NAM Version 4 Science Briefing : Expanded Version

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10 March 2017

OVERVIEW

- **NAMv4 : Specific deficiencies targeted include:**
  - **Very high QPF bias in CONUS nest in warm season**
  - **Low QPF bias in 12 km NAM parent**
  - **Summer 2-m T warm bias; Winter 2-m Td moist bias**
  - **Improve coastal visibility**

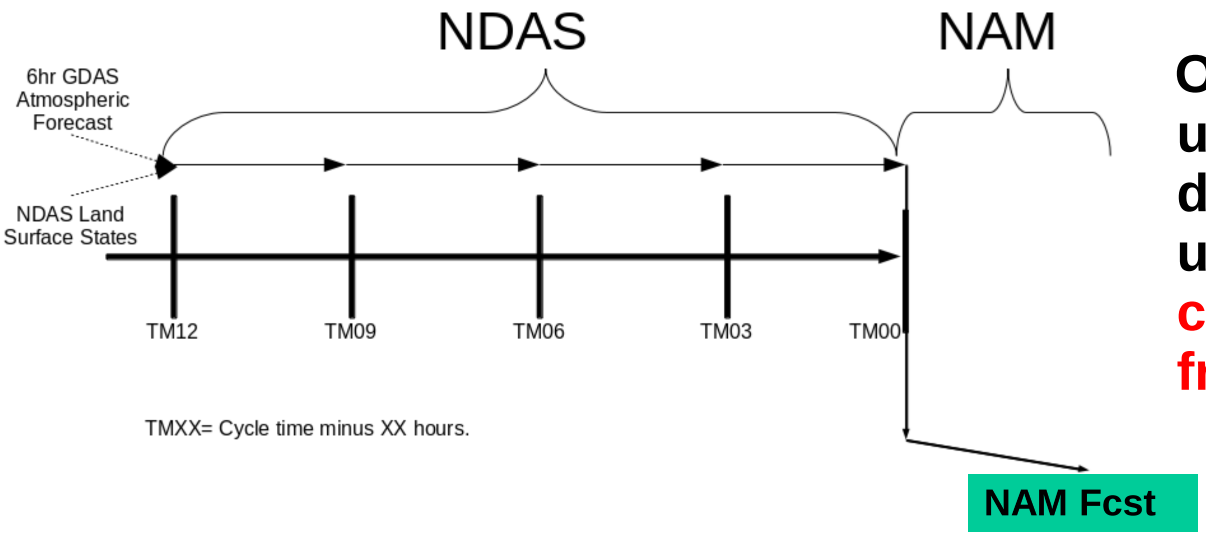
NAMv4 : What We Changed (1 of 2)

- **Resolution Changes**
  - **CONUS (4 km) and Alaska (6 km) nests → 3 km**
  - **AK and CONUS On-Demand Fire Weather nests → 1.5 km**
- **Select Model Changes**
  - **Updated microphysics → Improved stratiform precip, better anvil reflectivity, lower peak dBZs, reduce areas of light/noisy reflectivity; reduce CONUS nest high QPF bias in warm season**
  - **“Stability”changes → More frequent calls to physics, update Q every timestep, calculate cloud condensation every time step, mix out superadiabatic layers**
  - **Improved effect of frozen soil on transpiration and soil evaporation → Improved cold season Td bias**
  - **Cloud droplet radius change in F-A microphysics → 2-m T warm bias in summer**
  - **Convection changes for 12 km NAM parent → Improved low QPF bias in cool season**
- **Data Assimilation**
  - **6-h DA cycles for parent + 3km CONUS, AK nests w/hourly analysis updates → Less ‘spin-up’ time**
  - **Use of Lightning and Radar Refectivity-derived temperature tendencies in initialization**
    - **Improved short term (0-6 h) forecasts of storms in 3 km nest**
    - **Improved 0-12 h QPF**
  - **New satellite radiances, satellite winds → Improved IC’s**

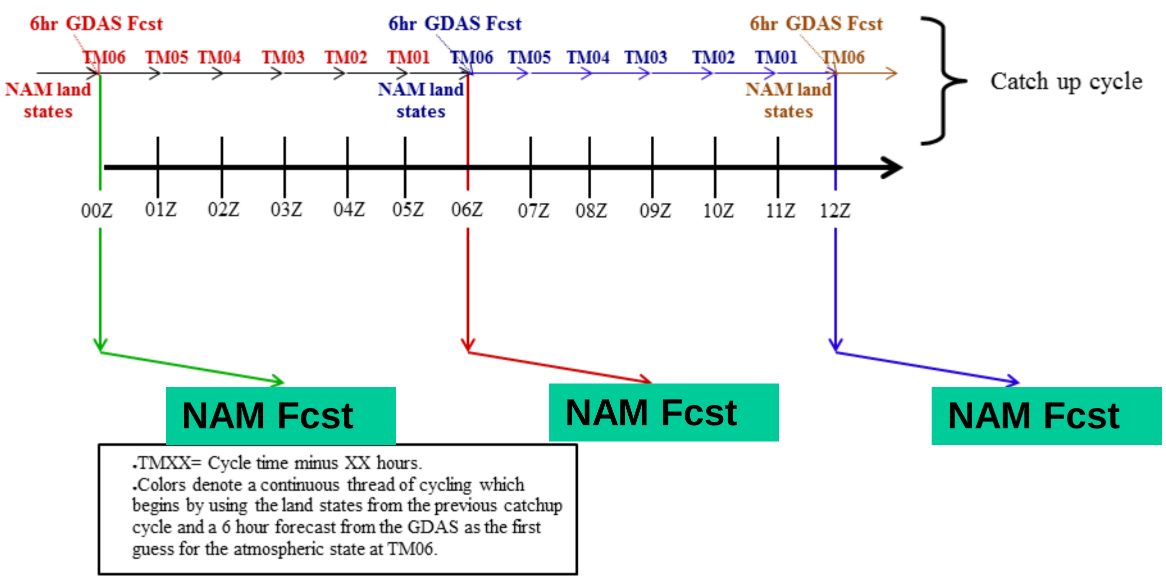
NAMv4 : What We Changed (2 of 2)

- **Other Science Changes**
  - **Tropical cyclone relocation in 12 km parent domain (Sandy Supplemental Funded)**
  - **Reinstate use of AFWA snow depth analysis with envelope adjustment**
  - **FLAKE (Fresh Water Lake) climatology in CONUS, Alaska, and Fire Weather nests**
  - **Reduced terrain smoothing for nests**
  - **Use NESDIS burned area data (30-day and 2-day average) in fire weather nest; greenness fraction, albedo and top layer soil moisture adjusted**
- **Output changes/Miscellaneous**
  - **Direct GRIB2 output from post-processing (complex compression)**
  - **Ceiling height changed from AGL to ASL**
  - **Hourly output to 60-h for NAM nests (will be added to MAG, as will FW nest); 3 km CONUS nest output grid same as ops HRRR**
  - **Threshold precip rate for categorical precip type set to 0.01 mm/h for all domains; improves spotty precip type coverage in NAM nests**
  - **Some legacy products/grids turned off (such as NAM FAX charts)**
  - **DGEX is discontinued ☺ 👍**

Data Assimilation Change : 12-h vs 6-h cycle



Ops DA = 12-h spin-up of 12 km parent domain, 3-h analysis updates. Nests not cycled; initialized from 12 km parent



NAMv4 DA = 6-h spin-up of 12km parent + 3 km CONUS/Alaska nest, with hourly analysis updates. Non-cycled nests initialized from 12 km parent

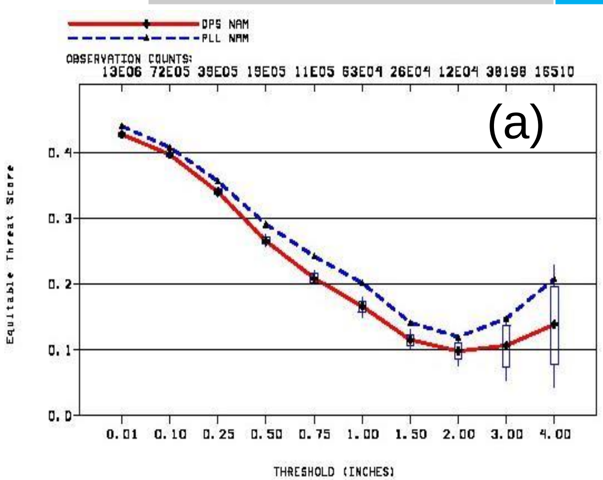
Ops vs Parallel NAM Scoreboards

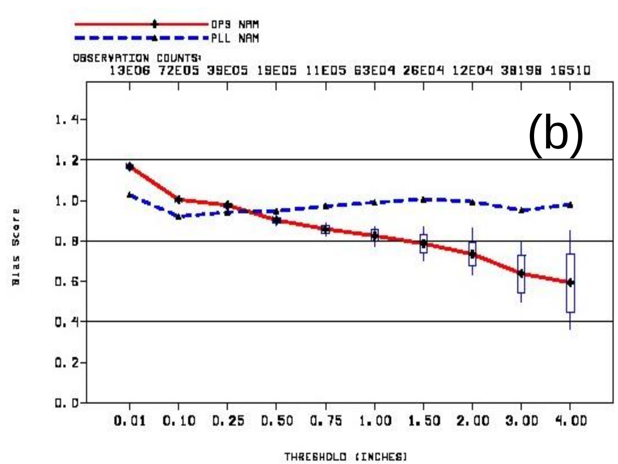
- “N” - Little or no difference between ops and para
- “+” = Parallel better than ops (blue)
- “-” = Parallel worse than ops (red)
- Orange boxes = mixed results

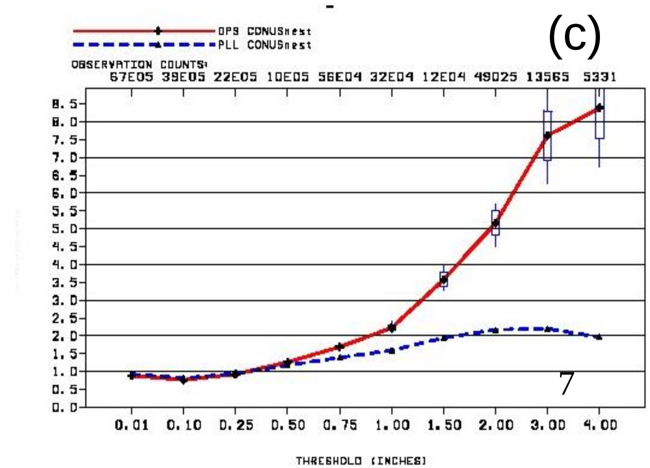
- There is no significance to the size of the “+” or “-”

Scoreboard : 24-h QPF ETS/bias

	12 km ETS	12 km Bias	CONUS Nest ETS	CONUS Nest Bias
Dec 15-Feb 16	+	+	+	+
Mar 16-May 16	+	+	+	+
June 16-Aug 16	N	- (at higher thresholds)	+	++ see (c)
Sept 16 – Nov 16	+ see (a)	+ see (b)	+	+
Dec 16 – Feb 17	+ (slight)	+	N	N (overall) (**wetter at higher thresholds in west, drier in east**)



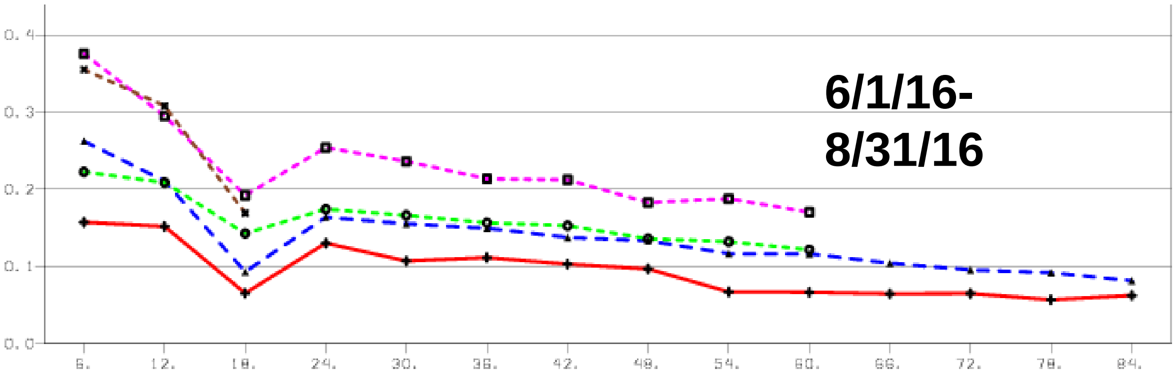


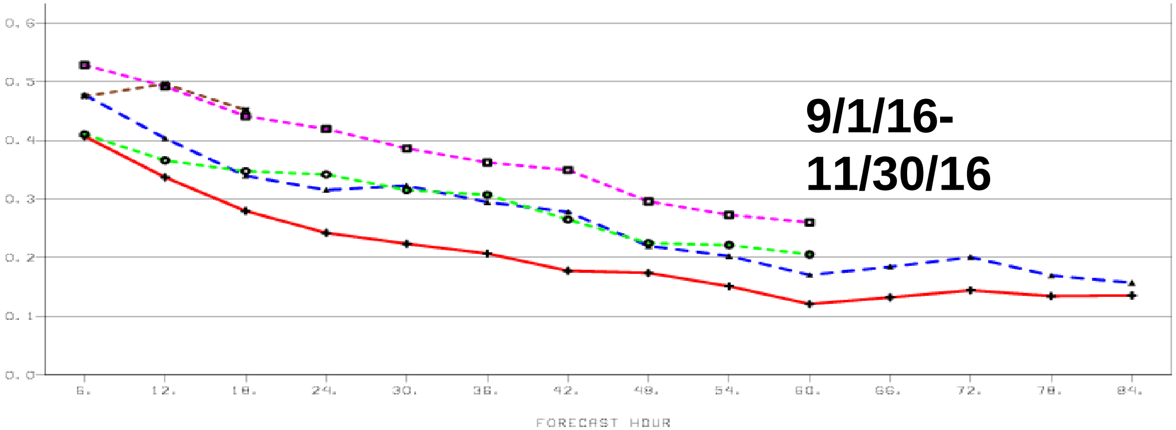


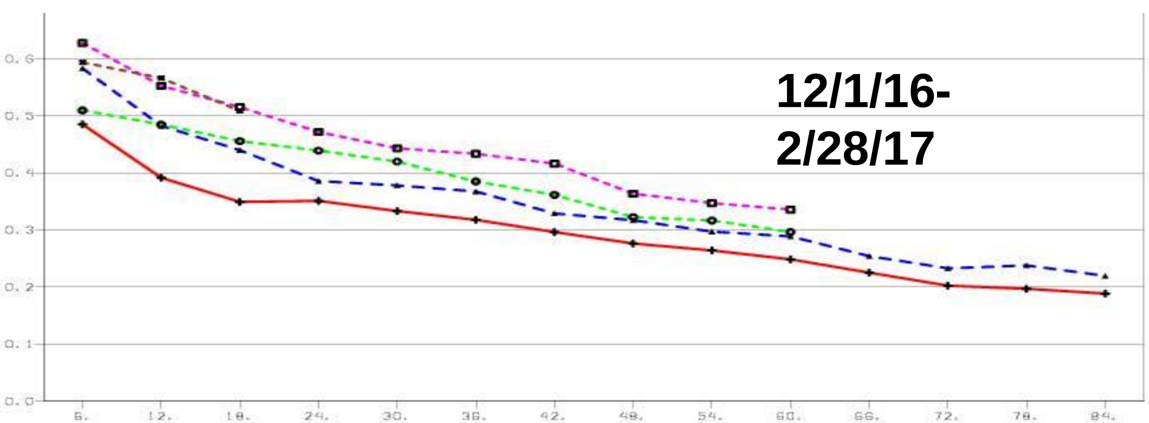
Warm Season High Bias in Heavy Rainfall in CONUS Nest

- Pointed out by WPC and others
- Seasonal, with largest biases in the summer.
- Much improved in 3-km NAMv4 over ops 4-km:
  - Improved data assimilation (hourly cycle)
  - Calling physics more frequently; advect specific humidity every dynamics time step; removal of supersaturated and superadiabatic layers
  - Microphysics modifications.

Seasonal 6-h QPF Fractional Skill Scores





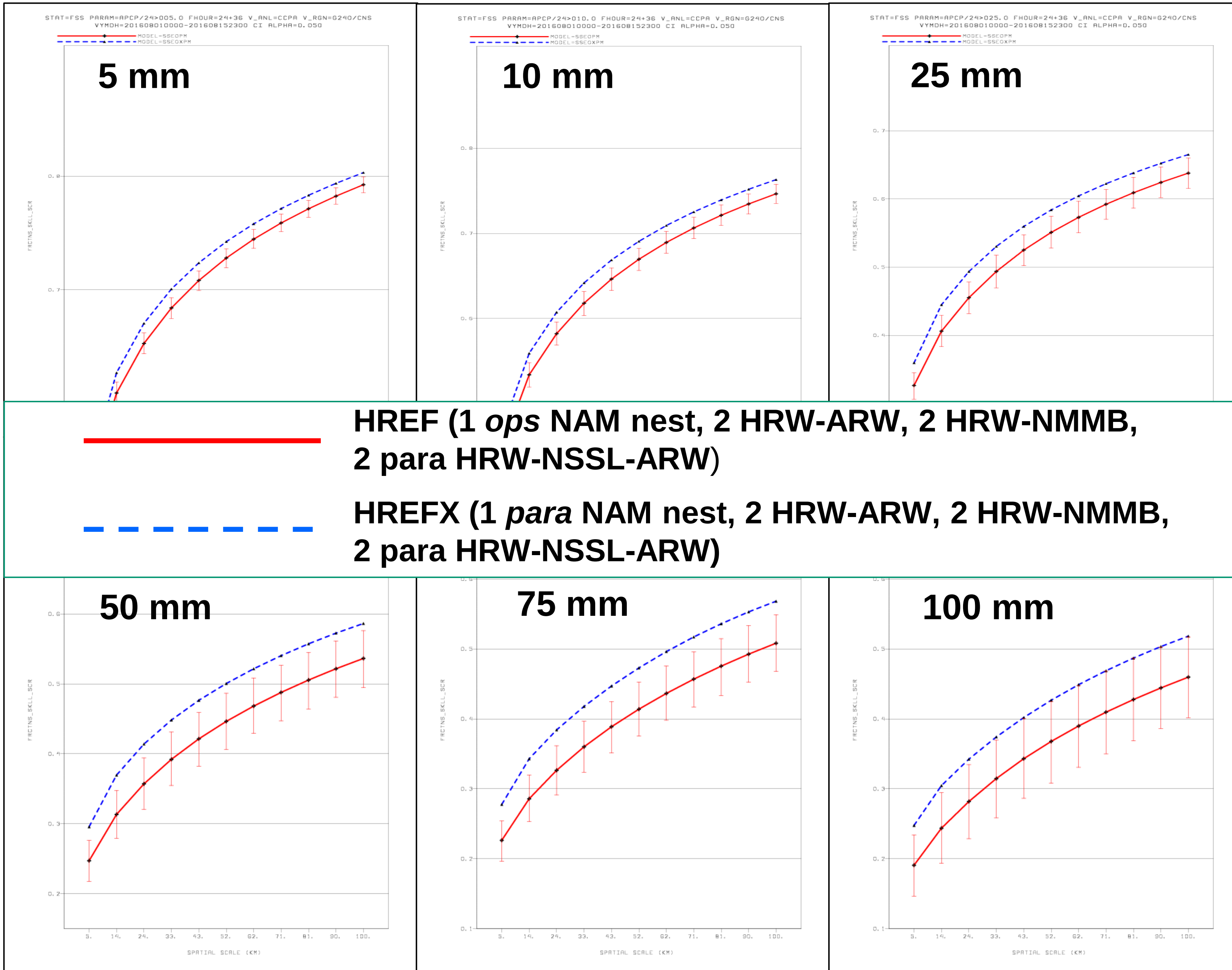


Horizontal Spatial Scale < 52 km

Threshold > 20 mm / 6 h

Ops NAM 12 km = Red
Pll NAM 12 km = Blue
Ops NAM 4 km CONUS = Green
Pll NAM 3 km CONUS = Magenta
HRRR = Brown

