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Q4FY11 NAM Upgrade Package Decision Brief

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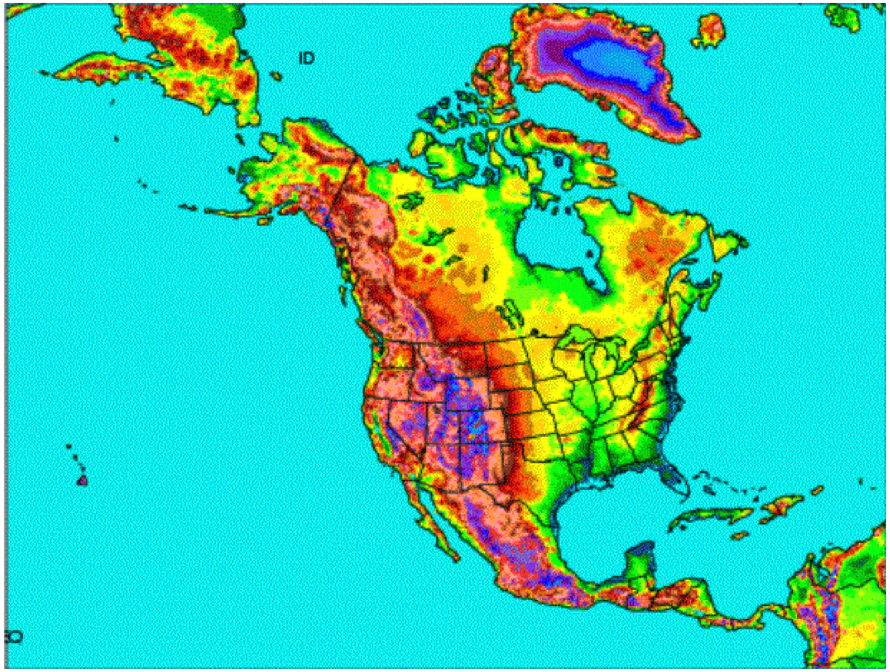
T O P I C S

- NEMS Infrastructure and NMMB Nesting
- NMMB Prediction Model & Passive Advection
- GSI analysis & NDAS upgrades
- Modified Physics and Parallel Testing
- FWIS, FWIS Cases and Smoke
- Post-Processing, Product Generation & Distribution
- Verification Results

September 2011 NAM Upgrade

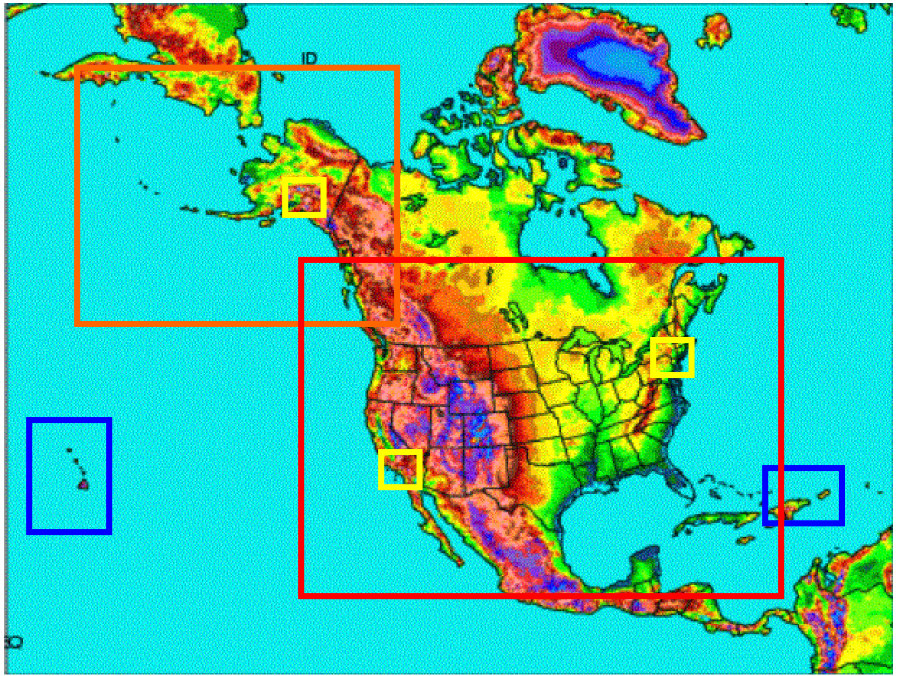
Current NAM

- WRF-NMM (E-grid)
- 4/Day = 6 hr update
- Forecasts to 84 hours
- 12 km horizontal grid spacing



New NAM

- NEMS based NMMB
- B-grid replaces E-grid
- Parent remains 12 km to 84 hr
- Four Fixed Nests Run to 60 hr
  - **4 km CONUS nest**
  - **6 km Alaska nest**
  - **3 km HI & PR nests**
- **Single placeable 1.33km or 1.5 km FireWeather/IMET/DHS run to 36hr**



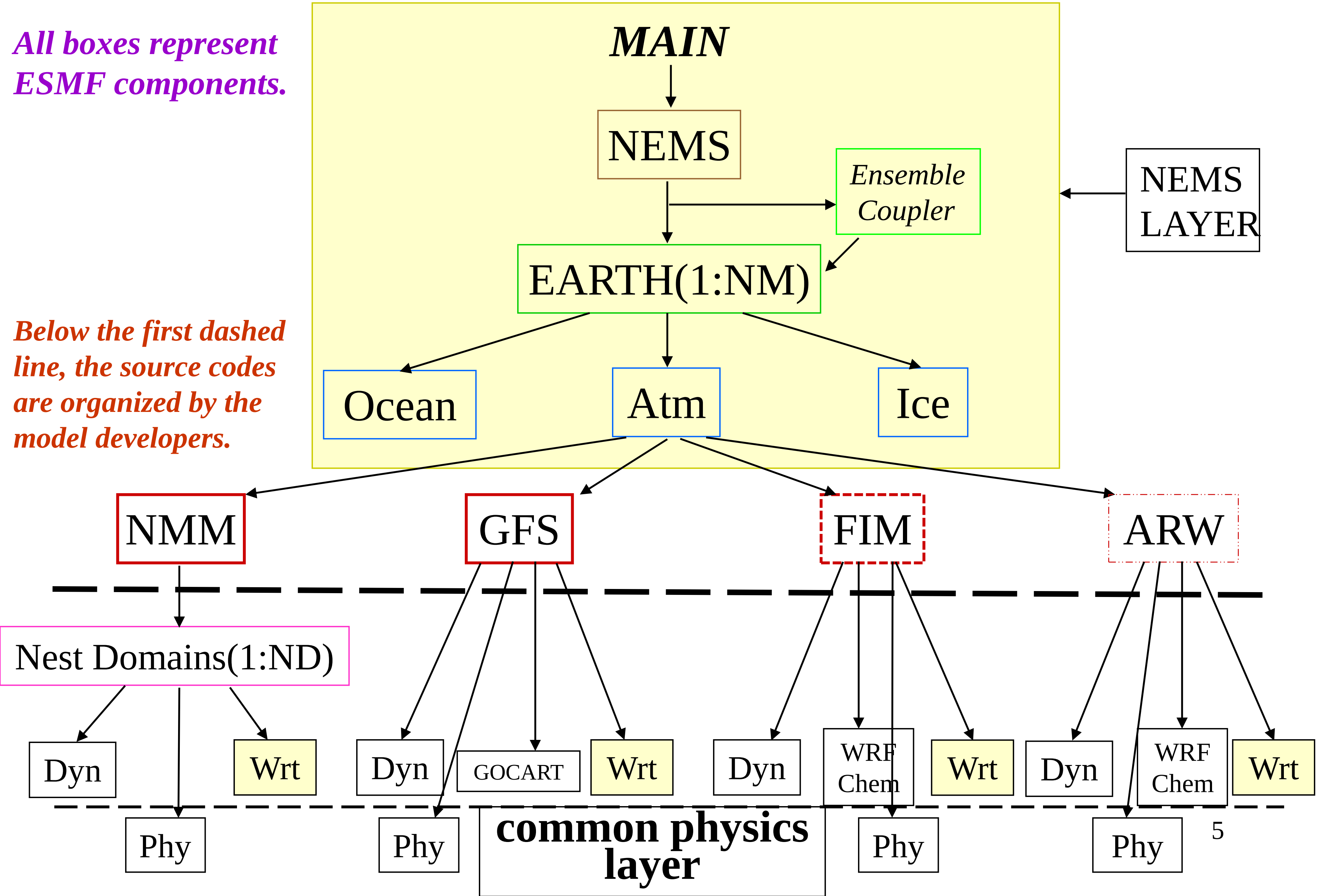
There is Agreement & Commitment on a 'One NOAA' Modeling Framework

- This goes back to the first days of Admiral L.
- The ultimate target is a completed NOAA framework of ESMF components within which NOAA scientists can work efficiently
- Consistency with NUOPC is expected as well
- NCEP has been building NEMS for this purpose
- Community involvement is expected and encouraged
- Support for ESMF has moved permanently from NCAR/SCD to NOAA/ESRL

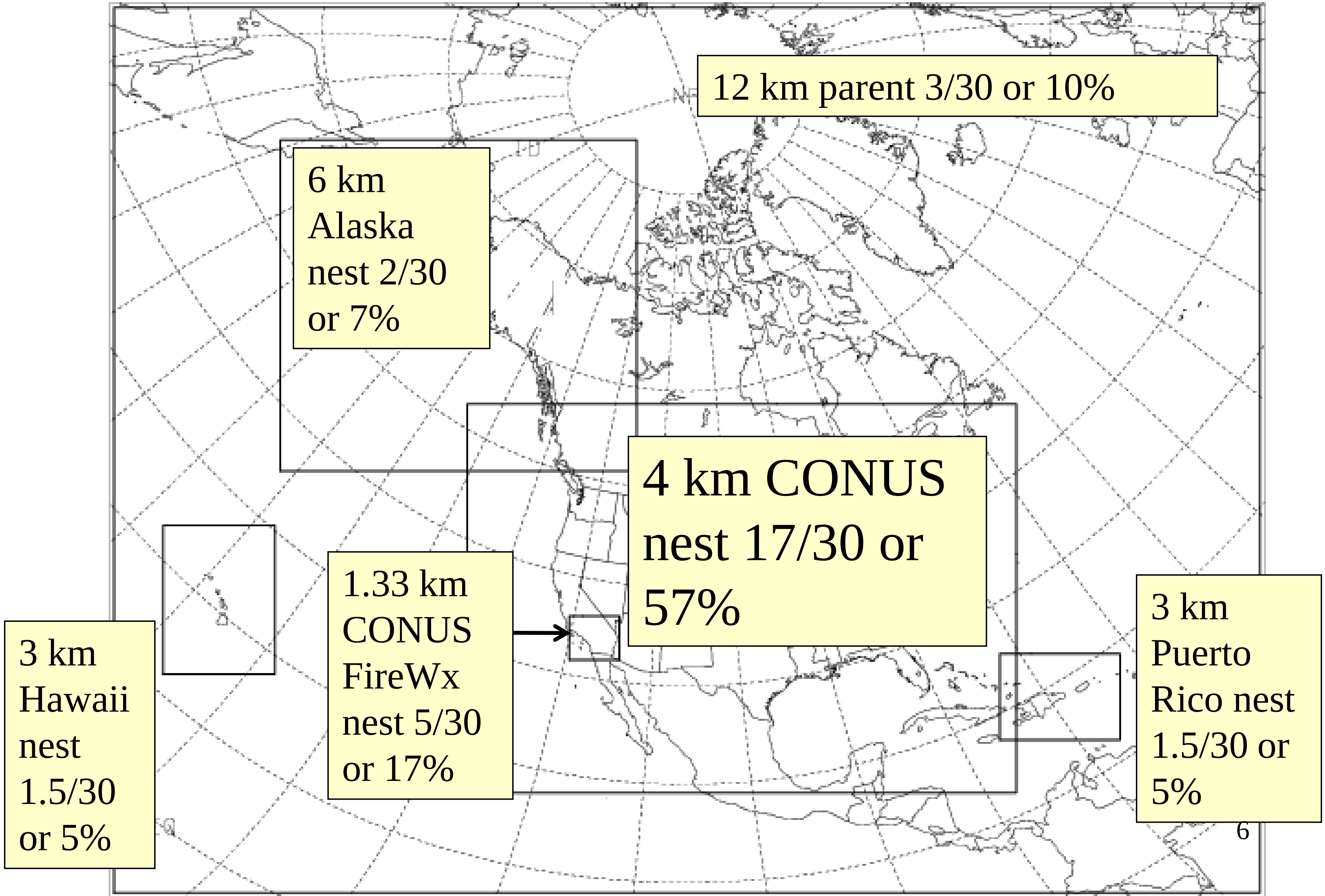
NEMS Component Structure

All boxes represent ESMF components.

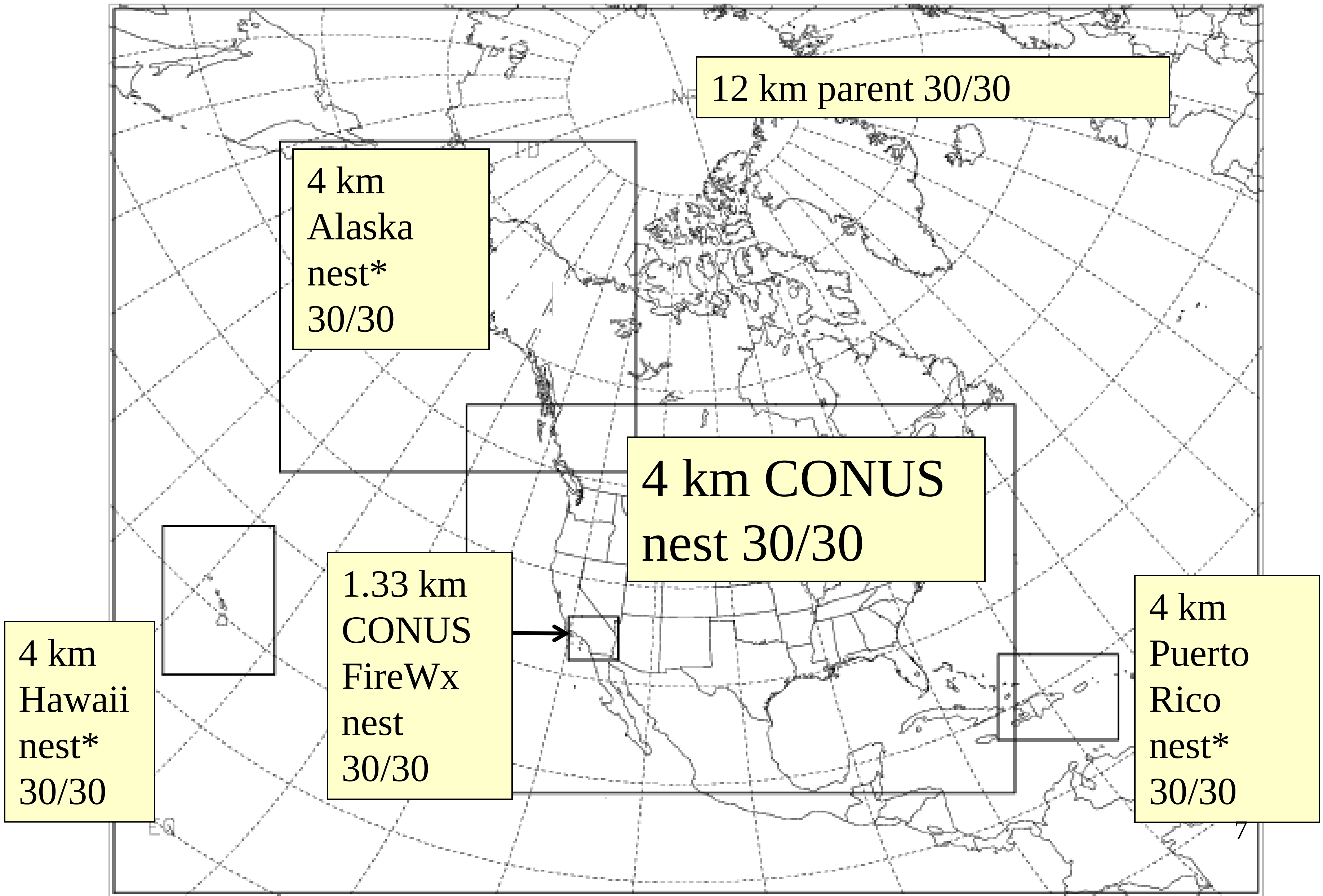
Below the first dashed line, the source codes are organized by the model developers.



Runtime & optimal node apportionment for NMMB nesting with a Fire Wx nest over CONUS (30 nodes): 12 hr fcst in 1619 s [Matt Pyle]



WRF-NMM takes 3.6 times longer to run comparable nesting with Fire Wx nest over CONUS (30 nodes): 12 hr fcst in 5857 s [Matt Pyle]



Why Does It Run So Much Faster?

	NMMB	NMM	
Runtimes	1619 s	5857 s	3.6 x faster
			Contribution to speed up
New Model Dynamics	NMMB	NMM	~2%
Infrastructure	NEMS	WRF	~2%
Nesting	• NMMB specific • Outside of the NEMS infrastructure • Processor apportionment • 1-way nests solved simultaneously	• ~Core independent* • Part of the WRF infrastructure • No processor apportionment • 1-way nests solved sequentially	~96%
Horizontal resolution step down ratio	Any integer ratio, e.g. 2:1, 3:1, 4:1, …	Only 3:1*	0% this relates to flexibility, not speed

Why is it so much faster*? [Tom Black]

- NEMS itself is not providing much of the speedup. The fundamentally simple architecture / environment of the NEMS infrastructure gave me the freedom to do the nesting inside the NMMB where it sits below / outside the NEMS infrastructure.
- WRF's nesting is part of the infrastructure, applies all processors to all domains / nests and solves them in sequence. This is identical to their 2-way nesting which can be very inefficient for a 1-way nesting strategy as Matt's test demonstrates.
- We believe WRF approach can also be significantly improved upon for 2-way nests even if they are moving.

*Recall WRF-NMM nesting was done by S.G.Gopalakrishnan with substantial assistance of J.Michalakes

Hypothetical NMMB Simultaneous Run

Global [with Igor & Julia] and NAM [with CONUS nest]

12 km NAM NMMB

9 km **Julia** NMMB

4 km NAM-nest NMMB

9 km **Igor** NMMB

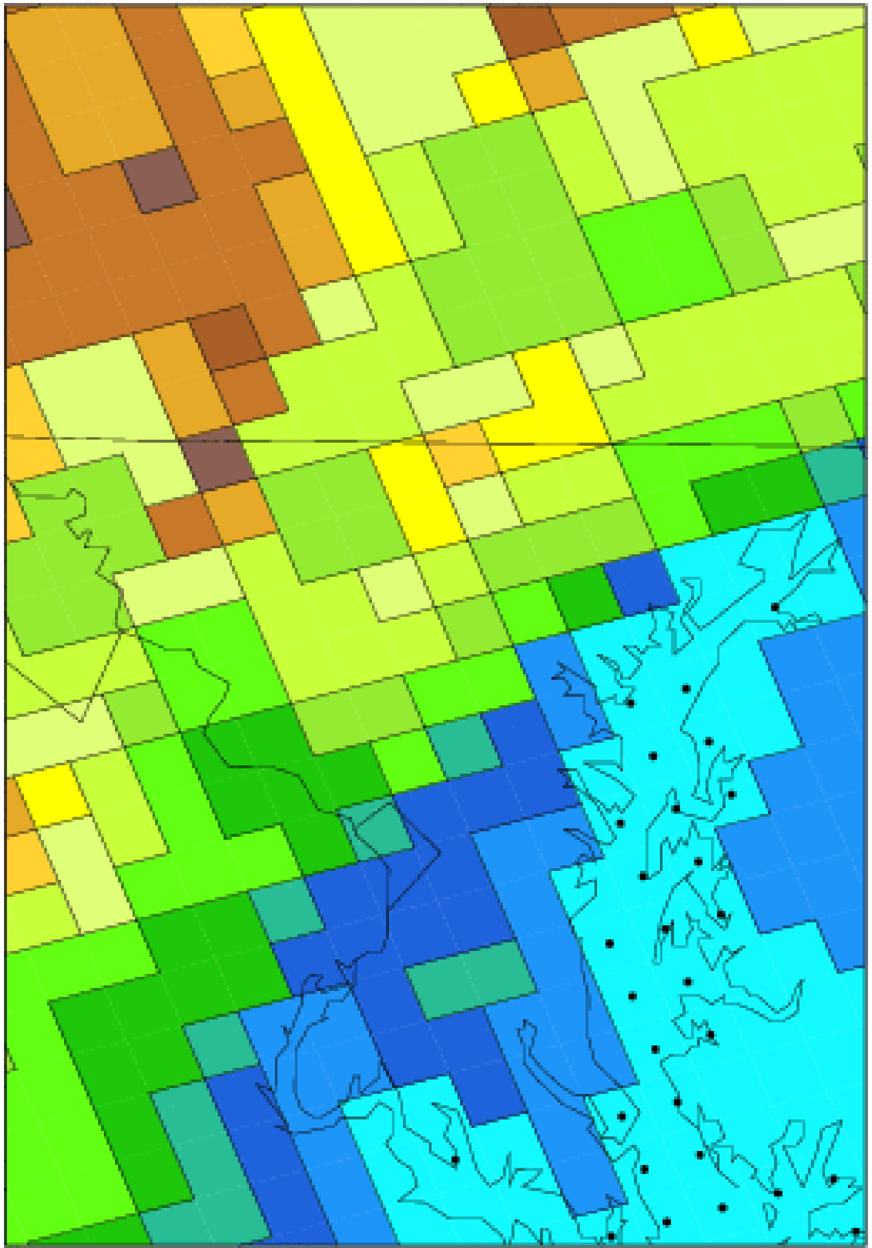
12 km NAM NMMB

27 km Global NMMB

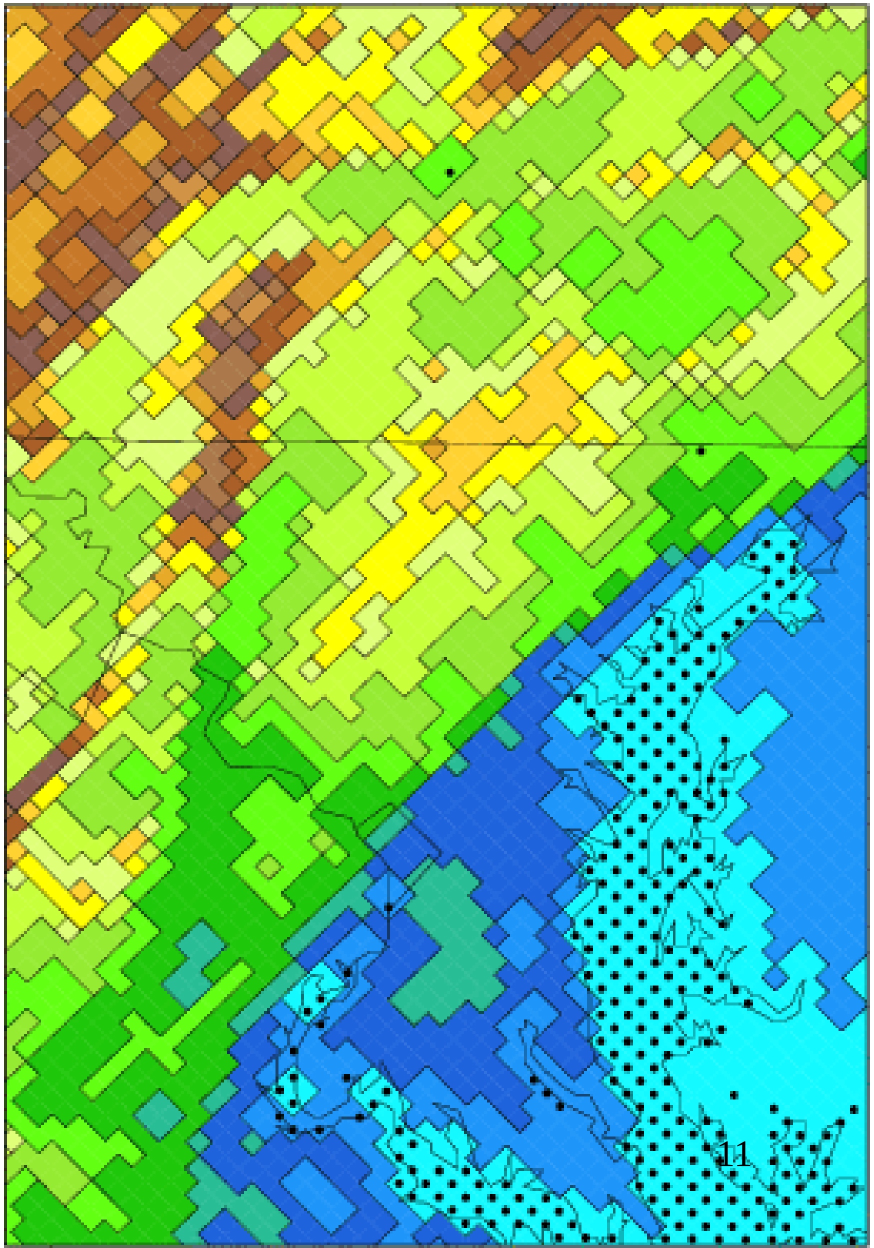
27 km Global NMMB

Dots represent water points Domain is Chesapeake Bay

12 km Terrain

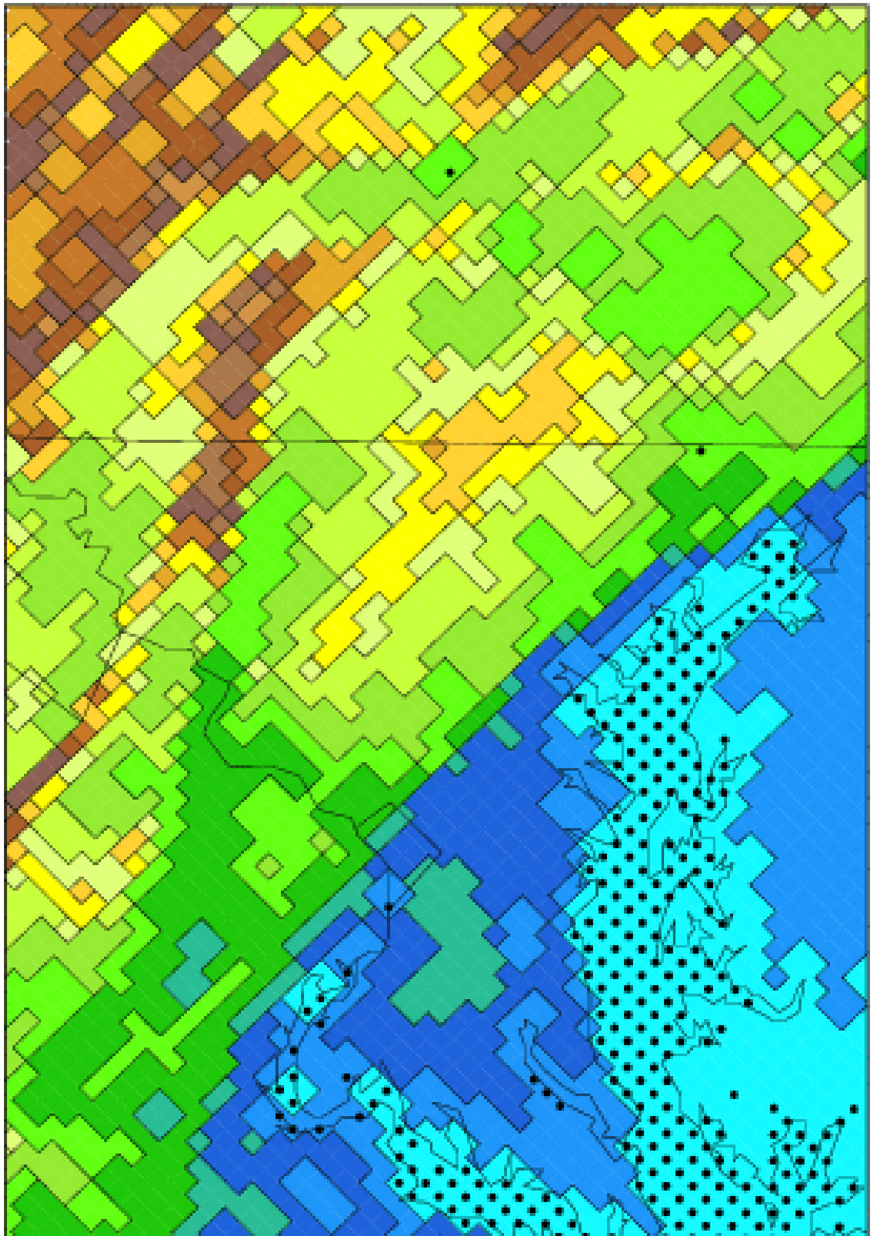


4 km Terrain

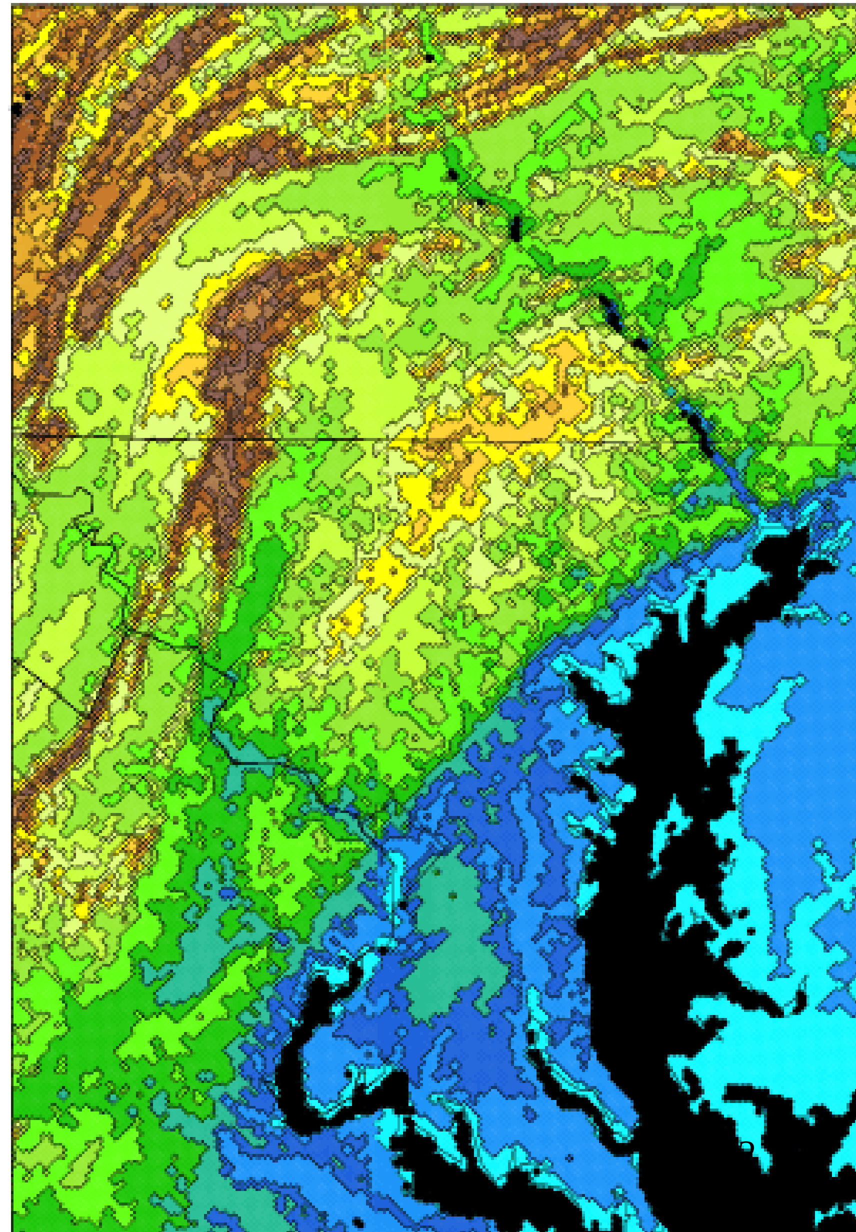


Dots represent water points Domain is Chesapeake Bay

4 km Terrain



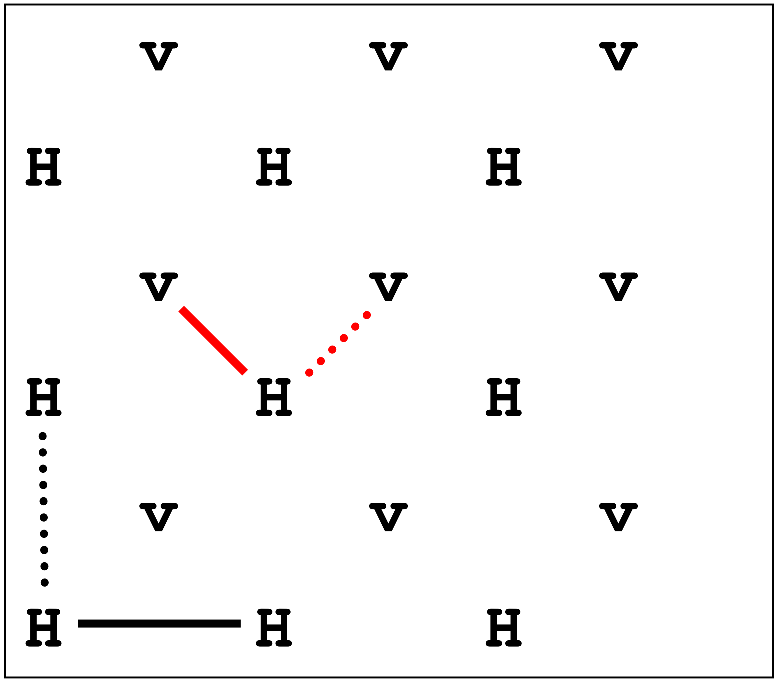
1 km Terrain



NEMS Preprocessing System (NPS) for NMMB (courtesy Matt Pyle)

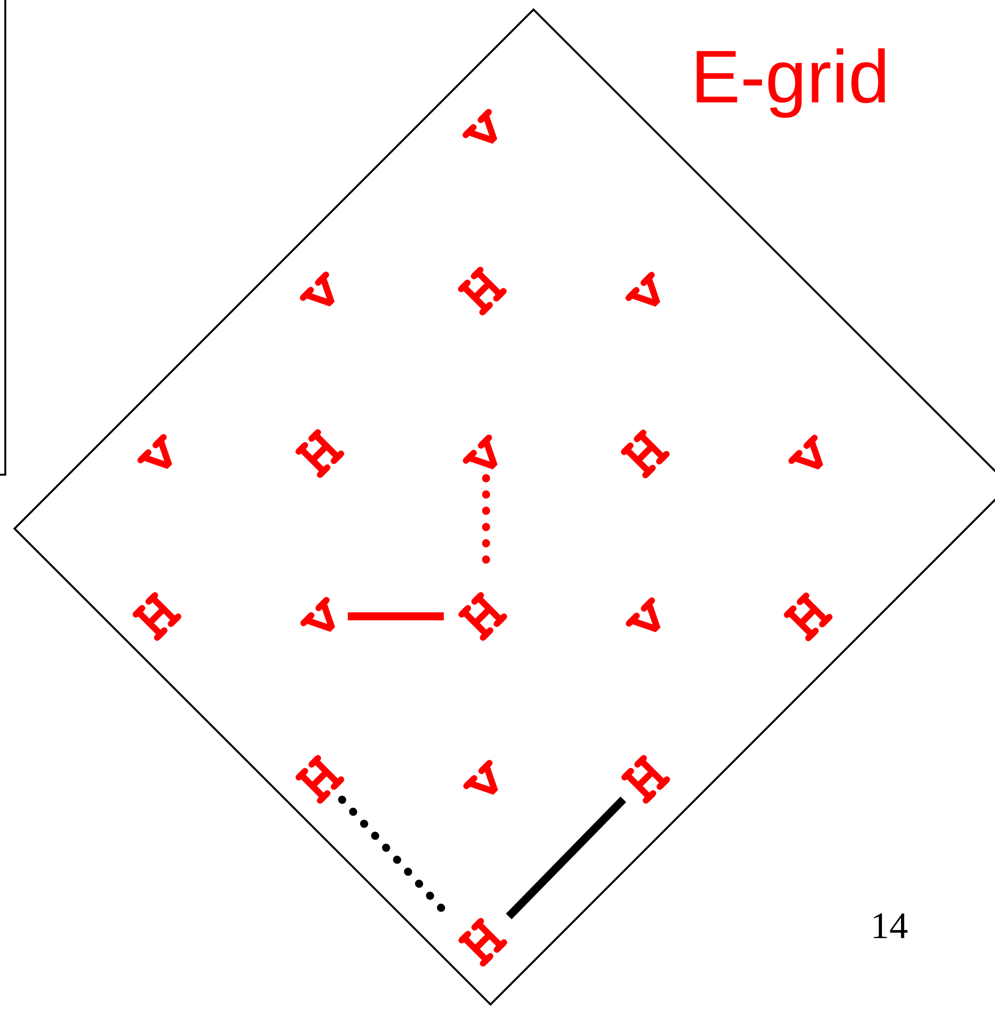
- To create the 1st guess at the start of NDAS (at time T-12hr), NPS uses GFS spectral coefficients (rather than post-processed pressure level fields on a 1 deg lat/lon grid as has to be done with WRF'sWPS)
- Lateral boundary conditions for the parent are also based on GFS spectral coefficients (as is done in current NAM but not in WRF REAL)
- Change to NEMS code (in Feb 2011) to read base albedo (snowfree) from NEMSIO input file created by NPS - previously had only read dynamic albedo, leading to its use as the base albedo, leading to erroneously high albedo over shallow/patchy snow cover. (Thanks to George Gayno & Jun Wang)

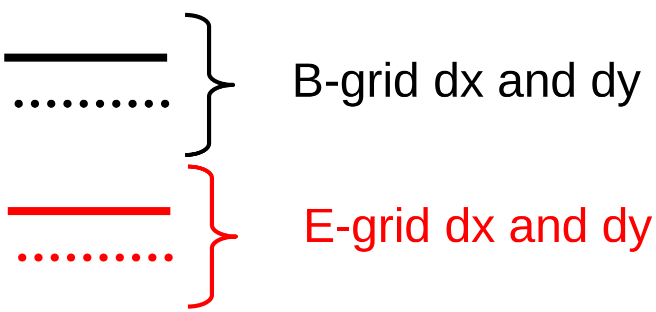
NMMB stands for Nonhydrostatic Multiscale Model on B-grid [Zavisa Janjic]



B-grid

B-grid is just an E-grid rotated 45 degrees (and vice-versa)





Zavisa Janjic's NMMB - 1

- NMMB = Nonhydrostatic Multiscale Model on B-grid, but no real difference in dynamics versus current NMM
- These are the main B-grid & NMMB advantages:
  - The B-grid requires narrower halos, i.e. less communications;
  - On the globe, polar filtering on the B-grid is more effective and the polar boundary condition is more straightforward;
  - E-grid code was more complex , indirect addressing (slower too) and was more difficult for debugging and maintenance;
  - The B-grid is better for application of the model in idealized 2D studies, e.g. in the x-z plane;
  - NEMS physics interface streamlined compared to WRF infrastructure, facilitating development, debugging and maintenance.

Zavisa Janjic's NMMB - 2

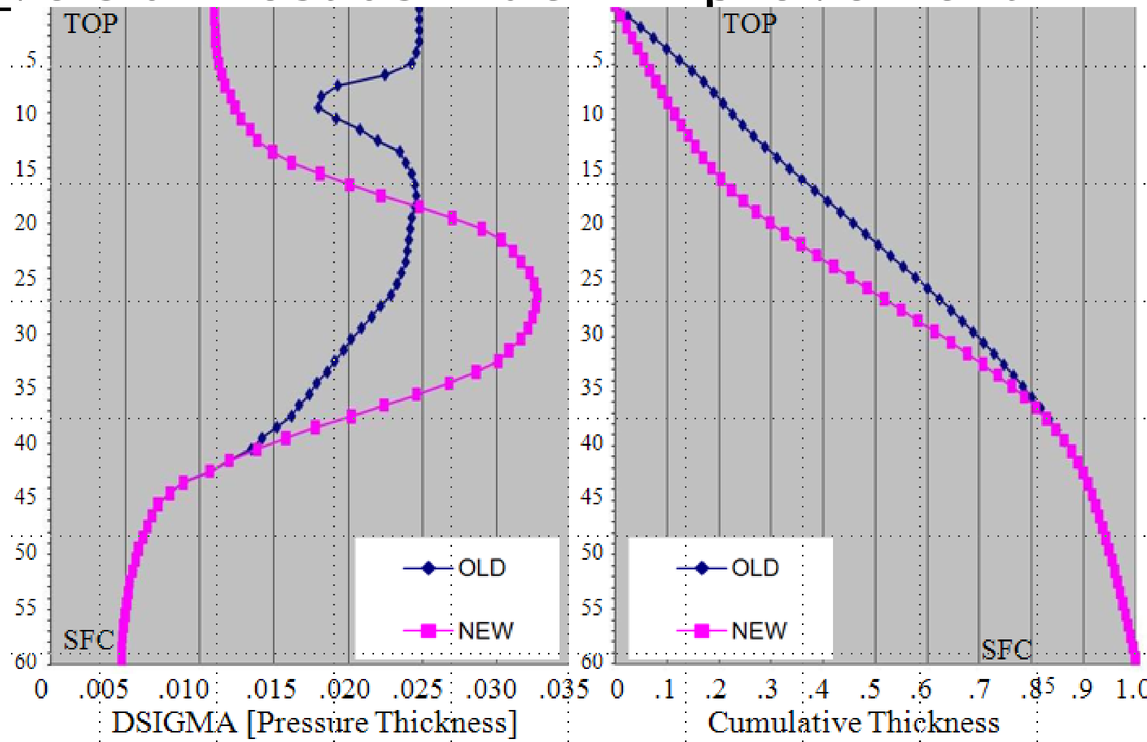
- Other NMMB differences / enhancements:
  - New Eulerian passive advection
  - New generalized hybrid vertical coordinate embodies:
    - Sangster 1960; Arakawa and Lamb 1977; "SAL"
    - Simmons and Burridge (1981) "SA" + Eckerman (2008)
    - Hybrid used by GFS
    - New vertical distribution has more layers in the stratosphere
  - Multiple [WRF + GFS] physics options available (via NEMS and its common physics layer)
  - 5 rows used for lateral boundary transition zone
  - Diffusion for specific humidity and cloud water is increased by 4x (equivalent to setting smag2=0.8)

Zavisa Janjic's NMMB - 3

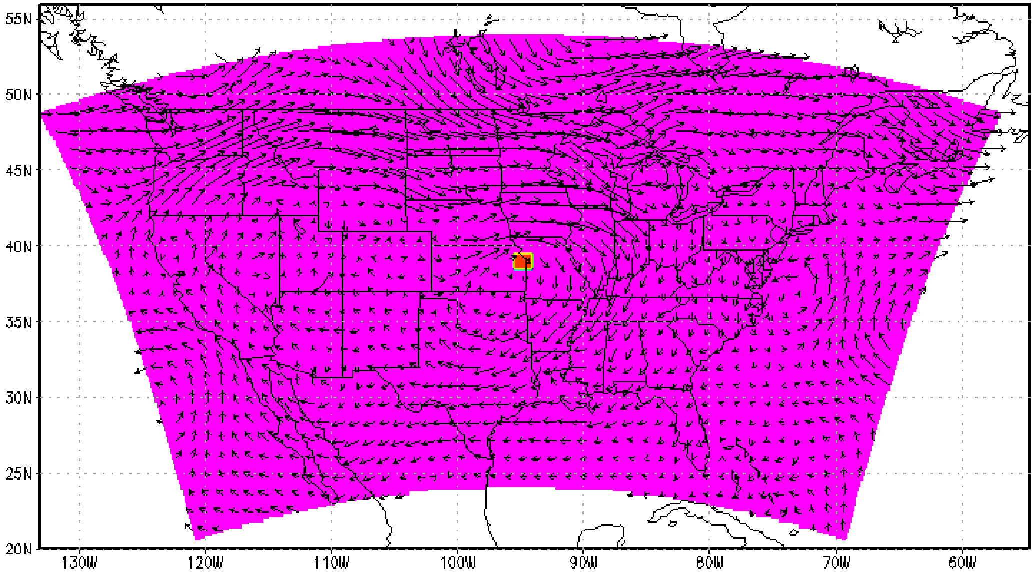
- NMMB differences / enhancements for **the nests:**
  - Increase Smagorinsky constant for 2nd order diffusion (smag2) from 0.2 to 0.4 for all nests
  - Gravity wave drag/mountain blocking turned on and lateral boundary transition zone set to 3 rows for the Alaska nest
  - Changed parameter CODAMP (divergence damping constant) from 12 to 9 for all nests except Fire Wx
  - To remove computational noise in the Fire Wx nests, dw/dt is gradually reduced as you approach the model top (by assuming attenuation of dw/dt of the form $\cos^2$ in the top 15 mb of the atmosphere)

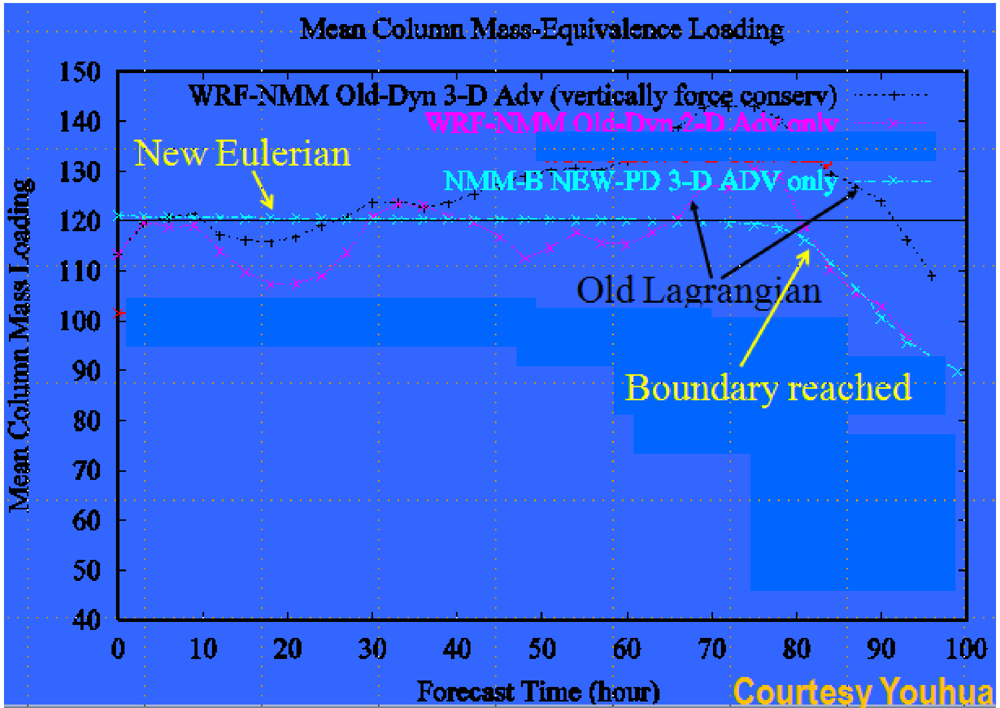
Vertical Coordinate & RRTM Tests

- Results of tests of the 12z 2/28/09 case with RRTM and modified vertical level distribution
  - http://www.emc.ncep.noaa.gov/mmb/mmbpll/radlevtests.html
  - RRTM too expensive for too little improvement
  - 70 levels also too expensive for small benefit
  - Redistributed 60 levels almost as much improvement as 70 levels with no added expense so this was our solution of choice



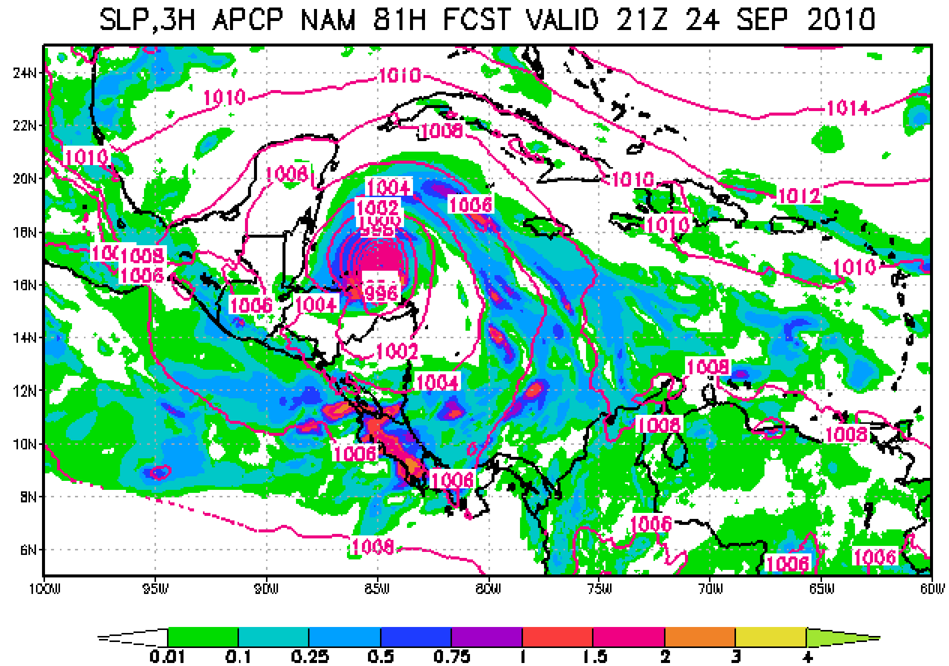
Janjic Eulerian Passive Advection

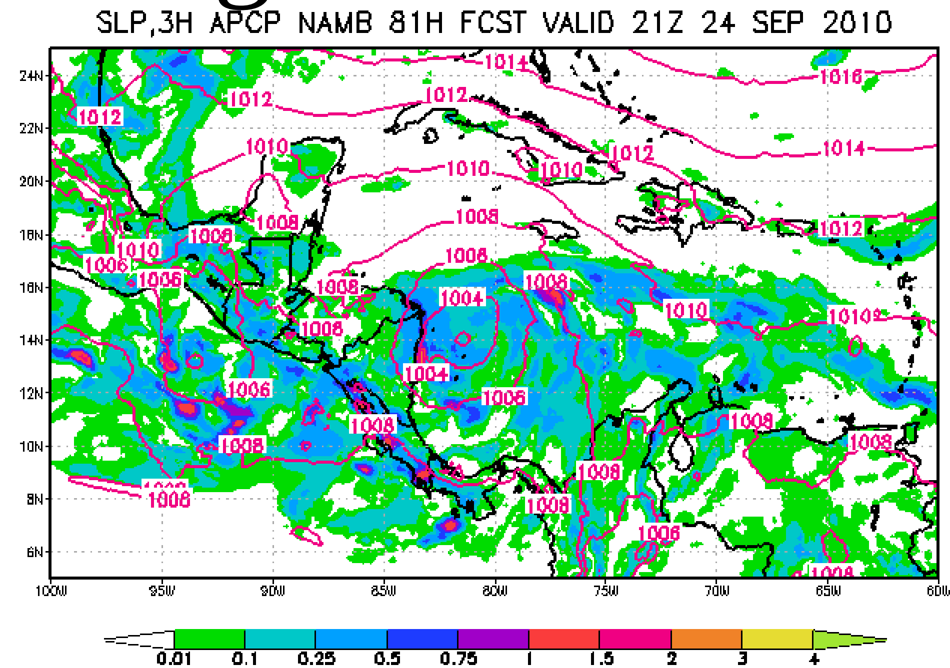




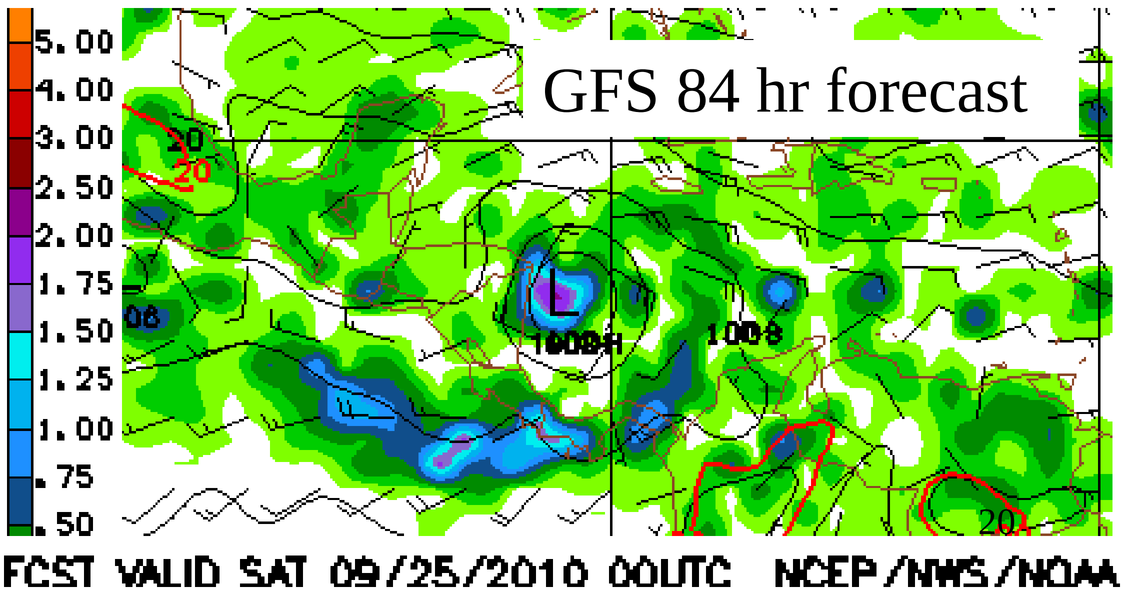
- Regional NMM-B with 3-D tracer advection (no tracer physics & diffusion)
- Tracer initialized at center of the domain from bottom to top (cuboid form)
- Zero lateral boundary conditions
- 500 hPa field shown
- Run courtesy of Youhua Tang

Case of NAM Boguscane

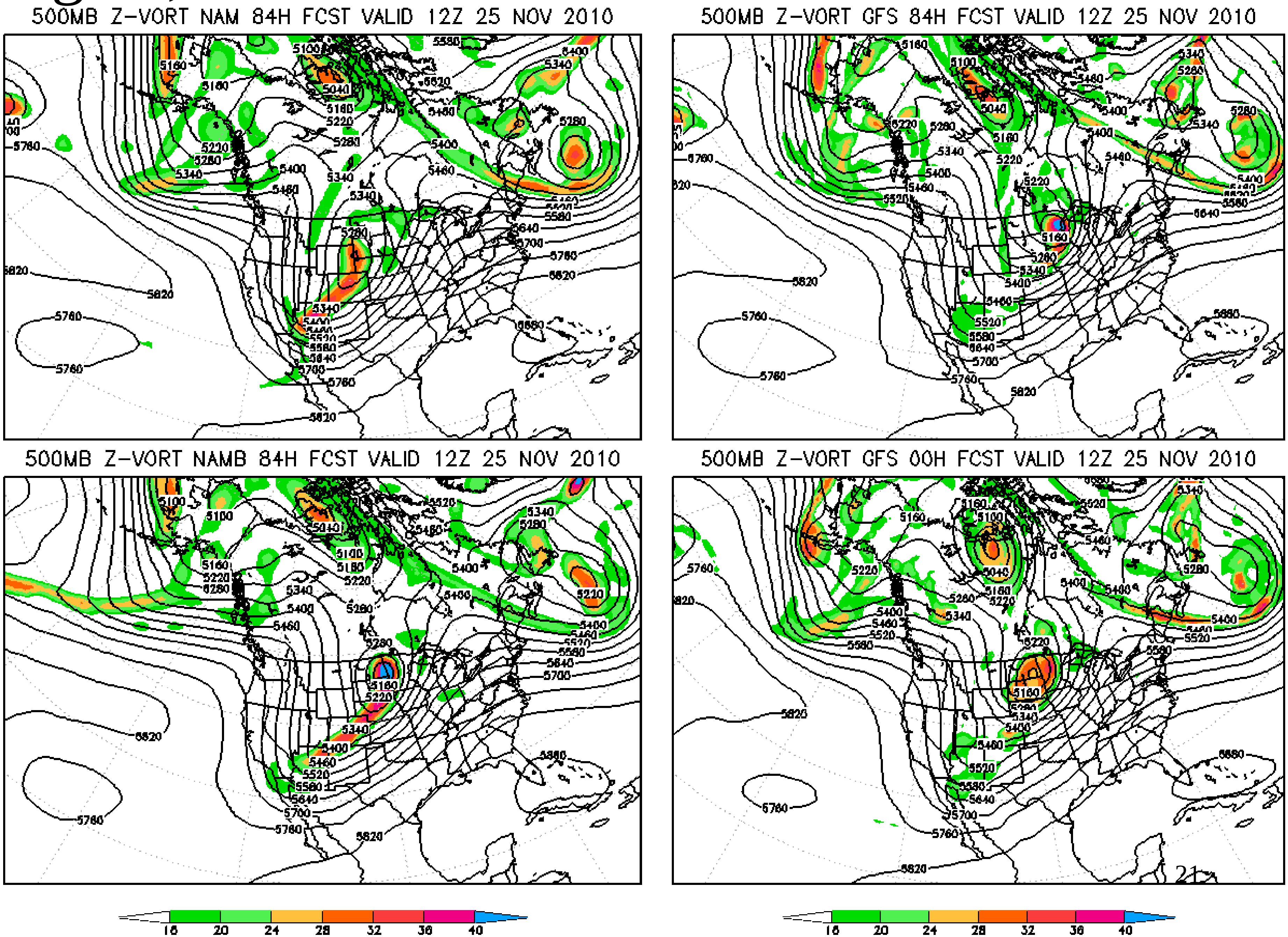




- NAM, on left using NMM with old passive advection, develops a deep boguscane
- NAMB, on right using NMMB with new passive advection, does not and it agrees with GFS & reality.



