

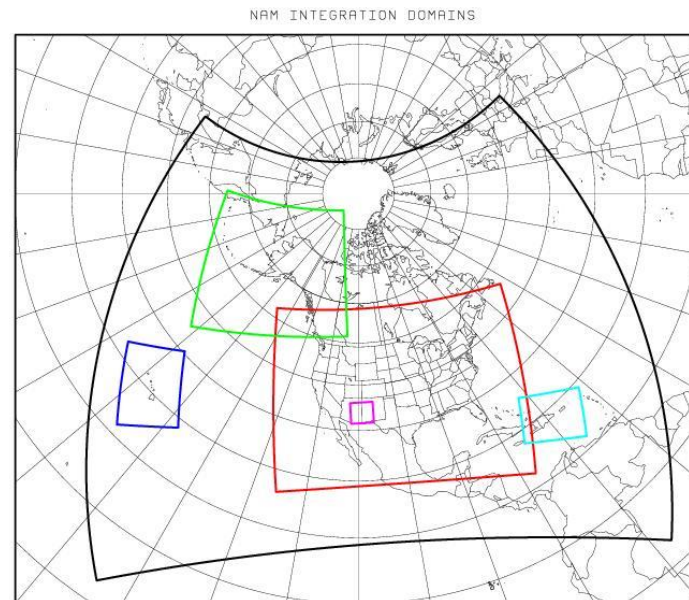


Regional Air Quality Modeling Progress at NOAA/NWS/NCEP

Jeff McQueen, Pius Lee, Jianping Huang,
Daniel Tong, Li Pan, Perry Shafran,
Eric Rogers, Geoff DiMego, Ivanka Stajner
September 9, 2014

NAM V3.1 Model Changes

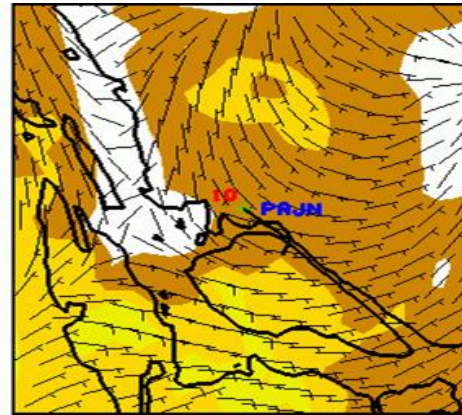
- **Replace legacy GFDL radiation with RRTM**
- **Modified Gravity Wave Drag/Mountain Blocking**
 - **More responsive to subgrid-scale terrain variability**
 - **Target** : Improve synoptic performance without adversely impacting 10-m wind forecasts
- **New version of Betts-Miller-Janjic convection**
 - **Moister convective profiles, convection triggers less**
 - **Target** : Improve QPF bias from 12-km parent, esp. in warm season
- **Ferrier-Aligo microphysics**
- **Modified treatment of snow cover/depth**
 - **Use forecast rime factor in land-surface physics**
 - **Target** : Reduce snow depth in marginal winter conditions w/complex precipitation type
- **Reduce roughness length for 5 vegetation types**
 - **Target** : Improved 10-m wind in eastern CONUS



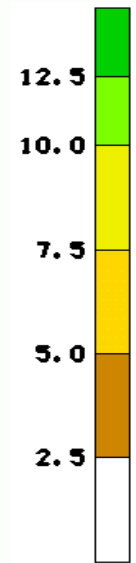
NAM 12 km parent, nests and 1.3 km fire weather domains

Changes to Downscaled Grids

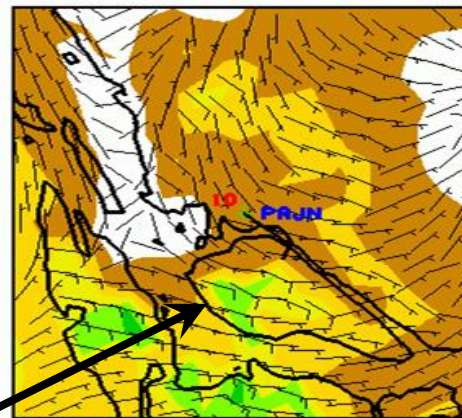
- 5 km CONUS / 6 km Alaska DNG grids extended to 192-h via DGEX
- Addition of Haines Index for Fire weather
- Improved 10-m wind treatment
 - Use mass-consistent wind field model
 - Based on velocity potential, incorporating local terrain gradients



Ops downscaled
NAM AKNEST
(3 km)



PROD AK3 SMART SFC SPEED (KTS) FORECAST PAJ



Parallel
downscaled NAM
AKNEST (3 km)

AK3 SMART SFC SPEED (KTS) FORECAST PAJ***** 140423/2100Y003

Improved representation
of the effects of local
terrain on winds

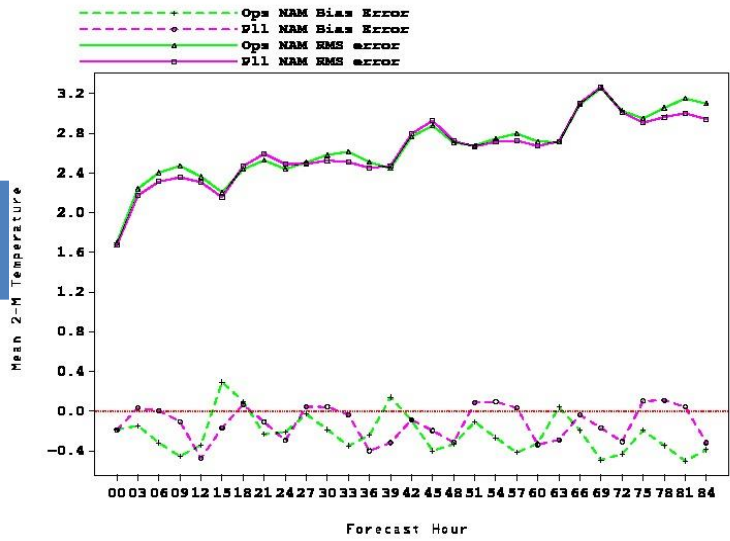


Surface fields : 2-m T RMS (solid) / bias (dashed) error over CONUS: 00z cycles; Green=ops, Magenta=p11

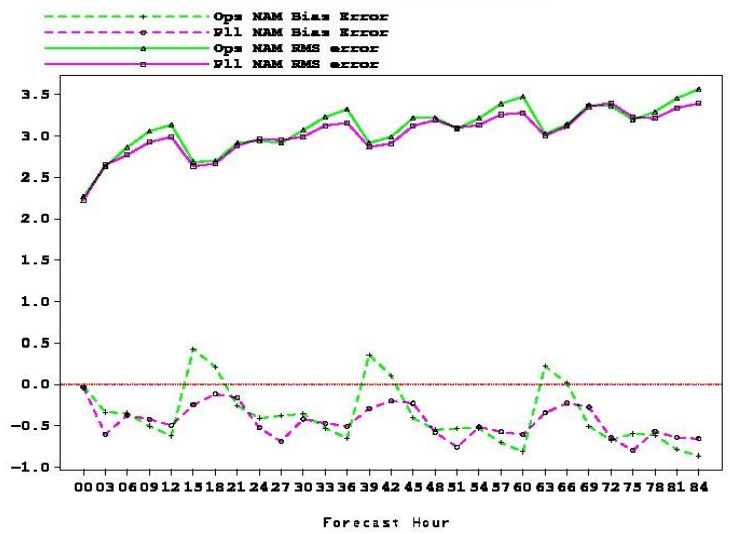
East CONUS

West CONUS

Forecast 2-M Temperature vs sfc obs over eastern CONUS (00Z cycle) for ops NAM, p11 NAM from 201403010000 to 201405311200

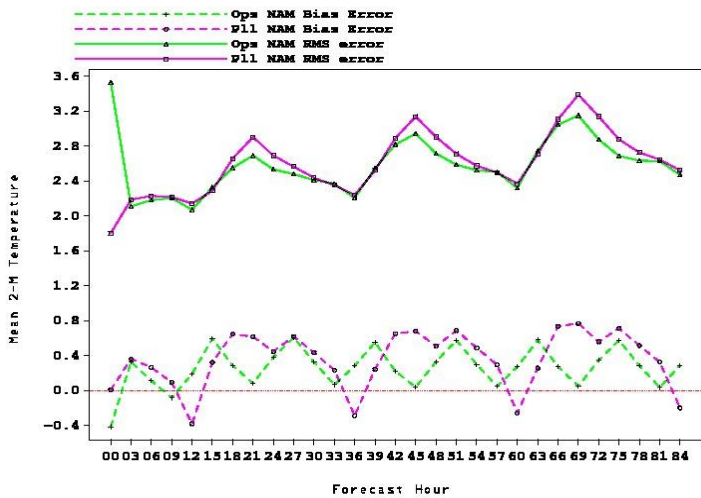


cast 2-M Temperature vs sfc obs over western CONUS (00Z cycle) for ops NAM, p11 NAM from 201403010000 to 201405311200

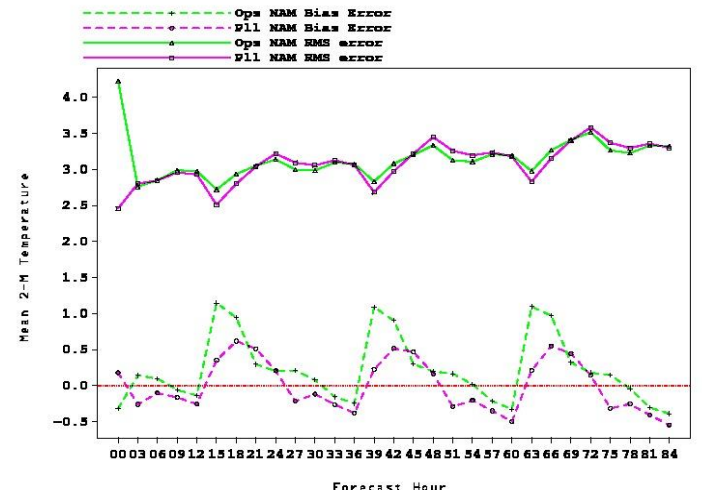


Spring 2014
3/1 – 5/30/14

Forecast 2-M Temperature vs sfc obs over eastern CONUS (00Z cycle) for ops NAM, p11 NAM from 201406010000 to 201408021200



Forecast 2-M Temperature vs sfc obs over western CONUS (00Z cycle) for ops NAM, p11 NAM from 201406010000 to 201408021200



Summer 2014
6/1-8/3/14

Surface fields : 10-m Wind RMS (solid) / bias (dashed) error over CONUS: 00z cycles; Green=ops, Magenta=pl1

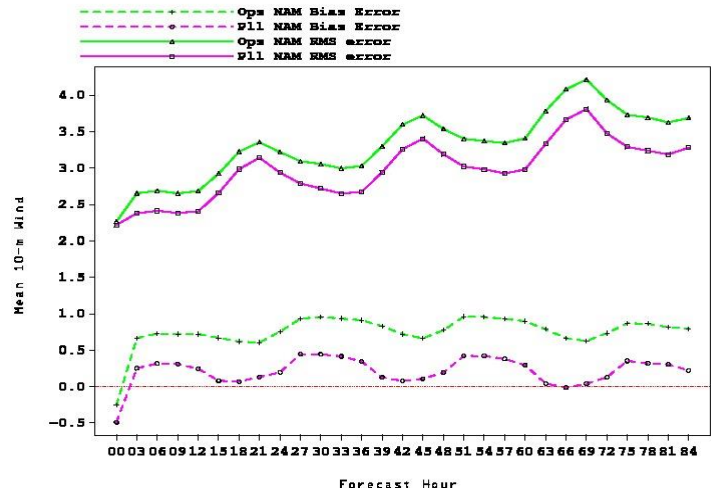


East CONUS

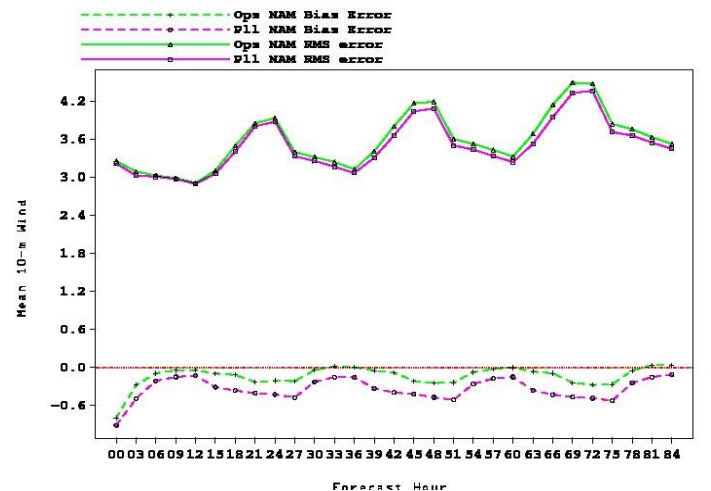
West CONUS

Spring 2014
3/1 – 5/30/14

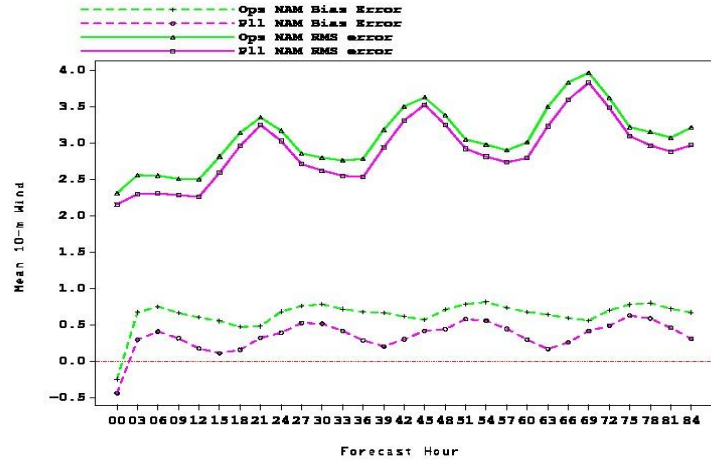
Forecast 10-M Wind vs sfc obs over eastern CONUS (00z cycle) for ops NAM, pl1 NAM from 201403010000 to 201405311200