Improvement of HREF QPF Skill (as measured by 24-36 h Fractional Skill Score) with inclusion of para NAM 3 km nest : 1-15 Aug 2016



Scoreboard : 850-100 mb RMS height error, 12 km NAM

	CONUS 24-h	CONUS 48-h	CONUS 72-h	Alaska 24-h	Alaska 48-h	Alaska 72-h
Dec 15-Feb 16	+	+	+	+	+	+
Mar 16-May 16	N	N	+ (slight)	+ (slight)	+ (slight)	N
Jun 16-Aug 16	+ (> 400 mb) - (< 400 mb)	Same as 24-h	Same as 24-h	N	N	N
Sep 16-Nov 16	+ (slight)	+ (slight)	+ (slight)	N	N	N
Dec 16-Feb 17	+	+	+	N	N	N

Scoreboard : 850-100 mb RMS Temp error, 12 km NAM

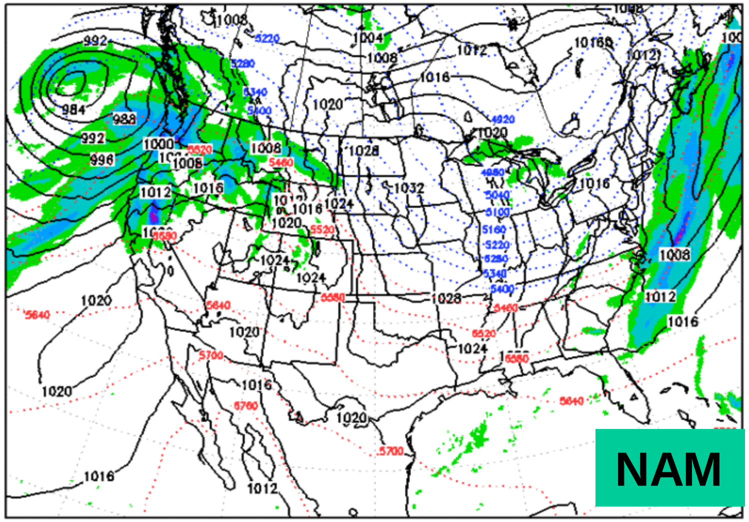
	CONUS 24-h	CONUS 48-h	CONUS 72-h	Alaska 24-h	Alaska 48-h	Alaska 72-h
Dec 15-Feb 16	+ (slight)	+ (slight)	+	N	+	+
Mar 16-May 16	+ (slight)	+ (slight)	+ (slight)	+ (slight)	+ (slight)	N
Jun 16-Aug 16	N (> 400 mb) + (< 400 mb)	Same as 24-h	Same as 24-h	Same as CONUS	Same as CONUS	Same as CONUS
Sep 16-Nov 16	+	+	+	+ (slight)	+ (slight)	+ (slight)
Dec 16-Feb 17	+	+	+	**N (> 400 mb) + (< 400 mb)**	**N (>500mb) + (< 500mb)**	**N (>700mb) + (<700mb)**

Scoreboard : 850-100 mb RMS vector wind error, 12 km NAM

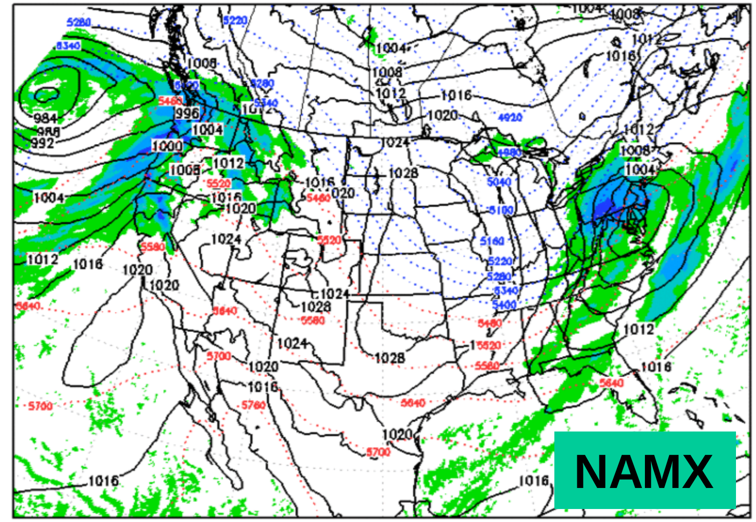
	CONUS 24-h	CONUS 48-h	CONUS 72-h	Alaska 24-h	Alaska 48-h	Alaska 72-h
Dec 15-Feb 16	N	N	N	N	+ (slight)	+ (slight)
Mar 16-May 16	N	N	N	N	N	N
Jun 16-Aug 16	N	N	N	N	N	N
Sep 16-Nov 16	+	+	+	N	N	N
Dec 16-Feb 17	+	+	+	+ (< 500 mb)	N	N

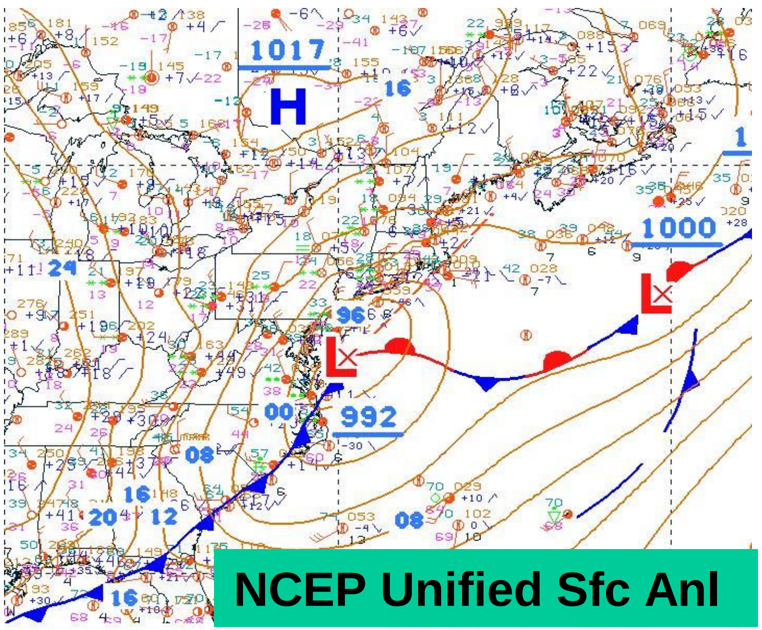
Ops NAM vs NAMv4 : 84-h SLP fcst valid 12z 2/9/2017

SLP,3–H APCP NAM 84H FCST VALID 12Z 09 FEB 2017



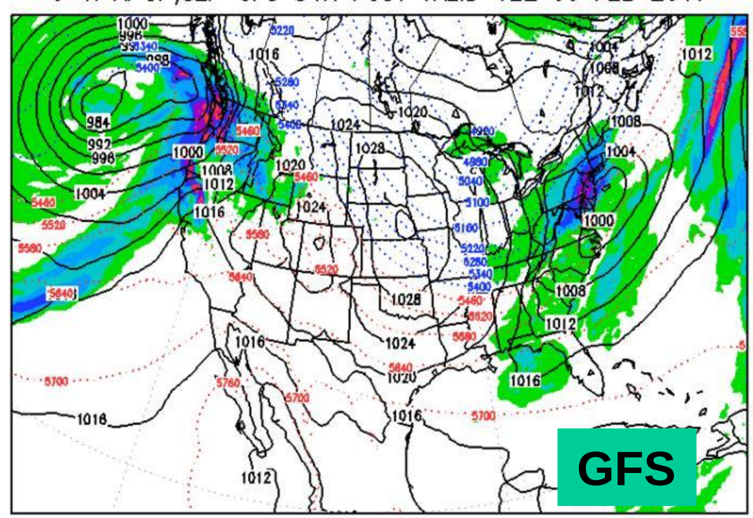
SLP,3–H APCP NAMX 84H FCST VALID 12Z 09 FEB 2017

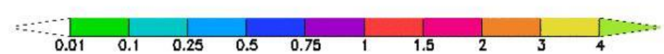




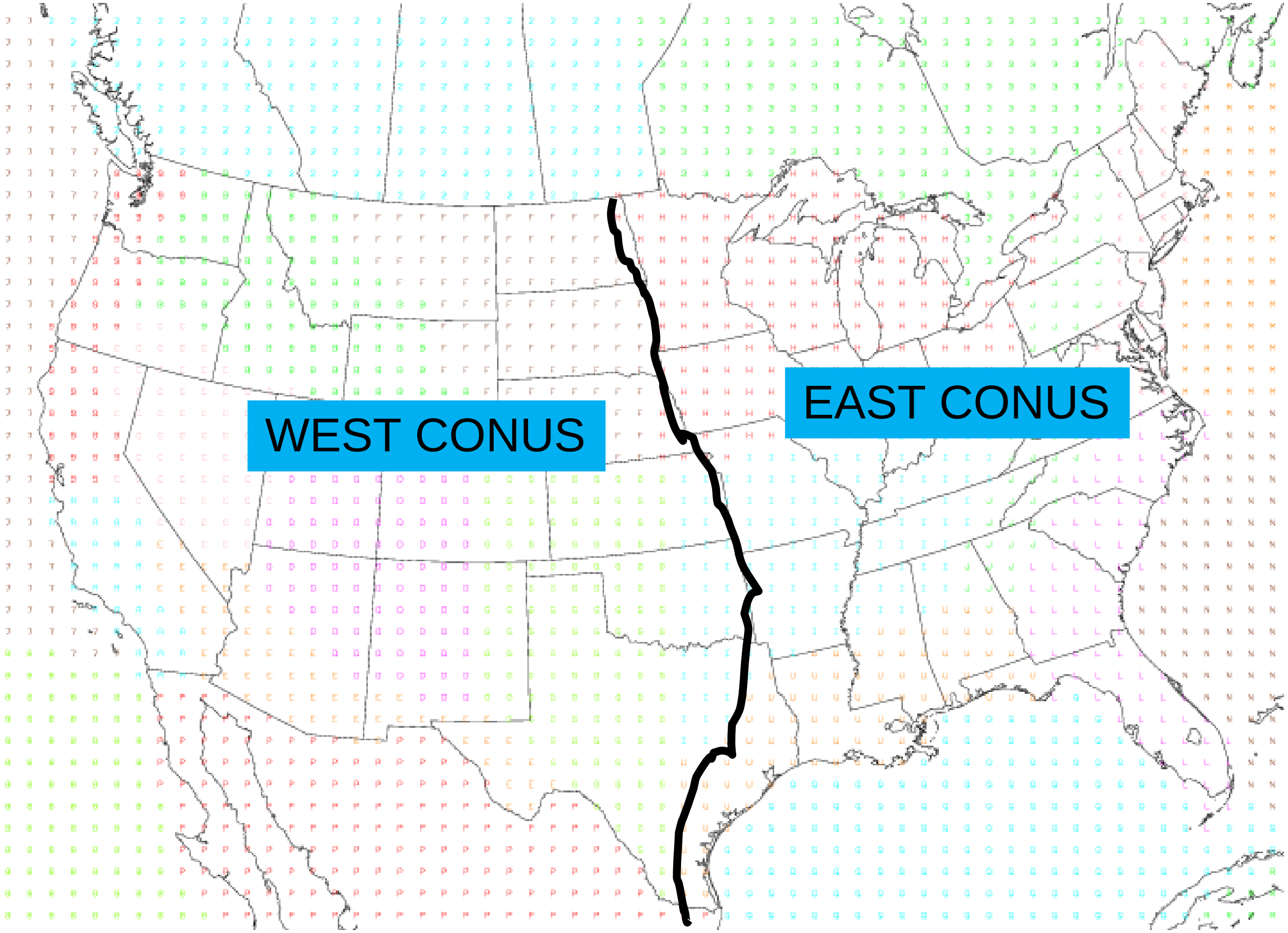
12 UTC FEBRUARY 09 2017 – NATIONAL WEATHER SERVICE

6–H APCP,SLP GFS 84H FCST VALID 12Z 09 FEB 2017

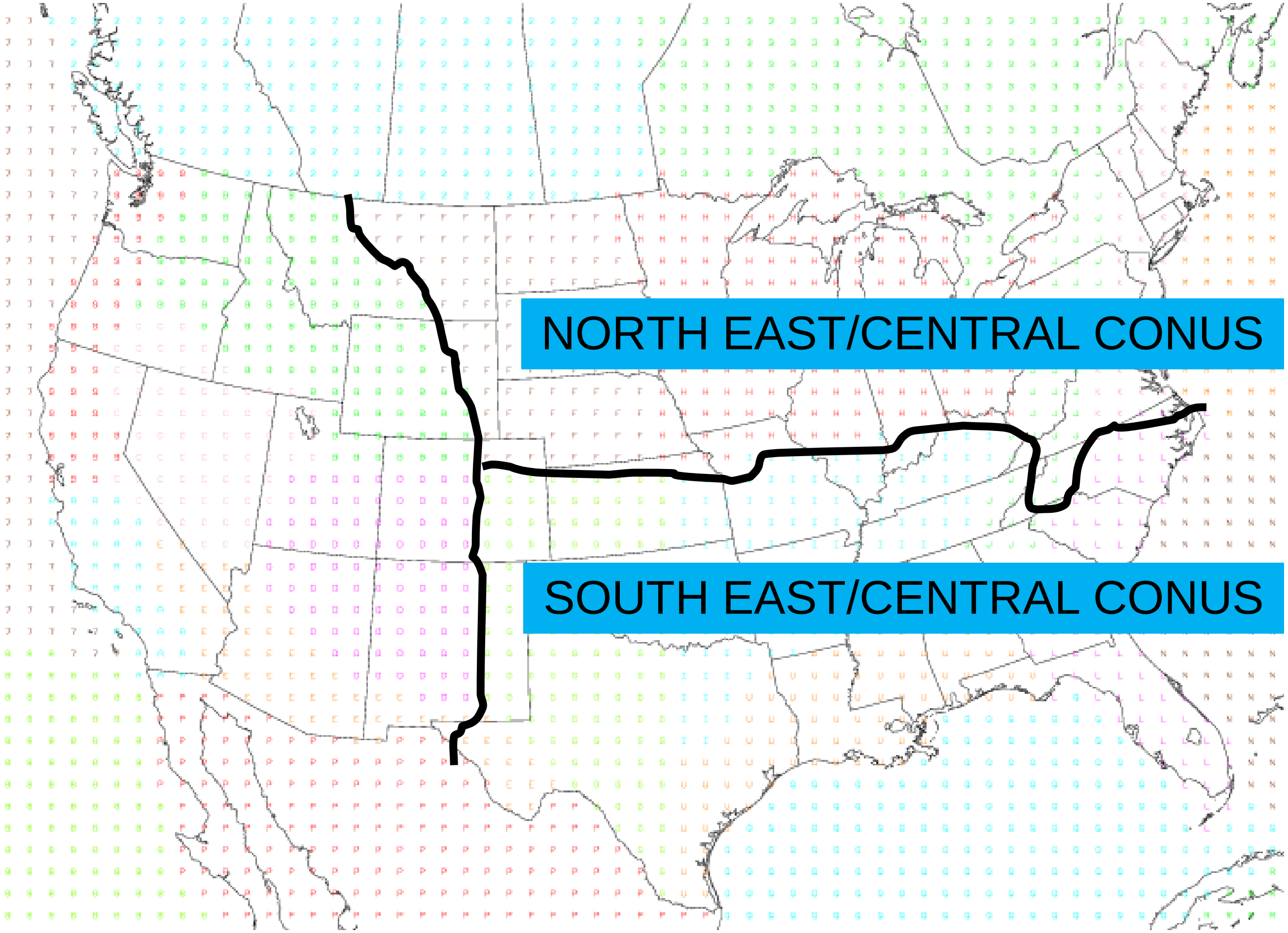




Surface verification sub-regions



Surface verification sub-regions



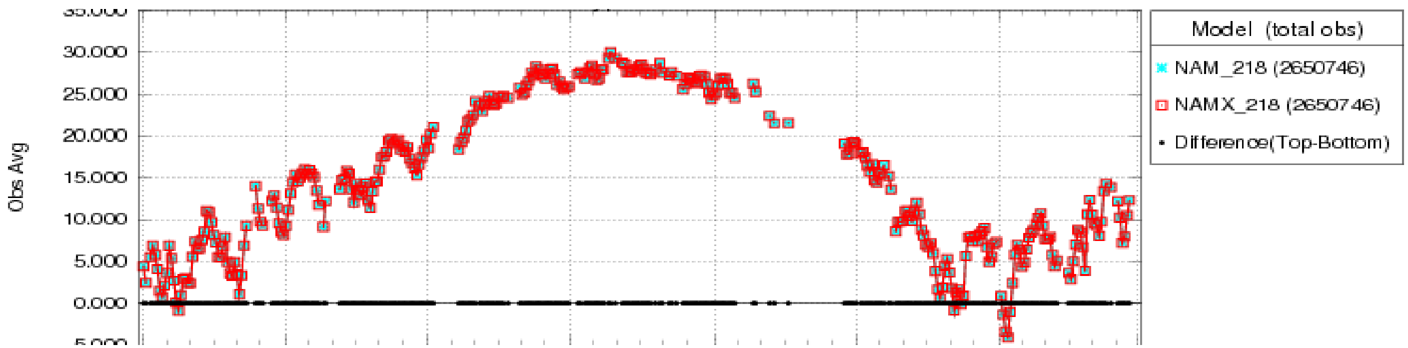
Scoreboard : Diurnal 2-m Temp Bias, 00z cycle, 12 km NAM

	Eastern CONUS	Western CONUS	North East/Central CONUS	South East/Central CONUS	Alaska
Dec 15-Feb 16	+ (slight)	N	+	N (Day) - (Night,slight)	N
Mar 16-May 16	- (Day) + (Night)	-	- (Day) + (Night)	- (Day) + (Night)	- (slight)
Jun 16-Aug 16	+	+ (0-21 h) - (24-84 h)	+	+	-
Sep 16-Nov 16	- (Day) + (Night)	- (Day) N (Night)	+	- (Day) N (Night)	N
Dec 16-Feb 17	- (Day) N (Night)	- (slight)	N (Day) + (Night)	N (Day) - (Night)	N