Again, NMMB more similar to GFS than NAM



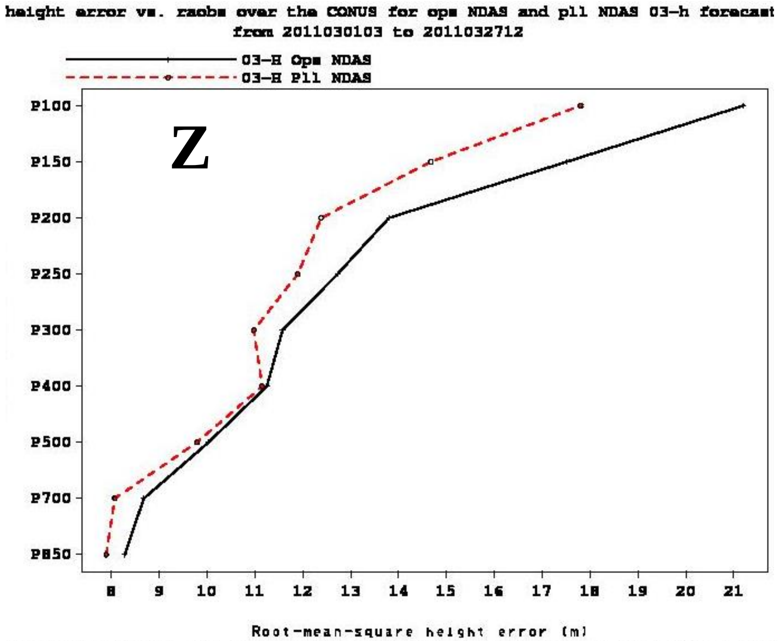
Regional GSI Obs Changes in NAM

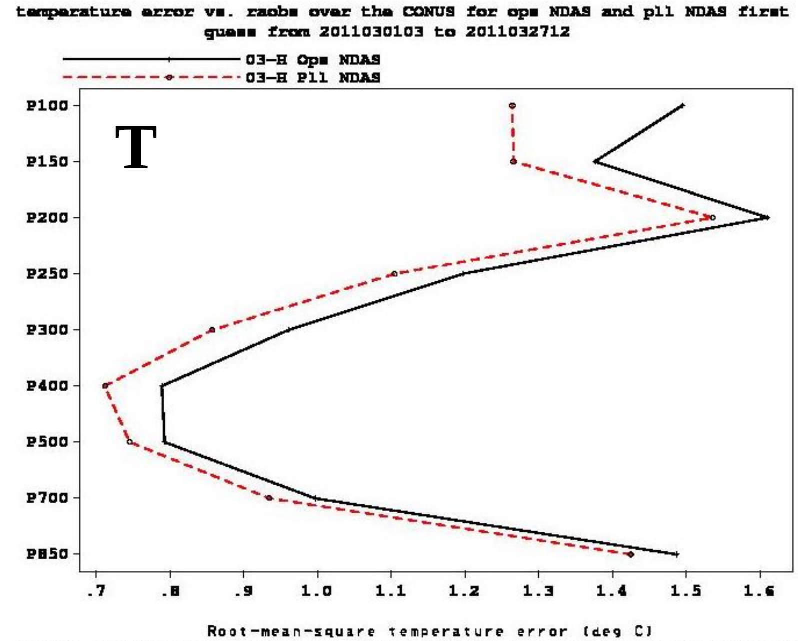
- Add new conventional obs
  - MESONET p_s, T, q with RTMA's dynamic reject list (mesonet winds already used in NAM with both reject & use lists)
  - ACARS moisture (WVSS-II)
  - CAP/MAP Profiler winds (but only below 400 mb)
  - RASS Profiler T_v (virtual temp)
  - WINDSAT & ASCAT ocean winds (from scatterometer)
- Stop using estimated sfc pressures
- Add new satellite obs
  - Satellite Radiances
    - AMSUA from aqua & NOAA19 (exCh8)
    - HIRS4 from NOAA19
    - IASI from METOP-A
  - Refractivity
    - GPS radio-occultation (e.g. COSMIC)
- Turn off NOAA15 AMSUB
- Radar 88D winds
  - Fix height assignment error
  - Increase ob error of Level 3 88D winds
  - Turn off use of Level 2.5 88D winds except over Alaska
- Use retuned ob errors (via Derozier et al.)
- Use NMMB background errors

Changes to the NAM Data Assimilation System (NDAS)

- First guess at T-12 reflects relocation of tropical cyclones
- Use of 1/12th deg SST (RTG_SST_HR) in place of ½ deg
- GSI updates 2 m temperature & moisture and 10 m winds with portion of 1st layer correction
- 5X divergence damping in NMMB in NDAS only

NDAS First Guess vs RAOBs

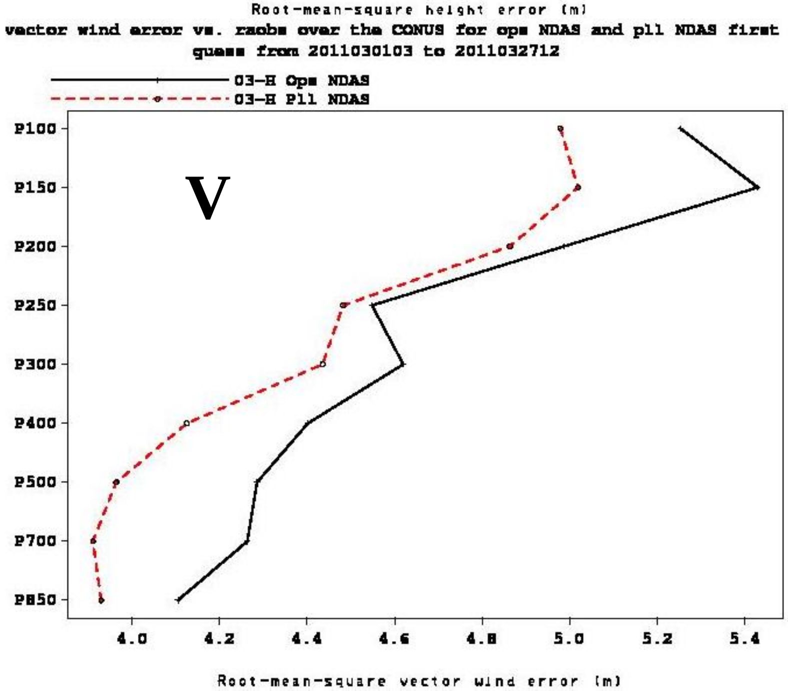


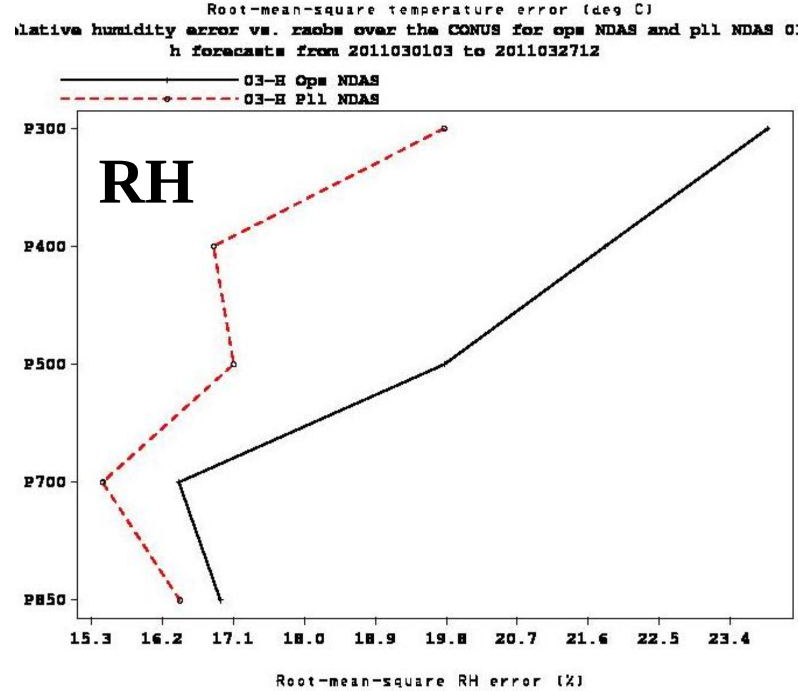


March
2011

Black/
Solid =
Opnl

Red /
Dash =
Parallel





Real-Time Parallel Testing

- Two NMMB/NDAS parallels
  - 1st: Control running since 7/29/2009
  - 2nd: Experimental running since 12/1/2009
  - 4 fixed domain nests only in experimental running since 7/12/2010 ... insufficient resources to run nests in both parallels
  - 1 placeable FWIS nest running in either CONUS (1.33km) or Alaska (1.5km) nest running since 12/8/2010

Summaries of Changes to Real-Time Parallels

- The saga (agony?) of testing & physics tuning etc. can be partially gleaned from a perusal of the change logs for the NAMB and NAMX real-time parallels
- To make it a little easier than having to slog through them, Eric Rogers has a condensed list of all the major changes through January 2011 including GSI- and nest-related changes here: http://www.emc.ncep.noaa.gov/mmb/mmbpll/paralog/nambchanges_chronology.html

Other Summaries of Physics Development

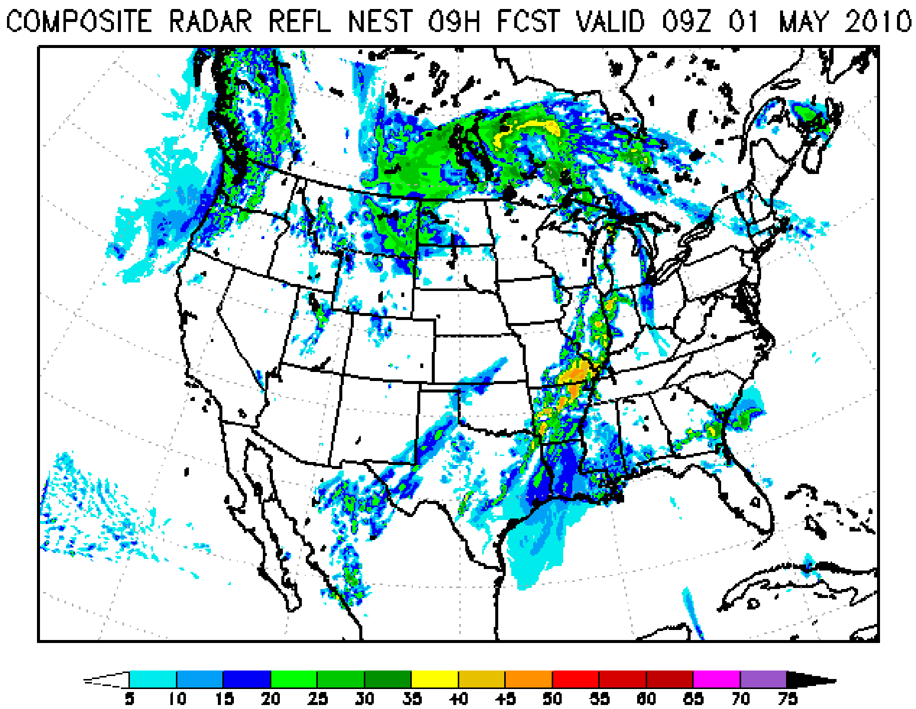
- Brad Ferrier's compilation of what the NAM/NMMB team did during 2010+ is available online here http://www.emc.ncep.noaa.gov/mmb/bf/presentations/Ferrier_2010-report_11-24-2010.ppt see also his AMS talk at http://ams.confex.com/ams/91Annual/webprogram/Paper179488.html and Weiguo Wang's AMS poster at http://ams.confex.com/ams/91Annual/webprogram/Paper179160.html
- Zavisa Janjic's AMS talk at http://ams.confex.com/ams/91Annual/webprogram/Paper182175.html
- Eric Roger's AMS talk at http://ams.confex.com/ams/91Annual/webprogram/Paper178795.html

Major Physics Changes

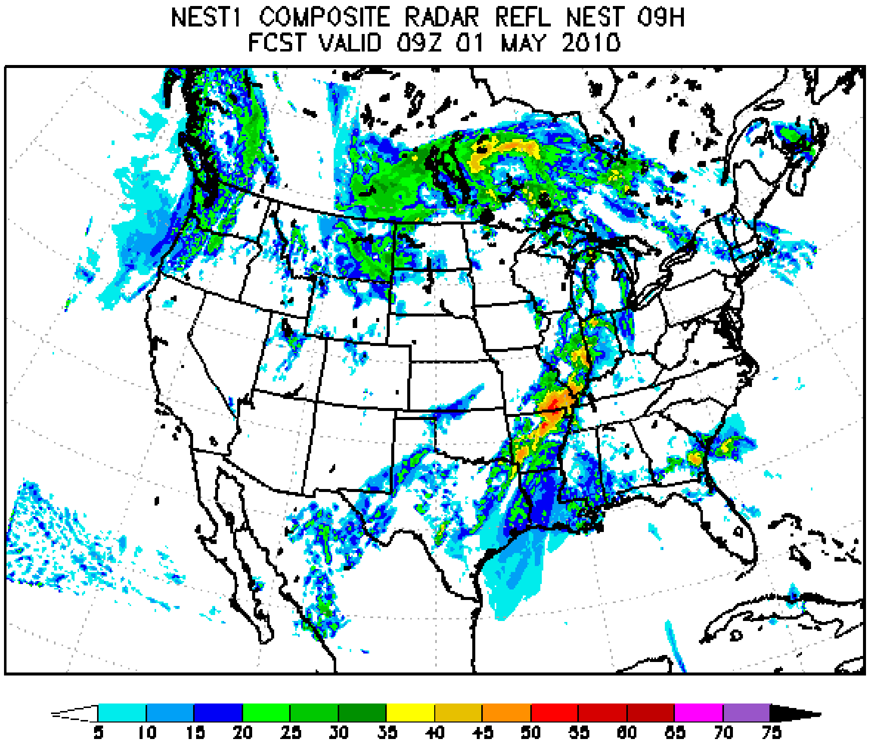
- Universal changes
  - Microphysics modifications
    - To get thicker cloud & higher peak reflectivity
    - To improve cloud fractions
  - MODIS-based IGBP land-use replaces USGS plus 3 corresponding Zo adjustments
- Changes related to nested domains
  - BMJ_DEV allows “just a little” parameterized convection
    - fres=0.25 (resolution factor for dsp's)
    - fr=1.00 (land factor for dsp's)
    - fsl=0.75 (reduction factor for "slow" dsp's over land)
    - fss=0.75 (reduction factor for "slow" dsp's over water)

Impact of microphysics change

Ops ferrier



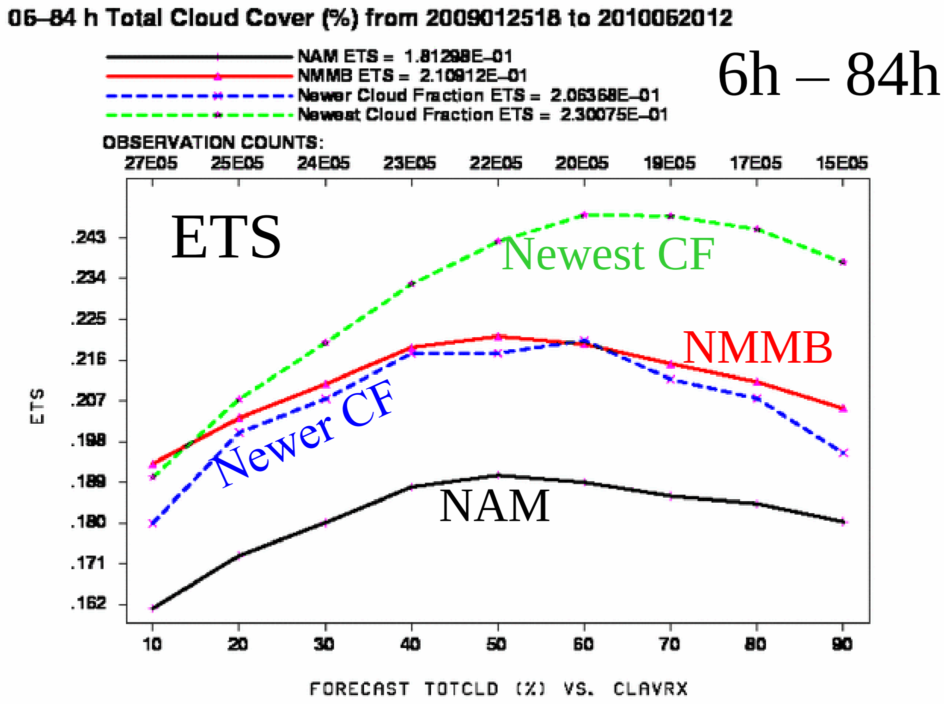
Revised ferrier

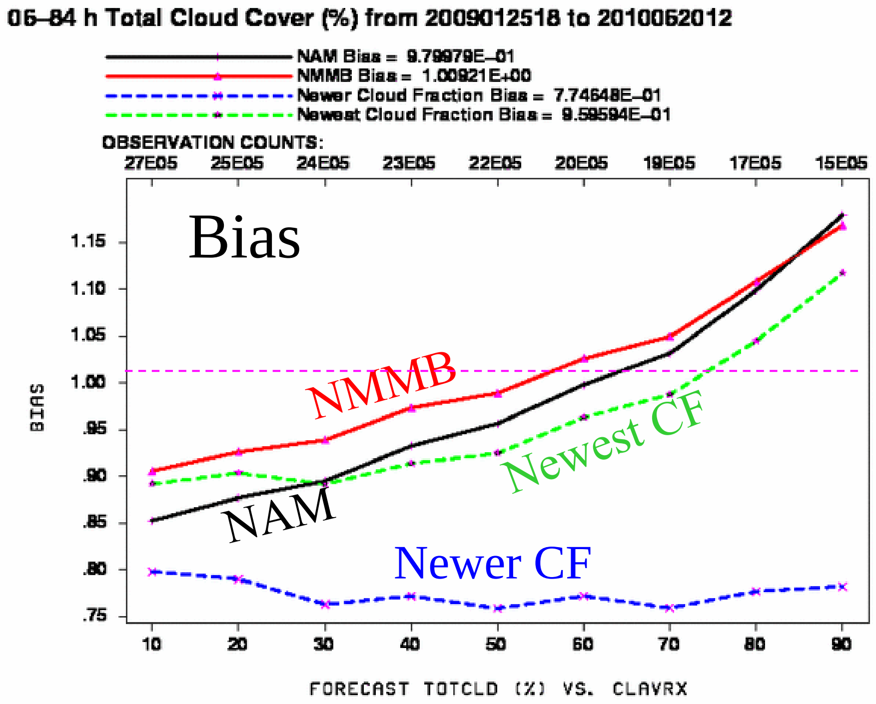


- Higher peak dBZ & Rain Rates (1D column runs)
- Small impact on QPF
- Improved >50 dBZ, but worse (higher) biases ≤45 dBZ

Impact of cloud fraction changes

Verification versus CLAVR [Colón *et al.*]

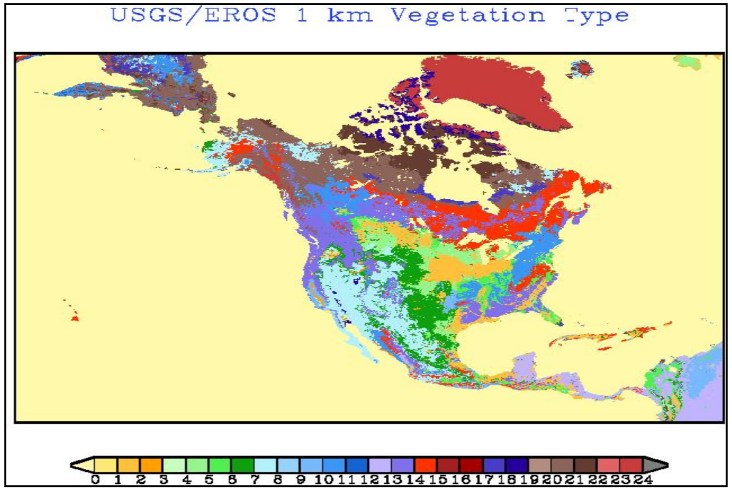




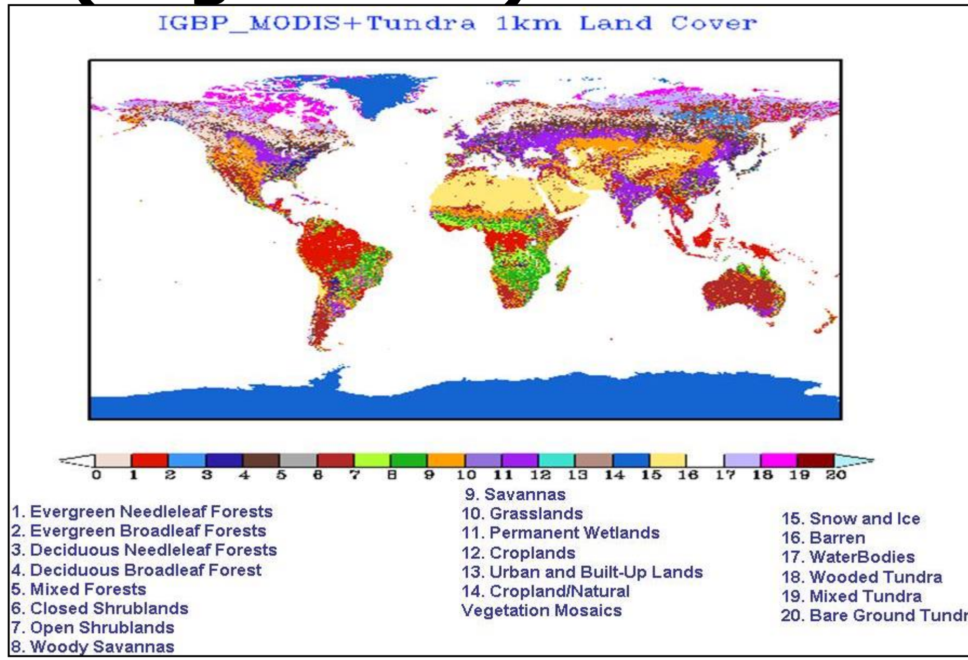
NAM, NMMB runs use the "old" cloud fractions
Newer CF – NMMB run using newer cloud fractions
Newest CF – NMMB run using the newest/latest cloud fractions

Reduced high (overcast) bias for high, thin cirrus
Improve scores vs CLAVRx using <u>newest</u> formulation

Latest NAMX test started 9/21; MODIS IGBP land-use (vegetation)

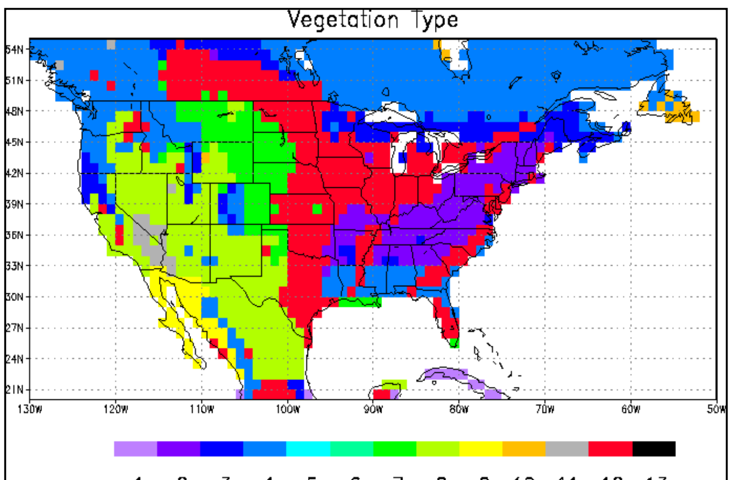


24-class 1-km USGS (NAM, NLDAS)



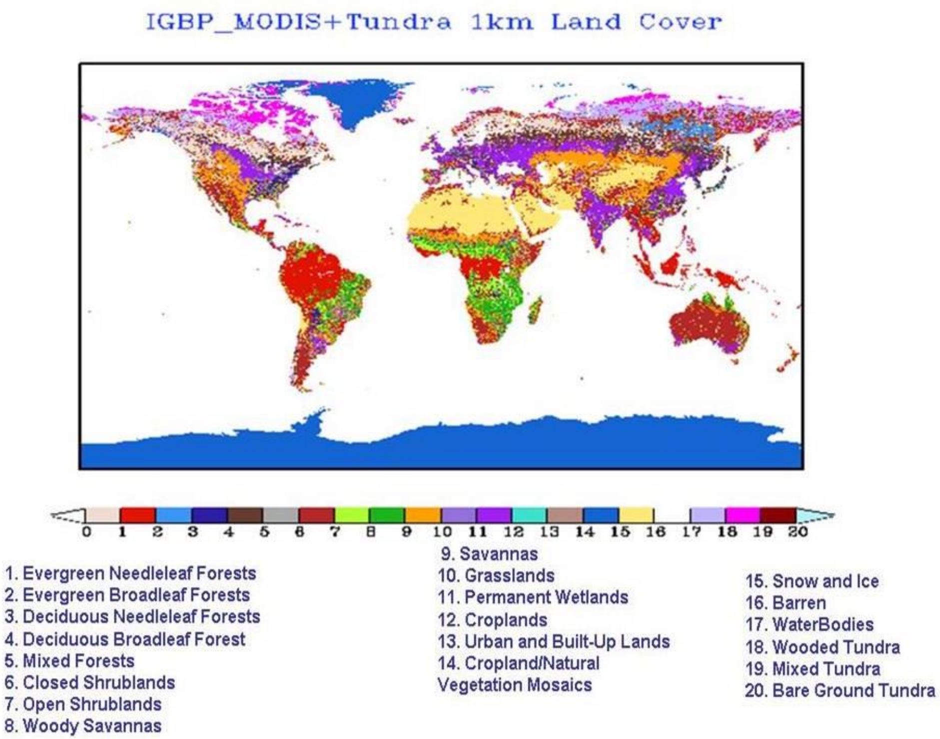
NEW 20-class 1-km extended-IGBP-MODIS

Boston U. (Mark Friedl



13-class 1-deg SiB (GFS, CFS)

MODIS-IGBP land-use specifications will replace USGS (Wong and Ek, Conference on Hydrology)

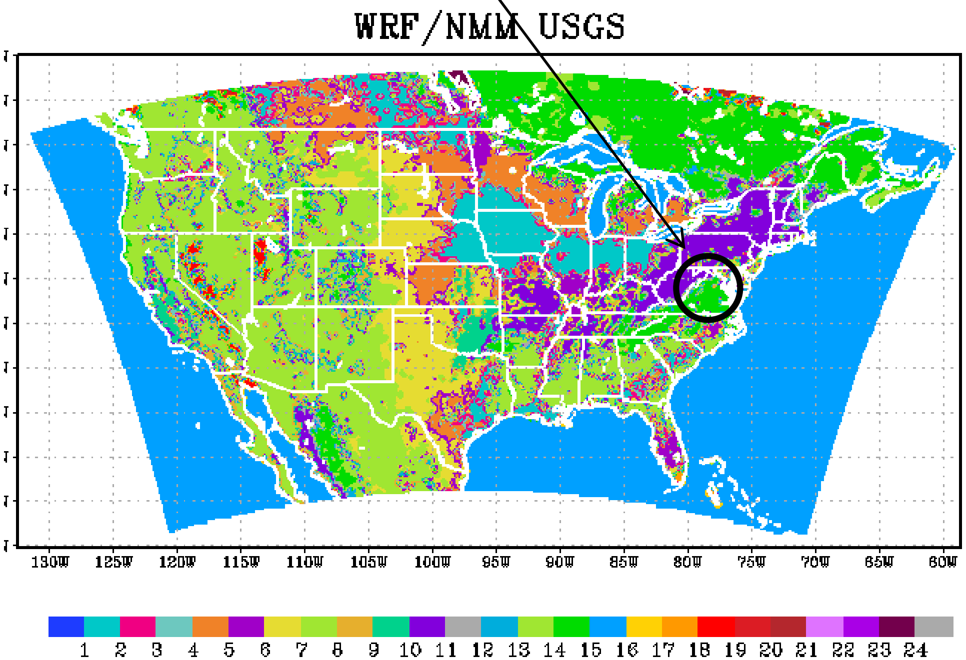


Classification Scheme	IGBP	USGS
Satellite Instr.	MODIS 2001-2006	AVHRR 1992-1993
Coastline	More Details	
Urban	More	
Evergreen	More in Alaska	More in SE of US
Deciduous Broadleaf	More in SE of US	
Savanna		More in Oklahoma

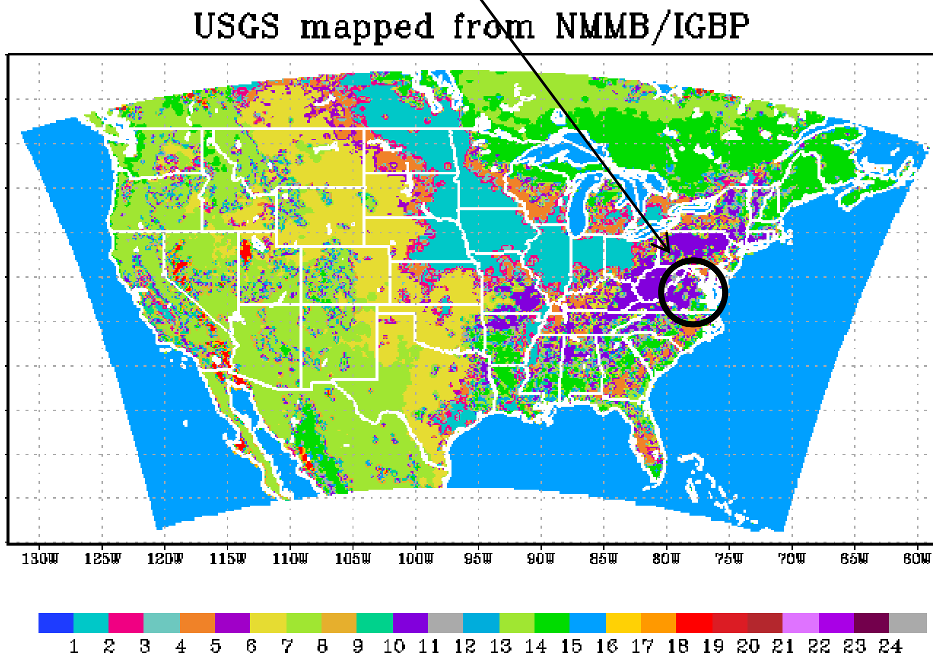
Little difference in near-sfc T, Td between NMMB runs w/ IGBP & USGS land-use (based on many tests run for all seasons)

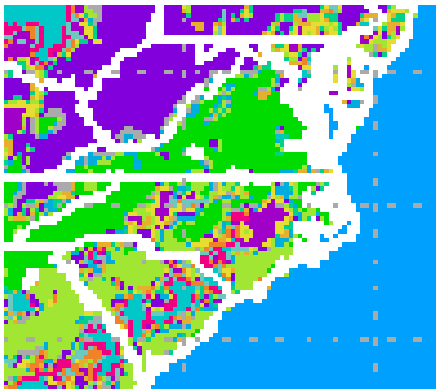
Local Impact of NMMB new IGBP Land Use

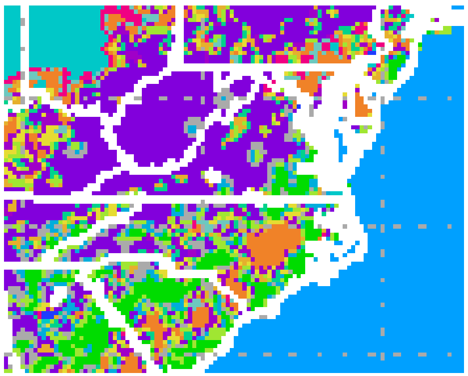
15: Mixed Forest



11: Deciduous Broadleaf Forest





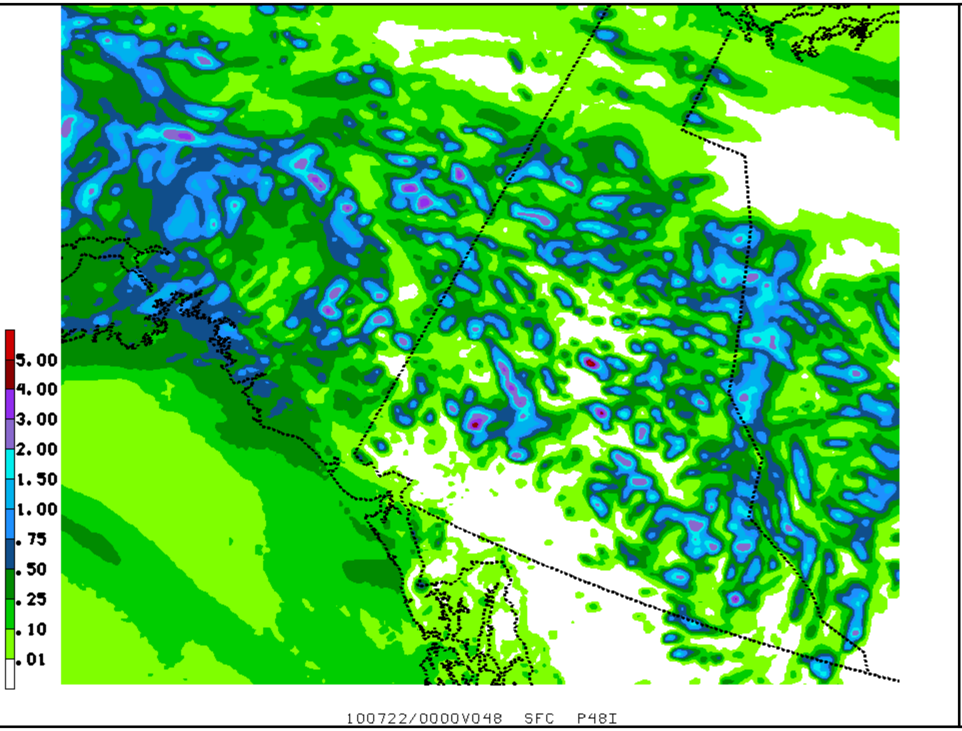


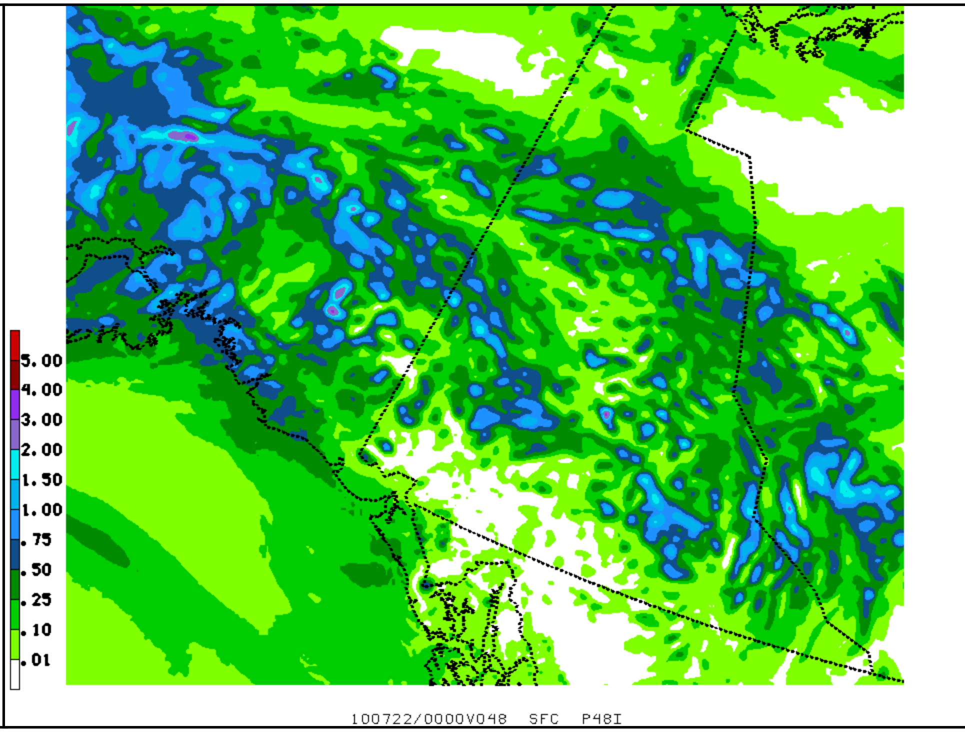
Modified BMJ convection for NMMB nests (~Matt Pyle for Alaska talk)

- Different model forecast customers interpret high-resolution guidance differently, e.g. literal vs. qualitative, because they are driven by different needs.
- With NMMB implementation of convection allowing nests in NAM, an effort is being made by EMC to satisfy both camps ... everyone needs a good challenge, right?

Example of the ROCK and the HARD PLACE

6 km NMMB nest 48 h total precip ending 20100722/00Z





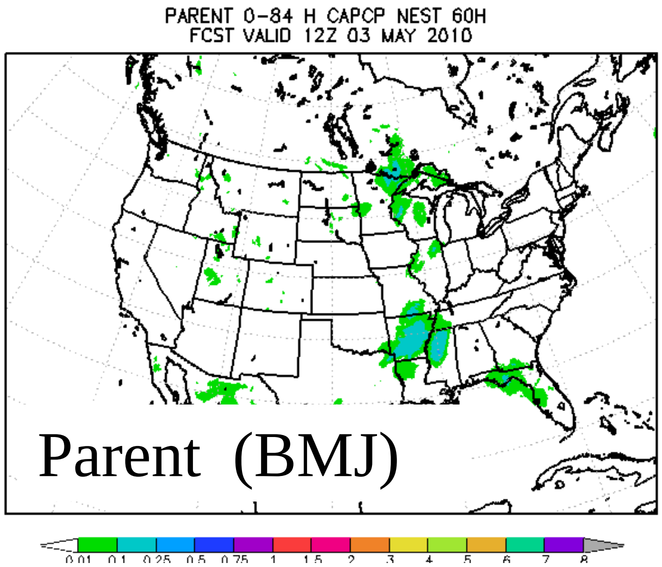
without parameterized convection
Max precip = 4.91”
SPC is happy, but HPC is sad!

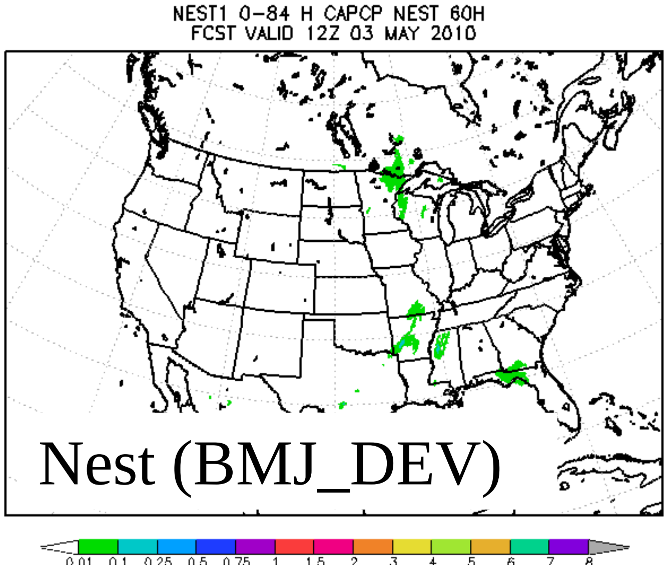
with Janjic BMJ_DEV convection
Max precip = 3.39”
HPC is happy, but SPC is sad!

Janjic Modified Convection in Nests

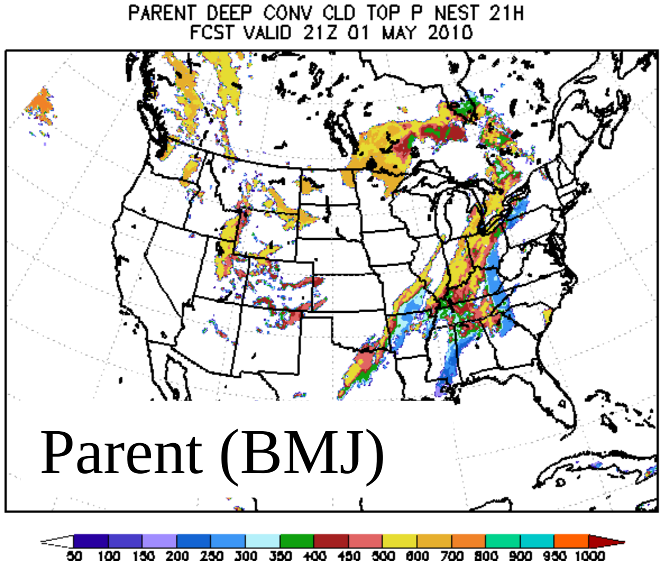
- BMJ_DEV tests in 4-km CONUS runs
  - Moister profiles
  - Less triggering of deep convection
  - Reduced convective QPF
  - Better QPF bias vs running w/o convection
  - Improved surface & upper-level scores (not shown)
  - Small impact on CAPE forecasts

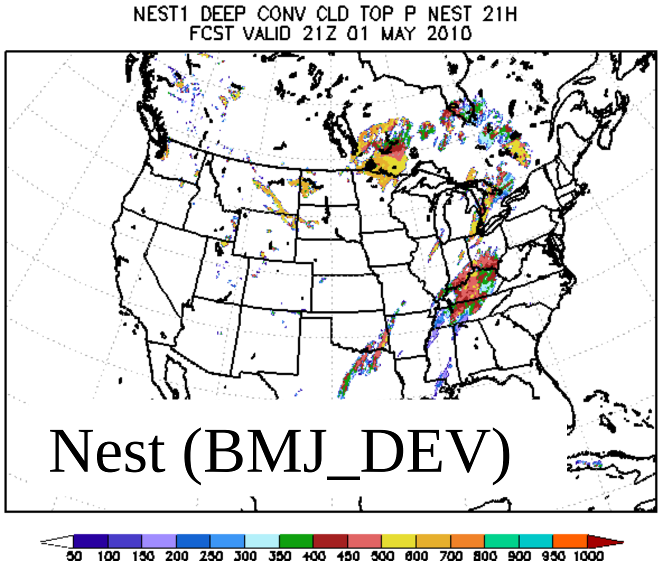
Reduced BMJ_DEV triggering in 4-km nest





0-84 h
Cu QPF

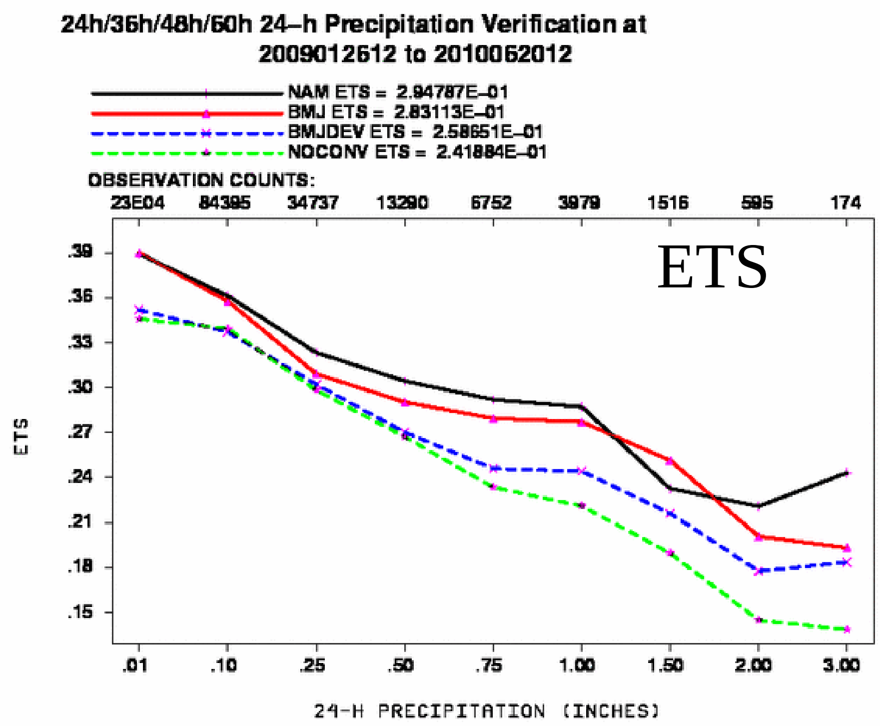


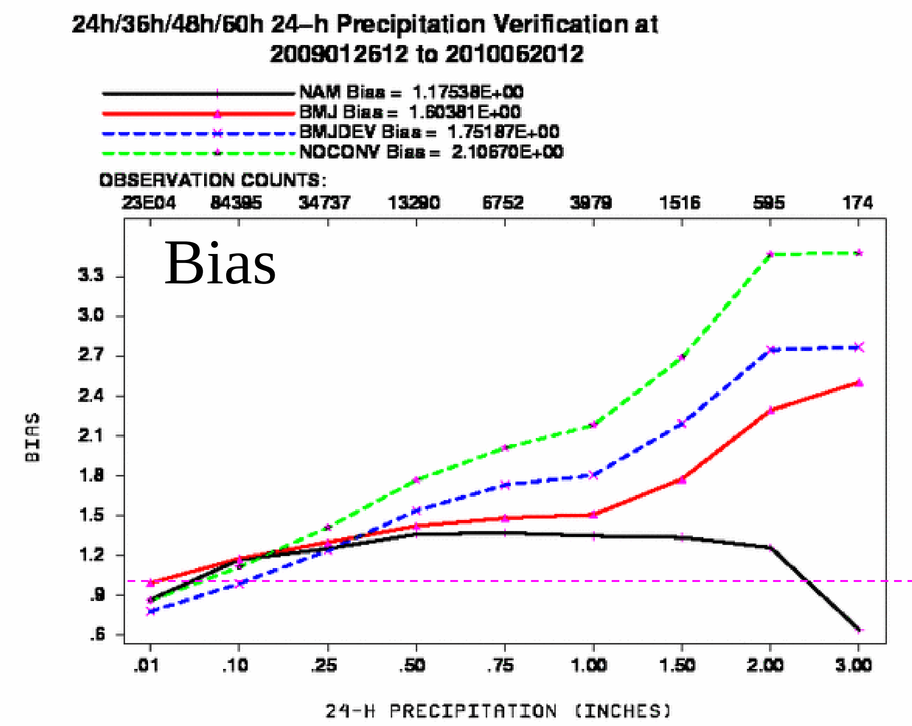


Deep Cu
Cloud Top
Pressure
(hPa)

QPF Verification in NMMB Nests

BMJ_DEV raises ETS & lowers Bias



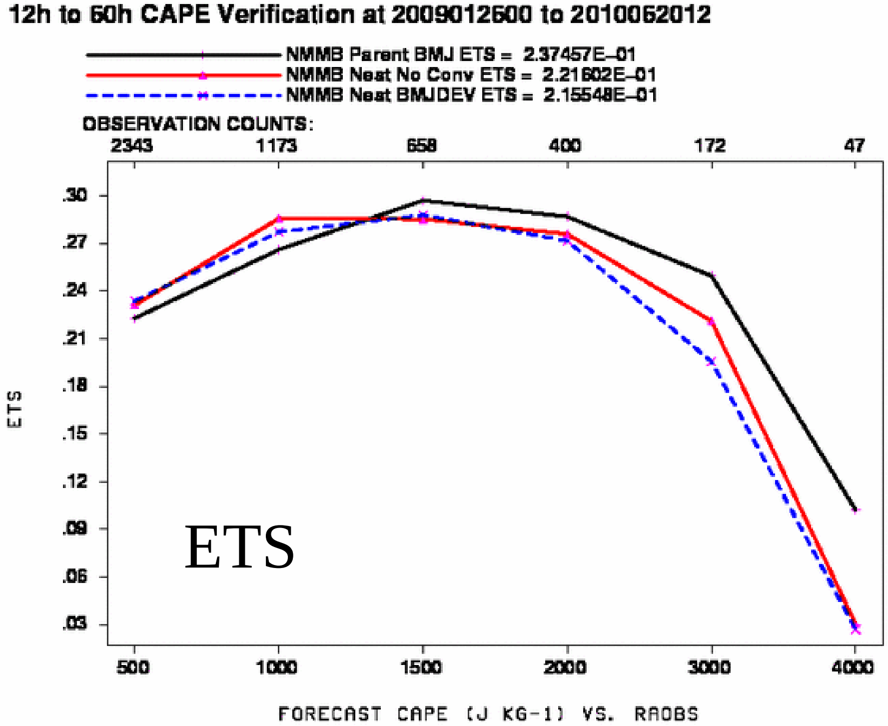


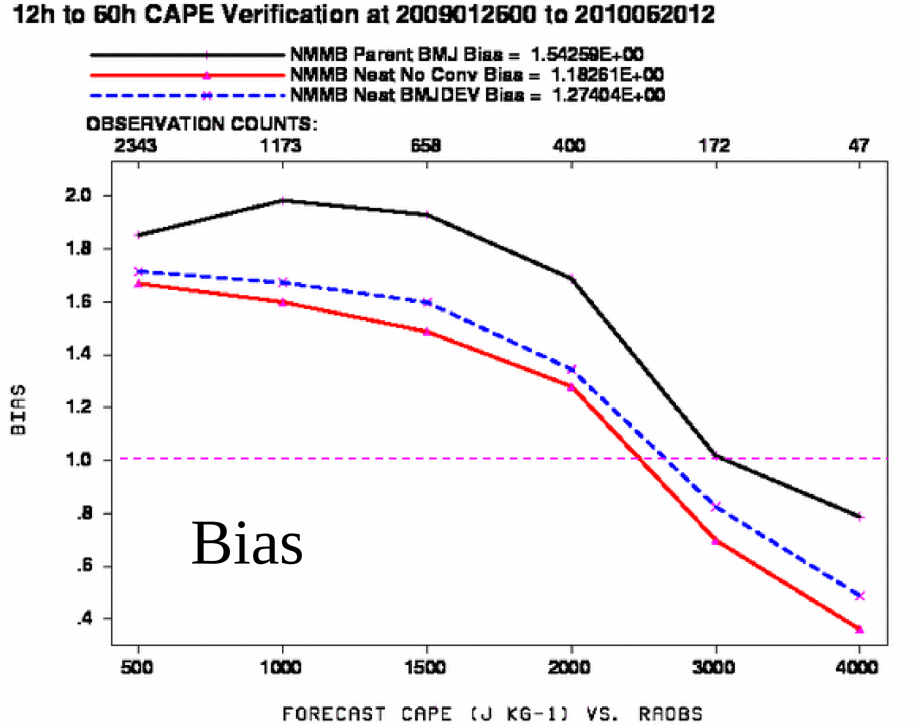
NAM ETS = 2.94787E–01
BMJ ETS = 2.83113E–01
BMJDEV ETS = 2.58651E–01
NOCONV ETS = 2.41884E–01

NAM Bias = 1.17538E+00
BMJ Bias = 1.60381E+00
BMJDEV Bias = 1.75187E+00
NOCONV Bias = 2.10670E+00

CAPE Verification in NMMB Nests

BMJ_DEV has small effects on CAPE

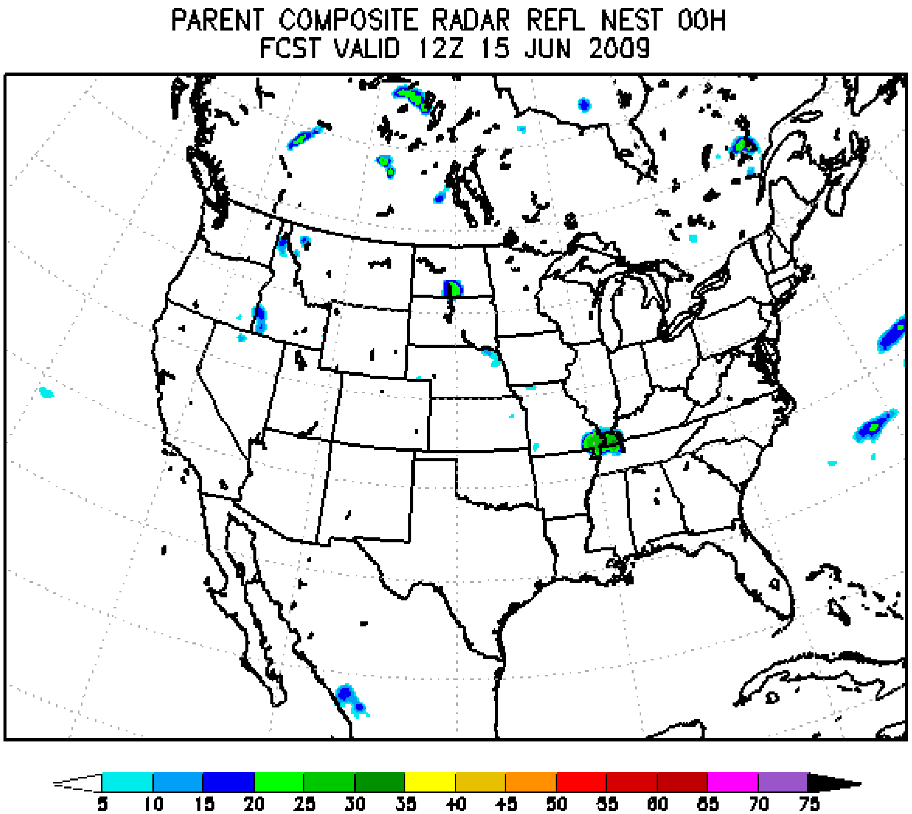


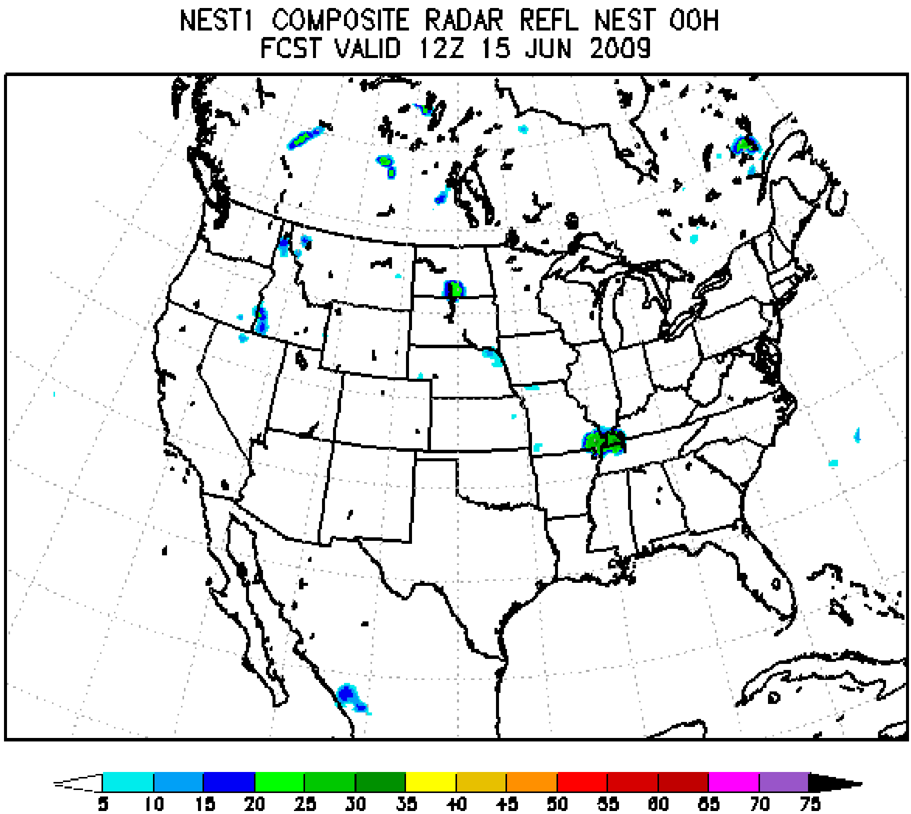


NMMB Parent BMJ ETS = 2.37457E–01
NMMB Nest No Conv ETS = 2.21602E–01
NMMB Nest BMJDEV ETS = 2.15548E–01

NMMB Parent BMJ Bias = 1.54259E+00
NMMB Nest No Conv Bias = 1.18261E+00
NMMB Nest BMJDEV Bias = 1.27404E+00

Parent & Nest Reflectivity Loop



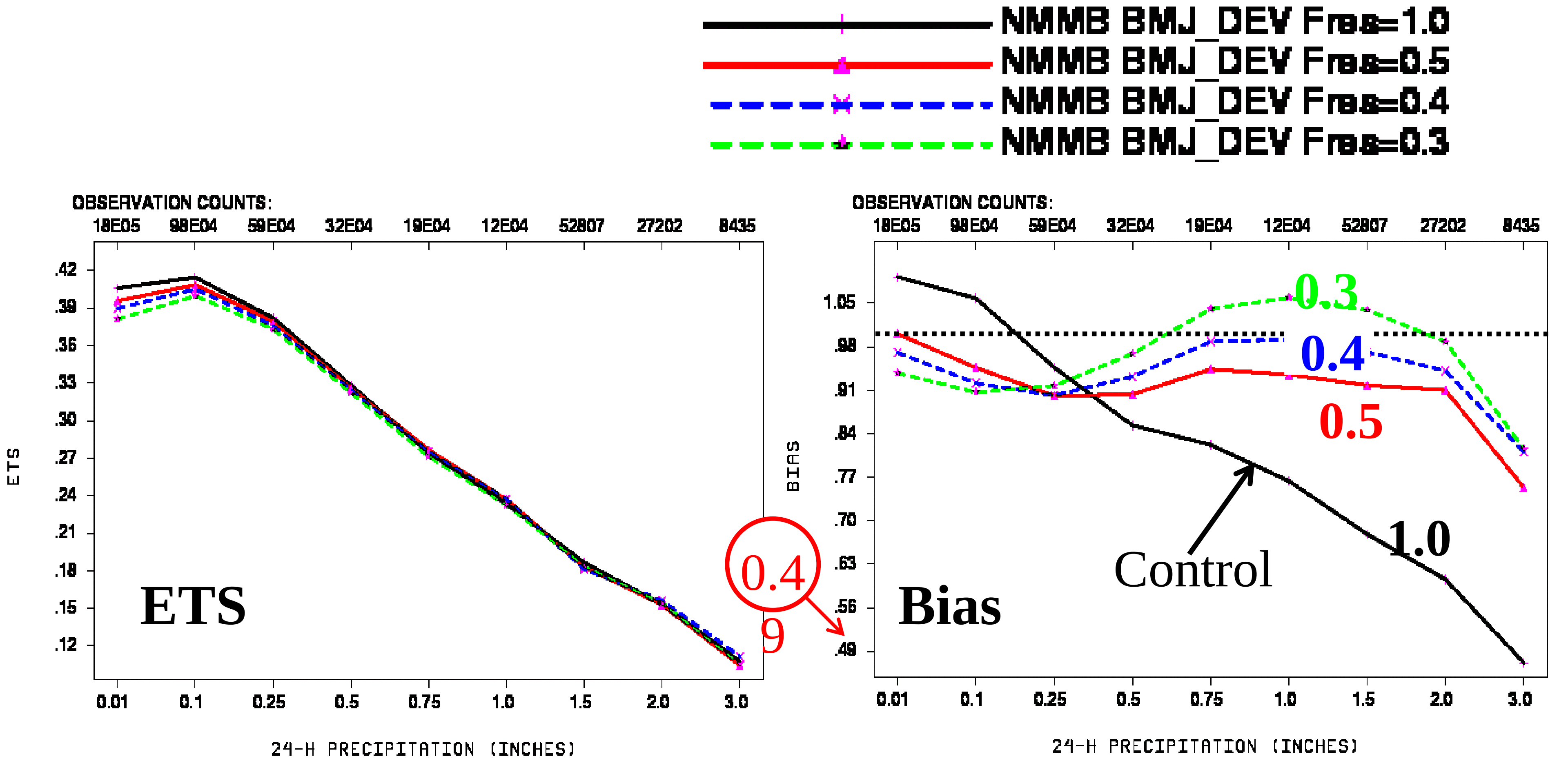


Left: 12-km PARENT (Launcher parent domain ~1/2 size of NAM)
- Control BMJ convection (same as in NAM)
- Modified Ferrier microphysics

Right: 4-km CONUS "NEST" domain (inside launcher parent)
- BMJ_DEV convection (reduced triggering)
- Modified Ferrier microphysics

From Janjic, Tests and graphics courtesy of Ferrier

- **Does the same approach work at 12 km?**



- **Yes!**
- **Being tested for next opportunity to upgrade NAM**

Fire Weather / IMET-DHS Support (FWIS) Runs

- Locations selected daily for next 4 NAM runs.
  - SOP developed among National Interagency Fire Center (NIFC) in Boise, the SPC and SDM – using IMET SharePoint site.
  - Regions, other NCEP centers and NWS-DHS liaison can all nominate locations
  - Default position is Washington, DC but the SDM can also persist previous day's positions
- Until CONDUIT connection, FWIS runs can be viewed at Eric Rogers' most excellent website:

http://www.emc.ncep.noaa.gov/mmb/mmbpll/firewx/

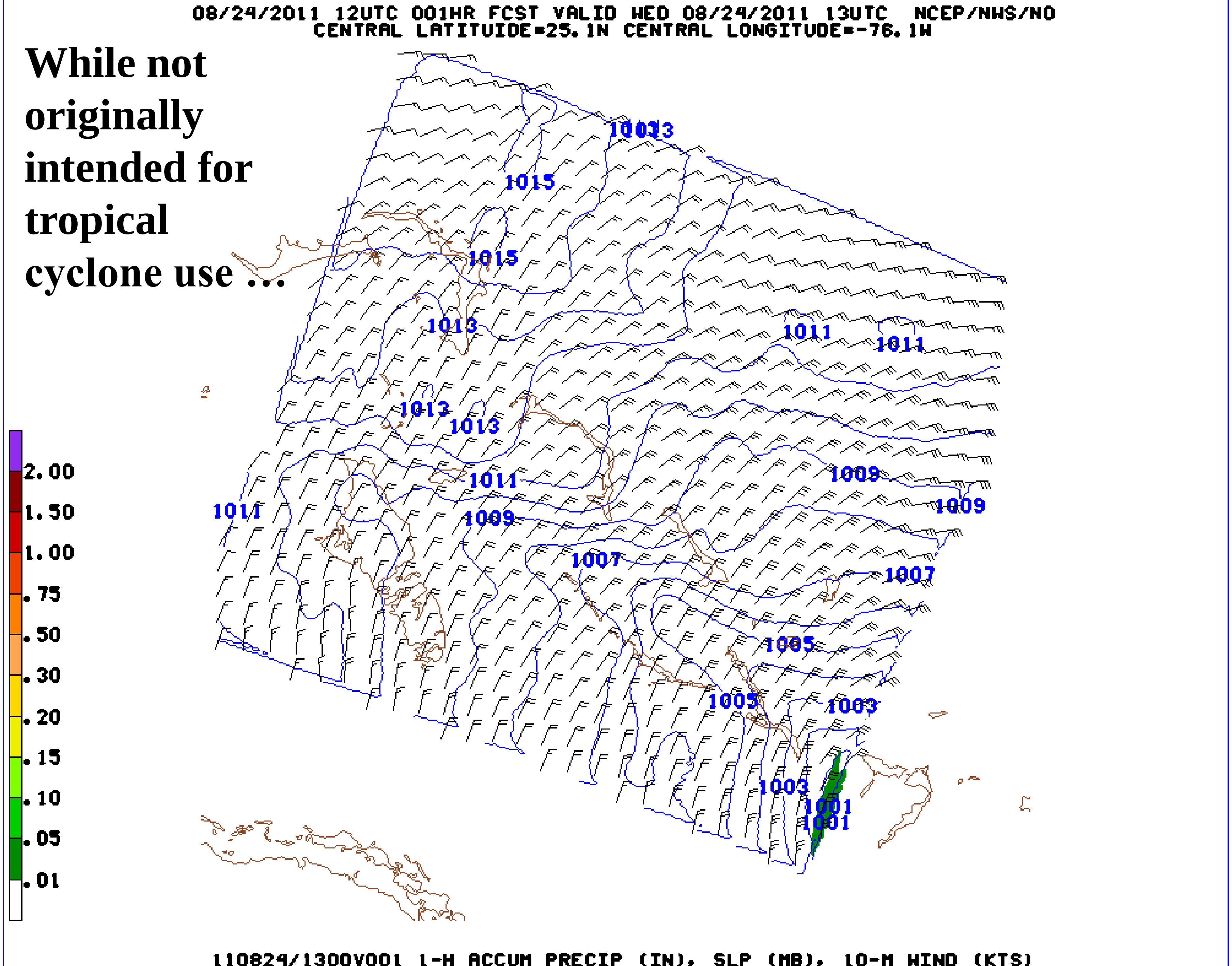
NAM Fire Weather High Resolution Nested Runs

This page will show selected fields from the most recent 00z, 06z, 12z, and 18z NAM Parallel High Resolution "Fire Weather" nested run. This nest runs inside either parallel NAMX CONUS or Alaska nest. It runs to 36-h and has a resolution of 1.333 km (if in CONUS) or 1.5 km (if in Alaska).