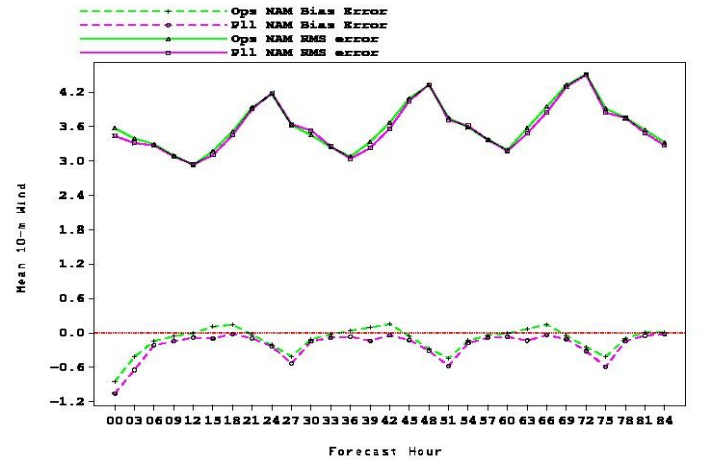
Forecast 10-M Wind vs sfc obs over western CONUS (00z cycle) for ops NAM, pl1 NAM from 201403010000 to 201405311200



Forecast 10-M Wind vs sfc obs over eastern CONUS (00z cycle) for ops NAM, pl1 NAM from 201406010000 to 201408021200

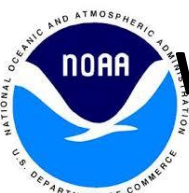


Forecast 10-M Wind vs sfc obs over western CONUS (00z cycle) for ops NAM, pl1 NAM from 201406010000 to 201408021200



Summer 2014
6/1-8/3/14

Reduced high 10-m wind bias in East CONUS with roughness length changes

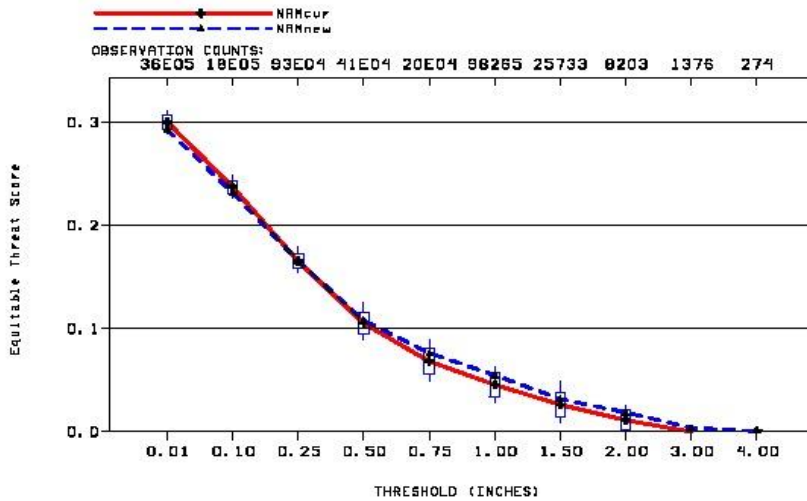


Warm Season Retrospectives : NAM-12 Control (red) vs Parallel (Blue) QPF scores : ETS (top), Bias (bottom)

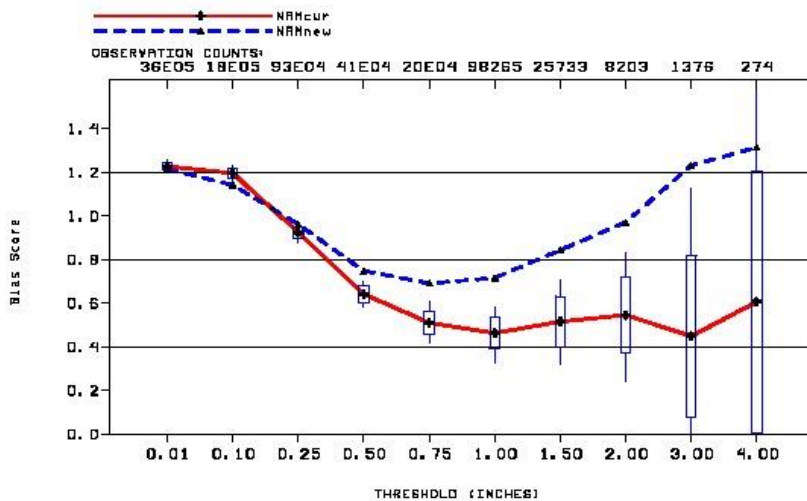
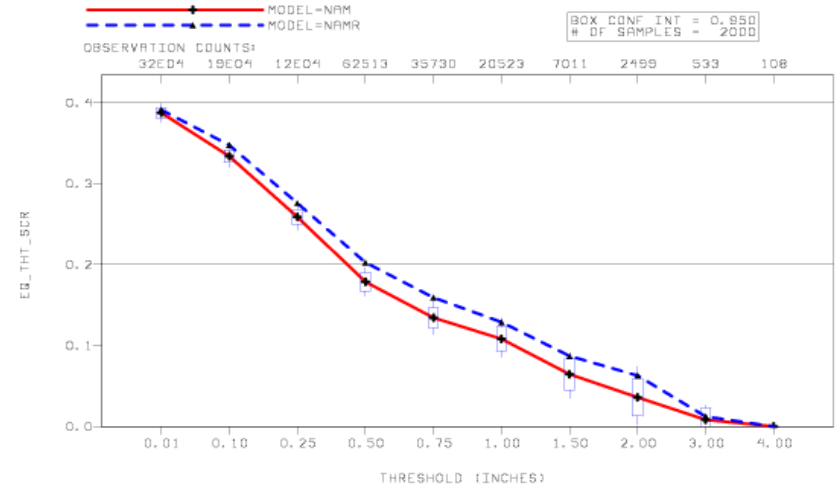
July 2011

June 2013

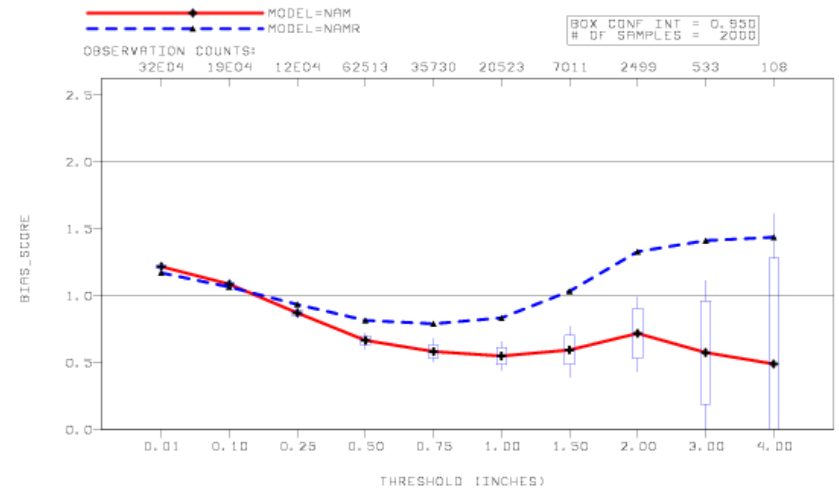
24-84 h CONUS precip verification for 201107060000 to 201108032300



STAT=FHO PARAM=APCP/24 FHOURL=24+36+48+60+72+84 V_RGN=G212/RFC
 VYMDH=201306020000-201306282300 CI ALPHA=0.050



STAT=FHO PARAM=APCP/24 FHOURL=24+36+48+60+72+84 V_RGN=G212/RFC
 VYMDH=201306020000-201306282300 CI ALPHA=0.050





NAM V3.1 Summary/Conclusions

- Improving large-scale synoptic performance, especially at day 2-3 (more so during cool season)
- Higher warm-season QPF bias in 12 km parent
- Dramatically improves convective structures in the CONUS 4 km nest
- Dropping legacy GFDL radiation for RRTM allows for better collaboration on radiation scheme enhancements with global branch
 - *NEMS Global Aerosol Capability interactive radiation tests*



HYSPLIT UPGRADE

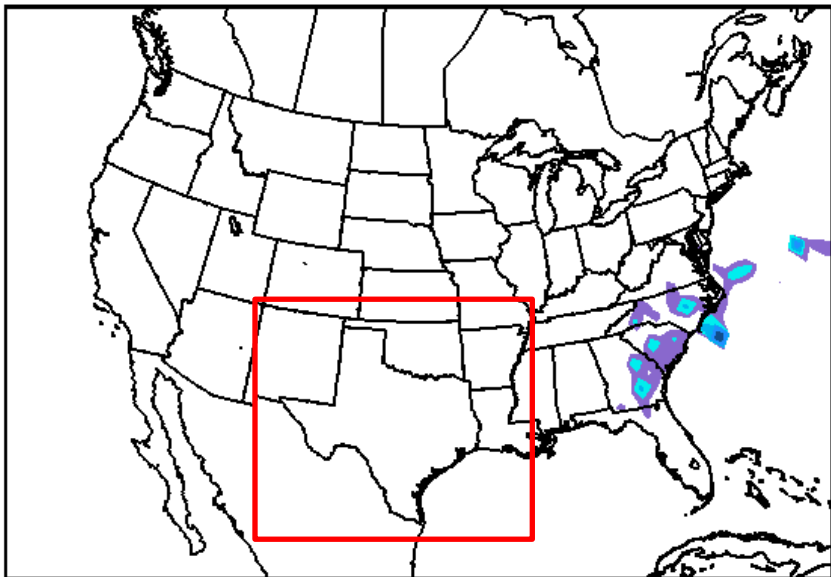
This project is an NWS and NCEP milestone for Q4FY14

HYSPLIT description : Current Operational Dispersion Products

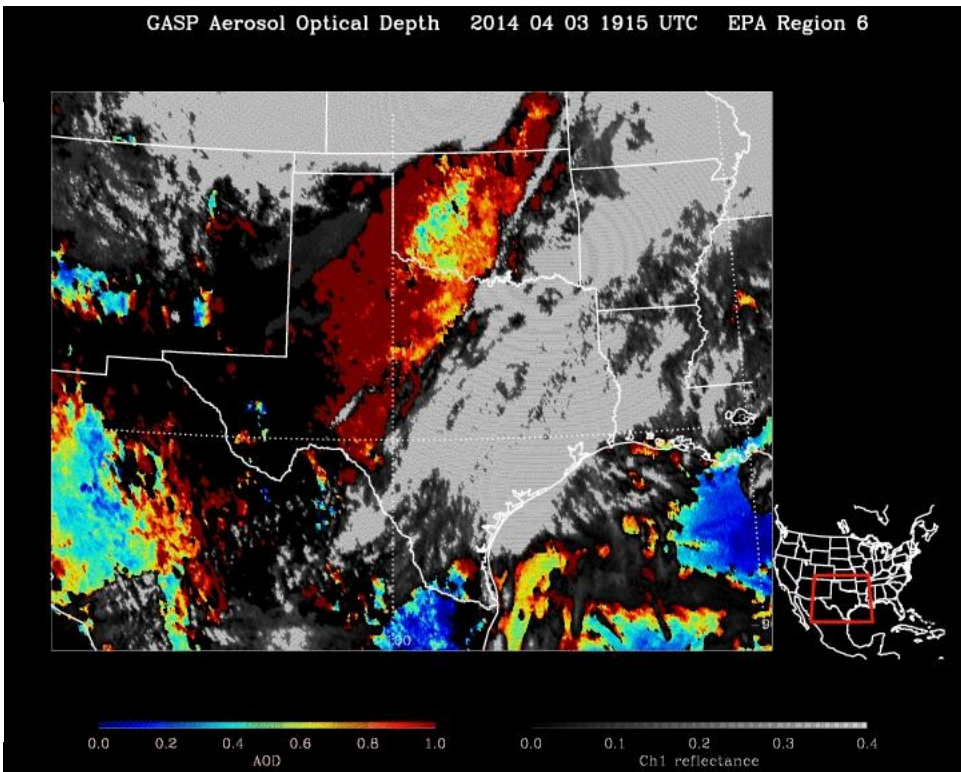
- 48-hour wild-fire **smoke** forecasts (06 UTC cycle) for CONUS, AK, HI
Upgrade: inclusion of Canadian/Mexican fires
- 48-hour **dust** forecasts (06 and 12 UTC cycles) for CONUS
- 48-hour **volcanic ash** forecasts whenever requested by the ICAO-designated U.S VAACS (Washington, DC, Anchorage, AK).
- 72-hour radiological emergency response plume forecast when requested per the **WMO-RSMC** arrangements (IAEA or other country's NMS).
- 48-hour back-tracking product when requested per the WMO/RSMC arrangement
- 16-hour dispersion forecast for **HAZMAT**-type (chemical spill, explosion, etc.) incident upon the request of a WFO; and for about 25 pre-determined locations 4x/day



HYSPLIT Wild fire Smoke Application



OPERATIONAL HYSPLIT SFC SMOKE forecast US 140403/1800V012



NESDIS GASP Imagery of fire smoke on April 3, 2014. Smoke primarily from Mexican fires not included in operational HYSPLIT Smoke forecast system.



