Evaluation of Operational and Experimental CMAQ Ozone and PM

http://airquality.weather.gov

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September 14, 2016

CMAQ Air Quality Forecasting System

12 km Ozone/Particulate Matter predictions run at 06/12 UTC to 48 forecast hours

NAM-12

NWS/NCEP

Interpolate to CMAQ grid

USFS BlueSky (from HYSPLIT)

HMS Smoke & Fire detection NOAA/NESDIS

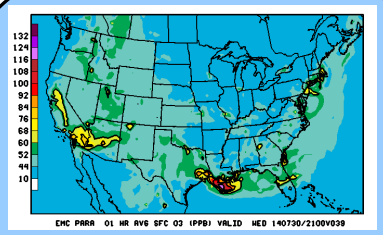
O3/PM Emissions PREMAQ

06z

24-hr pre-analysis run with 1 day old smoke

EPA AIRNOW O3/PM *observations*

CMAQ (v5.0.2)



NDGD Display

- PM Bias Corr.
- G2O FVS

Jianping Huang

CMAQ weaknesses Identified

- Overprediction of ozone in Eastern U.S. in Summer
  - Especially along coastal cities (NYC, DC, Cleveland)

    →Update National Emission Inventory point sources to 2011 (project to 2016)

    → *Reduce NOx emissions based on OMI satellite trends*

    → *Update CMAQ chemistry/biogenic emissions to EPA V5.0*

- Underprediction of particulate matter (PM) in Summer and near wild-fires

  → *Update 9 year old USFS BlueSky smoke emission system*

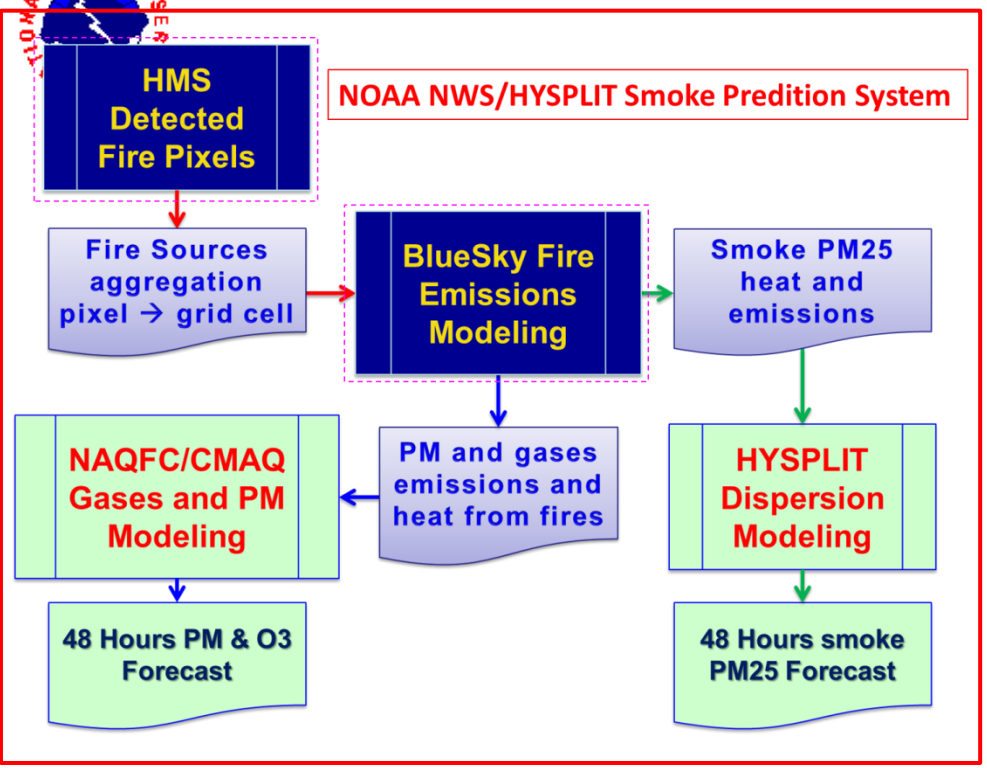
  → *Introduce 24 h pre-analysis cycle to correct fire time mismatch with CMAQ initial time*

- Underprediction of Ozone and PM when strong fires are present outside CMAQ domain

  → *Test NGAC full aerosol predictions for CMAQ lateral boundaries*

- Overprediction of PM during winter-time stagnation episodes (cold, stable)

  → *update emissions/chemistry as in bullet 1*

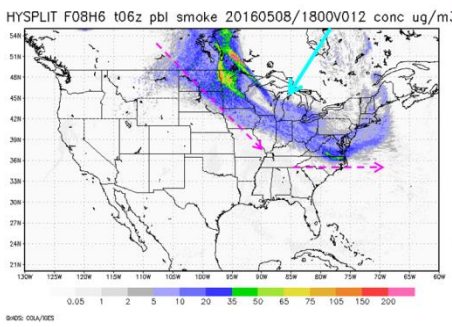


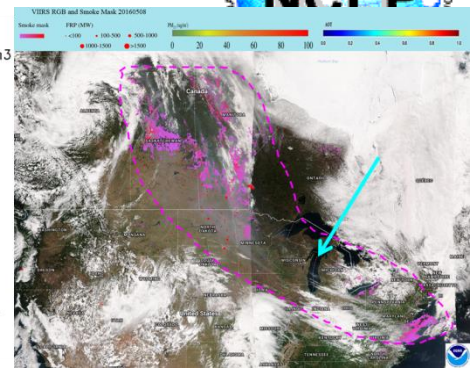
New Updated BlueSky:

- The Fuel Characteristic Classification System version 2 (FCCS2) which includes a more detailed description of the fuel loadings with additional plant type categories.
- Explicit fuel load map for Alaska
- improved fuel consumption model and fire emission production system (FEPS).

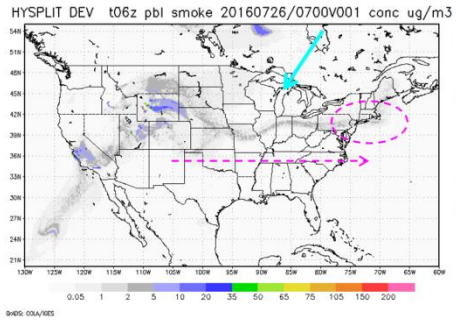
Courtesy Ho-Chun Huang, EMC

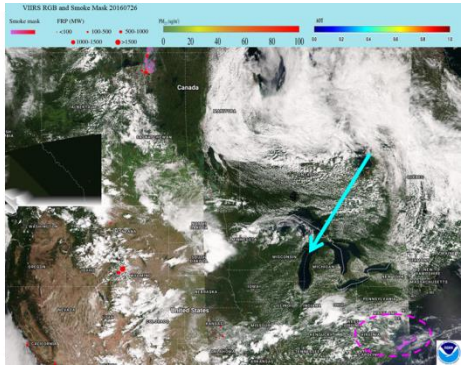
May 2016 Ft McMurry (Canada) Fires



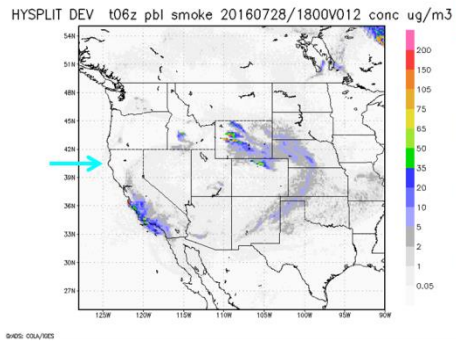


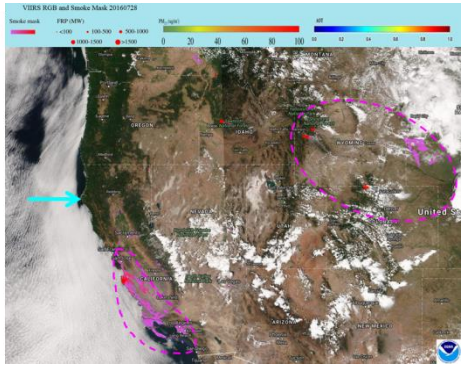
July 2016 Northern Wyoming Fires





July 2016 California Big Surf Fires





HYSPLIT/Smoke prediction

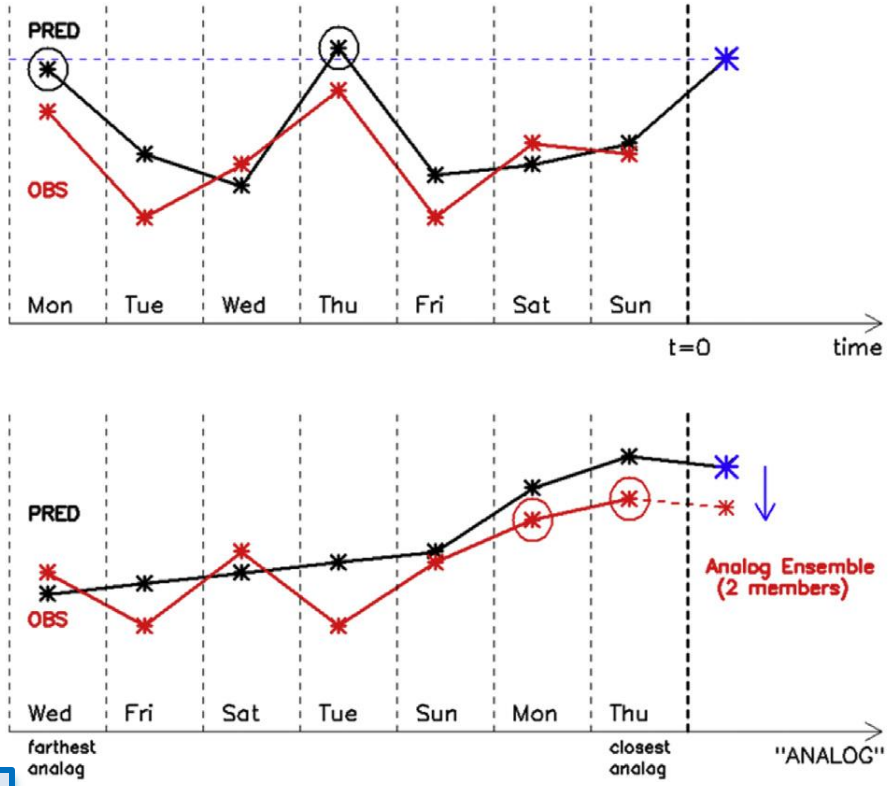
eIDEA Smoke Mask

Analog Ensemble for $PM_{2.5}$ Bias Correction

- **Analog metric is determined by (Monache et al. 2011)**

$$\|F_t, A_{t'}\| = \sum_{i=1}^{N_v} \frac{w_i}{\sigma_{f_i}} \sqrt{\sum_{j=-\tilde{t}}^{\tilde{t}} (F_{i,t+j} - A_{i,t'+j})^2},$$

where F_t is current NWP forecast valid at future time t, $A_{t'}$ is analog at past time t', N_v is the number of variables , $\tilde{t}$ is half the number of additional computation time, w_i weight, σ_{f_i} standard deviation



(Source: Djalalova et al., 2015)

