

National Air Quality Forecast Capability: Updates to Operational CMAQ PM2.5 Predictions and Ozone Predictions

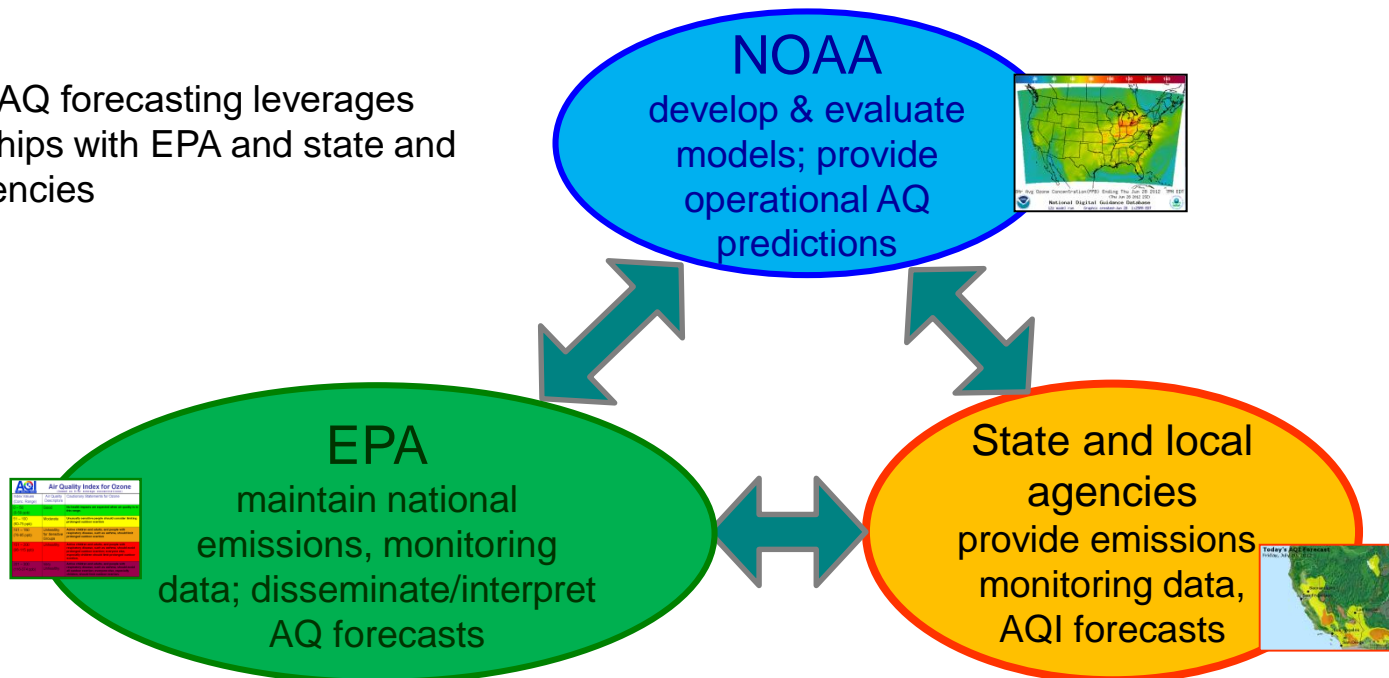
Operational Readiness Review

January 21, 2016

Background

- **Ongoing implementation of NOAA/NWS National Air Quality (AQ) Forecast Capability operationally to provide graphical and numerical guidance, as hourly gridded pollutant concentrations, to help prevent loss of life and adverse health impacts from exposure to poor AQ**
 - *Exposure to fine particulate matter and ozone pollution leads to premature deaths: 50,000+ annually in the US (Science, 2005; recently updated to 100,000 deaths; Fann, 2011, Risk Analysis)*
- **Direct impact on reducing loss of life: AQ forecasts have been shown to reduce hospital admissions due to poor air quality (Neidell, 2009, J. of Human Resources)**

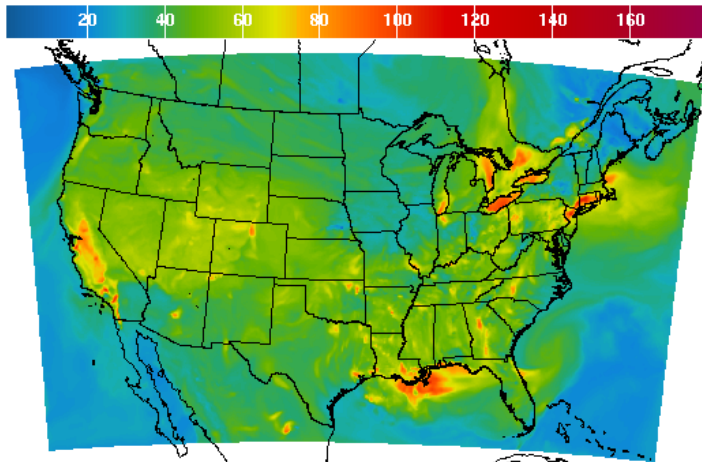
- NOAA's AQ forecasting leverages partnerships with EPA and state and local agencies



CMAQ products and testing

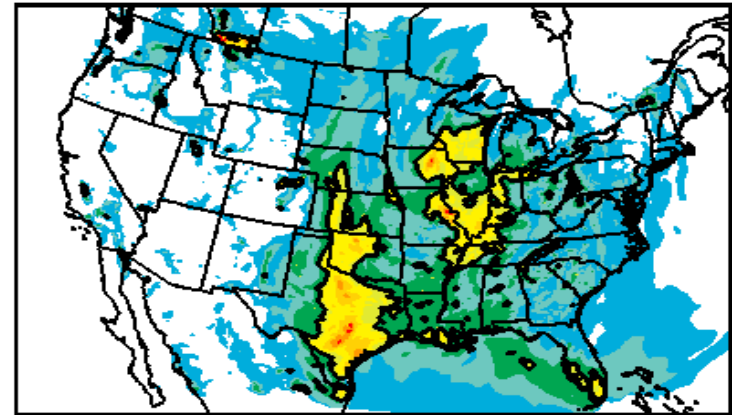
<http://airquality.weather.gov/>

<http://www.emc.ncep.noaa.gov/mmb/qa/cmaqbc/web/html/index.html>



1Hr Avg Ozone Concentration(PPB) Ending Wed Jul 29 2015 7PM EDT
(Wed Jul 29 2015 23Z)
National Digital Guidance Database
12z model run Graphic created-Jul 29 12:23PM EDT

Ozone predictions

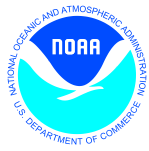


PARA PM2501 TUE 160105/1300V001



Testing of PM2.5 predictions

- Operational ozone predictions implemented for NE US in 2004, EUS in 2005, CONUS in 2007 and Nationwide in 2010
- Accuracy maintained over past 10 years: accounting for significant pollutant emission changes, weather model upgrades, and tighter warning thresholds used by state and local AQ forecasters in response to EPA's more stringent pollutant standards
- Developmental testing of semi-quantitative aerosol predictions based on pollutant emissions, begun in 2005



Ozone predictions



Operational predictions at <http://airquality.weather.gov>
over expanding domains since 2004