Canada/ Mexico Emission impact

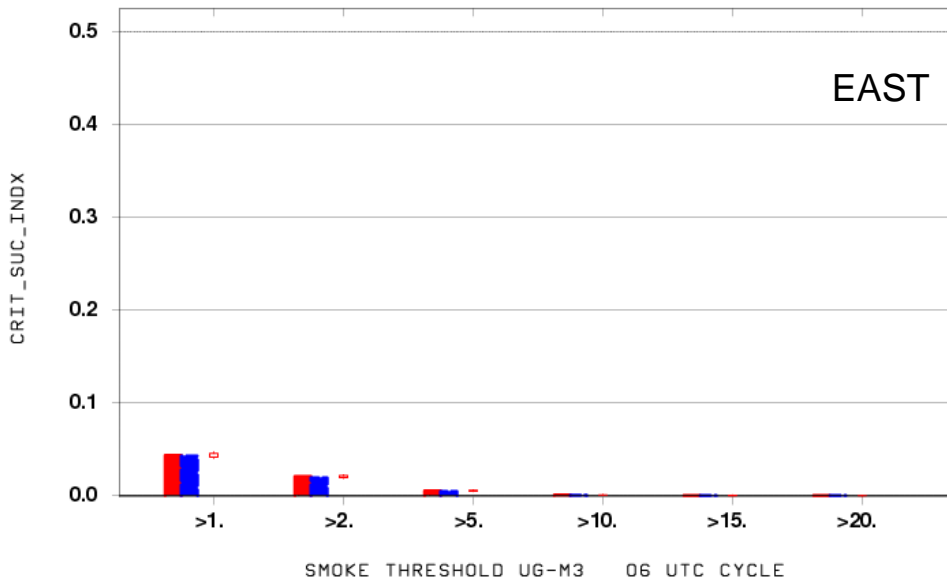
July 8 – Sept. 15, 2013 East and West Regions



01 H SMOKE CRIT_SUC_INDX AVGED BY THRESHOLD
 20130708 TO 20130915
 SMOKEWEMISS

■ HYSPLIT 01 -> 48 HRS CRIT_SUC_INDX
 ■ SMOKEWEMISS EAST-US 01 -> 48 HRS CRIT_SUC_INDX

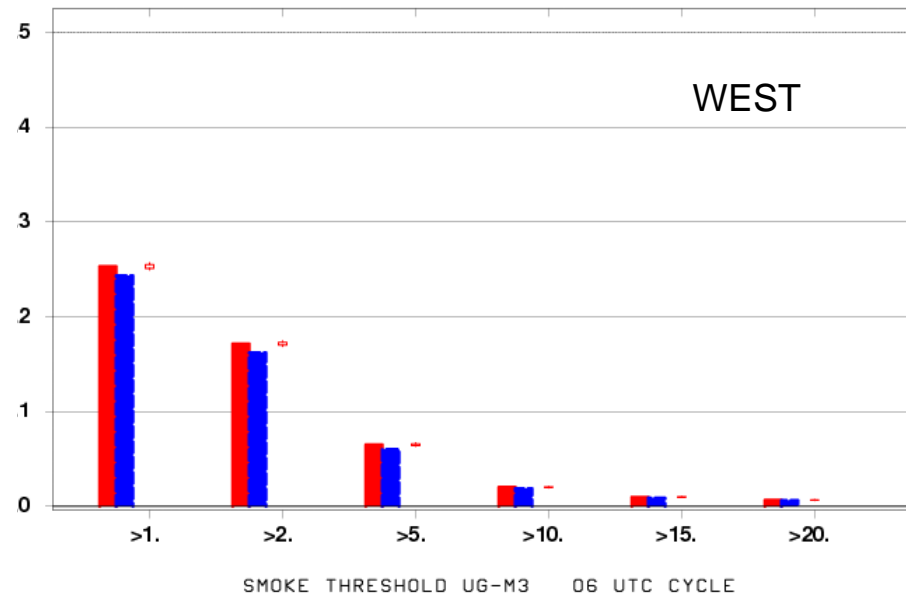
OBSERVATION COUNTS:
 19E06 19E06 16E06 51E05 11E05 267236



01 H SMOKE CRIT_SUC_INDX AVGED BY THRESHOLD
 20130708 TO 20130915
 SMOKEWEMISS

■ HYSPLIT 01 -> 48 HRS CRIT_SUC_INDX
 ■ SMOKEWEMISS WEST-US 01 -> 48 HRS CRIT_SUC_INDX

OBSERVATION COUNTS:
 24E06 24E06 20E06 97E05 40E05 16E05



- <http://www.emc.ncep.noaa.gov/mmb/aa/fvs/hysplit/web/html/fho.html>
- Degraded forecast for low smoke concentrations (< 5 ug/m3) with Puff option



Canada/ Mexico Emission impact July –August, 2014 CONUS CSI verification

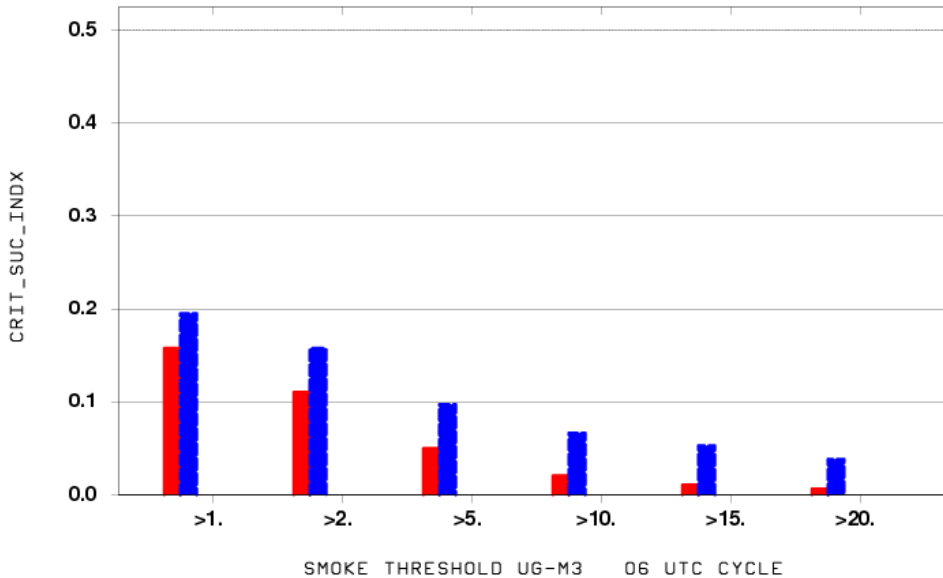


01 H SMOKE CRIT_SUC_INDX AVGED BY THRESHOLD
20140724 TO 20140823
CONUS

■ HYSPLIT-PROD 01 -> 48 HRS CRIT_SUC_INDX
■ SMOKE-V7.2.2-NCO-PARA 01 -> 48 HRS CRIT_SUC_I

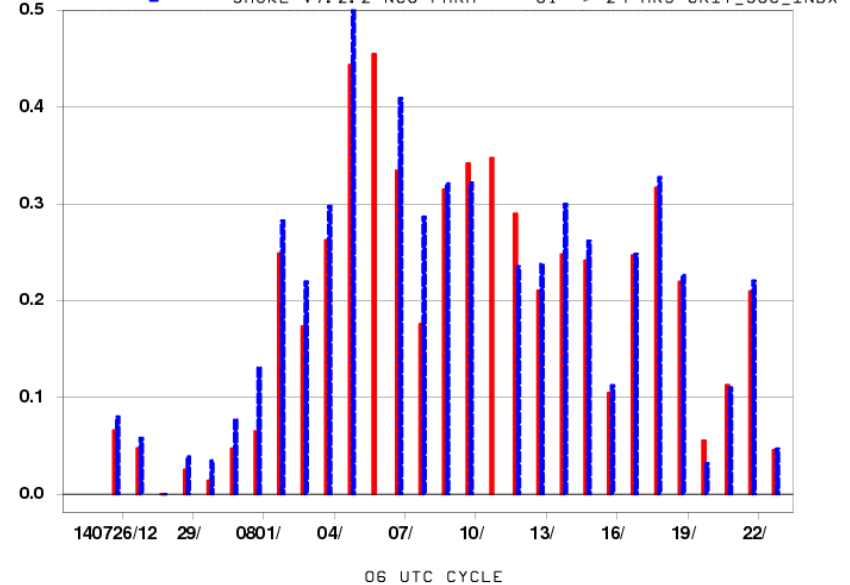
OBSERVATION COUNTS:

34E05 34E05 29E05 13E05 440607 166720



01 H SMOKE CRIT_SUC_INDX
CONUS

■ HYSPLIT-PROD 01 -> 24 HRS CRIT_SUC_INDX
■ SMOKE-V7.2.2-NCO-PARA 01 -> 24 HRS CRIT_SUC_INDX



<http://www.emc.ncep.noaa.gov/mmb/aq/fvs/hysplit/web/html/fho.html>

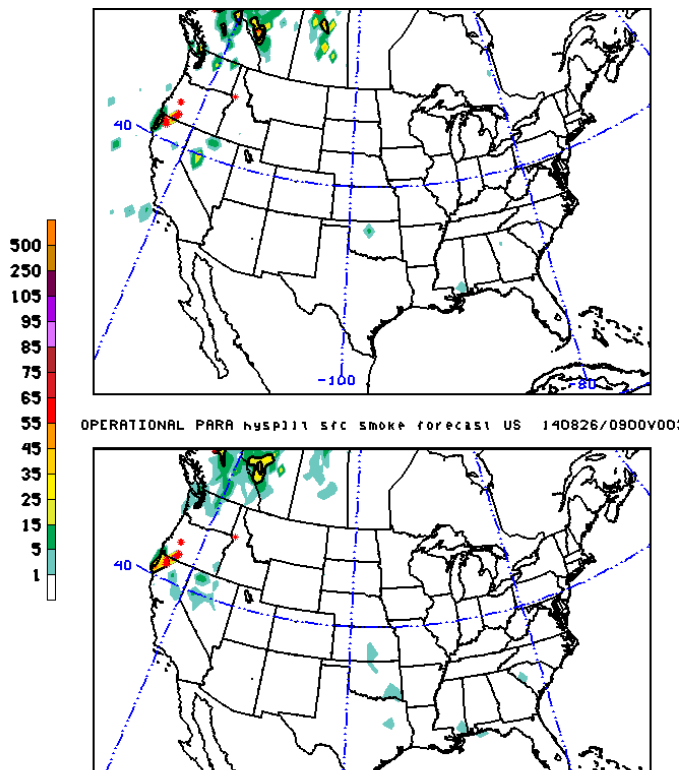
Using NDFD 5 km G227 model output grid

- Parallel using Particle model approach
- Good improvements with Canada/Mex emissions

Smoke Application Summary

Use of Canadian and Mexican emissions yields improved forecasts for real-time and retrospective HYSPLIT simulations

- Recommend implementation given the relative importance of higher smoke concentrations on human health.



