Recent Performance of the NOAA Air Quality Forecasting Capability and the Impact of Driving Meteorology

http://www.emc.ncep.noaa.gov/mmb/aq

Jeff McQueen, Jianping Huang, Ho-Chun Huang, Perry Shafran– NCEP/EMC
Amanda Sleinkofer – Millersville University
Pius Lee, Li Pan, Daniel Tong –NOAA/ARL
Ivanka Stajner, Sikchya Upadhaya – NWS/STI

October 25, 2017

Meteorological processes influencing air quality

- Coastal sea/bay breeze flows

- Complex topographical processes
    - → mountain/valley flows; trapping, cold pools

- Urban meteorology
    - → urban boundary layer, in canyon, skim flows

- Land surface/air-surface exchange
    - → Deposition, biogenic emissions

- Aerosol interactive radiative/cloud microphysical processes

- Clouds and aqueous phase chemistry, wet deposition

- Vertical mixing esp in stable boundary layers

# NAM Forecast System - Version 4 (March 2017)

- **Resolution Changes**
  - CONUS (4 km) and Alaska (6 km) nests → **3 km**
  - Sync AK and CONUS On-Demand Fire Weather nests → **1.5 km**

- **Select Model Changes**
  - Updated microphysics → **Improved stratiform precip**
  - **Reduce incoming SW Rad under clouds:** reduce warm season 2-m T warm bias
  - More frequent calls to physics → **Physics/dynamics more in sync**
  - **Improve effect of frozen soil on transpiration and soil evaporation** → **Improve cold season 2-m T/Td biases**
  - Adjustment to convection in 12 km NAM
  - Modify latent heat flux treatment → **Improve visibility along CA coast**

- **Data Assimilation**
  - DA cycles for 3 km nests → **Much less 'spin-up' time**
  - Use of Lightning/Radar Refectivity-derived temperature tendencies
    - **Improved short-term forecasts of storms at 3 km**
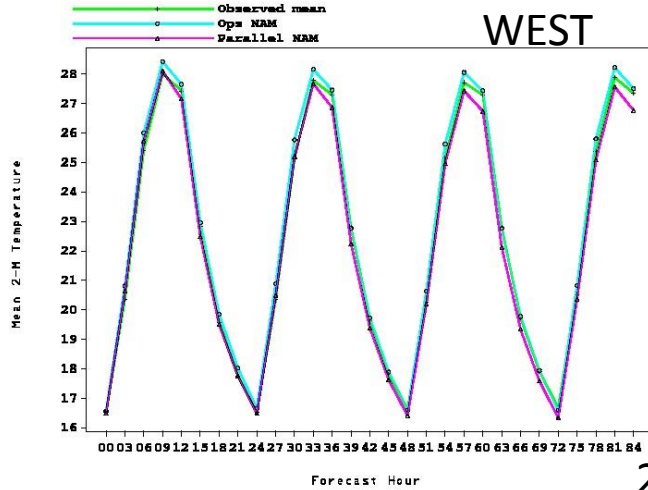 - New satellite radiances, satellite winds

DA
3 km
1.5 km
12 km
DA
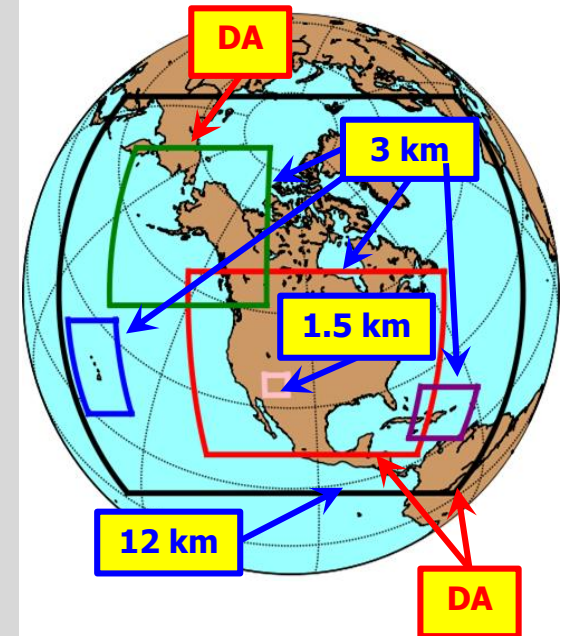
DA: Data Assimilation Cycle

Courtesy Eric Rogers, EMC
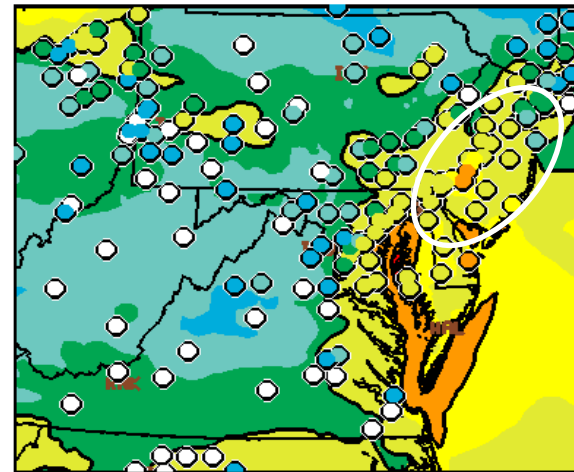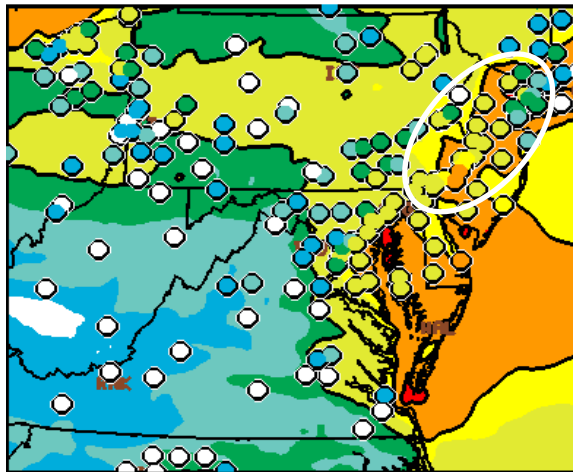
3

NAM March 21, 2017 Upgrade

Mean 2-M Temp vs. sfc obs (12Z cycle) over the Western US for ops NAM and p11 NAM forecasts from 201607190000 to 201608291200

WEST

Mean 2-M Temp vs. sfc obs (12Z cycle) over the Eastern US for ops NAM and p11 NAM forecasts from 201607190000 to 201608291200
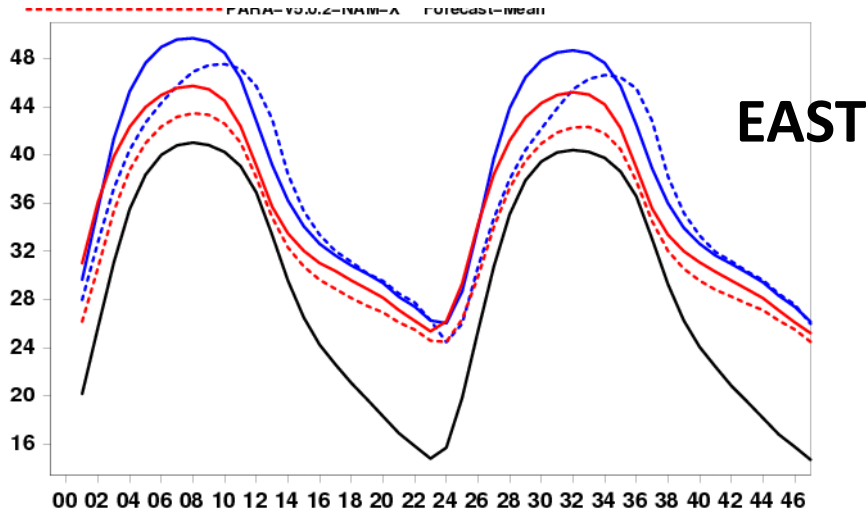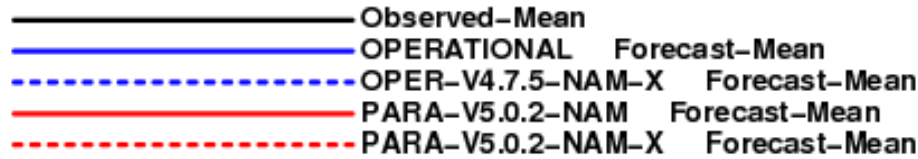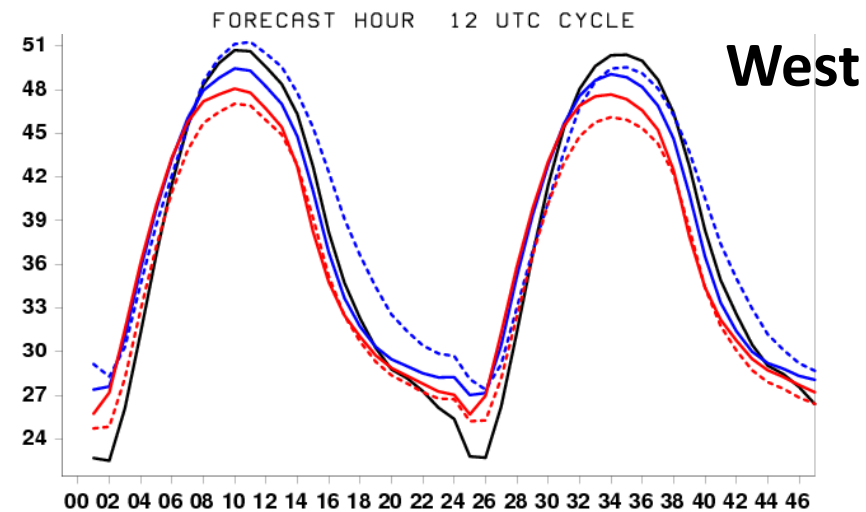
EAST

