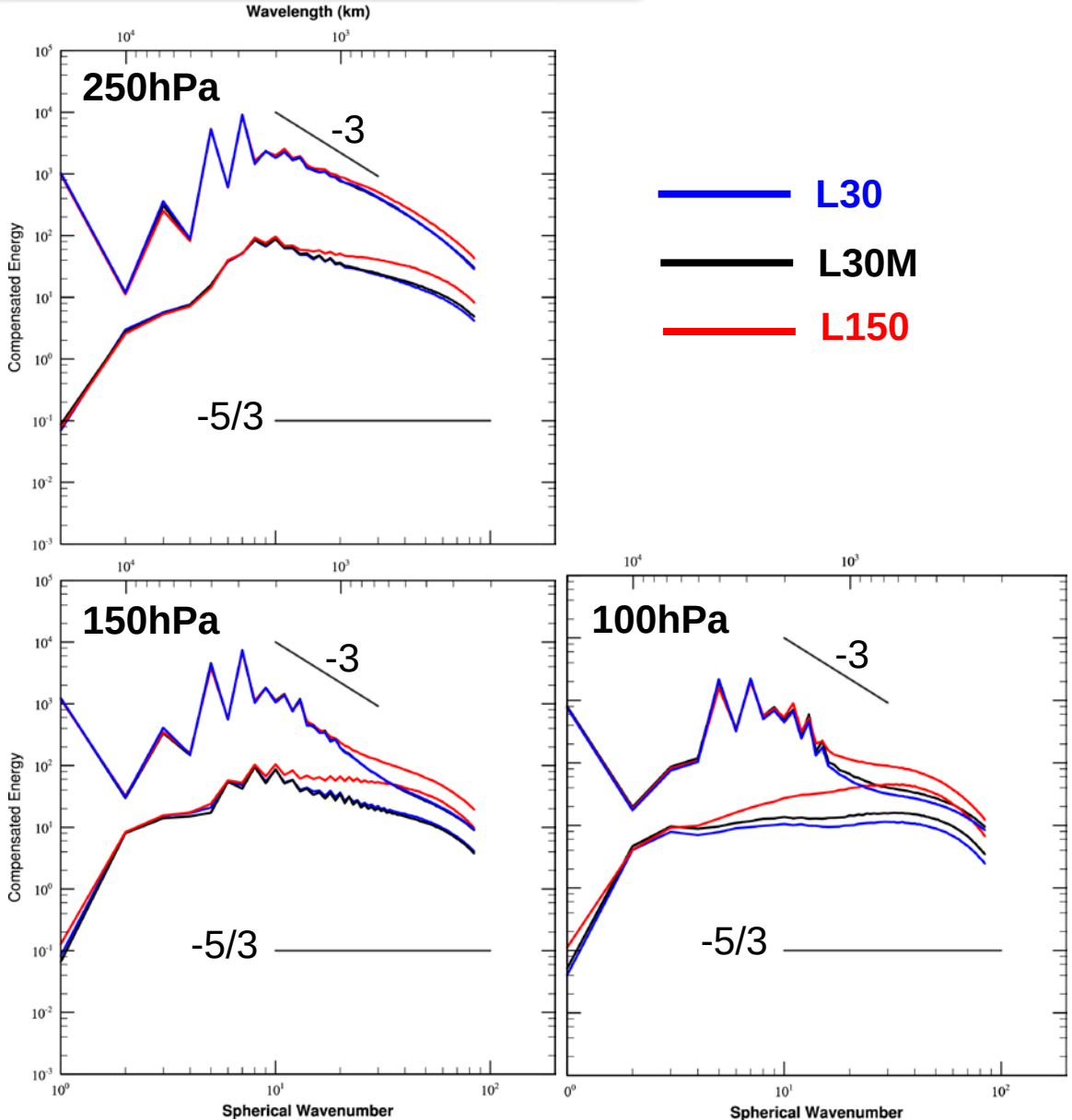


CAM-MPAS APE


Westward
Symmetric/Background
Eastward
h=50
h=25
h=12
n=1 IG
Kelvin
3 days
6 days
n=1 ER
30 days
L30
L30M
L150
Frequency (cpd)
Anti-Symmetric/Background
n=2 IG
n=0 EIG
MRG
Zonal Wave Number