August 26, 2014 Smoke forecast



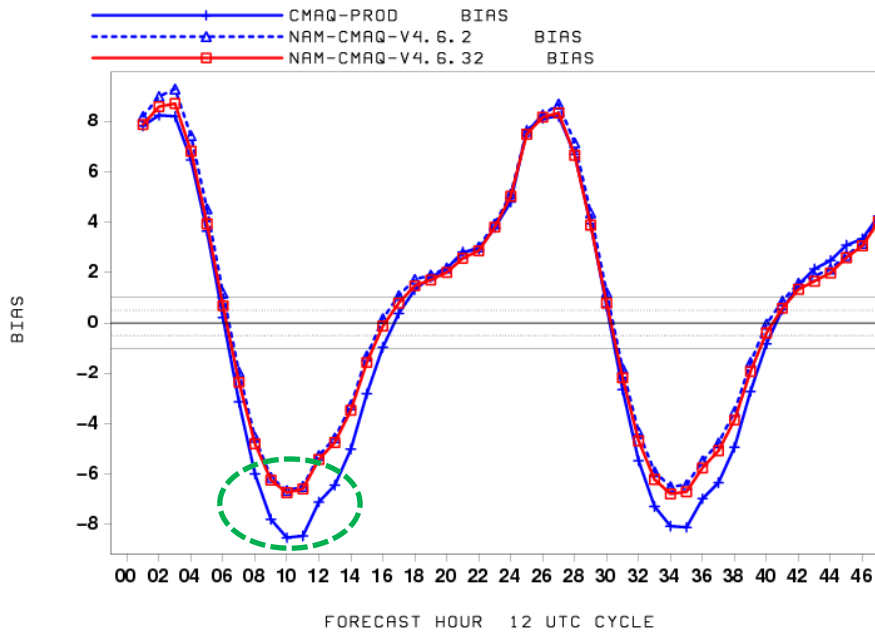
CMAQ V4.6.3 CB05/AERO-4

- **V4.6.2**: April 28, 2014
 - Inclusion of latest **EPA Carbon Bond 5 (CB05) chemical mechanism.**
 - Inclusion of **AERO-4 aerosol chemistry.**
 - Updated anthropogenic emissions with 2014 Dept. Energy projections.
- **V4.6.3**: June 13, 2014
 - **Modulate fugitive dust emission:** suppress over ice/snow.
 - **Incorporate NESIDS HMS wild fire smoke. CONUS**
 - **Incorporate real-time surface dust emissions (wind dependent). CONUS**
 - *NTR, organic nitrate photolyzed and removed quicker.*
 - Layer specific time step was added to speed up code.
- **V4.6.3v2**: June 27, 2014
 - Correction to overestimates of dust emissions
 - repartition percent going to PM2.5, mix beyond first level
- **V4.6.31**: July 16, 2014 With NAM Parallel
 - Turned off gas emissions from fires.
 - Ozone predictions will not be impacted by inclusion of smoke emissions.

1 hour Avg Ozone Performance

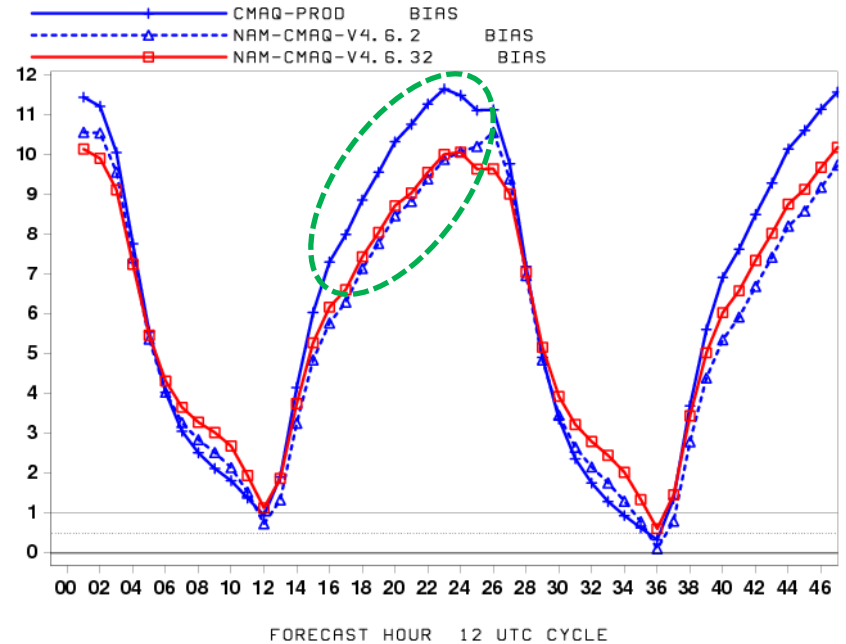
Observed, Prod, V4.6.2, V4.6.31

OZON/1 BIAS AVGED BY FCST HRS
20140715 TO 20140809
WEST-US



Western U.S.

OZON/1 BIAS AVGED BY FCST HRS
20140715 TO 20140809
EAST-US

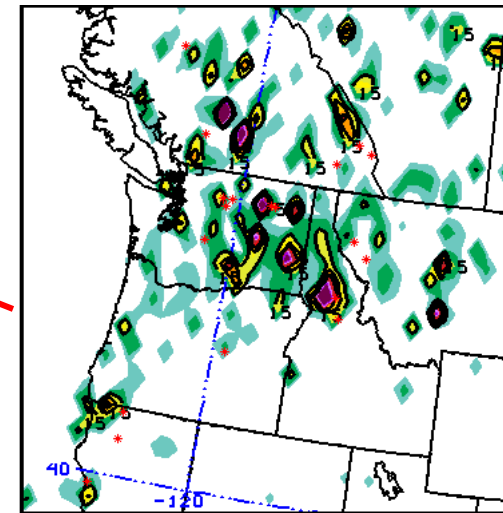
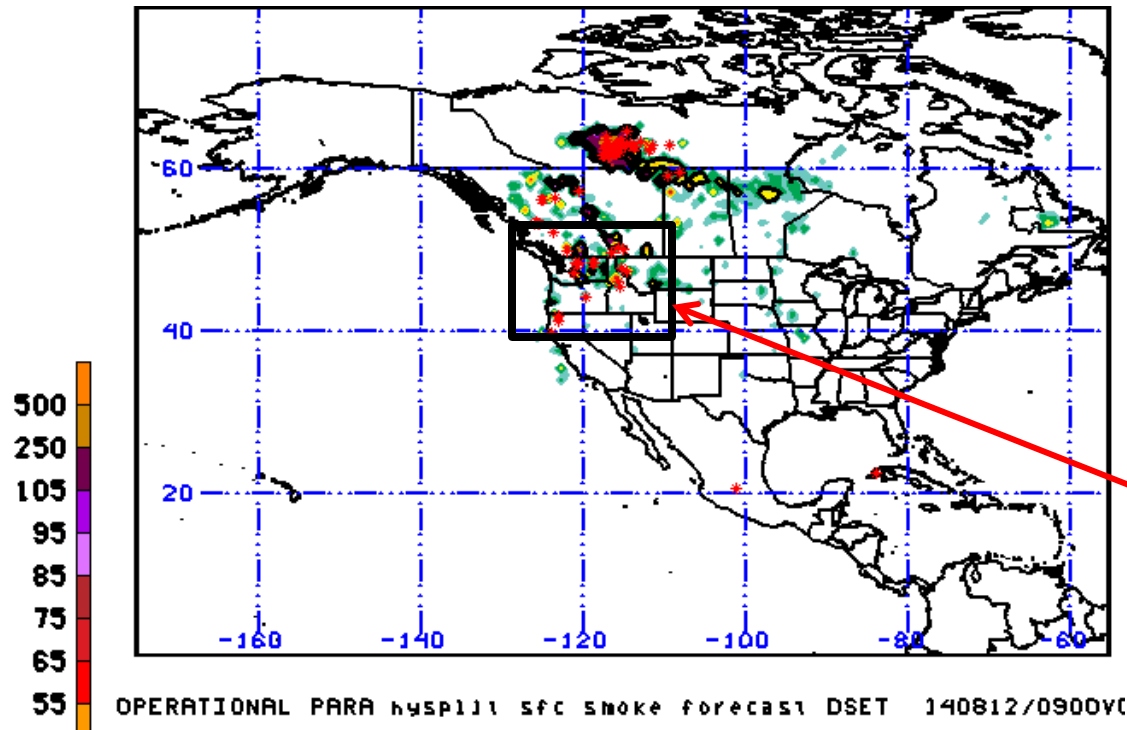


Eastern U.S.

Improvement in Western U.S esp during the day
Improvement in Eastern U.S. at night.

Inclusions of real-time smoke emissions

- NESDIS Hazard Mapping System (HMS) provides fire points
- USFS BlueSky system run within HYSPLIT provides fire emissions (organic carbon, black carbon...)



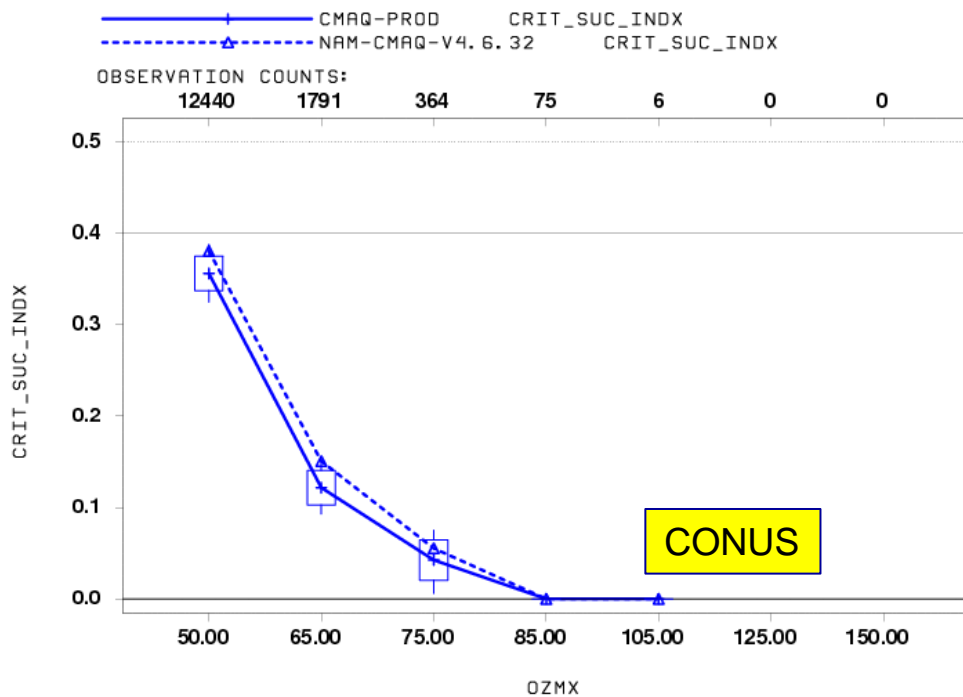


8 hour Avg Daily Max Ozone Performance

Skill Score: Prod, V4.6.3

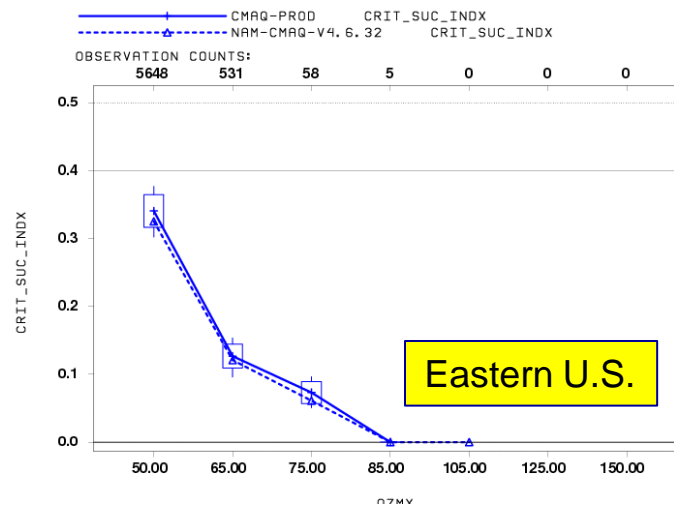


48 H OZMX/8 CRIT_SUC_INDX VALID 1200 GMT AVGED BY THRESHOLD
20140715 TO 20140830
CONUS

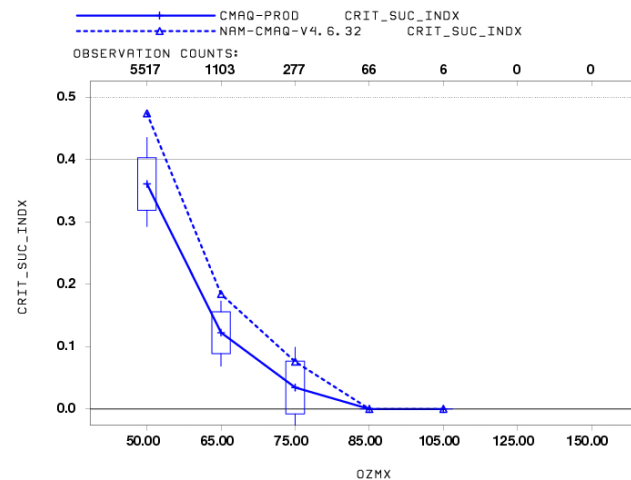


Significant improvement in Western U.S for most thresholds

48 H OZMX/8 CRIT_SUC_INDX VALID 1200 GMT AVGED BY THRESHOLD
20140715 TO 20140830



48 H OZMX/8 CRIT_SUC_INDX VALID 1200 GMT AVGED BY THRESHOLD
20140715 TO 20140830





1 hour Avg Daily Max Ozone Performance

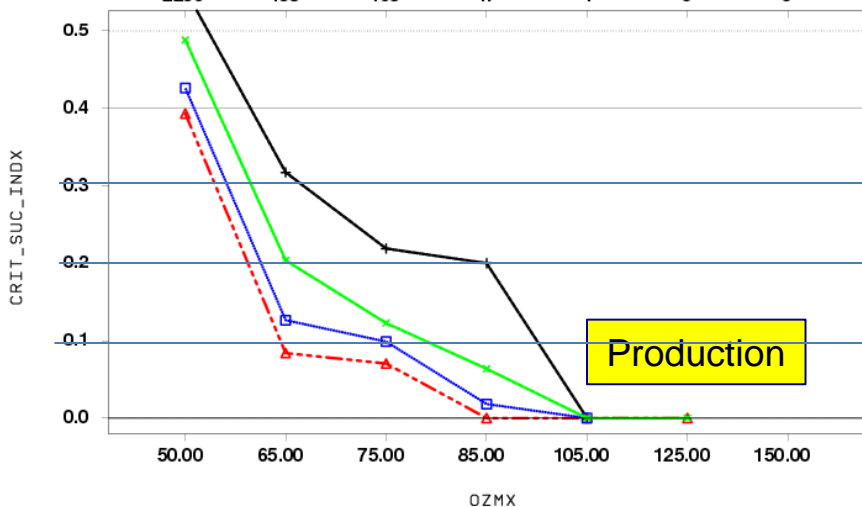
Skill Score: Prod vs V4.6.3

48 H OZMX/1 CRIT_SUC_INDX VALID 1200 GMT AVGED BY THRESHOLD
20140715 TO 20140830

—+—	CMAQ-PROD	NORTHEAST	CRIT_SUC_INDX
- - -△-	CMAQ-PROD	SOUTHEAST	CRIT_SUC_INDX
—□—	CMAQ-PROD	MIDWEST	CRIT_SUC_INDX
—×—	CMAQ-PROD	SWEST-COAST	CRIT_SUC_INDX