Model: Linked numerical prediction system



Operationally integrated on NCEP's supercomputer

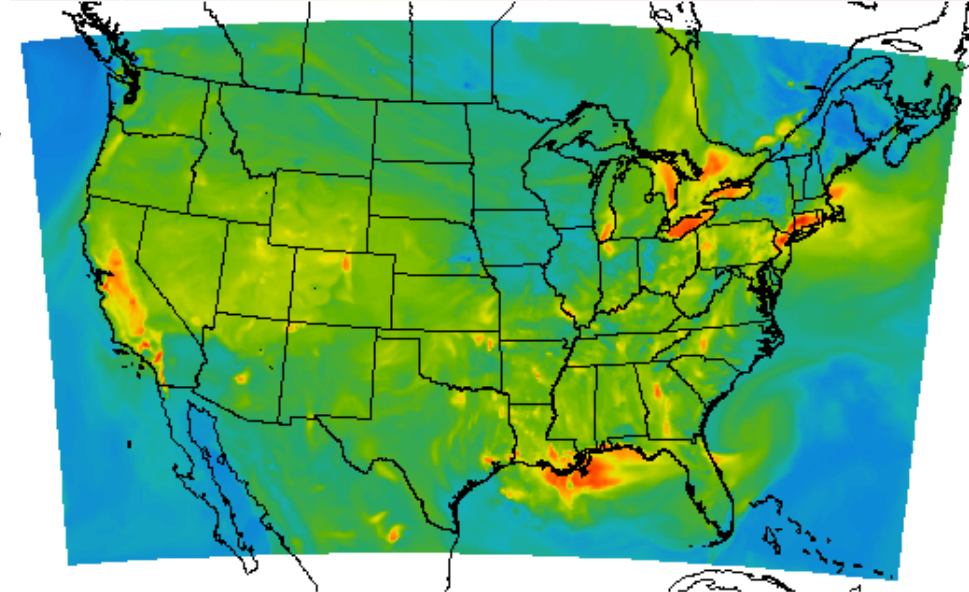
- NOAA/EPA Community Multiscale Air Quality (CMAQ) model
- NOAA/NCEP North American Mesoscale (NAM) numerical weather prediction

Observational Input:

- NWS compilation weather observations
- EPA emissions inventory

Gridded forecast guidance products

- On NWS servers: airquality.weather.gov and ftp-servers (12km resolution, hourly for 48 hours)
- On EPA servers
- Updated 2x daily



1Hr Avg Ozone Concentration(PPB) Ending Wed Jul 29 2015 7PM EDT
(Wed Jul 29 2015 23Z)



National Digital Guidance Database
12z model run

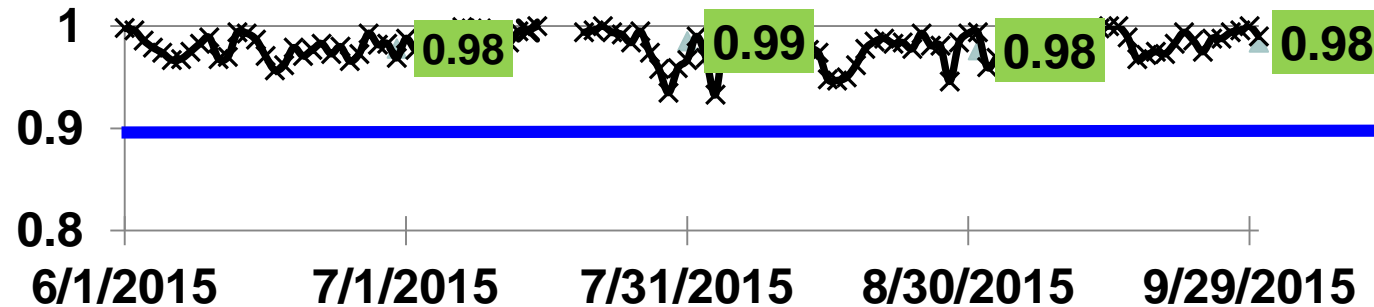


Graphic created-Jul 29 12:23PM EDT

Verification basis, near-real time: Ground-level AIRNow observations of surface ozone

Customer outreach/feedback

- State & Local AQ forecasters coordinated with EPA
- Public and Private Sector AQ constituents



Operational
CONUS, wrt 75 ppb Threshold

Maintaining prediction accuracy as the warning threshold was lowered and emissions of pollutants are changing

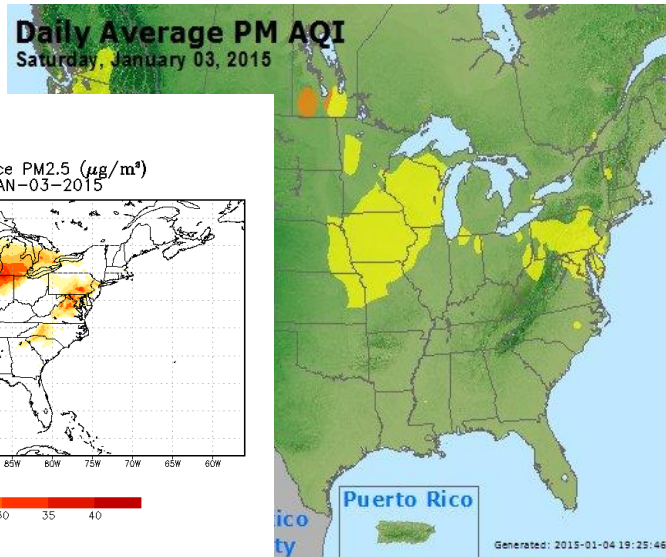
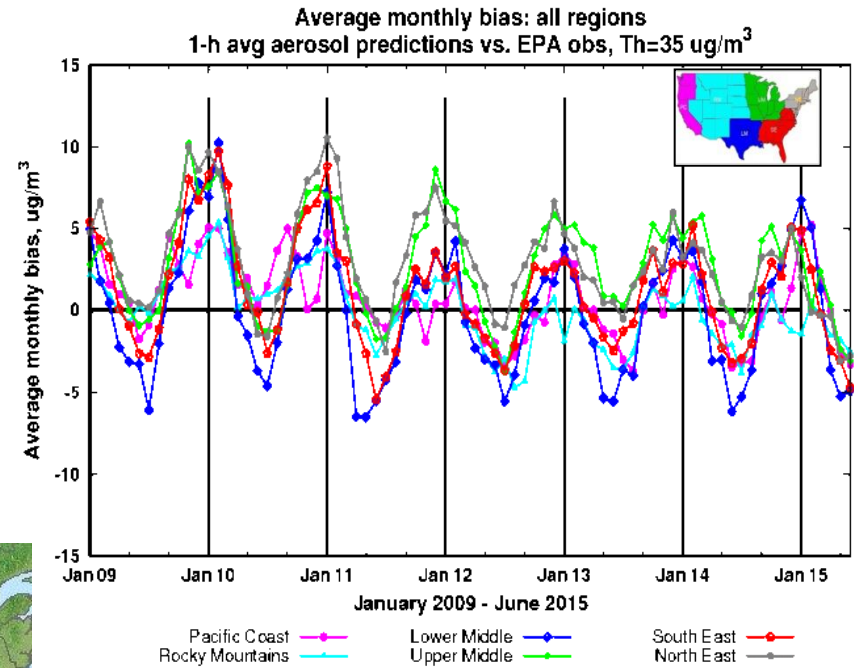
Testing of PM2.5 predictions

AQ Forecaster Focus group access only. Test predictions produced by operational air quality system since January 2015

Aerosols over CONUS

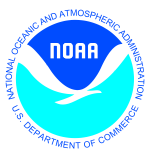
From NEI sources only before summer 2014

- CMAQ:
 - CB05 gases, AERO-4 aerosols
 - Sea salt emissions
- Seasonal prediction bias, testing bias correction post-processing algorithm



Forecast challenges

- Improving sources for wildfire smoke and dust – in testing since summer 2014
- Chemical mechanisms eg. SOA
- Meteorology eg. PBL height
- Chemical boundary conditions/trans-boundary inputs



Updates to CMAQ system



Changes made for this upgrade:

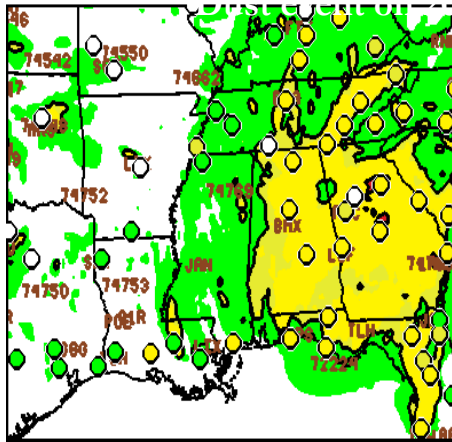
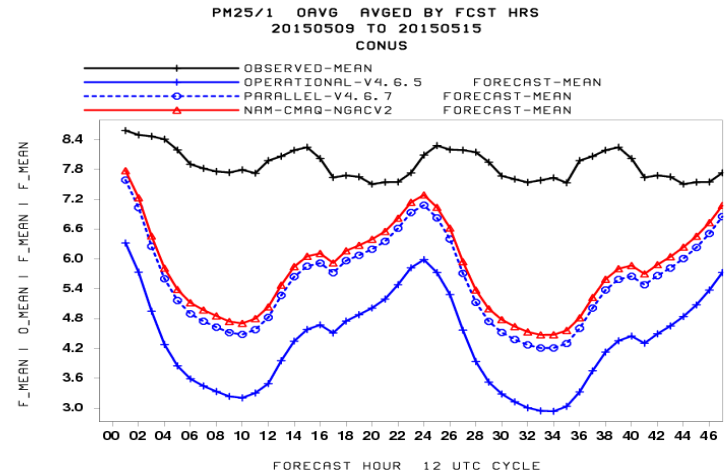
- Include global contributions of dust-related aerosol species at the CMAQ lateral boundaries from the NEMS Global Aerosol Capability (NGAC) forecasts
- Increase vertical levels from 22 to 35
- Analog ensemble bias correction for predictions of fine particulate matter