2 m Temperature

PROD DAY1 OZMXO8 20160708 12Z CYC

DPARA DAY1 OZMXO8 20160708 12Z CYC
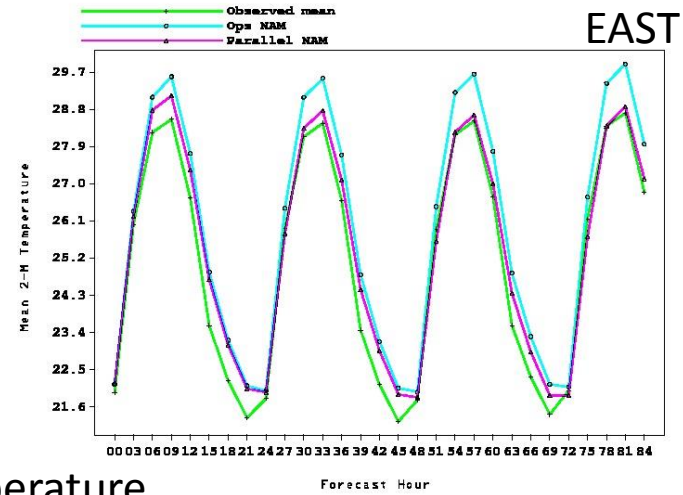
NAM - CMAQ V4.7   NAM-V4 - CMAQ V4.7

40.0   45.0   50.0   54.5   65.0   70.5   86.0   106.0

4

July 2016 NRT CMAQ Prod vs V5.0.2
1 h avg Diurnal Ozone

- *CMAQ V5.0.2 NAM-V4*: improvement in ozone over-prediction over the East

- *CMAQ V5.0.2 NAM-V4*: Strongest underestimate over West

- Meteorological impact nearly as large as CMAQ/Emissions upgrade

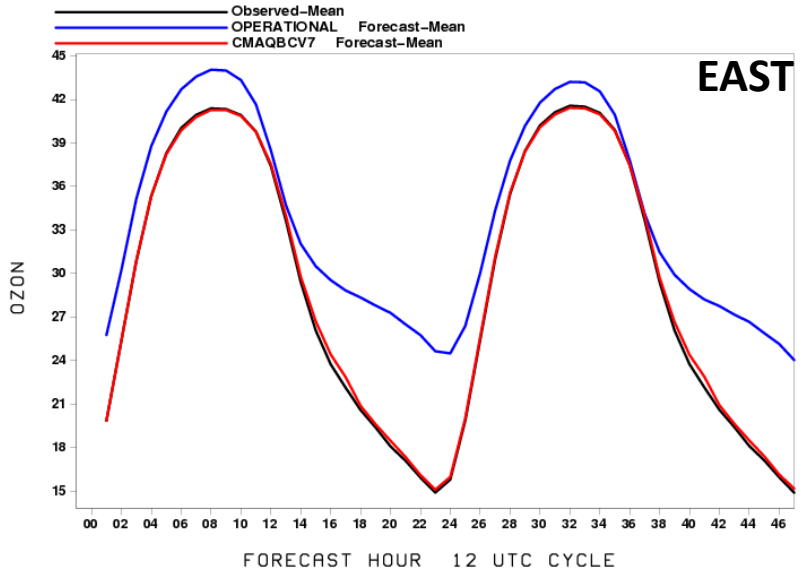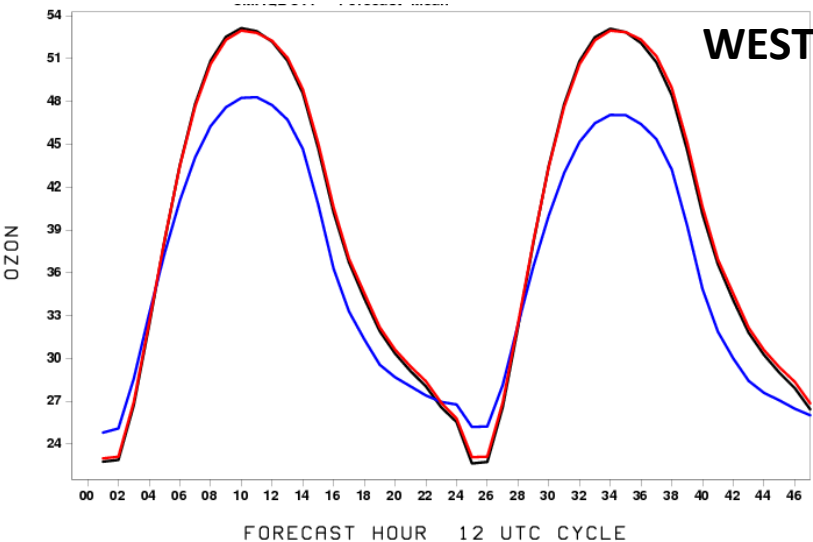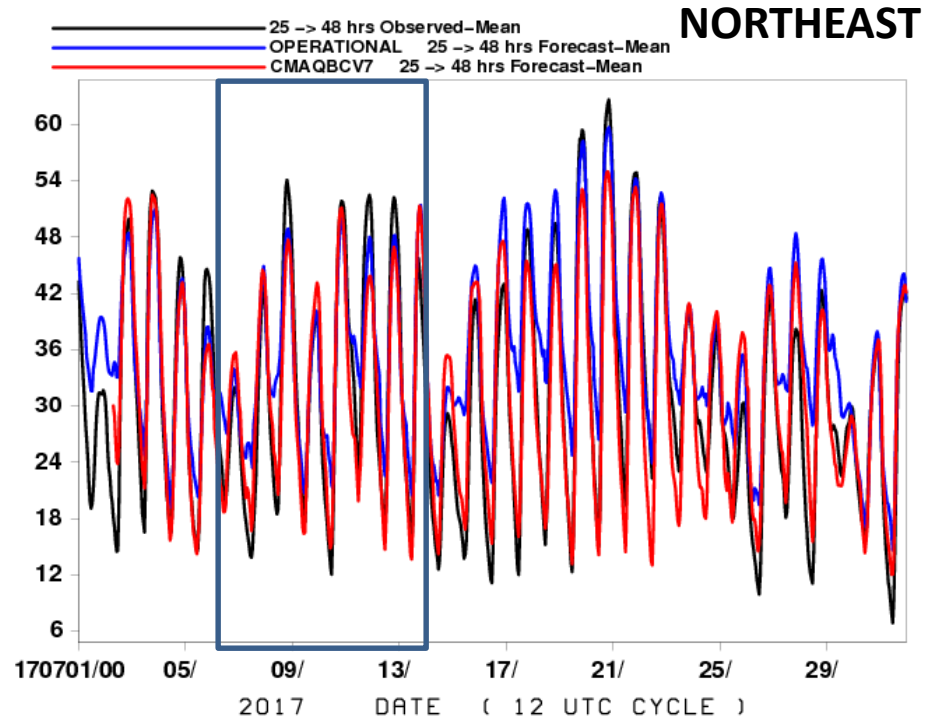# Ozone Errors: July 2017
Obs vs Raw vs Bias Corrected