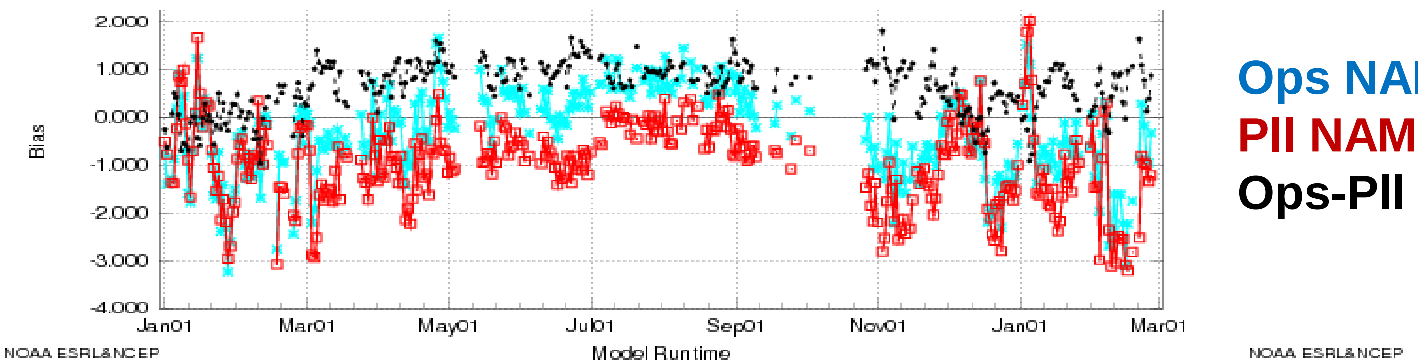
Change addressing daytime 2-m T warm bias in summer

- **Cloud droplet effective radius no longer forced to be between 10-15 microns, can be as low as 5 microns. This change reduces incoming surface shortwave fluxes under liquid clouds and will reduce daytime 2-m T bias.**

Time Series of CONUS-averaged surface temperature at 21z from 1/1/16 – 3/2/17



2-m T bias 69-h forecast from 00z run (21z valid time) from 8/1/15-3/2/17



Ops NAM = Blue
Pll NAM = Red
Ops-Pll = Black

Summer 2016 : Change reduces ops NAM warm bias
Winter : Little difference in 2015/16 (limited liquid clouds), bigger diff in 2016/17 (warmer winter in CONUS)
Spring/Fall 2016 : Change leads to cool bias in pll NAM

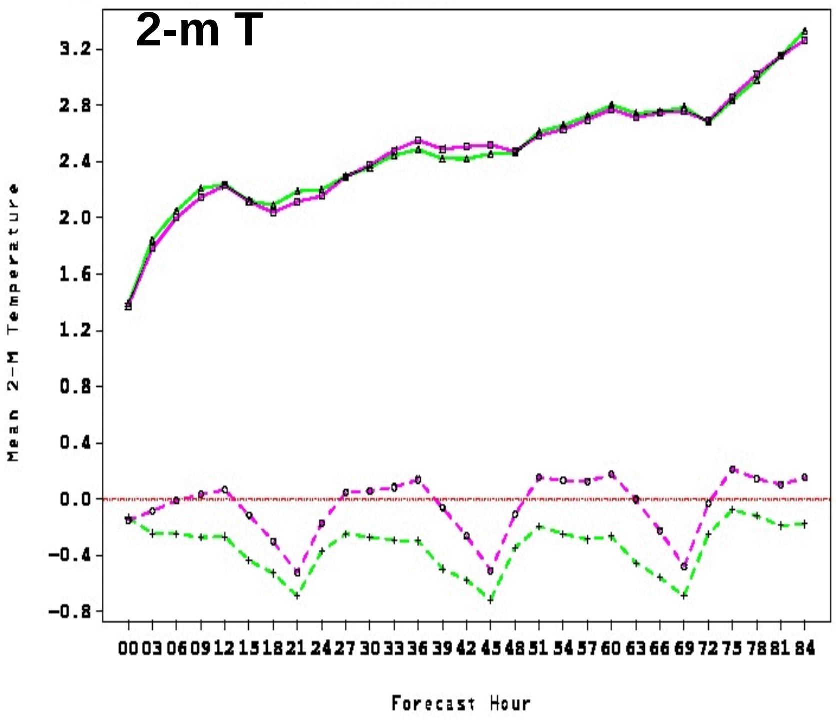
Scoreboard : Diurnal 2-m Td Bias, 00z cycle, 12 km NAM

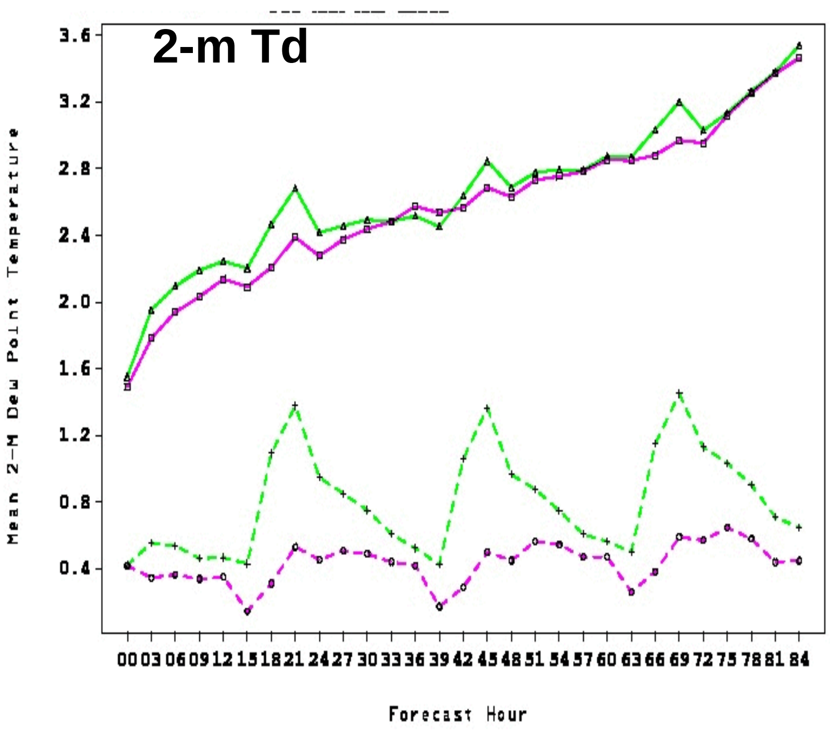
	Eastern CONUS	Western CONUS	North East/Central CONUS	South East/Central CONUS	Alaska
Dec 15-Feb 16	+	+	+	+	N
Mar 16-May 16	+	+	+	+	+ (slight)
Jun 16-Aug 16	N	-	+ (slight)	- (slight)	- (slight)
Sep 16-Nov 16	+ (0-60 h) - (63-84 h)	+ (0-36h) - (39-60h)	+	- (Slight)	+
Dec 16-Feb 17	+	+	+	+	N

Model change to target high Td bias in cool season

- **Threshold snow depth (water equivalent in meters) that implies 100% snow coverage is increased by 4x;**
- **Consider effects of frozen soil on plant transpiration and canopy conductance (reduce direct evaporation from the soil → ice not available to plants for evaporation). Leads to improved latent heat calculation from frozen soil.**

Northern CONUS 2-m T/Td Diurnal RMS (solid)/Bias (dashed); Ops NAM=green, Pll NAM=magenta : 12/1/16 – 1/2/17, 00z cycle

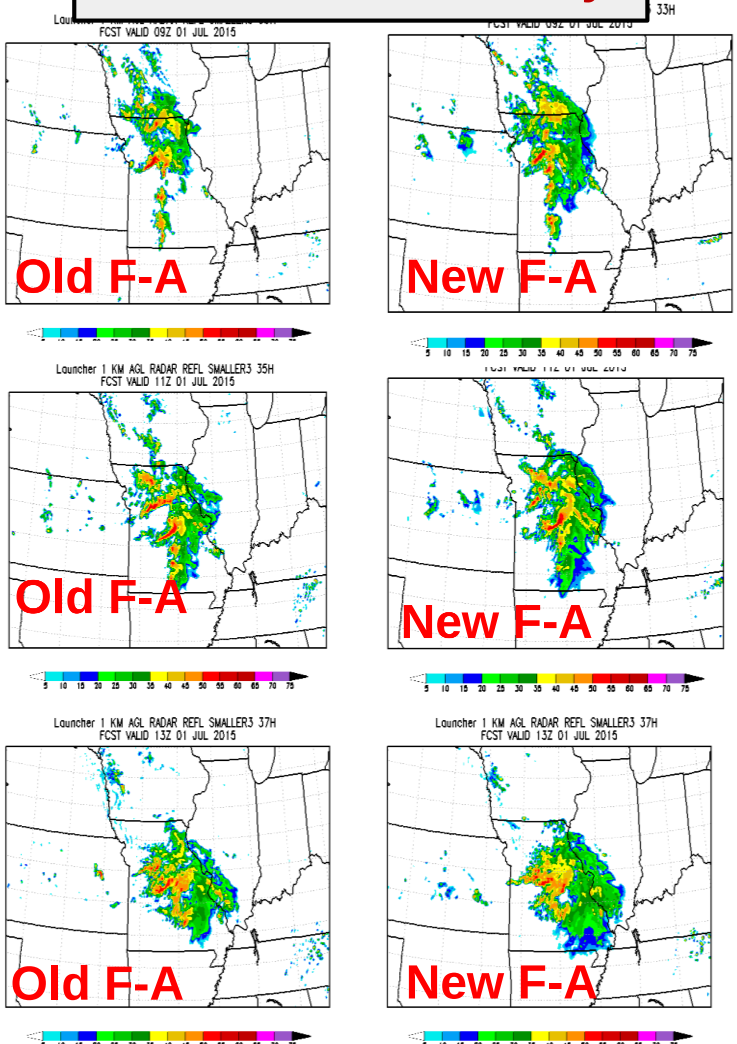




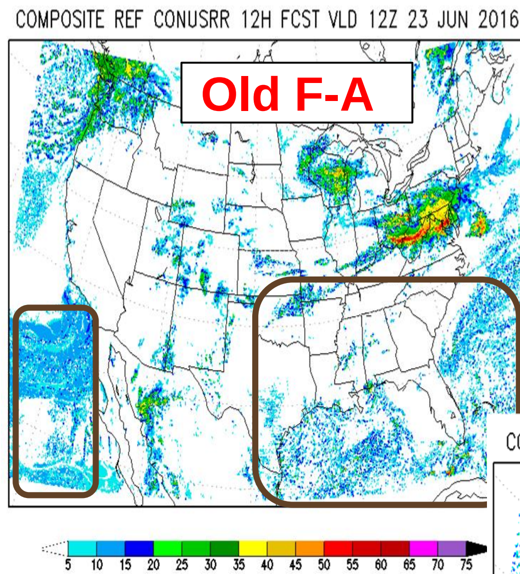
Refectivity Improvements from Ferrier-Aligo (F-A) Microphysics Changes

Increased rainfall below stratiform anvils

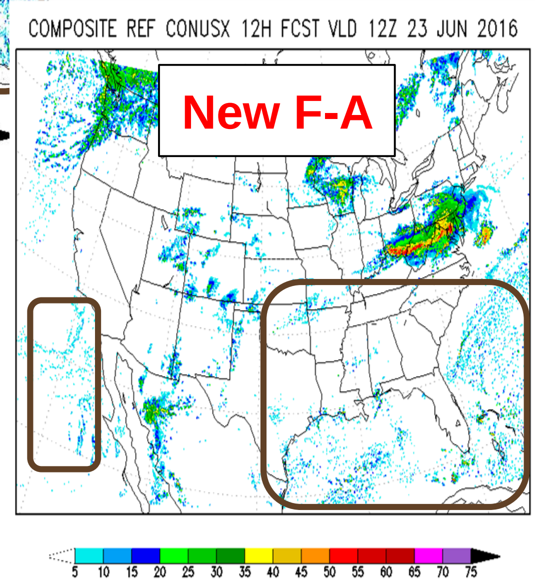
1-km AGL Reflectivity



Composite Reflectivity



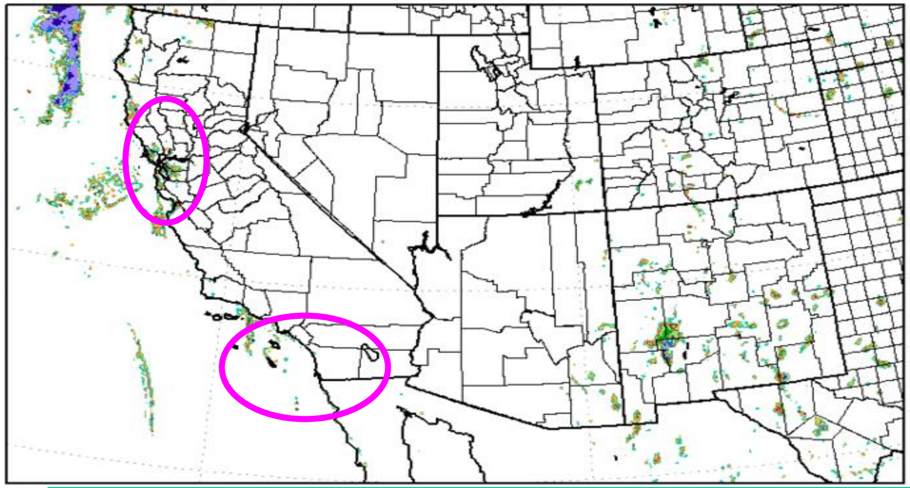
Echoes from small rain drops formed in thin PBL clouds



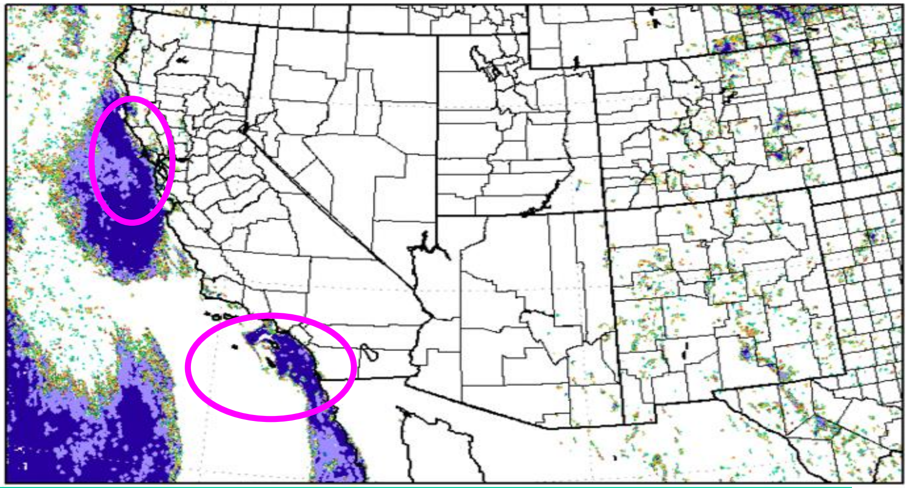
Reduced dBZ - rain treated as drizzle in thin PBL clouds

Visibility Improvements : In Ops NAM, LH fluxes shut off when lowest model layer RH=95%; removed in NAMv4

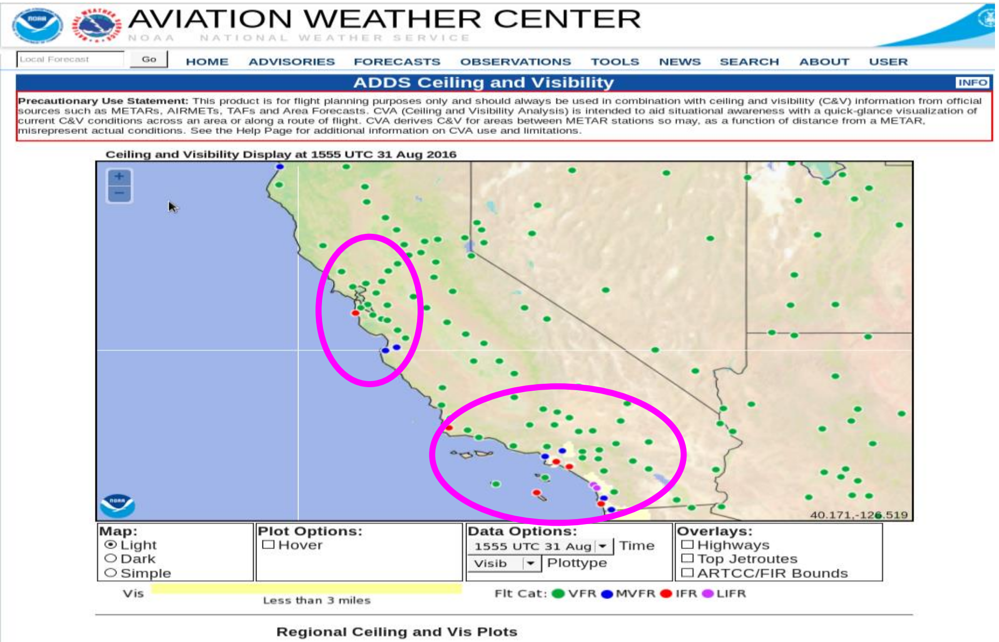
VISIBILITY (KM) OPSNEST 39H FCST VALID 15Z 31 AUG 2016



VISIBILITY (KM) PLLNEST 39H FCST VALID 15Z 31 AUG 2016



Left (OPS Nest): Very little visibility reduction ; Right (PLL Nest): Visibilities are significantly reduced

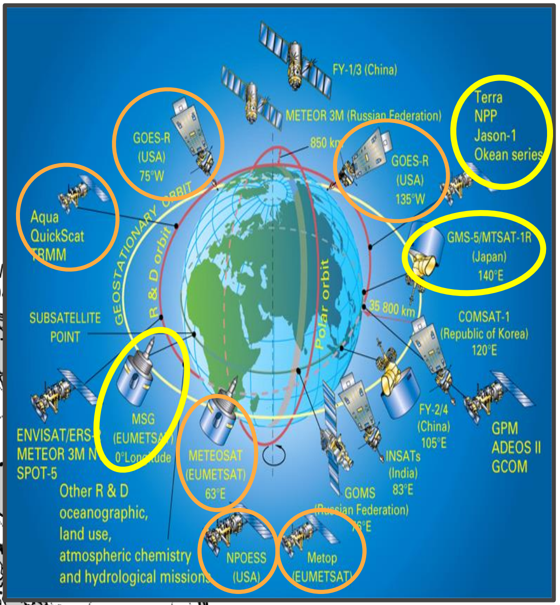


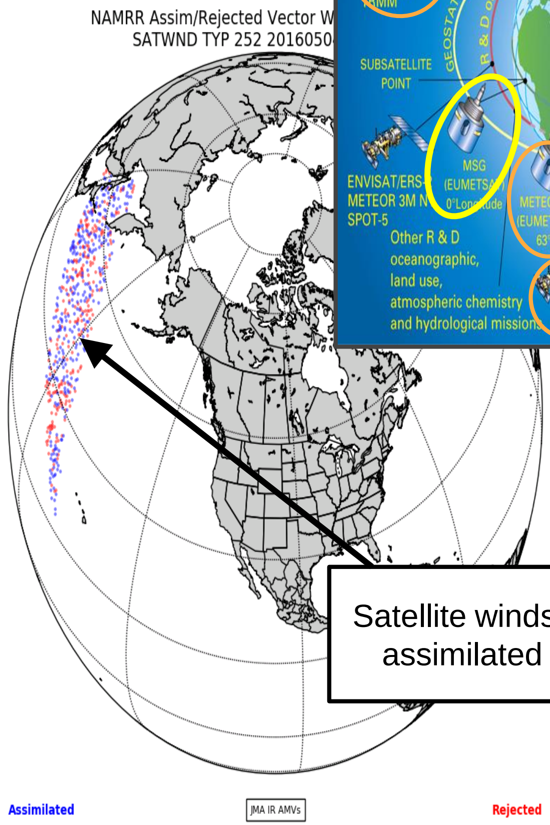
Visibility obs (55 min later) from AWC showed areas of reduced visibilities (red and blue dots)