Expected Benefits from this upgrade include:

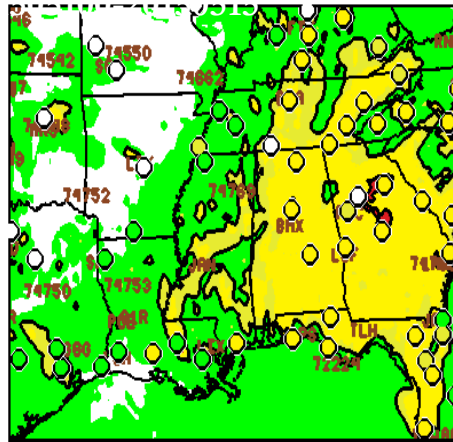
- Initial public distribution of raw and bias corrected particulate matter (PM_{2.5}) products
- Improved raw and bias corrected fine PM_{2.5} products
- Comparable performance for ozone with a slight decrease in bias

Dynamic LBCs from NGAC

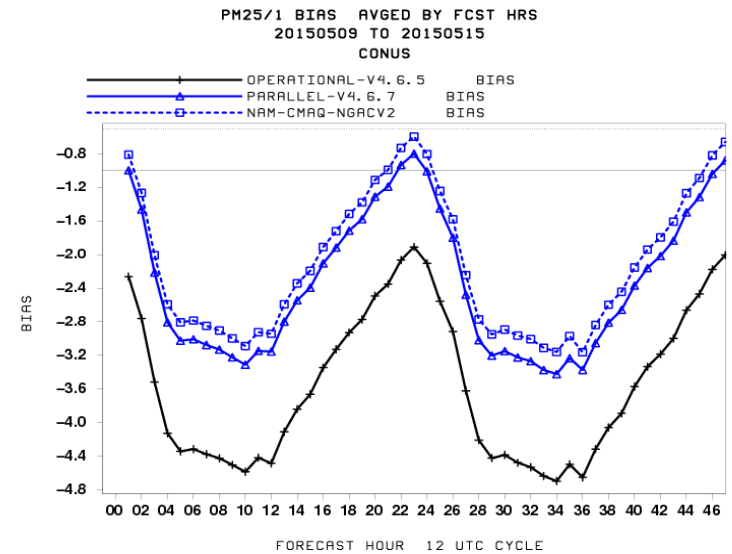
- Operational NAM-CMAQ using static LBCs versus experimental NAM-CMAQ with dynamic LBCs from NGACv1 and from NGACv2.
- The inclusion of LBCs from operational NGAC forecast is found to improve PM forecasts, for CMAQ Q1 2016 implementation. Initial tests show that using NGACv2 forecast as LBC further improves CMAQ PM forecast.



PROD DAY2 PMX01 20150510 12Z CYC



PARA2 DAY2 PMX01 20150510 12Z CYC

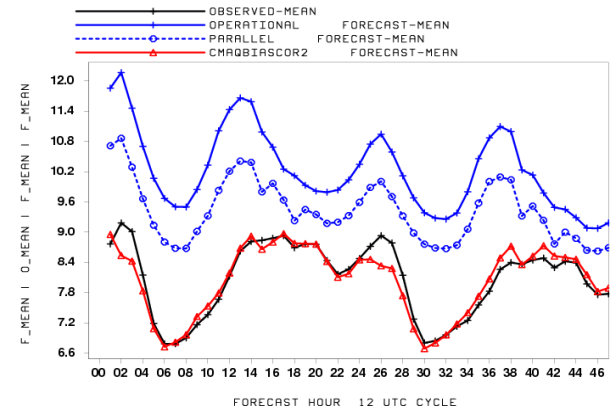
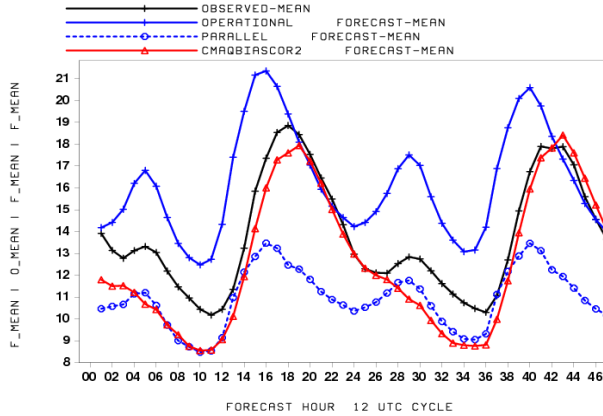


Bias Correction for PM2.5 predictions

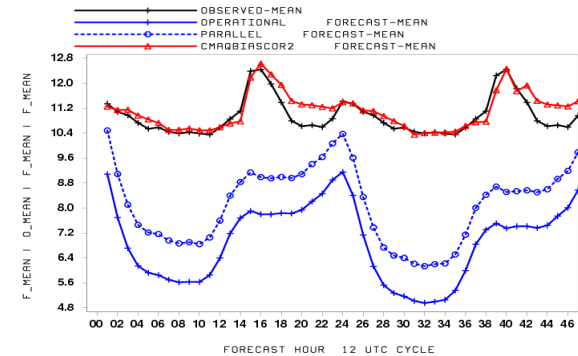
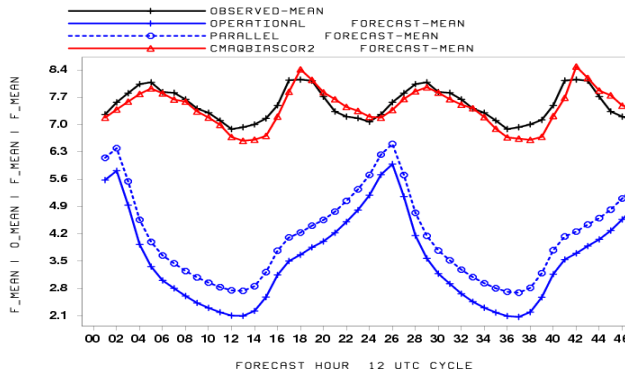
Western US

Eastern US

Winter
(Jan 2015)



Summer
(July 2015)



Djalalova, L. Delle Monache, and J. Wilczak: PM2.5 analog forecast and Kalman filter post-processing for the Community Multiscale Air Quality (CMAQ) model, Atmospheric Environment, Volume 108, May 2015, pp.76–87.