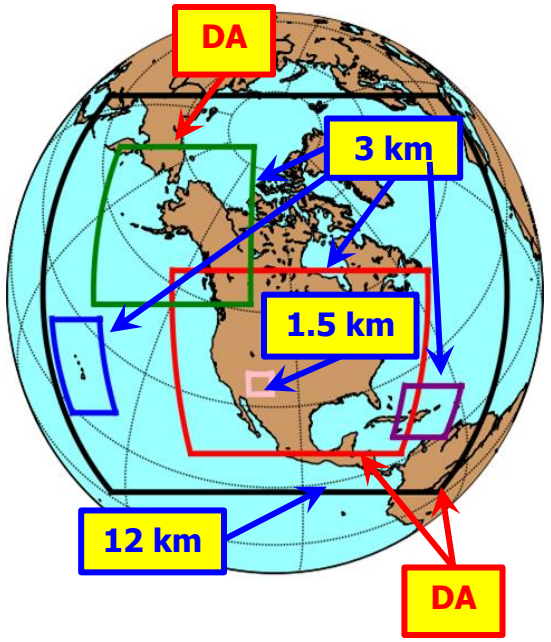
Implementation in NAQFC

- **Variables for Analog search**: **$PM_{2.5}$, T_2, WS/WD**
- **Ensemble members: 5**
- **Training period**: **one year**

Courtesy Jianping Huang, EMC

NAM Forecast System - Version 4 (Q1FY17)

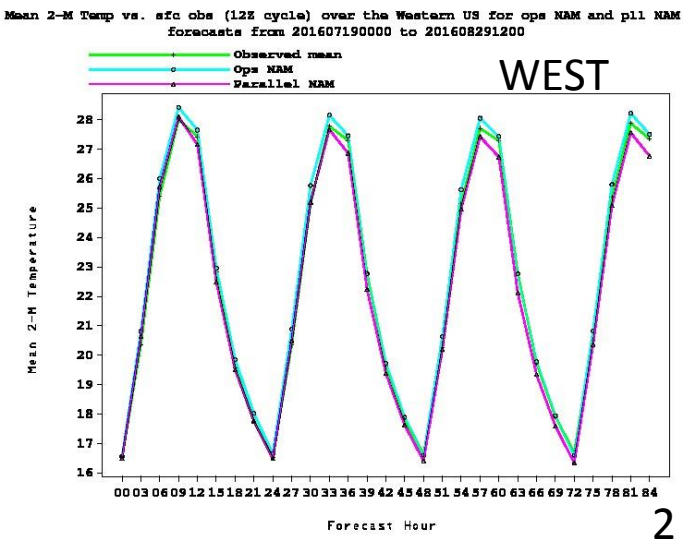
- **Resolution Changes**
  - CONUS (4 km) and Alaska (6 km) nests → **3 km**
  - Sync AK and CONUS On-Demand Fire Weather nests → **1.5 km**
- **Select Model Changes**
  - Updated microphysics → **Improved stratiform precip., better anvil reflectivity, lower peak dBZs, smaller areas of light/noisy reflectivity (rain treated as drizzle), improved nest QPF bias in warm season, reduce warm season 2-m T warm bias**
  - More frequent calls to physics → **Physics/dynamics more in sync (e.g. improved upper air, improved nest QPF)**
  - 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 → **Improve QPF**
  - Modify latent heat flux treatment → **Improve visibility along CA coast**
- **Data Assimilation:**
  - DA cycles for 3 km CONUS and AK nests → **Much less 'spin-up' time**
  - Use of Lightning and Radar Refectivity-derived temperature tendencies in initialization
    - **Improved short-term forecasts of storms at 3 km**
    - **Improved 00-12 hr QPF**
  - New satellite radiances, satellite winds → **Improved Inital Conditions**