OBSERVATION COUNTS:

2296 498 163 47 4 0 0

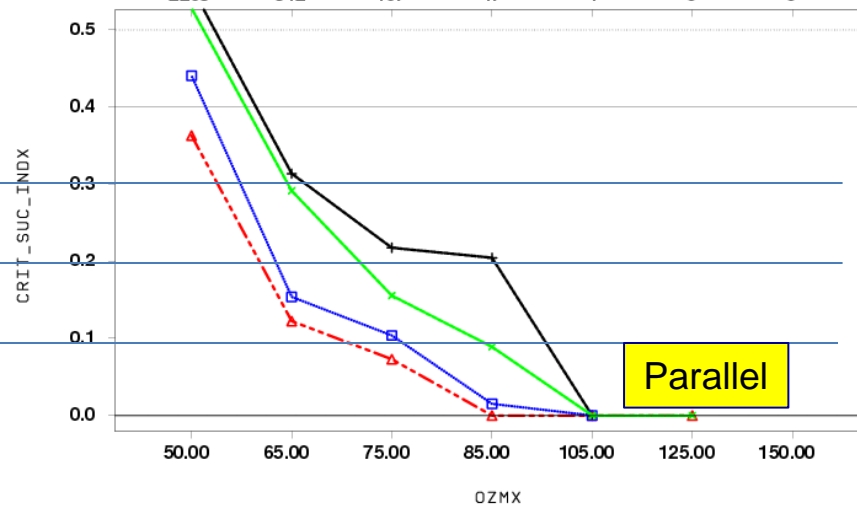


48 H OZMX/1 CRIT_SUC_INDX VALID 1200 GMT AVGED BY THRESHOLD
20140715 TO 20140830

—+—	NAM-CMAQ-V4.6.32	NORTHEAST	CRIT_SUC_INDX
- - -△-	NAM-CMAQ-V4.6.32	SOUTHEAST	CRIT_SUC_INDX
—□—	NAM-CMAQ-V4.6.32	MIDWEST	CRIT_SUC_INDX
—×—	NAM-CMAQ-V4.6.32	SWEST-COAST	CRIT_SUC_INDX

OBSERVATION COUNTS:

2268 512 167 47 4 0 0



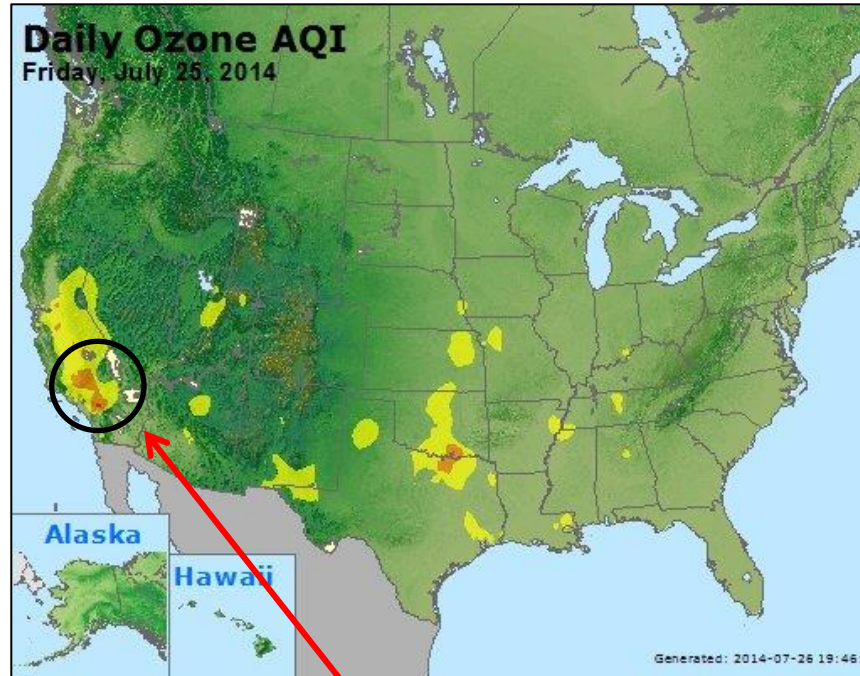
Significant improvement over:

SW US >65 – 85 PPB

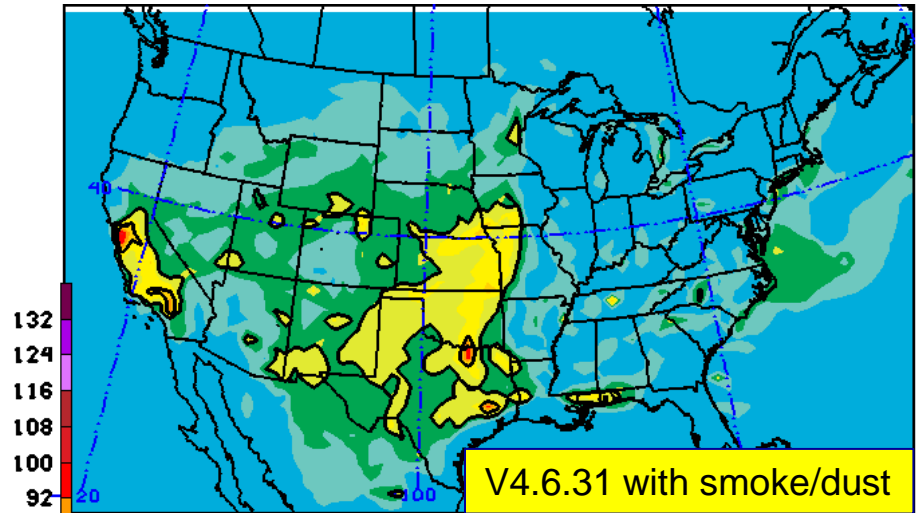
SE US >65 PPB



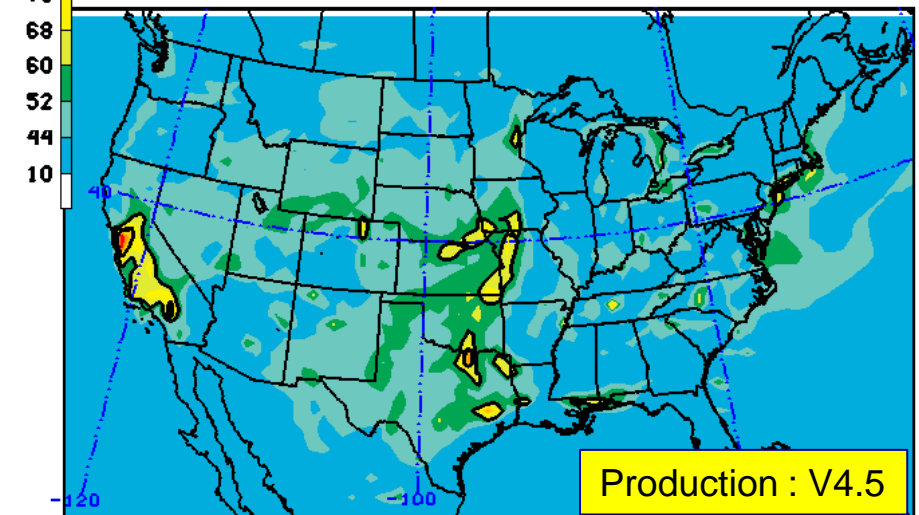
Ozone Predictions July 25, 2014 Case



Experimental run better captures Code Orange Event in Southern California



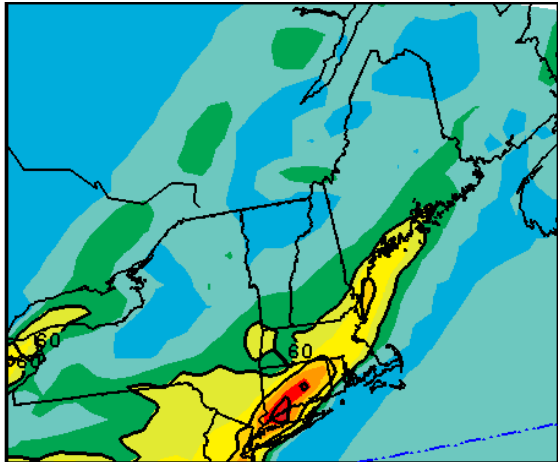
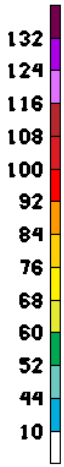
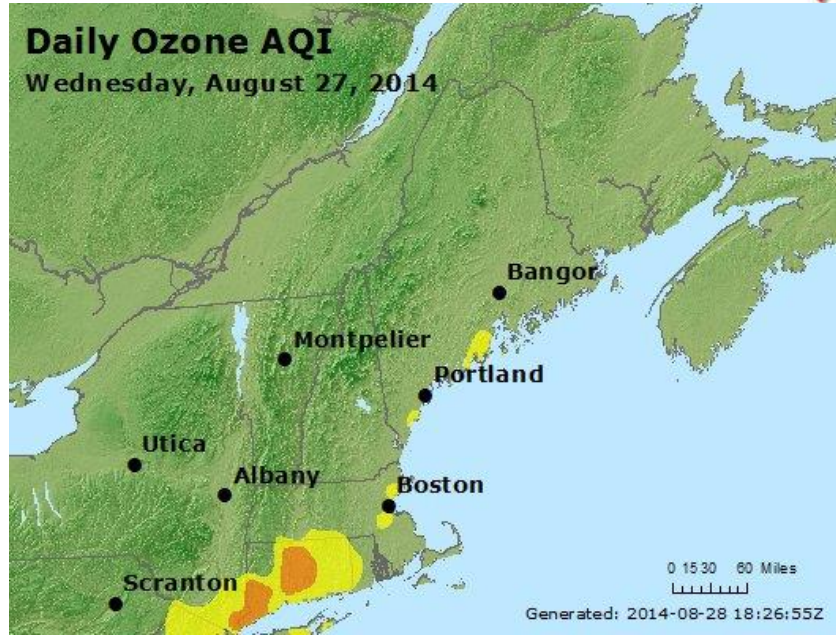
EMC EXPERIMENTAL V4.6.31 aqm sfc OZCN01 forecast DSET



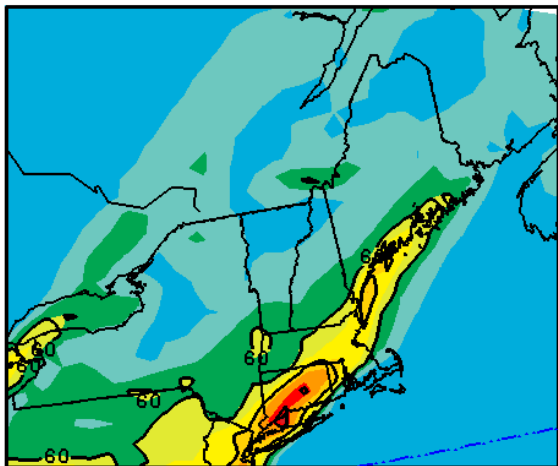
OPERATIONAL prod aqm sfc OZCN01 forecast DSET 140726/0000V092