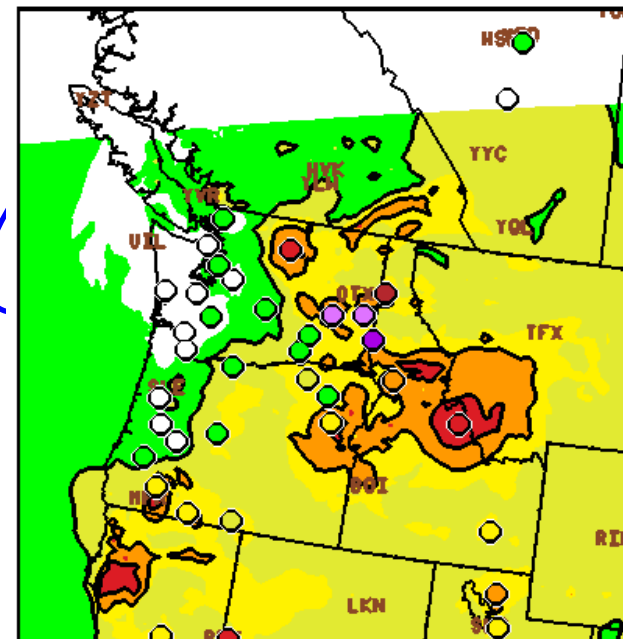
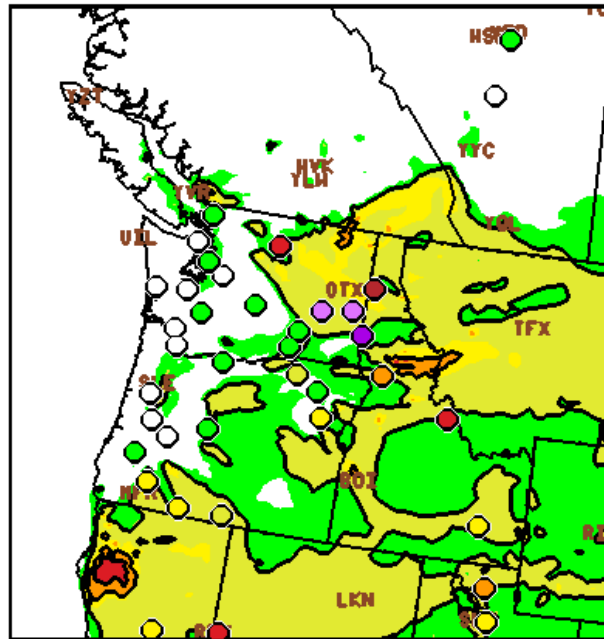
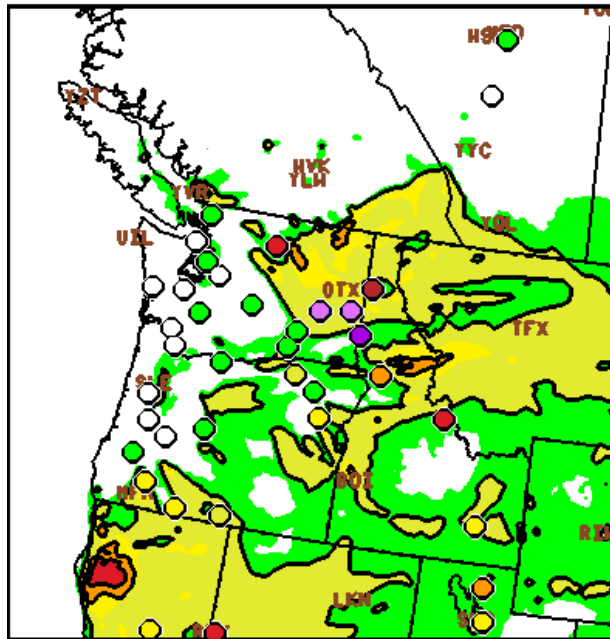
Western Fires

August 21, 2015 1hr PM2.5 Max

From Operational V4.6.5 AQ Model

Experimental V4.6.7 AQ model

Experimental AQ model w/ bias corr.



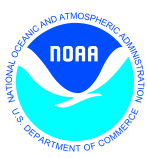
PROD DAY1 PMHX01 20150821 06Z CYC~

PARA1 DAY1 PMHX01 20150821 06Z CYC

DPARA BIAS COR DAY1 PMHX01 20150821 06Z CYC



Most sites impacted by fire smoke are severely underpredicted. Bias correction improves predictions.



EMC evaluation



Operational ozone predictions

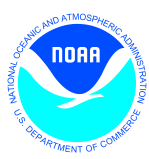
- **Small improvement with AQ model v4.7.0**
- **Over-prediction in most regions of US except for Southern California**

Experimental PM predictions

- **Positive impact from updated emissions and NGAC LBCs (dust only)**
- **Significant improvement with Analog Bias Correction**

Bias Correction may have limitations for rare high PM events

- **Improve analog matching technique for these events**
 - *Wild fire smoke, dust storms, winter stagnation*



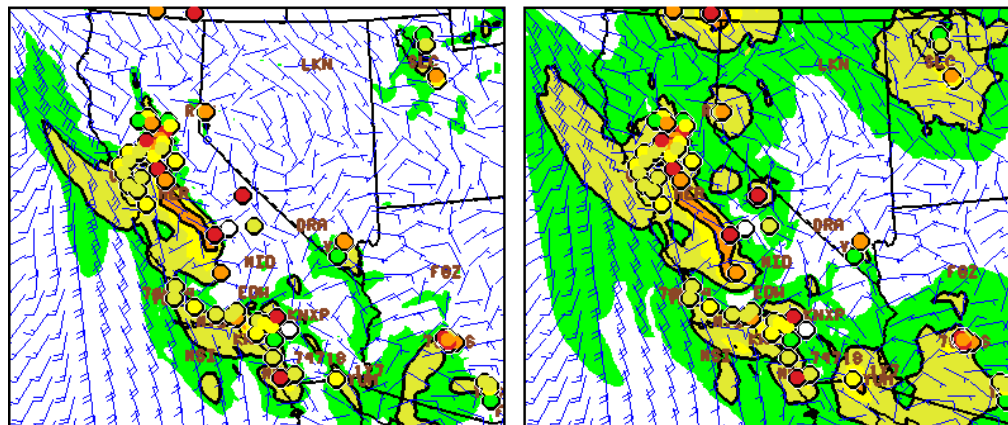
Testing with Forecaster Feedback

- AQ forecasters have been involved in providing early feedback on testing of this model upgrade.
- Initial feedback was collected during the AQ forecasters focus group workshop in September 2015.
- Frozen model version predictions were provided by EMC retrospectively since July 1, 2015 and continued by NCO since December 6 as the 30-day parallel testing.

NAQFC evaluation process

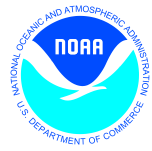
Coordination with a Focus Group of State Air Quality forecasters:

- Retrospective and real-time runs for July 2015 – Present and extreme events
 - May 10-11, 2015 Saharan dust storm intrusion; June 10-12, 2015 Canadian smoke intrusion
- Provision of comparison graphics for key areas
 - Production, Parallel vs bias corrected Parallel with observations overlaid
- Provision of MS Excel ready (Ascii) time series files at AQ sites delivered to forecaster
- Enable region specific feedback on model performance