CAM-MPAS APE


Height (km)
dz (m)
L150
L30M
L30

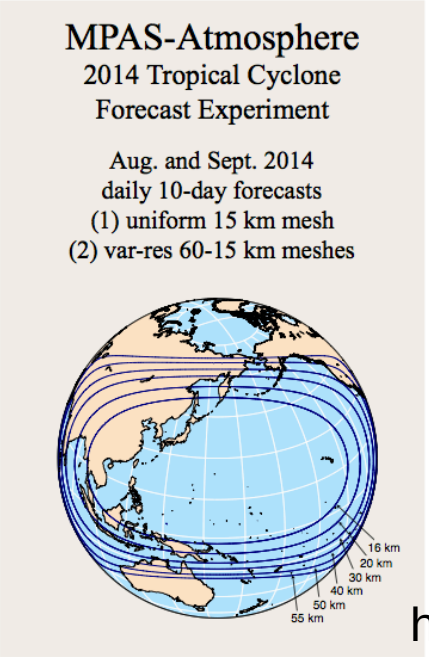

Wavelength (km)
250hPa
150hPa
100hPa
-3
-5/3
Compensated Energy
Spherical Wavenumber
L30
L30M
L150

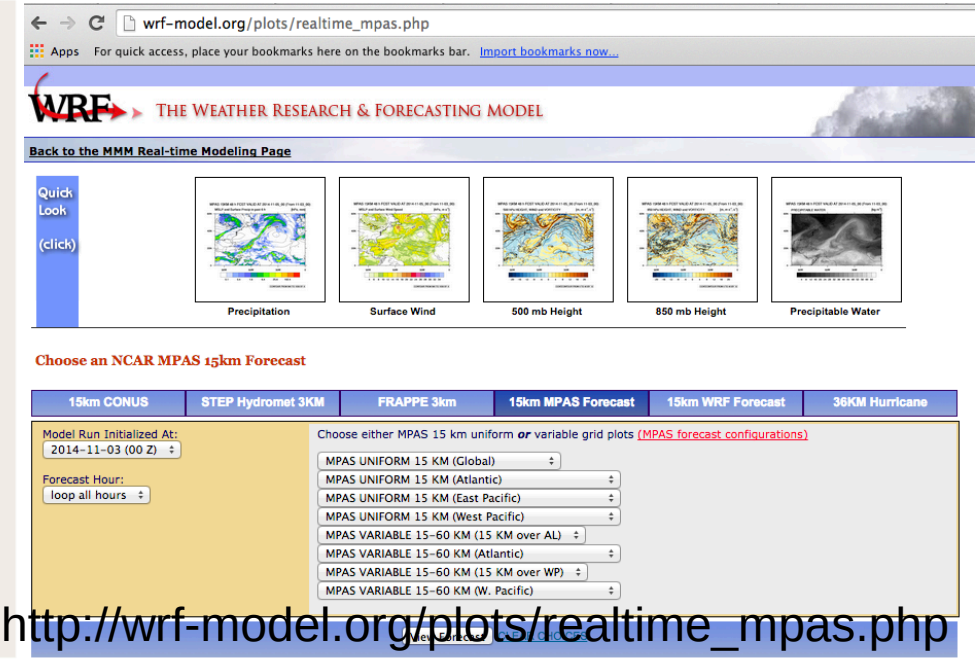
Summary

- CAM-MPAS will be in the branch very soon
- But, diffusion coefficient should be revised based on the CAM simulations
- Regarding to vertical resolution, sensitivity is shown in CAM-MPAS
- In the KE spectra, the results are not converged yet even in dz~ 250m
- Very welcome to share idea, information for CAM-MPAS (shpark@ucar.edu)

Future Plans

- More simulations are needed for CAM-MPAS (AMIP type)
- Weather Forecasting using CAM-MPAS (with variable resolution)





