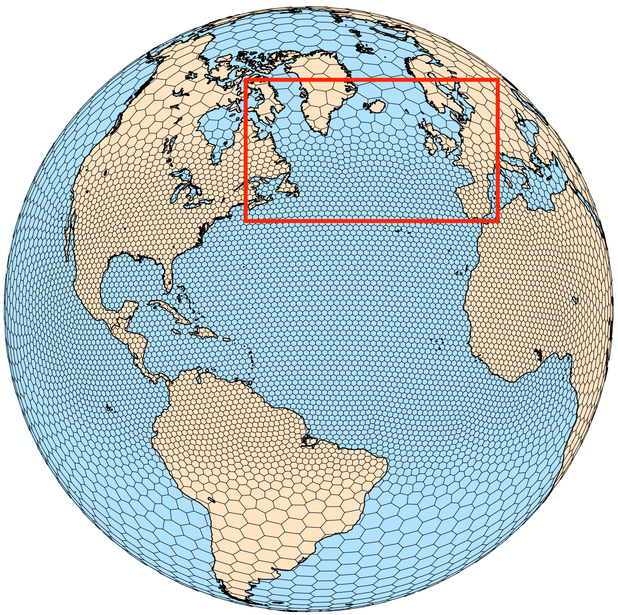
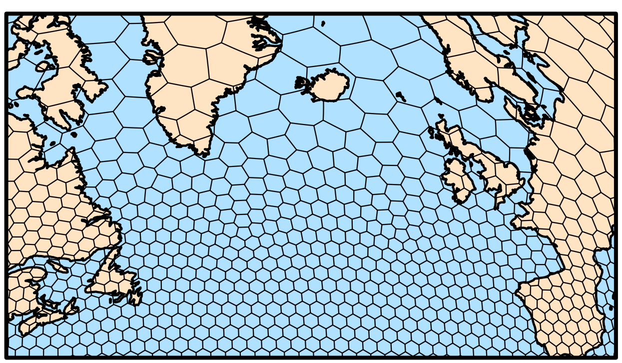
MPAS
Model for Prediction Across Scales

Hazardous Weather Testbed Spring Experiment 2015
Forecasts Results from MPAS



MPAS consists of geophysical fluid-flow solvers based on unstructured centroidal Voronoi (hexagonal) meshes using C-grid staggering and selective grid refinement.



MPAS-Atmosphere:

- Nonhydrostatic global atmospheric model
- Time integration as in Advanced Research WRF
- Spatial discretization similar to ARW except for Voronoi mesh accommodations.

Bill Skamarock, Lou Wicker (NSSL), Steven Cavallo (OU), Adam Clark (NSSL), Joe Klemp, David Ahijevych, Wei Wang, Morris Weisman, and many other contributors

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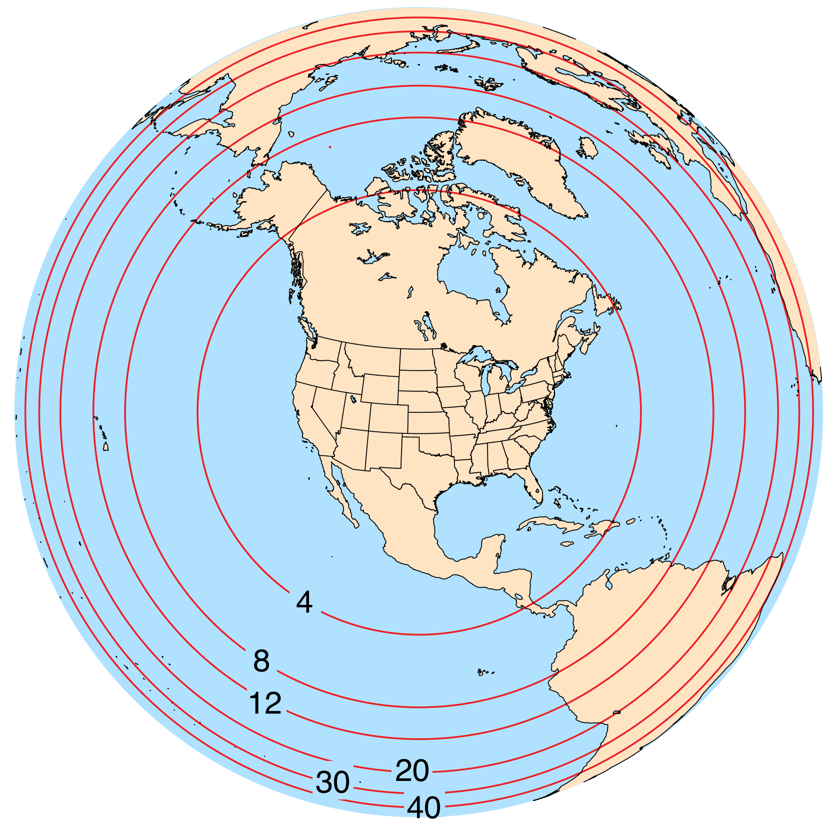
Application Test
NOAA SPC/NSSL HWT
May 2015
Convective Forecast Experiment
Daily 5-day MPAS forecasts
00 UTC GFS analysis initialization

Application question:
Can a global variable-resolution convection permitting model provide extended range severe weather guidance?

Modeling question:
Will the MPAS parameterizations (convection, microphysics) result in appropriate behavior of the modeled precipitation processes in the mesh transition region?

MPAS mesh mean cell spacing (km)



3-50 km mesh, Δx contours 4, 8, 12, 20, 30 40 km
approximately 6.85 million cells
68% have < 4 km spacing
(158 pentagons, 146 septagons)

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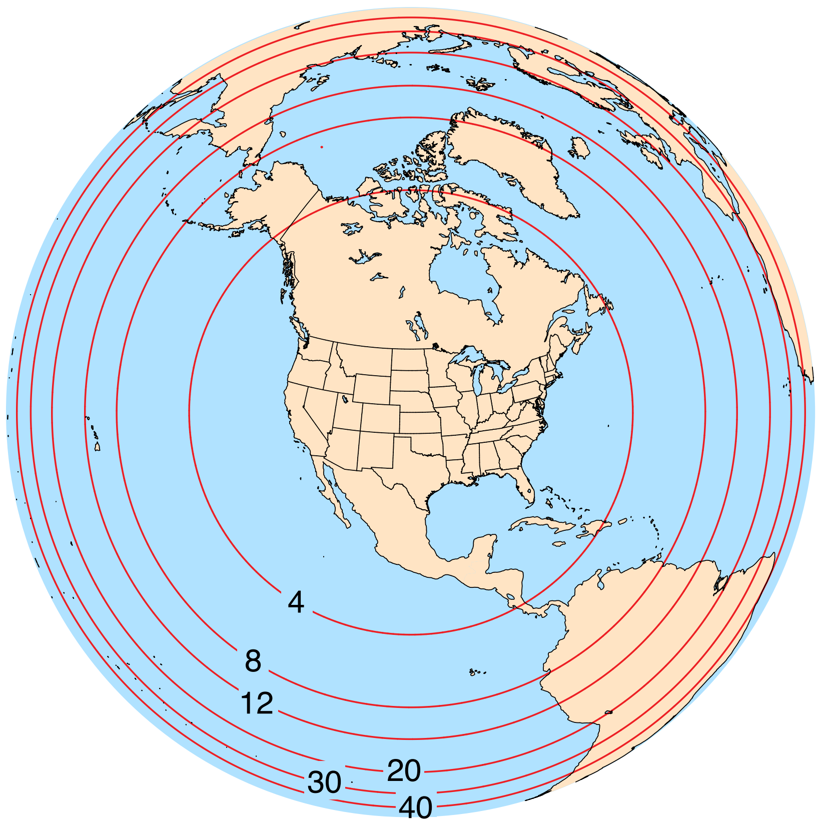
MPAS mesh:

50 – 3 km variable resolution.
CONUS is the 3 km region.
Very smooth transition.

MPAS Physics:

- WSM6 cloud microphysics
- Grell-Freitas convection scheme (scale-aware)
- Monin-Obukhov surface layer
- MYNN PBL
- Noah land-surface
- RRTMG lw and sw.

MPAS mesh mean cell spacing (km)



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Grell-Freitas Convection Scheme in MPAS

<u>Scale-aware/aerosol-aware (Grell and Freitas, 2014, ACP)</u>

- Stochastic scheme (Grell and Devenyi, 2002).
- Scale aware by adapting the Arakawa et al approach (2011).
  - Relates vertical convective eddy transport to convective updraft/downdraft fraction σ:

$$\rho \overline{w\psi} = (1-\sigma)^2 M_c(\psi_c - \bar{\psi})_{adj} \quad \text{with} \quad M_c \equiv \rho \sigma w_c$$

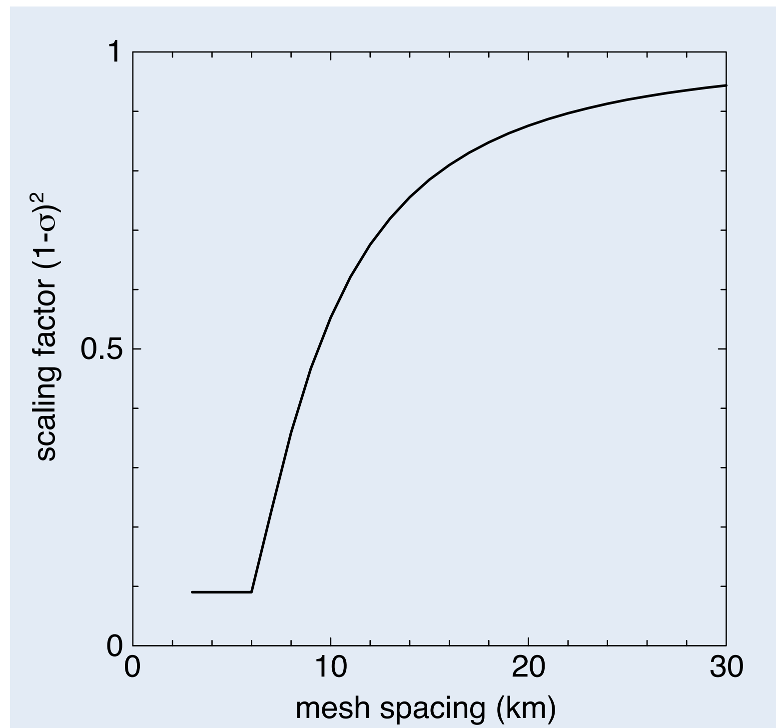
  - GF: σ is the fractional area covered by active updraft and downdraft plume.

$$\sigma = \frac{\pi R^2}{A_{grid\ cell}},\ R_{conv} = \frac{0.2}{\varepsilon},\ \varepsilon = 7 \times 10^{-5}$$

entrainment rate (fixed)

$$\sigma_{max} = 0.7$$

  - At very high resolution (dx < 3km) parameterized convection becomes much shallower – cloud tops near 800 mb (down from 200-300 mb).
  - Temperature & moisture tendencies decrease as resolution increases.