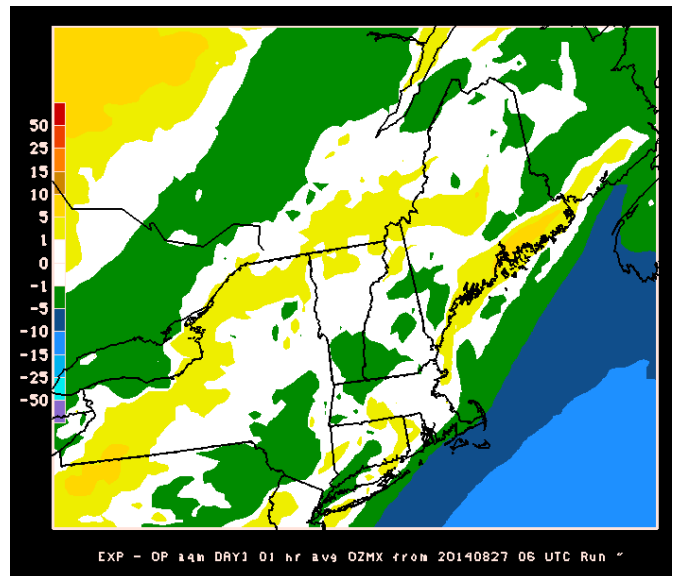
August 27, 2014 NE US exceedence



EMC EXP V4.6.32 aqm sfc DAY1 OZMXD1 20140827 06



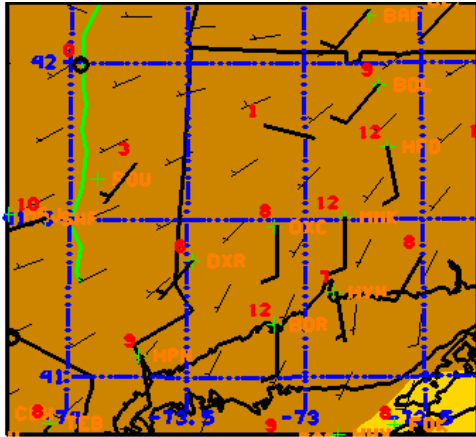
OPERATIONAL prod aqm sfc DAY1 OZMXD1 20140827 06Z Cycle "



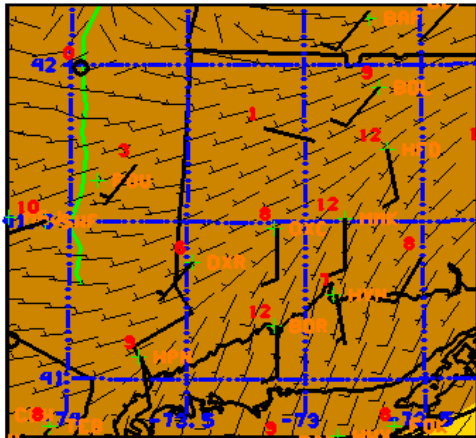
EXP - OP aqm DAY1 01 hr avg OZMX from 20140827 06 UTC Run "

NAM Parent vs Nest

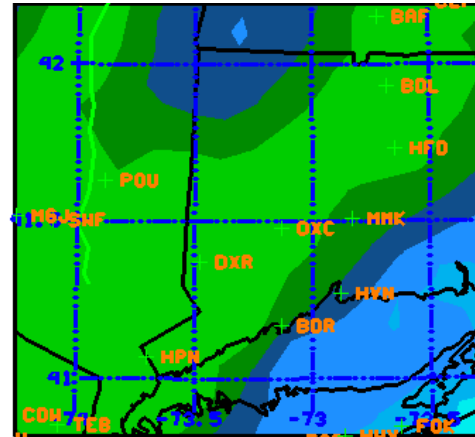
August 27, 2014 21 UTC



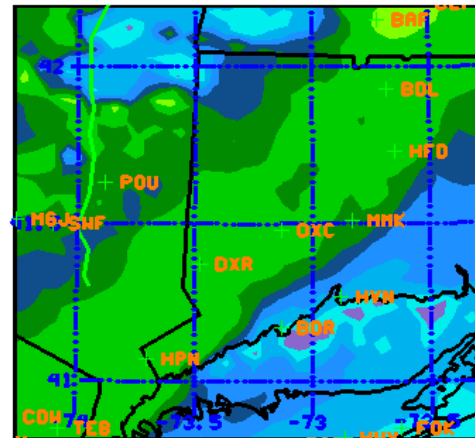
MESO 12 NAM 10 M SPED CT*** 140827/2100V015



MESO CONUSNEST NAM 10 M SPED CT*** 140827/2100V0



MESO 12 NAM SFC PBL HGT (M) CT*** 140827/2100V015

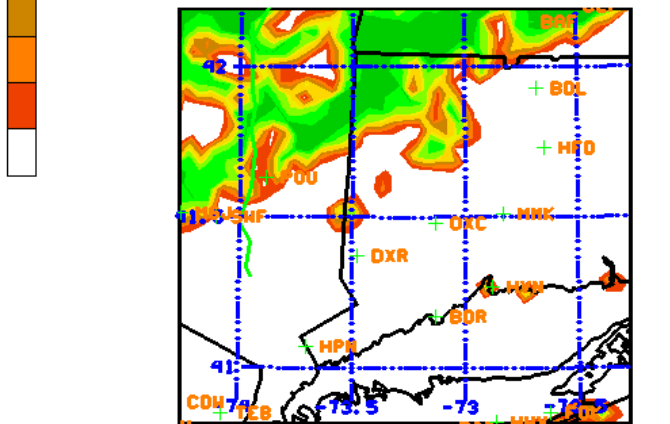
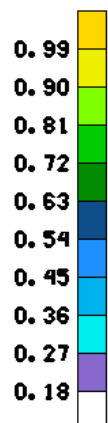
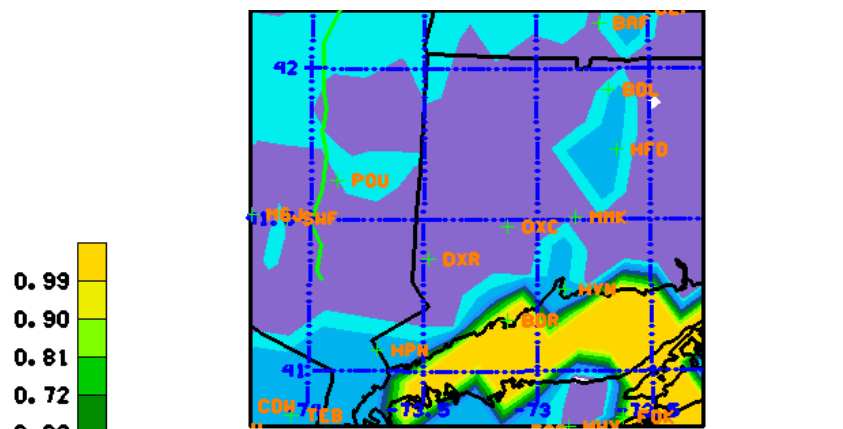
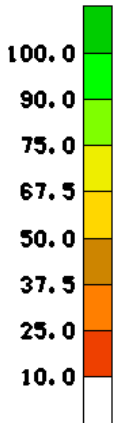
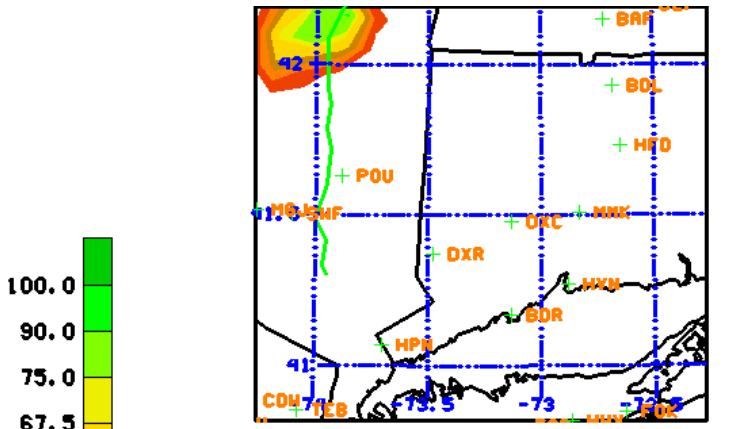


MESO CONUSNEST NAM SFC PBL HGT (M) CT*** 140827/2100V015 -

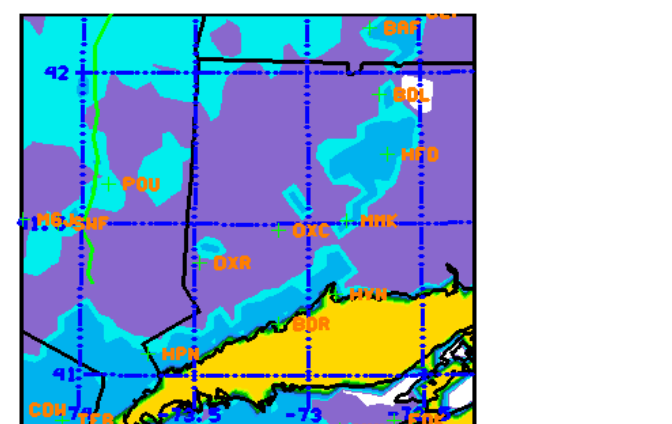
Marine Layer moves further inland with NAM Nest
But winds are weaker than observed

NAM Parent vs Nest

August 27, 2014 21 UTC



MESO CONUSNEST NAM SFC TOTAL CLOUD FRAC CT*** 1401



MESO CONUSNEST NAM 0 : 10 M SOIM CT*** 140827/2100V015

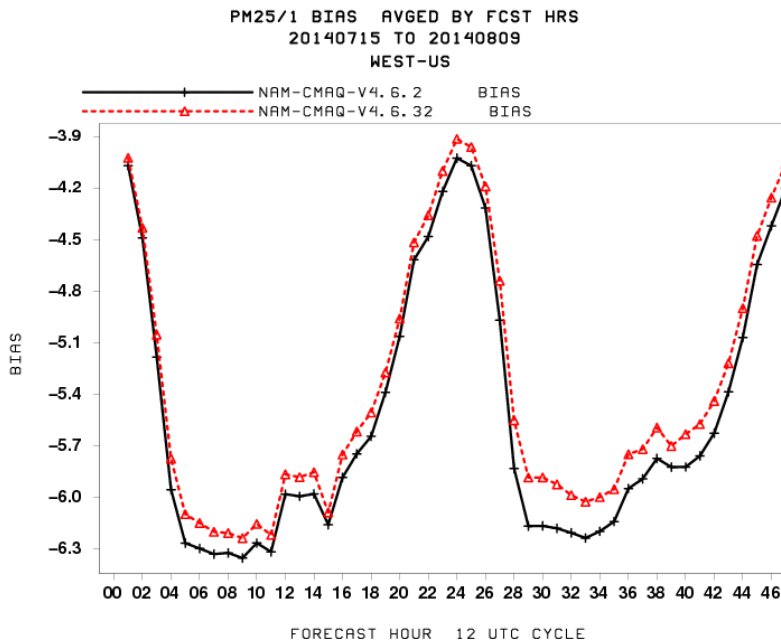
Frontal clouds better delineated with Nest
Can contribute to weaker ozone plume



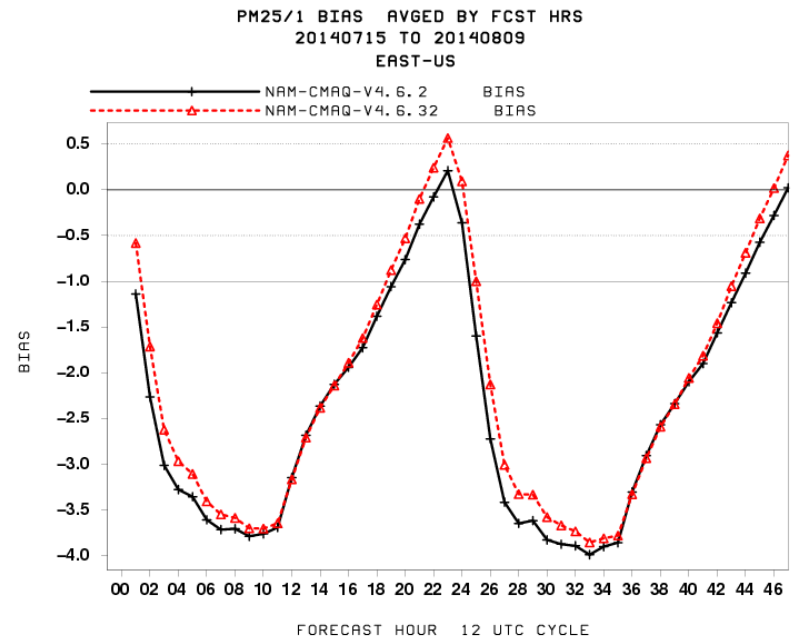
PM Performance

Obs, V4.6.2, V4.6.31

July 16-August 9, 2014



Western U.S.



Eastern U.S.