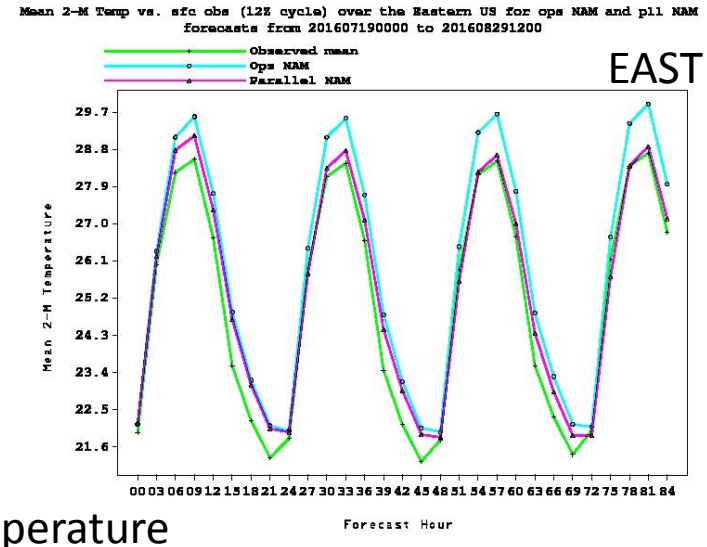
DA: Data Assimilation Cycle

Courtesy Eric Rogers, EMC

Upcoming NAM Q1FY17 Upgrade

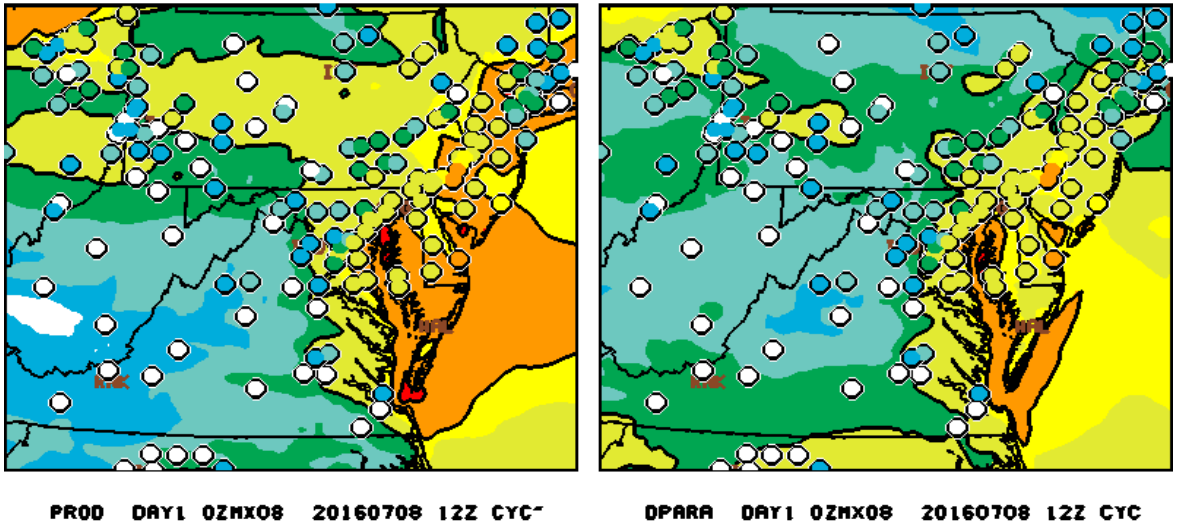


WEST



EAST

2 m Temperature



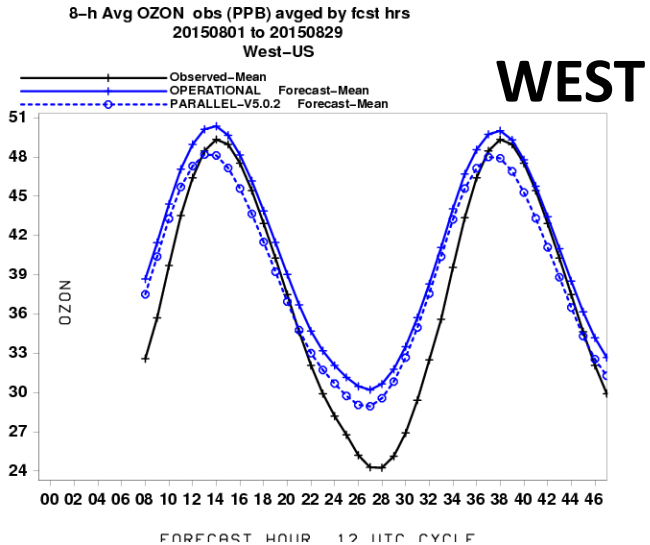
NAM - CMAQ V4.7

NAM-X - CMAQ V4.7

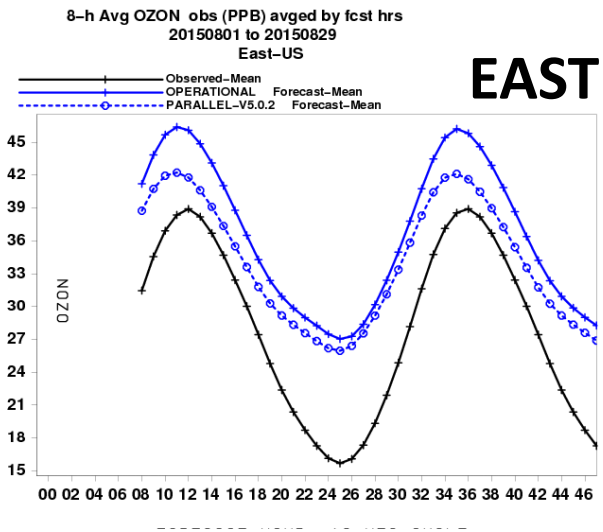
NAM-CMAQ V4.7.5 vs V5.02

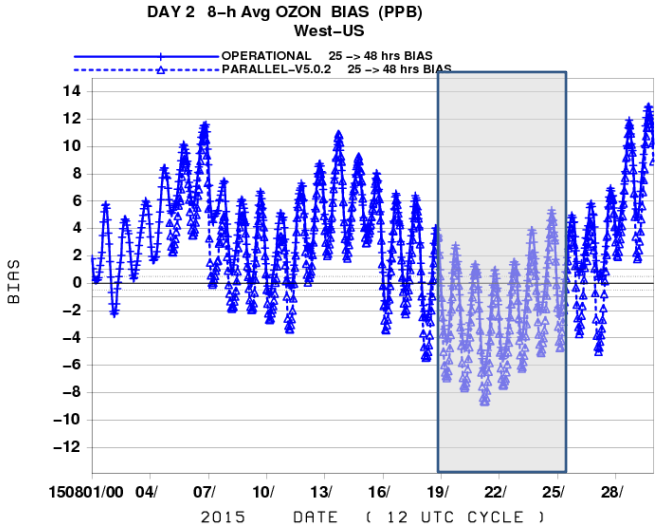
Ozone West vs East August 2015

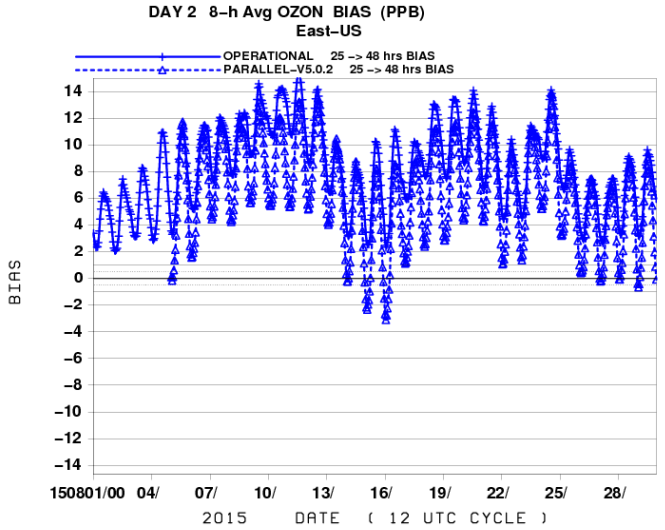
WEST



EAST



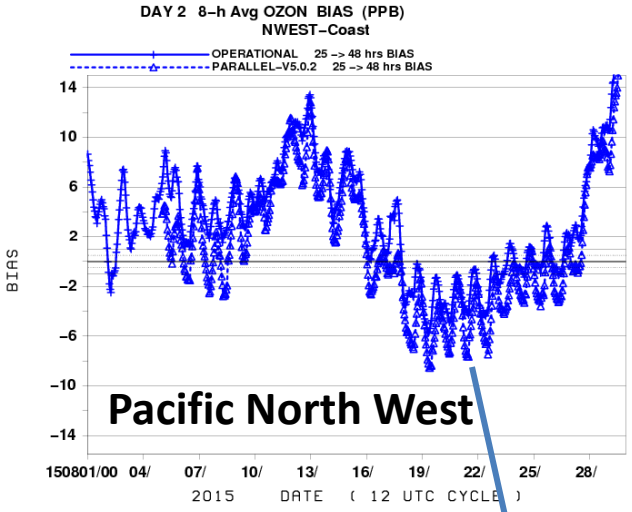


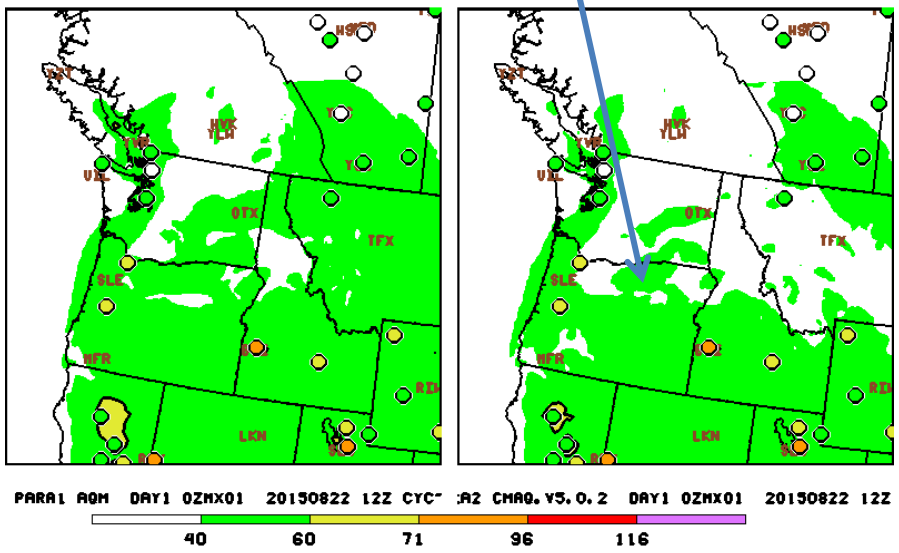


Improved over the East
Underprediction over the West esp during active fires

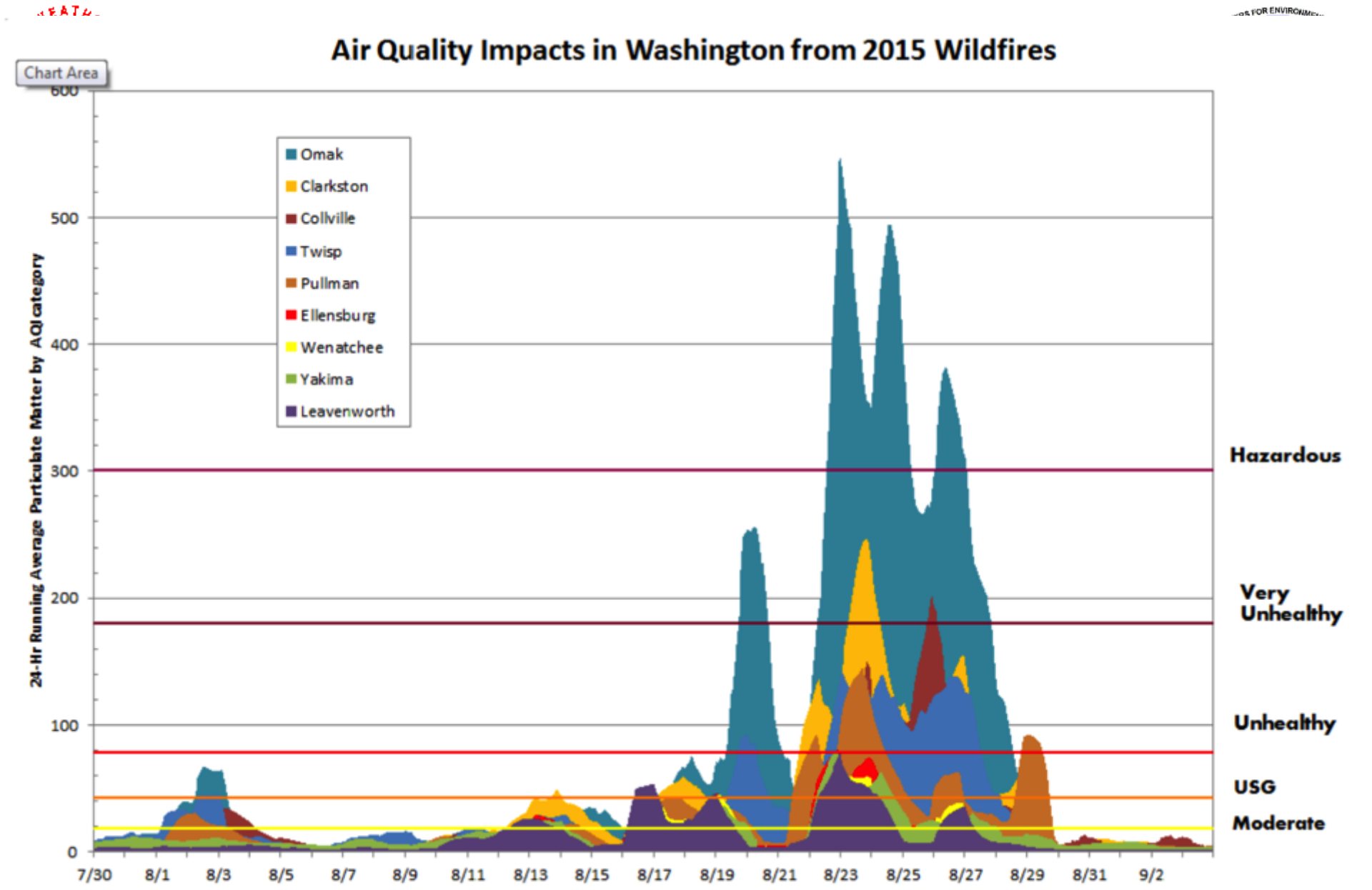
NAM-CMAQ V4.7.5 vs V5.02

Ozone Underprediction near fires (August 2015)



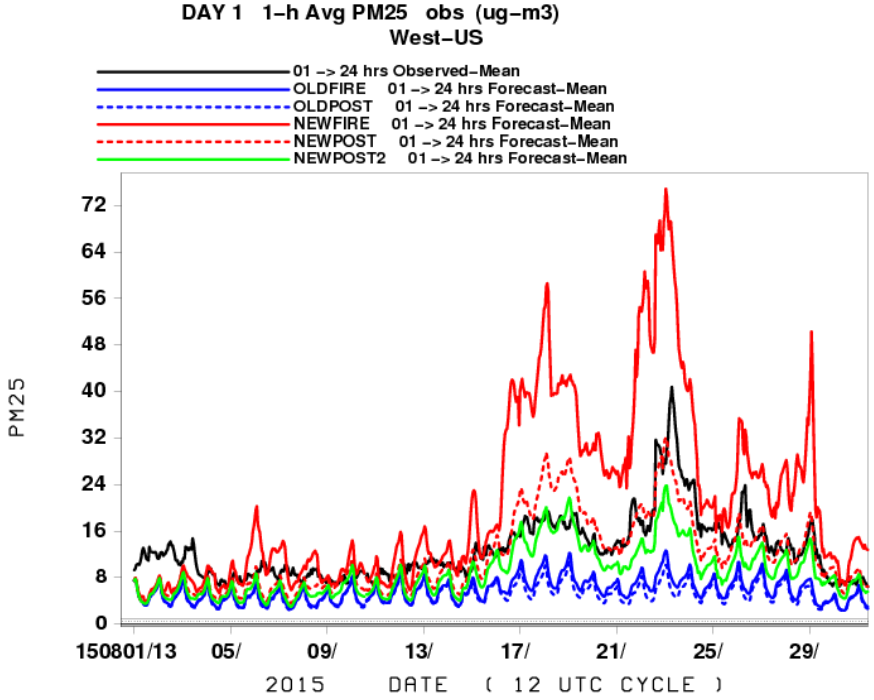


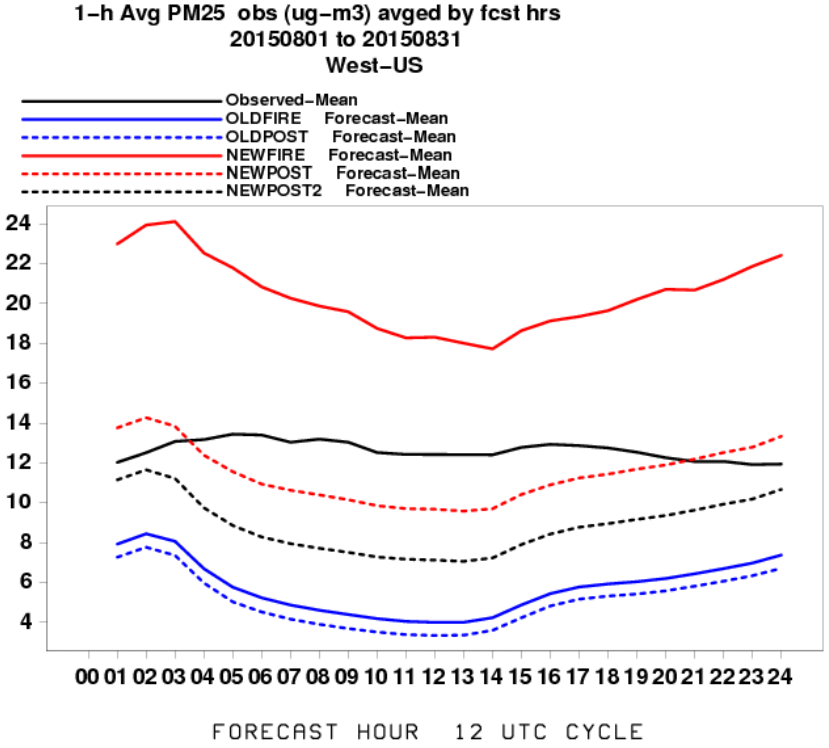
Importance of wild fire gas emissions on ozone: 8/22/15