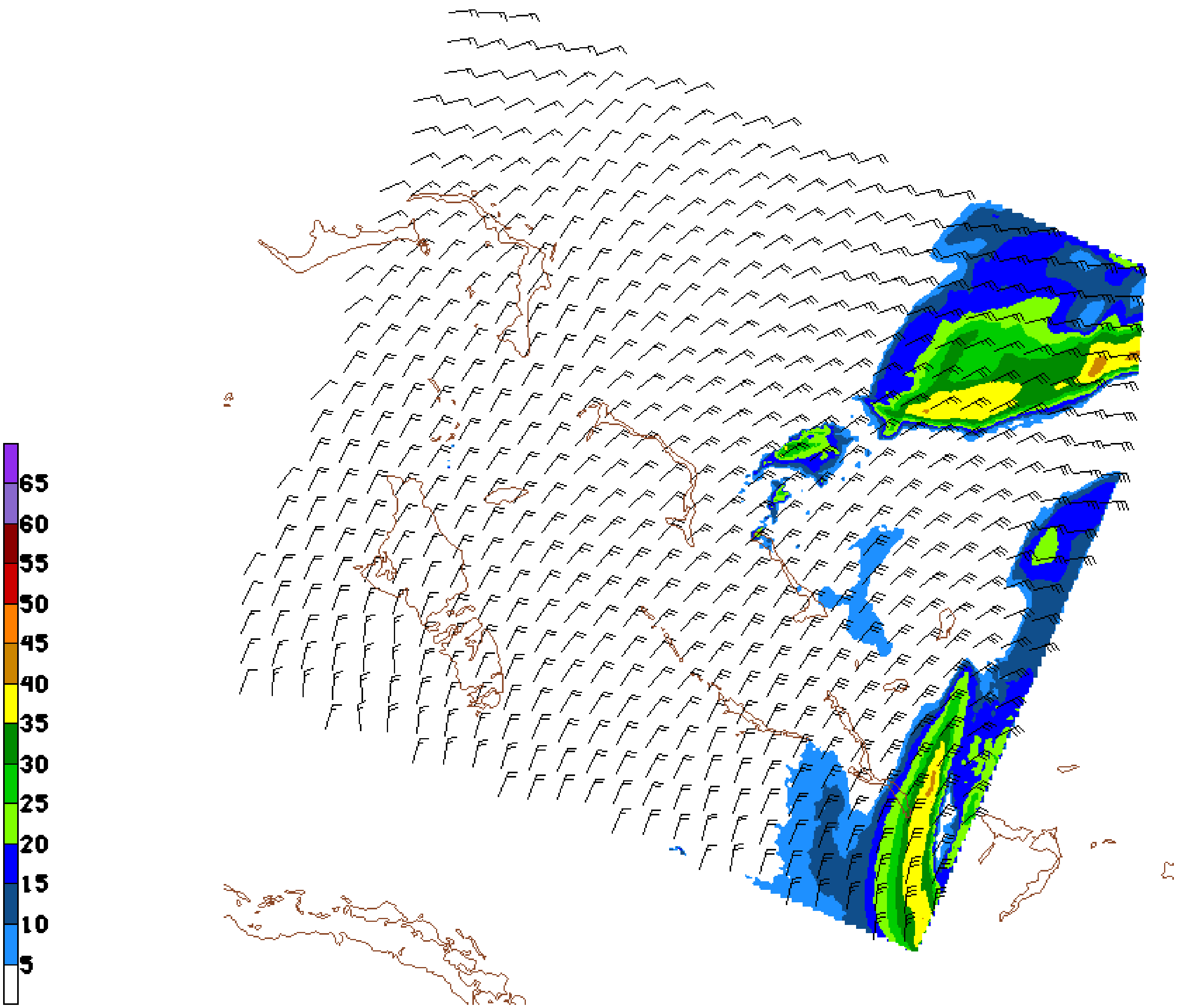
During parallel testing the domain will move around to test this capability over different regions.

Parameter	Most recent 00z Run	Most recent 06z Run	Most recent 12z Run	Most recent 18z Run
Haines Index	X	X	X	X
Ventilation Rate	X	X	X	X
Transport Wind, Terrain Height	X	X	X	X
PBL Height	X	X	X	X
1-H Minimum Relative Humidity, 10-m Wind	X	X	X	X
Sea-level Pressure, 1-h Accumulated Precip, 10-m Wind	X	X	X	X
1-h Accumulated Convective Precip, 10-m Wind	X	X	X	X
Categorical Precipitation Type	X	X	X	X
Composite Radar Reflectivity, 10-m Wind	X	X	X	X
1000 m AGL Radar Reflectivity, 10-m Wind	X	X	X	X
Shelter (2-m) Temperature, 10-m Wind	X	X	X	X
Shelter (2-m) Relative Humidity, 10-m Wind	X	X	X	X
Terrain Height, 10-m Wind	X	X	X	X
Total Column Condensate	X	X	X	X
925 mb Height, Wind	X	X	X	X
850 mb Height, Temperature	X	X	X	X
700 mb Height, RH	X	X	X	X
500 mb Height, Wind	X	X	X	X
250 mb Height, Wind	X	X	X	X
250 mb Wind Speed	X	X	X	X

While not originally intended for tropical cyclone use …



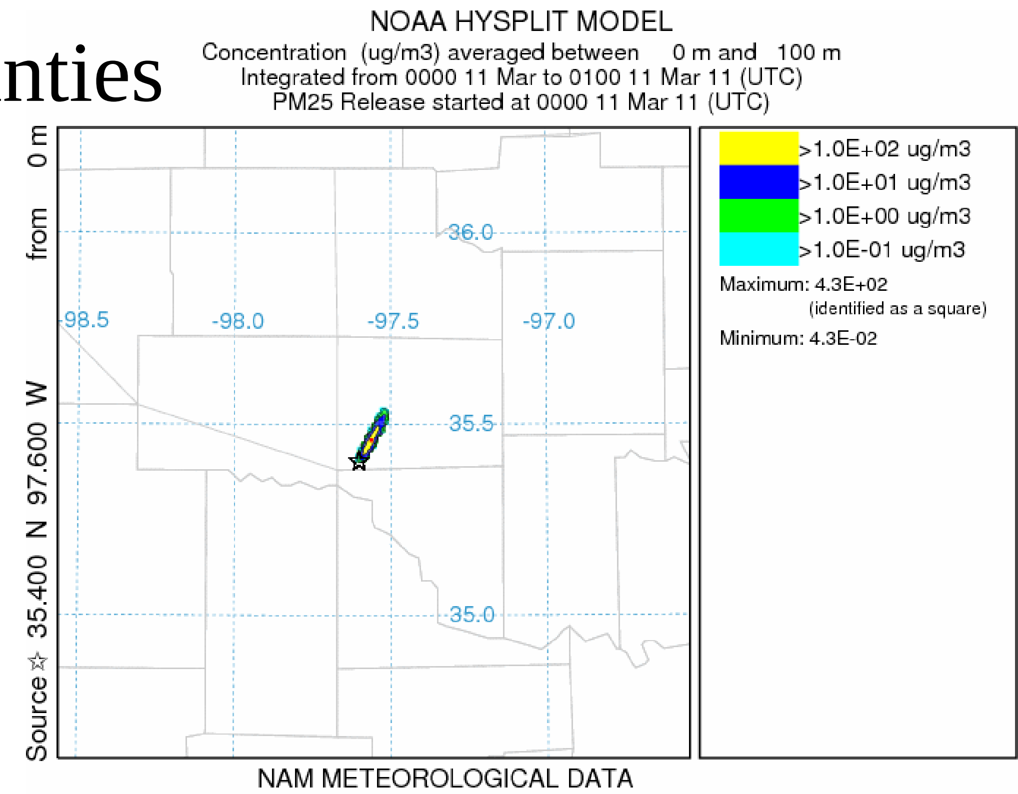
08/24/2011 12UTC 001HR FCST VALID WED 08/24/2011 13UTC NCEP/NWS/NO
CENTRAL LATITUIDE=25.1N CENTRAL LONGITUDE=-76.1W



110824/1300V001 COMPOSITE REFLECTIVITY, 10-M WIND

Smoke Predictions via NOAA/ARL's HYSPLIT Dispersion Model

- Wild-fire smoke applications driven by NAM, NAM nests & FireWx/IMET-DHS Support runs available via NOAA/ARL's READY-testbed site
- Example for March 11, 2011 fires in Central OK: Harrah and Chatow counties



New NAM Post-Processing [Hui-Ya Chuang]

- 80m AGL for wind generation folk
- Fire weather parameters
  - max/min T 2m, RH 2m & 10m wind
  - Ri based PBL height (Mixing Height), transport wind, ventilation rate, and Haines Index.
  - Chance of Wetting Rain, thunder & lightning parameters come from smartinit.
- SPC requests
  - Change to use virtual T for CAPE/CIN & LI, see NOUS41 KWBC 121438 PNSWSH
  - Hourly maxima of 1000 m reflectivity, updraft velocity, downdraft velocity, and updraft helicity
- Radar echo top height for aviation folk

Display Links 2011 NAM Upgrade

•Displays of grid domains and file inventories can be found at http://www.emc.ncep.noaa.gov/mmb/namgrids/

•Displays of these runs can be seen at:

http://mag.ncep.noaa.gov/NCOMAGWEB/appcontroller

and

http://www.emc.ncep.noaa.gov/mmb/mmbpll/nampll_nmmb/

Eric Rogers' Display Links for 2011 NAM Upgrade

http://www.emc.ncep.noaa.gov/mmb/mmbpll/eric.html#tab2

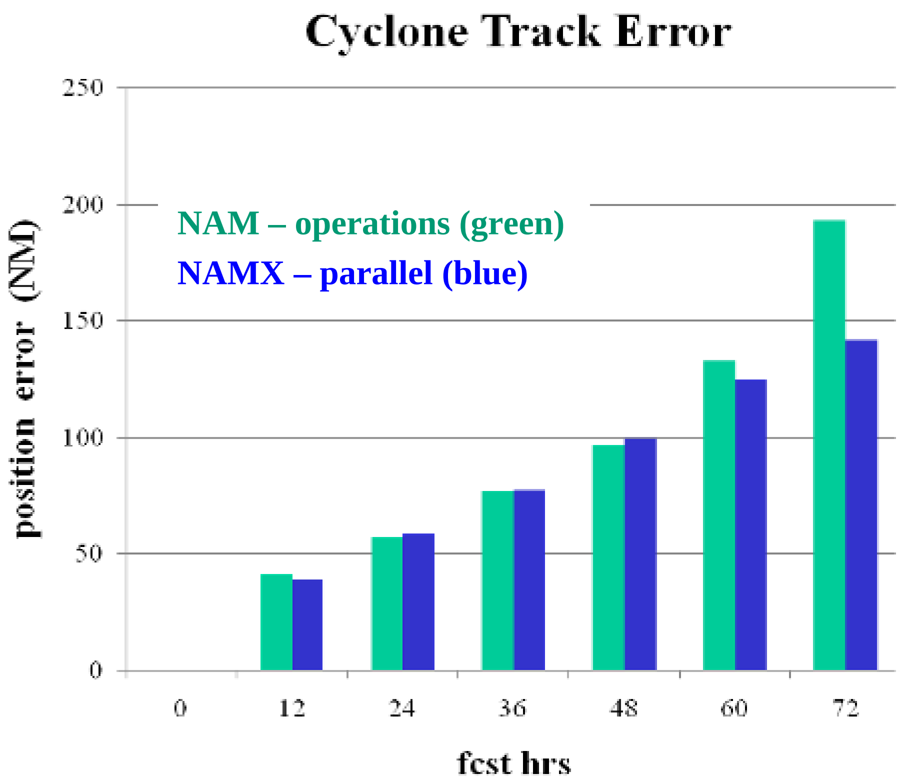
Web Page	Models Displayed	Forecast Length	Forecast frequency	Animation?	Archive of past forecasts?
4 km WRF-NMM Parallel - 00z cycle 4 km WRF-NMM Parallel - 12z cycle	WRF-NMM (CONUS domain), WRFV2.2+ code	36-h	1 hour	Yes	1 day
4 km NEMS-NMMB Parallel - 00z cycle	NEMS-NMMB (CONUS domain), Eulerian passive-substance advection	36-h	1 hour	Yes	1 day
00z/12z 12 km NEMS/NMMB North American Mesoscale Parallel (Ops NAM vs NAMX) 06z/18z 12 km NEMS/NMMB North American Mesoscale Parallel (Ops NAM vs NAMX)	Ops NAM (WRF-NMM), NEMS/NMMB (North American domain)	84-h	3 hour	Yes	6 days (00z/12z runs only)
00Z/12z Nested NEMS-NMMB runs (parent = NAMX parallel) 1. 6 km Alaska 2. 4 km CONUS 3. 3 km Hawaii 4. 3 km Puerto Rico **06Z/18z Nested NEMS-NMMB runs (parent = NAMX parallel)** 1. 6 km Alaska 2. 4 km CONUS 3. 3 km Hawaii 4. 3 km Puerto Rico	NAMX, Nested NMMB run	60-h	3 hour	Yes	7 days (00Z/12Z cycles only)

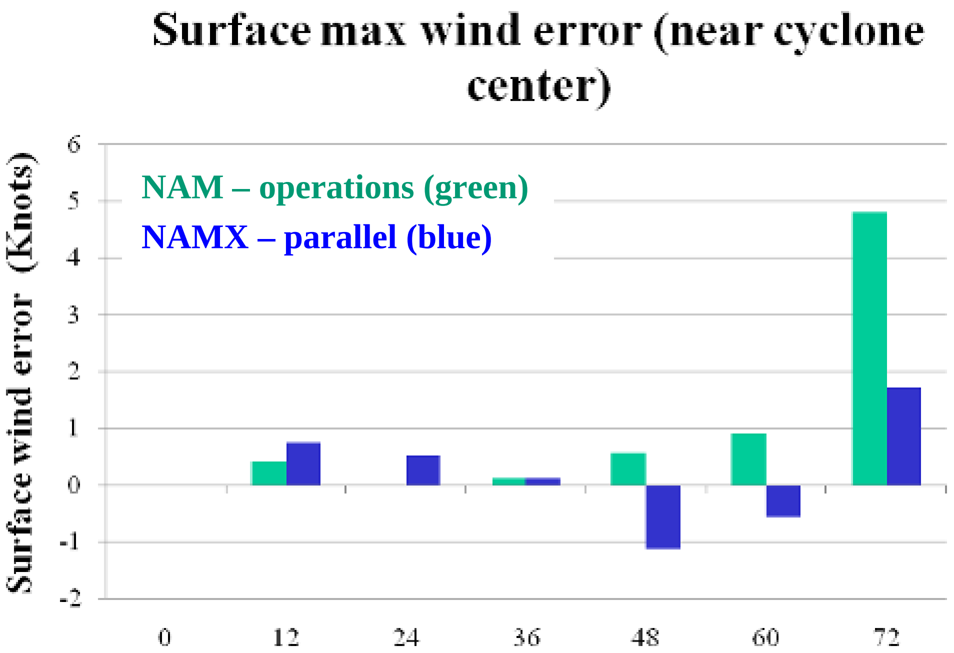
And there are even more …

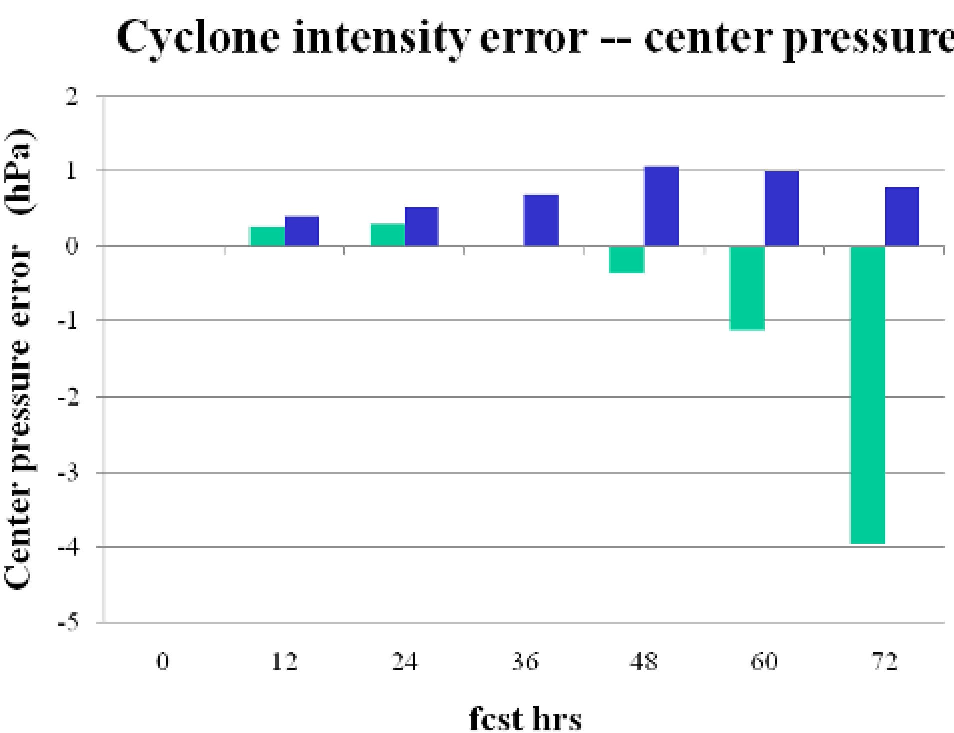
NAM Logistics after Upgrade

[Special thanks to Becky Cosgrove & Brian Gockel & Linda Miller]

- 12 km NAM parent output essentially unchanged
- NAM nest gridded output
  - Full complement on **ftp server** , on **NOMADS** in Q1FY2012, and possibly on CONDUIT.
  - Form the basis for downscaled numerical guidance (NAM-DNG already on AWIPS-SBN aka 'smartinit')
    - Much closer to NDFD resolution than 12 km parent
    - Fast-track OSIP project to sanction existing NAM-DNG as well as double-resolution 2.5 km CONUS and 3 km Alaska
- FWIS gridded output
  - Full complement on FTP server & through CONDUIT
  - CONDUIT provide link (via LDM) to regional servers providing FX-Net support to IMET laptops in the field







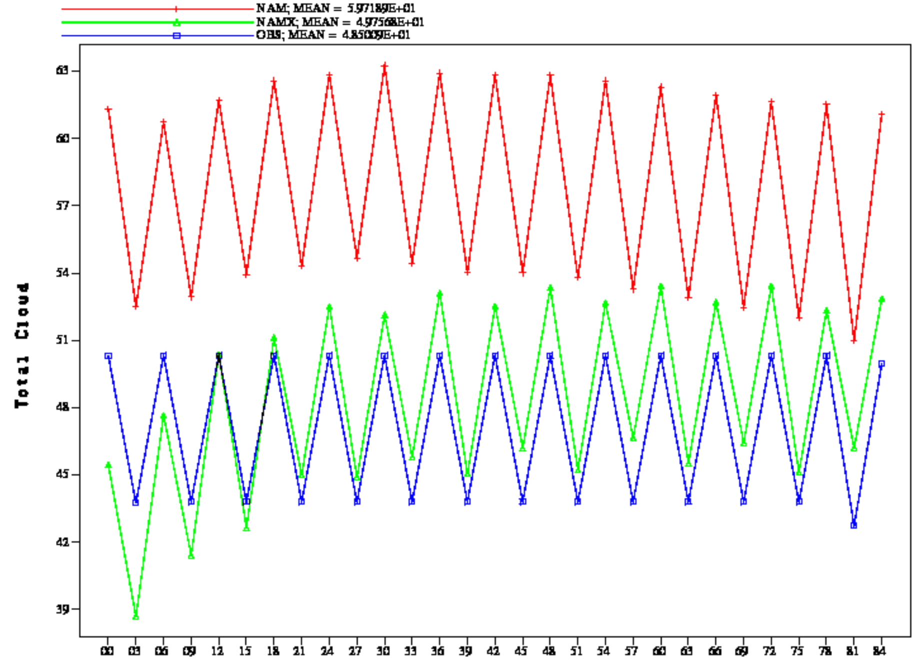
Various mean cyclone errors for operational NAM (green) versus NAMX parallel (blue) for the 7-month time period from 00z October 1, 2010 to 18z April 30, 2011

Number of forecast cases for each forecast range, Grid 221

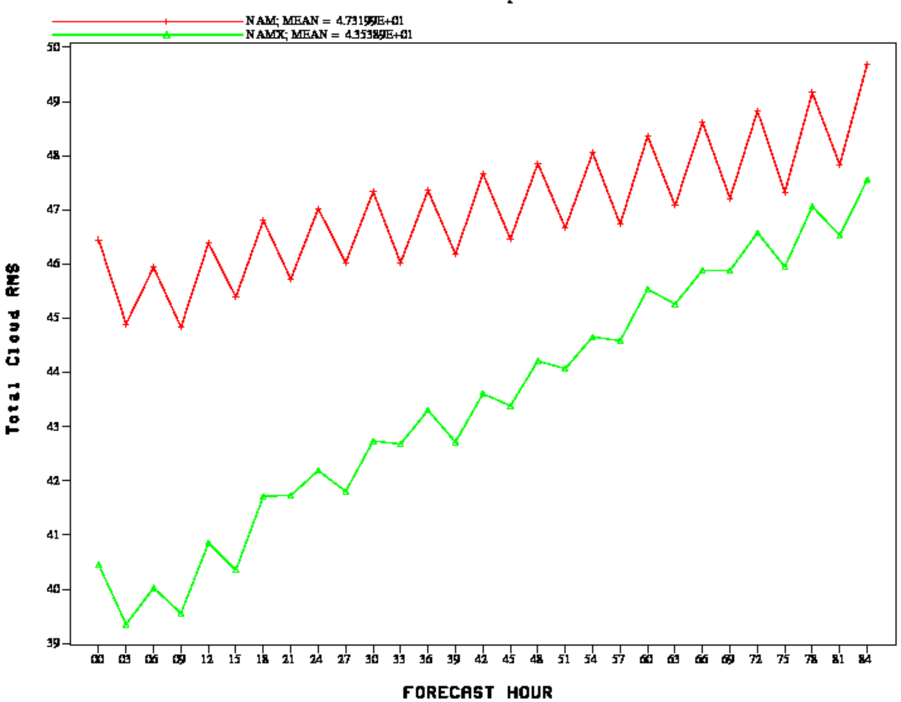
hrs	00	12	24	36	48	60	72
NAM	1421	1145	443	213	103	51	27

Verification Cloud vs METAR

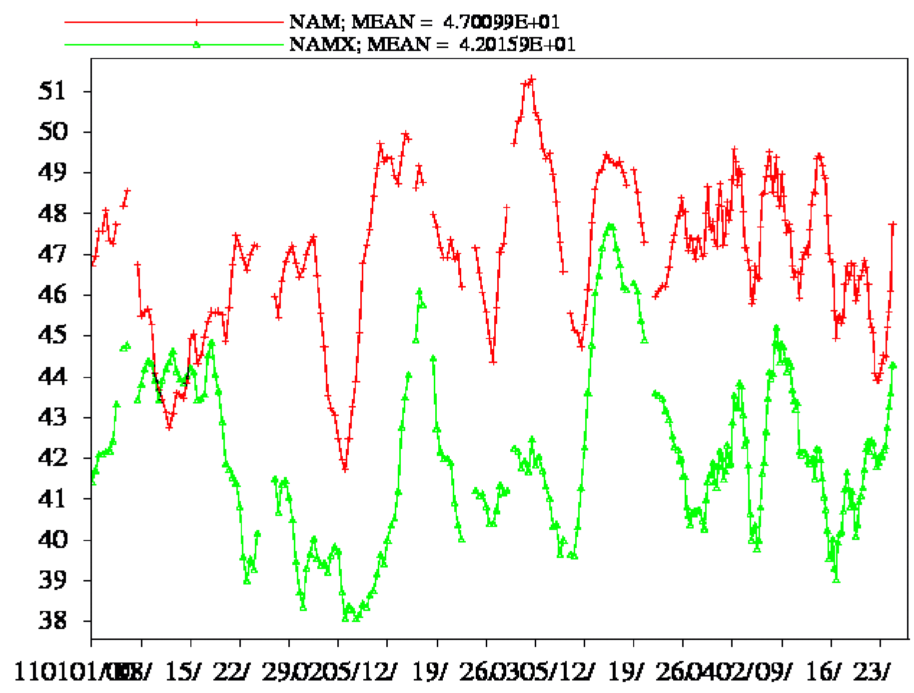
Diurnal Total Cloud 1 Jan 2011 to 30 Apr 2011



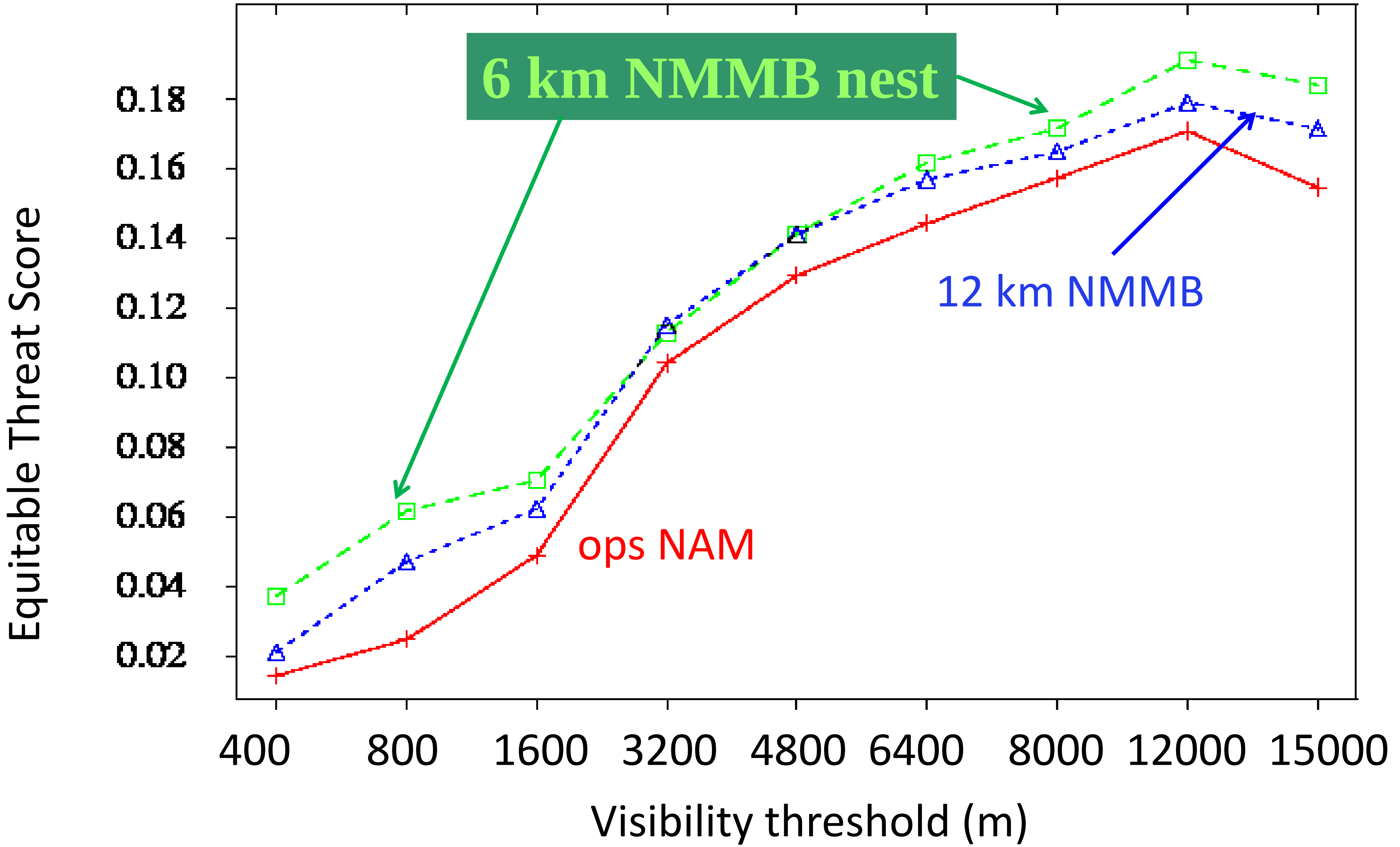
Diurnal Total Cloud RMS 1 Jan 2011 to 30 Apr 2011



Total Cloud RMS 1 January 2011 to 27 April 2011

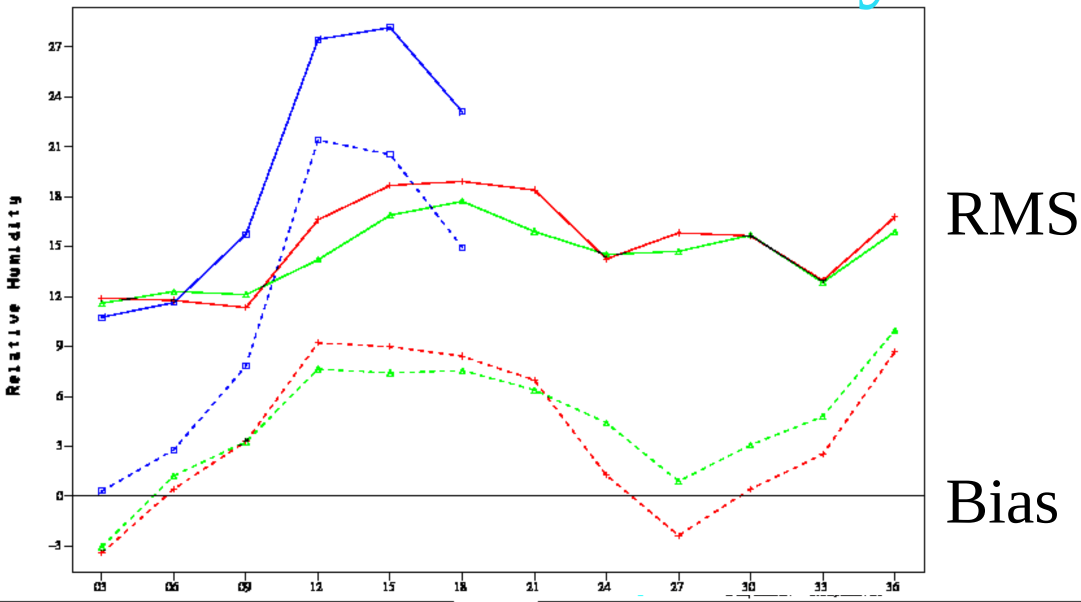


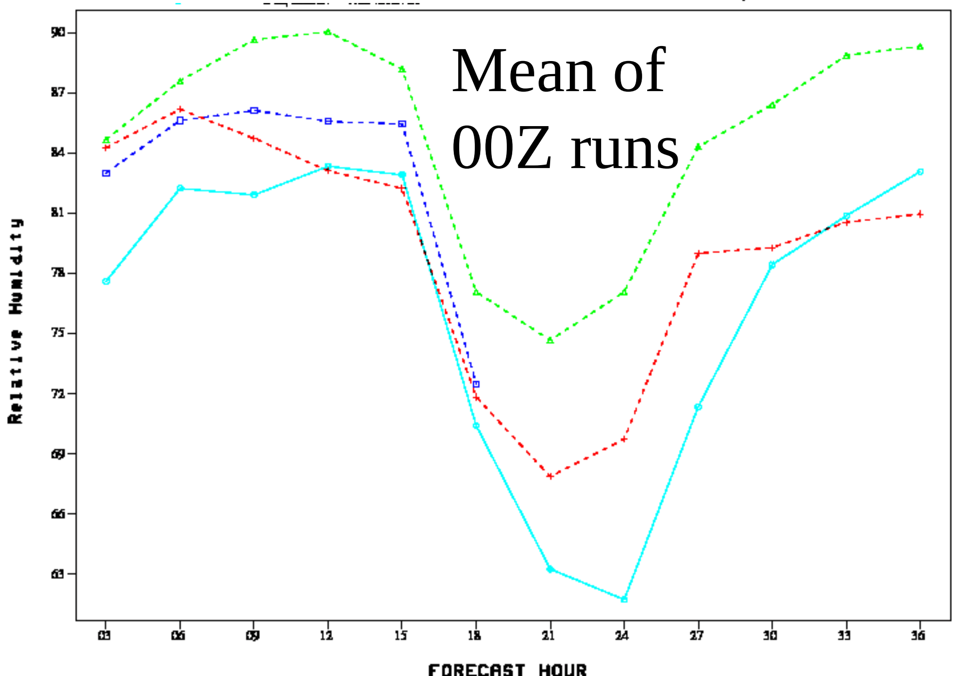
Visibility Verification over AK
1 Sep 2010 to 1 Jan 2011

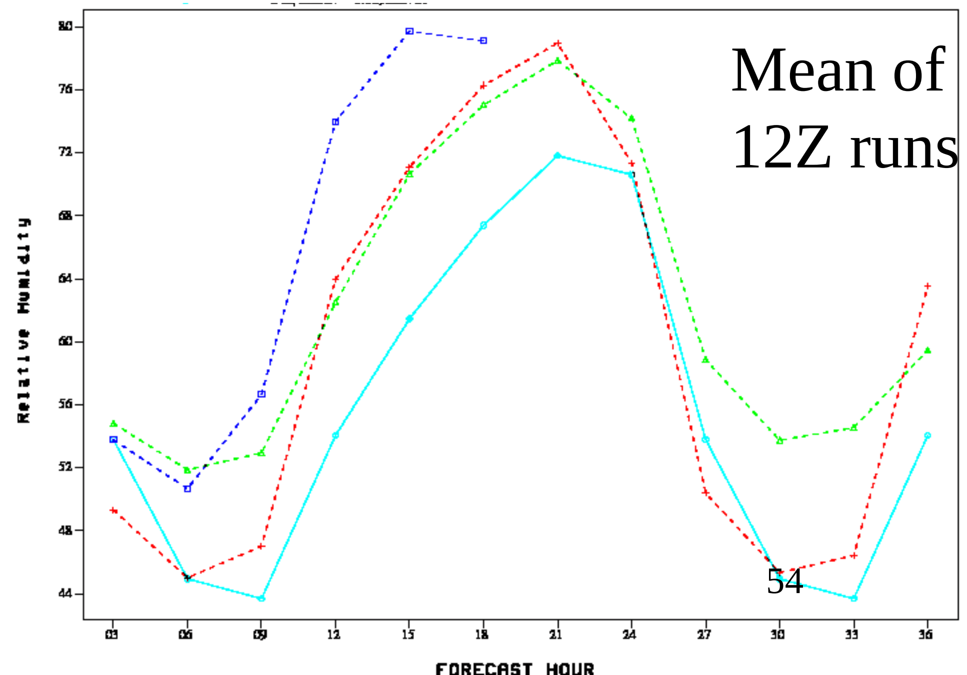


Slide courtesy Perry Shafran via Matt Pyle

NAM, RUC & FWIS Run Verification vs Mesonet Relative Humidity Obs







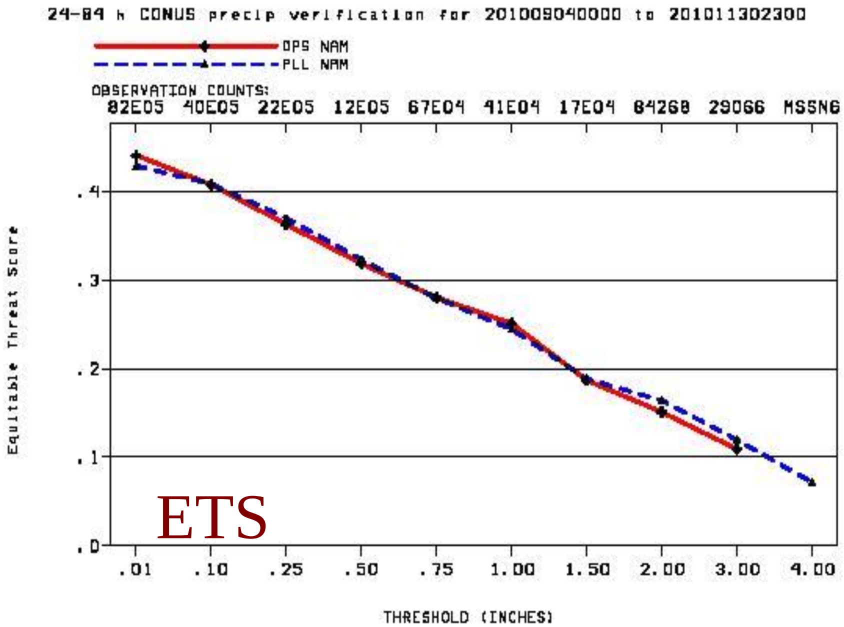
Four seasons of NMMB parallel statistics: September 2010 – August 2011

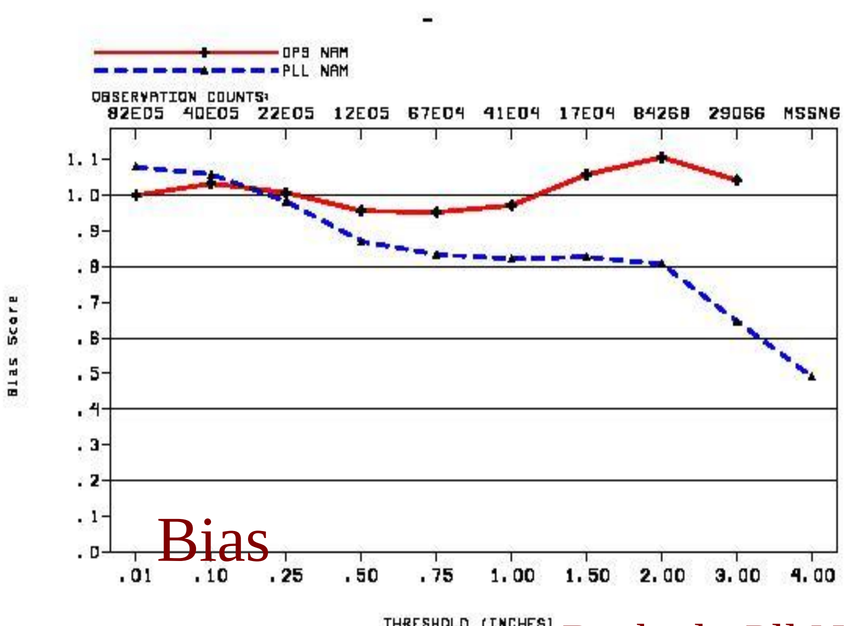
- NMMB parallel
  - EMC development parallel until 6/13/2011
  - NCO parallel 6/13/2011 - present
- Parallel was “frozen” on 3/23/2011, only bug fixes thereafter

QPF

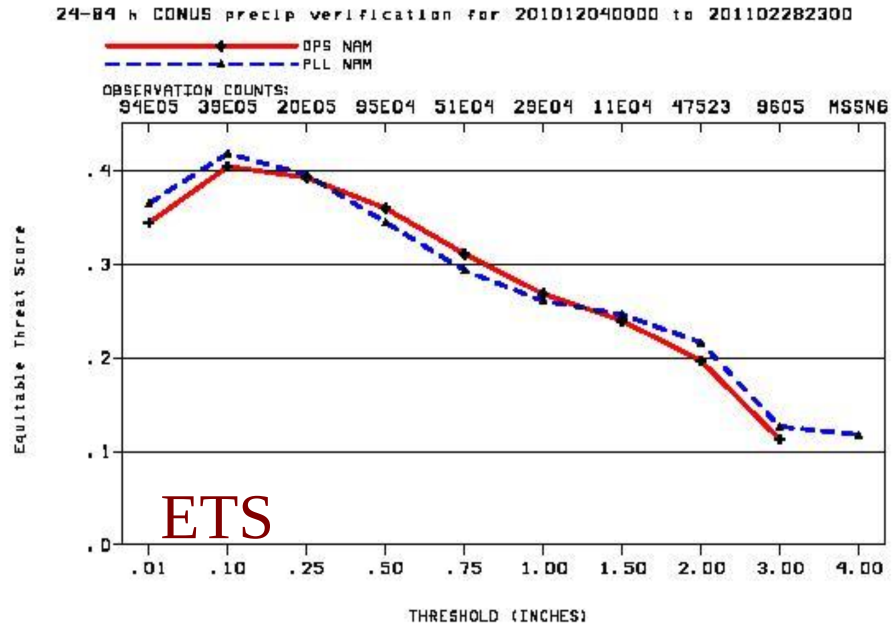
- Equitable Threat and Bias scores for all 24-84 h forecasts:
  - Ops NAM = Solid Red Lines
  - Parallel 12 km NAMX = Dashed Blue Lines
  - Parallel 4 km CONUS = Dashed Green Lines
- 12 km Parent (NAMX)
  - ETS comparable to current NAM (except August when its better)
  - Bias lower especially for high amounts
- 4 km CONUS nest
  - ETS better than NAMX and often NAM too (except August when NAMX wins)
  - Bias better than NAMX and often NAM too

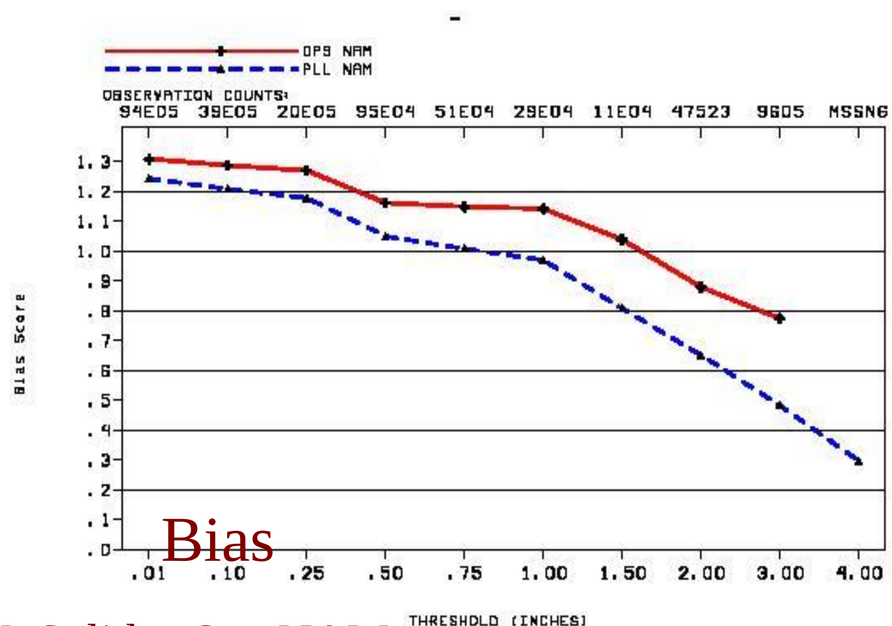
September–November 2010 QPF scores





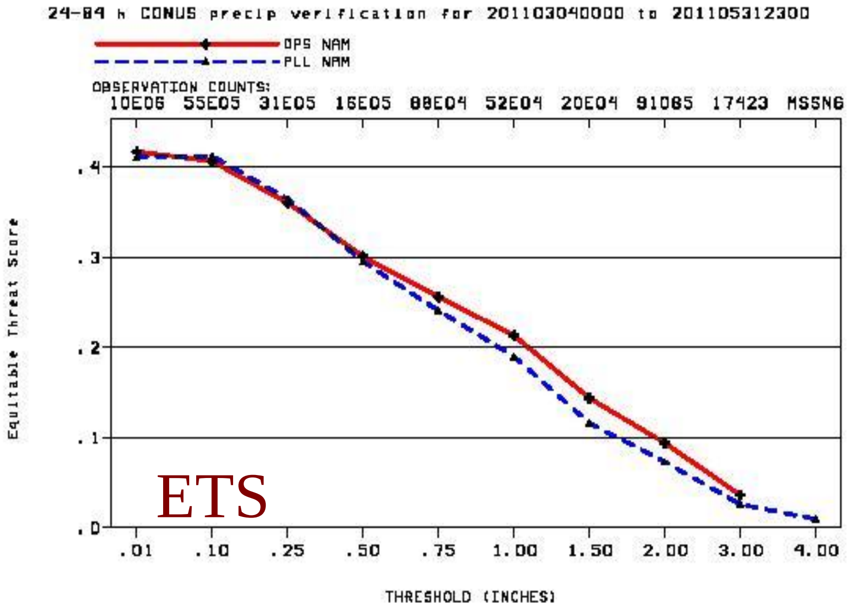
December 2010–February 2011 QPF scores

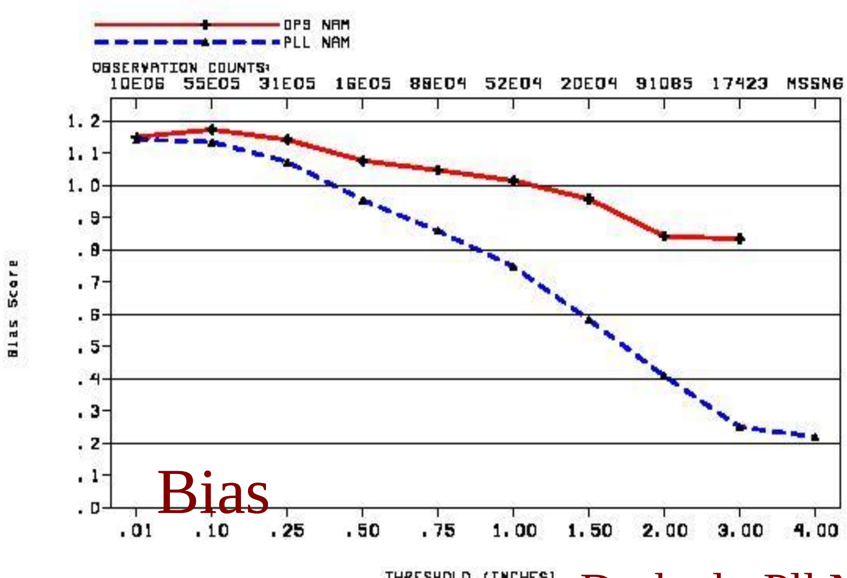




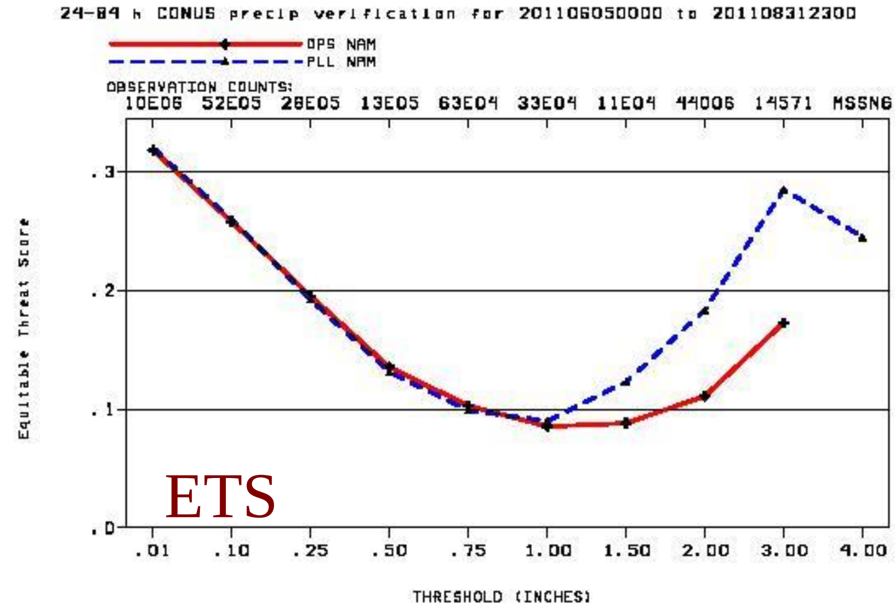
Dashed= Pll NAM, Solid = Ops NAM

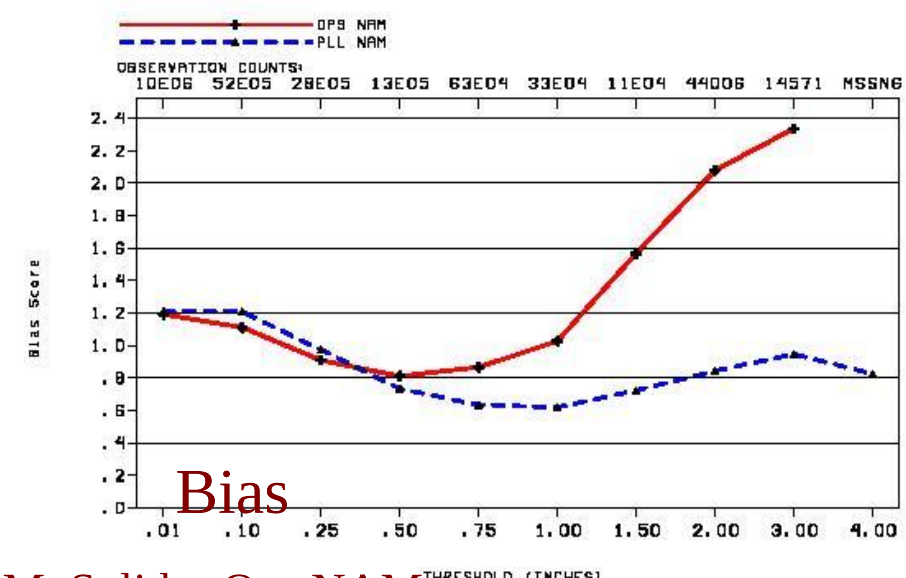
March – May 2011 QPF scores





June – August 2011 QPF scores





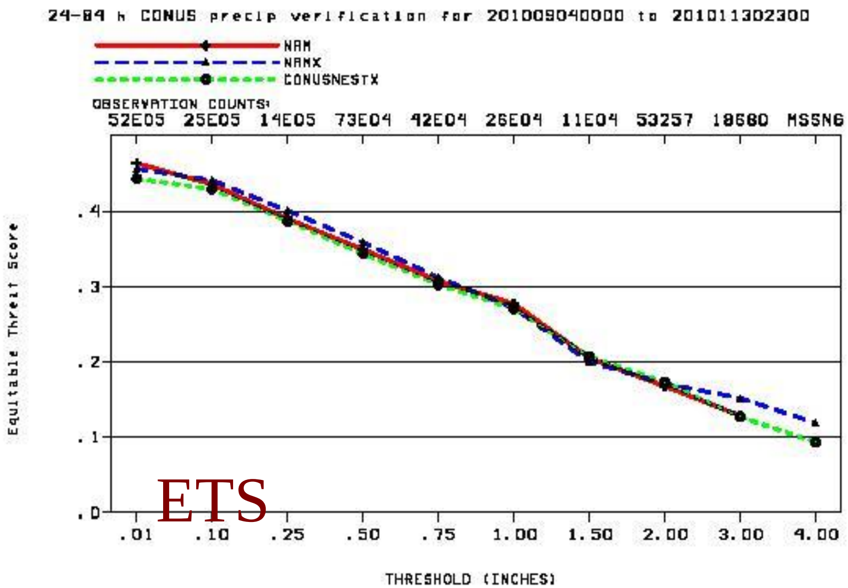
Dashed= Pll NAM, Solid = Ops NAM

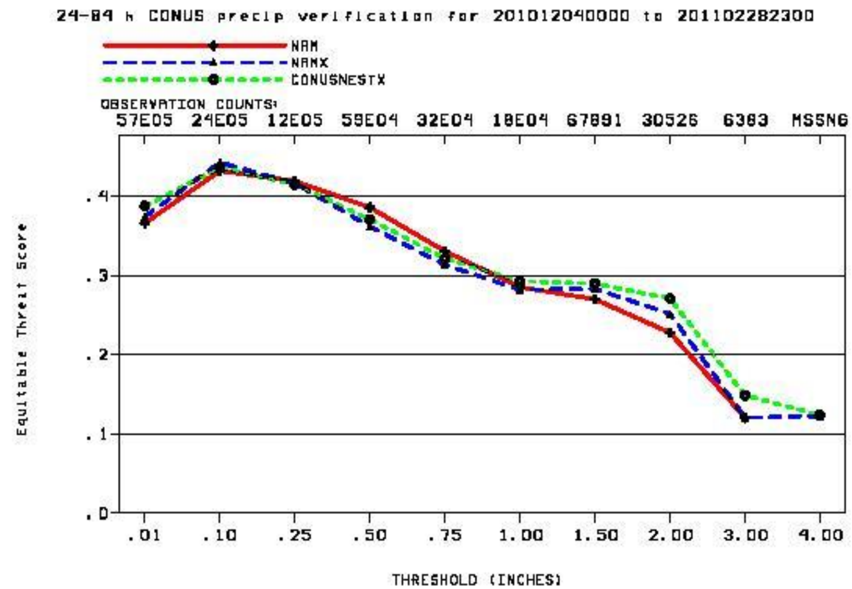
Four seasons of NMMB parallel statistics : NAM nests