BACKUP SLIDES

New Observations in NAMv4: Aircraft and Satellite

- More aircraft data from Sandy Supplemental & TAMDAR
  - Aeroméxico, ADS-C, Air Wisconsin
- New Radiances:
  - METOP-B: HIRS4 (monitored) AMSUA, MHS, IASI
  - NOAA NPP: ATMS, CRIS
  - METEOSAT-10: SEVIRI
  - DMSP-F17: SSMIS
- New Satellite Winds:
  - Himawari-8
  - METEOSAT-7,-10: Imager WV AMVs
  - NOAA-15, 18, 19: AVHRR IR AMVs
  - METOP-A,-B: AVHRR IR AMVs
- New GPS
  - METOP-B (subtype 3)



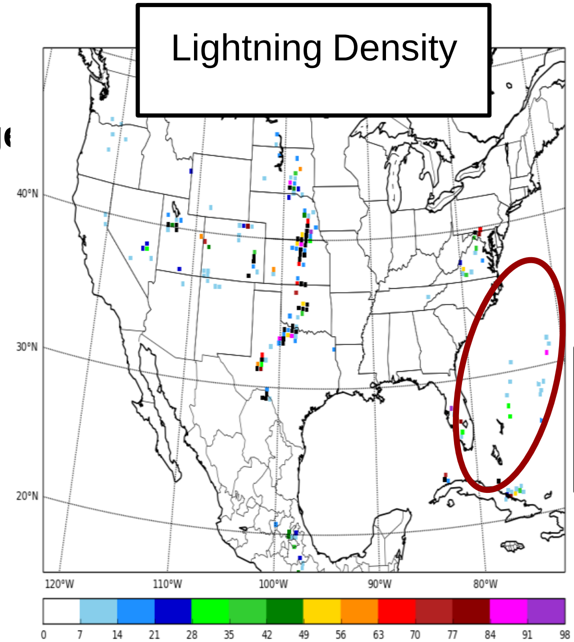


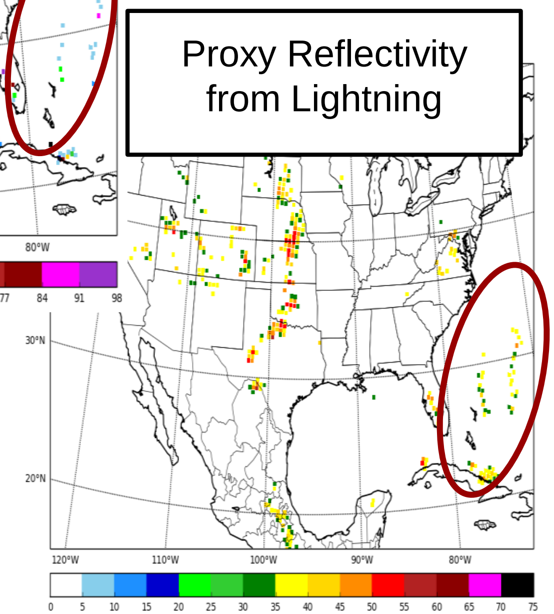
Satellite winds from JMA Himawari-8 (IR) assimilated in developmental NAMv4

New Observations in NAMv4: Lightning Data

Assimilation of Lightning Observations

- **Clear indication of convective storm(s)**
  - **Can provide data where radar coverage is poor or non-existent**
  - **Current obs from NLDN and ENI networks**
- **Current approach: Convert lightning observations to reflectivity**
  - **Use reflectivity in cloud analysis**
  - **Discussion ongoing with colleagues for other methods**





Updates to F-A Microphysics

- **Increased relative humidity threshold for the onset of condensation from 98% to 100% in the 3-km NAM nest.**
- **Nucleation of small ice crystals uses Fletcher for T ≥ -21°C and Cooper for colder temperatures; their number concentrations (# conc.) are ≤ 250 L^{-1} as in Thompson scheme.**
- **Allow much larger # conc. of snow at cold temperatures (also limited to ≤ 250 L^{-1} as in Thompson scheme), which increased size of anvils and reduced high reflectivity bias.**
- **Reduced widespread light reflectivity from shallow PBL clouds:**
  - **Added a new drizzle parameterization that reduced drop sizes & increased their # conc based on Westbrook *et al* (2010, *Atmos Meas. Tech.*).**
  - **Delayed onset of drizzle/rain by (1) increasing assumed cloud droplet # conc. from 200 to 300 cm^{-3}, and (2) allowing cloud water autoconversion (self collection) to rain to occur only for cloud water content >1.25 g m^{-3}.**

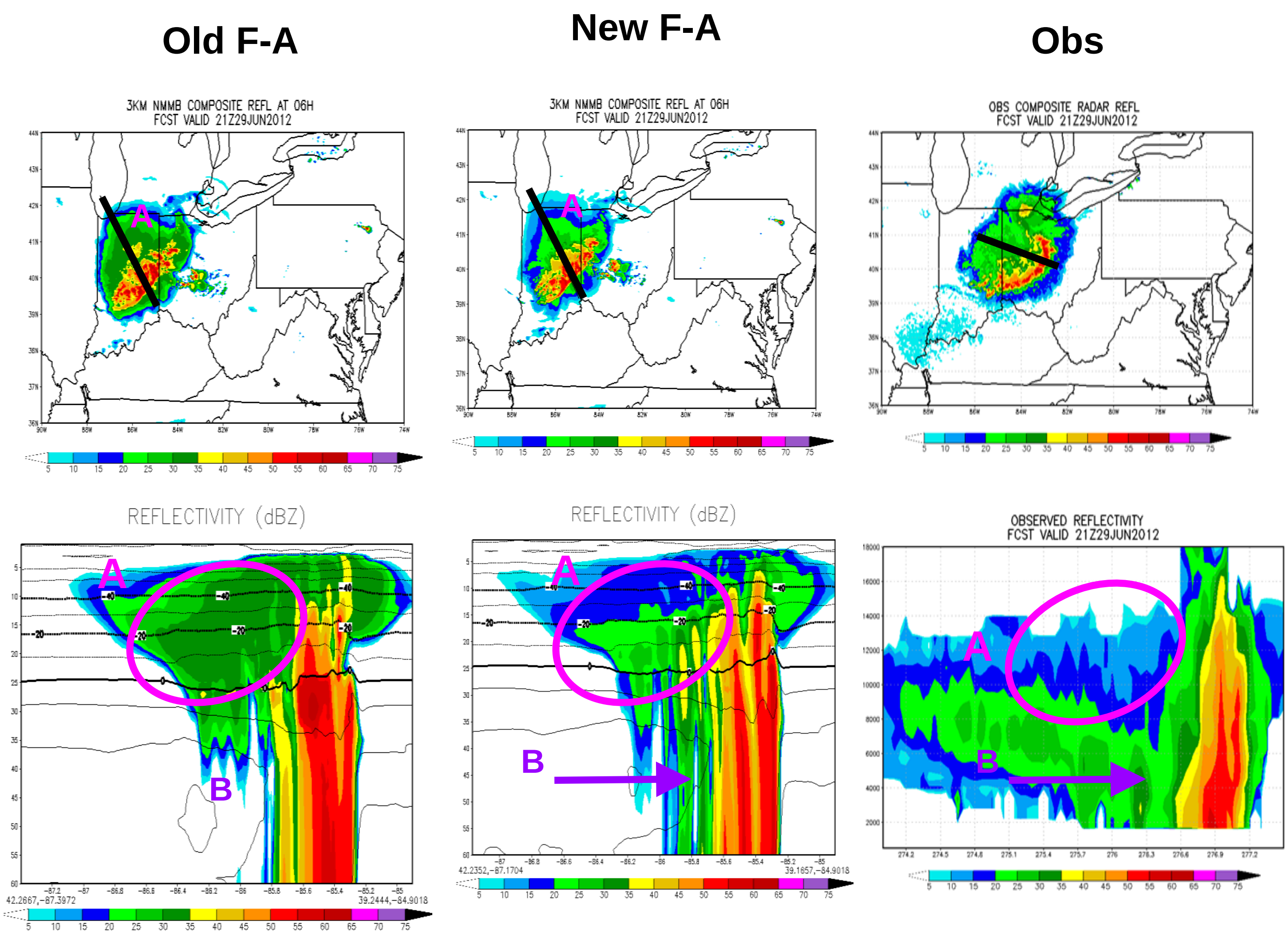
Updates to F-A Microphysics (cont.)

- Use Thompson graupel fall speeds for large graupel/hail (D_{mean}=1 mm) to reduce area of broad convective regions seen in operational NAM nest.
- Assume mean drop sizes fixed in stratiform rain with height below stratiform melting layers (following Thompson scheme)
  - Reduced rain evaporation in drier subcloud air.
  - Improved vertical structure of radar reflectivity.
- Reduced high bias in heavy rainfall:
  - Added a transition to allow for more gradual changes in graupel density and # conc. between convective and stratiform regions.
  - Reduced light-moderately rimed ice fall speeds.
  - Fixed a bug pointed out by ESRL-PSD, in which the change reduced the size of the snow/graupel particles and reduced their fall velocities.

Impact of Microphysics Changes

A - Reduced reflectivity in stratiform anvils

B - Increased reflectivity & rainfall below anvils



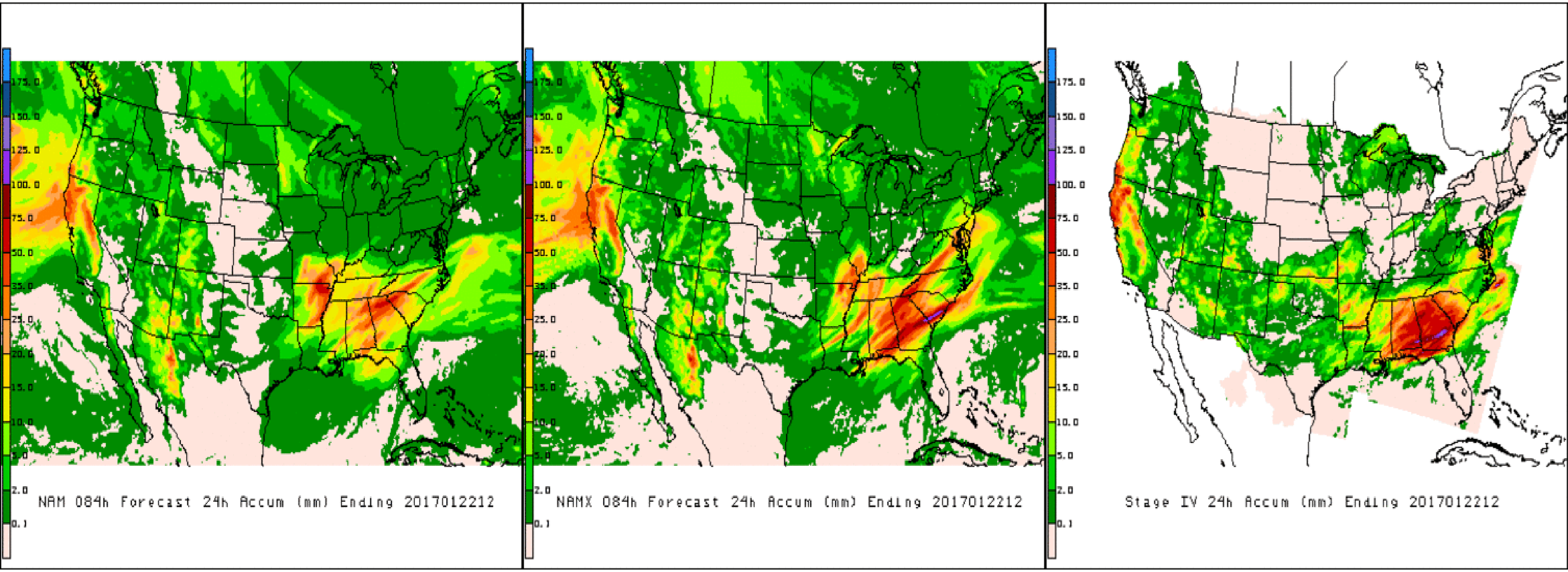
(Note different vertical coordinate)

Convection changes for NAM 12 km: "Some deep" convection

- Catalyst was trying to improve 12 km NAM QPF bias
- Several iterations tested before settling on:
  - Deep convection w/reduced triggering
  - Call *old (current ops) shallow convection first, if it aborts call *new shallow convection to attempt to maintain thermodynamic stability
- Improves bias and ETS

- * "Old" shallow cu : Stratocumulus-type (upward moisture and downward heat transport)
- ** "New" shallow cu : Cumulus congestus-type (upward heat and moisture transport)

Improving QPF bias in parent 12 km NAM : 22 January 2017 example

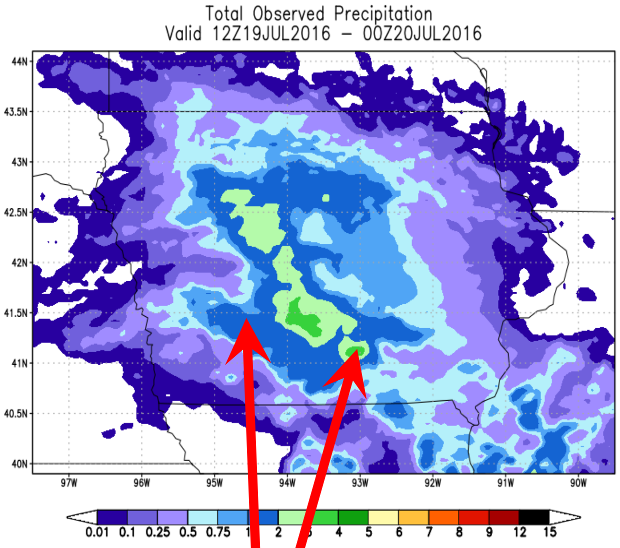


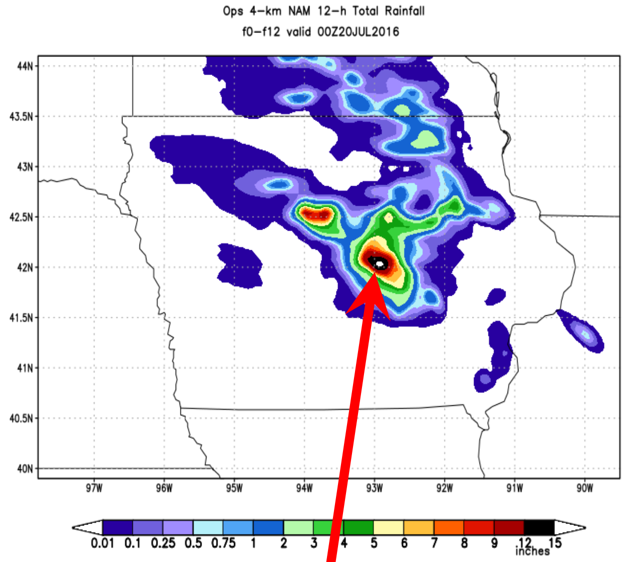
July 19 2016 IA Rain Event:
0-12h Rain Accumulation

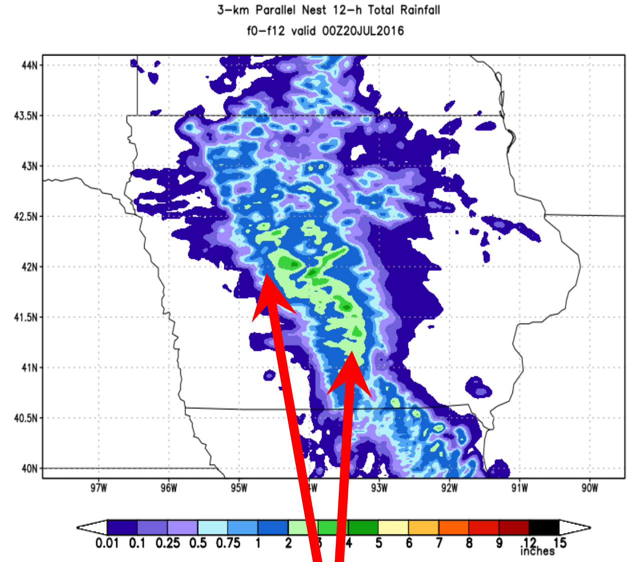
Observations

4-km Ops Nest

3-km Parallel Nest







1 - 3 inches

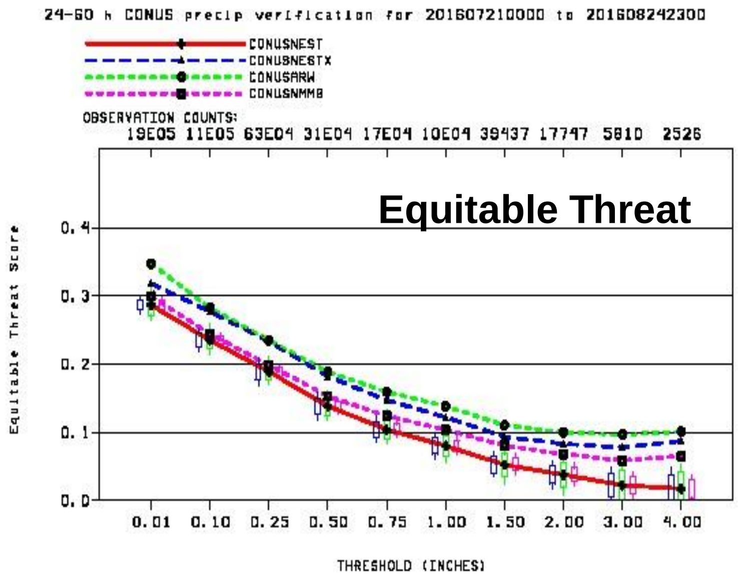
15 inches

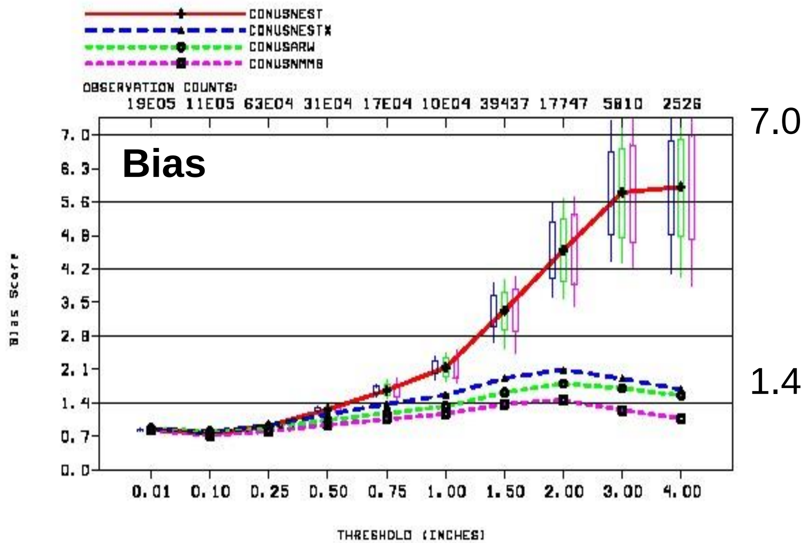
1 – 4 inches

Nest QPF scores for July-August 2016 vs HiresW ARW/NMMB

Ops 4 km Nest = Red
Pll 3 km Nest = Blue
Ops 3 km Hiresw ARW = Green
Ops 3 km Hiresw NMMB = Magenta