From: Narrative Timeline of the Pacific Northwest 2015 Fire Season. USDA Forest Service.
http://www.wfmrda.nwcg.gov/docs/_Reference_Materials/2015_Timeline_PNW_Season_FINAL.pdf

CMAQ V4.7 PM Performance
Aug 2015 Western U.S. Wild Fires



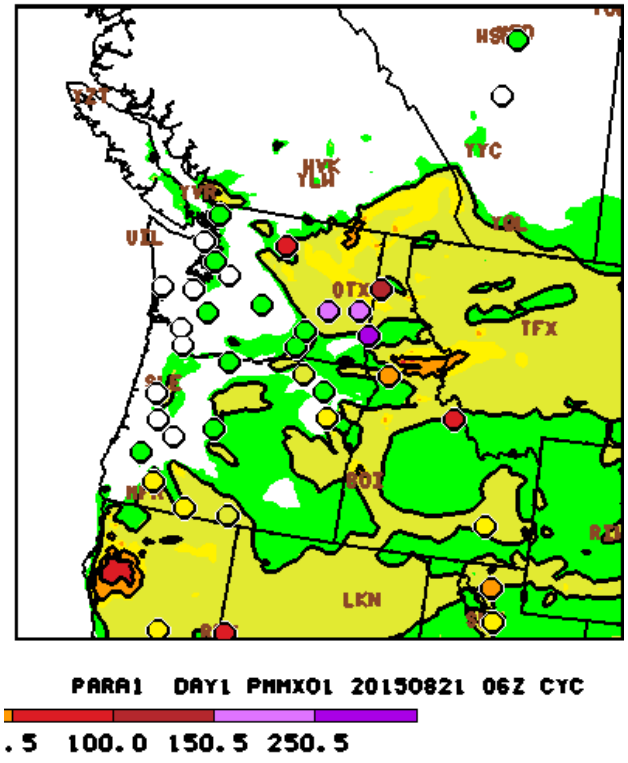


- Impact of fire initialization time (solid vs *dashed* red line)
- Impact of different BlueSky systems (dashed blue vs *dashed* red line)

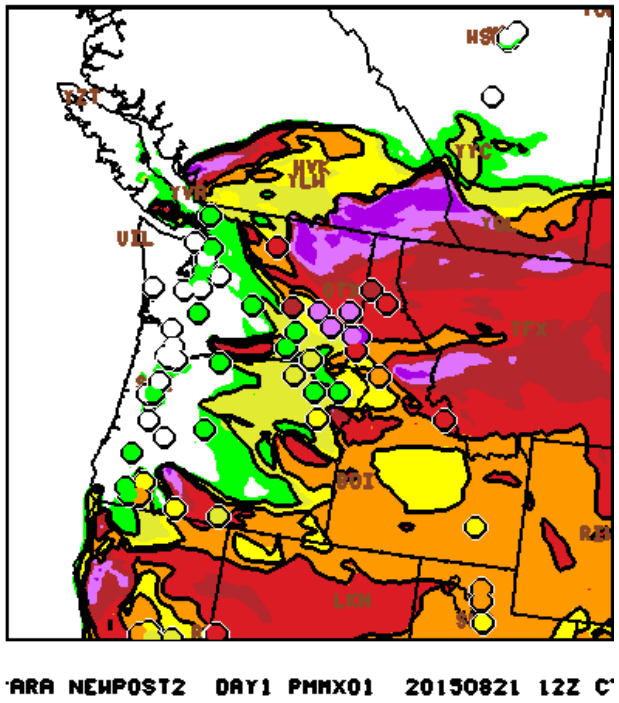
Western Fires

August 21, 2015 1hr PM2.5 Max

Operational V4.7



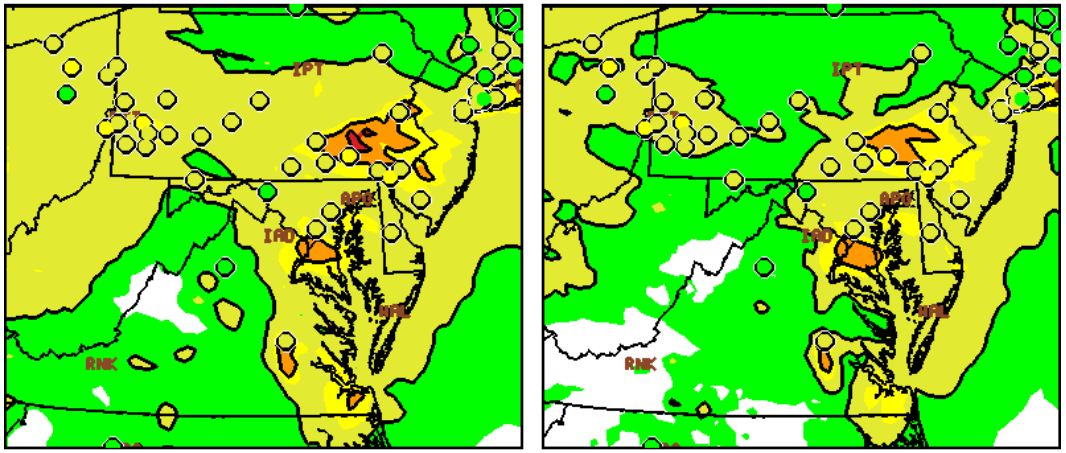
BlueSky v3.5.1 &
Current day locations



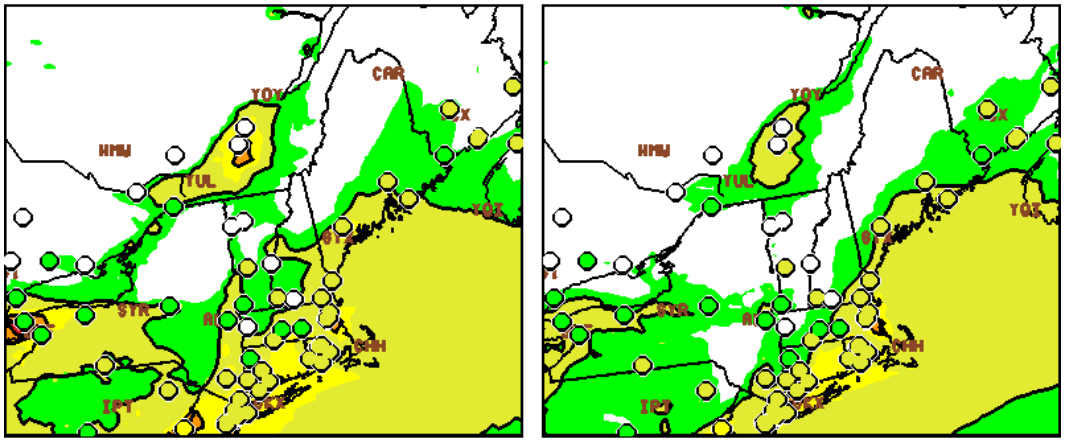
Operational runs: Most sites impacted by fire smoke are severely under-predicted.
Experimental tests: Updated BlueSky and use of current day fire info

V4.7 vs V5.02 1 hr max **PM**

Winter Case



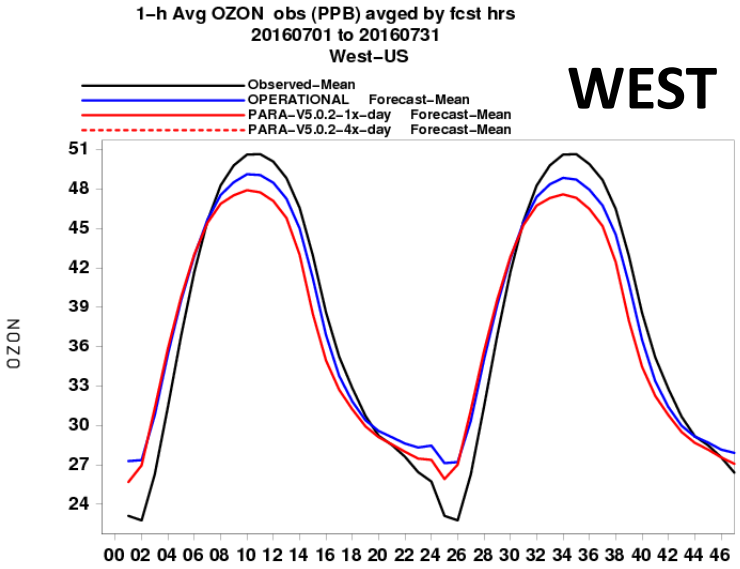
2/17/16

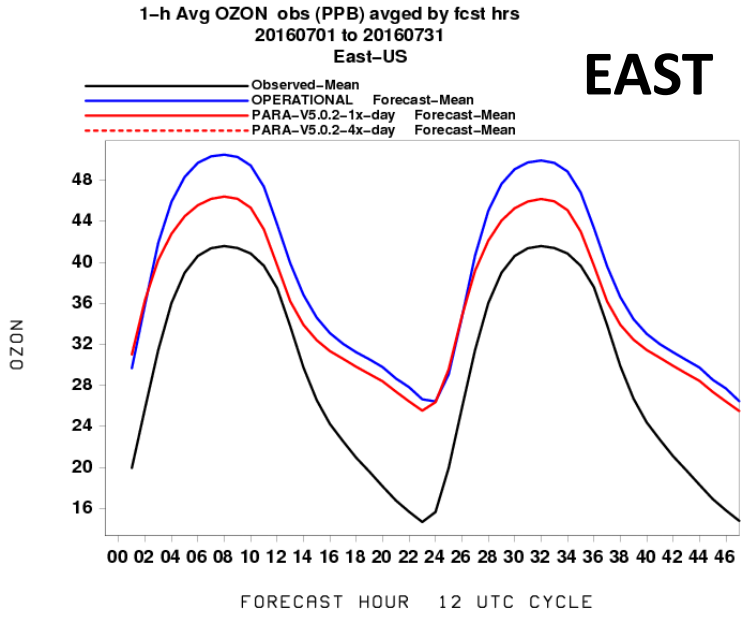


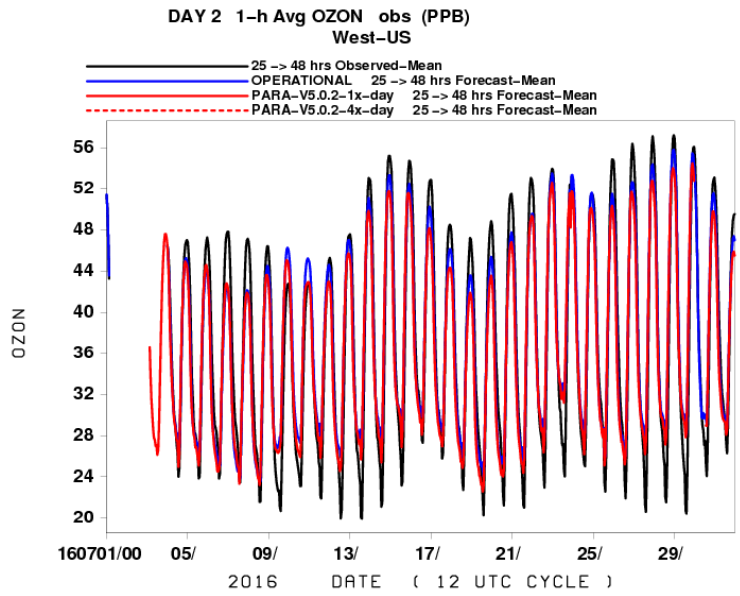
2/21/16

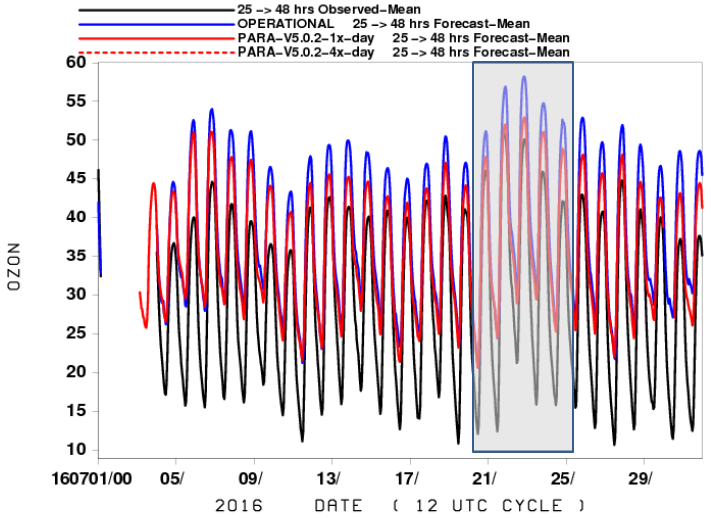
Large improvements to correct for overprediction during Eastern U.S. stagnation episodes