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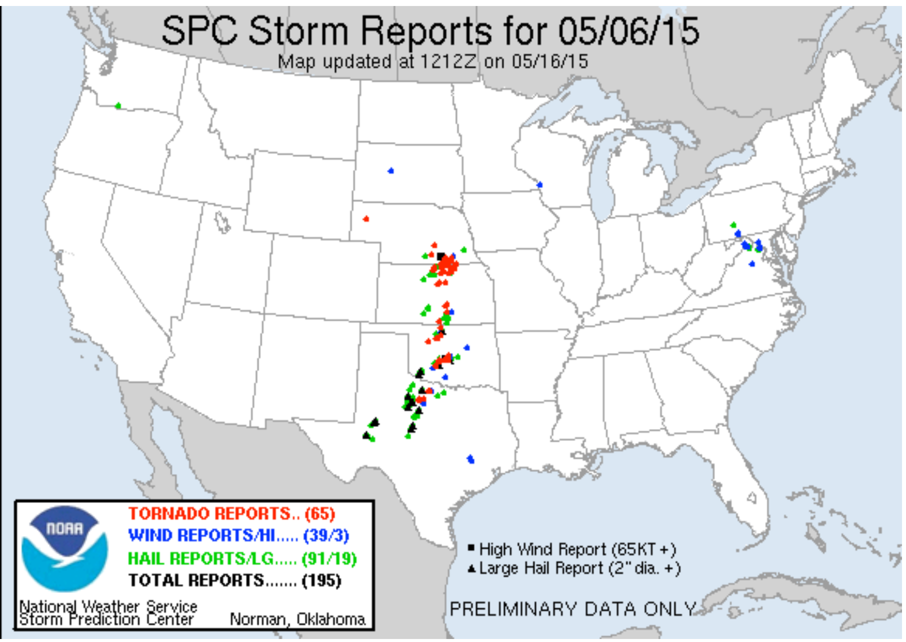
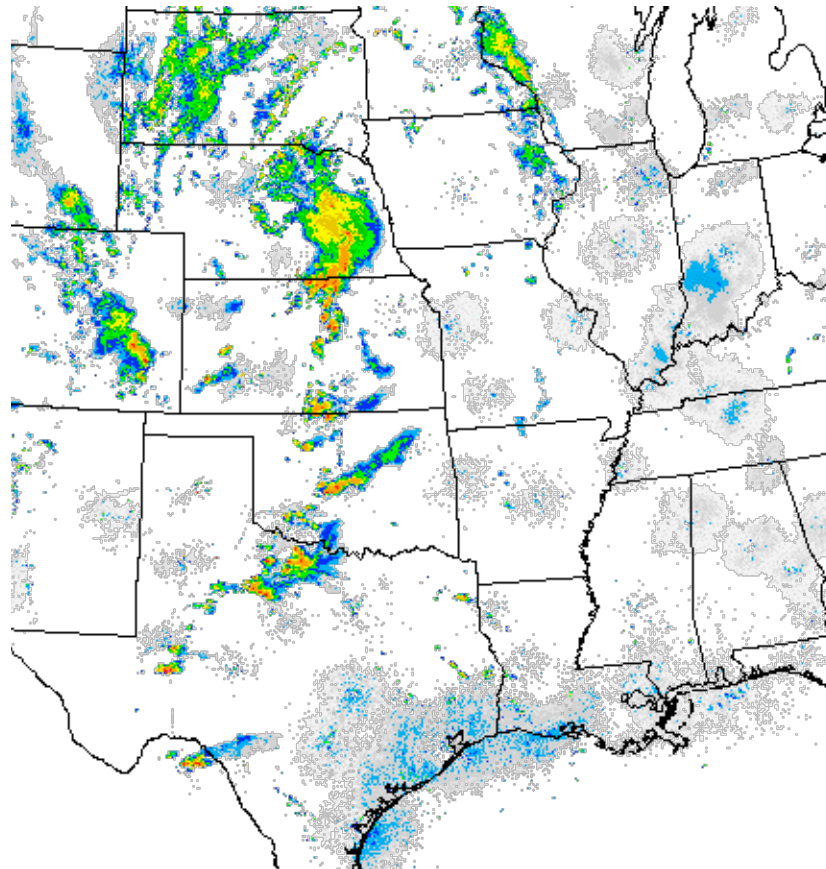
Spring Experiment 2015
Forecasts Results from MPAS



Reflectivity, NOAA SPC archive
valid 2015-05-07 00 UTC



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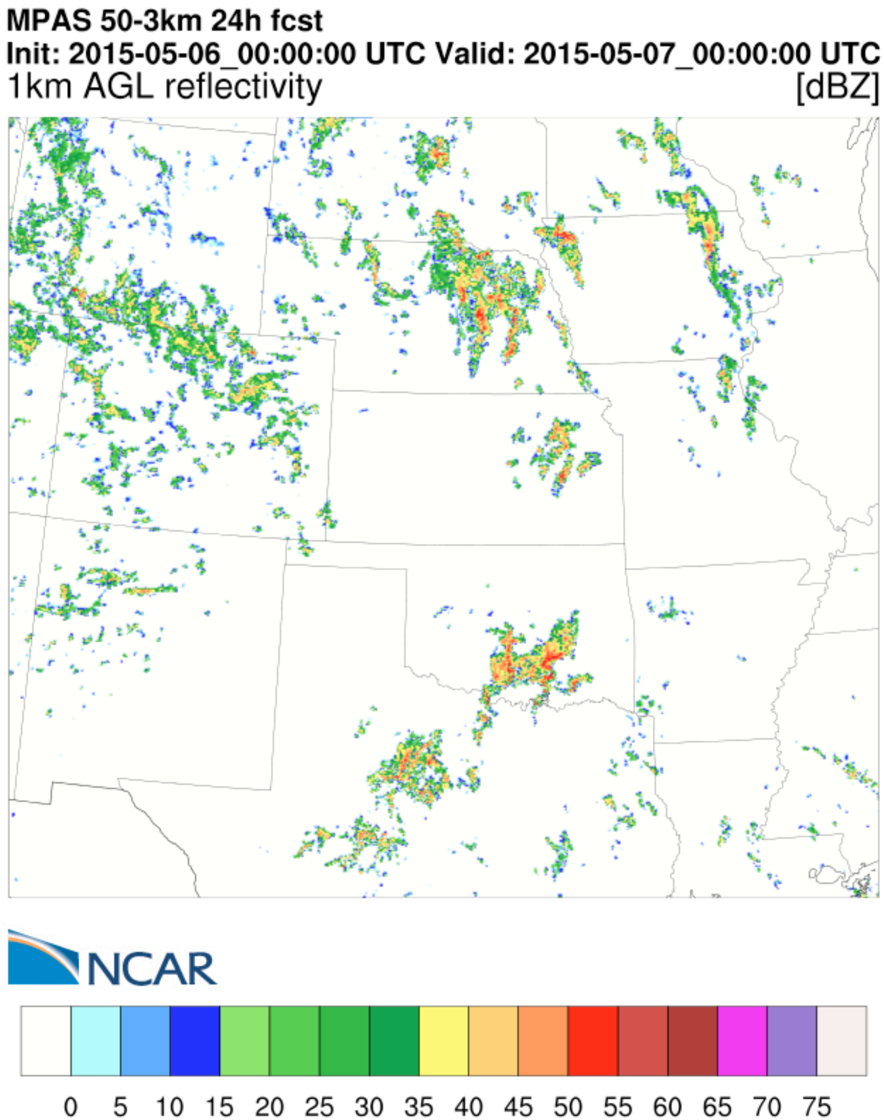
Spring Experiment 2015
Forecasts Results from MPAS



Reflectivity, NOAA SPC archive
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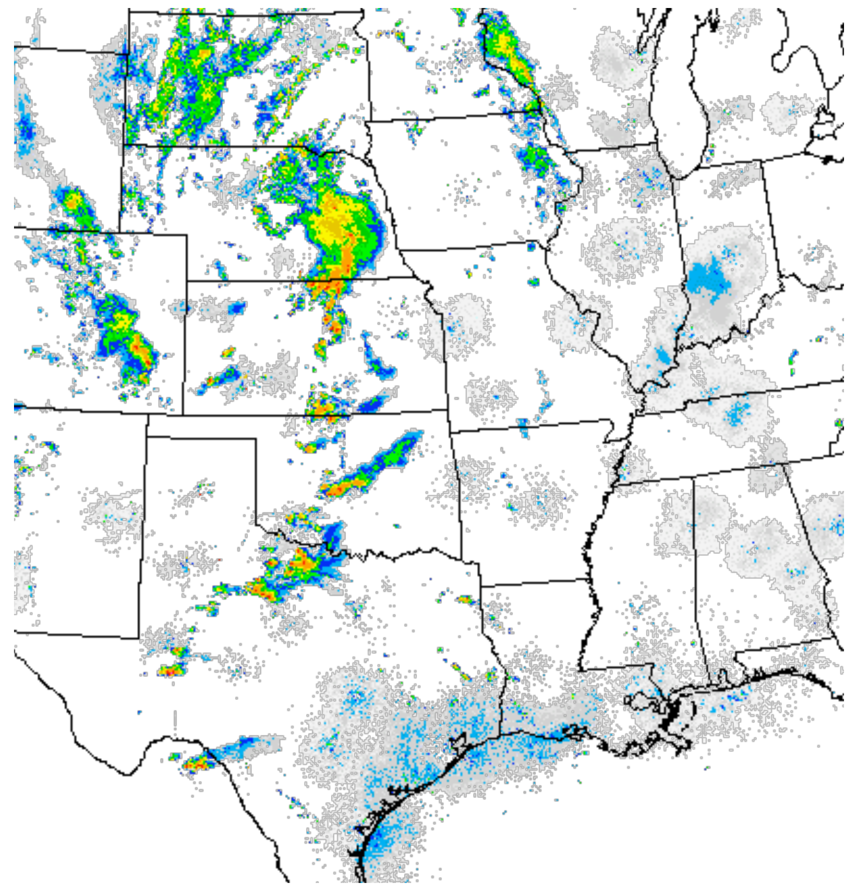