1-h Avg OZON obs (PPB) avged by fcst hrs
20170701 to 20170731
East-US

Observed-Mean
OPERATIONAL   Forecast-Mean
CMAQBCV7   Forecast-Mean

EAST

WEST

DAY 2 1-h Avg OZON obs (PPB)
Northeast

25 -> 48 hrs Observed-Mean
OPERATIONAL   25 -> 48 hrs Forecast-Mean
CMAQBCV7   25 -> 48 hrs Forecast-Mean

NORTHEAST

East : Overprediction overall but underprediction for July 10-12 exceedences
West: Continued underprediction
O3 BIAS CORRECTION:
→ Diurnal performance good, overcorrects some events (July 10-12, 18-21)
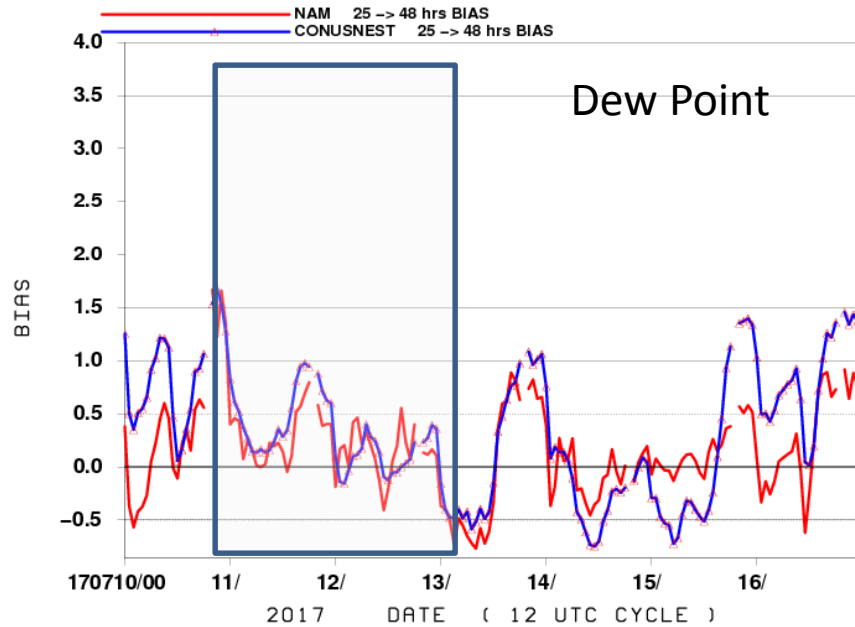*Jianping Huang, NCEP*

NE 25-48h T/Td Bias NE U.S.
July 10-16, 2017
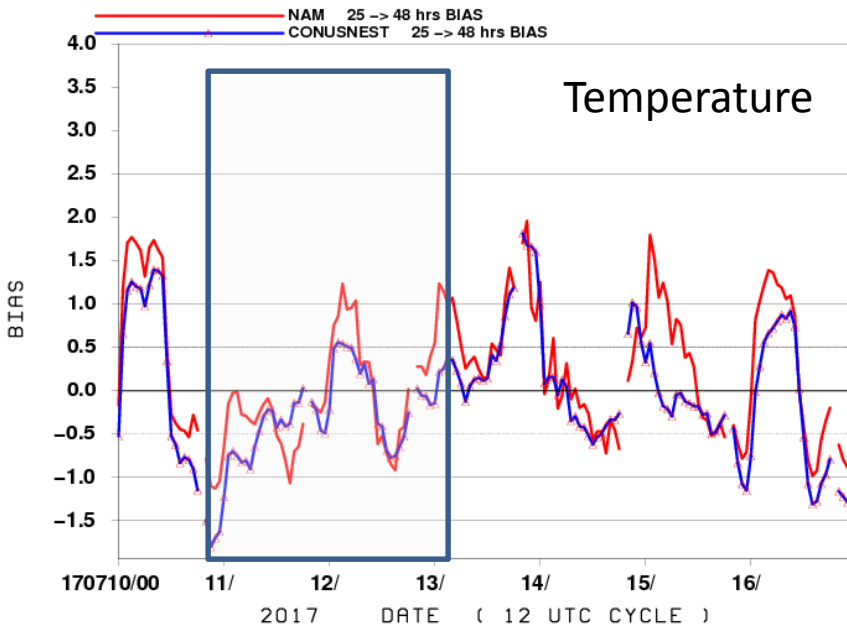
Cool, moist biases on 11th and 12th coincides with ozone underprediction