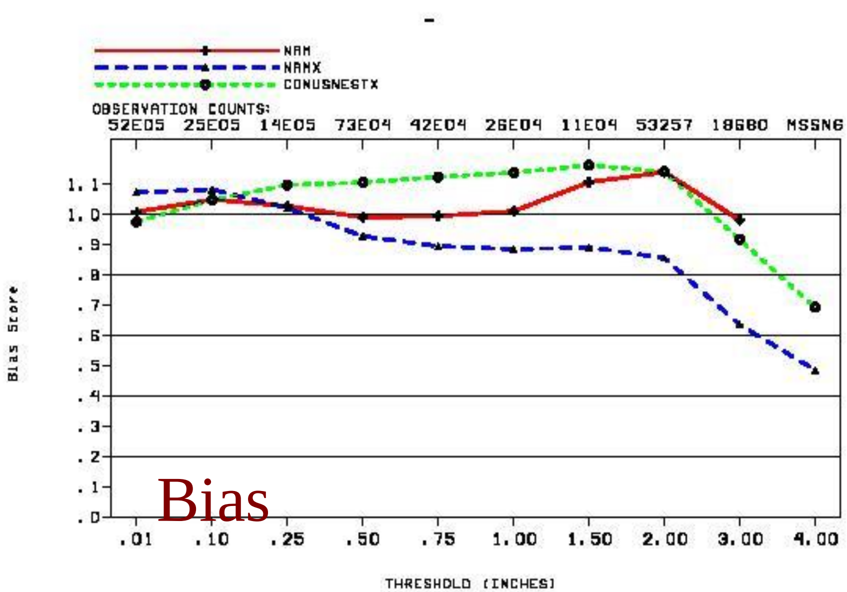
- Equitable Threat and Bias scores for all 24-60 h forecasts:
  - Ops NAM = Solid Red Lines
  - Parallel 12 km NAMX (parent run to nest) = Dashed Blue Lines
  - Parallel 4 km CONUS nest : Dashed Green Lines
  - Note:
    - 2x/day CONUS nest runs started 13 July 2010
    - Nests ran with explicit convection until 8/29/2010, “BMJ_DEV” with less active convection thereafter
    - 3/1/11 – 3/22/11 was dropped from sample as the NAMX parallel (w/nests) was testing a radiation change that is not in the final NAM change package

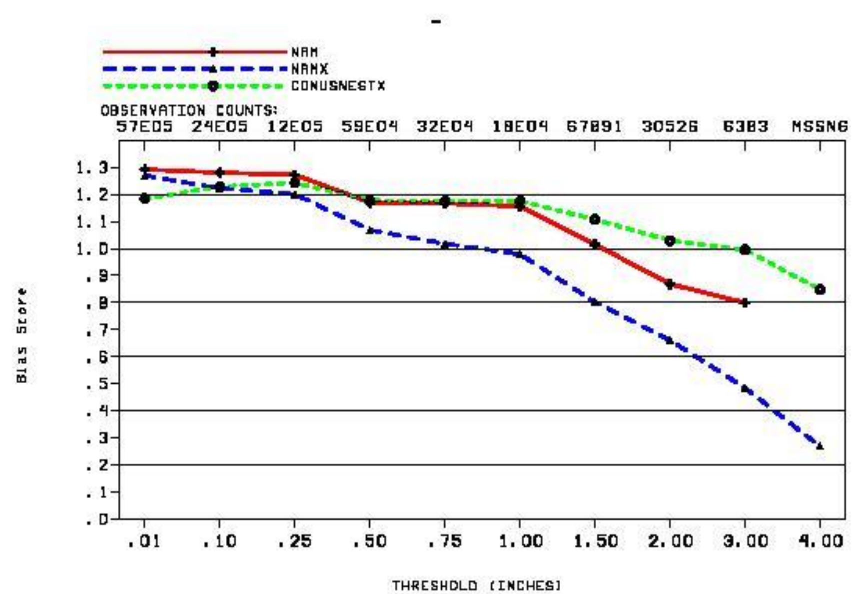
September - November 2010 QPF scores

December 2010–February 2011 QPF scores





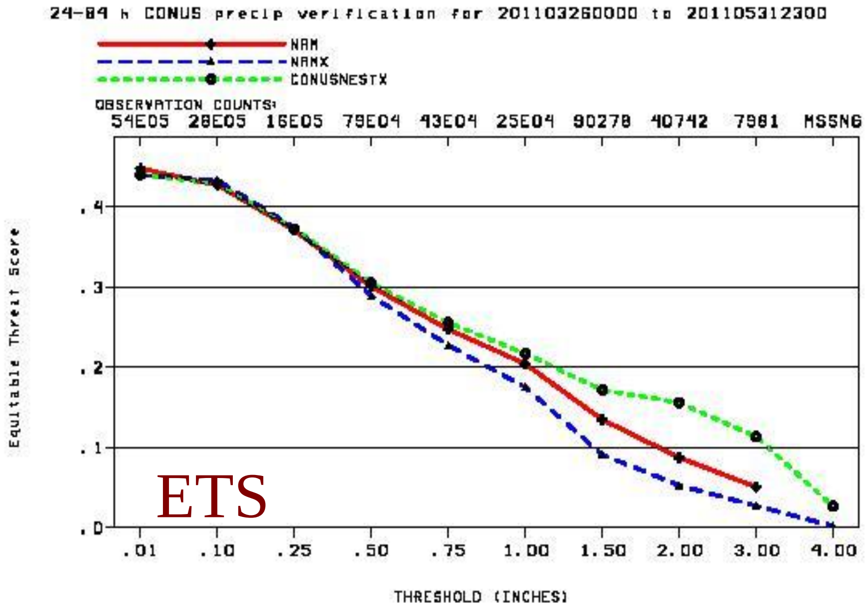


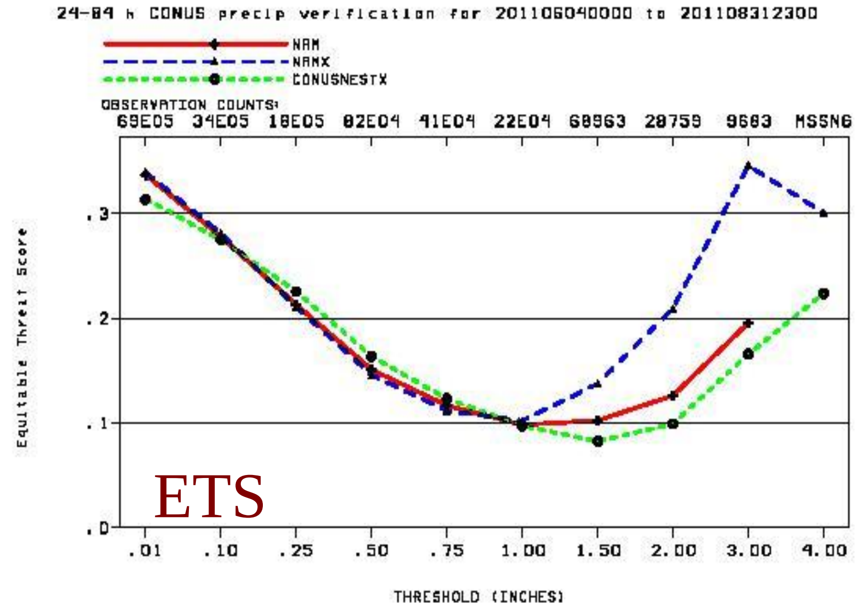


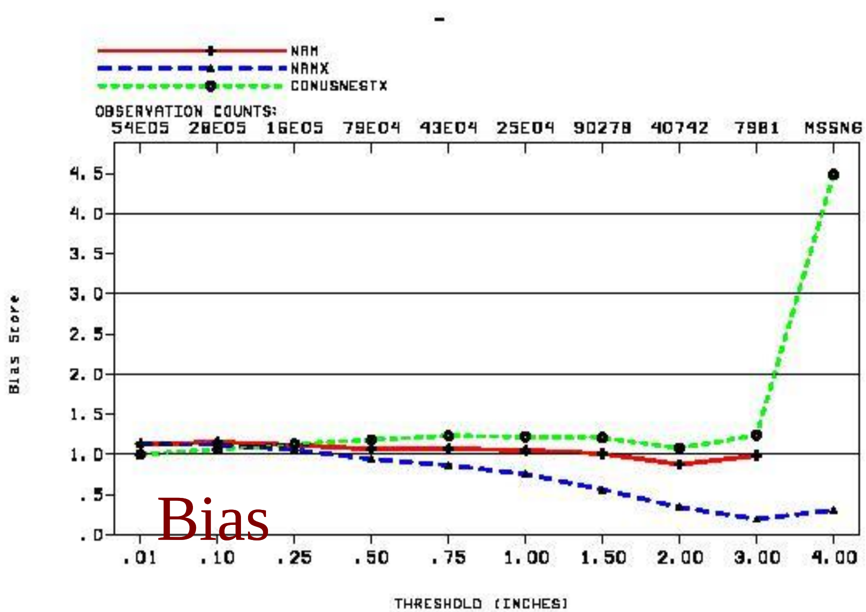
NOTE : Nest ran with explicit convection until 8/29/2010

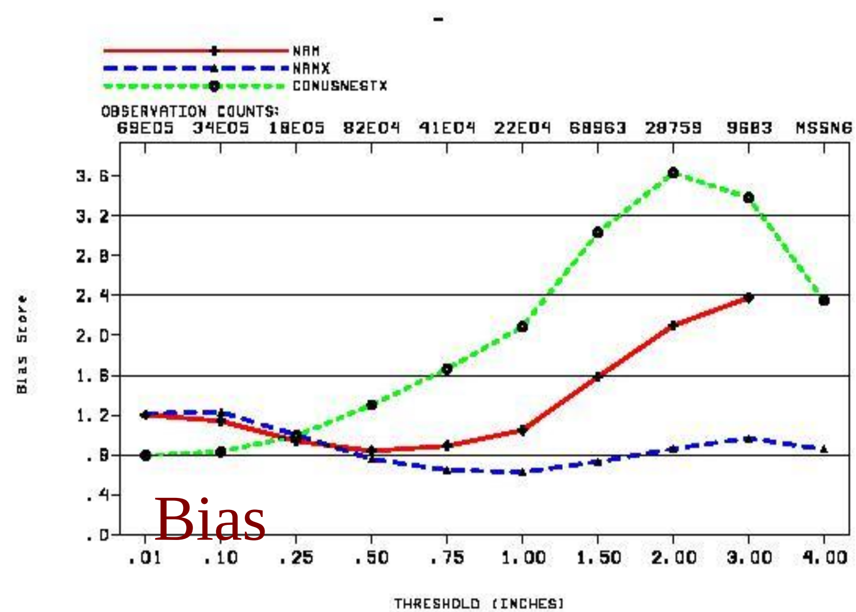
March – May 2011 QPF scores

June - August 2011 QPF scores





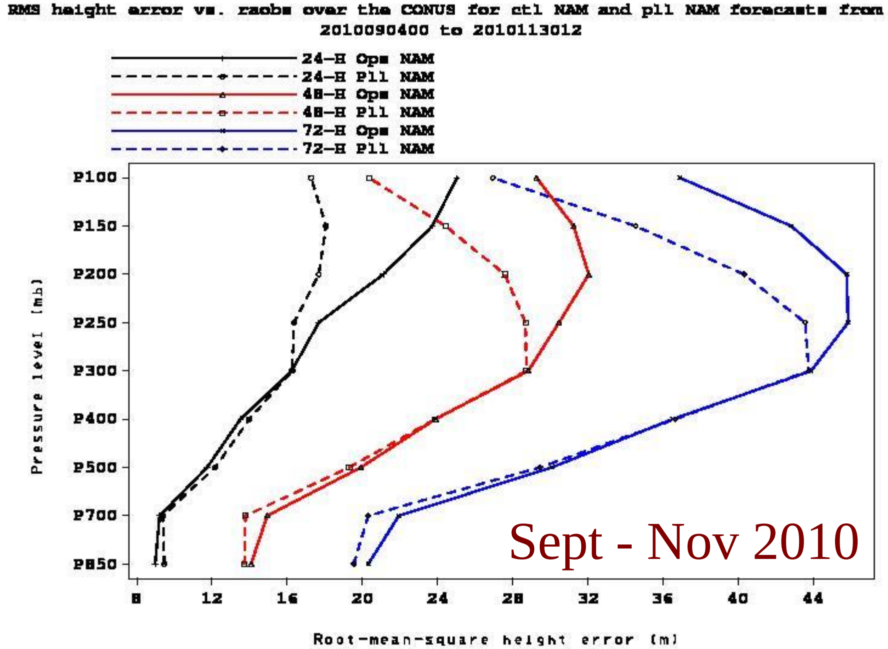


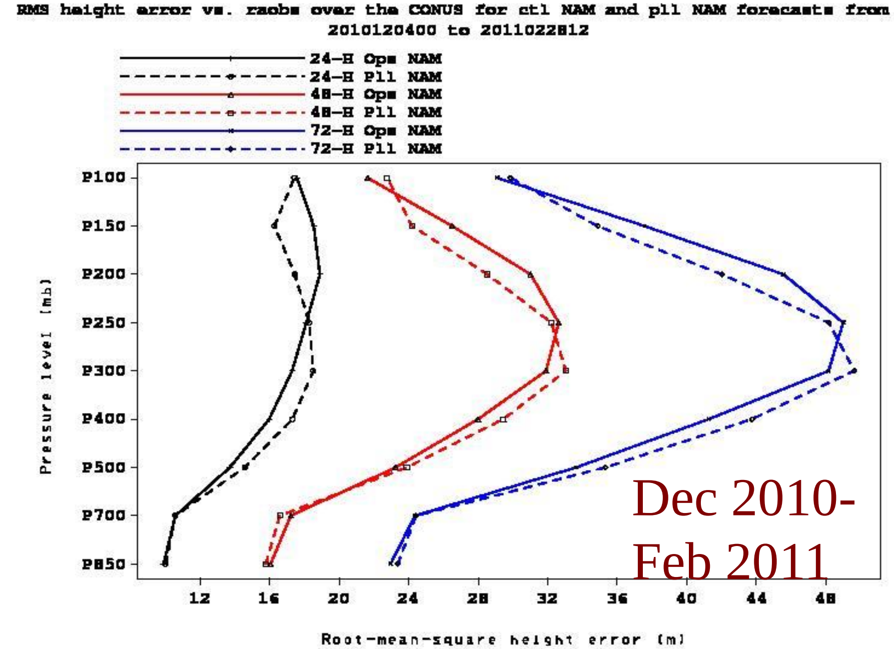


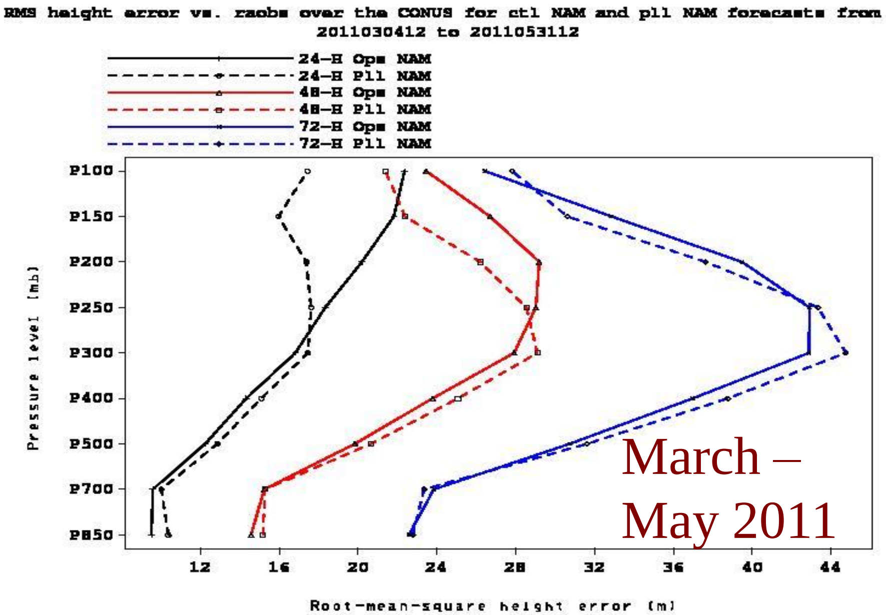
Four Seasons of Upper-Air stats vs raobs

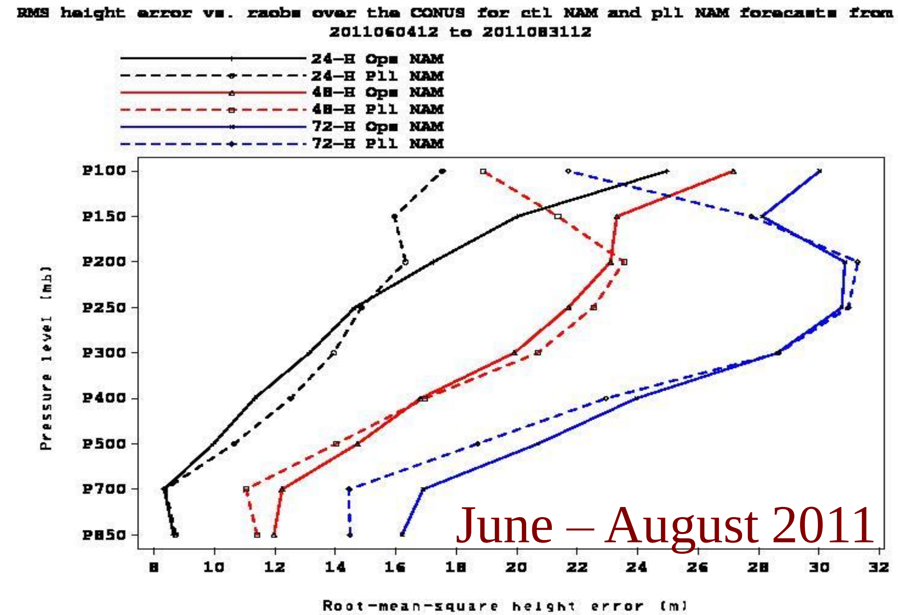
- 24, 48-h, 72-h forecasts vs raobs
  - Ops NAM = Solid Lines
  - Parallel 12 km NAM = Dashed Lines
  - Black = 24-h Forecasts
  - Red = 48-h Forecasts
  - Blue = 72-h Forecasts
  - CONUS verification region is grid #212
  - Alaska verification region is grid #216
- Generally favorable for NAMX better than NAM over both CONUS and Alaska
  - Heights comparable to better esp. in strat.
  - Lower temp bias away from sfc where cooler
  - Lower RH bias away from sfc where comparable
  - Winds generally better throughout

Day 1,2,3 CONUS RMS Height error: Dashed=Pll NAM, Solid=Ops NAM

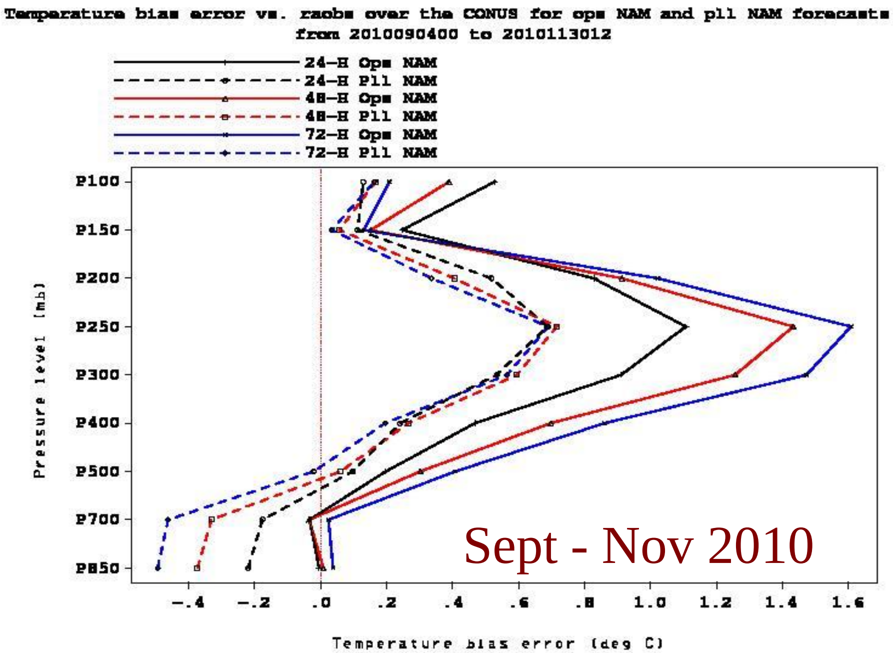


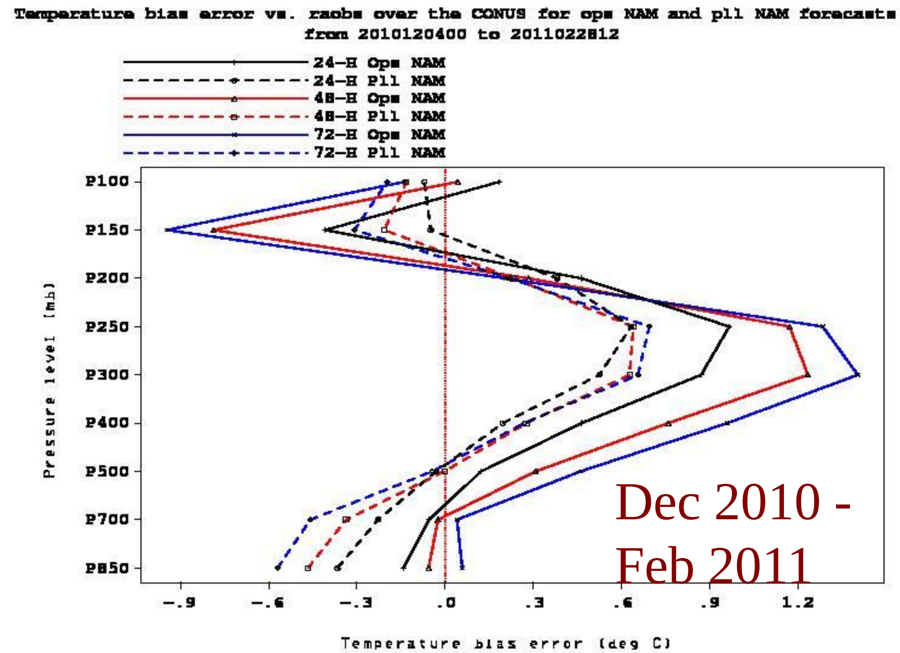


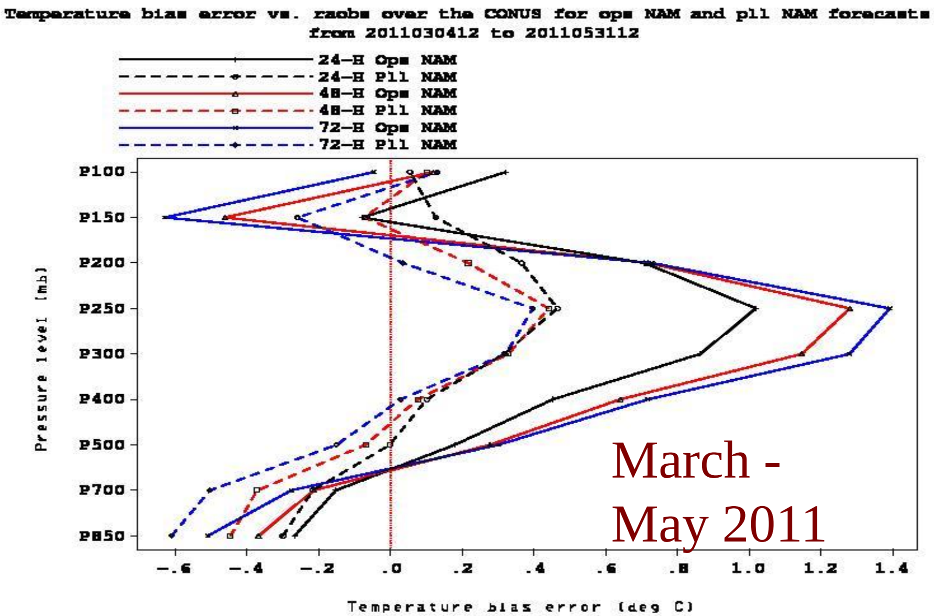


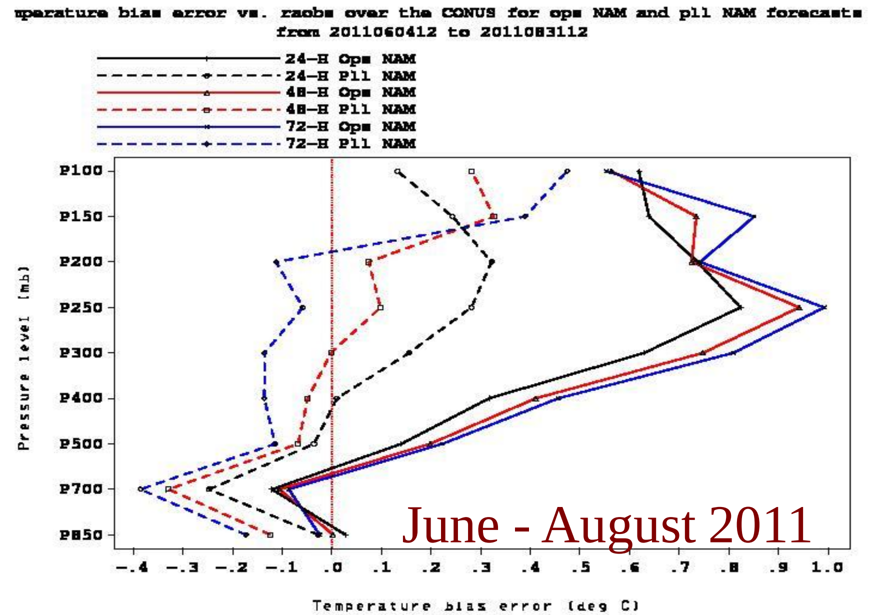


Day 1,2,3 CONUS Temp Bias: Dashed=Pll NAM, Solid=Ops NAM

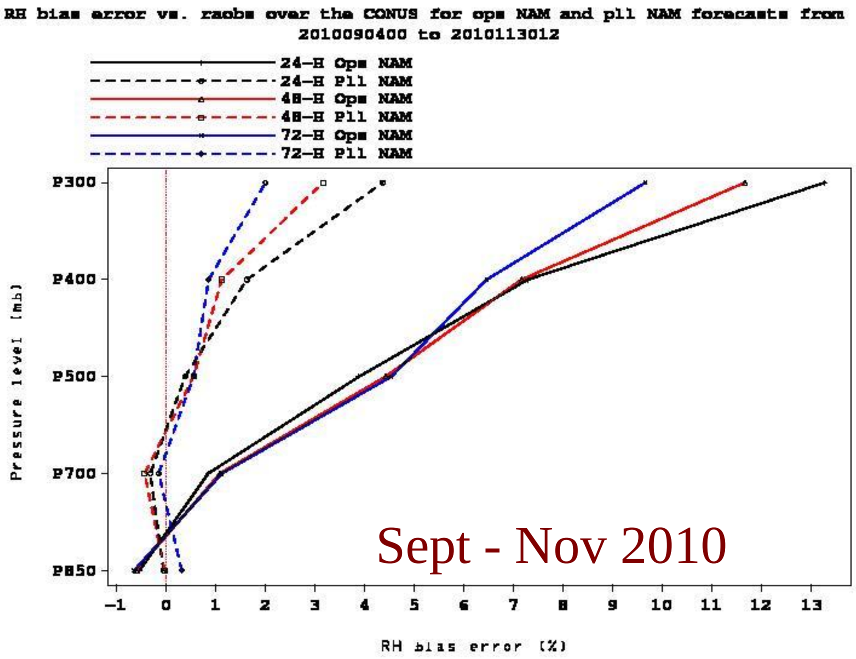


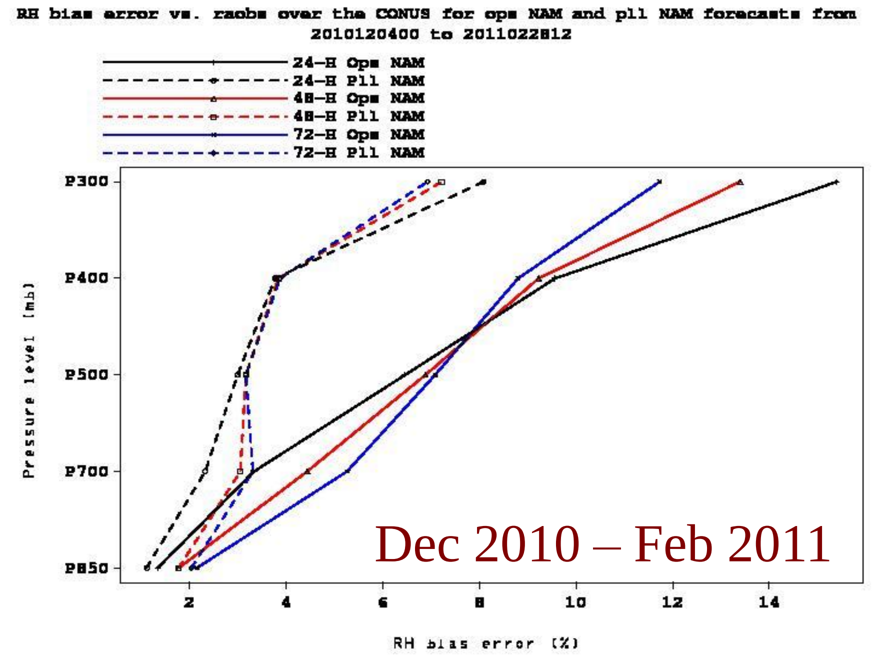


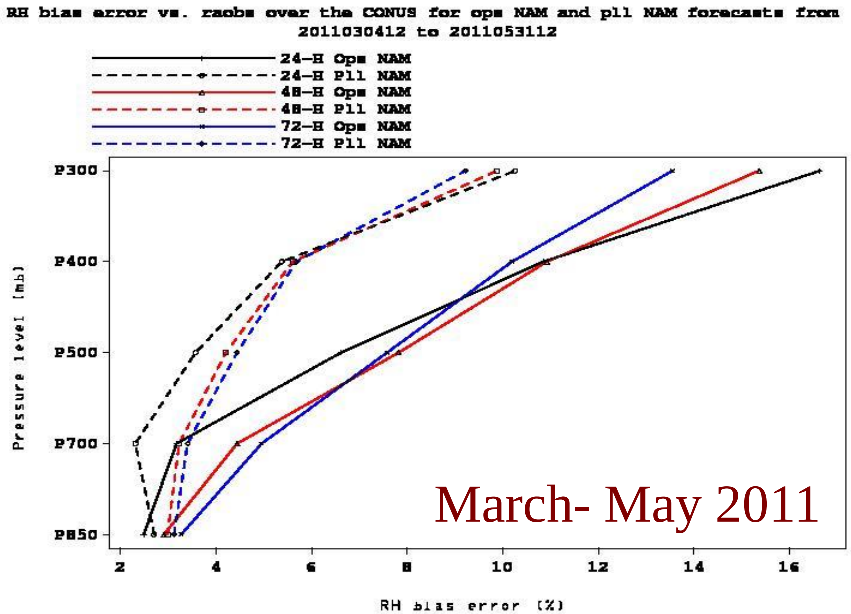


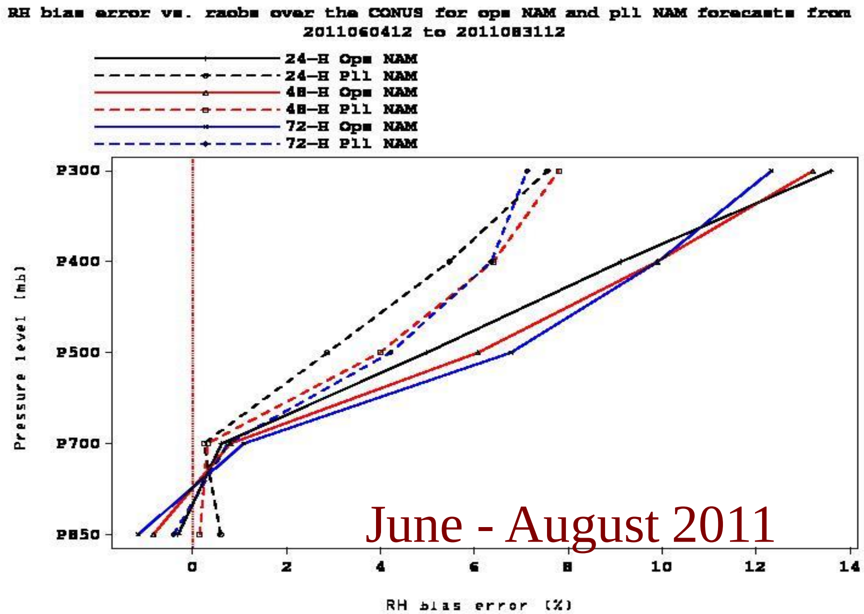


Day 1,2,3 CONUS RH Bias: Dashed=Pll NAM, Solid=Ops NAM

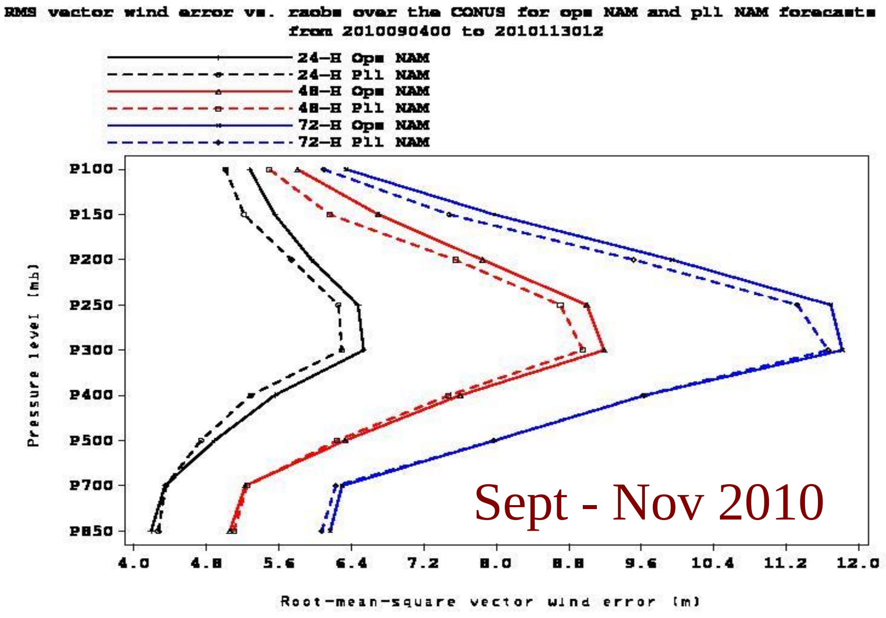


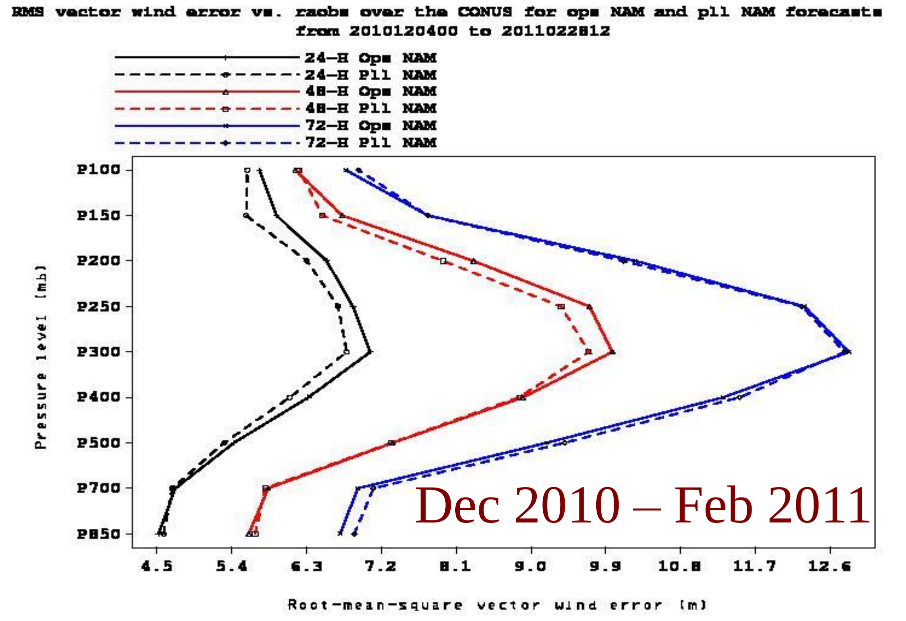


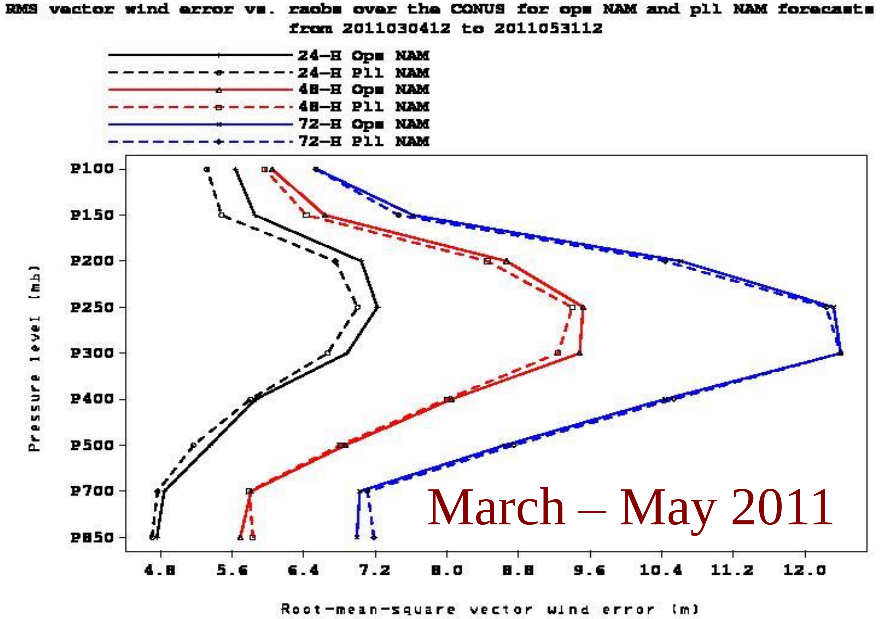


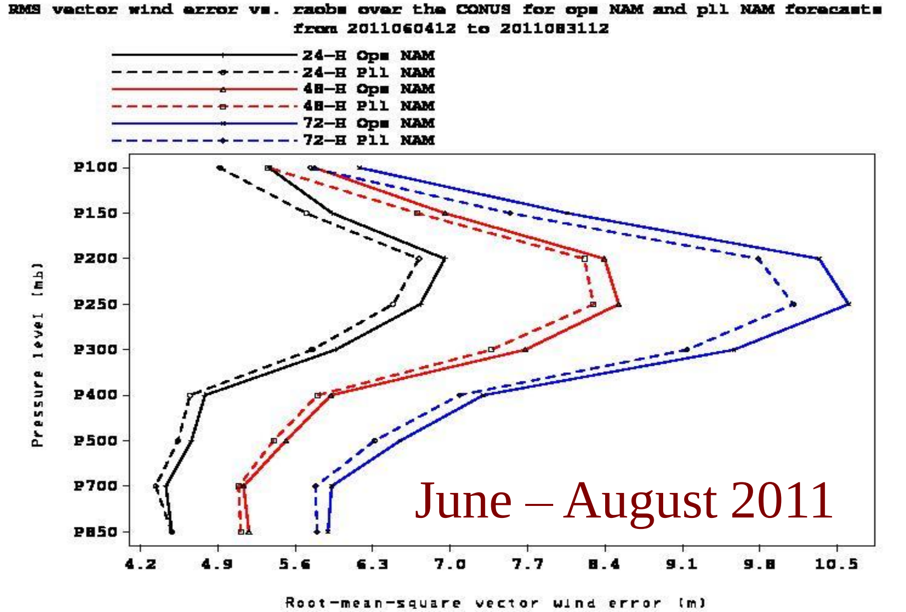


Day 1,2,3 CONUS Vector Wind RMS error: Dashed =Pll NAM, Solid=Ops NAM





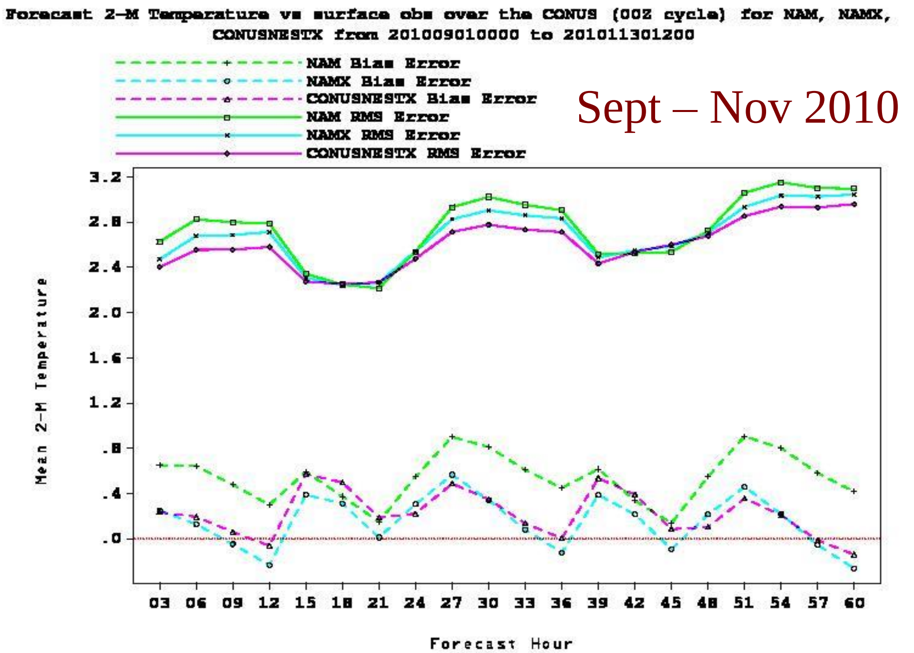


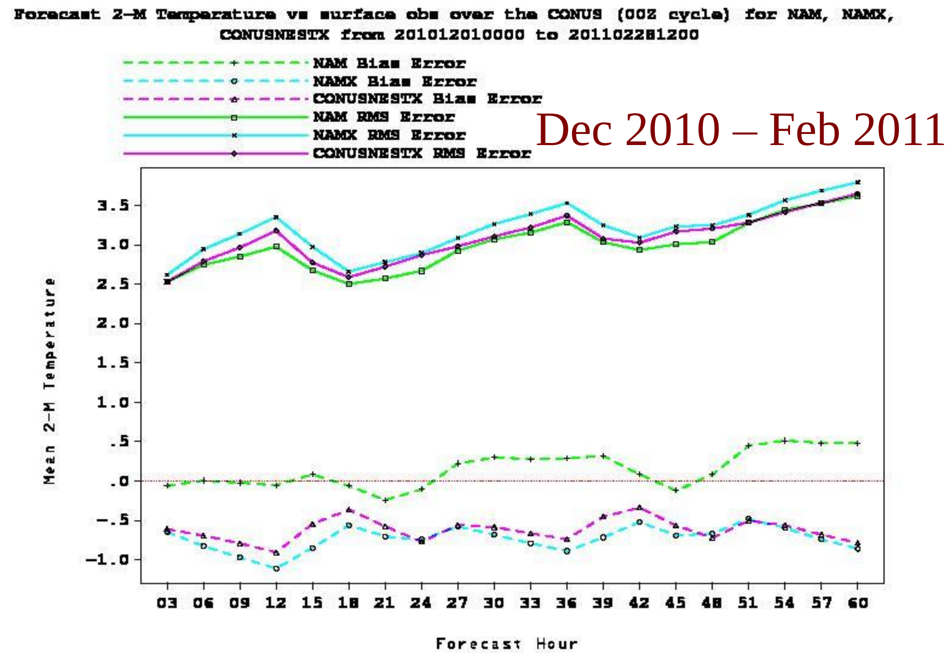


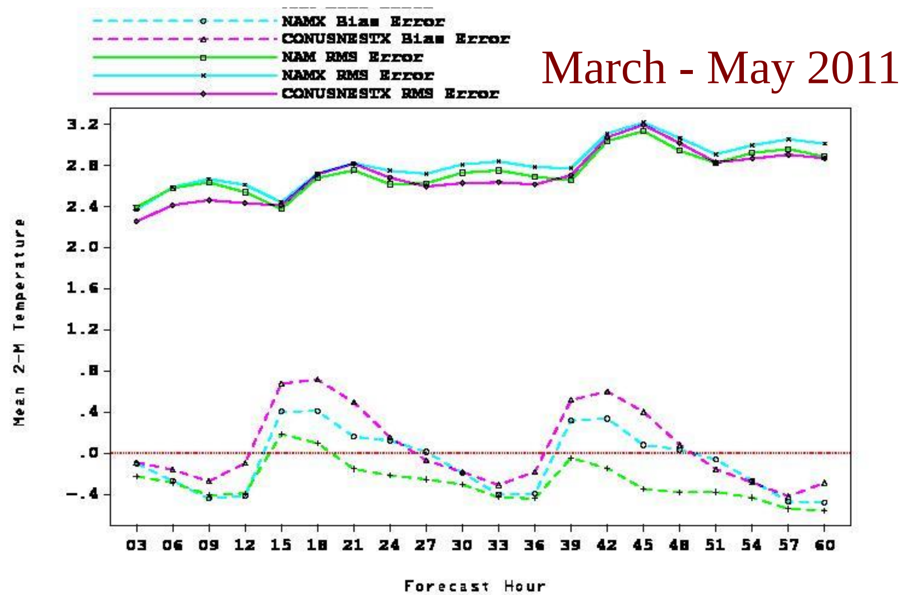
Four Seasons of Surface stats vs obs

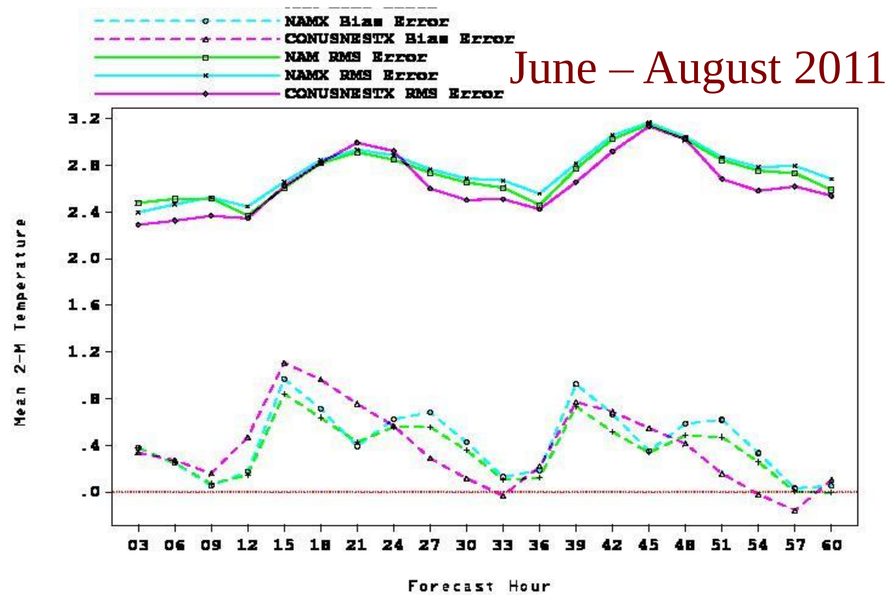
- Mean diurnal RMS & bias for shelter T/Td/Wind
  - Solid Lines : RMS error
  - Dashed Lines = Bias error
  - Ops NAM = Green
  - Parallel 12 km NAMX = Blue
  - Parallel "nestX" = Magenta
  - Parallel NAMX used USGS land-use (same as ops) until 9/14/2010, IGBP MODIS thereafter
  - Gravity wave drag/mountain blocking turned on in Alaska nest on 9/24/10 (not used in other nests)
  - 2-m Dew Point Temp stats not available for Summer/Fall 2010 for NAM nest due to data count discrepancies for NAM nests in verification codes
  - CONUS surface verification: combination of 14 CONUS subregions
  - Alaska surface verification: combination of "NAK" and "SAK" subregions
- A mixed bag (but nothing catastrophic) with seasonal and regional variability in conclusion compounded by issues with albedo bug during winter and dew point verification bug in summer/fall.

CONUS 00z Cycle 2-m Temp RMS/Bias

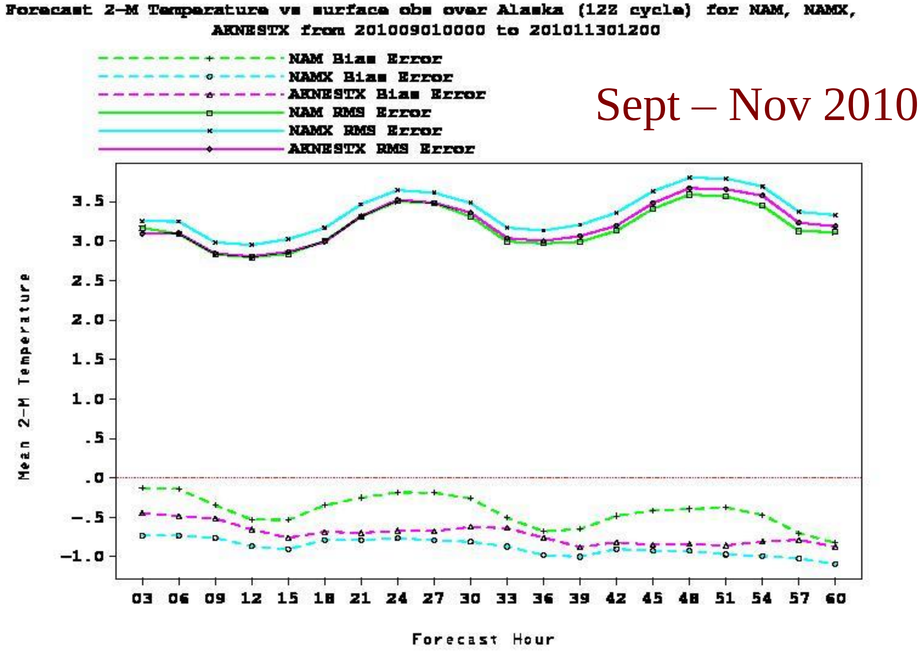


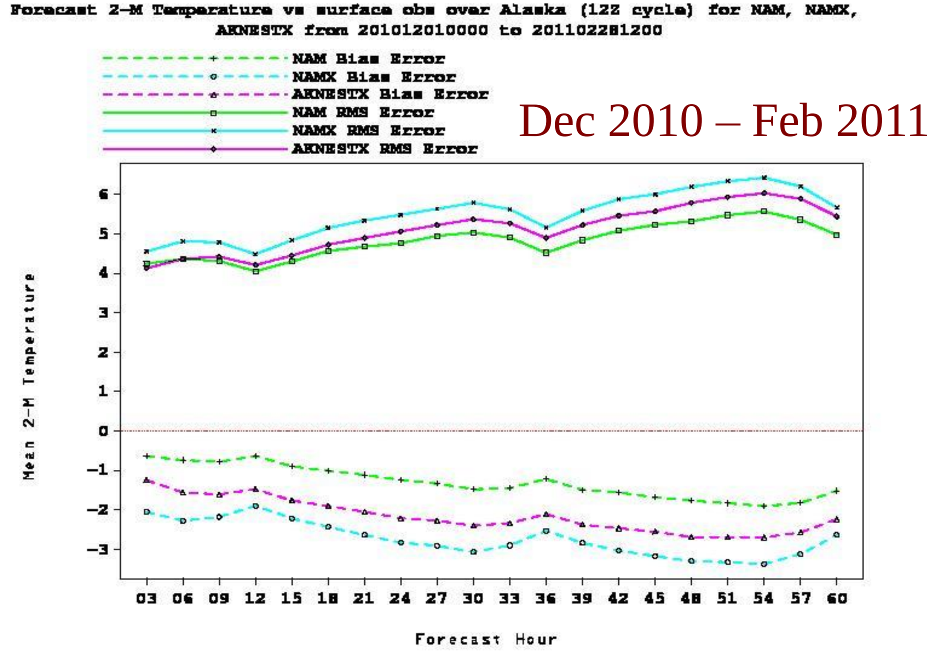


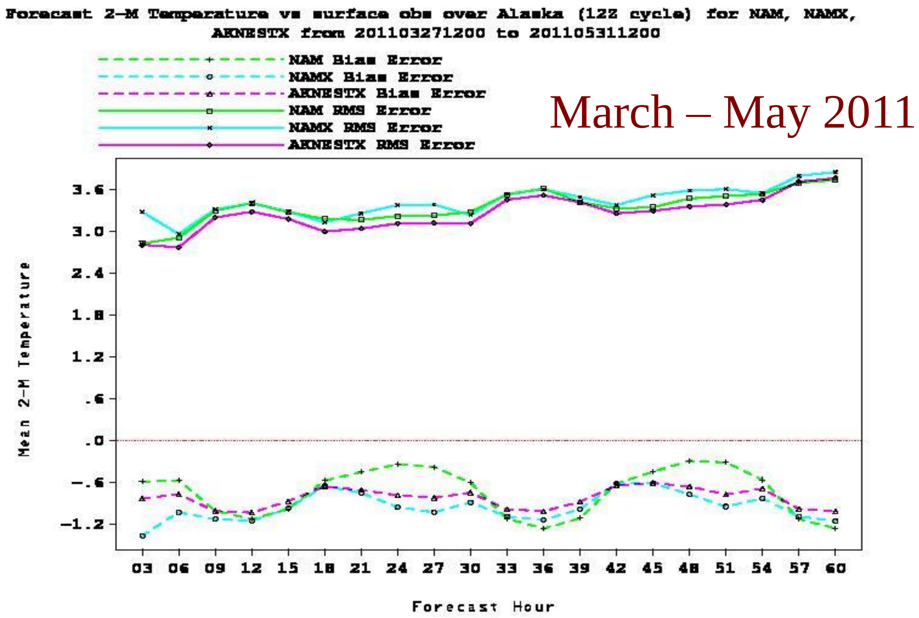


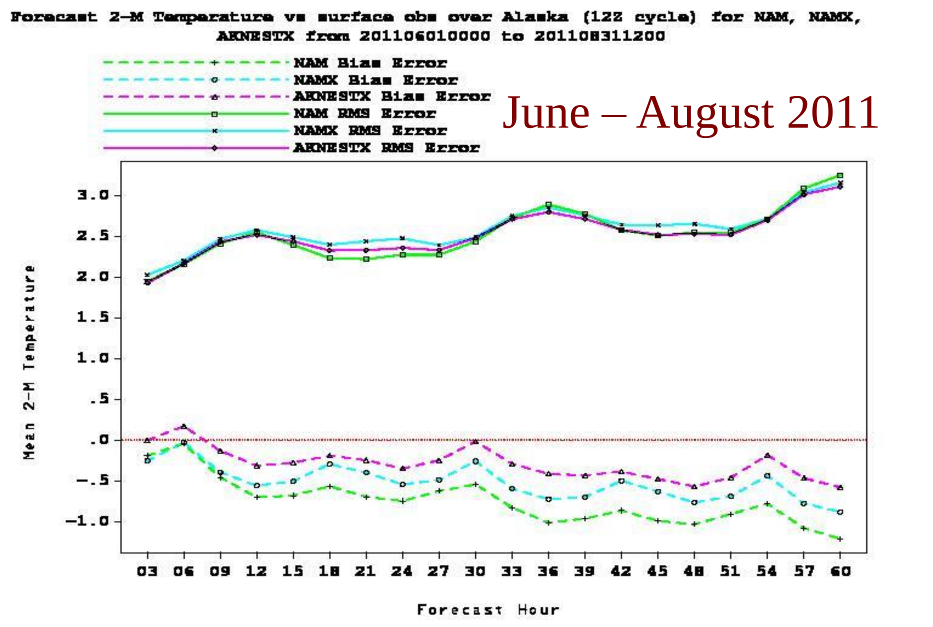


Alaska 12z Cycle 2-m Temp RMS/Bias









Ops vs Parallel DGEX: June–August 2011

- QPF (CONUS only): slightly lower ETS and bias (like parent)
- Upper air: better over CONUS & Alaska (again like parent), crossing over in Alaska only at 192 hr
- Near-surface Temp. RMS / bias: comparable RMS but a little warmer throughout for both CONUS (warmer warm bias) & Alaska (warmer cool bias)
- Near-surface Wind RMS/bias: mixed better/ comparable RMS for CONUS/Alaska but reduced fast bias over CONUS and reduced slow bias in Alaska

Addressing Concerns About the NAM Upgrade:

Read-Ahead Material Prepared by EMC 09/16/11
updated with relevant feedback
slides from original 9/12/11 decision briefing

Summary of Reviewers' Recommendations

	NMMB 12 km	Nests	Comment
MDL			MOS from ops NAM, "updated equations for NMMB should mitigate most of the negative impact"
NCO			"Feedback re: NAM benefits showed mixed results but all support implementation"
Eastern Region			"Subjective and event/case based, Eastern Region conditionally recommends implementation, conditions positive or neutral objective verification results and evaluations from the national centers"
SPC			"SPC approves implementation of the NAM 12 parallel, SPC recommends implementation of Fire Nest, Focused efforts are needed to improve the convective scale structure, intensity, and realism of storms in the NAM Nest"
AWC			"AWC recommends operational implementation of the NAM-Parallel"
OPC			"No show stoppers"
HPC			"HPC Recommends Implementation"

Accept
Accept with reservations
Beside the point, positive tone

SPC NAM Evaluation

– **Major Findings**
  - **4 km CONUS Nest**
    – The NAM CONUS Nest typically generated storms that exhibited broader, weaker, and less useful reflectivity signatures, and much weaker storm intensity characteristics as revealed by updraft speed and updraft helicity products
      » Updraft speed and updraft helicity were typically 2-5 times smaller compared to other high-resolution models
    – On many outbreak days, the NAM Nest failed to generate storms indicative of high severe weather potential
    – It is not uncommon for convective storms in the NAM Nest to have effective resolution considerably coarser than the 4 km grid would suggest
    – Overall, the NAM Nest does not provide the same level of guidance as other high-resolution models, and ***its current performance is not useful for SPC and NWS severe weather forecasting***
    – **Recommendation:** Focused efforts are needed to improve the convective scale structure, intensity, and realism of storms in the NAM Nest

SPC NAM Nest Evaluation

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    - **Recommendation:** Focused efforts are needed to improve the convective scale structure, intensity, and realism of storms in the NAM Nest

EMC Response to SPC's Concerns About the NAM Nests (1 of 2)

- Discussions were held between EMC and SPC in April. The following were discussed and, at the time, SPC said they understood our position and strategy (see next slide) and would not block implementation of the NAM upgrade. They do support implementation with acknowledgement that EMC will continue to improve the 4km nest performance for severe weather applications
- The NAM upgrade is not replacing an existing useful tool for SPC with an inferior one
- NAM nests are brand new and their implementation will not degrade the quality of SPC guidance in any way

EMC Response to SPC's Concerns About the NAM Nests (2 of 2)

- SPC already benefits from NCEP running WRF-ARW and WRF-NMM in the HiResWindow in operations multiple times per day and continued running of WRF-NMM (older version preferred by SPC) in Matt Pyle's special twice daily runs.
- Among the various sources of severe weather guidance used by SPC, the new NAM nests just won't be one of them in its initial form.
- EMC will seek ways to bring out structure and strength of convection while preserving the utility of nest guidance for the other users

Non Severe Weather Applications of the NAM 4km Nest (1of 2)

- The NAM nests were not designed or tuned to provide the severe weather guidance needed by SPC
- The NAM nests were designed to provide NWS WFOs and other users with basic weather guidance, e.g. QPF
- The nest resolutions were selected to match the NDFD grids on which WFOs produce their gridded forecasts
- Currently, the NAM-DNG WFOs use to initialize their GFE, is downscaled from NAM's 12 km to local NDFD resolutions [5.9-2.5 km] by the not-so-accurately-named "smartinit" processing
- Having NAM nests will mean very little (if any) downscaling will be needed to produce NAM-DNG.