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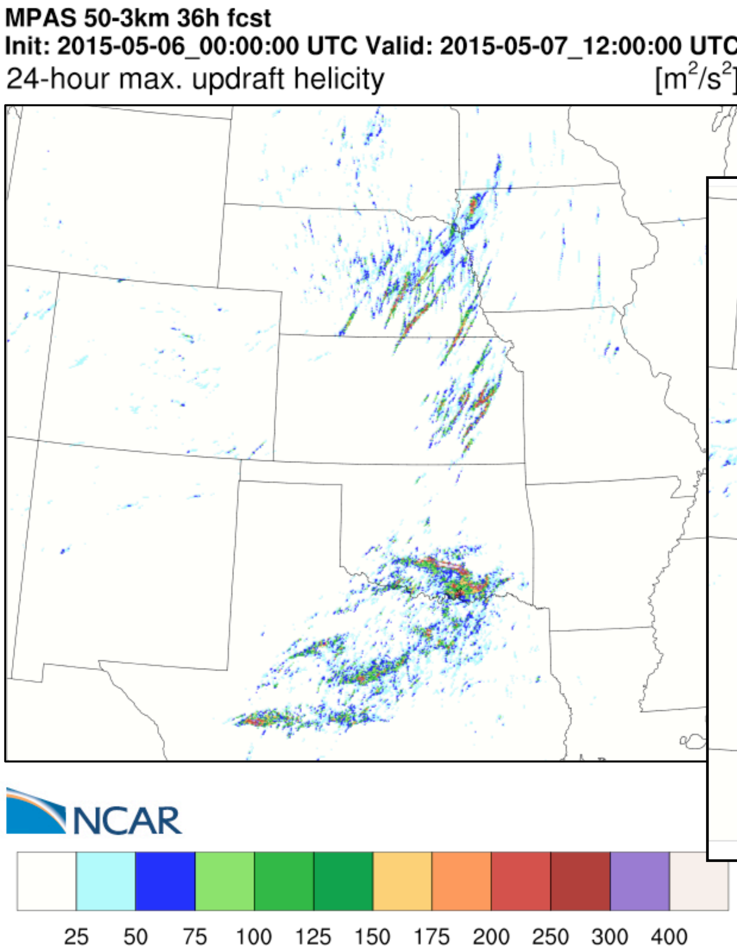
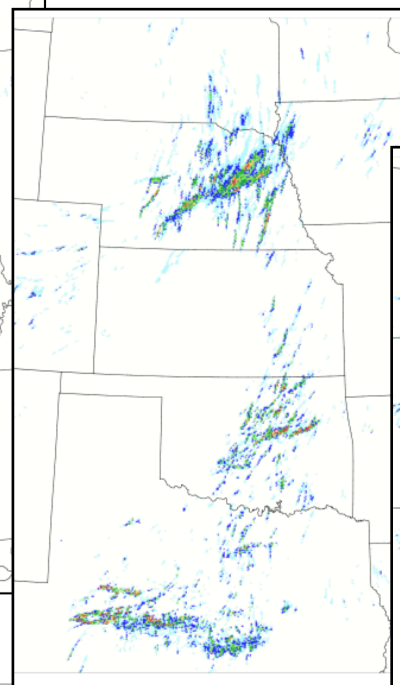
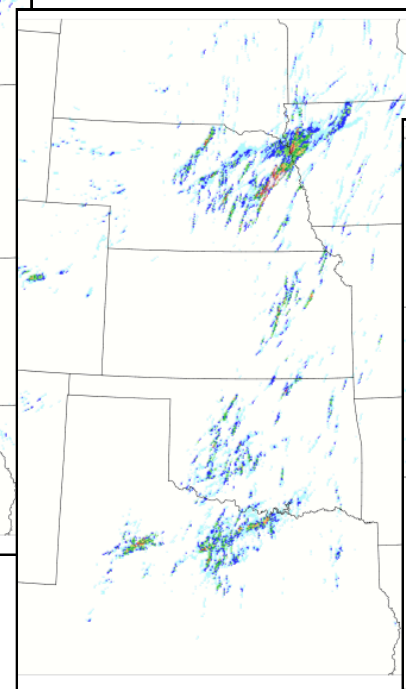
Hazardous Weather Testbed Spring Experiment 2015
Forecasts Results from MPAS