July 12, 2017 NAM-CMAQ V5 Performance

CMAQ 8h Ozone Max: Day 2

CMAQ 8h Ozone Max: Day 1

Bias Corrected 8h Ozone Max: Day 2

8h Ozone Max: Day 1 Mdl-Obs
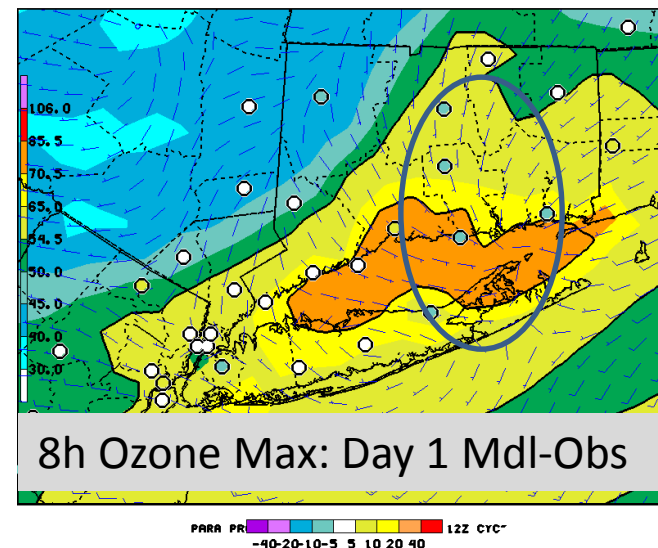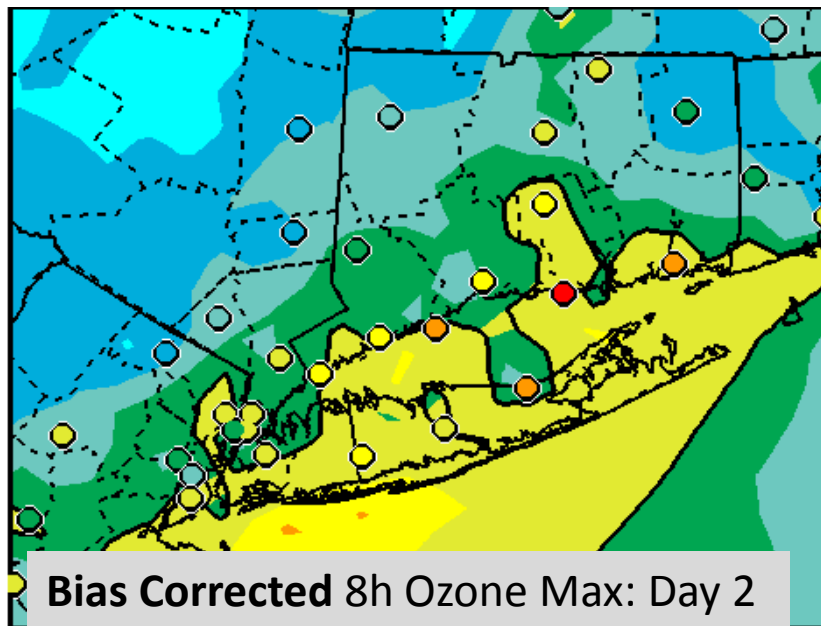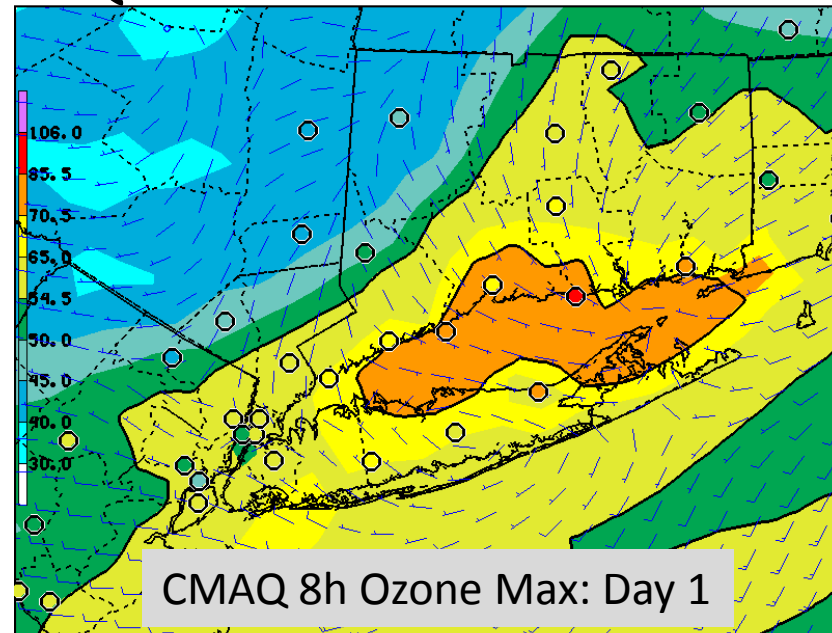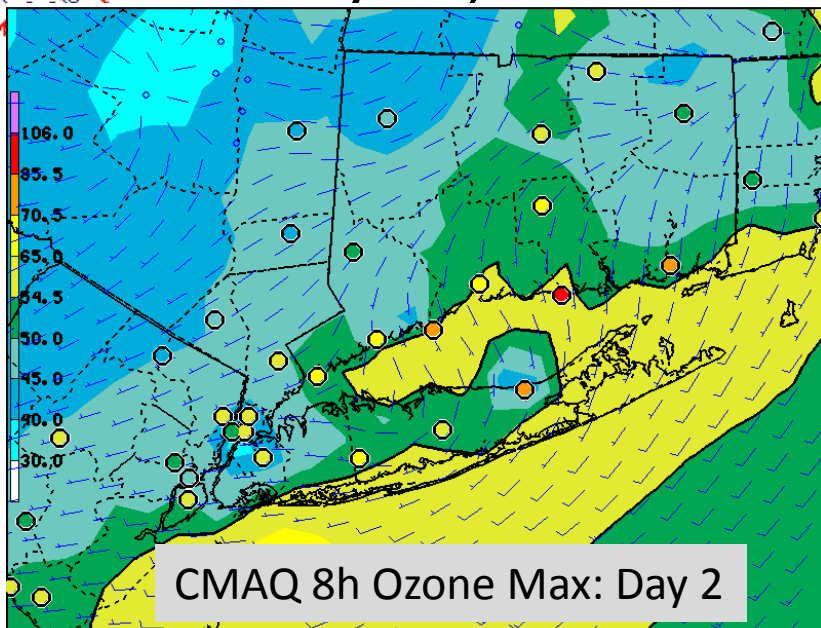
- Continued less ozone predicted for day 2
- O3 Bias correction.improved over LI

NAM Nest derived cloud cover

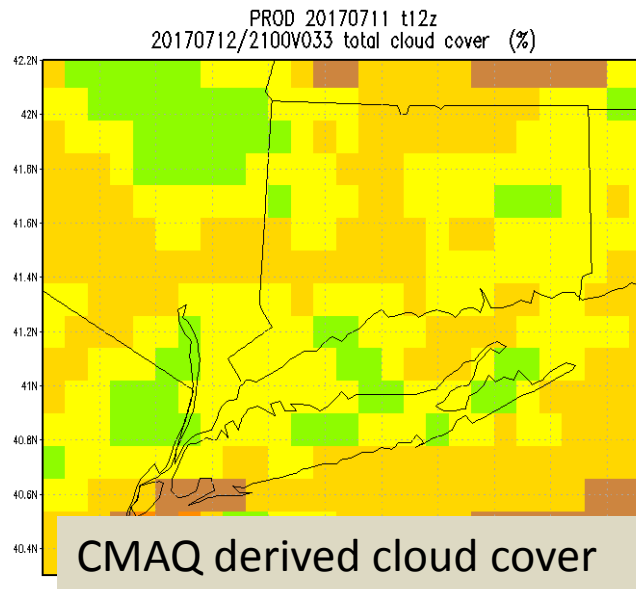COM2 PROD   CONUSNEST NAM SFC   TOTAL CLOUD FRAC BDRxI
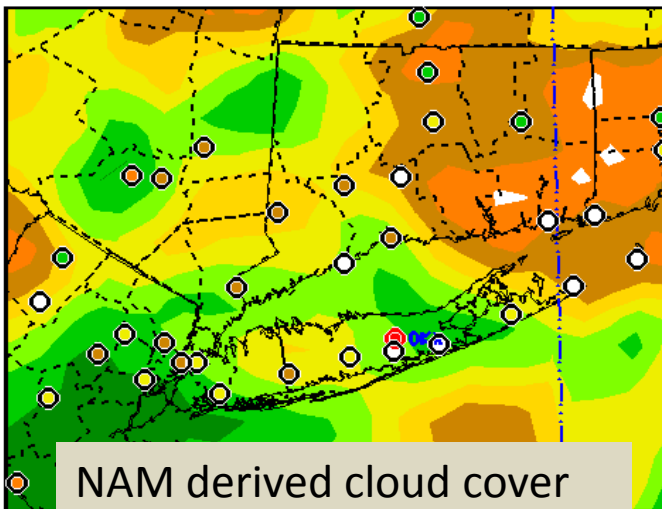
NAM derived cloud cover

COM2 PROD   12 NAM SFC   TOTAL CLOUD FRAC BDRxx   170712/2100

PROD 20170711 t12z
20170712/2100V033 total cloud cover (%)

CMAQ derived cloud cover

GrADS: COLA/IGES

- NAM-12 cloud cover too high and extent too broad, CMAQ less
- NAM nest captures clearing along LIS and CT better

July 12, 2017 NAM-CMAQ V5 Performance
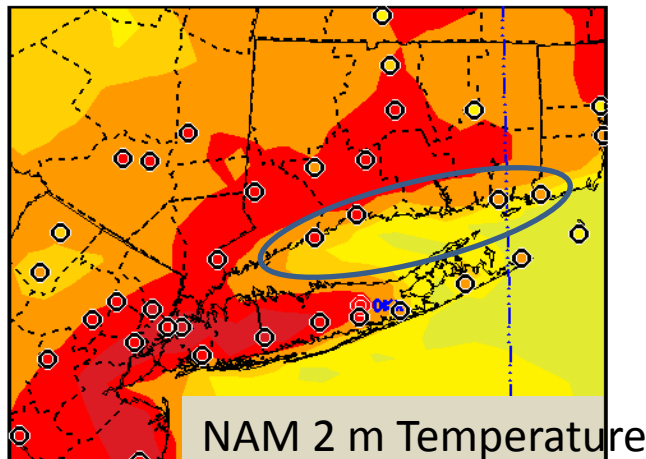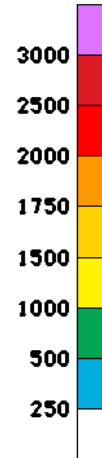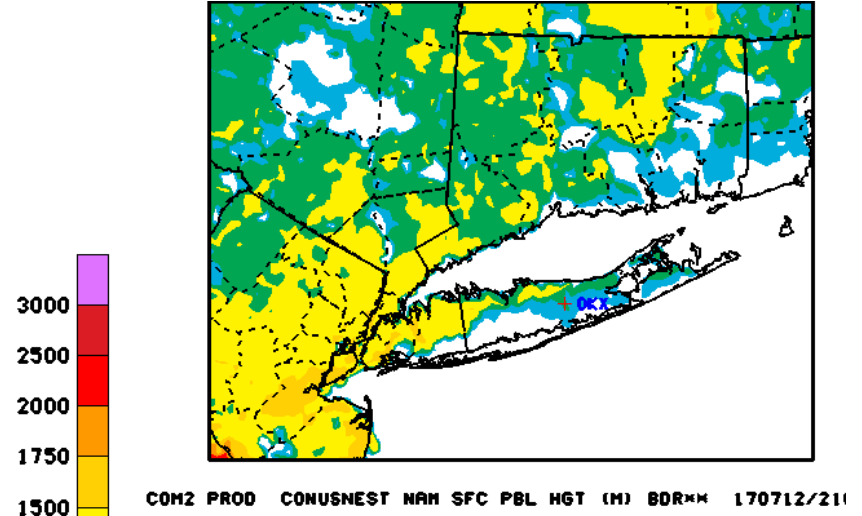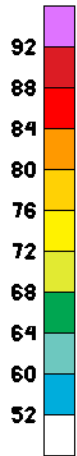## NE U.S. NAM vs Nest 7/11/ 12Z 33 h forecast
2m temperature, PBLH