PARA DAY1 PHMX01 20160102 12Z CYC~ PARA BIAS COR DAY1 PHMX01 20160102 12Z CY





Summary of Forecaster Feedback

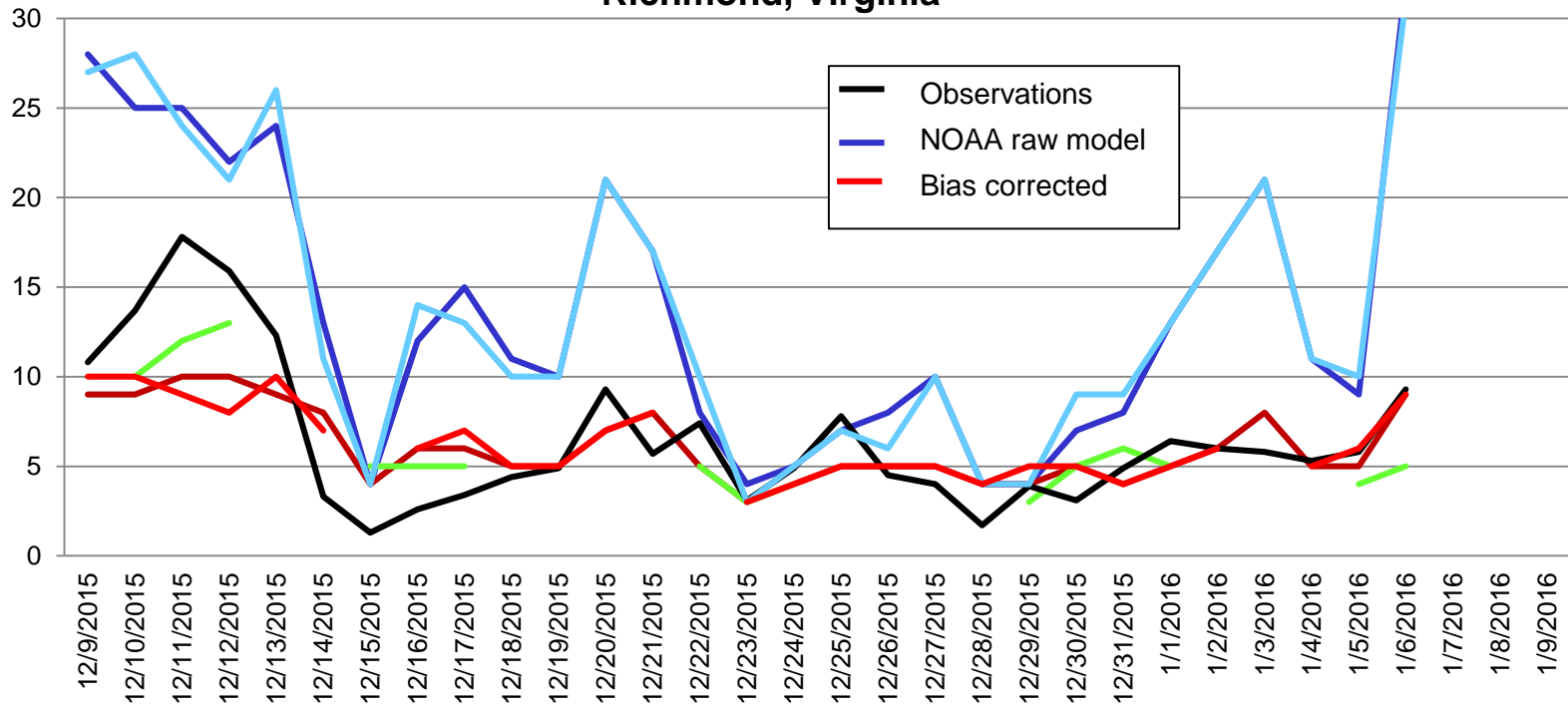


Received recommendation to implement as proposed from AQ forecasters from Virginia, Texas, Maryland, South Carolina, Maine, Pennsylvania, Connecticut, Washington with the following caveats:

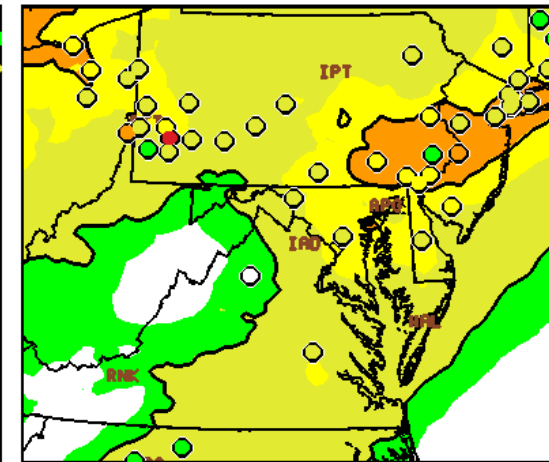
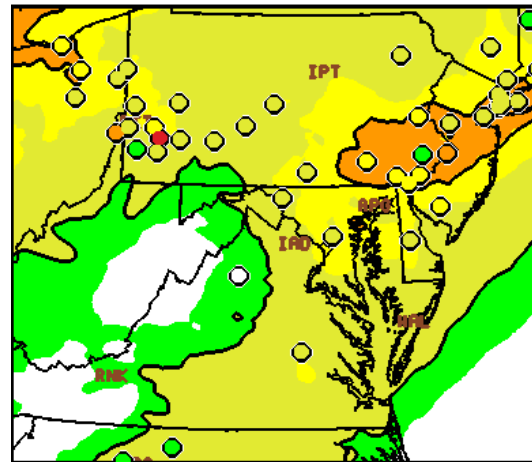
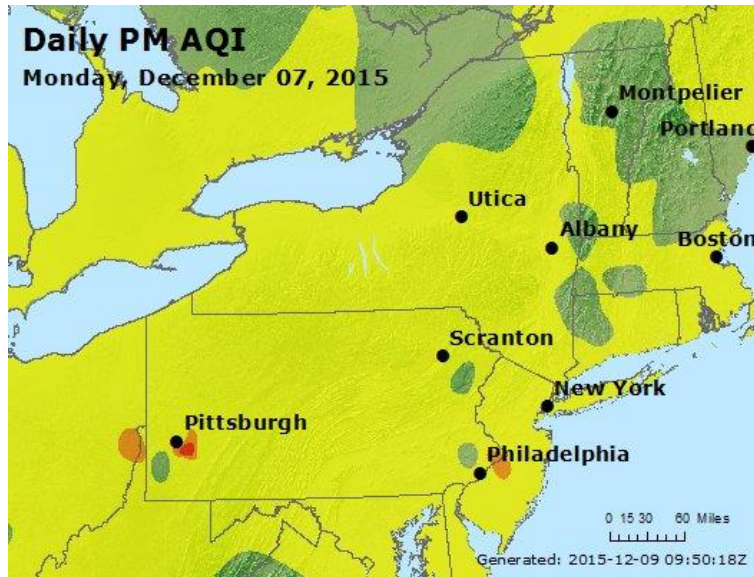
- MD forecaster recommend use of bias corrected PM2.5 over raw PM2.5 output as it largely over predicts the daily average.
- TX forecaster recommend inclusion of distant/international PM2.5 transport.
- PA forecaster recommend both the direct model predictions and the bias corrections, since they give complementary information on PM2.5 magnitude (bias correction) and trends (direct model predictions).
- CT forecaster: Bias- corrected model over-predicts in the GOOD AQI range which is a dis-benefit for the bias –corrected PM2.5. Otherwise, I would recommend implementing the model.

PM2.5 Feedback: Virginia

6z/12z NOAA Ozone Model, Forecasts and Observed PM2.5, Richmond, Virginia



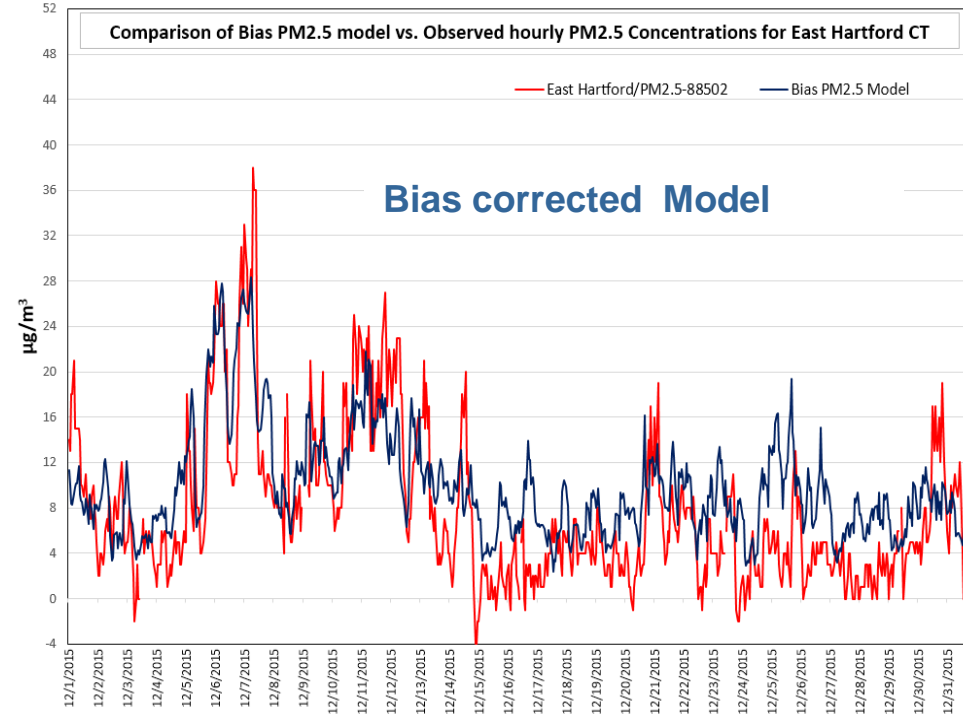
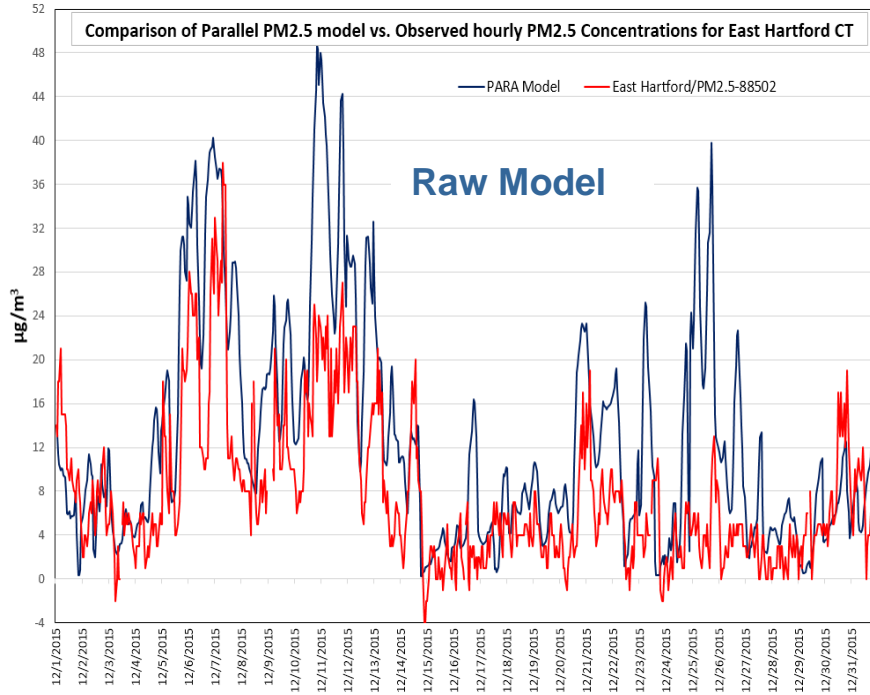
- The PM products have been quite useful for our daily air quality forecasts. We use the product every day.
- The bias corrected PM products are generally better compared to the raw model predictions, even within the relatively short evaluation.