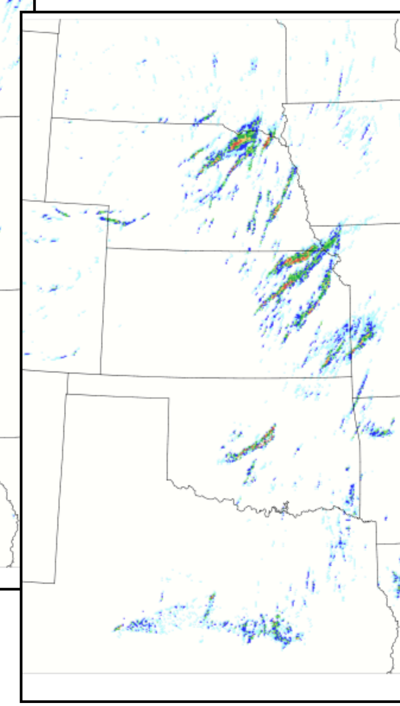
60h forecast



84h forecast



108h forecast

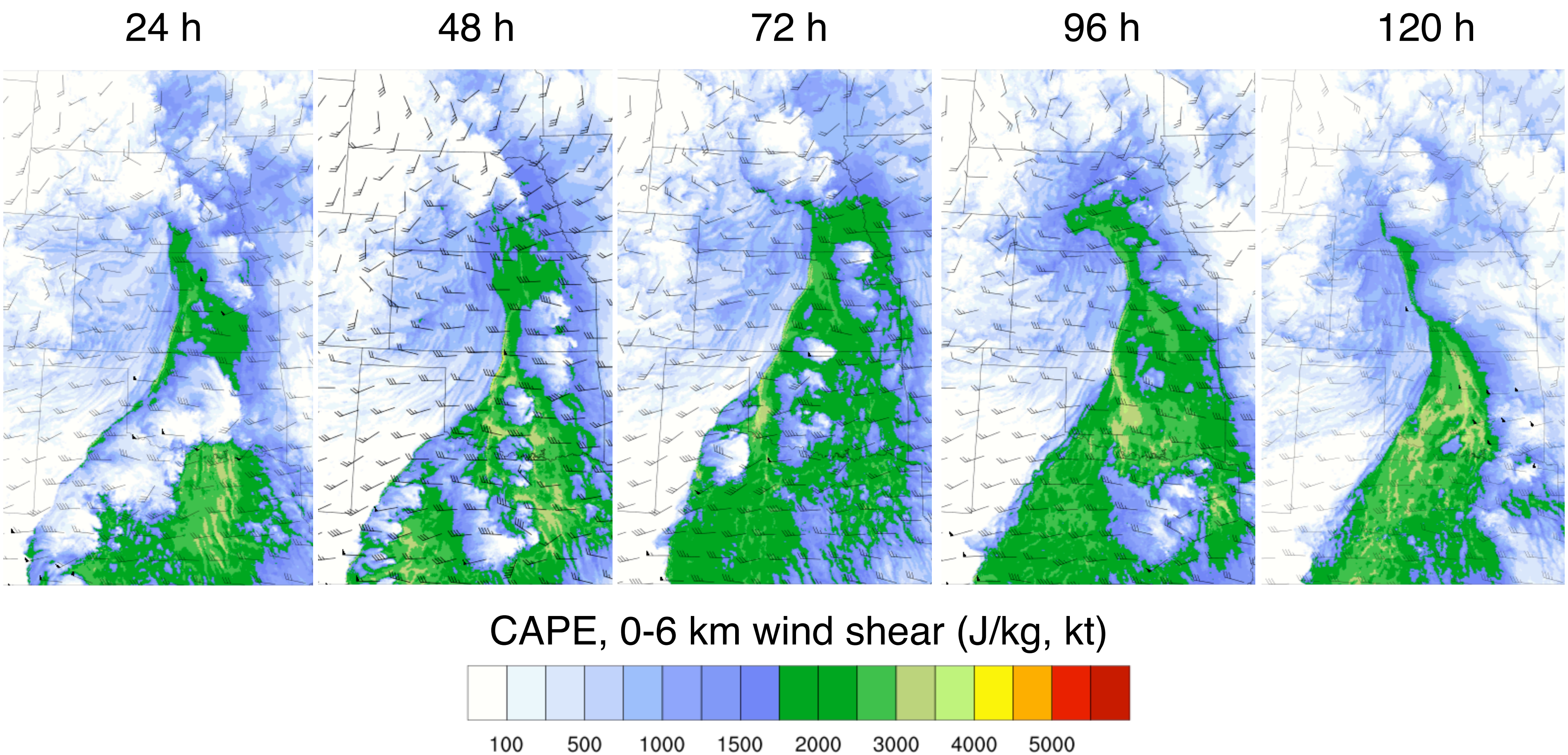


24 hour maximum updraft helicity
Forecasts valid 2015-05-07 12 UTC

Hazardous Weather Testbed
Spring Experiment 2015
Forecasts Results from MPAS

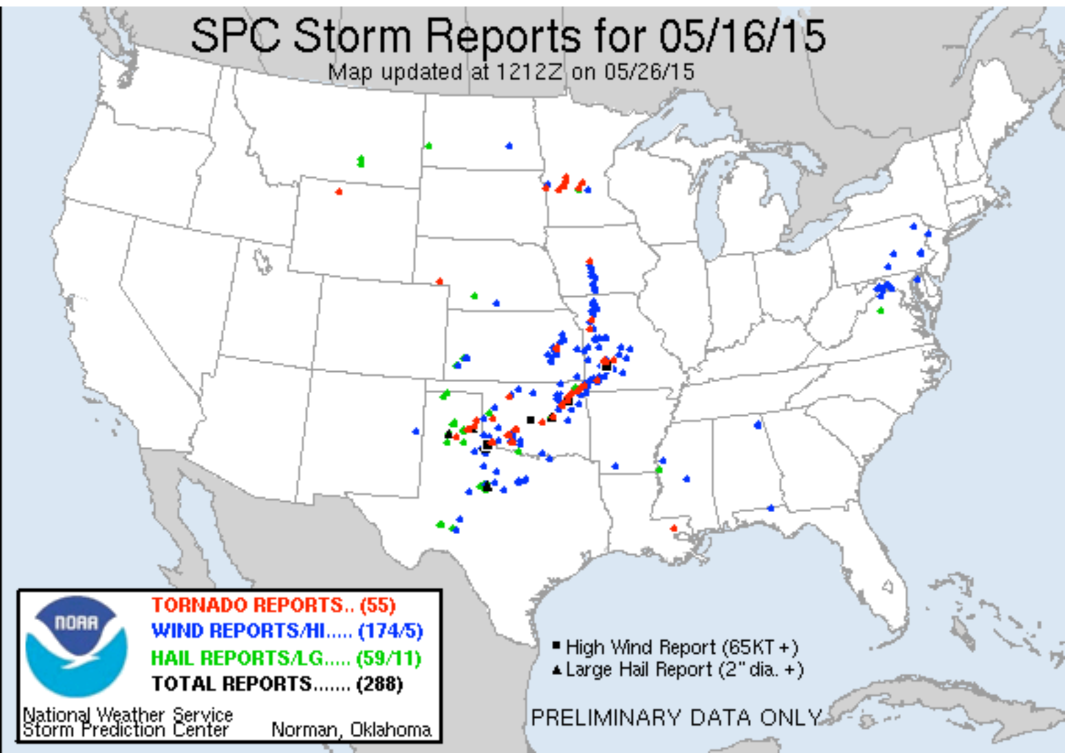
MPAS
Model for Prediction Across Scales

Forecasts valid 2015-05-7 00 UTC

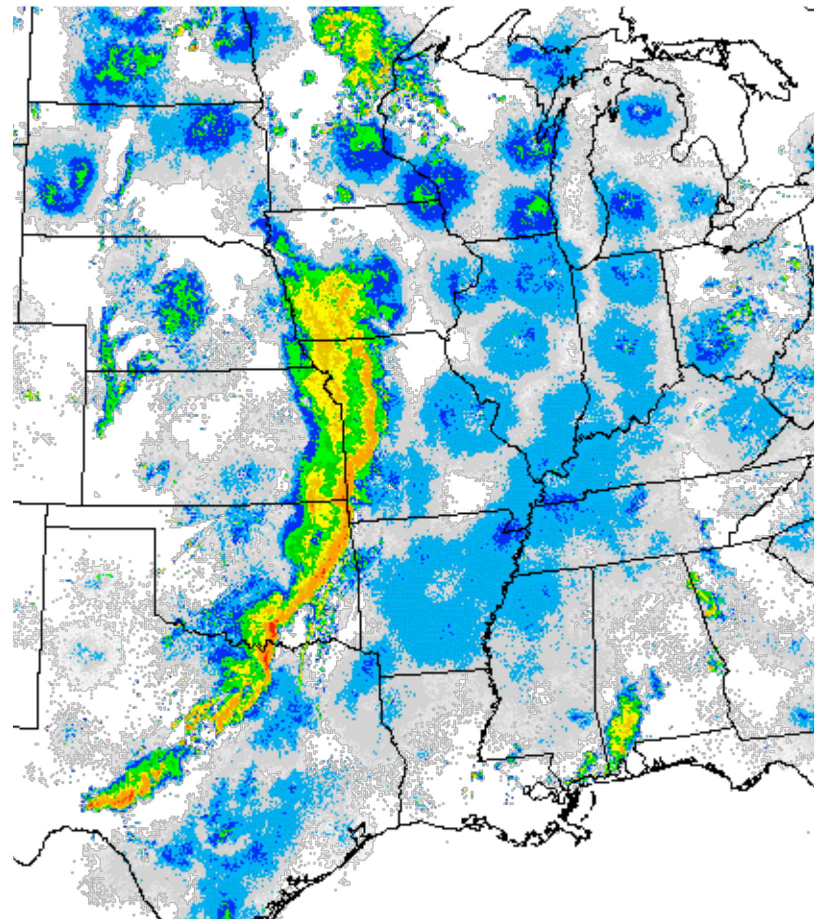


Hazardous Weather Testbed Spring Experiment 2015

Forecasts Results from MPAS



Reflectivity, NOAA SPC archive
valid 2015-05-17 06 UTC



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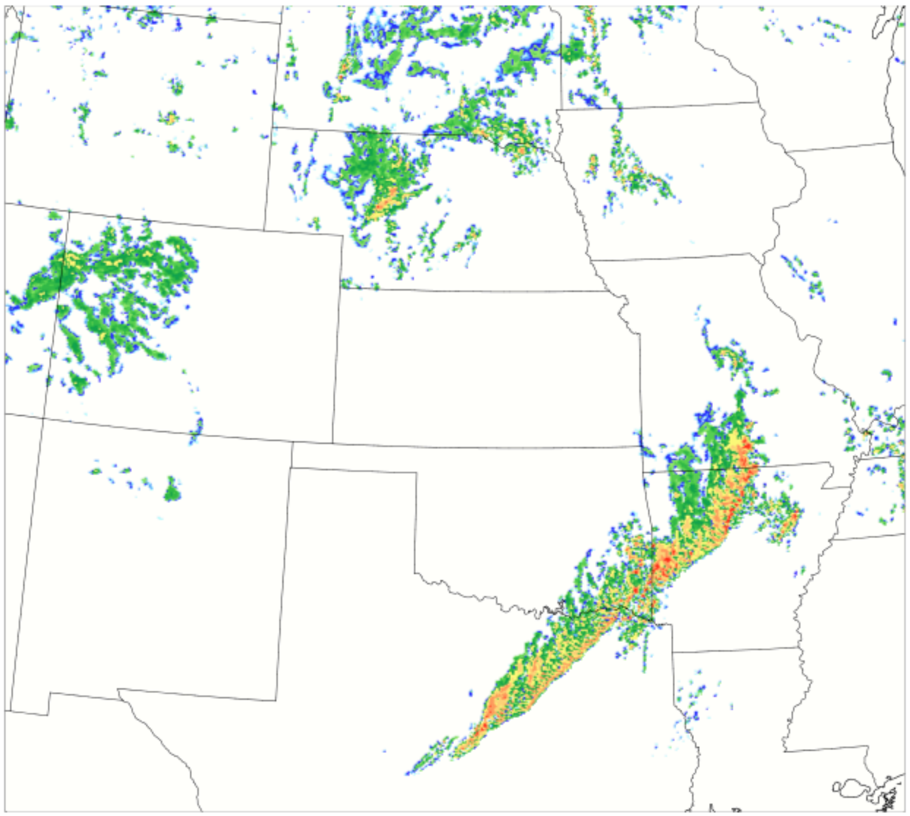
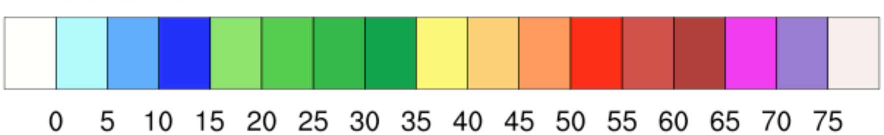
Model for Prediction Across Scales

Hazardous Weather Testbed
Spring Experiment 2015
Forecasts Results from MPAS

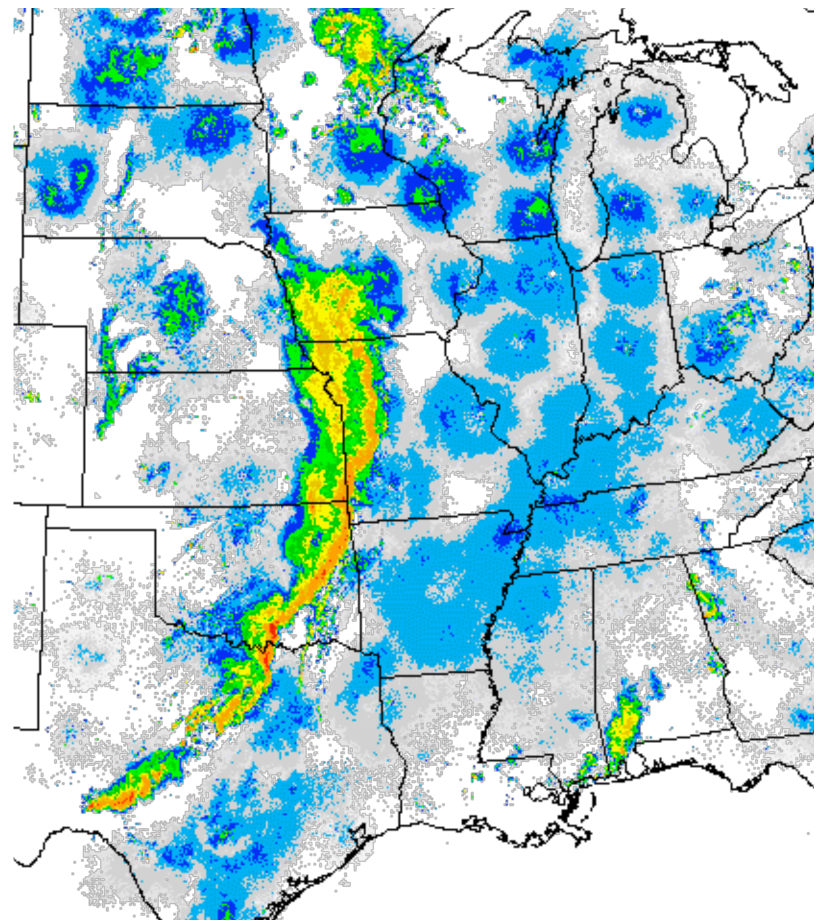
MPAS 50-3km 30h fcst
Init: 2015-05-16_00:00:00 UTC Valid: 2015-05-17_06:00:00 UTC
1km AGL reflectivity [dBZ]



NCAR



Reflectivity, NOAA SPC archive
valid 2015-05-17 06 UTC



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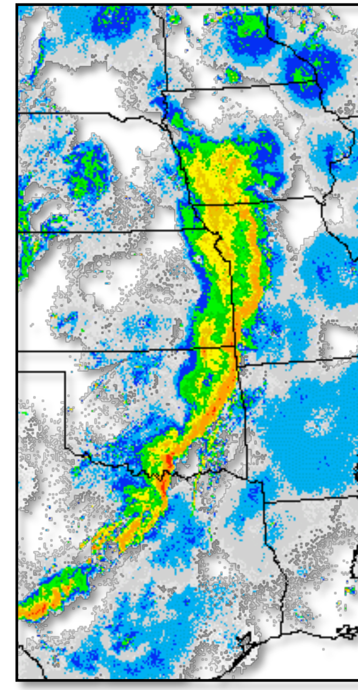
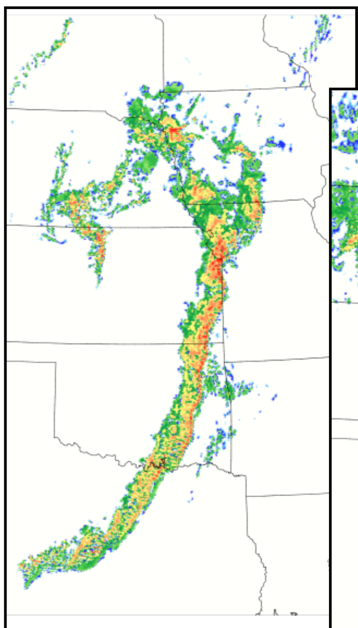
Hazardous Weather Testbed
Spring Experiment 2015
Forecasts Results from MPAS