http://wrf-model.org/plots/realtime_mpas.php

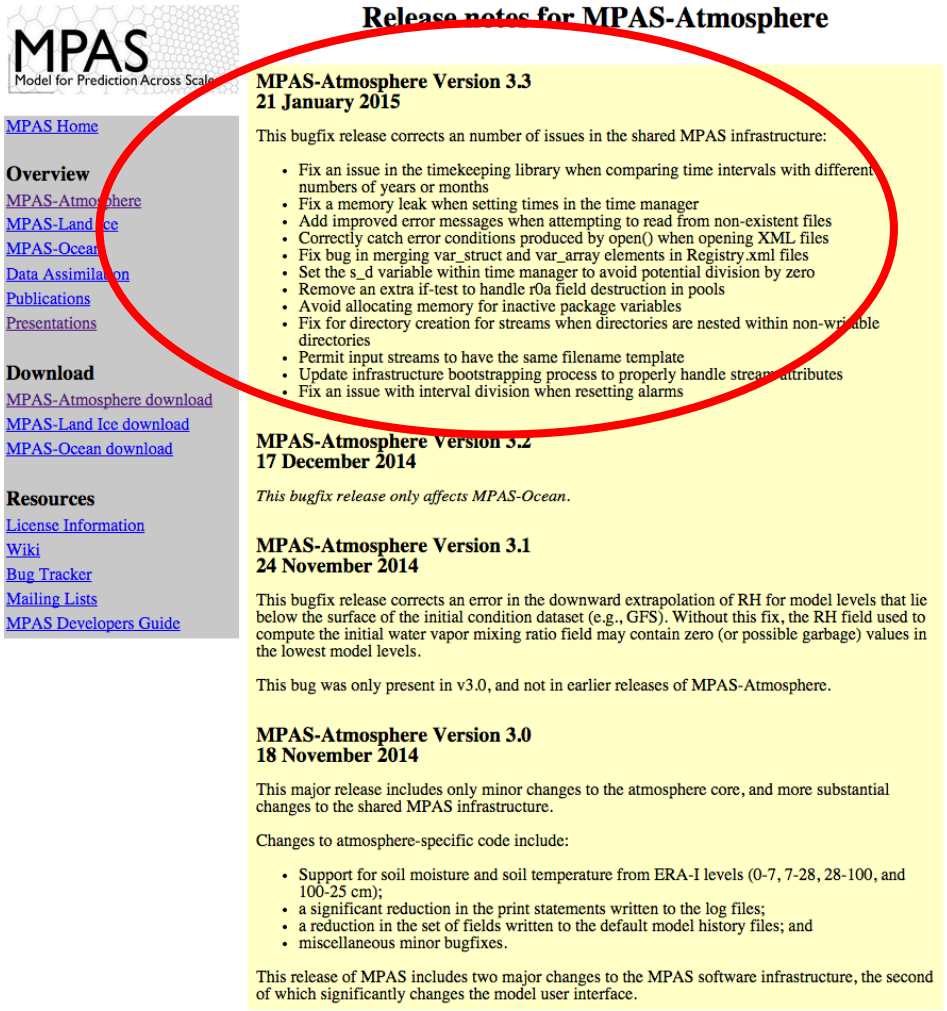
- CAM-MPAS will be up-to-date (current MPAS is v3.3)
- Dynamical core comparison inside of CAM

Thanks for Mike Levy and Mariana Vertenstein

Current Status of MPAS

MPAS release is available at

http://mpas-dev.github.io



MPAS
Model for Prediction Across Scales

MPAS Home

Overview
MPAS-Atmosphere
MPAS-Land Ice
MPAS-Ocean
Data Assimilation
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Release notes for MPAS-Atmosphere

MPAS-Atmosphere Version 3.3
21 January 2015

This bugfix release corrects an number of issues in the shared MPAS infrastructure:

- Fix an issue in the timekeeping library when comparing time intervals with different numbers of years or months
- Fix a memory leak when setting times in the time manager
- Add improved error messages when attempting to read from non-existent files
- Correctly catch error conditions produced by open() when opening XML files
- Fix bug in merging var_struct and var_array elements in Registry.xml files
- Set the s_d variable within time manager to avoid potential division by zero
- Remove an extra if-test to handle r0a field destruction in pools
- Avoid allocating memory for inactive package variables
- Fix for directory creation for streams when directories are nested within non-writable directories
- Permit input streams to have the same filename template
- Update infrastructure bootstrapping process to properly handle stream attributes
- Fix an issue with interval division when resetting alarms

MPAS-Atmosphere Version 3.2
17 December 2014

This bugfix release only affects MPAS-Ocean.

MPAS-Atmosphere Version 3.1
24 November 2014

This bugfix release corrects an error in the downward extrapolation of RH for model levels that lie below the surface of the initial condition dataset (e.g., GFS). Without this fix, the RH field used to compute the initial water vapor mixing ratio field may contain zero (or possible garbage) values in the lowest model levels.

This bug was only present in v3.0, and not in earlier releases of MPAS-Atmosphere.

MPAS-Atmosphere Version 3.0
18 November 2014

This major release includes only minor changes to the atmosphere core, and more substantial changes to the shared MPAS infrastructure.