Dissemination of NAM Nests

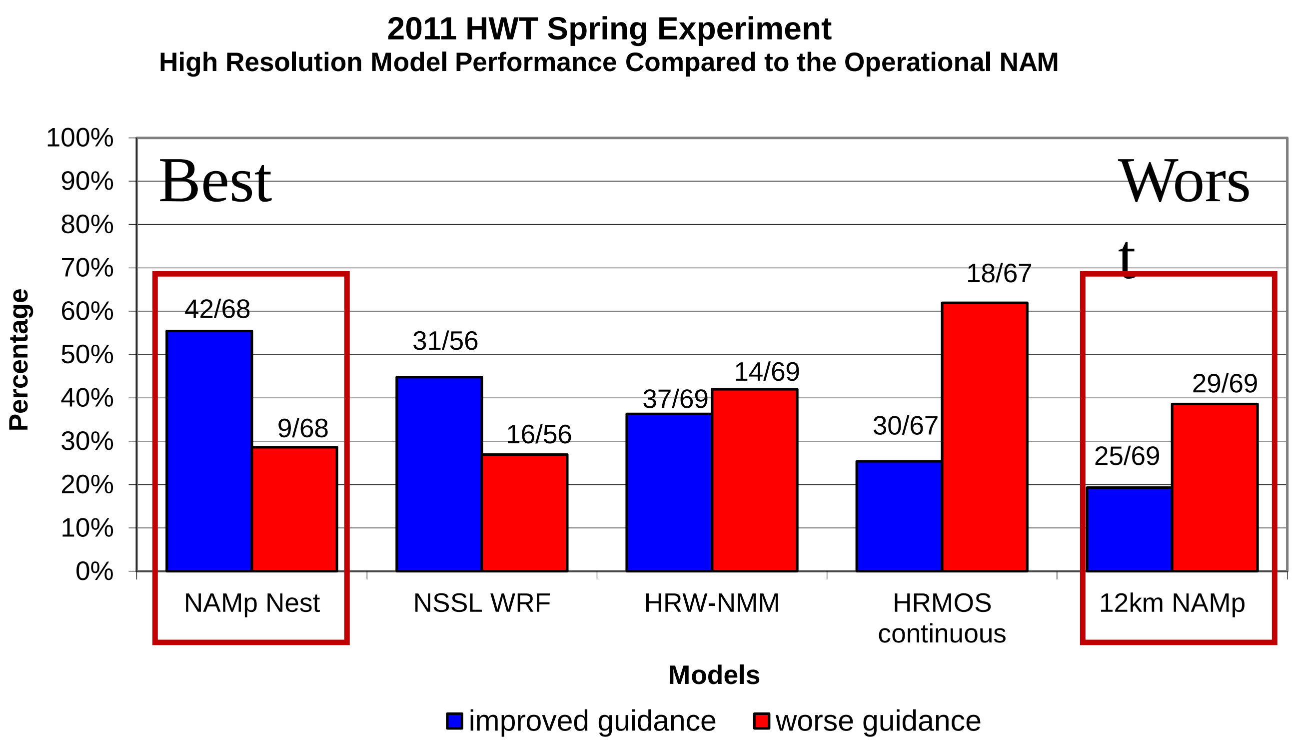
- NAM-DNG is already distributed to WFOs via AWIPS-SBN and thus available to private sector users via NOAAPORT. This is the primary distribution mechanism for NAM nest fields including QPF and simulated reflectivity.
- New double resolution NAM-DNG grids will be made for CONUS and Alaska which anticipate the future move of NDFD to those resolutions and recognize & support the fact that a majority of WFOs are already doing their forecast prep at those double resolutions.
- NWS/HQ, the OSIP/TOC/SBN enterprise, NCO & EMC have geared up to distribute the new NAM-DNG grids.

FROM HPC/DAVE NOVAK   Day 1 Warm-Season QPF

May 9 – June 10, 2011

- 4 km CONUS nest best among guidance evaluated
- 4 km CONUS nest substantially better than operational NAM

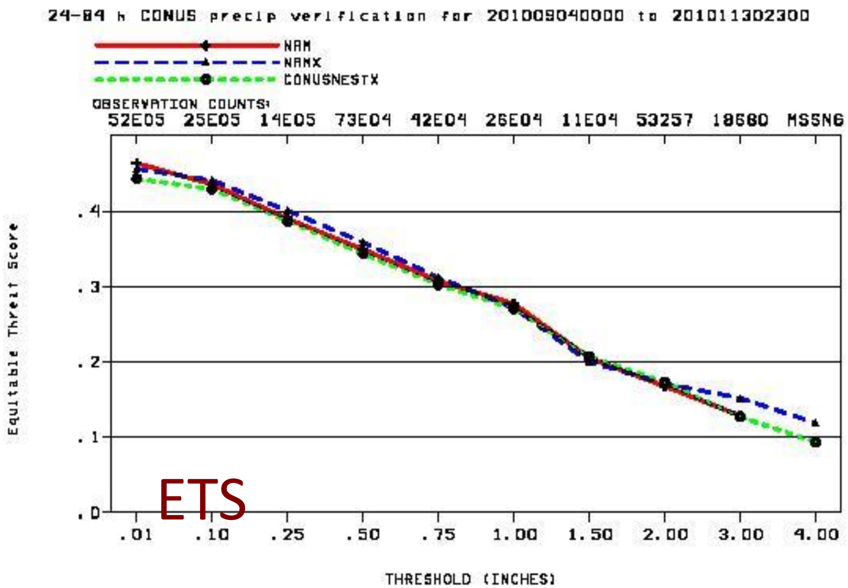
- 12 km parallel NAM worst among guidance evaluated
- 12 km parallel NAM worse than operational NAM

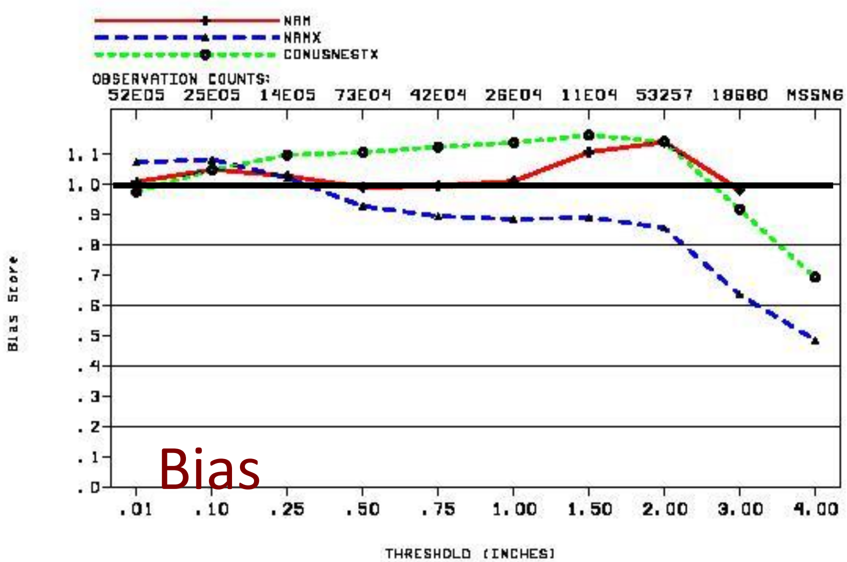


Analysis of the NAM 12km Parent QPF

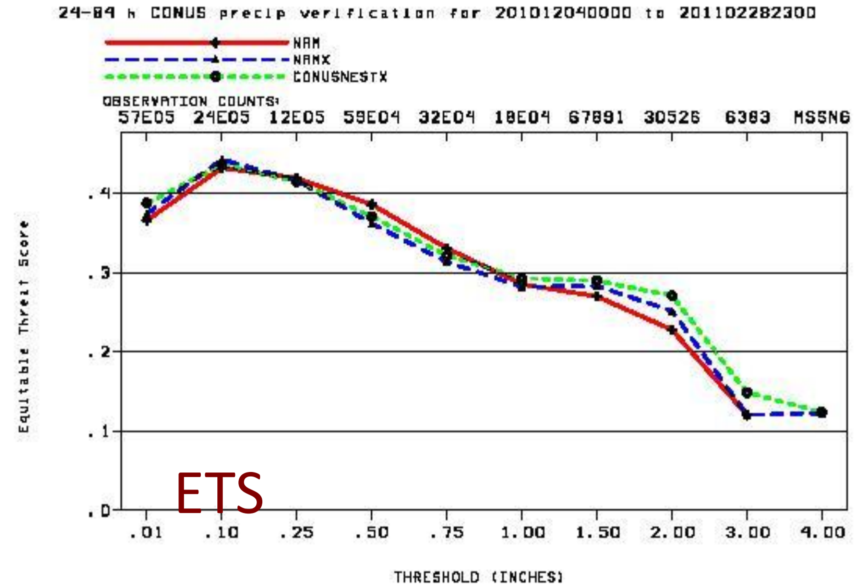
- The HPC results (HMT Day-1 warm season QPF) were limited to 23 days spanning 5 weeks (9 May - 10 June) in Spring 2011 (small sample)
- The QPF stats produced during the NAM development cycle span a full year and are broken down by season (see next two slides)
- Overall, Eq. Threat Scores are comparable to current 12km NAM and are significantly better in Summer (June-August) 2011 for large amounts
- When they are somewhat worse (Spring, March-May), the higher quality of the 4km nest's QPF more than compensates
- Comparable ETS despite lower bias [especially during Spring] implies more hits without false alarms

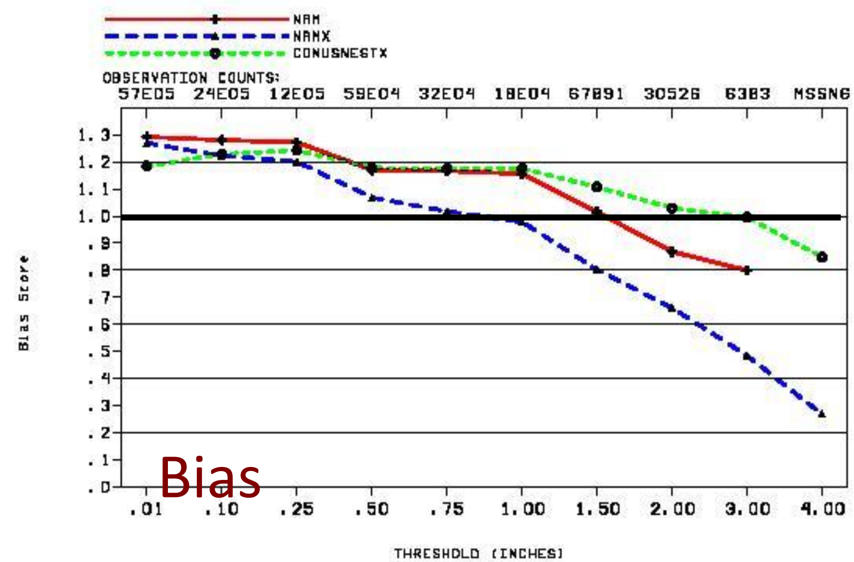
September - November 2010 QPF scores





December 2010 – February 2011 QP

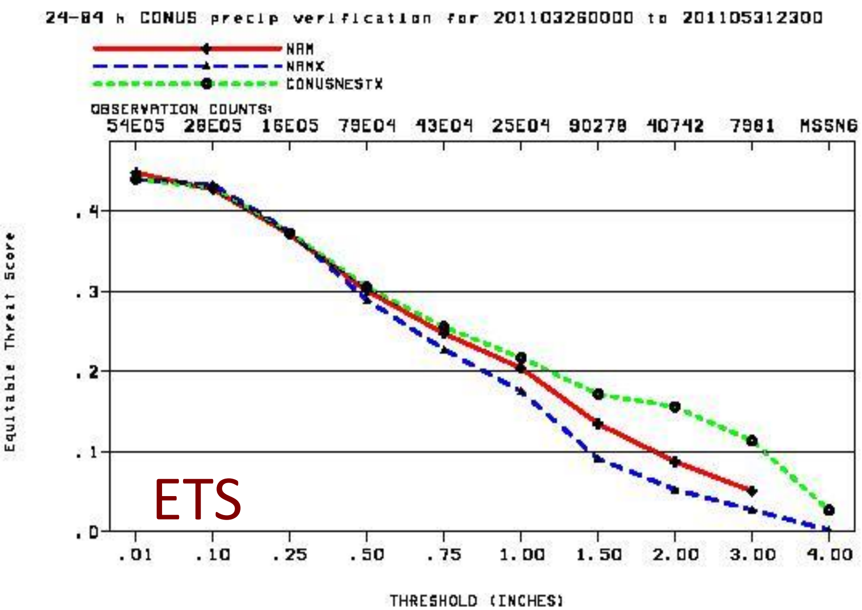


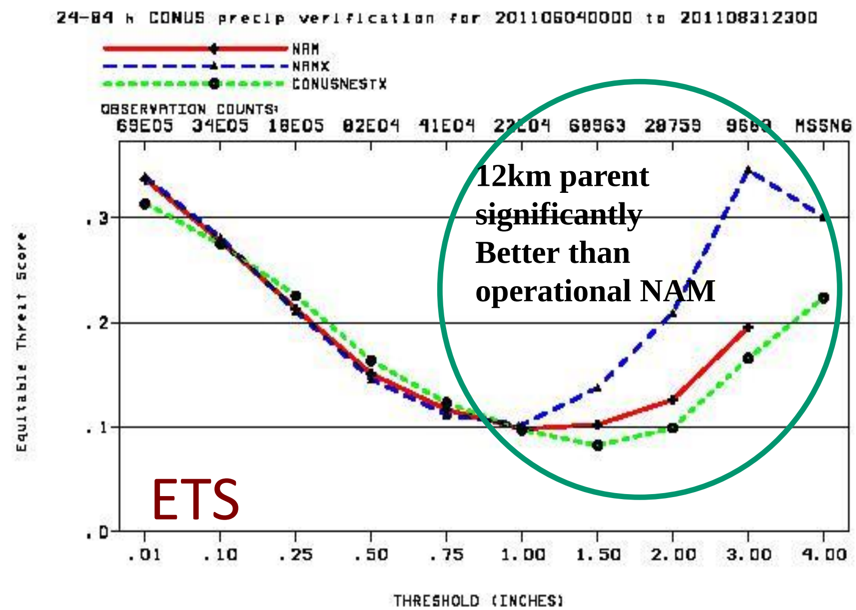


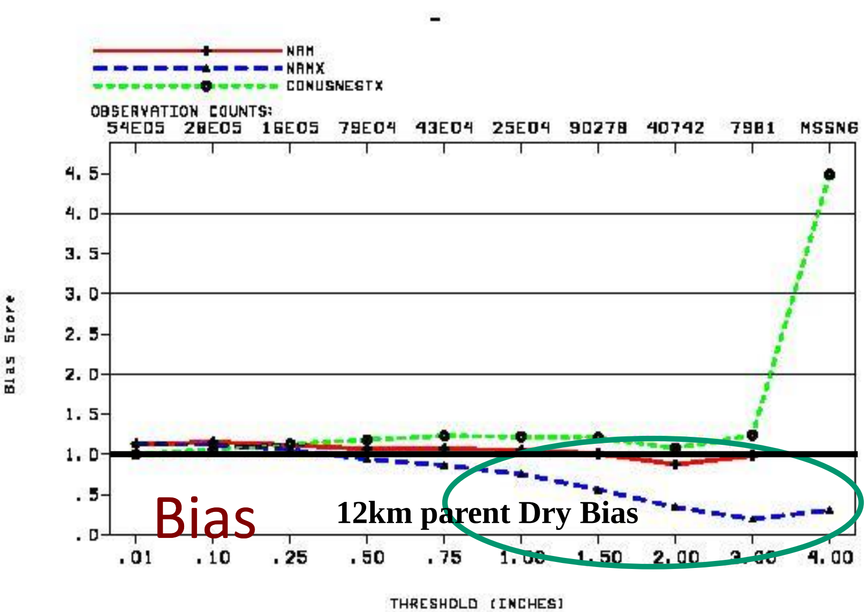
NOTE : Nest ran with explicit convection until 8/29/201

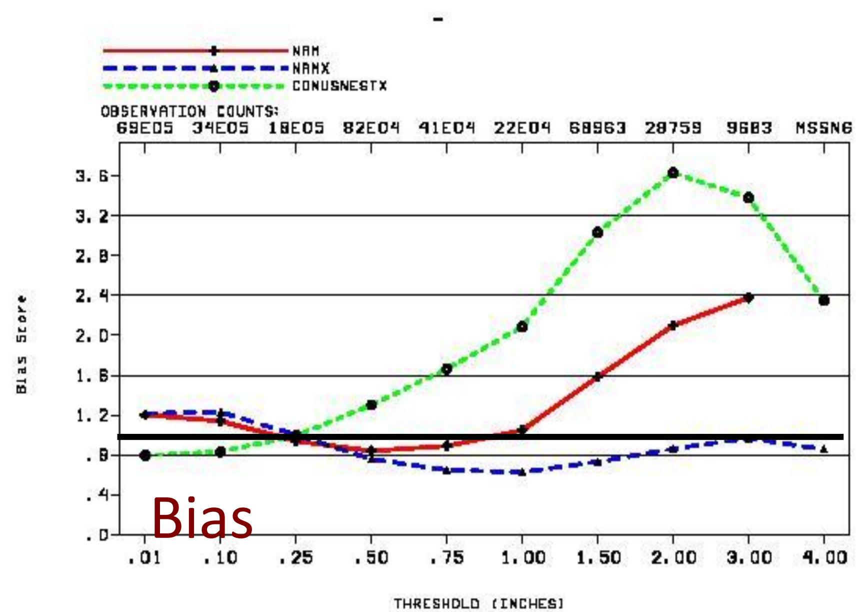
March – May 2011 QPF scores

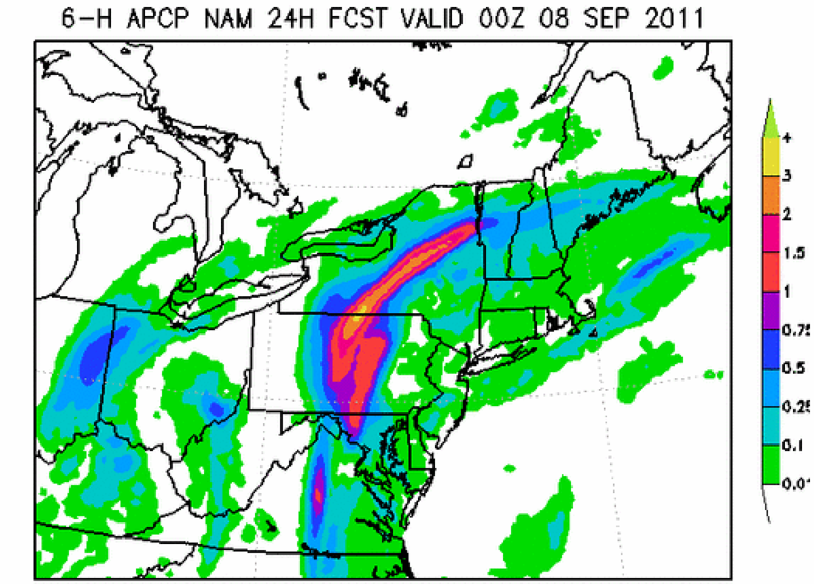
June - August 2011 QPF scores

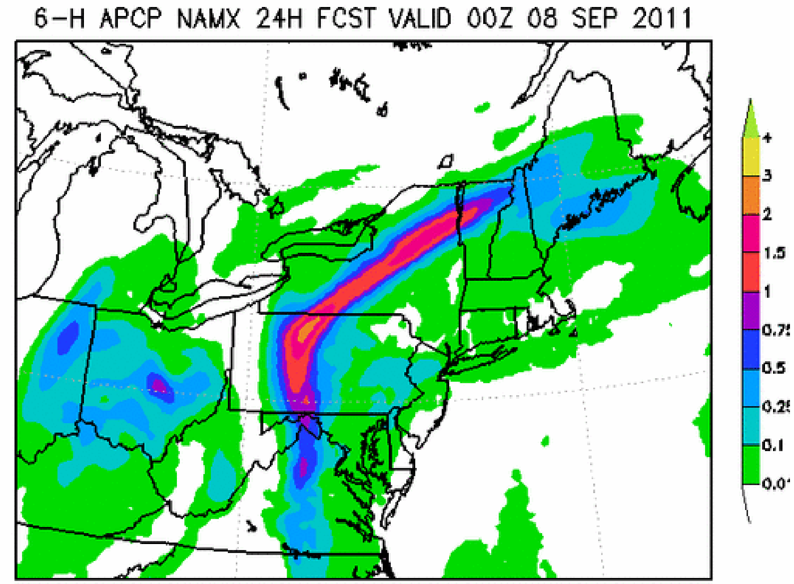




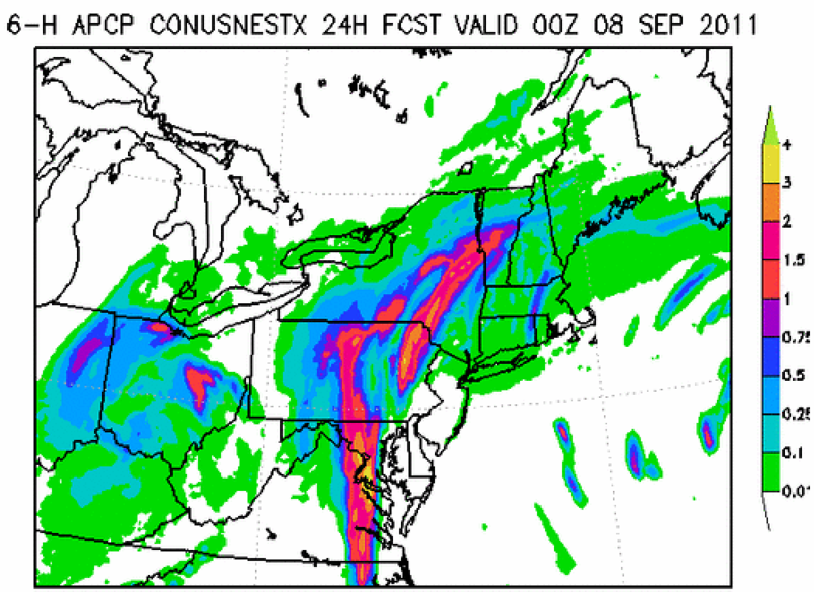


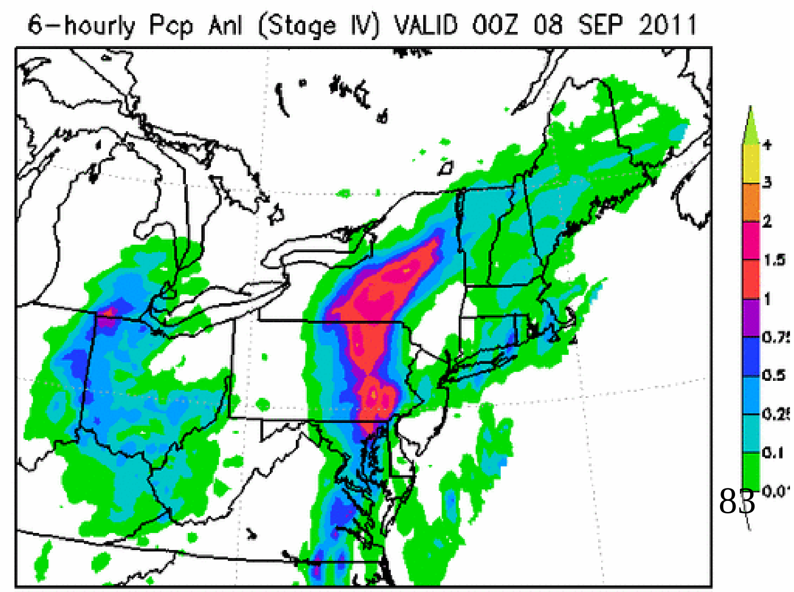


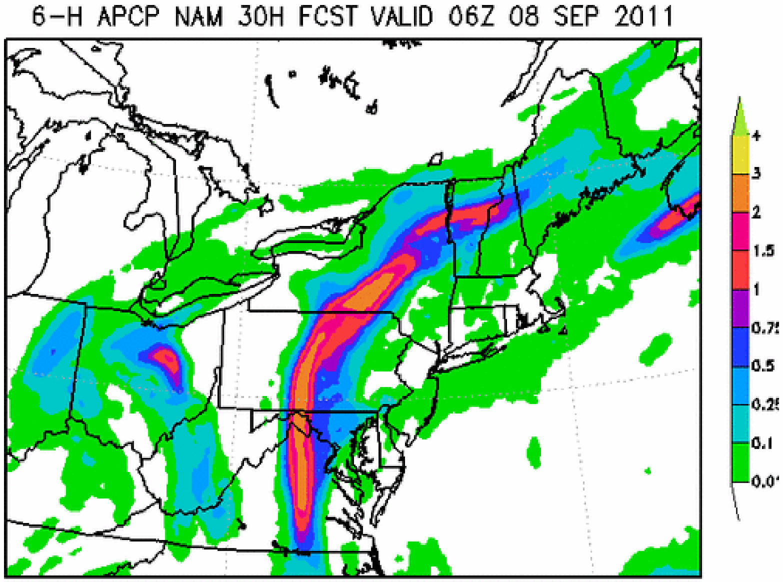


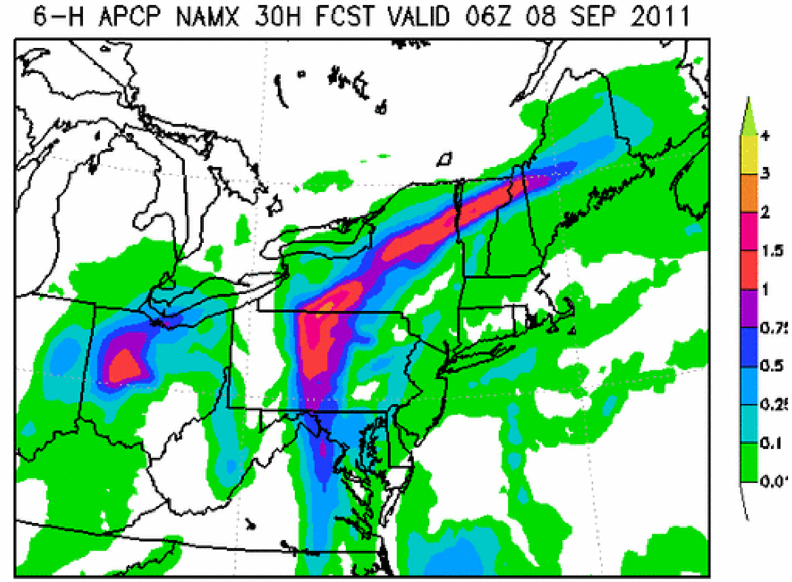


NAM 4km nest captured Lee’s locally heavy precip at 24hr r

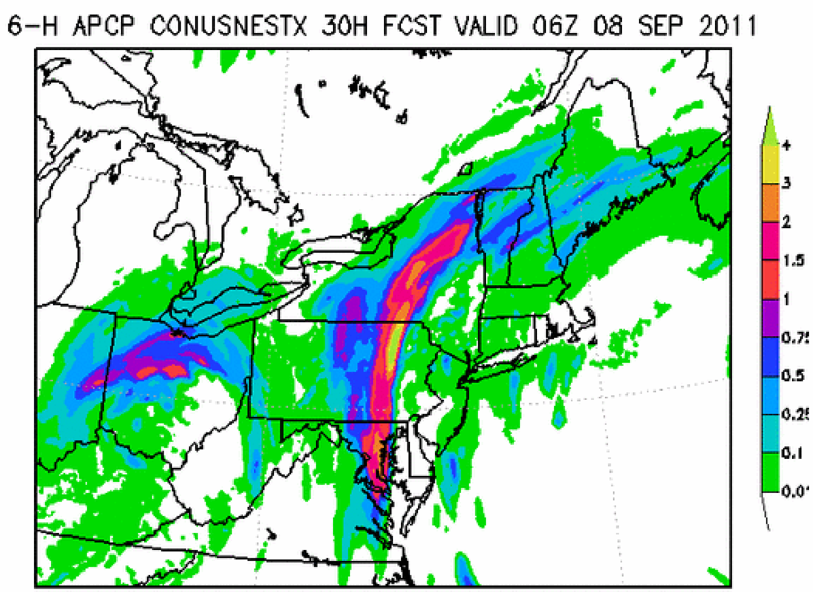


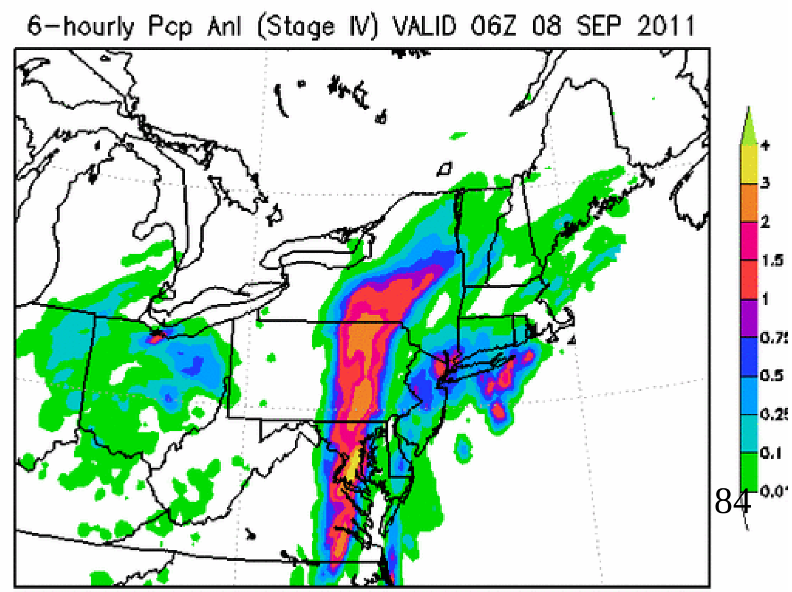




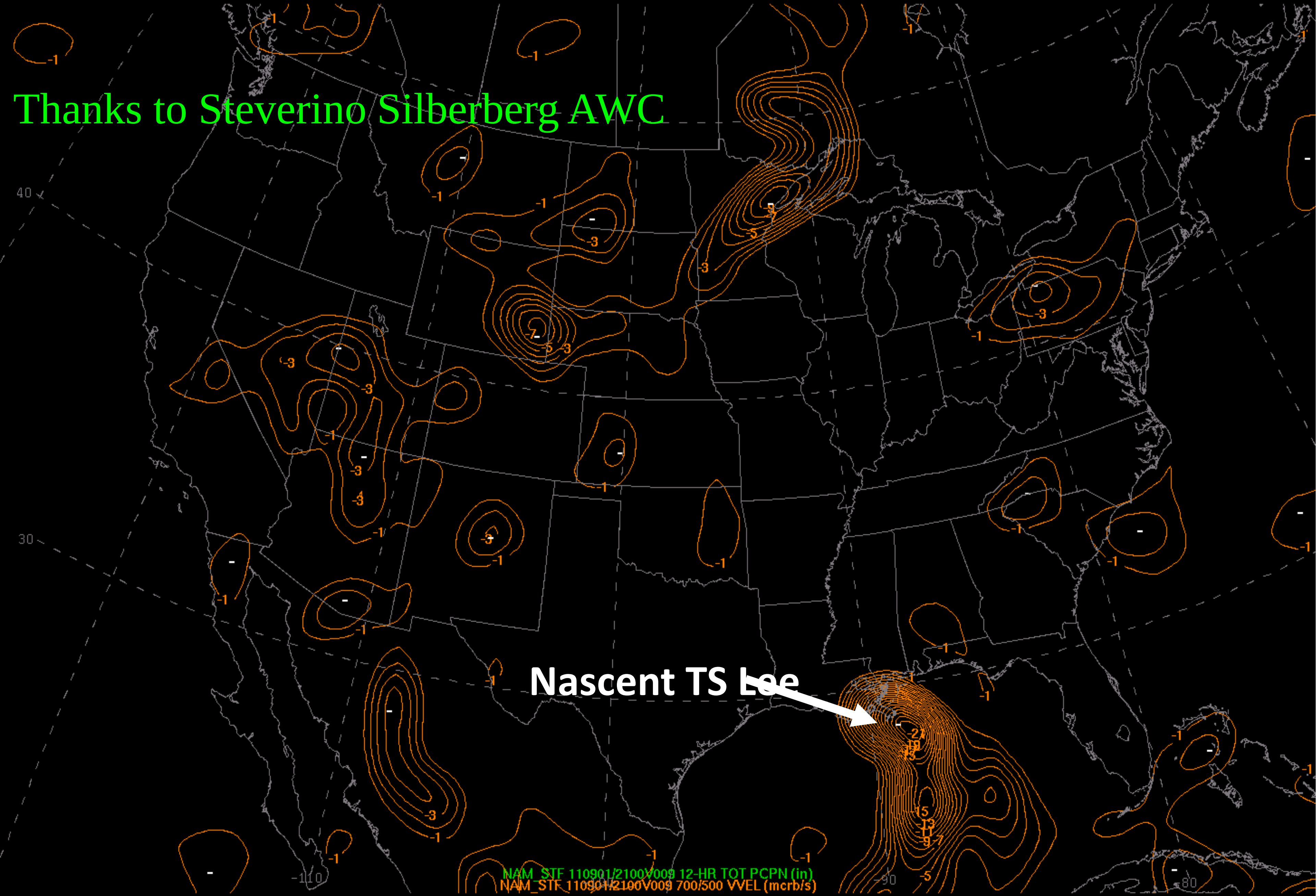


NAM 4km nest captured Lee’s locally heavy precip at 30hr r

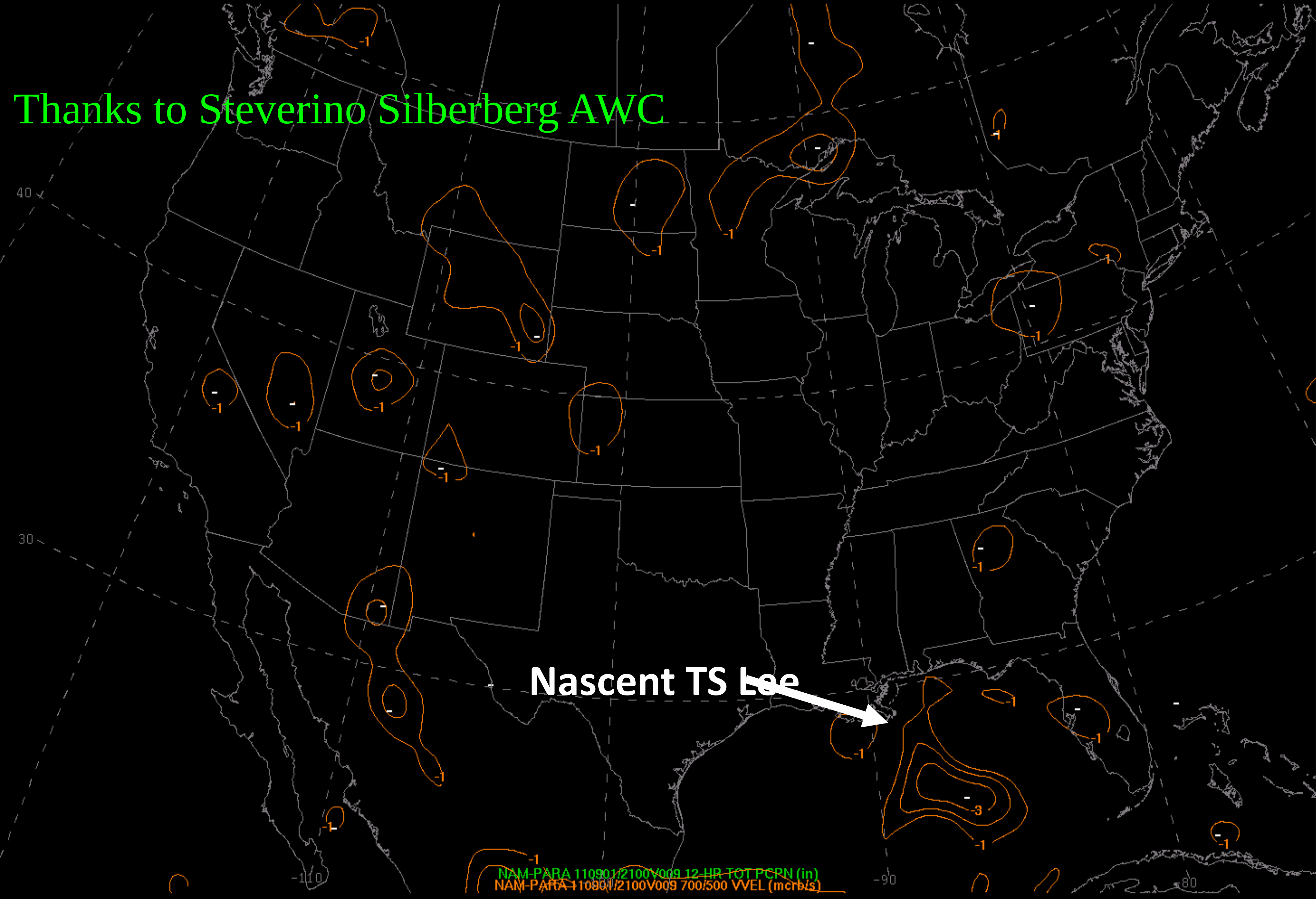




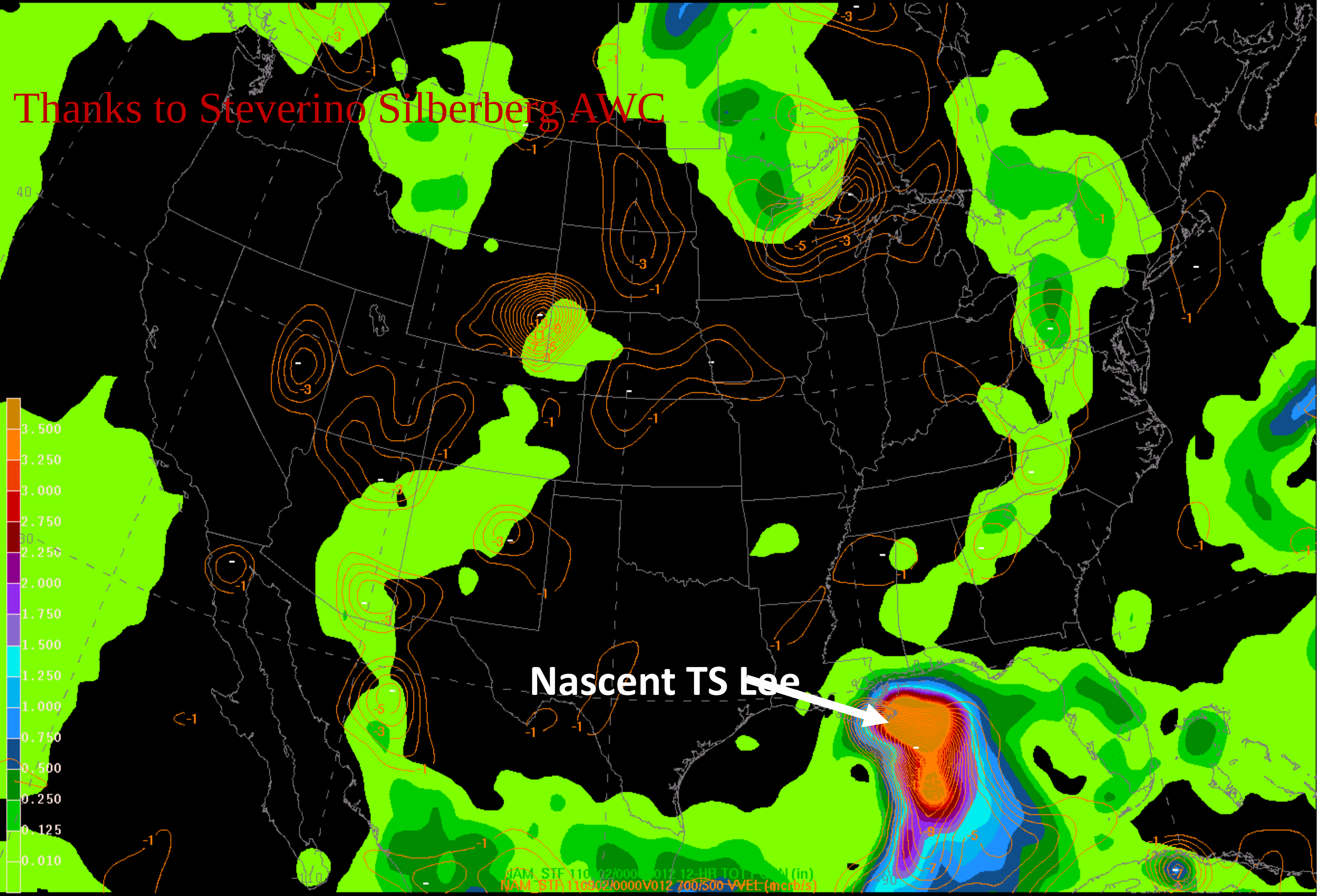
NAM 700-500 Omega<-1 valid 20110902_21V009



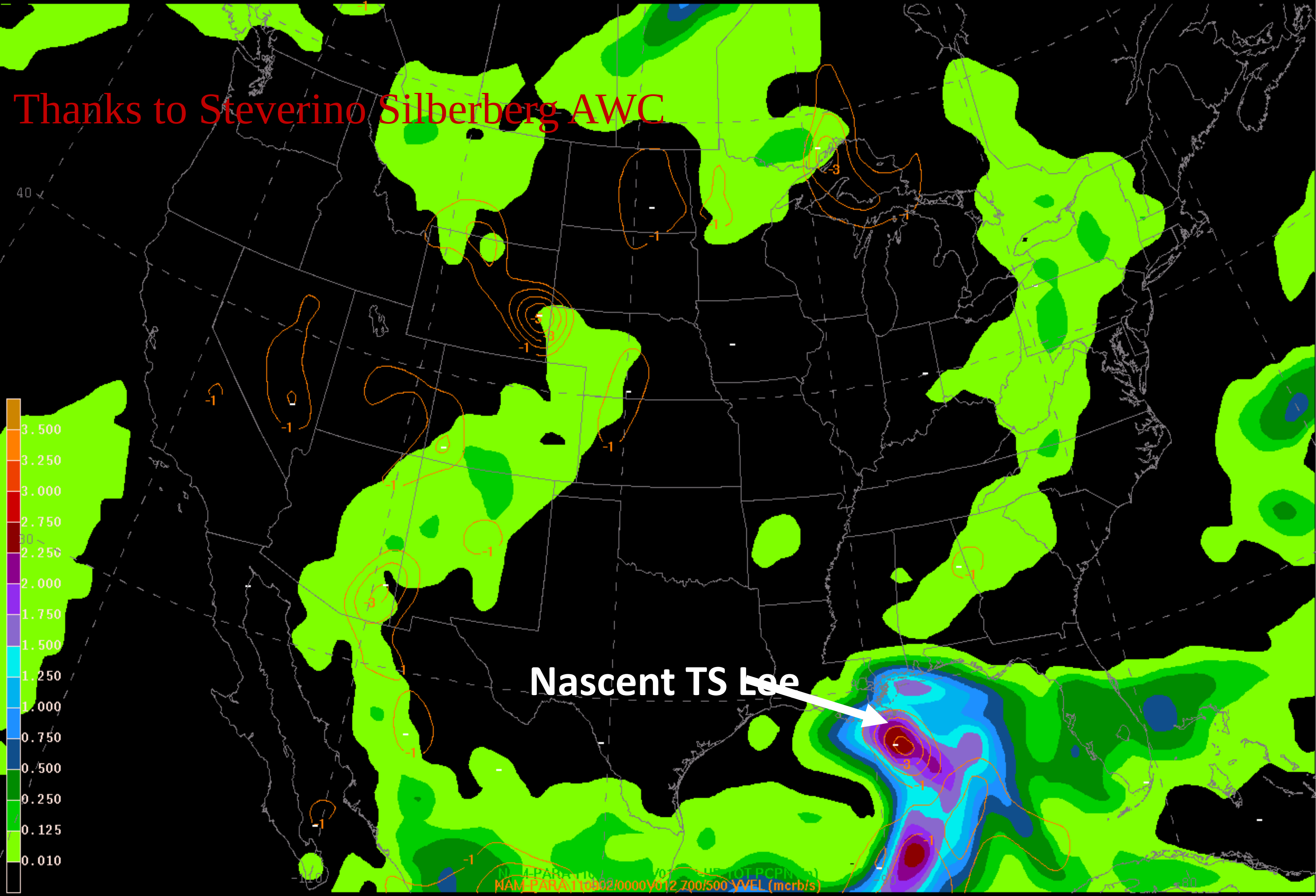
NAM-Parallel 700-500 Omega<-1 valid 20110902_21V009



NAM 700-500 Omega<-1 & QPF12 valid 20110902_00V012



NAM-Parallel 700-500 Omega<-1 & QPF12 valid 20110902_00V012



Issue of Vertical Velocity Being too Weak (1 of 3)

- There is nothing wrong in the model
- We have many examples of indirect evidence indicating the above
- All the verification statistics which show new NMMB is comparable or better than current NMM, e.g. the fits to RAOBs and QPF Equitable Threat Scores

Issue of Vertical Velocity Being too Weak (2 of 3)

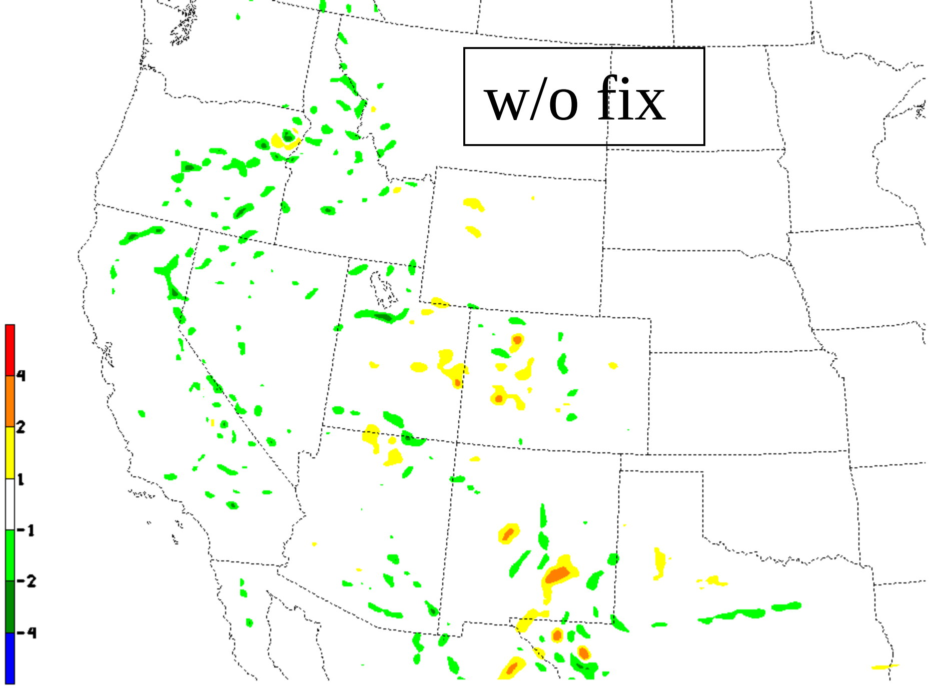
- Investigation has indicated a discrepancy in the model output of the vertical velocity between the operational NAM and the NMMB
- The difference: In the NMMB the Barotropic component of vertical velocity (due to external mode) is removed from the total vertical velocity for the purpose of computing nonhydrostatic vertical acceleration
- Therefore, from the NMMB we are currently outputting and viewing a quantity less than the total vertical velocity—hence it’s smaller then it should be
- Recommendation: The Barotropic component should be added back in the total before outputting vertical velocity. See next slide for impact of this fix to the model output.

Issue of Vertical Velocity Being too Weak (3 of 3)

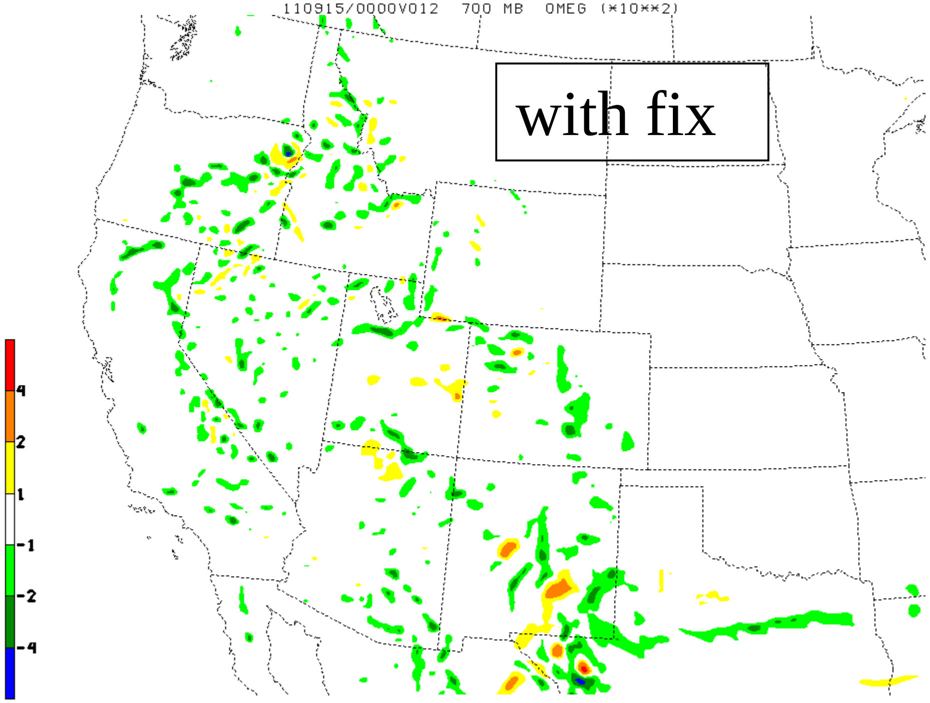
- NOTE: Due to logistical reasons in the NEMS-NMMB code, the 00-h vertical velocity in the parallel NAM does not have the barotropic component added back to it
- Reason: 00-h omega is the field in the NDAS first guess model restart file, which is passed through the 00-h analysis unchanged. (This also applies to all fields not changed by the analysis (T, V, q, p*), or derived from analyzed fields)
- Vertical velocity field passed through the assimilation in the full model restart file is the field with the barotropic part removed, used to compute the nonhydrostatic vertical accelerations.
- Barotropic component added back once the model starts integrating.

700mb Omega Before & After Fix

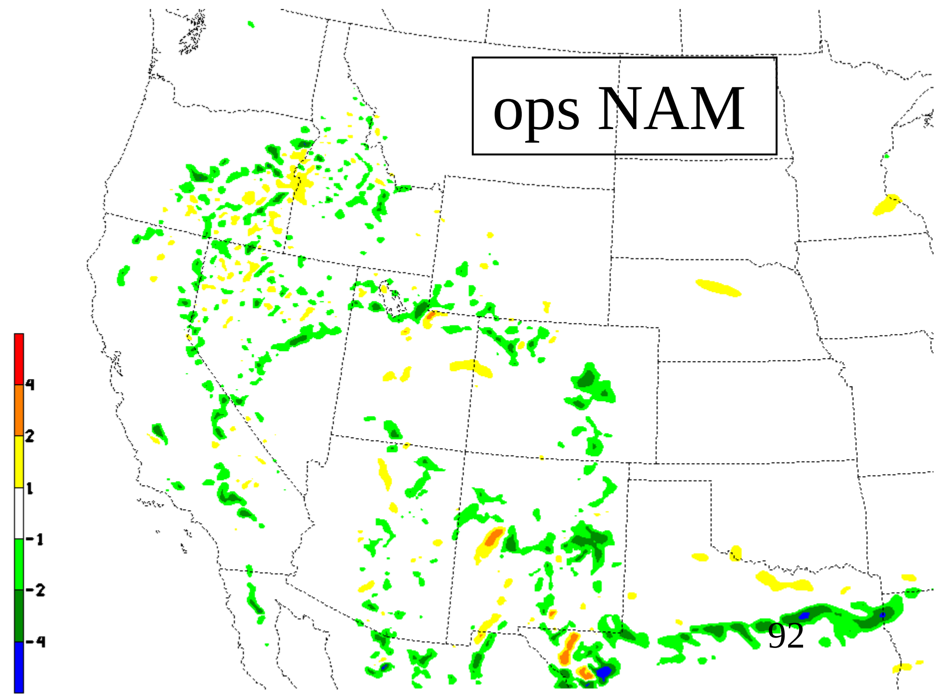
- Virtually all other forecast fields were bit identical including QPF.