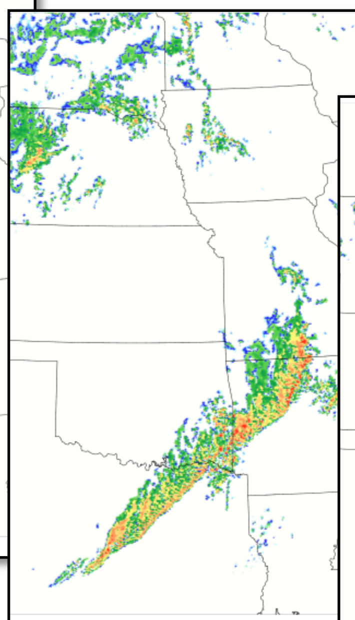


Reflectivity
NOAA SPC archive
2015-05-17 06 UTC

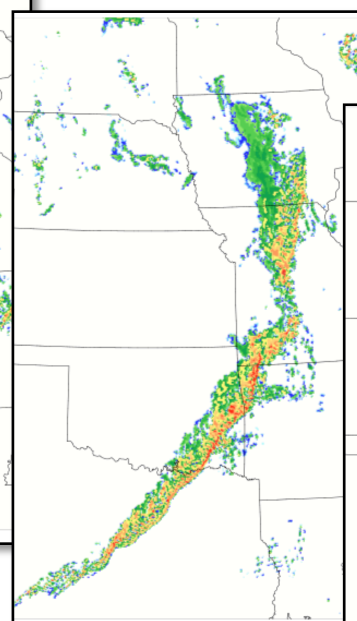
6 h forecast



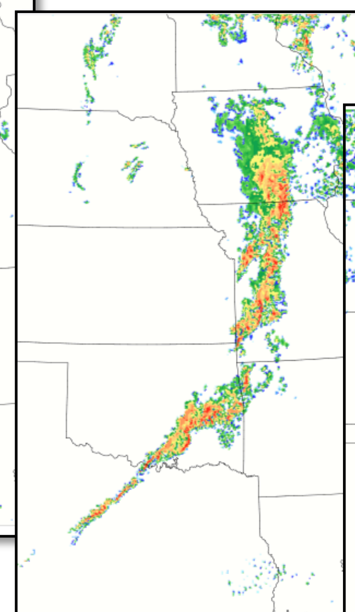
30 h forecast



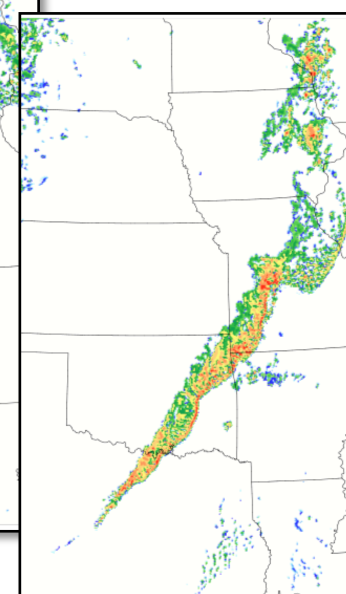
54 h forecast



78 h forecast



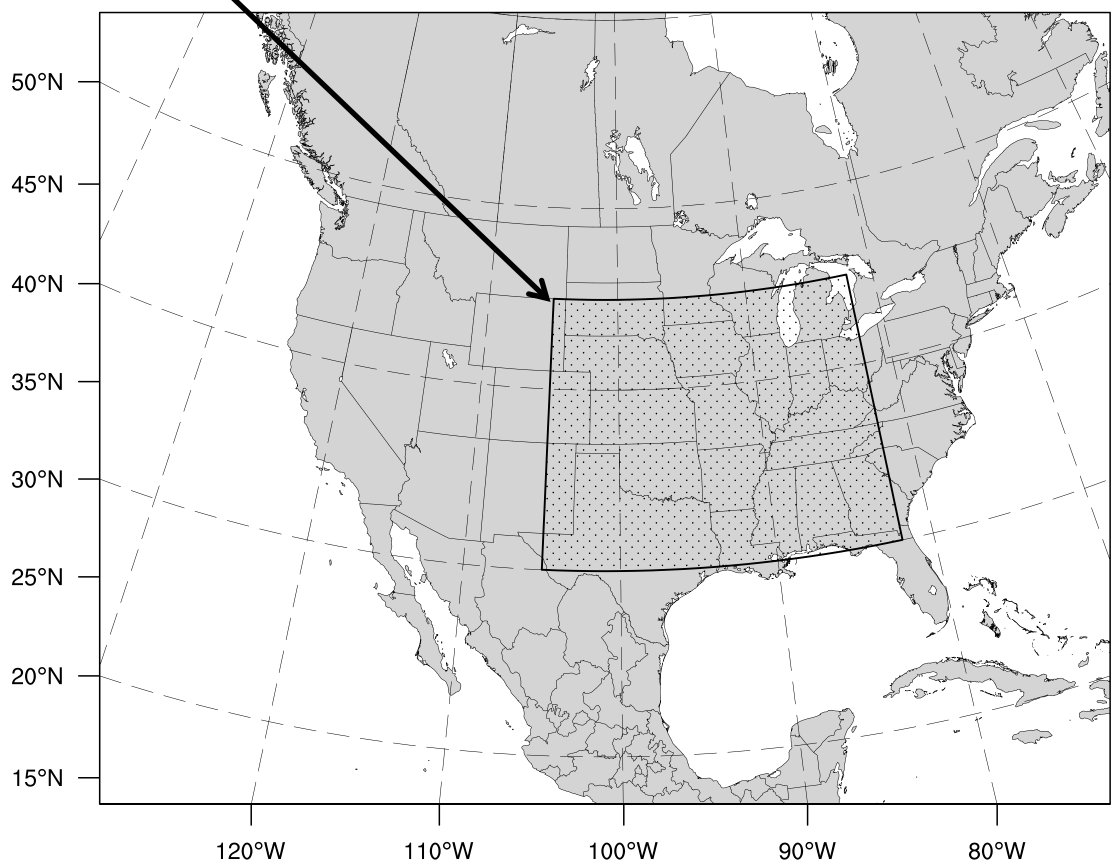
102 h forecast



1 km AGL reflectivity
Forecasts valid 2015-05-17 6 UTC

Hazardous Weather Testbed
Spring Experiment 2015
Verification against ST4 precipitation analyses

Verification region



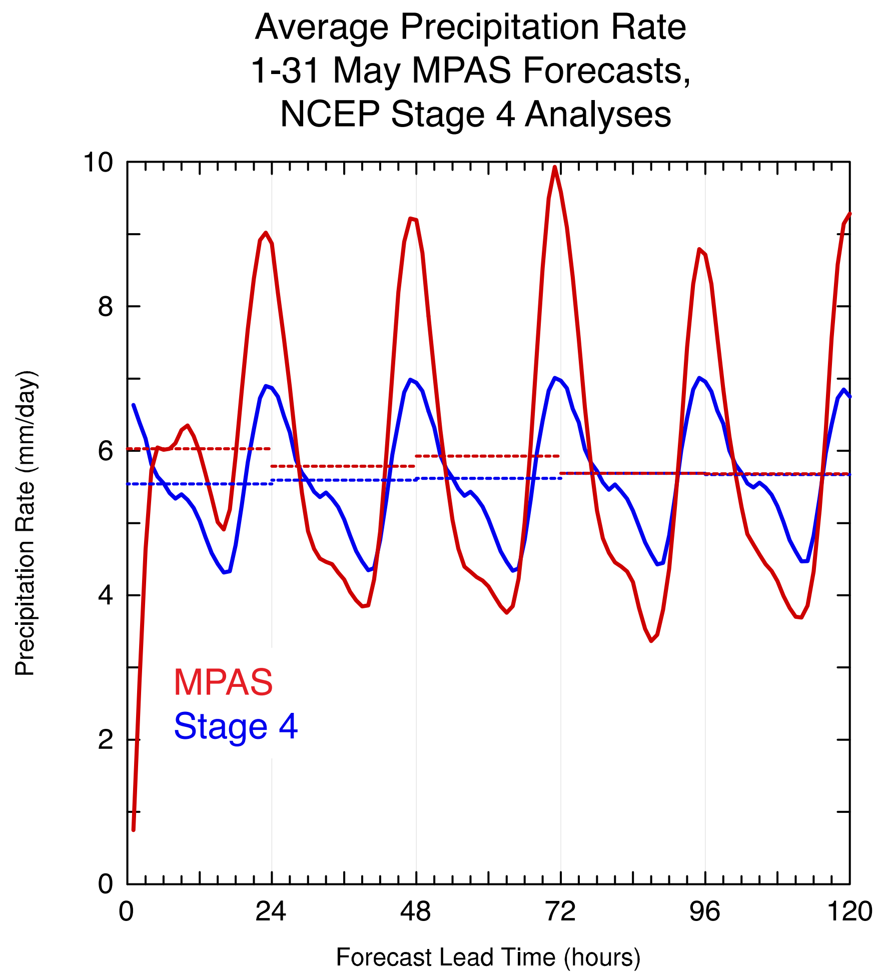
MPAS
Model for Prediction Across Scales

Hazardous Weather Testbed Spring Experiment 2015

Verification against ST4 precipitation analyses

- Timing of diurnal precipitation maxima and minima is very good.
- Significant over-estimation of diurnal precipitation maxima.
- Significant underestimation of diurnal precipitation minima.
- Over (under) estimation does not improve over time.

- Daily average precipitation (dashed lines) shows a small positive bias early, decreasing over time.



MPAS
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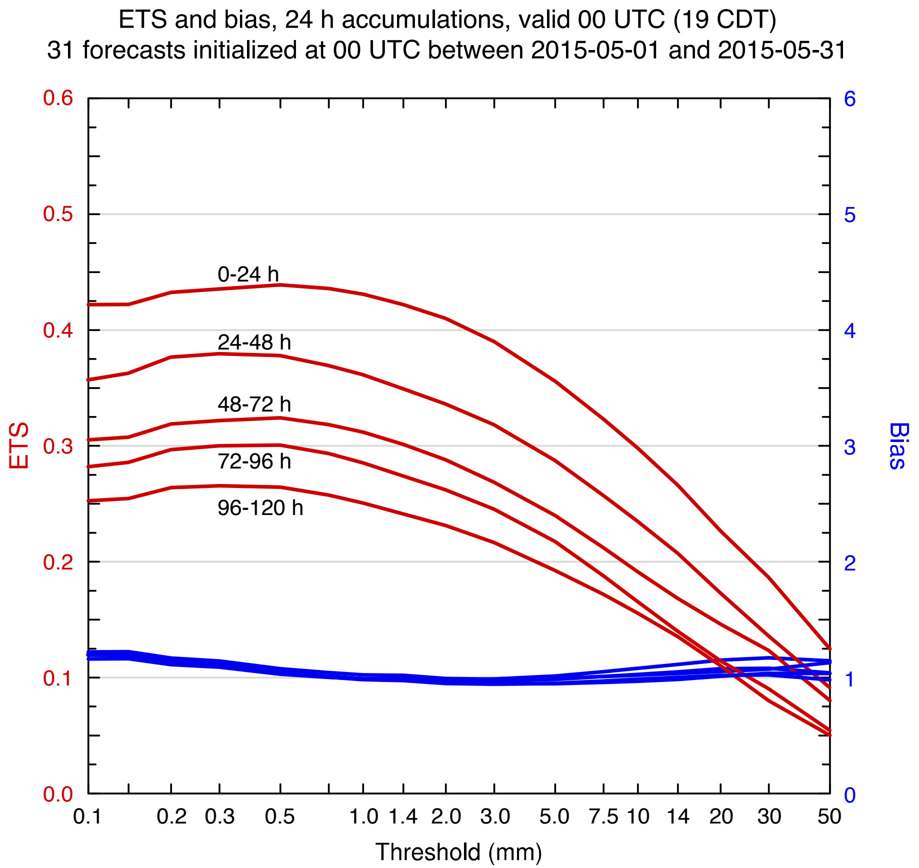
Spring Experiment 2015