Note significant improvement
In NAM Nest QPF Bias



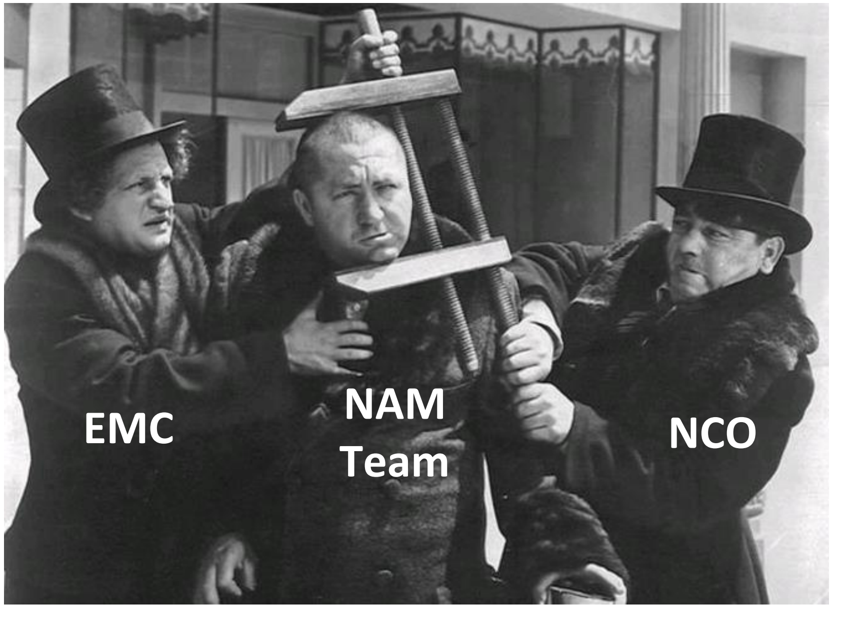


Additional Model Changes

1. **Update moist processes every other time step (sfc layer, land sfc, PBL, & microphysics for all domains; GWD & convection in parent only)**
2. **Advect specific humidity every time step (rather than every other time step)**
3. **Calculate cloud condensation every time step to remove supersaturations**
4. **Mix out superadiabatic layers that form in strong updrafts**
5. **These were part of the "Joaquin" changes**

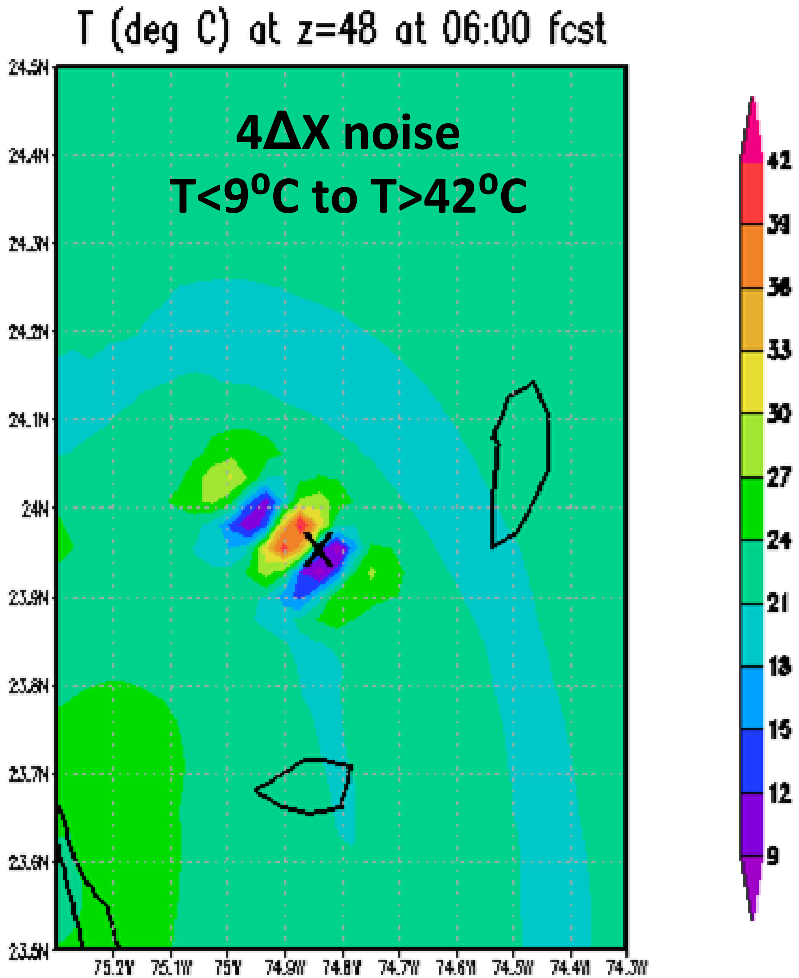
Changes to address CONUS nest failures with Joaquin

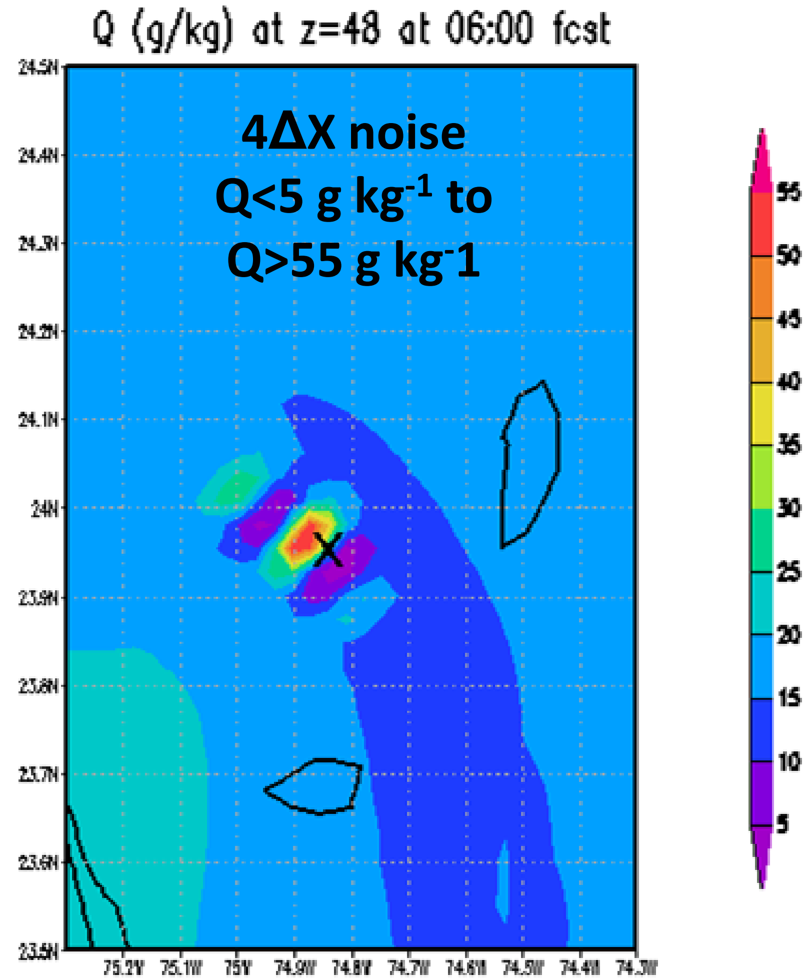
- **Production 4-km NAM CONUS nest had 3 failures associated with Hurricane Joaquin (20150929 – 20151002)**
  - **Temporary fix was to run pre-2014 nest configuration with "BMJ lite" for stability (small amount of deep convection)**
- **There was also a failure in the 3-km real-time parallel NAM nest**



Numerical Instability

~920 hPa

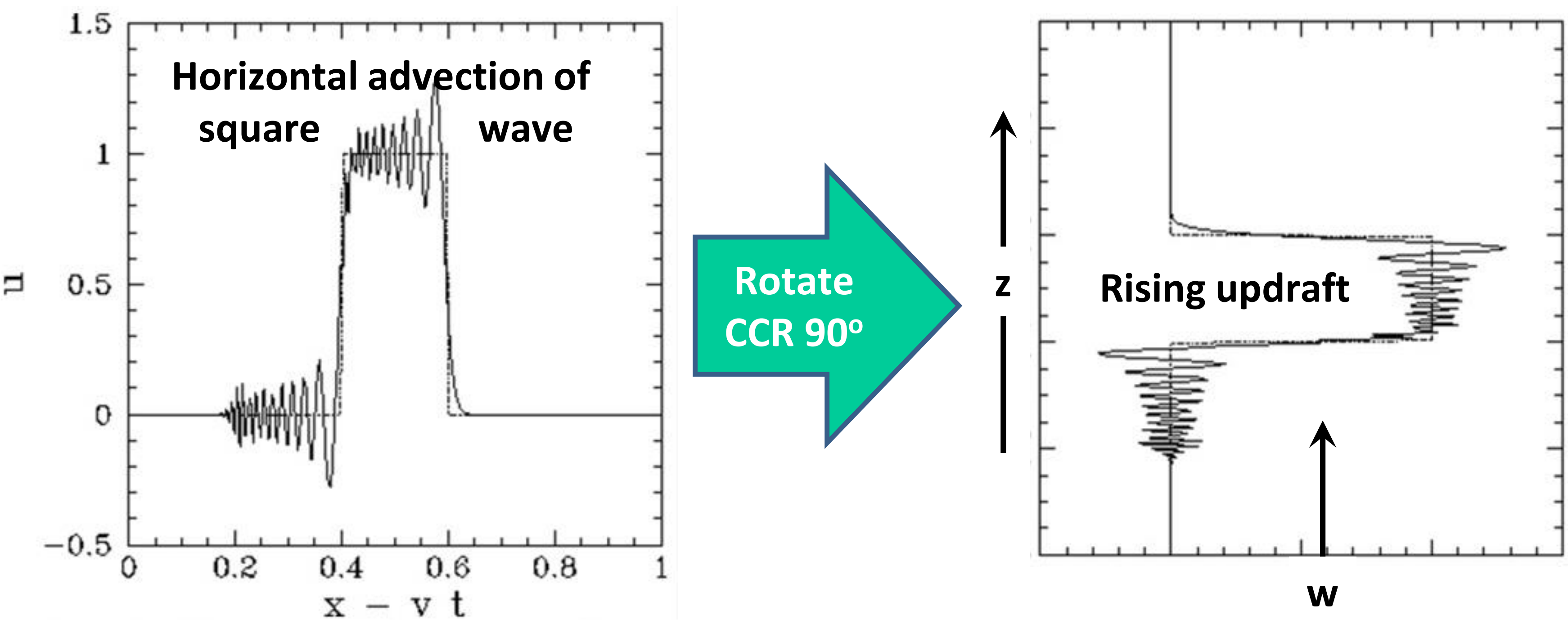




Large instabilities at 880 – 950 hPa

Noisy Temperature Profiles : Why?

- **Oscillations primarily due to Crank-Nicolson (CN) vertical advection (Vadv)**



"Unfortunately, the Crank-Nicholson scheme does a very poor job at advecting wave-forms with *sharp leading or trailing edges*…. It turns out that all *central difference* schemes for solving the advection equation suffer from a similar problem." (Left figure & notes from Prof. Richard Fitzpatrick, Univ. Texas)

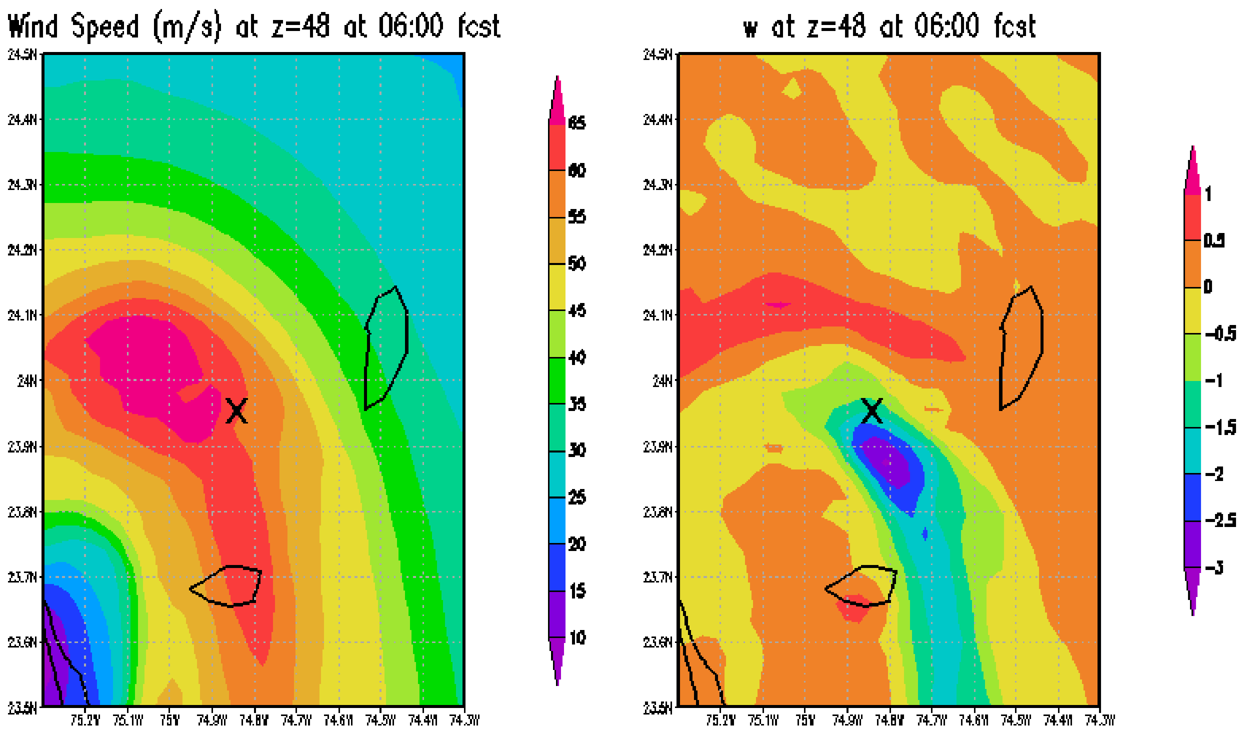
Numerical Instability

- Numerical instability was eliminated when
  - Advecting moisture fields every time step
  - Did not require updating moist physics every time step

Left: Instability appeared along the outer edge of a local wind maximum.

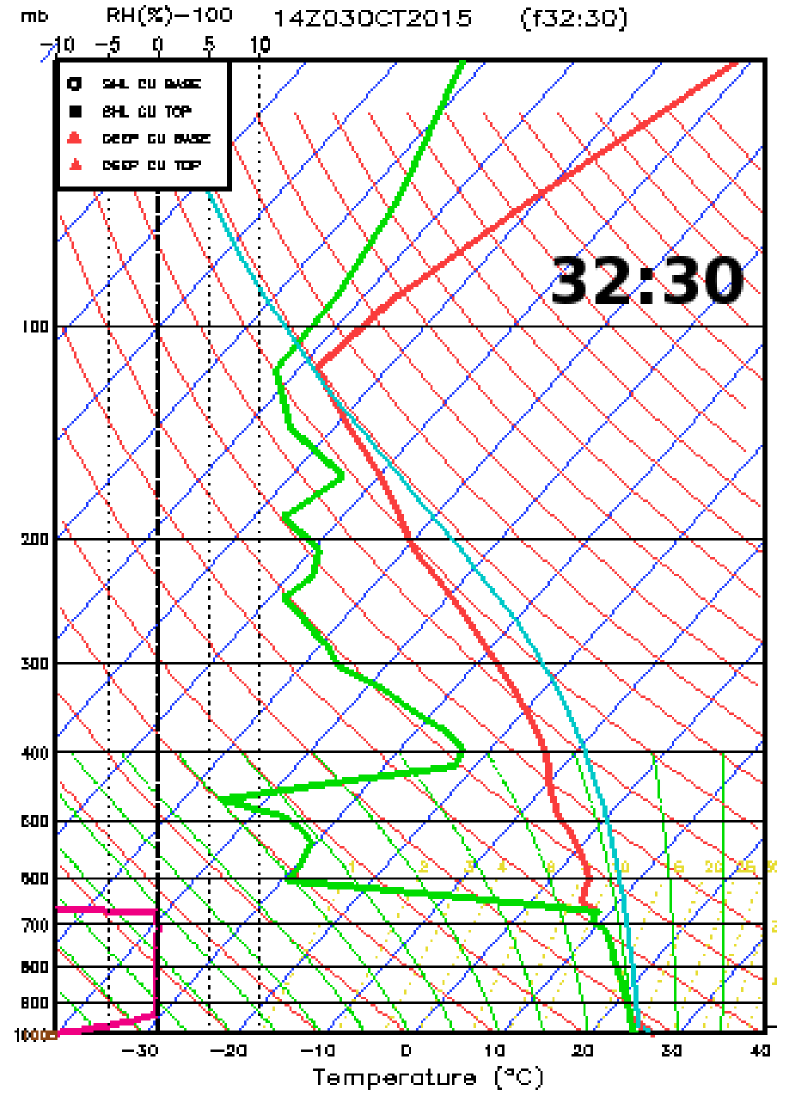
Right: It developed at the leading edge of modest ***descent***. Vertical motions were generally weak and well behaved.

The instability led to the model failures.