110915/0000V012 700 MB OMEG (*10**2)



110915/0000V012 700 MB OMEG (*10**2)



110915/0000V012 700 MB OMEG (*10**2)

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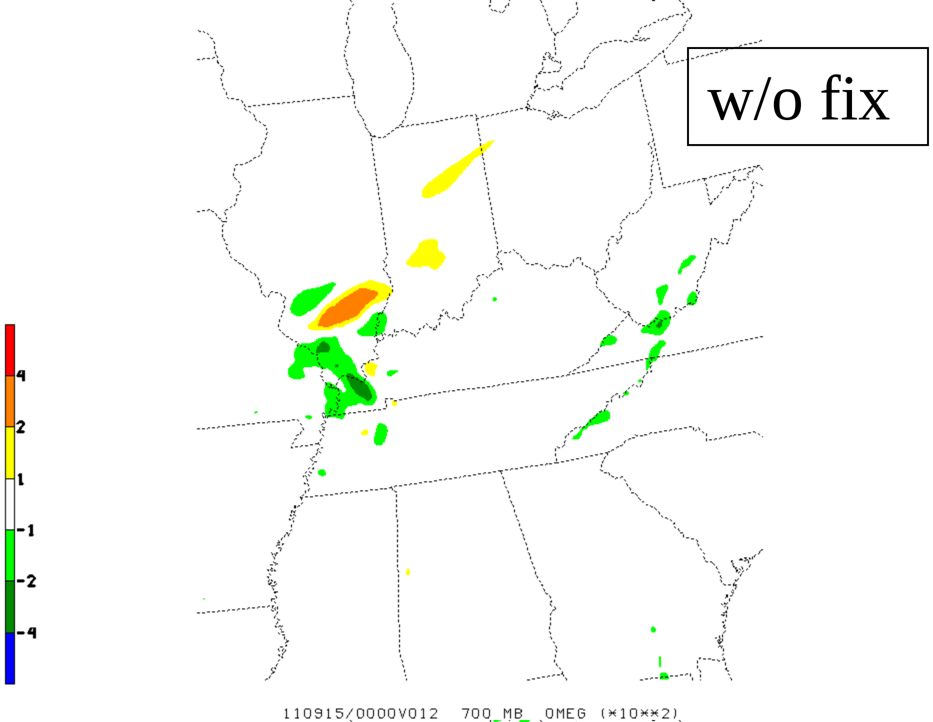

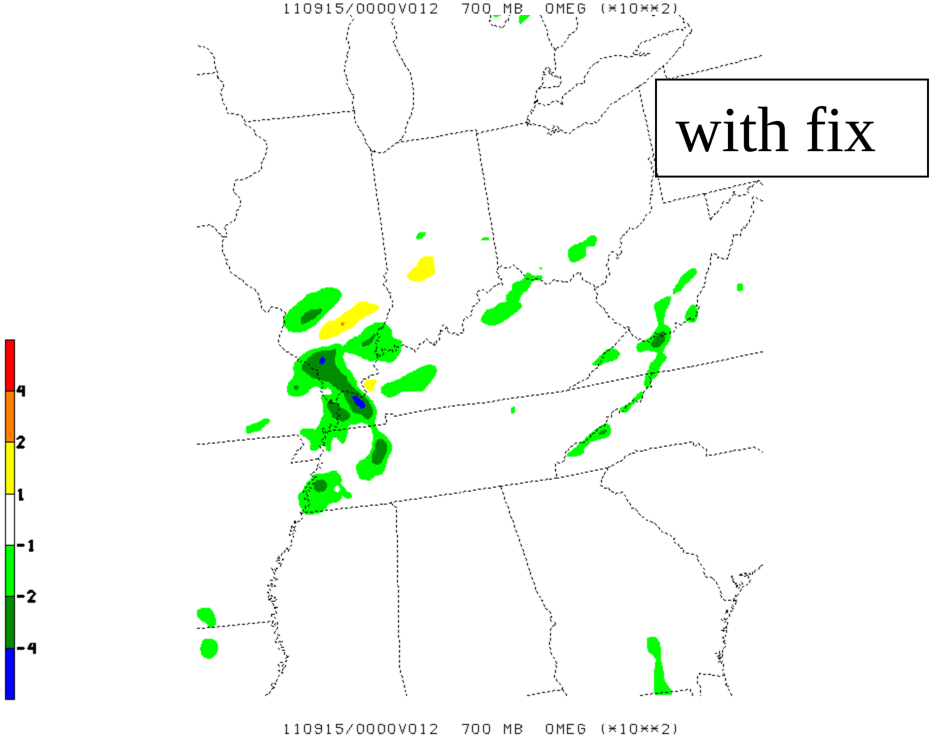

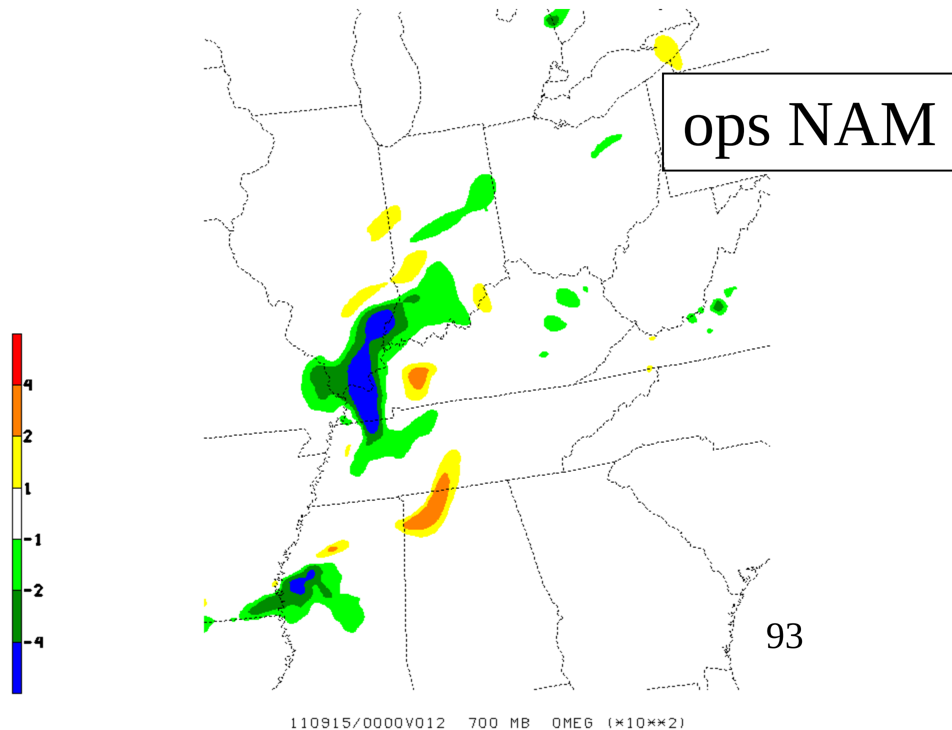

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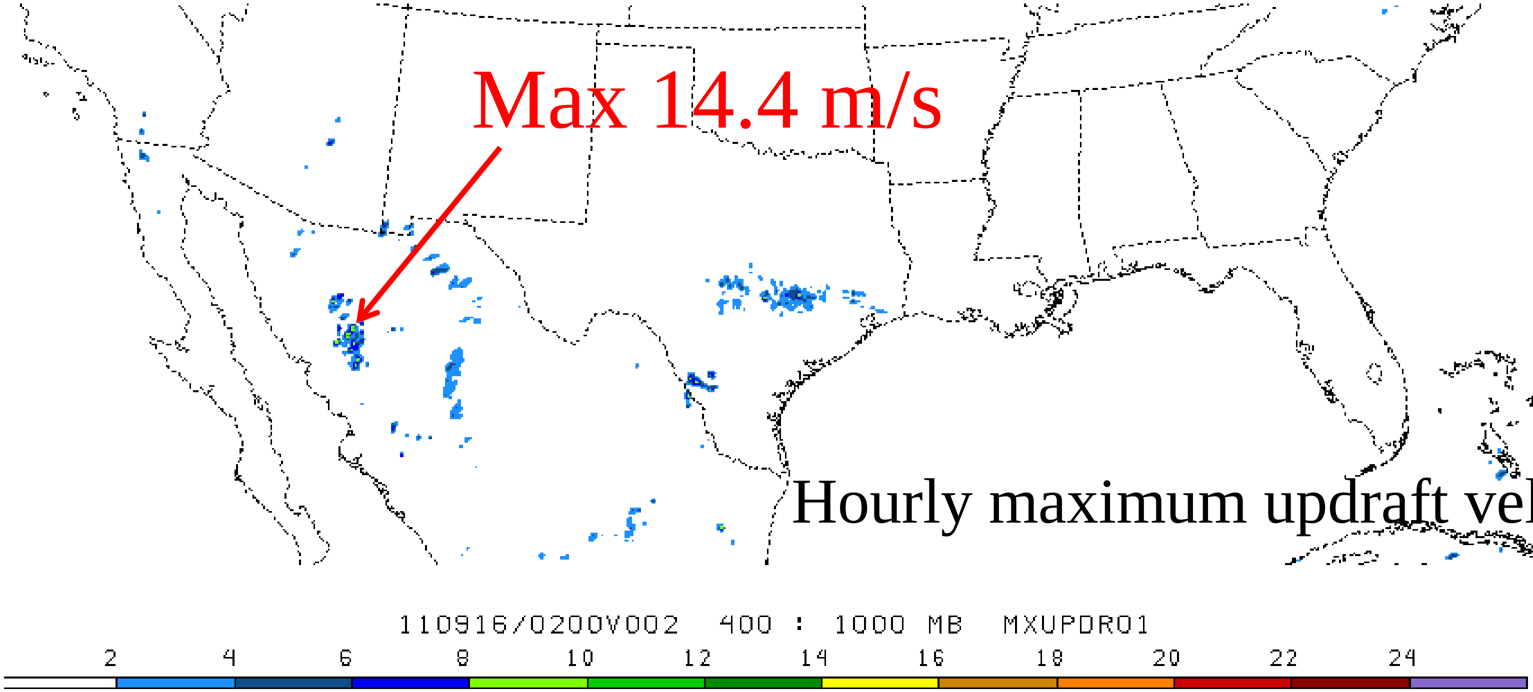
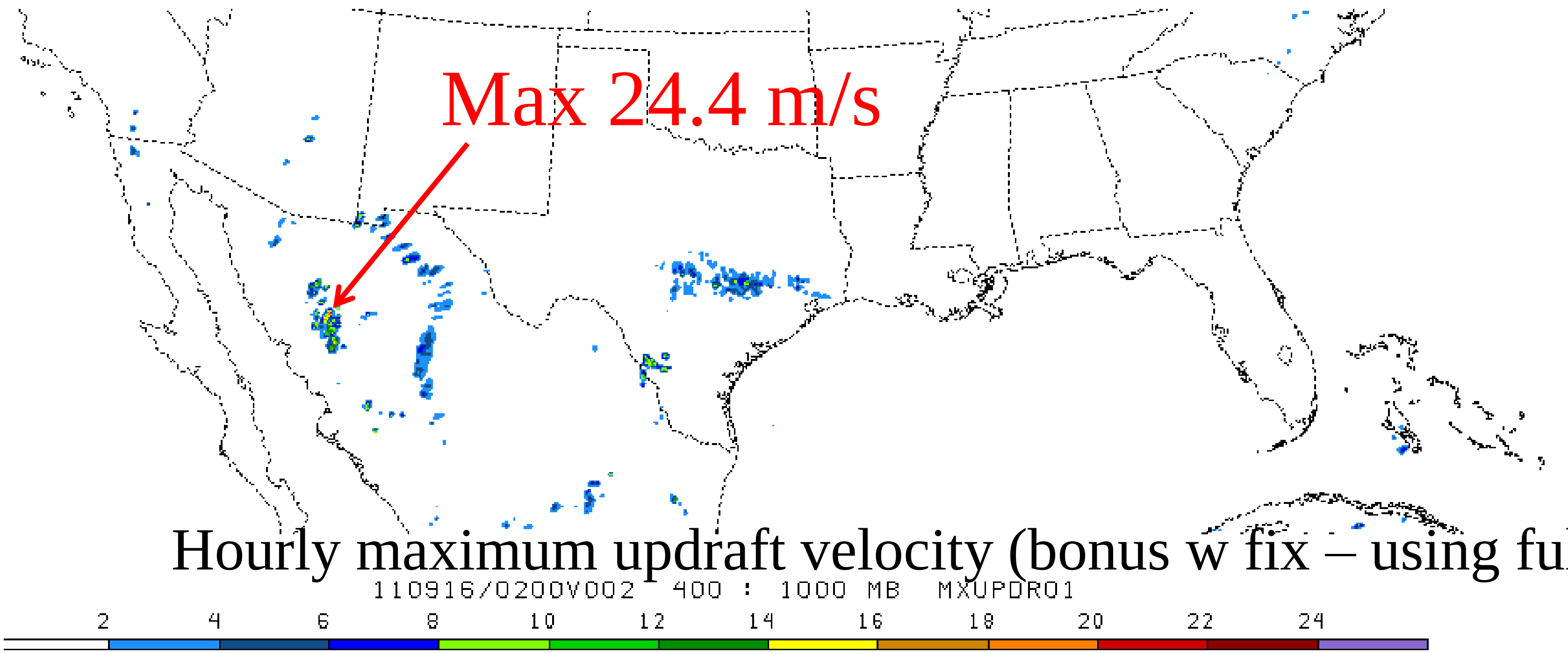
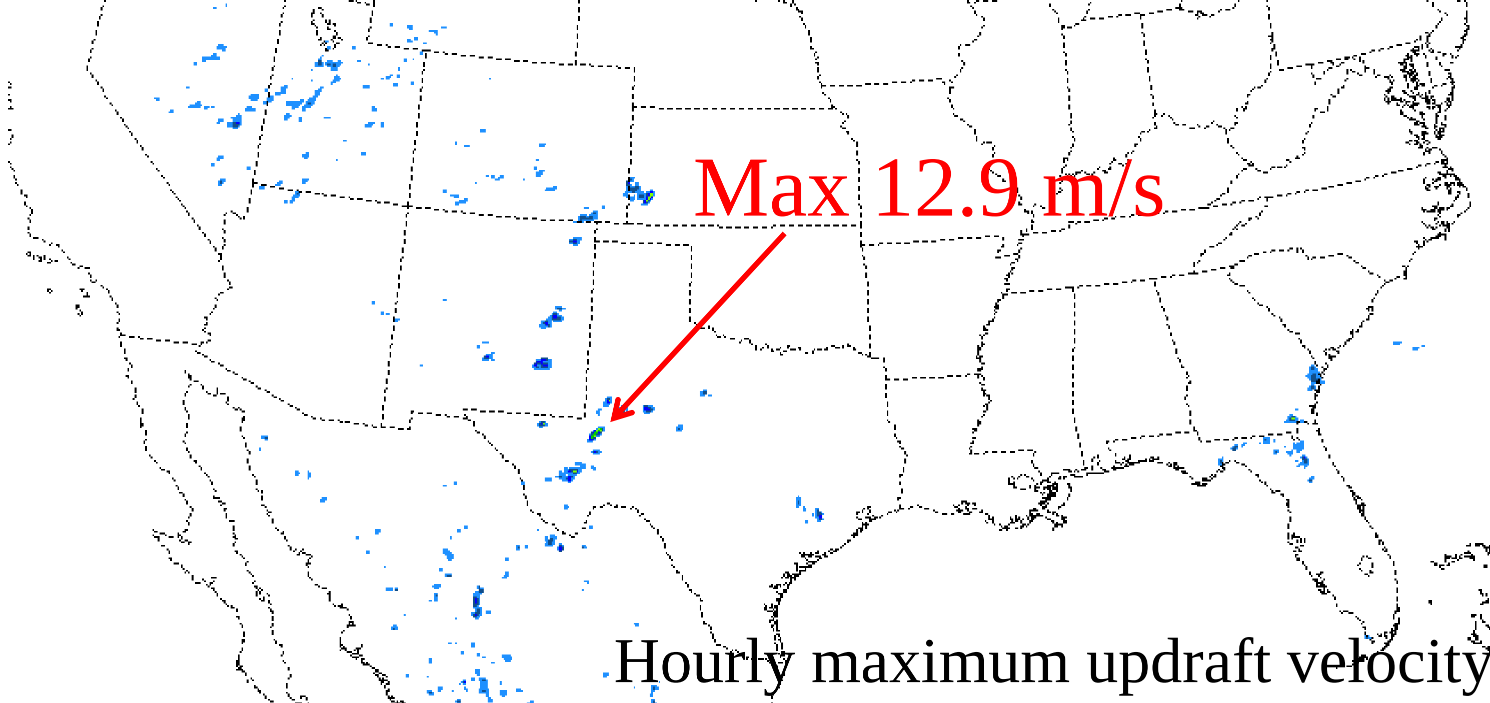


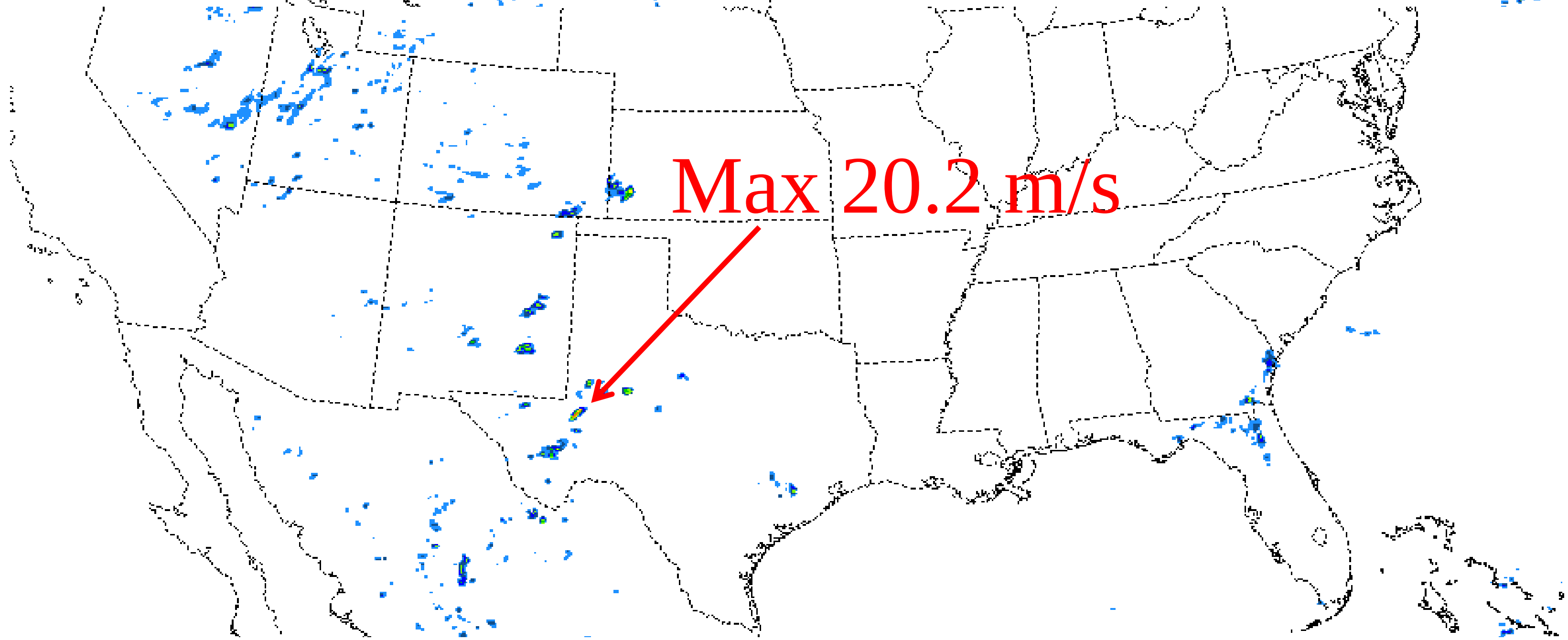
Hourly maximum updraft velocity (no w



Hourly maximum updraft velocity (bonus w fix – using full w f02



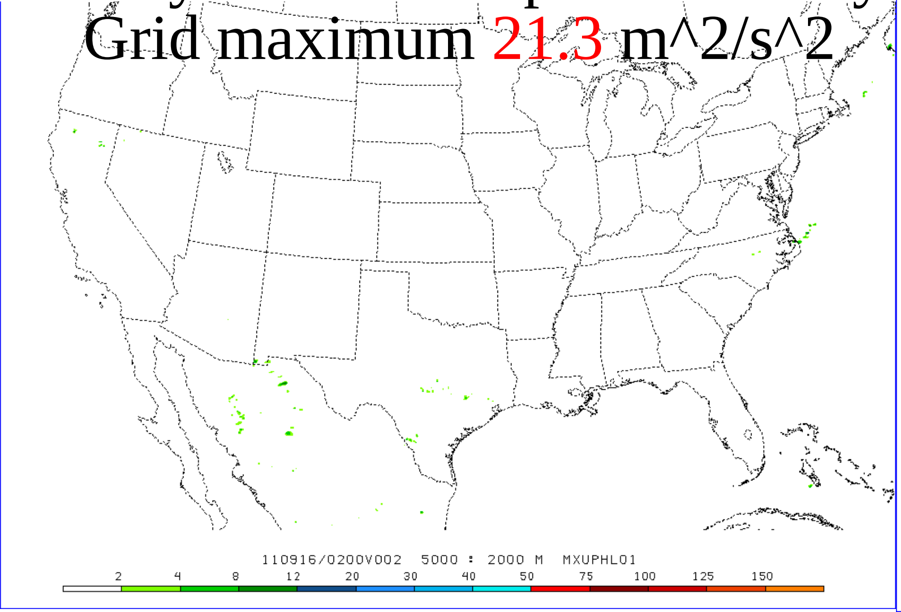
Hourly maximum updraft velocity (no w fix)



Hourly maximum updraft velocity (bonus w fix – using full w in

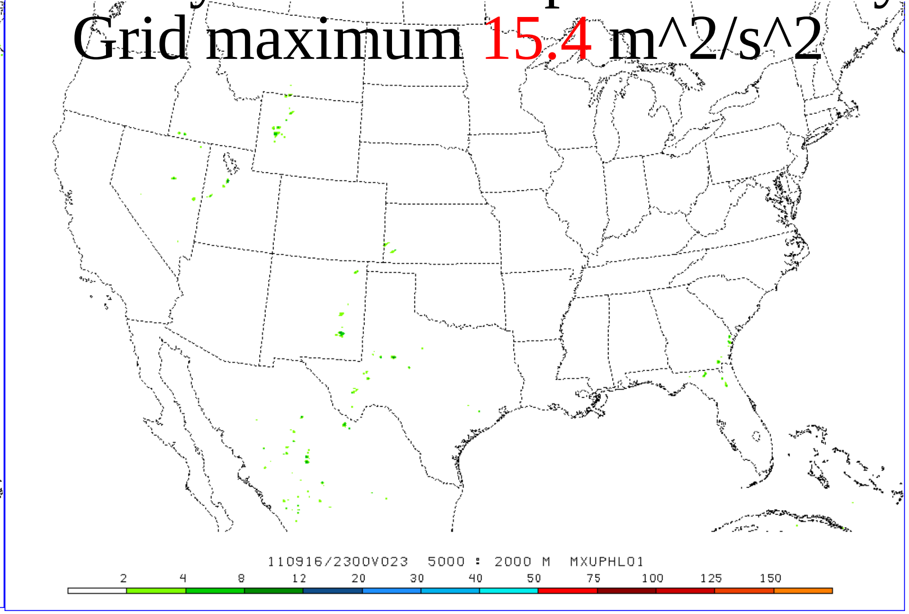
Hourly maximum updraft helicity

Grid maximum 21.3 m^2/s^2



Hourly maximum updraft helicity (no

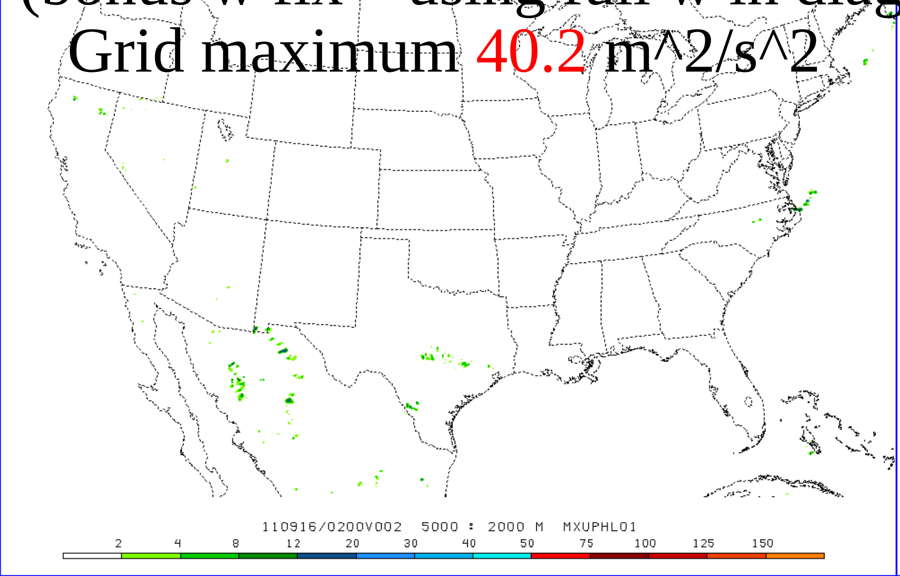
Grid maximum 15.4 m^2/s^2



Hourly maximum updraft helicity

(bonus w fix – using full w in diag…

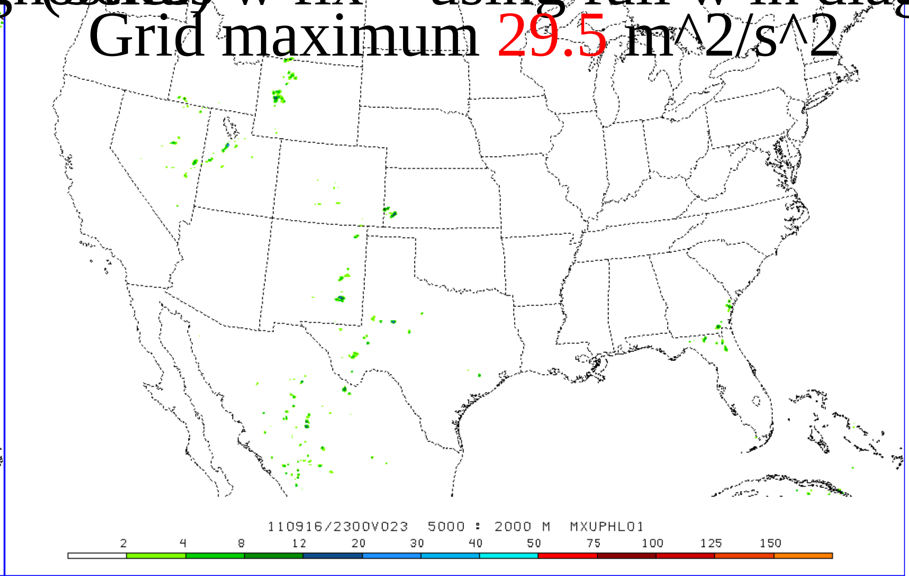
Grid maximum 40.2 m^2/s^2

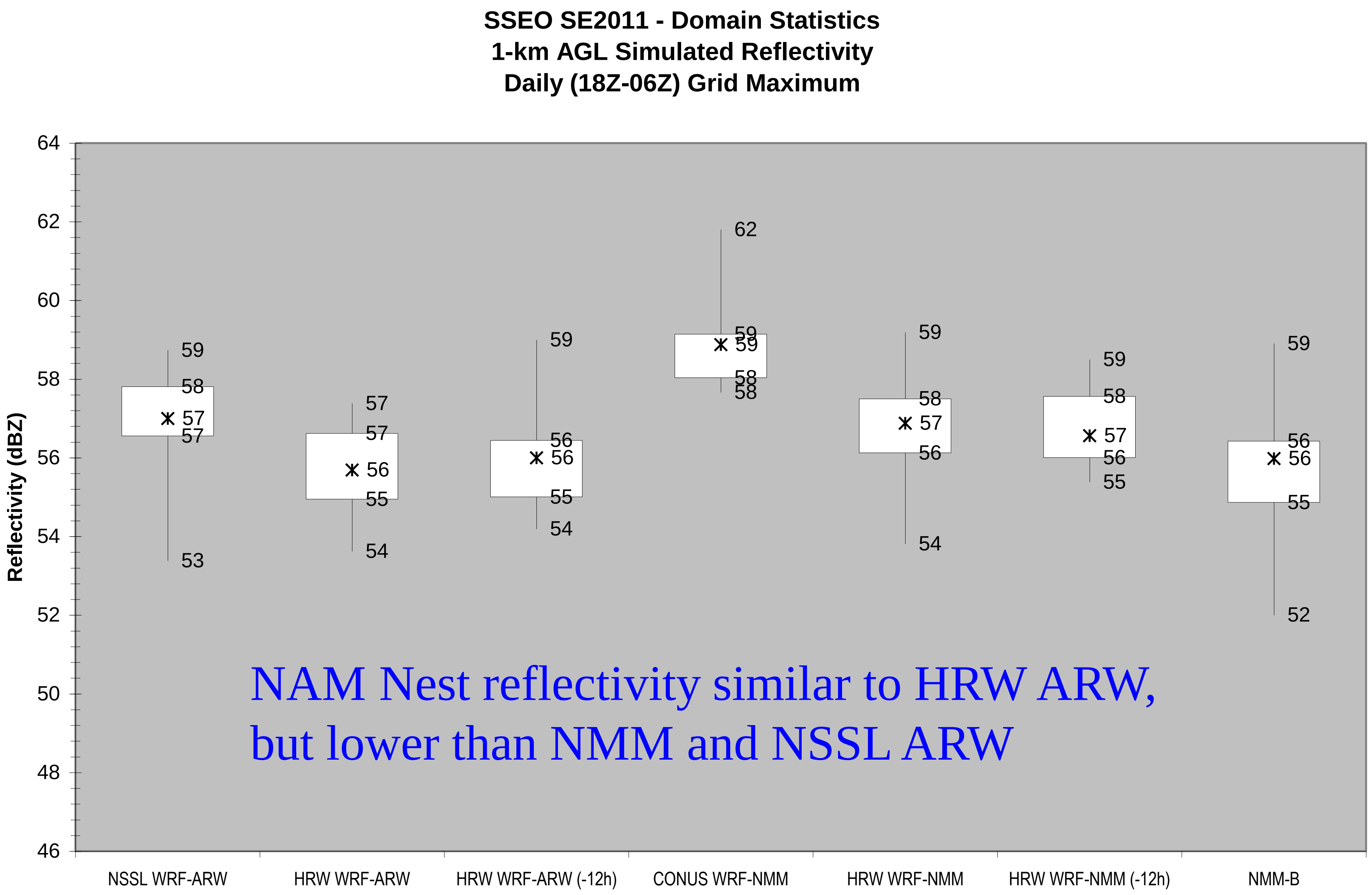


Hourly maximum updraft helicity

(bonus w fix – using full w in diagnost

Grid maximum 29.5 m^2/s^2





SSEO SE2011 - Domain Statistics
1-km AGL Simulated Reflectivity
Daily (18Z-06Z) Grid Maximum
Reflectivity (dBZ)
64
62
60
58
56
54
52
50
48
46
NSSL WRF-ARW
HRW WRF-ARW
HRW WRF-ARW (-12h)
CONUS WRF-NMM
HRW WRF-NMM
HRW WRF-NMM (-12h)
NMM-B
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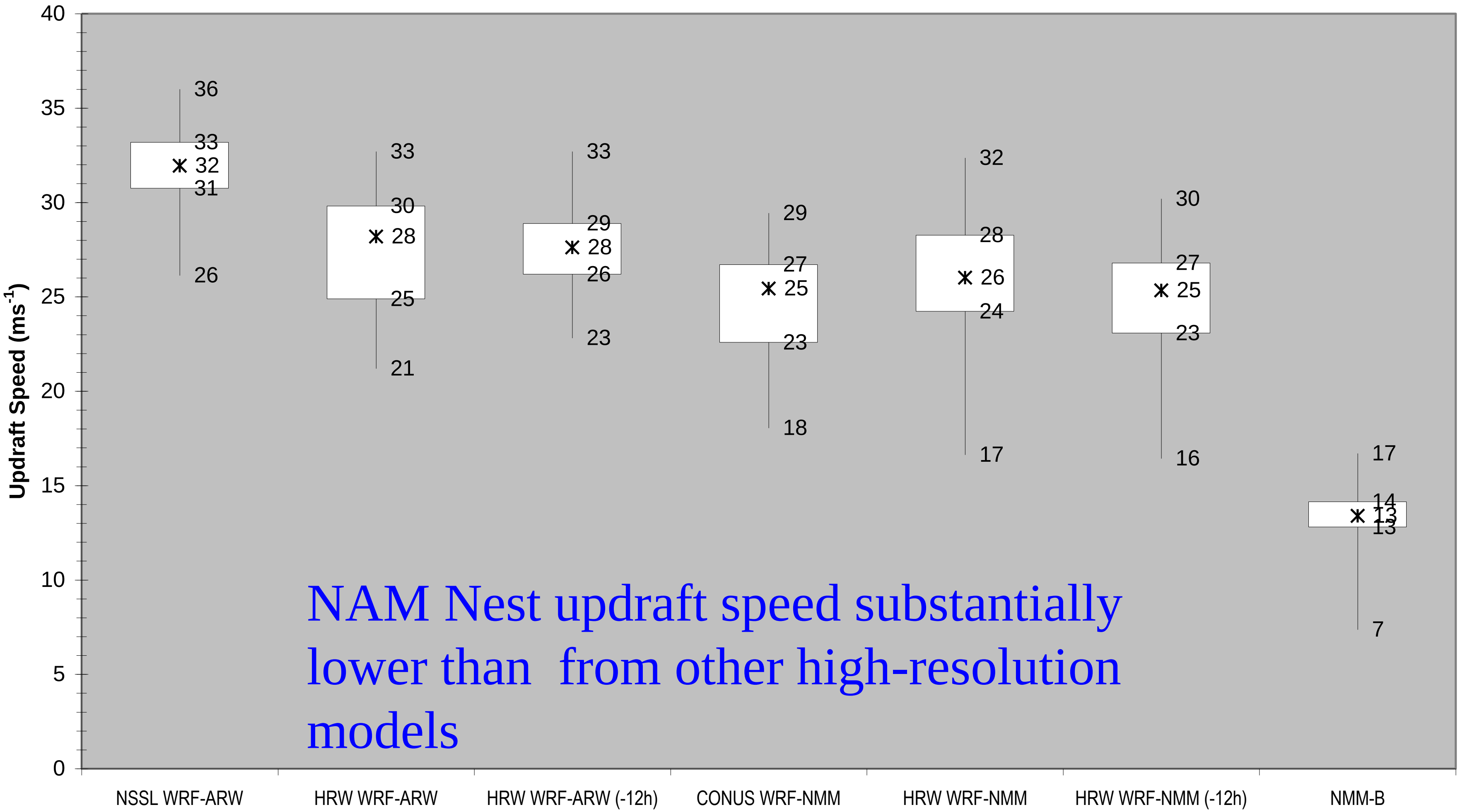
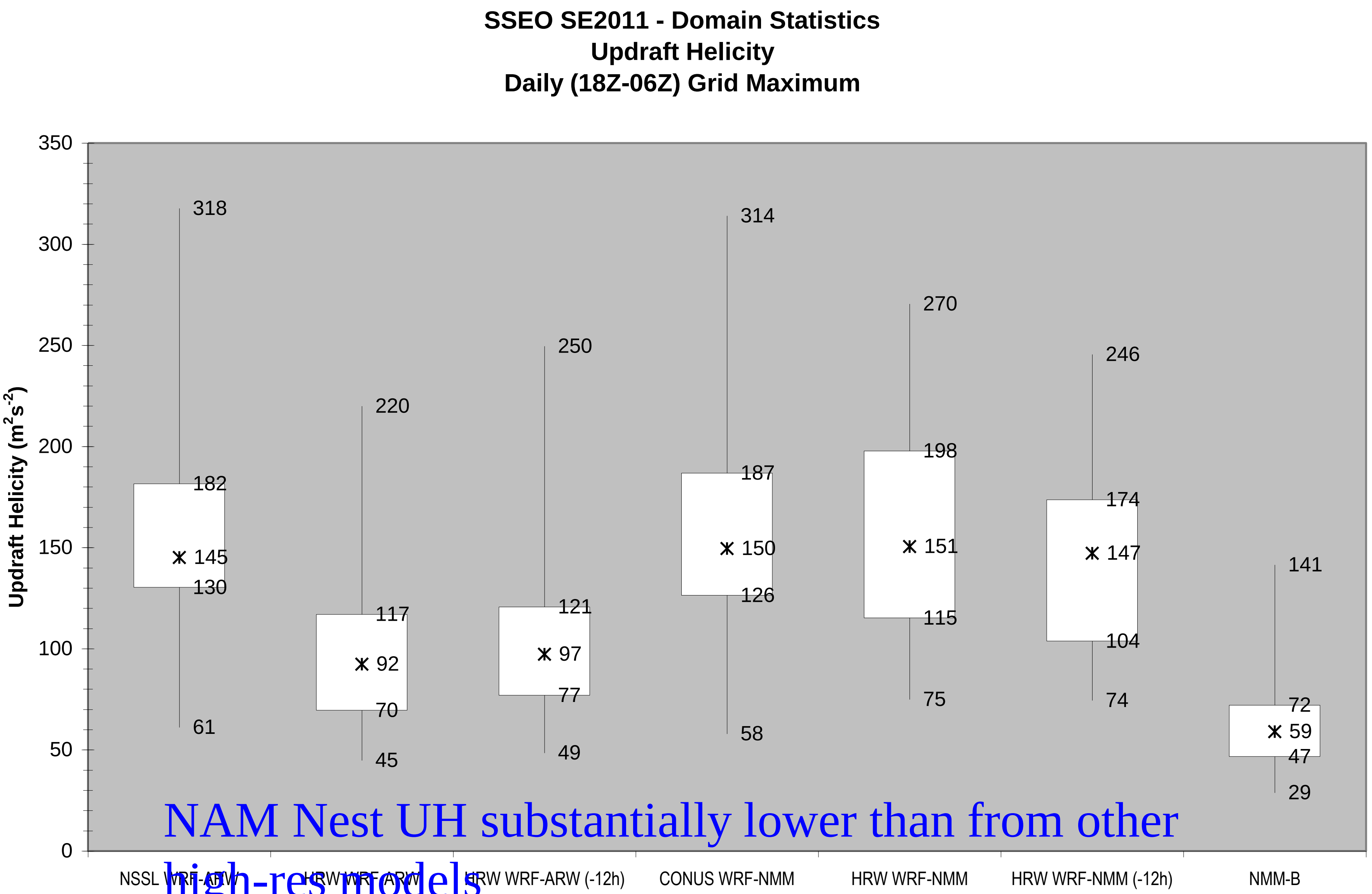
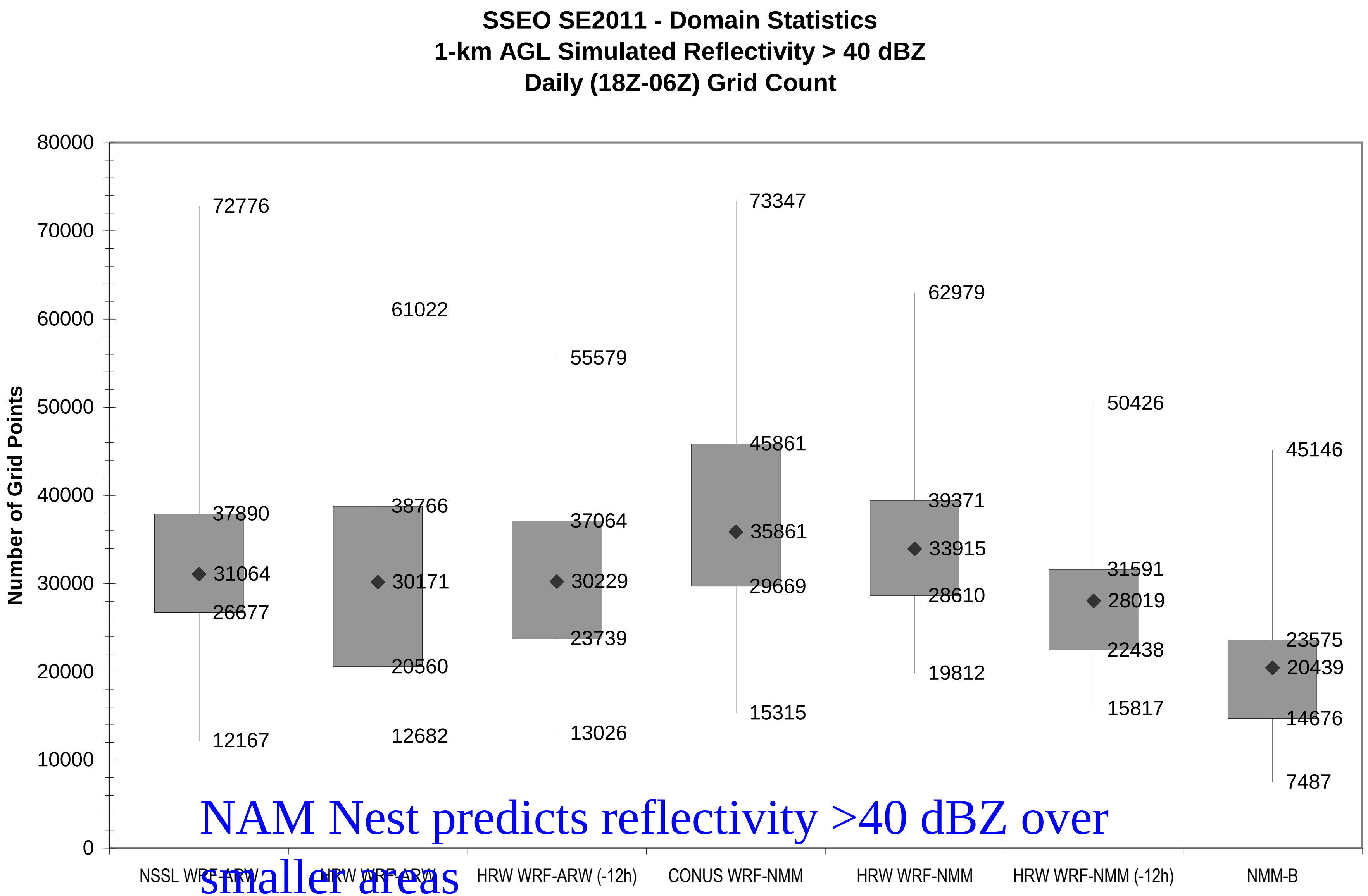
NAM Nest reflectivity similar to HRW ARW,
but lower than NMM and NSSL ARW

SSEO SE2011 - Domain Statistics
Updraft Speed
Daily (18Z-06Z) Grid Maximum



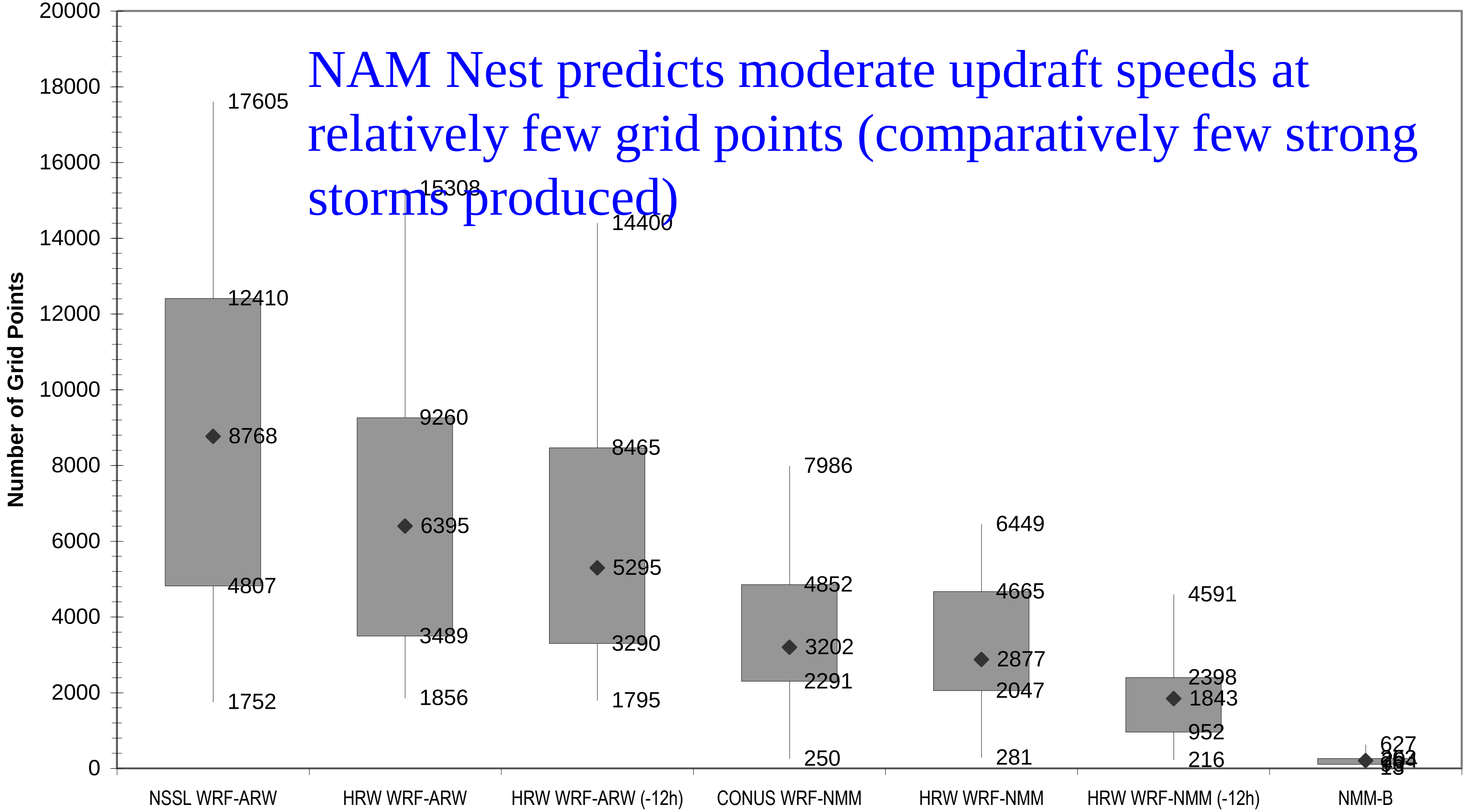


NAM Nest UH substantially lower than from other high-res models

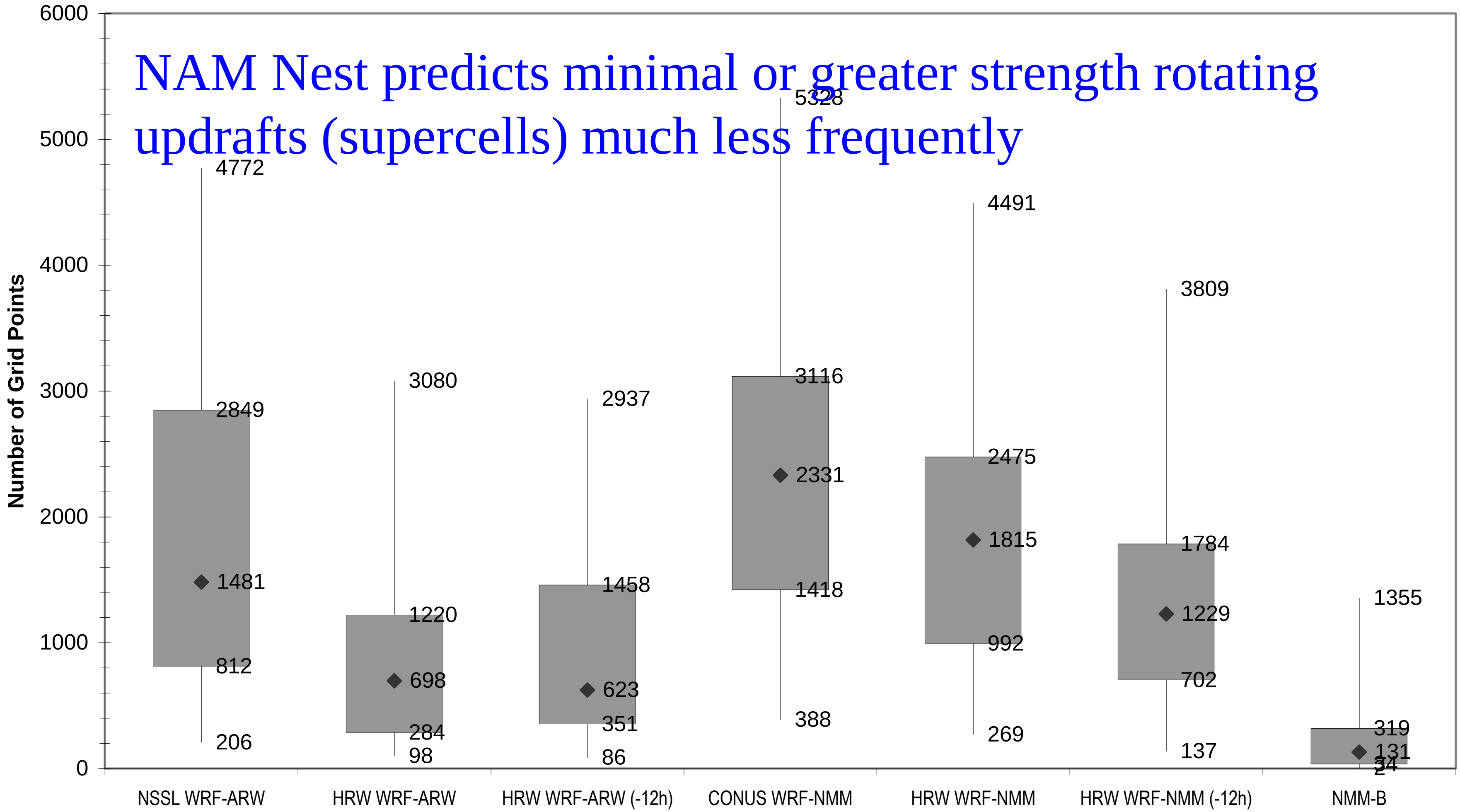


NAM Nest predicts reflectivity >40 dBZ over smaller areas

SSEO SE2011 - Domain Statistics
Updraft Speed > 10 ms^{-1}
Daily (18Z-06Z) Grid Count



SSEO SE2011 - Domain Statistics
Updraft Helicity >25 $m^2 s^{-2}$
Daily (18Z-06Z) Grid Count



EMC's Action Items

- Get nesting and total vvel fixes to NCO
- After fixing the model to output total vertical velocity:
  - Rerun the AWC case Sept 1, 2011
  - Rerun the SPC case 27 April, 2011
  - Rerun other case(s) for SPC
- Implementation, however, is not contingent on these results

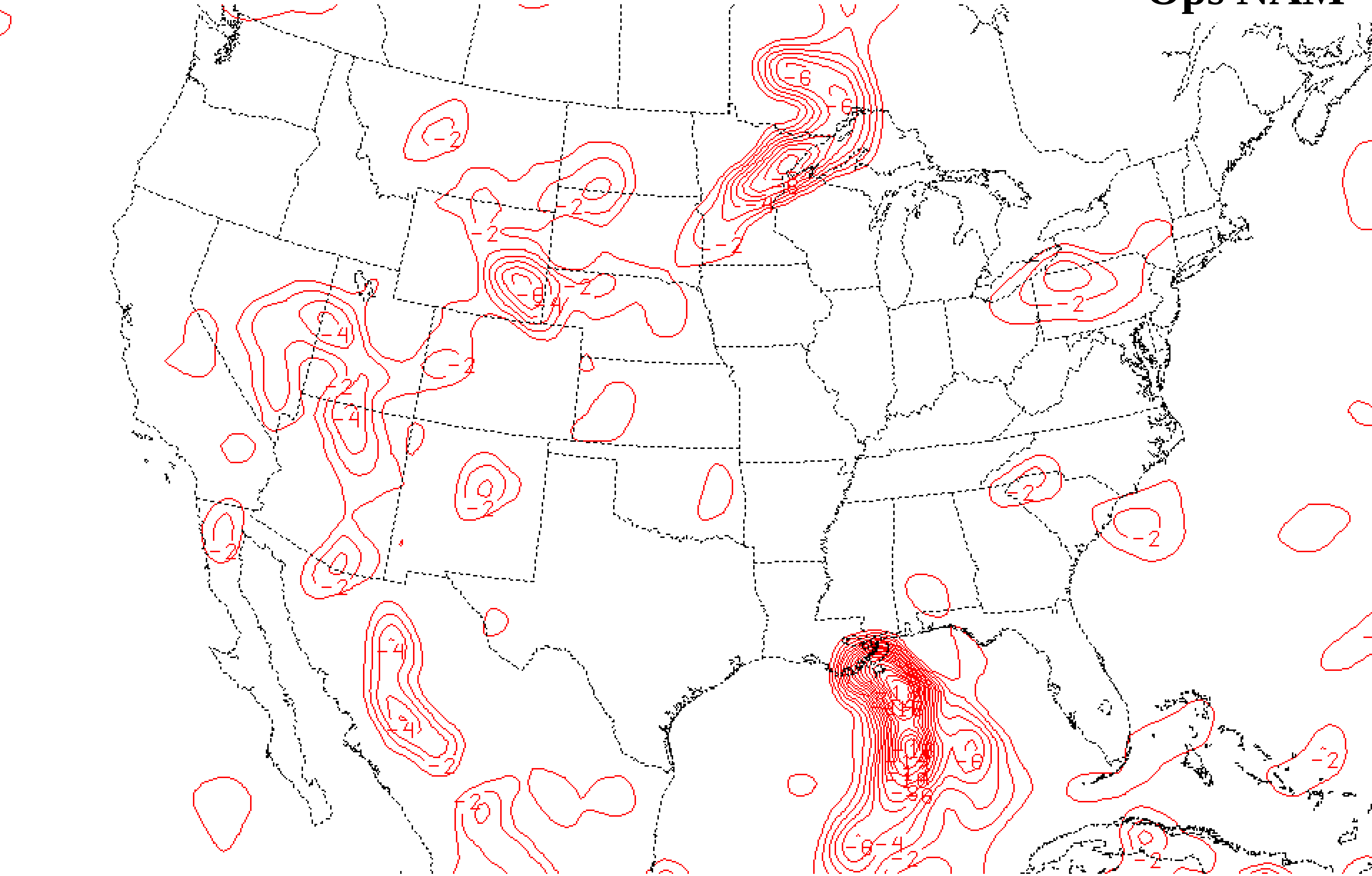
Matt Pyle's Rerun added 9/22/2011
AWC 0901/21Z omega example

- Slides 2 and 3 simply redisplay the ops NAM and parallel NAM from the AWC example (noting the caveat of the 3rd bullet below)

- The key comparison here is between slides 4 and 5, showing a clean test of the NAM code modification made over a slightly smaller 12 km grid spacing domain:
  - Slide 4 shows the forecast using the original parallel NAM code
  - Slide 5 shows the forecast using the updated parallel NAM code

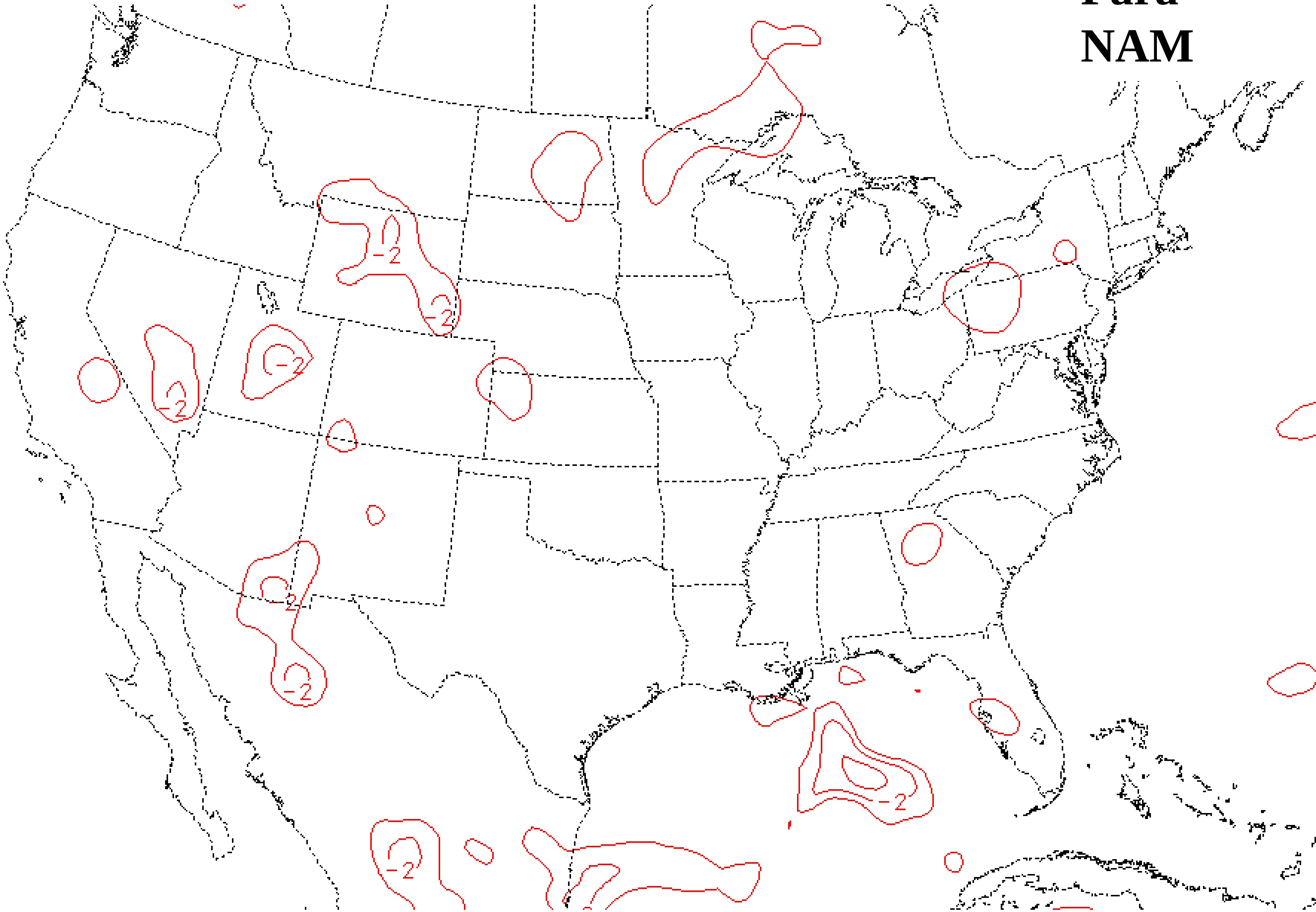
- Note that all examples here went through slightly different processing than the real-time production/parallel files shown in the original AWC example:
  - Everything started on the 12 km grid 218, which was horizontally interpolated to 90 km grid 104.
  - A 9-point horizontal smoother was used in plots to mimic the smoothing applied in the operational generation of grid 104 (but not applied in my interpolation).