NAM 2 m Temperature

NAM PBLH

COM2 PROD   CONUSNEST NAM 2 M   TMPF   BDR✕✕   170712/210

COM2 PROD   CONUSNEST NAM SFC PBL HGT (M) BDR✕✕   170712/21(
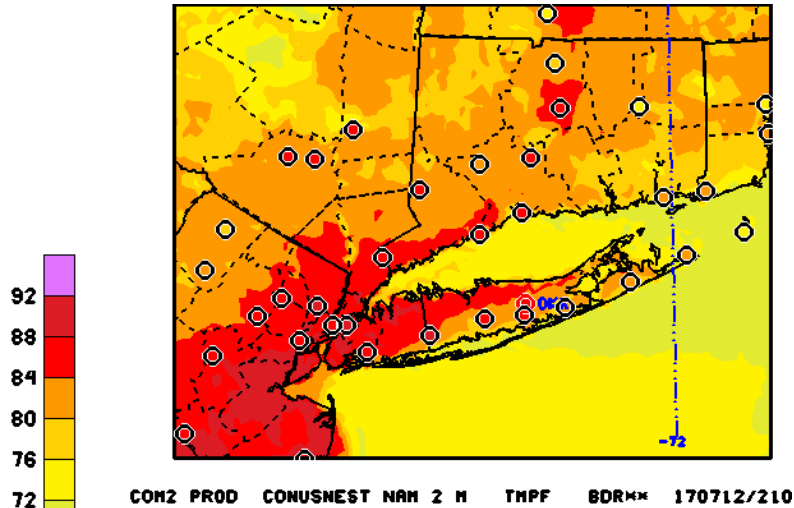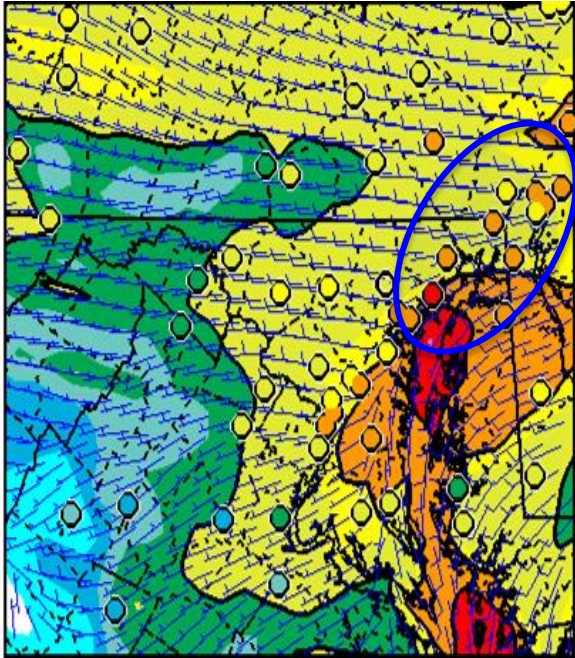
COM2 PROD   12 NAM 2 M   TMPF   BDR✕✕   170712/2100V03:
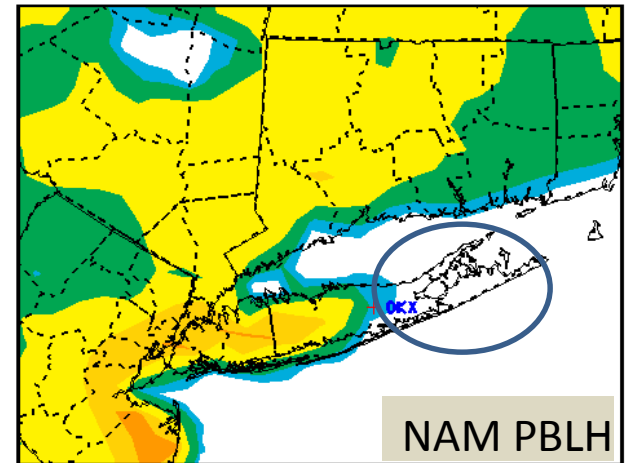
COM2 PROD   12 NAM SFC PBL HGT (M) BDR✕✕   170712/2100V03

NAM: Temps too cool over CT coast, Nest better

PBLH Evaluation
June 13, 2017, 21 UTC

1 hr ozone

PBLH

NEST 3km
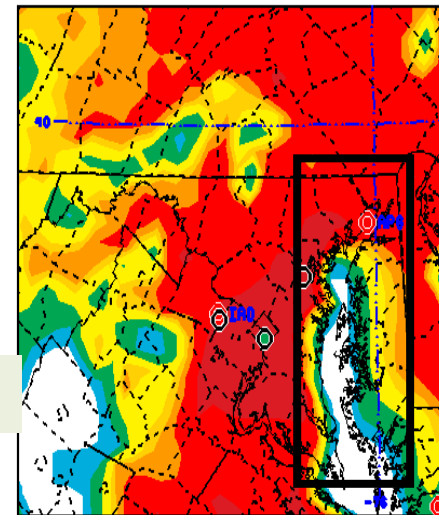
PARA 4X-DAY   OZCNO1   TUE 170613/2100V009
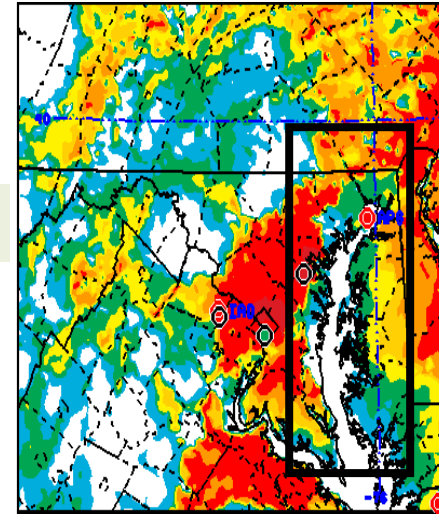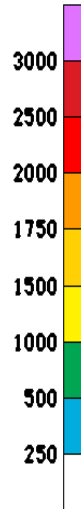
PROD CONUSNEST NAM SFC PBL HGT (M) MDxx   170613/2100V009

NAM-12

PROD 12 NAM SFC PBL HGT (M) MDxx   170613/2100V009

- Winds coming from the bay brought the marine air inland

- The NAM NEST 3km tended to bring the MBL further inland in the northern Chesapeake bay area, especially north of Baltimore