Noisy Temperature Profiles

- **But high-frequency oscillations (noise?) remained even in runs where all fields were advected and moist processes were updated every time step (right; 5-min skew-Ts from 32 h 30 min to 33 h 30 min).**
- **Also seen in other runs for different cycles with different physics options.**
- **Oscillations are transient.**
- **Many more runs were made with 5-min output to study cause(s).**

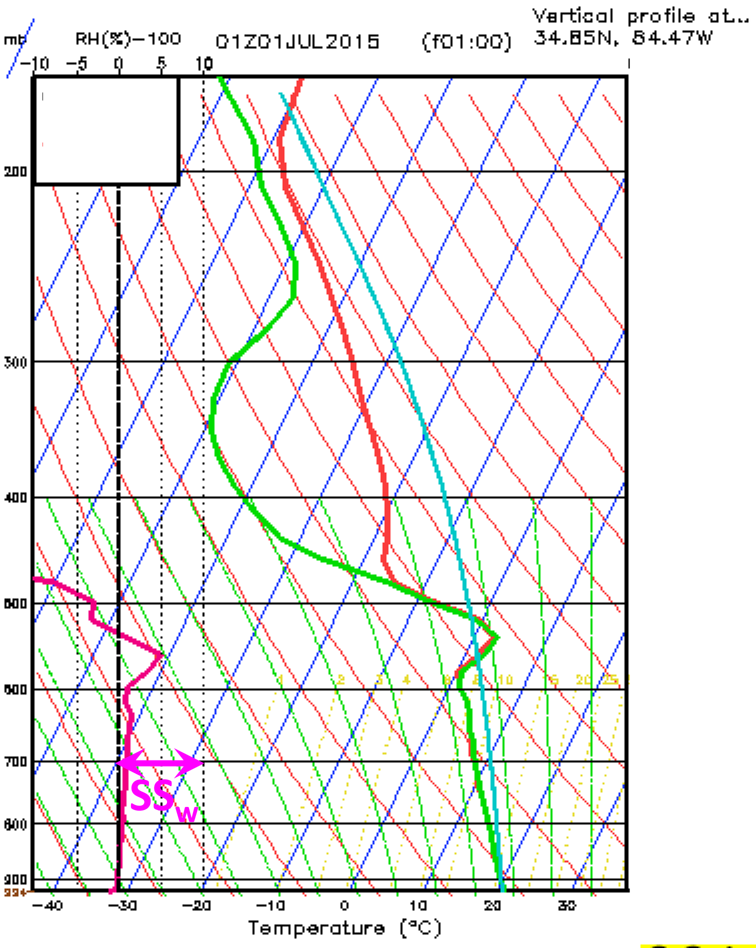


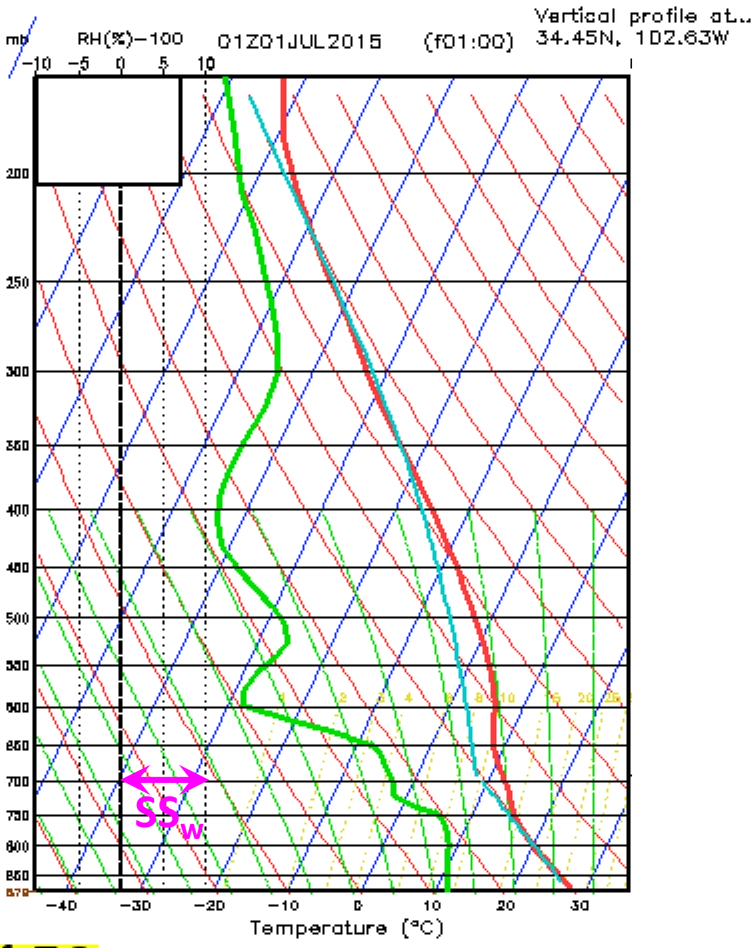
Noisy Temperature Profiles

- **The following changes were tested**
  - **Adjustments to Crank-Nicholson vertical advection off-centering**
  - **Minimum TKE (function of height) increased by 10x from surface to model top**
  - **Run with different versions of shallow convection**
  - **Horizontal averaging (filtering) of vertical velocity**
  - **T, Q adjustments(only this was successful)**
    - **T adjust: mix out all superadiabatic layers ($\Gamma > \Gamma_d$)**
    - **Q adjust: remove supersaturations w/r/t water by cloud condensation every other time step when moist physics are not called**
- **Tens of thousands of profiles were analyzed from 5-min forecast output at locations where domain-maximum values occurred in updraft velocities, surface rainfall rates, lapse rates, and supersaturations**

Most Extreme Examples
(2016070100 – WPC Case)

Without (left) and with (right) Joaquin changes





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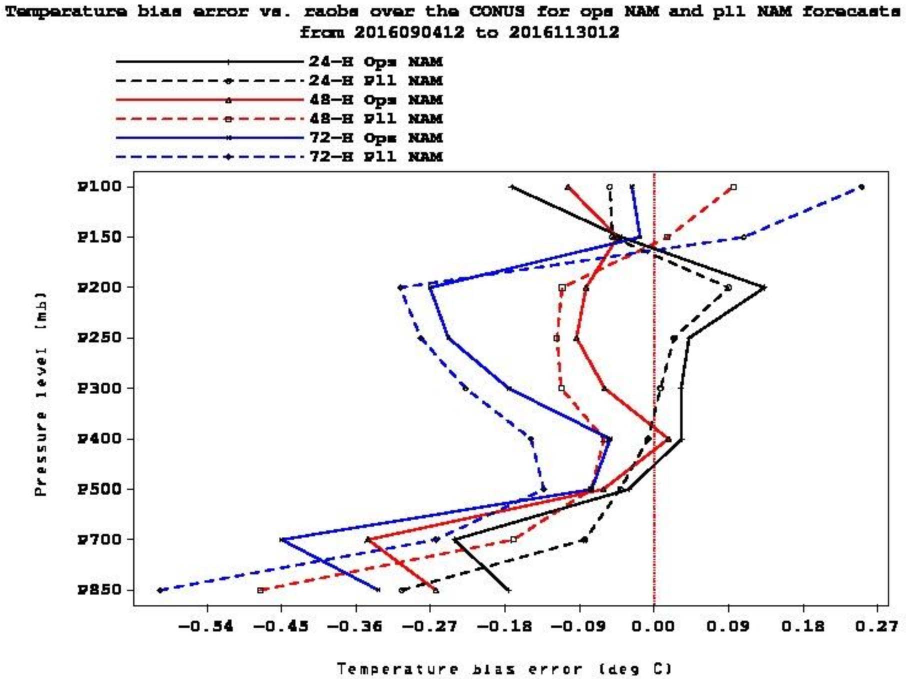
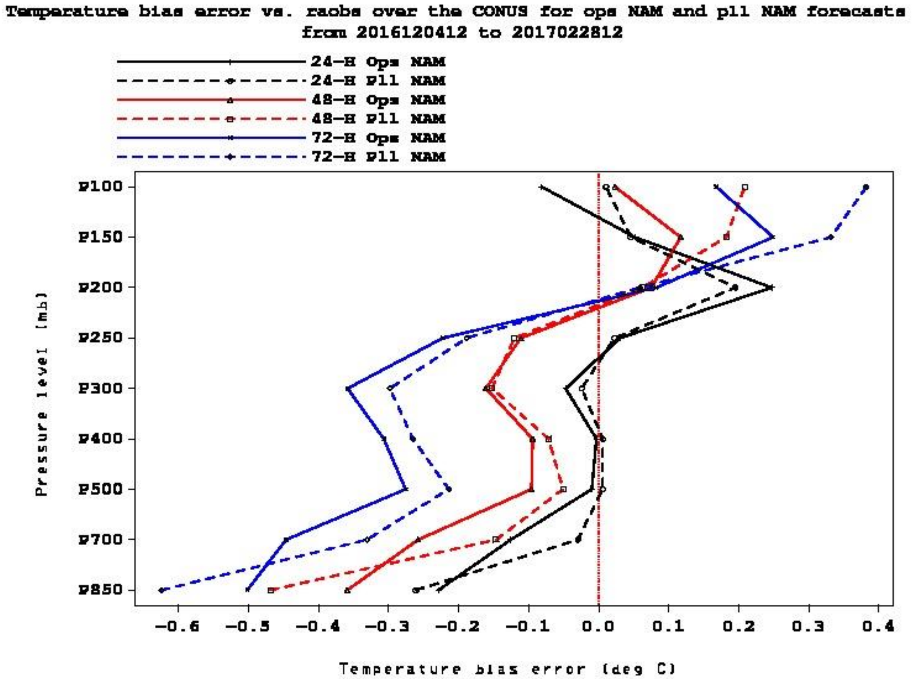
Why I did not do a 850-100 mb T bias scorecard

Sept – Nov 2016



Dec 2016 – Feb 2017



Ops = Soild lines, Parallel = Dashed lined

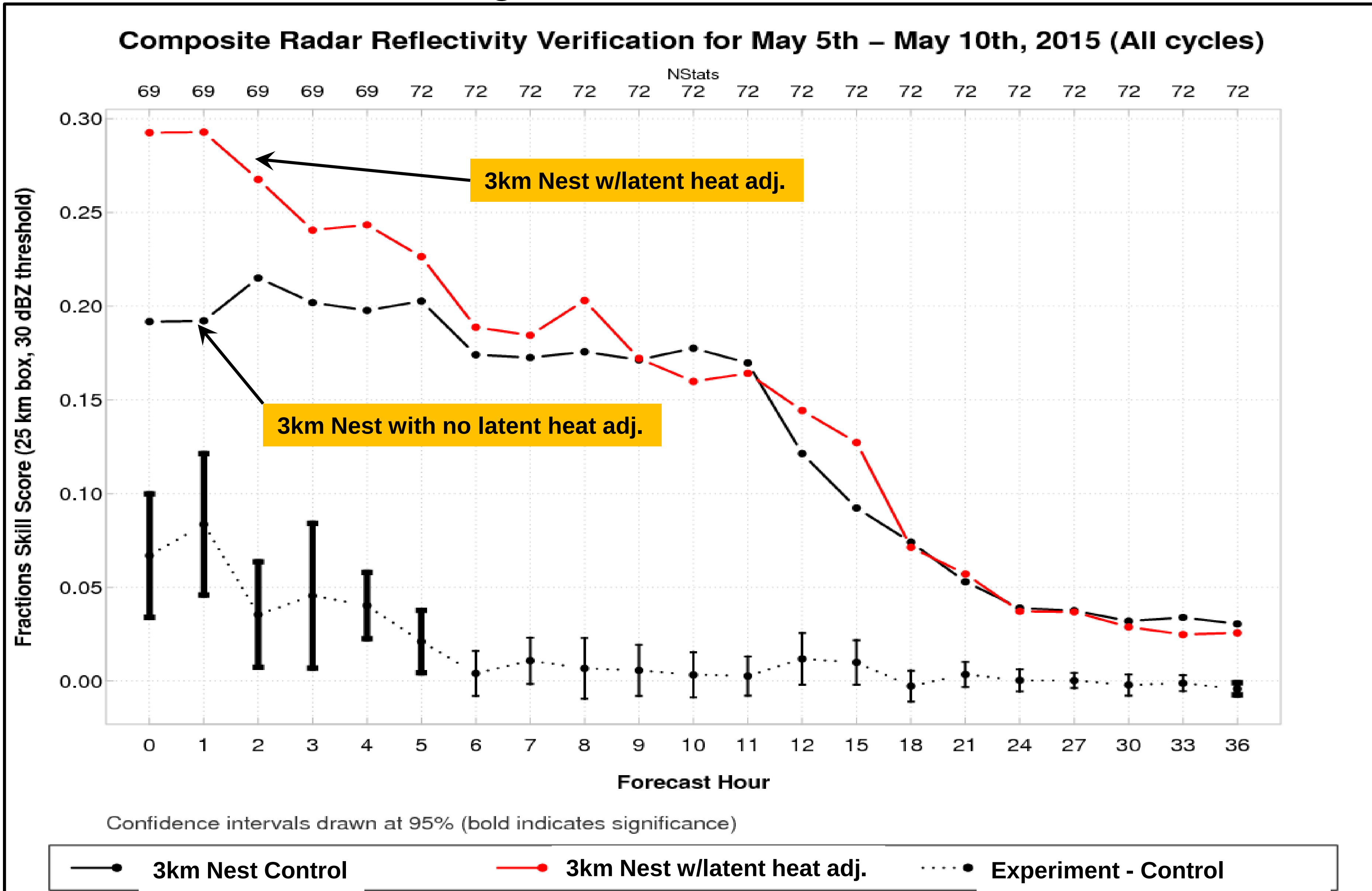
Scoreboard : Diurnal 2-m Temp Bias, 00z cycle, Nests

	Eastern CONUS	Western CONUS	North East/Central CONUS	South East/Central CONUS	Alaska
Dec 15-Feb 16	N	+ (Day) - (Night)	+	N	N
Mar 16-May 16	- (Day) + (Night)	- (Day) + (Night)	-	- (Day) + (Night)	N
Jun 16-Aug 16	+ **(0-36h, 51-57h)** - **(the rest)**	+ (Day) N (Night)	-	+	-
Sep 16-Nov 16	- (Day) + (Night)	- (Day) N (Night) (slight)	- (Day) + (Night)	- (Day) + (Night)	+ (Slight)
Dec 16-Feb 17	N	N	+	N (Day) - (Night)	+ (Slight)

Scoreboard : Diurnal 2-m Td Bias, 00z cycle, Nests

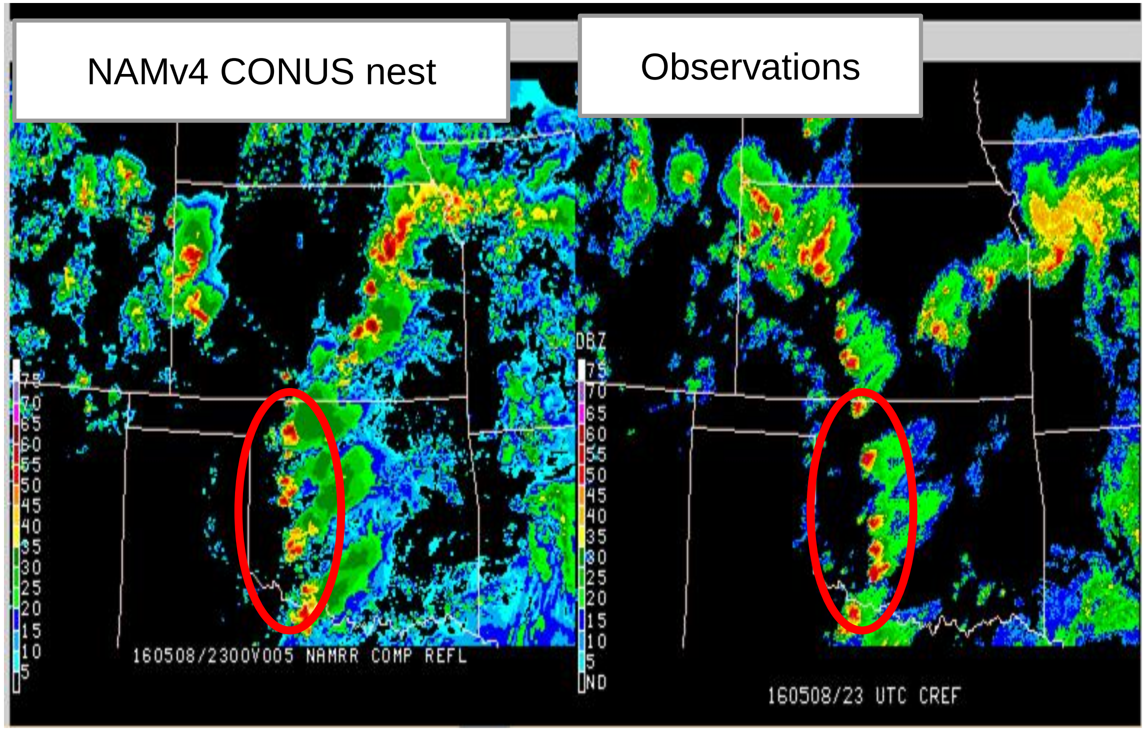
	Eastern CONUS	Western CONUS	North East/Central CONUS	South East/Central CONUS	Alaska
Dec 15-Feb 16	+	+	+	+	- (slight)
Mar 16-May 16	+	+	+	+	+
Jun 16-Aug 16	N	N	N	-	+ (0-39h) - (42-60h)
Sep 16-Nov 16	N	+	+ (slight)	- (Slight)	+
Dec 16-Feb 17	+	+	+	+	- (slight)

Reflectivity improvements from DA : Impact of reflectivity-derived latent heating adjustment in parallel NAM nest digital filter initialization



