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

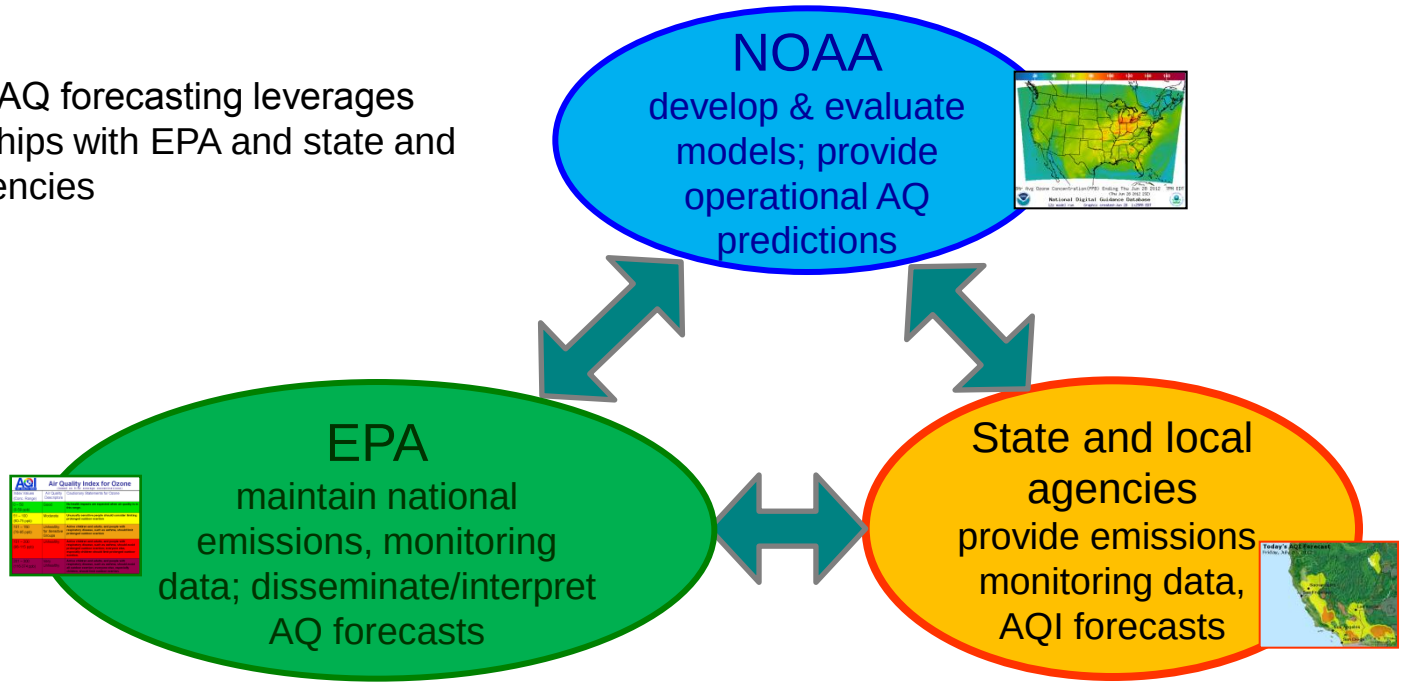
Operational Readiness Review

January 21, 2016

Background

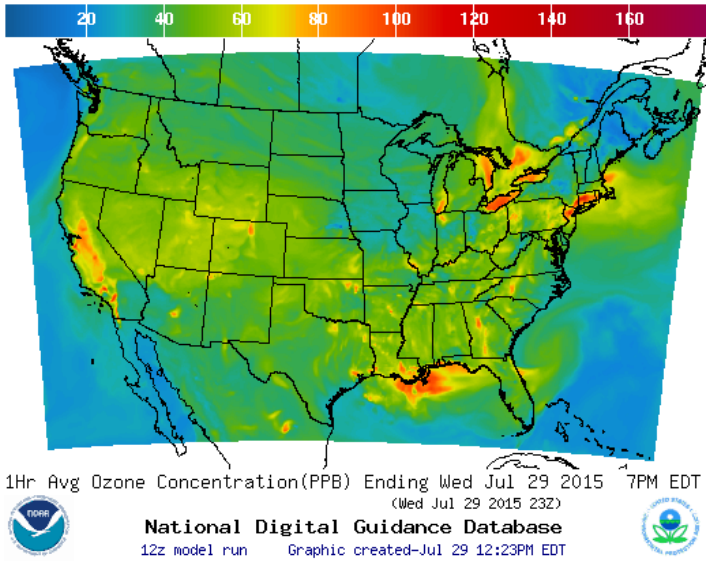
- **Ongoing implementation of NOAA/NWS National Air Quality (AQ) Forecast Capability operationally to provide graphical and numerical guidance, as hourly gridded pollutant concentrations, to help prevent loss of life and adverse health impacts from exposure to poor AQ**
  - *Exposure to fine particulate 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