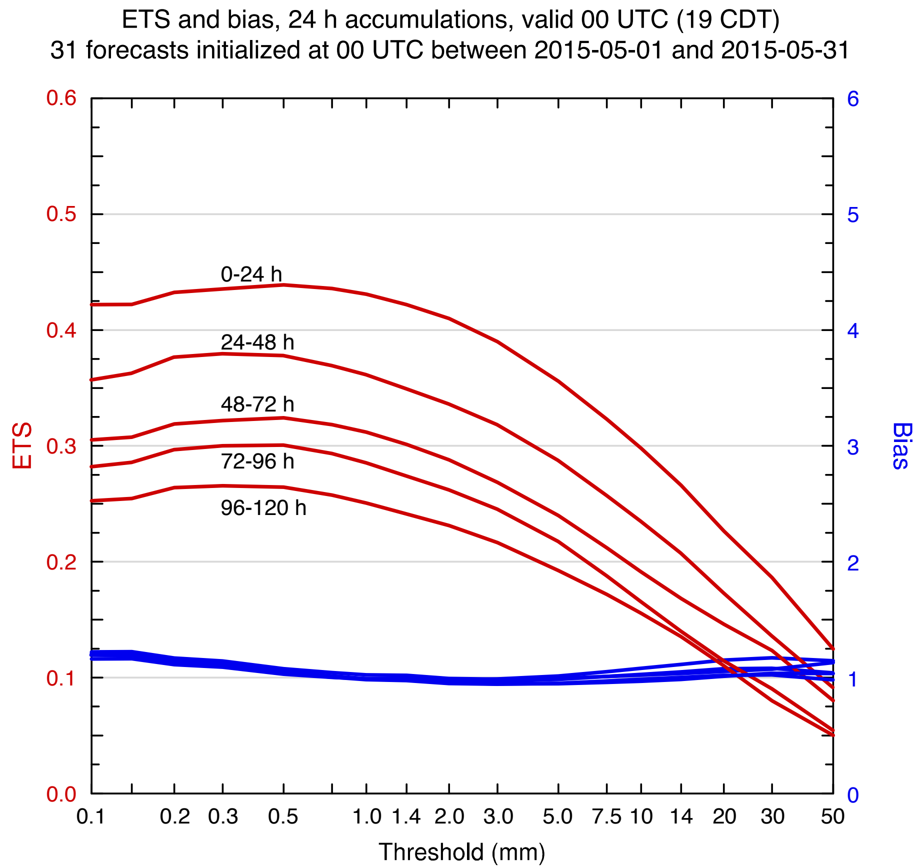
Verification against ST4 precipitation analyses