Changes to atmosphere-specific code include:

- Support for soil moisture and soil temperature from ERA-I levels (0-7, 7-28, 28-100, and 100-25 cm);
- a significant reduction in the print statements written to the log files;
- a reduction in the set of fields written to the default model history files; and
- miscellaneous minor bugfixes.

This release of MPAS includes two major changes to the MPAS software infrastructure, the second of which significantly changes the model user interface.

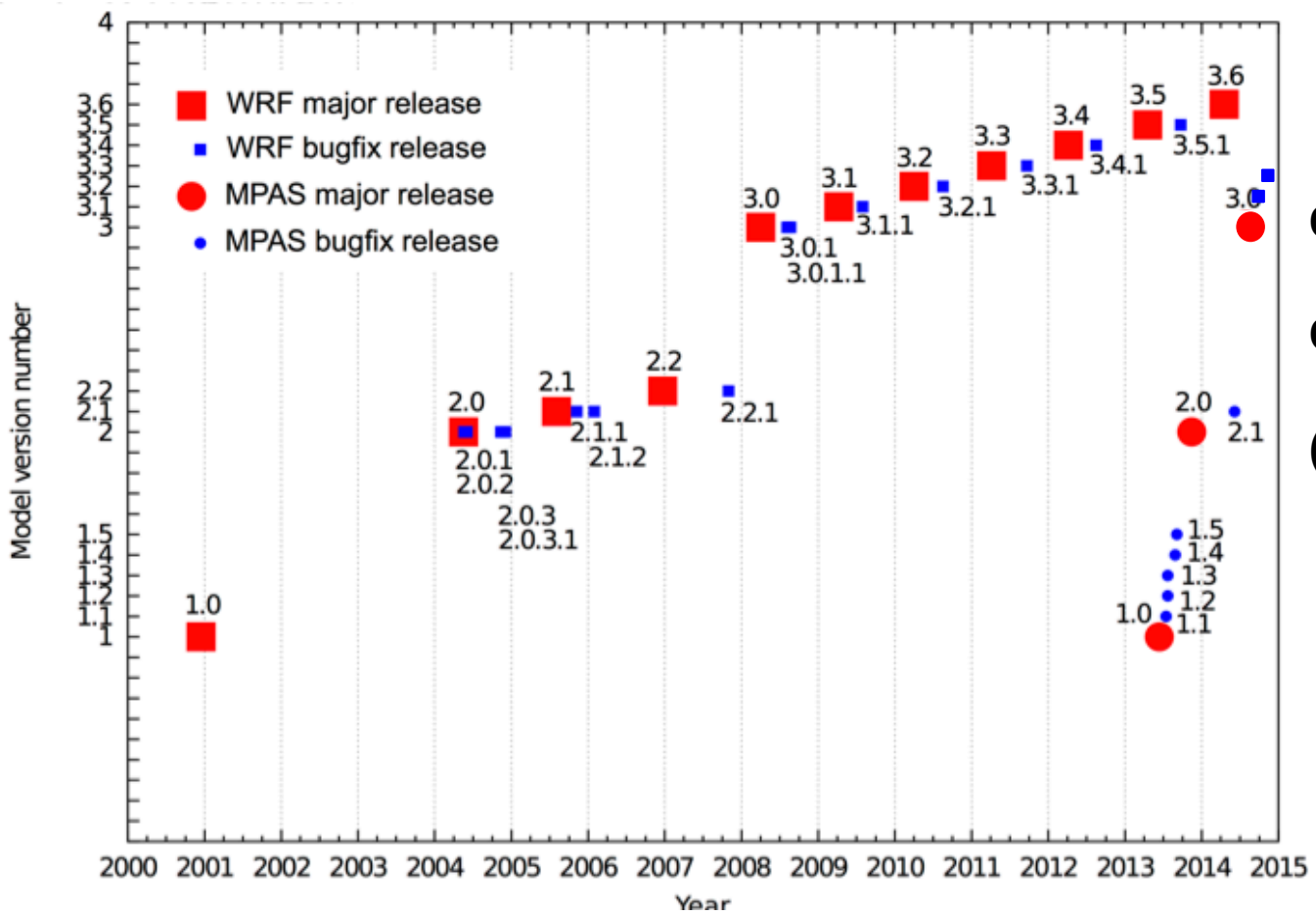
Current version is : v3.3

CAM-MPAS is based on v2.0

Current Status of MPAS

MPAS release is available at

http://mpas-dev.github.io



Current version is : v3.3

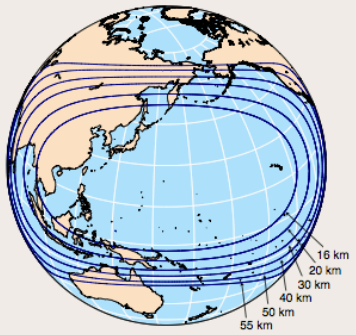
CAM-MPAS is based on v2.0 (but, major bugs are up-to-date)