Ops NAM



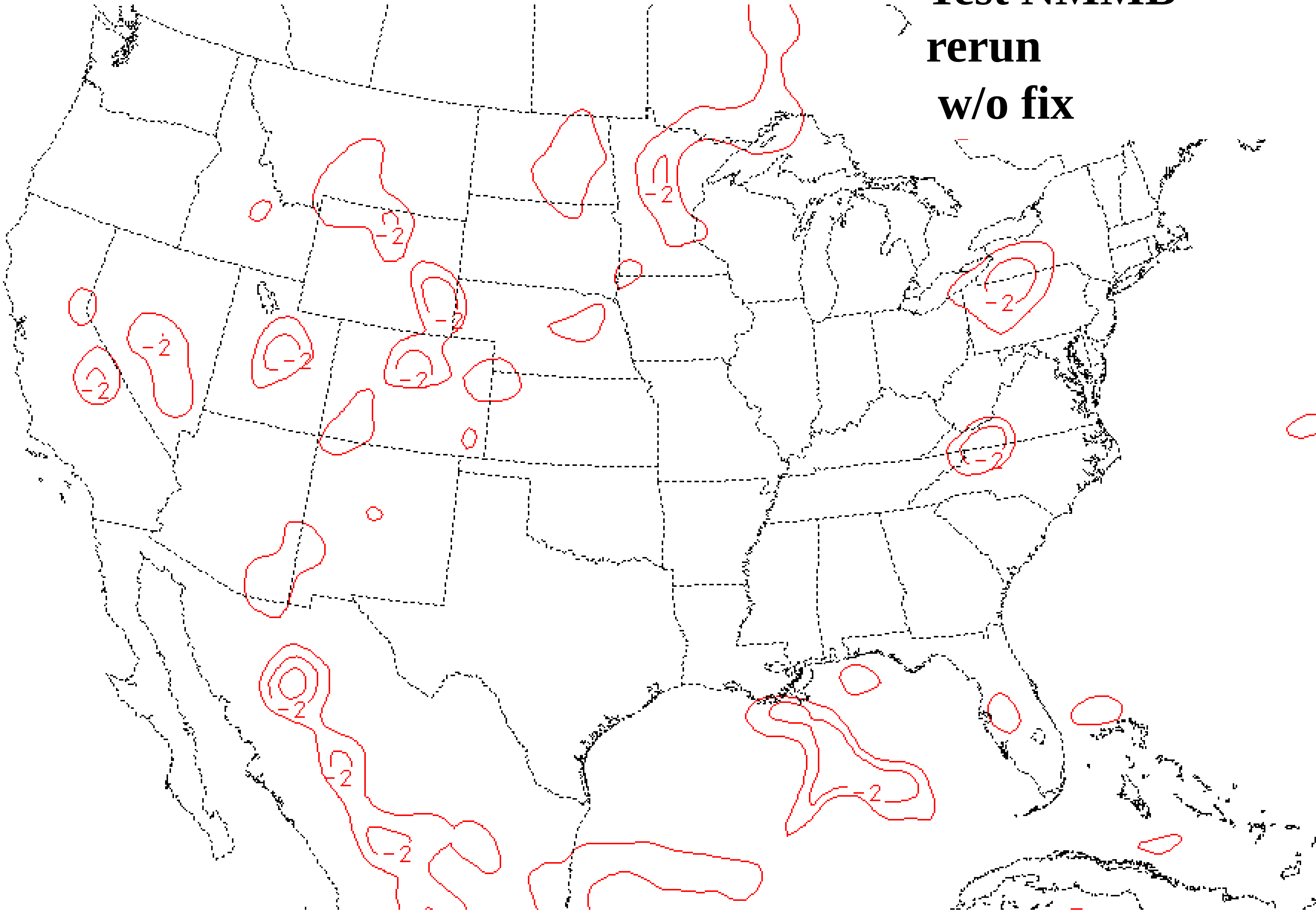
110901/2100V009 700 : 500 MB SM9LAVOMEG (*10**3)

Para NAM



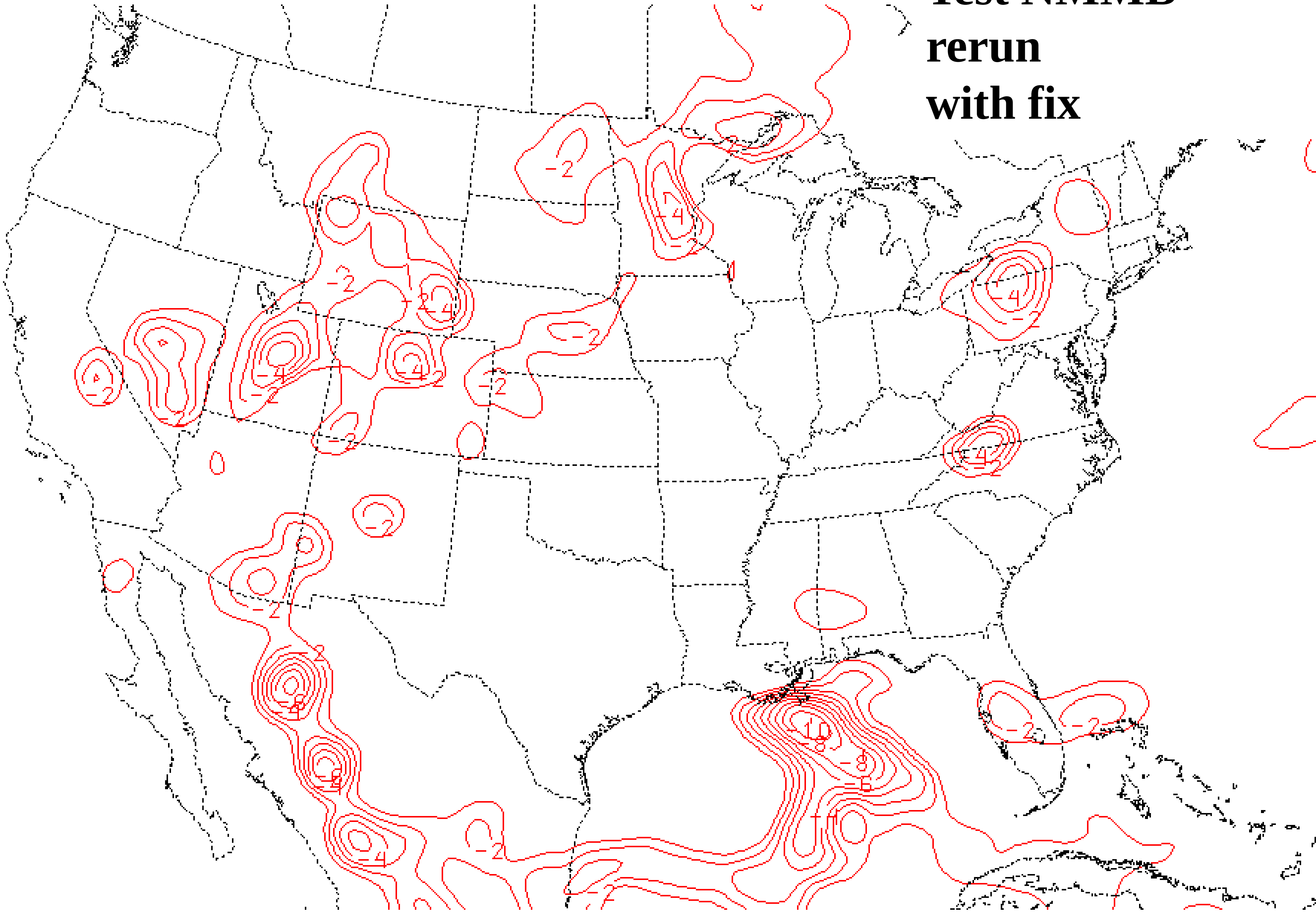
110901/2100V009 700 : 500 MB SM9LAVOMEG (*10**3)

Test NMMB rerun w/o fix



110901/2100V009 700 : 500 MB SM9LAVOMEG (*10**3)

Test NMMB rerun with fix



110901/2100V009 700 : 500 MB SM9LAVOMEG (*10**3)

Is weaker vertical velocity the reason there is a dry bias in QPF in the parent domain?

- Weaker vertical velocity and reduced precipitation are closely interrelated and feed back on each other: weaker vertical velocities mean less precipitation, and less precipitation means weaker vertical velocities. There is no clear cause and consequence relationship.
- There is another big piece effecting precipitation amounts in NMMB.
- NMMB uses the new more accurate and more conservative scheme for advecting passive variables like water vapor and condensate (cloud + hydrometeors), whereas the current NAM uses the old scheme which introduces spurious moisture sources.
- We know the new scheme results in less precipitation and cloud amounts as we saw when it was turned on in the WRF-NMM in the HiResWindow.
- This also contributes to weaker vertical circulations.

If nothing is wrong in the model, then why is the vertical velocity still weaker after the output fix?

- Zavisa says, in addition to the output issue & passive advection effect, there are likely two more reasons:
  - There is more horizontal diffusion in new NMMB than in current NMM
  - There is more divergence damping in new NMMB than in current NMM
- Matt Pyle (see below) has done a couple of sensitivity tests with smaller amounts of diffusion and divergence damping in NMMB both individually and together. Indeed, the magnitude of the vertical velocities (still without the barotropic component) increases when either or both are decreased.

Why is there more diffusion and divergence damping in NMMB than in NMM?

- These are the result of a myriad of pre-implementation case studies & parallel testing.
- After many tests, Brad found that increased diffusion had a big effect on improving the location and intensity of NMMB QPF predictions of the May 2010 Tennessee floods. Further tests showed that almost all of the improvement could be gained by targeting the increased diffusion *only to the moisture variables*.
- Our QPF statistics & case studies had indicated a tendency for the current NAM to overdo heavy precip (high bias especially in summer and fall) and these increased amounts of diffusion and divergence damping were seen as helping that situation.

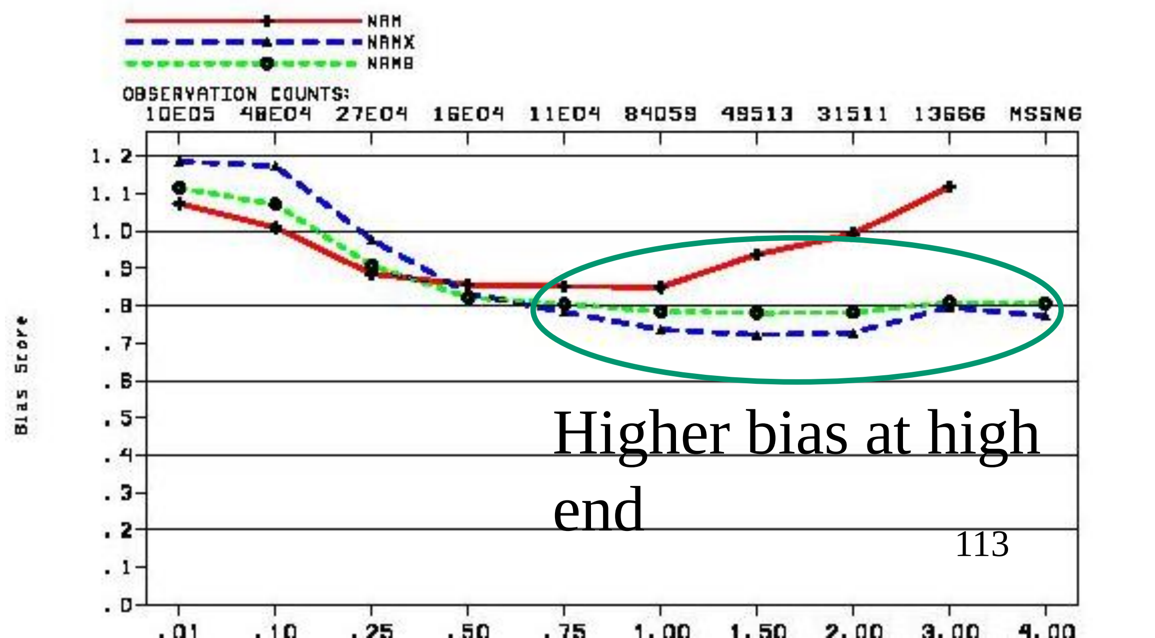
Can we improve the low QPF bias of the parent?

- Recall, this was not a problem throughout the year.
- For the warm season, Zavisa has recommended a change to the BMJ convection following the adjusted version used in the new nests (so called BMJ_DEV).
- Eric Rogers has been testing this in a parallel (see next slide).
- QPF performance for a limited period (2 weeks of testing) was significantly improved, but we see some mixed results with some of the fcst-vs-raob performance statistics.
- Brad can also tune the cloud & precipitation microphysics once decisions have been made about whether to change diffusion & divergence damping and put in BMJ_DEV or not.

Red = NAM

Blue = NMMB

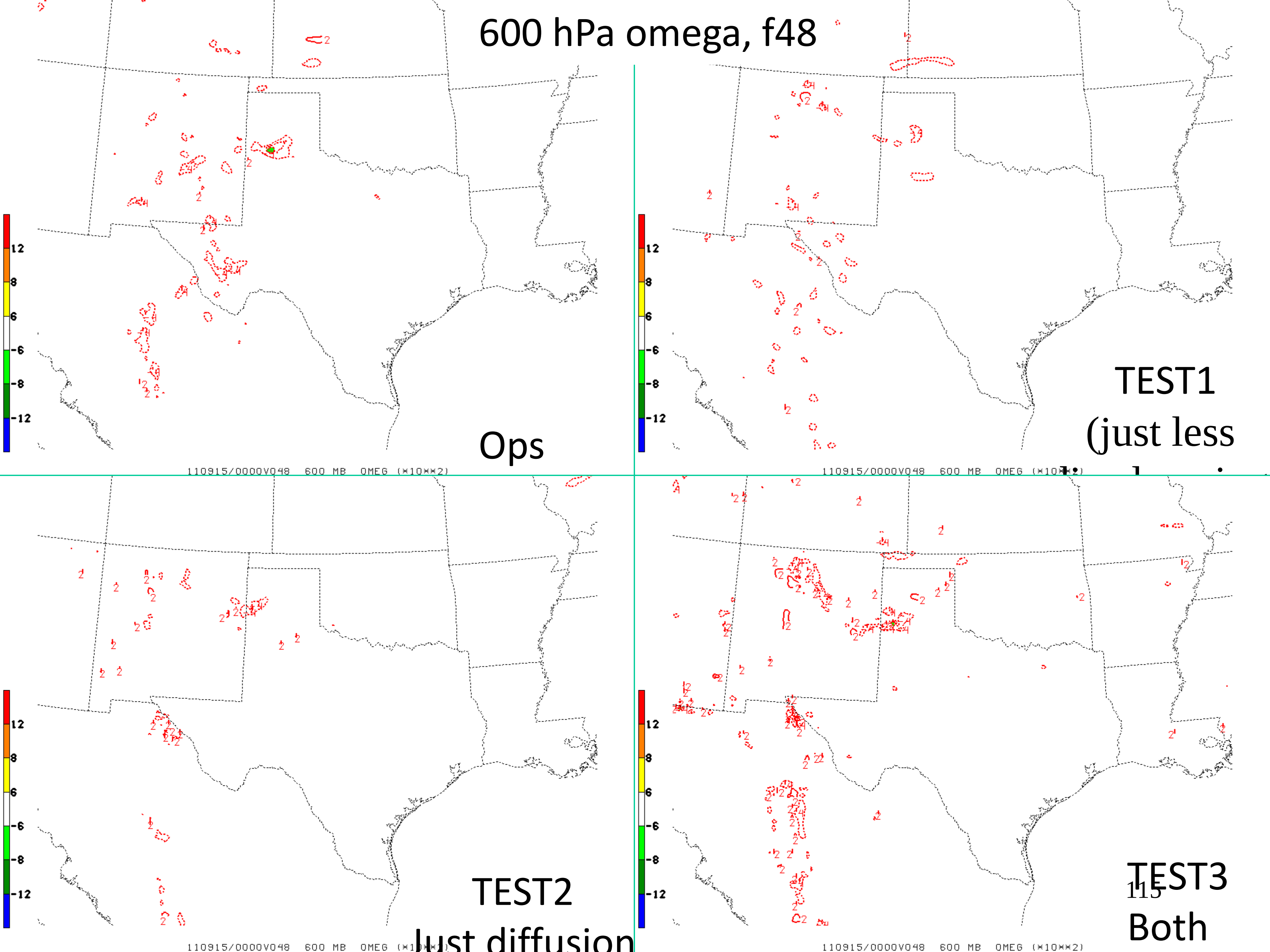
Green = Eric's test of fres=.75



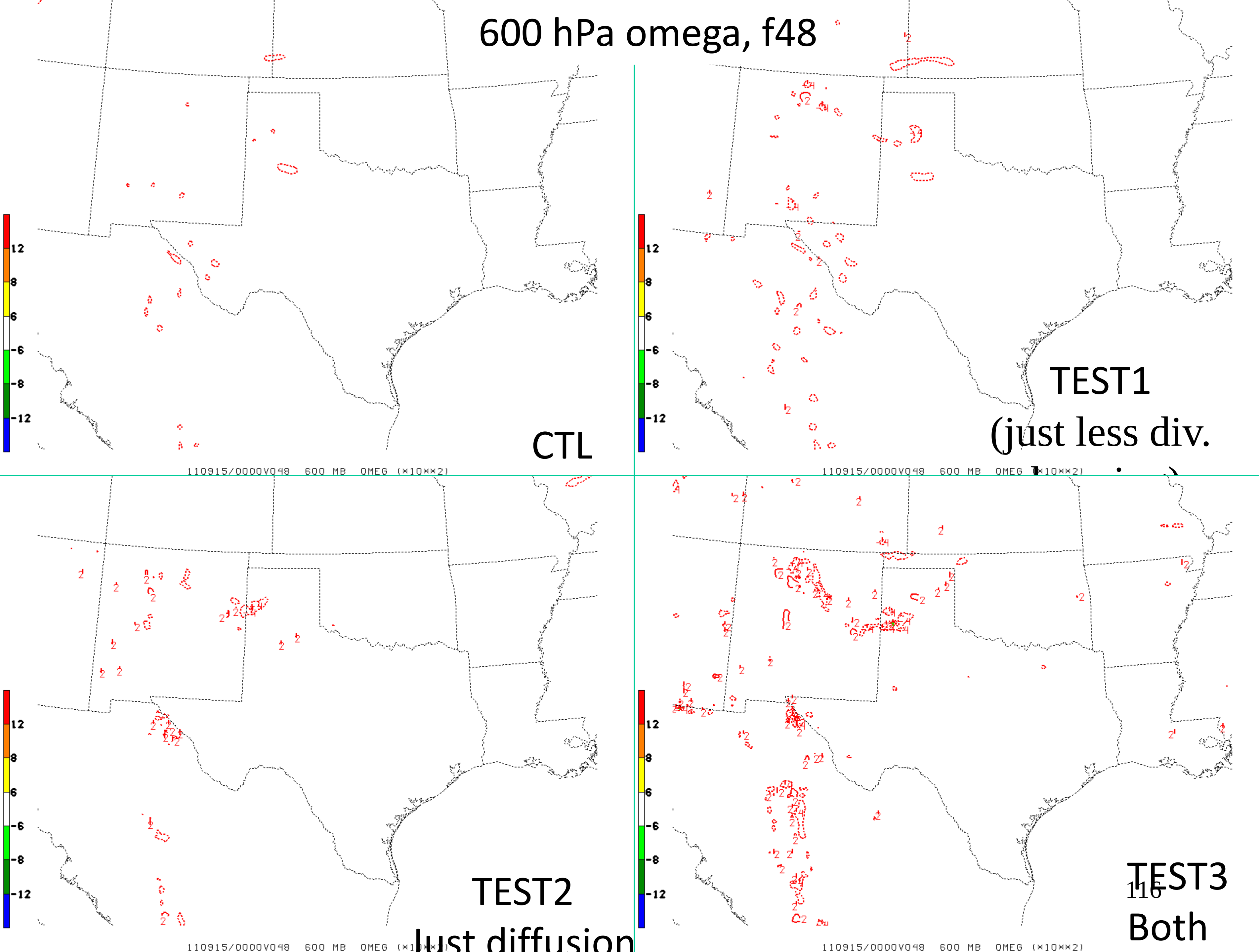
Quick diffusion/div damp test

- Performed before the barotropic component was added back in to the total vertical velocity
- 12 km/60 level, 524x397 domain centered @ 40N, 100W. GFS IC/LBC.
- Ran a CTL configuration and three tests:
  - CTL: codamp=9.0, smag2=0.4 (12 km NAMB levels)
  - TEST1: codamp=3.0, smag2=0.4 (just less div damping)
  - TEST2: codamp=9.0, smag2=0.1 (just less hor diff)
  - TEST3: codamp=3.0, smag2=0.1 (lowers both div damp, hor diff)
- Lowering divergence damping, particularly when combined with lower diffusion significantly increased vertical velocities.
- Much less impact on precipitation.

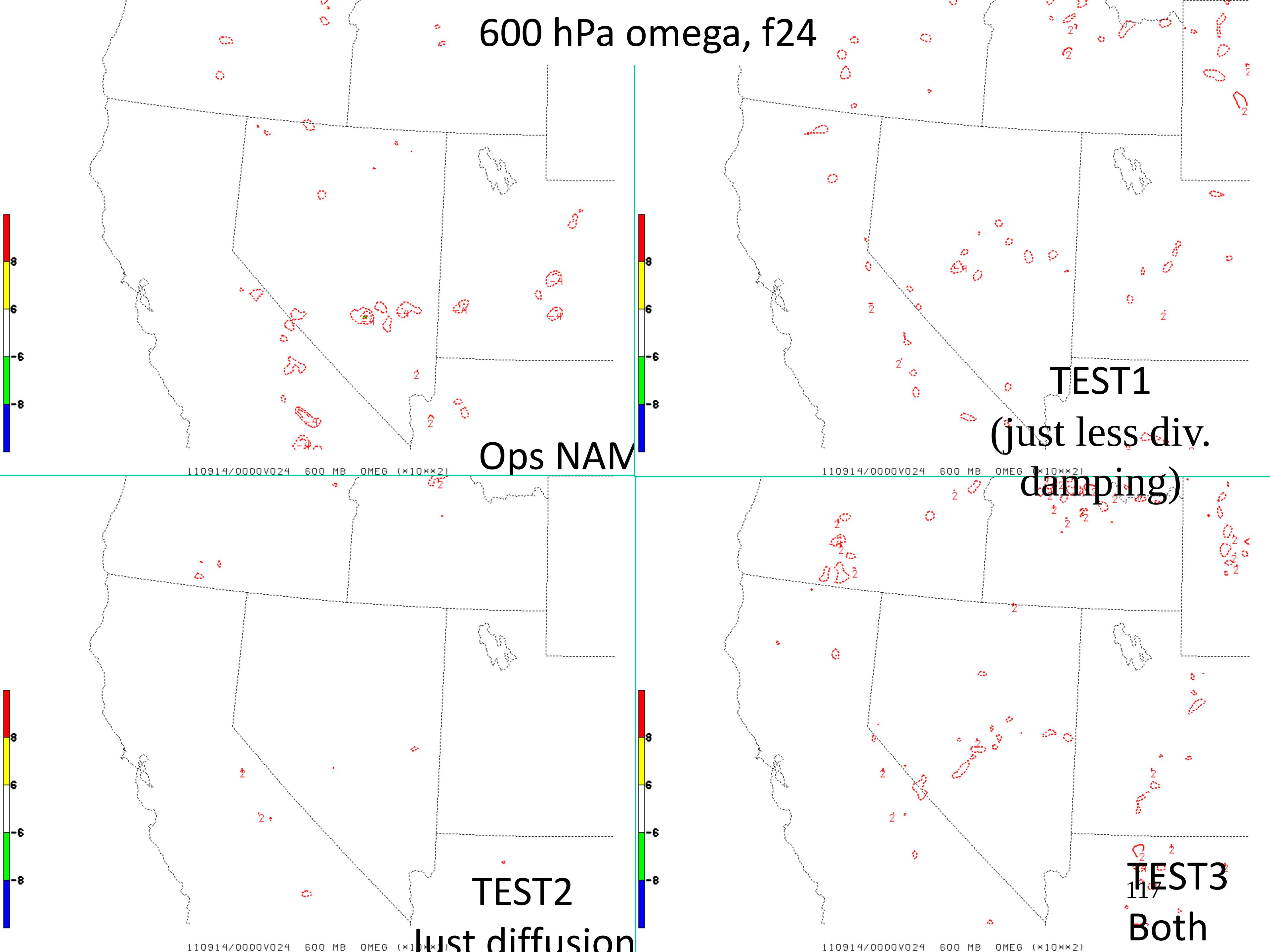
600 hPa omega, f48



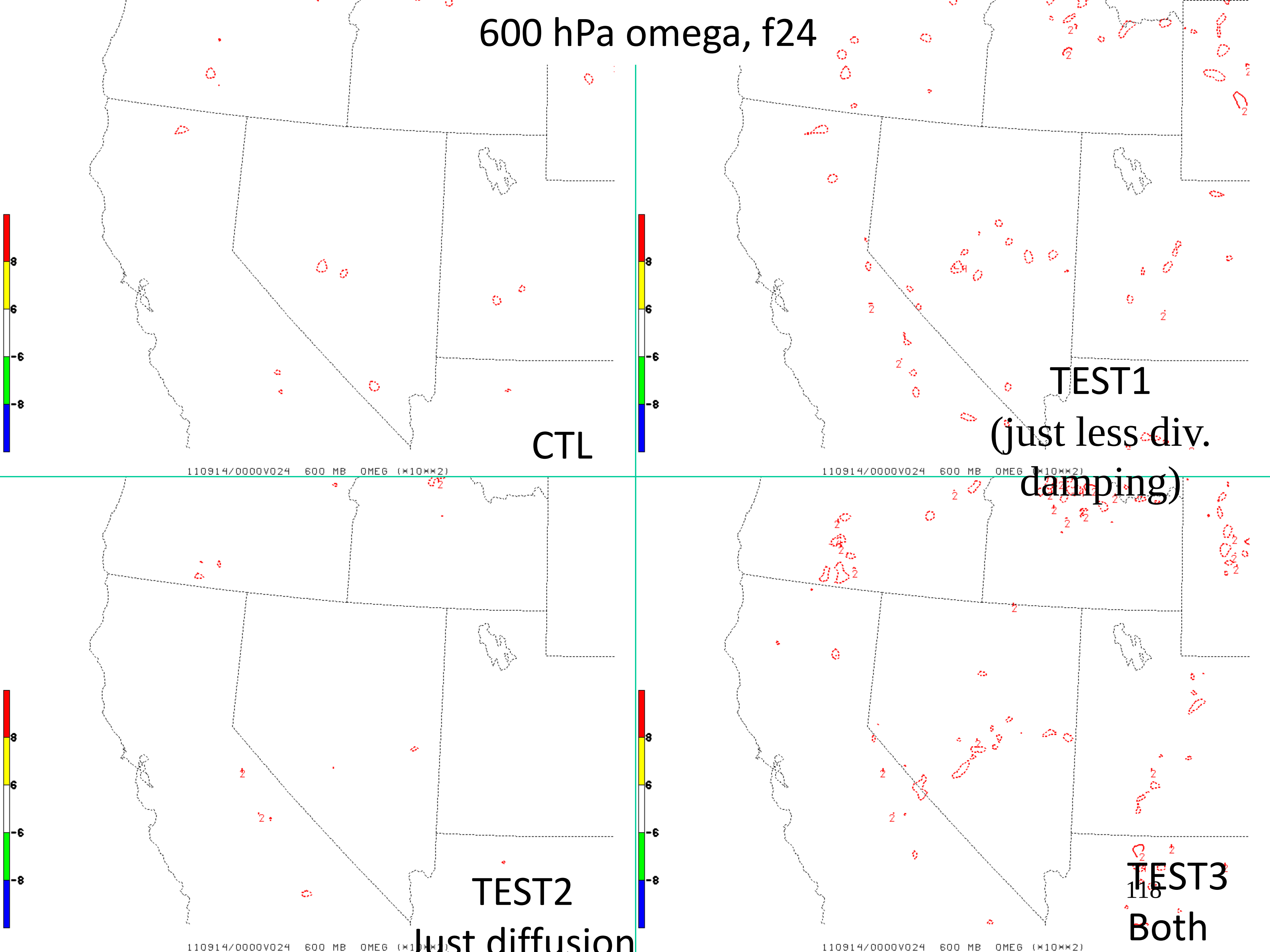
600 hPa omega, f48

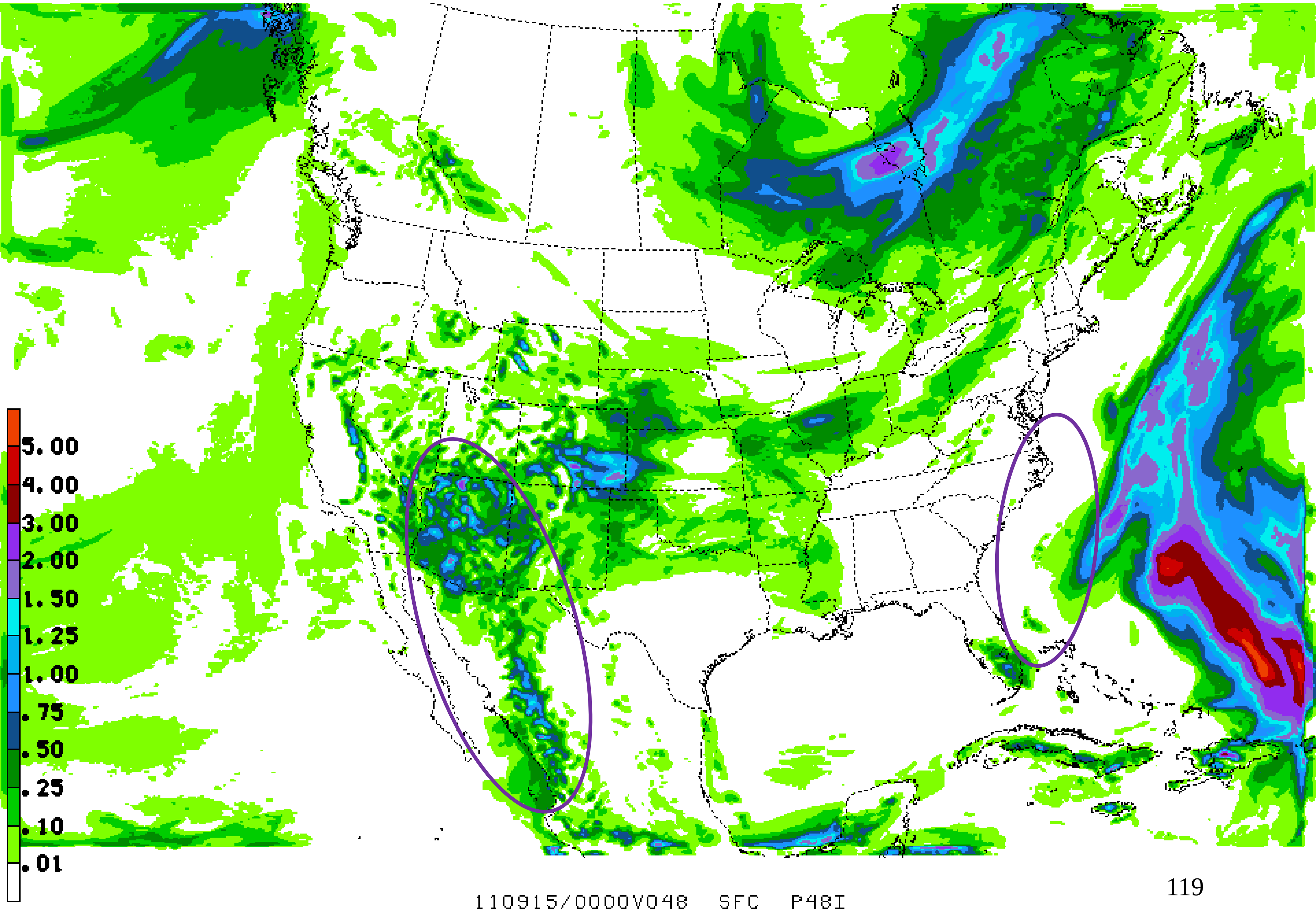


600 hPa omega, f24



600 hPa omega, f24

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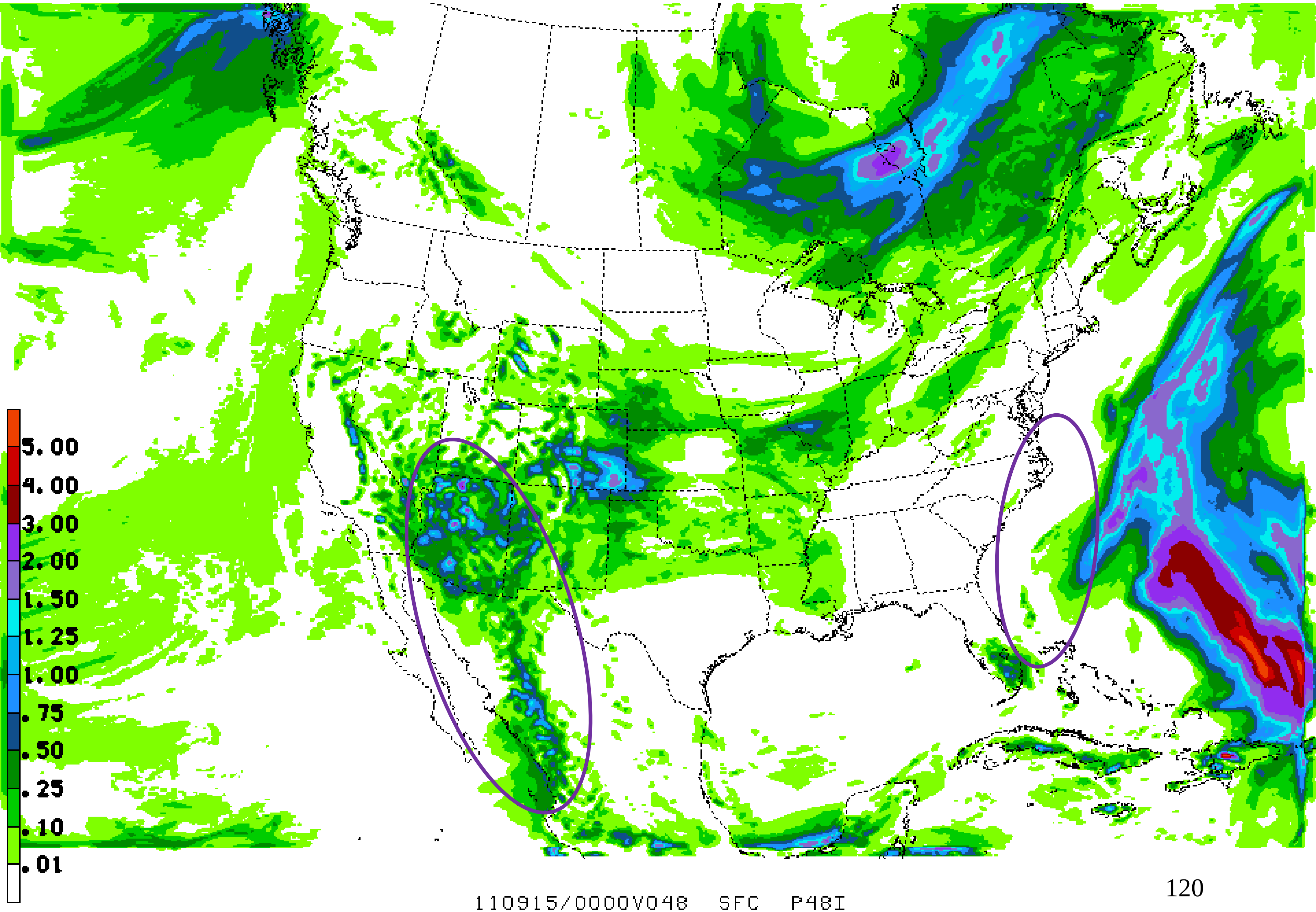
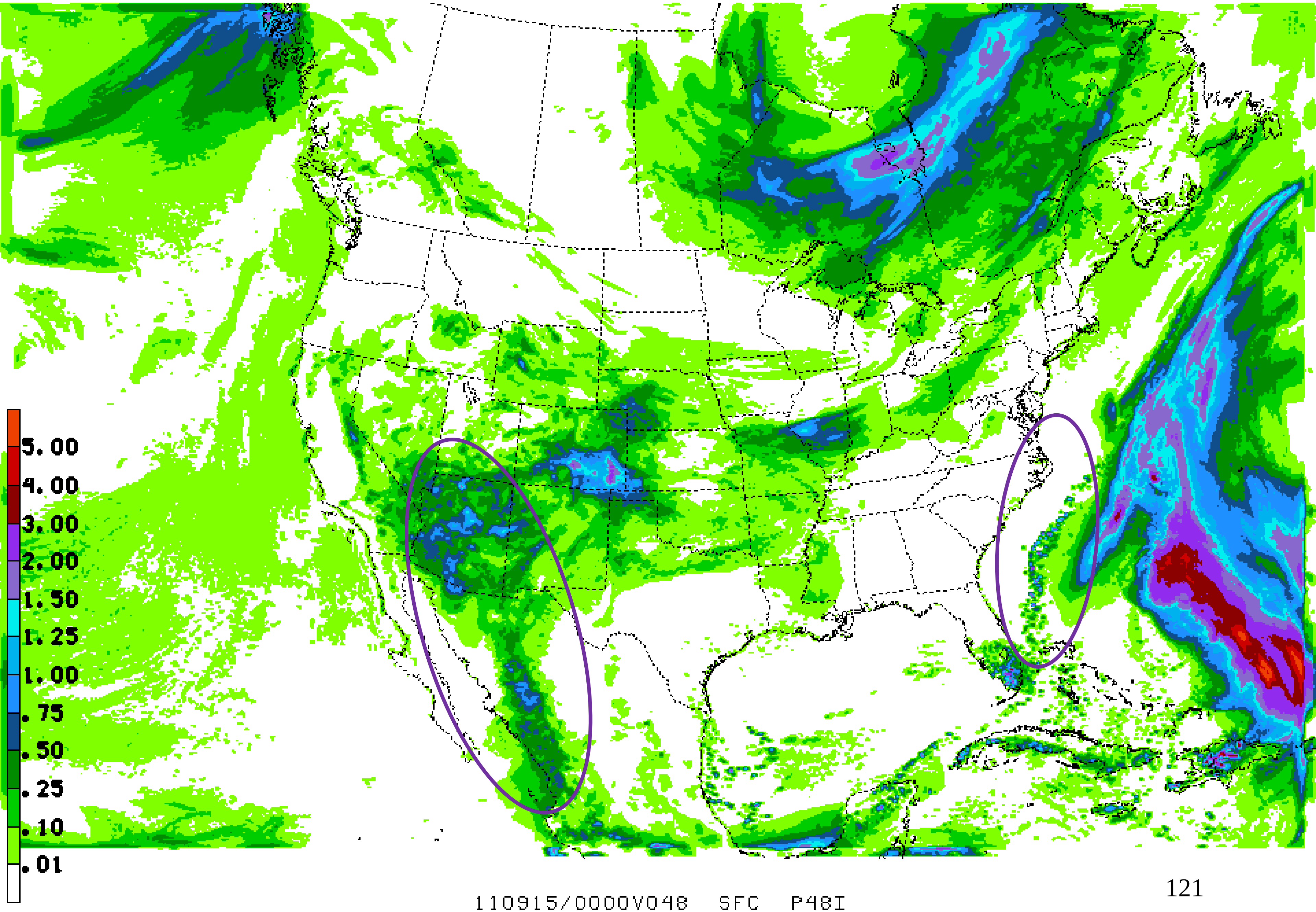
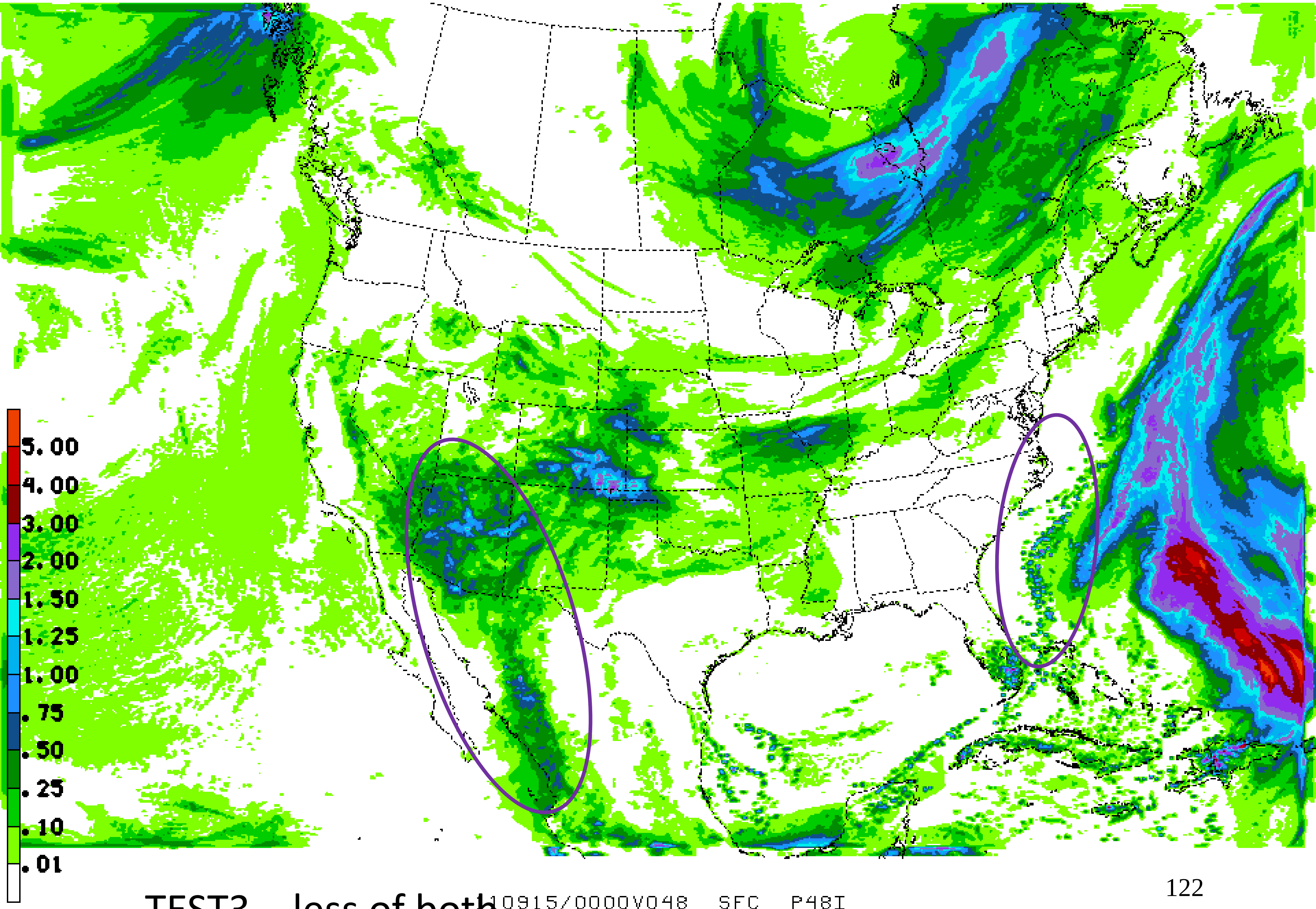
CTL



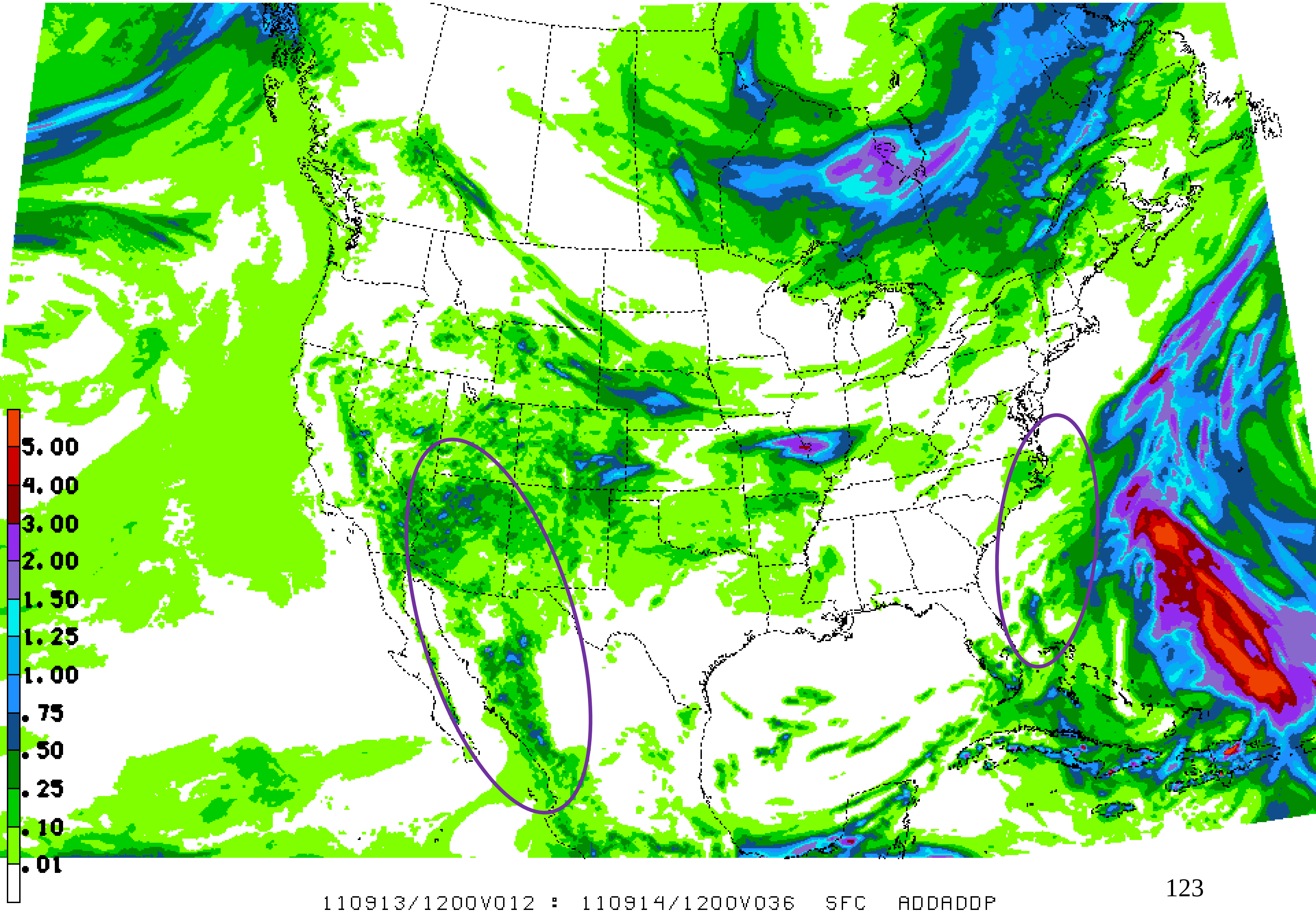
TEST1 – less div damp



TEST2 – less diffusion



TEST3 – less of both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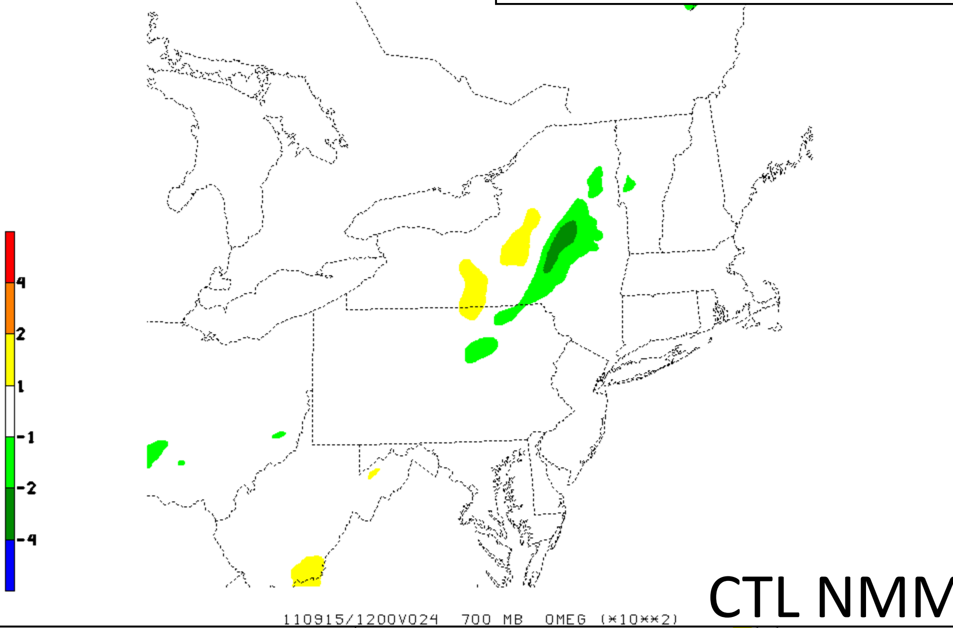
110913/1200V012 : 110914/1200V036 SFC ADDADDP

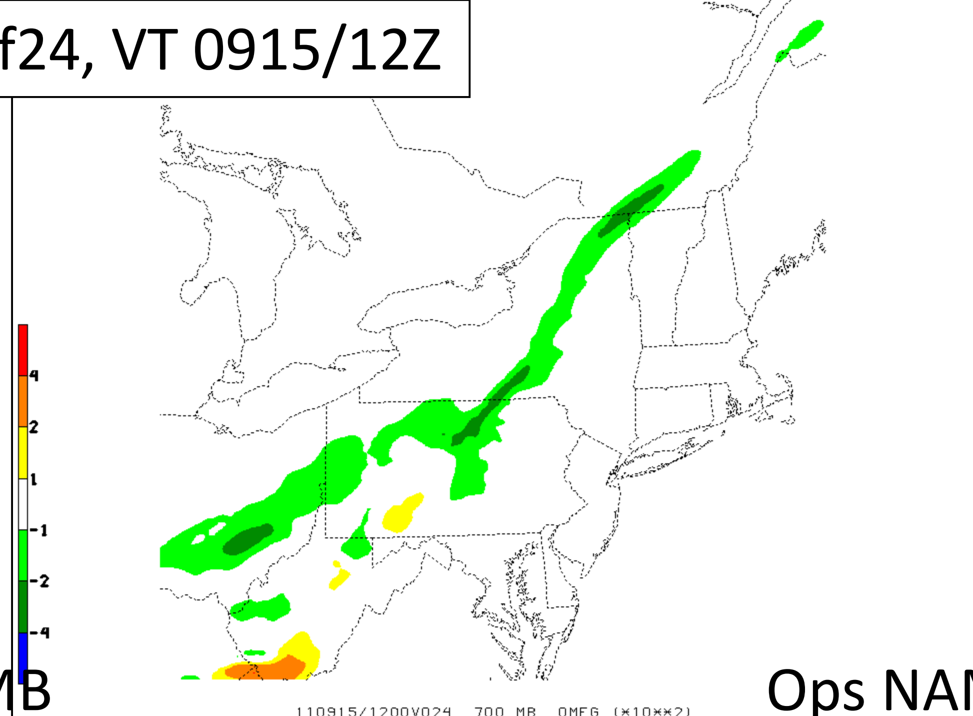
Ops NAM

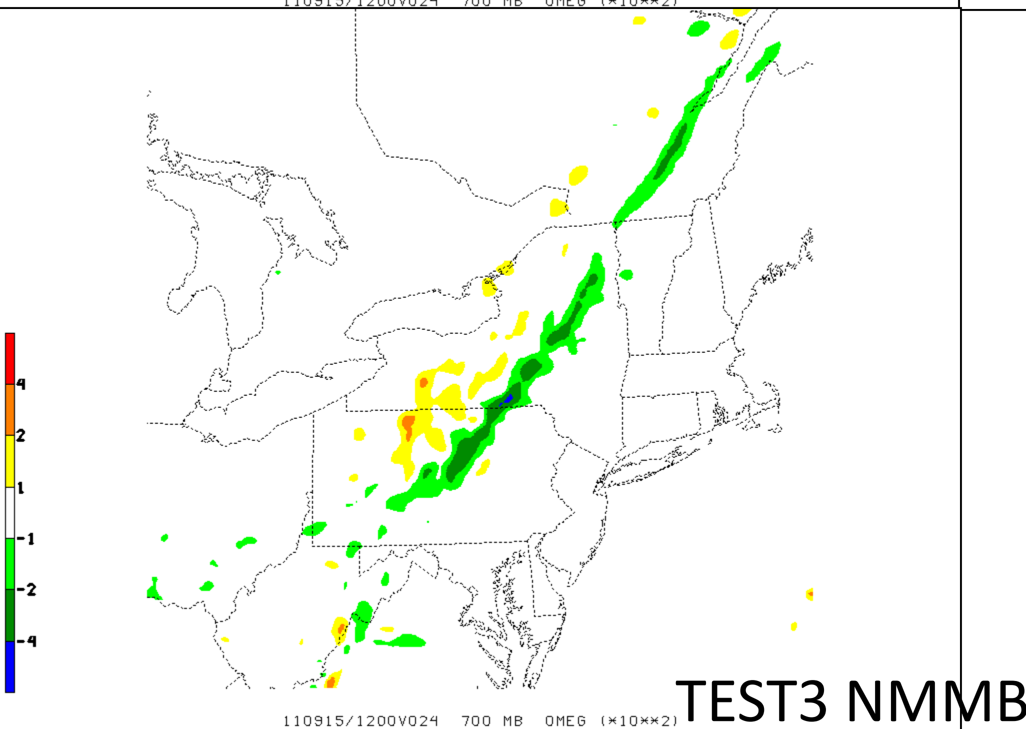
Quicker diffusion/div damp test

- 12 km/60 level, 584x497 domain centered @ 40N, 100W. GFS IC/LBC. 20110914/12Z cycle
- Ran a CTL configuration and one test:
  - CTL: codamp=9.0, smag2=0.4 (12 km NAMB levels)
  - TEST3: codamp=3.0, smag2=0.1 (lowers both div damp, hor diff)

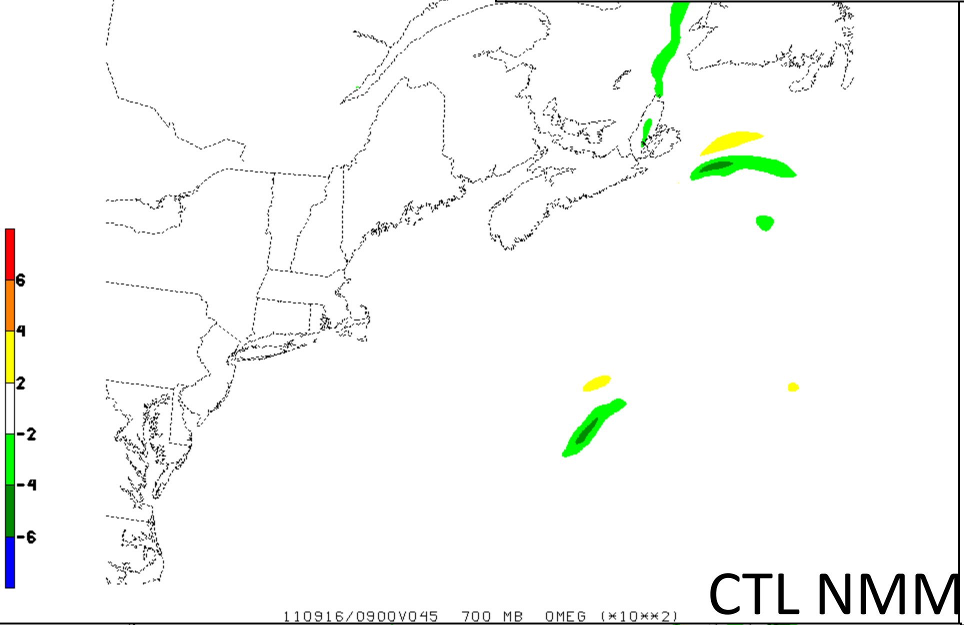
700 hPa omega, f24, VT 0915/12Z

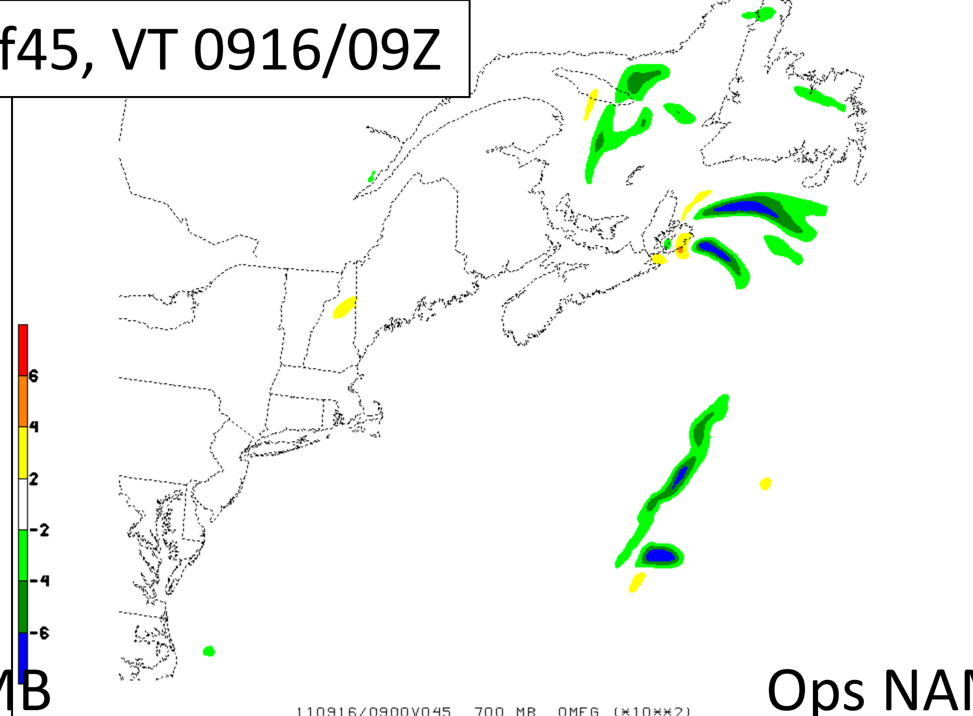


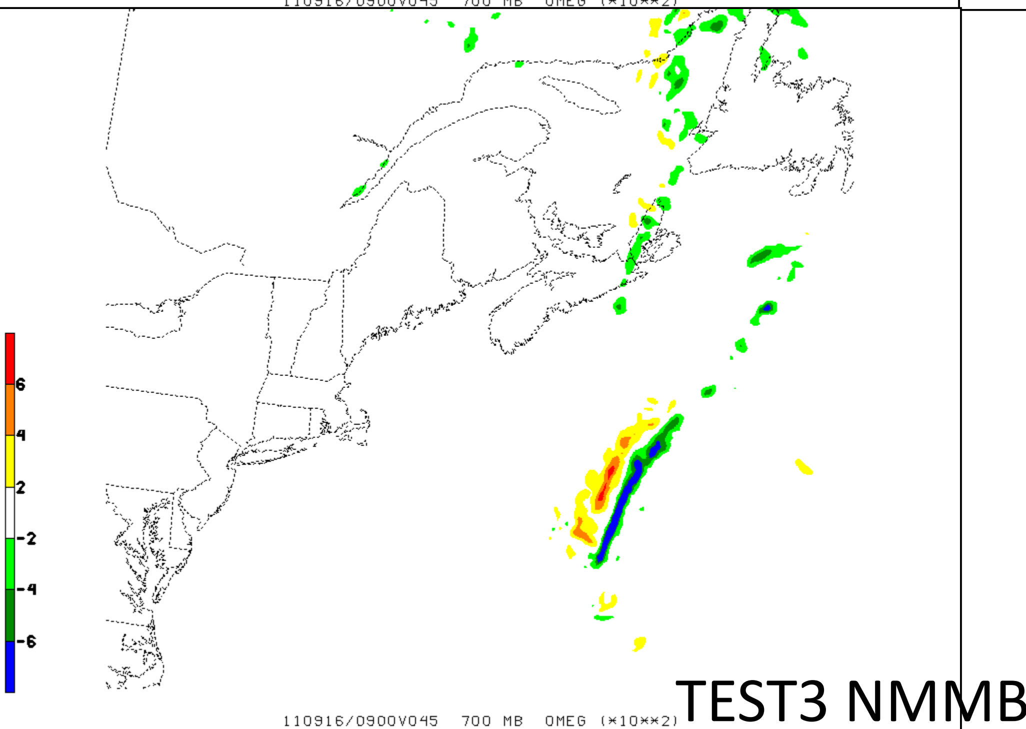




700 hPa omega, f45, VT 0916/09Z







Can we fix the low convection intensity problem in the nests for SPC?