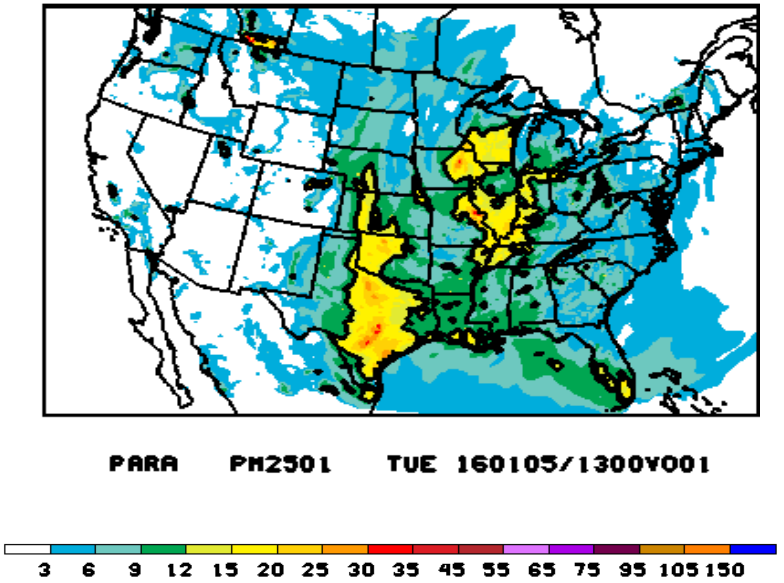
CMAQ products and testing

http://airquality.weather.gov/



Ozone predictions

http://www.emc.ncep.noaa.gov/mmb/aq/cmaqbc/web/html/index.html



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*

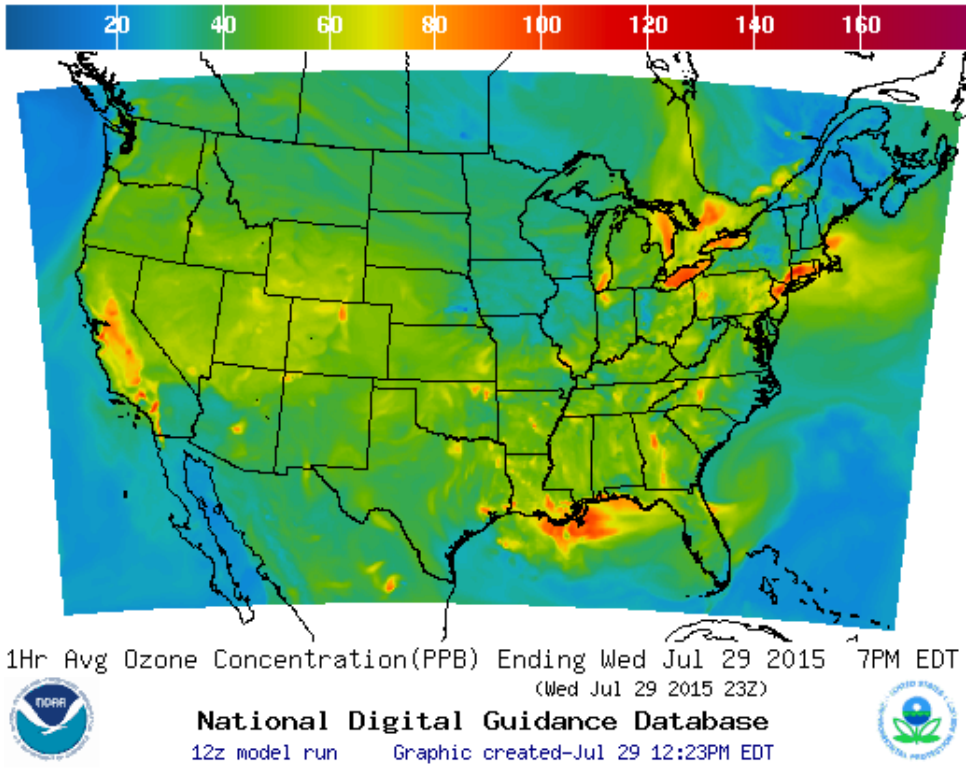
Gridded forecast guidance products

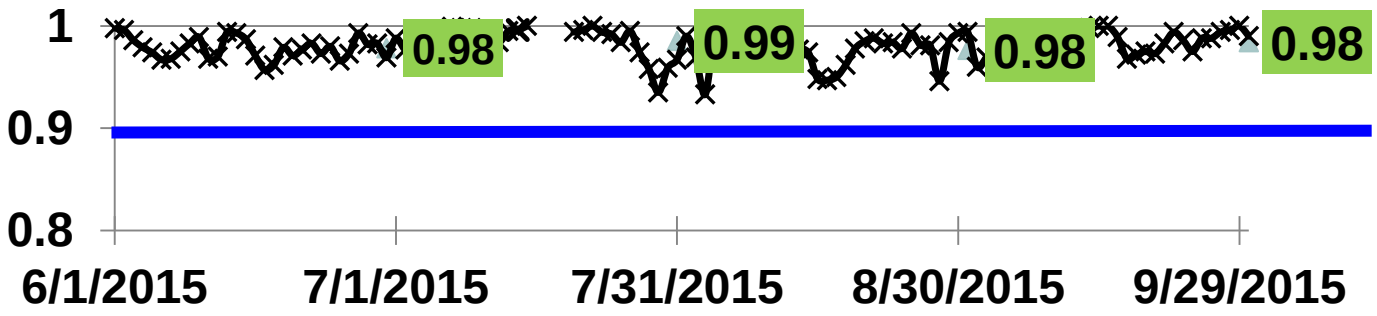
- *On NWS servers: airquality.weather.gov and ftp-servers (12km resolution, hourly for 48 hours)*
- *On EPA servers*
- *Updated 2x daily*

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

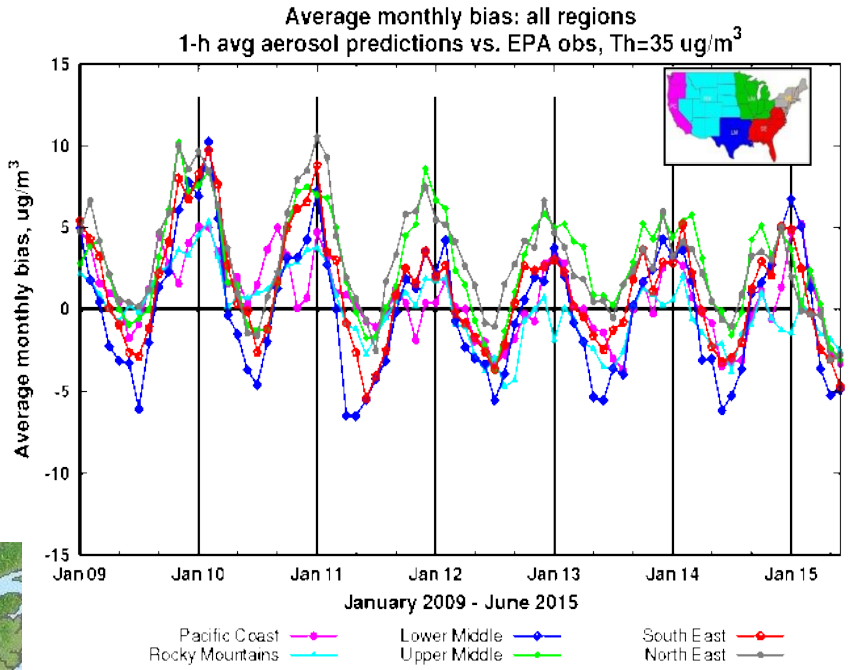
AQ Forecaster Focus group access only. Test predictions produced by operational air quality system since January 2015

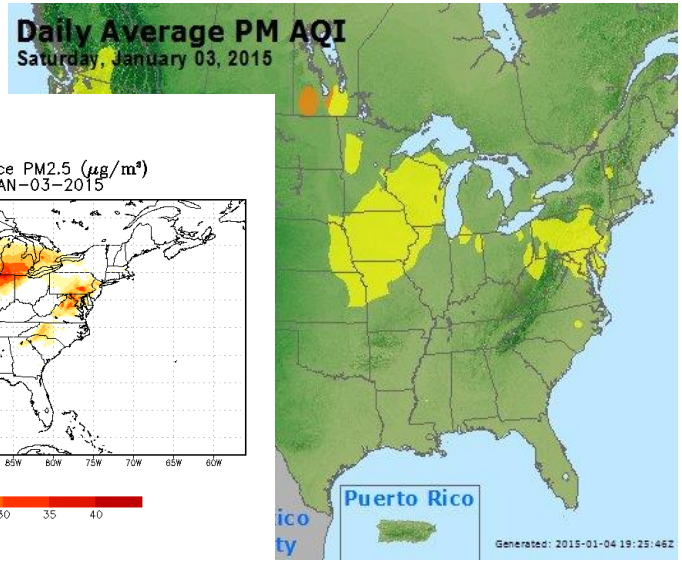
Aerosols over CONUS

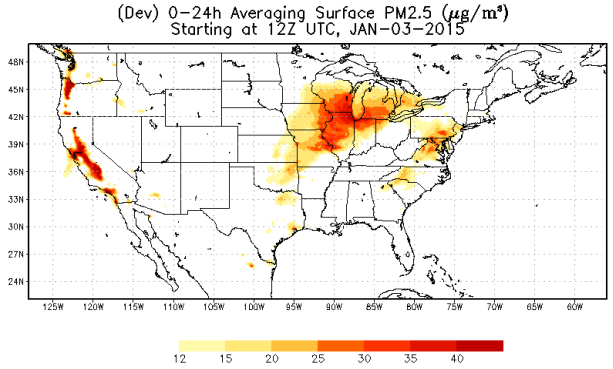
From NEI sources only before summer 2014

- CMAQ:
  CB05 gases, AERO-4 aerosols
- Sea salt emissions

- Seasonal prediction bias, testing bias correction post-processing algorithm







NAQFC PM2.5 test predictions

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:

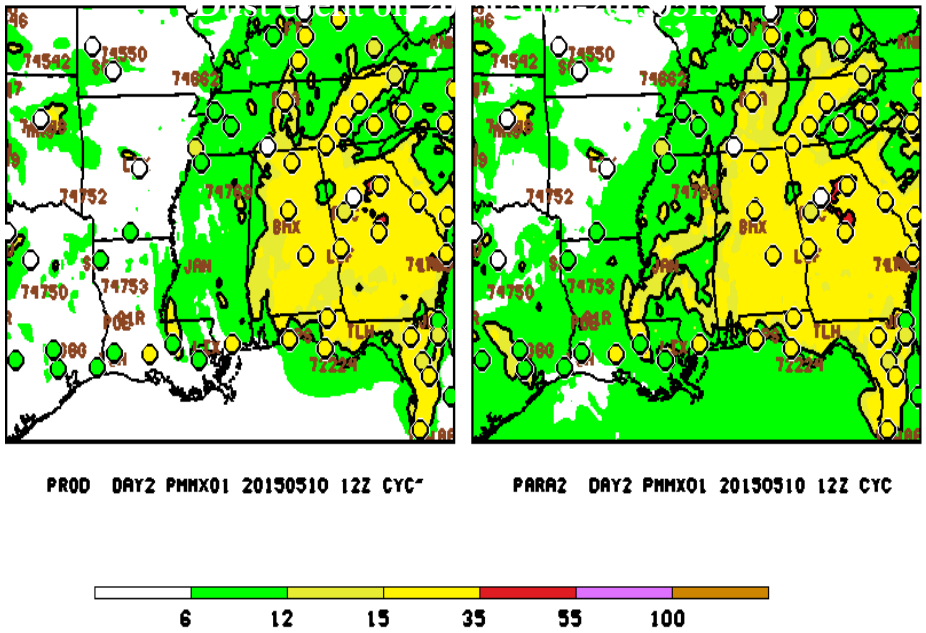
- Include global contributions of dust-related aerosol species at the CMAQ lateral boundaries from the NEMS Global Aerosol Capability (NGAC) forecasts
- Increase vertical levels from 22 to 35
- Analog ensemble bias correction for predictions of fine particulate matter

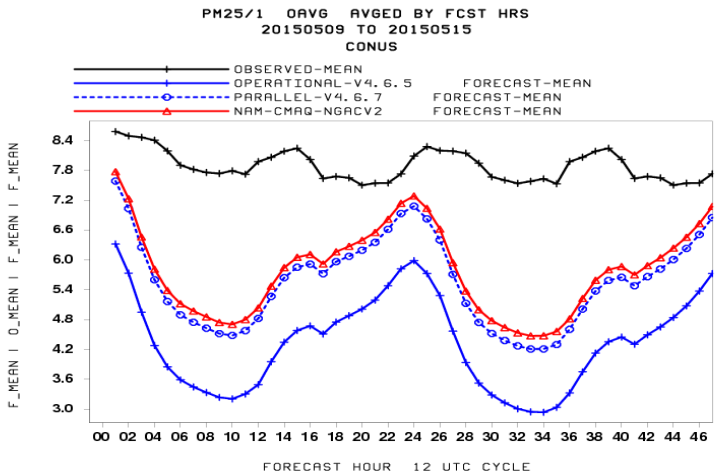
Expected Benefits from this upgrade include:

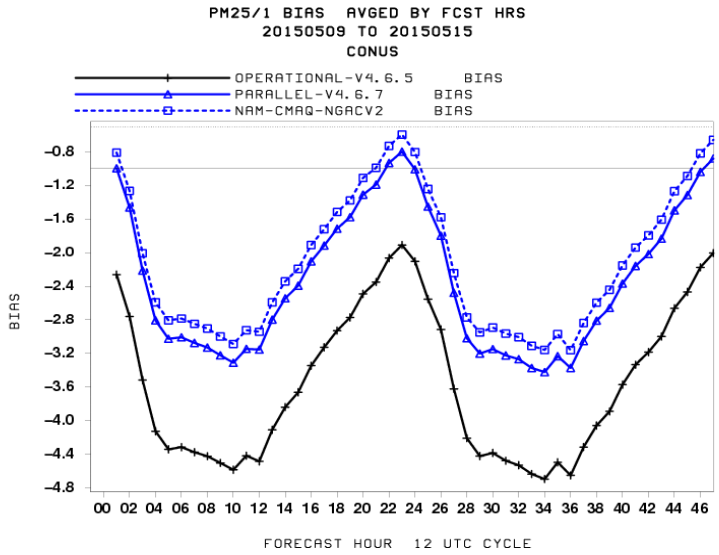
- Initial public distribution of raw and bias corrected particulate matter (PM2.5) products
- Improved raw and bias corrected fine PM2.5 products
- Comparable performance for ozone with a slight decrease in bias

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.







From NGAC Q12016 implementation CCB Oct 30 2015

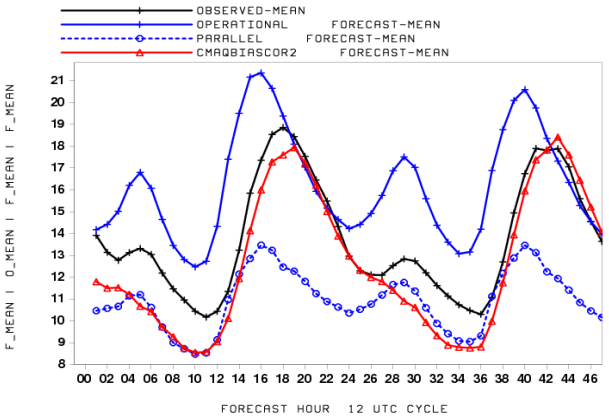
Jeff Mcqueen and Jianping Huang

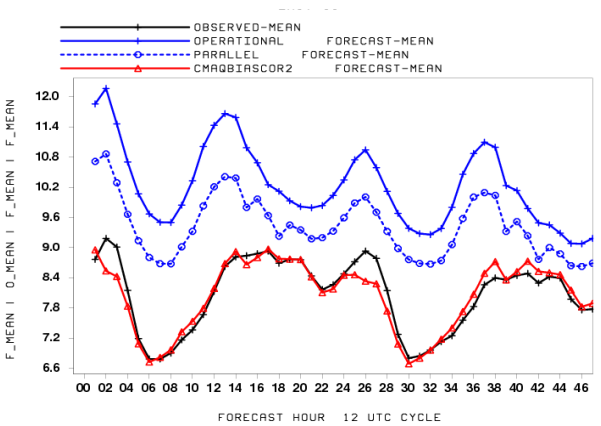
Bias Correction for PM2.5 predictions

Western US

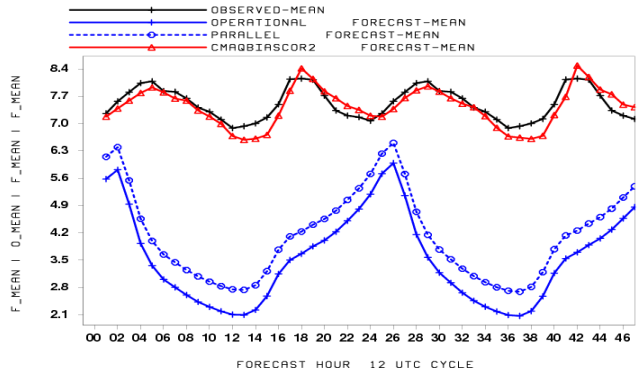
Eastern US

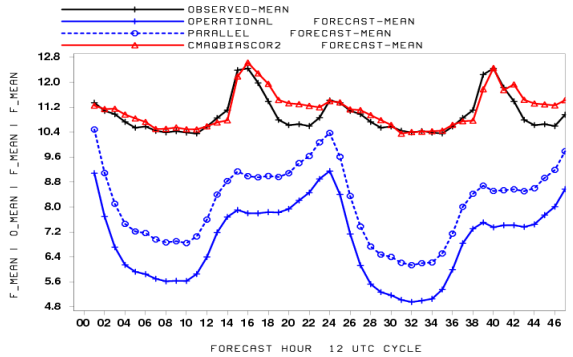
Winter
(Jan 2015)