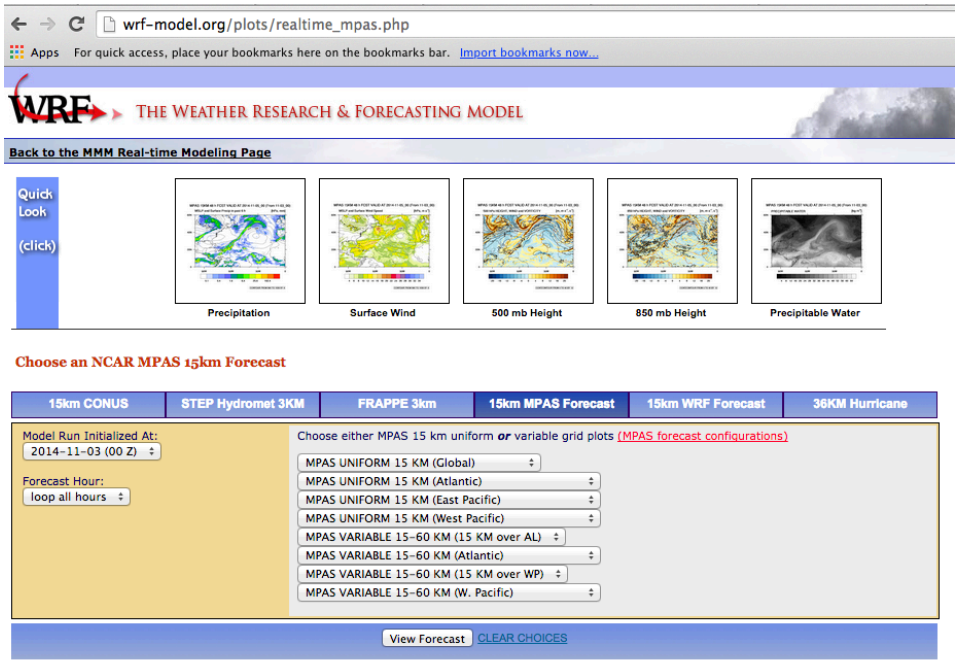
Recent Activity of MPAS

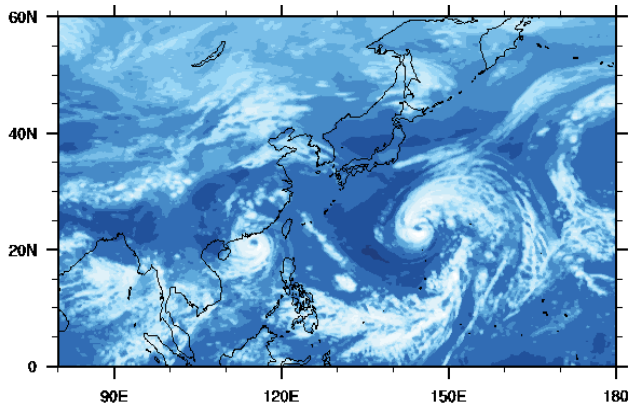
- 10 days weather forecasting (15km) for Typhoon and Hurricane (2014)

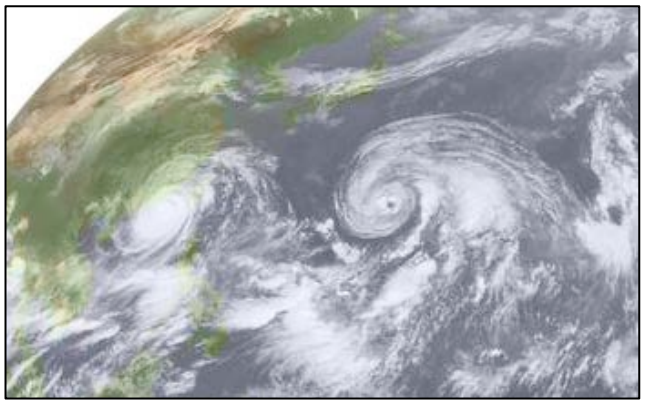
MPAS-Atmosphere
2014 Tropical Cyclone
Forecast Experiment