Courtesy: Amanda Sleinkofer

11A

NAM-12 vs NAM-3 km nest vs
Howard U – Beltsville, Maryland
Lufft Ceilometer PBLH (June 13, 2017)
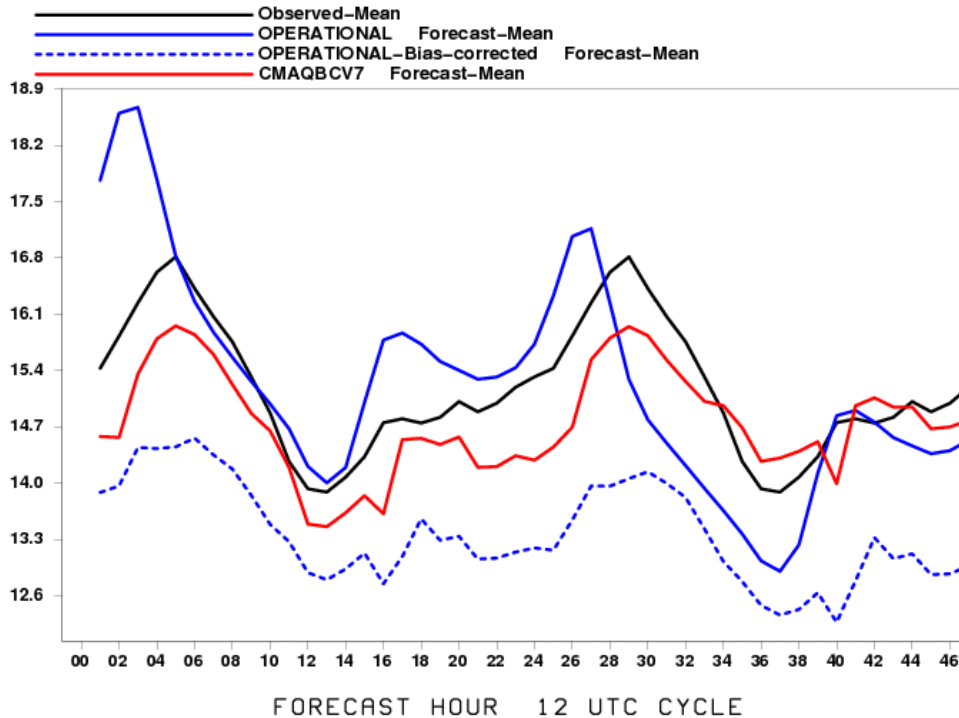Day 1 (solid) & Day 2 (dashed) forecasts
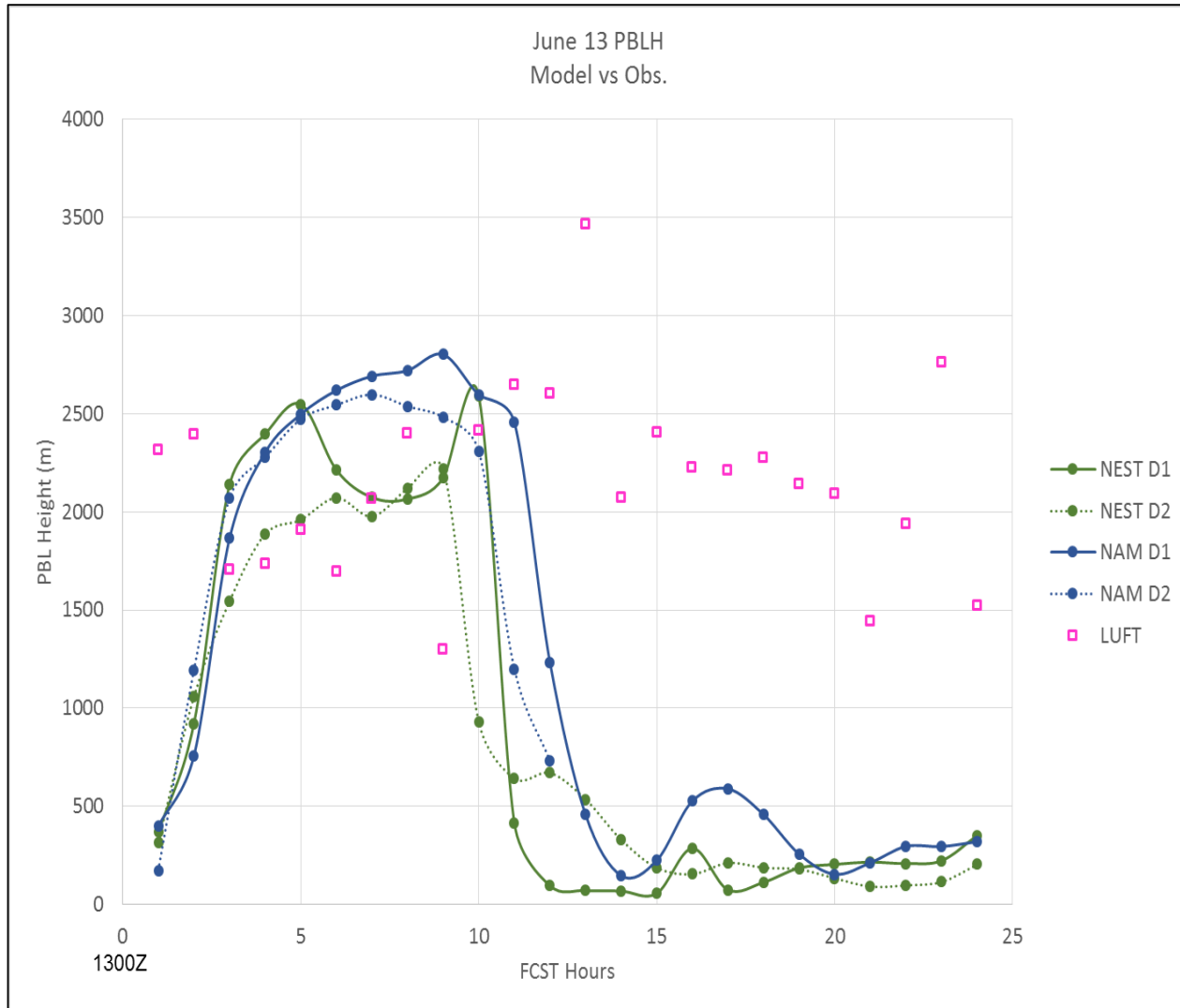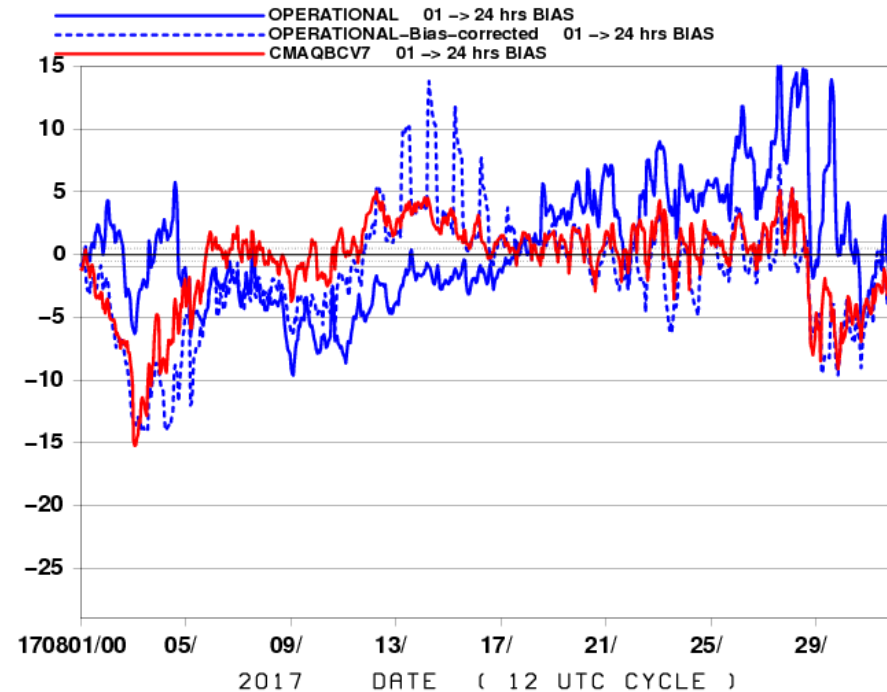
August 2017 PM Predictions
1 h avg PM BIAS   West

1-h Avg PM25 obs (ug-m3) avged by fcst hrs
20170801 to 20170831
West-US

- Observed-Mean
- OPERATIONAL   Forecast-Mean
- OPERATIONAL-Bias-corrected   Forecast-Mean
- CMAQBCV7   Forecast-Mean