July 2016 NRT Prediction
1 h avg Ozone



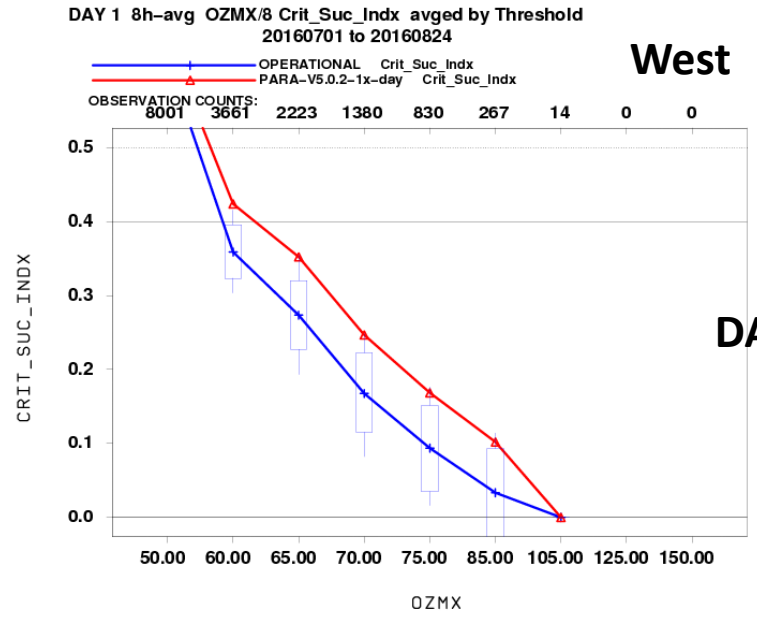






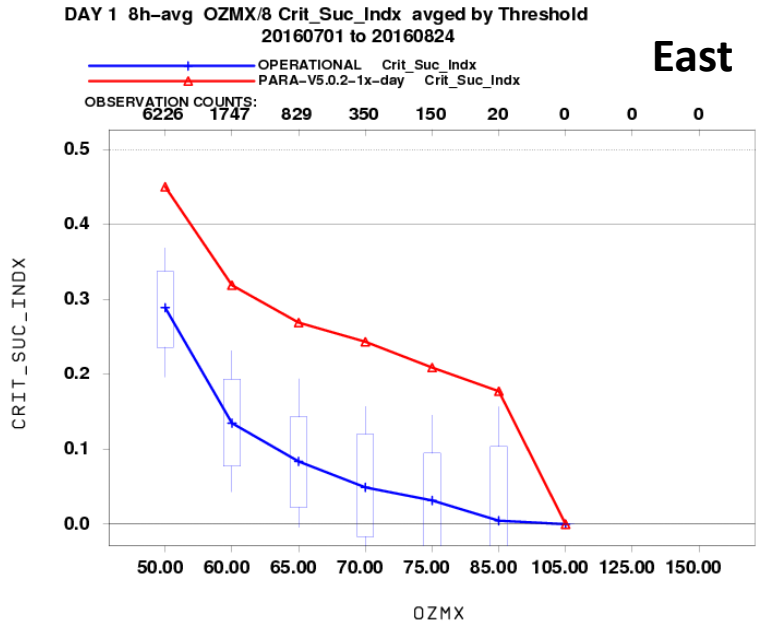
- **Continue to see improvement in ozone over-prediction over the East**

July-August 2016 NRT Prediction
8 h avg Ozone Skill Score (CSI)

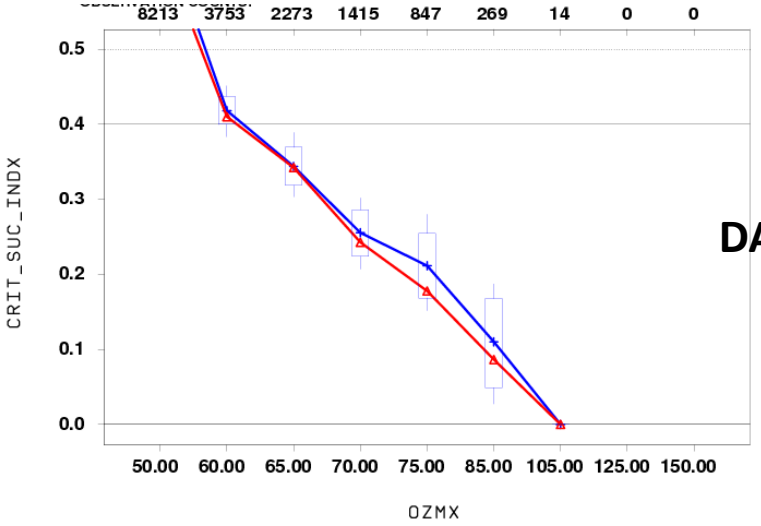


West

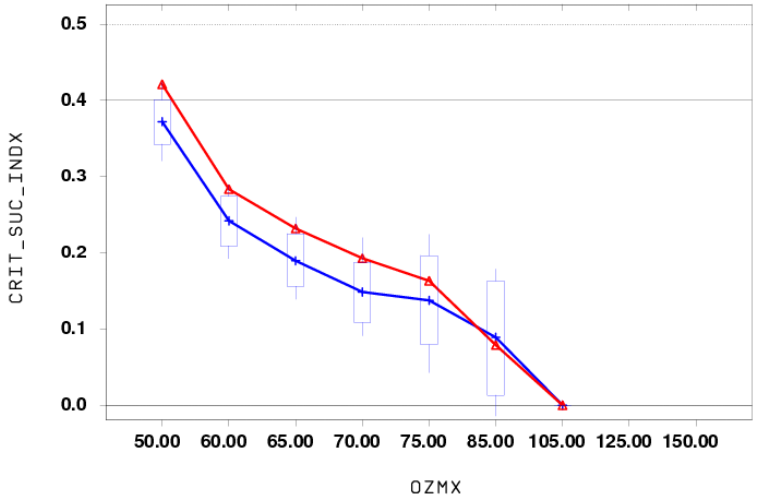
DAY 1



East



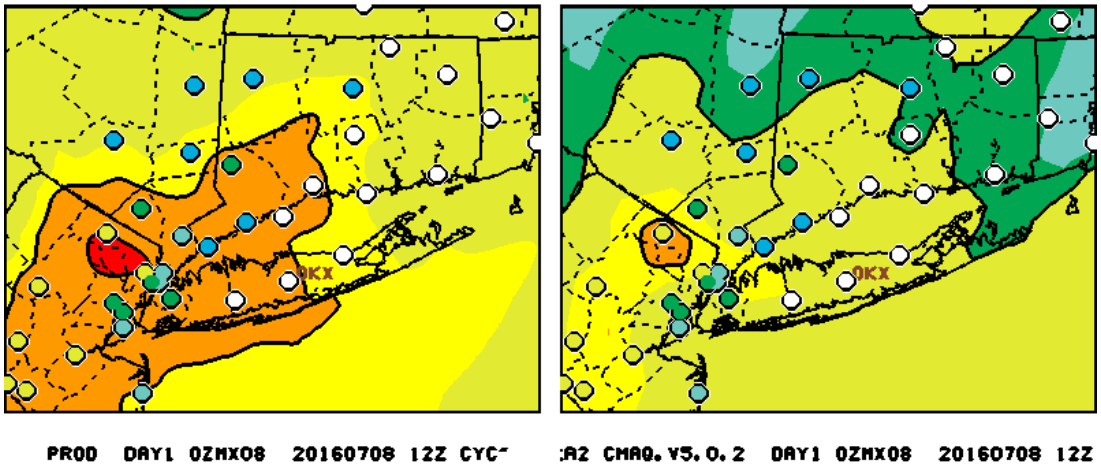
DAY 2

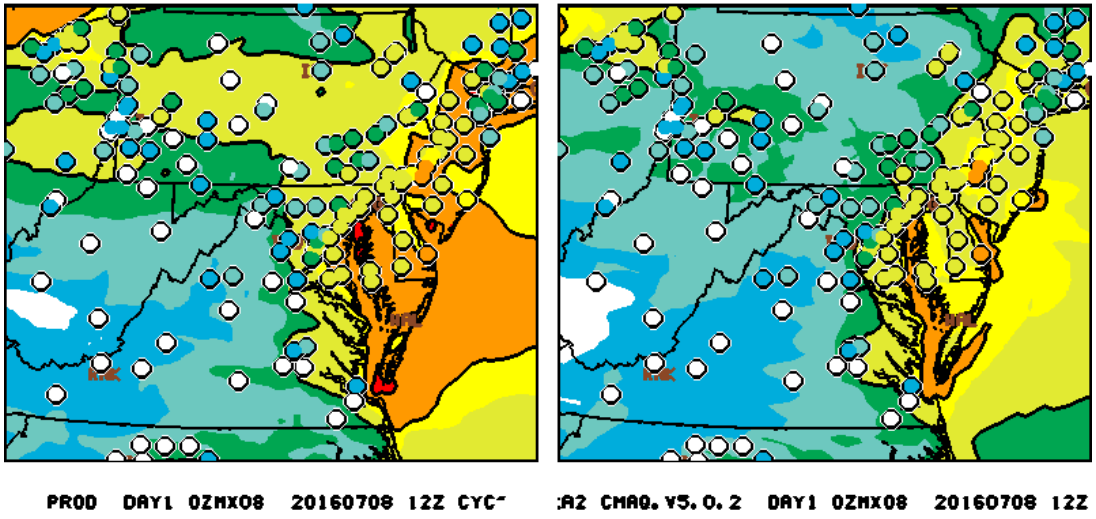


Larger improvement for Day 1 CSI

Summer 2016 NRT prediction

July 08, 2016 12Z run Day 1 8h Max **ozone** forecast



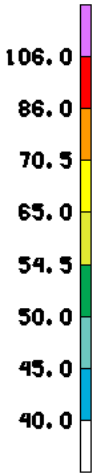


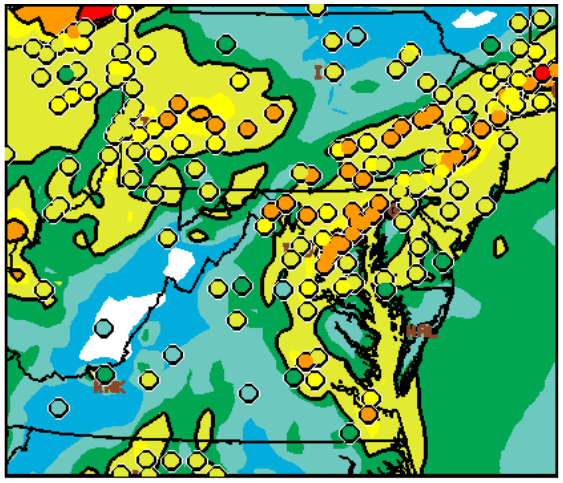
V5.02: Large improvement for non-event

V5.02: - Improved upon strong overprediction for Eastern Shore, NJ and NY
 - underpredict S. NJ, DE code orange