Aug. and Sept. 2014
daily 10-day forecasts
(1) uniform 15 km mesh
(2) var-res 60-15 km meshes

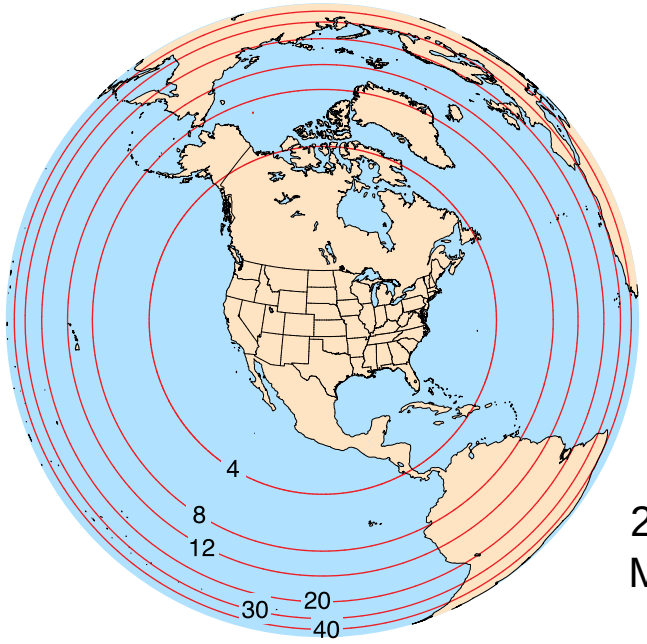




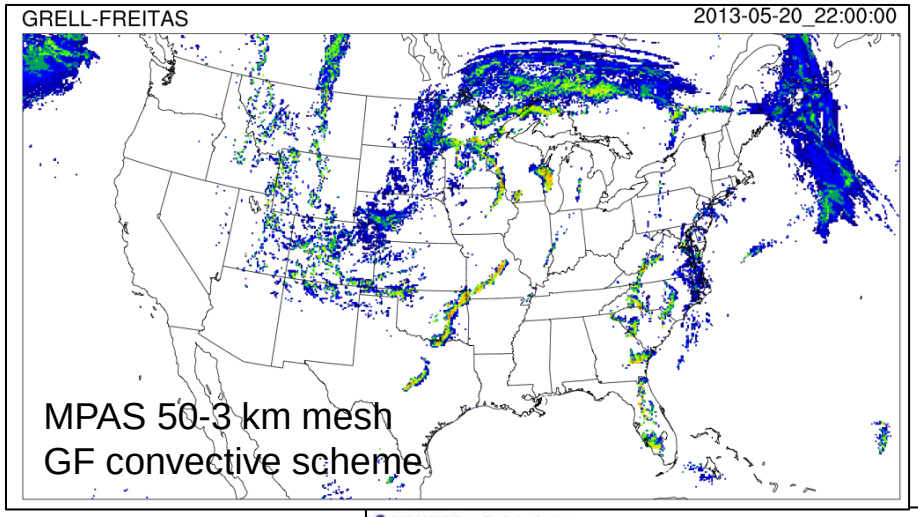




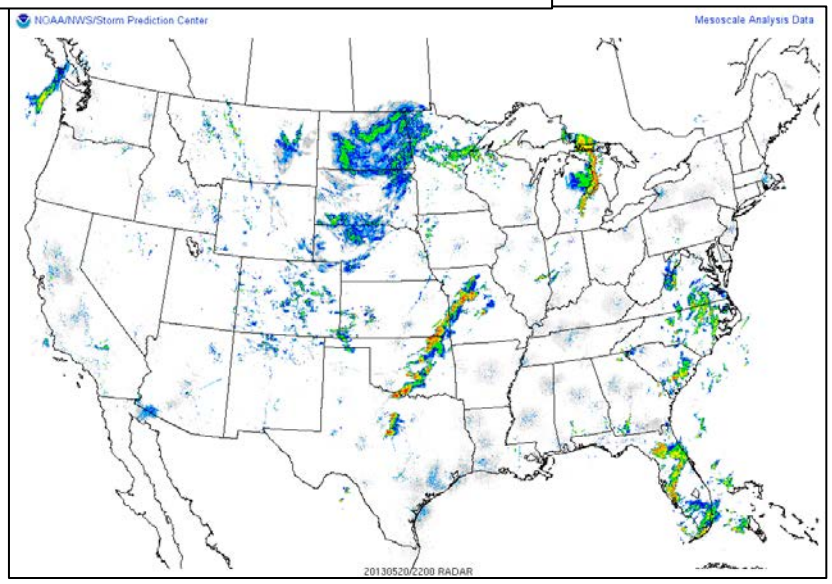
Recent Activity of MPAS



3-50 km mesh, Δx contours 4, 8, 12, 20, 30, 40
approximately 6.85 million cells
68% have < 4 km spacing