FORECAST HOUR 12 UTC CYCLE

DAY 1 1-h Avg PM25 BIAS (ug-m3)
West-US

- OPERATIONAL   01 -> 24 hrs BIAS
- OPERATIONAL-Bias-corrected   01 -> 24 hrs BIAS
- CMAQBCV7   01 -> 24 hrs BIAS
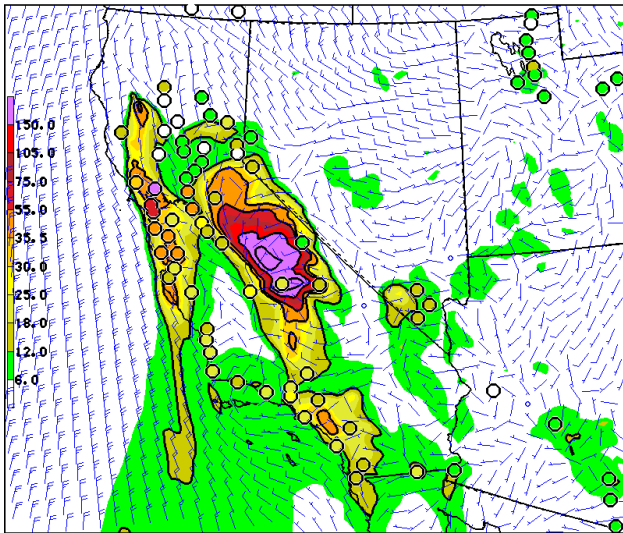
2017   DATE (12 UTC CYCLE)

- WEST: Underpredict PM transitions to overprediction.
- *Bias Correction* w/ V5. analogs better than oper BC
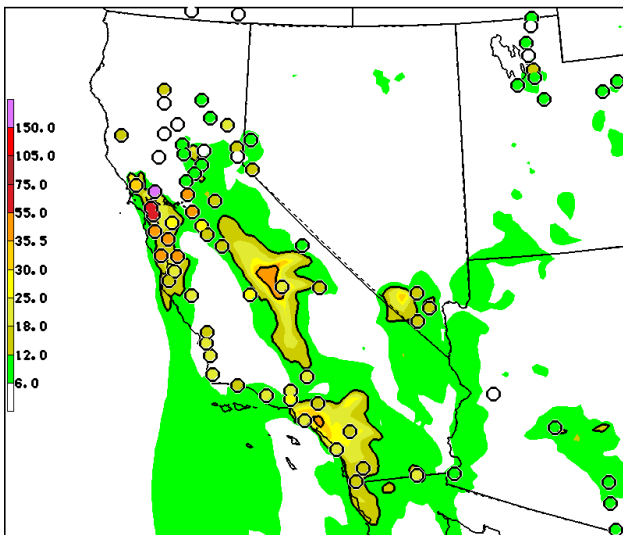-   - More consistent smoke event analogs ?

13

Northern California Fires
October 13, 2017 PM 2.5 predictions

Day 1

Day 2
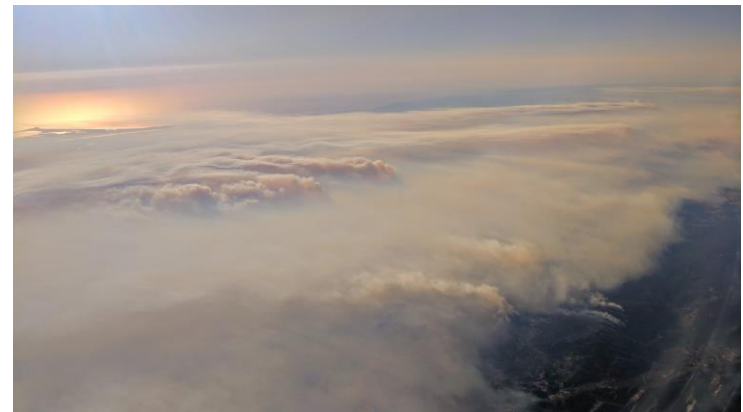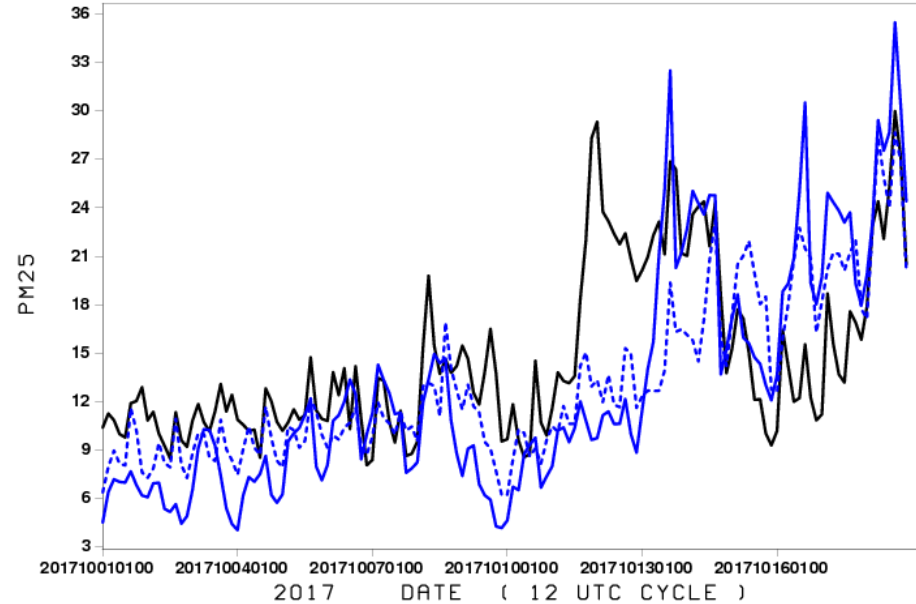
Summary

- *V5.0.2 Ozone w/ NAM V4*
  - Improvement correcting over-prediction esp along coasts
    - Long Island Sound (CT DEP analysis), Lake Erie/Michigan and Ohio Coastline
  - Improved for marginal or non-events
  - Still Missed exceedences in NE with overprediction of cloudiness
  - *Remarkable overall improvement with KFAN ozone bias correction but* overcorrects for episodes in East

- *PM*
  - Large positive impact near forest fires :
    - Updated BlueSky and 24 h pre analysis run
    - Underprediction when external sources (Canadian fires) are impacting CONUS
    - Emission timing and ejection height uncertainties
  - Continued overprediction in Winter from raw predictions
  - Exp PM bias correction w/ V5 analogs improves performance (Summer)

- Normally Updated NAM alone improves ozone overprediction forecast
  - Amount of incoming radiation under clouds critical

Future Emphasis

- Extend to 72 hours, update emissions to 2014 base
- Near real-time fire locations, strength, emissions
  - Canadian & external source impacts (testing)
  - Improved temporal profiles (testing) and plume rise algorithms
- NGAC full aerosol boundaries
- Unification of AQ systems
  - HYSPLIT smoke/dust → NGAC Aerosol
  - CMAQ ozone & total PM
  - HRRR-smoke