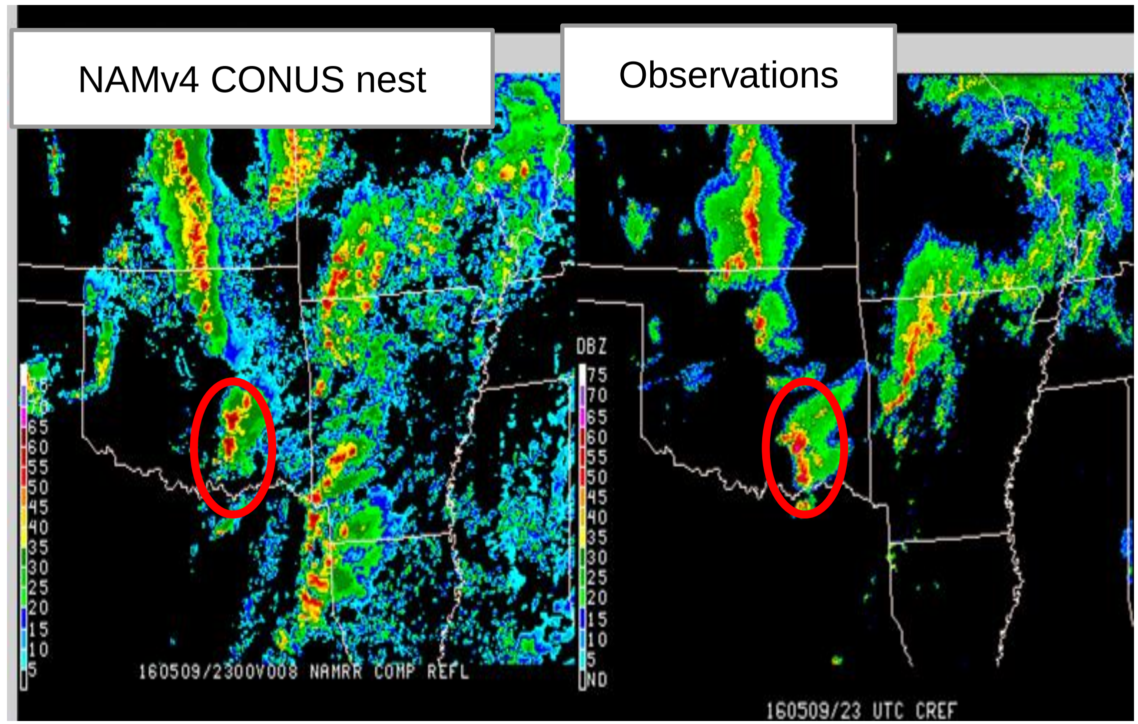
HWT Case Study 1: May 8th, 2016

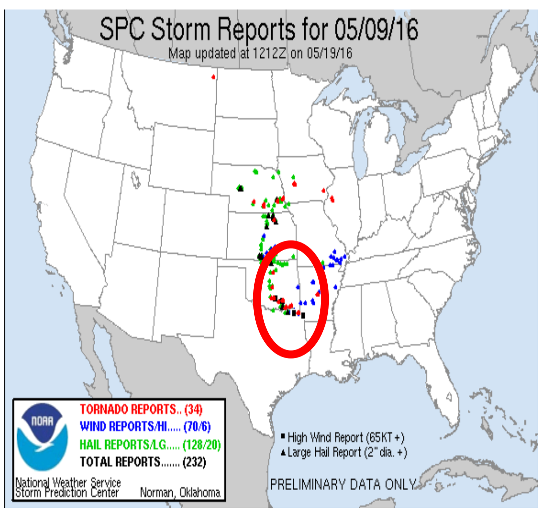
- 18Z Cycle
- 5 hour forecast
- NAMv4 3 km CONUS nest



HWT Case Study 2: May 9th, 2016

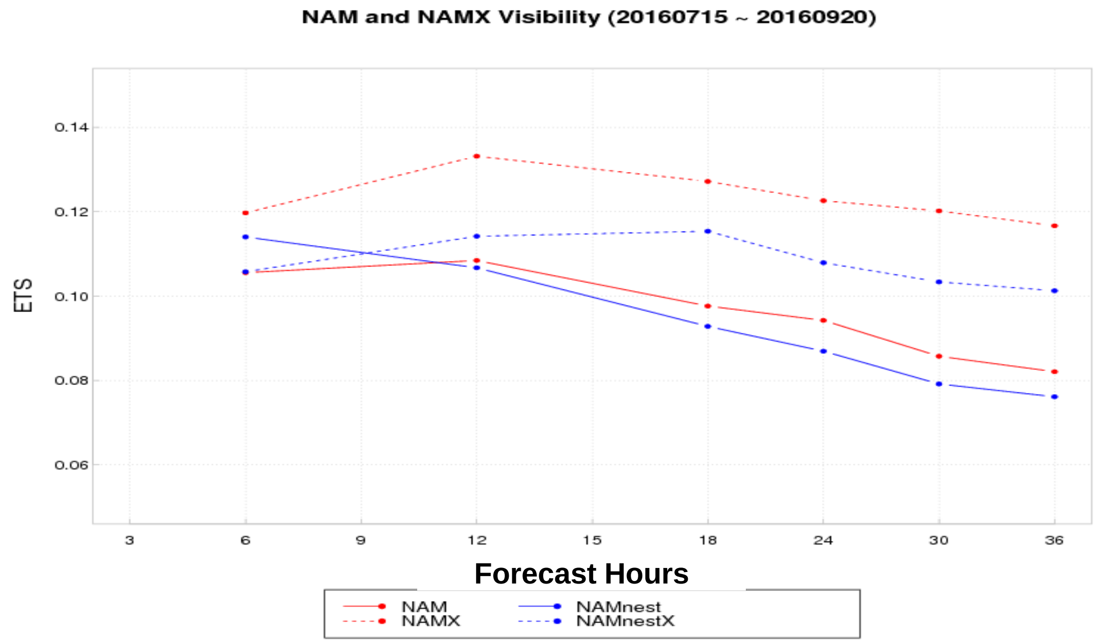
- 15Z Cycle
- 8 hour forecast
- NAMv4 3 km CONUS nest
- Strongly tornadic supercell well forecast by 3 km NAMv4 CONUS nest

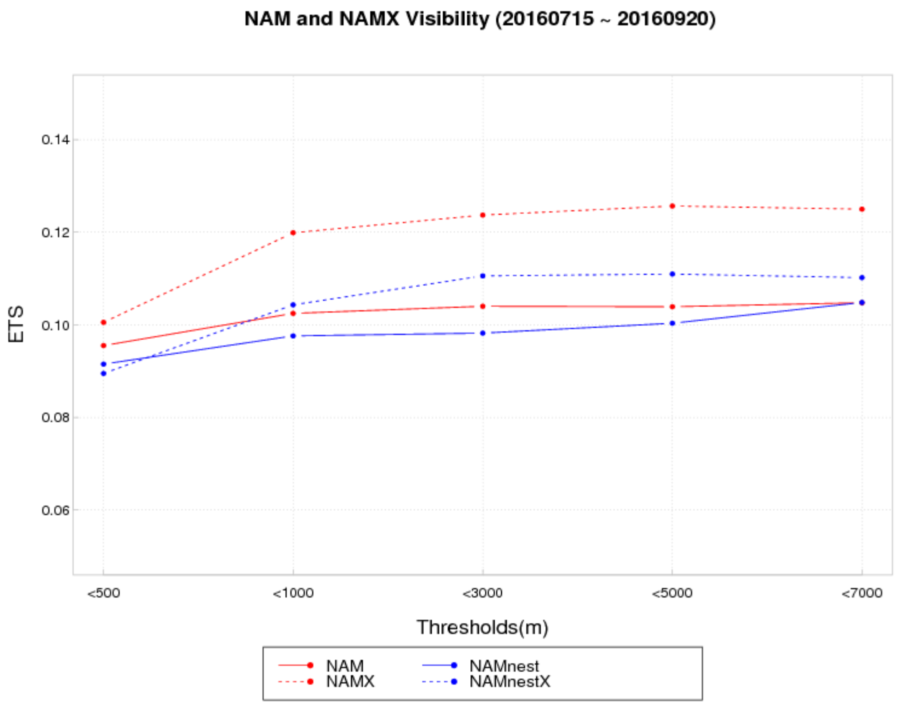


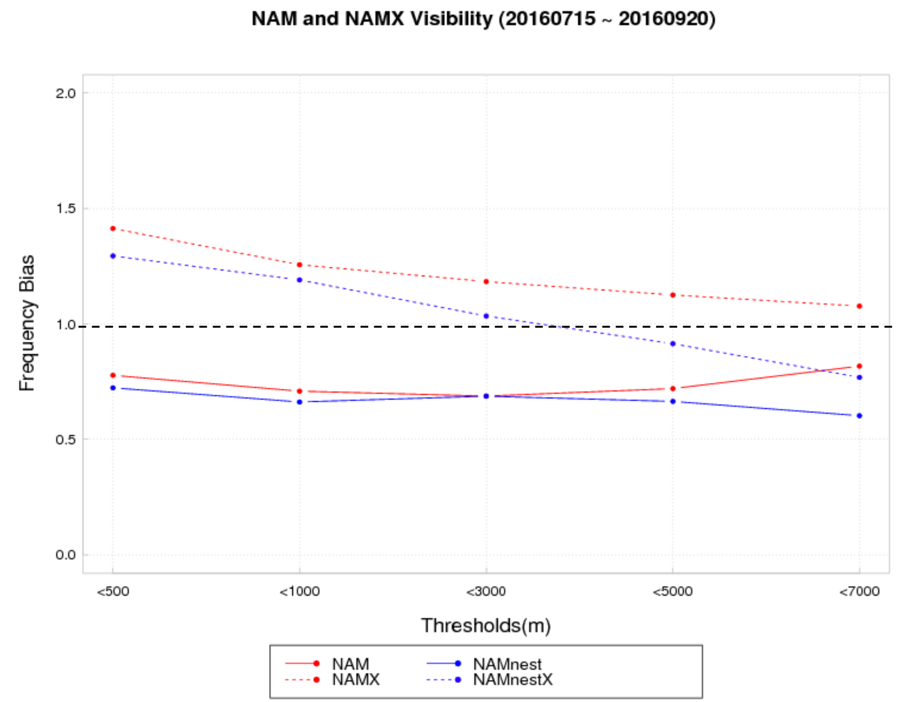


Visibility Verification 6/1/16-9/20/16

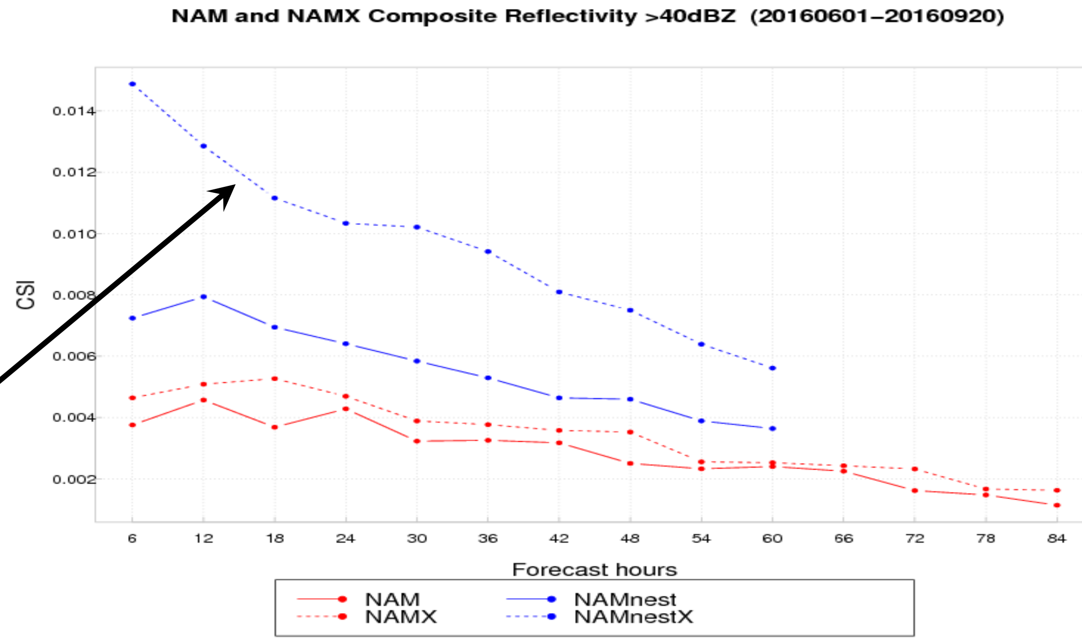
Solid : Ops NAM
Dashed : Pll NAM



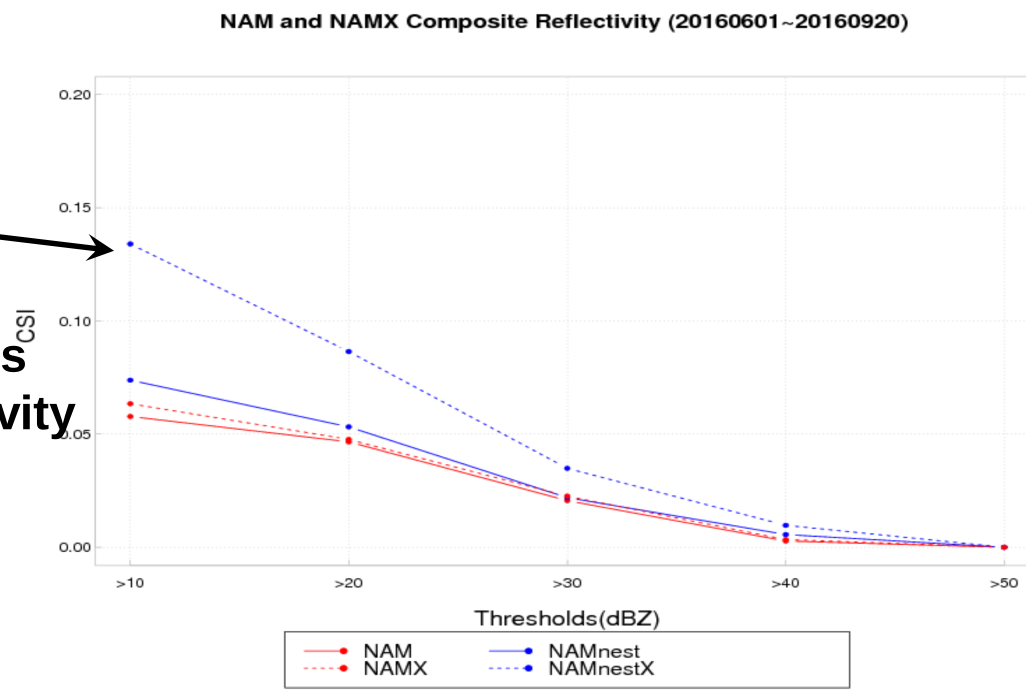




Composite Reflectivity Verification 6/1/16-9/20/16



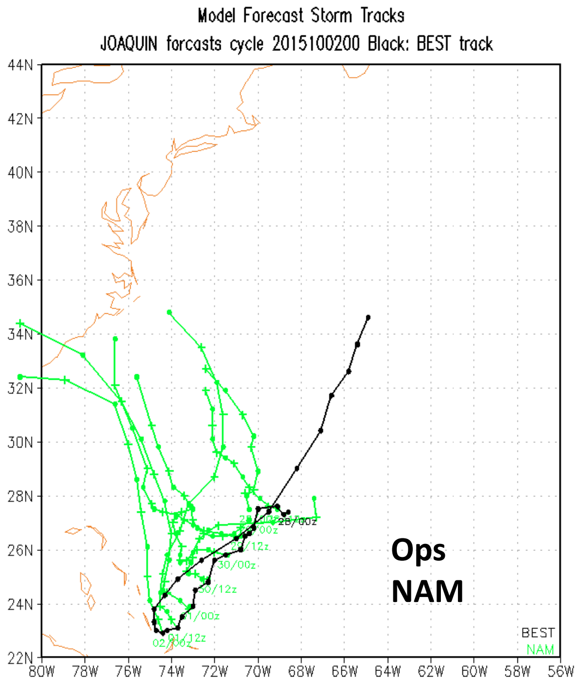
Higher CSI for parallel CONUS nest

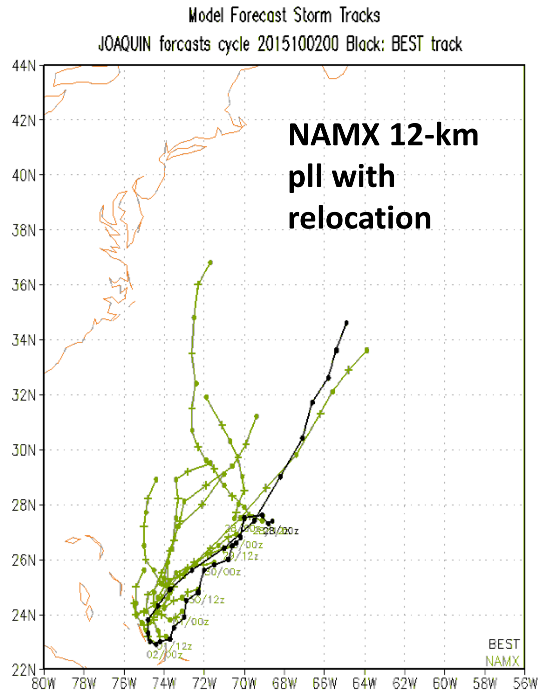


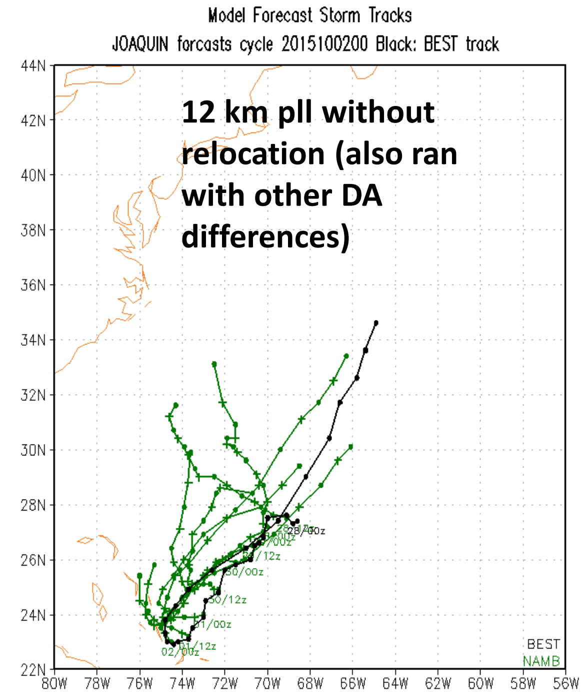
Biggest improvement at lower thresholds; impact of microphysics changes to reduce spurious areas of light/noisy reflectivity

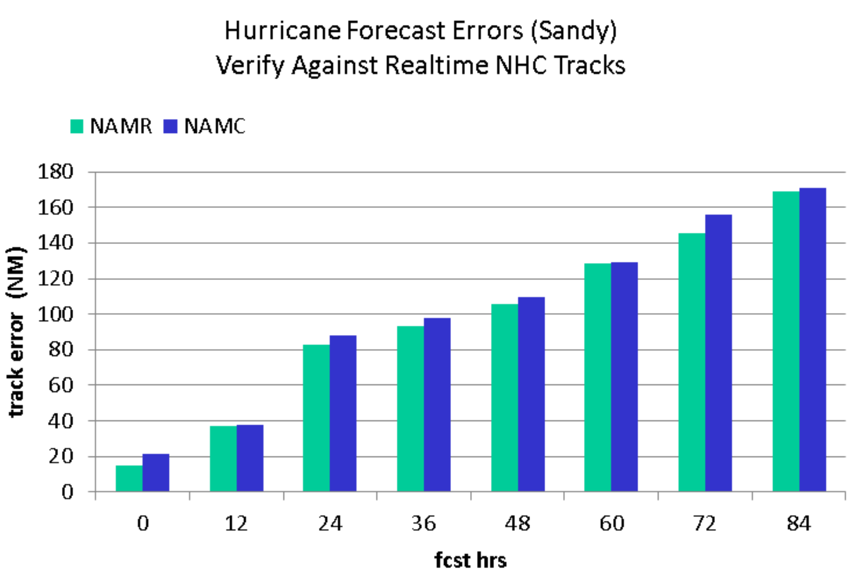
Tropical cyclone relocation/performance in NAM V4