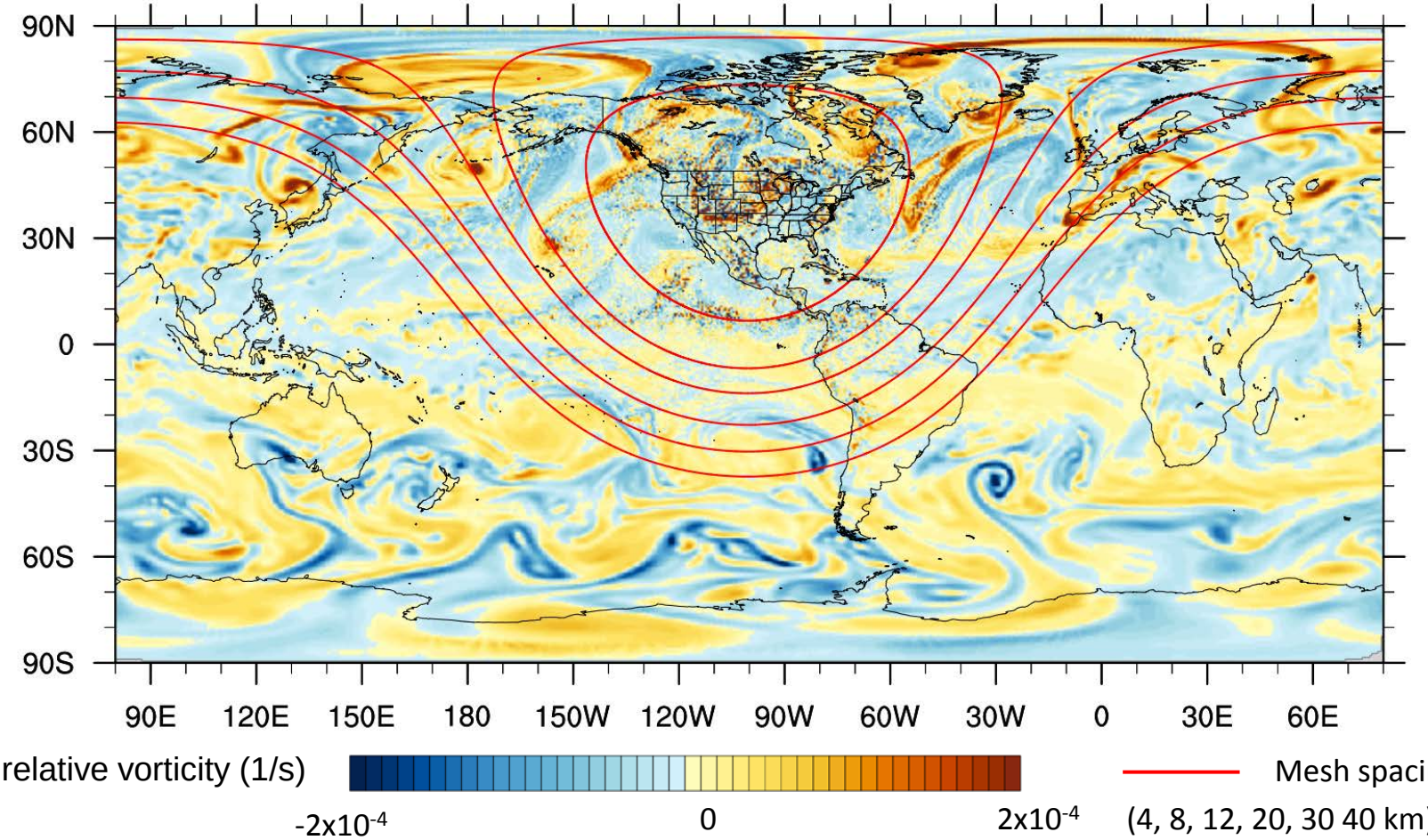


Radar reflectivity
2013-05-20_22:00
Moore OK tornado



Recent Activity of MPAS

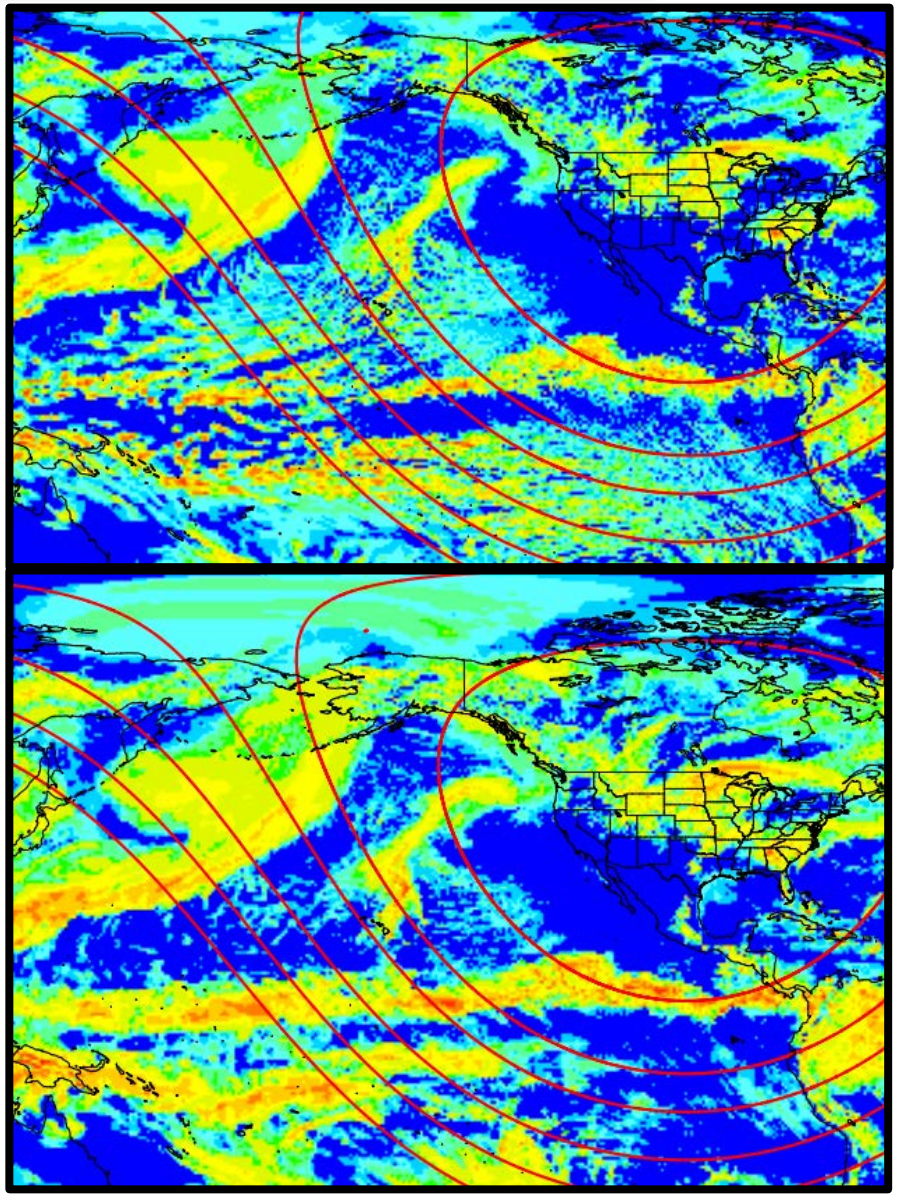
MPAS 50-3 km mesh
2 day 22h forecast valid at 2013-05-20_22:00 500 hPa relative vorticity



Recent Activity of MPAS

MPAS 50-3 km mesh,
No deep convection scheme
3 day 12h forecast valid at 2013-05-21_12:00
Accumulated precipitation

MPAS 50-3 km mesh,
Grell-Freitas convection scheme
3 day 12h forecast valid at 2013-05-21_12:00
Accumulated precipitation



Mesh spacing
(4, 8, 12, 20, 30 40 km)