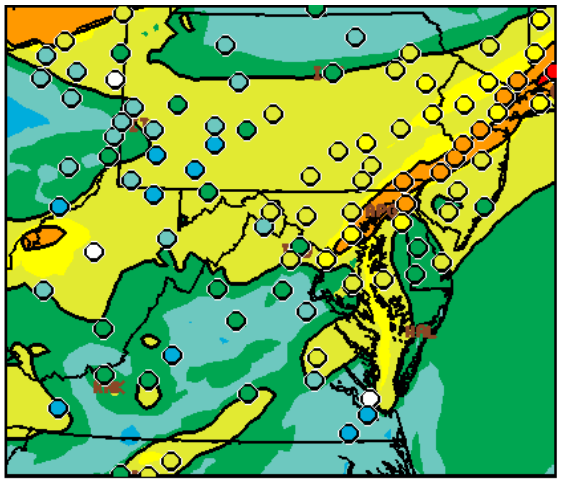
Summer 2016 NRT prediction

July 21-22 , 2016 12Z run Day 1 8h Max **ozone** forecast

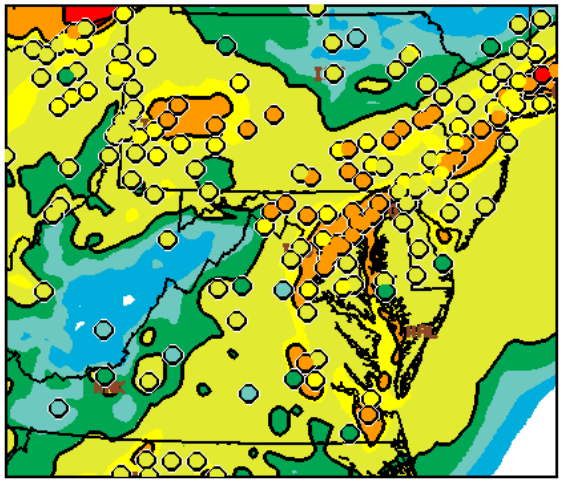




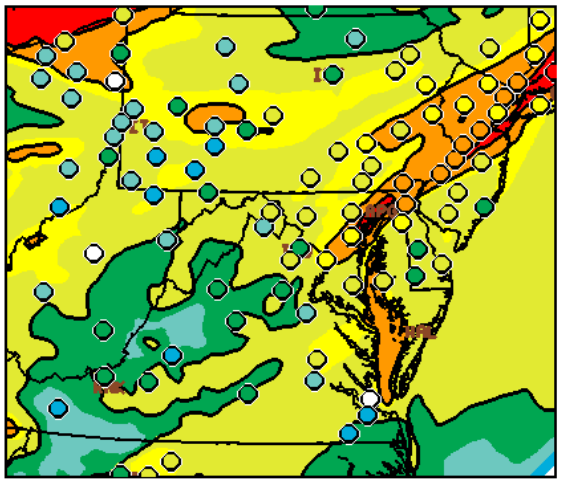
PARA2 CMAQ.V5.0.2 DAY1 OZMX08 20160721 12Z CYC



PARA2 CMAQ.V5.0.2 DAY1 OZMX08 20160722 12Z CYC



PROD DAY1 OZMX08 20160721 12Z CYC

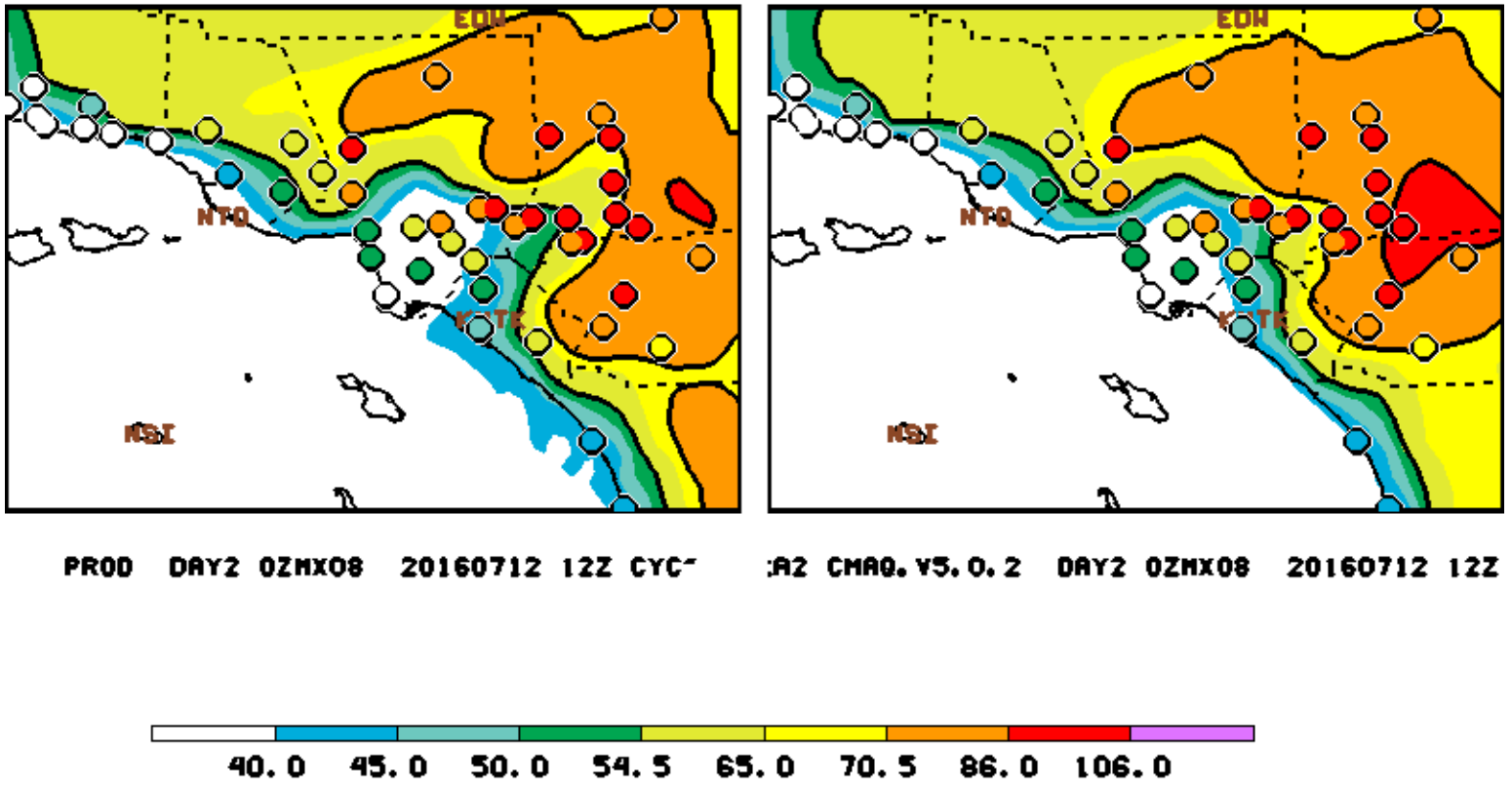


PROD DAY1 OZMX08 20160722 12Z CYC

V5.02: - Can miss some exceedences (7/21/16) but improved Overpredictions on 7/22/16 in NE PA, NY, NY

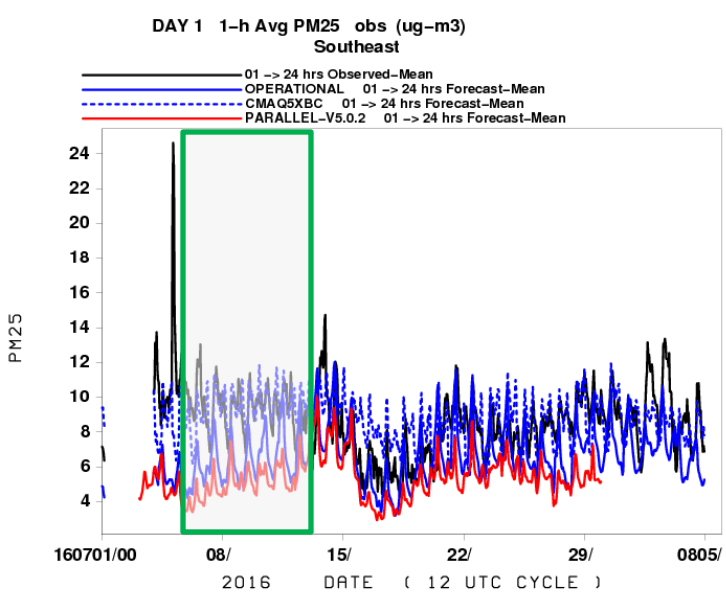
Summer 2016 NRT Prediction

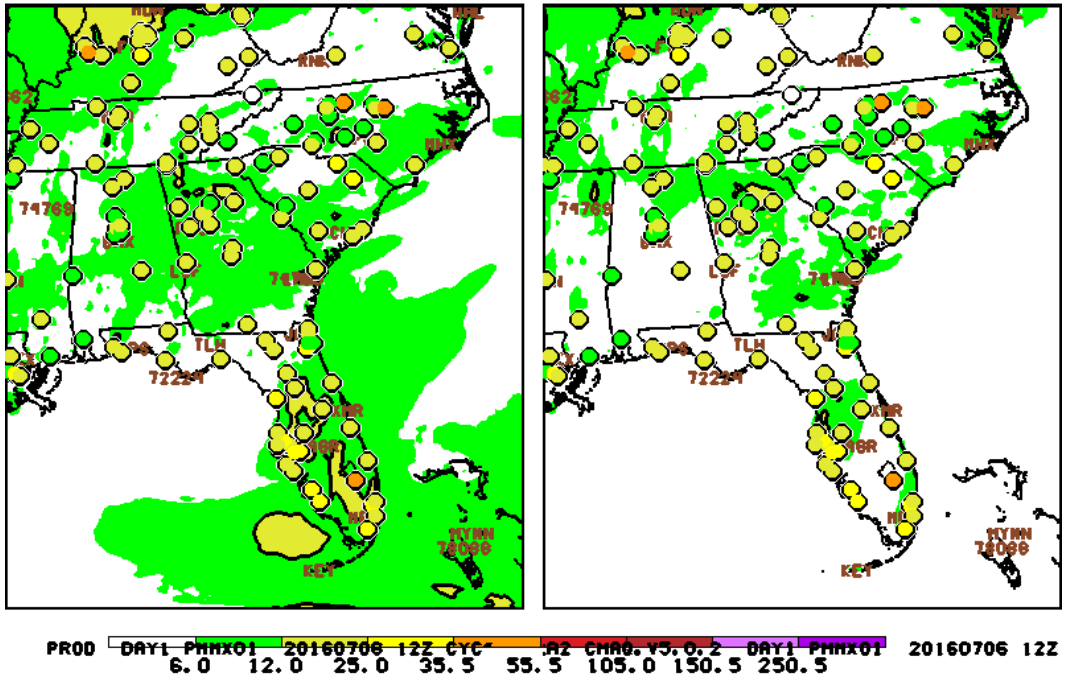
July 12, 2016 12Z run Day 2 8h Max **ozone** forecast