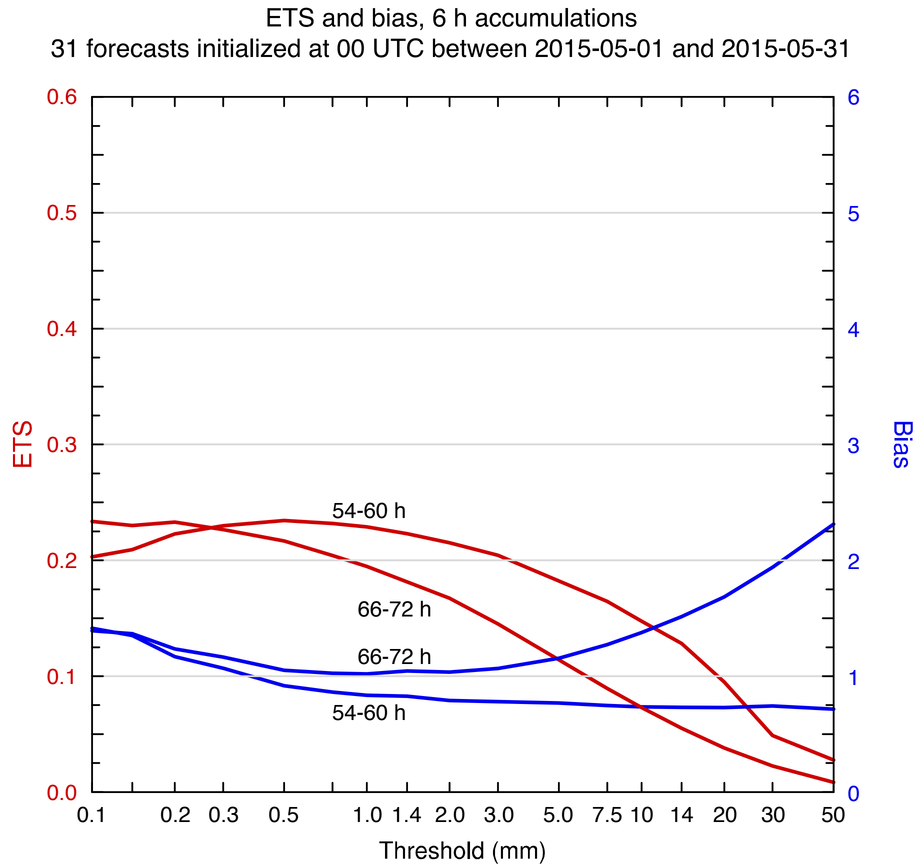
24 h accumulations

Hazardous Weather Testbed Spring Experiment 2015

Verification against ST4 precipitation analyses



24 h accumulations



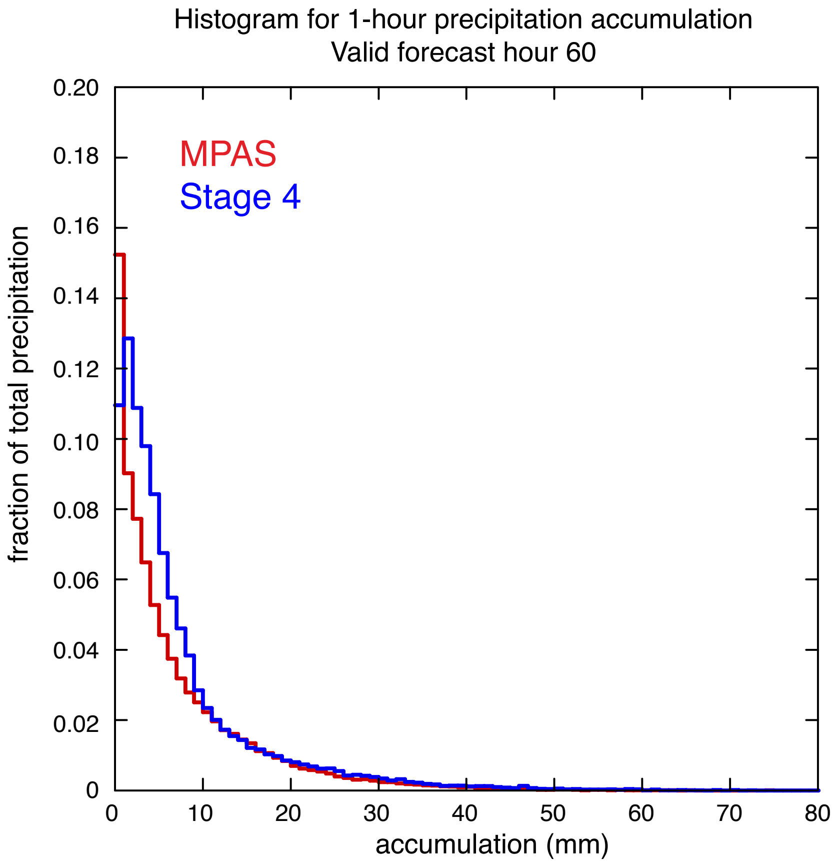
6 h accumulations

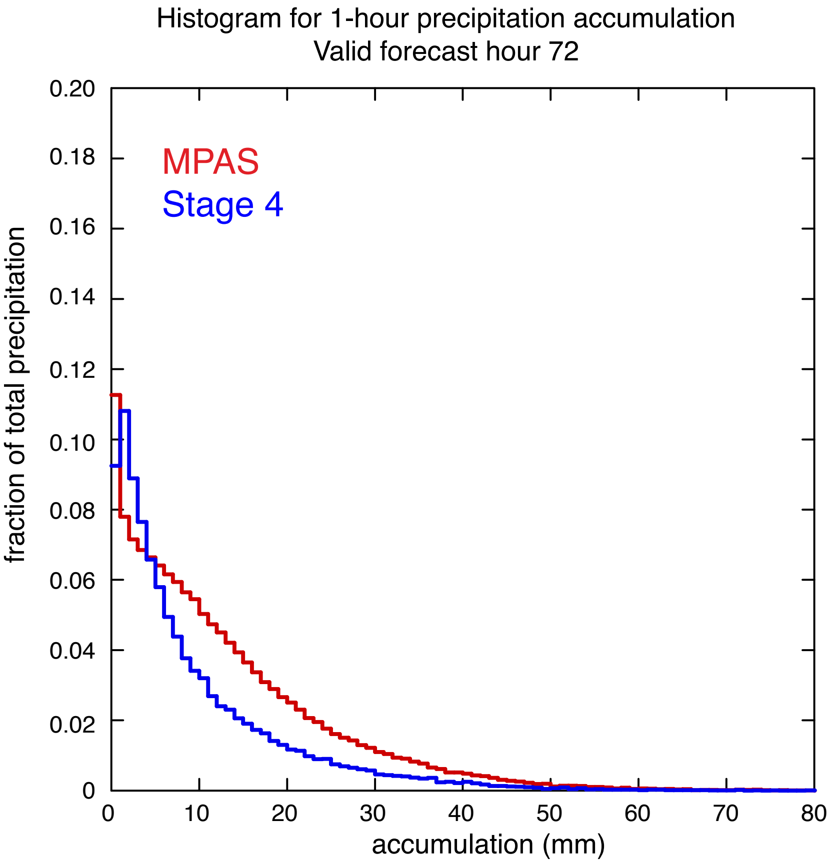
MPAS
Model for Prediction Across Scales

Hazardous Weather Testbed Spring Experiment 2015

Verification against ST4 precipitation analyses

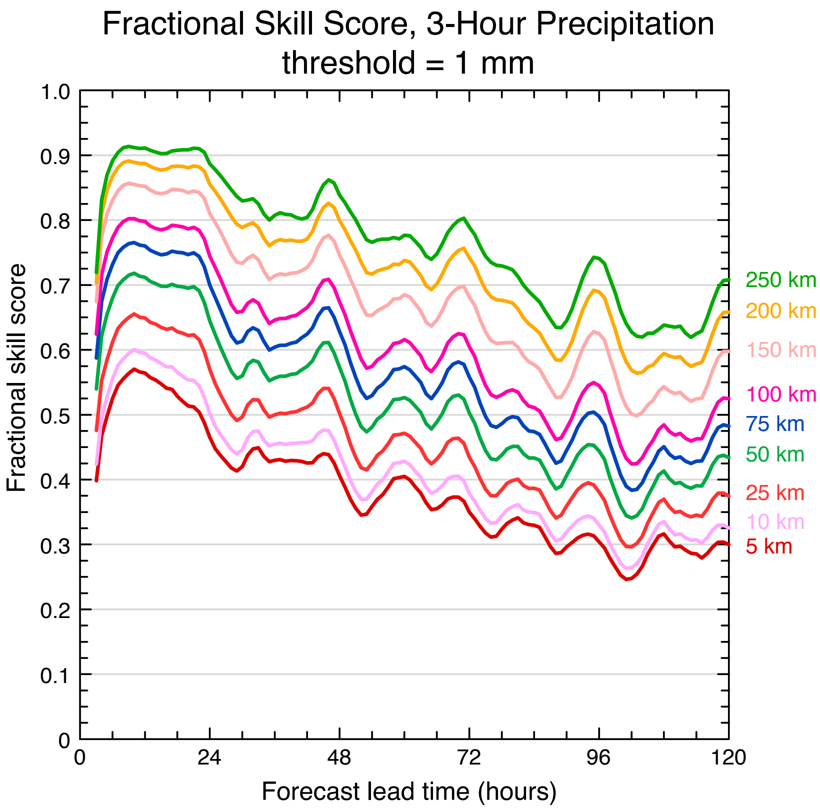
1-31 May 2015 forecasts

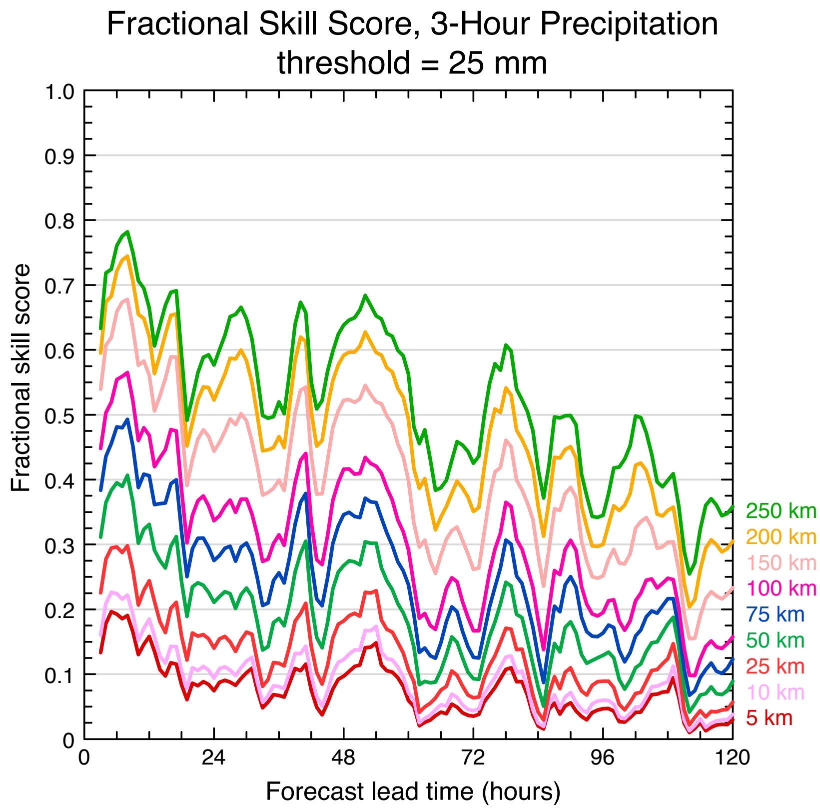




Hazardous Weather Testbed
Spring Experiment 2015

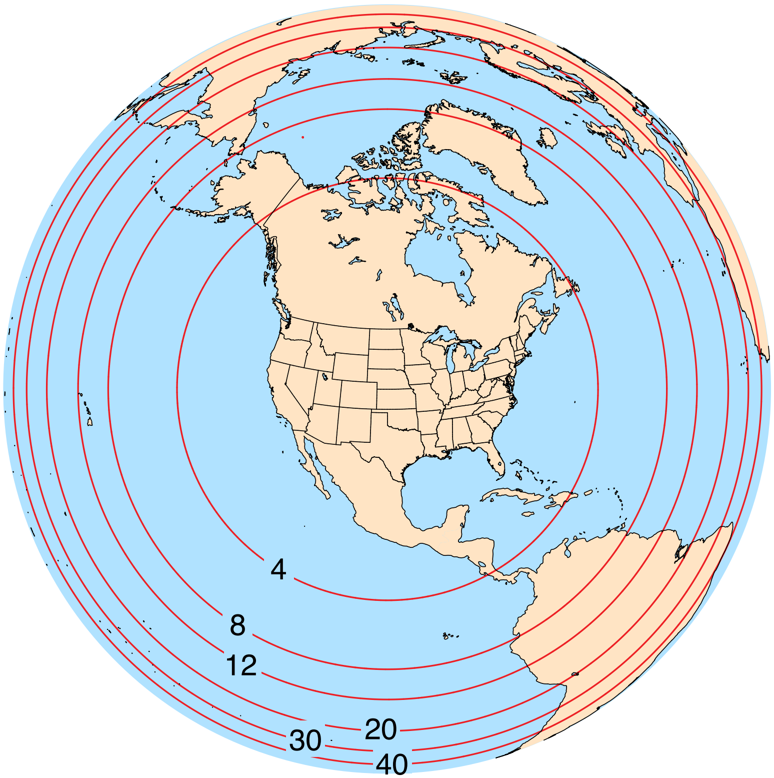
Verification against ST4 precipitation analyses





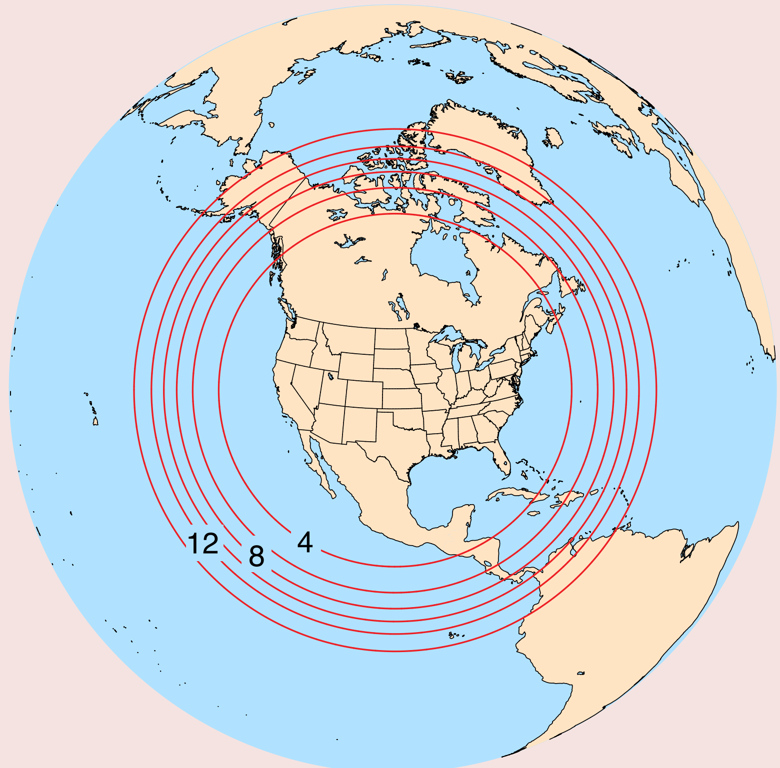
MPAS
Model for Prediction Across Scales

HWT Spring Experiment
5-day forecasts, 50 – 3 km mesh
1-31 May 2015



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

PECAN field campaign
3-day forecasts, 15 – 3 km mesh
7 June – 15 July 2015



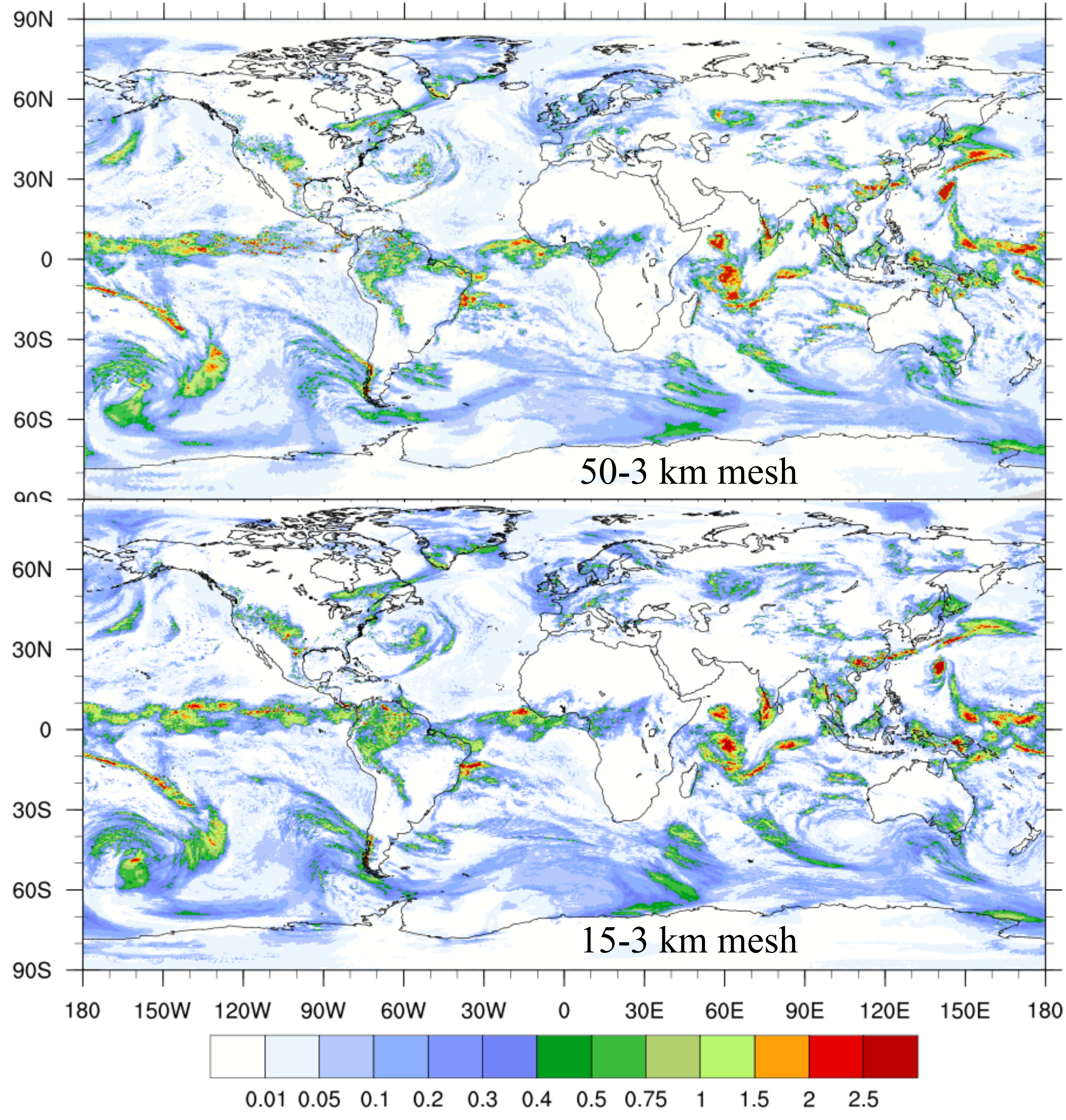
3-15 km mesh, Δx contours
approximately 6.5 million cells
50% have < 4 km spacing