- Fixing vertical velocity output to reflect the total vertical velocity will improve two out of three statistics – reflectivity is unchanged with that fix.
- Yes, eventually, but we need more time to test all the ramifications on the accuracy & usefulness of the other guidance parameters. This will be a tough balancing act.
- We can increase the intensity of vertical circulations by reducing the diffusion or divergence damping or both. This can be done selectively for the nests but not the parent.
- We can also increase the texture/structure of both precip and reflectivity by decreasing the diffusion (see Pyle result above).
- BMJ_DEV convection activates fairly infrequently in the nests so the only option is probably to turn it off altogether.
- Brad can also tune the cloud & precipitation microphysics once decisions have been made about whether to change diffusion and/or divergence damping and to run with BMJ_DEV or not.
- This retuning exercise will be greatly hampered by lack of sufficient computing, and the result will most likely benefit only SPC.
- But, we are not giving up on this challenge.

Additional considerations [original]

- Much improved computational efficiency and increased throughput.

  Runtime for NAM w/ nests –

  Current opnl code: > 4 hours

  New code: 70 minutes
- 2.5 minute delay is only on cirrus
- Fix to nesting known already for the Fire Weather failure.

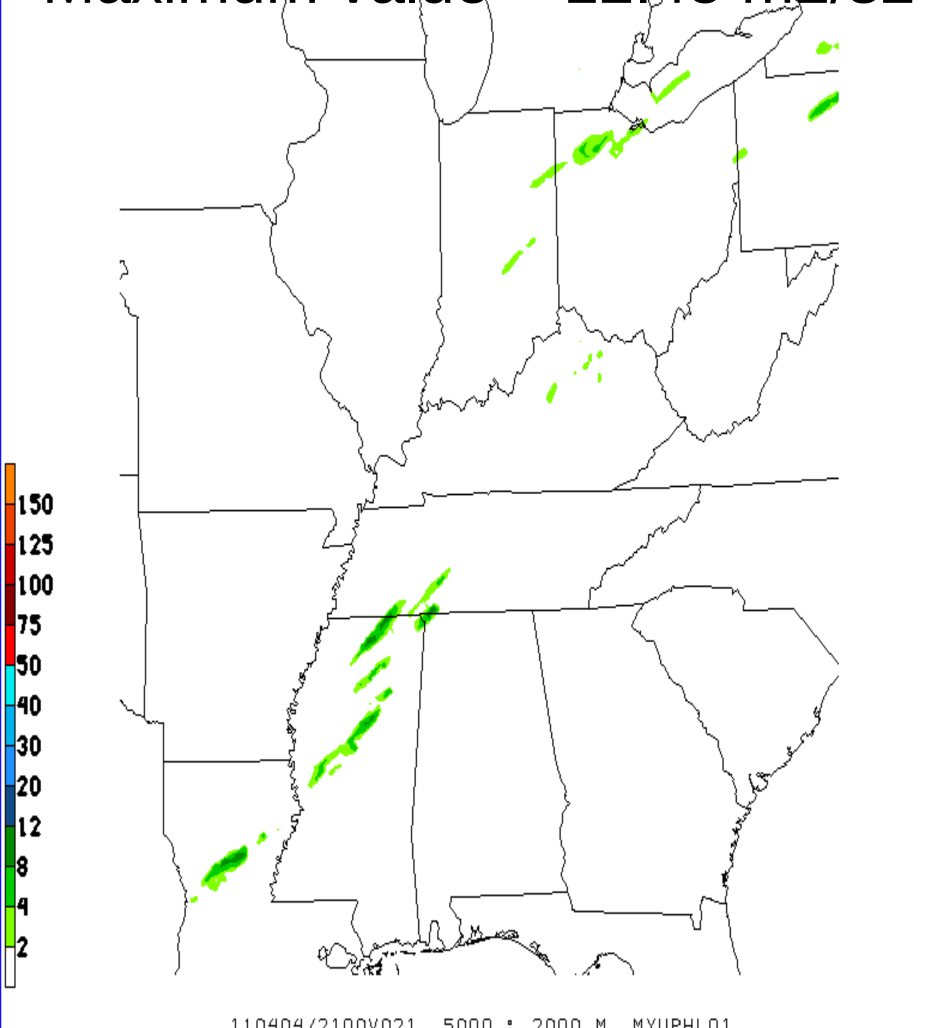
Additional considerations (enhanced)

- New NAM is doing 11 times more work than the current NAM.
- To finish in same amount of time, the new NAM is using only 7.7 times more compute resources!
- NAM completion 2.5 minute late is only on cirrus, it finishes 1 minute early on stratus.
- Fix to FireWx nest failure is known and ready to submit.

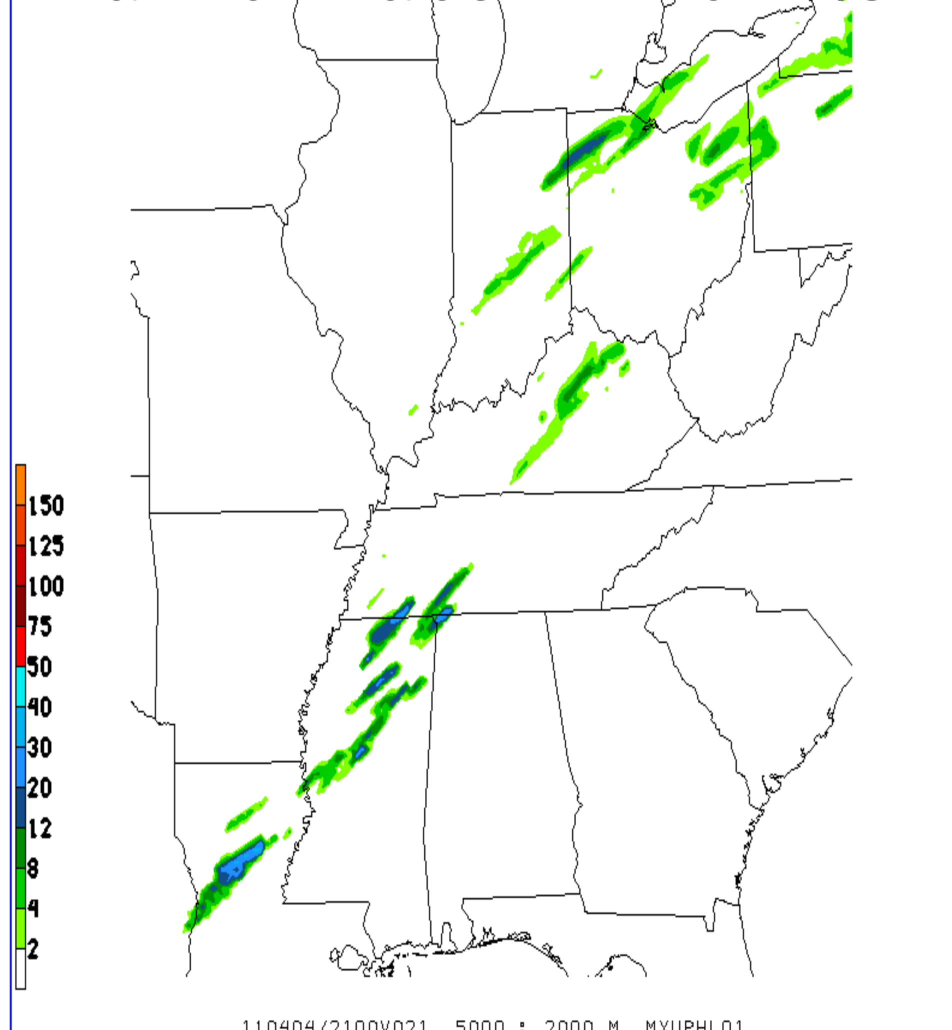
CONUS Nest reruns of selected severe wx events for SPC

00z 4/4/11 cycle; 21-hr forecasts: Hourly maximum updraft helicity

Original 4km CONUS nest run
Maximum value = 12.45 m2/s2



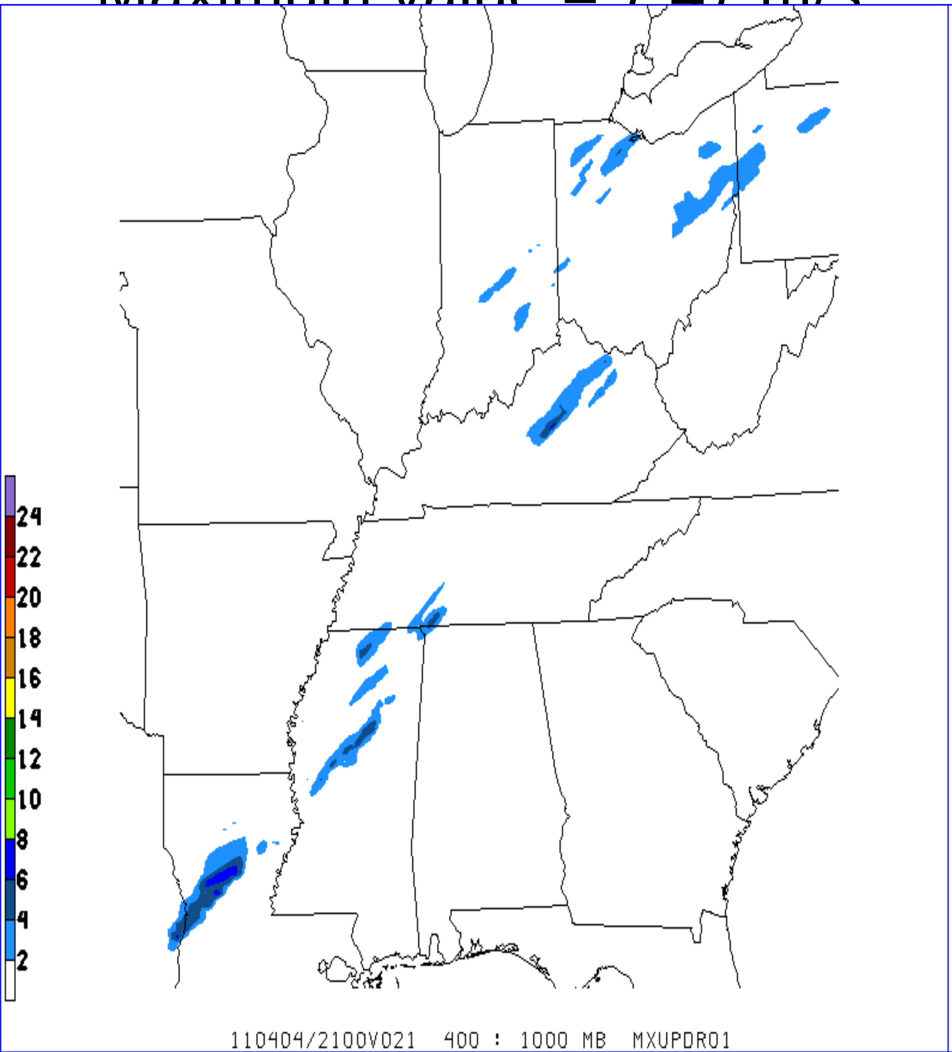
Rerun with vertical velocity fix
Maximum value = 41.20 m2/s2

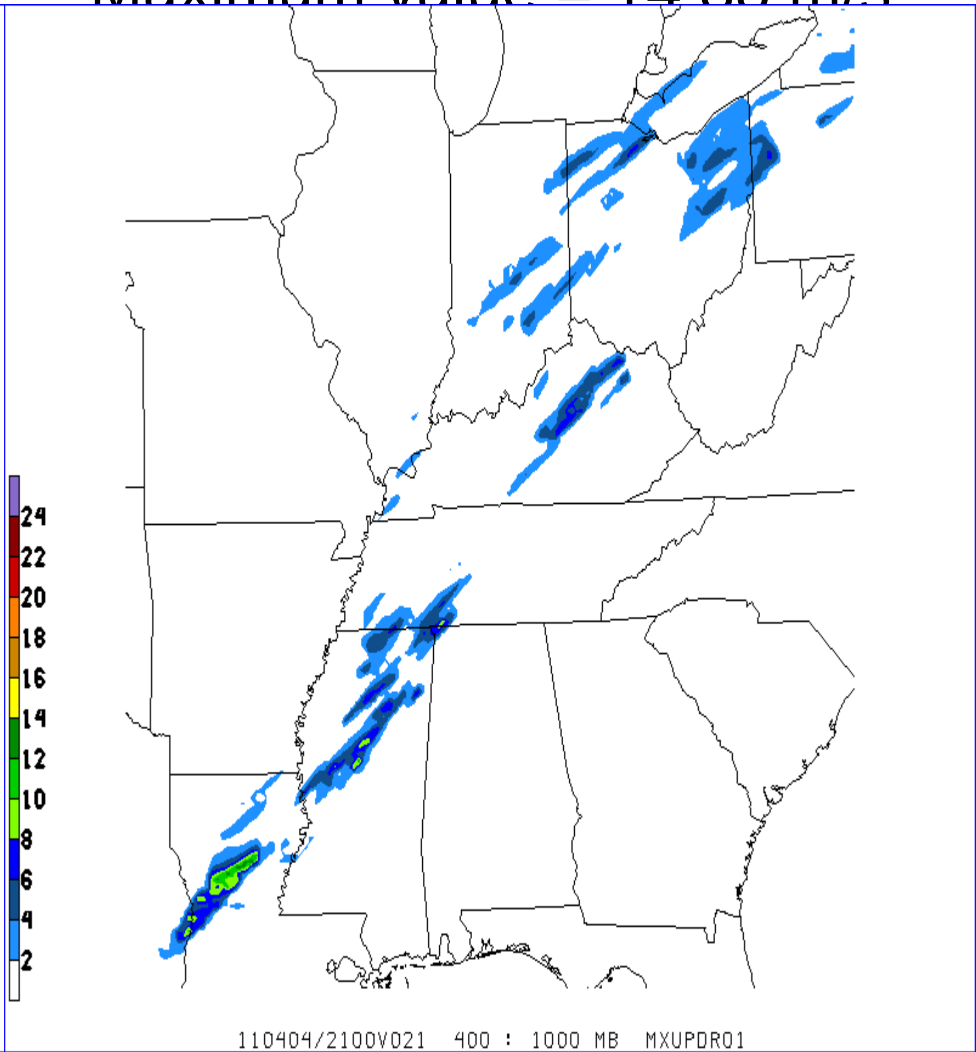


00z 4/4/11 cycle; 21-hr forecasts: Hourly maximum updraft speed

Original 4km CONUS nest run
Maximum value = 7.47 m/s

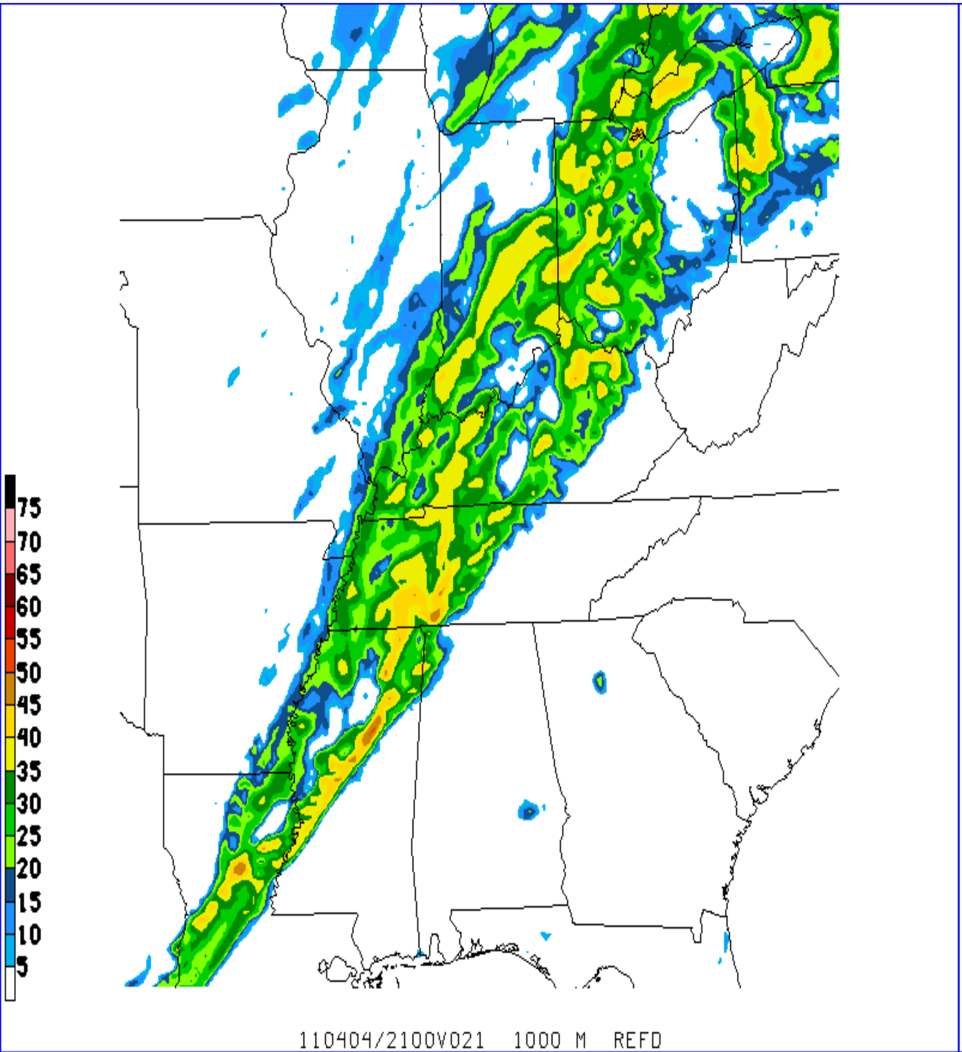
Rerun with vertical velocity fix
Maximum value = 14.38 m/s



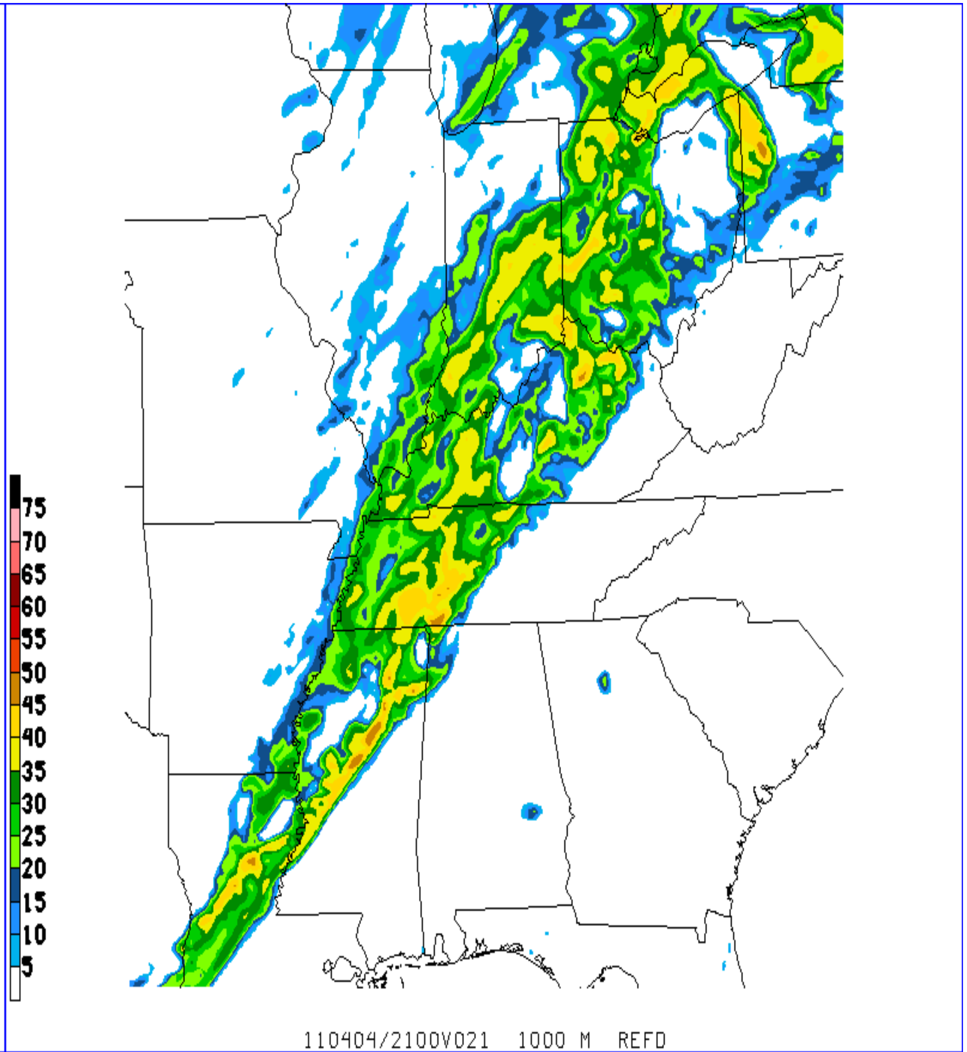


00z 4/4/11 cycle; 21-hr forecasts: 1 km AGL reflectivity

Original 4km CONUS nest run



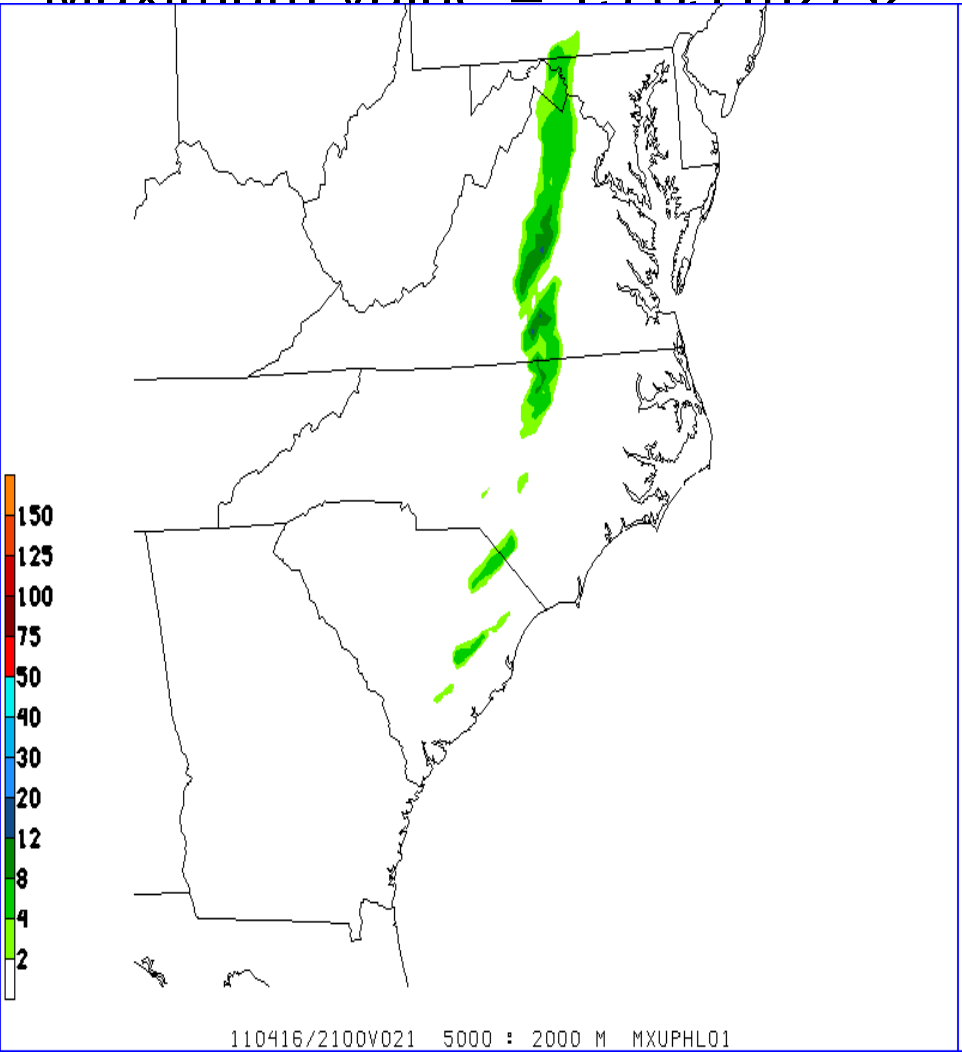
Rerun with vertical velocity



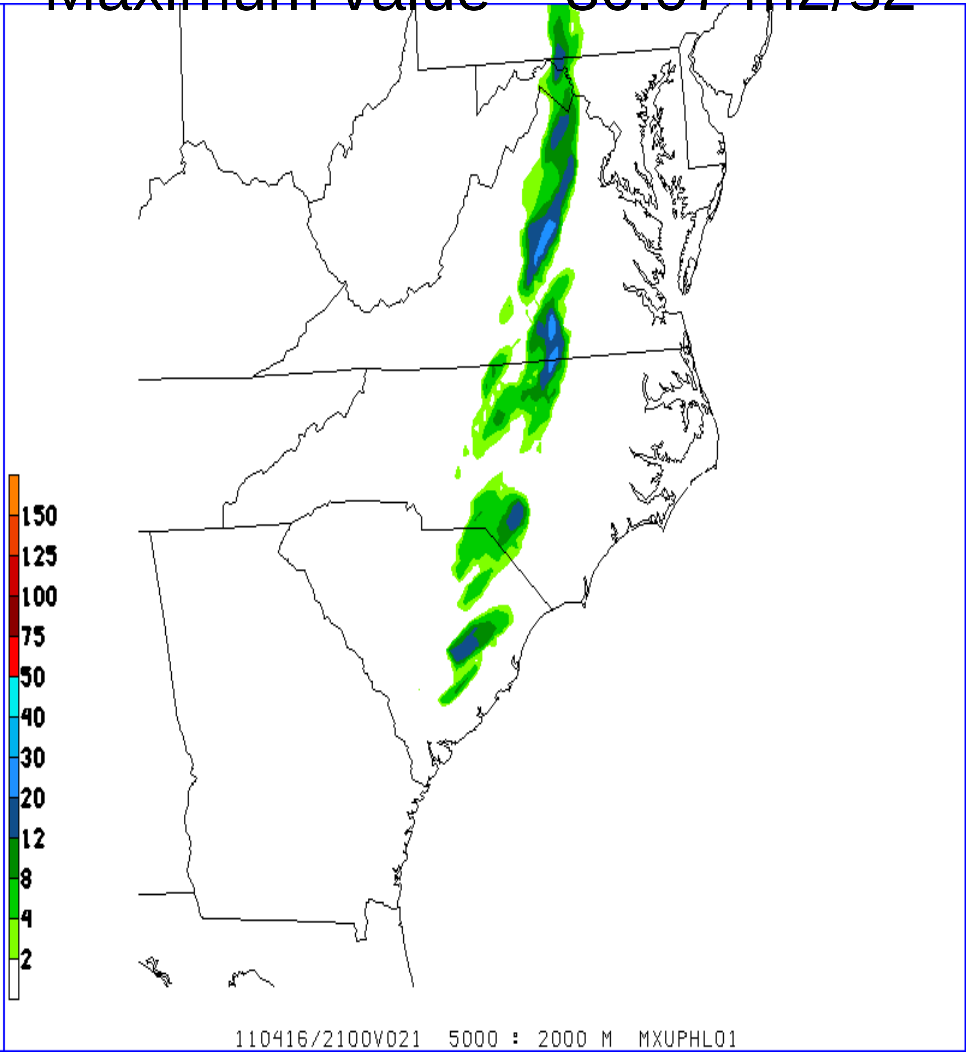
00z 4/16/11 cycle; 21-hr forecasts:

Hourly maximum updraft helicity

Original 4km CONUS nest run
Maximum value = 13.83 m2/s2

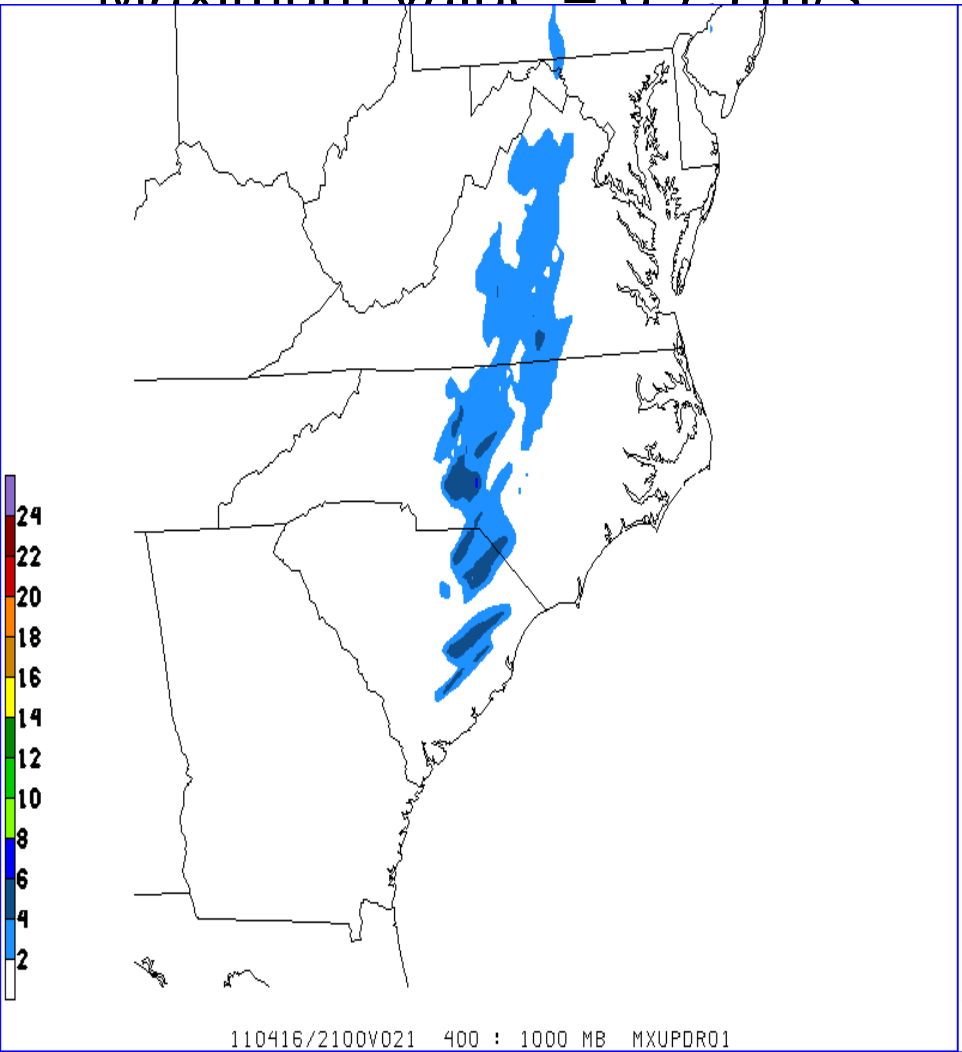


Rerun with vertical velocity fix
Maximum value = 30.07 m2/s2

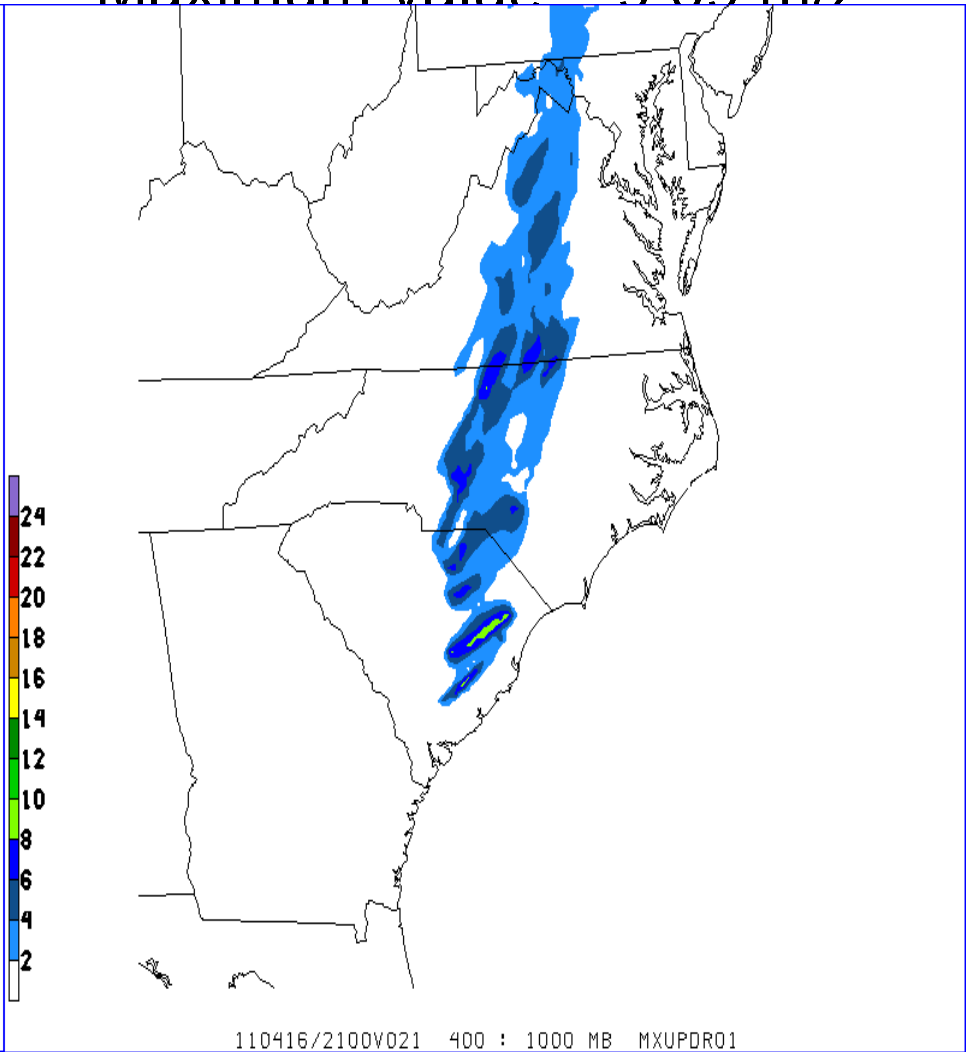


00z 4/16/11 cycle; 21-hr forecasts: Hourly maximum updraft speed

Original 4km CONUS nest run
Maximum value = 6.75 m/s

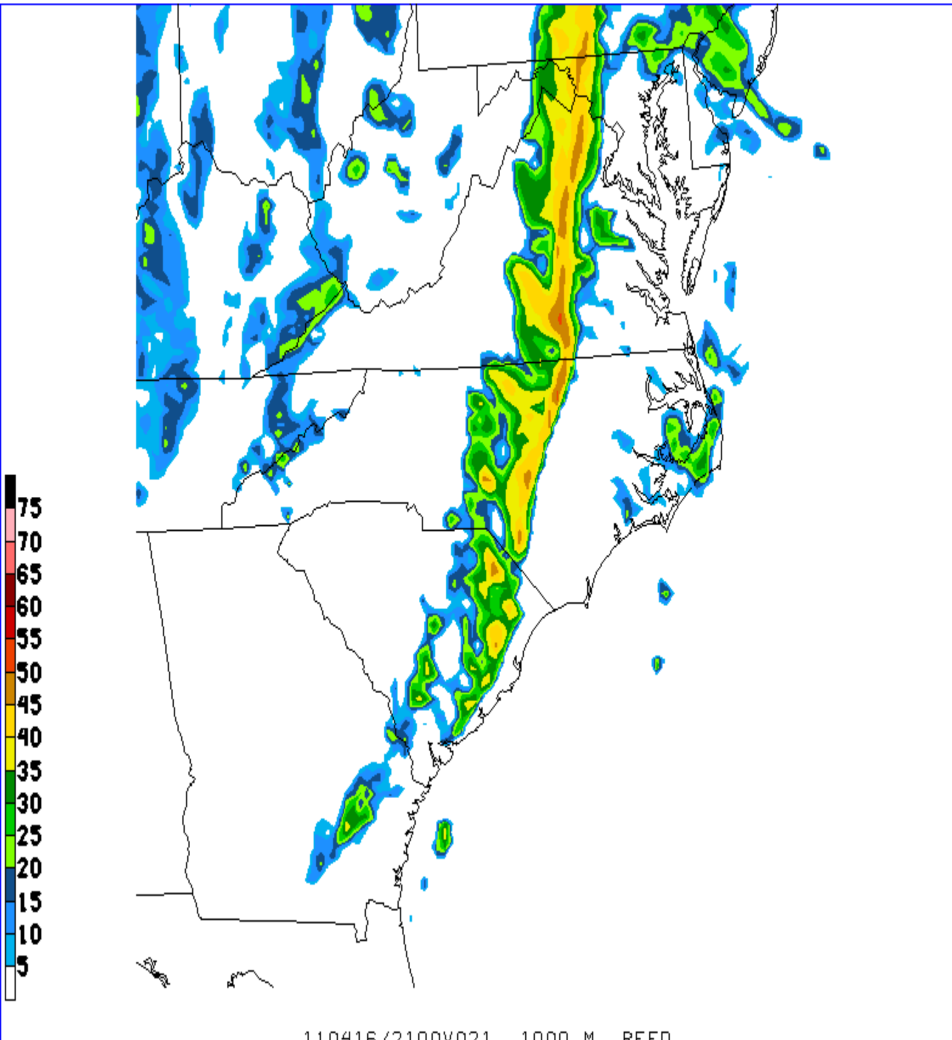


Rerun with vertical velocity fix
Maximum value = 9.09 m/2

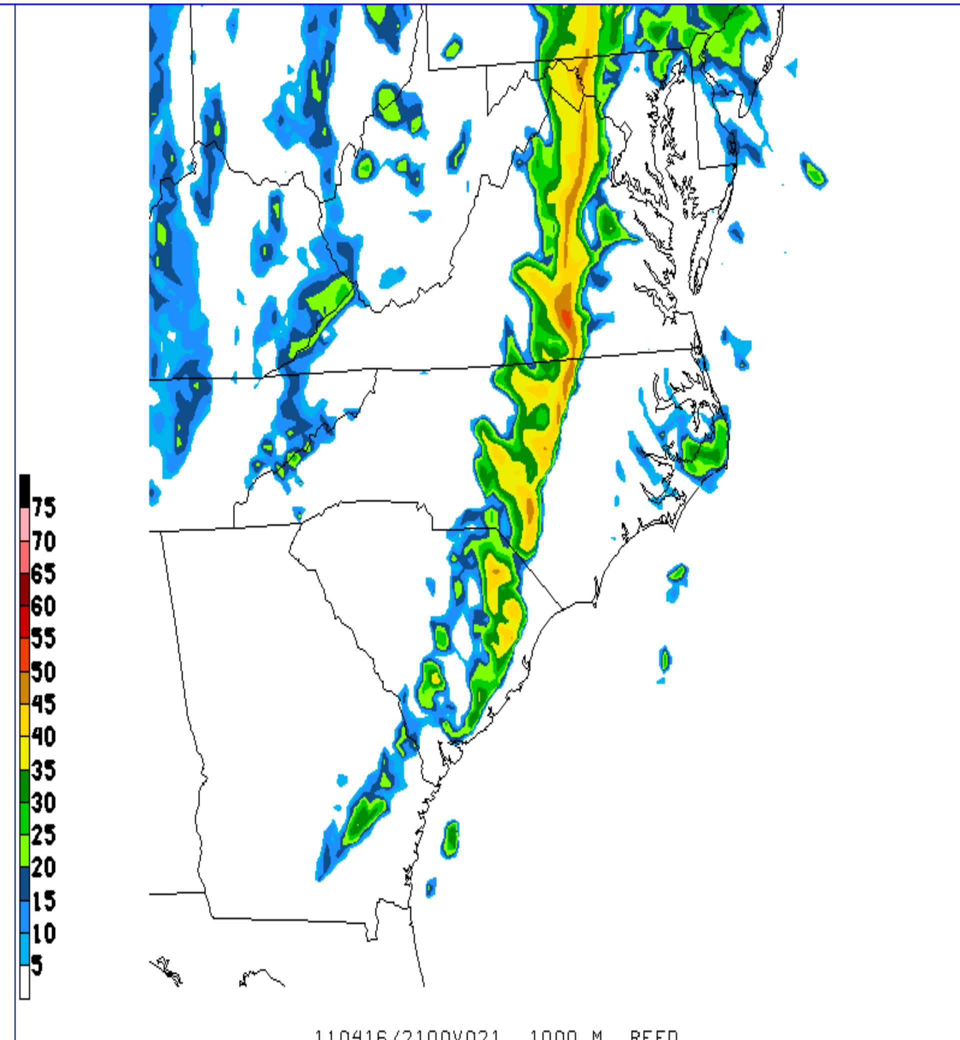


00z 4/16/11 cycle; 21-hr forecasts: 1 km AGL reflectivity

Original 4km CONUS nest run

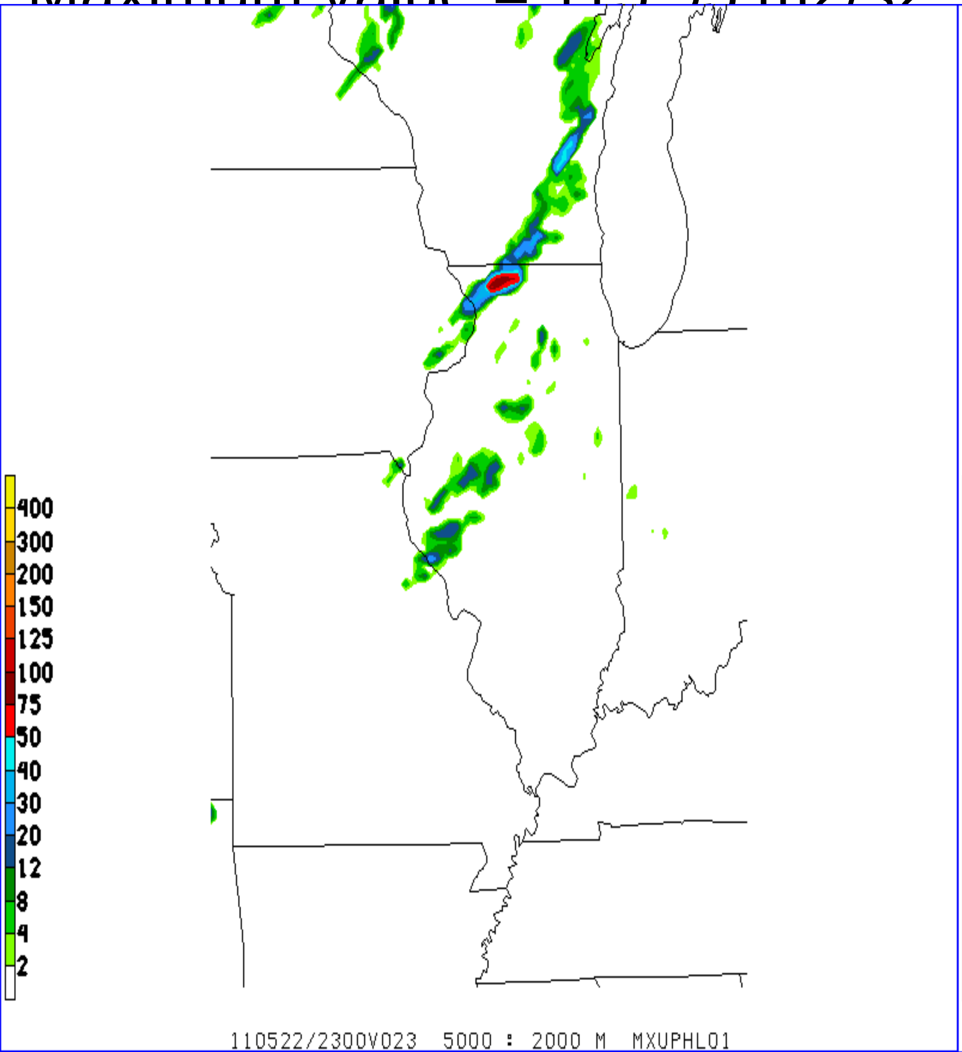


Rerun with vertical velocity

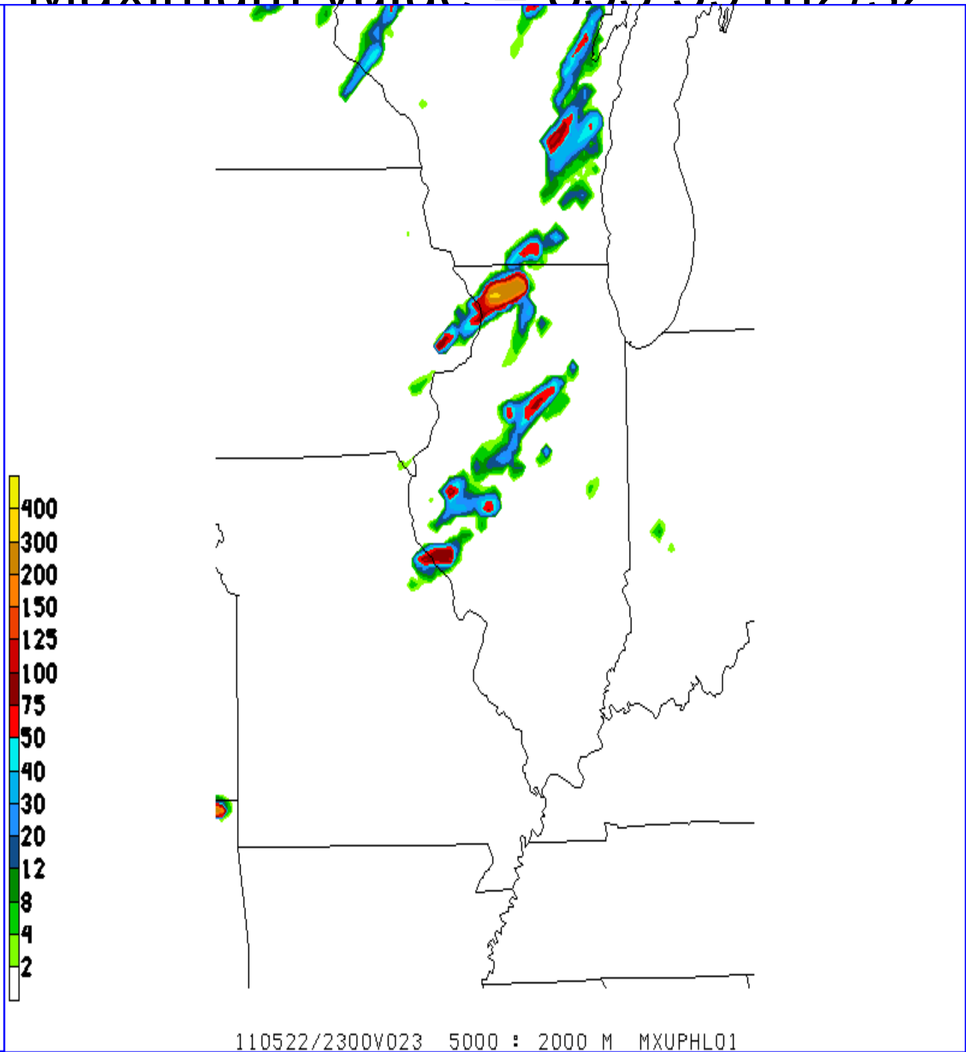


00z 5/22/11 cycle; 23-hr forecasts: Hourly maximum updraft helicity

Original 4km CONUS nest run
Maximum value = 115.95 m2/s2



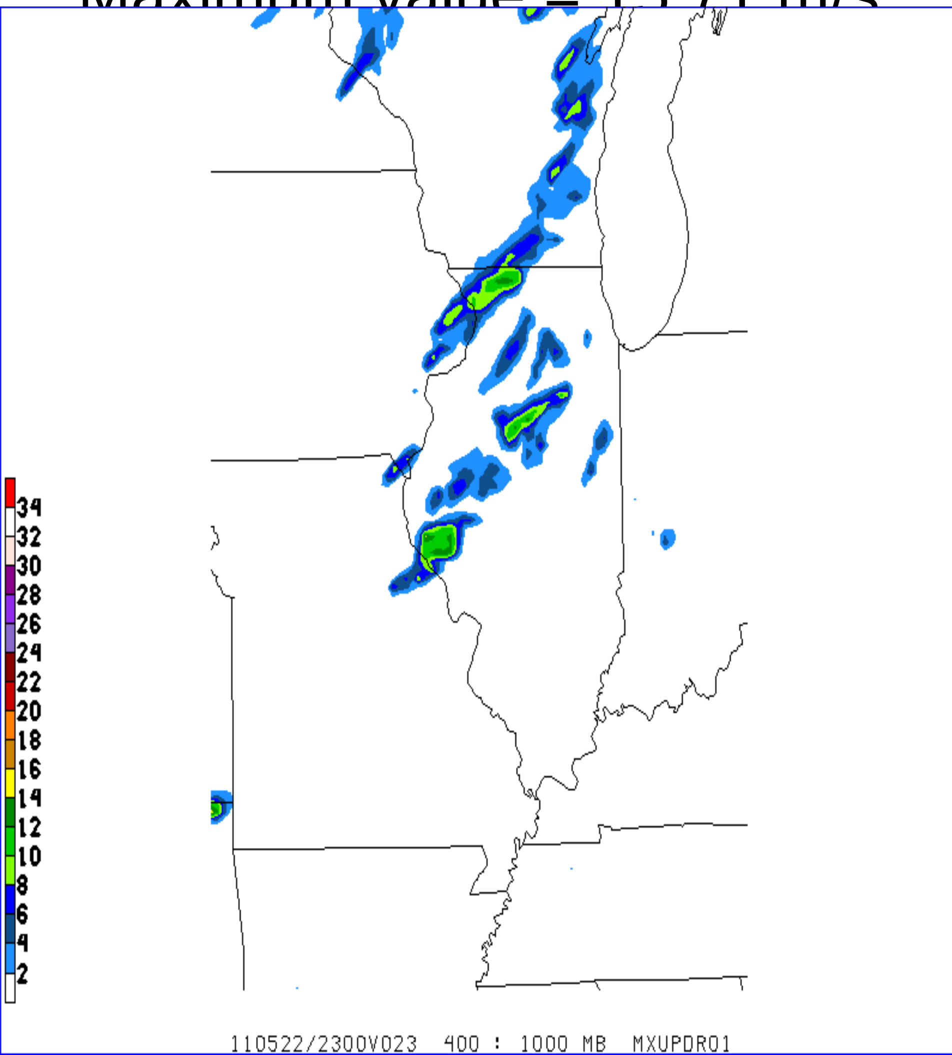
Rerun with vertical velocity fix
Maximum value = 355.59 m2/s2



00z 5/22/11 cycle; 23-hr forecasts: Hourly maximum updraft speed

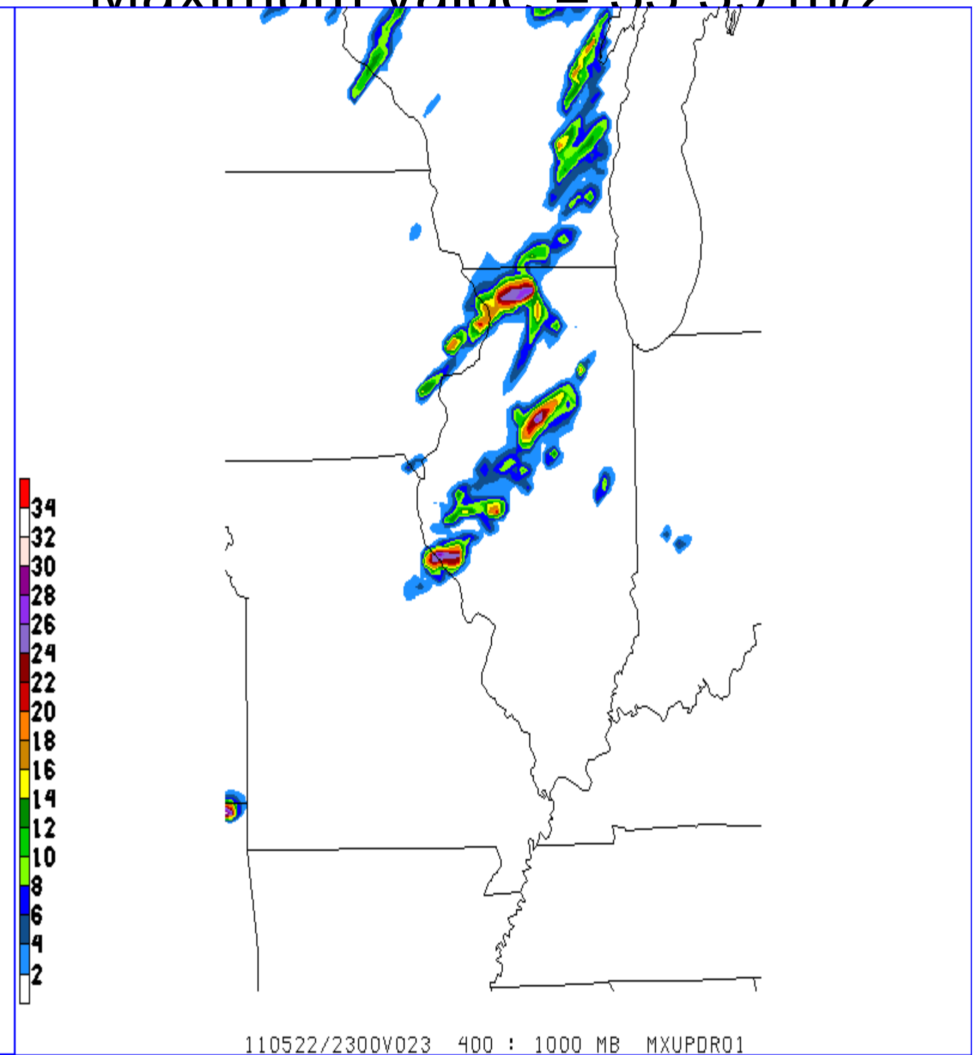
Original 4km CONUS nest run

Maximum value = 15.71 m/s



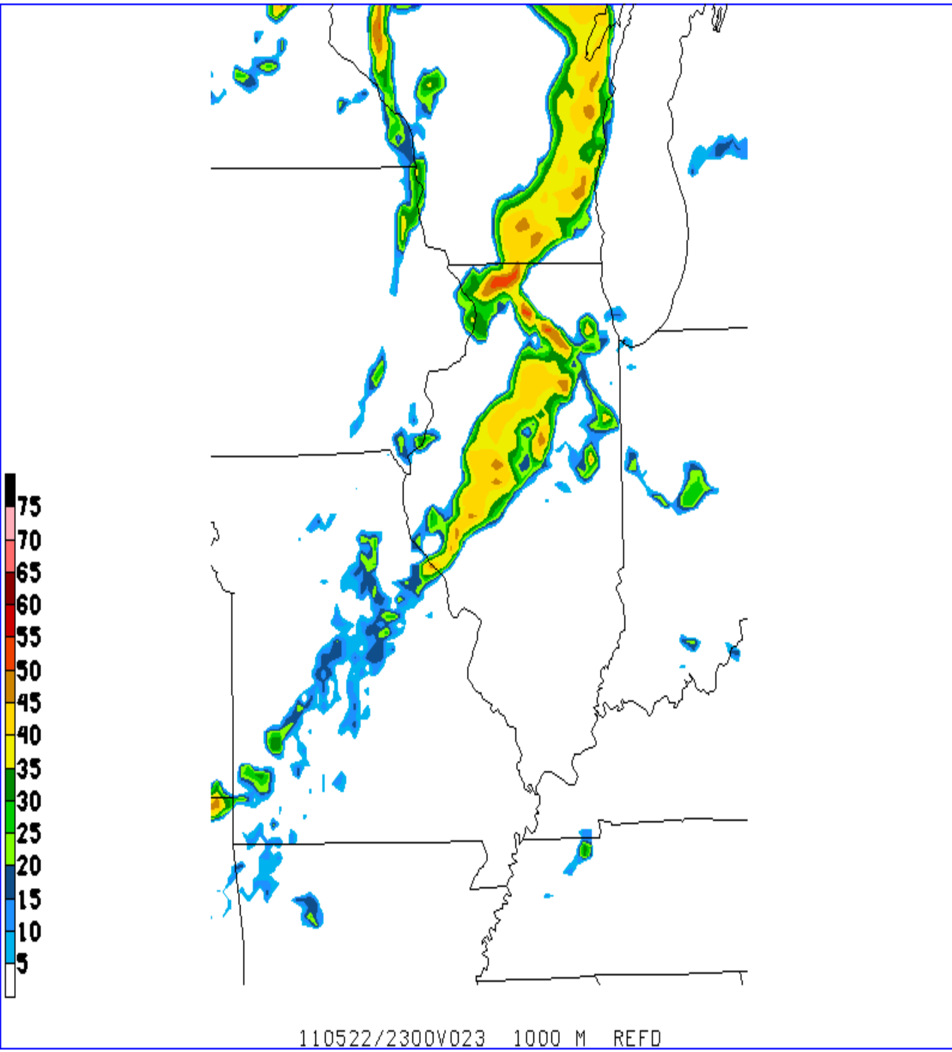
Rerun with vertical velocity fix

Maximum value = 33.39 m/2



00z 5/22/11 cycle; 23-hr forecasts: 1 km AGL reflectivity

Original 4km CONUS nest run



Rerun with vertical velocity