V5.02 more ozone formation in NOx saturated California

Summer 2016 NRT Prediction
July 6, 2016 Dust event

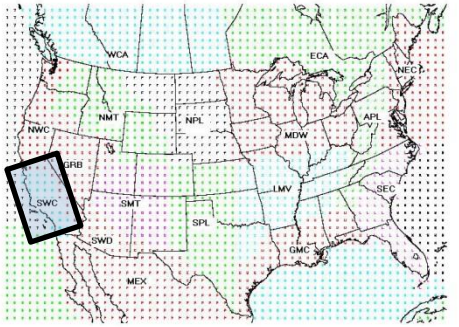




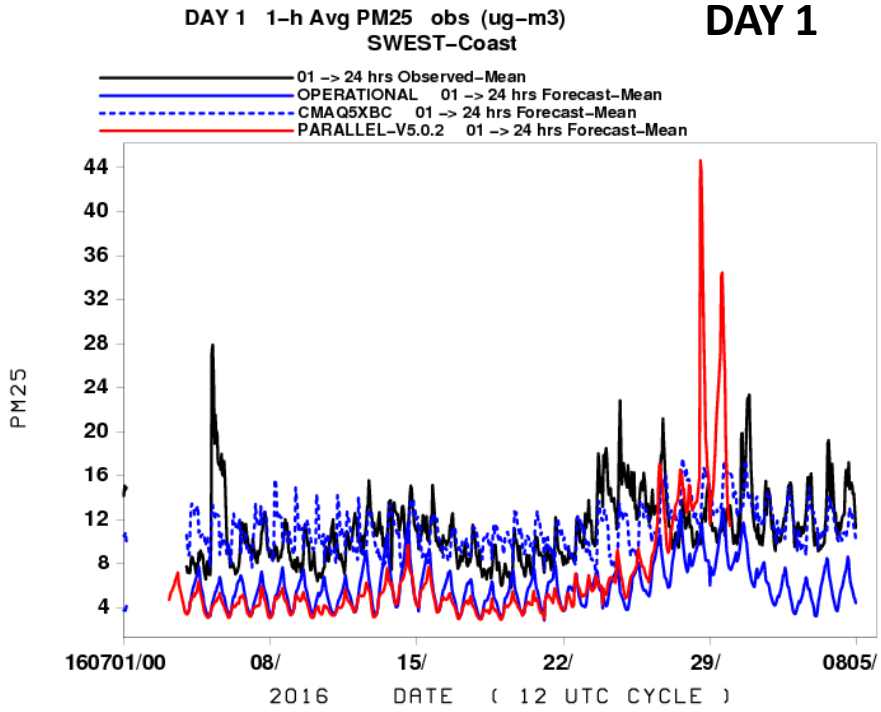
Southeast

- **V5.0.2 misses Saharan Dust Intrusion (red line)**

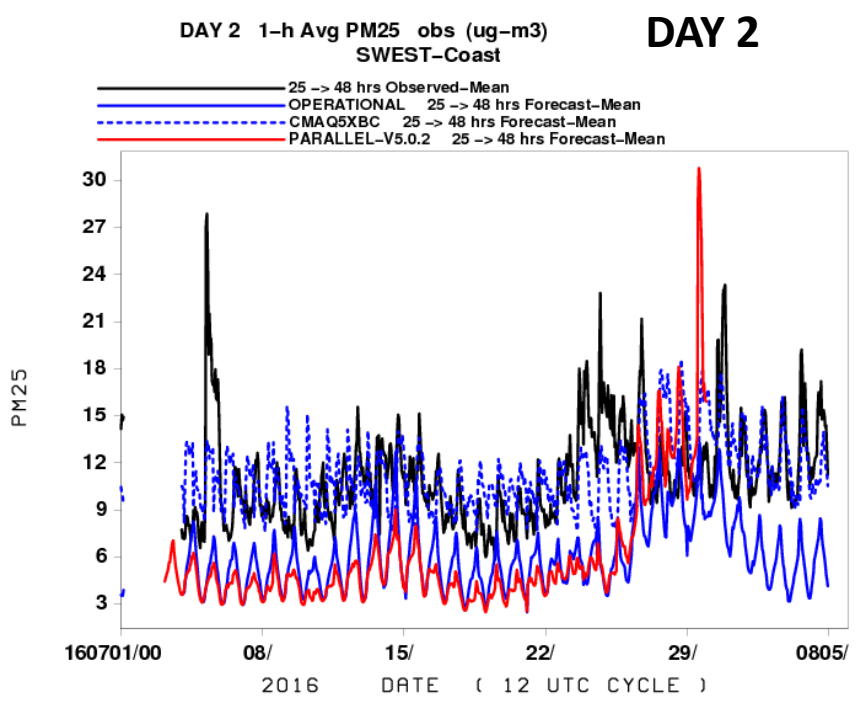
JULY 2016 NRT Prediction
1 h avg PM : South West U.S. Fires



DAY 1



DAY 2

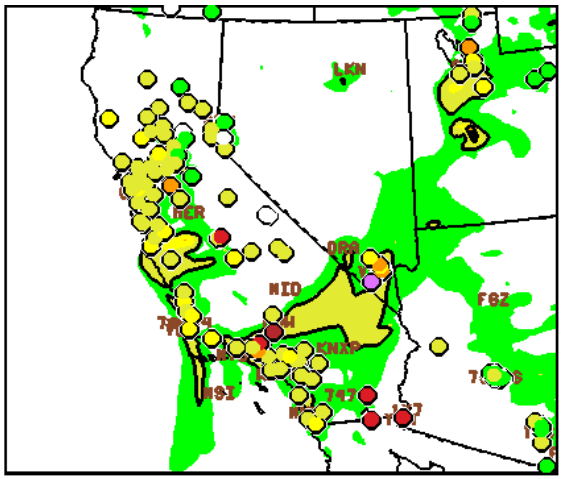


South West Coast

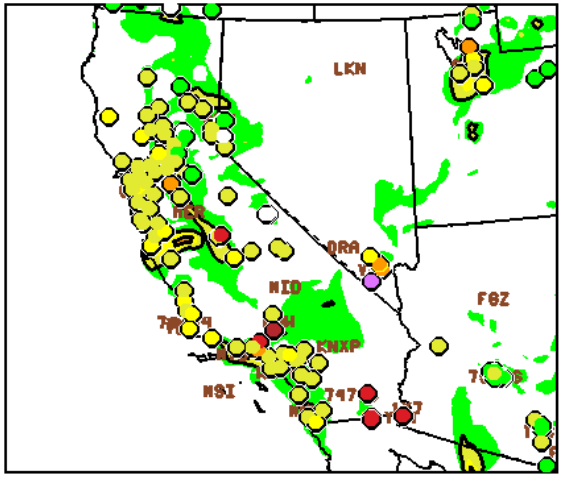
- Overprediction of wild fire smoke events in AM
  - No diurnal emissions profile used

PM California Fires

July 24, 2016 12Z run Day 1 1hr Max PM2.5 forecast



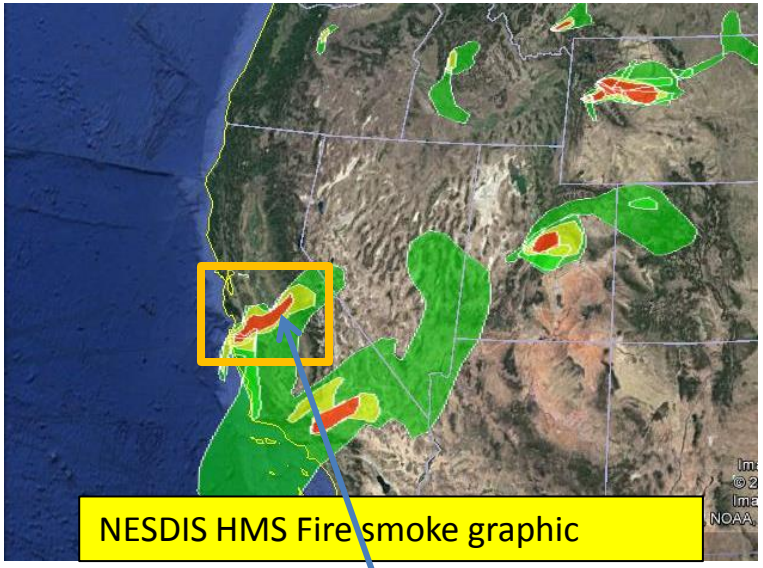
PARA2 CMAQ.V5.0.2 DAY1 PMMXO1 20160724 12Z CYC