Retrospective analysis for Dec 7, 2015 shows model hits in PHL and PIT but over-forecasted for Susquehanna and Lehigh Valleys in PA.

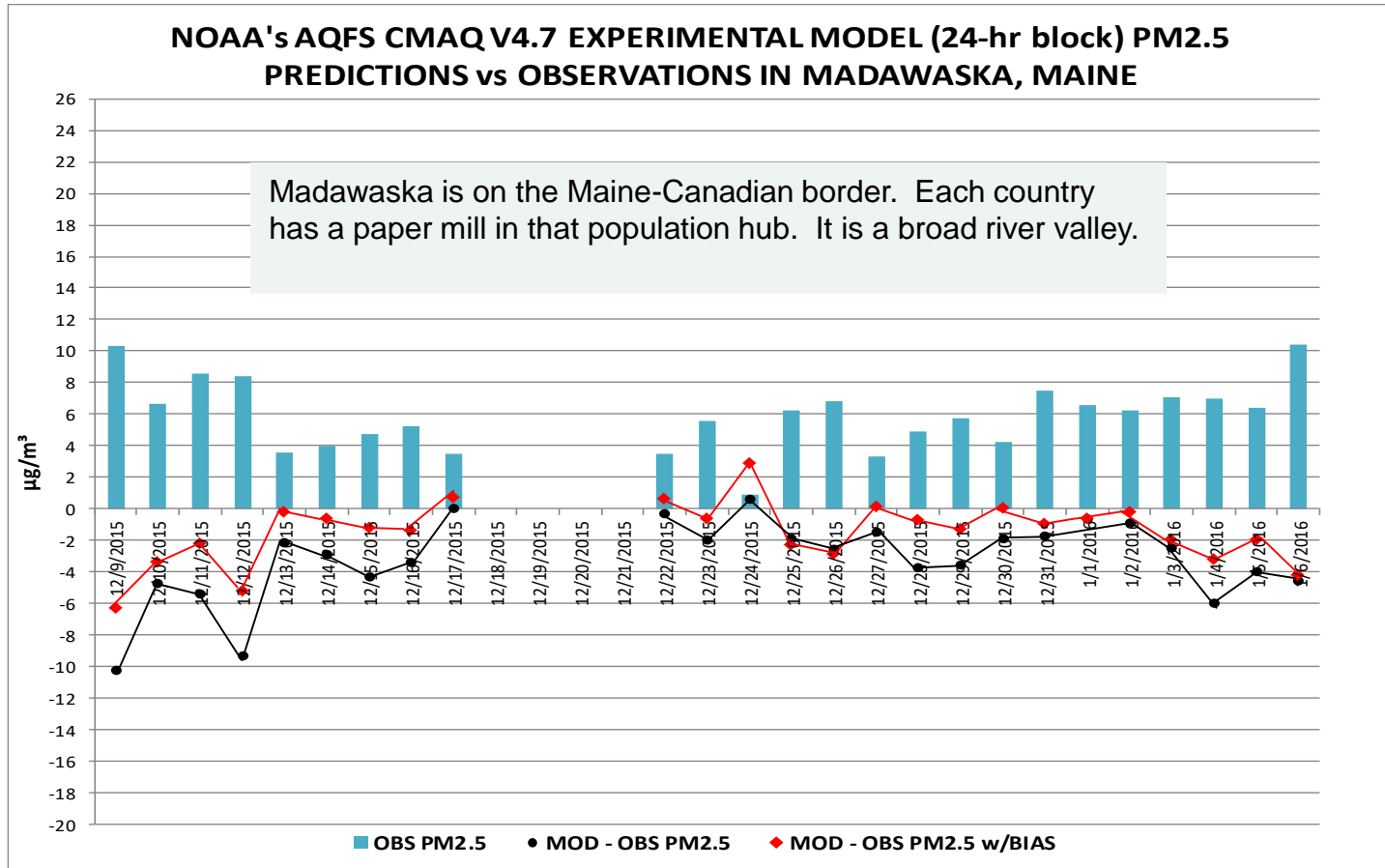
- Overall, NOAA raw model over-predicted PM2.5 consistently in PHL during this early December event
- Forecasters can adjust to model's positive bias since it is relatively consistent
- NOAA model correctly predicted onset and end of event
- Model is extremely useful for identifying beginning and end of poor air quality events
- The bias correction does reduce the tendency of the NOAA model to over-forecast, but at the expense of removing some of the variation in predicted PM2.5 that is helpful to us.

PM2.5 Feedback: Connecticut

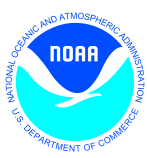


- Used same-day 24 hour predictions for the East Hartford CT monitor for December 2015
- Parallel model run continues to over estimate hourly PM2.5 concentrations;
- Bias- corrected model over-predicts in the GOOD AQI range but under-predicts most MODERATE and above;
- Bias-corrected has much less spread but only slightly better R² correlation.

PM2.5 Feedback: Maine



- During the winter months Maine’s most frequent issue is local emissions combined with nocturnal inversions.
- Knowing what the regional scale model is expecting will still inform the forecaster.
- During the remainder of the year this model would be even more useful in forecasting because that is when regional events dominate.



Additional PM2.5 Feedback



Texas

- These products are useful for helping give context to our daily air quality forecasts.
- The model generally does well in identifying the location of the highest PM2.5 from local/continental sources, though it typically over-predicts concentrations. They have improved quite a bit in this regard, particularly with the built-in bias correction.
- It appears that distant/international PM2.5 transport is not currently taken into account, though I understand this is a planned future enhancement.

Maryland

- With a bias correction, public dissemination is more possible, but I would stress caution.

South Carolina

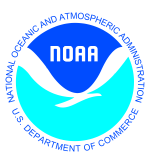
- We recommend proceeding with making this product available to all with respect to other programs and possible PM forecasting implementation in the future within our own state.

Washington

- We mostly use the NOAA forecasts if/ when our local model products fail or are providing ambiguous guidance.

Connecticut

- The bias-corrected PM2.5 model has a real dampening effect on the hourly concentrations. The big benefit is that it lowers the over-predictions on many day. The down-side is that it over-predicts values in the GOOD AQI range. The over-prediction of GOOD AQI is a dis-benefit for the bias – corrected PM2.5, otherwise, but this can be further improved . Otherwise, I would recommend implementing the model.