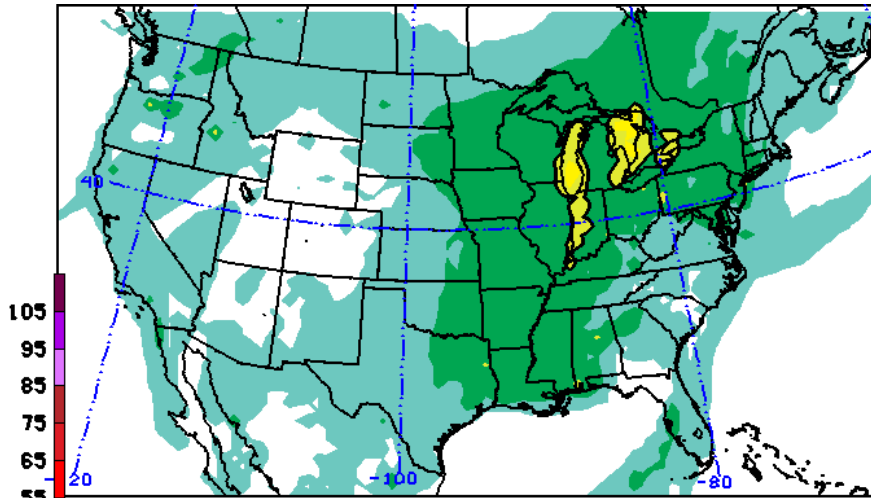
Inclusion of smoke/dust with V4.6.3 small

- Larger impact out west and at night

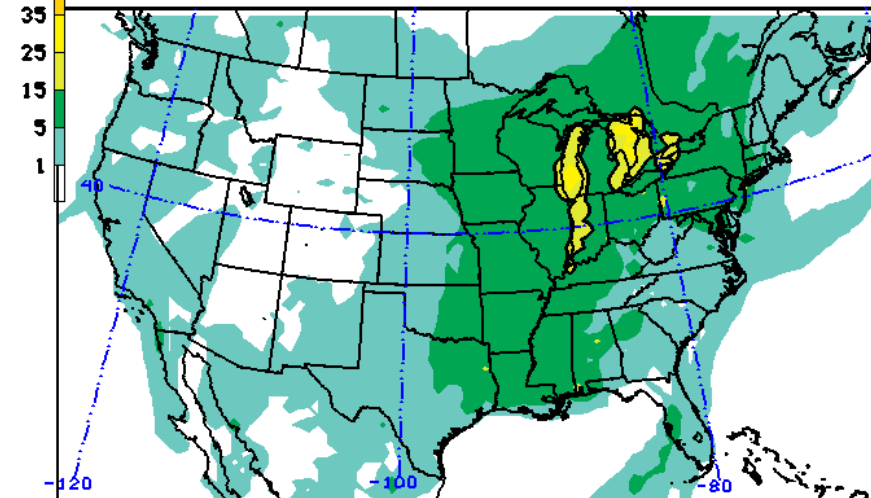
PM2.5 Predictions

Smoke influence on total PM

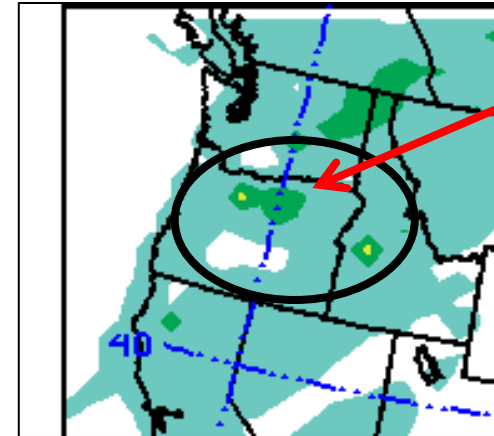
July 21, 2014 case



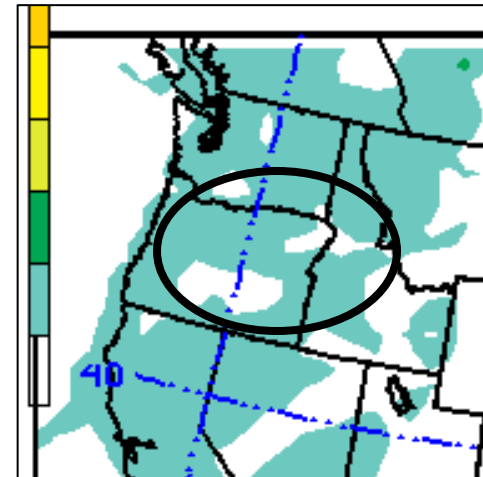
EMC EXPERIMENTAL V4.6.3 a4m sfc PM2501 forecast



EMC EXPERIMENTAL V4.6.2 a4m sfc PM2501 forecast DSET 140721/2100V009

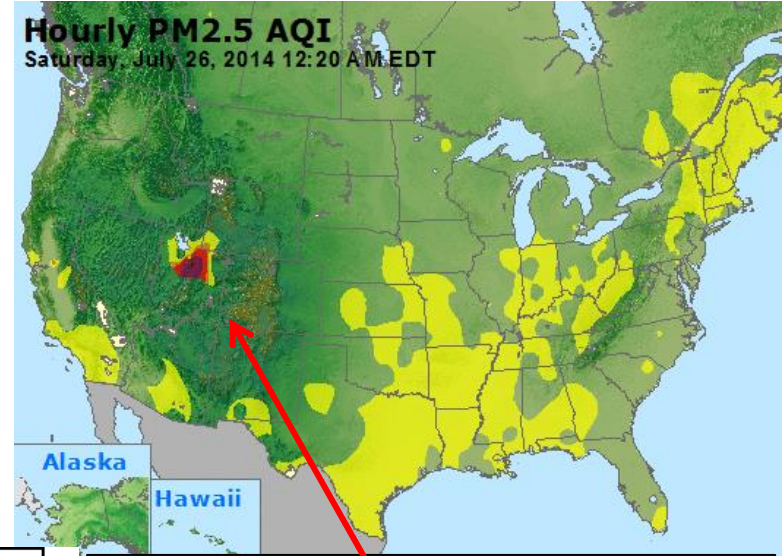
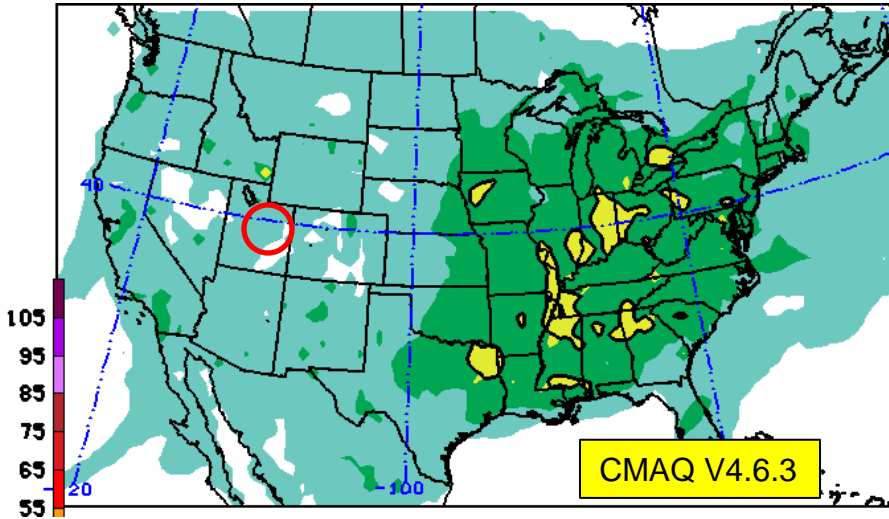


Wild fires included

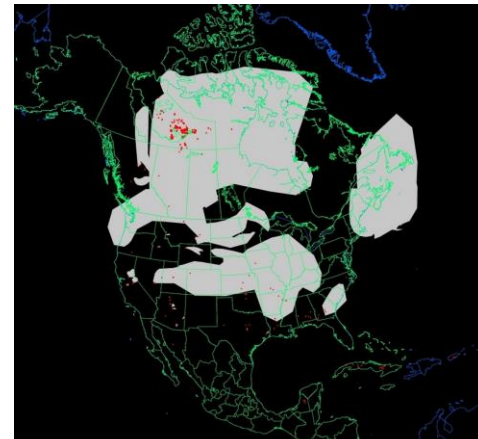
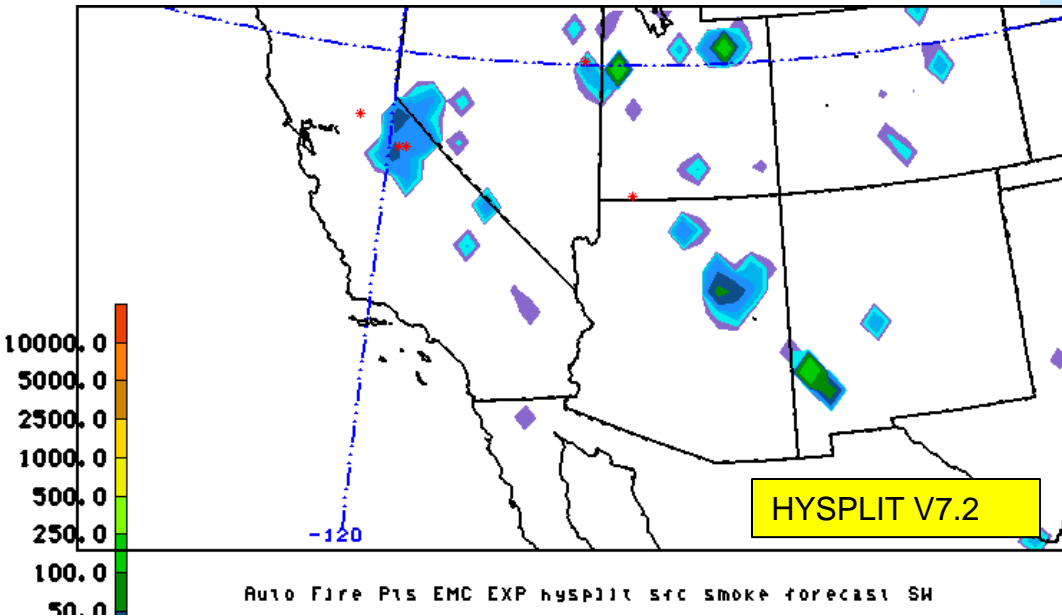