Summer
(July 2015)

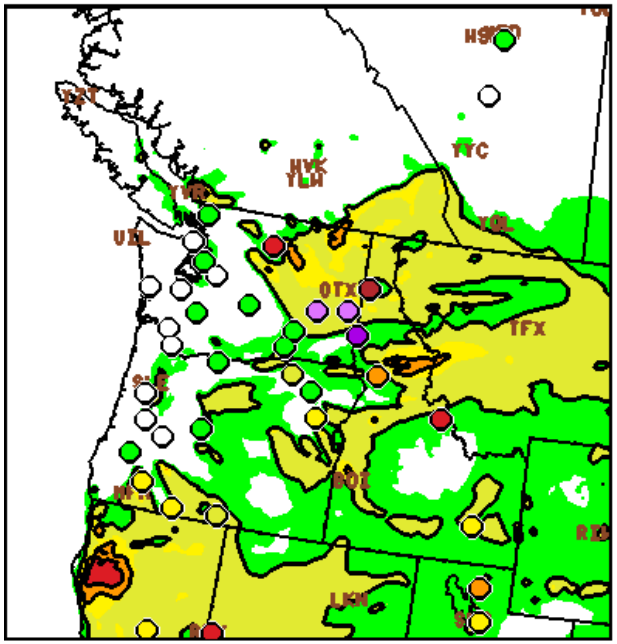




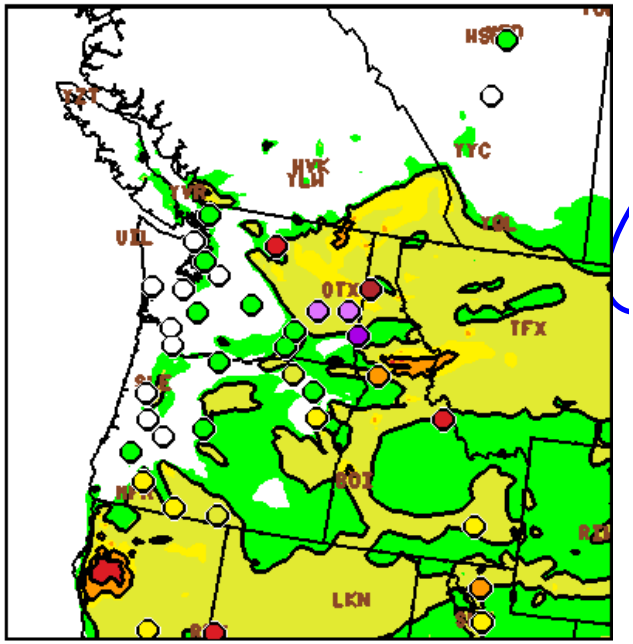
Djalalova, L. Delle Monache, and J. Wilczak: PM2.5 analog forecast and Kalman filter post-processing for the Community Multiscale Air Quality (CMAQ) model, Atmospheric Environment, Volume 108, May 2015, pp.76–87.

Western Fires
August 21, 2015 1hr PM2.5 Max

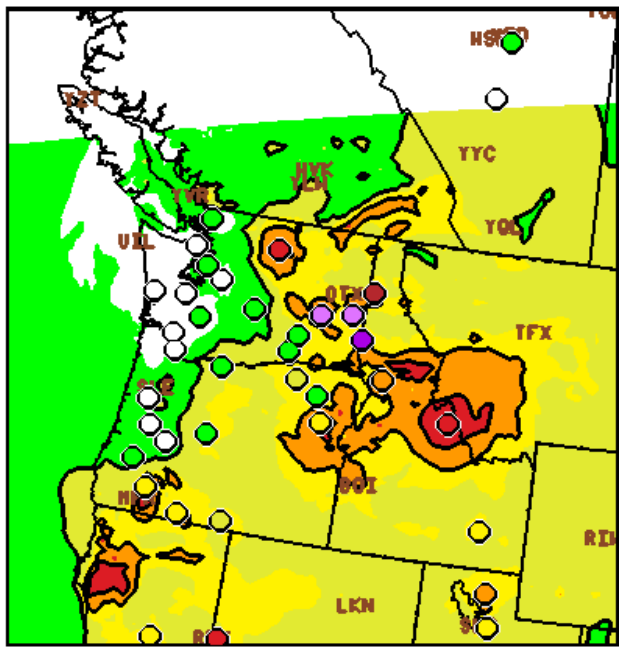
From Operational V4.6.5 AQ Model



Experimental V4.6.7 AQ model



Experimental AQ model w/ bias corr.