MPAS
Model for Prediction Across Scales

15 May forecast test comparing the response on the two meshes

2015-05-15 00 UTC Initialization

120 hour forecasts
24 h accumulated precip

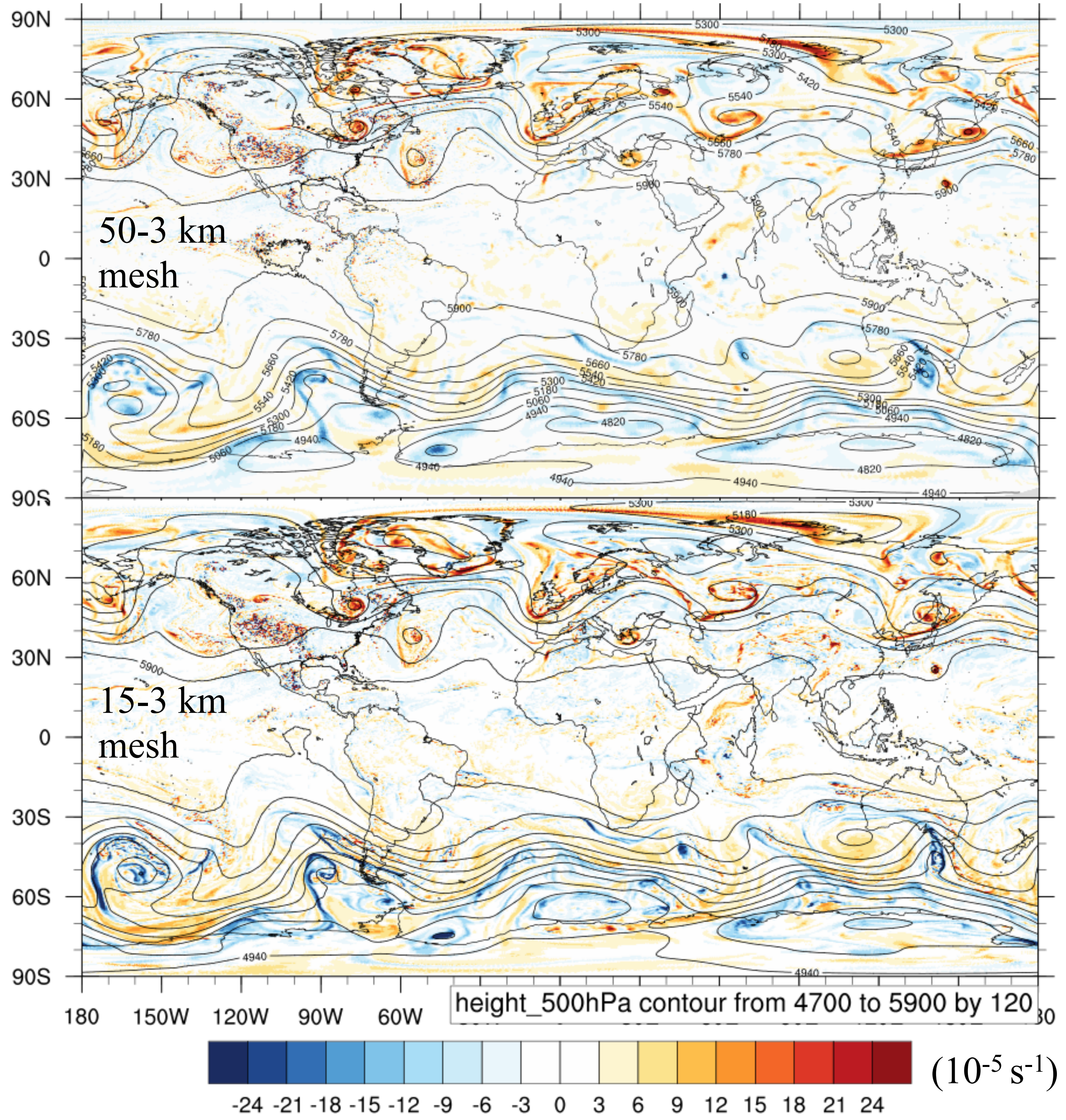


MPAS
Model for Prediction Across Scales

15 May forecast test comparing the response on the two meshes

2015-05-15 00 UTC Initialization

120 hour forecasts
500 hPa relative vorticity



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Forecasts Results from MPAS

Summary

Variable-resolution, nonhydrostatic-scale atmospheric simulations are viable

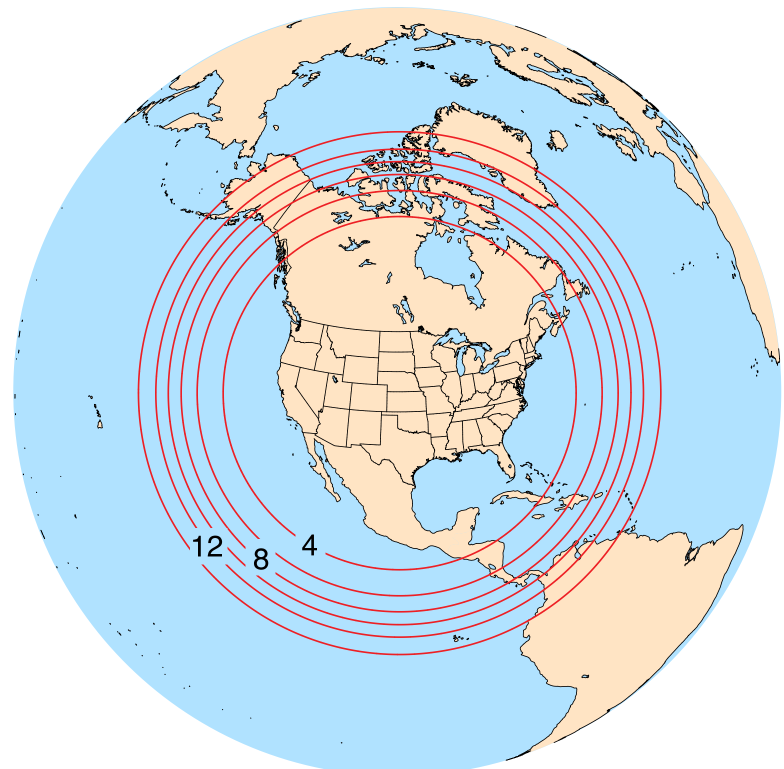
- Fidelity of convection similar to that in ARW.
- Preliminary HWT MPAS forecasts may contain some extended-range convective guidance.
- Simulation rates >100 days/day are attainable.
- GF convection scheme appears to be viable for hydrostatic-nonhydrostatic scale-aware applications.

Challenges

Scale-aware physics:

- *Convection*
- Microphysics
- Boundary layer

Data assimilation on variable meshes



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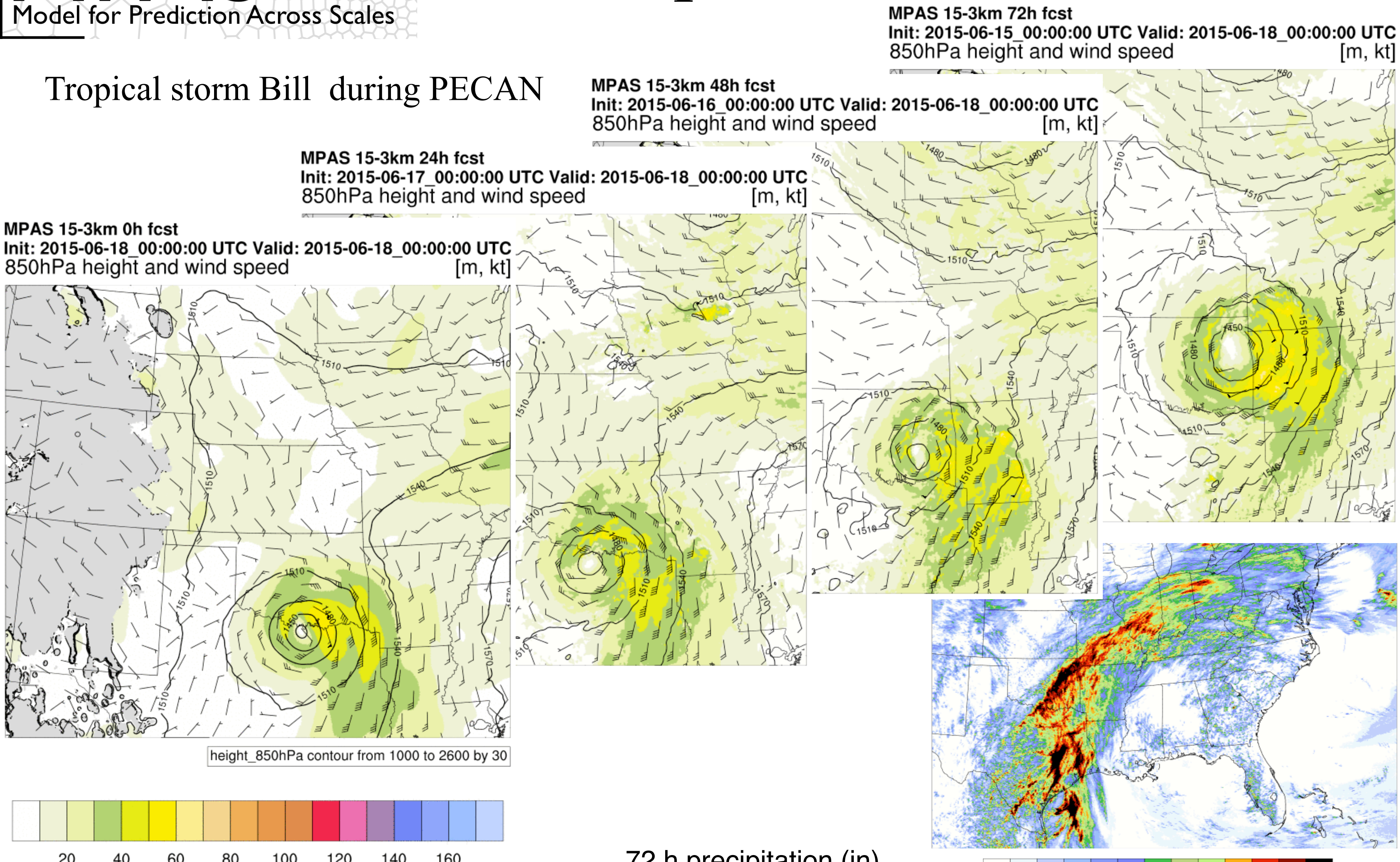
Tropical Storm Bill

Tropical storm Bill during PECAN



GFS analysis on the MPAS mesh

72 h precipitation (in)
valid 00 UTC 19 June 2015