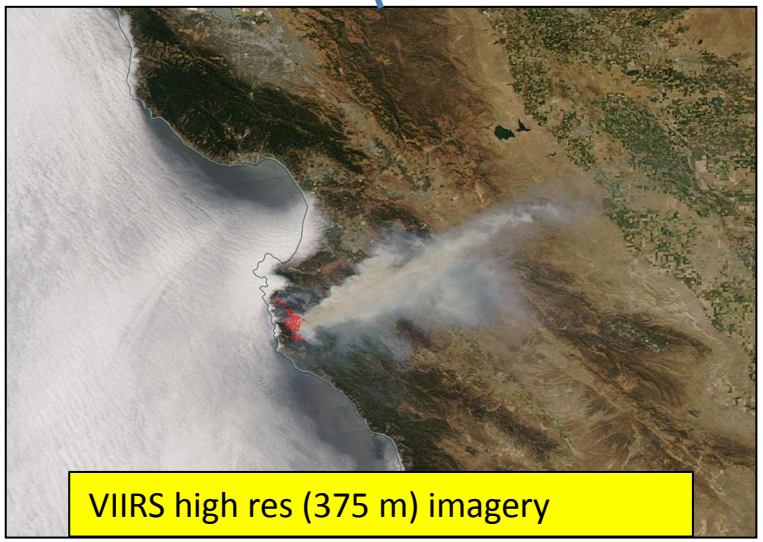
PROD DAY1 PMMXO1 20160724 12Z CYC

250.5
150.5
105.0
55.5
35.5
25.0
12.0
6.0

Some signature from fires in V5.02

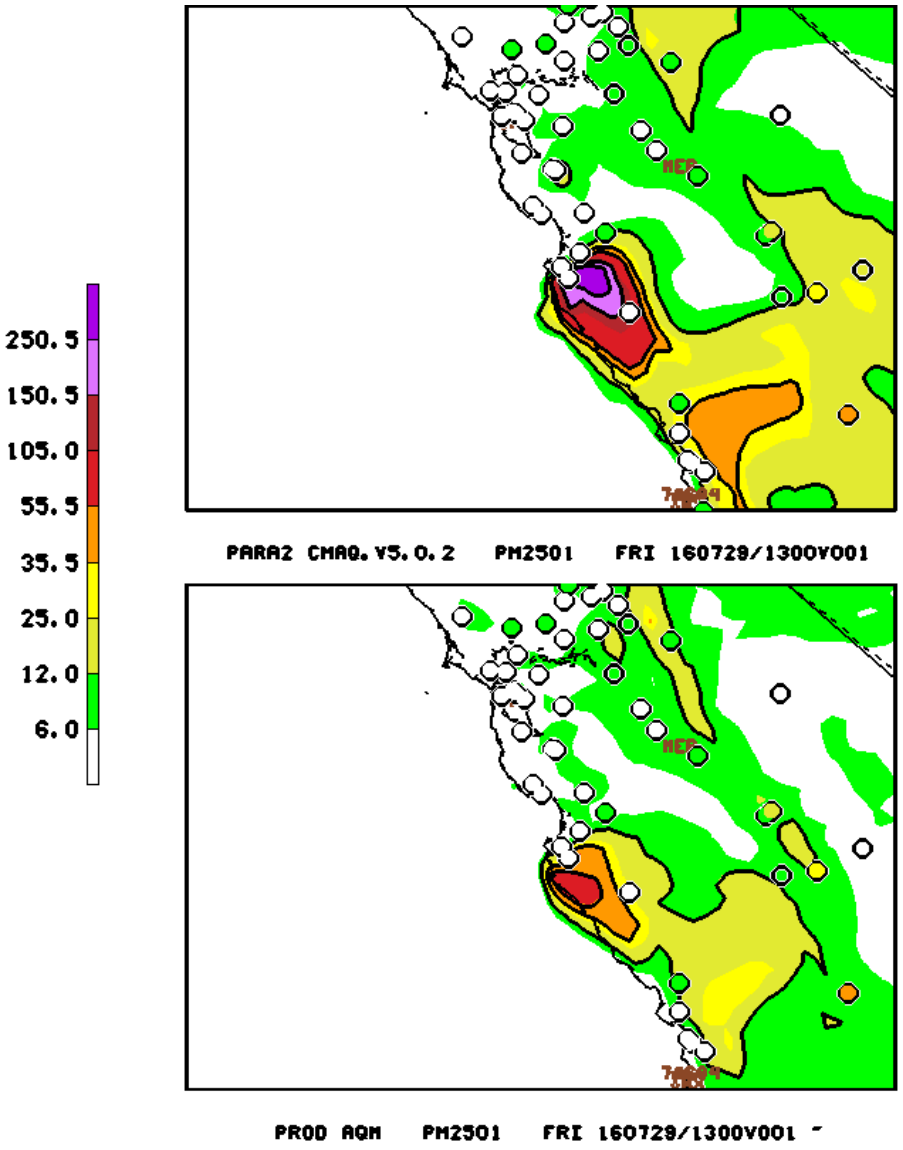


NESDIS HMS Fire smoke graphic



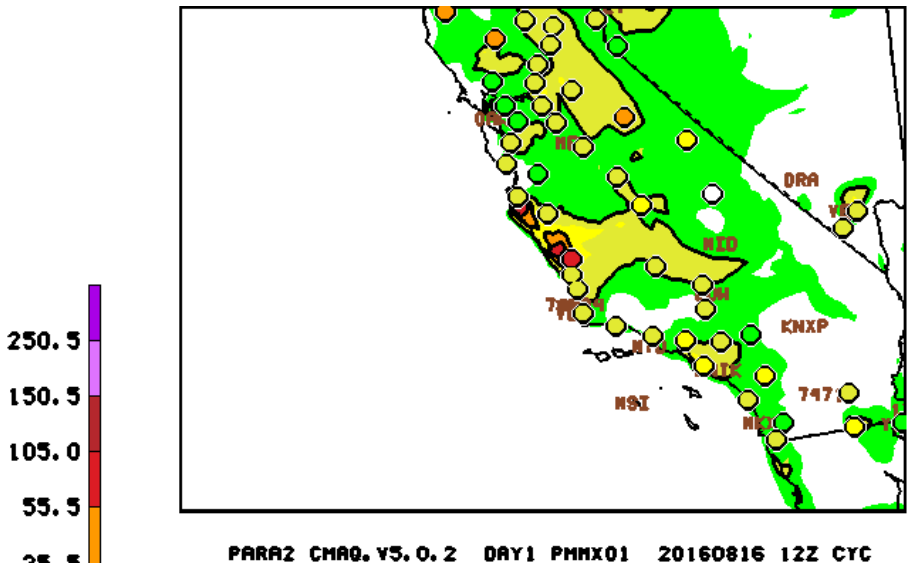
VIIRS high res (375 m) imagery

July 29, 2016 Big Sur Fire forecast and comparison to PM measurements

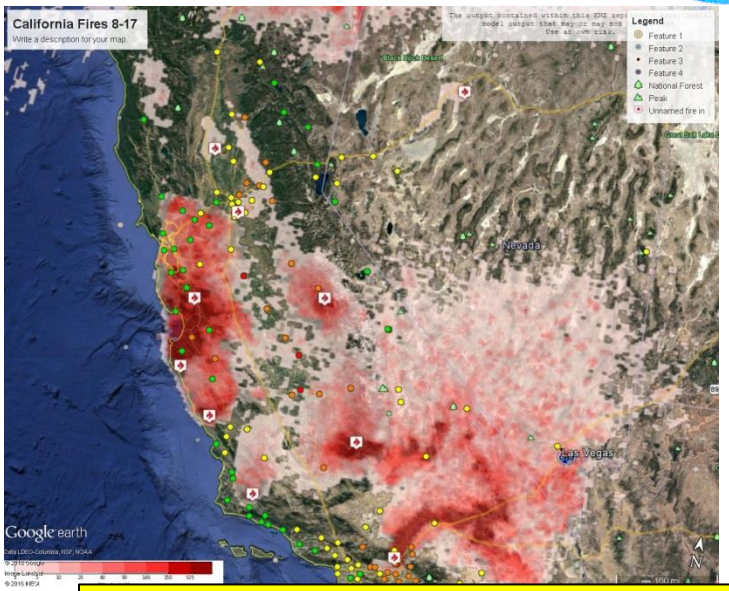


Smoke Emissions
- Location
- Magnitude
- Ejection height
- Diurnal evolution

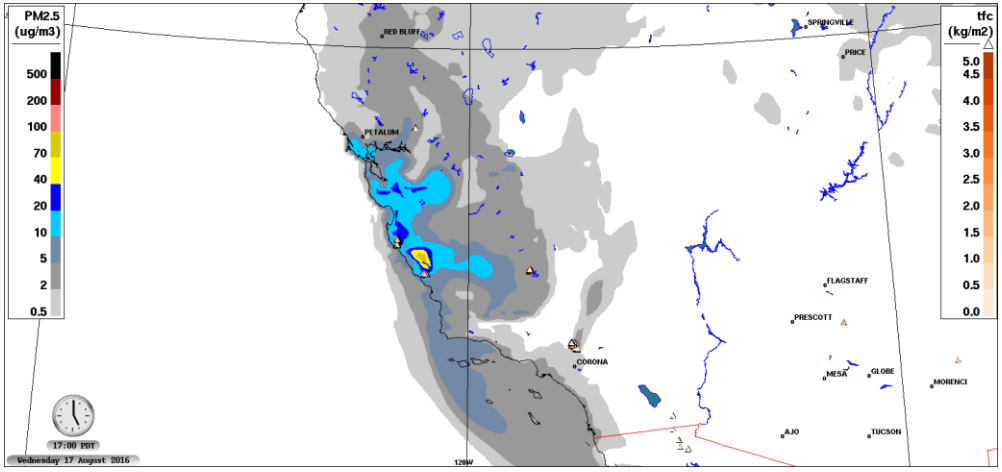
August 17, 2016 Big Sur and Blue Cut Fires



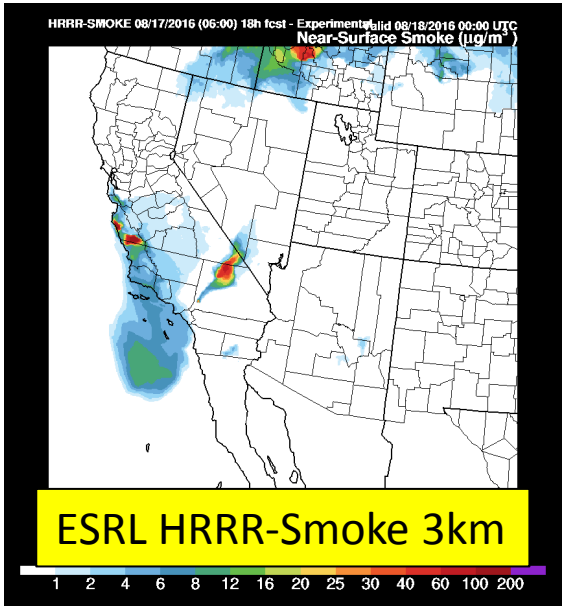
NAM-CMAQ 12 km total PM



USFS NAM-Nest HYSPLIT smoke



Env. CA. GEM-MACH



ESRL HRRR-Smoke 3km

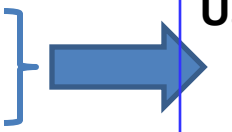
Summary

- *Ozone*
  - Improvement correcting over-prediction esp along coasts
    - Long Island Sound
    - Lake Erie/Michigan and Ohio Coastline
  - Much improved for Southwest and marginal or non-events
- *PM*
  - Large positive impact near forest fires :
    - updated BlueSky and24 h pre analysis run
    - Underprediction when external sources (Saharan dust, Canadian fires) are impacting CONUS

- <u>FY17 Implementation Remaining Issues</u>
  - Inclusion of NGAC boundaries correctly
  - Run time and CPU usage
  - NAM-X impact (positive so far, more optically dense clouds)
  - Smoke plume impact
    - Decreases with forecast time
    - Emission timing and ejection height uncertainties

Potential future emphasis

- Assimilation of satellite data (AOD, radiances..)
- Near real-time fire locations, strength, emissions
  - Top down (satellite) vs Bottom up (BlueSky) approaches
  - Improved plume rise algorithms
  - Canadian, Mexican & external source impacts
- Unification of AQ systems
  - HYSPLIT smoke/dust → NGAC Aerosol
  - CMAQ ozone & total PM
  - HRRR-smoke



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

- Temporal (Kalman Filter) bias correction
- Improved Evaluation
  - use of VIIRS/GOES-R..
  - Operational models for field experiments (ESRL FireX 2018, NASA FASMEE)