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*

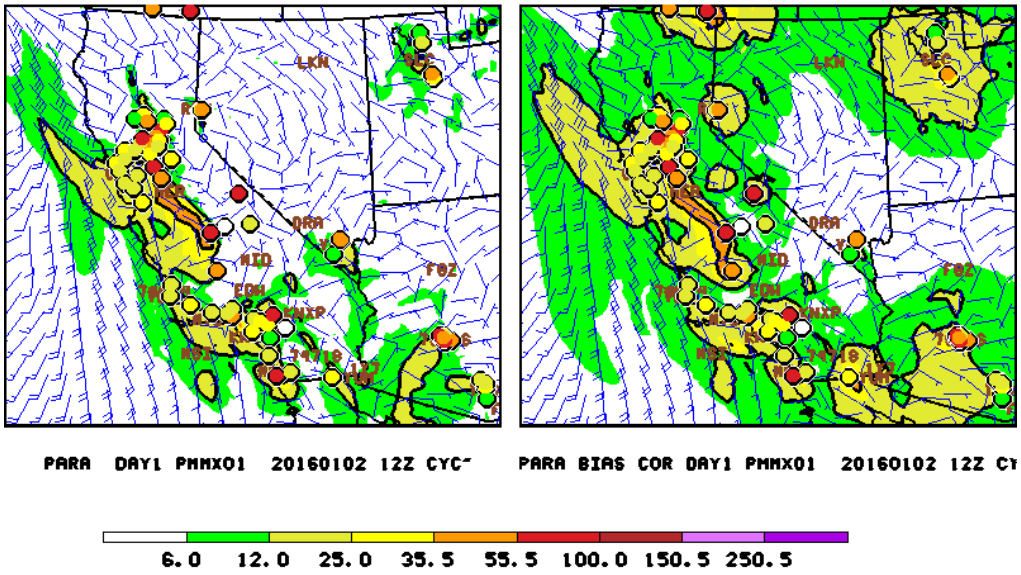
Testing with Forecaster Feedback

- 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

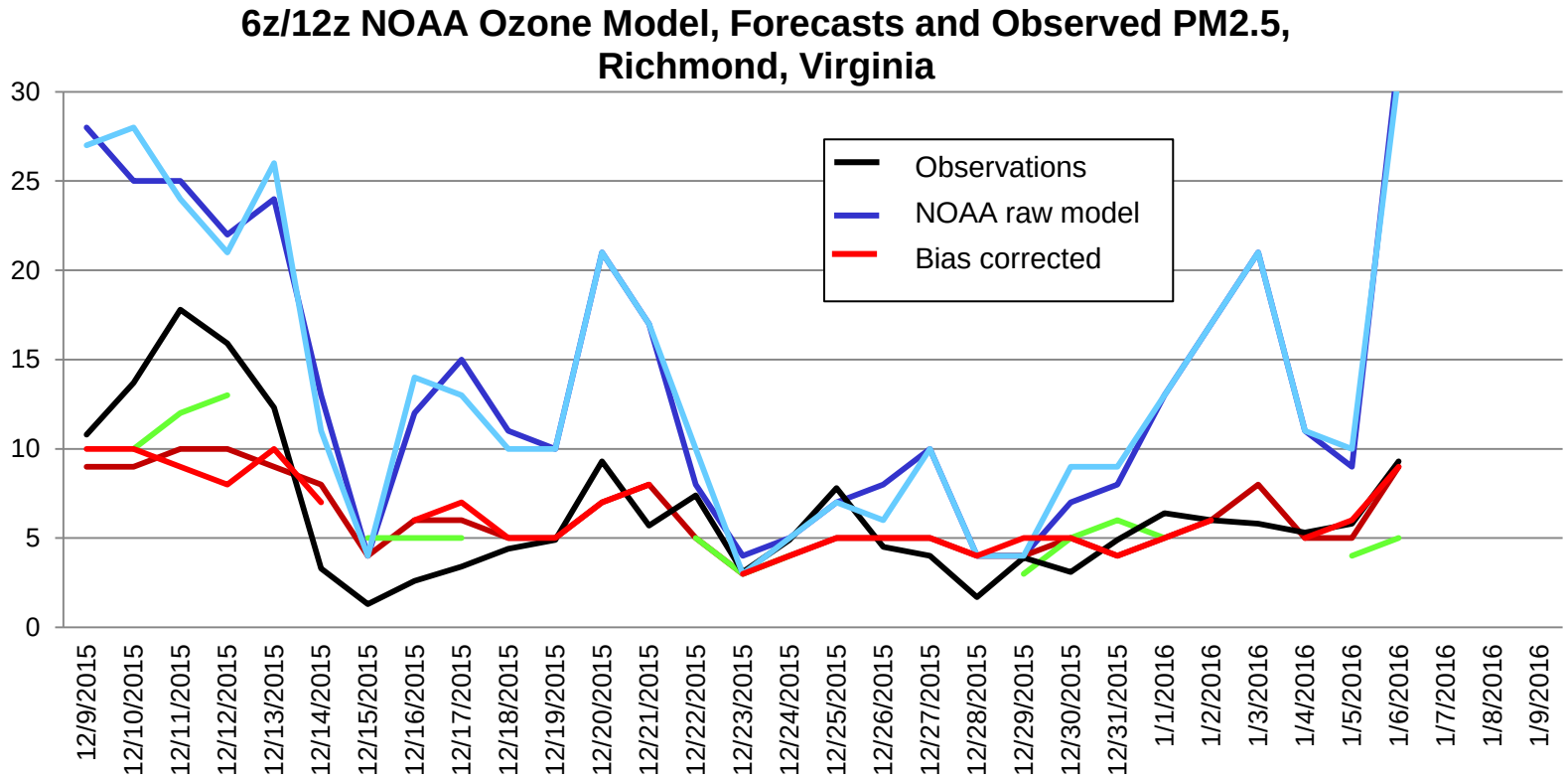


Summary of Forecaster Feedback

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

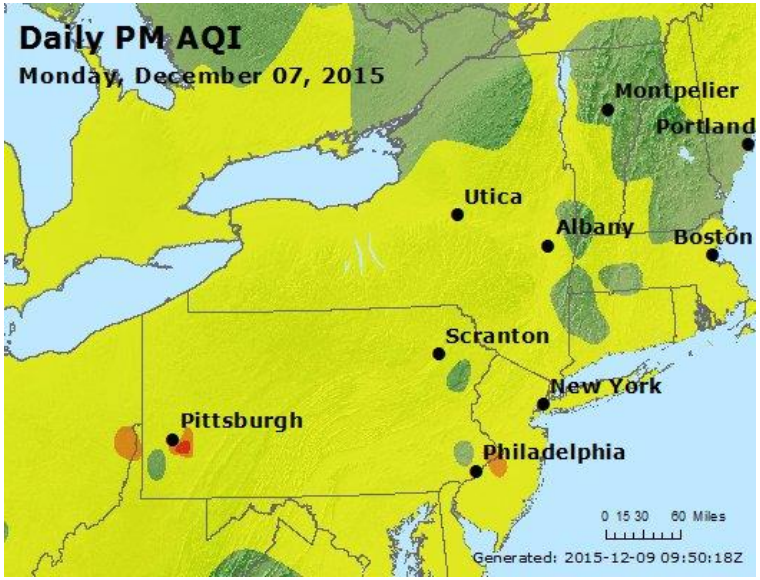
- MD forecaster recommend use of bias corrected PM2.5 over raw PM2.5 output as it largely over predicts the daily average.
- TX forecaster recommend inclusion of distant/international PM2.5 transport.
- PA forecaster recommend both the direct model predictions and the bias corrections, since they give 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.

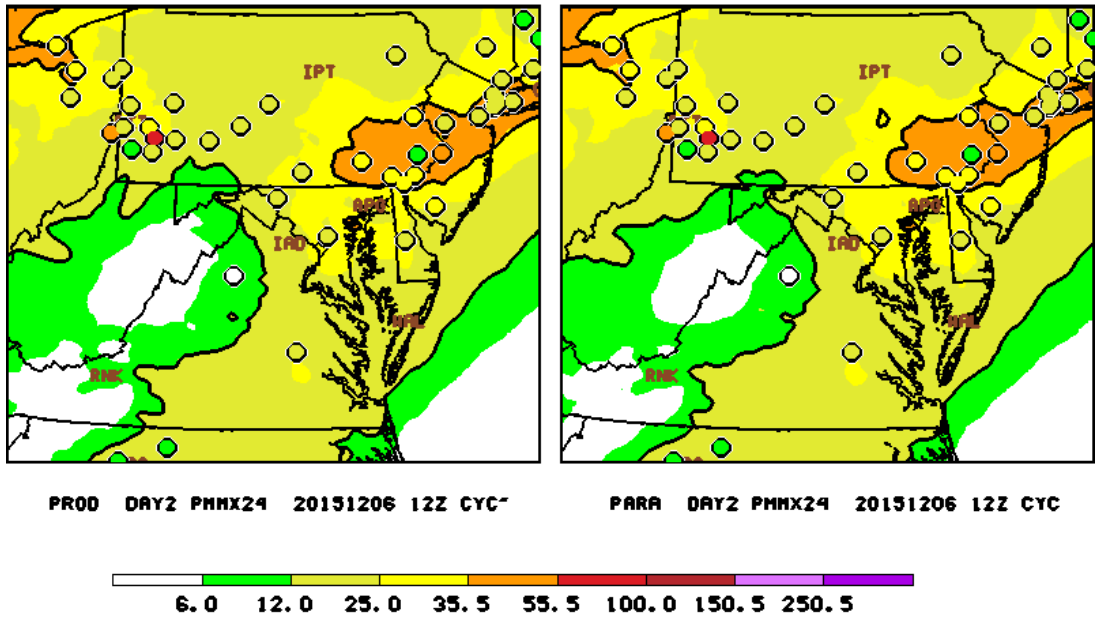
PM2.5 Feedback: Virginia



- 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.