  NGGPS ESRL/EPA FV3-CMAQ
  - Inline allows for High Resolution

- Bias Correction:
  - Implement Ozone Kalman Filter bias correction (testing)
  - PM: Use CMAQ V5 predictions as analogs (testing)
- Improved Evaluations
  - Use of VIIRS/GOES-16/AERONET AOD, CALIPSO aerosols
  - Evaluate Operational models for field experiments (ESRL FireX 2019, FASMEE)
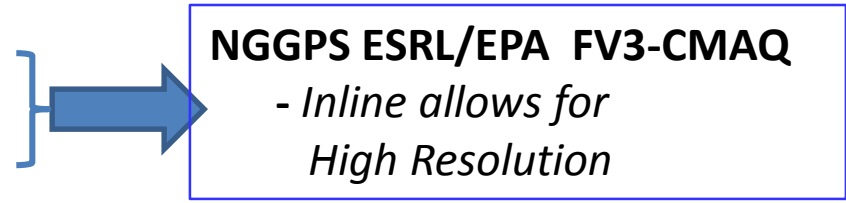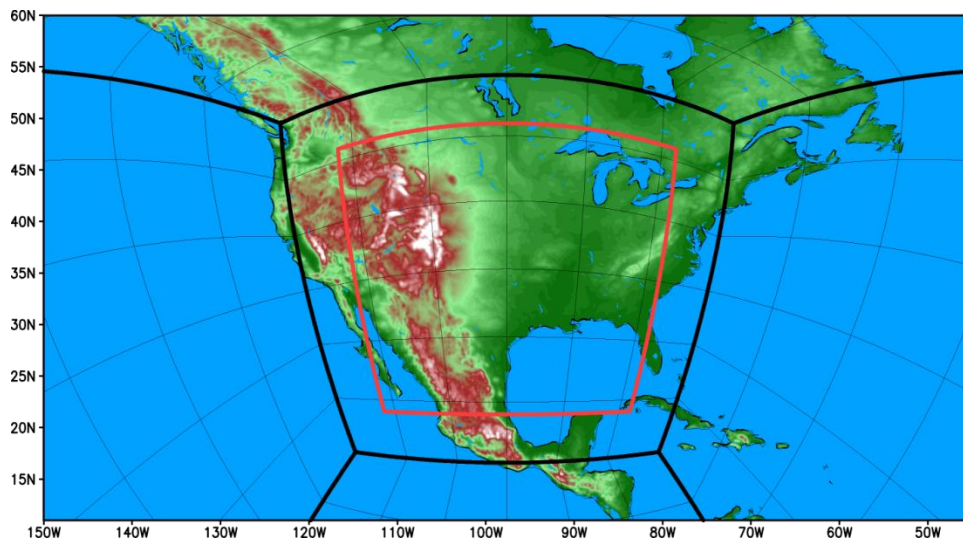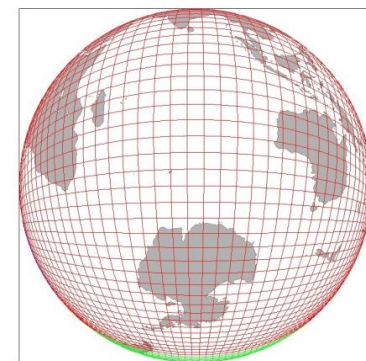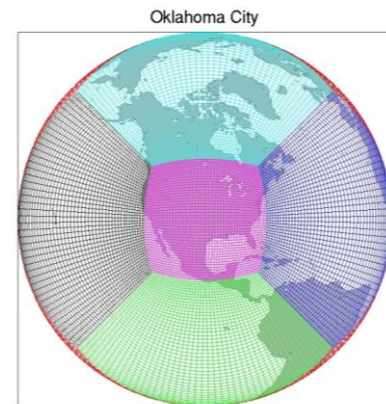
Thunderstorm-resolving resolution in a unified meso-global prediction system (FV3-GFS)

1) **Grid stretching (smooth variation of grid spacing)**

1) **2-way nesting (Harris and Lin 2014)**
   FV3 is uniquely suitable for 2-way nesting, due to the application of two-time-level Finite-Volume transport scheme

2) **Optimal combination of the "stretching" and "nesting"**

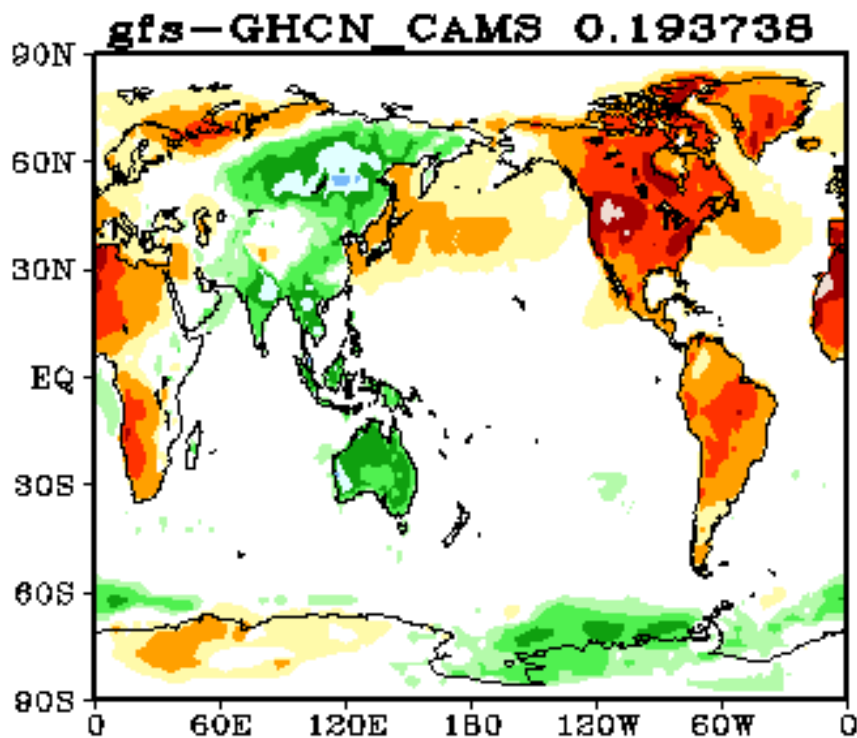

Oklahoma City

FV3-GFS

→ **FY19 Global : 9 km L64**
→ **Regional: 3km nest or stand alone**
→ **aerosol aware microphysics/radiation option**

S.J. Lin, NOAA/GFDL

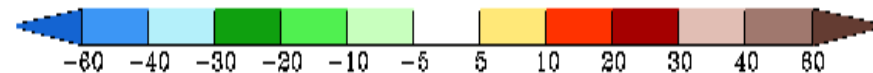# GFS-FV3 Comparisons (13 km)
June- July 2017 Day1

2 m Temperature
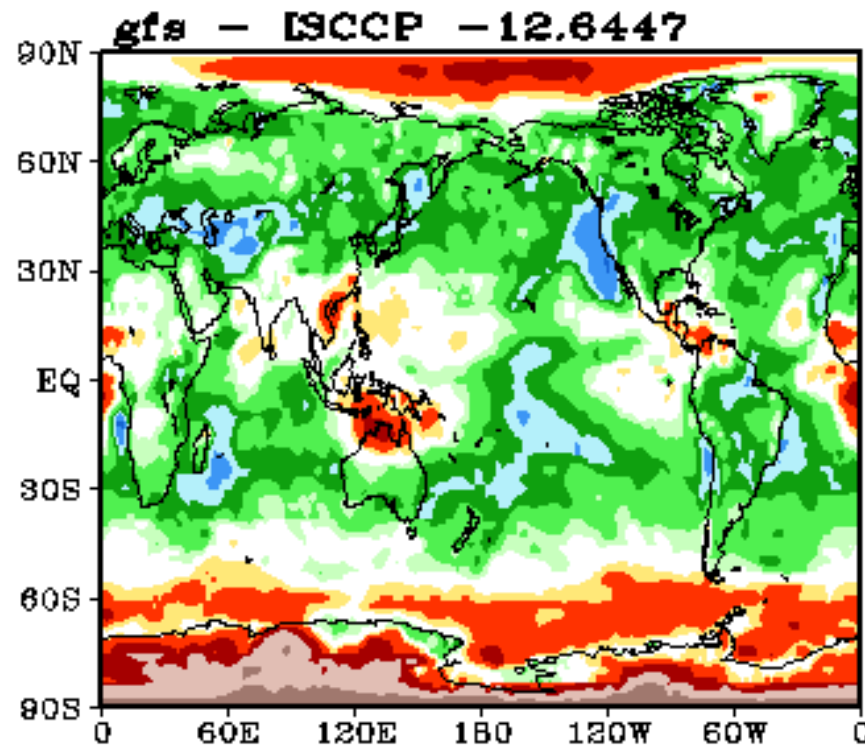
Cloud cover

GFS-FV3 too warm and under-predicts clouds over North America

BACKUPS

BACKUPS

Web pages
CMAQ V5.0.2

- Real-time parallel runs (July 2016-Present
  - http://www.emc.ncep.noaa.gov/mmb/aq/cmaq/web/html/max.html

- No NOx adj/NAM-X/4x-day cycling (Aug. 7-Sept 10)
  - http://www.emc.ncep.noaa.gov/mmb/aq/cmaqnox11/web/html/max.html
- Gridpoint NOx adj/NAM-X/1x-day cycling (Aug. 1-Sept 10)
  - http://www.emc.ncep.noaa.gov/mmb/aq/cmaqnox/web/html/max.html
- Verification statistics (prod,para, cmaqnox11, cmaqnox)
  - http://www.emc.ncep.noaa.gov/mmb/aq/fvs/web/html/regular.html