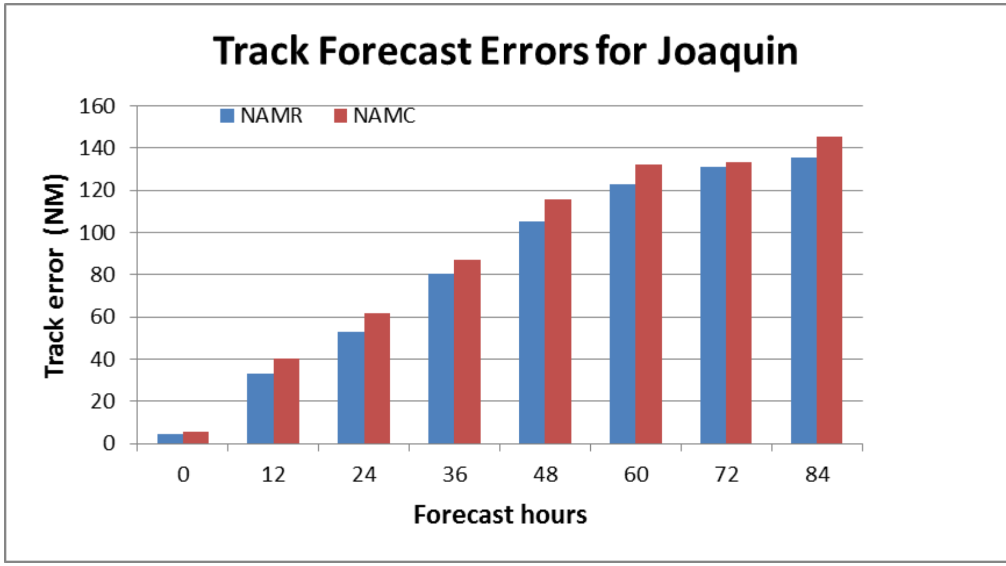
- TC relocation in NAM is Sandy Supplemental funded effort
- Done at start of 6-h assimilation cycle (tm06) and for the on-time NAM (tm00) analysis
- NOTE for next slide : NAMv4 physics changes (convection) lead to better TC tracks in NAM 12 km parent for Joaquin, probably bigger impact from this than TC relocation





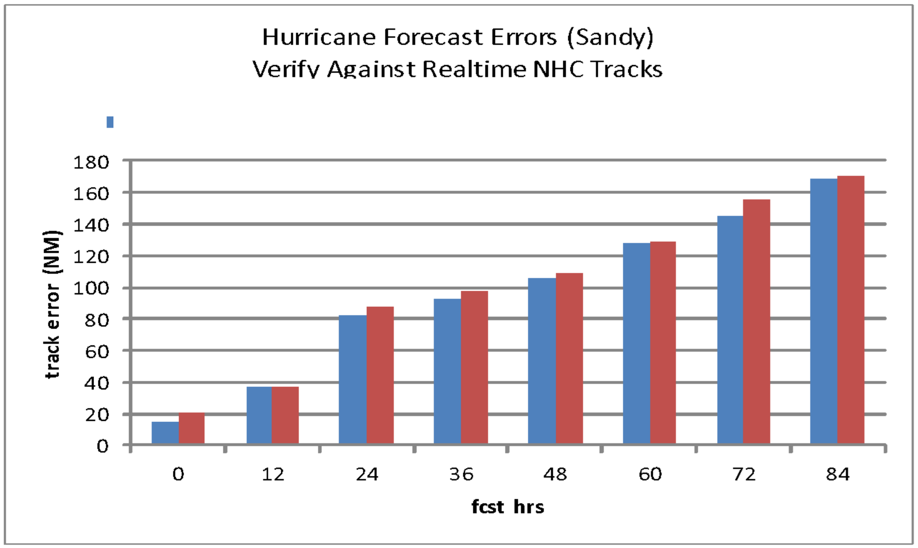


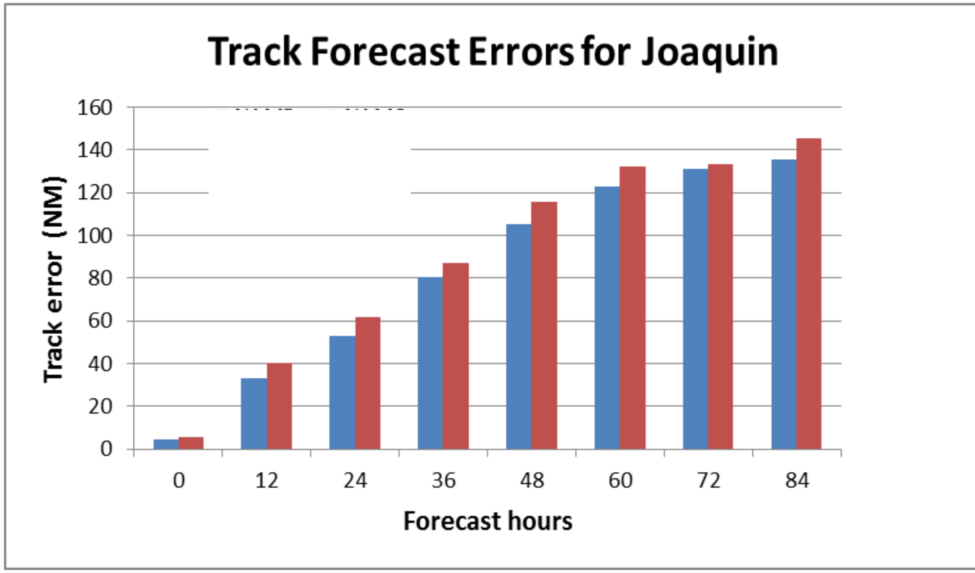




NAMR = NAM run with TC relocation, NAMC = control run without TC relocation

Impact of NAM TC Relocation on Sandy and Joaquin Track Errors



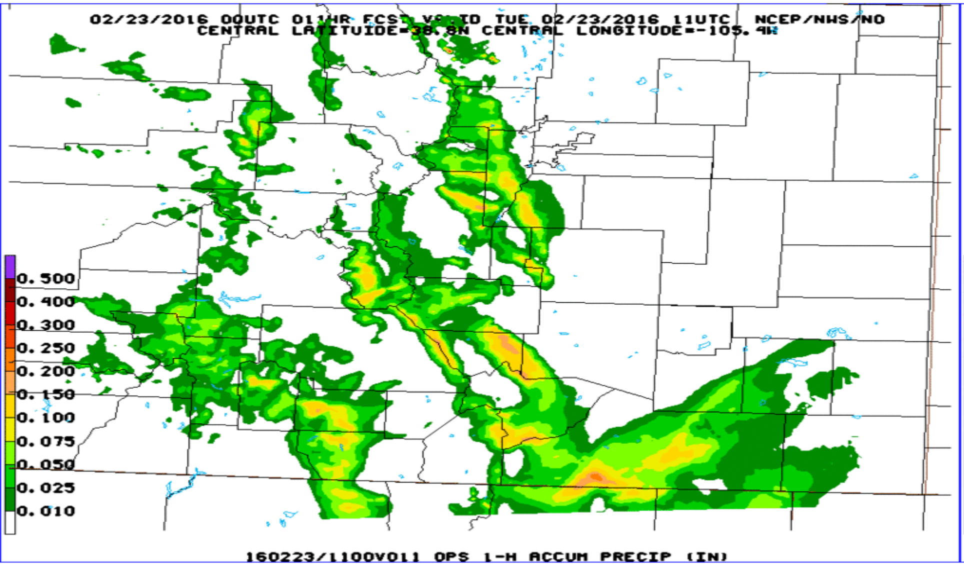


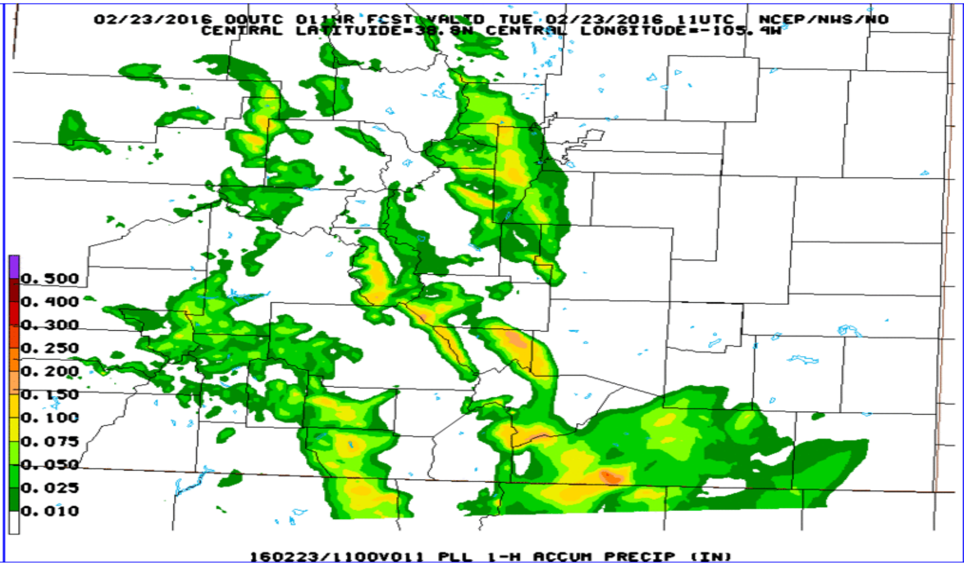
Red = Control run with no TC Relocation
Blue = Experimental run with TC Relocation

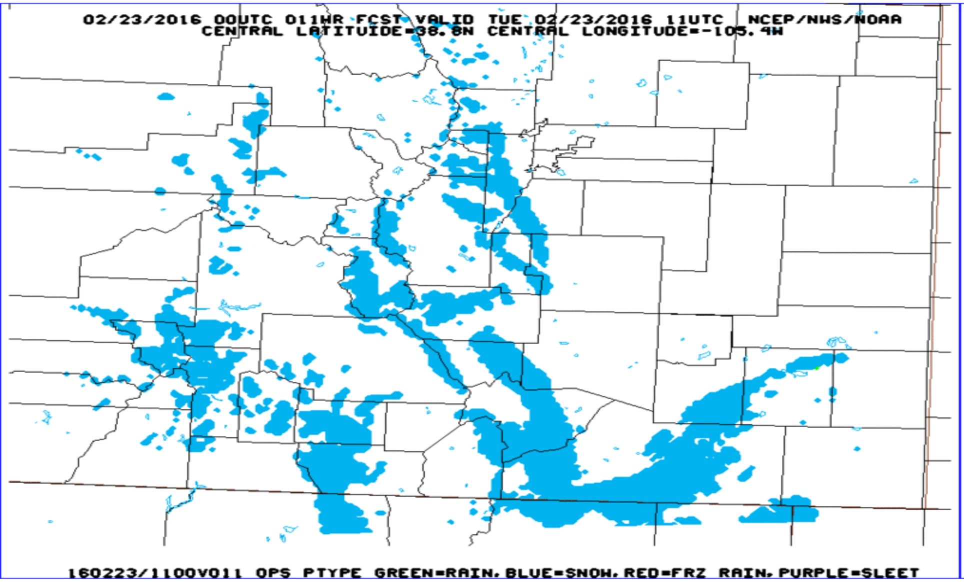
Post-processing changes

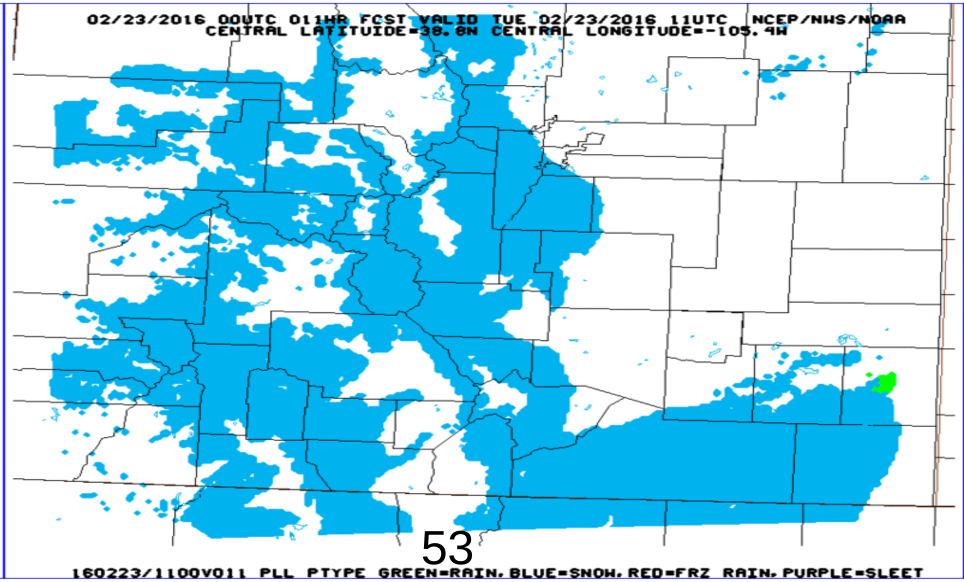
- All NAM output will be GRIB2 direct from the post-processing (current ops makes GRIB1 which is converted to GRIB2 for distribution) with complex compression for 12 km output grid and CONUS/Alaska nests; still JPEG compression for Hawaii/Puerto Rico/Fire Weather nests
- Ceiling height computation changed from above ground level to above sea level (consistent with RAP/HRRR)
- Add output GSD version of visibility calculation (labeled w/vertical level = cloud base, not surface, so that only AWC will use it)
- CONUS nest output grid will change to the same grid as that from the HRRR ; 3 km Alaska nest will be output on the 3 km Alaska DNG grid
- Threshold precip rate for categorical precip-type calculation set to 0.01 mm/h for all NAM domains instead of varying by resolution; the latter led to spotty p-type depiction in NAM nests (especially in the fire weather nest as noticed by Steve Z. at LWX)

Fire weather nest (ops on the left, pll on the right) 1-h accumulated precip and instantaneous p-type (nest is over Colorado)



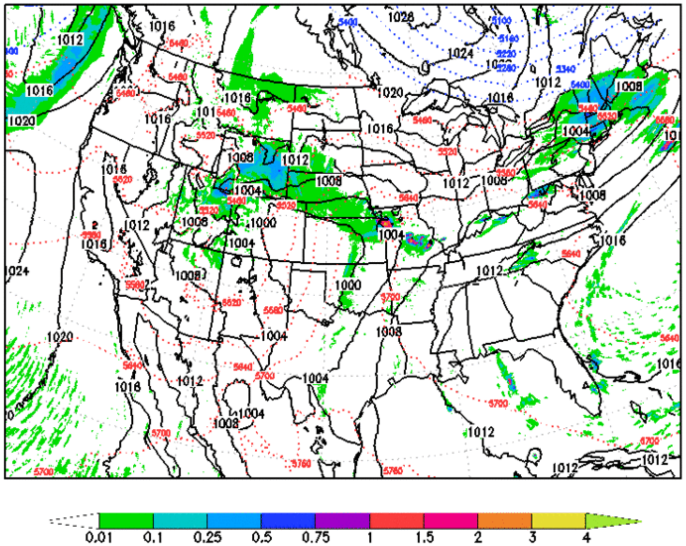






P-type computation change: better in Parallel Nest

SLP,3-H APCP OPSNEST 18H FCST VALID 18Z 26 APR 2016



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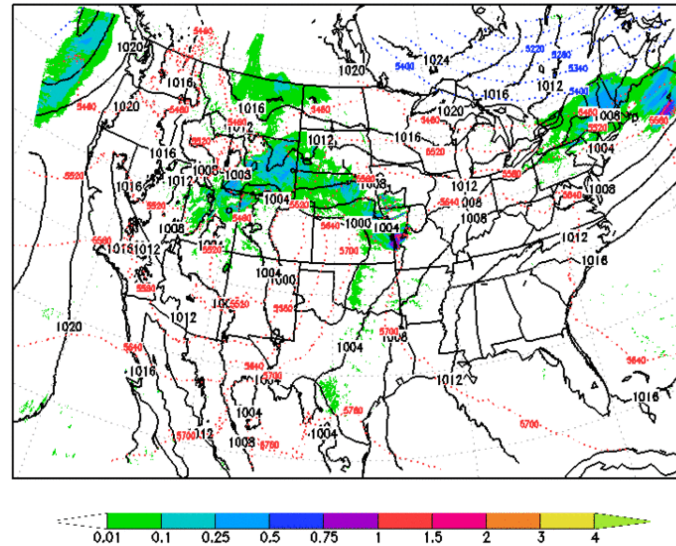
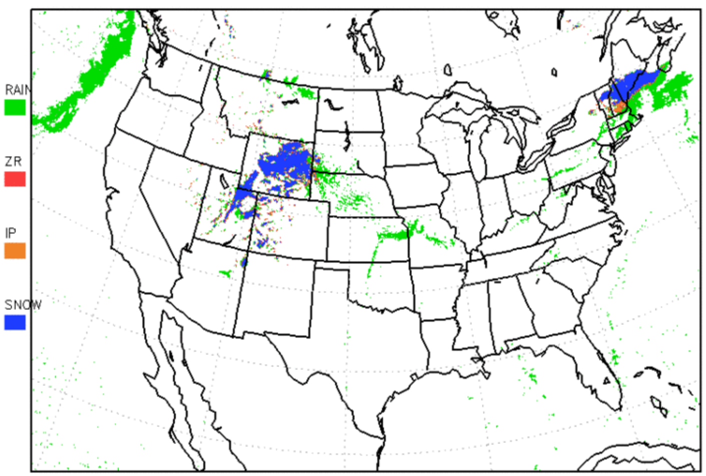


PRECIP TYPE OPSNEST 18H FCST VALID 18Z 26 APR 2016



Based on Prate=0.325 mm/h

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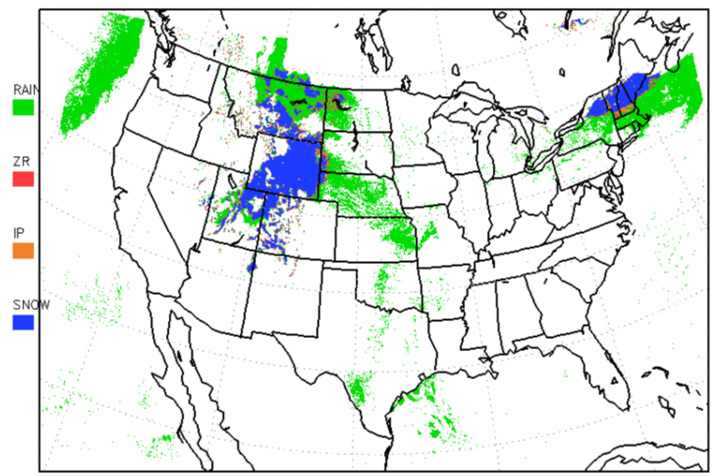

Based on Prate=0.01 mm/h

NAMv4 : Products slated for removal

- DGEX model run : turned off

- From NOAAPORT:

- **Legacy NAM FAX charts** →
- **22 km Alaska grid #217**
- **5 km CONUS and 6 km Alaska DNG grids**

- From NCEP servers (NOMADS)

- **NAM tiles**
- **190.5 km LFM lookalike grid**
- **Grid #216, 217 ICWF files**