PM2.5 Feedback: Philadelphia

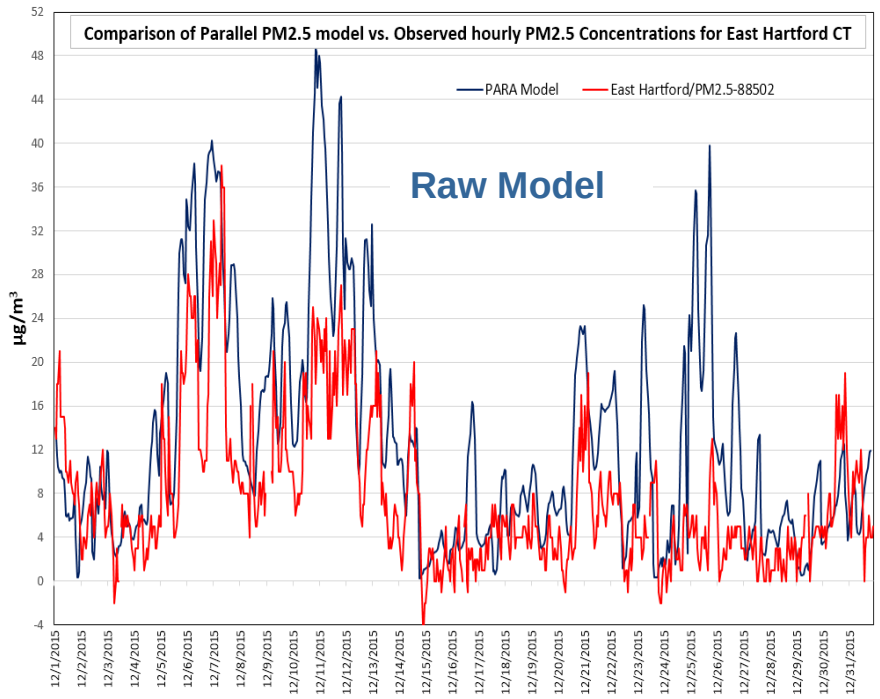


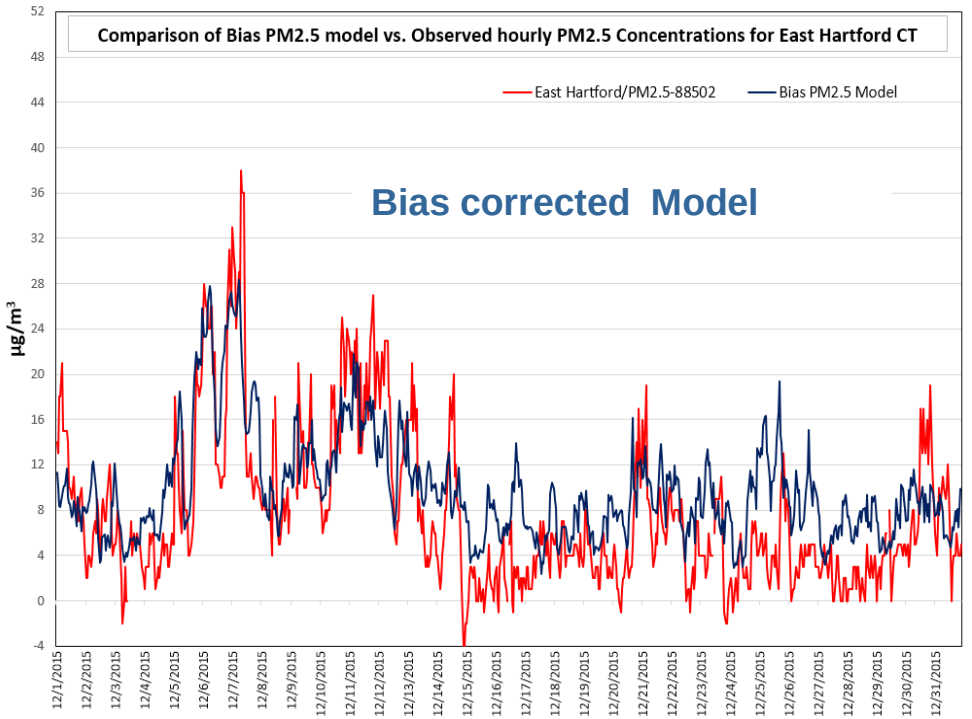


Retrospective analysis for Dec 7, 2015 shows model hits in PHL and PIT but over-forecasted for Susquehanna and Lehigh Valleys in PA.

- 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.