Ozone Feedback

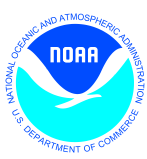


South Carolina

- SCDHEC forecasters recommend implementing the proposed upgrades to [AQ model] version 4.7. There is a slight decrease in bias observed for South Carolina and the SE Coast region. RMSE has also improved slightly. We did not see any degraded performance as a result of the proposed change.

Maine

- Most of the time the model was within .005 ppm (5 ppb) of the obs. So that is fairly good. It would be better if it was consistent.

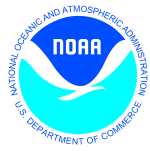


Recommendation for Implementation



Recommendation:

NWS deploy updated CMAQ for operational ozone predictions, initial public distribution of bias corrected particulate matter (PM2.5) products, and potentially raw PM2.5 products as an update of operational air quality product suite from the same system.



Acknowledgments:

AQF implementation team members



Special thanks to previous NOAA and EPA team members who contributed to the system development

NOAA/NWS/STI

Ivanka Stajner

NAQFC Manager

NWS/AFSO

Jannie Ferrell

Outreach, Feedback

NWS/OD

Cynthia Jones

Data Communications

NWS/OSTI/MDL

Marc Saccucci, Dave Ruth

Dev. Verification, NDGD Product Development

NWS/STI

Sikchya Upadhayay

Program Support

NESDIS/NCDC

Alan Hall

Product Archiving

NWS/NCEP

Jeff McQueen, Jianping Huang, Ho-Chun Huang

AQF model interface development, testing, & integration

*Jun Wang, *Sarah Lu*

Global dust aerosol and feedback testing

**Brad Ferrier, *Eric Rogers,*

NAM coordination

**Hui-Ya Chuang*

Geoff Manikin

Smoke and dust product testing and integration

Rebecca Cosgrove, Steven Earle, Chris Magee

NCO transition and systems testing

Mike Bodner, Andrew Orrison

HPC coordination and AQF webdrawer

NOAA/OAR/ARL

Pius Lee, Daniel Tong, Li Pan

CMAQ development, adaptation of AQ simulations for AQF

Hyun-Cheol Kim, Youhua Tang

Ariel Stein

HYSPLIT adaptations

NESDIS/STAR *Shobha Kondragunta*

Smoke and dust verification product development

NESDIS/OSDPD *Liqun Ma, Mark Ruminski*

Production of smoke and dust verification products,

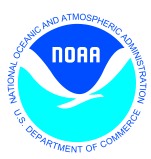
HMS product integration with smoke forecast tool

EPA/OAQPS *partners:*

Chet Wayland, Phil Dickerson, Brad Johns, John White

AIRNow development, coordination with NAQFC

* Guest Contributors



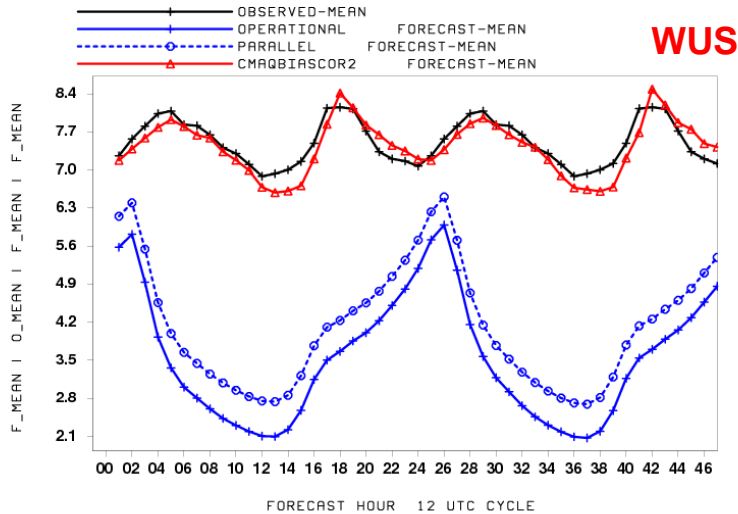
Back-up



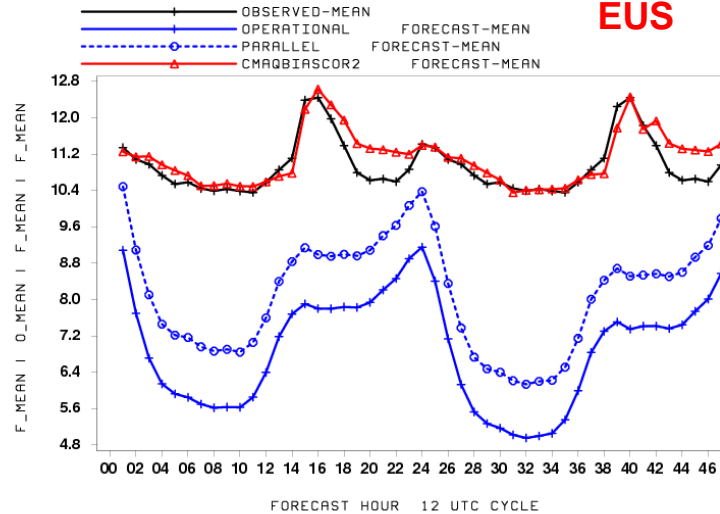
CMAQ PM Performance : July 2015



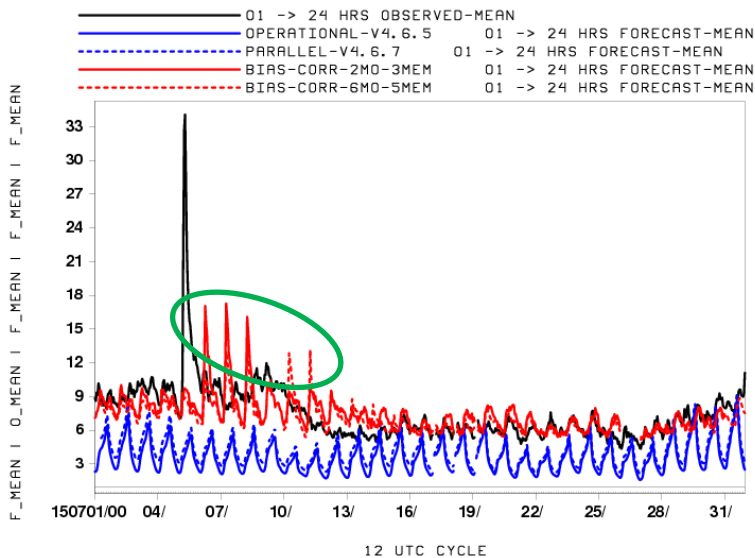
PM25/1 OAVG AVG'D BY FCST HRS
20150701 TO 20150731
WEST-US



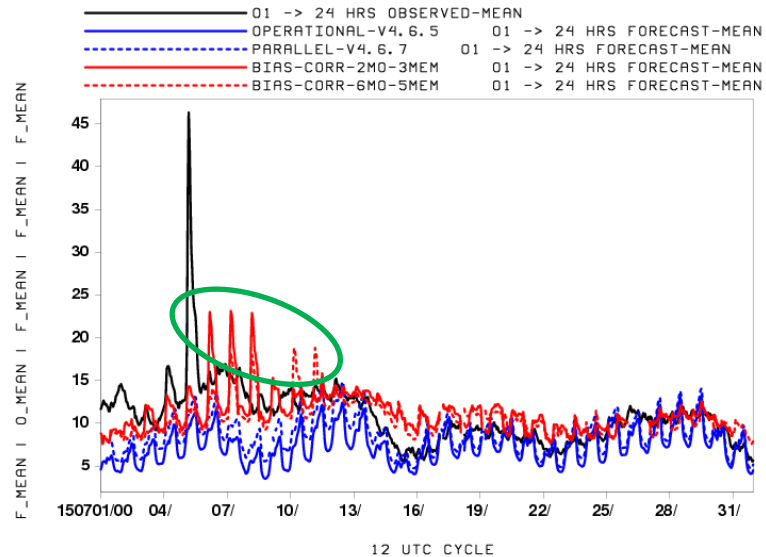
PM25/1 OAVG AVG'D BY FCST HRS
20150701 TO 20150731
EAST-US