PM2.5 Predictions

Valid July 26, 2014 06 UTC Utah fires/dust



Utah PM exceedence driven by smoke/dust not captured by V4.6.3

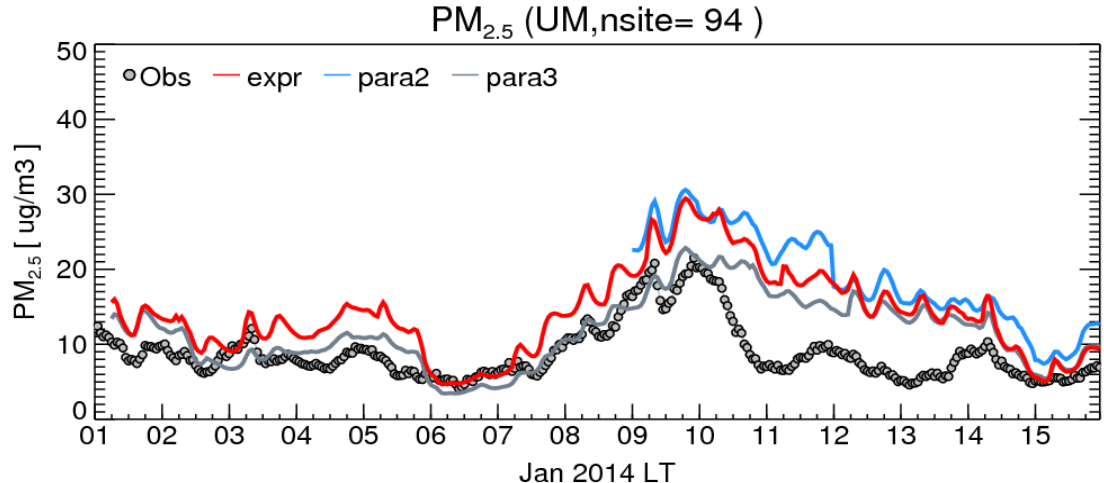


North America covered with smoke

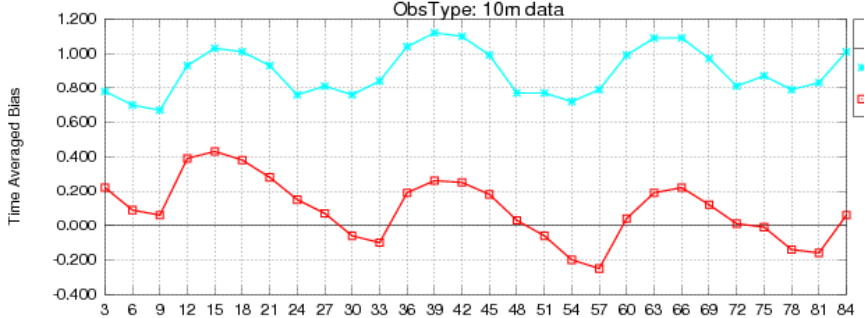


January 2014 PM error over MidWest

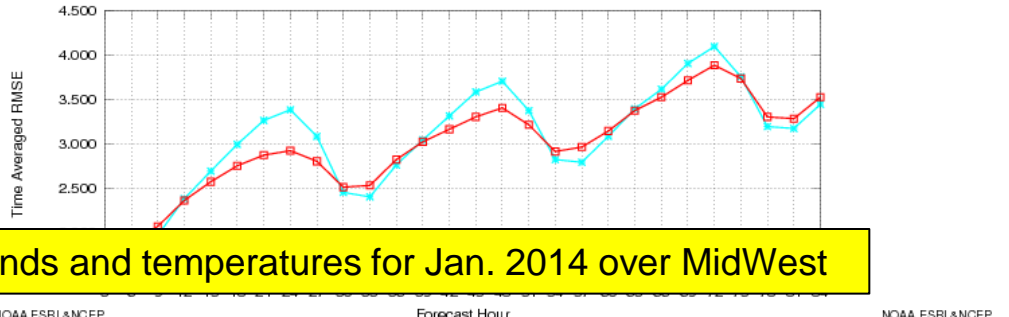
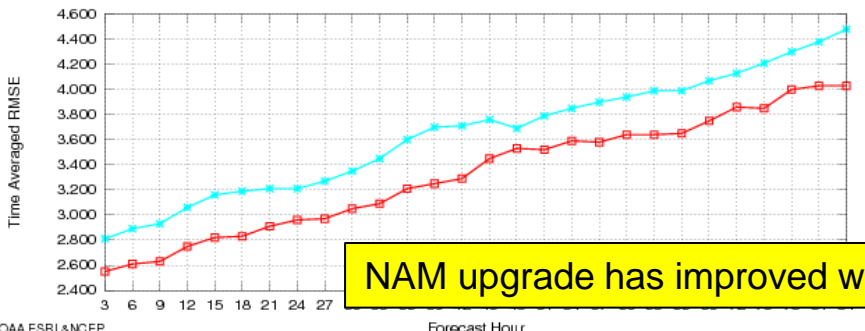
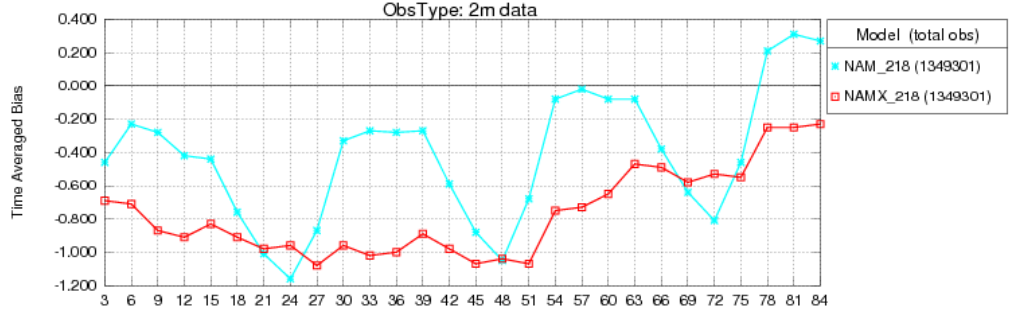
NAM vs NAMx



SFC Vector Wind, Runtime: 12Z, ObsType: 10m data



SFC Temperature, Runtime: 12Z, Forecast Hour: ALL, 01 JAN - 30 JAN 2014, MDW



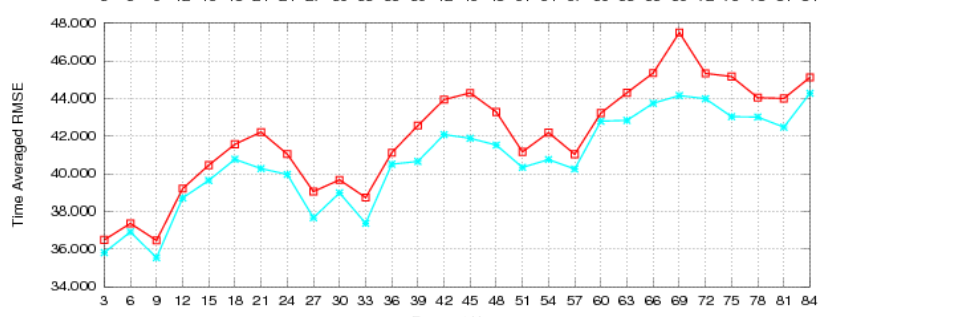
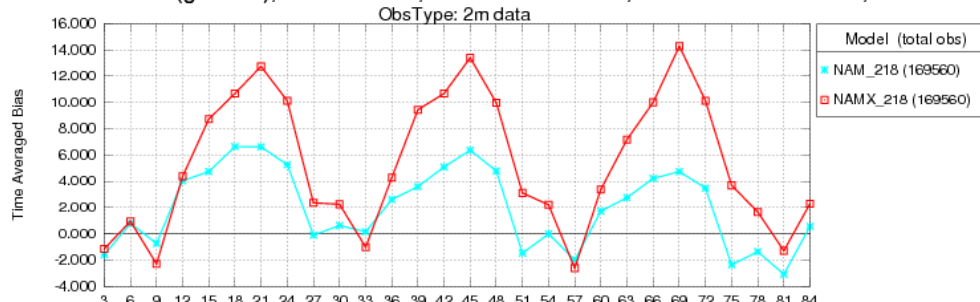
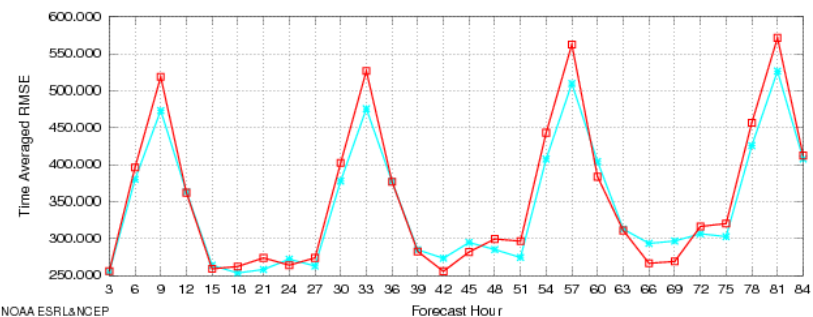
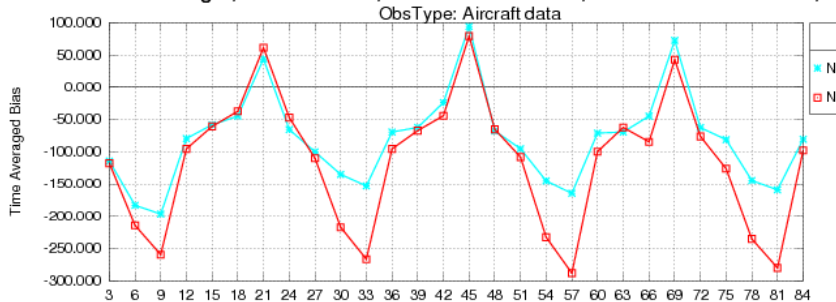
NAM upgrade has improved winds and temperatures for Jan. 2014 over MidWest



NAM vs ACARS PBL Height

January 2014

1000 hPa PBL Height, Runtime: 12Z, Forecast Hour: ALL, 01 JAN - 30 JAN 2014, C: SFC Total Cloud (gridtobs), Runtime: 12Z, Forecast Hour: ALL, 01 JAN - 30 JAN 2014, Natl



NAM upgrade has larger PBL Height underprediction in evening over Midwest And cloud overpredictions Nationally.

Too little mixing in stable air with upgraded NAM ?



PRODUCTS



CMAQ currently generates:

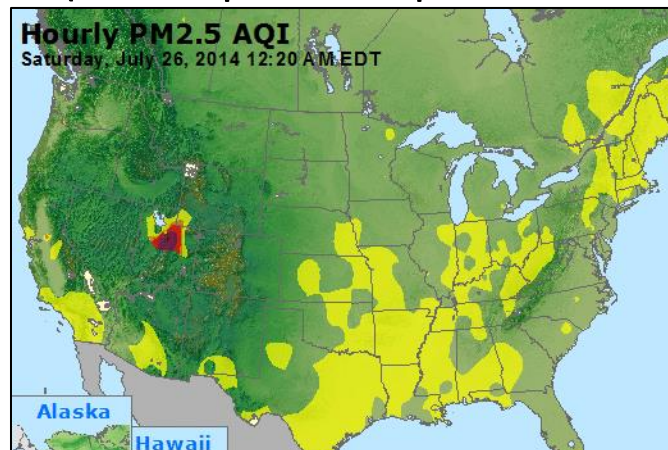
- 12 km hourly surface ozone grib files hourly,
- 8 hourly ozone averages
- Day 1 and Day 2 one and eight hour average ozone daily maximum

<http://www.emc.ncep.noaa.gov/mmb/aq/cmaq/web/html>

<http://www.emc.ncep.noaa.gov/mmb/aq/hysplit/web/html>

- Changes:

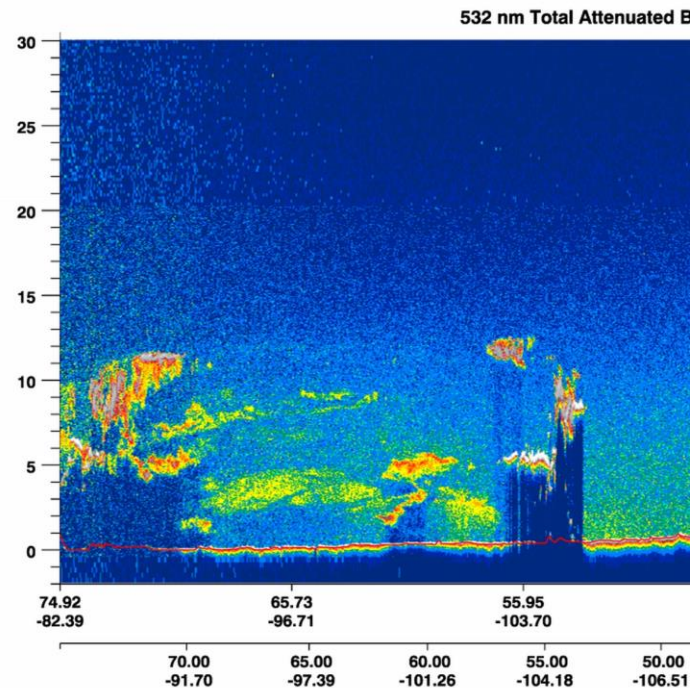
- Add 12 km hourly and 24 h avged surface Particulate Matter 2.5 um (PM2.5) grib files (developmental product only)



PM 2.5 observations for July 26, 2014

CMAQ Summary

- **Ozone predictions improved** with latest changes to V4.6.3
- Some improvement in PM performance with smoke emissions
- Increased smoke preprocessing time delays product availability by up to 1 hr
- Impact of smoke/dust on PM likely too small (still strong underpredictions)
- Decreased Mixing with NAM upgrade in Stable conditions may contribute to winter time PM biases
- 4 km Nest could provide useful Information to identify processes Not resolved with 12 km runs (eg: sea breezes, convective clouds)

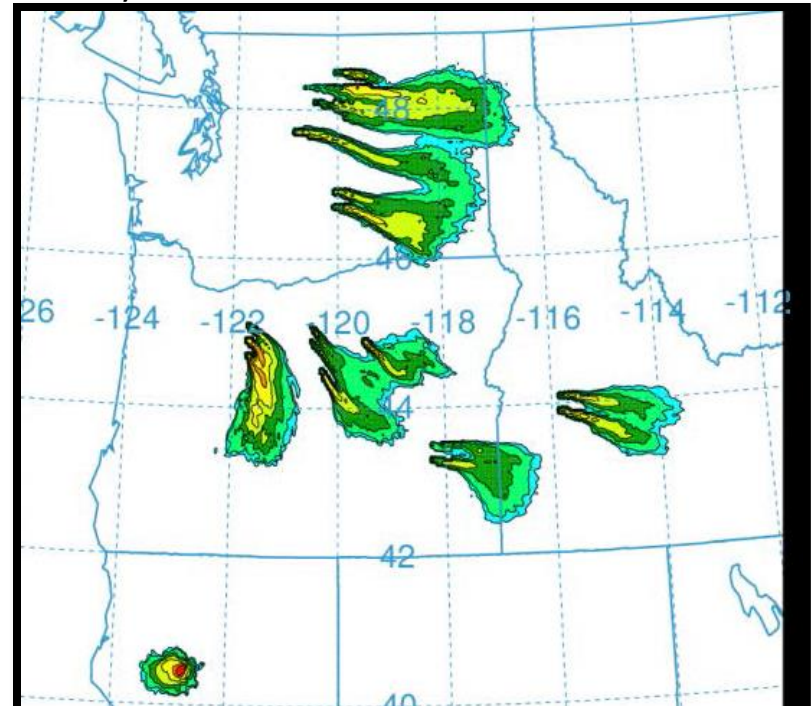


CALIPSO overpass of July 24, 2014 major Canadian fires. Complicated multi-layer plume pattern observed.

Future plans

- Short term (1-2 years)

- Include NGAC real-time aerosol boundary conditions
- Improve smoke emissions
 - Update Bluesky emissions
 - (forest load, consumption, spread emissions)
 - Evaluate NGAC Fire Radiative Power smoke emissions approach
 - Evaluate plume rise (additional met constraints)
- Improve dust emissions
 - NAM gust vs speed
 - DNG winds
 - Soil moisture impact
- Include ESRL bias correction
 - At stations
 - spreading technique to grid
- High Resolution smoke/dust modeling



HYSPLIT smoke driven with NAM 4 km
July 19, 2014