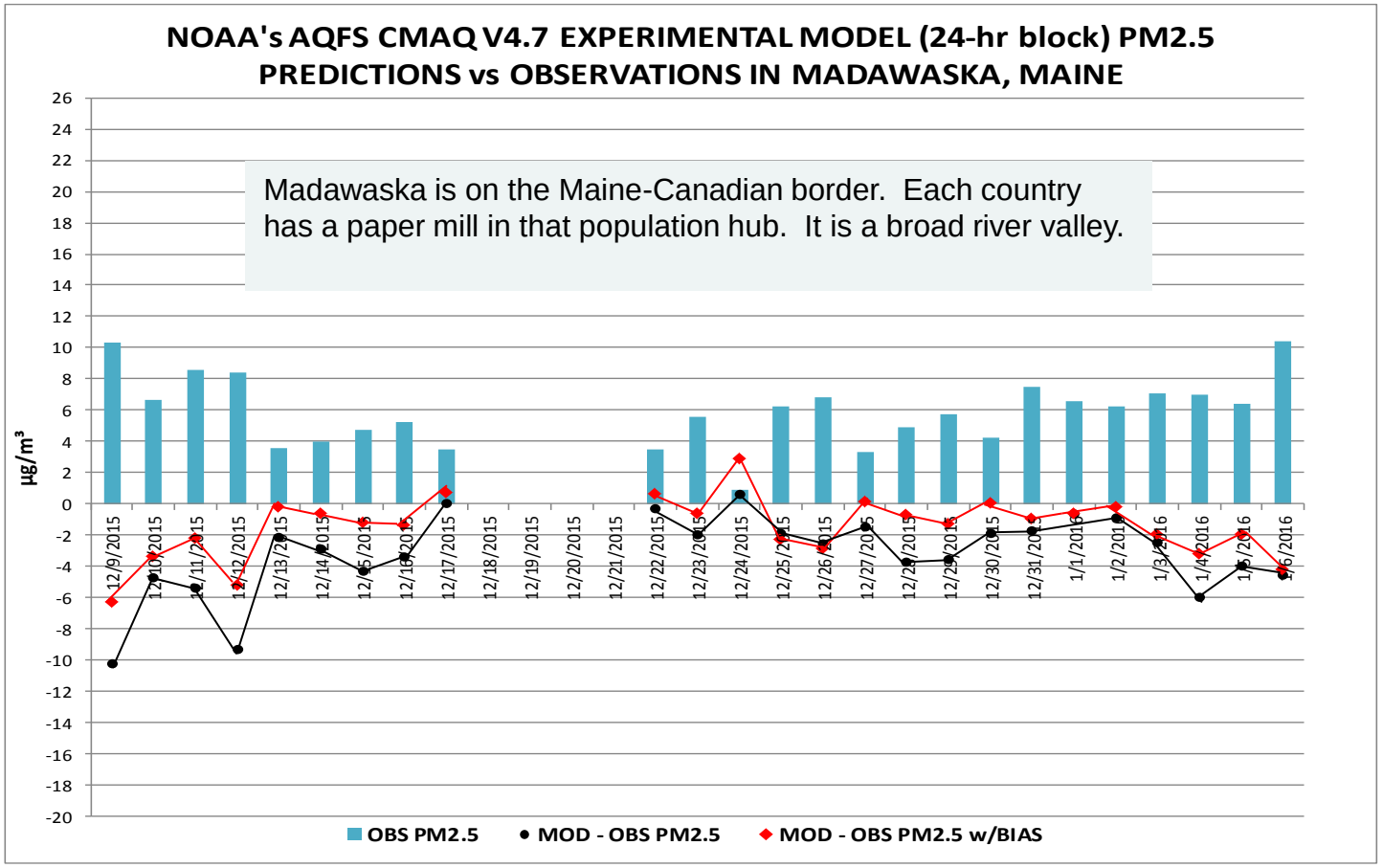
PM2.5 Feedback: Connecticut





- 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 R^2 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, *Hui-Ya Chuang**		**NAM coordination**
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**
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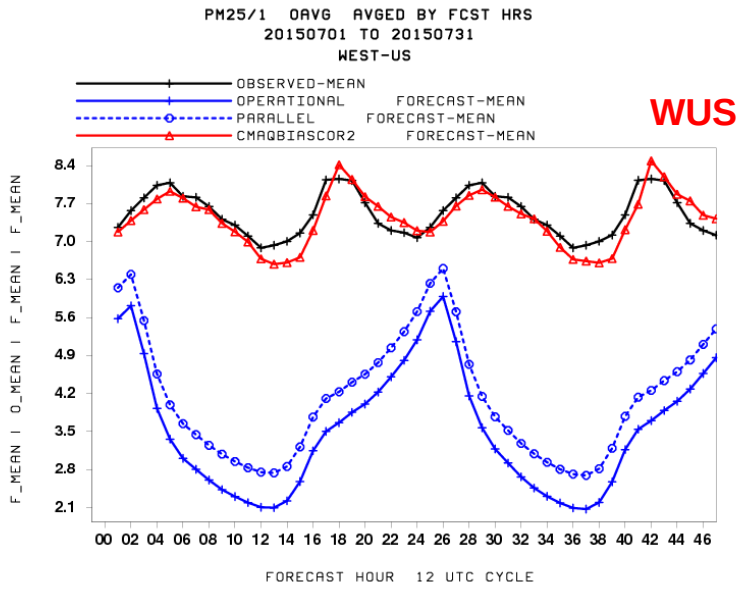
Pius Lee, Daniel Tong, Li Pan		**CMAQ development, adaptation of AQ simulations for AQF**
Hyun-Cheol Kim, Youhua Tang		
Ariel Stein		**HYSPLIT adaptations**
NESDIS/STAR	***Shobha Kondragunta***	***Smoke and dust verification product development***
NESDIS/OSDPD	***Liqun Ma, Mark Ruminski***	***Production 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



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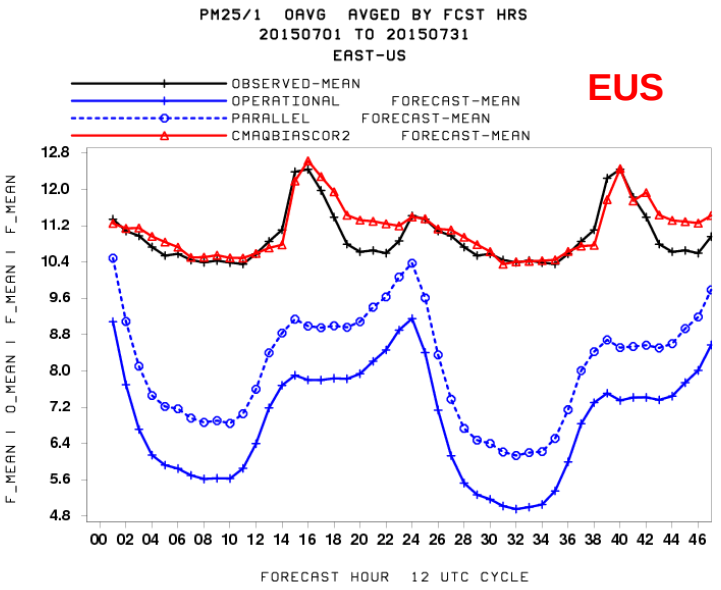

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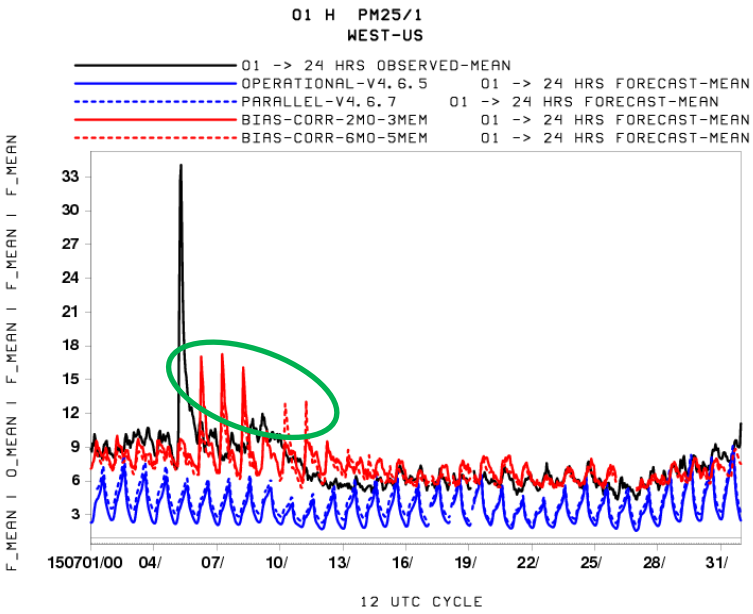
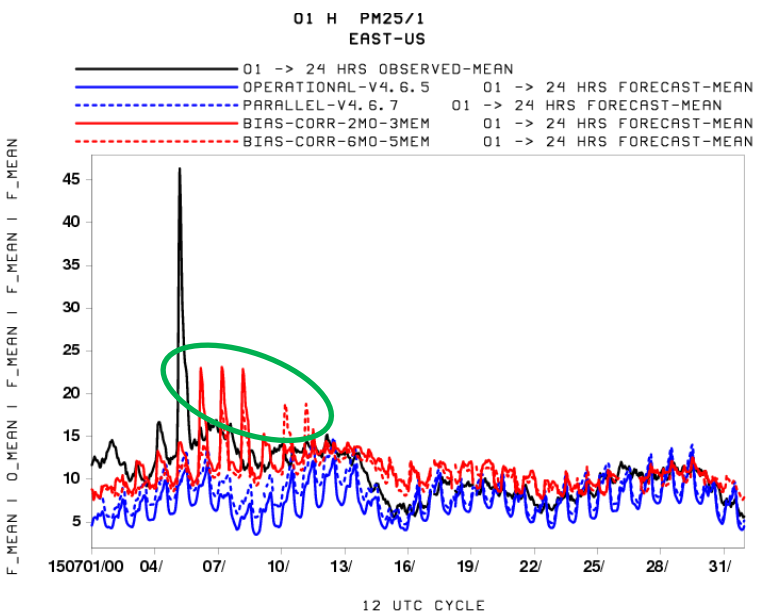
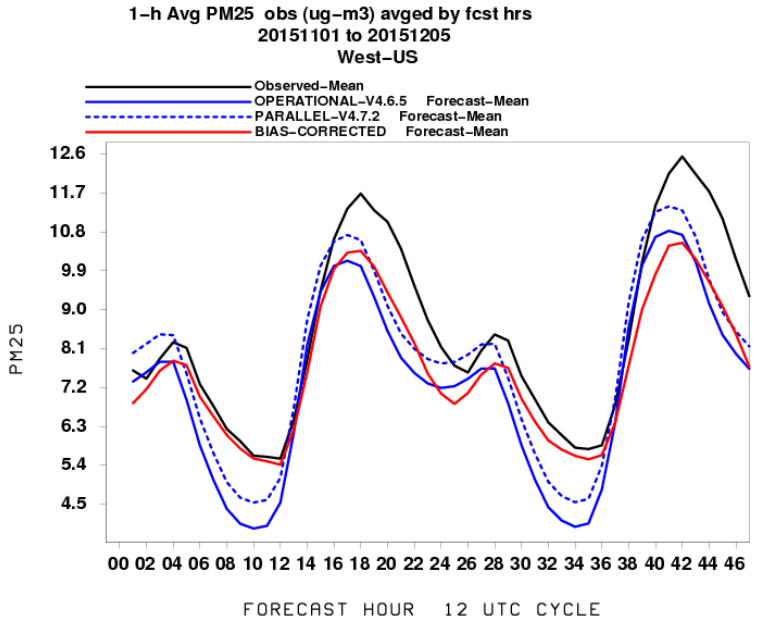
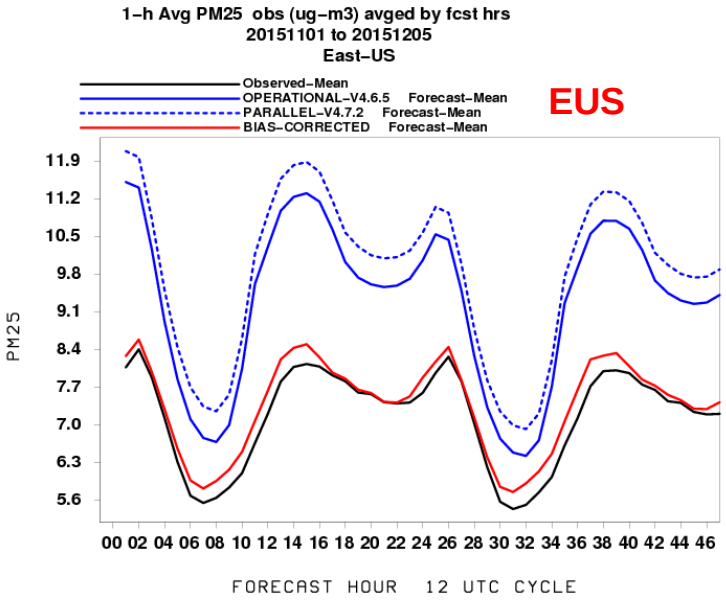
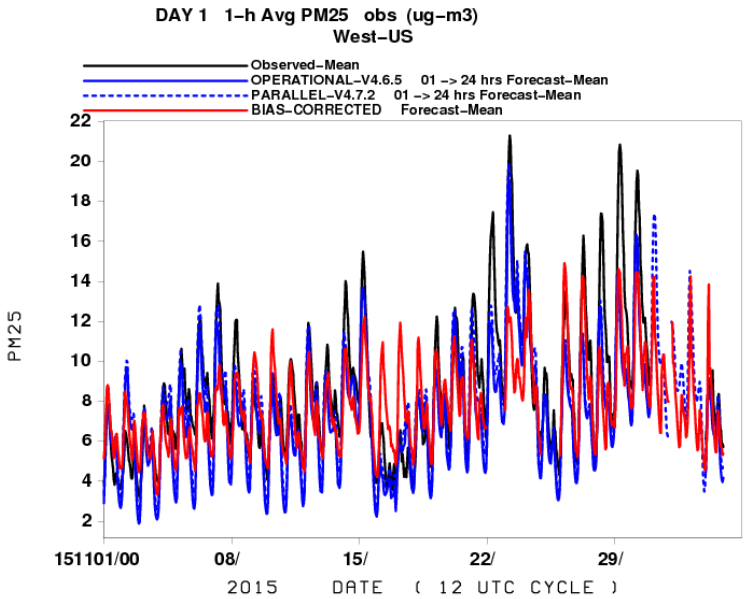