01 H PM25/1
WEST-US



01 H PM25/1
EAST-US

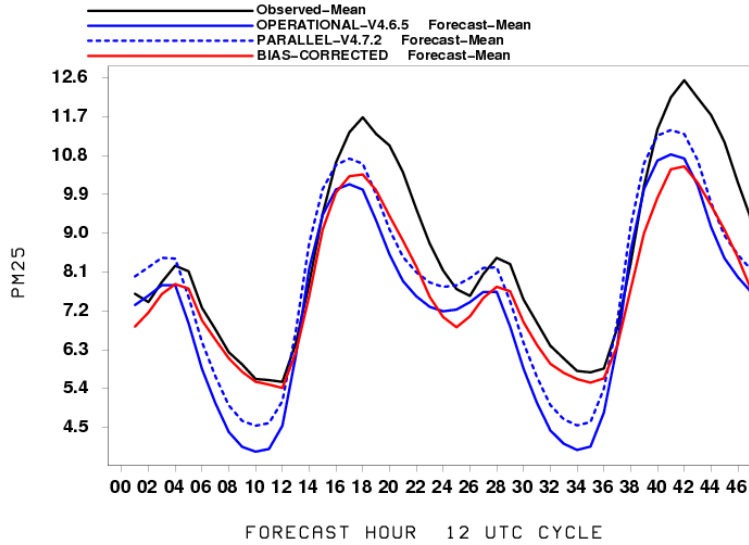




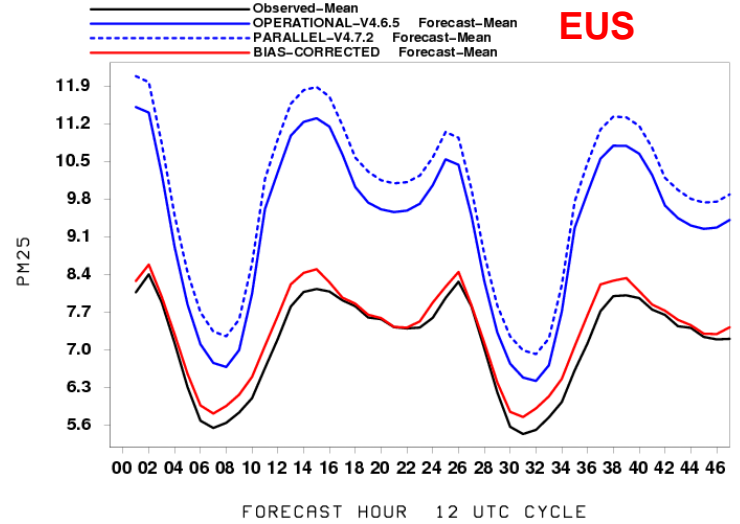
CMAQ PM Performance : Nov 2015



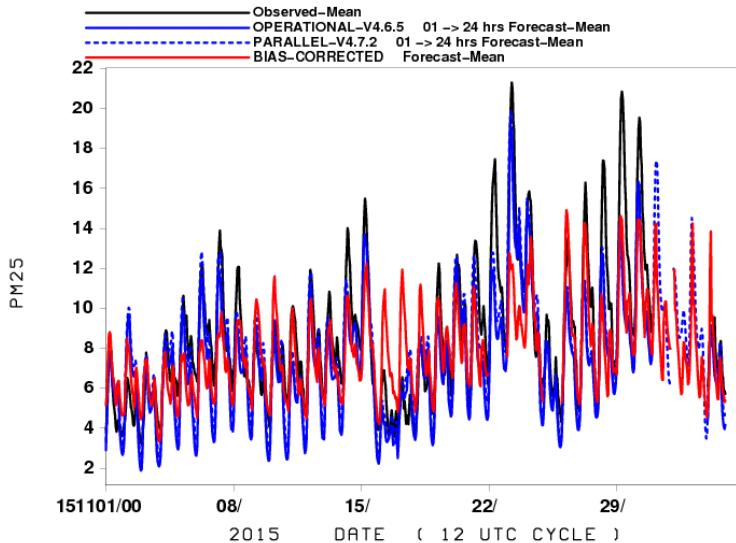
1-h Avg PM25 obs (ug-m3) avged by fcst hrs
20151101 to 20151205
West-US



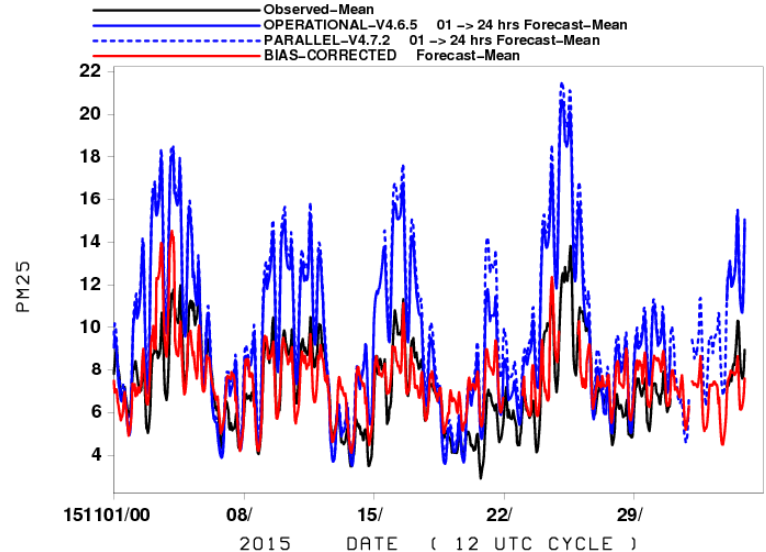
1-h Avg PM25 obs (ug-m3) avged by fcst hrs
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East-US



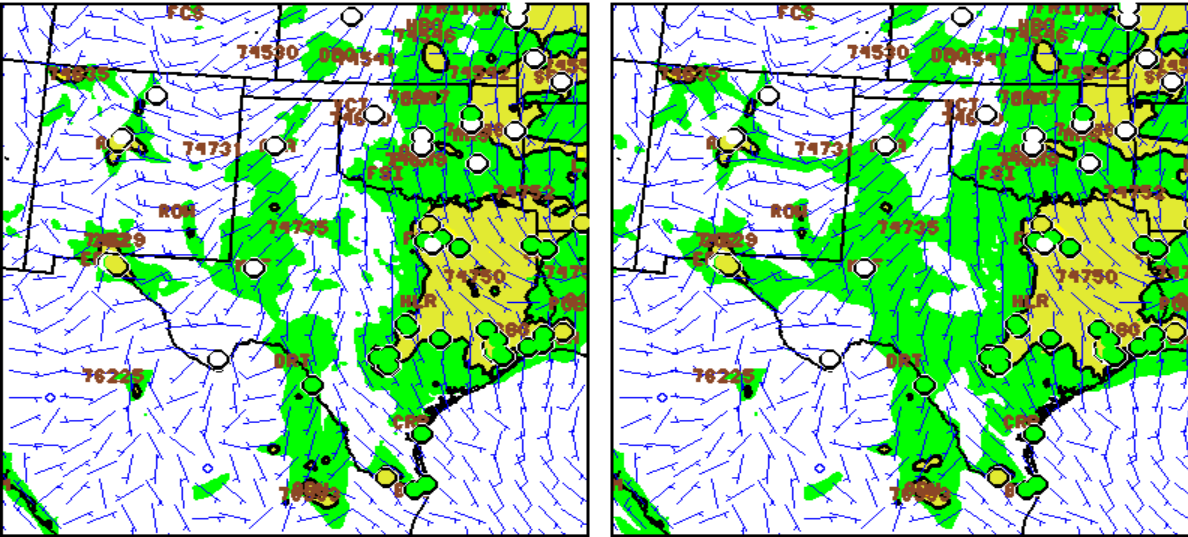
DAY 1 1-h Avg PM25 obs (ug-m3)
West-US



DAY 1 1-h Avg PM25 obs (ug-m3)
East-US



PM2.5 Feedback: Texas



PROD DAY1 PMMX24 20151209 06Z CYC-

PARA DAY1 PMMX24 20151209 06Z CYC



Local Sources Example
December 9, 2015