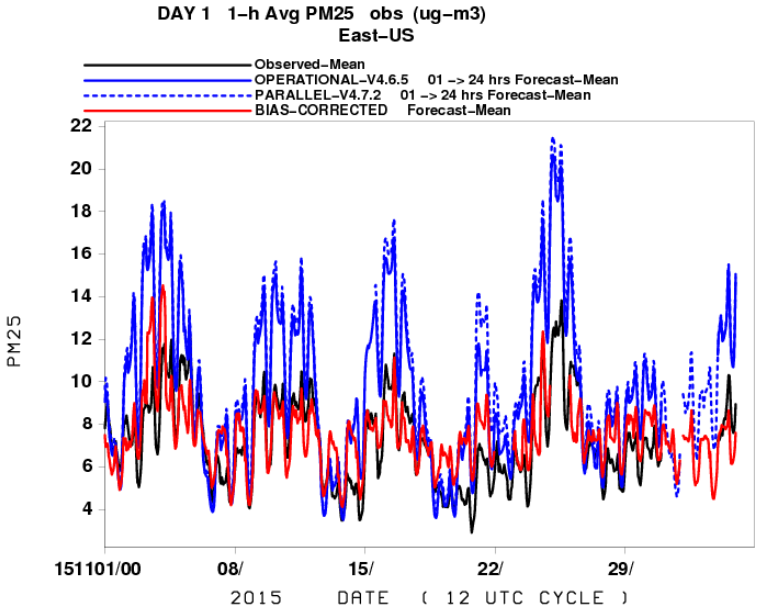


CMAQ PM Performance : Nov 2015

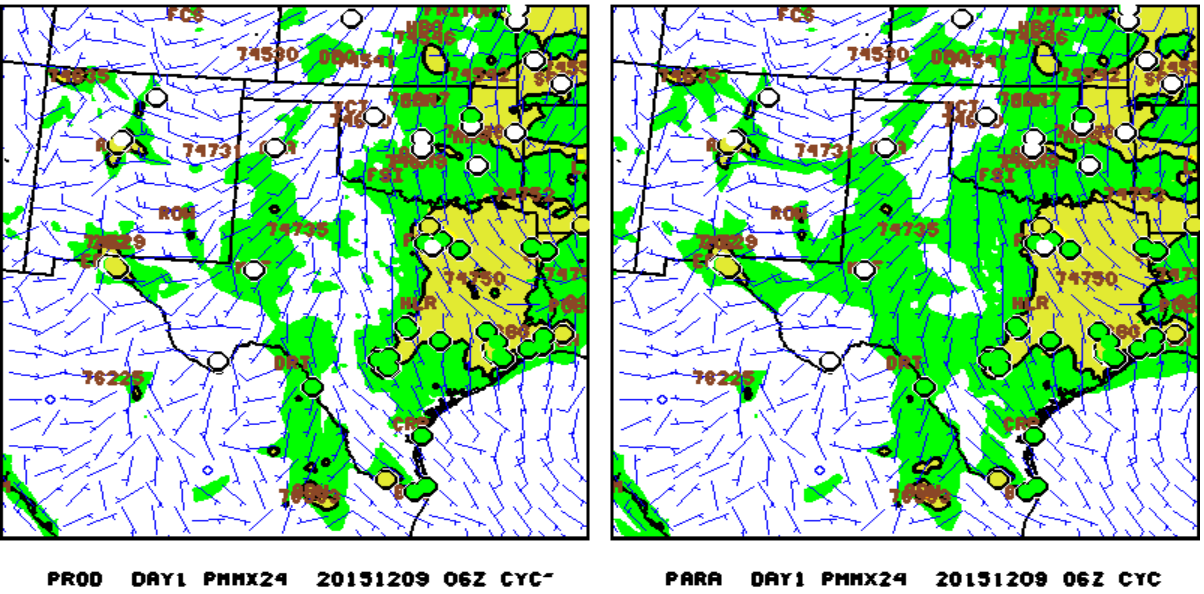








PM2.5 Feedback: Texas



Local Sources Example
December 9, 2015